ISSN 1307-3729

REHVA

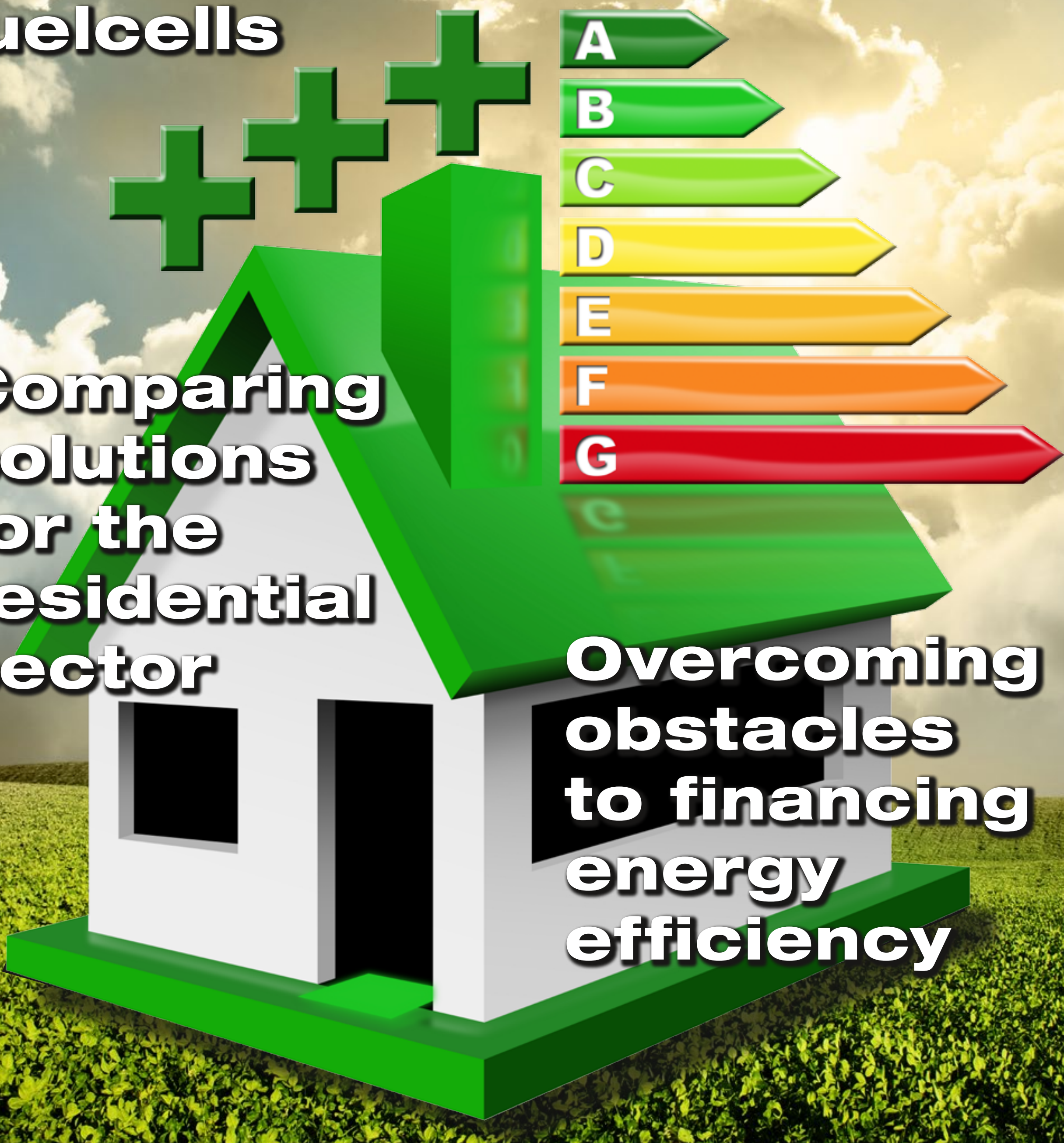
Federation of European Heating, Ventilation and Air Conditioning Associations

The REHVA European HVAC Journal

Volume: 57 Issue: 1 February 2020 www.rehva.eu

HVAC technologies as drivers for future energy transition

Heat Pumps, Fuelcells



Comparing solutions for the residential sector

Overcoming obstacles to financing energy efficiency

The REHVA European HVAC Journal

www.rehva.eu

Volume: 57 Issue: 1 February 2020

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PUBLISHER
TEKNİK SEKTÖR YAYINCILIĞI A.Ş.
Barbaros Mahallesi, Uğur Sk. No: 2/2
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The role of the HVAC sector towards energy transition*

Nowadays, since we are becoming more aware of the effects of climate change and global warming, a drastic change in the world energy system is required. Especially considering the building sector, which is responsible of about 40% of the global final energy consumption, the role of HVAC technologies becomes crucial, also due to their double vocation. Indeed, they should provide work not only in a more efficient and sustainable way, but they should also ensure high comfortable and healthy indoor environmental conditions by minimum energy consumption. To achieve such results, the pillars will be: energy diversification, energy efficiency and digitalization.

Since the current fossil-fuelled energy paradigm is no longer suitable both at the European and the international levels, energy strategies and policies are pushing towards the end-uses energy diversification, in order to move in the direction of a low-carbon society. In this scenario, the 2017 Energy Technology Perspective, developed by the International Energy Agency, explored for example the benefits and challenges of diverse electrification scenarios in all the economic sectors. In this context, particular emphasis was given to the role of the building sector, due to its great potentialities in terms of further electrification. Moreover, the increasing penetration of HVAC electric technologies provides interesting opportunities also to promote the integration of Renewable Energy Sources on buildings. In this framework, the role of HVAC systems is crucial and their optimal exploitation will be beneficial, enhancing the integration of local Renewable Energy Sources, the reduction of Green House Gases and air pollutants' emissions and the increase of grid stability at once.

On the other hand, efforts are still needed to further increase the efficiency of HVAC technologies. Indeed, the growing energy demand, mainly due to the increasing space cooling needs and the high comfort standards, requires a reduction of primary energy consumption of such technologies.

Moreover, the latest digital technologies offer the potential to increase energy efficiency using devices analysing and processing a huge amount of data, in order to better manage the building energy system. In fact, the digitalisation provides a new layer of data in buildings that can be exploited from an energy and social standpoint. For instance, the combination of digitalisation and electrification allows the direct communication between the building and the grid, enabling some innovative services to optimize both generation and demand sides, i.e. the demand-response. Moreover, the interaction between Internet of Things' solutions and HVAC systems leads to a greater involvement of building occupants. Indeed, using real-time systems linked to smart interfaces, consumers can be more aware of their energy wastage and make their own energy choices more consciously. In these terms, it can be argued that occupants' engagement will be the key for success in this energy changeover. It is interesting that advanced HVAC technologies are ready for the market: the challenge, to ensure their penetration, is show that through cost-benefit analyses they are also sustainable form an economical and financial point of view. ■

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Drivers for energy transition of Italian residential sector

In the view of the needed energy transition, the work aims to evaluate the potential electrification of the Italian building sector, identifying the possible drivers towards its realization and exploring possible policy strategies that could push it. The work is part of the "Electrify Italy" project, developed by Politecnico di Torino and Massachusetts Institute of Technology, in cooperation with Enel Foundation.

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Keywords: energy transition, electrification potential, residential building sector, thermal uses, financial convenience, environmental impact, policy strategies

The current energy paradigm is not sustainable, being largely dependent on fossil fuels. Therefore, a transition of the actual energy system is strongly desired, aiming to overcome its limits in terms of pollution, energy efficiency, optimal resource allocation and consumption. Nowadays, electrification is perceived as a possible way of transitioning the current system towards a more sustainable one, allowing higher energy efficient consumption at demand side and boosting the spread of renewables sources at production level.

Buildings are responsible for more than one third of total primary energy consumption and emit around 36% of total greenhouse gas (GHG) emissions in the atmosphere [1]. Therefore, the role of the building sector in the realization of the advocated transition is crucial, and strong efforts still need to be undertaken at both private and public sides. Looking at the EU stock characteristics, most of the built volume is residential and old [2], thus asking for retrofit interventions and appropriate policy measures able to foster its transition. Deeping on Italy, the building sector in 2017 consumed approximately 43% of total final energy consumption and emitted 39% of total Italian emissions, with the residential sector alone accounting for around 22% [3].

Looking at the Italian stock characteristics, residential buildings account for almost 90% of the built volume [4], and they are less electrified than commercial ones (electricity represents 18% and 51% of the final energy consumptions of the residential and non-residential buildings, respectively), demonstrating that the highest potential for electrification stands in the residential sector. Here, the most energy-consuming services are space and water heating, which represent roughly 80% of the total energy consumption [3], besides being the less electrified services, thus having the highest potential for electrification. Starting from these figures, the work is intended to explore the potential electrification of the Italian residential building sector, starting from existing technologies and identifying the possible drivers towards its realization. Moreover, the analysis wants to identify possible policy strategies that could push the electrification of the residential buildings, exploring innovative elements of price mechanisms and market dynamics.

Method

The study aims to compare alternative technological solutions for space and water heating in case of a retrofit intervention, in order to understand the most important factors influencing building owners' choices towards electric technologies. Indeed, when dealing with future diffusion of electric technologies, the main issues are costumers' choices and market directions. From the costumer point of view, it is fundamental to understand which could be the technologies that they are willing to choose, while from the market standpoint, it is worth exploring how market mechanisms and policies will realistically push costumers' choices. The work identifies two possible drivers of the electrification process, at private and public sides. Financial convenience and attractiveness are defined as the main drivers at private side, and they are addressed in terms of global cost, a financial parameter usually used to compare different alternatives in retrofit interventions. Its calculation accounts for the initial investment cost and the annual costs (discounted at the present value with a constant interest rate), including maintenance and energy costs [5]. In this study, global cost is defined per each alternative over a 20-years period (lifetime of typical heating systems) and existing incentive mechanisms (Ecobonus and Conto Termico 2.0) are added to the formula, discounted at the present value. This index allows to estimate the financial convenience of a technology over other competing ones, since it combines all the expenses borne by the building owner and, thus, it could represent a relevant benchmark for making investment decisions. From the public standpoint, instead, bearing in mind the ambitious targets conceived for the building sector in terms of emissions reduction (90% reduction by 2050 with respect to 1990 levels [6]), policy makers will realistically define measures capable of forcing the market towards the adoption of low-carbon solutions, making them more financially attractive for the investors. CO_{2eq} emissions caused by the adoption of a certain technology is thus selected as a driver for future electrification at public side. Moreover, PM emissions are accounted too, when comparing the alternative technological options. Indeed, due to the recent concern on air pollution, especially in urban areas, it is likely that PM is going to be a criterium to control in future energy planning.

The work was structured according to the following steps:

- Characterization of the current residential building stock through a reference building approach;
- Identification of the technological alternatives;
- Environmental and financial assessment of each alternative.

To characterize the current residential building stock, whose thermal uses are the focus of this work (see "Introduction"), the reference building approach [7] is deployed. The Italian building stock is divided into a set of representative reference buildings, according to different typologies (Single-Family Houses, SFH, and Multi-Family Houses, MFH), periods of construction ("before 1980", "1981-2000", "after 2001"), and locations (5 geographical zones are identified: North-West, North-East, Centre, South and Islands). Moreover, the RBs are divided into urban (67% of the total floor area) and extra-urban buildings (33% of the total floor area), where urban areas are defined as municipalities with more than 10,000 inhabitants [4]. Each RB is characterized by specific envelope and system characteristics according to TABULA database [7]. Energy needs for space and water heating are defined by means of quasi steady-state simulations, while energy consumptions are calculated assuming suitable generation efficiencies.

When considering a retrofit intervention, the model allows only three alternatives for space heating (condensing gas boiler, biomass boiler and electric heat pump) and four options for water heating (condensing gas boiler, biomass boiler, electric boiler and electric heat pump). Both biomass boiler and electric heat pump, for the sole space heating, need the use of a thermal storage, which cost is added to the global cost formula.

Global costs (private side driver) and emissions (public side driver) are calculated for 2030 and 2050, in order to evaluate the expected evolutions of the competitiveness of the technologies in future years, based on different assumptions. Energy prices are forecasted based on IEA projections [8], while CO_{2eq} emission factors for electricity are varied according to the evolution of the power generation mix predicted in the "Electrify Italy" project [9]. The study is developed considering the following assumptions:

- Restriction of biomass use in urban environment, in accordance with existent environmental policy constraints (Some Italian regions (i.e. Piemonte, Lombardia, Emilia Romagna) have imposed constraints to the installation of biomass heating systems in urban areas, due to local air pollution issues.);
- Incentives mechanisms fixed as in 2015 (Ecobonus and Conto Termico 2.0);
- Introduction of non-progressive concessional tariff for SFH with heat pumps as sole space heating system in the global cost calculation.

Results & Discussion

Customers' choices are a key factor in the process of electrification of the residential sector and are driven by several factors, among which the most important one is the financial convenience, here addressed in terms of global cost. In Italy, electric technologies, even if already competitive in the market, are still slightly disadvantaged, due to the higher investment costs and energy prices for electricity. Nevertheless, electric heat pump has a strong advantage with respect to its competitors, due to the possibility of providing both space heating and cooling. For this reason, in order to compare the solutions on equal terms, the cost for a multi-split air conditioning system is added to the global cost for gas technologies (in terms of investment cost) as an opportunity cost. This modification is applied only in urban areas, where the impact of air-conditioning is significantly stronger, due to the higher temperatures and the worse outdoor air quality than in extra-urban context. An example of global cost calculation is here reported for an RB (MFH built before 1980, located in North-West) and for the space heating service. In urban area, where the competition exists between gas and electric technologies (being biomass excluded), the extra global costs of heat pump is always lower than 15%; in extra-urban context, biomass is still slightly convenient in 2030, while in 2050 energy costs projections clearly disadvantage it with respect to heat pump.

However, when considering the environmental impacts, electric technologies are the most environmentally performing. **Figure 2** compares the considered technological solutions for the same RB based on their emission footprints (in terms of direct CO_{2eq} and PM10 emissions), and thus showing how heat pump represents the best environmental compromise. Conversely, gas technologies are the worst in terms of CO_{2eq} emissions, while biomass is the highest PM10 emitter.

The paper aims also to explore in which direction the market and the policy context might push costumers' choices towards electrification, by investigating how innovative elements in terms of market regulation mechanisms and pricing models can impact on the global cost results. In particular, the study reports the variations of the delta global costs between electric and gas technologies for the urban area and between electric and biomass technologies for the extra-urban context caused by the introduction of these measures. The first measure ("HP tariff") considers the extension of the non-progressive concessional tariff for electricity to heat pumps installed in MFH for space heating and in both SFH and MFH for water heating (excluded in the current regulation). The second analysis ("Constant price") explores the influence of energy prices, analysing an ideal situation in which

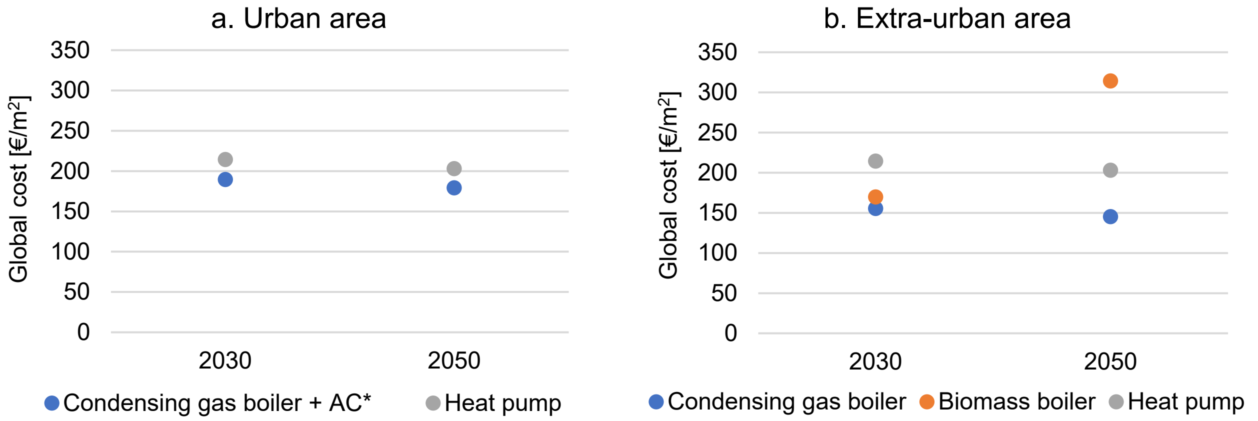

Figure 1. Global cost in 2030 and 2050 for MFH < 1980 North-West for space heating: a. urban area; b. extra-urban areas.

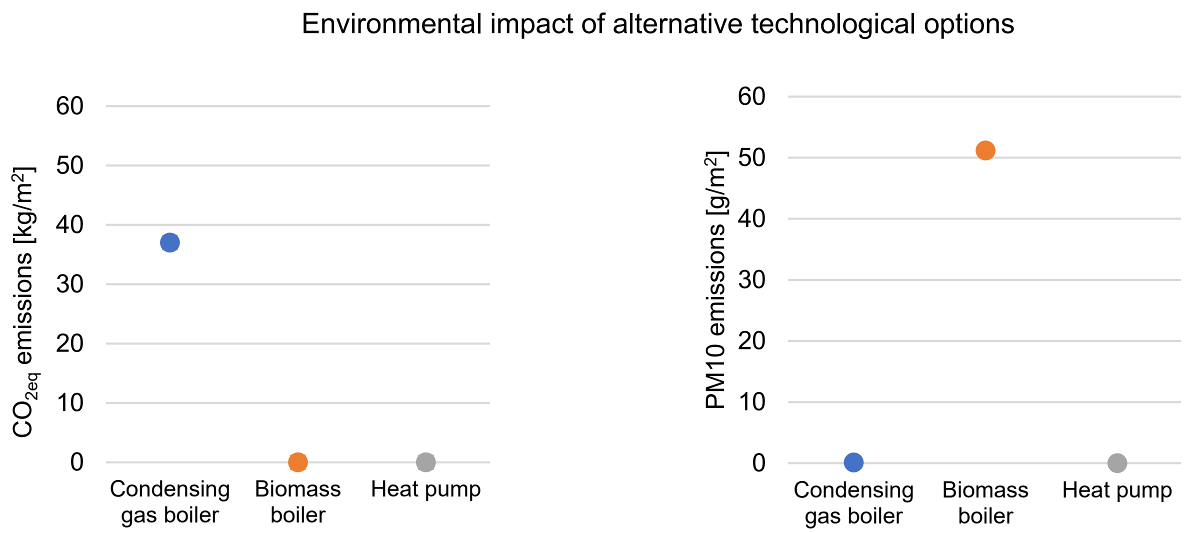

Figure 2. Environmental performances (in terms of direct emissions) of the technological options for MFH < 1980 North-West – space heating: a. CO_{2eq} emissions; b. PM10 emissions.

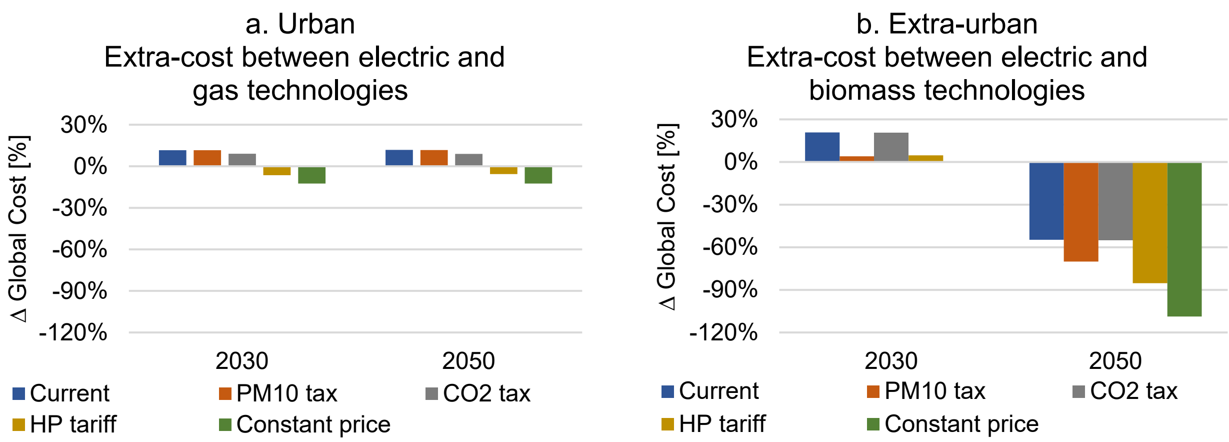

Figure 3. Delta global costs of heat pumps with respect to the competing technological option for MFH < 1980 North-West – space heating: a. gas-heat pump competition (urban); b. biomass-heat pumps competition (extra-urban).

gas and electric prices are kept constant to current values. Finally, the introduction of environmental taxes as market regulation mechanisms is investigated as a policy attempt to face the air pollution issue and to force the achievement of the emission reduction targets at building scale. Two measures are evaluated, considering the adoption of a taxation on CO_{2eq} ("CO_2 tax") and on PM10 ("PM10 tax") emissions for space and water heating systems.

In urban area, competition exists only between gas and electricity, due to the exclusion of the biomass. In this context, the PM taxation has a marginal impact on the global cost, conversely to the CO_2 taxation, which surely disadvantages gas. Still, environmental costs are not enough to make electric technologies competitive, thus asking for appropriate financial measures to facilitate its diffusion; indeed, both "HP tariff" and "Constant price" scenarios help reversing the results, advantaging heat pumps. In extra-urban context, environmental costs can push costumers' choices towards electric technologies; extra-costs of heat pumps with respect to biomass technologies reduce of almost 30% when adopting the PM tax, due to the high emissions caused by biomass combustion. Differently from urban area, financial measures have lower impact on results. However, it is worth noting that energy prices are among the most influencing parameters, as shown by the "Constant price" scenario in both contexts, meaning that the price model plays a key role in future diffusion of technologies.

Conclusions

The significant impacts that the building sector has on environment and society are forcing private and public stakeholders to find possible solutions for unlocking the transition of the entire sector towards a sustainable one, considering electrification as a possible solution. Focusing on the residential sector and on thermal uses (which are the least electrified services in buildings), the study aims to compare alternative existing technological solutions (condensing gas boiler, biomass boiler, electric boiler and electric heat pump) for space and water heating in case of a retrofit intervention, in order to understand the most important factors influencing building owners' choices towards electric technologies. Financial convenience is identified as the private side driver, while environmental protection (in terms of CO_{2eq} and PM emissions) is defined as the public side driver. Moreover, due to the role that market and policy dynamics play in the future transition of the building sector, the paper aims to explore in which direction the policy context might push costumers' choices, by investigating innovative elements in terms of market regulation mechanisms and pricing models. ■

Acknowledgment

The work is part of the project "Electrify Italy", developed by Politecnico di Torino and Massachusetts Institute of Technology, in cooperation with Enel Foundation [9].

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New evaluation metrics: the H2020 Mobistyle project contribution

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In energy planning for the building sector, it is possible to identify two needs: i) considering the multiple benefits of renovation strategies in evaluation procedures; ii) educate occupants about their impacts on buildings energy consumptions to control the performance gap. In this paper the H2020 Mobistyle project contribution is underlined.

Keywords: key performance indicators, KPIs, building performance, indoor environmental quality, IEQ, productivity, Mobistyle.

Most of the energy consumptions in buildings is related to space conditioning. In particular, the energy demand for cooling is expected to increase in the next years, and mechanical ventilation systems are more and more needed in high performing building to guarantee comfort to the occupants without compromising the energy performance of the building itself. As a consequence, the HVAC sector has a key role in bolstering the improvement of the energy efficiency of the building sector and the subsequent reduction of energy-related greenhouse gases (GHG) emissions. In particular, the European Roadmap to 2050 has identified the need of the building sector to achieve by 2050 a 90% reduction of GHG emissions with respect to 1990 level [1]. In this regard, the need to prepare a national plan addressing the existing building stock is stressed in the new Energy Performance of Building Directive 2018/844/UE [2]. In particular, the Directive underlines that building renovation strategies have to be fostered taking into account the multiple benefits coming from retrofit as the increase in comfort, air quality, health, etc.

Figure 1. The multiple benefits of energy efficiency according to the new EPBD [3].

The new EPBD also introduces the concept of the building readiness to smartness, defined as the capability to respond to both the occupants and the grid needs. This concept is measured as a percentage score, obtained as a weighted sum of the building readiness over the maximum score possible in regarding to different criteria. Within these criteria, also comfort, health and information to the occupants are mentioned as areas of interest. The methodology is based on a check-list approach, where the analyst has to identify the set of technologies inside the building and define their level of functionality that, according to a predefined scoring system, correspond to a specific level of readiness to smartness per each impact area. In this framework, a challenge in the planning of renovation strategies is the definition of proper metrics and tools able to take into account the multiple benefits related to the renovation itself. Technologies that can be deployed in the renovation process, as innovative HVAC technologies, should be evaluated taking into account their impacts not only in terms of energy efficiency, but also on the matters mentioned in the updated regulation panorama (i.e. indoor air quality, comfort, health, etc.).

Another challenge to tackle while planning renovation for buildings is the broadly recognized issue of the energy performance gap. It is defined as the difference between the real energy consumption of a building and the one assessed during its design phase. This discrepancy is mainly due to the influence of occupants. Consequently, education of occupants to increase their awareness about how their actions impact on energy consumptions of buildings cannot be disregarded in pursuing the European goals for the building sector.

In this paper, the H2020 Mobistyle project contribution is underlined, with a particular attention on the need of the implementation of new Key Performance Indicators (KPIs).

The H2020 Mobistyle project contribution

Mobistyle is a Horizon2020 European project aiming to drive behavioural changes in buildings occupants, leveraging on the three issues of energy, indoor environmental quality (IEQ) and health [4]. To reach this objective, personalized ICT solutions (Mobile App, Game and Dashboard) are deployed at different demo cases level. The Mobistyle approach is based on the provision of personalized feedback and on the deployment of a tailored awareness campaign to increase people perception about how their habits can influence energy consumptions and IEQ in buildings, but also their health and well-being. The set of tools and methodologies deployed within Mobistyle project and the experience obtained in the pilots represent a contribution with regards to the need to educate occupants about their impacts on energy consumptions of buildings to control the performance gap.

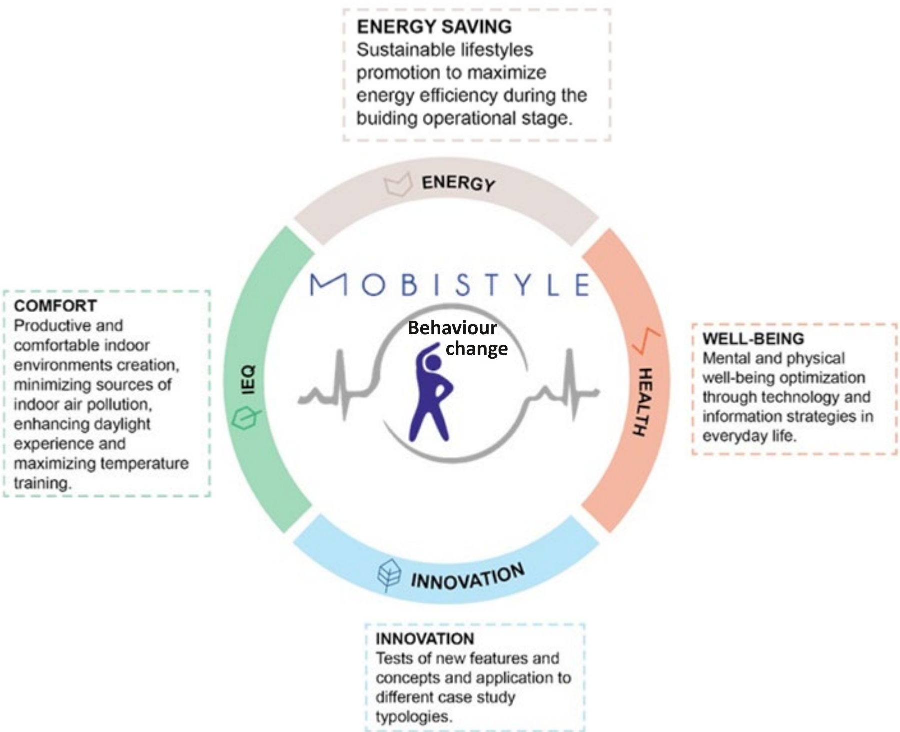

Figure 2. The Mobistyle concept.

However, this set of tools need a validation process according to a well-defined evaluation procedure. Accordingly, the objective of Working Package 3 is to formulate a methodology to (i) define, gather, elaborate and address energy, IEQ and health data to users aimed at providing a behavioral change [5], [6], and to (ii) evaluate the effectiveness of the proposed Mobistyle strategies [7]. Within Mobistyle, some single-domain KPIs are identified as part of the evaluation methodology to measure the outcomes of the project in terms of energy consumptions, IEQ and occupant behavior patterns in the different demo cases before and after the Mobistyle solutions deployment [7]. More interestingly, the KPIs to be displayed to the users through the ICT tools are defined according to the specific behavioral action plans, and translated into meaningful information and actionable tasks for building occupants [6]. The core of this paper is in the further implementation of the traditional single-domain KPIs towards new KPIs able to give a contribution with regards to the need to define new metrics able to take into account multiple benefits in the evaluation procedures.

Development of new KPIs

To define new KPIs, the starting point is thinking about the traditional domain KPIs and the expected correlations, keeping in mind value and relevance of the proposal:

- Value: Which is the derived knowledge from the new KPI?
- Relevance: Who would be interested in the new KPI and for which purpose?

In the followings, different examples of KPIs developed within Mobistyle project, with some insights about possible stakeholders which would be possibly interested in them, are reported.

Environmental performance

A fist indicator proposed is the carbon intensity of the stock, defined as the sum of all the final consumptions of the stock weighted on the GHG emission factors characteristic of each energy carrier. This KPI can be used to know the specific environmental performance of the stock and to identify possible improvements brought by the exploitation of different fuels. It can be a relevant index for the policy makers, whose need, between others, is to identify how far the building stock is from a targeted performance. Accordingly, within Mobistyle, a benchmark value on a set of residential building located in Aalborg, Denmark, will be computed based on the **Equation (1)**.

IEQ performance

In interventions aiming at improving the energy performance of a building, it's fundamental to improve also the IEQ. The Mobistyle project focuses on thermal comfort and indoor air quality, monitoring the indoor air temperature, the indoor air relative humidity and the indoor concentration of both CO_2 and Volatile Organic Compounds (VOC). There are several studies which try to assess to which extent the overall comfort perception of the occupants is influenced by each of these parameters [8]. Thus, another new KPI is represented by the sum of weighted percentage of hours in class II of comfort (as defined according to the EN 15251 [9]) according to the four measured parameters over the total hours of the monitoring period.

Each parameter has the same weight ($\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4$), but by changing them it is possible to assess which parameter is influencing the most the overall percentage of hours in comfort and thus to disclose to the occupants where the criticalities in terms of IEQ are. The KPI is validated by its application to different demo cases of the Mobistyle project. Similarly, the nominator of **Equation (2)** can be replaced with a measure of severity of discomfort.

$$\frac{\sum_{d=1}^{365}(district\ heating\ consumptions)_d \cdot coeff.emiss_{DH} + \sum_{d=1}^{365}(electicity\ consumptions)_d \cdot coeff.emiss_{el}}{\sum_{d=1}^{365}(district\ heating\ consumptions)_d + \sum_{d=1}^{365}(electicity\ consumptions)_d} \quad (1)$$

$$\left[\frac{\mathrm{kg}_{\mathrm{CO_{2eq}}}}{\mathrm{kWh}}\right]$$

where "*d*" is for day of the monitoring period and "*coeff. emissx*" are the emission factors characteristic of each energy carrier *x*.

$$\alpha_1 \frac{\sum_{d=1}^{n}(Oh - \mathrm{hOR}(T))_d}{n \cdot Oh} + \alpha_2 \frac{\sum_{d=1}^{n}(Oh - \mathrm{hOR(RH)})_d}{n \cdot Oh} + \alpha_3 \frac{\sum_{d=1}^{n}(Oh - \mathrm{hOR(CO_2)})_d}{n \cdot Oh} + \alpha_4 \frac{\sum_{d=1}^{n}(Oh - \mathrm{hOR(VOC)})_d}{n \cdot Oh} \quad (2)$$

$$[\%]$$

where "*d*" is for day of the monitoring period; "*n*": total number of days; "*Oh*" are the total daily hours and "hOR(*x*)" the daily hours where the parameter *x* is out from the comfort range; "*T*": hourly mean indoor air temperature, "RH": hourly mean indoor relative humidity; "CO_2": hourly mean CO_2 concentration; "VOC": hourly mean Volatile Organic Compounds concentration.

Human performance: productivity economic value

When there is not correspondence between the energy manager (who is paying for the energy bills) and the occupants (who is benefitting from the guaranteed comfort), the former could be interested not on the comfort level, of interest of the latter, but on the economic implication of a potential discomfort. Then, another KPI is defined borrowing the model developed in [10], reported in **Equation (3)**.

In particular, the function defines the level of performance in % based on the indoor temperature "*T*" (with 100% of performance around 22°C). The computation proposed in this paper is performed on an hourly-base, considering the hourly mean temperature per each working day as input. The productivity level is monetized by multiplying the percentual obtained thanks to this model for the hourly salary of an employee, as defined in **Equation (4)**.

$$p = (0.1647524 \cdot T - 0.0058274 \cdot T^2 + 0.0000623 \cdot T^3 + 0.4685328) \quad (3)$$

$$\sum_{d=1}^{n} \left(\sum_{i=1}^{Oh} (0.1647524 \cdot T_i - 0.0058274 \cdot T_i^2 + 0.0000623 \cdot T_i^3 + 0.4685328) \cdot L_i \right)_d \quad [€] \quad (4)$$

where "*d*" is for day of the monitoring period; "*n*": total number of days; "*Oh*" are the total daily hours; "*T*": hourly mean indoor air temperature per each hour *i*; "*L*": hourly salary of an employee per each hour *i*.

The KPI will be validated on the Slovenian demo case (some offices in the university building). The outcome represents the economic value of keeping proper temperature level in office spaces. If the energy bill for climatization (normalized over the number of occupants) is divided by the result of **Equation (4)**, both computed on data covering the same time span, new knowledge about the financial balance between the costs to keep comfortable indoor temperature (through climatization) and the benefits in terms of productivity can be disclosed.

