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EPB standards: Why choose hourly calculation procedures?

Are patterns of use the key to resource efficiency in existing buildings?

Long-term monitoring of the thermal environment in office buildings


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Contents

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Revision of the EPBD and Energy Efficiency Directive (EED) is opportunity for all EU consumers and our business

Last year the RJ reported about the negotiations of the European Parliament. This year, January 31st the Permanent Representatives Committee (the EU ambassadors COREPER) confirmed the agreement reached between the Estonian presidency and the European Parliament in December 2017 on the revised Energy Performance of Buildings Directive (EPBD).

Temenuzhka Petkova, Minister of Energy of the Republic of Bulgaria stated: "Today we reached a major milestone for improving the energy efficiency of our citizens' homes. The Bulgarian Presidency is pleased to arrive at this result on the directive on the energy performance of buildings, which is one of the priority items on the agenda of the Council. The 'energy efficiency comes first' principle is a key element of the Energy Union. Boosting the energy efficiency of buildings is one of the most effective ways of improving EU citizens' quality of life, contributing to the achievement of a low-carbon economy, impacting economic growth, job creation and investments."

This is an important step to finalise the revision process of the EPBD. The review of the energy performance of buildings directive amends Directive 2010/31/EU and it complements measures under the energy efficiency directive as well as EU legislation on energy efficiency of products. It is part of the **Clean Energy package** presented by the Commission on 30 November 2016.

After the endorsement by the European Council, the European Parliament will have to approve the agreement. Currently the vote in plenary is scheduled for the 16 April 2018. After this formal approval of the regulation by the Council and the Parliament, the directive will be published in the Official Journal of the EU, and it will enter into force twenty days later. The transposition period for this legislation is 20 months. To conclude: all EU Member States shall implement all EPBD measures within 2 years' time by April 2020.

Does this timeframe help us? It is good to know that our national regulators are soon obliged to enforce energy saving measures for existing and new buildings. However, the early adapters in many EU MS's are already realising successful NZEB projects, but this is still not the mainstream. REHVA's professional community shouldn't wait any longer. The required renovation rate of our existing building stock is far too low. In many EU countries the building and HVAC industry is complaining about a lack of well trained workers. REHVA is partner in the PROF-TRAC project (PROFessional multi-disciplinary TRAining and Continuing development in skills for nZEB principles; see www.proftrac.eu)[1] and will support the REHVA members to bridge the skills gap among NZEB professionals, technical experts, architects and managers involved in nZEB design and construction and are addressing this gap with courses and dissemination of material.

Our professional community shouldn't wait for the expected regulatory support for energy saving measures to renovate and develop nZEB solutions. Act today, convince your colleagues and contracting parties that this is the only possible future for the build environment and our HVAC industry. ■

JAAP HOGELING
Editor-in-Chief

[1] European Multi-level Skills offensive. The key to ensuring public support for the Energy Transition. Organised by Housing Europe as part of the PROF/TRAC project Brussels, 20 February 2018.

EPB standards: Why choose hourly calculation procedures?

The set of Energy Performance of Buildings (EPB) standards has been published in summer 2017. For the calculation of the energy performance the overarching EPB standard (EN ISO 52000-1) lists different options for the time interval (hourly, monthly, seasonal, yearly and bin). This article provides some background information why an hourly time interval is recommended.

Keywords: energy performance of buildings, EPB standards, EN ISO 52000 family, hourly calculation procedures, EPB Center.

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Previous series of articles (REHVA 2015/1, REHVA 2016/3 and REHVA 2016/6) introduced the new set of international (CEN, CEN ISO) standards for the assessment of the overall energy performance of buildings (EPB).

The strongest interest is in those EPB standards that are 'collectively' needed to calculate the overall energy performance, either for existing buildings, for new buildings or for new building designs.

The core of the energy performance calculation can be found in:

- EN ISO 52000-1, *Energy performance of buildings – Overarching EPB assessment – Part 1: General framework and procedures* ([1], [2]); and
- EN ISO 52016-1, *Energy performance of buildings – Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads – Part 1: Calculation procedures* ([3], [4]),

supplemented by series of other EPB standards (see overview in [9]):

- providing input data on:
  - outdoor climatic conditions,
  - indoor environment conditions and conditions of use,
  - building components,
- assessment of the energy performance of the technical building systems for heating, cooling, ventilation, domestic hot water and lighting, as function of –and interacting with- the energy needs calculation and with building or system automation and control;
- 'post-processing' of the overall and partial energy performance into numerical indicators, energy requirements and ratings.

Overarching EPB procedures (EN ISO 52000-1)

EN ISO 52000-1 provides the modular and overarching framework for the assessment of the energy performance of buildings. It provides a common basis for calculated and measured energy performance, and also for energy performance inspection, at whole building, building units or building element level. The framework comprises:

- identification and classification of the building or building unit to be assessed ("assessed object") and zoning,
- determination of the assessment boundary and perimeters,
- assessment of the energy flows at the assessment boundary, and,
- weighting of the energy flows according to primary energy factors or other metrics, e.g., CO_2 emission and aggregation to the energy performance and the renewable energy contribution.

Calculation time intervals

For the calculation of the energy performance the overarching EPB standard (EN ISO 52000-1) lists different options for the time interval: hourly, monthly, seasonal, yearly and bin. This article provides some background information why an hourly time interval is recommended. The calculation interval is one of the key issues to obtain a transparent and coherent overall structure, with all of the interactions at different levels and with a coherent set of input data.

For use in the context of building regulations it is essential that the procedures to calculate the energy performance of a building are not only **accurate**, but also **robust** (applicable to a wide range of cases). It is also essential that they are **reproducible** (unambiguous) as well as **transparent** and **verifiable** (e.g. for municipalities, to check compliance with national or regional minimum energy performance requirements) and **applicable/affordable** (e.g. for inspectors, assessing the energy performance assessment of an existing building).

In other words, it is important to find a balance between transparency, robustness and reproducibility of the calculation method, an affordable and reliable set of input data, and sufficient appreciation of the wide variety of available energy saving technologies.

Therefore, the accuracy of the model should always be in proportion with the limits and uncertainty in input data and with the required robustness and reproducibility of the method: a balanced accuracy.

Consequently, the most accurate, complete and state of the art method is not necessarily the most appropriate method for a specific calculation.

Many technologies, in particular for low energy buildings, are strongly and dynamically interacting with the hourly and daily variations in weather and operation (solar blinds, thermostats, needs, occupation, accumulation, mechanical ventilation, night time -free cooling- ventilation, weekend operation, etc.). This has a strong effect on the heating and cooling calculation.

Therefore, it is no surprise that the choice between hourly or monthly calculation procedures is most prominently visible in the calculation of the energy needs for heating and cooling.

Energy needs for heating and cooling (EN ISO 52016-1)

EN ISO 52016-1 provides the procedures for the calculation of the energy needs for heating and cooling. It supersedes the well-known EN ISO 13790:2008 (*Energy performance of buildings -- Calculation of energy use for space heating and cooling*).

In line with the overarching EPB standard, it contains a monthly and an hourly calculation method, side by side. A "bin" method is not an option, as explained further on. A building simulation tool is not recommended either, as also explained further on.

As introduced in previous articles ([5], [6], [7]), one of the main new features of EN ISO 52016-1 is the new specific hourly method to calculate the energy needs for heating and cooling, internal temperatures and sensible and latent heat loads, in parallel to the simple monthly method which remained in essence the same as the method in EN ISO 13790.

With the **hourly calculation method** the thermal balance of the building or building zone is made up at an hourly time interval.

Additional applications covered in the hourly method of EN ISO 52016-1 are:

- calculation of **internal temperatures**, e.g. under summer conditions without cooling or winter conditions without heating;
- calculation of heating or cooling load under **system design** conditions.

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

In the **monthly calculation method** of the energy needs for heating and cooling, correction or adjustment factors are required to account for the dynamic effects mentioned above, in a kind of statistical way. These factors are usually pre-calculated, based on a large series of building simulations with e.g. variations of daily weather and conditions of use.

What is "bin" and why is "bin" not an option here?

"Bin" refers to a statistical method, where the frequencies of occurrence of short time interval values for one or more boundary condition variables (e.g. hourly values for the outdoor air temperature) are allocated to defined intervals (the "bins"). The calculation is then done bin by bin, by using the value of the variable in the middle of the bin as a boundary condition and multiplied by the frequency of the respective bin.

This method is especially of value when calculations with longer time intervals for some parts (e.g. monthly or seasonal for the building) need to be combined with calculations of technologies where the influence of the variation of a driving force is essential and averaging is not acceptable (e.g. the outdoor temperature for air-to-water heat pumps).

The limitation of the bin method is that there is no 'memory' between the bins. In case of energy storage systems or in case of heat accumulation in building elements, a bin does not know how much heat was accumulated or released during the previous time interval, because the bins are not sequential in time as e.g. an hourly time interval.

This limitation is the reason why a bin method is not an option for the calculation of the energy needs for heating and cooling in a building: the heat accumulation in the building mas typically stretches over several days.

Why not recommend a full dynamic building simulation tool?

A standard reference method for the calculation of the energy performance of buildings should be realistic, sufficiently sensitive (=discriminating between technologies and their performance), fair and robust. But a standard calculation method should also be affordable, reliable, verifiable, transparent, reproducible and affordable.

Typically a detailed full dynamic simulation tool is regarded as a suitable alternative reference approach, provided that sufficient information is available on all the input data (including operating conditions) and their variations.

In practice, however, a detailed full dynamic simulation tool introduces a lot of choices, details and complexities that makes it quite a job to use it as a reference tool for a standard method to calculate the energy performance of buildings; in particular for use in the context of building regulations where reproducibility and transparency are key quality aspects of the standard method.

Conclusion: depending on the technologies and/or physical processes a suitable reference method is **a tailored choice** and not necessarily a detailed simulation tool.

Tailored hourly method: same input data needed from the user as for the monthly method

A direct hourly calculation does not need the correction factors that are needed in the monthly method to account for the dynamic effects. But the challenge for an hourly method is to avoid the need for too many input data from the user, which would introduce uncertainties that could easily lead to a loss of overall accuracy.

The hourly and the monthly method in EN ISO 52016-1 are closely linked: they use as much as possible the same input data and assumptions.

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

This **tailoring to the goal** enables to avoid the need for extra input to be supplied by the user compared to the monthly calculation method.

And the hourly method yields as additional output monthly results which can be compared with the monthly method or be a basis for the derivation of the correlation factors for a monthly method for a specific location and building type. See flow chart in **Figure 1**.

In the hourly method, only the standard writers will have to introduce extra data: hourly operation schedules and weather data. On the other hand, the standard writers don't need to prepare and maintain tables with pre-calculated factors (on operation of blinds, effect of solar shading, etc.).

Moreover, these hourly data are available anyway, e.g. for applying the principle of equivalence for novel technologies. The hourly method brings these data to the visible foreground of the method.

System specific calculation of the energy needs for heating and cooling

The hourly calculation procedures in ISO 52016 1 are best suited to reveal the influence of the system on the energy loads and needs for heating and cooling:

- undersized heating or cooling power,
- recoverable heat losses,
- adjustment of the temperature set-points (value and time-schedule) due to imperfect system control, and
- limitation of the heating or cooling season for the calculation defined by the operation time of the respective technical systems.

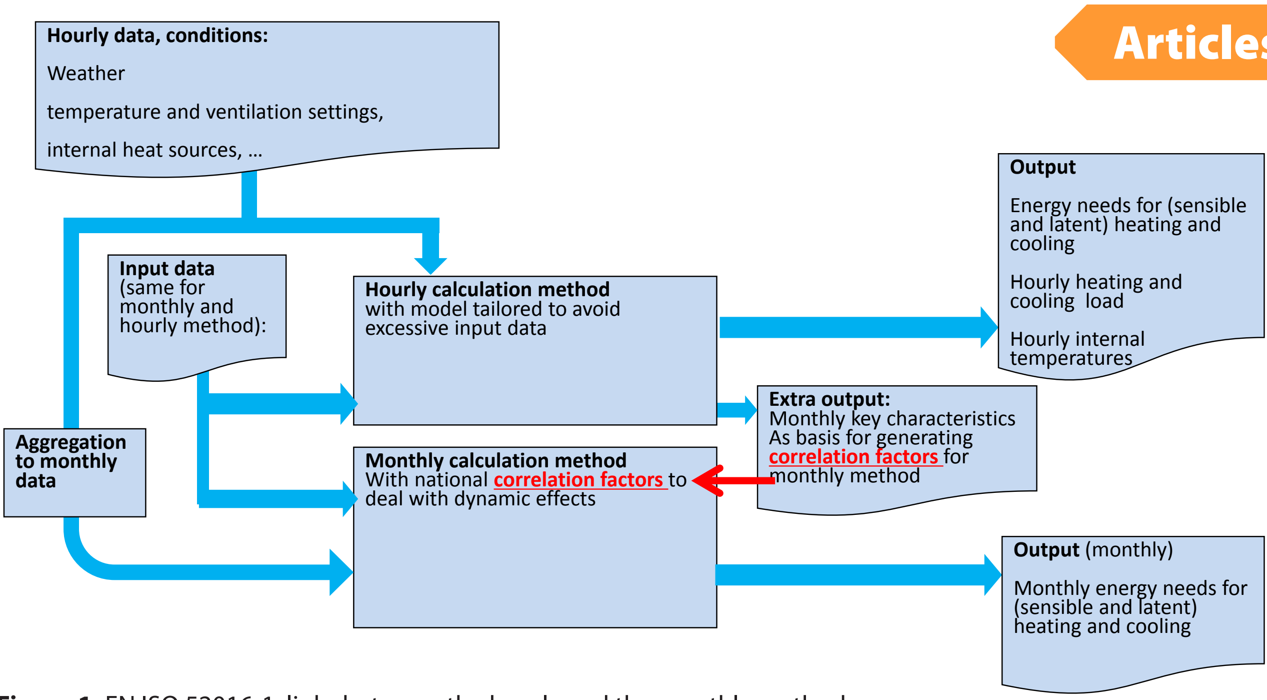

Figure 1. EN ISO 52016-1: links between the hourly and the monthly method.

But also for the interaction the other way around: to take into account the influence of the calculated hourly heating and cooling load and indoor temperature on the performance of the technical systems and their components (as described in the system related EPB standards).

Thermal balance

As illustrated in **Figure 2** versus **Figure 3**, the thermal balance in buildings changes dramatically compared to the past: nowadays the solar and internal gains have a relatively much larger influence on the energy needs for heating and cooling.

Due to relatively much larger solar and internal gains the (low) energy needs are much more dependent of the highly fluctuating heat gains, in combination with the heat accumulation in the thermal mass of the building. This makes it much more difficult to find proper and robust correction factors that are needed to take into account the dynamic effects.

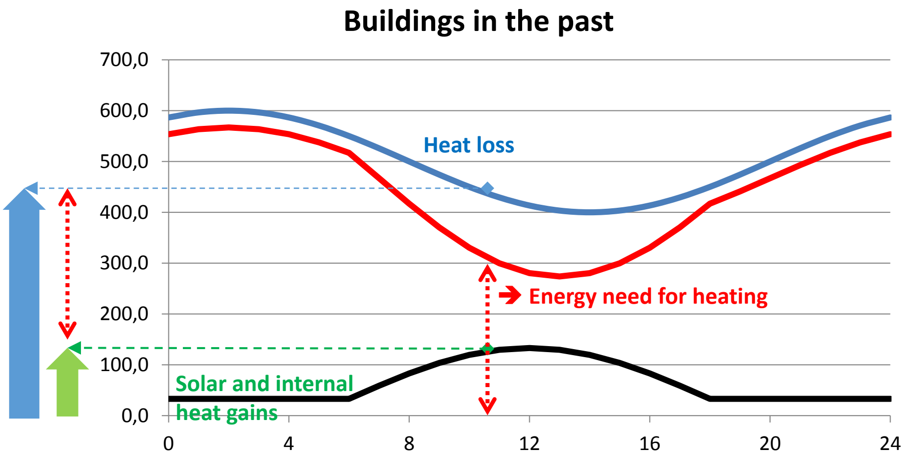

Figure 2. Illustration of the thermal balance in case of buildings in the past: the difference between the heat losses and the heat gains (➔ the energy need for heating) is large and much less fluctuating as in low energy buildings (compare **Figure 3**).

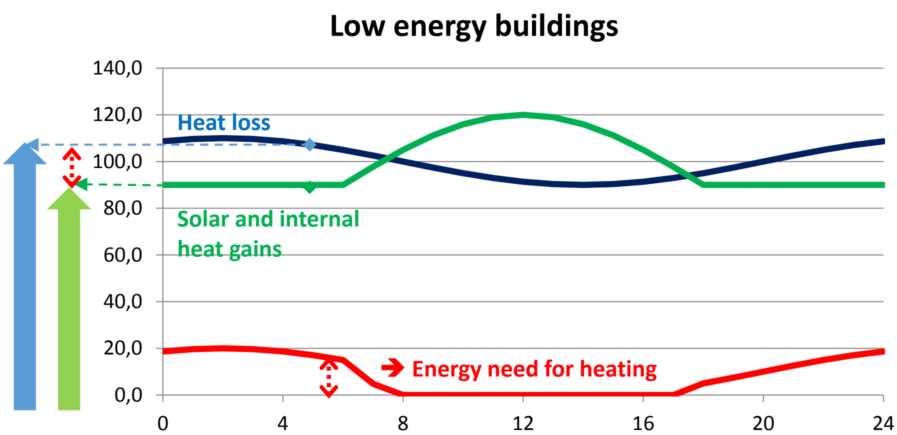

Figure 3. Illustration of the thermal balance in case of low energy buildings: the difference between the heat losses and the heat gains (➔ the energy need for heating) is small and more fluctuating.

Heating and cooling needs in the same month?

Another major drawback of the monthly method is the following.

Because there are possibly months with both heating and cooling needs, and because this cannot be predicted without doing the actual calculation, two *independent* calculations are performed:

1) for each month a calculation of the *heating needs*, with assumptions for the heating mode (e.g. on the use of solar blinds, ventilation, etc.)
2) for each month a calculation of the *cooling needs*, with assumptions for the cooling mode (e.g. on the use of solar blinds, ventilation, etc.)

Evidently this can lead to strange assumptions and to incomprehensible results.

In the hourly method it is simply determined at hourly basis whether there is a heating or a cooling need and the inertial effect of heating or cooling or overheating during previous hours is taken into account automatically.

More dynamic effects

A number of other dynamic effects add to the problems for a monthly method in addition to the influence of hourly and daily variations in weather:

The hourly and daily variation in operation and/or in energy performance of dynamic technologies or processes (see **Figure 4**).

Examples of relevant dynamic technologies or processes (related to building and building elements or technical building systems and their interactions):

- nocturnal temperature set back, occupation (internal gains) and operation (ventilation system, shutters/blinds, …);
- weekend temperature set back, occupation (internal gains) and operation (ventilation system, shutters/blinds, …)
- solar shading by e.g. overhangs (passive heating, cooling needs, lighting needs);
- movable solar shading provisions (cooling and lighting needs);
- adaptive facades;
- nocturnal ventilation (free cooling);
- heat recovery unit (ventilation): frost protection in winter; use of by-pass in summer;
- variable ventilation air flow rates;
- heat pump, with performance strongly depending on the source temperature and with auxiliary back up heater;
- other system components with load dependent system efficiencies;
- cooling system with limited cooling capacity (comfort cooling).

In the monthly method these influences are taken into account by monthly **correlation factors**, such as the utilization factors for heating and for cooling needs, supplemented by **additional correction factors** (e.g. for night and weekend temperature set back) and **detailed pre-calculated tables** that are based on agreed reference cases which cannot always be representative for all building types and ages.

Some of these tables can be very voluminous, e.g.:

- Solar shading factors (for overhangs or other shading objects): shading reduction factors per location, orientation and tilt, per month (provided in

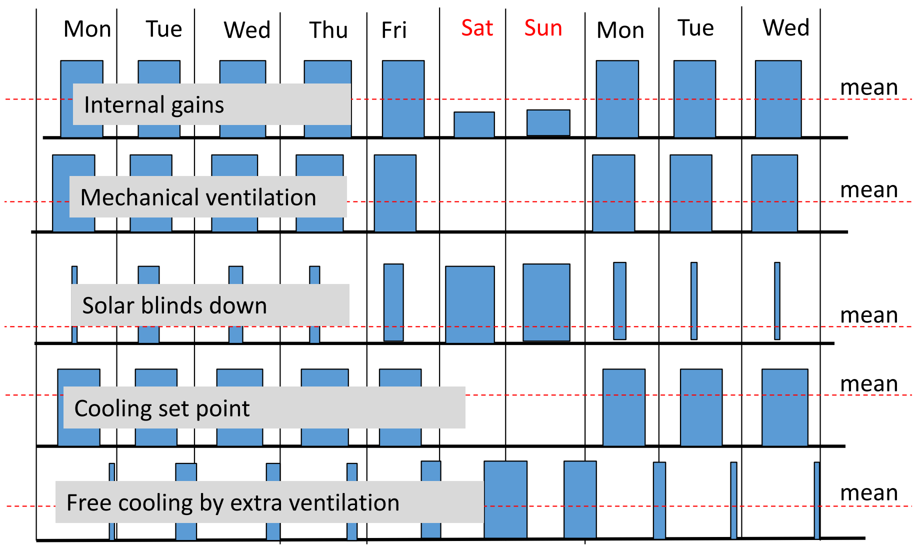

Figure 4. Illustration of hourly patterns that have a dominant influence on the thermal balance, with as a consequence that the use of monthly mean values can be problematic, even more so in case of buildings with deviating weekend operation.

EN ISO 52016-1 for only a few selected cases). In the hourly calculation method it takes only a few equations (provided in EN ISO 52016-1).

- Movable solar shading provisions: for each set of criteria for open/closed: pre-calculated tables with time-average (weighted) reduction factor for the solar energy transmittance of windows per location, orientation and tilt, per month (provided in EN ISO 52016-1 for only a few selected cases). In the hourly calculation method the choice between properties for "open" and properties for "closed" are simply determined hourly, on the basis of the criteria for open/closed (provided in EN ISO 52016-1).

In the monthly method, the interaction between the calculation of the energy needs and the system energy use can lead to the need for several additional correction factors. And it is often difficult to predict to what extent these might be neglected, because that will depend on the specific situation.

For example: preheating and precooling in an air handling unit to a constant supply air temperature (output): see **Figure 5**: the fluctuating outdoor temperature leads to momentary preheating followed by momentary precooling. In the hourly method this is correctly calculated; in the monthly method, when the preheating and precooling is simply based on the average outdoor temperature the energy needs may be significantly underestimated.

Transparency

As shown in the examples above, for low energy buildings and buildings with dynamically (inter-)acting technologies, the monthly method is no longer the simple transparent method that it used to be. Due to the necessity to introduce several correction or adjustment factors, the original transparency and robustness of the monthly method has been lost: the more of the above mentioned dynamic technologies and processes are included in the monthly calculation method, the less transparent the monthly calculation method becomes, and the more an hourly method becomes transparent.

Level playing field

In case of a simple monthly method the designer's choice for, e.g., applying external movable solar shading, or the quality of the heat recovery unit, or the choice for a bypass in the heat recovery unit, or for comfort cooling, will be based on a highly simplified, very average situation, disregarding the specific impact which is a function of the specific design or given building. There is no level playing field for these techniques.

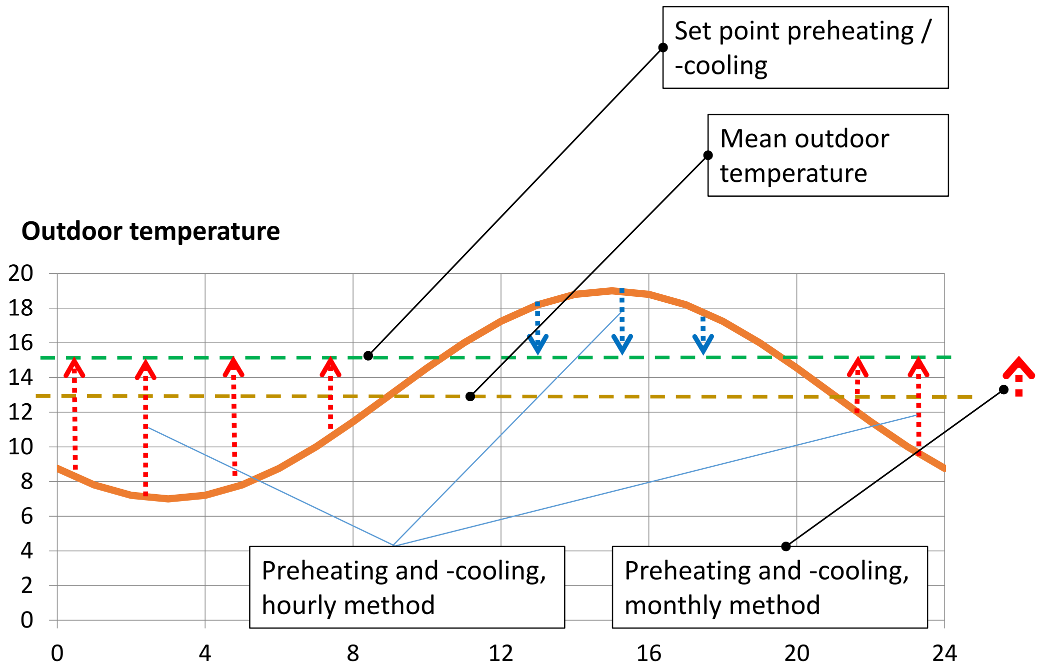

Figure 5. Illustration of the need for additional correction factors in the monthly method: the calculation based on the monthly calculation method may strongly underestimate the, preheating and precooling needs in an air handling unit.

As a consequence, having a monthly method, the pressure will increase to come up with tabulated correction factors to differentiate between specific low and high quality technologies. These tabulated values are derived by hourly calculation methods, but will make the monthly method more complicated and less transparent than intended.

By the way, an hourly calculation method does not require that all input quantities and all parts of the calculation are hourly based: if a component has a small impact on the overall result, or if it's functioning is only a very weak function of the actual conditions, it may assumed to be constant. This applies for instance for the *U*-value of building elements, but also for several components in the technical building systems.

EPB Center

More information on the set of EPB standards, with extensive background information and explanation, is provided at the website of the EPB Center [9].

One of the recently added features of the website is a complete overview of all EPB standards and their accompanying technical reports (http://epb.center/support), with information how the documents can be obtained. At each document a link is provided to the page in the ISO catalogue or CEN database where a summary and other information on the document can be found.

Conclusion

The set of Energy Performance of Buildings (EPB) standards has been published in summer 2017. For the calculation of the energy performance the overarching EPB standard (EN ISO 52000-1) lists different options for the time interval: hourly, monthly, seasonal, yearly and bin. This article provides some background information why an hourly calculation time interval is recommended.

In case of low energy buildings and in case of modern high performance technologies that are sensitive for the dynamic conditions and dynamic user requirements a well-chosen hourly calculation method is more transparent, more accurate and not necessarily more complex than a simple monthly method.

The claim that the monthly method can be useful for simple cases, like for existing residential buildings, may be true if no mayor energy efficiency improvements are going to be considered. However, this is in strong contrast with the energy saving policy we are committed to. ■

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Paper presented at World Sustainable Built Environment Conference 2017 Hong Kong, Transforming Our Built Environment through Innovation and Integration: Putting Ideas into Action; 5-7 June 2017.

Are patterns of use the key to resource efficiency in existing buildings?

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This article discusses the influence of occupancy patterns in energy consumption in buildings. There is growing call to normalize buildings with patterns of use and with occupancy patterns in particular. Occupancy data was collected in an office building for one month in order to calculate the peak occupancy of the case study area. This also enabled the occupancy and energy consumption patterns to be compared. In addition to this, the energy consumption of the case study building was simulated in order to explore how energy consumption is influenced by different workplace arrangement strategies. It has been shown that daily occupancy curves add valuable information regarding the control strategies of the energy using systems in office buildings. It has also be shown that the peak occupancy rate of the individual building areas is also valuable data as it holds the key to how many desks are needed for a set group of people. It is clear that the amount of space reserved has a big implication on rental costs and energy consumption. The data has multiple uses and can even be used to rent out unused spaces to the public via a growing number of sharing economy websites that focus on spaces in commercial buildings.

Keywords: resource efficiency; energy efficiency; utilisation rate

The current method of analysing the environmental impact of existing buildings is to normalise consumption by building size. This is done for energy, water and carbon dioxide and building size is typically defined by net internal area. The simple reason for doing this is that buildings of different sizes can be compared with one another. This practice is reinforced by national building regulations which aim to reduce consumption in buildings and the legal requirements regarding energy efficiency commonly present their target criteria in the format of energy per unit area such as kWh/m^2. The problem with this is that the influence of the occupancy patters are being overlooked when we only consider the amount of energy consumed and the building size.

For example the Finnish national energy efficiency regulations for buildings has defined the maximum amount of energy that new buildings can consume and this is presented in the format of energy per square meter [1]. In order to simplify the comparison for different buildings, the regulation assumes that the buildings are occupied in a standard manner. If office buildings are taken as an example, then the predefined occupancy pattern is 5 days a week from 07:00–18:00 and during these hours it is assumed that 65% of the staff are present. It can clearly be seen here that the influence of the building's individual occupancy patterns are being overlooked. However, there is growing call to normalize buildings with patterns of use and with occupancy patterns in particular [2,3,4,5]. The most comprehensive approaches have called for energy to be normalized by the combination of area and total person hours per year where total person hours per year is the sum of all of the time that each building user spent in the building during the year in question [2,4]. Furthermore, this intention has been included in European Standard EN15643-1 which advocates that patterns of use should be used in the sustainability assessment of buildings [6]. At present, the legal requirements for energy efficiency are only imposed on buildings when they are being designed or renovated and at this point the energy consumption and patterns of use that are used are estimated and not measured values. There is no legal pressure to conform any post-occupancy energy consumption requirements.

It has been widely discussed that office buildings are only partially occupied during opening hours. The British Council for Offices stated as recently as 2013 that occupancy levels are typically between 60-70% [7]. This means that on average in office buildings 30-40% of the desks are empty during working hours. In addition, there is a wide variation between occupation densities from 7 m² of floor area per person to as much as 19 m² per person for private offices [8]. According to the British Council for Offices the mean occupation density is 10.9 m² per occupied workspace [7]. It is important at this point in the discussion, to note that consumption should be normalised by measured post-occupancy patterns and not the occupancy patterns used in design. Energy consumption has in the past been presented in the form of energy per person where the number of people has been defined by the number of desks in the building or number of staff that the building has been designed for. However, these design numbers are not suitable due to the low occupancy levels of buildings during their use. Also, Dooley [4] points out that energy per person does account for occupation density but does not account for working hours per day which also influences consumption. Thus, energy normalised by the combination of area and total person hours per year is a more suitable metric than energy per person.

Patterns of use have a strong influence on the environmental impact of the existing building stock. If office buildings are on average 30-40% empty during working hours then energy is being consumed by the unused area even if it is empty. It is being heated in winter, cooled in summer, ventilated and background lit all year round. Also, the embodied carbon emissions of the materials used to construct the building are not being optimised if a large portion of the building is consistently unused. Underutilised buildings can contribute to urban sprawl as new buildings are being built on the edge of cities while many spaces that are already constructed are unused. This is similar to how AirBnB has optimized the use of homes and this has resulted in less new hotels being built. Increasing the use of our existing buildings will make the built environment more resource efficient and will reduce the need for new buildings to be built. It also makes sound financial sense to optimise space use as according to a report published in 2014 by Finnish space efficiency experts, Rapal, the average annual cost per annum of a workstation in Helsinki is € 9225 [9]. The report also notes that Helsinki has only the 15th most expensive occupancy costs in the world and thus the cost per workstation is even higher in a number of other cities.

Public bodies are now beginning to see this error and are starting to increase the use of their buildings. In 2014, it was reported that spaces in government buildings in Seoul, South Korea, were being opened and offered for use by the public. At the time of that publication 970 empty spaces, such as conference rooms and auditoriums had already been used in 22,931 cases [10]. This is part of wider plan in Seoul to promote sharing of unused resources in order to achieve a more practical and sustainable way of living. At this point it should be clarified that the aim for efficient use of space should not compromise the comfort or productivity of the building users and it has been shown by many researchers that it is possible to provide quality and productive indoor workspace environments at high occupancy densities [11,12,13,14,15].

The European Commission plans to reduce greenhouse gas emissions by at least 80% by 2050, compared to 1990, with the intention of keeping climate change below two degrees Celsius [16]. In order to achieve this, the building sector must be considered. Previous research has stated that the building sector consumes approximately 39% of the total energy consumption and emits approximately 35% of the total CO_2 emissions in Europe and thus it is an important sector when aiming to reduce global greenhouse gas emissions [17]. This article focuses on office buildings which is the largest commercial building sector in terms of floor space and energy use in most countries [18]. The aim of the article is to uncover: can measured occupancy data assist the implementation of resource efficiency and energy efficiency strategies in existing buildings?

Research methodology

In order to collect empirical data on energy consumption and usage patterns, two video cameras were installed in an office building in Helsinki, Finland. The dome video cameras were chosen as they were compatible with a commercial people counting software which is typically used in retail buildings to monitor the number of visitors over a period of time. The studied area was a portion of the third floor of a three floor office building. Its floor area was approximately 650 m² and it mainly comprised of a large open office area, three meeting rooms, a small kitchenette and a break area. The case study area can be seen enclosed by a red box in **Figure 1**. This area was chosen as it was the only part of the building that had less than three entrance and exit routes and this greatly simplified the installation and the analysis of the camera data. The analysis of a whole floor could not be done as it was not possible to study people movement at the main entrance to each floor. The reason for this was that the camera software could not function correctly if the cameras were installed inside the door as at this point there was movement in two perpendicular directions (in/out of the door and movement up/down the adjacent corridor). In addition to this, there was a fire zone in the stair core outside the entrance to each floor which meant that this location was not suitable for camera installations. **Figure 2** shows a camera installed in the ceiling of the case study building and **Figure 3** shows an image from the people counting software which displays a real-time view from one of the cameras and the most recent results from that camera.

The study was carried out for the whole month of May 2016. May was suitable from an energy consumption point of view as it is falls outside the hottest and coldest periods of the year. May was also suitable from an occupancy point of view as it was not affected by the Finnish summer holiday period which generally occurs from June to August. Thus the results for May should be a suitable representation of the whole year. Cameras were installed as the existing building systems were not considered adequate to count the number of building users accurately. A time card system is in place for the building users to clock in and out but it is not used by all

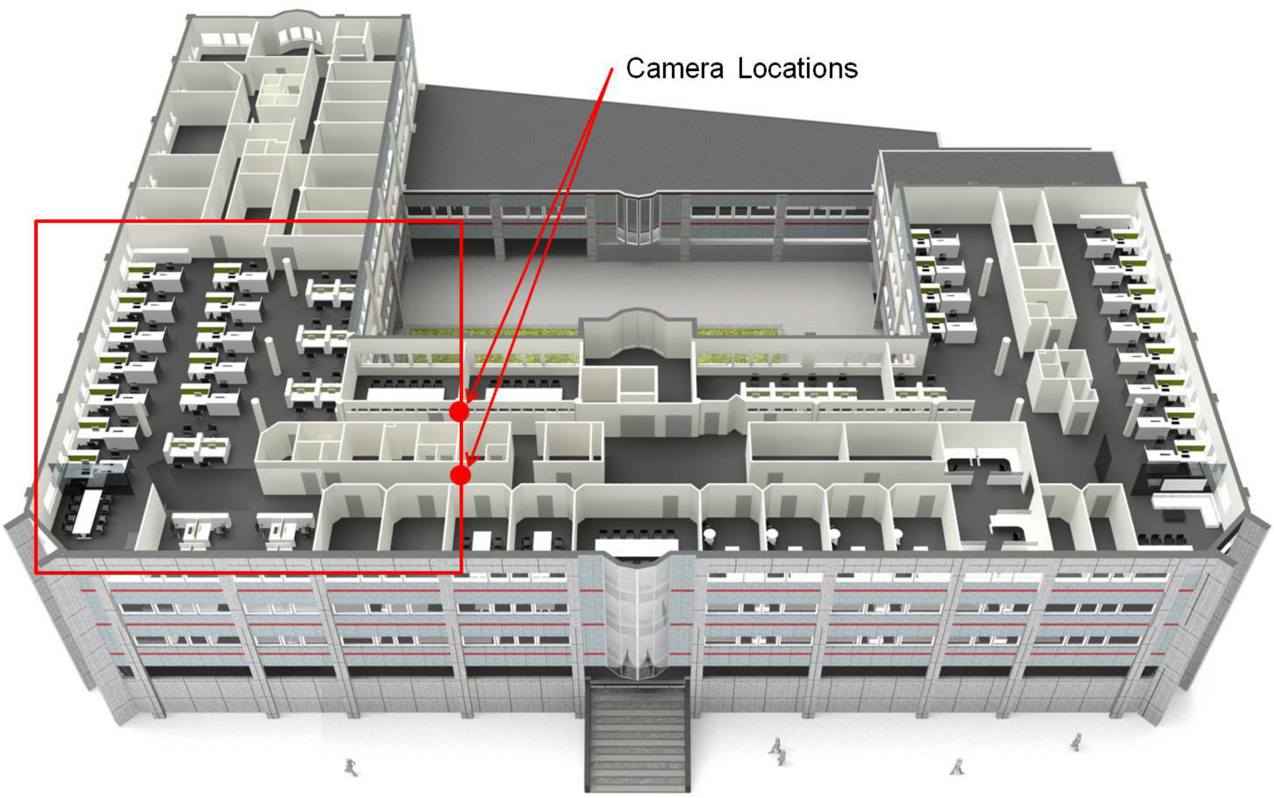


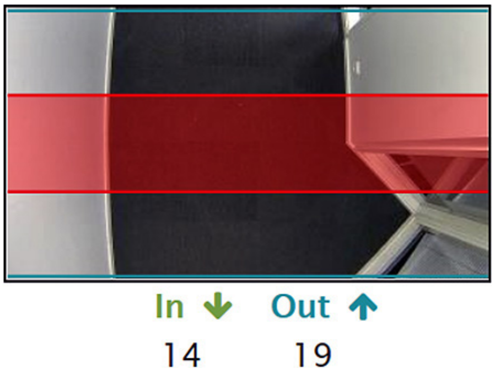
Figure 1. The Camera Locations and the Studied Area within the Case Study Office Building.

employees and it is not used by visitors. RFID cards are used to open the doors to each floor in the building but this system could not be used to count people because of a tailgating problem. Tailgating is when where many people enter or leave the building after one person has unlocked the door with their card. The cameras were installed in the ceiling and pointed straight down so that the faces of the people passing beneath them could not be seen. This meant that privacy was less of an issue when compared to other security camera systems which are pointed directly at people as they approach. This is an important point as it has been claimed by previous researchers that privacy is the main factor that prevents vision based occupancy monitoring from being widely implemented [19].

The purpose of the software is to count the number of people passing in real-time and also to calculate their direction of travel. The output file of each camera reports the number of people that travel in each direction for each 15 minute interval. The data from the cameras was then combined to calculate the number of people that occupied the case study area for each for each 15 minute interval of the month in question. The case study building is open for 16 hours each day from 06:00 - 22:00 and the counting software was reset to zero at midnight every night. One simple way of detecting error within the results of the counting software was to view the occupancy after 22:00. If the software reported that there was someone still occupying the studied area after 22:00 then it had failed to correctly detect all of the people that had left the studied area during the day and if the combined count was negative after 22:00 then it had failed to correctly detect all of the people that had entered the studied area during the day.

The energy consumption of the case study area during the month of May 2016 has been calculated by using the measured energy consumption for the whole building and proportioning this by area. The building is occupied by only one company and all areas have a similar function and utilisation rate and thus this was considered the best approach in the absence of sub-metering for the case study area. In addition to this, energy simulations were made to further understand the results of the occupancy measurements. The annual energy consumption of the building was calculated in order to examine the energy consumption of the case study open office with three alternative floor areas where each floor area relates to different workplace arrangement strategy. A full dynamic energy simulation was created using the programme IES Virtual Environment.

Figure 2. An Installed Camera in the Case Study Building.



	In	Out
12 seconds ago	0	1
20 seconds ago	2	0
45 seconds ago	0	1
58 seconds ago	1	0
1 minute ago	2	3
2 minutes ago	2	2
4 minutes ago	1	0
6 minutes ago	3	3

Test accuracy

Figure 3. An Image from the People Counting Software.

Post-processing of Data

During the study it was observed that the results continuously reported a positive number of occupants after 22:00 and thus the software was not correctly detecting all of the people that had left the studied area during the day. In order to account for this error, the footage of one full day was observed for both cameras and a manual count was carried out. The comparison of the counting software and the manual count showed that the error was relatively evenly distributed over the whole day. It was observed that the error was caused by a counting error at the times of the day when large groups of people enter or leave the space simultaneously such as the beginning of the day, at the beginning and end of lunchtime or in the evening. Based on this, following method for error correction was developed. Time periods with higher number of simultaneous passengers are presumed to have higher probability of counting error and therefore higher correction is applied to these periods, while for periods with lower number of simultaneous passengers, lower correction is presumed respectively. This not only removes the error but it also preserves occupancy profile.

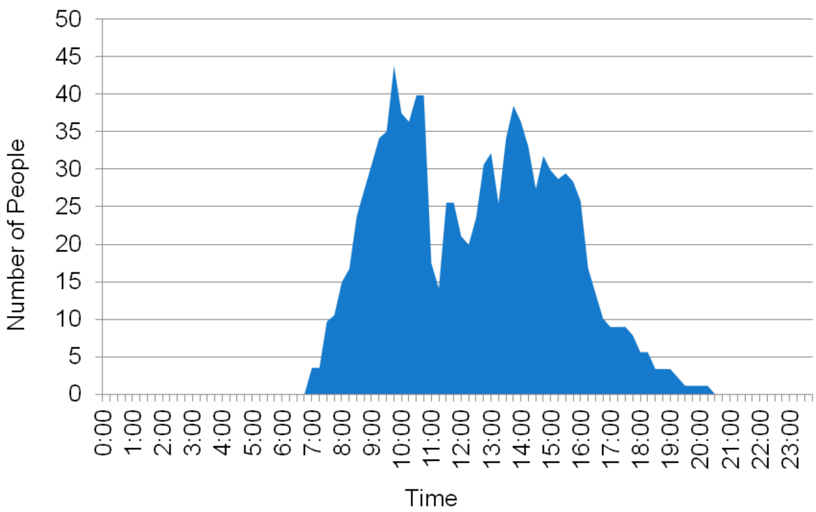


Figure 4. The Peak Occupancy Rate of the Open Office Area.

Results and discussion

Space Utilisation of the Open Office Area

The measured peak occupancy of the open office area is particularly interesting with regard to the size of the area and required number of desks. The peak was measured on Tuesday the 10th of May and the occupancy curve for that day may be seen in **Figure 4**. The open office area does not operate on a one desk per person policy and instead a desk sharing workplace arrangement strategy has been introduced to the area. In total there are 66 employees and the number of desks is 54. The result is an average desk allocation density of 8.85 m². When the peak day is used to compare the measured occupancy with the design occupancy we see that the peak measured occupancy of 44 people is 18.5% lower than the number of desks and that the measured occupancy is 33% lower than the total number of staff. It was also observed that the utilisation for all 5 weekdays is similar as may be seen by **Figure 5**.

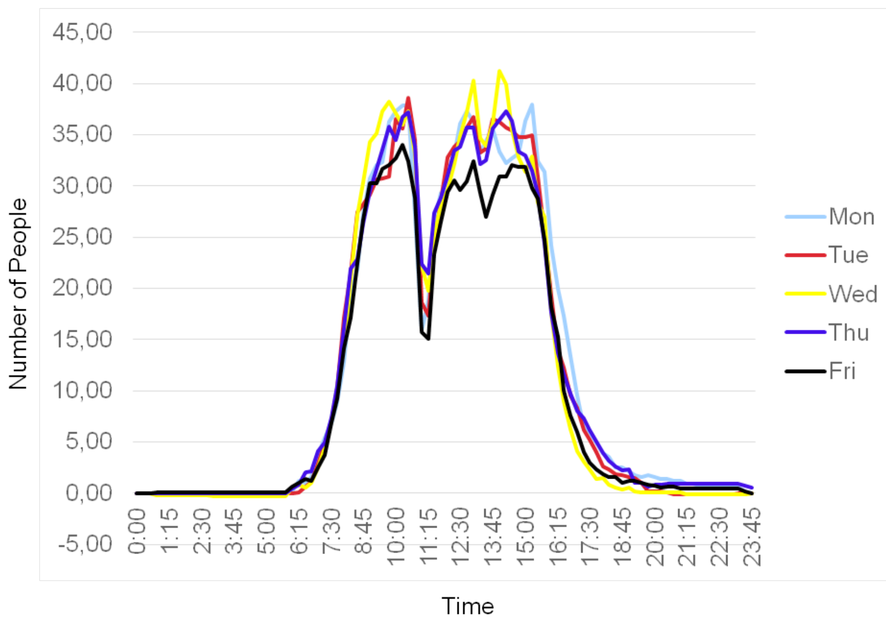


Figure 5. The Average Occupancy Rate for Each Weekday of the Case Study Area.

Energy Consumption for the Day of Peak Occupancy

The collected data also enables the measured occupancy to be compared with the energy consumption of the case study building and this in turn enables the logic of the building management system (BMS) schedules and the overall control strategy of the building's energy consuming systems to be interrogated. By comparing the occupancy curve and the energy consumption curve we can see when energy was consumed and this can be compared to the level of occupancy. This is demonstrated by **Figure 6**. It is important to note that the **Figure 6** shows the percentage that each hour contributes to the total energy consumption for the peak occupancy day. The **Figure 6** also shows the percentage that each hour contributes to the total person hours for that day. For example, it can be seen that 27.4% of the energy is consumed from midnight to 07:00 and 21:00 to midnight when the area is unoccupied and 34.1% of the energy is consumed from midnight to 07:00 and 19:00 to midnight when the occupancy rate is less than 1% of the total person hours per day.

The breakdown of the energy consumption suggests that the heating consumption is relatively steady over the course of the whole day and this can be explained by a background heating demand in the night-time and a moderate load in the day-time as the internal gains from people, equipment and lighting assist the heating of the building. The electricity consumption has been subdivided into lighting, small power, ventilation and cooling and the comparison of these consumptons with the level of occupany may be seen in **Figure 7**.

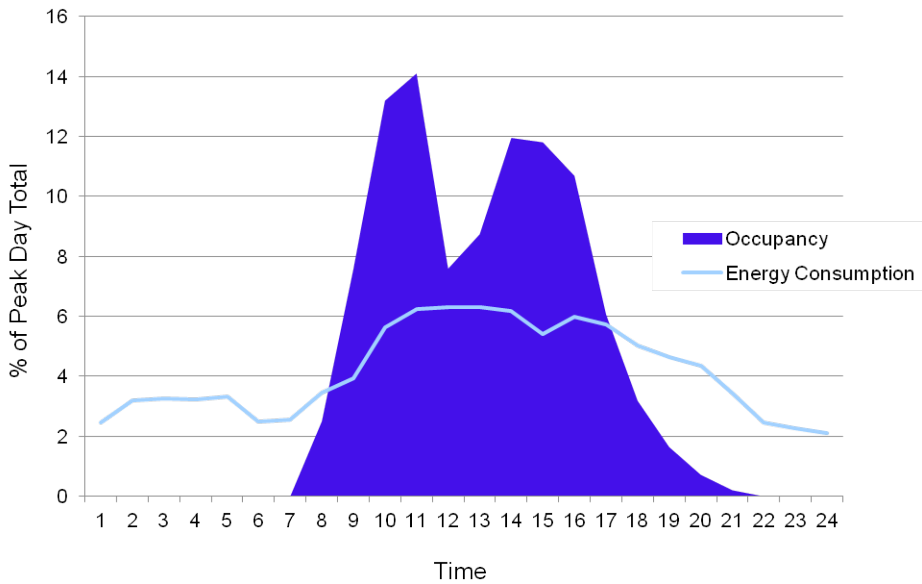


Figure 6. The Proportion of Total (Heating and Electricity) Energy Consumption and the Occupancy Rate for Each Hour of the Peak Occupancy Day.

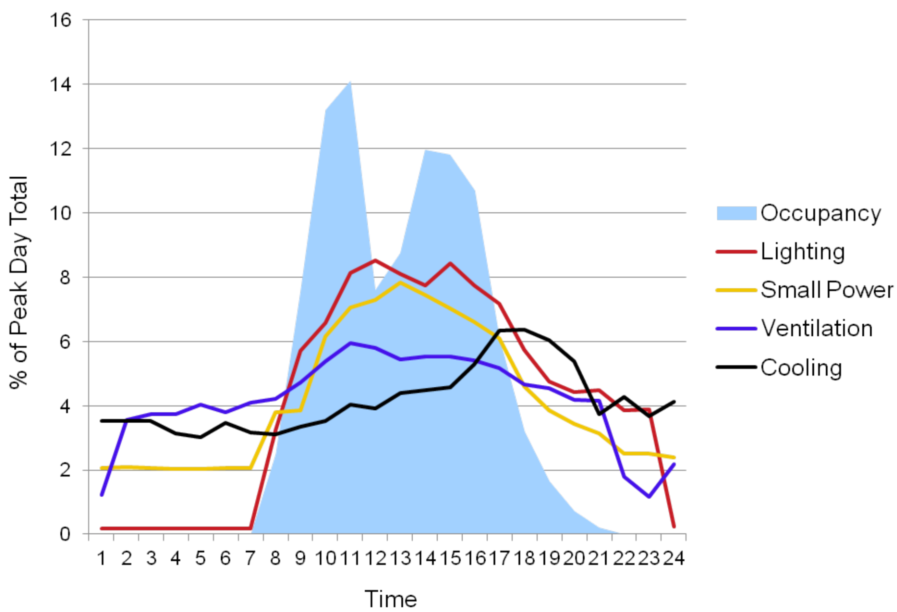


Figure 7. The Proportion of the Electrical Energy Consumption and the Occupancy Rate for Each Hour of the Peak Occupancy Day.

From the evidence provided by **Figure 7** it can be deduced that the lighting control systems are suitably configured in the morning (00:00-07:00) but less so in the night-time (21:00-00:00). Also there is surprisingly high small power load, ventilation and cooling load outside of the buildings operational hours (06:00-22:00). It is typical to heat buildings at night-time but it can be expected that the electrical loads are easier to switch off outside the operational hours. Furthermore, if we apply the same comparison to the electrical consumption that was done to the energy consumption above we see that: 23.7% of the electrical energy is consumed from midnight to 07:00 and 21:00 to midnight when the area is unoccupied and 31.6% of the electrical energy is consumed from midnight to 07:00 and 19:00 to midnight when the occupancy rate is less than 1% of the total person hours per day.

Workplace Arrangement Strategy and Energy Consumption

The desk sharing workplace arrangement strategy of the open office area provided enough desks for 54 of the 66 staff and as a result the office space can assumed to be 18% smaller than if a desk had been provided for each employee. A dynamic energy simulation was used to compare the energy consumption implications of optimising the number of desks in office areas. In all, the energy consumption of three alternative open office areas were simulated. The first office area was 644 m^2 and represented the scenario where each member of staff was allocated a desk and the second office area was 527 m^2 and represented the studied open office area with 54 desks. The final simulation concerned an office area of 429 m^2 which represented the scenario where the number of desks matched the measured peak occupancy of the open office area which was 44 people. The energy consumption of all three areas can be seen in **Table 1**.

Table 1. The Energy Simulation Results for the Open Office Area.

Simula-tion	Number of Employees	Number of Desks		Area		Annual Energy Consumption	
#	#	#	(%)	(m^2)	(%)	(MWh)	%
1	66	66	100	644	100	85.6	100
2	66	54	82	527	82	73.2	86
3	66	44	67	429	67	59.6	70

The results show that optimising the size of the occupied area has a substantial impact on energy consumption. The current policy of providing 54 desks for 66 people has reduced the energy consumption by 14% compared to the calculated energy consumption of the traditional one desk per person strategy. However, our calculations show that the energy consumption could be reduced by a further 16% if the number of desks were to match the measured peak occupancy.

Conclusion

The original objective of this study was to explore if occupancy data can assist the implementation of resource efficiency and energy efficiency strategies in existing buildings. It is acknowledged that the data is difficult to obtain, however, it was demonstrated that usage patterns are an important factor in understanding the energy consumption of a building.

It has been shown that daily occupancy curves add valuable information regarding the control strategies of the energy using systems in office buildings. The case study building is open from 06:00-22:00 and it is important to understand if the building is occupied for the whole day. It is clear that the building is very likely to be occupied from 09:00-17:00 but without occupancy data it is impossible to accurately know the occupancy rates at the beginning and end of the day. The schedules of the energy consuming systems can be optimised based on the collected data. It is common place for the energy consuming systems to have schedules but maybe the spaces could have schedules too. New workplace arrangement strategies are emerging all the time and they are being driven by the rise of remote working and new hot desking strategies such as coworking. In offices that practice desk sharing it can be assumed that all employees have laptops and can sit at any desk. With this in mind one future area of research shall be to examine the benefits of gradually shutting down the building. For example instead of having the whole building open from 06:00-22:00, two of the three floors could be shut down from 18:00 onwards as at this time the occupancy rate is less than 10% of the peak occupancy.

The peak occupancy rate of the individual building areas is also a valuable piece of information and in a building with desk sharing it can be used to calculate the minimum number of workplaces that should be available. The fact that only providing 44 desks for 66 employees reduces the energy consumption by 30% shows that the amount of area that is reserved is a key driver in the energy consumption of offices. Resource efficient workplace arrangement strategies that focus on space optimisation reduce costs associated with rent and energy and also reduce the environmental impact of buildings through energy reduction and through the reduced need for new buildings.

Another emerging strategy is to rent out unused spaces in commercial buildings to the public via sharing economy websites which essentially act as the AirBnB of commercial buildings. There are already a number of these websites such as Eventup, Splacer, Venuetastic, Venuu, and Flextila. Occupancy data can show the building managers when their spaces are empty and thus are available to be offered online.

One clear limitation of this study was that the area in which occupancy was measured was a small portion of the case study building. If the occupancy of the whole building could have been measured then the energy consumption of the studied area could have been more accurately calculated. The small case study area also contributed to the weekend occupancy being difficult to measure. It was observed that the daily energy consumption at the weekend is approximately 30% of typical weekday total and it is estimated that the peak occupancy is less than 5% but the occupancy could not be accurately calculated. Further studies are required to understand the strategies that could be employed in order to reduce the environmental impact of the weekend days as the building must be able to operate as normal but that occupancy rates are very low. ■

Acknowledgements

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Long-term monitoring of the thermal environment in office buildings

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Keywords: Indoor Climate Quality Performance, long-term monitoring, open-plan work environments, building management system

Abstract

Existing guidelines on monitoring of Indoor Climate Quality (ICQ) do not adequately address long term monitoring. A better understanding of the collection and analysis of monitored data, extending over a long-time period is required. This study aimed at addressing the aforementioned research gaps. The study took place in two office buildings, during two periods each: February & May (case I) and April & June (case II). Thermal environment data was obtained across several locations in the room. Results showed that measurement of temperature was most critical in the open-plan office floors. Local heat sources had a significant influence on the measured temperatures. To collect representative data with the help of building management system (BMS) sensors, existence and fluctuation of local heat sources should be considered at the start of the ICQ assessment. Based on this information, the minimal distance between BMS sensor and workplace location can be determined. In the design process, the field study protocol can be used as a tool to predict the number of sensors and distance from occupants.

Recent studies have put focus on the importance of monitoring buildings during their operation and maintenance phases [1–4]. The body of data obtained through such monitoring provides essential information about a building's energy consumption and Indoor Climate Quality (ICQ) and can be used to control and optimize its performance [1–3,5]. The accuracy and applicability of the conclusions from the gathered data depends on the quality of the data (reliability) gathered and data interpretation (data-analysis) [6]. Compared to energy consumption and service control, ICQ monitoring is less addressed. Current standards like ISO 7730 [7], NEN-EN 15251 [8], ANSI/ASHRAE standard 55 [9] and Dutch ISSO guidelines also do not provide details for long-term ICQ monitoring [6,10–12]. Drawing uninformed conclusions during monitoring and analysis may affect the comfort perception, well-being, and productivity of occupants [8,12–14] and building energy use [6,8,15]. Reliability of the ICQ data is strongly dependent on sensor location. Sensor location is usually chosen in accordance with guidelines, as from ISSO publication 31 [16]. However, such guidelines are cursory, making ICQ assessment at a detailed level a topic in need of comprehensive investigation. For this reason, the current work investigates the influence of the location of the building management sensor on its measurement and recommendations were formulated for long-term monitoring needs.

Method

Case studies

Indoor climate of two existing open-plan offices in the Netherlands were monitored, during two periods each (**Table 1**). Both environments are ventilated, cooled and heated by an induction system and regulated by one BMS sensor located on the wall (at 1.5 m height from floor). The BMS sensor records indoor temperature and relative humidity every five minutes. Data from the BMS sensor is analysed with the help of a data platform [17]. In both case studies is the data platform developed by the same company, to oversee buildings remotely and to optimize their maintenance. In both locations, occupants have the possibility to effect small changes to air temperature by local thermostats and are able to avoid direct sunlight by using indoor sunscreens. There was no outdoor sun protection.

Objective measurement

Indoor climate data from different locations in the open-plan work environment was collected and compared with the data from the data platform to assess differences in ICQ over the whole floor. The measurement locations have been given in **Figure 1** and **Figure 2**. At the start of the measurement period, the measurement equipment was calibrated and the BMS sensors' measurements were compared against the calibrated equipment to avoid discrepancies.

Objective measurements were undertaken at three levels: room level, local level and micro level (**Figure 3**). The room level gave insight to the overall conditions of the room and was measured with the help of two kinds of sensors: 'BMS sensor' and 'room sensor'. Room level sensors were placed according to the Dutch guidelines [16,18]. At this level, air temperature, relative humidity and CO_2-concentration were determined every 2 minutes using transmitters (**Table 2**). Since the recorded air temperature may be affected by radiant sources and may not provide a measure of solely the air temperature, we refer to the measured values as *'exposed temperature'* (ET).

Table 1. General information about the case studies. (Measurement period 1 and 2 are defined as M1 and M2).

Case	Year of construction	Location	Surface area [m²]	Max. # occupants	Parameters BMS sensor	M1	M2
Case A	2010	Son	~140	41	-Exposed temp	Feb	May
Case B	1956 (renovated: 2007-2009)	's-Hertogenbosch	~620	68	-Exposed temp -Relative humidity	Apr	Jun

Table 2. Overview of the measurement equipment.

Measurement	Device	Type	Accuracy	
Room level & Local level	T/RH/CO_2 sensor	Eltek GD47 Transmitter	Temp.	± 0.4°C (–5°C to 40°C)
			RH	± 2°C (10% to 90%)
			CO_2	25°C: 0 – 5000 ppm < ± 50 ppm + 3% of measured value. Temperature dependence: 2 ppm $\frac{CO_2}{°C}$ over the range 0 to +50°C
	Data logger	Grant SQ 1000 series	–	± 0.1 of reading
Micro level	iButton	Maxim DS1921	Temp.	± 0.4°C (15°C to 46°C)

Local level thermal conditions around workstations were measured in the same way as the room level. At this level, the sensors (GD47 transmitter) were placed near each workplace group, at a height of 1.1 m above the floor. Micro level measurements focused on individuals, i.e., the thermal condition around a person. On each measurement day, four to six of the participants who had volunteered to be a part of the study were selected to represent random location on the floor-plan. IButtons (DS1921, Maxim) were placed next to the chair of the participant, where they recorded ET every minute. The best location for the iButton was explored through a set of preliminary measurements to limit the influence of the body heat.

Data-analysis

The collected data was collated using Matlab (R2016b). IBM SPSS Statistics 23 was used for statistical analysis. Only data corresponding to working hours (8:00 AM-06:00 PM) was processed. Preliminary analysis

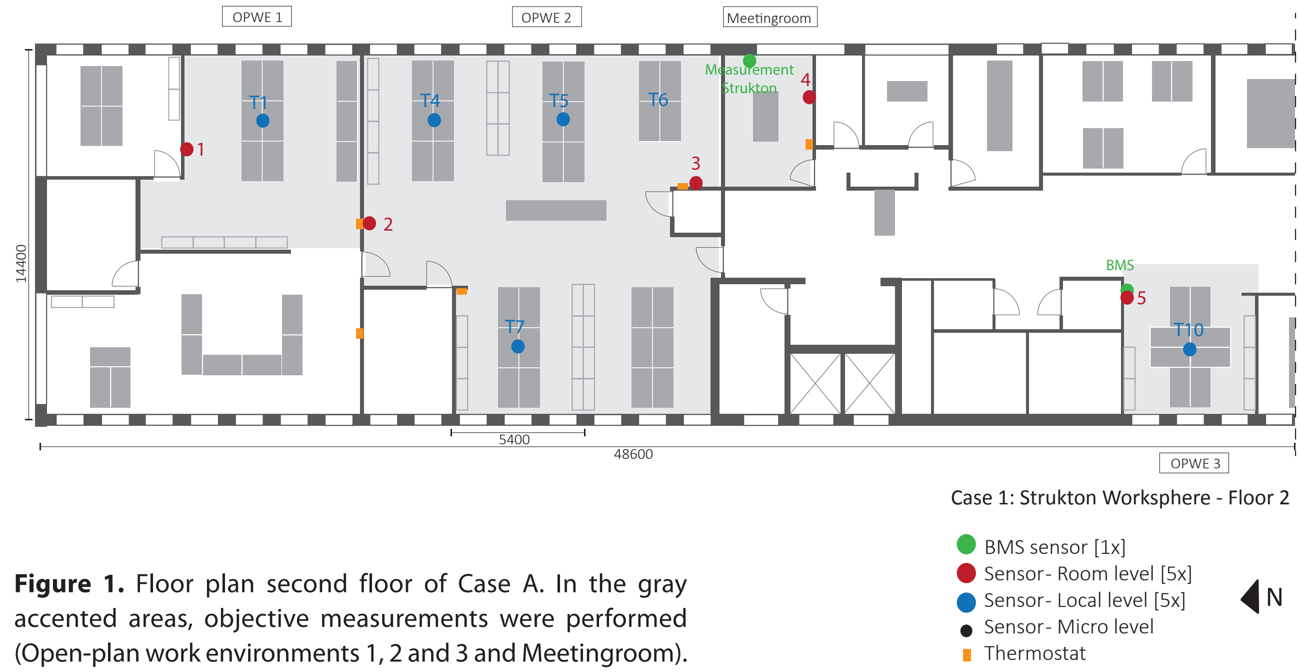


Figure 1. Floor plan second floor of Case A. In the gray accented areas, objective measurements were performed (Open-plan work environments 1, 2 and 3 and Meetingroom).

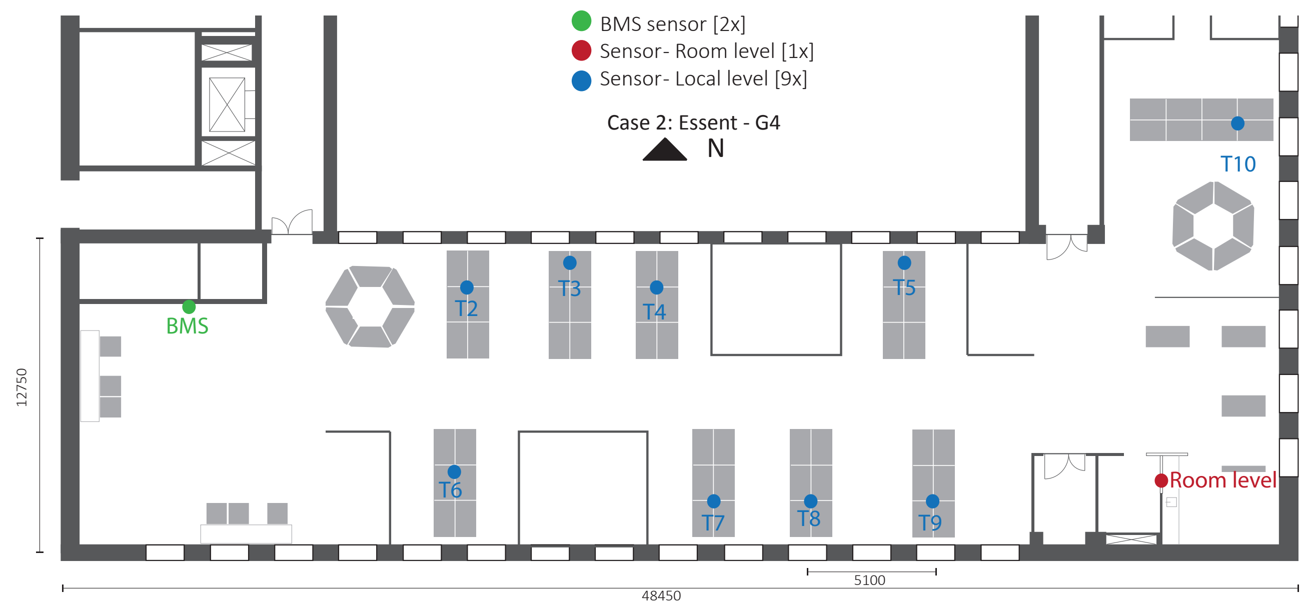


Figure 2. Floor plan for observed area of Case B. The BMS sensor is located in the left corner. An extra room sensor was placed on the right side of the floor. The sensors at local level are illustrated in blue.

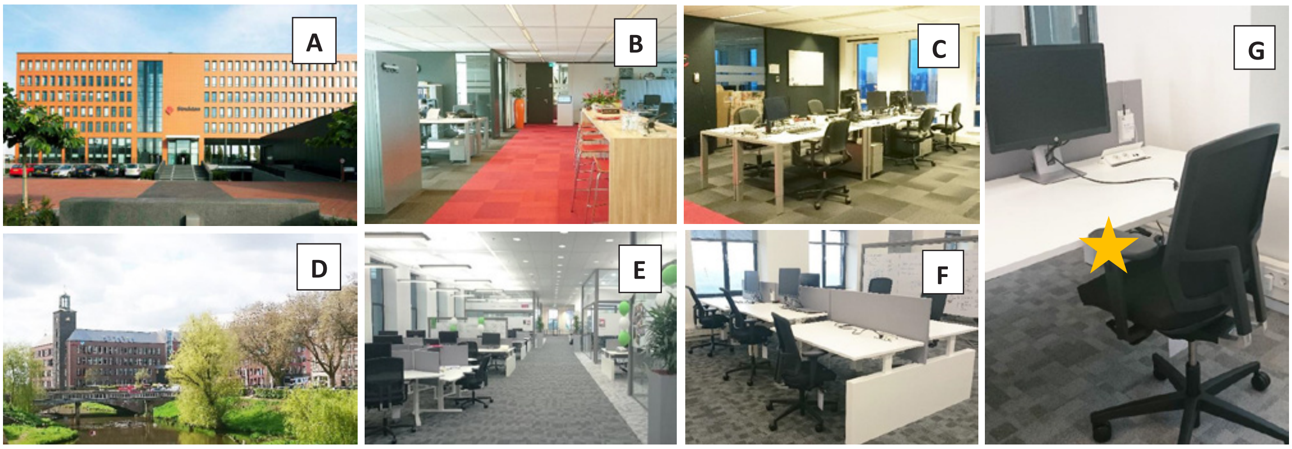


Figure 3. Images from Case B (a-c) and Case A (d-f), depicting the buildings and the different localities of monitoring: b) & e) room level, c) & f) local/desk level. The micro environment for temperature measurements is depicted in g) where the star marks sensor location.

showed the indoor conditions did not correlate with outdoor weather conditions, and hence observations for both periods were analysed together. The two buildings were examined separately. Statistically significant differences were examined with the Mann-Whitney U test. Significance was tested at 5% level. Correlations were determined by the *'Pearson product moment correlation'*.

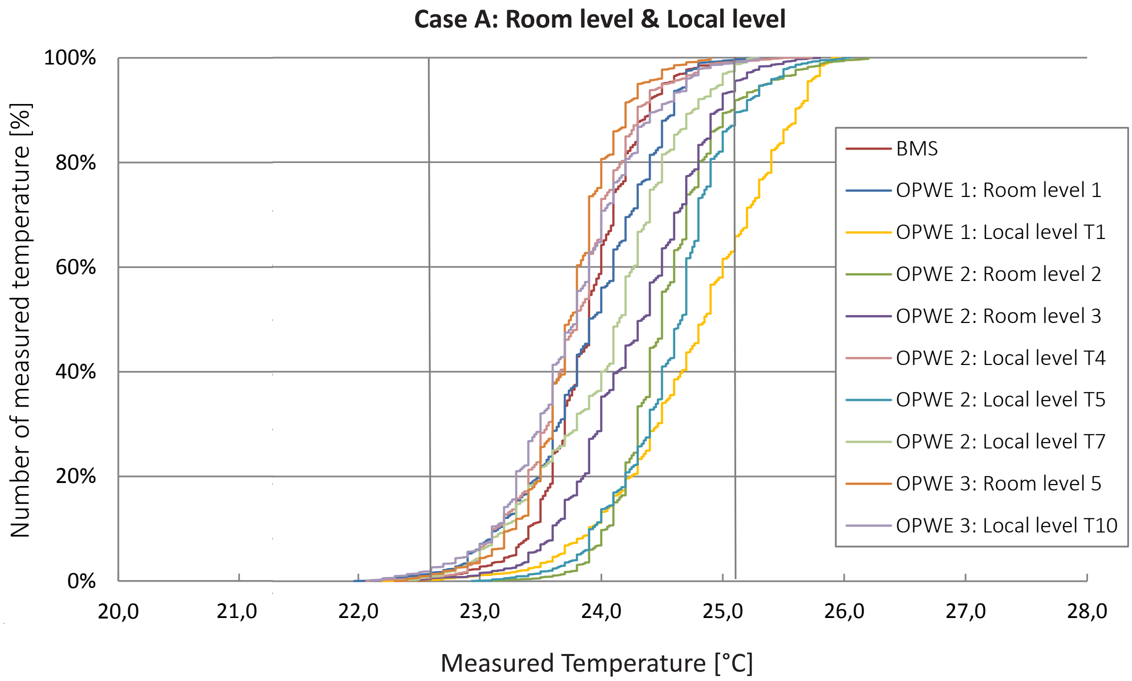
Results & Discussion

BMS data in relation to data at room level, local level and micro level

Data from room, local and micro level were compared and linked to the BMS data. In both case studies, differences in CO_2-concentration and relative humidity between the room sensor and local sensor were relatively small and no practically significant difference between the measured values could be found. Based on these results it may be concluded that the original BMS sensor location could provide representative data related to the CO_2-concentration and relative humidity for the examined open plan spaces.

However, variation of ET through the open-plan work environments was significant. The results have been plotted in cumulative frequency distribution (CFD) graphs (**Figure 4**). Differences between sensors are smaller when data behaves in a similar pattern and plotted lines had a similar temperature range. In the best case, the difference between the BMS data and the rest of the monitoring levels are limited, so that BMS data is representative of the local conditions.

For most cases, the local ET exceeded BMS measurements by 1°C or more. The only exception was for OPWE 3 at Case A (**Figure 1**). We believe the differences in the ETs were mainly due to local heat sources, for example, the occupants, computers, and solar radiation through windows. Therefore, the distance between BMS sensor and workplaces is important when it comes to reliability of the measurements. In both locations, the BMS sensors were more than 3 m away from occupied workplaces. When distance between room level and local level sensors were less than 3 m, the differences in recorded ETs were minimal. For instance, in OPWE 3 of Case A, the BMS sensor was within 2 m of the work stations. No significant difference could be found between the ETs at local level and BMS. The impact of the distance between sensors is clarified using correlations between the BMS, room, local and micro sensors.