Mobistyle Open User Platform (MOUP)

The Mobistyle platform collects all the methodologies and tools developed during the project. The bridge between the Mobistyle platform and the external market of stakeholders is represented by the Mobistyle Open User Platform (MOUP), a software service based on open standards. Its main value proposition lies in giving additional combined information from the gathered data to the stakeholders through new KPIs. Accordingly, the KPIs proposed in this paper will be tested and offered via the MOUP as benchmark values on combined information about buildings performances.

Conclusions

To summarize, the paper wanted to underline the contribution of the H2020 Mobistyle project in face of the two identified needs of i) taking into account the multiple benefits of renovation strategies; ii) educating occupants about their impacts on buildings energy consumptions to control the performance gap. In particular, new KPIs relevant for different stakeholder (policy makers, building occupants and building managers), which will we tested within (and offered via) the MOUP, has been discussed. ■

Acknowledgments

This work is part of the research activities of an international project financed by European Community MOBISTYLE – Motivating end users Behavioral change by combined ICT based tools and modular Information services on energy use, indoor environment, health and lifestyle. It has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement No. 723032.

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ALDREN Consortium Partners at the European Parliament.

The ALDREN event in the EU Parliament

– Grounding the Green Deal Implementation on European standards and tools

On the 22nd January the ALDREN project (www.aldren.eu) held an event in the European Parliament together with a **host MEP Ljudmila Novak** (EPP Group) on the topic "*Encouraging investments and accelerating the movement towards a nearly zero-energy non-residential building stock*". The event was also endorsed by the support and participation of several Members of the European Parliament (MEPs), and the European Commission. During the welcome speech, the host MEP Ljudmila Novak indicated that "*In the EU, we can be proud on many proposals and decisions, such as "Clean Energy Package", "Paris agreement" and the most recent renewed commitments to act in the area with the European Green Deal, and following the objective of net-zero emissions by 2050*". However, the host MEP highlighted that "*Improving the energy efficiency of buildings is and must be at the heart of the EU actions and its role and potential to contribute to the EU environmental, energy and climate objectives is significant*".

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Overall, representatives from the European Parliament and European Commission stated that we need to address climate and energy issues urgently. "*Our house is burning* *and flooding*" mentioned **Pau Garcia Audi**, the representative from DG Energy, EU Commission. The energy poverty, health & wellbeing, the coherent application of the ambitious EU policy targets in the Member States by the building professionals, reliable and technology neutral implementation of the "Clean Energy Package" were among the topics discussed during the event. The Green Deal will very likely open the Energy Performance of Building Directive (EPBD) again, informed **MEP Miapetra Kumpula-Natri** (S&D Group).

The market expectations for ALDREN, encouraging investment and how the building professionals could contribute to the "renovation wave" announced in the Green Deal were discussed in a round table session moderated by REHVA President **Frank Hovorka**. Property Owner (Allianz Real Estate), Real Estate Association (EPRA), Industrials (EUROACE), Building professionals (FEANI), Service providers (EFIEES) and Environmental Organisations (OID) were panellists of the round table session.

In the welcome speech ALDREN consortium leader **Mathieu Rivallain** (CSTB) explained that the ALDREN project is funded by the European Union's Horizon 2020 Research and Innovation Program. The ALDREN objectives are to achieve higher renovation rates and better renovation quality of buildings by overcoming market barriers. The back-bone along the whole deep renovation process in the ALDREN project is an improved European Common Voluntary Certification Scheme (EVCS).

He underlined that it is the **right time** and the **right place** to organise such an event to discuss with key actors from the top political level (EU Parliament, EU Commission) and professionals involved in the building renovations (financial institutions, major real estate companies, building professionals and industrials), the reasons why the building renovation rate and quality is behind target and to get feedback if the solutions proposed by the ALDREN project could help to improve the situation.

Host MEP Ljudmila Novak (EPP) opening the ALDREN event.

Pau Garcia Audi representing DG Energy, European Commission.

MEP Miapetra Kumpula-Natri (S&D) introducing her views on tackling challenges in renovation of buildings.

REHVA President Frank Hovorka moderation a roundtable with panellist from Property Owners (Allianz Real Estate), Real Estate Association (EPRA), Industrials (EUROACE), Building professionals (FEANI), Service providers (EFIEES) and Environmental Organisations (OID).

It was the **right time** because initiatives, as the EU Green Deal and other actions related to Climate Change especially in the Building sector, are taken now at the highest level in Europe: in the Parliament, in the Council and in the Commission. Building energy renovation is planned to be highly on political agenda as **a flagship** while tackling climate changes.

It was also the **right place** for this event because the **successful implementation** of the ambitious EU targets on Climate Change, requires that the whole implementation chain, from the **legislative level** (the EU Parliament), where the objectives are defined, to the **implementation on field** by qualified professionals, should be **coherent, consistent, unambiguous.**

But when it comes to deep renovations in buildings, the **implementation chain is not coherent**. Today in Europe there are at least 34 different national /regional implementations of the EU policy, leading to different results regarding energy performance for the same building. The ALDREN project showed that, according to the assumptions taken, the **main numeric indicator** of energy performance requested by the Energy Performance of Building Directive (EPBD) could vary from **73 kWh/m².year to -5 kWh/m²**.

twined, facing technological and non-technological barriers. MEP Ljudmila Novak mentioned the need for a common language to describe the quality of buildings, and the role of EPC's sharing best practise. MEP Miapetra Kumpala-Natri underlined the need to take care about health and well-being when renovating buildings. She reported about the experience made in Finland.

Mathieu Rivallain concluded that Energy performance (EP) assessment of buildings should:

1. be **comparable** all over Europe,
2. be **reliable** (expectation should be reach in reality),
3. **improve health & wellbeing** (indoor air quality, climate change resilient buildings),
4. **define roadmaps** to nearly Zero Energy Building (nZEB),
5. favour communication between all involved stakeholders
6. provide indicators to financial support to achieve EU climate targets.

Johann Zirngibl (CSTB), former ALDREN Consortium Leader, presented how the ALDREN outcomes could provide answer to these market requests.

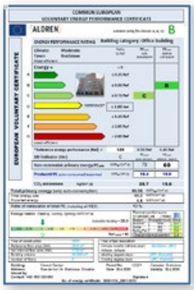
Presentation of ALDREN project and various inputs on buildings renovation presented by (left to right) Johann Zirngibl (CSTB), moderator Mathieu Rivallain (CSTB), Pau Garcia Audi (DG Energy, European Commission), host MEP Ljudmila Novak (EPP) and MEP Miapetra Kumpula-Natri (S&D).

Following the facts above, the following directions were discussed:

- How under such conditions a coherent policy could be defined?
- How under such conditions the building professionals can optimise building renovation by using the best EU practise?
- How under such conditions there could be a technologic neutral level playing field and fair competition for products and systems EU wide?

Besides coherent implementation, the participants underlined that deep renovation is a complex issue, inter-

1) EU Comparability: ALDREN Energy Performance Certificate (EPC)



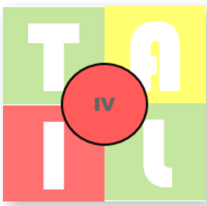
Energy Performance Certificates (EPC) could play a key role as information to building owners to trigger renovation, for the assessment of improvements achieved by renovation and for quality benchmark for financial instruments. The ALDREN EPC:

- uses **best practise**, based on **CEN and ISO standards**,
- defines a **common scale** to be used EU wide, based on cost optimum,
- is **technology neutral** and consider the **newest innovative technologies** (e.g. on-site wind turbines)
- provides **underlying indicators** (energy needs, final energy, renewables, etc),
- takes into account the **interaction between the building and the grid,**
- integrates the **resilience of the building to climate change.**

2) Reliability and confidence – avoid a "Building gate"

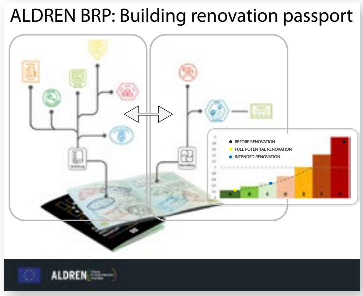
The sad experience in the car industry shows that it is fundamental that the expected and promised results should be reach on field. The building sector should avoid a "building gate". Buildings should be designed for performance and not only for compliance. The energy bills should be lower, the Greenhouse gas emissions should be reduced in practice. The ALDREN procedure **verifies** the actual performance **by measurements**.

3) Preserving and improving health & wellbeing – building must be climate change resilient



People spend most of their lives in buildings. Fourteen Green Building certification schemes have been reviewed to analyse the parameters used to assess the Indoor Environmental Quality (IEQ). ALDREN classified them into **four major IEQ components TAIL:** Thermal (T), Acoustic (A), Indoor air quality (I), visual environment (L). TAIL is "Levels" compatible. The ALDREN TAIL indicator allow to **communicate easily on IEQ**.

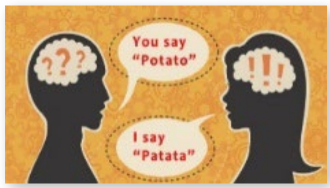
4) Building passport – Roadmap to nZEB – Green Deal compatible (2050 ready)



The Building Renovation Passport (BRP) is **complementary** to the Energy Performance Certificate (EPC). It provides a step by step **renovation roadmap until the nearly zero energy building level.** The **buildings renovated today** must be **EU Green Deal compatible, 2050 ready**. ALDREN provides a renovation roadmap, without **look-in effects and suboptimal renovation.**

5) ALDREN Common language – from the boiler room to the board room

Nobody can trigger deep renovation alone. ALDREN indicators & outcomes facilitate the communication between the key market players, "**from the boiler room to the board room**". ALDREN **links** the **energy quality of buildings** to three **financial indicators** as **costs, risks and value and reduces risk for finance providers** by resumed information.



6) Indicators for financial support to achieve EU climate targets – linking EU funding to EU tools

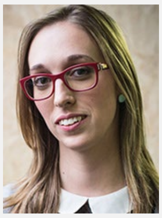
The financial sector will be the motor of the EU Green Deal and a fundamental leverage to trigger building renovation. Eligibility rules should be defined in a lending policy taxonomy where building professionals can build on when implementing the EU policy. The European Investment Bank (EIB) described in the document "*EIB ENERGY LENDING POLICY Supporting the energy transformation Draft 24 July 2019*" how such rules could look like. For example, the eligibility rules for building renovation define what will be funded: "*All capital expenditure related to energy efficiency improvements to the building envelope and building systems. The expected energy savings can be estimated through an energy audit, comparison between the energy performance certificate before and after the works, or any other transparent and proportionate method acceptable to the Bank*".

This definition is still quite general and should be detailed, taking into account the market request for a common, holistic and reliable approach. In some Member States, national funding is already linked to national standards. Therefore, when it comes to EU level, EU funding should be linked to European standards. The ALDREN project could contribute with the common Energy Performance Certificate, common indictors and best practise based on CEN and ISO standards to define precisely the requested building quality in lending rules.

The host MEP Ljudmila Novak closed the meeting with four main takeaways on how to possible boost buildings renovation. Firstly, encouraging the need for a common European scale and common digital tools for reliable assessment methodologies, taking into account different national conditions and implementations per each member state. Secondly, providing a common language of all included sectors and to make sure to take into account the needs of citizens and their role as they are crucial target group while designing renovation solutions. Thirdly, working together to encourage comparability of energy performance ratings across the EU and finally, highlighting the need for a clear financing rules in financial institutions, such as European Investment Bank. Investors should be informed well in advance about the eligibility rules of the bank's lending policy, like the minimum level of ambition of projects or that all technologies are properly deployed.

At the end of the event, participants expressed their wish that this event should be the starting point of fruitful future cooperation between all stakeholders supported at the highest political level. ■

Fuel cell cogeneration for building sector: European status



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The advantages of fuel cell based micro-cogeneration systems are the high electrical and total efficiency coupled with zero pollutants emission, which makes them good candidates for distributed generation in the building sector. The status of installations, worldwide and European initiatives and the available supporting schemes in Europe are presented.

Keywords: cogeneration; fuel cell; micro-CHP; building sector; demonstration project; supporting schemes

General context

Cogeneration is defined as the simultaneous generation of thermal and electrical energy in one process. The technological implementations of this concept are known as combined heat and power (CHP) systems. Cogeneration can be applied to different scales, from large centralized plants to buildings. Decentralized cogeneration systems installed in buildings are gaining an increasing interest and reaching wide diffusion, aiming to produce electricity and heat near end-users, meeting the demand for heating, hot water, while providing electricity to replace or supplement the grid supply. This concept is called "micro-cogeneration" (micro-CHP), defined as the local combined production of heat and electricity with an electric output lower than 50 kWel according to Directive 2004/8/EC. Micro-CHP can be applied to different kinds of end-users, from private dwellings to public and commercial buildings. In the residential sector, electrical capacities are typically up to 5 kWel and heat capacities up to 20 kWth, while in public and SME buildings, the ranges are 5–50 kWel electrical and up to 250 kWth thermal [1].

Three are the main micro-CHP technology types currently available: internal combustion engines (ICEs), external combustion cycles – Stirling engines, Organic Rankine Cycles (ORC) – and fuel cells (PEMFC and SOFCs). The large majority of commercial micro-CHP units currently installed are based on ICEs, Stirling engines and ORCs. The ratio between electrical and thermal generation varies between technologies, with lower ratios for combustion devices, thus better suited to large buildings with high heating loads, while fuel cell systems can reach electrical efficiencies up to 60% [2], being thus fit for self-consumption schemes of auto-generated electricity.

Micro-CHP systems are in the early phase of commercialization. In 2015, worldwide micro-CHP sales accounted to 270 000 units, with 15% of units installed in Europe and the remaining part mostly in Japan [3].

The main advantage of micro-CHP is that allows achieving a larger primary energy efficiency – above 80% [4] – compared to the separate production of heat and electricity, thanks to the recovery of waste heat from the process. The reduction in primary energy use due to higher efficiency results in the reduction of greenhouse gas (GHG) emissions, even if CHPs are not a zero-emission solution, because the vast majority are fuelled by natural gas. The increase in energy efficiency also results in lower operating costs for the users. On the user side, another advantage relies in the capability of micro-CHP systems to help transform consumers into energy 'prosumers' (i.e. producers and consumers), putting them at the core of future energy systems. From the point of view of the global European energy system, micro-CHP can also provide all the advantages of distributed electricity generation: help the grid stability by generating electricity close to consumption at times of need and improve the security of electricity supply. On top of that, micro-CHP diffusion has an economic impact, creating and safeguarding jobs [3].

Besides the aforementioned benefits, there are still some drawbacks or barriers hindering the wide adoption of micro-CHP units in the building sector. The most important are: the high first-capital cost, the lack or limited financial support to ensure a suitable payback period and sometimes administrative hurdles, such as authorization to electric grid connection. On top of that, local micro-CHP generation based on combustion technologies brings about environmental concerns regarding local emissions (such as NOx, CO, SOx, particulate matter, unburned hydrocarbons, etc.) [4]. The last drawback is overcome by the fuel cell micro-generation, which has near-zero local emission of pollutants because the core technology is not based on the combustion of fuels.

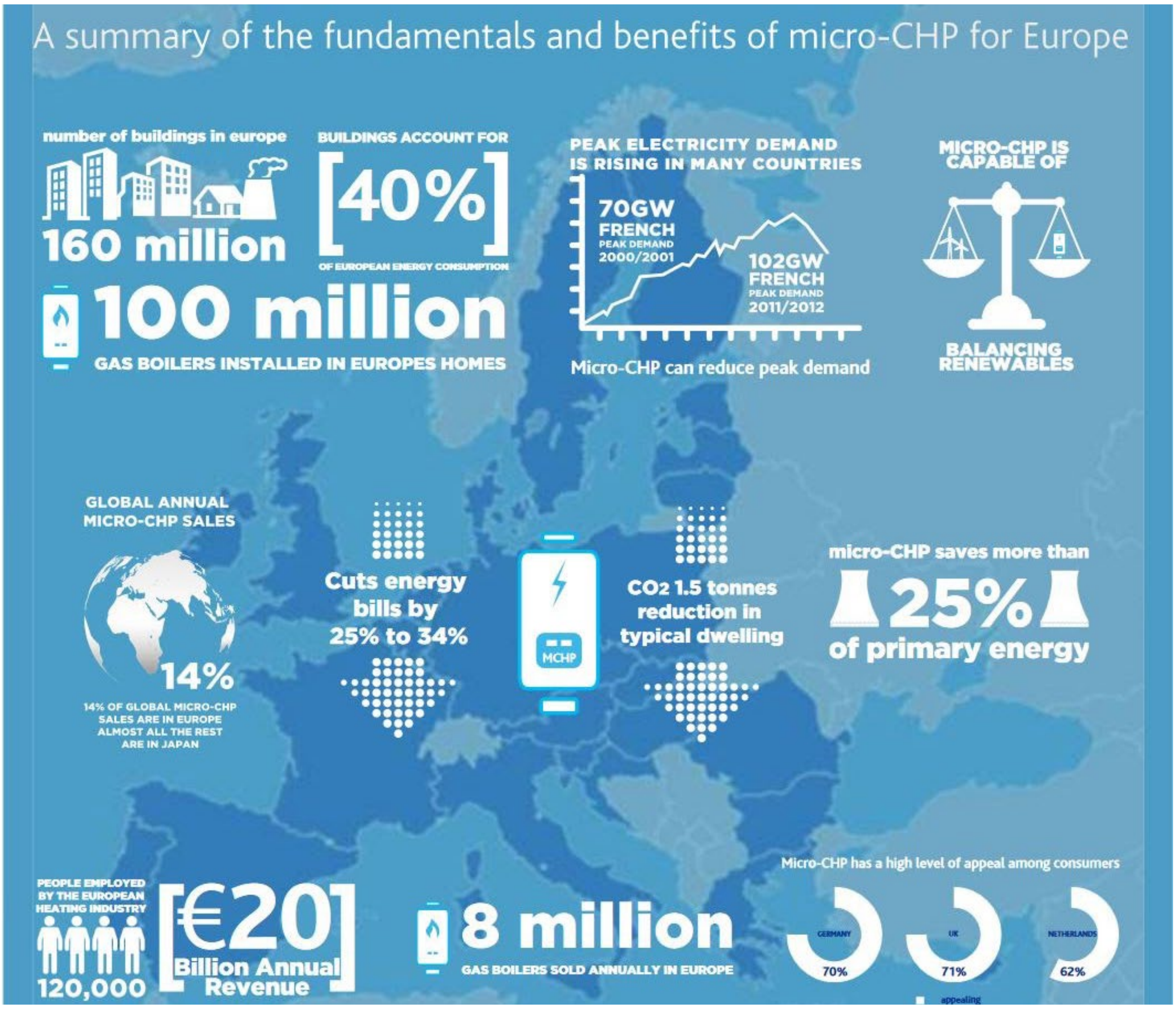

Figure 1. Benefits of micro-cogeneration in the building sector [3].

Fuel cell systems for the residential building sector

Fuel cell based micro-CHP systems could be a good candidate for the residential sector. Almost all the FC-based micro-CHP installations worldwide are considering FC systems of 0.5–1.5 kWel since most of the units are operated at constant point without modulation (electrical power production is sized to cover a "base load", while peaks are supplied by the grid). The authors have studied in previous works [5–7] the performance of high temperature SOFC and low temperature PEMFC cogeneration systems under different regulating strategies, configurations (heat pump, battery, etc.) and economic scenarios.

The first important launch of fuel cell based micro-CHP systems for residential use took place in Japan with the Ene.Farm project. As of December 31st, 2018, a total of 292 654 commercial Ene.Farm units has been deployed in Japan. The Japanese government supported for a long period the Ene.Farm program, with high initial subsidies, then gradually reduced as the industry matures and costs come down until subsidy will be unnecessary. **Figure 2** shows the trend of number of installations and costs from 2009 to 2017 in Japan. Investment cost for a FC-CHP system decreased from 24 900 € to 9 400 € (costs are referred to a typical size of 0.7–1 kW).

Europe has followed the Japanese initiative by financing fuel cell based micro-CHP installations in the framework of two projects, called Ene.field and PACE, financed by the private-public platform Fuel Cell and Hydrogen Joint Undertaking. Furthermore, a dedicated national program in Germany (KfW433) has helped the widespread use of the technology. According to the last available data from 2019, about 10 000 fuel cell micro-CHP systems have been deployed in Europe [8].

The Ene.field project (European-wide field trials for residential fuel cell micro-CHP, 2011–2017) has demonstrated more than 1 000 small stationary fuel cell systems (1046 units: 603 SOFC and 443 PEMFC) for residential and commercial applications in 10 countries, installing a total capacity of approximately 1 155 kW of distributed power generation. Among the installed units, more than 5.5 million hours of operation have been reached in total, with more than 4.5 million kWh electricity produced. **Figure 3** shows a map of the Ene.field project installations across Europe.

Germany has been the most successful market for Ene.field in terms of deployment numbers, with more than 750 units installed here. Funding from the national

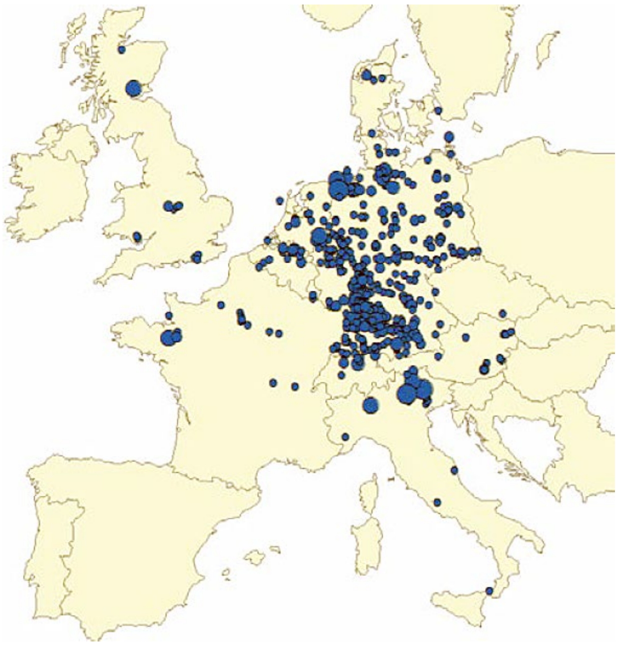

Figure 3. Locations of micro-CHP units demonstrated in the Ene.Field project.

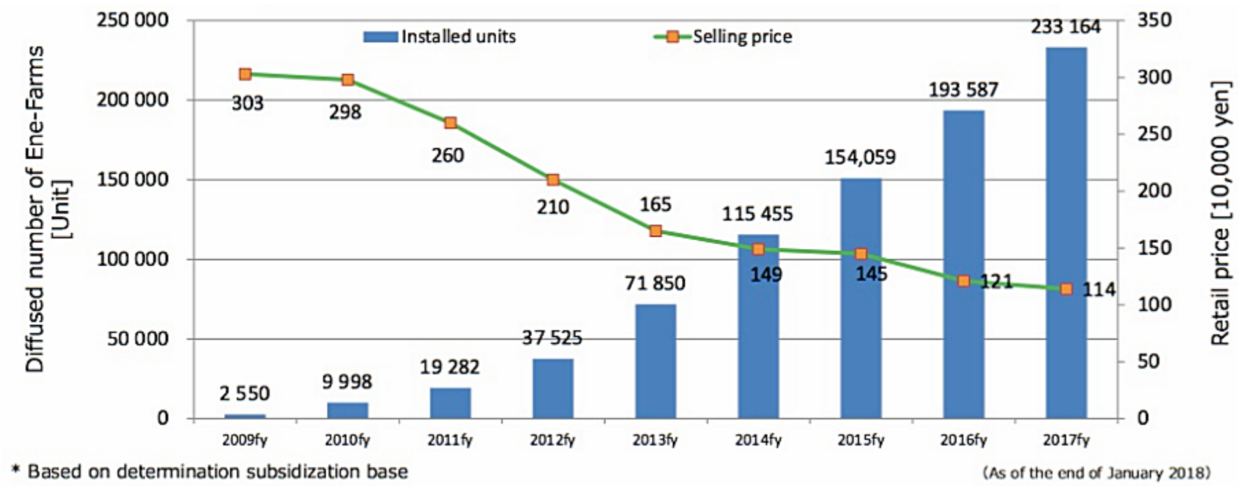

Figure 2. Locations of micro-CHP units demonstrated as of November 2016.

support schemes helps decrease the investment costs, and therefore favours the ramping up of the installation numbers. Moreover, high electricity prices make the technology more attractive in Germany than in other European countries [9].

Real-life data from the field trial shows average electrical efficiencies of 37% for the SOFC systems and 32% for the PEMFC systems. Average thermal efficiencies are 46% for SOFC and 57% for PEMFC. It is important to mention that these are average values within all the systems installed and standard deviations are very high (for electrical efficiency, st. dev. is 30–59% for the SOFC and 48–66% for the PEMFC).

The second step of the European fuel cell based micro-CHP diffusion has been the ongoing PACE project (Pathway to a Competitive European FC mCHP market, 2016–2021). The project is on track to achieve its target of installing 2 800 fuel cell micro-CHP units in households across Europe by 2021. As of January 2019, more than 1 200 fuel cell units have been sold, nearly half of the project's target number. Last year saw significant increases in sales in several countries, with exponential growth in Belgium thanks to a favourable investment climate [10].

The only country where specific subsidies for fuel cell systems are available is Germany, where the Cogeneration Act was passed in 2002 and revised several times, most recently in January 2016. Here the fuel cell market appears to be in transition, somewhere between the pilot phase and market diffusion [2,11]. The programme [12] provides a grant between 7 050 and 28 200 € per fuel cell – depending on the electrical output of the fuel cell system – for installation in new or existing buildings, and for residential and non-residential buildings. Fuel cell are subsidized in the power range from 0.25 to 5.0 kW electrical power. The economic support could include the investment cost for the fuel cell system and its installation, the cost of the full maintenance contract in the first 10 years and the costs for the services of the energy efficiency expert.

A CHP-based Feed-in-Tariff was also available in the United Kingdom but was stopped in March 2019. Italy also has a cogeneration systems dedicated supporting scheme, which includes a relatively low price paid for the electricity produced and a reduction on the taxes paid on the natural gas fed to the system. Anyway, both the UK and IT supporting schemes were referred to generic micro-cogeneration systems and not specifically to fuel cell, as happening in the German case.

Fuel cell systems for the non-residential building sector

When discussing about opportunities for FC micro-CHP systems, the residential building sector is not the only accessible market. Non-residential building sector includes all the commercial activities and office buildings. This market is addressed in the framework of a dedicated European project, ComSos (Commercial-scale SOFC systems, 2018–2020). The project aims to validate and demonstrate fuel cell based combined heat and power solutions in the mid-sized power ranges of 10–60 kW, referred to as Mini FC-CHP. ComSos goal is the installation of 20–25 units in the mid-size power range, from 3 European producers (Convion Oy, SOLIDpower SPA and Sunfire GMBH). Unlike the PACE and Ene.field initiative, ComSos focuses only on SOFC systems, because of the superior advantages of the technology among the competitors (high efficiency and zero emissions). A dedicated market analysis was developed to define the best business cases for the installation of the SOFC system. Some results are presented below.

The main criteria for the selection of the best suitable market for the SOFC-CHP installation are the availability of a base load – essential to run the SOFC at a near-constant power output through the lifetime – and optimal energy prices (electricity price higher than NG price). The spark spread, defined - in this framework - as the difference between the electricity and natural gas prices (in €/kWh), is one of the key elements which is influencing the economic sustainability of the fuel cell installation (without any specific supporting scheme).

Supermarkets have been found as the best candidates for the installation of the FC-CHP system. For medium-large size supermarkets, it is possible to define a quite constant Energy Intensity in the range 600–800 kWh/m². A dedicated modeling of the SOFC system coupled with a typical supermarket (with hourly electrical and thermal profiles retrieved from [13]) has been developed in the framework of the project. **Figure 4** shows the results for a 60 kW SOFC module installed in a supermarket in different countries (with different consumption profiles depending on the location) in the hypothesis of a subsidized scenario. The most striking, even if expected, finding is the direct and strong correlation between the spark spread and the Relative Pay Back Time (RPBT), defined as the time in which the SOFC investment starts to become economically more convenient than the base scenario (electricity from the grid and heat from a natural gas boiler). The correlation between the energy prices difference and the economic performance of the investment is pointed out. Best markets for the SOFC installation are Italy, the UK, Spain and some US cities.

Conclusions

The status of fuel cell technology of the building sector worldwide is covered in the present work. Both landmark projects and supporting schemes are reviewed. The case of Japan shows how the diffusion of fuel cell based micro-CHP systems is feasible and that the optimal size for residential buildings lies in the range 0.4–0.7 kW electrical. In Europe, different EU-funded initiatives and German dedicated subsidies are pushing the market entry of these systems. The overall number of installed units in Europe still lacks behind the Asian numbers. However, results from demonstration projects gave credibility to the whole fuel cell sector showcasing the high performance of this concept and underlined criticalities on which producers should focus (cost reduction and improved lifetime). Increased sales should be encouraged by subsidies to improve the near-term economics of micro-CHP units, and may be crucial for the technology to reach the mass market and hence for the EU to harvest the anticipated environmental and system benefits, while creating new jobs.

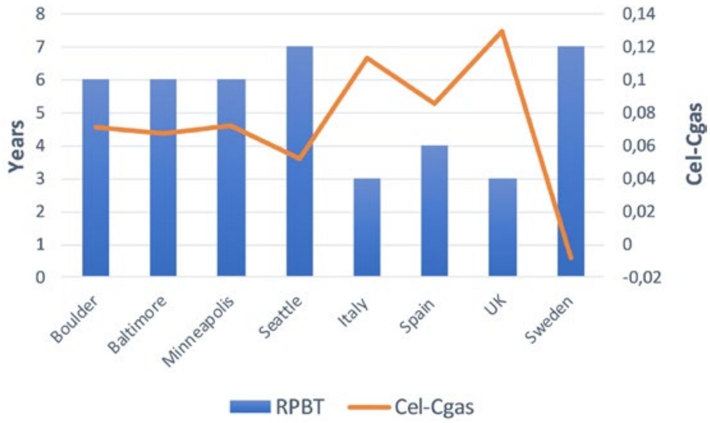

Figure 4. Results of the analysis of FC system installation in supermarkets.

On November 19th 2019, industry and stakeholders from the energy sector launched the Joint Declaration on Stationary Fuel Cells for Green Buildings to draw attention to the tremendous potential of stationary fuel cells to decarbonise the buildings sector. The signatories acknowledge that households and small businesses will play a vital role in the energy transition. With heating and cooling in buildings responsible for 36% of carbon emissions in Europe, they call for action to reduce our carbon footprint in the buildings sector with efficient, renewable and decentralised smart energy solutions. ■

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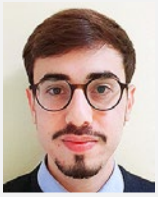
Overall energy performance of polyvalent heat pump systems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Buildings account for almost 40% of energy consumption in Italy, being one of the most energy-consuming and polluting sectors. The increasing electrification of HVAC systems requires an effort on the adoption of more efficient and sustainable technologies. The article aims to quantify the potential of polyvalent heat pumps, also in comparison to traditional heat pumps.

Keywords: polyvalent heat pumps, performance coefficients, gaussian load curves, partial load, energy savings, economic savings

The necessity to reduce primary energy consumption and greenhouse gases (GHG) emissions and to improve the energy efficiency of the power generation technologies is the objective of a wide range of policies within the energy sector in Europe [1]. Focusing on the building sector, due to the significant impact that HVAC systems have on the overall energy consumption of non-residential buildings (e.g. commercial, hospital, public administration ones, etc.), to achieve the European targets more efficient technologies should be used.

Traditional HVAC systems use different generation units to provide separately space cooling and space heating. For cooling, chillers are the most used technology; they produce chilled water in order to remove heat. On the other hand, boilers, heat pumps and district heating are used to produce hot water for space heating terminals. Reversible heat pumps, which can generate both hot or chilled water accordingly to the season, represent a more recent solution. However, it is not uncommon, due to building design and different use of the different spaces within the building, to have simultaneous requirements of heating and cooling in the same building. In this situation, both generation units should be used, and, in case of heat pumps, only one service can be provided at once.

In this framework, hybrid heat pumps, also called polyvalent heat pumps, represent a smart and low-energy solution to the conditioning needs in systems where the heating demand is combined simultaneously or independently with the cooling request. In fact, these technologies are able to recover the heat removed from the space that needs to be cooled and, instead of rejecting it to the external environment, they use this heat to produce hot water for heating purposes (space heating or domestic hot water production). Therefore, the potential of the polyvalent units is twofold: firstly, they can supply both heating and cooling at once; moreover, they can achieve such result using a single fuel.

Whereas such technologies are used for applications of power to heat using electricity as energy carrier, the combination of renewable generation systems on-site can give additional benefits, such as reduction in dependency from the energy grid and decarbonization of the local energy system.

The Polyvalent heat pump: operation modes and applications

Focusing on the polyvalent heat pump technology, it may be useful to briefly introduce its operation modes and its possible applications.

In this study, the considered polyvalent units are 4-pipes heat pumps equipped with a flexible heat recovery system that allows three operating modes: heating only, cooling only or both heating and cooling contemporary. Each unit consists of three heat exchangers:

- A main heat exchanger to produce hot water or chilled water;
- A secondary heat exchanger to produce hot water only;
- A condenser/evaporator for heat rejection or heat absorption, depending on the system operating mode.

In detail, the analysis was focused on the 4-pipes technology, aiming to demonstrate the benefits aroused from the use of the polyvalent unit, where automatic management of hot and chilled water supply is required independently or contemporary. For this reason, the AUTOMATIC mode is studied.

In this mode there are three possible operating configurations, as shown in **Figure 1**:

- AUTOMATIC 1 (A1): operation as air or water-cooled chiller (depending on the unit) only to produce chilled water at the main exchanger;
- AUTOMATIC 2 (A2): operation as air or water-cooled chiller (depending on the type) for the simultaneous production of chilled water at the main exchanger and hot water at the secondary exchanger;
- AUTOMATIC 3 (A3): operation as a traditional heat pump to produce hot water at the secondary exchanger.