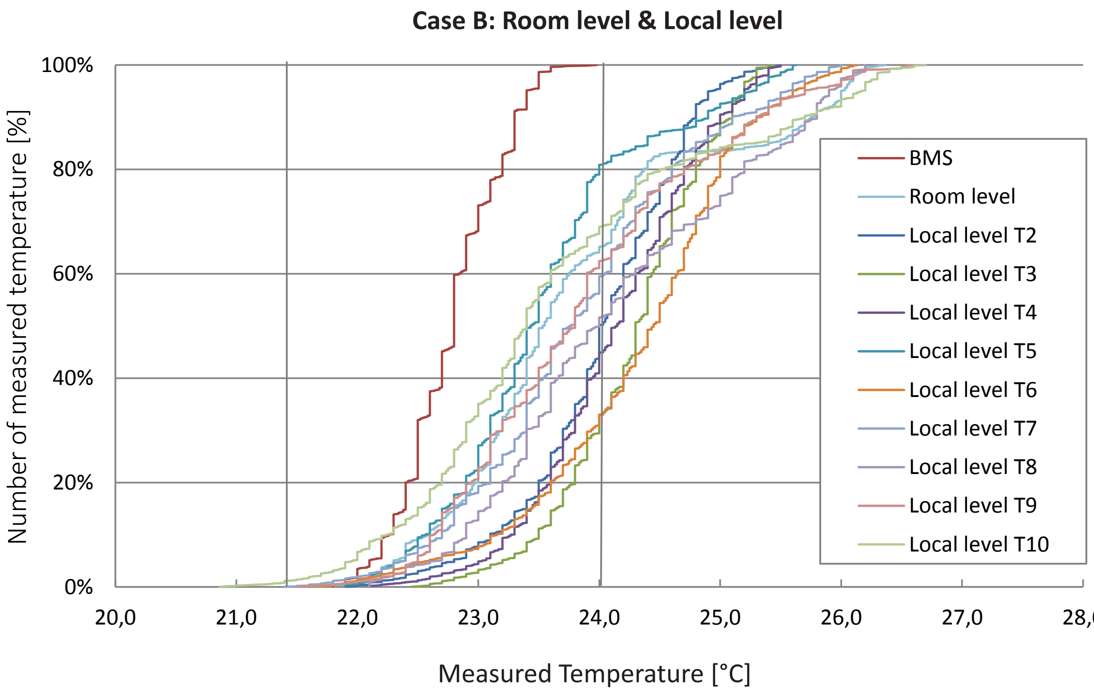


Figure 4. CFD-graph from room level (top) and local level (bottom) of Case A & Case B. The graph shows the distribution (smallest to largest) and frequency temperature range of each sensor. The temperature range of the BMS sensor is illustrated with the vertical lines.

Table 3 and **Table 4** show the correlations for both case studies. In Case B, larger distance between sensors resulted in weaker correlations (**Figure 5**). Better correlation may thus be achieved between local and BMS ETs by using a larger number of BMS sensors, spread across the open plan workspace. Notice for example in **Table 3** that the room sensor position has a stronger correlation with local & micro level than the BMS position. Thus, a minimum number of BMS sensors are required in order to have a representative indication of the ICQ.

For Case A, because the floor has been divided into multiple spaces (OPWE 1, 2 & 3 and Meeting room) the situation was different. Regardless of the distance between sensors, the sensor located in a different space always had a weak correlation with the BMs sensor ($r < 0.306$, $p < 0.05$) (**Figure 6**). To collect representative thermal data in Case A, a BMS sensor would be required for each space. Adding extra room sensors increases the strength of the correlations in both cases, where the closest room sensor has the strongest correlation with the relevant local and micro sensor. Overall, ET at room level (BMS sensor and room sensors) was better correlated to ET at local level than the temperature at mirco level.

The relation with micro level was more complex. Only 65% of the correlations (local with micro) were of a high enough value (**Table 3 & 4**). Due to the large differences in micro ET for each table and each person, no reliable relationship or trend could be found. Accurate measurements at micro level are dependent on several parameters. For instance, the activity of the person sitting in the chair, the position of the chair and distance to local heat sources can be important information to explain differences in micro measurements.

Objective data collection

Though quantitative conclusions from this study are case specific, certain qualitative conclusions regarding objective data measurement for indoor climate quality

Table 3. Pearson product moment correlation BMS-Room-Local-Micro (Case B) for four local situations, here $p < 0.001$. The distance between sensors has influence at the strength of the correlation (T4 strongest correlation with the BMS sensor, T10 weakest correlation). Moreover, a weaker correlation is found on the south side of the floor plan, due to solar radiation (T6).

Table	BMS senor		Room sensor		Local sensor	
T4	BMS ~ Local T4	0.847	Room ~ Local T4	0.717		
	BMS ~ Micro T4	0.434	Room ~ Micro T4	0.685	Local T4 ~ Micro T4	0.755
T6	BMS ~ Local T6	0.687	Room ~ Local T6	0.678		
	BMS ~ Micro T6	0.512	Room ~ Micro T6	0.655	Local T6 ~ Micro T6	0.624
T8	BMS ~ Local T8	0.657	Room ~ Local T8	0.881		
	BMS ~Micro T8	0.634	Room ~ Micro T8	0.704	Local T8 ~ Micro T8	0.868
T10	BMS ~ Local T10	0.095	Room ~ Local T10	0.891		

Table 4. Pearson product moment correlation BMS-Room-Local-Micro (Case A) for three local situations. Here $p < 0.001$.

Table	BMS senor		Room sensor		Local sensor	
T1	BMS ~ Local T1	0.306	Room ~ Local T1	0.855		
	BMS ~ Micro T1	0.401	Room ~ Micro T1	0.357	Local T1 ~ Micro T1	0.352
T5	BMS ~ Local T5	0.267	Room ~ Local T5	0.728		
	BMS ~ Micro T5	0.279	Room ~ Micro T5	0.479	Local T5 ~ Micro T5	0.492
T10	BMS ~ Local T10	0.955	Room ~ Local T10	0.941		

monitoring may be provided. In order to have a representative indication of the ICQ, the maximum distance between sensors should be considered during design of the monitoring system. The number of sensors depends on the floor plan design specifically, obstacles and boundaries. The number of sensors can be optimized by test measurements on different measurement levels.

The spacing of sensors can also be affected by local heat sources as they can influence the ET. If local heat sources, such as occupancy and solar radiation, are relatively consistent, CO_2-concentration, relative humidity, and ET can be determined at room level with a distance of 3 m to the workplaces, assuming the ventilation system is effective. Moreover, a higher frequency for recording data would be recommended to register fluctuations in ET. In Case A and Case B, local heat sources cannot be ignored in the comfort analysis due to changing occupancy and lack of outdoor shading. Hence, for these office spaces, BMS sensors need to be placed at a closer distance (< 3 m) to workstations.

Conclusion

This study provides results from field measurements that can aid decision making regarding the position of BMS sensors and the collection of objective data in open-plan offices. Results of the objective measurements show little differences in CO_2-concentration and relative humidity between BMS, room and local sensors. A larger difference is found for ETs. The existing BMS sensors did not yield a representative indication for the complete floor space when it came to ET.

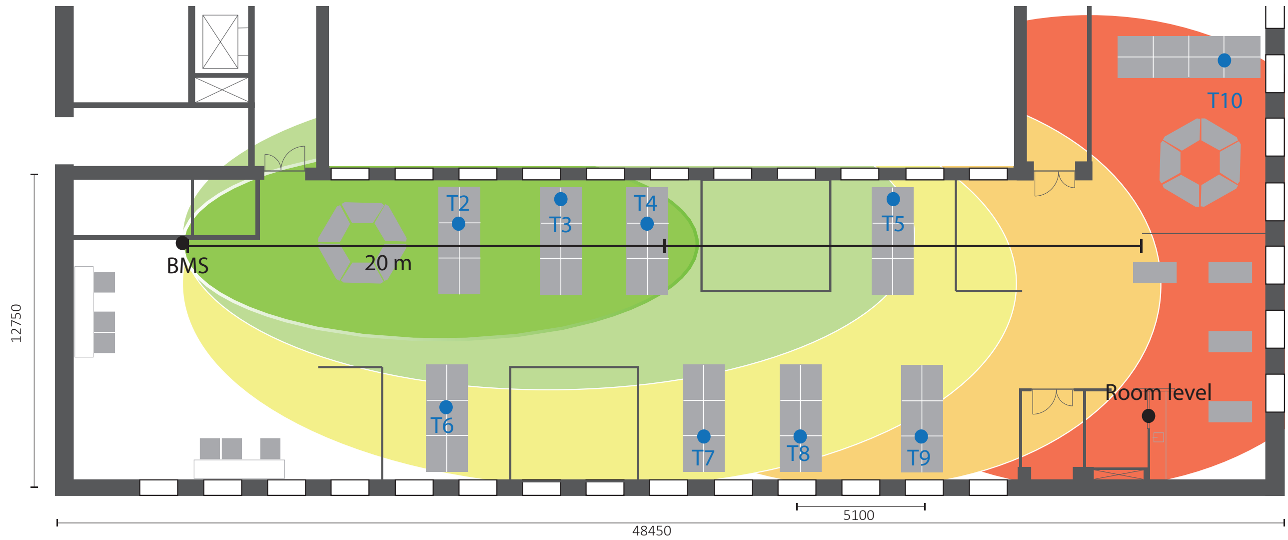


Figure 5. The influence of distance between sensors and solar radiation for the correlation between the BMS sensor and local sensors.

Figure 6. The correlation is weak when sensors are not located in the same room (regardless of the distance between sensors.

Local heat sources and distance between sensors have a significant influence on the measured value of ET. These parameters need to be considered during design of the monitoring system. Floor plan (enclosed spaces, obstacles, and floor area) and the existence and fluctuation of local heat sources influence sensor positioning requirements. The field study protocol as described in this method is useful for determining monitoring level and sensor separation.

As results of this study are based on just two office buildings with an induction system under specific weather conditions, it is recommended to further develop the application of the method in more varied office settings, occupant demographics, and outdoor weather conditions to further the conclusions and recommendations formulated herein. ■

Acknowledgment

Cooperation of all the occupants during the measurements is acknowledged gratefully. Our thanks to Wout van Bommel for the help and cooperation with the field measurements.

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Current Situation and Actions for ZEB in Japan

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This article provides information regarding current net-zero energy building (ZEB) activities, including the ZEB definitions and methodologies in Japan.

Keywords: ZEB, Methodology, Definition, Current activities in Japan, Best practices

This article has been revised to include contents presented at the REHVA Conference held in Brussels in November 2017. Herein, we will introduce the concepts, definitions, and latest trends related to net-zero energy buildings in Japan. Note that definition and evaluation method related to ZEB were released by the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan (SHASE.J), the Subcommittee on ZEB Definition (Chaired by Dr. Hideharu Niwa) in August 2015, and that the Ministry of Economy, Trade and Industry (METI) of Japan issued a national ZEB definition based on the SHASE.J definition in December that same year.

In this report, the latest ZEB trends will be introduced, along with related design guidelines and advanced ZEB practices. In addition, the details of one of the advanced practices will be introduced as an example of the energy saving and renewable energy technologies being used for achieving ZEB. We will conclude this article by reviewing the future prospects for ZEB activities in Japan.

Current situation and methodology for ZEB in Japan

Activities related to ZEB in Japan were launched since the 2008 Toyako Summit [1] held in Hokkaido, after which numerous efforts were made to promote ZEB from global warming and energy conservation viewpoints. Furthermore, in the aftermath of the East Japan Great Earthquake in 2011, ZEB realization came to be recognized as an important task in terms of energy supply stabilization and security concerns.

It has been said that the origin of ZEB in Japan can be found in traditional Japanese houses, such as the one shown in **Figure 1**, which are designed to facilitate a pleasant transition from outdoor to indoor environments, minimize cooling and heating demands, and maximize the use of renewable energy and natural materials. These characteristics can still be considered acceptable measures for ZEB in the present day.

Figure 2 shows an overview of the ZEB design method. These include optimizing both internal and external building environments (1, 2), suppress heating and cooling load by using passive technologies (3, 4), and improving energy efficiency by adopting active technologies (5, 6, 7). Through these efforts, we aim to achieve the ultimate energy saving and furthermore aim to realize ZEB with renewable energy usage (8), and appropriate energy management (9).

ZEB definitions and evaluations in Japan

The characterization of ZEB definition in Japan dates back to 2009 when a qualitative definition was presented by the METI study group on realization and development of ZEB [3]. Thereafter, in August 2015, SHASE.J released its Guideline on ZEB Definition and Evaluation via its ZEB Definition Subcommittee [4], thereby providing a concrete and quantitative definition that reads in part, "*A net zero-energy building is a building that has high energy saving through load reduction, natural energy use and high efficient systems and appliances without decreasing the environmental quality both indoors and outdoors. With the introduction of on-site renewable energies, the on-site energy generated will be equal to or greater than the actual energy consumed within*

Figure 1. Traditional Japanese house "kyo machi ya". [2]

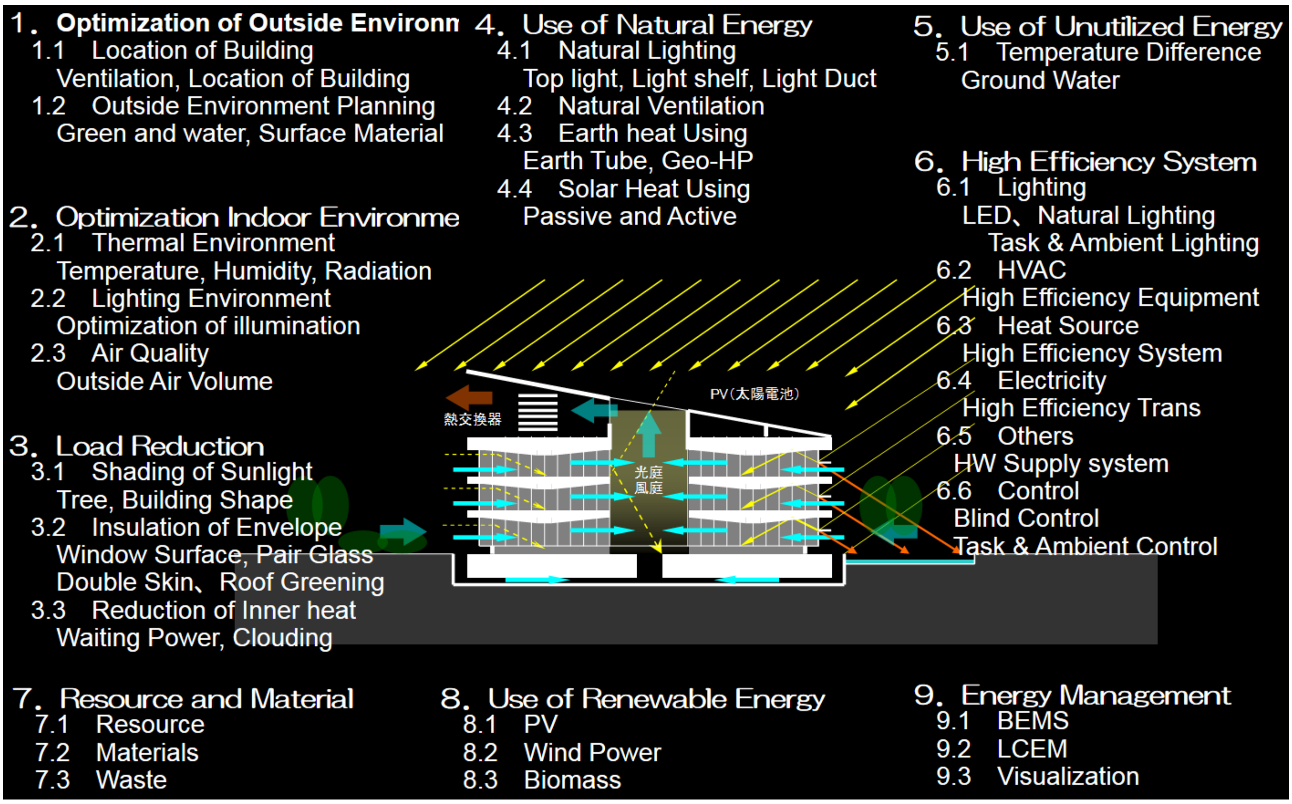
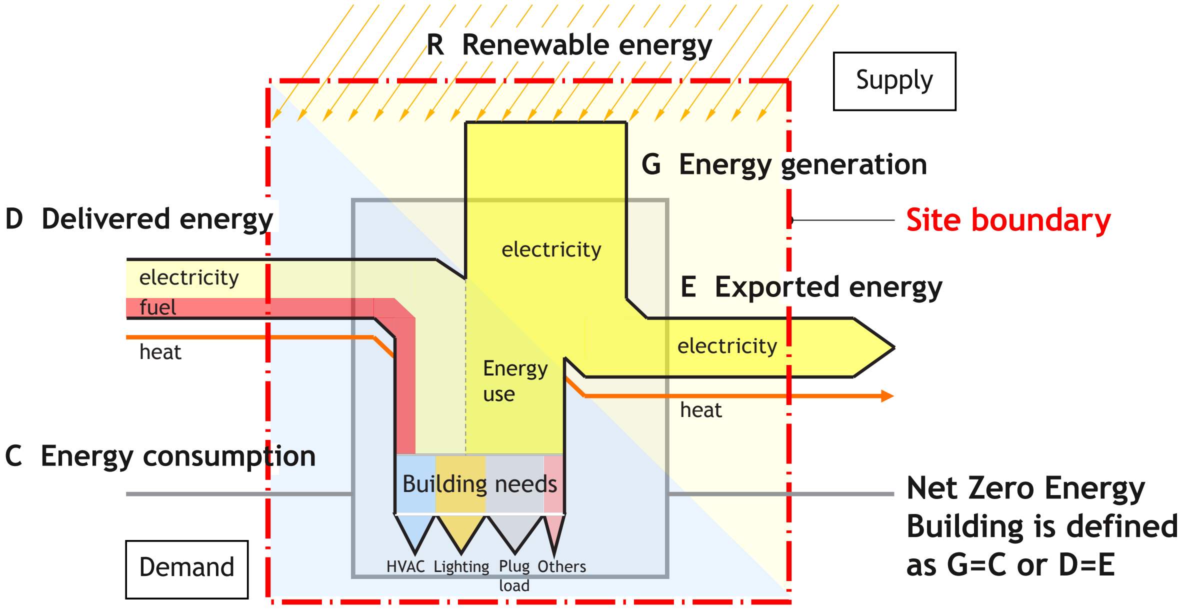


Figure 2. ZEB design methods overview.

the building in the course of a year." A graphical overview of this quantitative definition is shown in **Figure 3**.

ZEB definition boundary conditions, energy performance measurement indicators, and evaluation standards, etc., are also shown in the guideline. In principle, the indicator is primary energy consumption, but carbon dioxide (CO_2) emissions or energy costs can also be used. The primary energy coefficient (conversion factor), which basically follows the regulations contained in the Japan Energy Conservation Act, allows the primary energy coefficient to be set up on a case-by-case basis.

Figure 4 shows the ZEB evaluation method. Depending on degree of energy saving achievement and renewable energy usage, they are ranked as ZEB, Nearly ZEB,



G*: Normalized energy supply = <Energy generation of target building> / <Energy consumption of reference building>
C*: Normalized energy demand = <Energy consumption of target building> / <Energy consumption of reference building>

Figure 3. ZEB quantitative definition.

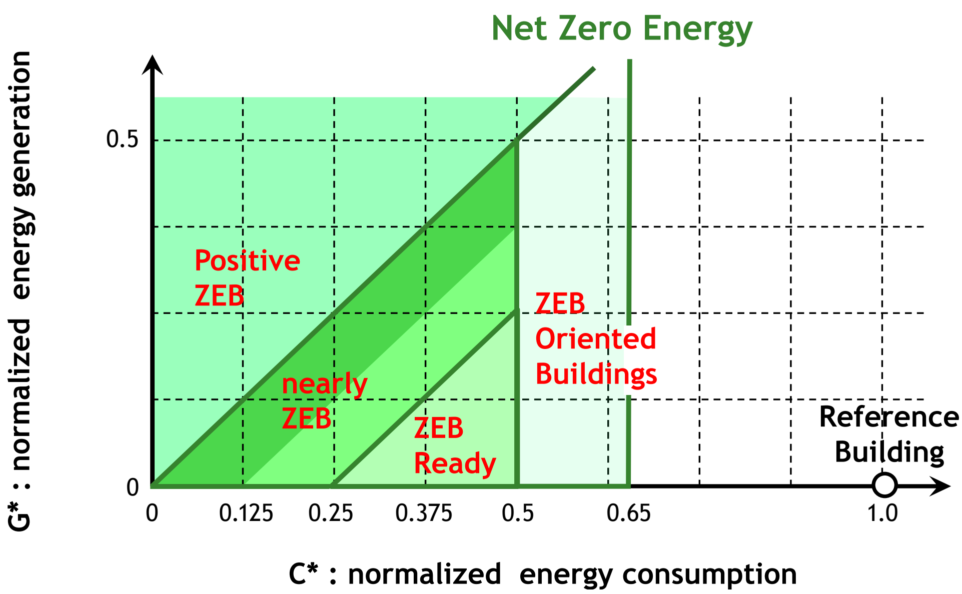


Figure 4. ZEB evaluation.

ZEB Ready, and ZEB Oriented. This guideline contributed to the development of the national ZEB definition issued by METI in December 2015 [5].

Current ZEB activities in Japan

The Japanese government aims to achieve ZEB with regard to new public building by 2020 and with regard to all new buildings on average by 2030 [6]. To facilitate these goals, the government has conducted various policy development activities including formulating the ZEB roadmap [5] shown in **Figure 5**, developed demonstration projects, and published a design guideline [7][8] shown in **Figure 6**.

Regarding the ZEB road map, distinctions were made between government and private organization promotion projects instituted to achieve ZEB status. To date, ZEB design guidelines for small offices, large offices, hospitals, and supermarkets have been published, but other facilities will be added in the future.

SHASE.J, which has made an overwhelming commitment to spreading ZEB activities in its 21st century vision [9], has published ZEB advanced case collections [10], has been developing ZEB design methods, and trying to make cooperative research with REHVA.

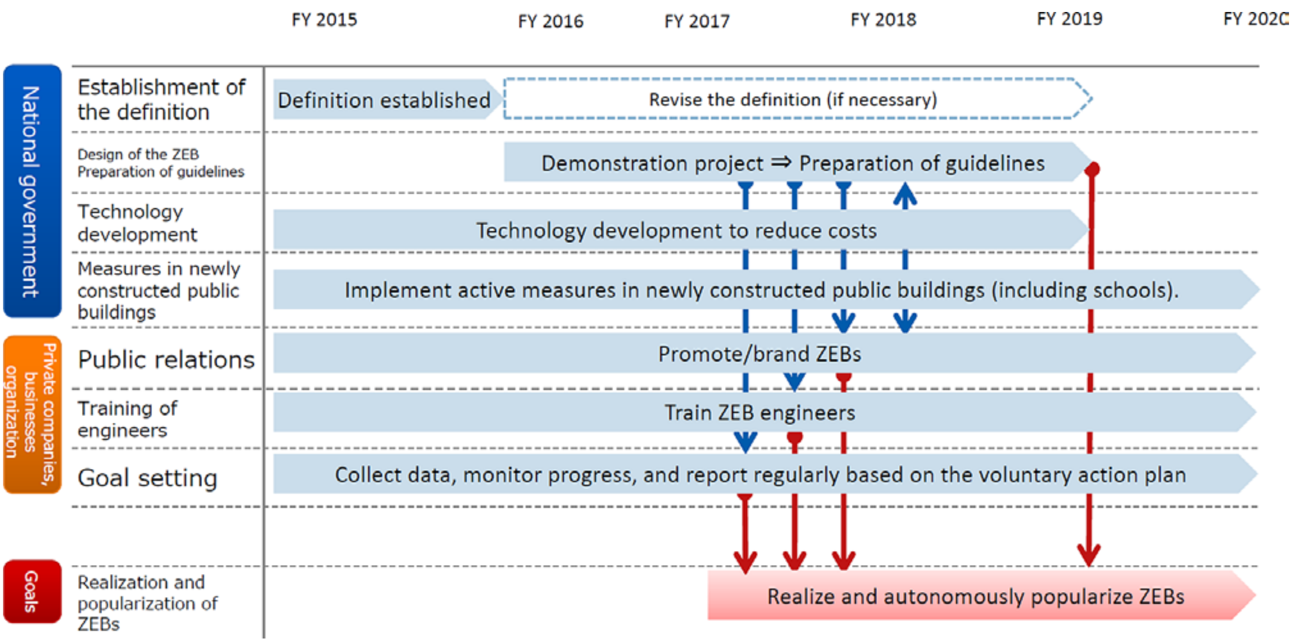


Figure 5. ZEB roadmap.

Figure 6. ZEB design guideline.

Figure 7 shows the ZEB advance case collections published by SHASE.J. Since Japan has both high temperature and high humidity climates, both cooling and heating demands are required. A previous study has shown that while a three-story office building can achieve ZEB, it is difficult to accomplish this for buildings having more than three floors.

In the above-mentioned case collection book, 14 advanced buildings are introduced, and various effective approaches under Japan climate conditions are presented. These examples are organized under the ZEB definition and evaluation methods formulated by SHASE.J. The major usages presented are office, research, and education facilities. Of the 14 building examples, 11 are new constructions and three are renovations. A total of four of the 14 buildings have actually been ranked as ZEB.

Figure 8 shows the Taisei Corp. ZEB demonstration building, while **Table 1** shows an outline of the building. This office building, which is listed in the "Zero Building Advanced Case Collection", has achieved 76% energy saving and 27% energy generation. As a result, it is actually ranked as a "net Plus Energy Building". The main energy saving technologies are its "T-Light Cube" day-lighting system and its task ambient systems for lighting and air-conditioning. The air-conditioning system uses the wasted heat exhausted from a fuel cell. For energy generation, newly developed organic thin film photovoltaic (PV) modules were mounted on the walls.

Figure 8. ZEB Best Practice example (Taisei Corp.).

Table1. Building outline.

Location	Yokohama city, JAPAN
Building type	Office
Total floor area	1,277.32 m^2
Number of floors	3 floors, 1 penthouse floor
Completion	June 2014
Certification	CASBEE S rank, BELS ★★★★★ (five star), LEED-NC platinum

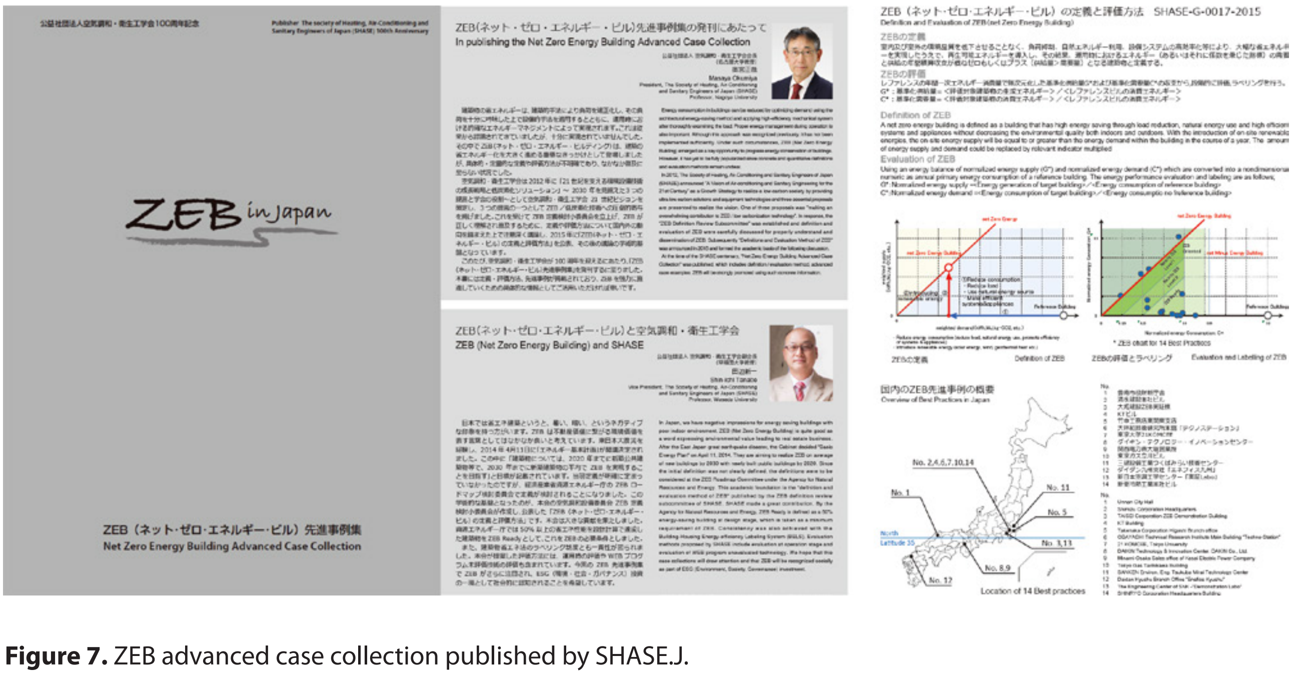


Figure 7. ZEB advanced case collection published by SHASE.J.

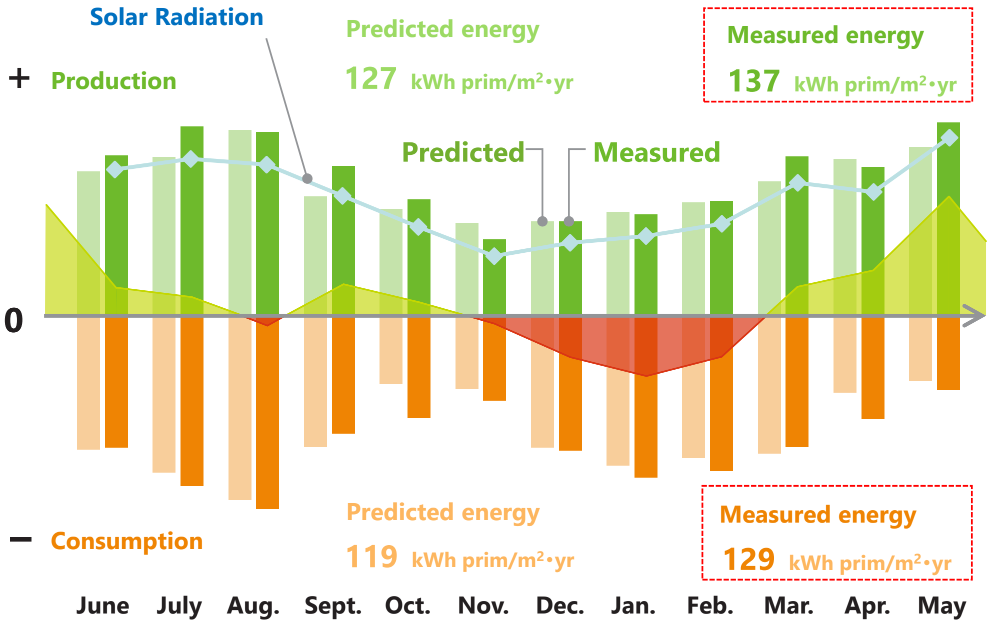


Figure 9. Annual primary energy balance.

Figure 9 shows the energy balance for one year following the building's completion. The annual primary energy consumption was 129 kWh/m², while the generated energy was 137 kWh/m². Thus, ZEB status has been realized.

Conclusion

In Japan, the importance of ZEB realization has been increasing from the viewpoints of global warming, energy conservation, and energy security. Since the definitions and evaluation methods were announced in 2015, various policies and measures have been instituted aimed at spreading and promoting ZEB buildings. In order to further facilitate these goals, in addition to cost reductions and further technology developments, increasing the social value of ZEB will be of paramount importance. ■

Acknowledgments

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MLIT: Ministry of Land, Infrastructure, Transport and Tourism

MOE: Ministry of the Environment

GIFT ONE Tower

India's First District Cooling System at GIFT City

District cooling system is a well known and energy efficient technology adopted across the world. District cooling system has been implemented in India for the first time at Gujarat International Finance Tec-City (GIFT City). The first phase of this District cooling system with a capacity of 10,000 TR is in operation since April 2015.

Keywords: GIFT City, District cooling, chilled distribution network, energy transfer station, stratified thermal energy storage tank, diversity factor, utility tunnel

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GIFT City

GIFT City is India's first globally benchmarked International finance service centre (IFSC), developed by the Government of Gujarat through a joint venture company named Gujarat International Finance Tec-City Company Limited. GIFT City is a global financial and IT services hub, a first of its kind in India, designed to be at par with or above globally benchmarked financial centres such as Shanghai, La Defense – Paris, London, Hong Kong, Singapore, Dubai, etc. It is being developed on 886 acres (359 hectares) of land comprising of a multi services Special Economic Zone (SEZ) with IFSC and a domestic finance centre.

GIFT City has developed the first phase of world class infrastructure facilities such as:

- District cooling system (DCS),
- Automated waste collection system (AWCS),
- Underground utility tunnel,
- Availability of electricity from two different substations (ensuring 99.999% electrical power availability).

Such quality and magnitude of infrastructure is being implemented for the first time in the country.

Figure 2. Master plan of GIFT City.

District Cooling System

District cooling system (DCS) distributes thermal energy in the form of chilled water from a central source to multiple buildings through a network of underground pipes for use in space cooling. The cooling or heat rejection is usually provided from a central cooling plant, thus eliminating the need for separate systems in individual buildings.

District cooling system is known as District heating system when used for heating in colder countries. District cooling or heating systems are widely used across the globe.

DCS consists of three primary components (**Figure 1**).

1. The central cooling plant.
2. The chilled distribution network.
3. The consumer system or energy transfer station.

The *central plant* generates chilled water with compressor drive chillers or absorption chillers. Large size centrifugal chillers with higher efficiency are usually installed to take advantage of the economies of scale. Apart from energy efficient chillers, the central plant consists of chilled water pumps, cooling towers with condenser water pumps, thermal energy storage tank, electrical power distribution system and control system for centralized automation and control of equipment.

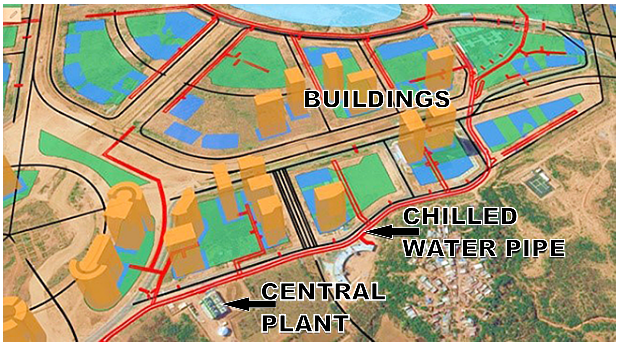

Figure 1. District cooling system components.

The *distribution network* consists of pre-insulated chilled water supply and return pipes. These pipes are either buried or in underground trenches.

The *consumer system* or energy transfer system (ETS) consists of heat exchangers, tertiary circulation pump, chilled water piping in buildings, AHUs and the air distribution system. The heat exchangers exchange thermal energy between DCS chilled water and building chilled water.

DCS Adoption at GIFT City

GIFT City has been developed on 886 acres of land with a total built up area of 62 million square feet, and includes commercial buildings, residential buildings, social buildings such as hotel, club and malls, and a hospital. The overall area is divided into three zones based on functionality.

- Domestic tariff activity (DTA),
- Special economic zone – processing area (SEZ – PA),
- Special economic zone – non-processing area (SEZ – NPA).

Figure 2 shows the master plan of GIFT City.

The estimated air conditioning load requirement for these developments will be about 270,000 TR, which requires electrical power demand of 240 MW for the air conditioning load only, considering each building with its own plant.

A feasibility study was carried out between various available systems, and District cooling system (DCS) was finalized considering the following salient advantages:

- High efficiency system – lower energy consumption,
- High diversity,
- Better reliability,
- Lower space requirement at building level,
- Reduced noise and vibration at building level,
- Lower operating and maintenance cost for the centralized facility,
- Lower electrical demand for individual building.

Based on these features, GIFT City has been planned with DCS. The plant capacity requirement will be 180,000 TR considering a suitable diversity factor for development of 62 million square feet built up area for various developments. This brings down the electrical demand to 150 MW. The total requirement of 180,000 TR for the city will be met with three plants of 60,000 TR located such that the distribution network can be optimized.