The possibility to recover free energy and concretely use it represents the main difference between polyvalent and reversible heat pumps. Thus, hybrid units can find application in different sectors: residential buildings, hospital, offices, hotels, shopping centres. Both in the residential and in the tertiary sector (where complex surfaces and volumes characterize buildings), the simultaneous production of hot and chilled water may be required in some periods of the year, especially in the intermediate seasons (spring and autumn). This may occur due to large indoor thermal loads (e.g. electric equipment) in specific areas, to the different orientation of the building and/or to the different nature of occupants use of the indoor spaces. In all cases, the higher the heating and cooling loads required simultaneously, the greater the potentiality of the polyvalent heat pumps will be.

Methods

The aim of the study was to compare the performance of polyvalent heat pumps with respect to that of reversible heat pumps through the use of specific performance coefficients defined ad hoc. To do this, the methodology is divided into three steps:

1) Load curves and capacity curves modelling, in order to define the energy inputs of the model.
2) Creation of the algorithm for estimating the energy output
3) Definition of originally developed coefficients to make a comparison between performances of polyvalent and traditional heat pumps from an energetic and an economic standpoint.

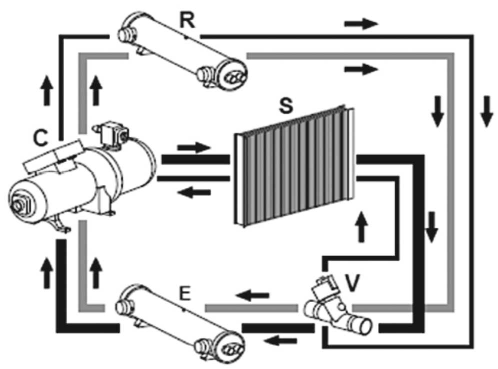


Figure 1. Working principle of the polyvalent heat pump. V=expansion valve, E=evaporator (main heat exchanger), C=compressor, R=heat recover (secondary heat exchanger), S=condenser/evaporator [2].

Load and capacity curves modelling

The approach involved the use of theoretical and normalized Gaussian load curves. The choice of Gaussian shape is justified by the similarity to real load curves. Normalization was carried out with respect to the peak power, in terms of both heating and cooling.

As mentioned before, the potentiality of the polyvalent heat pump is higher when the contemporary demand of heating and cooling grows, where contemporaneity is intended as the simultaneous presence of both heating and cooling load in the *i-th* hour of the year. The percentage of contemporaneity was calculated as in **Equation (1)**:

$$\%cont = \frac{h_{cont}}{h_{year}} \quad (1)$$

where h_{cont} represents the sum of the hours of contemporaneity during a year, and h_{year} are the 8 760 hours of the year.

Therefore, bundles of Gaussian pairs were created to evaluate different stages of contemporaneity, varying the standard deviation of the curve, by step of 50. In this way, 16 pairs of Gaussian curves were obtained, leading to a contemporaneity range from 13% up to 86%.

Figure 2 shows a pair of the obtained load curves, imposing a curtailment of values smaller than 10% of peak power, while in **Figure 3** the distribution of the different operating modes is shown.

In order to meet load demand, also capacity load curves were modelled. To strengthen the comparison between polyvalent and reversible heat pumps, similar characteristics were selected. Therefore, to explore different kinds of units, the analysis was carried out considering four diverse configurations, including: air condenser, four pipes, bi-circuits and different numbers of compressors, respectively 2,4 and 6 according to the chosen units. Additionally, the previous examples were analysed considering the use of an inverter for the two compressors unit. To each polyvalent unit corresponds a heat pump with the same characteristics, for a total of four pairs "polyvalent-reversible" heat pumps.

Starting from full load capacity data, from the producer datasheets, capacity curves were modelled, taking into account the two most influencing parameters for an air-condensing unit: the external air temperature and the operation at partial load.

First of all, weather data from the European software *Photovoltaic Geographical Information System* (PVGIS) for the city of Turin were used.

Then, since the full load capacity for the temperature defined by the European standard [3] are available, capacity curves in function of the air temperature were obtained by linear interpolation.

The combined effect of the influence of the external air temperature and the operation in partial load conditions was then investigated, using **Equations (2) & (3)**. Thanks to the datasheets, the part-load levels of the units and the relative quantities involved were known.

When using polyvalent heat pump, in A2 operating mode, the main condenser is by-passed, while the heat recovery heat exchanger is used. Therefore, the influence of temperature is worthless.

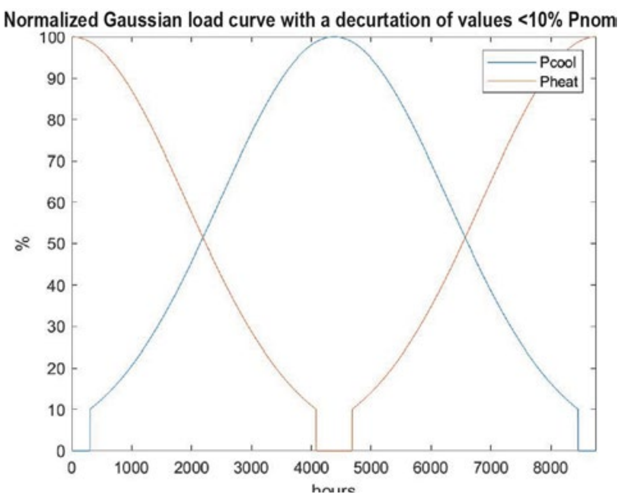


Figure 2. Example of Gaussian load curves.

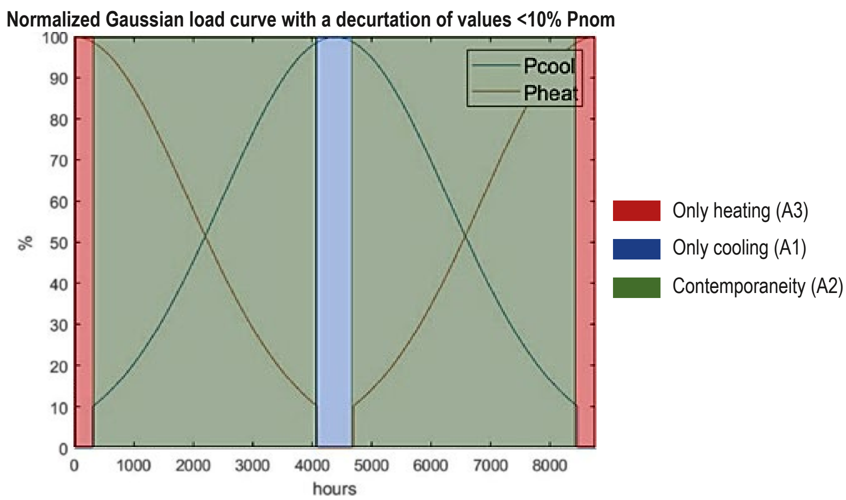


Figure 3. Operation mode during a year.

Algorithm

Once load and capacity curves were defined for each hour of the year, the algorithm for the calculation of the energy consumption and coefficients was implemented.

It is worth noting that, when reversible heat pump is considered, the algorithm is allowed to choose only between cooling only and heating only modes. For this machine, when contemporaneity occurs, it was assumed that heat pump is able to cover only the highest load, while the other one remains uncovered. On the other hand, polyvalent heat pump can shift between all the three operating modes.

For both polyvalent and reversible heat pumps, when the capacity of the unit is exceeded, demand is met using an electric boiler.

Overall performance evaluation

In order to show a global picture about the energy performance of the system on yearly basis, some additional coefficients are defined. The first coefficient here introduced considers the portion of non-served load of the two compared units and it is called *Non-Served Load Coefficient (NSLC).* The *NSLC* is defined by **Equations (4)–(6)**.

This coefficient allows to estimate the energy convenience of the polyvalent unit with respect to the traditional machine.

$$Capacity(Text, PL) = DC_{fl}(Text) * \frac{DC_{pl,i}}{DC_{nom}} \quad (2)$$

$$Pel(Text, PL) = Pel_{fl}(Text) * \frac{Pel_{pl,i}}{Pel_{nom}} \quad (3)$$

where

DC_{nom} = Nominal capacity at nominal conditions [kW];

$DC_{fl}(T_{ext})$ = Nominal capacity as a function of external air temperature (T_{ext}) [kW];

$DC_{pl.i}$ = Nominal capacity at the *i-th* partialisation degree of the unit [kW];

Pel_{norm} = Absorbed electrical power at nominal conditions [kW];

$Pel_{fl}(T_{ext})$ = Absorbed electrical power as a function of external air temperature (T_{ext}) [kW];

$Pel_{pl.i}$ = Absorbed electrical power at the *i-th* partialisation degree of the unit [kW].

A second coefficient is here introduced, named *Total Performance Coefficient (TPC)*, to give emphasis on the "cost" of production of the thermal energy (heating + cooling) in term of electricity needed and is defined by **Equation (7)**.

At last, an economic coefficient, called *Fuel Expenditure Coefficient (FEC)*, was proposed, in order to compare the energy costs in both cases. It is inversely proportional to the *TPC* (**Equation (8)**).

For the economic evaluation, the price of electricity for non-domestic low voltage customers, with available power greater than 16.5 kW, was considered.

$$NSLC = \frac{Qns_{hp} - Qns_{poly}}{SE_{tot,hp}} \quad (4)$$

where

$$Qns_{hp} = Q_{elbu} + Q_{rem} \quad (5)$$

$$Qns_{poly} = Q_{elbu} \quad (6)$$

Qns_{hp} = load non-served by the traditional heat pump [kWh];

Qns_{poly} = load non-served by the polyvalent heat pump [kWh];

$SE_{tot,hp}$ = energy supplied by the heat pump [kWh];

Q_{elbu} = energy supplied by the electric backup [kWh];

Q_{rem} = load non-served due to contemporaneity (traditional heat pump cannot serve both loads) [kWh].

$$TPC = \frac{E_h + E_c}{E_{el}} \quad (7)$$

$$FEC = \frac{C_{el}}{E_h + E_c} \quad (8)$$

where

E_{el} = electric energy needed to meet the demand [kWh];

E_c = cooling energy supplied [kWh];

E_h = heating energy supplied, using polyvalent units this terms account also for the "free" recovered heat [kWh].

C_{el} = annual electricity cost [€], obtained from the product between annual electricity consumption and electricity price.

The value of 0.14 €/kWh was obtained as the average, for the year 2019, of the "*quota energia*" only (cost for energy, transport and management of the meter) defined by *Autorità di Regolazione per Energia Reti e Ambiente* (ARERA) [4], with IVA and excise duties not accounted.

Results and discussion

Simulations were run for all the four pairs of polyvalent and heat pumps. For the sake of brevity, only the results of the four compressors units are discussed. However, it is important to note that the trend of the coefficients is the same for all four pair of units considered.

NSLC

As reported in **Figure 4**, when contemporary demand of heating and cooling increases, the value of the first coefficient grows and it clearly appears how the capability of the polyvalent heat pump of generating simultaneously heating and cooling allows meeting a larger user's demand. For example, for a medium stage of contemporaneity of 52% (taken as reference value of contemporaneity hereinafter), the hybrid unit is able to meet almost 15% more demand with respect to the corresponding heat pump.

TPC

Figure 5 shows *TPC* for the reversible heat pump (HP) and the polyvalent heat pump (POLY), considering a 52% stage of contemporaneity. The blue bars represent the ratio between the cooling energy and the correspondent electricity consumed by the units, while the red bars represent the ratio between the heating energy and the correspondent electricity. *TPC* is then defined as the sum of the two contributions. As it can be seen in the figure, the red bar is much larger for the polyvalent heat pump, since the heat recovered in the hybrid machine is completely "free", not being produced by a fuel.

FEC

Figure 6 shows *FEC* for a 52% stage of contemporaneity. In this graph, the red bars represent the ratio between the cost associated to electricity consumed and the corresponding heating energy produced, while blue bars refers to cooling. The trend is specular to the *TPC*, being its direct consequence. Conversely to the previous situation, the red bar is lower for the polyvalent unit, since the recovered heat is not accounted as a fuel expenditure. When considering a 52% contemporaneity value, the economic saving associated to the use of the polyvalent heat pump is almost 32%. As expected,

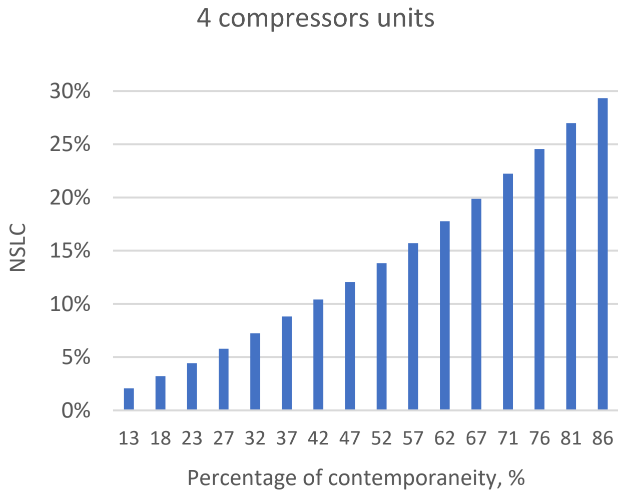


Figure 4. NSLC with respect to percentage of contemporaneity.

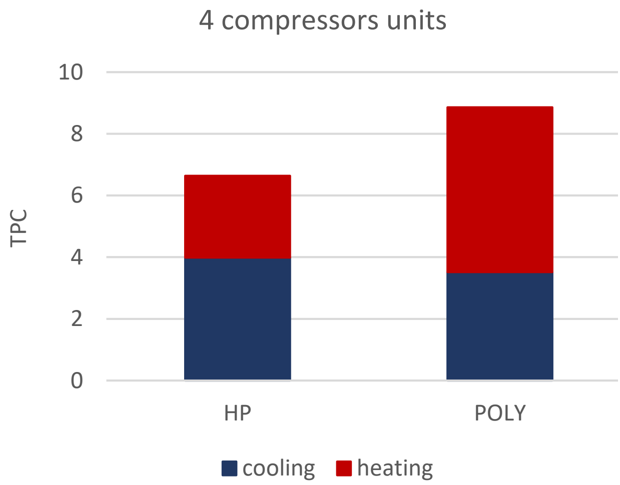


Figure 5. TPC for 52% of contemporaneity.

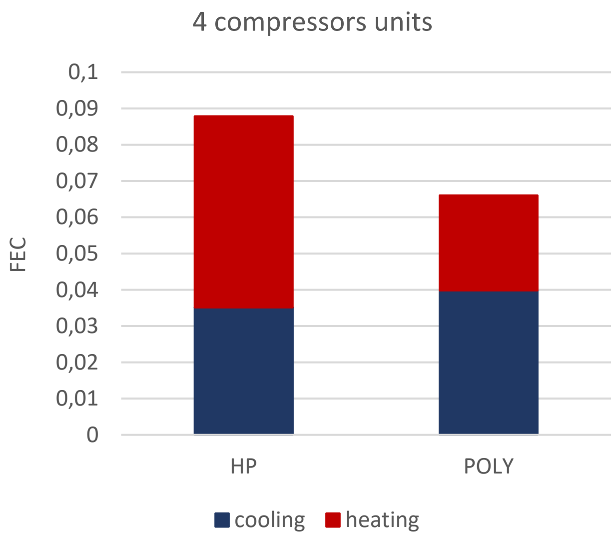


Figure 6. FEC for 52% of contemporaneity.

this value grows when the percentage of contemporaneity increases, reaching the maximum value of 73% of savings for the 86% of contemporaneity. Considering the medium range of contemporaneity (between 32% and 71%), the obtainable savings span from 13% to 55%.

Conclusions

The need for reducing the energy and environmental impact of HVAC systems is leading to the development and use of more sustainable technological solutions. Among them, polyvalent heat pumps can be cited, which main benefit with respect to existing technologies is the capability of meet contemporary heating and cooling demands, and thus representing an interesting technological solution for many applications. Thanks to the introduction of newly developed coefficients, the efficacy of polyvalent units with respect to traditional heat pump was highlighted. The capability of this innovative solution to exploit the potential free energy derived from the heat recovery can lead to significant savings in terms of energy consumption and fuel expenditure. As expected, convenience increases when the hours of simultaneous request for heating and cooling grow. To provide a complete analysis of the economic benefits of these units, cost-benefit analyses will be carried out in future works, allowing to encompass also other economical parameters, as investment and maintenance costs. ■

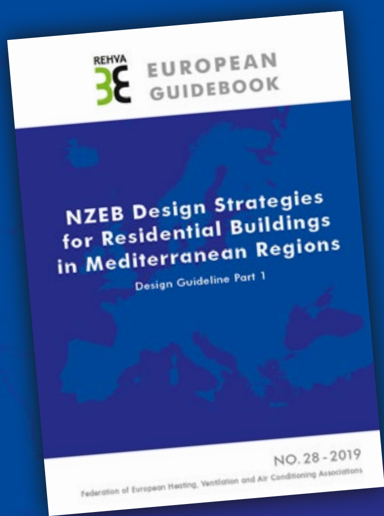
References

[1] European Commission, A Roadmap for moving to a competitive low carbon economy in 2050, 2011.

[2] RHOSS SpA proprietary technical documentation.

[3] UNI EN 14825 - Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling - Testing and rating at part load conditions and calculation of seasonal performance.

[4] ARERA, electricity cost for 2019, https://www.arera.it.



Overcoming Obstacles to Financing Energy Efficiency in the HVAC and Building Sector

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As a strategic analyst at Joule Assets Europe, Divia is responsible for policy and market development. She also supports Joule's European projects through research, analysis and modelling.

Introduction

The impact of building energy use in the EU and the need for energy efficiency in the HVAC and building sector is undisputed. As building stock is responsible for approximately half of the total energy demand in the EU and roughly 36% of its CO_2 emissions, the mandate for more efficient buildings is expected to only grow stronger. While there is ample opportunity to power buildings with renewables, strive for nearly zero-energy buildings and upgrade building stock to be smarter, digitized and interactive, the obstacle of accessing finance continues to limit what can be achieved today.

Therefore, decoding the financial mechanisms that have the potential to drive investment and increase the pace of market growth is vital for developing the sector and mitigating climate change.

Energy efficiency as an asset

Understanding the big picture financial engineering processes that can advance investment in energy efficiency starts with looking at energy savings as an asset, a **sellable item**.

For an investor this means, for example, paying for a HVAC upgrade upfront and then being paid back out of the money saved by the building owner through lowered energy bills. For the building owner, this could look like redirecting money toward an investor, which would have otherwise been paid in energy costs caused by an inefficient HVAC. This process turns energy efficiency into an 'asset' – meaning that the savings are turned into an item which can be measured and sold. This concept is the basis of green investment in an energy efficiency context and a starting point for more ambitious large-scale financing necessary for the energy transition.

Shortfalls to gaining financing

Joule Assets Europe works with financiers and investors across Europe to facilitate investment in energy efficiency and small-scale renewables projects. Through SEAF Horizon 2020 work, Joule developed a platform called eQuad to help European energy efficiency project managers (ESCOs or energy service companies, engineering firms, and construction companies) access appropriate project finance while lowering upfront due diligence costs for investors.

The assessment of numerous potential energy efficiency measures on eQuad highlighted the shortfalls of standalone energy efficiency projects from an investor's vantage point and the difficulty typical energy efficiency projects face in meeting investment criteria. In many instances, projects were too small to attract the interest of investors. Moreover, aggregating projects was often not possible, as the varying measures frequently had different levels of risk.

Joule's experience with eQuad showed that many of the essential building blocks needed to establish investment in energy efficiency assets are currently missing. These key elements include common practices for setting measurability in agreements, determining how risk is evaluated, and selling energy efficiency as a service successfully to end clients. Like other industry professionals in this sector, Joule has witnessed that the different ways these elements are being understood, discussed and executed has led to a general lack of clarity that often results in project failure. **Increased failure rates, time, due diligence and costs, are all by-products of this status quo.**

Building the foundation for investment and growth

To develop the foundation for financing multiple projects under good conditions for both parties, Joule is working to create a standard set of structural documents and procedures. These foundational elements include standardized risk assessment protocols to eliminate lengthy due diligence, investor-grade Energy Performance Contracts and standardized sales processes for creating robust pipelines.

By solving the ambiguity around issues like risk assessment, project valuation and sales through standardization, more investors can successfully engage with the industry and failure rates are lowered. Similarly, the development of robust customer-focused sales processes that offer energy efficiency as part of a managed service as opposed to a sales of a technology (e.g. the sale of a managed service versus the sale of HVAC) are enabled by these improvements and facilitate the participation of more and more customers. These changes are increasingly important in an evolving and competitive market like that of energy.

Bringing investors onboard

At present, each investor uses their own methodology and benchmarks to uniquely evaluate projects. Since this is done independently in-house, it is valuable to understand the process and how project developers can get projects ready to meet investment criteria. In order to gain insight on the various investment criterion and minimum thresholds to engage investors, Joule has collected these criteria from multiple investors compiled during their negotiation activities and reviewed them with their investor partners. Willingness to invest in energy efficiency upgrades and technologies like cogeneration, Building Management Systems and HVAC was broadly seen across the board. Several investors would further invest in projects like district heating or generation such as solar photovoltaics or other renewable energy systems.

Finance types of the different investors varied from 10–100% equity to straight debt as well as included other models. The sampled investors were largely agreeable to Energy Performance Contracts of either guaranteed or shared savings. In terms of size criteria, the minimum project size considered by investors was commonly 50,000 € with a minimum portfolio size of 1 to 5 million euros.

While investing in standalone energy efficiency measures are often not lucrative enough for investors, who typically look to fund projects of at least 1 to 5 million euros, pooling together assets/projects can make groups of energy efficiency measures attractive. This is the case for most commercial or industrial energy efficiency projects that widely vary in cost but often fall in the range of 150,000 to 1 million euros. However, in order to aggregate projects successfully, they must be comparable and follow the same format. Therefore, standardized customer contracts and project risk mitigation measures are required (both of which are now available for review).

Value of aggregation and securitization

Given the gap between standalone projects and the bar for investor interest, the aggregation of energy efficiency measures is needed to meet an investor's threshold and gain financing for most projects.

Going a step further, once financing is achieved, securitization of assets can offer further value to the investment community. Securitization as a process allows energy efficiency assets to be bundled again or repackaged for sale or trade in larger units. The potential impact of these kinds of mechanisms are significant as they would open a door to the type of large-scale investment and transition currently limited.

Although aggregation and securitization may seem like simple solutions, the legal implications and due diligence for each energy efficiency project involved can increase time and cost to the point that it is no longer feasible. Therefore, as mentioned above, standardizing the quality and contractual framework associated with each asset (each project) is required as a first step to accelerate the due diligence and legal obligation preventing market growth, as well as enable project aggregation. As part of the LAUNCH consortium, Joule Assets works alongside TNO, BNP Paribas Fortis, EnerSave Capital and New Energy Group to develop standardization and securitization models for energy efficiency measures.

While there are many implications of projects like LAUNCH, small and medium sized enterprise are in a unique position to benefit from the developing foundation for aggregation of sustainable energy assets.

Links to broader policy

In the midst of new policy direction influencing plans such as the European Green Deal or the strategy behind the declaration of climate emergency, there is a need for holistic systems change. Addressing access to financing for a just and inclusive energy transition is a crucial piece of this greater systems change.

The widespread use of financial mechanisms like off-balance sheet financing and implementation of standardization and securitization models for energy efficiency measures will improve access to financing and involvement for all citizens and sectors. Policies that enable these tools will help to unlock access to capital along with the reality of a more efficient Europe for all.

Case study: financing HVAC-as-a-Service

A HVAC company serving industrial customers by installing best-in-class technologies procured on a project-by-project basis wanted to increase their competitiveness by improving their offering to customers to provide HVAC-as-a-Service (HVACaaS). The new business model means that the company offers financing for the technology, perform the installation, and provide maintenance.

In setting up this new business line, the company went to their local bank to secure a financing solution and learned that they would need to apply individually for project financing on a one-off basis. In addition, the bank would view the company on-balance sheet every time they applied. This restricted the number of projects the company could take on at any given time and introduced a cumbersome and inefficient process. As a result of this news, the company was at risk of not being able to develop its HVACaaS business line and in jeopardy of losing the 400,000 € pipeline of projects it had already secured.

Turning to eQuad as a tool, the company was able to present their pipeline as a portfolio of bankable projects for investors and receive an off-balance sheet solution from an investor. The investor then worked with Joule to structure a Special Purpose (SPV) of 5 million euros entirely owned by the fund. The advantage of the SPV was that it facilitated the company to pay for the upfront and maintenance costs of their initial pipeline as they established capital for future projects. Through eQuad, the company was able to accelerate the development of their HVACaaS solution. ■

Heat Balances by using heat pumps

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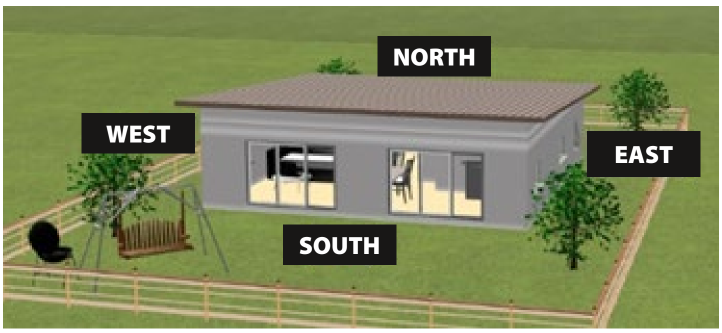
The methodology of heat balance calculation can be different. We use dynamic (detailed) simulations, quasi-stationary methods - monthly method, correlation (static) day-stage method with a fixed heating period length, and also dynamic methods with a specified time step - a simple hourly method. The main aim of this work is to use and demonstrate the importance of the new hour method (EN ISO 52016-1) in comparison with the commonly used monthly method. The energy requirements for heating, cooling and hot water production are calculated using the Simulation 2018 software with an hourly step. Using the heat pump with an hourly step is calculated energy intensity model house.

Nowadays, the construction of new houses and reducing their energy intensity is becoming an increasingly discussed topic. From 2020, a new EU directive will be in force – it mandates the construction of environmentally friendly buildings and contains stricter requirements for the energy performance of buildings. It will be an obligation to design such a house. The key aim of this diploma work is to point out to the importance of the hourly method, which works according to EN ISO 52016-1 – It calculates more accurate values by using hour time step and this is the way to move the building into higher energy category.



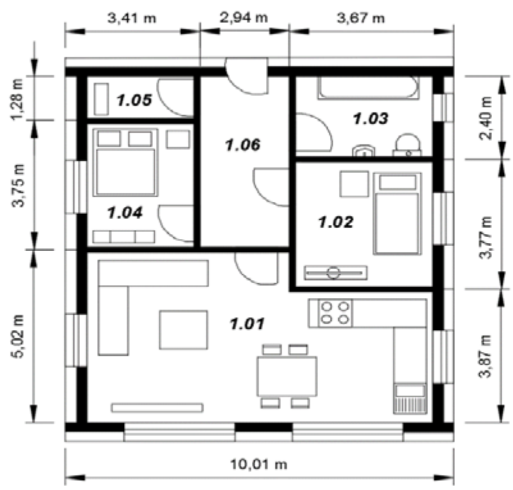


Figure 1. Model house.

Methodology of this work

1. Model house

The first step of this work is a simple design of a house in two climatic areas (one warmer and one colder) according to the principles of low-energy house design. The building has a compact shape, high-quality materials are used, it is suitably oriented to the cardinal points (p.o. large windows are oriented to the south side because of solar gains, rooms like technical room or laundry are on the north side of house).

Simulation 2018 software is used for energy analysis of the model house, this SW works with a new hourly calculation model according to Articles 6.5.6 to 6.5.13 of EN ISO 52016-1. This model is based on re-compilation and solution of the system of balance equations in individual time steps, taking into account the energy balance at the level of the zone (room) and at the level of partial constructions. At least five balance equations corresponding to the number of nodes in the structure model (from 5 to 30) shall be compiled for each "opaque" structure, depending on its composition. For "translucent" structures, a two-node model is used.

2. Design of a heat source power

The heat source power is based on the external calculation temperature and the associated heat loss consisting of the passage of heat and ventilation. Climatic data were provided by SHMU institute. Both the hourly and monthly methods are used to demonstrate the difference in the performance regime over the selected 4 days in each season. The theoretical required heat output is determined as the difference between heat loss and heat gain. The value of heat loss is calculated for each hour of the day and heat gains (indoor and solar) are evaluated by Simulation 2018 based on location, altitude, building orientation, used materials, house occupants and other factors. The theoretical heat source power calculated in this way does not take into account heat accumulation!

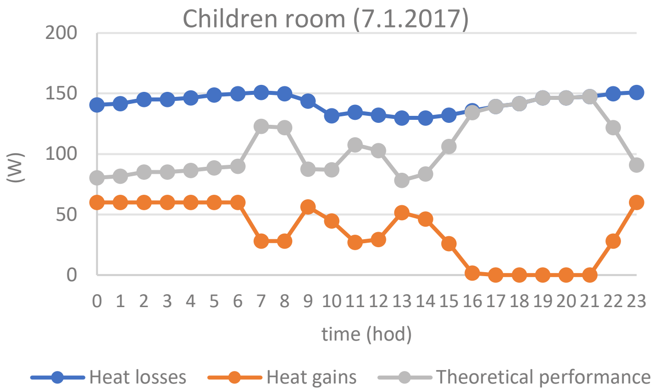


Figure 2. Theoretical heat source power.

However, Heat accumulation is taken into account:

- in the building construction - the specific heat capacity, the thermal conductivity and the density of each layer of material are specified;
- room equipment - according to EN ISO 52016-1 standard value of 10 000 J/(m²K) is assumed for common rooms - if the value is set to 0, the state for a completely empty room would be calculated;
- in the air.

Calculation in the software run in the "free float" mode, that means without the providing heat/cold from the source (the indoor air temperature therefore depends only on the boundary conditions). The output of the calculation is a protocol containing a graph of the resulting temperature in the room (reaction of the room) to the boundary conditions, which are mentioned heat gains, outdoor temperature and ventilation.

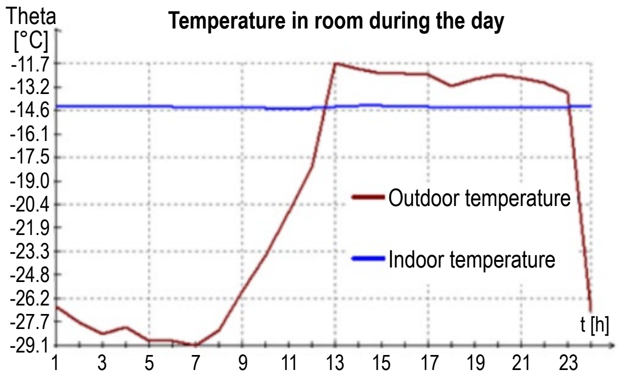


Figure 3. Course of outdoor and indoor temperature.

The heat required to heat the mass of the room air is determined from the calorimetric equation:

$$Q = m_{vz} \cdot c_p \cdot (t_v - t_n) \text{ (kJ)}$$

It takes into account the amount of air in the room (m_{vz}) that will need to be heated (cooled), the heat capacity of the air (c_p) at given conditions and pressure 101.3 kPa and of course the temperature difference (resulting room temperature t_v – designed temperature t_n). This calculation is performed for each temperature throughout the day.

The heat output of the heat/cold source calculated from the calorimetric equation can be entered into the software. After its installation we get a graph of the resulting temperature in the room and it is possible to find out whether the heat source is oversized, sufficient or it is necessary to increase it. Of course, it will be oversized because of the heat accumulation from heating process. The heat output values are optimized so that the resulting room graph shows the design temperature in the room.

3. Calculation of building energy demands

The hourly and monthly method is again used to calculate the energy demands for heating, cooling and hot water production throughout the year. Regarding the hourly method, the same procedure as explained in the design of the heat source (where 4 days were selected to determine the required heat source output) is applied, but by this way every room and every day is analysed hourly for both selected temperature regions. EN 15316-3-1 is used to determine the annual energy demand for water heating.

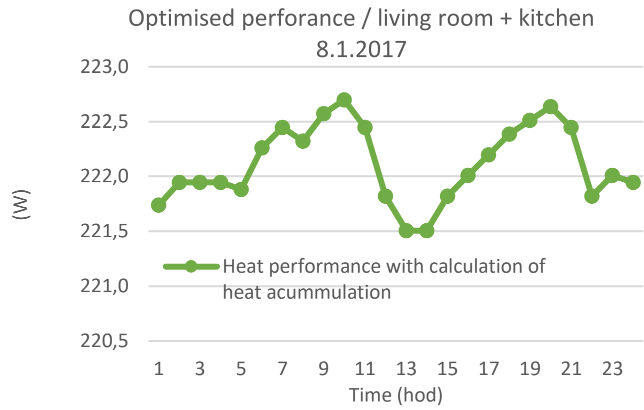


Figure 4. Resulting optimized required heat source power (heat accumulation taken into account).

4. Calculation of energy intensity

The global indicator of energy intensity is primary energy entering to the transformation process – kWh/(m²/year), which is largely dependent on the selected heat source. The technologies compared are heat pumps (colder region - ground/water, warmer region - air/water) and electric boiler with cooling circuit. The primary energy consumption is determined by:

- by SPF pursuant to Decree no. 324/2016 Z.z.
- using the SCOP
- hourly step with the corresponding heating coefficient

An example hourly calculation for warmer region:

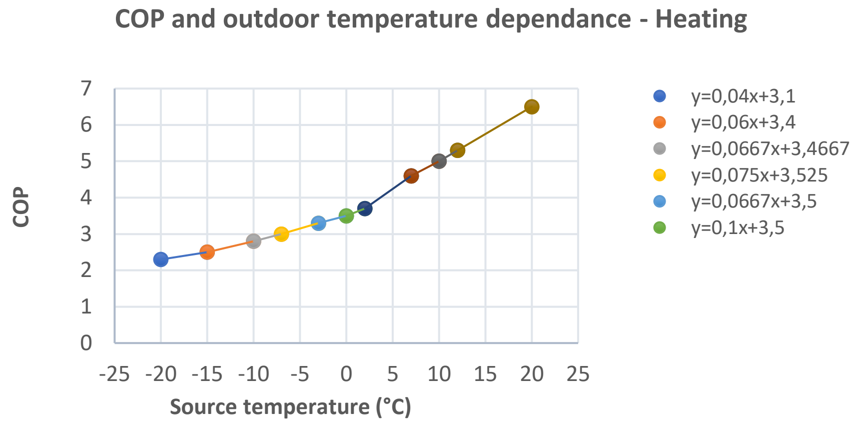


Figure 5. COP/EER dependence on outside temperature.

The selected air-water heat pump from the manufacturer Protherm - Genia Air Split is 5 kW. To calculate hourly energy consumption, it is necessary to know the COP / EER value at each hour of the year at a given hourly temperature. The subsequent hourly heat / cold consumption will be determined by the equation below.

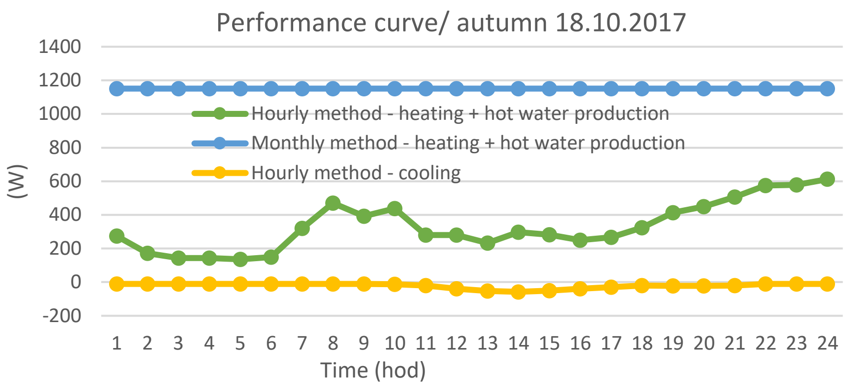


Figure 6. The resulting heat output curves on the selected autumn day.

$$\text{hourly energy consumption(kWh)} = \frac{\text{hourly energy demand (kWh)}}{\text{COP/EER}}$$

The information datasheet shows the COP coefficient dependence on the outside temperature – COP is given for temperatures –20, –15, –10, –7, –3, 0, 2, 7, 10, 12, 20°C. I consider the system temperature at the outlet of 35°C, when operating the pump in heating mode - the model house has low temperature floor heating.

When hot water is heating, an outlet temperature of 55°C is considered. The cooling coefficients of the EER are used for temperatures of 15, 20, 25, 35, 46°C. The other COP/EER values are derived using linear dependencies (**Figure 5**) between them according to EN 14825. The total energy consumption of the house is calculated, multiplied by the primary energy factor. According to Decree no. 324/2016 Z.z , PEF value for electricity is 2.2. The result is a global indicator of primary energy in kWh/m².year, which determines the classification of the building into the energy class.

Results

1.Heat source power

Figure 6 shows the resulting heat output power curves of the whole house with water heating on a selected autumn day in warmer region calculated with an hourly step compared to the power calculated by the monthly method. The monthly method based on the average temperature indicates only the need for heating, while the detailed hourly method shows, besides heating also the need for cooling during the lunch hours.

2. Energy demands and energy intensity

The difference between the heating and cooling energy needs of a model house calculated by the hourly and monthly method reaches up to 20%. The procedure with an hourly calculation step is more accurate, more flexible, and does not need much more input data. The hourly method analyses in detail the solar and indoor gains, ventilation and, in particular, the heat accumulation, which is taken into account in the building construction, furniture and equipment in the room and in the air. The monthly method according to EN ISO 13790 with an adaptation factor provides a rough estimate based on conventional assumptions, which may, in some cases, suit but do not allow to optimize heat pump solutions in more detail. The hourly method, an hourly step, allows more detailed access to a building requiring both heating and cooling. In the monthly calculation, it is also difficult to check the need for cooling in the months when it is still heating. The lowest value of primary energy consumption is demonstrated by the hourly calculation method. This principle is suitable for heat pumps as it more precisely takes into account the calculation with the corresponding COP in relation to

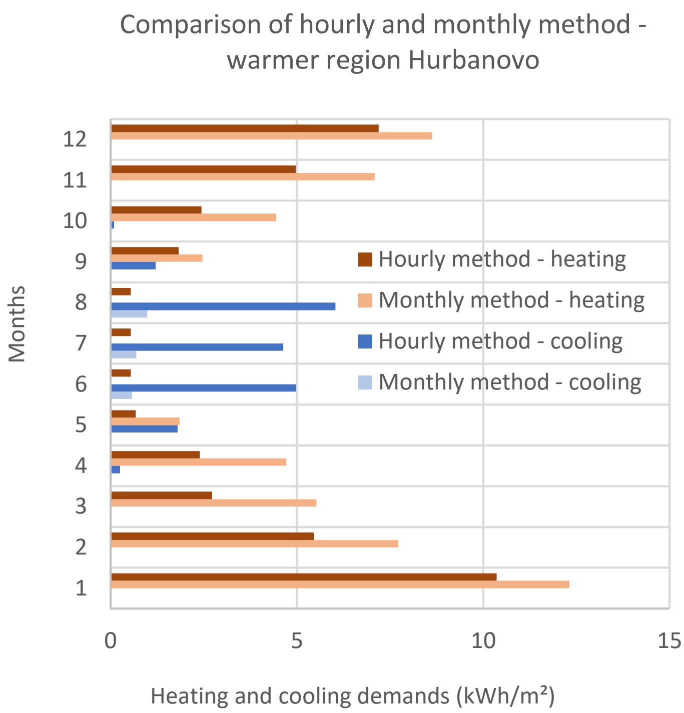
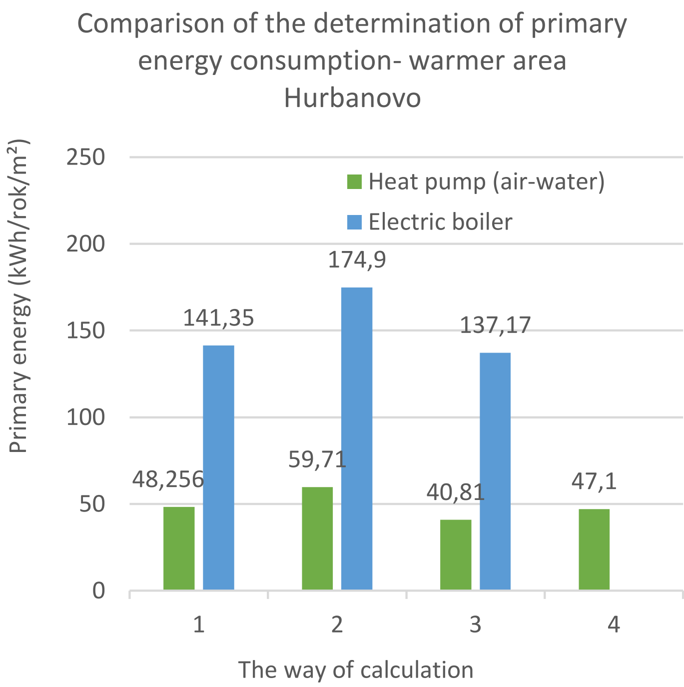


Figure 7. Comparison of energy requirements in kWh/m² per year calculated by monthly and hourly method. The figure shows not only the lower energy demand calculated by the hourly step, but also the cooling demand in April, May, September, which remained hidden using the monthly method.



1 - Decree no. 324/2016 Z.z. Hourly method	2 - Decree no. 324/2016 Z.z. Monthly method
3 - Hourly calculation	4 - Calculation with SCOP

Figure 8. Comparison of energy intensity expressed in primary energy in kWh/m² per year calculated by monthly and hourly method shows high consumption for electric boiler and lowest consumption calculated per hour.

Table 9. The resulting comparison of energy intensity. A house with a heat pump is classified in a higher energy class as opposed to a house with an electric boiler, which moves the house to class B.

Hurbanovo - warmer region							
The way of determination of energy consumption	The way of determination of energy demands	Energy demand for heating (kWh/rok/m²)	Energy demand for hot water production (kWh/rok/m²)	Energy demand for cooling (kWh/rok/m²)	Source of heat	Primary energy consumed (kWh/rok/m²)	Building category
Order 324/2016 Z.z.	Order 324/2016 Z.z. Hourly method	39.74	23.95	18.98	Heat pump air-water	48.256	A0
					Electric boiler	141.35	B
	Order 324/2016 Z.z. Monthly method	54.76	23.95	2.25	Heat pump air-water	59.74	A1
					Electric boiler	174.9	B
Hourly calculation	Hourly method	39.74	23.95	18.98	Heat pump air-water	40.81	A0
					Electric boiler	137.17	A1
Calculation with SCOP	Hourly method	39.74	23.95	18.98	Heat pump air-water	47.1	A0

the outside temperatures for each hour of the year. The COP is calculated per hour and depends on the load rate and temperature of the low potential heat source.

Discussion

This diploma work shows that, in contrast to the monthly method, the hour method is a more accurate way to determine the energy requirements (energy needs) of a building. The difference between heating needs is up to about 20%. Also, the monthly method is not able to accurately describe the building's cooling needs. The hourly method analyses in detail processes in the building, i.e. solar and indoor gains, ventilation and especially heat accumulation. Another big difference is the power mode of the heat source, where there is also a significant difference between the methods used.

Difference of primary energy consumption as a global indicator between hourly calculation method and monthly method according to Decree no. 324/2019., in both cases (both cold and warm areas) reaches a lower value of about 15%.

The difference in primary energy consumption between the hourly calculation and the SCOP calculation is about 13% lower. The hourly method is important for heat pumps because the calculation by the hourly step more accurately takes into account the COP corresponding to the given temperature conditions, i.e. the load rate and the source temperature. The calculation by seasonal heating or cooling coefficient, similar to the monthly method according to the Decree, is less accurate.

When calculating with the monthly method, it is difficult to check the need for cooling, for example, in April, May, September, when there are still heating requirements. A building without cooling may seem better. The hourly step can also calculate the need for cooling and maintain the internal environment parameters when calculating the energy performance of a building.

Conclusion

The above results and the way of determining both the energy demands and the energy intensity with an hourly step contribute to the specification of the requirements for heating, cooling, water heating and significantly help in the correct design of technical equipment of buildings, especially heat pumps with possible use of photovoltaic electricity. The hourly method, an hourly step, allows for a more specific approach to a building requiring both heating and cooling. The task for the future will be to improve the calculation methodology, to beat up and automate the calculation and to gradually introduce it into a practice. ■

prEN 17423 Reporting of Primary Energy Factors and CO_2 emission coefficient

for a correct estimation of the real impact of building on energy and climate change

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Introduction

The scope of prEN 17423:2019 is the reporting of the choices related to determine Primary Energy Factors (PEF) and CO_2 Emission factors for energy delivered to or exported by buildings to be used in EN ISO 52000-1. The standard has passed with success the public enquiry stage in October 2019 and will be proposed for formal vote in 2020.

Policy support

One reason for drafting this prEN 17423 is related to the Energy Performance of Buildings Directive (EPBD). The Directive requests in Article 9 that the definition of nearly zero energy buildings shall include a numerical indicator of primary energy use expressed in kWh/m^2 per year. The primary energy factors used for the determination of the primary energy use considered relevant European standards referred to in this article.

The building energy performance rating based on primary energy allows considering the global impact of the building related to energy. Primary energy rating is the latest stage of building codes requirements starting with energy losses related to products, energy needs of buildings, energy use of the building systems and energy carrier.

Today, with the primary energy indicator, the requirements of buildings are no longer the expression of means (e.g. the type of windows) but performance orientated. This allows building professional to optimize the building e.g. according to its localization, and to determine the best solution for each building. The primary energy rating is often considered as technically neutral, establishing a level playing field between all building technical solutions. It is depending on choices made regarding the determination of PEF (see below) because some equipment losses may be outside the building. For example, the distribution and generation losses of district heating or when using electrical heating are occurring outside the building. But if technical solutions, with parts of the systems located outside the building perimeter should be taken into account at building level, also the related losses should not be forgotten when evaluating the real impact of the building. This makes the difference between primary energy and final energy, where in case of the final energy approach, the losses outside the building are neglected.

The other reason for drafting this prEN 17423 is related to Climate Change. The climate change impact of a building is measured by its CO_2 emissions, and buildings should evolve towards nearly zero emissions, in order to contribute to the objective of carbon neutrality being pursued by a growing number of countries. The CO_2 emissions of a building are as important to consider as its energy consumption. Similarly, CO_2 emissions should be considered whether they occur outside or inside the building perimeter (district heating or electricity generation, vs gas boiler).

The impact of PEF and CO_2 emission coefficient

Primary Energy Factors (PEF) and CO_2 emission coefficients impact strongly the expression of the energy performance of the buildings as they are the multiplication factor for the whole calculated building energy use and CO_2 emissions.

Table 1 indicates the PEF used in the building regulation of several European Member States (MS) and the default values of EN-ISO 52000-1 "Energy performance of buildings – Overarching EPB assessment".

Table 1 shows that for these two examples, for natural gas, the non-renewable PEF (f_{Pnren}) varies from 1.09 (MS1) to 1.17 (MS2). Only due to the different PEF's,

Table 1. *PEF used in building regulations of European Member States (MS) and in EN-ISO 52000-1.*

Energy carriers		**Primary energy factors**								
		Member State 1			**Member State 2**			**EN ISO 52000-1**		
		f_{Pnren} [1)]	f_{Pren} [1)]	f_{Ptot} [1)]	f_{Pnren}	f_{Pren}	f_{Ptot}	f_{Pnren}	f_{Pren}	f_{Ptot}
Fossil fuels	Solid	1.11	-	1.11	1.46	-	1.46	1.1	0	1.1
	Liquid	1.11	-	1.11	1.11	-	1.11	1.1	0	1.1
	Gaseous	**1.09**	-	1.09	**1.17**	-	1.17	1.1	0	1.1
Bio fuels	Solid	0.20	-	-	0.2	-	-	0.2	1.0	1.2
	Liquid	0.50	-	-	0.3	-	-	0.5	1.0	1.5
	Gaseous	0.18	-	-	-	-	-	0.4	1.0	1.4
Electricity		**1.90**	0.60	2.50	**2.60**	0.40	3.00	2.3	0.2	2.5

[1)] f_{Pnren} = non-renewable PEF; f_{Pren} = renewable PEF; f_{Ptot} = total PEF the buildings in MS1 heated by natural gas have a lower primary energy consumption of around 7% in comparison with MS2.

The differences are much higher for electricity. For electricity the non-renewable PEF ranges from 1.9 (MS1) to 2.6 (MS6) which is a variation of around 37%.

These variations impact international benchmark and the definition of nearly zero energy buildings. According to the PEF's, the nZEB level will be reached more or less easily by certain technologies.

The ratio of the PEF between energy carriers is also a key element in the competitiveness of the technical building systems. In MS1 the ratio between electricity to natural gas is 1.74 whereas in MS2 it is 2.2. This means that in MS1 it would be easier to sell electrical solutions.

A similar analysis could show that CO_2 emission coefficients are different across countries because for example, the energy systems are different, but also because of differences in approaches or assumptions for the determination of the CO_2 coefficients.

These few examples clearly show that there is a need for transparency in order to:

- make international benchmark of building on energy and CO_2 performance more credible and reliable;
- make the energy performance and CO_2 emissions requirements technically neutral and fair.

Therefore, the determination of the PEF and CO_2 emission coefficient should be based on transparent assumptions. Of course, there could be a national political preference for one or another energy carrier depending on the national energy context (e.g. energy independency). But this preference should be explicitly expressed in the building code requirements and not hidden in factors. Otherwise the real consequence of the choices will also be hidden, introduce a wrong metrics leading strong difference between calculation and reality.

The objective and the content of prEN 17423

The standard prEN 17423 provides a transparent framework for reporting the choices to determine PEFs and CO_2 emission coefficients for energy delivered-to and/or exported-by the buildings as described in EN ISO 52000-1:2017. The PEFs and CO_2 emission coefficients of exported carriers can be different from those chosen for delivered energy. This standard can be considered as a supporting/complementing standard to EN ISO 52000-1, as it requires values for the PEFs and CO_2 emissions factors to complete the EPB calculation.

The target group of this standard are the users of the set of EPB standards, for example national standardization experts, building authorities in charge of defining the PEFs and CO_2 -emission coefficients, but also building professional (e.g. designers) using these values in their calculation. The understanding of the underlying choices related to PEF and CO_2 values, for example if and how exported energy is taken into account, is important for the optimisation of buildings.

In prEN 17423 there are new and more choices, but some PEF and CO_2 emission coefficient are already determined and reported in other standards (e.g. EN 15316-4-5 district heating, EN ISO 52000-1 overarching standard). The choices have been summarized in prEN 17423. Therefore, chapters of these other standards have been copied into prEN 17423 to make a consistent, easy to read standard, without the need to consult additional documents.

The outcome of the whole standard is resumed in the normative Annex A (see **Table 2**). It provides a template to report the main methodological choices that impact PEF and CO_2 emission coefficient values. No mandatory quantitative reporting of data is requested. Please note that **Table 2** is related to the version sent out for public enquiry. It is not the final version and may again change depending on the comments received.

Future transposition of CEN prEN 17423 on ISO level

By the extensive adoption and use of International Standards in the built environment considerable savings in energy, CO_2 emissions and finance can be achieved. Especially through the application of standards for energy efficient design of buildings, energy and CO_2 emissions could be reduced significantly.

Therefore, during the last ISO/TC 163 & 205 meetings held in Seoul, Republic of Korea, September

2019, the prEN 17423 has been presented in the ISO Joint Working Group related to Building Energy Performance. This presentation got a positive echo. It was decided to launch an enquiry for a new Work Item related to this topic also on ISO level and on the basis of CEN prEN 17423 standard. ■

Table 2. *prEN 17423 A.2 Reporting template for choices per energy carrier.*

Reference document (document describing the quantification of PEF and CO_2)			
(ref)			
Energy carrier	$f_{P;nren}$	$f_{P;ren}$	$f_{P;tot}$

Choices related to the perimeter of the assessment (6.1)					
Geographical Perimeter	☐ European	☐ National	☐ Regional	☐ Local	☐ Other[1)]

Choices related to calculation conventions (6.2)				
Time resolution	☐ Hourly	☐ Monthly	☐ Annual	☐ Other
Data source value	☐ Real historic	☐ Simulated historic	☐ Forward looking	☐ Other
Net or Gross Calorific Value	☐ Net calorific Value		☐ Gross calorific value	

Choices related to the input data (6.3)					
Available energy sources	☐ include all energy sources	☐ exclude self-consumed on-site generation	☐ exclude dedicated delivery contracts		☐ Other
GHG considered	☐ CO_2 only	☐ CO_2 equivalent 20 years	☐ CO_2 equivalent 100 years		☐ Other
Biogenic carbon	☐ carbon neutrality		☐ biogenic CO_2, CH_4 accounted		☐ Other
Conventions energy conversion	☐ Zero equivalent ($f_{P;nren}$=0)	☐ Direct equivalent ($f_{p;y}$=1)	☐ Technical efficiencies	☐ Physical energy content	☐ Other
Conventions PEF exported energies	☐ resources used to produce		☐ resources avoided		☐ Other

Choices related to the assessment methods (6.4)						
Energy exchanges	☐ ignoring exchanges		☐ net exchanges	☐ exchanges with different associated PEF and CO_2		☐ Other
Multisource generation	☐ Average calculation approach			☐ Other (e.g. marginal) specify approach and technical reference		
Multisource energy output system	☐ Power loss method	☐ Carnot method	☐ Alternative production method	☐ Residual heat method	☐ Power loss ref method	☐ Other
Life cycle method (LCA)	☐ no LCA			☐ full LCA		☐ Other

1) when the "other" tick box is used, one should specify this.

References

For an overview of all EPB standards see www.epb.center

prEN 17423 Energy performance of buildings - Determination and reporting of Primary Energy Factors (PEF) and CO_2 emission coefficient — General Principles, Module M1-7 : 2019.

EN ISO 52000-1 Energy performance of buildings — Overarching EPB assessment — Part 1: General framework and procedures : 2017.

EN 15316-4-5 Energy performance of buildings - calculation of system energy requirements and system efficiencies - Part 4-5: District heating and cooling ; Module M3–8-5, M4–8-5, M8–8-5, M11–8-5 : 2017.

Cost optimisation and life cycle assessments of nearly zero energy buildings

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The CoNZEBs project aims at reducing barriers for deployment of low-energy housing by identifying solutions sets for reduction of construction costs as well as the long-time life cycle cost and life cycle environmental impact.

Keywords: solution sets, cost reduction, life cycle costs, life cycle environmental assessments, global warming potential, non-renewable primary energy

Introduction

The EU Horizon 2020 research project CoNZEBs (Solution sets for the cost reduction of new Nearly Zero-Energy Buildings (NZEB) - 01/06/17 to 30/11/19), identify and assess technology solution sets that lead to significant cost-reductions of new NZEBs in four EU member states (Denmark, Germany, Italy and Slovenia). All solution sets have been assessed by life cycle costs (LCC) analysis and life cycle environmental assessment (LCA) providing a longer-term perspective than the construction costs. Some results obtained are quite remarkable as they indicate that a balance point between energy saving measures and renewable energy (solar) supply has been crossed. In other words, the LCC and LCA analyses show that both for economic and environmental reasons it pays off to reduce insulation levels and introduce PV-systems and/or solar heating systems on NZEBs. Results from this work – primarily for one of the countries – Denmark – is presented in the following.

Solution sets

In the project, solution sets have been developed, which are a combination of technologies, i.e. building fabric and technical building systems that together with ordinary building components constitute a building that meets the NZEB requirements.

Analyses of the solution sets was carried out using national tools for proving compliance with energy performance requirements.

The solution sets are for Denmark:

1. High efficiency insulation in exterior walls resulting in lower construction costs for foundations, window fittings and roofs.
2. Domestic hot water (DHW) solar heating; reduced insulation in walls, roof and floor.
3. Four-layer windows; water saving fixtures; natural ventilation (illegal as balanced mechanical ventilation is required in new multi-family houses); heat recovery on grey wastewater.
4. Reduced insulation in walls, roof and floor; decentral mechanical ventilation; efficient water fixtures.
5. Reduced insulation in walls, roof and floor; decentral mechanical ventilation; roof PV panels.

In the solutions sets shown above, decrease of the insulation level at the thermal envelope is one of the common features. This is natural when considering the resulting cost reductions that include lower costs for insulation material, lower costs for window installation, smaller facade area, smaller foundations and roof when maintaining the same habitable area.

In some countries, replacement of traditional heating systems with less costly ones are also among the solutions. In some cases, this is not legal due to national legislation that e.g. prohibits direct use of electricity for space heating.

In NZEBs, domestic hot water is one of the prime contributors to the building's energy demand. Hence, in some solution sets, water saving fixtures or heat recovery on the grey wastewater have been used to reduce the energy demand for domestic hot water. This opens for use of less efficient/costly solutions elsewhere in the building and thus lowering the investment costs.

A summary of cost optimisation results from the Danish calculation are shown in **Table 1**.

Life Cycle Cost (LCC) and Life Cycle Environmental Impact Assessment (LCA) calculations

All the identified solution sets are further assessed regarding cost savings using LCC and with respect to the environmental impact using LCA analysis, which both provide a long-term perspective than just the reduced investment costs. The results of the LCC and LCA are compared to those obtained for conventional minimum energy performance (min. EP) buildings, conventionally built NZEBs and buildings that go beyond the NZEB level – zero-energy or even plus-energy houses. For Denmark the beyond NZEB has been defined as a "0-energy building", without including household electricity.

The LCC used for this analysis is resulting in the total net present value (NPV) of the technology solution sets over a fixed period of 30 years. The LCA calculations in this project cover two phases: Production and Use. Generally, the input values/parameters to use for the LCA calculation in both phases are available in each country. An overall decision has been made on how to handle the input to the two phases for each country. For this work, it was agreed to focus the results on two LCA parameters: Non-renewable primary energy (NR-PE) use and global warming potential (GWP), known as CO_2-equivalent emissions. Both NR-PE factors and GWP emissions due to different energy supply options during the use phase have been analysed by each country.

The beyond NZEB, the Typical NZEB and the range of the results from the solution sets are compared to the min. EP building. The range of NZEB solution sets is interpreted as the interval between the best and the worst NZEB solution set result with respect to the LCC and LCA results obtained individually. The two improved technologies that constitute the difference between min. EP and typical NZEB building are the starting

Table 1. *Summary of cost results from analyses of solution sets. Building envelope is the average U-value of the building fabric. GFA is gross floor area.*

	Danish solution sets					
	Typ. NZEB	DK-1	DK-2	DK-3	DK-4	DK-5
Building envelope [W/m²K]	0.26	0.26	0.31	0.21	0.31	0.31
Energy costs$_{(GFA)}$ [€/(m²yr)]	11.8	11.8	11.8	11.7	11.7	11.7
Investment costs$_{(GFA)}$ [€/m²]	1247	–2.1	–5.5	–18.1	–15.0	–12.6

point to each alternative NZEB solution set. They are: 3-layer windows instead of 2-layer window and a mechanical ventilation system with good heat recovery, instead of one with average recovery. The results are presented in **Figures 1-3** as differences compared to the min. EP building.

Figures 1-3 show that all the alternatives to the min. EP buildings are more environmental friendly, when comparing greenhouse gas emissions in the form of kg CO_2-equiv./m^2 and non-renewable primary energy use to the min. EP building. However, from a purely economic perspective, only one of the solution sets and the beyond NZEB building are more cost-effective than the min. EP building. The beyond NZEB building is a more cost-efficient solution than the min. EP building, due to the economic value of larger energy savings than those of the NZEB.

Conclusions

Investment cost reductions in the four countries range from 1 €/m² (with a slightly better energy performance) to 94 €/m², with the highest cost savings in an Italian solution set. Solution sets can obviously not be compared directly across climate zones and national legislation. However, it is envisaged that some solutions in another country's solution set may inspire to new combinations and hence new solution sets.

One of the main ideas of the CoNZEBs project was to investigate if LCC and LCA analyses conducted over a time-span of minimum 30 years would cast

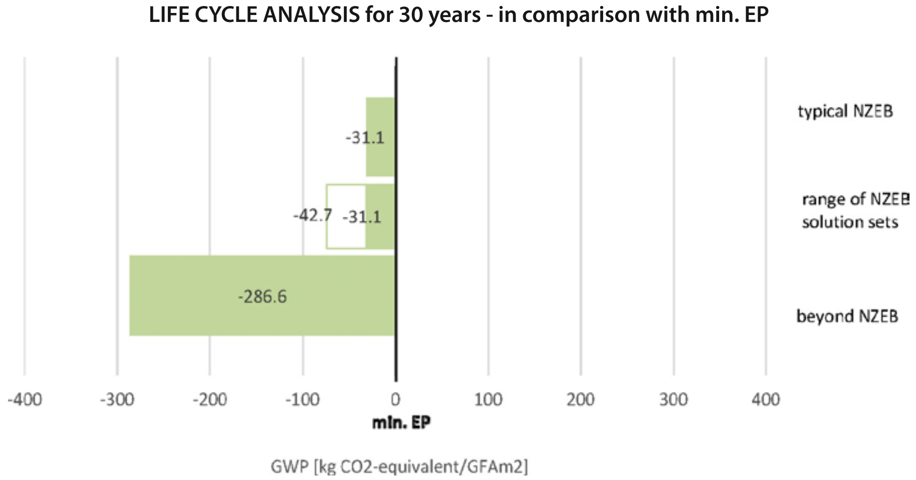

Figure 1. GWP analysis for typical NZEB, range of NZEB solution sets and beyond NZEB in comparison with min. EP.

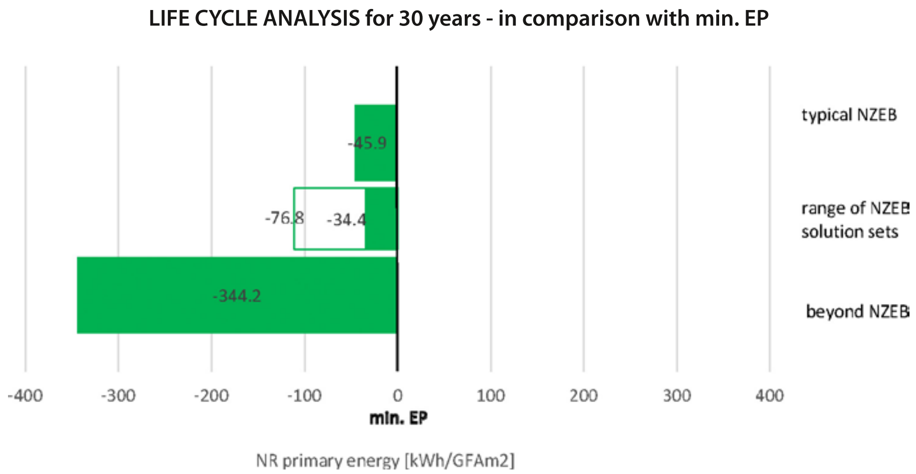

Figure 2. NR-PE energy analysis for typical NZEB, range of NZEB solution sets and beyond NZEB in comparison with min. EP.

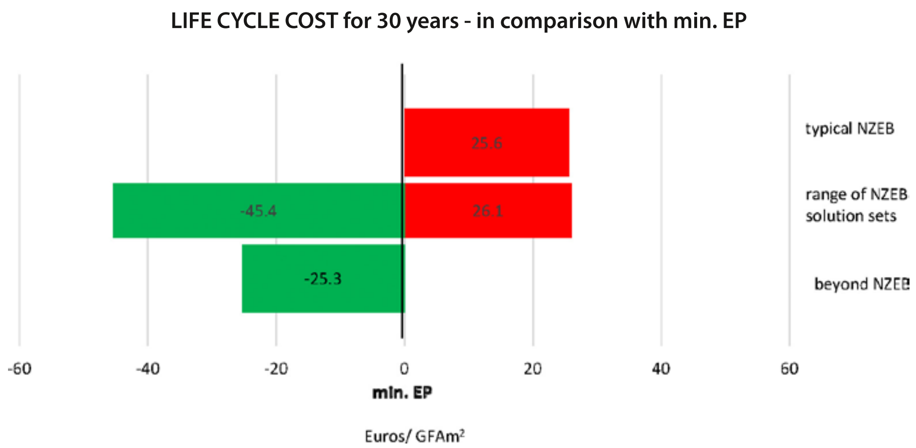

Figure 3. NPV for the different improved energy performance levels compared to minimum EP – Denmark.

Figure 4. Illustration of typical multi-family houses used for the CoNZEBs solution set analyses in Denmark, Germany, Italy and Slovenia.

more light over what is the most cost-effective and environmental friendly building energy level – min. EP, NZEB or beyond NZEB.

The analyses are carried out for well-defined reference/typical multi-family buildings in each country (**Figure 4**) for each of the three energy use levels.

One of the overall conclusions, based on the Danish results are: Typical NZEB is less cost-effective than min EP, but beyond NZEB can be more cost-effective. Both NZEB and beyond NZEB can be more environmentally friendly than min. EP. The different solutions for NZEB reduce the CO_2-equivalent emissions by 31 to 43 kg/m² over a 30-year period. For the beyond NZEB, the total number is 287 kg/m². This compare to the typical total CO_2-equivalent emissions over a 30-year period of a new conventional building in Denmark of 400-500 kg/m². Interesting is also that several of the solutions sets show that the insulation levels can be reduced by only adding a solar heating or PV system, or implementing energy efficient water taps - in all cases showing improved GWP compared to the typical NZEB. It needs to be said that reduction of insulation thicknesses are relatively small – about 50 mm – thus these reductions does not compromise the indoor thermal comfort nor diminish the resilience and passive habitability. One of the solutions sets even showing improved cost-efficiency compared to the min. EP building.

So far, the results for Denmark has reached the goal of pointing the way for optimum design of new buildings in the future.

On the project website (www.conzebs.eu) there are information about all the results obtained in the project. Among them is a survey of users' experiences and expectations of low-energy buildings, and a brochure on the benefits of living in low-energy buildings. ■

Acknowledgements

CoNZEBs is a EU Horizon 2020 project on the topic 'Cost reduction of new Nearly Zero-Energy buildings' (call H2020 EE 2016 CSA, topic EE-13-2016). As such, it receives co-funding by the European Union under the Grant Agreement No. 750046.

CoNZEBs project is a co-operation between four different countries: Germany (Fraunhofer IBP & ABG-FH), Denmark (Kuben, BL & SBi/AAU), Italy (ENEA & ACER RE) and Slovenia (GI ZRMK & SSRS). The partners are from different research organisations and national housing organisations. Fraunhofer IBP leads the project.

The authors like to thank our colleagues for their involvement and commitment in the project.

Decision Support Tool for Energy Flexible Office Buildings

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We present a tool that helps building designers design office buildings with high energy flexibility. The tool provides them with information they need in order to choose building and system parameters to achieve the highest amount of energy flexibility possible and satisfy the comfort of the occupants.

Keywords: Office building, energy flexibility, productivity loss, decision support tool, building design, self-consumption, building performance simulation

Background

When stepping forward as a society, any move towards a greener future should include buildings as a main focus. The growing need of decarbonizing our energy, calls for the integration of more renewable energy sources (RES) such as solar and wind. Many RES has a stochastic nature. This results in fluctuations in the electricity production by RES and this increases the risk of discrepancies between energy supply and demand. One way to deal with this mismatch is by using demand side management. The so-called energy flexibility of buildings can be used for this purpose. The energy flexibility of a building is the ability of a building to manage its demand and generation according to local climate conditions, user needs and grid requirements [1]. An example of energy flexibility is utilizing the thermal mass of the building and use pre-heating and pre-cooling methods to achieve load shifting when energy demand is high. Energy flexibility is also one of the pillars in defining the smartness of a building and a vital factor in supporting future energy systems. To exploit and utilize an energy flexible building, its full potential should be known along with how other indicators such as cost and comfort are affected by exploiting this potential.

Design Tool for Building Energy Flexibility

In this article we present a tool that helps building engineers in the design process. The tool supports designers in every step of the design process when choosing building parameter values and thermal comfort strategies. The tool is developed in corporation with BAM; a major construction company with its headquarters in the Netherlands. The tool is focused on office buildings in the Dutch market and targets both new office buildings and renovation offices. By just a few clicks, the designer can select the design parameters that are fixed already and he can leave open the ones that they want to explore. Subsequently the decision support tool presents the best available design solutions. These solutions score the highest on both energy flexibility and productivity/comfort, but also show the lowest energy consumption and cost (investment and operational). Using the tool, designers can quickly and easily get vital information about the performance of the building design and receive support on how to optimize the design in order to arrive at a high-performance office building. The tool focuses on comparing building design variations and how their performance compares with each other. Note that the tool does not provide predictions on the actual energy or comfort performance during operation. A fully functional version of the tool with the appropriate user-friendly designed interface is not available yet, but is work in progress.