Each plant has been designed with chilled water based stratified thermal energy storage tank, which can be charged during off-peak period and discharged during peak period, thus bringing down the chiller capacity to 150,000 TR and also reducing the electrical demand to 135 MW only. Thus, electrical demand reduction from 240 MW to 135 MW has been achieved with the help of District cooling system. In line with electrical power requirement, makeup water would also reduce. **Figure 3** shows a graphical representation of this.

Based on the above study, GIFT City is proposed to be served with three DCS plants of equal capacity (60,000 TR each). Each plant is proposed to be interconnected through chilled water piping laid in the utility tunnel for improving redundancy. **Figure 4** shows the master plan of GIFT City with DCS plant location.

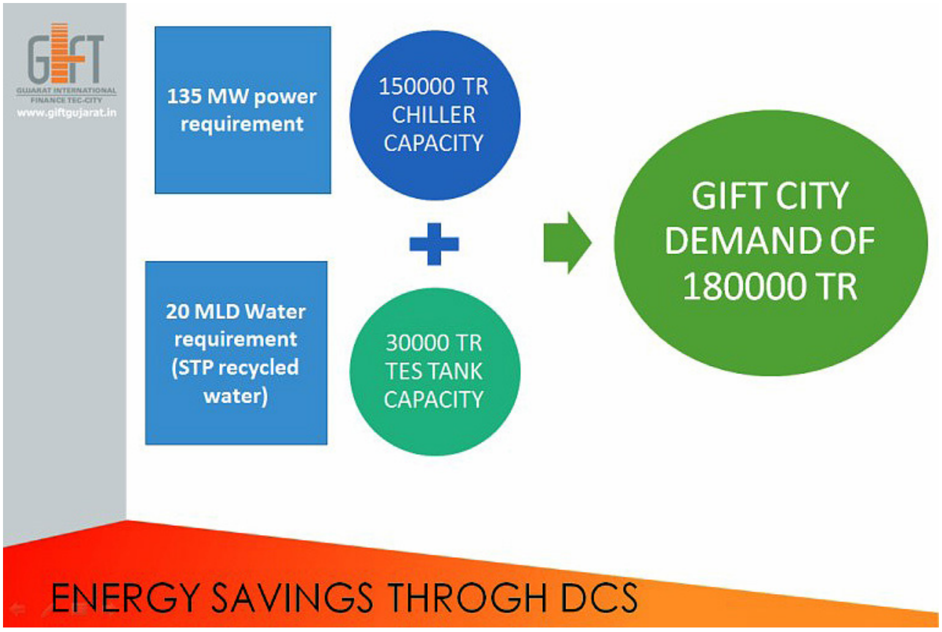

Figure 3. 180,000 TR DCS capacity.

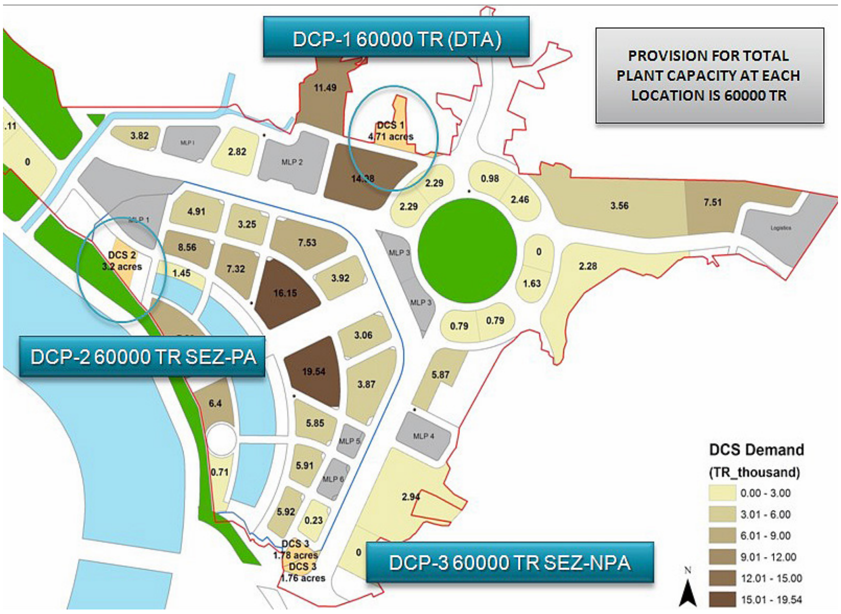

Figure 4. Master plan of GIFT City with DCS plant location.

The chilled water generated at DCS plant will be circulated to each building through chilled water pipes. These pipes are laid in the specially constructed underground utility tunnel. This tunnel houses all city level utilities. It provides huge benefits for installation, operation and maintenance of all systems. **Figure 5** shows a view of the utility tunnel.

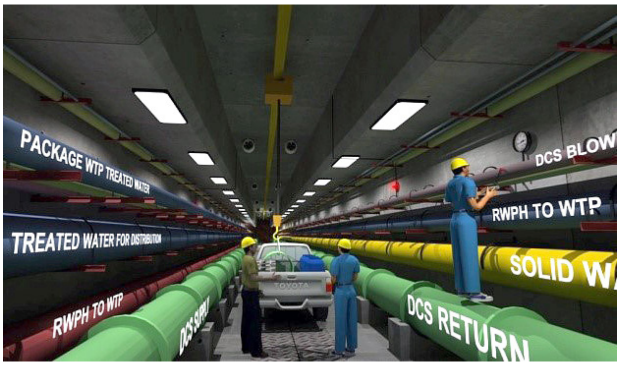

Figure 5. Utility tunnel.

Development of DCS in GIFT City (Phase -1)

As GIFT City is planned to be developed in phases based on occupancy growth, the development of DCS plants and utility tunnel for the entire GIFT City would also be taken up in different phases to match the actual city development. It is critical to design the DCS such that it caters to the air conditioning needs of the city at initial as well as peak load stages. Following are the key parameters that were analysed and built into the system design to meet the critical loads as well as cost economics of the overall system:

- Demand assessment
- Planning in line with city development
- Flexibility in plant design
- Optimization of piping network
- Physical infrastructure for current and future scenarios
- Optimization of plant energy consumption
- User satisfaction

DCS Plant -1 (DCP -1)

DCS plant is also being developed in phases in line with the phase wise development of the city. At DCP-1 location, the ultimate plant capacity planned is 60,000 TR for meeting the total requirement of the fully developed DTA area. DCP-1 of 60,000 TR will have 50,000 TR of chillers and 10,000 TR of thermal energy storage (TES) systems. **Figure 6** shows the phase wise development of DCP-1 chiller plant up to 50,000 TR.

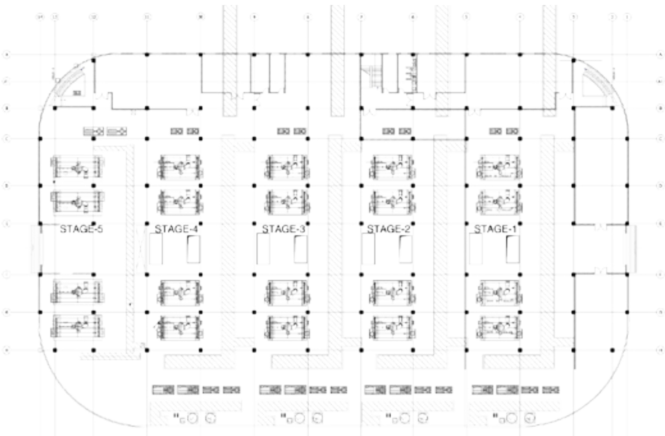

Figure 6. DCP-1 (60,000 TR): 50,000 TR chiller + 10,000 TR TES tanks.

Presently, the Phase-1 (stage-1) plant installed at DCP-1 has a capacity of 10,000 TR. The plant building for DCP-1 has been constructed with special emphasis on the requirement of installation, operation and maintenance space for all equipment. It is a two storey building. The ground floor area, being used for chillers, secondary pumps, TES pumps, HT and LT electrical rooms, has a height of 8 meters. The first floor area, being used for primary pumps, condenser pumps, BMS (control) room and PLC panels, has a height of 4 meters. Cooling towers with RCC basins are mounted at terrace level. The current plant building can accommodate DCS equipment for 20,000 TR capacity, whereas the equipment installed is for 10,000 TR. The salient features of various equipment are listed below.

The chillers are centrifugal type with 2500 TR capacity each and working on 11 kV power supply. The chillers are arranged in series counter flow arrangement to achieve a high temperature difference of 9°C. It means a pair of two chillers will deliver 5000 TR. These are AHRI certified energy efficient chillers with COP of 6.65 at AHRI condition and Non-standard Part Load Value (NPLV) of 0.473.

The 9°C temperature difference reduces chilled water flow to 1.5 GPM/TR. The lower flow rate per ton will provide the following benefits:

- Reduced primary and secondary pump capacity.
- Reduced size of chilled water pipe and other accessories.
- Lower flow rate means reduced energy consumption.
- Higher temperature difference will reduce chilled water energy losses.

Figure 7 shows the installed chiller at DCP-1.

The TES tank with a capacity of 10,000 TR-hr was constructed during Phase-1. It is a stratified chilled water storage tank, which stores thermal energy in the form of chilled water. It is an insulated tank with a diameter of 20 meter and a height of 13 meter. The TES tank will be charged by running the chiller at best efficiency point during off peak period. The TES tank will be discharged during peak load time to cater to air conditioning load beyond the chiller capacity. TES tank of 10,000 TR-hr can cater to 2500 TR load for 4 hours. Figure of merit (FOM) represents the performance of a TES tank. FOM for the installed tank is 0.9. To monitor thermal storage capacity, temperature transmitters are installed at every 300 mm height.

Figure 8 shows the TES tank installed at DCP-1.

Figure 7. 10,000 TR chillers at DCP-1.

Figure 8. TES tank at DCP-1.

All pumps at DCP-1 are horizontal split casing centrifugal type with EEF-1 motor for better efficiency and ease of maintenance. The secondary and TES tank pumps are working on variable frequency drive (VFD).

Chilled water piping and condenser water piping inside the plant are planned in trenches and above 4m for ease of operation and maintenance. **Figure 9** illustrates the pipe routed below the ground trench.

Figure 9. Chilled water pipe routed below the ground trench.

The cooling towers are single cell induced draft type with RCC basin. They are CTI certified. The cooling tower fans are VFD driven. Sewage treatment plant (STP) treated water is used as make up water in cooling towers; this reduces the requirement of fresh water. **Figure 10** shows the cooling towers.

Figure 10. Cooling towers.

The DCP plant building is air conditioned through chilled water generated at the plant, which helps in increasing the life of all equipment.

Above all, the equipment are controlled and interlocked such that the system can achieve maximum efficiency. DCP-1 plant is designed to generate chilled water at a power consumption of 0.9 kW/TR.

DCS system for 62 Mn sq ft will provide air conditioning at about 0.65 kW/TR.

Figure 11 and **12** show the SCADA screens of chilled water circuit and condenser water circuit.

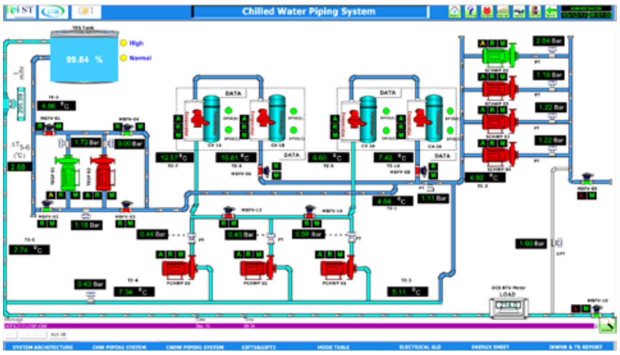

Figure 11. Chilled water circuit (SCADA Screen).

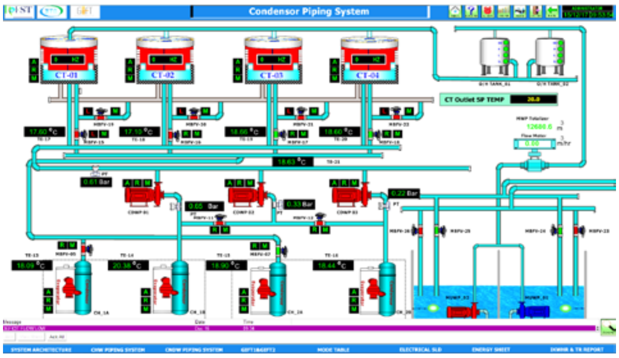

Figure 12. Condenser water circuit (SCADA Screen).

Chilled Water Distribution

Chilled water generated at DCP-1 is distributed to various building through pre-insulated pipes of 650 mm diameter. The chilled water network laid down in stage-1 is of approximately 3000 m length. Stress analysis was carried out for pipe installation, and expansion joints are provided based on the stress analysis results. These pipes are laid in the utility tunnel with branch tapping for future connection to buildings.

Pre-insulated pipe insulation is designed considering temperature loss of maximum 0.5°C in chilled water distribution. Pre-insulated pipes incorporate an automated leak detection system to detect the exact location of the leakage point, so that rectification if required can be done in minimal time.

The utility tunnel is planned to carry all utility pipes and cables such as raw water pipe, portable water pipe, make up water pipe for cooling tower from STP, blow down water from cooling tower to STP, automated waste collection pipe, data cables, electrical cables, etc. along with chilled water pipes. The chilled water pipes are laid on RCC pedestal at ground level.

The utility tunnel is one of the unique infrastructure features at GIFT City. **Figure 13** shows the chilled water pipe installed in the utility tunnel.

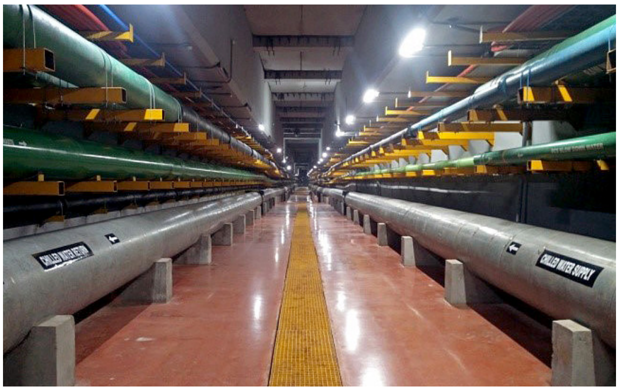

Figure 13. Chilled water pipe in utility tunnel.

Part Load Operation

During the early phase of operation, the available load with DCS was very low due to low occupancy in various buildings. This was expected and considered during the design stage. To operate DCP-1 plant of 10,000 TR efficiently for low load, the following philosophy is being adapted:

- TES tank is charged during night hours with the help of one chiller of 2500 TR. The time to charge is around 4 to 5 hours. The chiller is operated during the night hours to get the benefit of low atmospheric temperature and lower electrical tariff.
- TES tank is discharged during day time and building load is being met by operating the TES tank pump and secondary pump only. Chiller operation is not required during the day time.

Metering and Control

Chilled water supply to each building (User) is measured with an energy meter. The User will be charged based on energy consumption. **Figure 14** shows the scheme of metering at each building level. Metering and control on DCS side consists of energy meter, pressure independent control valve and isolation valves.

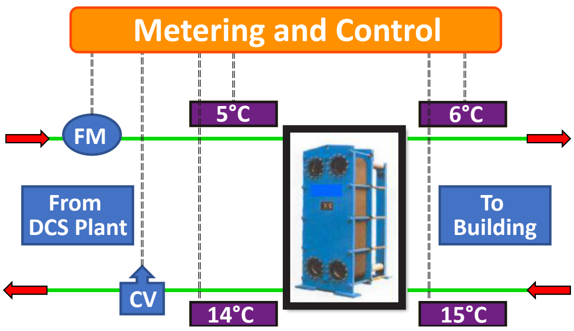

Figure 14. Metering and control.

Pressure independent control valve modulates the flow based on return temperature to ensure 14°C return temperature to DCP, to avoid the adverse effect of chilled water temperature on chiller energy performance.

Instrumentation and Control

To control various parameters at the consumer end (building) and provide DCS facility without any interruption to the end user, special emphasis is given at the design stage itself by working closely with the design consultant of the building and the contractor appointed by the developer. Energy transfer station (ETS) room at each building is reviewed critically by GIFT DCS team in terms of specifications of all equipment such as plate type heat exchanger (PHE) and pumps and operation and maintenance space availability. The scope bifurcation at the interface of DCS and building system is identified.

Instrumentation and Control (Automation)

Control system architecture for District cooling plant is based on redundant PLC and SCADA control system. All automatic and manual logic controls are programmed in PLC. The automatic process sequence and logic functions are developed in ladder and functional block languages.

PLC handles all sequencing control and safeguarding actions. The SCADA operator workstation provides operator interface, including colour graphics, faceplates, alarms, logging, trends, diagnostics, etc.

Figure 15 shows SCADA control room at DCP-1.

ETS Room (Consumer System)

The consumer system at the building ends consist of PHEs, chilled water pumps, chilled water piping, AHUs and air distribution system. The PHE exchanges thermal energy between DCS chilled water and building chilled water circuit. **Figure 16** shows the ETS room at GIFT-ONE Tower at GIFT City.

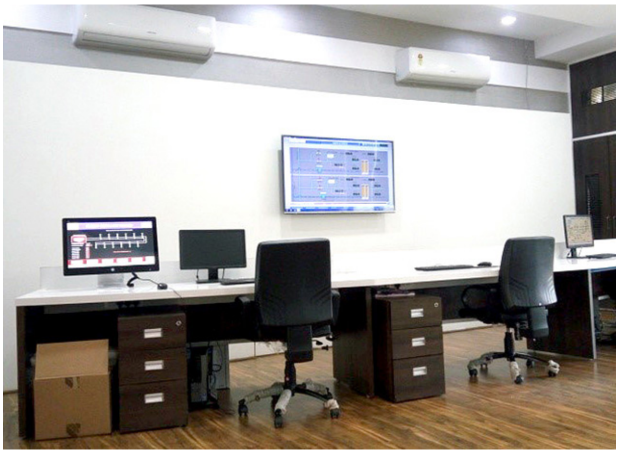

Figure 15. SCADA control room at DCP-1.

Figure 16. ETS room – GIFT ONE Tower.

Currently six buildings in GIFT City, namely GIFT ONE Tower, GIFT TWO Tower, Signature Tower, Tata Data Centre, Aspire-1 and C4 building are air conditioned with the District cooling system. More buildings are under construction and will be working on DCS in the coming years.

Sustainable Development with DCS

DCS ensures sustainable development through the following features:

- Lowering down the power demand and energy efficient system operation for air conditioning, reducing CO_2 emissions.
- Lower make up water consumption.
- Make up water for cooling tower is treated with water from STP, hence conserving fresh water.
- Chiller is selected with non-CFC green refrigerant gas R134a and the refrigerant is stored at DCS plant location only, thus reducing the environmental impact due to the refrigerant.
- Reducing the plant capacity, which minimizes the use of natural resources.

Conclusion

DCS is an energy efficient and sustainable air conditioning technology for future development in India. DCS technology must be viewed as a solution for increase in atmospheric temperature in urban areas, and promoted and adopted for large scale projects. The installation at GIFT City will go a long way towards inspiring the adoption of this technology by large projects in the country. ■

Radiators, convectors and energy efficiency

Improving energy efficiency has been a key objective in the construction industry over the last few decades. New energy-efficient features have been sought also for components such as radiators and convectors.

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The suppliers of heat emitters have advertised and promoted positive individual features of the product, like higher heat radiation, lower back wall losses and quicker response to control. But this is not that simple: energy efficiency is associated with the heating process and therefore the matter has to be seen in the whole, not as a sub-optimization of the details.

There are of course differences between different radiators and convectors, but the question is, what are the differences in terms of comfort, energy efficiency and in the end money?

The purpose of this article is to provide answers to these essential questions with objective measurement-based information.

The considered heat emitter types and relevant aspects

In **Figure 1**, the considered heat emitter types are illustrated.

For comparison of the heating process in buildings, following functions of heat emitters are essential:

- Human response to the heat emission
- Heat radiation into the room
- Back wall heat losses
- Temperature control function
- Heat output capacity at partial loads
- Influence on heat generation

Secondary and from the comparison perspective unimportant items like heat storage and distribution (pipe work) losses as well as other control methods have not been taken into consideration in this review.

Main part of the measurement results referred to in this article are from laboratory tests performed by Dr. Konzelmann at the WTP GmbH Berlin (**Figure 2**) and from the analysis done by Professor Kurnitski and his team at the Tallinn University of Technology as well as from our in-house analysis [1].

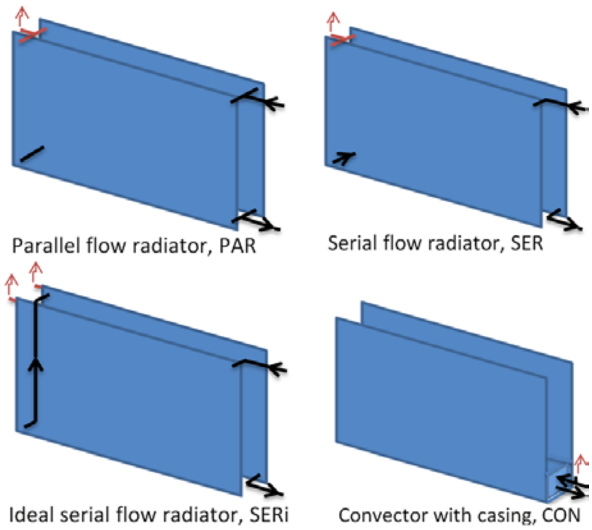


Figure 1. Investigated heat emitters: Normal 2-panel radiator with parallel flow (PAR), typical 2-panel radiator with serial flow (SER), ideal 2-panel radiator with serial flow (SERi), conventional round tube/lamella convector with or without casing (CON) and ideal convector (CONi) like trench convector (not illustrated). ↑ = Air bleed.

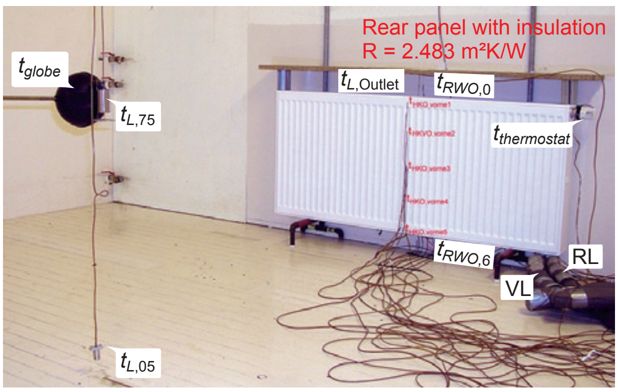


Figure 2. Measurement set up at the WTP GmbH Berlin lab.

In laboratory measurements, we wanted to find out how a normal 2-panel radiator (PAR) and a typical 2-panel radiator with serial flow (SER) behave under the control of a thermostatic radiator valve under comparable conditions. Conclusions of the ideal 2-panel radiator with serial flow (SERi), conventional convector (CON) and ideal convector (CONi) function can also be drawn with sufficient accuracy from the measurement results.

Human response to the heat emission

Humans are to detect small and rapid temperature variations in their environment. Up to 0.1 degrees step changes at operative temperature are measured in our own experimental tests. Instead, slow temperature changes, less than one degree in 15 minutes [2], are not perceived, because the human body's own heat regulation system is able to adapt to that change under normal conditions. This provides an explanation why we do not experience a problem, when the thermostat regulates the radiator water flow and the radiator temperatures shift correspondingly.

The best location of the radiator is beneath the window where it blocks the downdraught, the convection flow from the cold window surface. Another important feature of the radiator is its thermal radiation, which compensates for the radiant effect of the colder window surface, creating the conditions for thermal comfort. In fact, the radiator beneath the window extends the usable interior space.

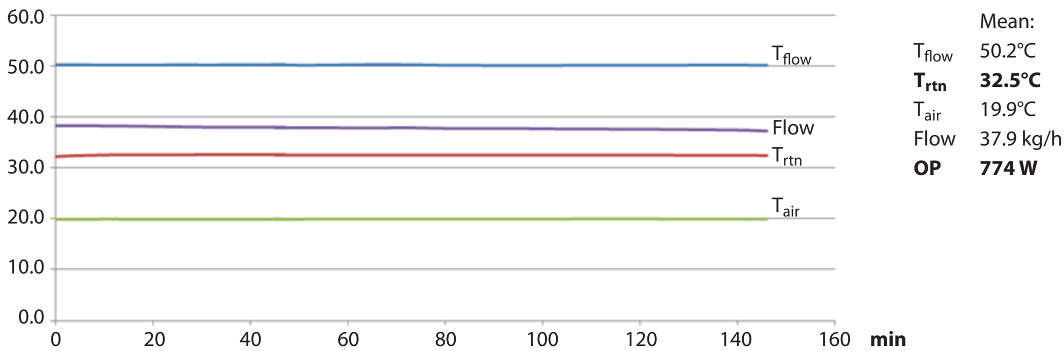
Emitter temperatures and heat losses

Measurements at 75% part load conditions [3]

The 75% part load means that the free heat gain rate is 25%. The free heat gains consist of internal heat gains and solar radiation influence. The average cabin cooling effect was 774 W. Flow temperature was set on 50°C. Thermostatic radiator valve TRV was a conventional proportional one and water flow rate lowered to a level of around 1/3 $\dot{m}_N$, where the PAR radiator heat output was in balance with the heat demand. Differential pressure was kept constant in all measurements. Nominal flow rate, $\dot{m}_N$, is the flow value of the radiator measured in the EN 442 conditions and temperatures flow = 75°C, return = 65°C and air = 20°C.

As shown in **Figure 3**, The main observations of the test results are that the SER had around 15% lower heat output capacity than PAR and resulting to a 26% higher flow rate and to around 3.7°C higher return water temperature. SER got also an average front panel temperature of 4.5°C higher and 2.5°C lower average rear panel temperature than the PAR ones.

Average 301 and 303: Parallel – Part load 75%



Average 101 and 103: Serial – Part load 75%

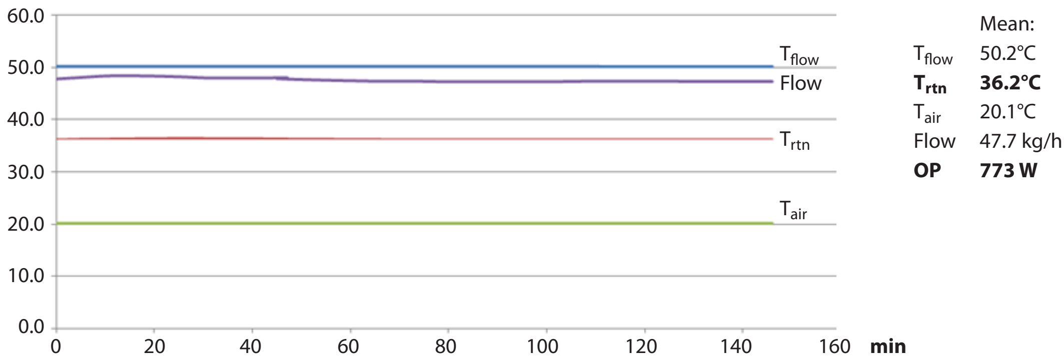


Figure 3. PAR and SER running with TRV control at 75% part load conditions.

Theoretically, the SERi heat output capacity could be a bit higher than SER although own laboratory measurements of a commercial product did not confirm this difference [1]. Obvious is that SERi gets at same conditions practically the same flow rate and return temperatures as PAR. Due to the lower flow rate than SER at these conditions the front and rear panel temperatures are slightly lower than the SER ones. For comparison purposes (**Table 1**) we can well approximate the SERi panel temperatures: the front 4.0°C higher than the PAR one and the rear respectively 3.5°C lower than the PAR one. Convector features are handled in the later part of this review.

Table 1. 75% part load measurement results.
* Estimated value

T_{flow} = 50°C T_{air} = 20°C Φ_{cool} = 774 W	T_{rtn} °C	T_{front} °C	T_{rear} °C
PAR	32.5	39.1	40.1
SER	36.2	43.6	37.6
SERi	32.5*	43.1*	36.6*
CON	–	–	–
CONi	–	–	–

Panel radiator heat output capacity depends not only on the temperatures, but also on the flow rate and the pipe connection. Radiators with top-bottom-same-end (TBSE) as well as top-bottom-opposite-ends (TBOE) connections are not so sensitive to the water flow rate changes that bottom-bottom-opposite-end (BBOE) connections are. This function is shown in the redrawn graph of Schlapmann [4], **Figure 4**. Here we can also see the reason why SER has a reduced heat capacity: the SER rear panel is connected as BBOE and the heat capacity is clearly lowered at smaller water flow rates. – **Increased SER radiator sizes are needed**.

Measurements at 42% part load conditions [3]

A 42% part load means that the heat gains cover 58% of the heat demand. Measurements were carried out with an average cabin cooling effect of 875 W and flow temperature of 70°C in order to get well-measurable function values.

Thermostatic radiator valve TRV starts to reduce the water flow to the level on which the radiator heat output corresponds with the heat demand. The proportional control is no longer reached and the control mode starts to fluctuate as on-off. Water flow shut-off time is around 30% of the on-off cycle, however, with PAR a bit longer than with SER.

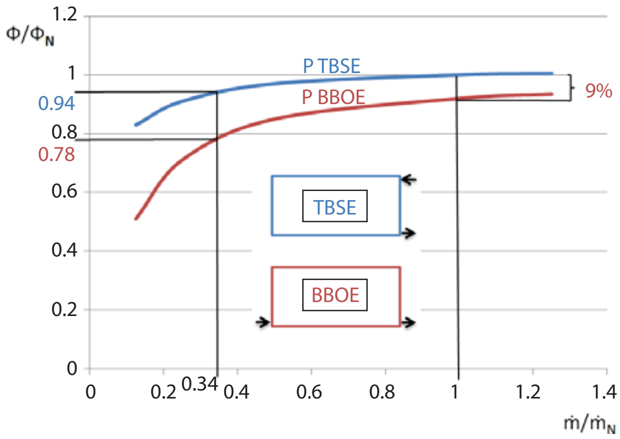


Figure 4. Panel radiator heat capacity depends also on flow rate and connection type.

Temperature control function

At start phase of the fluctuation both temperatures, air and globe, react a bit quicker with PAR than with SER, due to the higher output capacity of PAR, **Figure 5**. However, this difference equalizes due to the fact that **TRV determines the pace**: During regular fluctuation both radiators PAR and SER have the same cycle time, **Figure 6**. And that is why there are no practical differences in the controllability of radiators. Convectors may benefit slightly from the reduced output capacity at high heat gain rates and the shut-off time can be shorter. This feature is described in the chapter *Return water temperature influence*.

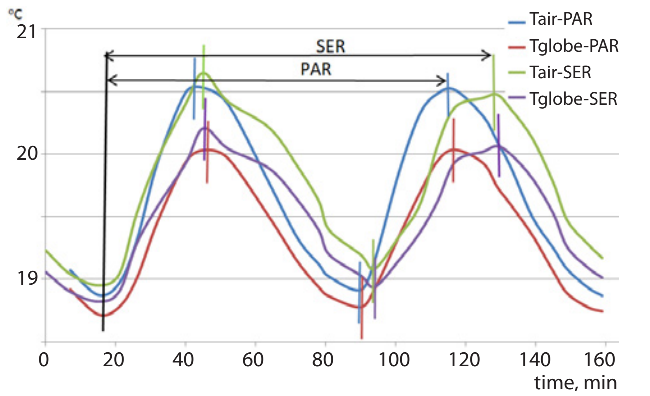


Figure 5. PAR heats up the room slightly quicker than SER.

Due to the insufficient differences at on-off modes, the temperature fluctuation impact on the energy use has not been taken into consideration in this article (generally it depends on the control used).

Water flows fluctuate between 0 and 60 kg/h. Flow-rate-weighted average return temperatures of SER were 2.1°C higher than the PAR ones. Front panel mean temperature of SER was 5.3°C higher than PAR. Rear panel mean temperature was correspondingly 3.2°C lower for SER.

Condition for a PAR (radiator type 22-600-1400), where T_{flow} = 70°C and T_{rtn} = 32°C with continuous flow, in other words TRV is still in proportional mode, corresponds to the heat gain rate of 35%. Obviously the TRV can modulate the flow up to this 35% heat gain rate and at higher heat gains the TRV changes over to on-off operation. Corresponding SER values and estimated SERi values are shown in **Table 2**.

Norm and old building

For comparison purposes two different building types have been selected, old and norm: A post WWII building without thermal insulations layers in the walls, but 2-glass-windows and a norm building representing both newer building types, from the 90s, and renovated older buildings. Old and norm building features displayed in **Table 3** have been used for calculations.

Table 2. 42% part load results.*Estimated value

T_{flow} = 70°C T_{air} = 20°C Φ_{cool} = 875 W	Weighted T_{rtn} °C	T_{front} °C	T_{rear} °C
PAR	32.1	40.3	40.7
SER	34.2	45.6	37.5
SERi	32.1*	45.1*	36.5*
CON	–	–	–
CONi	–	–	–

Table 3. U-values of reference buildings

	External wall U-value	Window U-value
Old building	1.39 W/m²K	2.8 Wm²K
Norm building	0.27 W/m²K	1.2 W/m²K

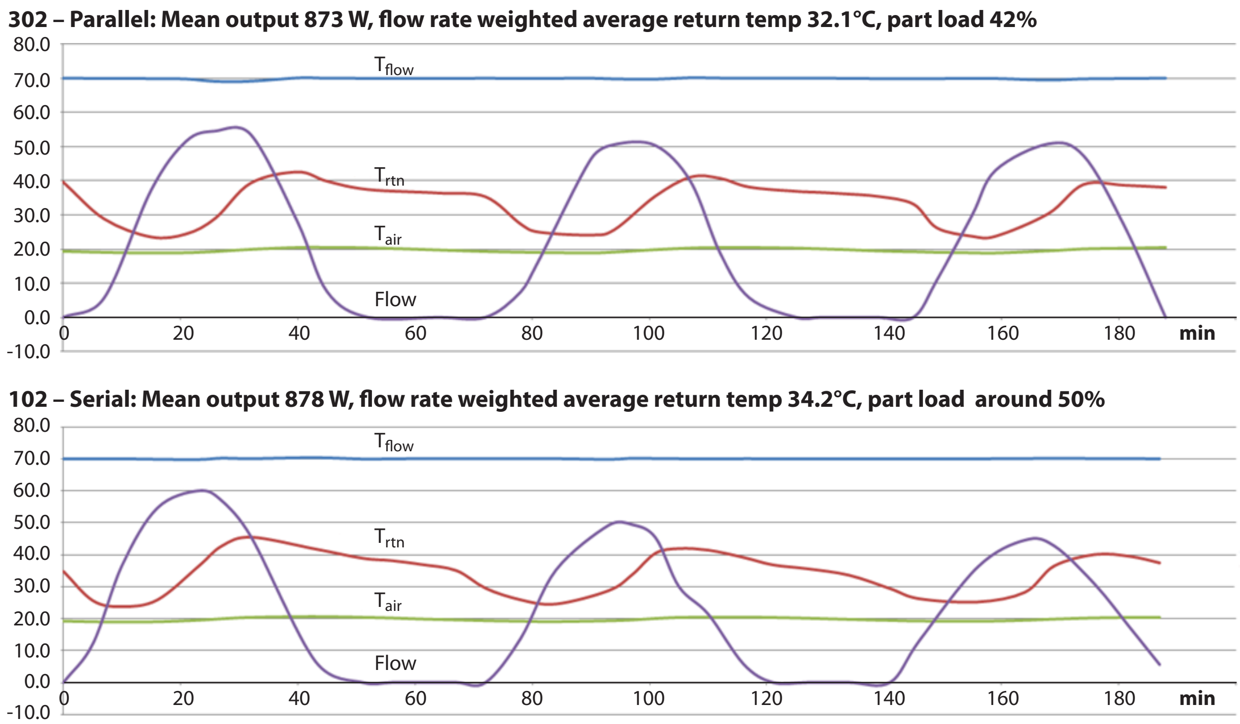


Figure 6. PAR and SER running with TRV control at 42% part load conditions. On-off-mode.

Climate conditions are taken according to Dresden (Germany), where the design outdoor temperature is -15°C.