Development of the tool

The tool is based on a database which contains simulation results of 839.808 office building variations. Each database entry contains scores on several relevant performance indicators. A building performance simulation software (EnergyPlus) and machine learning are used in order to develop the database. The database is filled with cases that are simulated and cases whose results are predicted through surrogate models developed by classification algorithms. The predicted results from the machine learning algorithms are validated to be sufficiently accurate for this study [2].

Interviews with the potential users of the tool were performed in order to identify the requirements of the tool, the relevant performance indicators and the design parameter variations that needed to be included in the database.

Performance Indicators

The following performance indicators are selected based on the interviews.

- Cost: Divided in operational and investment cost
- Yearly energy consumption: in electricity assuming a heat pump connecting to the delivery system with a COP of 3.
- Productivity loss: Productivity loss is based on and calculated through thermal comfort and indoor climate. Using PMV values and air temperature along with freshness and CO_2 concentration in the offices, productivity loss in the cases that the tool investigates, is calculated based on the average loss according to several studies that have been presented in literature [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13]. More information on the calculation can be found in [14].
- Energy flexibility: Quantifying the energy flexibility that each design variation potentially can offer is implemented through two different assessments and their corresponding indicators: the characterization assessment and self-consumption assessment.

Energy flexibility characterization

Energy flexibility characterization is included in this project by utilizing the suggestions of [15]. Grønborg et al. suggest that a static building can be characterized based on its flexibility potential and introduces a novel methodology, the Flexibility Function. The Flexibility Function assumes a building in a steady state for every time step and a penalty signal that is given by the controller (price, CO_2 etc.). The signal aims to control the demand. Before the signal, the building is operated in the highest (in winter) or lower (in summer) breach of the temperature range that is acceptable. When the signal is received from the building, the terminal system is either shut down or lowers its setpoint to save on operational cost (as seen in **Figure 1** that the setpoint is lowered). The

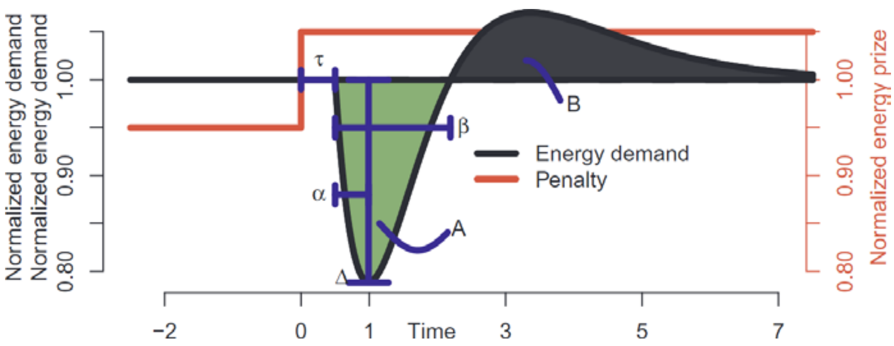

Figure 1. Building response to a penalty signal [15]

terminal system starts to consume energy again when the comfort or temperature values fall outside the accepted range of values. (e.g. when PMV<-0.7 or >0.7, or Top<20 or Top>25).

That way, as seen in **Figure 1**, the area labelled as A is considered as the amount of energy that can be shifted and it can give an indication of the potential of energy flexibility a building design can provide. In the simulations for the energy flexibility characterization, a weather file with constant temperature and no irradiation is used, which eliminates the effect of weather conditions. This allows us to compare different building design variations and to suggest which one has the ability to shift a greater amount of energy. Note that by eliminating the influence of the climate, the building orientation does not play a role in the comparison of different building design variations.

With respect to acknowledging the effect that the weather can have on the ability of a building design to offer energy flexibility, and to inspect the self-consumption of each design, a second set of indicators is used. Note that per building variation another simulation (including a realistic weather file) is necessary to assess these indicators.

Self-Consumption

The On-site Energy Matching (OEM) and On-site Energy Fraction (OEF) can help the user to identify the matching of generation and demand for each design. OEM represents the percentage of the energy generation on-site that is used to cover the demand of the model, while OEF represents the percentage of the energy demand of the building that is covered by its generation [16].

Building design variations

The building variations that are investigated in this project were agreed with BAM engineers in order to ensure that typical Dutch office parameters are included and that expectations are met. Different envelope parameters are studied such as external wall Rc value (e.g. Rc value of 3.5 to 9 m²K/W), room dimensions and orientation. Moreover, the layout type (open plan or cellular) of the office building was investigated along with the thermal capacity (e.g. heavyweight, lightweight), glazing parameters such as U value (e.g. 0.8 to 3 W/m²K), g value, Window to Wall Ratio (e.g. from 0.4 to 1), thermal comfort control strategies (e.g. different setpoints), different heat/cold delivery systems, occupancy scenarios and internal heat gains.

Thermal Comfort Control Strategies

Thermal comfort requirements form one of the main boundary conditions for energy use in buildings. With that they set criteria for the heating and cooling demand. Considering thermal comfort control strategies, the typical strategies that are normally applied in Dutch offices are considered and furthermore, different strategies that were the outcome of field thermal comfort control studies at TU/e through the iCARE project are included [17].

Loomans and Misha suggest that occupants have a connection with the outside temperature for at least 20 min, and a diurnal variation of 3°C is not noticeable in an office environment. Finally, they suggest that a transitional space can have 2°C difference in the setpoint without jeopardizing the comfort of the occupants. All observations of the iCARE research and their combinations are implemented in this project as parameter values in the thermal comfort control strategies. One more extreme value for each strategy proposed by iCARE is also included to explore the effect it could have on the indicators chosen. In total, 27 thermal comfort control strategies are investigated in this project.

More information on the assumptions and design parameters can be found in [14].

Filtering the database – A case study

This section gives an example of a case study building and the possible design variations that can be found using the developed database.

Step 1: Building design exploration

The case study building that is used to showcase the tool is a building in need of renovation. The case study building resembles the BAM building D in Bunnik. Assumptions are made for the fixed parameters and for the parameters which are still open to investigate. The tool-user is assumed to be a designer who is mainly concerned about the operational cost of the office building. **Figure 2** shows the input page of the tool. The parameters that the user can input are depicted. If a parameter is decided, the user can "lock" it; only the results with the locked parameters are presented in the results tab. The unlocked cells, which include a dash instead of a parameter value, represent the undecided parameters; the designer wants to explore various values for these parameters.

In this example, the decided parameters are:

- Heavyweight construction
- 4.5 meters façade
- 6 meters office depth
- WWR 0.7
- Adjacent temperature the same as the offices and corridor
- Air based heating and cooling system

Undecided parameters:

- U-value glazing
- G-value glazing
- Type of offices
- Occupancy scenario
- Thermal comfort control strategies

Presenting the results in a simple list, can obscure valuable information to the designer, while a more complicated approach such as a 3d graph can overwhelm the user and either confuse him or discourage him to use the tool. Interviews and literature review is used to identify the most valuable way to depict the results. In order to provide the most information without confusing the user, a 2d scatter plot is used. In order to decide which indicators will be taken into account in each graph, the conflicting indicators are considered. In every graph, the users can choose one of the design solutions on the graph and get all the information on that solution (building parameters, indicators' results, etc.).

Filtering of the database returns 5800 possible design variations. These design variations and their KPIs are presented in **Figure 3**. The figure shows all 5 800 designs on 2 axes. Normalized Investment Cost is on the x axis and Normalized shiftable energy on the y axis in the left graph, while on the right graph

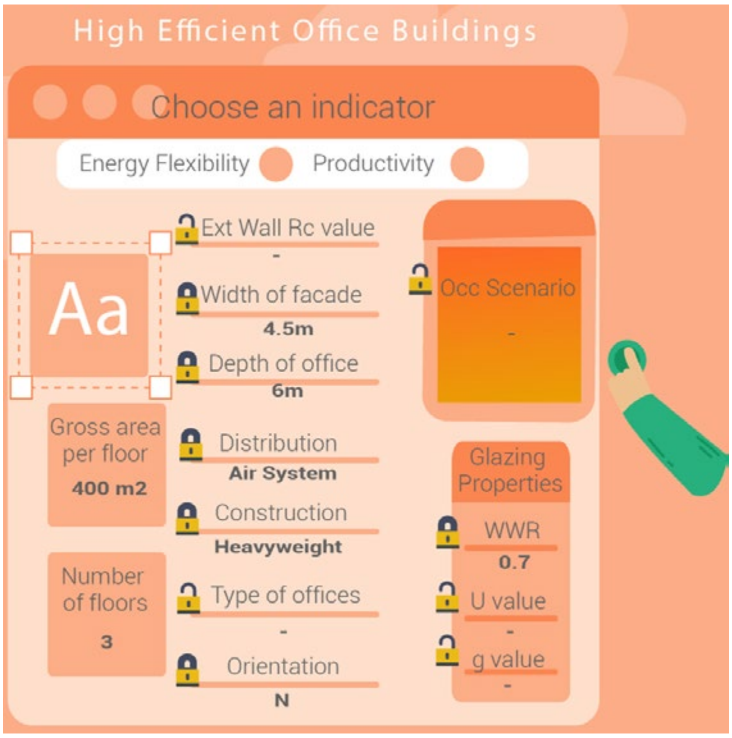

Figure 2. Mock Up of the input page of the product.

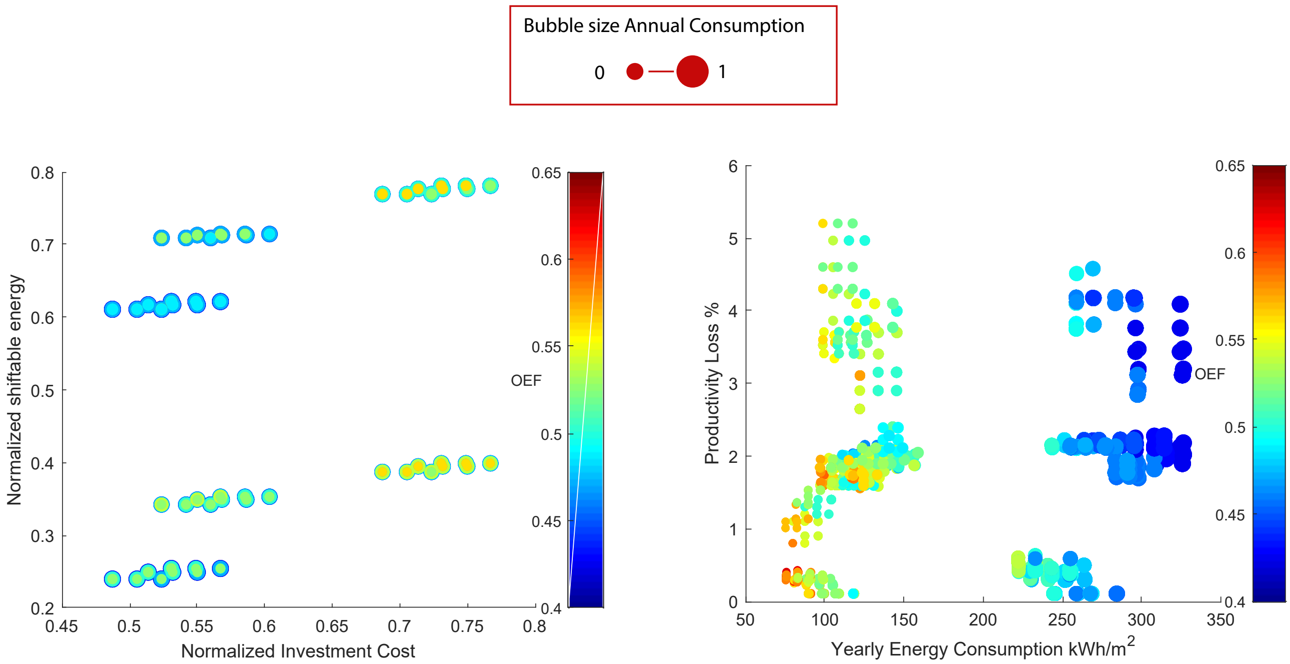

Figure 3. Results from filtering the database based on example 2.3 - All results.

Yearly Energy Consumption and Productivity Loss related to the levels of thermal comfort and indoor climate are included. Each dot/bubble represents one building design solution. There are 5800 dots on each of the graphs. Shiftable energy based on the characterization method does not include the effect of the weather and occupants, which results in a lot of cases performing the same. These dots show overlap in the figure. The size of the bubble though represents the annual consumption and the colour represents OEF, so there are a few dots that score the same on the shiftable energy but have different annual consumption (size) and different OEF (colour).

Depicting all results on a graph might be confusing, so **Figure 4** includes only the Pareto solutions of the filtered results. That way, the designer can choose from the best ranking solutions. Again, the size of the bubble represents annual consumption, while the colour represents self-consumption (OEF).

Pareto efficiency is a state of allocation of resources from which it is impossible to reallocate so as to make any one individual or preference criterion better off without making at least one individual or preference criterion worse off. The tool-user can stop at this stage, choose the solution he finds more satisfactory and do not spend more time on the tool. However, if needed, the user can dive deeper in the results and get even more information.

Step 2: Detailed information per building design

As a second step, the option is given to choose a specific design parameter in order for the user to receive more information about how different design parameters affect the performance. The user will still see the same Pareto solutions, however the parameter values of the selected design parameters are presented through the colours of the bubbles.

For example **Figure 5 and Figure 6** still show the same performance indicators as in the previous figures, but the colours of the bubbles represent the Rc-values of the exterior wall and U-value of the glazing.

By examining **Figure 5**, the designer can extract information on how Rc-values and U-values affect productivity loss and potential shiftable energy. These figures show that the external wall Rc-value is not that dominant as all three investigated Rc-values are present on the Pareto front, while also low Rc-value cases offer high potential shiftable energy. On the other hand, even though all three investigated U-values are also part of the Pareto front solutions, it is clear that lower U-values offer higher shiftable energy potential.

Regarding the productivity loss in **Figure 6**, it shows again that the Rc-value does have an important effect, while the U-value seems to be more important. The cases that are included in the Pareto front for productivity loss and yearly energy consumption only include the lowest U-value investigated.

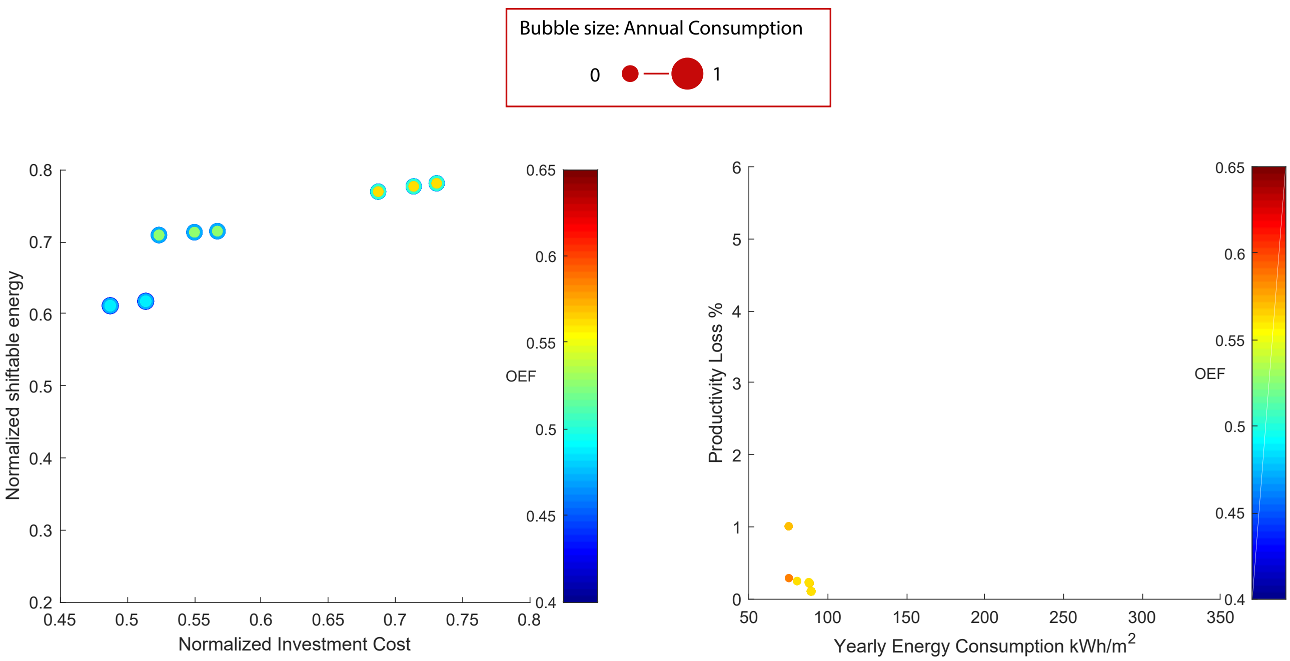

Figure 4. Results from filtering the database based on example – Pareto solutions.

Each building design variation can be studied thoroughly through all their parameters and results. For this case study building, operational cost is assumed to be the most important performance indicator. If the user selects the solution depicted on the productivity loss graph with the lowest operational cost, he/she can see all the building parameter values of that solution. The productivity loss, even though it is higher than of the other solutions, is still a percentage of 1%. Each bubble represents a building design variations and by clicking on it, the user can see its specific parameter combination and its result on different Performance Indicators as seen in **Figure 6**. By examining all the results of this building variation, it can be seen that the shiftable energy that a building envelope like this can offer is not in the range of the Pareto front solutions but it is also not in the lower part of the spectrum. So this solution is believed to be one of the fitter ones for this renovation case.

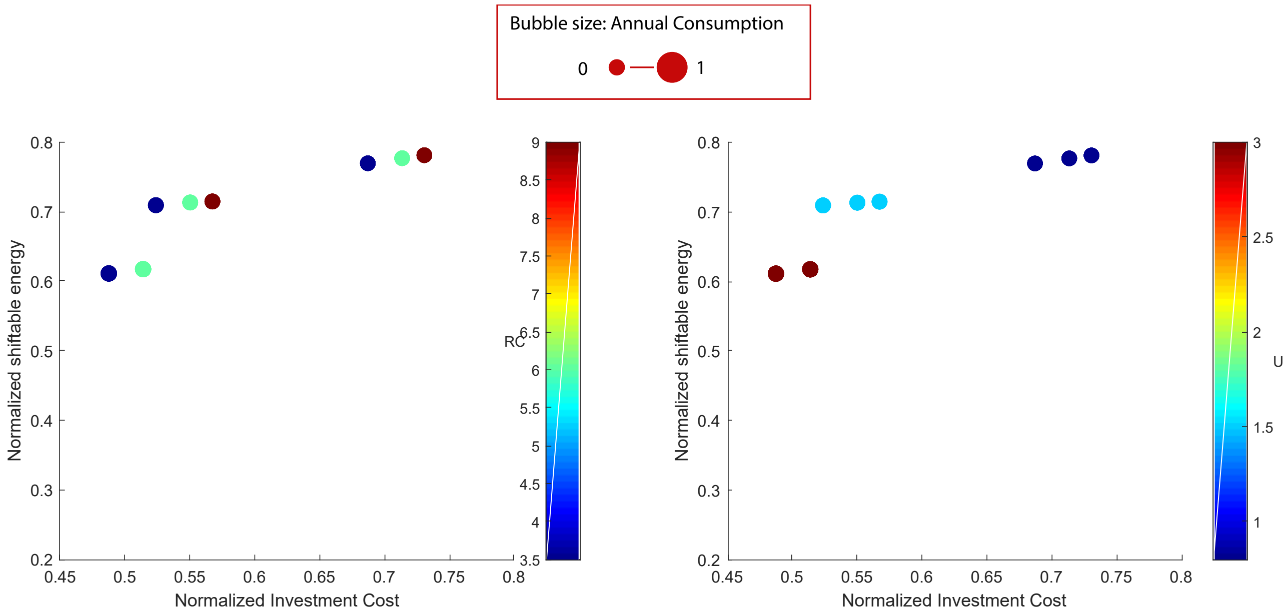

Figure 5. Results from filtering the database based on example - Pareto solutions -Energy Flexibility -Design Parameters.

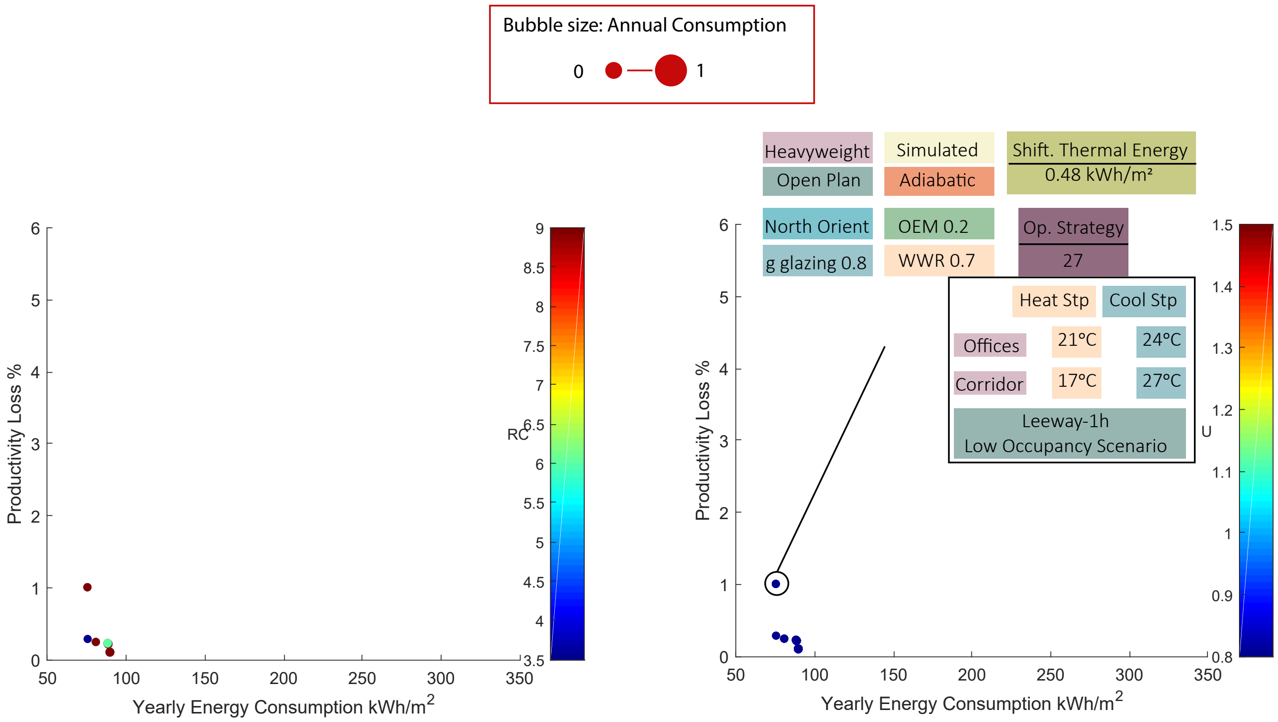

Figure 6. Results from filtering the database based on example- Pareto Front Results - Productivity Loss - Design Parameters.

Step 3: Sensitivity analysis

As a third step the user can get more detailed information about a specific design solution. When the user chooses a specific solution, along with the specifics of the parameter combination, box plots appear. The box plots show how one design parameter affects the performance indicators (**Figure 7, Figure 8**). To showcase an example: if the user chooses one of the design solutions from the decision space in **Figure 3, Figure 4, Figure 5** or **Figure 6,** the box plots show how this specific building solution reacts to changing one parameter at a time. **Figure** 7 and **Figure 8** depict the case study showcased in **Figure 6** and how the building reacts to keeping all the other parameters constant and changing the exterior wall Rc-values etc. in regards to the annual energy consumption and the flexibility potential from the characterization assessment.

There are cases where the different variations investigated in this database do not return different results. E.g. for the specific case we chose, the annual energy consump-

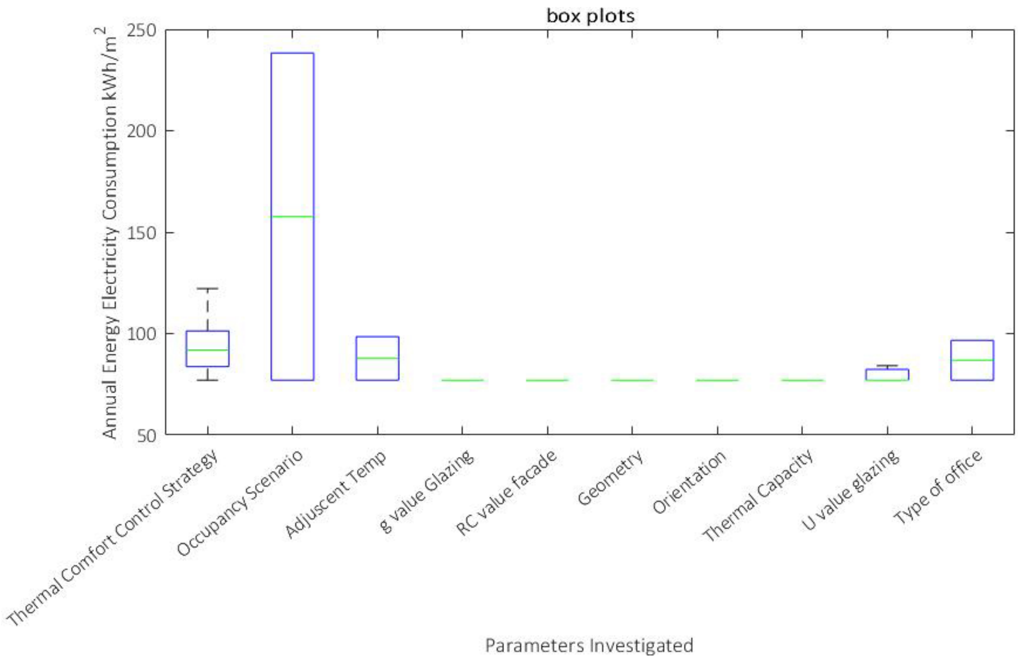

Figure 7. Box plots for each building variation investigated; each box shows the performance variation that is expected when changing the corresponding building parameter within defined ranges - Annual Energy Electricity Consumption.

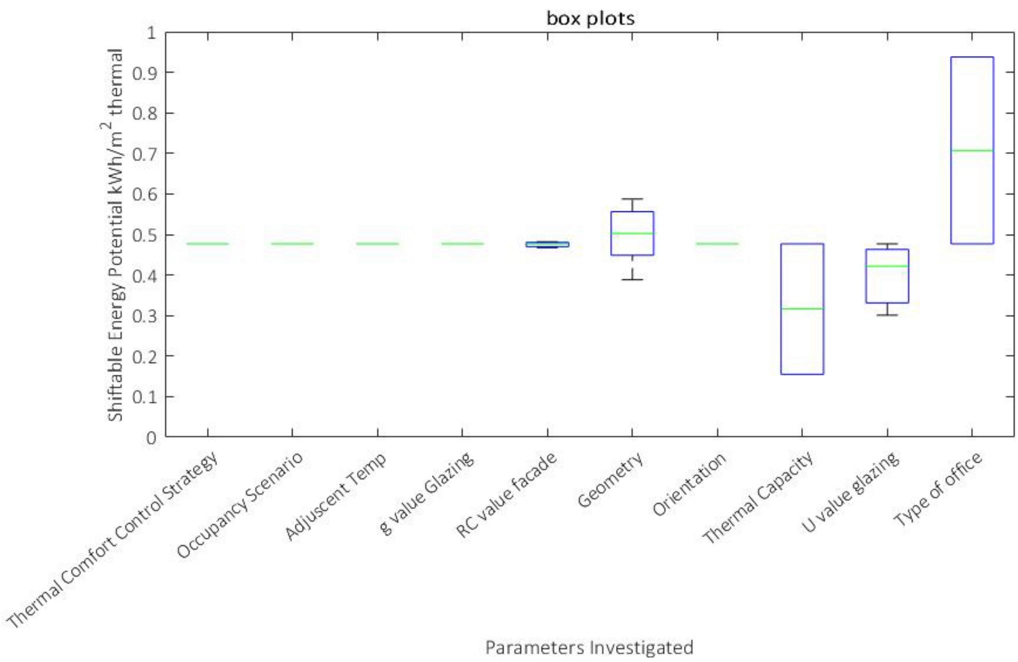

Figure 8. Box plots for each building variation investigated; each box shows the performance variation that is expected when changing the corresponding building parameter within defined ranges – Shiftable Energy Potential.

tion is the same no matter which Rc-value of the façade, the g value of the glazing or the geometry. Moreover, as the shiftable energy (flexibility potential) is based on the characterization assessment that exclude weather and occupant effects, the different control scenario, occupancy scenarios or orientation make no difference in the results.

More box plots based on other KPI's can also be presented. That way, the user can get a more complete overview of the way each parameter affects each KPI and they can make more informed decisions on their final design.

By using one or all three steps of the visualization process depending on the time and effort the designer wants to invest, they can receive valuable information about the building, make informative decisions and decide to use the best parameters based on the important indicators at the time.

Wrap Up

Thermal mass can be potentially important for energy shifting and it should be taken into account when investigating the shifting potential of a building, note that utilizing the thermal mass of a building does not include extra costs.

Using the tool takes no more than a few minutes, does not require special training or knowledge and returns valuable information and suggestions on how to get the most out of the building's abilities. The tool can also be used to investigate the flexibility that an already existing building can offer. It can also be used to assess the energy flexibility that a portfolio of buildings can offer, or a tool to investigate the influence of various thermal comfort control strategies on the Performance Indicators. The tool aims to contribute to the design of more flexible office buildings and help to assess the potential value of offices as active members of the energy infrastructure. ■

Acknowledgement

C. Papachristou is (50%) supported by the Dutch Technology Foundation STW (under project nr. 11854; i-Care), which is part of the Netherlands Organization for Scientific Research (NWO), and which is partly funded by the Ministry of Economic Affairs. Further financial support (50%) is provided through the Eindhoven University of Technology. The in-kind support from employees at BAM to support the design process of the tool is much appreciated.

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Characteristics of a newly built general hospital in Romania

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It is well known that the design and execution quality of a construction may dramatically influence the real behavior and performance of a building. This point is even more important for healthcare buildings as they have unique and rigorous criteria from multiple perspectives such as structural, architectural, HVAC and indoor environment quality. This paper presents the case study of Mioveni Hospital building, recently built in southern Romania, and is focused on emphasizing the specific architectural and building installations characteristics and design conditions of such type of building. The case study building has in total eight floors and a built area of approximately 17 448.54 m². The whole process of accomplishing all that means the Mioveni City Hospital, embodied a sustained effort from the design phase to the commissioning phase. From a professional point of view, it was a complete and challenging experience and the final outcome merits all the efforts made in this venture.

General description

Constructing a hospital of the dimensions and importance of the Mioveni City hospital is by far one of the largest current achievements in the Romanian medical and social environment of the past years. This investment was a challenge for both the recipient and the design teams as well as for construction companies involved in the project. The new hospital building is located at the address of the existing Municipal Hospital "Sfântul Spiridon" in Mioveni. The city hospital is designed to have a continuous hospitalization capacity of 250 beds. The new hospital also included setting up entirely new medical specialties, such as the one for interventional cardiology fitted with an angiograph. The beneficiary wanted to create a new hospital to accommodate the sections of the old hospital as well as new parts to accommodate diverse and complex medical services for the benefit of the population of Mioveni City.

The design of the hospital was performed following a series of normative acts specific to the hospital construction, as follows:

- NP 015 - 1997 - Design and verification of the hospital construction and of the installations necessary for their application [1];
- ORDER no. 914 of July 26, 2006 - for the approval of the norms regarding the conditions that a hospital must respect in order to obtain authorized sanitary permits for operation [2];

ORDER No. 1096/2016 - regarding the modification and completion of the Order of the Minister of Health no. 914/2006 for the approval of the norms regarding the conditions that a hospital must comply in order to obtain the sanitary authorization of functioning [3].

Considering the limitations imposed by the land, the building was developed vertically with a height regime consisting of basement, ground floor and 6 levels. The plan form of the basement and the ground floor is rectangular and the floors from 1 to 6 have the form of the letter 'H', as it can be seen in **Figure 1** and **Figure 2**. **Table 1** describes the functionality of each floor of the hospital.

Table 1. *Functional layout of the hospital building.*

Floor	Functionality	Useful floor area [m²]
Basement	Morgue, Kitchen, Laboratory, Laundry Room	2 448.63
Ground floor	Emergency Unit, Investigations, Ambulatory	2 020.44
1st Floor	Operating Block, Sterilization, Cardiology, Intensive Care	1 936.50
2nd Floor	Maternity, Operating Block and Neonatology	1 721.87
3rd Floor	Gynecology, Pediatrics	1 721.91
4th Floor	Internal medicine	1 719.75
5th Floor	Cardiology, Surgery and Neurology	1 715.93
6th Floor	Pharmacy, Administrative spaces	1 788.46

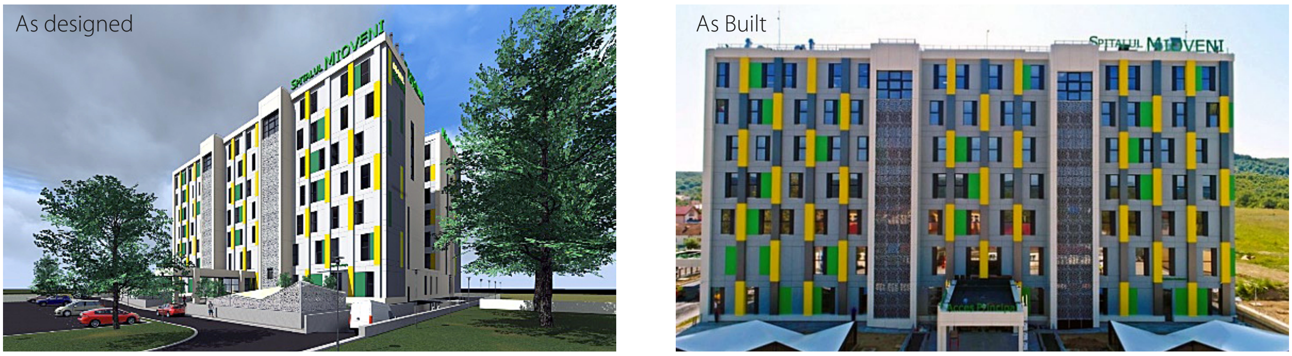
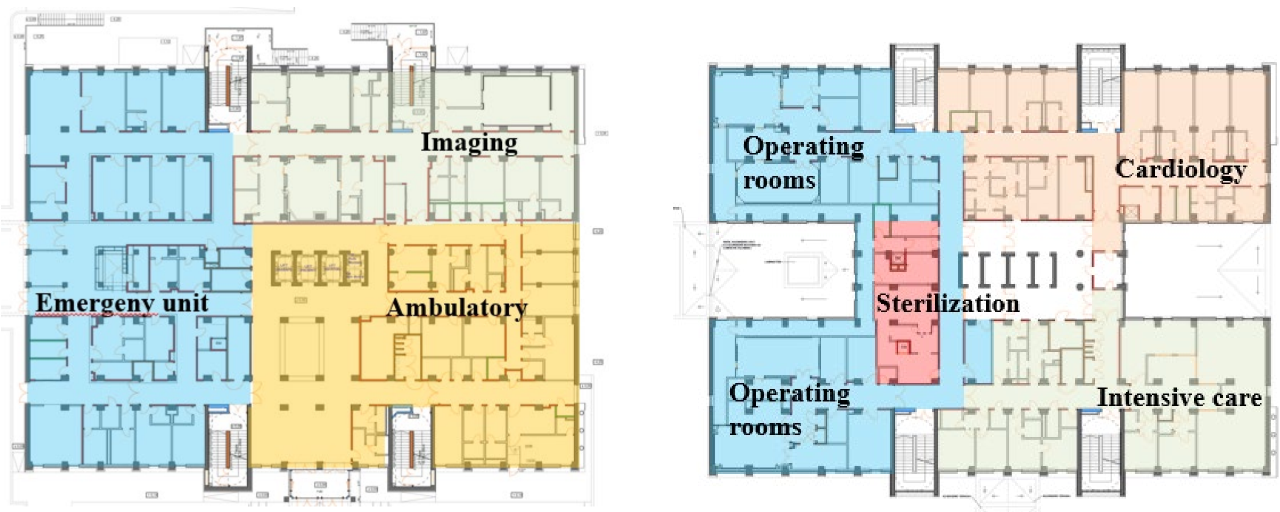


Figure 1. Hospital view.



a) Ground floor

b) First floor

Figure 2. Ground floor and first floor plans of the hospital.

The structural system of the building consists of reinforced concrete frames and diaphragms. The floors are made of reinforced concrete and the roof is terrace type. The exterior walls are made of reinforced concrete and masonry, provided with ventilated facade system and 10 cm thick insulation made of basaltic mineral wool. The ground slab was insulated with 10 cm of extruded polystyrene and the roof was isolated with 20 cm of extruded polystyrene. Energy efficient windows have been fitted with aluminium joinery provided with sealing gaskets and triple-glazed windows.

Building Installations system

Ventilation and air conditioning

The ventilation and air conditioning of the entire hospital is carried out with the help of 18 air handling units (AHU). The sizing and choice of the air handling units was made according to the served spaces and the number of air changes required for each space (according to NP 015 - 1997 and I5 - 2010). The air purity conditions in the rooms of the hospital units imply an adequate level of filtration, which determines the number of filtration stages. All ventilation systems are connected to an energy management and monitoring system - Building Management System. The sizing of the AHUs has been designed to ensure the number of air changes required in the rooms to which each AHU is connected, according to the normative NP 015 [1]. The hospital rooms are classified in 4 classes, which have as main criterion the air purity expressed by the essential requirement in the field that is, lack of germs (asepsis). Air exchanges range from 2 air exchanges per hour for offices, corridors and cabinets, up to 20 air changes per hour for operating rooms. Each of the 5 operating rooms is equipped with an AHU that works without air recirculation, the air introduced will be 100% fresh air. The AHUs in the operating rooms are equipped with intermediate fluid heat recovery, steam humidification, heating and preheating battery, cooling battery, inlet and outlet fans, and will have 2 stages of input filtering. The air supply for the operating rooms is realized through stainless steel filter ceilings with vertical laminar flow, equipped with HEPA 14 Filters. **Figure 3** captures the isometric view of the ventilation system that serves the operating rooms and intensive care area.

The ventilation and air treatment for the areas allocated to the intensive care unit and the operating unit will be carried out with the help of 2 AHUs. The introduction of the air for the intensive care rooms, post / preoperative spaces, the medical washes and the instrument washes are performed by swirl / anemostats, and induction units located in the false ceiling, equipped with HEPA filters 13. The air evacuation is done by swirl anemostats. with 4 directions located in the false ceiling. During periods without activity the fresh air flow in the intensive care rooms will be maintained at 50% of the nominal flow. The design of the ventilation and air conditioning installation of the laboratory area was done according to the National Biosafety Guide for medical laboratories. Each laboratory is equipped with a differential pressure control system with which the depression against the adjacent corridor will be maintained, min 10 Pa. For the evacuation of the vitiated air from the 8 laboratories, there were

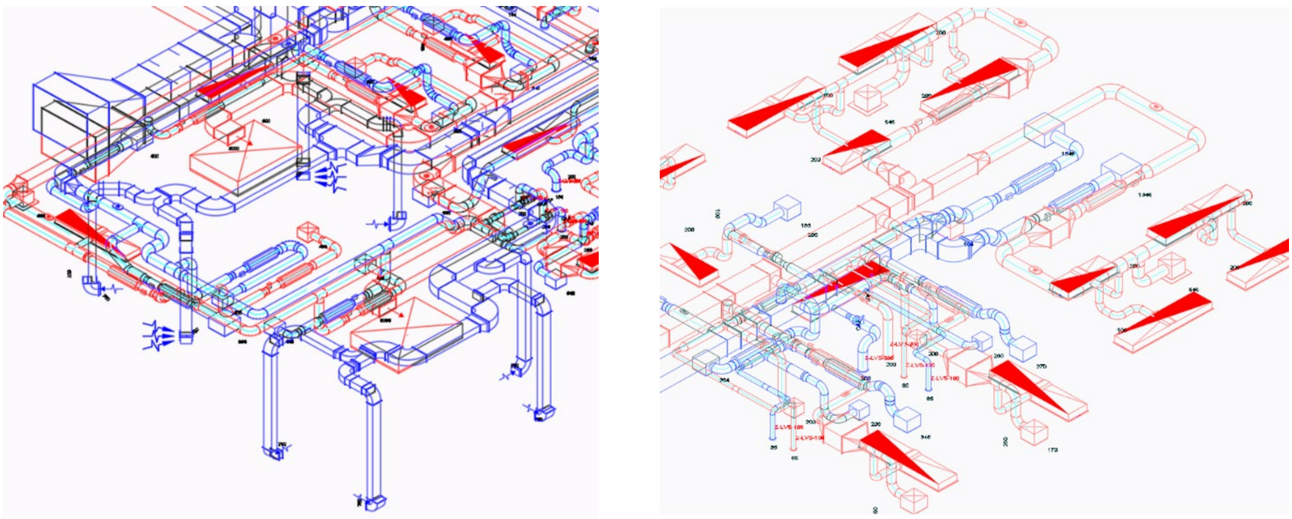


Figure 3. Isometric view of ventilation system operating rooms and intensive care rooms.

provided swirl grids equipped with HEPA 13 filters, connected to an exhaust fan with the flow rate of 2 740 m³/h.

Heating and cooling systems

The boiler is composed of 3 steel boilers (3 x 900 = 2 700 kW) equipped with dual burners with gas (modulating) and diesel fuel (in two stages). The basic fuel is methane gas, diesel being used as an alternative in case of problems in methane gas supply. The boilers operate in cascade and are controlled by BMS to maintain a constant flow temperature of 70°C ± 1°C. BMS also rotates the basic boiler at a number of operating hours for uniform wear of the equipment. To supply the vital consumers, it is necessary to operate two boilers out of three, one being a reserve. Cooling is provided by 3 chillers (3 x 800 kW = 2 400 kW) mounted on the outside of the building. The chiller compressors are screw type, and their cascade is done through BMS to maintain the primary flow temperature to the value set at 5°C. In order to supply consumers in the situation of extreme summer climatic conditions, it is necessary to operate two chillers out of three, one being a reserve. The chillers also work during the winter period in free-cooling-free cooling mode.

Domestic hot water

Domestic hot water preparation (DHW) is done in semi-instantaneous mode with 2 heat exchangers (2 x 300 kW) and 5 storage vessels, boilers 5 x 1 000 l (**Figure 4**). The main source of thermal energy is a circuit from the boiler - 600 kW - hot water 70/50°C. The secondary source for DHW preparation is solar energy - four fields of 20 flat solar panels each with a surface area of about 2.3 square meters (**Figure 5**).

Figure 4. Solar panels installed on the roof.

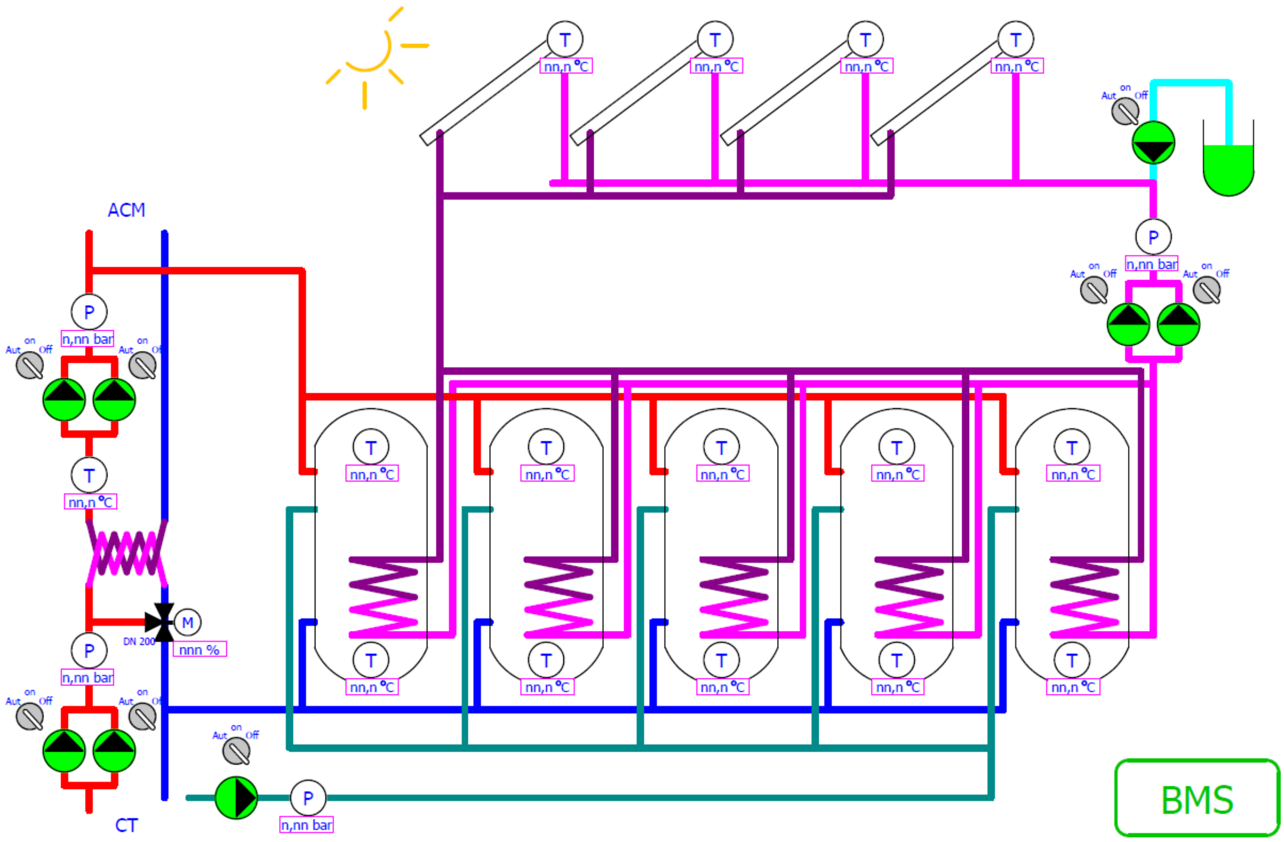


Figure 5. DHW control scheme

They are mounted on the cover of the main building (over the 6th floor) with the orientation of SV and inclination of 45°. The captured thermal energy is transported in the coils of the 2 boilers. The thermal power of the solar system in peak mode is about 150 kW (maximum temperature 130°C).

Electrical engineering

The main source of electricity is the National Energy Network. The supply is made through a medium voltage connection point, powered by two lines from National Energy Network and a transformer station with two units of 2 000 kVA, 20 / 0.4 kV, which are 100% mutually reserved. The transformers are located in the basement of the main building. The backup source consists of two 1 250 kVA generator sets, which automatically start after a maximum of 15 seconds and run in parallel. The generators are equipped with a synchronization panel that will allow them to operate in parallel. The generator sets are located in the basement of the main building. The backup source with an interruption time of maximum 0.5 seconds will consist of two uninterruptible power supplies of 250 kVA each, connected to an external bypass. Energy-efficient LED-type luminaires were used for lighting.

Building Management System (BMS)

The hospital is equipped with a building management system (BMS) to ensure the automatic operation, control and supervision of heating, ventilation, air conditioning and lighting systems. The BMS maintains the pressure difference between the clean or polluting rooms and the adjacent ones, the control of the lighting system and the electrical distribution boards. The design of the BMS was made on the basis of data on heating, ventilation and air conditioning, lighting installations and architecture of the building. BMS is an efficient tool in optimizing energy consumption. Its parameters must be set in such a way as to ensure the designed operating parameters (temperatures, lighting level, pressures, etc.), with a minimum energy consumption of the installations. To illustrate the interface of the BMS system, print screen images are presented in **Figures 6 and 7**.

Energy certification of the hospital

The energy certificate was prepared according to the Methodology of Calculating the Energy Performance of Buildings MC001-2006 [4]. The analysis of the energy certificate shows the classification of the building in class A of energy performance. **Figure 8** shows an extract from the Certificate of Energy Performance of the hospital from which the early mentioned classification results. The fact that this hospital was classified in the energy performance class A, shows that in addition to the functional, architectural, structural design and hospital design concerns of the hospital, the designers have given importance and energy efficiency of the hospital so that the operating costs of the building related to energy consumption should be as small as possible.

Discussion

The whole process of accomplishing everything that means the Mioveni City Hospital represented a sustained effort of all those involved from the design phase to the commissioning phase. It was a complete and challenging experience from a professional point of view, but the satisfaction of the final result deserves

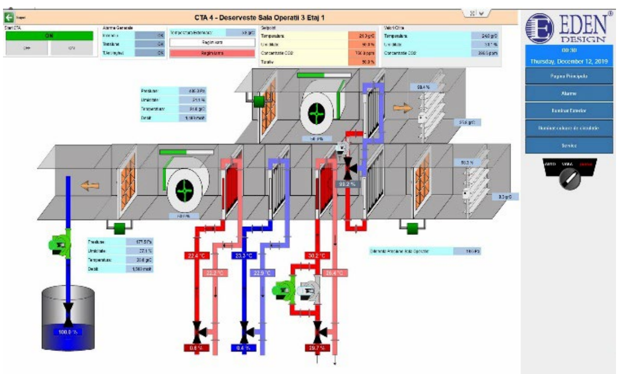


Figure 6. BMS – CTA 4 control panel.

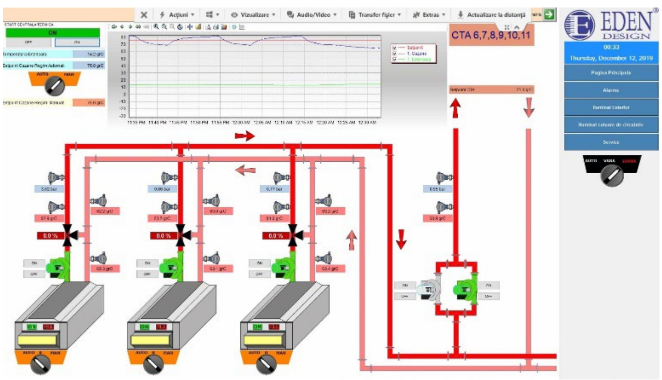


Figure 7. BMS – control panel of heating plant.

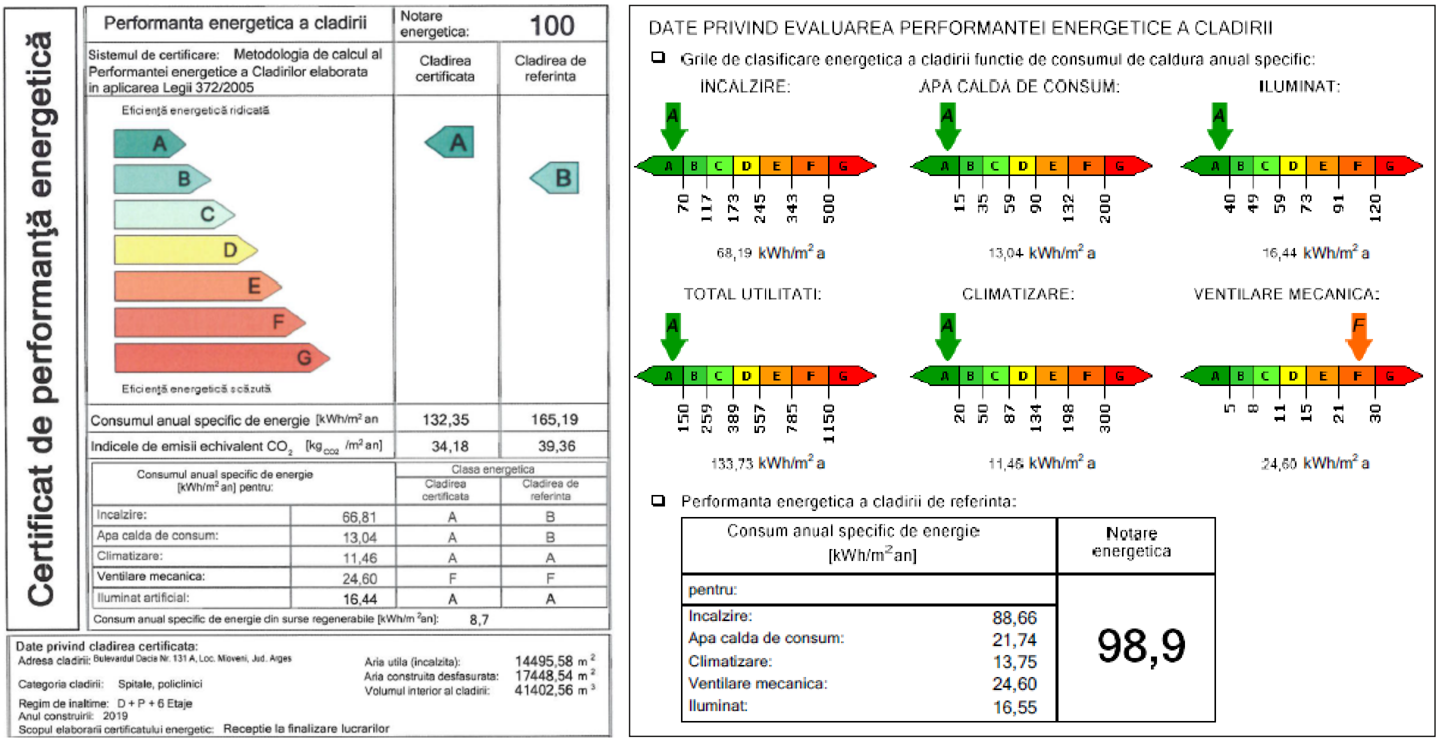


Figure 8. Energy performance certificate of the building.

all the efforts made in this project. Within the project of Mioveni Hospital new concepts were and are promoted: digitalization and medical computerization with the possibility of remote monitoring of patients; BIM - Building Information Modeling - modeling the building from the design phase to the operation and maintenance phase. Mioveni City Hospital is one of the few new hospitals built in Romania in the last 30 years. In other words, the design and construction of new hospitals in the Romanian public sector currently very rare activities. And from this perspective, Mioveni Hospital is a unique building project at the moment and can be regarded as a reference building for the further development of the built environment in the Romanian health sector. ■

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[3] Order no. 1096/2016 regarding the modification and completion of the Order of the Minister of Health no. 914/2006 for approving the norms regarding the conditions that a hospital must fulfil in order to obtain the sanitary authorization to operate.

[4] Mc 001/2006 - Methodology for calculating the energy performance of buildings.

An interview with

Prof. Francesca Romana D'Ambrosio

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Q.1) It is well known that worldwide there is an increasing need for an energy transition. Let us focus on HVAC and building sector. Since nowadays it consumes more than 40% of final energy consumption and causes 36% of the total energy-related CO_2 emissions, it will play a crucial role in the realization of such transition. In your opinion, which could be the solutions or actions that could help the achievement of a low-carbon built environment?

Prof. Francesca Romana D'Ambrosio: Today, also the building sector should be the driver for spreading technological innovation. In this direction, the most recent European Directive on buildings' energy performances (EPBD) combines the aspects related to the building and HVAC technologies with the world of digitalization. In fact, it translates the current necessities of reducing the energy demand from the building sector on the maximization of the HVAC systems' efficiency, also through the integration of Renewable Energy Sources (RES) on the building-plant system. Coupling these aspects with the emerging digital instruments,

which allows the monitoring and interpretation of the building energy behaviour, the most suitable actions to guide the building sector towards the energy transition can be identified, integrating a network of energy suppliers and energy consumers where the buildings can play a crucial role.

Q.2) The European building stock is characterized by high percentages of buildings built before 1980, when energy efficiency requirements were not in place. In your opinion, which could be the opportunities for improving the energy behaviour of these buildings? Which will be their role in the transition of the building sector?

Prof. Francesca Romana D'Ambrosio: The European building sector's energy transition inevitably relies on the implementation of efficient policies regarding the existing building stock. The building boom of the second half of 20th century took place when the attention to energy efficiency was very limited. It is evident for everyone that acting on the existing building stock requires more difficult political and technical paths compared to the ones that would be necessary to build new, since the implementation of new technologies has to face several boundary constraints. At the same time, the low energy performances of our existing building stock represent a huge opportunity of enhancement. In these terms, there are two possible paths. On one side, there is the possibility of focusing the policies on the achievement of relatively small improvements on large building stock categories. On the other one, policies could pursue major energy savings on a limited quantity of buildings or building categories. Another aspect to take into account is the necessity of clearly characterize which is the relation between the energy intervention solutions and their economic and financial implications, both in terms of initial investment and global cost. In fact, in the current market, the technological penetration cannot take place if not guided by economic and financial analyses, that should be exploited both at a National and European level.

Q.3) Several forecasting scenarios look at electrification as a possible pathway for realizing the transition of the HVAC technologies and the building sector. Do you agree with this consideration? If yes, which technologies would enhance the electrification of buildings final uses (e.g. RES integration)? Conversely, if not, which will be the technologies that will drive the transition (e.g. district heating)?

Prof. Francesca Romana D'Ambrosio: I will answer to the second question first. District heating relies on a territorial policy. The implementation of policies allowing the electric energy penetration in the building sector relies on individuals' choices. These are two different possible paths. The first requires that the territorial planner introduce district heating as a development action in an urban settlement. This is a meritorious action but requires a long implementation time and a political endorsement. The other requires, from a policy maker side, the introduction of guiding or facilitating instruments for the implementation of electric technologies to substitute the non-electric systems, such as boilers. However, focusing for example in the transition from gas boilers to electric heat pumps, this introduces also infrastructural problems. In fact, a large diffusion of electric heat pumps would require an electric infrastructure capable of supporting the required energy loads and power. At the same time, referring again to this type of choice (the introduction of an electric generator such as a heat pump), this would require also the integration of low-temperature terminals in order to maximize the energy efficiency of the whole building-plant system. Looking at this perspective, the theme of economic and financial analyses represents, again, a fundamental aspect to evaluate the viability of these solutions.

Q.4) Nowadays, digitalization is spreading, and this is already affecting the building sector. In particular, buildings are moving from highly consuming units to energy producing ones, shifting the role of occupants from pure consumers to prosumers. In your opinion, which will be the positive and/or negative effects that this phenomenon will have on society? Which are the opportunities for future development of flexible and digital devices in buildings?

Prof. Francesca Romana D'Ambrosio: An objective analysis of the current society brings to the evidence of an evolution towards a system in which data are fundamental to convey all individuals' actions to the policy makers. At the same time, the evidence that a digitalization process could interpret the building and its dynamic behaviour requires it to participate to the evolutionary transition of the society. As for the mobility sector, the buildings' one is moving along its digitalization path. However, this is a fundamental process to cover through digitalization all the other aspects of human life. Moreover, we cannot think to an evolution of the energy market in terms of use and production of different entities and subjects (like in the case of prosumers) without a building connected to the network and exchanging data with the surrounding. In these terms, the development of a society in which the building becomes part of a connected network is fundamental for a transition towards a system in which the energy market becomes, really, a free one. ■

An interview with
Prof. Livio Mazzarella

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Q.1) It is well known that worldwide there is an increasing need for an energy transition. Let us focus on the HVAC and building sector. Since nowadays it consumes more than 40% of final energy consumption and causes 36% of the total energy-related CO_2 emissions, it will play a crucial role in the realization of such transition. In your opinion, which could be the solutions or actions that could help the achievement of a low-carbon built environment?

Prof. Livio Mazzarella: There are several actions that can be pursued to achieve a low carbon built environment. Before to focus on HVAC systems, the first step is to reduce as much as possible the buildings energy requirements lowering the loads and growing up the users' consciousness on the environmental impact of their actions. Nowadays, for instance, the plug-load energy use is often greater than the energy needs for heating and cooling. A second step is continuing improving the building envelope performance, but, personally, I believe that in new buildings, they are already close to cost effective solutions and further improvements would have very high marginal costs. Thus, coming to the HVAC, the main point is how to foster renewable energy source exploitation while increasing the overall system efficiency. The use of RES alone is not a solution, because we do not have to confuse energy availability with its potential: the second for RES is finite and then using RES with low efficiency systems is a wrong solution. Thus, the first action is to push for high efficiency emission, distribution and air treatment systems (for instance, low and very low temperature systems, possible only if coupled with high performance envelope). This can be achieved through setting up legal requirements on both components and system efficiencies. A second action is to facilitate a transition to RES exploitation without imposing too ambitious levels of coverage: a not economic or technical feasible requirement (i.e. RES share) could result in a very low real exploitation. There are two levels of intervention: on-site use of RES and a full electric scenario where RES are used to feed the grid. At the first level, the building heat and cold generators technology is involved plus on-site PV systems, while at the second level the use of power station feed with RES or anyhow no carbon combustion based. These two actions have very different time scale and thus have to be pursued in parallel.

Q.2) The European building stock is characterized by high percentages of buildings built before 1980, when energy efficiency requirements were not in place. In your opinion, which could be the opportunities for improving the energy behaviour of these buildings? Which will be their role in the transition of the building sector and more specifically of HVAC technologies?

Prof. Livio Mazzarella: This is the main problem. The yearly renewal ratio of the existing building stock is very low (few percent); thus, any action on that is not giving any important result in the short time. For instance, the Italian plan to NZEB transition in ten years of existing building estimates a fuel saving (natural gas) that corresponds to switching off for two days a gas power station of 1 TW. Then, in Italy, we have another problem: the culture of conservation. We are used to rehabilitate building more than rebuilt them from the scratch. That means that the economically achievable energy saving, and the CO_2 saving, is lower, and some time, much lower, than what is possible with a complete replacement, and it is very difficult to push for complete replacement. When an important envelope rehabilitation in not possible or feasible (historic buildings or just landscape fashion conservation), the only way is again to improve as much as possible systems efficiencies and to use RES. The problem is that in such cases low temperature emission systems are probably not able to guaranty the required comfort temperatures and landscape reasons may limit the installation of PV system on the buildings themselves. Thus, the most feasible way, which can be applied on large scale, is a transition to a full electricity scenario or RES driven scenario, where several not mutually exclusive options are possible: direct electric heating or electric heat pump heating and cooling with RES produced electricity, low district heating and cooling system feed by RES driven generators (solar, biomass, etc.) with water-to-water heat pumps to rise up the temperature level when needed. The first step in such direction is very easy to be implemented in Mediterranean countries, where the need of cooling is fast growing. It would be enough to oblige to install reversible heat pump systems, when a cooling system is going to be installed, replacing in such way also the convention gas boiler for heating, if any exists.

Q.3) To meet the climate change ambitions, there is the need for a stronger effort from policy makers and stakeholders. In your opinion, which are the barriers, economic and social, that they should overcome in order to accelerate a transition toward "high energy performing and environmental friendly" buildings? And, thus, which are the investment needs, strategies and policies that could stimulate a cost-effective renovation of buildings towards decarbonization?

Prof. Livio Mazzarella: The main barrier toward high energy perform buildings is the actual structure of the buildings market, at least in Italy. Only few buildings are designed, built, owned and used by the same subject: usually companies are designing, building and then selling out buildings, apartments or houses to future owners, who have not been involved in the previous building life cycle stages. These owners are just operating the building as it is. The company convenience is just to maximise their income lowering the production costs as much as possible until this does not affect the customers' perceived quality of the building. Thus, for new constructions, or the final owner is always involved in all stages (I do not see the way), or a more stringent quality check has to be introduced by law as commissioning to assure high quality performing buildings in practice. For the existing buildings stock, if we like to maintain how landscape and cultural heritage (not demolition and reconstruction), the only way is to force for centralised heating and cooling systems (district heating and cooling systems), combined or not combined with water-to-water heat pump systems at the single building level, together with electric power generation via RES. The centralised H&C systems can be realised in modular way (i.e. step by step) and at the beginning may use high efficiency conventional generators with a limited fraction covered by RES generators to move later to full RES use. In this way, the investment cost may be more affordable for the communities.

Q.4) Smart buildings and city are recognized concept, but still few examples of smart buildings/cities are available worldwide. Which will be the role of HVAC sector in the realization of a smart building and city? Considering the current situation of Italian cities, which could be the barriers for the implementation of a smart energy city and the benefits that this could create for the society?

Prof. Livio Mazzarella: As said before, our culture of conservation is somehow a barrier to "smart" buildings and cities as they are usually thought today: new building, new futuristic landscape, etc. Land availability is also a barrier for new constructions. We have to reuse all in a "smart way", this our challenge for Italian smart buildings and cities. That means that, if we cannot lower to much the energy needs (because interventions on the envelope are limited), the provided energy carriers have to be as much possible CO_2 free and all CO_2 non-free generators have to be moved outside of the towns, in centralised systems where CO_2 emissions can be better managed, dispersed or reduced via sequestration, and so on. The role of HVAC systems in this scenario is then to be very high efficient and to be able to work effectively with low temperature for heating and high temperature for cooling while assuring the required IEQ (indoor environmental quality). In this way, less power and energy has to be provided at "lower quality" lowering the installation and running cost of the district heating and cooling systems. ■

Why your next heating system will be a heat pump

Heat pumps are not a technology of the future. In new construction, they are already the standard in many European countries. The replacement market is not far behind. As Europe moves to decarbonize homes, heat pumps are our best bet, says Patrick Crombez of Daikin Europe.

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The EU pledges to "play a central role" in achieving net-zero greenhouse gas emissions by 2050. This was recently confirmed in Brussels [1], after wrapping up the COP25 talks in Madrid. The automotive industry, agriculture and travel industry have already made efforts to reduce or eliminate carbon emissions from energy sources. Next on the list of policy makers and regulators is housing.

Decarbonization of the home is next in the shift towards a sustainable economy.

On a national level, the Netherlands will kiss gas goodbye soon [2], the French government is stimulating [3] oil boiler replacements and Finland is aiming [4] to be carbon neutral by 2035. Lower Austria has outright prohibited [5] oil heating in new buildings.

The one thing they have in common is that they are all betting on heat pumps to replace fossil fuel heating systems. And they're right. Heat pumps are more than ready to take on the challenge of home decarbonization. They are not a technology of the future, but an established solution, ready to go mainstream.

Psychological challenges

In Sweden, heat pumps are the default heating system today. In new buildings in some other European countries, heat pumps are steadily reaching 50 percent market share.

In the replacement market, however, it seems that homeowners haven't quite caught on yet. And the main challenges for mainstream heat pump adoption in this market, seem psychological rather than technological.

Many people simply don't understand how a heat pump works.

Others are of the opinion that heat pumps are noisy, can't look nice or simply aren't there yet in terms of reliability. You can't entirely blame homeowners for entertaining assumptions about heat pumps that are no longer valid today, because the pace of innovation in heat pumps is indeed brisk.

For instance, heat pumps made huge strides in efficiency in the last decade. Air-to-water heat pumps in general tend to show a drop in efficiency when outdoor temperatures go down. At sub-zero temperatures, heat pumps traditionally needed a little help from the electricity grid to offer the required comfort. Of course, this threatens the cost-savings and reduction of emissions that heat pumps offer.

Newer generations of heat pumps are increasingly capable of high efficiencies, even at lower outdoor temperatures.

Beyond the choir

Another psychological barrier is the lack of knowledge among installers and architects. This will be a key challenge for the heat pump industry. We should go beyond preaching to the choir of installers and professionals who are already familiar with heat pumps. We should open conversations with installers who have mostly worked with fossil fuel boilers. They should feel comfortable recommending heat pumps in the replacement market. It helps, of course, that heat pumps have become easy to install, easy to use and that they look good too – consumers today expect great design.

The burden of starting that conversation is on the industry. If we succeed, it will greatly accelerate the adoption of heat pumps.

Of course, regulation can offer a nudge in the right direction here. The Netherlands is a prime example: it is already offering training on renewables for installers. This supports the shift towards renewable heating solutions.

In other markets, it's more a matter of removing incentives for fossil fuel that create a barrier for more sustainable alternatives to enter the market. In Belgium, for instance, the price of gas is low compared to the price of electricity.

The shift to heat pumps requires awareness and attention from all stakeholders.