Outdoor temperature of 0°C has been chosen as reference, because it is reasonably near to the mean temperature of the heating season.

Reference room is 16 m², window 1.4 x 1.5 m² and heat emitter size 1.4 x 0.6 m². Heating system design temperatures are 70/55/21°C for old building and 55/45/21°C for norm building. System flow temperatures at T_{out} = 0°C are in old building 50°C and in norm building 41°C. Air change rate is 1/h in both cases. Full load heat demands are in the old building 890 W and in the norm building 420 W. Heat gain rates are at these conditions in old building 25% and in norm building 35%. Default is that at both conditions the TRV works in proportional flow mode.

These conditions are chosen in order to show the maximum differences between the heaters. However, in practice the differences are smaller.

With help of the conversion graph in **Figure 7**, based on the measured temperatures, it is possible to estimate the average panel temperatures from the flow and return temperatures of radiator (**Table 4** and **5**).

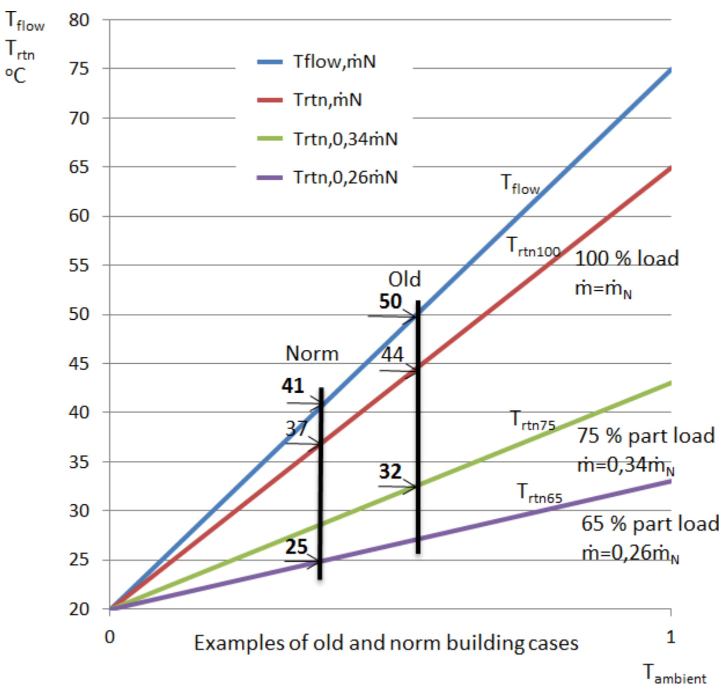


Figure 7. Radiator temperatures of PAR and SERi in relation to the flow temperature and the part load rate.

Table 4. Radiator surface temperatures, old building. *Selected value

Old building	PAR	SER	SERi	CON	CONi
Front panel mean, °C	39.1	43.6	43.1	31*	–
Rear panel mean, °C	40.1	37.5	36.6	31*	–

Table 5. Radiator surface temperatures, norm building. *Selected value

Norm building	PAR	SER	SERi	CON	CONi
Front panel mean, °C	28.0	31.0	29.8	25*	–
Rear panel mean, °C	28.2	27.0	26.5	25*	–

Operative temperatures

Based on these average front panel temperatures it is possible to calculate the heat radiation influence according to ISO 7726 standard. Measurement point is in the middle of the room at 0.6 m above floor level, referring to a person in a sitting position. These calculations are made by Equa Simulation Finland Oy [5].

There is no standardized calculation method for energy estimations, but the following calculation method, mean operative temperature MOT, is commonly used. In **Tables 6** and **7** are the calculated air temperatures giving the same operative temperatures of 21°C at different heat emitter cases. SER shows the lowest air temperature due to the highest radiation and CONi respectively the highest. SERi is quite similar as SER.

Table 6. Air temperatures giving the same 21°C MOT, old building.

Old building	PAR	SER	SERi	CON	CONi
Air, °C	21.38	21.26	21.27	21.59	21.90

Table 7. Air temperatures giving the same 21°C MOT, norm building.

Norm building	PAR	SER	SERi	CON	CONi
Air, °C	21.14	21.05	21.06	21.21	21.32

Heat radiation influence

Reference location Dresden's design outdoor temperature for heating is -15°C. Climate data for the calculations is taken from the Weather Underground.

Degree-day value of the old building with base temperature 17°C is 2902 and the difference of one degree corresponds with 10% difference in energy use.

Norm building degree-day value with base temperature 15°C is 2354 and the difference of one degree corresponds with 12% difference in energy use.

Tables 8 and **9** show how much operative temperature differences (**Tables 6** and 7) add to energy needs of different emitter types.

Table 8. Heat radiation influence in old building.

Old building	SER/SERi	PAR	CON	CONi
Additional energy	0	+ 1.2%	+ 3.3%	+ 6.4%

Table 9. Heat radiation influence in norm building.

Norm building	SER/SERi	PAR	CON	CONi
Additional energy	0	+ 1.0%	+ 1.8%	+ 3.1%

Back wall losses

From the measurement results of WTP GmbH Berlin it is possible to calculate, with good degree of accuracy, the back wall heat losses caused by the heat emitter, see **Table 10, 11** and **12**.

Table 10. Emitter back and back wall temperatures in old building. *Selected value

Old building	PAR	SER	SERi	CON	CONi
Emitter back mean, °C	40.1	37.5	36.6	31*	–
Back wall mean, °C	29.5	28.1	27.6	24.7	–

Table 11. Emitter back and back wall temperatures in norm building. *Selected value

Norm building	PAR	SER	SERi	CON	CONi
Emitter back mean, °C	28.2	27.0	26.5	25*	–
Back wall mean, °C	23.3	22.6	22.4	21.6	–

Table 12. Back wall losses caused by the heat emitter.

Additional energy need	PAR	SER	SERi	CON	CONi
Old building	+2.24%	+1.91%	+1.79%	+1.10%	–
Norm building	+0.36%	+0.28%	+0.26%	+0.18%	–

Following the back wall temperature values the radiator back wall losses can be calculated at outdoor temperature of 0°C.

Influence of leak flow on serial panel radiators

Bleeding of the air is a problem at construction of the serial panel radiators. In order to get the serial panel radiator to function ideally, both panels, front and rear, should be bled separately. To enable this, complicated air venting arrangements are needed. Therefore, the product costs will increase.

All commercial SER products are compromised by having a tiny opening between the front and rear panels. This helps to bleed the air through the same air vent at the upper end of the radiator, but it inevitably leads to a leak flow from front panel to rear panel resulting in a situation, where the top of the rear panel is warmer than the flow water from the front to back panel. This prevents the water rising up in the rear panel, which causes an additional reduction on the output capacity of the rear panel particularly at the part load conditions. This has been found in the measurements [3].

The leak flow in SERi radiator reduces also the output capacity and equalizes the front and rear panel temperatures. However, the disadvantage is not as serious as in SER radiators.

Serial panel radiator has an increased flow resistance. When parallel panel radiator resistance corresponds with around kv 3.3, serial panel resistance is more than the double, kv 1.3. The pressure difference between the panels can be a few hundred Pascal even in normal sizes of serial radiators and the leak flow through even smaller openings is unavoidable.

Return water temperature influence on heat generation

As shown in **Figure 4** panel radiator output capacity depends also on the connection type and flow rate. We can recognize that SER radiator's rear panel connection is BBOE type and thereby SER radiator capacity is always smaller than the PAR one. In addition, the leak flow reduces the output capacity further.

As mentioned above in the 75% part load case, the return water temperature of SER radiator was measured 3.7°C higher than in the PAR. Also, in the 42% part load case this reduction was remarkable – the higher return water temperature, the higher the condensing boiler and heat pump fuel consumption.

Heat output capacity of convectors with round pipe/lamella construction depends strongly on the water flow type, turbulent or laminar. When the flow rate is decreased, the convector output capacity decreases in accordance with the Reynolds number. This dependence, according to Dr. Konzelmann [3], is shown in **Figure 8**.

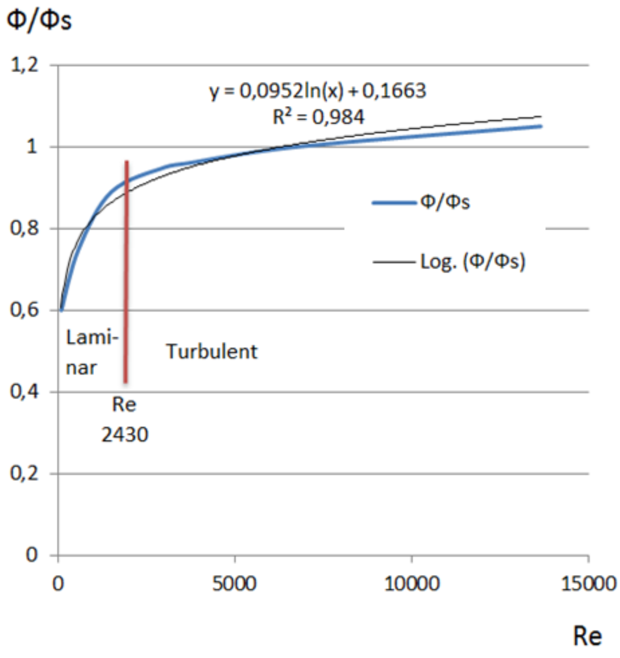


Figure 8. Convector heat output depends on water flow conditions

Example: Typical convector construction with heat output capacity at dT50K (EN442) is 800 W. In case of 75% part load, flow temperature of 50°C and 248 W heat demand, the return water temperature rises up to a level of 39°C.

– Comparable case, PAR radiator with a return water temperature of 33°C.

Note. This heat output capacity reduction effect has not been taken into account in the product standards EN442 and EN16430: standard heat output values are valid only at full load conditions with relatively high water flow rates. Design flow rates are often clearly lower, which leads to incorrect design selections.

In **Figure 9** we can find, according to Professor Oschatz's measurement and study [6], the dependence of heating system return water temperature on the condensing gas boiler combustion efficiency: trend line value 0.4%/K. The burner load rate has also a slight influence on the efficiency: the lower load the higher efficiency and respectively the higher load the lower efficiency.

Annual coefficient of performance, COPa, is also linked not only to the system flow water temperature, as often assumed, but also to the system return water temperature. According to the calculations done the change of one degree in system water temperature gives a COPa change of 1.2% [8]. In addition, the COP value depends on the heat pump condenser temperature. It is also measured that the system flow water temperature has a 2/3 and system return water temperature a 1/3 influence to the condenser temperature, **Figure 10**.

In conclusion, we can say that in both condensing boiler and heat pump, lowering the system return water temperature by one degree, the heat generation efficiency rises by 0.4%.

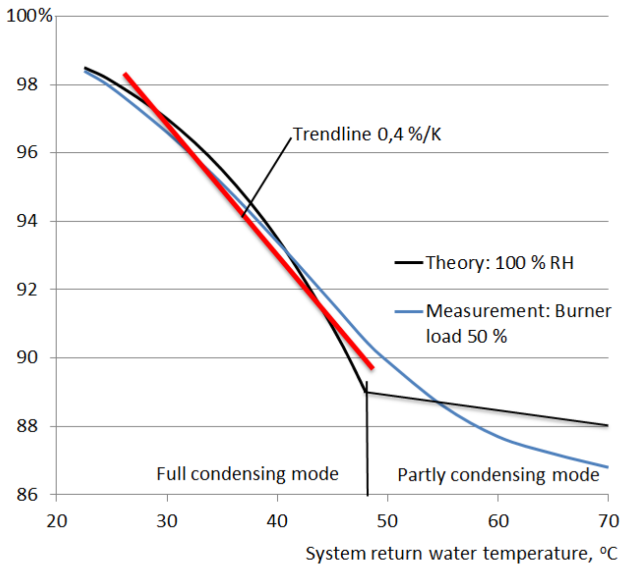


Figure 9. Condensing boiler combustion efficiency depends on system return water temperature

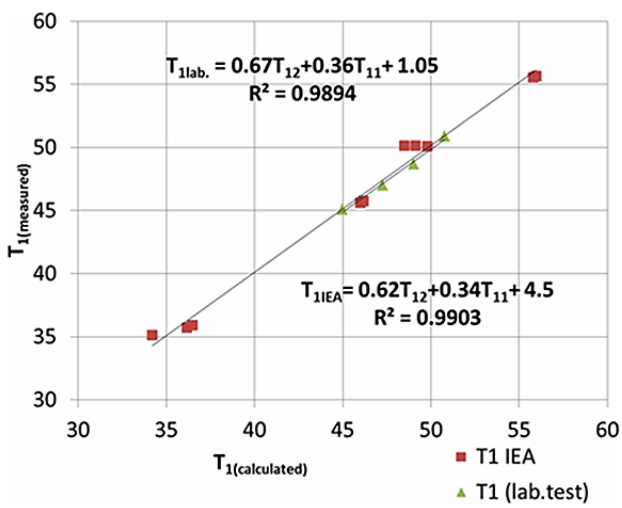


Figure 10. Influence to heat pump efficiency, Prof. Kurnitski [7]. Flow water temperature 2/3 and return water temperature 1/3.

When using the return water temperatures from the 75% par load case, SER has 3.7°C higher return water temperature than PAR and SERi, and CON and CONi respectively around 6°C higher than PAR and SERi, following figures for **heat generation efficiencies** can be calculated, **Table 13**. These values are valid for both reference buildings with a reasonable accuracy.

Table 13. Relative heat generation influence and additional energy needs.

Heat generation influence	PAR/SERi	SER	CON/CONi
Additional energy	0	+1.5%	+2.4%

Summary

Table 14 shows a collection and summary of the relative effect of different heat emitters on the heating system efficiency: additional energy need.

Table 14. Relative effect of different heat emitters on system efficiency

Additional energy need	PAR	SER	SERi	CON	CONi
Old building	+3.4%	+3.4%	+1.8%	+6.8%	+8.8%
Norm building	+1.4%	+1.8%	+0.3%	+4.4%	+5.5%

Discussion

According to the results differences between the radiators in both old and norm buildings are very small, max 1.5%. However, the convectors differ clearly from the radiators.

Heat radiation differences of different radiator types are so small that they are practically out of human perception capability [9].

When the functional differences between the radiators are small, the decisive difference is their price. But how much more money is meaningful to invest in radiators that are claimed to be more energy-efficient?

Example: In a typical German detached house of 170 m² from the mid-90s the space heating energy is around 15 000 kWh per year. When using the gas price of 0.065 €/kWh, the heating bill is around 975 €/a. The result difference between a "standard radiator" and an "ideal serial panel radiator" is 1.1%. The corresponding energy cost difference is on average 10.70 €/a. This divided typically into 10 radiators results in maximum annual savings of 1.07 € per radiator. For instance, the price of an "**ideal serial panel radiator**" for the end user is several dozens of euros higher than the price of a standard radiator. This extra price, for example **30 €** for the end user, divided by 1.07 €/a leads to a pay-back time of 28 years!

The reduced heat output capacity of the "**typical serial panel radiator**" causes needs to increase the radiator size: for example, a typical 10% addition increases the price for the end user by around **25 €,** and this without any pay-back.

The additional heating energy demand and the lack of radiant effect of convectors seem to be more noticeable: there must be additional arguments for convector selection.

In modern energy efficient buildings, which are better insulated and often equipped with heat recovery ventilation, the heating energy demand is only half or less of the "norm building" used in this review. Therefore, the small differences of radiators in new buildings are completely irrelevant from the energy saving point of view.

In conclusion, it is clear that there is no tangible, financial nor physiological benefit for home owners to pay the increased cost associated with the alleged but unsubstantiated "more energy efficient radiators". **– A standard radiator is the best option.** ■

References

[1] RETTIG ICC Research Centre, EN442 laboratory.

[2] ASHRAE ANSI standard 55.

[3] WTP GmbH Berlin, EN 442 laboratory.

[4] Schlapmann, HLH 9-76.

[5] Equa Simulation Finland Oy.

[6] Technical University of Dresden.

[7] Tallinn University of Technology.

[8] IVT VPW2100 software.

[9] Human Thermal Model, VTT Technical Research Centre of Finland.

Reporting on the ventilative cooling workshop held October23, 2017, Brussels

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International workshop on "ventilative cooling in buildings: now & in the future" was attended by 62 persons from 15 countries attended. This workshop aimed at discussing the implementation of ventilative cooling as well as its role to guarantee good thermal summer comfort in commercial, educational and residential buildings. The programme firmly built on the results of IEA-EBC Annex 62:

- The ventilative cooling potential excel tool that allows to assess the effectiveness of ventilative cooling solutions taking into account climate conditions, building envelope thermal properties, occupancy patterns, internal gains and ventilation needs
- A book with design guidelines derived by the expert group which should be under review in the next weeks
- An overview of the ability of national energy performance calculation methods to properly take into account ventilative cooling solutions
- An overview of solutions and technologies that can be implemented, including lessons learnt from 15 case studies analysed within the project
- An analysis of relevant CEN and ISO standards and the identification of gaps to fill to increase the adoption of ventilation cooling solutions

The interaction with the audience after these presentations, reflected the interest and need for such tools. These tools will be gradually available on the venticool website. In the discussions, besides purely ventilative cooling solutions, appropriate solar shading was often mentioned as a pre-requisite. Several participants thought that Phase Change Materials (PCM) and personal comfort solutions (e.g., using micro-evaporators) could be major new elements influencing future design solutions. It was also acknowledged that, while ventilative cooling solutions can be effective on multiple aspects including comfort, energy use, power demand and costs, it also requires more work at design stage, possibly with dynamic simulations including airflow modelling, as well as more post-occupancy care, in particular to inform occupants. Several attendees also stressed the need to learn from user interaction and that "visible" automatic controls (e.g. window opening or solar shading controls) need to be understandable for user.

Smart readiness indicator

There were debates about the objectives of the smart readiness indicator (https://smartreadinessindicator.eu/) to be included in the future Energy Performance of Buildings Directive. Since only its broad contours are defined at this stage, it is clearly too early to assess the relevance of a single indicator for the scope foreseen and how this could affect the uptake of ventilative cooling; however, in principle, accounting for electricity grid management and indoor climate would converge with the goal sought with ventilative cooling solutions.

Building Information Modelling (BIM)

The development of Building Information Modelling (BIM) could also be seen as an opportunity for ventilative cooling as it could ease thermal comfort evaluation and, thereby, encourage designers to look into efficient solutions to prevent overheating. Nevertheless, the structuring of the huge amount of data to be included in BIM objects to cover possible applications, could be a serious hurdle to make this happen in the near future.

The IEA-EBC project

This workshop was also the occasion to discuss a new IEA-EBC Annex proposal building on the findings of IEA Annex 62, but looking more broadly at the issues of smart overheating prevention and cooling in changing urban environments. The scope goes beyond the boundaries of the building, addressing also heat island mitigation and outdoor comfort, and includes active cooling as a complementary measure to passive techniques. The goal is to foster "resilient" cooling solutions, i.e., solutions that either maintain or adapt to maintain their function as outdoor temperatures rise without augmenting stress on the outdoor environment.

In summary, there is no doubt that overheating prevention and cooling will be high on political agendas with the effects of global warming, which we are just starting to experience. The workshop showed an alternative path to the generalisation of full mechanical cooling capacity implementation which would be both energy demanding and detrimental to urban heat island and the adoption of passive cooling techniques. The discussions further stressed challenges and opportunities for research and technology development on resilient cooling to fight and adapt to climate change, in a constantly evolving context of regulations and information technology. This could be the core theme of a new IEA-EBC project. ■

Post navigation

IEA EBC Annex 62- Ventilative Cooling- 8th Expert Meeting, Gent, Belgium, October 24-25, 2017.
http://venticool.eu/iea-ebc-annex-62-ventilative-cooling-8th-expert-meeting-gent-belgium-october-24-25-2017/

18-19 September 2018, Conference, Juan-les-Pins, France | 5th venticool – 39th AIVC – 7th TightVent Conference, 2018.
http://venticool.eu/18-19-september-2018-conference-juan-les-pins-france-5th-venticool-39th-aivc-7th-tightvent-conference-2018/

New standardization projects on ventilative cooling and natural and hybrid ventilation systems

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VELUX A/S

New Work Items (NWI's) relevant to ventilative cooling applications have been approved by the European Committee for Standardization (CEN) and the International Organization for Standardization (ISO) (see also Venticool newsletter June 2017 edition [1]). The scope of this work is to make technical documents focusing on design aspects of ventilative cooling, and natural and hybrid ventilation systems in residential and non-residential buildings.

The projects are progressing well and have now officially started under CEN/TC 156 (Ventilation for buildings) and ISO/TC 205 (Building environment design). Some of the projects have developed further than others, e.g. the ISO standard (see below) where some of the contents have already been discussed. The others are still in the initial phase of setting up task groups and discussing the scope.

The initiated projects are planned as Technical Specifications (normative documents of lower status than EN Standards), an EN standard under CEN/TC 156, and as an ISO standard under ISO/TC 205.

More specifically, four projects relevant to ventilative cooling applications, have already started:

Ventilative cooling systems

- Main focus: Thermal comfort (prevent overheating)
- Document type: A CEN Technical Specification
- Work started in CEN/TC 156 WG/21

Natural and hybrid ventilation systems in non-residential buildings

- Main focus: Indoor air quality
- Document type: CEN Technical Specification
- Work started in CEN/TC 156 WG/20

Design process of natural ventilation for reducing cooling demand in energy-efficient non-residential buildings

- Main focus: Thermal comfort (design process to prevent overheating)
- Document type: ISO standard
- Work started in ISO/TC 205 WG/2

Expansion of Natural and Hybrid ventilation in residential buildings in upcoming "Revision of EN 15665:2009 and CEN/TR 14788:2006"

- Main focus: Indoor air quality
- Document type: Goal is to merge both documents into one document (e.g. EN standard)
- Work started up in WG/2 in CEN/TC 156

The technical documents are a good opportunity to define design aspects and processes of ventilative cooling and natural and hybrid ventilation systems on the European and International scene e.g. by applying findings from the Venticool platform and the upcoming IEA EBC Annex 62 reports on ventilative cooling due later in 2018 (see also Venticool workshop on ventilative cooling [2]).

Post navigation

New release: Energy Efficiency and Indoor Climate in Buildings.
http://venticool.eu/new-release-energy-efficiency-and-indoor-climate-in-buildings/.

IEA EBC Annex 62- Ventilative Cooling- 8th Expert Meeting, Gent, Belgium, October 24-25, 2017.
http://venticool.eu/iea-ebc-annex-62-ventilative-cooling-8th-expert-meeting-gent-belgium-october-24-25-2017/

[1] http://venticool.eu/download/1564/

[2] http://venticool.eu/feedback-from-the-ventilative-cooling-workshop-on-october-23-2017-in-brussels/

New standardization project on Primary energy factors and Greenhouse gas emission factors

Start of new work in CEN/TC371 on the series of EPB standards: the development of a standard procedure to asses Primary Energy Factors (PEF) and CO_2 emission factors to be used for Energy Performance of Buildings declarations.

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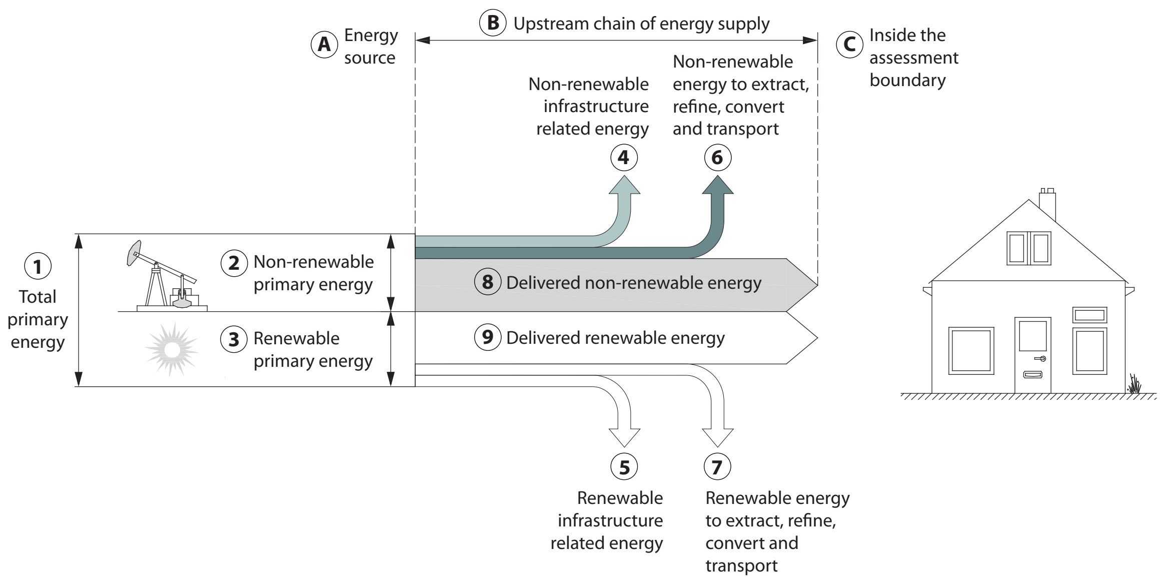
CEN/TC371 WG1 is working on developing a method for (re) calculation and reporting of primary energy factors (PEF or also known as primary energy conversion factors) and the connected CO_2 emission factors for various fuels and other energy resources. This work is very important in the context of energy performance assessment of buildings. This new standard for determination of the PEF and CO_2 factors is expected to be used in relation to the EU Energy Performance of Buildings Directive (EPBD).

There is a need for greater clarity and transparency about the considerations, assumptions and choices that have been made when determining the value of these energy conversion factors and related CO_2 emission factors. The standard is linked to EN ISO 52000-1, the overarching standard for determining the energy performance of buildings. This standard includes a table B.16 presenting default values for these factors. In clause 9.6.2 of this standard the concept of primary energy factor is illustrated in **Figure 1**.



$$f_{Ptot} = \frac{1}{8+9} \qquad f_{Pnren} = \frac{2}{8+9} \qquad f_{Pren} = \frac{3}{8+9}$$

Figure 1. Primary energy factors (see EN ISO 52000-1 clause 9.6.2).

The PEF describes the efficiency of converting energy from primary sources (like fossil fuels…) to secondary energy carriers (e.g. electricity) that provides the services delivered to the end user to heat, cool, ventilate etc.. the building. In the EPBD the PEF is used to calculate the Energy Performance of buildings, which is then expressed in terms of primary energy.

Further explanation on PEF: Annex H of EN ISO 52000-1 explains as follows:

Primary energy is defined as energy from renewable and non- renewable sources which has not undergone any conversion or transformation process. (EPBD art 2). The related primary energy factors (PEF) are defined as:

- non-renewable primary energy factor taking into account only non-renewable energy overheads of delivery to the point of use, excluding renewable energy overheads and primary energy components;
- renewable primary energy factor taking into account only renewable energy overheads of delivery to the point of use, excluding non-renewable energy overheads and primary energy components;
- total primary energy factor. The total PEF is the sum of the non-renewable primary energy factor and the renewable primary energy factor.

The total primary energy use is a coherent way for setting technical building system requirements because some systems (e.g., direct electrical emitters) have some of their systems losses outside the building assessment boundary (e.g., electricity generation). The total primary energy factor takes into account the losses outside the assessment boundary. Only energies delivered through the assessment boundary from the perimeters defined (e.g., nearby and/or distant) are taken into account to link the total primary energy use with the energy counters. A final note in this annex H expresses already the need for further description of the assessment procedure , which work is now has now started.

Importance of PEF's unambiguous determination for the market

Ensuring fair competition and a level playing field within the market for energy technologies, products and applications for construction is of great importance. In order to achieve this. It is very important that choices and assumptions with regard to the procedure for calculating the relevant PEF's are well established and recorded in an unambiguous and transparent manner. Including in the final energy performance assessment the greenhouse gas emission factors (expressed in kg of CO_2 equivalent per kWh) stimulate the use of environmentally friendly applications. The assumptions and boundary conditions of the calculation and final value of the PEFs is expected to differ between Member States due to the variation in their energy mix, but it is essential that the assessment is done in a transparent and unambiguous way. Changes in the energy market and within the construction sector also require regular recalculation of these PEF values. If the use of PEFs to calculate the Energy Performance of buildings is incorrect this may misguide market and policy makers, they expected calculated energy savings may be misleading. This should be avoided at any cost. ■

The Energy Efficiency Transformation in the European Heating and Cooling Market

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This article assesses the effects of the Ecodesign and energy labelling regulations with respect to space heating and cooling technologies. A detailed study of performance rating data over three years period (2014 - 2016) from an independent database of heating and cooling products on the European market is made. This enables to evaluate the energy efficiency evolution of these type of products and to identify how policies can further boost energy efficiency development and ensure its success. Results demonstrate the positive effects of the introduction of energy labels in the European market and the importance of reliable data. However, the facts presented suggest that adjustments on the requirements of minimum energy efficiency should be considered in the future revision of the ecodesign regulations and highlight the importance of reliable data to avoid jeopardizing the energy saving potential of these mechanisms.

Energy labelling enables customers to make informed choices based on the energy consumption of energy-related products. This entails several benefits: reduces energy demand and saves customers money on energy bills, contributes to innovation and investment in energy efficiency, and supports industries which develop and produce the most energy efficient products.

However, a lack of ambitious requirements and standardised/reliable data for heating and cooling technologies will lead to a risk that the cost effective and energy saving potential will not be fully utilized and that the consumers will lose their confidence in the energy labelling and other product information provided by suppliers.

The technologies considered in this study are: air conditioners, liquid chilling packages and hydronic heat pumps, rooftop and variable refrigerant flow units.

Comfort air conditioners (ACs) consist of a reversible heat pump that can be used for both heating and cooling the air in a room. This type of heating and cooling technology has gained increasing market penetration in recent years and thus, it has been included in the ecodesign (2009/125/EC) and energy labelling (2010/30/EU) European directives (implemented through regulations No 206/2012 and No 626/2011) to contribute with a large amount of energy savings in the European Union within the next 10 to 20 years. The products evaluated in this work have a capacity that varies between 2 kW and 15 kW [1].

Liquid chilling packages and hydronic heat pumps (LCP-HP) consist in electrically driven reversible heat pumps used for heating and refrigeration. Like air conditioners, LCP- HP units may be air-cooled or liquid cooled, but instead of heating and/or cooling air, they transfer heat to liquid water. The units considered in this work have a capacity up to 1500 kW (water-cooled) and 600 kW (air-cooled) [2].

Rooftop (RT) units consist of a blower, heating or cooling elements, filter racks or chambers, sound attenuators and dampers. They are used to condition and circulate air as part of a heating, ventilation and air condition (HVAC) system. Rooftops are designed for outdoor use, as it names indicates, typically the roof. The units considered in this work have a rated capacity up to 200 kW [3]. They can be air-to-air or water-to-air rooftop units.

Finally, variable flow refrigerant (VFR) units is a more recent HVAC technology (1982). A typical unit consist of one or several outdoor units – with the compressor and condenser, several indoor units –evaporator, refrigerant piping running between the outdoor and indoor units. These types of systems modulate the flow of refrigerant according to exact demands of one or several areas and are especially suited for large buildings with several rooms – commercial buildings, offices, schools, etc. In this study, only single module outdoor units used for cooling-only, heating-only and reversible units are considered. They can be air- or water- sourced. The units considered in this work have a rated capacity between 7.2 and 61.6 kW [4].

Methods

To assess the energy efficiency progress in heating and cooling European market, statistical analyses were made on reliable performance rating data of an independent database over a period of three years. The data studied is third-party certified, i.e. it proceeds from tests run at independent laboratories. The rating data studied includes:

- Coefficient of Performance (COP) and Energy Efficiency Ratio (EER): For all systems considered in this study the COP – energy efficiency in heating mode – and EER – energy efficiency in cooling mode – are defined as the ratio between the thermal energy delivered and electrical power absorbed by the unit at reference design conditions [1; 2; 3; 4].
- Seasonal Coefficient of Performance (SCOP) and Seasonal Energy Efficiency Ratio (SEER): The calculation of SCOP and SEER is in accordance with EN14511:2013, EN14825:2013 and the [6].
- Energy classes:
- AC: The energy classification for air conditioners is defined in the European Commision Regulation (EU) No 626/2011 supplementing the Directive 2010/30/EU [5]. See Annexes **Table** 7.
- LCP-HP: The energy classification for LCP-HP is defined in the Eurovent Certita Certification Rating Standard [2].
- RT: The energy classification for RT systems is defined in the Eurovent Certita Certification Rating Standard [3].

Results and discussion

Air Conditioners

Figure 1 and **Figure 2** reflect the effects of the entry into force of the ecodesign regulation requirements illustrated by the evolution of energy classes (introduced in Jan.2013 for AC units). Non-ducted AC units are classified with 10 different energy classes, from the best, A+++, to the worse, G. This sample includes more than 6500 AC units between the years 2014 and 2016. The share of non-ducted AC units with high energy efficiencies (classes A+, A++ and A+++) is larger than 50% and has smoothly increased along the years in both heating (**Figure 1**) and cooling mode (**Figure 2**). There are no units in the market labelled with classes lower than D.

The progress illustrated in **Figure 1** and **Figure 2** mirrors the positive effects of the regulations. However, in the recent revision of the European Commission of the Energy Labelling directive (2010/30/EU) [7] it was identified the need to update the energy labelling framework to improve its effectiveness. Customers compare labels across different product groups (for example, between ACs and dishwashers), and not all have the same number of classes,

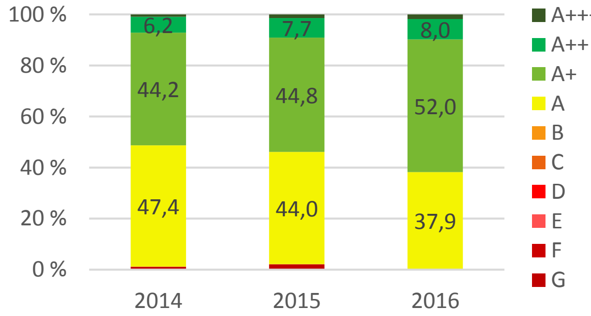

Figure 1. Seasonal Cooling Energy Efficiency – seasonal energy efficiency ratio (SEER) transformation of non-ducted AC units between 2014 and 2016.

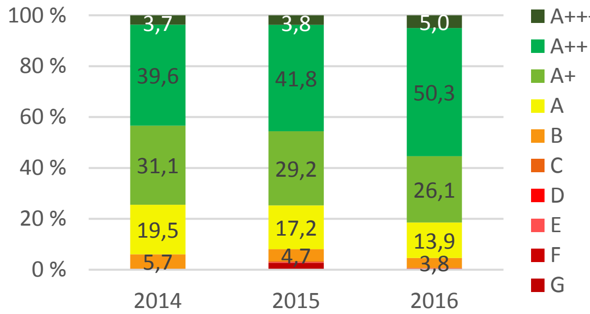

Figure 2. Seasonal Heating Energy Efficiency – seasonal coefficient of performance (SCOP) transformation of non-ducted AC units between 2014 and 2016.

i.e. some vary from A to G (7 classes) while others vary from class A+++ to class G (10 classes, case of AC units). This leads to some confusion making some customers believe that more efficient products could exist or, in the opposite case, that a class A product in a product group where classes vary, from A+++ to G, is very efficient. In the new revision, the Commission considers that the classification using letters from A to G has shown to be more effective for customers and intends to uniform this across products groups (except space and water heaters). For all other products, all class A+++ will be assigned class A, class A++ will be class B and so forth from Jan. 2019 [8].

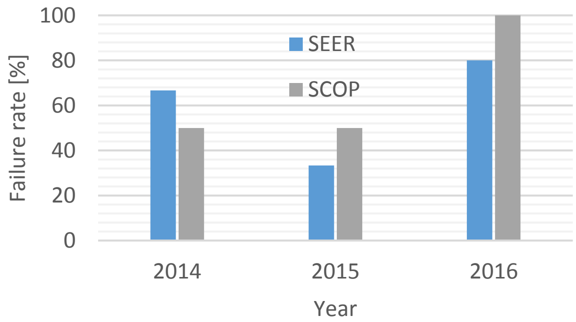

Figure 3. Failure rate of tested non-ducted AC units in the period 2014-2016 according to Eurovent Certita Certification testing campaigns.