Ambition

The ambition of the Heat Pump industry in this is quite clear: we want to see a heat pump in every European home. No new home should be built with a fossil fuel boiler and no old boiler should be replaced with a new boiler. Any lingering technological and psychological barriers, Daikin will take on through relentless innovation. ■

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CERTIFICATION PROGRAMMES

FOR DOMESTIC, COMMERCIAL AND INDUSTRIAL FACILITIES

Indoor Climate

- Chilled Beams (CB)*
- Comfort Air Conditioners (AC)*
- European Heat Pumps
- Fan Coils Units (FCU)*
- Heat Interface Units (HIU)*
- Liquid-to-liquid Plate Heat Exchangers (LPHE)
- Rooftops (RT)*
- Variable Refrigerant Flow (VRF)*

Ventilation & Air Quality

- Air Cleaners (ACL)
- Air Filters (FIL)*
- Air Handling Units (AHU)*
- Air to Air Plate Heat Exchangers (AAHE)*
- Air to Air Regenerative Heat Exchangers (AARE)*
- Fans
- Hygienic Air Handling Units (HAHU)
- Residential Air Filters (RFIL)
- Residential Air Handling Units (RAHU)
- Ventilation Ducts (DUCT)

Process Cooling & Food Cold Chain

- Condensing units (CDU)
- Cooling & Heating Coils (COIL)
- Cooling Towers (CT)
- Drift Eliminators (DE)
- Evaporating Cooling
- Heat Exchangers (HE)*
- Heat Recovery Systems with Intermediate Heat Transfer Medium (HRS-coils)
- IT Cooling (ITCU)*
- Liquid Chilling Package & Heat Pumps (LCP-HP)*
- Remote Refrigerated Display Cabinets (RDC)

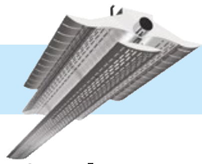
* All models in the production have to be certified

www.eurovent-certification.com

▼ Indoor Climate

Chilled Beams (CB)

CERTIFY ALL



Scope of certification

This Certification Programme applies to all Active and Passive Chilled Beams. Chilled Beams are presented by ranges but all ranges must be certified. This applies to all product ranges which have either catalogue leaflets with product details including technical data or similar product information in electronic format.

Certification requirements

For the qualification procedure: 3 units are selected from regular production and tested in the independent Laboratory selected by Eurovent Certita Certification.

For the repetition procedures (yearly): the number of units selected is limited to 1 unit/range.

Obtained performances shall be compared with the values presented in the catalogues or electronic selection from manufacturer's website.

Certified characteristics & tolerances

Cooling capacity: 3 conditions are required.

- Active: 80 – 100 – 120% of the nominal air flow rate (for 8°C temperature difference)
- Passive: 6 – 8 – 10°C temperature difference

Tolerance = 12% and +24% for the 3 single values; –6% for the average value.

Water pressure drop: tolerance = maximum (2 kPa; 10%)

ECC Reference documents

- Certification manual
- Operational Manual OM-12
- Rating Standard RS 2/C/001

Testing standards

- EN 14518: "Testing and rating of Passive Chilled Beams"
- EN 15116: "Testing and rating of Active Chilled Beams"

Comfort Air Conditioners (AC)

CERTIFY ALL

Scope of certification

This certification programme includes:

- AC1: comfort air cooled AC and air to air HP with cooling capacity up to 12 kW, except double duct and single duct units.
- AC2: comfort units with cooling capacity from 12 to 50 kW
- AC3: comfort units with cooling capacity from 50 to 100 kW

This programme applies to factory-made units intended to produce cooled air for comfort air conditioning (AC1, AC2, AC3). It also applies to units intended for both cooling and heating by reversing the cycle. AC1 programme units out of Regulation 206/2012 are excluded. AC2 and AC3 programme units out of Regulation 2016/2281 are excluded.

Participating Companies must certify all production models within the scope of the programme. For multi-split air conditioners, the number of indoor units is limited to 2, with same mounting type and capacity ratio 1±0.05. However, AC2 & AC3 units with 3 or 4 indoor units can be declared as an option.

Certification requirements

For the qualification & yearly repetition procedures: AC1: 8% of the units declared are selected and tested by an independent laboratory, and 30% of the selected units are tested at part load conditions. AC2 & AC3: 10% of the units declared are selected and tested by an independent laboratory.

Certified characteristics & tolerances

- Capacity (cooling and heating) –5%
- Efficiency (EER and COP) at standard rating conditions and part loads: –8%
- AC1 Seasonal Efficiency (SEER and SCOP): –0% (automatically rerated when Part Load efficiency criteria fails)
- AC2 & AC3 Seasonal Efficiency (SEER/η_{sc} and SCOP/η_{sh}): –0% (automatically rerated when Part Load efficiency criteria fails)
- A-weighted sound power level +0 dB (A) Auxiliary power +10%
- Minimum continuous operation Load Ratio: *LRcontmin* [%], COP/EER at *LRcontmin* and Performance correction coefficient at *LRcontmin* *CcpLRcontmin*.

ECC Reference documents

- Certification manual
- Technical Certification Rules ECP-1

Testing standards

- EN 14511 • EN 14825 • EN 12102

European Heat Pumps

The programmes AC, VRF, RT & LCP-HP also participate to the programme European Heat Pump

Scope of certification

- Electrically driven heat pumps for space heating
- (incl. cooling function)
- Electrically driven heat pumps used for heating
- swimming pool water (outdoors or inside)
- Dual-mode heat pumps, i.e. designed for space
- heating and domestic hot water production
- Gas absorption heat pumps (incl. cooling function)
- Engine-driven gas heat pumps (incl. cooling function)

Are excluded from the scope Cooling-only units, i.e. units declared only in cooling mode.

Certification requirements

Each range shall be certified according to one of the following related reference documents:

- OM-3 LCP-HP: "Operational Manual for the certification of Liquid Chilling Packages and Hydronic Heat Pumps"
- ECP-1 AC: "Technical Certification Rules for the certification of Air Conditioners"
- ECP-15 VRF: "Technical Certification Rules for the certification of Variable Refrigerant Flow systems"
- ECP-13 RT: "Technical Certification Rules for the certification of Rooftops"
- "Certification Reference for the Mark NF-414 for Heat Pumps"

Main certified characteristics & tolerances

- Heating and/or Cooling capacities P_h and/or P_c [kW], Electrical Power inputs P_e [kW] and Coefficient of performance COP
- Design capacity $P_{designh}$, Seasonal Coefficients of Performance *SCOP*, $SCOP_{net}$ and Seasonal efficiency η_s
- Minimum continuous operation Load Ratio *LRcontmin* [%], COP at *LRcontmin* and Performance correction coefficient at *LRcontmin CcpLRcontmin*
- Temperature stabilisation time t_h [hh:mm], Spare capacity P_{es} [W], Energy efficiency for water heating [COP_{DHW} & WH] or Global performance coefficient for a given tapping cycle COP_{global}, Reference hot water temperature θ'_{WH} and Maximum effective hot water volume V_{MAX} [l]
- Daily consumption for the draw-off cycle in question (Qelec)
- Annual consumption (AEC)
- Sound power levels L_w [dB(A)]

ECC Reference documents

- Certification manual
- Operational manual OM-17
- Rating standard RS 9/C/010

Main testing standards

Thermal performance:

- Heat pumps with electrically driven compressors
- Space heating & cooling: EN 14511-1 to 4; Seasonal performance: EN 14825
- Domestic hot water: EN 16147
- Direct exchange ground coupled heat pumps: EN 15879-1
- Gas-fired heat pump: EN 12309-1 to 5

Acoustics:

- Heat pumps and dehumidifiers with electrically driven compressors: EN 12102
- ISO 3741: Reverberant rooms or ISO 9614-1: Sound intensity, measurements by points

Indoor Climate

Heat Interface Units (HIU)

CERTIFY ALL

Scope of certification

The present certification scheme covers Heat Interface Units, defined as a packaged unit including at least one Domestic Hot Water heat exchanger and control elements.

The HIU may contain:
- An additional heat exchanger for heating
- Balancing elements
- 1 heating pump
- Metering possibilities

The HIU covered by the scheme are 3 pipes configurations. HIU with DHW capacity level above 70 kW are not covered by the certification scope. Only units for single family dwellings use are covered.

The covered technologies are:
- Domestic Hot Water technology only: HIU/DHW
- DHW and direct heating technology: HIU/DHW/DH
- DHW and direct heating mixed technology: HIU/DHW/DHM
- DHW and indirect heating application: HIU/DHW/IH

Certification requirements

The Heat Interface Unit certification program includes:
- Annual random selection of units and tests in an independent and accredited laboratory.
- Annual production site audit
- Unit labelling
- Certify-all principle

Certified characteristics & tolerance

- Maximal DHW capacity (kW)
- Return temperature during normal DHW tapping (°C)
- Minimal DHW flow rate (l/min)
- DHW reaction time (s)
- DHW Standby heat losses (kW)
- Capacity on temperature delta of 20 K (kW)
- Capacity on temperature delta of 10 K (kW)
- Difference between primary return temperature and secondary return temperature at 4kW (°C)
- Heat losses (kW)

ECC Reference documents

- Certification manual
- OM-26
- RS10/C/001

Testing standards

- Tests are conducted in accordance with the Test Regime Technical Specification, Rev-007 by BESA (Building Engineering Services Association), and in complement of testing specifications described in the Rating Standard RS/10/C/001.
- Units are both tested under High Temperature Conditions and Mid Temperature Conditions.

Fan Coils Units (FCU)

CERTIFY ALL

Scope of certification

This Certification Programme applies to Fan Coil Units using hot or chilled water. It concerns both non ducted and ducted fan coils:

- Non-ducted units: Fan Coil Units with air flow less than 0.7 m³/s and a published external static duct pressure at 40 Pa maximum.
- Ducted units: Fan Coil Units up to 1 m³/s airflow and 300 Pa available pressure.
- District cooling units and 60 Hz units can be certified as an option

Participating companies must certify all production models within the scope of the programme. Selection tools (software) are checked.

Certification requirements

Repetition procedure: the number of units to be tested each year will be proportional to the number of his basic models listed in the Directory, in an amount equal to 17% for Fan Coil Units with a minimum of one test.

Certified characteristics & tolerances

- Sensible capacity* **: –8%
- Total cooling & heating capacity * **: –7%
- Water pressure drop* **: +20%
- Fan power input*: +10%
- A-weighted sound power **: +2 dB(A)
- Air flow rate: –10%
- Available static pressure 0 Pa for medium speed and –5 Pa for other speeds
- FCEER & FCCOP
- Eurovent energy efficiency class

(*) At standard and non-standard conditions
(**) Tolerances for capacities are increased by 2% for variable speed units.

ECC Reference documents

- Certification manual
- Operational Manual OM-1A
- Rating Standard RS 6/C/002
- Rating Standard RS 6/C/002A

Testing standards

- Performance testing: EN 1397:2015
- Acoustic testing: EN 16583:2015

Liquid-to-liquid Plate Heat Exchangers (LPHE)

Scope of certification

This certification programme applies to plate heat exchangers designed for liquid/liquid heat exchange (without phase change) applications in the Heating Ventilation and Air Conditioning (HVAC) field and operated with clean water or clean water mixtures (ethylene/propylene glycol but also ethanol aqueous solutions).

The product categories covered are:

- Gasketed plate heat exchangers,
- Brazed plate heat exchangers
- Fusion-bonded plate heat exchangers

Certification requirements

The certification scheme is based on product performance testing by independent testing laboratories as well as manufacturing facility auditing and selection software checking.

For qualification (entry year): 1/4 of the models (4 models minimum) selected for testing + 1 audit/factory.

For the repetition procedure (annually): 1/10 of the models (2 models minimum) selected for testing + 1 audit/factory.

If more than 3 new models are introduced in the range during the declaration file annual update, then 1 extra test will be conducted.

The performances measured by the independent laboratory are compared to the selection software output data.

Certified characteristics & acceptance criteria

Capacity: -(3%+Mu)

Pressure drop on primary fluid circuit: +(10%+Mu), minimum +2kPa

Pressure drop on secondary fluid circuit: +(10%+Mu), minimum +2kPa

With Mu the expanded uncertainty calculated by the laboratory for the test in question (uncertainty analysis as per RS 7/C/010).

ECC Reference documents

- Certification manual
- Operational manual OM-25
- Rating Standard RS 7/C/010

Testing standards

Specific testing method in Rating Standard RS 7/C/010 notably based on, but amending, the following standards:

- EN 1148:1999+A1:2005
- EN 306:1997

▼ Indoor Climate

Rooftops (RT)

CERTIFY ALL

The Eurovent rooftop certification (RT) program covers air-cooled packaged rooftop cooling only and reversible units below 100 kW (in cooling mode), with an option to certify air to air units from 100 kW to 200 kW and water-cooled packages rooftops.

The Rooftop program regroups 14 participants of which the five main European manufacturers.

Eurovent certifies indoor and outdoor sound levels, cooling and heating capacity and efficiency. Certified performances provide transparency and fair comparison between manufacturers. It is also the basis for the reliable study of HVAC system energy performance.

For two years the program has evolved towards tests at part load conditions in order to prepare the certification of seasonal efficiencies (SEER & η_{sc}, SCOP & η_{sh}) of which the publication on the Eurovent Certified Performance (ECP) website is effective since 2018.

It was a strong willing of manufacturers involved in the program to be completely in line with the new Eco design Regulation (N° 2016/2281) applicable from 1st of January 2018 for several HVAC products as the rooftop units.

The next challenges of the programme will be the taking into account of the free cooling for the cooling efficiency and the heat recovery mode for the 3 & 4 damper rooftops, but obviously, the software certification will be a key item to comply with existing and coming certification of building energy calculations in the EU countries.

Committee chair:
Mr Alain Compingt
Regulatory and External Relationship, LENNOX EMEA

Mr Arnaud Lacourt
Head of Thermodynamics Department, Eurovent Certita Certification

Scope of certification

- This Certification Program applies to air-cooled packaged rooftop cooling only and reversible units below 100 kW (in cooling mode).
- Air to air units from 100 kW to 200 kW and water-cooled packages rooftops can be certified as an option.

Certification requirements

- For the qualification and repetition procedures (yearly) between 1 & 3 units are selected and tested, depending on the number of products declared.

Certified characteristics & tolerances

- Capacity (Cooling or Heating): –5%
- EER or COP: –8%
- Seasonal Efficiency in cooling: SEER & η_{sc} –8%
- Seasonal Efficiency in heating: SCOP & η_{sh} –8%
  Condenser water pressure drop: +15%
- A-weighted Sound Power Level: +3 dBA
- Eurovent Energy Efficiency class (cooling and heating)
- Eurovent Energy Seasonal Efficiency class.

ECC Reference documents

- Certification manual
- Technical Certification Rules ECP-13

Testing standards

- EN 14511 for Performance Testing
- EN 14825 for Seasonal Efficiencies
- EN 12102 for Acoustical Testing

▼ Indoor Climate

Variable Refrigerant Flow (VRF)

CERTIFY ALL

Launched in 2013, the VRF programme started with a restricted scope: outdoor units up to 50 kW, testable combinations up to limited number of indoor units (2 cassettes or 4 ducted units). But it was a first step to increase the integrity of the products performances on the market. From 2015, an annual factory audit has completed the requirements of the VRF programme.

Since 2018, an extended scope is proposed:

- Outdoor units up to 100 kW
- Combinations up to 8 indoor units (cassette or ducted) depending of the outdoor unit capacity
- Certified seasonal efficiencies (according to Ecodesign Regulation No 2016/2281 and No 206/2012 for VRF units below 12 kW)

Since 2019, the programme also covers high ambient VRF systems. To date, the VRF programme has 29 participants some of which are leading manufacturers.

Scope of certification

The certification programme for Variable Refrigerant Flow (VRF) applies to:

- Outdoor units used in Variable Refrigerant Flow systems
- VRF units below 12 ke as combination of outdoor and indoor units with the following characteristics:
  - Air or water source, reversible, heating-only and cooling-only.

VRF systems above 12 kW with data declared and published as combinations are excluded from the scope.

Heat recovery units are included in the scope but the heat recovery function is not certified.

High ambient systems are included in the scope but tested under specific conditions.

Certification requirements

- Qualification: units selected by ECC shall be tested in an independent laboratory selected by ECC.
- Repetition procedure: units selected from regular production shall be tested on a yearly basis.
- A factory visit is organized every year in order to check the production

Certified characteristics & tolerances

- Outdoor Capacity (cooling and heating): –8%
- Outdoor Efficiency (EER, COP) at standard rating conditions and part loads: –10%
- Seasonal Efficiency (SEER/ηsc and SCOP/ηsh): –0% (automatically rerated when Part Load efficiency criteria fails)
- A-weighted sound power level: 2 dB(A)

ECC Reference documents

- Certification manual
- Technical Certification Rules ECP-15

Testing standards

- EN 14511 • EN 14825 • EN 12102

ISO 15042:2017, SASO 2874:2016 and GSO 03 Draft for high ambient systems

▼ Ventilation & Air Quality

Air Cleaners (ACL)

Scope of certification

The scope of this new certification programme includes devices for collecting and/or destroying indoor air pollutants for residential or tertiary sector applications, such as:

- Devices equipped with a fan that circulates an air flow of between 15 m^3/h and 1,000 m^3/h
- Independent electrically-powered devices.
- Residential (domestic) and tertiary sector applications: bedrooms, living rooms, offices, waiting rooms, retail stores, etc.
- All types of technology: mechanical filtration, electrostatic filtration, plasma, ionization, UV-A or UV-C lamp, etc.

Certified characteristics & tolerances

At maximum operating speed:

- Purification efficiency: purified air volume flow rate for each pollutant category treated such as
  - Breathable particles suspended in the air
  - Gaseous pollutants (formaldehyde, toluene, etc.)
  - Microorganisms (bacteria and mould)
  - Cat allergen
- Energy efficiency: (purified air volume flow rate / absorbed electrical power).
- Recommended room area for each pollutant category.

At 1, 2 or 3 operating speeds:

- Device air circulation flow rate.
- **Energy**: absorbed electrical power.
- **Noise impact**: sound power level.

When tested in the laboratory the obtained performance data shall not differ from the declared values by more than the following tolerance values:

- Air circulation flow rate [m^3/h]: –5%
- Initial purified air flow rate [m^3/h]: –5%
- Sound power level [dB(A)]: +2 dB(A)
- Absorbed electrical power [W]: Maximum [+5%; +1 W]

ECC Reference documents

- Certification manual
- Operational manual OM-20
- Rating Standard RS/4/C/002
- NF-536

Testing standards

- NF B44-200:2016
- XP-B44-013:2009 may notably be used as a supplement in some particular cases identified in the NF-536 reference document.

Air Filters (FIL)*

CERTIFY ALL

Today, people spend most of the time inside of buildings. Hence, indoor air quality is a key factor to human health. Air filters removing fine dust from the air stream are the key component in building heating, ventilation and air conditioning systems to supply air of the required cleanliness and to ensure a high level of indoor air quality. With the air filter certification program, reliable and transparent filter data are ensured to customers. On a yearly base, four different filters are selected out of the product range of each participant for testing at independent laboratories according to EN ISO 16890: 2016, verifying the initial pressure drop, the filter ISO class rating and the ePM1, ePM1,min, ePM2.5, ePM2.5,min and ePM10 efficiencies, as well as the energy efficiency class to Eurovent document 4/11. Additionally, with the new energy efficiency label, Eurovent provides valuable data to enable users to select the most energy efficient air filters.

Committee chair: Dr. Thomas Caesar
Head of Filter Engineering Industrial Filtration Europe
Freudenberg Filtration Technologies SE & Co. KG

Scope of certification

- This Certification Programme applies to air filters elements rated and sold as ISO ePM1, ISO ePM2.5 and ISO ePM10 according to EN ISO 16890-1:2016 referring to a front frame size of 592x592mm according to standard EN 15805.
- When a company joins the programme, all relevant air filter elements shall be certified.

Certification requirements

- For the qualification procedures: 6 units will be selected and tested by an independent Laboratory selected by Eurovent Certification.
  Then each year 4 units will be selected & tested

Certified characteristics & tolerances

- Filter ISO class rating: no tolerance.
- Initial pressure drop: +10% + 5 Pa (minimum 15 Pa)
- ePM1, ePM1,min, ePM2.5, ePM2.5,min and ePM10 efficiencies: -7%-point
- Annual energy consumption +10% +60 kWh/a

ECC Reference documents

- Certification manual
- Technical Certification ECP -11

Testing standards

- EN ISO 16890: 2016
- Eurovent 4/21

▼ Ventilation & Air Quality

Air Handling Units (AHU)

CERTIFY ALL

Mr Gunnar Berg
Development Engineer, Swegon

Swegon has participated in the program for Air Handling Units from the start. The first priority at that time, and still is, was to find a way for fair competition. This is a long-term struggle where we try to cover all aspects from manufacturing to software performance predictions and its agreement with tests. We discuss and take decisions about mandatory performance in software printout, rules for the energy labelling, how to test and what to apply in the, on site, auditor check. Customers should go for Eurovent certified products, to get reliable data, and then they can cut the main cost and take care of the environment by minimising the use of energy.

Quentin Liebens
Project Engineer, Eurovent Certita Certification

In 2020 a new energy efficiency class (EEC) has been developed for warm climate. Indeed, the current EEC (in place since 2013) was made for a winter application (i.e. cold climate) and was not relevant for summer application. This new EEC comes in addition to the existing one and will consider three new features having an impact on the energy efficiency of an AHU installed in warm climate: humidity recovery, indirect adiabatic cooling and decrease of the pressure drop when the heat recovery system is on bypass mode. From E to A + this new classification will assess how an AHU perform in warm climates.

Scope of certification

This Certification Programme applies to all ranges of Air Handling Units that can be selected in a software. Each declared range shall at least present one size with a rated air volume flow below 3 m²/s. For each declared range, all Real Unit Sizes available in the software and up to the maximum stated air flow and all Model Box configurations shall be declared.

Participants shall certify all models in the selected product range up to the maximum stated air flow.

All ranges to be certified shall include at least one size with a rated air volume flow up to 3 m³/s.

Certification requirements

For the qualification procedure: the selection software will be verified by our internal auditor. A visit on production site will be organized. During that visit, the auditor will select one real unit per range, as well as several model boxes that will cover all mechanical variations.

The selected units will be tested and performances delivered by the selection software will be compared to the performances measured in an independent laboratory.

For the repetition procedures, the auditor will annually check the software conformity against the production data, and tests will be repeated every 3 years for the real unit and 6 years for the model box.

Certified characteristics & tolerances

- External Pressure: 4% or 15 Pa
- Absorbed motor power: 3%
- Heat recovery efficiency: 3%-points
- Heat recovery pressure drop (air side): max. of 10% or 15 Pa
- Water coil performances (heating/cooling): 2%
- Water coil pressure drop (water side): max. of 10% or 2 kPa
- Radiated sound power level casing: 3 dB(A)
- Sound power level unit openings:
  - 5 dB @ 125 Hz
  - 3 dB @ 250 – 8 000 Hz
- Casing Air Leakage: same class or higher

Energy efficiency labelling

- Energy efficiency class for winter application
- New! Energy efficiency class for summer application

ECC Reference documents

- Certification manual
- Technical certification rule ECP-5

Testing standards

- EN 1886: "Ventilation for buildings – Air handling units – Mechanical performance"
- EN 13053: "Ventilation for buildings – Air handling units – Rating & performance for units, components and sections"
- RS/6/C/011-2018 Hygienic AHU

▼ Ventilation & Air Quality

Air to Air Plate Heat Exchangers (AAHE)

CERTIFY ALL

Scope of certification

This Certification programme applies to selected ranges of Air to Air Plate Heat Exchangers. Participants shall certify all models in the selected range, including:

- cross flow, counter-flow and parallel flow units
- all sizes
- all materials
- all airflow rates
- all edge lengths
- plate heat exchanger with humidity transfer

Heat Exchangers with accessories such as bypass and dampers shall not be included.

Manufacturers shall declare production places and provenance of products is randomly chosen. The programme does not cover other types of Air to Air Heat Exchangers like Rotary Heat Exchangers or Heat Pipes. Combination of units (twin exchangers) are also included in the scope of the program.

Certification requirements

For each range to be certified, 3 units for qualification and 1 for yearly repetition will be selected by Eurovent Certita Certification and tested in an independent Laboratory.

Certified characteristics & tolerances

- Dimensions: ± 2 mm
- Plate spacing: ± 1% or ± 1 plate
- Temperature efficiency Dry: –3 percentage points
- Temperature efficiency Wet: –5 percentage points
- Humidity efficiency: -5%
- Pressure drop: +10%, minimum 15 Pa

ECC Reference documents

- Certification manual
- Operational Manual OM-8
- Rating Standard RS 8/C/001

Testing standards

- EN 308

Air to Air Regenerative Heat Exchangers (AARE)

CERTIFY ALL

Scope of certification

This Certification Programme applies to all ranges of Air to Air Regenerative Heat Exchangers (RHE) including sealing systems. Units sold without casing and sealing systems are also included. Participants shall certify all models in the ranges, including:

- all classes: condensation (non-hygroscopic, non-enthalpy) RHE, hygroscopic enthalpy RHE, hygroscopic sorption RHE
- all RHE geometry (wave height, foil thickness)
- all sizes (rotor diameters and rotor depths and surface areas of Alternating Storage Matrices - ASM)
- all materials
- all airflow rates
- all different types of sealing (if available)

Certification requirements

For the qualification procedures 1 unit per class of rotor will be selected and tested by an independent laboratory. For yearly repetition, 1 unit will be selected.

Certified characteristics & tolerances

- Temperature Efficiency: –3% points
- Humidity Efficiency: –5% points (min. tolerance 0.2 g/kg in absolute humidity of leaving supply air)
- Pressure Drop: +10% (min 10 Pa)
- Outdoor Air Correction Factor (OACF): 0.05
- Exhaust Air Transfer Ratio (EATR): +1% point

ECC Reference documents

- Certification manual
- Operational Manual OM-10
- Rating Standard RS 8/C/002

Testing standards

- EN 308
- ARI 1060

Fans

Scope of certification

This certification programme applies to the fans types that are intended to be used as Air Handling Units components.

Certification requirements

The certification scheme is based on product performance testing by independent testing laboratories as well as manufacturing facility auditing and selection software checking.

Two sub-programmes enable distinguishing performances certified for an impeller basic assembly on the one hand (sub-programme FAN-I) and for a complete assembly on the other hand (sub-programme FAN-C). In both cases, the fan assembly is evaluated in accordance with a wire-to-air approach. This approach consists in assessing the fan performance from the electric wire to the air discharge, accounting for all the components involved in the air stream generation that affect the performance data.

- For qualification (entry year) and repetition procedures (annually): 2 models (+ 1 extra model in case of confirmed failure) are selected from regular production and tested in independent laboratory + N aerodynamic test reports are provided by the applicant/participant.
- For qualification (entry year): N = Max ($N_{impeller}$; N_{motor}; N_{drive}) with $N_{impeller}$ the number of impeller sizes; N_{motor} the number of motor sizes and N_{drive} the number of drive types available in the range.
- For the repetition procedure (annually): $N = N_{factories}$ with $N_{factories}$ the number of factories involved in the certified range production.

The performances measured by the independent laboratory (or available in the reports) are compared to the selection software output data.

Certified characteristics & tolerances

- Static pressure difference (–4% or –15 Pa)
- Shaft power, including bearings (FAN-I) (+3%)
- Impeller efficiency (FAN-I) (–5 percentage points)
- Maximum fan speed (FAN-I) (–5%)
- Motor (electrical) input power (FAN-C) (+3%)
- Drive/control (electrical) input power (FAN-C) (+3%)
- Overall (static) efficiency (FAN-C)(–5 percentage points)
- Inlet/outlet LWfc by octave bands at 125 Hz (FAN-C) (+5 dB)
- Inlet/outlet LWfc by octave bands for 250 Hz - 8000 Hz (FAN-C) (+3 dB)

ECC Reference documents

- Certification manual
- Operational manual OM-22
- Rating standard RS 1/C/001

Testing standards

- ISO 5801:2007
- ISO 13347-2:2004

Hygienic Air Handling Units (HAHU)

Scope of certification

This programme applies to hygienic ranges of Air Handling Units. As an option of the Certification programme for Air Handling Units, only an already ECP certified range is eligible for the hygienic option.

The hygienic aspect of the AHU is certified based on a 3 levels classification, each level declaring an AHU suitable for different application:

- Level 1: Offices, commercial buildings, schools, hotels
- Level 2: Hospitals
- Level 3: Pharmaceutical, food processes, white rooms

The previous list is not exhaustive and must be used as a reference only. Final customer/user who has complete and detailed knowledge of the building application shall decide which Hygienic rating level is appropriate.

Certification requirements

Same as in the Air Handling Unit programme.

Certification characteristics & tolerances

Services characteristics:
The following services characteristics are certified.

1. Manufacturing
2. Maintenance
3. Quality Management System
4. IOM (Installation and Operational Manual)
5. Shipment

Hygienic characteristics:
The following hygienic characteristics are certified:

1. Materials
2. Casing performance
3. Components arrangement and performances (filters, coils, heat recovery systems, fans, humidifiers, dehumidifiers and silencers)

ECC reference documents

Certification manual

- OM-5-2016-rev1
- RS/6/C/011-2016 Hygienic AHU

Testing standards

- RS 6/C/005-2016
- EN ISO 846:1997
- EN ISO 2896:2001
- EN 10088-3:2014
- EN 1993-1-2:2005
- DIN 1946/4-6.5.1:2008
- EN 779:2012
- EN 1822:2010
- EN ISO 12944-2:1998

Residential Air Filters (RFIL)

Scope of certification

The programme scope covers the particulate and combination (particulate and gas) filters used in a residential ventilation unit and for which the following applies:

- the rated maximum air flow rate is comprised between 70 and 1000 m³/h included;
- the initial efficiency ePM10 is higher than or equal to 50%;
- the initial efficiency ePM1 is strictly lower than 99%;
- the ratio between effluent and influent concentrations measured at time zero is strictly lower than 20% (for combination filters only, see Rating Standard RS/4/C/003 for further details).

The programme scope covers filters for which the face area is lower than or equal to 300 mm x 600 mm. For the RFIL programme, the certify-all requirement as defined in the Certification Manual is applicable from January 1st of 2020 (see Operational Manual OM-21 for further details).

Certified characteristics & tolerances

When tested in the laboratory the obtained performance data shall not differ from the declared values by more than the following tolerance values:

- Initial pressure drop values: +10%+Mt or +10 Pa +Mt
- Initial efficiency values: −5 percentage points (absolute deviation)
- Minimum efficiency values: −5 percentage points (absolute deviation)
- Filter ISO ePMx class reporting value: −5 percentage points (absolute deviation)
- Adsorption capacity: −10%

Nota : Mt means "measuring tolerance"

ECC Reference documents

- Certification manual
- Operational manual OM-21
- Rating standard RS/4/C/003

Testing standards

- Eurovent 4/22:2015 (particulate filters and combination filters)
- SO 11155-2:2009 (combination filters only)

Ventilation Ducts (DUCT)

Scope of certification

The programme scope covers rigid and semi-rigid ventilation ductwork systems divided into the following sub-programmes:

- Rigid metallic ductwork systems with circular cross-section (DUCT-MC);
- Rigid metallic ductwork systems with rectangular cross-section (DUCT-MR);
- Semi-rigid non-metallic ductwork systems predominantly made of plastics (DUCT-P)

Each sub-programme applies to ductwork systems fitted with integrated sealing solution as described in relevant Rating Standard.

Certification requirements

The certification programme is based on product performance testing by independent testing laboratories as well as production sites auditing.

Certification characteristics & tolerances

The product performance testing will enable the verification of the following ratings accuracy:

- Air tightness class (all sub-programmes)
- Positive and negative pressure limits (all sub-programmes)
- Dimensions (DUCT-MC and DUCT-MR)
- Minimum and maximum service temperatures (DUCT-P)
- Resistance to external pressure (DUCT-P)

ECC reference documents

- Certification manual
- OM-19
- RS/2/C/002MC
- RS/2/C/003MR
- RS/2/C/004P

Testing standards

- Air leakage and strength testing:
  – EN 12237:2003 (DUCT-MC)
  – EN 1507:2006 (DUCT-MR)
  – EN 17192:2018 (DUCT-P) – New in 2020

Service temperature and resistance to external pressure

- (DUCT-P):
  – RS 2/C/004P and EN 17192:2018 – New in 2020

Ventilation & Air Quality

Residential Air Handling Units (RAHU)

CERTIFY ALL

The objective of the Eurovent RAHU certification programme is, through tests performed by a third-party, to verify the performance of a unit bought somewhere on the open European market. It is important for the RAHU certification to use a unit out of the serial production – no special samples. For us, as a manufacturer, it pays to develop good products that deliver what we promise. By utilizing certified products, the designers' task is easier as they do not need to make detailed comparisons or perform advanced tests. Consultants, engineers and users can select a product and be assured that the catalog data is accurate.

Certification is important for a designer/consultant/end user:

- No unnecessary risks – they can only use products that deliver what they promise "Eurovent certified".
- Well-functioning systems – the product delivers the promised capacity and performance
- Safer calculations on energy consumption is expected

Mr. Tobias Sagström
Global Product Manager Residential at Systemair AB

Scope of certification

This programme applies to balanced residential AHUs (supply and exhaust) with heat recovery sys-tems such as:

- Air-to-air **plate** heat exchangers
- Air-to-air **rotary** heat exchangers
- **Heat-pumps** with a nominal airflow below 1 000 m³/h.

Certification requirements

- Qualification test campaign: 1 test per heat recovery type.
- Repetition test campaign: 1 test every 2 years for each heat recovery type.
- Units are sampled directly from selling points.

Certified performances

- Leakage class
- Aeraulic performances:
- Airflow/pressure curves
- Maximum airflow [m³/h]
- Electrical consumption [W]
- Specific Power Input SPI [W/(m³/h)]
- Temperature efficiency / COP
- Performances at cold climate conditions
- SEC (Specific Energy Consumption) in [kWh/(m².an)]
- A-weighted global sound power levels [dB(A)]

Tolerances

- Leakage class 0
- Airflow –10%
- Temperature efficiency –3%-point
- Temperature efficiency at cold climate –6%-point
- COP / EER –8%
- A-weighted global sound power levels +2dB(A)
- Electrical consumption +7%
- Specific Power Input SPI +7%
- Disbalance ratio 0

ECC Reference documents

- Certification manual
- Operational manual OM-16
- Rating standard RS 15/C/001

Testing standards

- European standard EN 13141-7:2010

▼ Process Cooling & Food Cold Chain

Cooling & Heating Coils (COIL)

Heating Cooling Coils (HCCs) which enable the conditioning of different zones and flexibility in application in buildings are generally employed in compact and central station AHU. To meet the required extra capacity in various processes, they are also used as heating or cooling devices.