Today, the energy class of AC units is determined through the calculation of the seasonal energy efficiency ratio (SEER) and seasonal coefficient of performance (SCOP) of the unit. Compared to the previous requirements, before 2013, based on the energy efficiency ratio (EER) and the coefficient of performance (COP) a single standard operation condition, the SCOP and SEER are calculated based on measurements at six different ambient conditions (known as points A, B, C, D, E and F). They represent the fluctuating demand in residential buildings. Additionally, the new method takes into account the residual electric energy demand during standby and off-mode periods. Altogether, this gives a more realistic picture of the phase of use of AC for consumers.

The regulations demand the manufacturers to self-declare the performance data. These new requirements and its complexity stimulate manufacturers to be more knowledgeable about their products and discourages free-riders. Yet, empirical data from the last three years show that not all manufacturers are able to declare accurate performances (**Figure 3**). When compared to its performance data tested in independent labs, the share of non-conform declared ratings was above 30% and has significantly increased. This mismatch between declared and tested values will over and above have a negative impact on the confidence of end-use consumers and investors in this technology and certainly, jeopardize its potential to reduce energy demand and increase the energy efficiency in buildings. This emphasizes the importance of third party independent testing performed by market surveillance authorities and independent certification organisations. These organisations and their activity ensure the reliability of values declared and thus, promote energy efficiency and end-user confidence.

Since January 2013, the EU regulation No 206/2012 requires minimum levels of energy efficiency and sound power for all electric AC units with a rated capacity up to 12 kW for cooling or heating (if the unit has no cooling function). The minimum requirements depend on the rated capacity (<6 kW and 6-12 kW) and, since January 2014, also on the global warming potential (GWP) of the refrigerant (GWP > 150 or GWP ≤ 150), the working fluid of the unit.

Figure 4 shows the SCOP values of the products analysed in this study. All units seem to comply with the ecodesign minimum (SCOP ≥ 3.8) [5]. The units with larger capacity (>12 kW) have SCOP values less

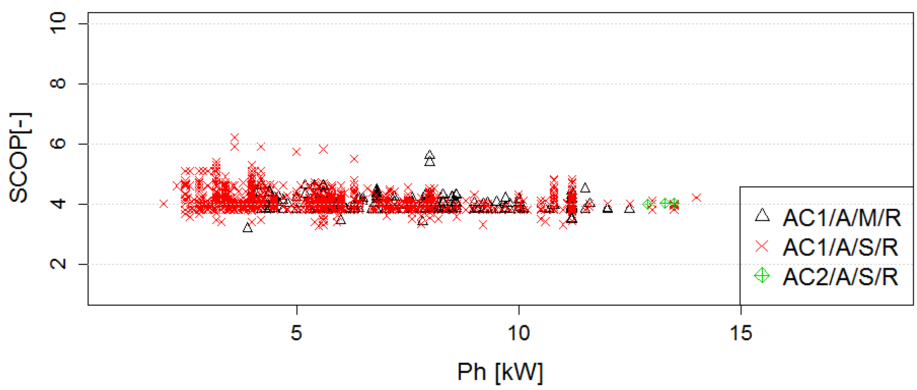

Figure 4. SCOP values dispersion for each of the non-ducted AC unit type according to its rated heating capacity (Ph). See Table 6 in Annexes for unit type.

spread than smaller capacities units. Together with this, it is evident that smaller capacity units can reach SCOP values much higher (max. = 6.2) than the minimum requirements imposed today.

Nonetheless, it is should be highlighted that the average SCOP has evolved in a very conservative way during the last three years. **Table 1** outlines the SCOP transformation of non-ducted AC units between 2014 and 2016. The Split Reversible units (…/S/R) represent the greatest progress with maximum of 0.96% SCOP increase between 2015 and 2016. Together with the high SCOP values, the facts suggest that a readjustment of the minimum requirements of the current regulation is recommended in the future. Rated capacities of AC units with a cooling capacity larger than 12 kW (AC2 in **Figure 4**) are plotted to exemplify what can be expected from larger units. It seems that their seasonal energy efficiency in heating mode is analogous to AC1 units.

Figure 5 shows the SEER values of the products analysed in this study. As it happens for SCOP, the larger capacity (>12 kW) units have SCOP values less spread than units with smaller capacities.

Table 2 outlines the SEER transformation of non-ducted AC units between 2014 and 2016. The SEER has evolved in an indisputable way for both split (…/S/R) and multisplit reversible (…/M/R) units. Given the existence of high SEER values, the question of the suitableness of the minimum requirements pops-up once more. In distinction to reversible units (…/R), the only cooling mode (…/C) units exhibit a deterioration of the seasonal energy efficiency ratio. Some of only cooling units have tested rated capacities below the EU minimum requirements (SEER≥4.3) [5].

This might be caused by the decreasing interest in units that only deliver cooling in buildings applications and therefore, manufacturers abandon their development.

Finally, under the ecodesign requirements a bonus is proposed to guide the market in the direction of the use of refrigerants with low global warming potential (GWP) falls short of expectation. The bonus consists in imposing lower minimum energy efficiency for AC units using low-GWP refrigerants (GWP < 150). The introduction of low GWP refrigerants represents certain technological challenges with respect to energy efficiency of AC units due to thermodynamic characteristics of new refrigerants but great benefits in terms

Table 1. Summary of average and std. deviation SCOP values for each non-ducted AC unit type.

Unit Type	SCOP Mean ($\bar{x}$)			SCOP Std. deviation (s)			Δ 14/15	Δ 15/16
Year	2014	2015	2016	2014	2015	2016	[%]	[%]
AC1/A/M/R	3.96	3.97	4.00	0.24	0.22	0.23	+0.25	+0.76
AC1/A/S/R	4.04	4.06	4.10	0.30	0.32	0.32	+0.46	+0.96
AC2/A/S/R	–	–	4.01	–	–	0.01	–	–

Table 2. Summary of average and std. deviation SEER values for each non-ducted AC unit type.

Unit Type	SCOP Mean ($\bar{x}$)			SCOP Std. deviation (s)			Δ 14/15	Δ 15/16
Year	2014	2015	2016	2014	2015	2016	[%]	[%]
AC1/A/M/C	–	6.36	6.27	–	0.66	0.41	–	-1.42
AC1/A/M/R	5.85	5.88	6.18	0.51	0.51	0.86	+0.51	+5.10
AC1/A/S/C	5.43	5.19	5.10	0.95	1.20	1.35	-4.42	-1.73
AC1/A/S/R	6.08	6.12	6.24	0.87	0.90	0.91	+0.66	+1.96
AC2/A/S/R	–	–	5.92	–	–	0.24	–	–

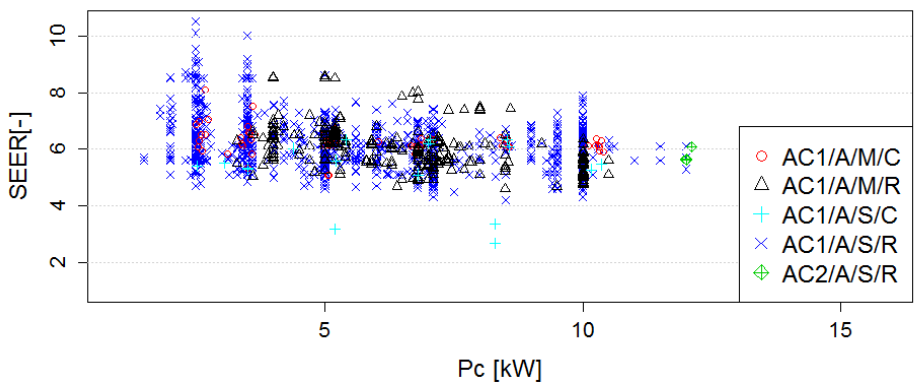

Figure 5. SEER values dispersion for each of the non-ducted AC unit type according to its rated cooling capacity (Pc). See Table 6 in Annexes for unit type.

of reduction of global warming gas emissions, in the case of leakage. According to this study (**Figure 6**) among over 6500 non-ducted AC products, low-GWP are not present in the market. The R410A refrigerant (GWP = 2088) is by far the dominating refrigerant used in the market of AC units in Europe while R32 (GWP = 675) has been gaining moderate importance. Perhaps, more stringent ecodesign minimum requirements for AC units using conventional refrigerants could also steer the market for the use of low GWP refrigerants.

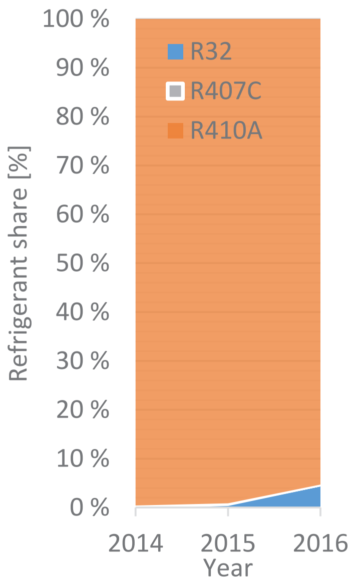

Figure 6. Evolution of refrigerants used in non-ducted AC units.

Liquid chilling packages and hydronic heat pumps

The COP of LCP-HP units in low temperature heating mode sorted by unit type are plotted against its capacity in **Figure 7**. Air source packaged reversible units (LCP35/A/P/R) tend to perform worse than any type of unit. Otherwise, the COP values of LCP-HP units seem to exhibit no significant statistical dependence between energy efficiency (COP) and its capacity.

The maximum average COP among LCP-HP units in low temperature (35°C) heating mode was 5.59 – in water based packaged (LCP-HP35/W/P/C) units, while the minimum was 3.89 in air based packaged reversible units (LCP-HP35/A/P/R). See **Table 3**.

Table 3. Summary of average and std. deviation COP and EER values for each LCP-HP unit type.

Unit Type	COP Mean ($\bar{x}$)	COP Std. deviation (s)	EER Mean ($\bar{x}$)	EER Std. Deviation (s)
LCP35/A/P/R	3.89	0.28	3.43	0.42
LCP35/A/S/R	4.34	0.31	3.38	0.33
LCP35/W/P/C	5.43	0.11	3.58	0.47
LCP35/W/P/R	5.32	0.35	6.80	0.80
LCP-HP35/A/P/H	4.21	0.16	5.64	0.48
LCP-HP35/W/P/H	5.59	0.43	-	-
LCP55/A/P/R	2.51	0.20	-	-
LCP55/A/S/R	2.83	0.21	-	-
LCP55/W/P/C	3.41	0	-	-
LCP55/W/P/R	3.33	0.18	-	-
LCP-HP55/A/P/H	3.2	0.37	-	-
LCP-HP55/W/P/H	3.69	0.15	-	-

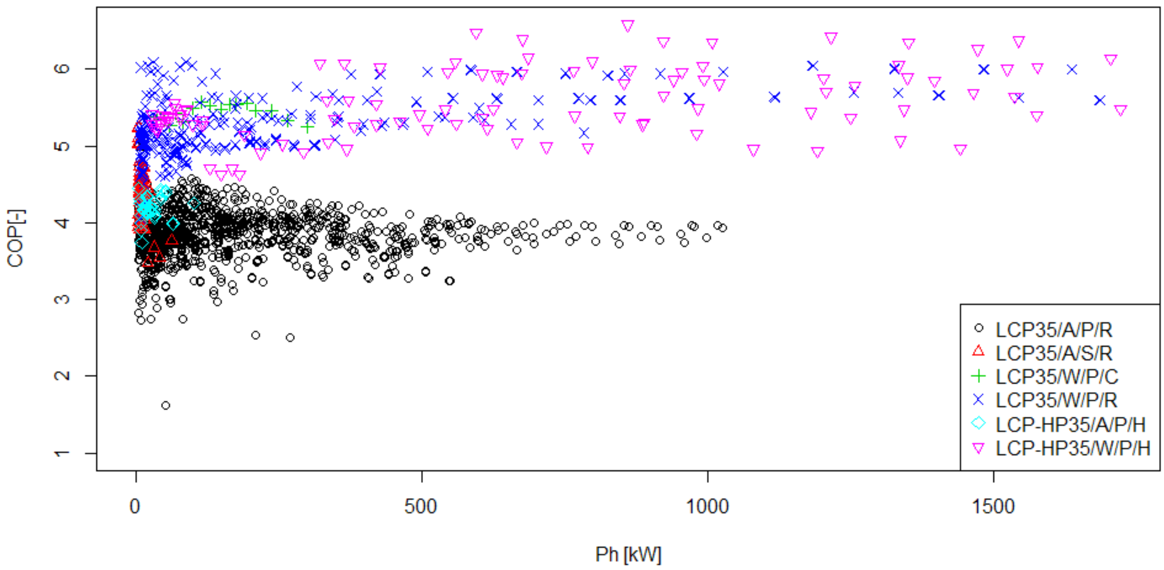

Figure 7. COP values dispersion of the LCP-HP type low heating mode (35°C) units according to its rated heating capacity (Ph). See Table 8 in Annexes for unit type.

In high temperature (55°C), as shown in **Figure 8**, the maximum average COP was reached water based packaged LCP-HP units (LCP-HP55/W/P/H), 3.69 and the minimum average 2.51 with air based packaged reversible units (LCP55/A/P/R). The different types of LCP-HP units show to be clustered in different COP value levels. This indicates that, particularly in high temperature heating mode, the different types of units should be considered independently with regards to minimum energy performance requirements.

Figure 9 shows the EER values of LCP-HP units during the period 2014–2016. The maximum average EER among LCP-HP units in low temperature heating mode was 6.80 – in the case of water based packaged reversible units (LCP35/W/P/R), while the minimum was 3.38 in air based split reversible units (LCP-HP35/A/S/R). See **Table 3**.

LCP-HP units are not yet considered under the energy labelling regulation. Thus, no study on the seasonal energy efficiency (SCOP and SEER). However, the Eurovent Certita Certification program [2], defines energy classes on the basis of the COP and EER values [2]. Results of the market transformation between 2014 and 2016 can be found in the following couple of figures (**Figure 10** and **Figure 11**). These results echo the stagnation of the LCP-HP market. In the last three years, there are no signs of significant positive evolution with respect to COP and EER values.

Rooftops

Figure 12 shows that RT present no clear dependence between COP and unit rated capacity. In addition, the latter figure reveals two clear clusters corresponding to water-based units with higher COP values than air-based units.

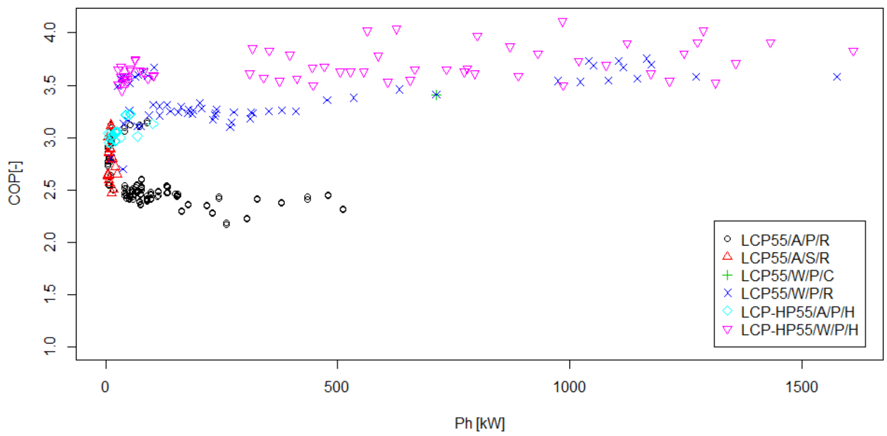

Figure 8. COP values dispersion of LCP-HP unit in high heating mode (55°C) units according to its rated heating capacity (Ph). See Table 8 in Annexes for unit type.

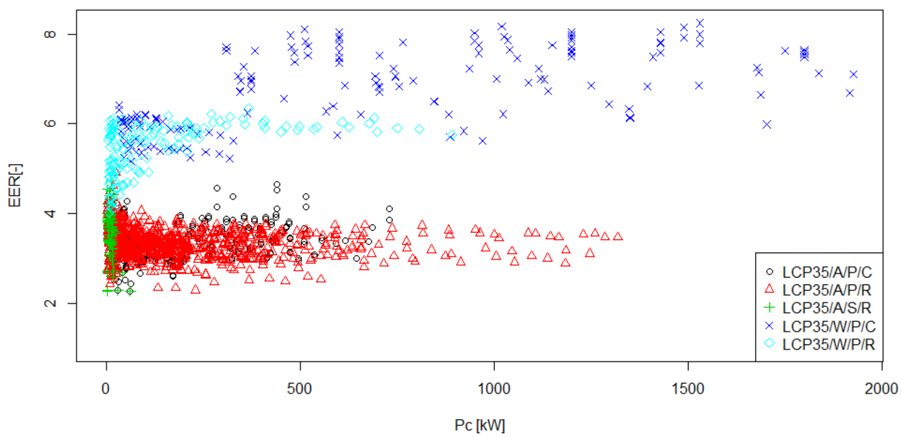

Figure 9. EER values dispersion LCP-HP units according to its rated cooling capacity (Pc). See Table 8 in Annexes for unit type.

Figure 13 shows that RT present no clear dependence between COP and the rated capacity of the unit in cooling mode, either. In addition, the latter figure reveals two clear clusters corresponding to water-based units with higher EER values than air-based units, both cooling only mode and reversible type.

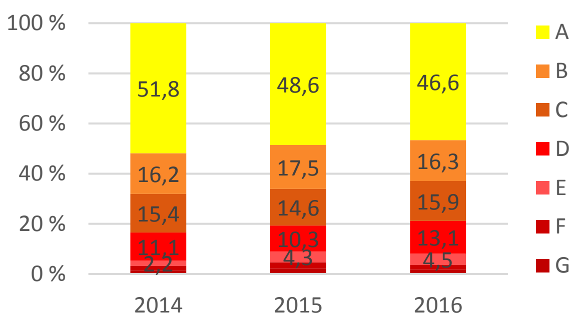

Figure 10. Coefficient of performance (COP) – transformation of LCP-HP between 2014 and 2016.

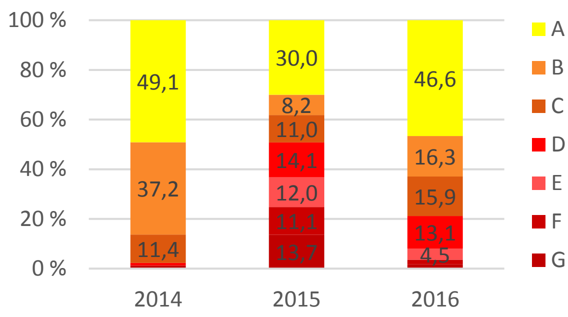

Figure 11. Energy Efficiency Ratio (EER) – transformation of LCP-HP between 2014 and 2016.

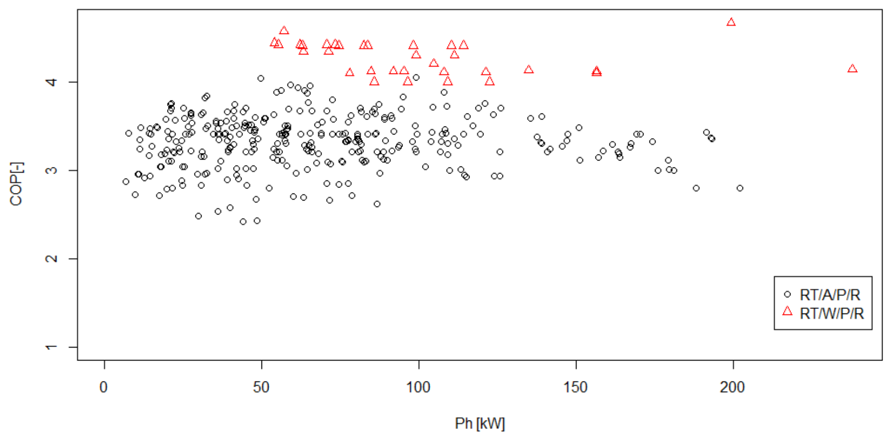

Figure 12. COP values dispersion for each of the RT unit type in heating mode according to its rated heating capacity. See Table 9 in Annexes for unit type.

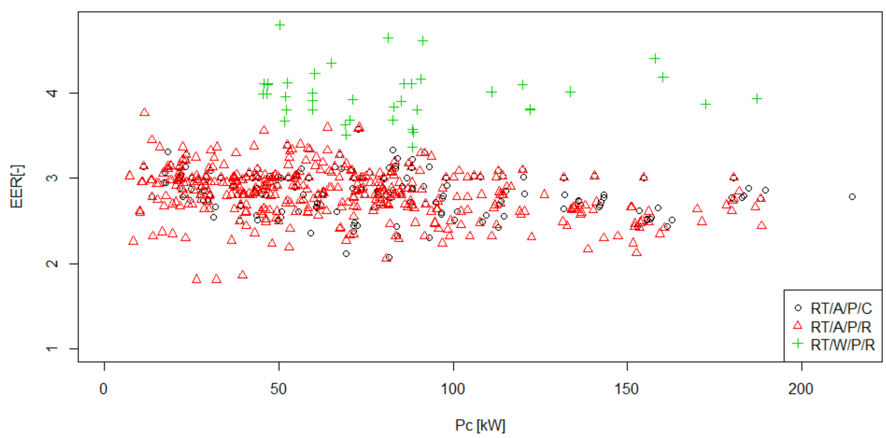

Figure 13. EER values dispersion for each of the RT unit type in cooling mode according to its rated cooling capacity (Pc). See Table 9 in Annexes for unit type.

Table 4 sums up average COP and EER values found for three different types of RT units (see types in **Table 9**). The water based packaged reversible systems (RT/W/P/R) present COP values 1.3 times higher than air heated units (RT/A/P/C and RT/A/P/R) in heating mode. The standard deviation values indicate a slight potential for positive effects to incite for energy performance improvement for heating applications.

The performance of water cooled RT units in cooling mode is also up to 1.4 times higher than air cooled packaged reversible units (RT/A/P/R). The standard deviation values indicate a slight potential for positive effects to incite for energy performance improvement in cooling mode.

Table 4. Summary of average and std. deviation COP and EER values for each RT unit type.

Unit Type	COP Mean ($\bar{x}$)	COP Std. deviation (s)	EER Mean ($\bar{x}$)	EER Std. deviation (s)
RT/A/P/C	–	–	2.87	0.23
RT/A/P/R	3.24	0.28	2.80	0.28
RT/W/P/R	4.31	0.19	3.94	0.30

As LCP-HP units, RT are not considered under the energy labelling regulation. Thus, no study on the seasonal energy efficiency (SCOP and SEER). However, the Eurovent Certita Certification program [3], defines energy classes on the basis of the COP and EER values. Results of the market transformation between 2014 and 2016 can be found in the following couple of figures (**Figure 14** and **Figure 15**) for air and water based RT systems. These results echo the stagnation of the RT market. Except with respect to water-based systems, in the last three years, there are signs of positive evolution on EER values. From 2014 to 2016, 19% passed from lower energy classes to class A.

Variable Flow Refrigerant

Figure 16 shows the COP values of VRF units in heating mode sorted by unit type against its capacity. It is shown that water- and air-sourced systems seem to have comparable performances. The evident vertical lines corresponding to different heating capacities are defined by the market.

Figure 17 shows the EER values of VRF units in cooling mode sorted by unit type against its capacity. Water-sourced units present higher energy efficiency that air-sourced in cooling mode, contrasting with what

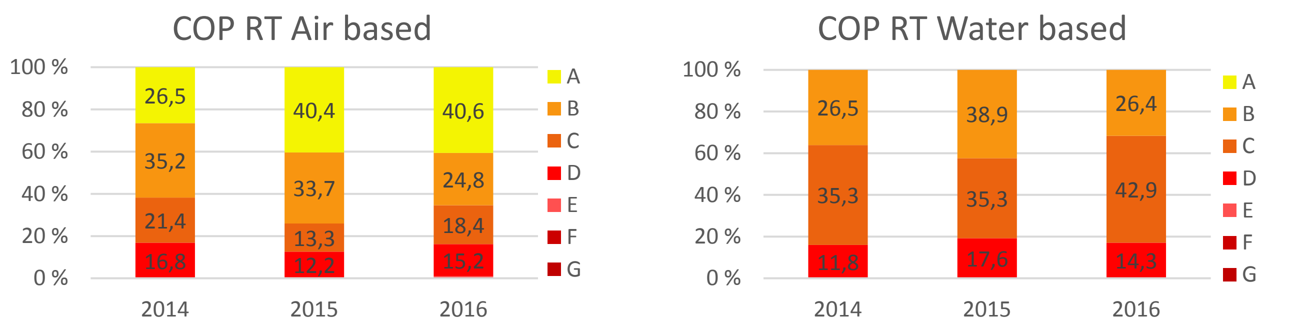

Figure 14. Coefficient of performance (COP) –transformation of RT for air and water based units between 2014 and 2016.

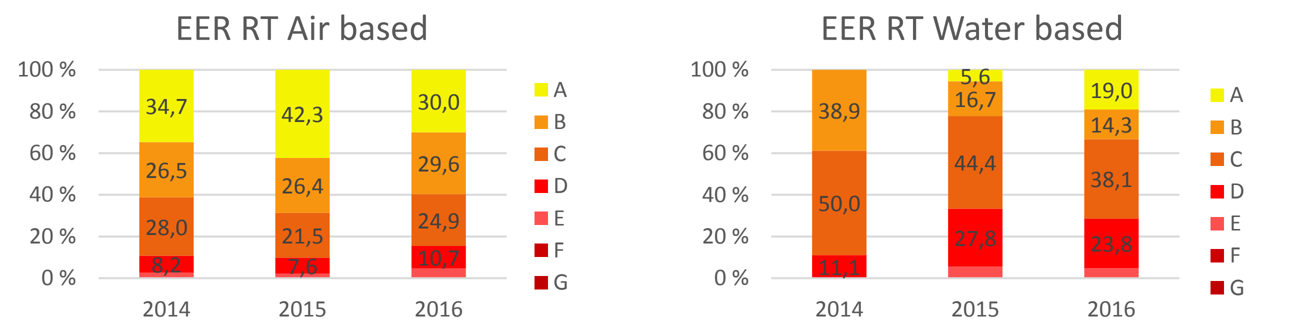

Figure 15. Energy Efficiency Ratio (EER) –transformation of RT for air and water based units between 2014 and 2016.

could be seen in heating mode, where these two types of units seem to show comparable performances (**Figure 16**). This could be a result of free-cooling. However, it is ambitious to conclude that this is a trend as there are only three samples of water-sourced units available in this dataset.

The maximum average COP among VRF units in heating mode was 4.53 –water based units (VRF/W/R), while the minimum was 4.22 in air based units (VRF/A/R). **Table 5** summarizes the mean and standard deviation of COP and EER for each unit type in the last three years period (2014-2016).

Air based types present a larger standard deviation than water based. Yet, this might be due to the smaller numbers of water based samples. Thus, the potential for policy effect should be the same for air- and water-sources VRF units.

VRF units are not considered under the energy labelling regulation or any certification program. Thus, no study on the seasonal energy efficiency (SCOP and SEER) or nominal conditions efficiency (COP and EER) were performed.

Table 5. Summary of average and std. deviation COP and EER values for each VRF unit type.

Unit Type	COP Mean ($\bar{x}$)	COP Std. deviation (s)	EER Mean ($\bar{x}$)	EER Std. deviation (s)
VRF/A/R	4.22	0.48	3.77	0.47
VRF/W/R	4.53	0.10	5.52	0.28

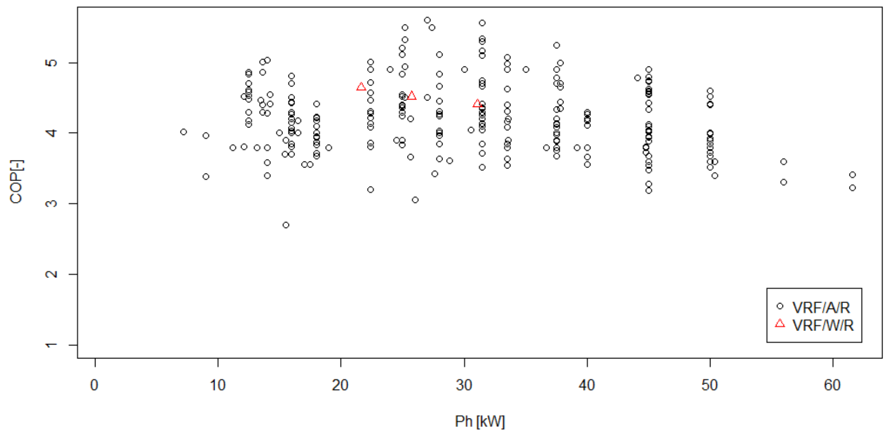

Figure 16. COP values dispersion for each of the VRF unit type in heating mode according to its rated heating capacity (Ph) See Table 10 in Annexes for unit type.

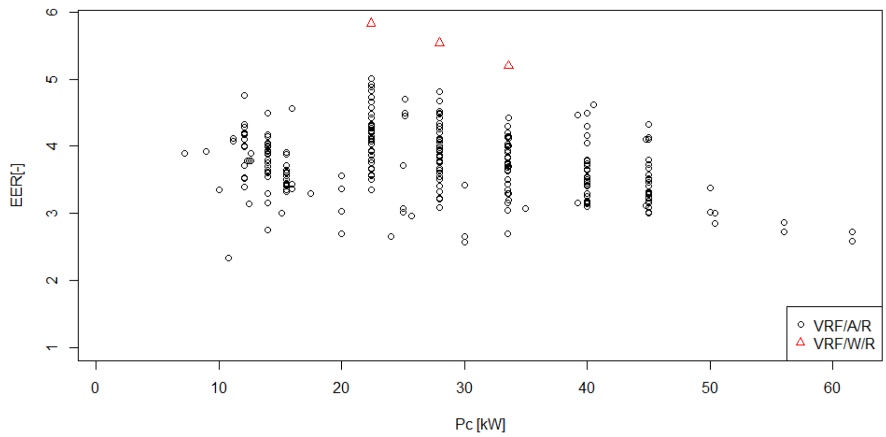

Figure 17. EER values dispersion for each of the VRF unit type in heating mode according to its rated heating capacity (Pc). See Table 10 in Annexes for unit type.

Conclusions

This study is based on accurate data of the performance of heating and cooling technologies tested in independent laboratories. The technologies considered in this study are: air conditioners, liquid chilling packages and hydronic heat pumps, rooftop and variable refrigerant flow units.

The statistical analyses performed and its results give an outlook of the technological progress in European heating and cooling market during the period of 2014 and 2016. The facts presented prove the positive effect of energy labelling implementation on energy efficiency improvement and confirm the importance of standardised/legit data for heating and cooling technologies. Furthermore, the facts strongly recommend the revision of the ecodesign requirements on the minimum energy efficiency in the future revision of the regulation in the matter of AC units. A review of the regulation No 206/2012 supplementing the Directive 2010/30/EU with regard to ecodesign requirements of AC products is planned. The Commission shall review the regulation No 206/2012 no later than 5 years from the date of entry into force.

With respect to the other technologies (liquid chilling packages and hydronic heat pumps, rooftops and variable flow refrigerant) studied in this work and its future application with regards to energy efficiency improvement, it is suggested that these systems should be discriminated by water and air-based units when defining minimum requirements. In addition, packaged and split systems also present distinguished performances.

Annexes

In this study, the AC units are classified according to their capacity:

- AC1: Comfort Air Conditioners and Heat Pumps rated up to 12 kW;
- AC2: Comfort Air Conditioners rated from over 12 kW up to but not including 45 kW cooling capacity.

Furthermore, they are also classified according to its heat source, system and mounting types. AC units reject heat from the room to water (water cooled unit) or air (air/air units) in cooling mode and, if reversible, they can also absorb heat from the water or air to the room in heating mode. **Table 6** condenses the AC units classification used in this study.

Table 6. Non-ducted air conditioners (AC) classification.

<table>
<tr><th>Programme</th><th>Code</th><th>Heat rejection</th><th>Code</th><th>System</th><th>Code</th><th>Operation</th><th>Code</th><th>Mounting</th><th>Code</th></tr>
<tr><td rowspan="3">Comfort Air Conditioners up to 12 kW</td><td rowspan="3">AC1</td><td rowspan="3">Air cooled</td><td rowspan="3">A</td><td rowspan="2">Split</td><td rowspan="2">S</td><td rowspan="3">Cooling only</td><td rowspan="3">C</td><td>High wall</td><td>W</td></tr>
<tr><td>Floor mounted</td><td>L</td></tr>
<tr><td rowspan="2">Multisplit</td><td rowspan="2">M</td><td>Cassette</td><td>C</td></tr>
<tr><td rowspan="4">Comfort Air Conditioners from 12 up to 45 kW</td><td rowspan="4">AC2</td><td rowspan="4">Water cooled</td><td rowspan="4">W</td><td rowspan="4">Reverse cycle</td><td rowspan="4">R</td><td>Ceiling suspended</td><td>S</td></tr>
<tr><td rowspan="3">Packaged</td><td rowspan="3">P</td><td>Built-in horizontal</td><td>B</td></tr>
<tr><td>Built-in vertical</td><td>V</td></tr>
<tr><td>Window</td><td>Wi</td></tr>
</table>

Table 7. Energy Classification for Air Conditioners except double ducts and single ducts.

Energy Efficiency Class	SEER	SCOP
A+++	SEER ≥ 8.50	SCOP ≥ 5.10
A++	6.10 ≤ SEER ≤ 8.50	4.60 ≤ SCOP ≤ 5.10
A+	5.60 ≤ SEER ≤ 6.10	4.00 ≤ SCOP ≤ 4.60
A	5.10 ≤ SEER ≤ 5.60	3.40 ≤ SCOP ≤ 4.00
B	4.60 ≤ SEER ≤ 5.10	3.10 ≤ SCOP ≤ 3.40
C	4.10 ≤ SEER ≤ 4.60	2.80 ≤ SCOP ≤ 3.10
D	3.60 ≤ SEER ≤ 4.10	2.50 ≤ SCOP ≤ 2.80
E	3.10 ≤ SEER ≤ 3.60	2.20 ≤ SCOP ≤ 2.50
F	2.60 ≤ SEER ≤ 3.10	1.90 ≤ SCOP ≤ 2.20
G	SEER < 2.60	SCOP < 1.90

Table 8 sums all the classes of LCP-HP units studied as classified by ECC [2].

Table 9 sums all the classes of RT units studied as classified by ECC [3] and **Table 10** sums all the classes of VRF units studied as classified by ECC [4]. ■

Table 8. Classes of LCP-HP units.

Programme	Code	Heat rejection	Code	System	Code	Operation	Code	Duct	Code	Compressor	Code
Liquid Chilling Packages	LCP	Air cooled	A	Packaged	P	Cooling only	C	Ducted	D	Centrifucal	C
		Water cooled	W	Split	S	Reverse cycle	R	Non Ducted	N	Other	O

Table 9. Classes of RT units.

Programme	Code	Heat rejection	Code	System	Code	Operation	Code
Rooftop	RT	Air	A	Packaged	P	Cooling only	C
		Water	W			Reversible cycle	R

Table 10. Classes of VRF units.

Programme	Code	Heat rejection	Code	Operation	Code
Variable Refrigerant Flow	VRF	Air	A	Cooling only	C
		Water	W	Reversible cycle	R

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NEx
Nature of Excellence by Eurovent – A new certification scheme

The demand of top quality products grows up more and more every day. Nowadays buildings designer doesn't only focus on the actual performance when they select an HVAC&R (Heating Ventilation Air-conditioning and Refrigeration) product for their projects, key elements such as durability, maintenance, controls, etc. are also considered. Currently many manufacturers of the HVAC&R market propose such products but no label/certification are in place to recognize them as such.

QUENTIN LIEBENS
Project Development Manager
Eurovent Certita Certification

It is the case of Air Handling Units (AHU) where reaching high performances is important but is not the only element to define a high-quality product. Today's AHUs provide so much more than just good performances.

NEx - Nature of Excellence by Eurovent

It's within this context that in 2017 Eurovent Certita Certification launched a brand-new mark to certify top rated products called NEx (Nature of Excellence). Proposing to the market a Eurovent NEx certified product and certificate is a testimony of the company capability of producing top in class rated product with awareness and carefulness towards environments, social and corporate governance. This is an added value to manufacturing company, but also to project/companies investing in Eurovent NEx certified product designed, engineered and integrated systems.

The first certification scheme developed under the NEx mark is for Air Handling Units. The aim of this certification scheme is to cover key topics such as durability, high product performance, recyclability, energy efficiency and many other criteria which define a high-quality product. The list of elements to define the quality of a product will never be exhaustive thanks to the evolution of the technologies and the end user demand. However, several elements are already essential and must be considered to define a top-rated product.

Durability of the products

The durability of a product is its ability to maintain its functions and performances over its life cycle. Lifetime of a product is fundamental, several elements influence the lifetime starting from the design of the product, typically:

- Design for reliability and robustness in order to assure that the product will not be easily broken or damaged.
- Design for repair and maintenance in order to ease the maintainability of the product and therefore ensure good performances through the years.

A product of quality is a product which last in the time. In the case of an AHU the selection of the material, whether it is a metallic or a non-metallic material is important, more specifically it must be resistant to the corrosion which could significantly decrease the lifetime of the product. Regarding the maintenance an AHU must be easily accessible for cleaning and for potential interventions on the components or alternatively easily removable component is preferable.

All those elements are covered by the NEx certification scheme in order to assure a durable product.

Recycle Ability

The notion of recycling can be complex when we talk about HVAC&R products. The European WEEE (Waste Electrical and Electronic Equipment) directive encourage the manufacturers of electrical and electronic products to take in charge the recycling of their products when their life come to an end. Only few products of the HVAC&R world come under the scope defined in the WEEE directive and an AHU is not one of them. However, this directive includes several elements applicable for AHU, although it seems complex to ask to a manufacturer to be in charge of the recycling of the product he sold due to the long life of the product, the end user can be informed of what can be recycled in the unit and how as a minimum. This would be a good starting point to move forward in the world of the recycling.

Controls of an Air Handling Unit and its integration in a ventilation system

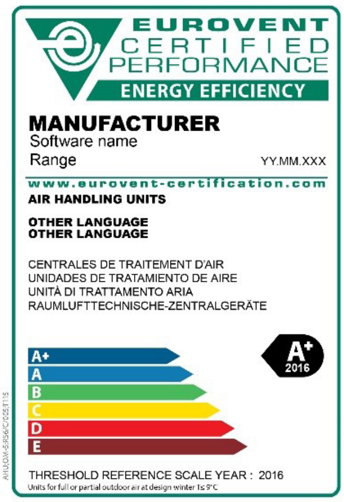
Most of the time an AHU is made to be integrated in a building as part of a ventilation system, ensuring its good integration and connectivity to the Building Management System (BMS) is a proof of quality. A unit properly controlled will provide the best of its capacity. To do so the connection shall be easy, we can talk here about a "plug and play" unit meaning that an electrical cabinet is delivered by the manufacturer itself with the unit.

The future is in the digital technologies, BIM (Building Information Modelling) is more and more used in building design and the HVAC&R products don't escape to the rule. Proposing a BIM file for an AHU is a clear added value, this ensures a proper integration of the unit in the design of the building and help for tomorrow's maintenance and commissioning, two elements which contribute to the durability of the product.

High performance of an Air Handling unit

Reaching a high performance is crucial and mostly requested by the building designers. The Eurovent Certified Performance (ECP) mark ensure the reliance of the certified product but cannot guarantee a high performance where the NEx certification set up thresholds for every certified performance of the model box and some of the real unit, as shown in the table below.

	Model Box	Real Unit
Casing Strength (CS)	D1(M)	D2(R)
Casing Air Leakage (CAL)	L1(M)	L2(R)
Filter Bypass Leakage (FBL)	F9(M)	F9(R)
Thermal Transmittance of the Casing (TT)	T2	–
Thermal Bridging Factor (TBF)	TB2	–



With regard to energy efficiency Eurovent Certita Certification released in 2016 an update of its Energy Efficiency labelling for AHU. Interrelationships to evaluate the energy efficiency of AHU are complex and even depend on climate conditions, with one single letter going from E to A+ the energy efficiency labelling for AHU represents balanced effects of air velocity in the fan section, heat recovery efficiency and pressure drop and fan efficiency.

The NEx certification scheme for AHU highlights energy efficient product by requiring only A and A+ air handling units, indeed a product of quality is a product which perform well with the minimum of energy consumed.

With all its requirements assuring a high-quality product the NEx (Nature of Excellence) certification is the perfect association of the ECP (Eurovent Certified Performance) certification. Whether you are a project manager, an architect, a contractor or an engineering consultant the combination of the two certification schemes will ensure you the selection of top rated products. ■

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Performance and Product Quality Certification for micro-Combined Heat and Power Units

ARNAUD MIRATON
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Eurovent Certita Certification has developed and published in December 2017 a certification scheme for micro-Combined Heat and Power (mCHP) units. The programme built under the French NF brand relies on state-of-art European testing standards and is in-line with the latest regulations. The construction of the scheme has been collectively realized with the major European key players of the mCHP field: mCHP manufacturers, research centers, testing laboratories, government authorities, prescribers and customer representatives.

Background

Product overview and certification scope

Gas fueled micro-Combined Heat and Power units refers to technologies fueled with gas that generate both heat and electricity at the same time and with an electricity power lower than 50 kW. The CHP technology has been used in the industrial sector since the 1960s but through technological development it has been adapted for domestic heat and power needs. The mCHP generators used in the unit are mostly internal combustion engines (ICE), Stirling engines and fuel cell technologies. The units commonly called mCHP boilers, are widely presented as the boiler of the future because of its high level of efficiencies and its consistency with the heat and power needs of low-energy housing.

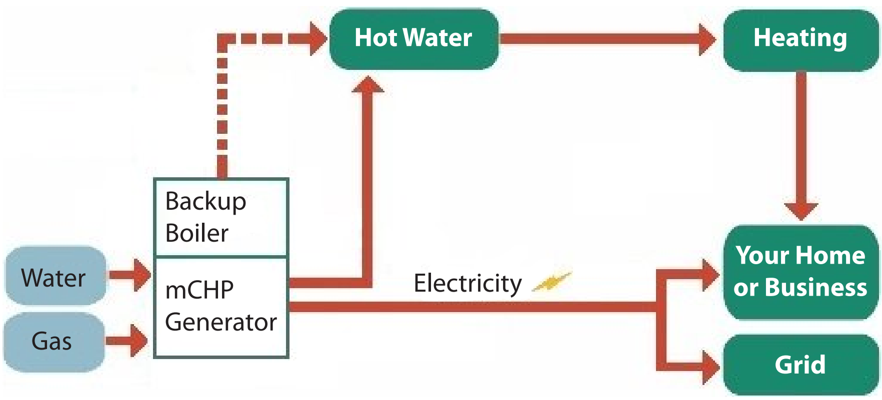

Figure 1. mCHP process diagram.

Certified performances:

Micro-combined heat and power unit		
Performance	**Denomination**	**Threshold**
Nominal thermal capacity (kWth)	$P_{thn\_CHP100+Sup100}$	-
Thermal efficiency (%) - based on lower heating value	$\eta_{th\_CHP100+Sup100}$	-
Electrical efficiency (%) - based on lower heating value	$\eta_{el\_CHP100+Sup100}$	-
Global efficiency (%) - based on lower heating value	$\eta_{CHP100+Sup100}$	-
Seasonal Efficiency (%)	η_s	$\eta_s > 102\%$
Auxiliary Electrical Energy Consumption (kW)	P_{auxmax}	-
Electrical nominal power (kWe)	P_{eln}	-
Standby mode losses (kW)	P_{stby}	-
Auxiliary energy in standby mode (kW)	P_{SB}	-
Thermal minimal power (kWth)	P_{min}	-
Nitrogen oxides emissions (mg/kWh)	NO_x	NOx < 70 mg/kWh (Stirling) NOx <240 mg/kWh (ICE)
Sound Power level(dB)	L_{wa}	-
Annual consumption of heating combustibles (GJ PCS)	Q_{HE}	-
Principal heat and power generator		
Nominal thermal capacity (kWth)	$P_{thn\_CHP100+Sup0}$	-
Thermal efficiency (%) - based on lower heating value	$\eta_{th\_CHP100+Sup0}$	-
Electrical efficiency (%) - based on lower heating value	$\eta_{el\_CHP100+Sup0}$	-
Global efficiency (%) - based on lower heating value	$\eta_{CHP100+Sup0}$	-
Auxiliary electrical energy consumption (kW)	P_{auxmin}	-
Auxiliary heat generator		
Nominal thermal capacity (kWth)	$P_{Sup\_CHP0+Sup100}$	-

The NF certification scope covers gas fueled mCHP units using an internal combustion engine, Stirling engine or a fuel cell technology. Units considered are gas fueled units that may include, as the case may be, a heat accumulator or/and a backup boiler. Units must be delivered as a complete unit or assembly of components referenced and designed to be installed together.

The mCHP domestic market: a young market with promising perspectives of growth

The technology has known up to now a non-uniform deployment through the World and Europe. Japan is considered as the precursor especially for fuel cell technologies, in Europe Germany has the lead. Several experimental demonstrations have been realized at European and National stages such as the ENE FIELDS project (1000 housings equipped in 11 European countries), the CALLUX project (800 units deployed in Germany) or EPILOG project in France… The technology has proved its worth and waits know to be fully supported and deployed in the European energy landscape.

The regulatory environment

The regulatory environment has evolved recently in France to consider these technologies on the market. In Particular, a decree for Feed-in tariffs for electricity (C16 decree) has been published, defining the electricity purchasing prices of mCHP units. The purchasing prices are defined according to the Primary Energy Savings (Ep) of the unit, calculated as follow based on the thermal end electrical efficiencies (η) of the machine, both certified in the NF mCHP certification scheme:

$$\mathrm{Ep} = \left(1 - \frac{1}{\frac{\eta_{th\_CHP100+Sup0}}{\eta_{Réf\_th}} + \frac{\eta_{el\_CHP100+Sup0}}{\eta_{Réf\_el}}}\right) \times 100\%$$

As well the French Thermal regulation for buildings (RT2012) has been updated to consider fully the three technologies of generators in the calculation tools.

At the European stage, two key regulations are considered in the scheme, the Ecodesign and Energy labeling (ErP) and the European regulation for gas appliances. More specifically, the ErP has been completed with two application regulations that deal with mCHP boilers: the regulations 811/2013 [1] and 813/2013 [2], both giving accurate expectations and thresholds on the performances of the units.

The NF micro-combined heat and power brand: an independent and third party recognition of the product's performances and quality

The NF certification brand, well-known in France and through Europe, guarantees the level of performances and product quality declared by the mCHP manufacturers. It generates clarity and transparency on the market, display understandable information on the performances and product quality, enabling end-users to compare objectively the products on the market.

The NF mCHP certification process is a reliable and robust process that includes yearly factory assessment audits and third-party product testing. The testing protocols, calculation methods, and denominations have all been harmonized to rate fairly and identically the products on the market.

Figure 2. NF mCHP marking.

The testing methods are based on the European testing standards **EN 50465 March 2015** "Gas appliances - Combined heat and power appliance of nominal heat input inferior or equal to 70 kW" and **EN 15036-1 mai 2007** "Airborne noise emissions from heat generators".

For further information on the NF mCHP certification scheme or to apply for the certification, please feel free to contact Eurovent Certita Certification (apply@eurovent-certification.com) specifying "NF-Micro Combined Heat and Power" in the mail object. There is no deadline as this is a voluntary registration. ■

Reference documents

[1] COMMISSION DELEGATED REGULATION (EU) No 811/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device.

[2] COMMISSION REGULATION (EU) No 813/2013 of 2 August 2013implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters

Seasonal Efficiencies for Rooftop units

After almost 20 years, Eurovent Certita Certification is well recognized on the European market for heating, ventilation and air-conditioning products. Currently 66% of the HVAC sold on the EU market are certified by Eurovent Certita Certification with the Mark "Eurovent Certified Performance" (ECP).

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Launched in 2007, the rooftops certification programme was the thirteenth programme of Eurovent Certita Certification. The current certified products and their performances are available 24h/24 on the ECP website.

Since the beginning of the programme, performances of rooftops used to be compared at fixed conditions, also named "Standard Rating Conditions" or "Nominal Conditions"

However, these conditions do not represent the usual operating conditions of the equipment over a season, which becomes especially important for the calculation of the energy efficiency.

From January 2013, the European Commission implemented step by step seasonal efficiencies for several types of heating and cooling devices:

- Residential Air Conditioners below 12 kW since 1st of January 2013;
- Air-to-water & water-to-water Heat pumps below 400 kW since 15th of September 2015.

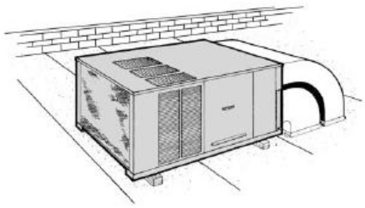
From 1st of January 2018, the European Commission will require that seasonal efficiencies be applied also to:

- Air-conditioners above 12 kW
- Variable Refrigerant Fluid systems
- Chillers
- **Rooftops units**.

Consequently, Eurovent Certita Certification has updated its rooftops programme in accordance with this new Regulation.

Scope of the programme

This certification programme concerns air-to-air and water-to-air rooftops below 200 kW (nominal capacity in cooling mode). It also applies to units intended for both cooling and heating by reversing the cycle.



Rooftop units are defined by the following features:

- Single packaged unit assembled in factory
- Common single frame
- Direct expansion system
- For Air-to-air unit, the outdoor side heat exchanger (condenser / evaporator) allows heat transfer with 100% outdoor (ambient) air.
- Designed to operate permanently outdoor
- The rooftop is designed to permanently handle 100% recycled air with the possibility of mixing partly the fresh air. Nevertheless, the rooftops are excluded from the ventilation unit regulation N° 1253/2014 (according to EVIA/Eurovent Guidance Document on Ecodesign requirements for ventilation units)
- The outdoor fan from an air-to-air rooftop could be ducted but for the certification tests, the unit must be not ducted.
- Rooftops could be equipped with 2, 3 or 4 dampers depending on heat recovery system included or not, even if the heat recovery mode is currently outside the certification programme.

Nevertheless, the following features are not certified:

- gas burners,
- pre-heaters,
- heaters,
- additional internal coil,
- heat recovery (plate, wheels, thermodynamic systems),
- exhaust fans.

Process of Certification:

The programme is split into three sub-programmes:

- One mandatory sub-programme: Air-to-air units up to 100 kW
- Two optional sub-programmes:
  – Air-to-air units from 100 kW to 200 kW
  – Water-to-air units up to 200 kW

The purpose of all Eurovent Certification Programmes is to encourage honest competition and to assure customers that equipment is correctly rated on the market. The purpose is achieved by verifying the accuracy of ratings claimed by manufacturers by continuing testing of production models, randomly selected, in independent laboratories.

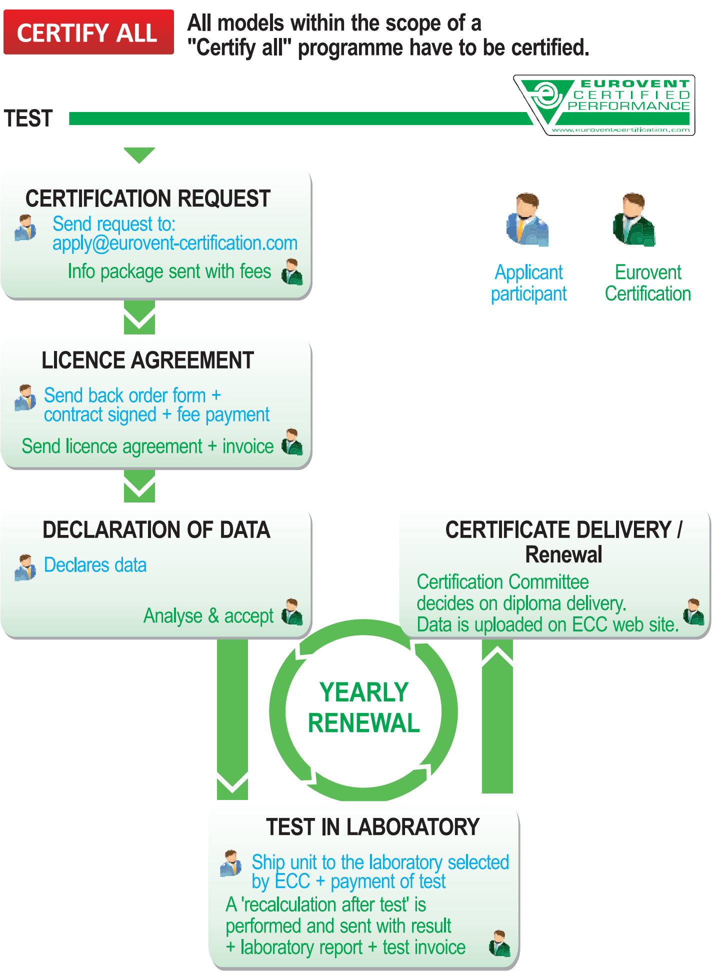


Figure 1. Steps in the certification process of the product performance.

One particularity of rooftop programme is to apply the "Certify-all" principle.

All standard products of the relevant certification programme manufactured or sold by a Participant inside the defined scope must be certified. "All products inside the defined scope presented, at least, on the European market".

"Certify-all" brings clarity and transparency and therefore increases the value of the whole system.

From standard rating conditions to Seasonal efficiencies

Performances of rooftops used to be compared at a fixed condition, also named "Standard Rating Condition" according the standard EN 14511.

Table 1. Operating conditions for standard rating (EN 14511:2013).

	INDOOR SIDE		OUTDOOR SIDE			
	Air entering °C		Air entering °C		Water °C	
	Dry bulb	Wet bulb	Dry bulb	Wet bulb	In	Out
Cooling	27	19	35	24	30	35
Heating	20	15 max	7	6	20*	
SOUND**	27	19 (±2)	20–35	–	30	35

* For units designated for cooling mode, the water flow rate obtained during the test at standard rating conditions in cooling is used.

** Same airflow and same available pressure as for the thermal test shall be used.

Commission Regulation (EU) No 2016/2281 of 30 November 2016 implementing Directive 2009/125/EC of the European Parliament and of the Council establishing a framework for the setting of ecodesign requirements for rooftops introduced on the European market after the 1st January 2018.

The Directive defines minimum energy efficiency for air-to-air rooftops as shown in **Table 2.**

Table 2. Requirements for minimum energy efficiency.

	Tier 1 *from 1st of January 2018*	Tier 2 *from 1st of January 2021*
Heating ηsh	115%	125%
Cooling ηsc	117%	138%

The seasonal efficiency is expressed by:
- ηsh for the heating mode [%],
- ηsc for the cooling mode [%].

These new performances come from SCOP & SEER mentioned in the EN14825 standard and given by the following formula:

$$\eta sh = 100 \times \frac{SCOP}{2.5} - 3\%$$

$$\eta sc = 100 \times \frac{SEER}{2.5} - 3\%$$

where:

- SCOP: Seasonal Coefficient of Performance for heating mode
- SEER: Seasonal Energy Efficiency Ratio for cooling mode
- 2.5 is the coefficient for power generation efficiency
- –3% is the correction that accounts for a negative contribution to the seasonal energy efficiency ratio due to adjusted contributions of temperature controls (for water-cooled units, an addition correction is required: –5%)

New Energy Efficiency Ratio and Standard for Rooftops

The ηsh and ηsc, mentioned in the Directive, represent the usual operating conditions of the equipment over a season. This operating condition can be better assessed by comparing equipment at representative reduced capacities.

Standard EN 14825 provides part-load conditions and calculation methods for calculating the SEER and SCOP of such units when they are used to fulfil the cooling and heating demands.

Other energy consumptions can occur when the unit is not used to fulfil the cooling and heating demands such as those from a crank case heater or when the unit is on standby. These consumptions are considered in the calculation methods for SEER and SCOP.

Cooling mode	Heating mode
Performances in Standard rating conditions (according EN 14511 standard)	
Cooling Capacity @ 35°C	Heating Capacity @ 7°C
EER @ 35°C	COP @ 7°C
Seasonal Performances (according EN 14825 standard)	
Cooling Capacity @ 35°C	Heating Capacity @ 7°C
EER @ 35°C	COP @ 7°C
ηsc	ηsh
Sound Power Level (according EN 12102 standard)	

Certification for Rooftops

All the conditions involved in the calculation of ηsc and ηsh are continuously tested by Eurovent certita Certification. In case of failure on any condition, the seasonal efficiency will be rerated according the result. The models in the same group (same overall dimension as the tested model) will be rerated by the deviation found on the tested model.

These Seasonal Energy Efficiency Ratio for cooling mode (ηsc & SEER) and Seasonal Coefficient of Performance for heating mode (ηsh & SCOP) came in addition to the well-known Energy Efficiency Ratio (EER and COP) and Sound Power Levels (Outside & Indoor sides), already certified.

Table 3. Part load conditions used for calculation of seasonal efficiencies ηsc and ηsh.

Cooling mode			Heating mode for Average Climate		
Conditions	Outdoor T°	Part load ratio	Conditions	Outdoor T°	Part load ratio
A	35°C	100%	A	–7°C	84%
B	30°C	74%	B	2°C	54%
C	25°C	47%	C	7°C	35%
D	20°C	21%	D	12°C	15%
			Bivalent	between –10°C and 2°C	100%

Existing Eurovent Energy labelling

The purpose of Eurovent Energy Efficiency Classes is to simplify the selection of the best units for each type of Rooftops. The classification is entirely voluntary, not related to any European Directive. The energy efficiency of Rooftops is designated by "Eurovent Certita Certification Class A" or "Eurovent Certita Certification Class B" in catalogues and in the Eurovent Certita Certification Directory of Certified Products.

The current Eurovent Energy Labelling has been defined according to the EER & COP at standard Rating conditions (EN14511).

The switch to Seasonal efficiencies will impact the Eurovent labelling. In the coming months, the New Eurovent Efficiency Classes will be based on ηsc & ηsh.

Data publication

Making the certified data easily available for end-users and consultants has always been a priority for Eurovent Certita Certification. Our directory of certified data, available since the creation of the company, and launched as an interactive website around 2001, brings reliable data to end-users. In addition to the certified data a dedicated description page for each certification programme containing the outline of the programme, definitions and rating conditions is made accessible and constantly updated to help visitors understand the value of certified data (http://www.eurovent-certification.com)

Conclusion

The usual energy efficiencies achieved at full load* are going to disappear gradually in order to be replaced by new performances which will allow specifying these units on a more representative way in terms of energy consumption.

The implementation of seasonal efficiencies and minimum requirements for rooftops will force the current market to change. The less efficient products will disappear progressively. With these new requirements, the verification of the published data by a third-party body, as Eurovent Certita Certification, remains a useful added value to verify the announce performance as a complement to the market surveillance, and to help comparing the products thanks to its online database.

In parallel to this regulation implementation, Eurovent Certita Certification is working on several topics of rooftops as the creation on a specific seasonal efficiency taking into account the free cooling and the certification of 3 & 4 damper rooftops including the heat recovery mode. ■

* Rating Standards Conditions according to EN 14511

REHVA Office Responsibilities

NATHALIE WOUTERS – Office and Membership Manager
- Office management, HR
- Membership liaison
- REHVA Student competition
- REHVA Awards
- REHVA Board meetings' secretariat
- REHVA Newsletter, Bulletin publication
- REHVA Annual meetings, General Assembly secretary
- EC, AC secretary
- MoU-s: follow-up and coordination

ANITA DERJANECZ – Managing Director
- REHVA office executive management
- REHVA Legal representative
- Business development
- EU policy and public affairs
- Commissioning certification scheme project
- EU project development and implementation
- ERC, TRC secretary

TIZIANA BUSO – Project Officer
- TRC secretary, support of Task Forces, and technical publications
- EU project implementation
- EU proposal writing
- Supporting REHVA technical seminars
- Commissioning certification scheme project

CHIARA GIRARDI – Publication and Promotion Officer, RJ Editor Assistant
- Publication of REHVA Guidebooks and Journal (as Editor Assistant)
- REHVA website content management
- REHVA promotional services and sales
- Supporters Contact
- REHVA Dictionary and App development
- REHVA presence at events and fairs, events management and promotion of REHVA events
- SC, PMC, COP secretary

GIULIA MARENGHI – Project Assistant
- Administrative support of general office management
- Financial and administrative reporting of EU projects
- EU project implementation – communication activities
- Reception and secretarial support

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

Supervised Commissioning Solutions

Cost and performance problems plague almost all building projects. Commissioning offers perhaps the best solution and a rapid return on investment. REHVA has partnered with COPILOT Building Commissioning Solutions to provide online solutions to supervise and certify the commissioning process. These solutions are delivered by local commissioning engineers.

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Keywords: commissioning, commissioning engineer, technical monitoring, HVAC performance, HVAC comfort

Buildings underperform

Quality costs = **10%**

Construction quality problems cost about 10% of sector turnover according to *Agence Qualité Construction* [1]. In France alone, this represents an annual cost of over €11 Billion.

While building remains a "bricks and mortar" industry, construction process & performance requirements are becoming increasingly sophisticated (**Figure 1**).

Listing a random sample of elements in the ecosystem, **Figure 1** illustrates the complexity of the environment in which we operate. Accelerating demands have not, so far, been matched by step improvements in building and construction technology and quality. Construction suffers from a mismatch between expectations and results (**Figure 2**).

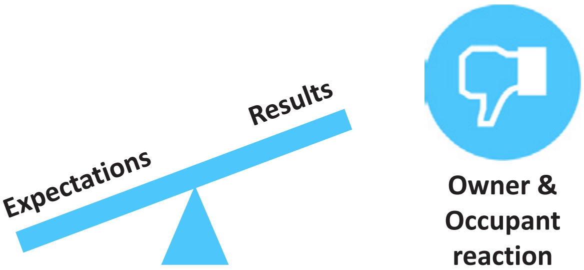


Figure 2. Construction suffers from a mismatch between expectations and results.

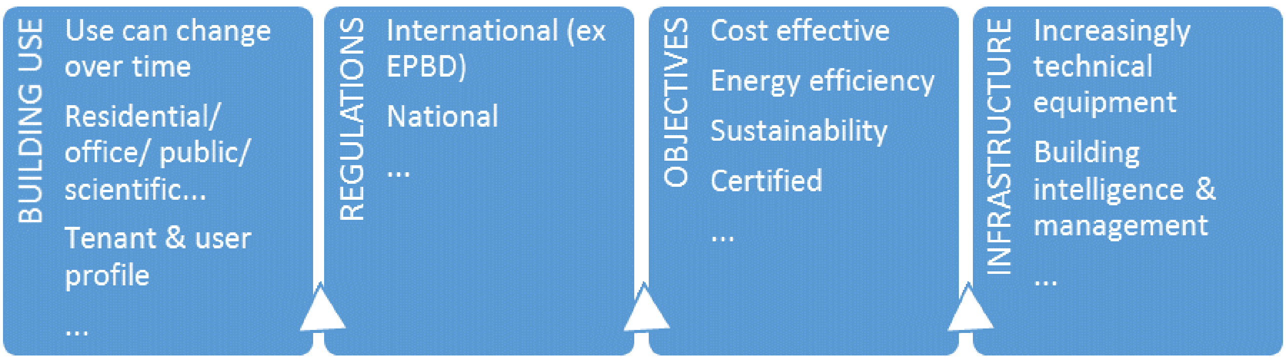


Figure 1. The complexity of the environment in which we operate.

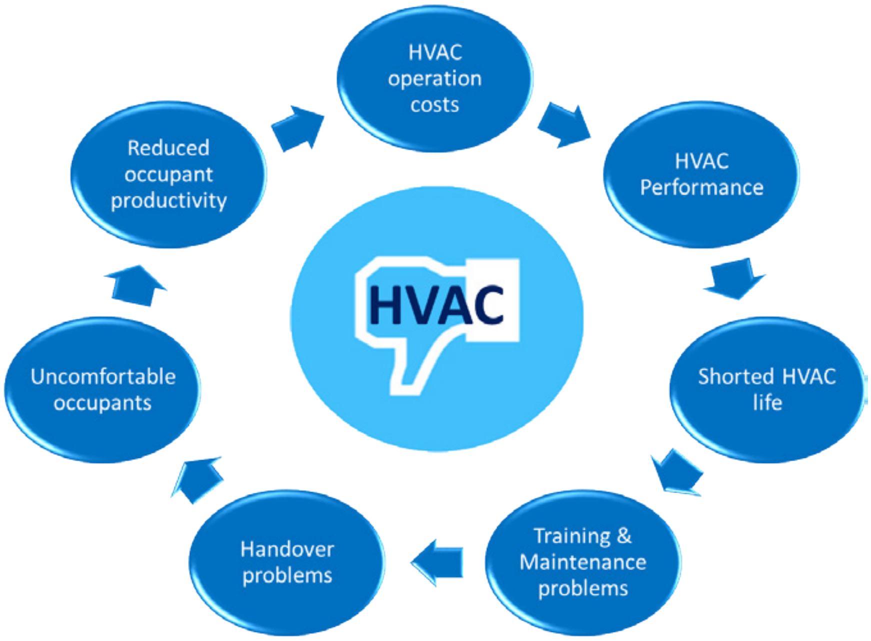


Figure 3. HVAC is among the biggest causes of owner and user dissatisfaction.

This mismatch can clearly be observed in owner and occupant dissatisfaction. Rather than theorise, think of where you work or live. Does the building satisfy your expectations?

- Is it functional / fit-for-purpose?
- Are you and your colleagues happy with the temperature all year around?
- Does it get stuffy or draughty?

Many buildings fail to satisfy these simple questions. And I have not listed critical issues like return on investment, operational costs, energy performance etc.

Two of the questions I listed pertain to Heating, Ventilation and Air Conditioning (HVAC). This is no accident, as HVAC is among the biggest causes of owner and user dissatisfaction (**Figure 3**).

Improve building performance via "Commissioning"

If we simplify the construction ecosystem as shown in **Figure 4**, we observe that successful execution of a building project depends on a number of actors.

The problem of coordination of multiple actors is complicated by the fact that certain actors may have diametrically opposed interests. Owners, for example, may want to ensure minimal investment costs and rapid delivery. Facility Managers privilege easy maintenance while Occupants tends to prioritise functionality and comfort.

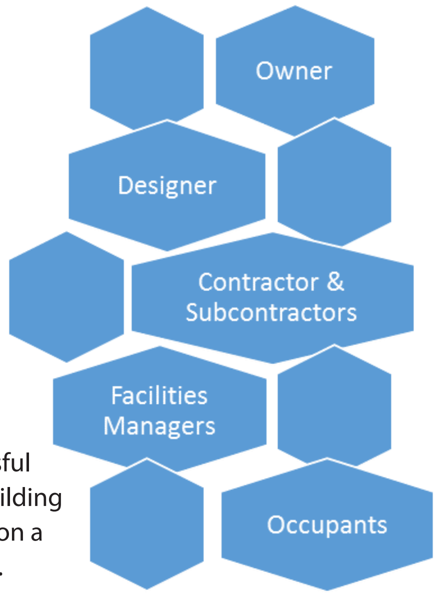


Figure 4. Successful execution of a building project depends on a number of actors.

Similarly, Designer and Contractor interests are not always aligned. The complexity of this bricks and mortar ecosystem is one of the prime reasons for quality problems.

There is a solution to manage problems arising from multiple actors, conflicting interests, unsatisfactory quality control and coordination: Commissioning. This is a quality-focused process for enhancing the delivery of a project. The process focuses upon **verifying and documenting that all of the commissioned systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements (OPR)**.

Commissioning is undertaken by qualified engineers who have extensive practical experience. Their role could be compared to a referee who verifies the work flow to ensure it complies to the rules of the game (i.e. the owner's project requirements).

The reference [2] return on investment research undertaken on commissioning proves its cost effectiveness. On a pure financial basis, median return on investment is a single year for retro-commissioning of existing buildings and four years for commissioning of new buildings.

1 year payback for existing buildings

4 years payback for new building

If one takes comfort and associated occupant productivity improvements into account, it seems likely that we are looking at payback in a matter of months

The interest of commissioning is evident; all the more if you subscribe to the theory that "a stitch in time saves nine". Investment in commissioning, which is estimated to add only about 0.5% to a building project, has a knock-on impact throughout the building's life cycle. The importance of this becomes particularly clear when one considers about three-quarters of life cycle costs occur after construction is completed!

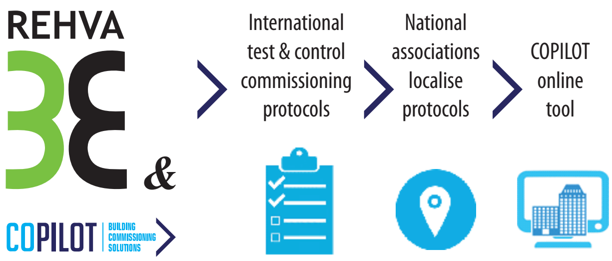
Reassure your clients with world class commissioning

Supervision and certification of the commissioning process offer additional reassurance. That is why **COPILOT Building Commissioning Solutions** entered into partnership with **REHVA** to develop solutions to satisfy this gap in the market.

COPILOT has developed a cradle-to-grave solution to avoid typical HVAC problems and deliver quality buildings. **We deliver online supervision to commissioning engineers and certify their work. COPILOT commissioning solutions can be used on new or existing buildings**.

COPILOT's solution is based on test and control commissioning protocols developed by international REHVA experts. These standardized protocols will be adapted to local regulatory and language requirements of different markets in collaboration with national HVAC engineer associations.

Professionalise HVAC Commissioning



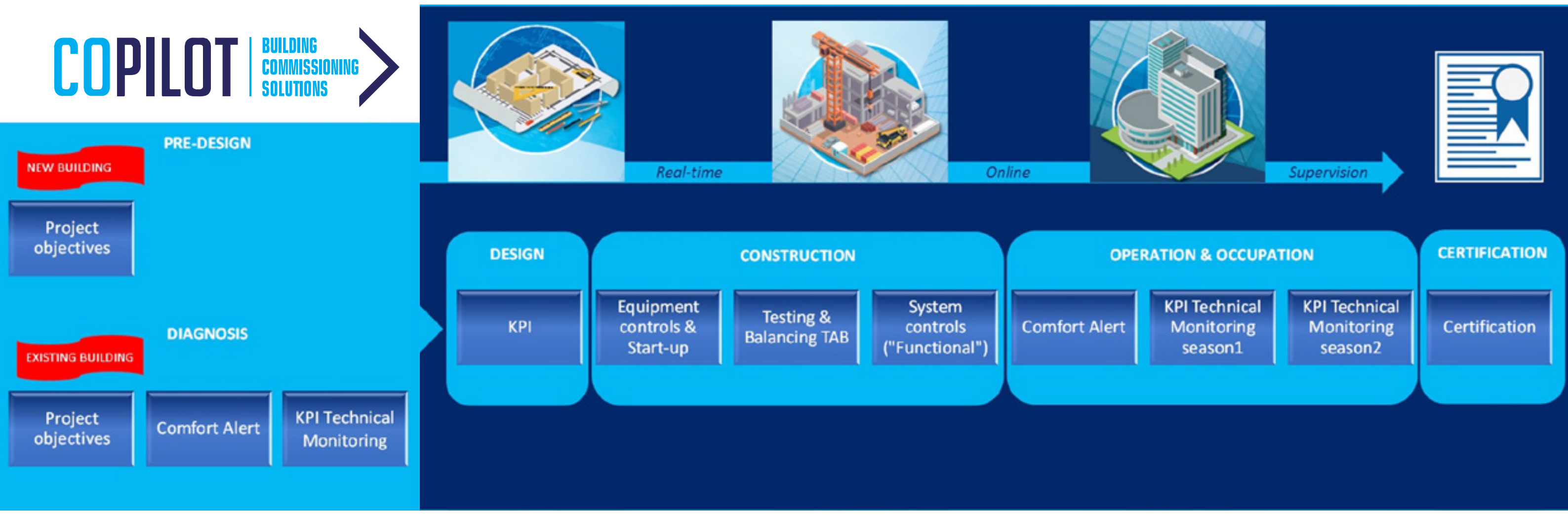
COPILOT accredits qualified and experienced commissioning engineers to deliver its online solutions. In this manner, COPILOT proposes a unique and independent commissioning supervision service. On successful completion of a project, COPILOT certifies the commissioning process.

Key role of Commissioning Engineer (CxA)

Avail of COPILOT supervision and certification of the commissioning process

Ideally COPILOT joins the project during the Pre-design phase when the owner formalizes his objectives. Follow-up during the Design phase will include reviewing designer plans, their conformity to owner requirements and the definition of measurable key performance indicators (KPIs).

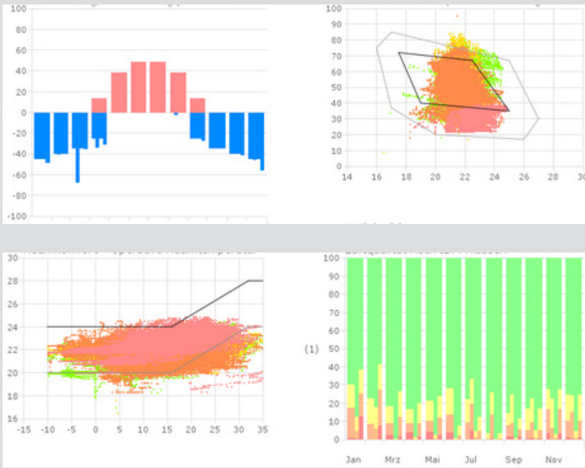
Sometimes COPILOT becomes involved during the Construction phase. In this case, we ensure that Pre-design and Design requirements are available and documented before supervising equipment and system balancing and testing. We seek confirmation that equipment works correctly on its own and as part of



Zoom: Technical Monitoring

COPILOT offers a stand-alone technical monitoring or trouble-shooting solution. In this case, the Construction phase may not exist. We will work with partners to identify objectives (equivalent to Pre-design phase) and KPIs (equivalent to Design phase). We will then monitor performance, analyse it against KPI requirements and prepare graphic report for easy interpretation.

We will certify successful projects that follow the COPILOT process.



the HVAC and building management systems, that all issues are resolved and documented as appropriate and that sufficient training is undertaken.

Once construction has been completed and the building is occupied and operational, COPILOT provides a Comfort Alert to generate qualitative occupant feedback on comfort performance. In parallel, COPILOT undertakes technical monitoring of HVAC performance compared to KPIs.

On successful completion, COPILOT certifies the commissioning process. COPILOT certification can also feed into credits for LEED and other building certifications.

Conclusion

Commissioning engineers have a key role to play in improving building quality, notably HVAC quality. COPILOT Building Commissioning Solutions has allied with REHVA to develop online cradle-to-grave commissioning supervision solutions. We work with local commissioning engineers and certify the commissioning process on successful completion of new or existing buildings. ■

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[1] Agence Qualité Construction, http://www.qualiteconstruction.com/uploads/tx_commerceaddons/tbs10_01.pdf.

[2] Mills, E. «Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse-Gas Emissions», Lawrence Berkeley National Laboratory (LBNL), 2009.

Sustainability and intelligent energy management in buildings at Light + Building 2018

Protecting the climate and the reduction of greenhouse gases are urgent issues for our society. One key to meeting these challenges successfully is the efficient and sustainable use of energy. And this means that energy efficiency in buildings acquires an outstandingly important role. This is because the major share of primary energy usage falls on supplying buildings and is well ahead of even vehicle traffic and industry. In Germany, for instance, there are 21 million buildings. The proportion of total energy usage accounted for by these buildings is 35 percent. According to the plans drawn up by the German government, the primary energy needs of buildings is to be reduced by 80 percent by 2050. The major share of energy usage in buildings is accounted for by domestic dwellings: detached and semi-detached houses use 39 percent of the total energy supply, multiple occupancy dwellings account for 24 percent. The remaining 37 percent are down to non-residential buildings.

One approach to the conservation of energy, alongside suitable modification of the building envelope, can be implemented through the use of intelligent building services systems. 'Smart' and integrated regulation of lighting, sun protection, ventilation and climate control equipment - as well as other technical systems - in individual rooms and in buildings as a whole, can save a great deal of energy and reduce CO_2 emissions. Moreover, because of their size, their situation and the different individual ways in which they are used, the greatest potential improvements in energy efficiency lie in non-residential buildings such as offices, schools and industrial premises, hospitals, shopping centres, conference centres, hotels and banks.

The energy that is supplied to a building can be divided into thermal energy, for heating, warm water and cooling, and electrical energy, for lighting and electrical and electronic appliances. Many different measures and technologies are required for efficient energy usage in buildings. A well-adjusted building automation system ensures that the appropriate amount of heat, cooling, ventilation and lighting is provided in each case, dependent on the need at any given time. This requires, on the one hand, 'intelligent' networking of the various installations such as the heating, ventilation, air-conditioning and cooling equipment, lighting, individual room controls, sun protection and access control. On the other hand, a thorough-going energy management system and continual adjustment of use, operation and consumption are all a precondition of greater energy efficiency in buildings.

If 'smart' building services technology is combined with the use of renewable energies, then the energy footprint is further improved. Renewable energy from wind, sun, water and the heat from the earth are sustainable resources and available for the long term. A photovoltaic installation, for instance, offers an excellent opportunity for creating electrical power from the sun's energy. In order to be able to use the solar electricity flexibly, the PV system needs to be linked to a storage facility of some kind. That way, the home-produced energy can be made available at times of peak demand. But the user gets optimum advantage from the energy produced, only if the PV system is integrated into the building's automation system.

Savings in the consumption of heating energy can be achieved through regulatory mechanisms in individual rooms. Sensors monitor the presence of someone in the room, as well as the temperature in the room and / or outside. The temperature is then adjusted accordingly, depending on the values returned for these various influences. The use of individual room regulation is particularly worthwhile in rooms that are little used or used for sporadic periods of time. It should be noted that the room sensors must, in order to work properly, be mounted in such a way as to be protected from environmental influences, including sunshine, incidental sources of heat, draughts etc. Modern individual room control systems also possess additional practical operational programmes which can be quickly activated and then deactivated. So, for example, the 'absent' function entails the activation of a previously programmed 'absent' temperature setting for all rooms.

Significant savings in electricity can also be achieved by modernising the technology of the lighting equipment. In this case, a change to LED or energy-saving lamps, the installation of sensors for lighting levels, or control via the 'human presence' sender ensure that savings are made. Suitable linking of the lighting system and the upstream building automation system ensures optimum exploitation of all potential opportunities for improving energy efficiency. As a result, considerable amounts of energy can be saved, in e.g. office buildings, with daylight and presence-activated lighting controls; presence sensors dim the lights in the workplace after a pre-determinable time of absence, then switch them off automatically and back on again when someone re-enters the room; or a daylight-dependent control mechanism is activated. This results in the artificial light's being switched on, only if the level of illumination is insufficient. Moreover, it is also possible to store individual lighting sequences that can be called up again at the push of a button.

Regulatory mechanisms for individual rooms and lighting management systems are just two examples of the way in which automation can improve the energy efficiency of buildings. Industry already provides the necessary technologies for this, today.

As part of its principal theme, the 'Smartification of everyday life', Light + Building will be directing its focus to 'intelligent' and networked buildings and will be presenting solutions and technologies, which aim as much at low levels of energy consumption and modern security requirements as they do at opportunities for individual, personalised designs and high levels of comfort and convenience. The industry, including the all the market leaders, will be showcasing its innovations in Frankfurt am Main, from 18 to 23 March. The trade visitors to the show will find solutions for energy-efficient building services systems, electrical and electronic installations and building infrastructure in Hall 8.0. Home and building automation, together with security technology, is located in Halls 9.0 and 9.1. Hall 11.0 is all about electrical installations and network technology, whilst design-orientated electrical and electronic installations and building services systems find a home in Hall 11.1. ■

Further information about Light + Building can be found at www.light-building.com

Successful REHVA seminar at the ASHRAE winter meeting in Chicago on 21 January 2018

Residential Ventilation Experiences in Europe and North America Towards NZEB Design and Operation

This seminar was sponsored by ASHRAE TC 2.1 Physiology and Human Environment and REHVA, and was chaired by Jaap Hogeling.

This session organised on basis of the MoU between ASHRAE and REHVA. With this technical session we want to share knowledge and experience in the field of residential ventilation between Europe and North America. Given the fact that residential, IEQ and NZEB are also main focus of ASHRAE strategy and the current ASHRAE presidential focus we considered this seminar as very beneficial for the ASHRAE membership and REHVA.

Summary:

Residential ventilation systems for nearly zero energy building design and operation requires new approaches. New European energy performance standards supporting these design procedures have been presented. Smart residential ventilation systems to reduce energy use in North America have been discussed. The new REHVA Guide Book with European design guidelines on high performance mechanical ventilation systems with heat recovery with room based airflow rate selection procedure and sizing principles with compensated cooker hood was presented. Common installations in new and renovated buildings and an example of a design solutions have been presented. Procedures for assessing ventilation rates based on CO_2 as tracer have been presented.

The 90 minutes seminar was very well attended, about 75 attendants, with a lively Q&A part after each presentation proved the relevance of the presentations.

Mechanical Ventilation in Nzeb Cortau House in Italy: Theoretical Performance, Real Effects and Occupants' Expectations

Stefano Corgnati, Ph.D., P.E., Associate Member, REHVA.

Mr. Corgnati presented his CorTau House building design which was constructed following the NZEB principles. One of the key challenges of the design was the integration of mechanical ventilation with heat recovery and dehumidification in summer, allowing the suitable integration with radiant floor used for cooling purposes too. The regulation and control of mechanical ventilation in actual operation conditions is fundamental if the energy performances calculated at design stage wants to be obtained in reality. The importance of training of occupants was explained, as a change of the habits related to opening/closing windows and to interacting with control systems is crucial for the successful operation and good energy performance of NZEB.

Residential Ventilation Standards and NZEB Homes in North America

Max Sherman, Ph.D., Fellow ASHRAE, LBL, Berkeley, CA, Senior Scientist at Lawrence Berkeley Laboratory; Professor at the University of Nottingham.

As high-performance homes reduce the thermal loads through the envelope, the energy required to provide minimum ventilation because a more and more important fraction of the total energy. ASHRAE Standard 62.2 provides a relatively high-degree of flexibility that allows homes to provide acceptable indoor air quality at significantly reduced energy costs. In addition to heat or energy recovery systems, standards 62.2 allows dynamic controls of ventilation rates to respond to demand and outdoor conditions. Such smart ventilation systems are discussed during this presentation.

New REHVA Guidebook on Residential Heat Recovery Ventilation: System Layouts, Sizing and Typical Solutions

Jarek Kurnitski, Tallinn University of Technology, Tallinn, Estonia.

NZEBs are well insulated, airtight and with good sound insulation. Therefore, balancing of ventilation, including the operation of cooker hood, as well as low noise levels are much more crucial issues than in older buildings. New information for designers and contractors to design and size a high performance mechanical supply and extract ventilation system with heat recovery is presented. Room based airflow rate selection procedure and sizing principles for constant pressure system with compensated cooker hood are provided. A simplified noise calculation procedure is introduced. The specific energy consumption and new ISO filter classification are introduced.

Implementing New and Classical CO_2 Tracer Gas Methods for the Assessment of Ventilation Indicators in Residential Buildings

Manuel Gameiro da Silva, Ph.D., Member, University of Coimbra, Coimbra, Portugal

Being naturally generated by buildings' occupants, CO_2 is many times selected as the tracer gas. A mathematical model for the time evolution of a contaminant in a uni-zone confined compartment is presented. The most common CO_2 meters are addressed. Various possibilities to develop AER from the curve fitting of experimental data will be explained, discussed and compared. A recent method based upon the response of CO_2 indoor concentration to the cyclic changes of its outdoor concentration, during non-occupancy periods, are introduced. Pros and cons of proposed methods will be discussed.

Upcoming REHVA Seminars

REHVA-ISHRAE seminar at ACREX 2018, 20 February

The well-established collaboration between REHVA and ISHRAE has brought to the organization of an interesting seminar about "Designing healthy nearly Zero Energy schools". The seminar is scheduled on Friday 23 February at ACREX fair in Bangalore. During the sessions, European and Indian experts will take the floor to explain how the HVAC industry can support and benefit from the challenge of coupling low energy use with healthy indoor environment in school buildings.

The need to guarantee a sustainable and healthy learning environment to the next generations is also the leading concept of the joint Task Force carried on by European and Indian experts, that will lead to the publication of a REHVA-ISHRAE Guidebook on Indoor Environmental Quality in nZEB schools in 2019.

Please find the seminar agenda below.

REHVA-ISHRAE seminar

AGENDA

ACREX 2018, 20 February

13:30	Registration
14:00	**Welcome and introduction: the REHVA-ISHRAE Task Force** *Vishal KAPUR, ISHRAE President*
14:10	**Status quo about IEQ in schools, health & learning performance effects** *Atze BOERSTRA, REHVA Vice-president*
14:30	**Thermal comfort in schools** *Jyotirmay MATHUR, Indian thermal comfort specialist, ISHRAE member*
14:50	**An Indian school's perspective on energy use and indoor climate in schools** *Kavita GUPTA SABHARWAL, NEEV Academy, Bengaluru*
15:10	Coffee break
15:30	**Improving energy & IEQ performance in practice** *Maija VIRTA, CEO at Santrupti Engineers, REHVA fellow and ISHRAE member*
15:50	**High performance ventilation systems for schools** *Eric FOUCHEROT, Director International Affairs at Eurovent Certita Certification*
16:10	**Energy performance of schools: past, present, future** *Nitin DEODHAR, ISHRAE Research Chair*
16:30	**Open discussion**
16:50	**Closing remarks** *Chandrasekaran SUBRAMANIAM, ISHRAE President Elect*

REHVA-AiCARR seminars at MCE 2018, 13-14 March

REHVA and AiCARR are offering two interesting international seminars at Mostra Convegno ExpoComfort, in March in Milan. The 2018 MCE theme is "the essence of comfort" and the technological innovation behind it. In line with these topics, REHVA will speak at the MCE AiCARR international seminar "IEQ (Indoor Environmental Quality): requirements and practices" on 14 March at 9:30.

REHVA and AiCARR are also organizing a joint seminar on 13 March from 14:00 to 16:30 titled "EPBD 2nd recast: opportunities and critical aspects". The seminar will draw attention to the most recent updates about the 2nd recast of the Energy Performance of Building Directive, presenting the final version formally approved at the end of January. Focus topics will be digitalisation and smart buildings, key new aspects influencing buildings and HVAC systems.

Please find the seminar agenda below.

REHVA-AiCARR seminars

AGENDA

MCE 2018, 13-14 March

13:30	Registration
14:00	**Welcome** *Francesca Romana D'Ambrosio, AiCARR President* *Stefano Paolo Corgnati, REHVA President*
14:10	**REHVA structure and activities** *Stefano Paolo Corgnati, REHVA President*
14:20	**EPBD 2nd recast: what's new** *Anita Derjanecz, REHVA Managing Director*
14:45	Questions
14:50	**The role of standards in the new EPBD** *Jaap Hogeling, REHVA Journal Editor-in-chief, Chairperson of CEN TC371*
15:15	Questions
15:20	**EPBD 2nd recast and building digitalisation** *Stefano Corgnati, REHVA President*
15:45	Questions
15:50	**Smart Readiness Indicator for buildings** *Livio Mazzarella, REHVA TRC Co-Chair, AiCARR Vice President*
16:15	Questions
16:20	**Open discussion and closing remarks**

REHVA seminar at Light+Building, 20 March

In the context of Light+Building 2018, REHVA organizes the seminar "Smart building & digitalisation in the new EPBD. Policies and implementation in practice" on the 20 March 2018, 13.30-16.00.

This seminar will deal with digitalisation of the construction sector and smart buildings, with invited speakers from academia, consulting companies and leading European HVAC manufacturer, that will cover the topics detailed in the agenda displayed below.

After the seminar REHVA will offer a reHVAClub reception cocktail, to foster networking opportunities with and for the participants.

AGENDA

REHVA seminar — Light+Building, 20 March

13:30	Registration and welcome
13:35	**2nd recast of the EPBD - Energy, IEQ, smart buildings & digitalisation** *Jarek Kurnitski, REHVA Vice-president*
14:00	**HVAC goes IoT - Smart water systems for sustainable buildings** *Ilari Aho, UPONOR*
14:25	**Next: Quality Management - How Digitalisation enables High Performance Buildings** *Stefan Plesser, Synavision GmbH*
14:50	**BIM for HVAC systems** *Henk Kraneberg, DAIKIN*
15:15	**Implementing Indoor Environmental Quality according to EPBD recast, new EN 16798-1** *Atze Boerstra, REHVA Vice-president*
15:40	Questions and discussion
16:00	**Closing remarks**

Join in at the REHVA Annual Meeting 2018 hosted by Atic in Brussels!

REHVA is pleased to invite its Members and Supporters to the 2018 REHVA Annual Meeting hosted by ATIC, the Royal Association of Heating, Ventilation and Climate Control Technology on Saturday 21 April – Monday 23 April 2018 in Brussels. This years' Annual Meeting is linked with the 80th Anniversary of ATIC celebrated with a special Anniversary Gala Dinner in the Magritte Museum, and a 1-day conference "Low Carbon Technologies in HVAC" organized by ATIC in the Train Word Museum in Schaerbeek. The Annual Meeting, held in the REHVA headquarter, will continue with the previous year's schedule having a REHVA Member Associations plenary meeting and an Advisory meeting between Past Presidents and the current REHVA Board to discuss strategic issues in an interactive and less formal way, followed by a shorter General Assembly the next day.

REHVA strategic meetings and General Assembly (21-22 April, REHVA Headquarters, MAI)

The Annual Meeting commence on Saturday 21st April with the usual REHVA committee meetings. A novum this year is that the TRC meeting will be split in two parts. At this 1st meeting on Saturday, participants will discuss about the annual action plan, membership issues and general strategy, while the Agenda of the 2nd part on Monday will be dedicated specifically to supporters. The committee meetings will be followed by the REHVA Members Plenary meeting and the Advisory meeting between REHVA Board and past REHVA Presidents. The first day will be closed by the traditional Welcome Cocktail organised by our host, Atic in the exclusive venue of the Magritte Museum in the centre of Brussels.

Magritte, The happy donor, 1966

The Sunday morning will be dedicated to the Board meeting, the MoU meeting with ASHRAE, and the traditional meeting of our sister organisation SCANVAC. The 62nd REHVA General Assembly will be held in the early afternoon, followed by the "Associate Society Alliance of HVAC" meeting organised with ASHRAE. This meeting will continue also the next day, Monday morning the 23rd April. All REHVA members and supporters are invited to attend this meeting to discuss about the global issues and representation of our sector.

On Sunday evening our host, Atic organise a festive banquet celebrating their 80th Anniversary and the traditional REHVA Awards Ceremony at the same time. The dinner will be organised in the Train World Museum in Schaerbeek, also the venue of the conference the next day. Atic will arrange shuttle to reach this unique venue in the outskirts of Brussel.

REHVA Supporters Day with Committee meeting, conference, and Student Competition (23rd April, Train World Museum)

Train World Museum, Ticket counter hall

The 3rd Day will be dedicated to REHVA supporters and features the Supporters Committee, separate TRC meeting discussing technical topics specifically dedicated to supporters, and the Conference "*Low Carbon Technologies in HVAC*" with the REHVA Student Competition. The goal of this conference is to give the opportunity to researchers and the academic community to exchange their ideas and findings and to bridge the gap with industry. The conference will focus on design and commissioning of HVAC-systems, sustainable heating/cooling technologies and energy storage, user demand and the changing boundaries in which the systems operate, which changes the way of performance optimization and evaluation both in the design and in the operational phase, including the new criteria like 'smart grid readiness' or new parameters to measure individual user comfort.

See below an overview table of the schedule of the 2018 REHVA Annual Meeting.

REHVA ANNUAL MEETING 2018 – BRUSSELS, BELGIUM

Venue: MAI, rue Washington 40, Brussels, Belgium

	Saturday, 21 April 2018	
09.00 – 10.30	**Education and Training Committee Meeting**	**Publishing and Marketing Committee Meeting and REHVA Journal Editorial Board Meeting**
10.30 – 10.45	*Coffee break*	
10.30 – 11.00	**External Relations Committee Meeting**	
11.00 – 12.00		
12.00 – 13.00	*Lunch*	
13.00 – 14.00	**Technology and Research Committee Meeting (Part 1)**	**Awards Committee Meeting**
14.00 – 15.00		
15.00 – 15.30	*Coffee break*	
15.30 – 17.00	**REHVA and Member Associations roundtable discussion (Presidents, Directors and delegates)**	
17.00 – 18.00	**Advisory meeting between Board of Directors and Past Presidents**	
19.00 – 20.30	**Welcome Cocktail - MARGITTE MUSEUM**	

Venue: MAI, rue Washington 40, Brussels, Belgium

	Sunday, 22 April 2018		
08.00 – 09.00	**REHVA/ASHRAE Meeting**		
09.00 – 12.00	**REHVA Board Meeting**	**COP Meeting**	**SCANVAC/BALTVAC meeting**
12.00 – 13.00	*Lunch*		
13.00 – 15.30	**General Assembly**		
15.30 – 16.00	*Coffee break*		
16.00 – 18.00	**Associate Society Alliance of HVAC (co-organised by REHVA and**		**Student Competition**
19.00	*ATIC Anniversary Dinner and REHVA professional awards*		

Venue: Train World in Schaerbeek

	Monday, 23 April 2018	
08.30 – 09.00	**REHVA/ATIC Conference: Low carbon technology in HVAC**	**Student Competition**
09.00 – 10.00		
10.00 – 12.30		**Technology and Research Committee Meeting (Part 2) - open to supporters**
12.30 – 13.30	*Conference networking Lunch*	
13.30 – 14.00	**REHVA/ATIC Conference: Low carbon technology in HVAC**	
14.00 – 16.00		**Supporters Committee Meeting**
16.00 – 17.00		

Venue: MAI, rue Washington 40, Brussels, Belgium

	Monday, 23 April 2018
09.00 – 12.00	**Associate Society Alliance of HVAC (organised together with ASHRAE) Part 2 - Result and conclusion**
12.00 – 14.00	*Lunch*

COLOR CODES

- REHVA meetings
- Parallel meeting
- Breaks and social activities
- Closed meetings
- Conference

Butterfly Valves and Actuators from Belimo. Innovative, user friendly, reliable.

The newly designed butterfly valves and the new PR actuators are the most intelligent, energy efficient and reliable high flow solution in the HVAC market. These actuators are a perfect retrofit solution also on other butterfly valves. Further advantages are:

- Easy installation thanks to lower height and reduced weight of the actuator
- Easy commissioning, parameterising and maintenance through Near Field Communication (NFC) via smartphone
- Guaranteed reliable operation through intelligent self-adjusting valve design
- 80% energy savings thanks to the combination of butterfly valve and actuator
- Good visibility thanks to the flexible visual position indicator

We set standards. www.belimo.eu

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Belimo Butterfly Valves and Actuators are now also available as 3-way solution

Innovative butterfly valves from Belimo designed specially for the HVAC market

The heating, ventilation and air-conditioning industry has very specific requirements with respect to butterfly valves – ones that could not previously be fulfilled in their entirety. Belimo showed with their butterfly valves and actuators that this gap is closed. Now Belimo has gone one step further and expanded its product range.

The Belimo butterfly valves are universally applicable as tight closing 2-way or 3-way valves for open-close, changeover and control applications (as mixing and diverting valve). This flexibility is guaranteed by the intelligent, energy-efficient and multifunctional PR actuator.

Especially the readily commissioning and parameterising through the integrated Near Field Communication (NFC) inspired the users. "With NFC I was able to commission the PR actuators in just a few minutes from my own smartphone. It is really easy to do and saves a lot of time," explains Andreas Wechner, Project Manager & Field Controls Representative at Trane (Schweiz) GmbH.

Belimo has also succeeded in reducing the torque requirement of the butterfly valves and the power consumption of the actuator. To be more precise, in some applications, these innovative butterfly valve-actuator combinations can be used to achieve energy savings of up to 80%.

Because it is not possible to see the position of butterfly valves from the outside once they have been installed, Belimo has developed a position indicator, that shows the position of the butterfly valve even from distance. Thanks to an integrated temperature and humidity sensor, the built in smart heating prevents condensation inside the actuator.

The Belimo butterfly valves and PR actuators are the most intelligent, energy-efficient and reliable high flow solution in the HVAC market. Since the launch in November 2016 the advantages of this product series are thereby obvious: simplicity of installation, the flexibility of application and durability. Belimo set new standards with the new butterfly valve-actuator combination.

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

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

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Network of 27 European HVAC Associations
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Events in 2018

Exhibitions 2018

Feb 27 - Mar 2	AQUA THERM Prague	Prague, Czech Republic	http://www.aquatherm-praha.com/en/
Mar 13 - 16	MCE – Mostra Convegno Expocomfort 2018	Milan, Italy	www.mcexpocomfort.it
Mar 18 - 23	Light + Building 2018	Frankfurt, Germany	http://bit.ly/2AFVWMb
May 22-24	ISH China & CIHE 2018	Beijing, China	http://bit.ly/2EMnJ0l
Jul 17-19	ASEAN M&E	Kuala Lumpur, Malaysia	http://aseanmne.com/
Sep 3-5	ISH Shangai & CIHE 2018	Shangai, China	http://bit.ly/2EbonUp
Oct 10-12	FinnBuild 2018	Helsinki, Finland	http://finnbuild.messukeskus.com/?lang=en
Oct 16-18	Chillventa	Nuremberg, Germany	https://www.chillventa.de/en

Conferences and seminars 2018

Feb 28 - Mar 2	WSED	Wels, Austria	http://bit.ly/2ilJt4M
Mar 12-15	Cold Climate HVAC Conference 2018	Kiruna, Sweden	http://www.cchvac2018.se
Mar 13	REHVA Seminar "EPBD 2nd recast: opportunities and critical aspects"	Milan, Italy	
Mar 20	REHVA Seminar "Smart building & digitalisation in the new EPBD. Policies and implementation in practice"	Frankfurt, Germany	http://bit.ly/2rKa1Zk
Apr 12-14	13th International HVAC&R Technology Symposium	Istanbul, Turkey	http://bit.ly/2BvXgB6
Apr 21-23	REHVA Annual Meeting	Brussels, Belgium	http://roomventilation2018.org/
Jun 3-6	ROOMVENT & VENTILATION 2018	Espoo, Finland	http://www.roomventilation2018.org/
Sep 11-12	Building Simulation and Optimization 2018	Cambridge, UK	https://www.bso2018.event.cam.ac.uk/
Sep 18-19	39th AIVC Conference: "Smart ventilation for buildings"	Juan-les-Pins, France	http://aivc2018conference.org/

REHVA Supporters packages contract 2018

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations
SUPPORTER

We would like to contract for a REHVA Supporters package in accordance with the details set out below.

❑ **Platinum** package includes:	❑ **Gold** package includes:	❑ **Silver** package includes:	❑ **Bronze** package includes:
❖ Annual Membership ❖ 6 full page advertisements in the REHVA Journal ❖ 50 Guidebooks ❖ 50 REHVA Journal copies and REHVA Restricted area access ❖ 1 speaker to REHVA seminar (Brussels event) with free entrance ❖ Logo and link on website ❖ 10 copies of new Guidebooks ❖ Video advertisement 250x250 upload on YouTube and shared on social media ❖ Long article in REHVA HVAC Journal (4-5 pages) ❖ 3 months of Static/GIF Banner 250x250 on the REHVA Website ❖ 1 Special Newsletter (5500 contacts) and REHVA news on the website (Short news) **Total Value 18 200 €** **Additional Discount = 16 500 €**	❖ Annual Membership ❖ 4 full page advertisements in the REHVA Journal ❖ 50 Guidebooks ❖ 50 REHVA Journal copies and REHVA Restricted area access ❖ Logo and link on website ❖ Short article in REHVA HVAC Journal (1-2 pages) ❖ 10 copies of new Guidebooks ❖ 2 months of Static/GIF Banner 250x250 on the REHVA Website ❖ 1 Special Newsletter (5500 contacts) and news as REHVA news on the website (Short news) **Total Value 15 400 €** **Additional Discount = 14 000 €**	❖ Annual Membership ❖ 4 full page advertisements in the REHVA Journal ❖ 20 Guidebooks ❖ 30 REHVA Journal copies and REHVA Restricted area access ❖ Logo and link on website ❖ 10 copies of new Guidebooks ❖ 2 months of Static/GIF Banner 250x250 on the REHVA Website ❖ Video advertisement 250x250 upload on YouTube and shared on social media ❖ 1 Special Newsletter (5500 contacts) and news as REHVA news on the website (Short news) **Total Value 12 900 €** **Additional Discount = 12 000 €**	❖ Annual Membership ❖ 2 full page advertisements in the REHVA Journal ❖ 30 REHVA Journal copies and REHVA Restricted area access ❖ 20 copies of new Guidebooks ❖ Logo and link on website ❖ 1 Special Newsletter (5500 contacts) and news as REHVA news on the website (Short news) ❖ 1 month of Static/GIF Banner 250x250 on the REHVA Website ❖ Video advertisement 250x250 upload on YouTube and shared on social media **Total Value 9 800 €** **Additional Discount = 9 000 €**

❑ **Customized** package (please select the services listed below) **-10% of the total amount above 6 600€**

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3 000€

❑ Advertisements in the REHVA Journal
- ❑ 2 ads / 3 200€
- ❑ 3 ads / 5 600€
- ❑ 6 ads / 7 200€

❑ REHVA Journal copies and REHVA Restricted area access
- ❑ 30 copies / 1 800€
- ❑ 50 copies / 3 000€

❑ 1 months of Static/GIF Banner 250x250 on the REHVA Website / 300€

❑ Guidebooks (shipping and handling of 10% not included)
- ❑ 20 copies / 800€
- ❑ 50 copies / 1 500€

❑ Special Newsletter (5500 contacts) and news as REHVA news on the website (Short news) / 500€

❑ Video advertisement 250X250 upload on YouTube and shared on social media / 200€

❑ Short article in REHVA HVAC Journal (1-2 pages) / 800€ upon REHVA Journal Editor's Approval, possibility to deliver extra copies to a major event of the supporter

❑ Long article in REHVA HVAC Journal (4-5 pages) / 1 200€ upon REHVA Journal Editor's Approval, possibility to deliver extra copies to a major event of the supporter

❑ 10 copies of new Guidebooks / 400€

❑ REHVA specialist expert participation in any event organised by the Supporter / 1 600€

❑ Supporter presenting at a REHVA international seminar (Brussels event) – 1 expert with free entrance / 1 600€

❑ Any specific service defined by Supporter
– price to be agreed depending on the service

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❑ **1** / IEQ and EPBD (February)	❑ **3** / Sustainability, circular economy and LCA (June)
❑ ACREX Special Edition / European HVACR Technologies (February) — *Please contact Giulia Marenghi at gm@rehva.eu to place an advertisement and/or an article.*	❑ **4** / Cold Climate (August) ❑ **5** / BIM and Digital (October)
❑ **2** / NZEB and CO2 footprint (April)	❑ **6** / TBD (December)
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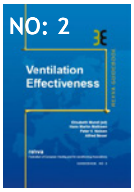
REHVA

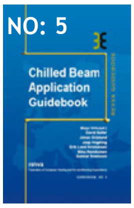
Federation of European Heating, Ventilation and Air Conditioning Associations

REHVA GUIDEBOOKS

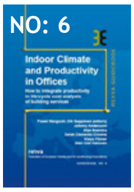
REHVA Guidebooks are written by teams of European experts



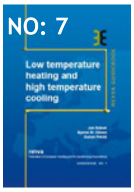
Improving the ventilation effectiveness allows the indoor air quality to be significantly enhanced without the need for higher air changes in the building, thereby avoiding the higher costs and energy consumption associated with increasing the ventilation rates. This Guidebook provides easy-to-understand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



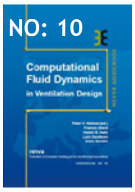
Chilled beam systems are primarily used for cooling and ventilation in spaces, which appreciate good indoor environmental quality and individual space control. Active chilled beams are connected to the ventilation ductwork, high temperature cold water, and when desired, low temperature hot water system.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



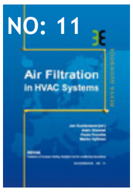
Indoor Climate and Productivity in Offices Guidebook shows how to quantify the effects of indoor environment on office work and also how to include these effects in the calculation of building costs. Such calculations have not been performed previously, because very little data has been available. The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



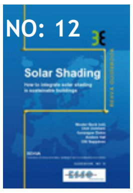
This Guidebook describes the systems that use water as heat-carrier and when the heat exchange within the conditioned space is more than 50% radiant. Embedded systems insulated from the main building structure (floor, wall and ceiling) are used in all types of buildings and work with heat carriers at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



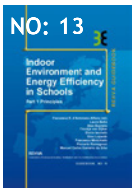
CFD-calculations have been rapidly developed to a powerful tool for the analysis of air pollution distribution in various spaces. However, the user of CFD-calculation should be aware of the basic principles of calculations and specifically the boundary conditions. Computational Fluid Dynamics (CFD) –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



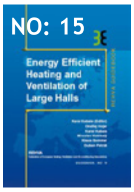
Air filtration Guidebook will help the designer and user to understand the background and criteria for air filtration, how to select air filters and avoid problems associated with hygienic and other conditions at operation of air filters. The selection of air filters is based on external conditions such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



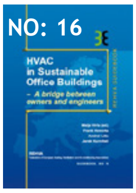
Solar Shading Guidebook gives a solid background on the physics of solar radiation and its behaviour in window with solar shading systems. Major focus of the Guidebook is on the effect of solar shading in the use of energy for cooling, heating and lighting. The book gives also practical guidance for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



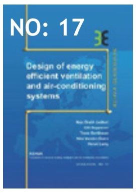
School buildings represent a significant part of the building stock and also a noteworthy part of the total energy use. Indoor and Energy Efficiency in Schools Guidebook describes the optimal design and operation of schools with respect to low energy cost and performance of the students. It focuses particularly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



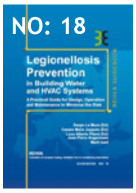
This guidebook is focused on modern methods for design, control and operation of energy efficient heating systems in large spaces and industrial halls. The book deals with thermal comfort, light and dark gas radiant heaters, panel radiant heating, floor heating and industrial air heating systems. Various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



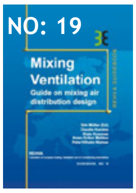
This guidebook talks about the interaction of sustainability and heating, ventilation and air-conditioning. HVAC technologies used in sustainable buildings are described. This book also provides a list of questions to be asked in various phrases of building's life time. Different case studies of sustainable office buildings are presented.



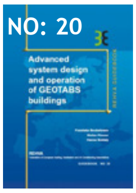
This guidebook covers numerous system components of ventilation and air-conditioning systems and shows how they can be improved by applying the latest technology products. Special attention is paid to details, which are often overlooked in the daily design practice, resulting in poor performance of high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



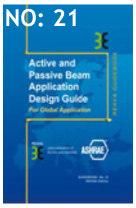
This Guidebook is a practical guide for design, operation and maintenance to minimize the risk of legionellosis in building water and HVAC systmes. It is devided into several themes such as: Air conditioning of the air (by water – humidification), Production of hot water for washing (fundamentally but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



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

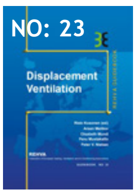


This guidebook provides comprehensive information on GEOTABS systems. It is intended to support building owners, architects and engineers in an early design stage showing how GEOTABS can be integrated into their building concepts. It also gives many helpful advices from experienced engineers that have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



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

This guidebook aims to provide an overview on the different aspects of building automation, controls and technical building management and steer the direction to further in depth information on specific issues, thus increasing the readers' awareness and knowledge on this essential piece of the construction sector puzzle. It avoids reinventing the wheel and rather focuses on collecting and complementing existing resources on this topic in the attempt of offering a one-stop guide.



Displacement ventilation has been originally developed in Scandinavian countries over 30 years ago and now it is also a well-known technology in different countries and climates. Historically, displacement ventilation was first used for industrial applications but nowadays it is also widely used in commercial premises.

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