With the application of these coils to high energy efficient heat recovery systems, the entire system becomes more compact as well as it avoids occupation of large spaces. Besides, they can be applied to Variable Air Volume (VAV) systems used for conditioning of hospitals, shopping centers and convention facilities.

The Certification programme for the HCCs has increased integrity and accuracy of the industrial performance ratings which provides clear benefits for end users who can be confident that the product will operate in accordance with design specifications. Also, by means of this certification programme users can collect reference data on the fundamental characteristics of the HCCs, such as capacity, pressure drop, mass flow complying with the standard of EN 1216.

Engin Söylemez, R&D
Test Engineer, Friterm A.Ş

Scope of certification

The rating standard applies to coils operating:

– with water or with a 0–50% ethylene-glycol mixture, acting as cooling or heating fluid.

– and without fans.

Certification requirements

- Qualification and repetition procedures: units declared will be selected and tested by an independent laboratory.
- The number of units will depend on the variety of coil material configurations and their applications for the applied range.
- The selection software will be verified in comparison with the test results.
- On-site audits (checking of software)

Certified characteristics & tolerances

- Capacity: –7%
- Air side pressure drop: +20%
- Liquid side pressure drop: +20%

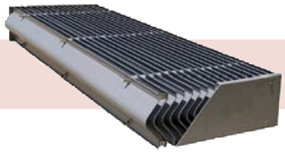
ECC Reference documents

- OM-9
- RS 7/C/005

Testing standards

- EN 1216:1998+A1/2002

Drift Eliminators (DE)



Scope of certification

The Certification Programme for Drift Eliminators applies to Drift Eliminators used for evaporative water-cooling equipment.

Certified characteristics & tolerances

The following characteristics shall be certified by tests:

- For counter-flow and cross-flow film fill, the average drift losses of the two tests at 3.5 m/s are less than 0.007% of circulating water flow rate.
- For cross-flow splash fill, the average drift losses of the two tests at 3 m/s are less than 0.007% of circulating water flow rate.

No tolerance will be applied on the average drift losses.

ECC Reference documents

- Certification manual
- Operational Manual OM-14
- Rating Standard RS 9/C/003

Testing standards

- CTI ATC-140

Cooling Towers (CT)

The importance of air conditioning and industrial cooling is constantly increasing in modern architecture and industrial process cooling. The human perception of comfort and the new challenges to reduce the electrical power consumption and CO_2 foot-print have designers striving for optimal system performances with the highest possible efficiencies. Reliable thermal performances are crucial to ensure these best efficiencies which are typical for cooling circuits driven by evaporative cooling equipment. On a yearly basis, one random picked cooling tower of each Eurovent-CTI certified product line will be full scale thermal tested by applying the CTI standard 201.

Eurovent Certita Certification guarantees the consistency of thermal testing and manufacturing of European and non-European companies that subscribe to the program.

Committee chair:
Mr Rob Vandenboer
Product Manager, Quality Manager
Evapco Europe, BVBA

The first ECC / CTI collaborative certification program for Cooling Towers

The Eurovent Certification Company (ECC, Brussels, Belgium) is pleased to announce the Certification programme for cooling tower thermal performance developed in cooperation with the Cooling Technology Institute Est.1950 (CTI, Houston, Texas, USA). The scope of the program includes standardized model lines for open circuit cooling towers, typically factory assembled. Standardized model lines are composed of individual models that are required to have published thermal rating capacities at corresponding input fan power levels.

Thermal performance certification via this program offers a tower buyer assurance that the capacity published for the product has been confirmed by the initial and on-going performance testing per the requirements of the program using CTI STD-201. It also offers for regulators of energy consumption related to cooling towers, that the capacity of the towers has been validated. Mini-mum energy efficiency standards such as the Eurovent Industry Recommendation / Code of Good Practice Eurovent 9/12-2016 and ASHRAE 90.1, which requires cooling tower energy efficiency

validation by the CTI certification process, are used by governments and by green building certification programs such as LEED™.

Scope of certification

This Certification Programme for Cooling Towers applies to product ranges (or product lines) of Open-Circuit series and Closed Circuit Cooling Towers that:

- Are manufactured by a company whose headquarter or main facility are located in Europe, Middle-East, Africa or India. After getting the Eurovent Certification, the CTI certificate could be requested.
- Have already achieved and hold current certification by the Cooling Technology Institute (CTI) according to CTI STD-201.

Certification requirements

For the qualification & yearly repetition procedures our internal auditor visits the production place and reviews the conformity of Data of Records. One unit per range is selected and tested by an independent test agency.

Certified characteristics & tolerances

- Certified characteristic shall be per CTI STD-201
- Entering wet bulb temperature: 10°C to 32.2°C (50°F to 90°F)
- Cooling range > 2.2°C (4°F)
- Cooling approach > 2.8°C (5°F)
- Process fluid temperature < 51.7°C (125°F)
- Barometric pressure: –91.4 to 105.0 kPa (27” to 31” Hg)

ECC Reference documents

- Certification manual
- Operational Manual OM-4
- Rating Standard RS 9/C/001

Testing standards

- CTI STD-201 RS
- ECC OM-4-2017

Evaporating Cooling

Scope of certification

The programme for Evaporative Cooling is divided in three sub-programmes, as it applies to Evaporative Cooling units in the following groups:

- Direct Evaporative Cooling (DEC)
  - Indirect Evaporative Cooling (IEC)
  - With primary outside air
  - With separation of external and room air
- Evaporative Cooling Equipment (ECE)
  - Water spray system
  - Wet media
  - Ultrasonic unit

Certification requirements

All products of a declared range that fall into the relevant sub-programme scope and are promoted by the Applicant/Participant shall be certified. This is a certification by range.

The certification programme is based on product performance testing by independent laboratories as well as manufacturing facility auditing. In the case of the IEC sub programme, the tests will be performed in the laboratory of the manufacturer supervised by an expert from an independent laboratory.

Certified characteristics & tolerances

- Cooling Capacity (all sub-programmes)
- Air flow (all sub-programmes)
- Efficiency (all sub-programmes)
- Water consumption (all sub-programme)
- Wet and dry pressure drop (ECE only)

ECC Reference documents

- Certification manual
- Operational Manual OM
- Rating Standard RS 9/C/004-005-006

Testing standards

- For direct evaporating cooling AS 2913-2000 standard RS9/C/004
- For indirect evaporating cooling ANSI/ASHRAE Standard 143-2015 RS9/C/005
- For evaporating cooling equipment ASHRAE 133-2015 RS9/C/006

Heat Recovery Systems with Intermediate Heat Transfer Medium (HRS-COIL)

Scope of certification

This certification programme covers the heat recovery exchangers with intermediate heat transfer medium corresponding to the category IIa ("without phase change") of the EN 308:1997 standard, that is Run Around Coils systems.

Certification requirements

Qualification procedure

- Product performance testing:
  - 1 coil per BMG to be selected
  - Selected coils paired into systems (1 "exhaust" coil + 1 "supply" coil)
- Operating software checking
- Audit of the manufacturing facilities

Repetition procedure:

- Product performance testing: 1 system to be selected (1 "exhaust" coil + 1 "supply" coil)
- Operating software checking
- Audit of the manufacturing facilities

Certification characteristics & tolerances

- Dry heat recovery efficiency [%]
- Air side pressure drop at standard conditions for each coil [Pa]
- Fluid side pressure drop for each coil [kPa]

When tested in the laboratory the obtained performance data shall not differ from the recalculated values ("test-check") by more than the following tolerance values:

- Dry heat recovery efficiency: –3 percentage points (abs. deviation)
- Air side pressure drop: Maximum [+10%; +15 Pa]
- Fluid side pressure drop: Maximum [+10%; +2 kPa]

ECC reference documents

- Certification manual
- OM-18
- RS 7/C/009

Testing standards

- EN 308:1997

▼ Process Cooling & Food Cold Chain

Heat Exchangers (HE)

CERTIFY ALL

EUROVENT CERTIFIED PERFORMANCE ENERGY EFFICIENCY CHECK ENERGY CLASS ON www.eurovent-certification.com

The purpose of the Eurovent "Certify-All" certification programme for heat exchangers is to encourage honest competition and to assure customers that equipment is correctly rated.

The programme covers 4 product groups:

- Unit Air Coolers
- Air Cooled Condensers
- Dry Coolers
- CO_2 Gas Coolers

The "Certify-All" principle ensures that, for heat exchangers, all models in the three product categories are submitted for certification, not just some models chosen by the manufacturer.

A product energy class scheme has been incorporated into the certification program, based on 6 classes from "A+" to "E" in order to provide a guide to the best choice of product: this enables the user to minimize life-cycle costs, including running costs which account for a much superior sum than the initial investment cost.

EVOLUTIONS OF THE PROGRAMME:

Extension of the scope of certification programme for Heat Exchangers

- to CO_2 applications
  Implementation in 2019
- to NH_3 applications

Committee chair:
Stefano Filippini
Technicalmanager - LUVE

Scope of certification

The Eurovent Certification Programme for Heat Exchangers applies to products using axial flow fans. The following products are excluded from the Eurovent Certification Programme for Heat Exchangers:

- Products units using centrifugal type fans.
- Units working at 60 Hz

In particular, the following products are also excluded from the certification programme for Dx Air Coolers, Air Cooled Condenser and CO_2 gas cooler:

- Product ranges of Dx Air Coolers with maximum standard capacity SC2 below 1.5 kW
- Product ranges of Air Cooled Condensers with maximum standard capacity under TD1 15 K is below 2.0 kW
- Products ranges of CO_2 gas coolers with maximum standard capacity under SC20 below 2.0 kW

Air coolers for refrigeration

Dry coolers

Air cooled condensers

Certification requirements

- Admission: units selected by Eurovent Certita Certification shall be tested in an Independent Laboratory selected by ECC
- Surveillance procedure: units selected from regular production shall be tested on a yearly basis.

Certified characteristics & tolerances

- Standard capacity –8%
- Fan power input +10% with a minimum of 3 W
- Air volume flow ±10%
- Dimensions and number of fins: Finned length ±0,5%, with a minimum of 5 mm
  - Height of the coil ±5 mm
  - Depth (width) of the coil ±5 mm
  - Total number of fins* ±4%, at least 2 fins
  - Diameter of (expanded) tube outside the coil* ±1 mm

  (*) except for the micro-channels
- Energy ratio R
- Energy class

For Dry Coolers:

- Liquid side pressure drop +20%

For Air Cooled Condensers and Dry Coolers:

- A-weighted sound power level: +2 dB(A)

ECC Reference documents

- Certification manual
- Operational Manual OM-2
- Rating Standard RS 7/C/008

Testing standards

- Thermal Performance EN 328
- Thermal Performance EN 327
- Thermal Performance EN1048
- Acoustics EN 13487

IT Cooling Units (ITCU)

CERTIFY ALL

Scope of certification

The present certification programme covers IT Cooling Units specifically designed and used to regulate air temperature and optionally air humidity of an enclosed space containing critical equipment such as IT equipment or telecommunication equipment.

The IT Cooling technologies considered in the scheme are Computer Room Air Conditioners Direct Expansion (CRAC) and Computer Room Air Conditioner Chilled Water (CRAH). HYBRID technologies pairing these technologies are also covered by the scope as an option.

The IT cooling units must be factory made units designed as a single packaged unit or a single split unit. Units must be 50 Hz frequency units, optionally 60 Hz units can be declared in addition to the 50 Hz. The units can be ducted or non-ducted units, as well on the air return or on the air supply. Floating floors air return or supply are considered as a duct.

Certification requirements

- Annual random selection of units and tests in an independent and accredited laboratory
- Annual production site audit
- Software certification extending the certification from standard functioning conditions to non-standard conditions

Certified characteristics & tolerances

- Net Total Cooling Capacity (kW)
- Net Sensible Cooling Capacity (kW)
- Power input (kW)
- Net EER Energy Efficiency Ratio (%)
- Net SHR Sensible Heat Ratio (%)
- Water pressure drop (Pa)
- Supply Air Flow (m^3/h)
- A-weighted sound power indoor side (dB(A))
- A-weighted sound power radiated by duct (dB(A))
- A-weighted sound power outdoor side (dB(A))

ECC Reference documents

- Certification manual
- OM 23
- RS/C/012

Testing standards

- EN 1451:2018
- EN 1397:2015
- ANSI/ASHRAE Standard 127-2012
- ASHRAE Standard 37
- EN 12102:2013
- EN 16583:2015

Condensing units (CDU)

CERTIFY ALL

Scope of certification

The CDU programme covers air-cooled and water-cooled stationary condensing units designed for low (LT) and/or medium (MT) temperature applications in the field of commercial and industrial refrigeration and operated with the following refrigerants:

- R134a and list of alternatives (MT)
- R290 and list of alternatives (MT and LT)
- R448A and list of alternatives (MT and LT)
- R410A and list of alternatives (MT and LT)
- R744 (MT and LT)

The list of alternative fluids is defined in OM-27.

The scope is limited to the refrigerating capacities comprised between

- 0.1 and 20 kW included (LT)
- 0.2 and 50 kW included (MT)

Certification requirements

The certification programme is based on product performance testing by independent testing laboratory as well as production sites auditing.

Certified performances & acceptance criteria

The product performance testing will enable the verification of the following ratings accuracy:

- Refrigerating capacity [W] .... –10%
- Coefficient of Performance COP at full load .... –10%
- Seasonal Energy Performance Ratio SEPR (EU 2015/1095) for Air Cooled CDU.. –10%
- Sound power level [dB(A)].. +3 dB(A)

ECC Reference documents

- Certification manual
- Operation manual OM-27
- Rating standard RS/14/C/002

Testing standards

- EN 13771-2:2017
- EN 13215:2016+prA1:2018
- ISO 9614-2:1996

▼ Process Cooling & Food Cold Chain

Liquid Chilling Package & Heat Pumps (LCP-HP)

CERTIFY ALL

The historical ESEER, first seasonal efficiency for cooling, created in 2007 by Eurovent Certita Certification, and deeply recognized on the European Market is living its last moments.

With the implementation of the new Ecodesign Regulation No 2016/2281, the year 2018 will be a crucial year for the chillers industry. The European Market has to change its reference efficiency and turn towards SEER and ηsc, the new seasonal efficiencies for cooling mode.

The LCP-HP program has prepared this change since 2 years, testing yearly a significant number of units at the new part load conditions in order to be able to publish from January 2018, certified SEER and ηsc. The SEER has to become the new reference also for the certification program.

Moreover, the scope of the program has been extended for 2018:

- Previously limited to 1500 kW, the water-cooled chillers above 1500 kW can be henceforth certified in option, up to the maximum capacity of the manufacturer laboratory.
- The 4 pipe units can be certified also in option.

Although the program was originally attended for comfort chillers, it is important to remind that process chillers and their SEPR can also be certified as an option.

Lastly, face to these recently regulatory changes for the industry, the certification will be always a strong way to guaranty the reliability of our declared performances to our clients.

Committee chair:
Mr Rafael Berzosas
Water Cooled Chillers Product Manager
Trane Europe, Middle East & Africa

According to the last Ecodesign Regulations (No 811/2013 - No 813/2013 – No 2016/2281) the programme proposes the certification of Seasonal efficiency for heating (*η*s & SCOP) or Chillers & Heat pumps with a design capacity below 70kW, Seasonal efficiency for cooling (*η*sc & SEER) for all comfort chillers and the seasonal energy performance ratio (SEPR) for process chillers.

The programme proposes also:

- From 2019, high ambient conditions for specific markets
- From 2020, the certification of the Selection software covering nonstandard conditions and units with options.

Scope of certification

- This programme applies to standard chillers and hydronic heat pumps used for heating, air conditioning and refrigeration.
- They may operate with any type of compressor (hermetic, semi-hermetic and open) but only electrically driven chillers are included.
- Only refrigerants authorized in EU are considered. Chillers may be air cooled, liquid cooled or evaporative cooled.

Can be certified as an option:

- Heating-only hydronic heat pumps, 60 Hz units, 4-pipe units, Air-cooled units between 600 kW and 2000kW
  Water-cooled units above 1500 kW.
- High ambient conditions for Middle East & India

Certification requirements

Qualification and repetition: a certain number of units will be selected by Eurovent Certita Certification and tested every year, based on the number of ranges and products declared. The selection software will be verified in comparison with the test results.

Certified characteristics & tolerances

- Cooling & heating capacity, EER & COP at standard rating conditions, TE: < –5%, ISEER
- Seasonal efficiencies SCOP & η_s: automatically rerated when Part Load efficiency criteria fails
- Seasonal efficiencies SEER & η_{sc}: automatically rerated when Part Load efficiency criteria fails
- Seasonal efficiency SEPR: automatically rerated when Part Load efficiency criteria fails
- A-weighted sound power level: > +3 dB(A) (> +2 dB(A) for units with *Pdesignh* below 70 kW)
- Water pressure drop: +15%

Testing standards

- Performance testing: EN 14511, SASO 2874
- Seasonal Performance testing: EN 14825, IS 16590
- Sound testing: EN 12102

ECC Reference documents

- Certification manual
- Operational Manual OM-3
- Rating Standard RS 6/C003 – RS 6/C/003A

Process Cooling & Food Cold Chain

Remote Refrigerated Display Cabinets (RDC)

CERTIFY ALL

Remote refrigerated display cabinets (RRDC) are the appliances for selling and displaying chilled and/or frozen foodstuff to be maintained within prescribed temperature limits.

Typically, food and beverage retailers are the direct customers of the refrigeration industry while the supermarket's customers are the end users of food and beverage retailers.

Food and beverage retailers ask for food safety and also for appliances with high-energy efficiency, supermarket's customers ask for food safety. Refrigeration industry has to face the hard challenge of satisfying both needs.

How is it possible to assure that the refrigeration appliances perform accurately and consistently to the reference standards? How is it possible to assure that what is rated by the manufacturer is properly rated?

There is only one way: It is necessary to join a globally recognized and industry respected certification program.

Eurovent Certita Certification program for RRDC is the only certification program in Europe that can assure that performance claims have been independently measured and verified. The factory audits and the product's performances tested in an independent and third-party laboratory make the difference!

Since 2011, Eurovent Certita Certification has also launched a voluntary energy label certification scheme, anticipating what only nowadays EC DG Energy is doing in the framework of Ecodesign and Energy Label Regulations. What better way to rate RRDC's energy consumption and to promote their energy efficiency?

What would you trust more: a self-declaration by the Manufacturer or what an independent, globally recognized and forerunner certification program is able to assure? Which one is better?

Maurizio Dell'Eva
Project manager
EPTA S.p.A. – MILANO (ITALY)

Scope of certification

- 100 basic model groups divided in 5 categories of remote units: semi-verticals and verticals (with doors); multi-deckers; islands; service counters; combi freezers.
- At least two references per basic model group representing 80% of sales shall be declared.
- One Bill of Material for each declared reference.

Certification requirements

- Qualification: sampling and test of one unit & Audit of one factory.
- Repetition test of one unit per brand every 6 months & Annual audit of each factory.

Certified characteristics & tolerances

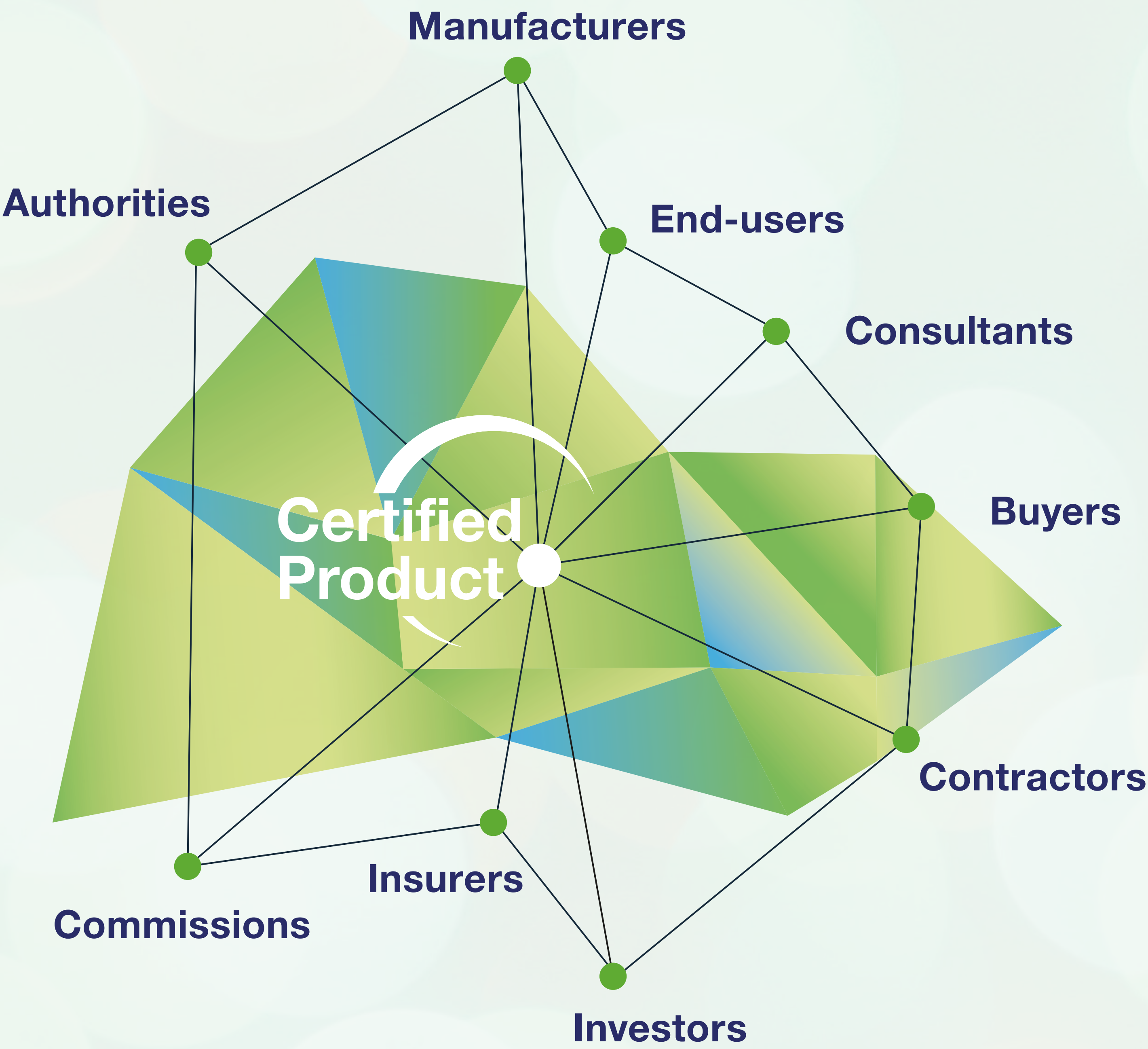
- Warmest and coldest product temp. ±0.5°C
- Refrigeration duty (kW) 10%
- Evaporating temperature –1°C
- Direct elec. Energy Consumption (DEC) +5%
- Refrigeration elec. Energy Cons (REC) +10%
- M-Package T_{class}: ±0.5°C
- Total Display Area (TDA) –3%

ECC Reference documents

- Certification manual
- Operational Manual OM-7
- Rating Standard RS 14/C/001

Testing standards

- EN ISO 29953 and amendments



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Eurovent Certita CERTIFICATION

The ALDREN meeting at the European Parliament “Encouraging investments and accelerating the movements towards a nearly-zero energy non-residential building stock”.

The ALDREN meeting

GIULIA MARENGHI – REHVA PROJECT COMMUNICATION OFFICER

The REHVA calendar of events 2020 has started off with a successful open meeting session organized at the European Parliament. The event showcased the results of **ALDREN**, project funded by the H2020 programme and aiming to promote the **European Common Voluntary Certification Scheme**

for buildings (ECVS) as a valuable tool to foster non-residential building stock renovation. The ALDREN project consortium has invited project stakeholders and policy makers to join the ALDREN experts and the event host, **Slovenian MEP Ljudmila Novak**, in a roundtable event where the outputs of the project have been presented in relation with the **EU political agenda priorities and trends in the field of buildings energy efficiency**, with a special attention to EU Green Deal. Keynote speakers from the European Parliament and the European Commission have shared their views and illustrated insights from the respective institutions and political groups concerning the buildings energy efficiency and Green Deal liaison: amongst those, **MEP Miapetra Kumpula-Natri** (previously shadow rapporteur for S&D on Energy Performance of Building Directive), who reported that the Green Deal will very likely open the EPBD again, and Policy Officer **Pau Garcia Audi** as a representative of **DG Energy**. **REHVA President Frank Hovorka**, who moderated the event roundtable, received feedback from major stakeholders about the project results and their relevance for the **building stock renovation issue**, a crucial aspect to be considered for the set-up of an EU-climate neutral economy not only for its benefits related to the CO_2 emissions reduction but also for its employment and socio-economic development potential. ■

◄ **Presentation of ALDREN project and various inputs on buildings renovation presented by (left to right) Johann Zirngibl (CSTB), moderator Mathieu Rivallain (CSTB), Pau Garcia Audi (DG Energy, European Commission), host MEP Ljudmila Novak (EPP) and MEP Miapetra Kumpula-Natri (S&D).**

▲ **The ALDREN event audience on 22nd January 2020 at the European Parliament.**

▲ **REHVA President Frank Hovorka moderating the meeting roundtable.**

Commissioning was discussed at the workshop TTMD for the first time in Turkey

The annual workshop bringing the professionals together, whose fresh contents have been developed by the Turkish Society of HVAC and Sanitary Engineers, TTMD every year, was held on 15-16 November 2019 at Istanbul Buyukada Anadolu Kulubu with the main theme of "Commissioning". Speakers from different disciplines invited by TTMD Board Members, academics, engineers specialized in the field, architects, property developers and many members of TTMD attended to the workshop organized by the TTMD Commissioning Committee for the first time in Turkey, where those members focused on the theme of "Commissioning".

In his opening speech, Chairman of the Board of Directors of TTMD **Dr. Kemal Gani Bayraktar** stated that they kept on sharing information with the sector and creating value by organizing the 21st of TTMD Annual Workshops which have been held uninterruptedly since 1999 and became a tradition. "TTMD Commissioning Committee and **AICARR, ASHRAE, ISHRAE and REHVA**," which are regarded as international associations, "support the organization of the workshop and are pleased to continue their works in coordination with national and international sectoral associations." Performing opening session were as well, **Ibrahim Biner**, Chairman of the Board of Directors of MTMD and ISKAV Chairman of the Board **Taner Yonet.**

After highlighting the fact that the workshop regarding Commissioning (Cx) was the first to be held in its specific field, TTMD Commissioning Committee Chair **Emre Ozmen** informed the participants about the workshop, objectives and Cx process of cost-benefit analysis by mentioning TTMD Commissioning Committee's scope and their tremendous work. Ozmen shared the historical progress of Cx and its cost-benefit analysis in America through the example project answering the questions of "What can be Cx Process or not?".

Keynote speakers, **Prof. Ubaldo Nocera from AICARR** and **Cormac Ryan from Copilot**, attended the *'Cx Approaches in the world'* session. **Professor Nocera** informed the participants about Cx's planning, pre-design, design, manufacturing, layout and operation after providing basic information and abbreviations on the concept of Cx, also mentioning Cx applications and the process of Cx in Italy. **Ryan** described Cx as a quality-oriented process in project delivery and touched upon COPILOT certification and its partnership with TTMD. He also shared the benefits of Cx by explaining the technical imaging and Full Cx certification processes.

The second session moderated by Emre Ozmen, on *'Cx Approaches in the World'* was attended by **Maija Virta from ISHRAE** who drew attention to the similarities between Turkey and India and shared information about the ISHRAE HVAC Guidebook content after explaining the Cx stages and scenarios. **Erick Melquiond from Eurovent** mentioned trainings they'd like to give and running several trial projects regarding the scope of cooperation with TTMD in Turkey, after pointing out that Copilot worked for adding value to projects as a 3rd party certification value. **Dr. Stefan Plesser**, attending the session live, provided information about the technical progress and the steps taken in certified building performance.

The session *'Commissioning Point of View in Turkey'*, moderated by **Ismet Mura (Aktes Engineering)**, was devided into two panels; the first attended by Cx providers; **Cuneyt Mert (GEPA Group), Oguzhan Ardic (SALT ECC)** and **Ilkin Sevigen (DIPM). Mert** said, "Cx is not a supervisor, but an auditor" and emphasized that the system works correctly and that the importance of making the right progress by placing the bricks on top of each other. **Ardic** pointed out that the biggest customers of these organizations are the state and that they did business with state-owned buildings. He also stated that if Turkey could make the state understand the concept of Cx, the involvement of Cx in public specifications would also improve the private sector. **Ilkin Sevingen** pointed out that he worked for many projects in both *domestic* and foreign yet in Turkey in the past, Cx was excluded

from the specifications in some projects of the public and therefore many important opportunities missed years ago. The second panel, seated by project owners and investors; **Hakan Guneri (MR Business Services Consulting), Burak Riza Toraman (Ronasans Real Estate Investment)** and **Mert Ayisik (Eczacibasi Property Development and Investment)** concluded that it is important institutions like TTMD could move forward with Cx specification and that the approval from accredited institutions is necessary.

The last session of the TTMD Commissioning Workshop was presented by **Prof. Walter Grondzik from ASHRAE** as a keynote speaker. Grondzik, first summarizing the historical process and developments of ASHRAE's Commissioning, he shared the prepared Guideline books and Cx applications in ordinary and high-performance buildings. Grondzik pointed out the importance of determining the owner's requests processes could be skipped until the construction stage starts, and a team needed during the designing stage. After addressing the benefits to be achieved with Cx, Grondzik informed the participants about the current state of the regulations and standards prepared by ASHRAE in the US.

Afterwards, workshop participants were divided into groups and worked on the Turkish terminology, dissemination, tendering and implementation of the Commissioning concept.

The closing speech of the workshop was delivered by Dr. Kemal Gani Bayraktar, who thanked to **TTMD Commissioning Committee, AICARR, ASHRAE, ISHRAE** and **REHVA** respectively for their contribution to the workshop and to Workshop Sponsors **Alarko Carrier, Danfoss, GEPA, Grundfos, Boreas, Eurovent** and **Form** to all participants. ■

SUCCESS STORY
PROMENADE GALLERIES, LINZ (AT)

Special protection for something special.

Belimo Safety Solutions are making a significant contribution to the fire protection of a special building.

At the centre of Linz, Austria, the Promenade Galleries are now located on an area of 12,000 m^2. Here, heritage-protected old buildings are skilfully combined with modern architecture, which offers a contemporary, urban living and working style as well as exclusive housing in all user spaces. For the Promenade Galleries project, six Linz companies have joined forces under the leadership of the electrical installation company ETECH as a joint venture for the entire technical building installation. In addition to the electrical installations, comprehensive networking and control technology, fire protection was also a focal point at the start of planning. In addition to European standards and directives, Austria also complies with state-specific regulations, making it one of the most progressive countries in the world in terms of fire protection. In all buildings with installed fire alarm systems, motorised fire dampers are mandatory and state of the art.

TYPE OF BUILDING
Multifunctional

PROJECT
Mixed use (offices, apartments, hotel, commercial, event hall, underground car park)

TRADE
Fire protection

PRODUCTS
Fire damper actuators
Smoke control damper actuators

Saving lives and protecting tangible assets in case of fire.

The owners of the Promenade Galleries even went one step further: "All fire damper actuators have to close the dampers in the evening as soon as the ventilation system is switched off so that fire and smoke cannot spread through the ventilation system in case of emergency", says Norbert Kaimberger, Project Manager and Authorised Signatory of ETECH. At the same time, regular closing and opening of the fire dampers is logged as a function test of operational readiness, which makes a decisive contribution to the safety of the building.

A new district in the heart of Linz.

The mixed use of the building is a challenge

Even at the beginning of the Promenade Galleries project, various specialist authorities were dealing with the different aspects of the trades and optimal networking of all fire protection systems. Coordinated planning early on was therefore of the utmost importance.

In order to uncover network weaknesses and deficiencies in fire protection installations, an integral test was carried out. This cross-system and system-wide test plays a central role when it comes to the safety of buildings and people. Safety-relevant plants and systems are checked with regards to their functions in the overall system, so that cross-trade safety functions perform reliably in normal situations and, above all, in case of an event.

A total of 1,720 m^2 of shopping space divided into eleven storesis available.

Taking account of different operating times

In order to prevent the spread of smoke and fire through ducts, the corresponding fire dampers close as a precaution in the parts of the building that are not being used at that time. The needs-based control of the total of 500 motorised fire dampers allows the different usage times in the building to be taken into account. For example, the operating times of the Oberösterreichische Nachrichten OÖN newpaper office significantly differ from those of other offices in the same ventilation area.

More than 100 journalists work in the newsroom of the Oberösterreichischen Nachrichten.

A central location and quiet surroundings are not necessarily a contradiction in terms.

Safetyoriented fire-protection concept

The fire protection concept of a building defines, among other things, safety targets. The greatest threat to humans and animals in case of fire is toxic smoke development. In order to ensure that escape and rescue routes remain smoke-free, smoke extraction devices are installed in the Promenade Galleries buildings. As soon as the fire alarm system detects smoke, extraction devices trigger automatically and the fire brigade is simultaneously notified.

In addition to the motorised fire dampers, there are six smoke control zones – three in the underground car park, the restaurant and the shopping area respectively. A central fire control system is responsible for the control and monitoring of 500 motorised fire dampers, 40 motorised smoke control dampers and six smoke extraction fans. This system automatically and periodically checks the function of all connected dampers. In addition, the saved test protocols support the technical staff during their regular inspections. Using the system, safety scenarios can be easily and flexibly adapted to new conditions, for example, when rooms are converted.

Proven products and unique service

The partnership with Belimo was clear for Project Manager Norbert Kaimberger from ETECH very early on. "We are now implementing the second project together with Belimo. The first was the construction of our new headquarters. Collaborating with Belimo work very well then like it does today", says Kaimberger. "If we have any questions, we receive an answer immediately or a competent Belimo specialist will visit us at the construction site. This service and proven products make Belimo the ideal partner".

Those responsible for the project from left to right: Martin Kaar (ETECH), Jürgen Obmauer (Belimo Austria), Paolo Cuturi (Project manager), Stefan Buchli (Belimo Switzerland) and Norbert Kaimberger (ETECH).

IMPRESSIVE ADVANTAGES OF BELIMO SAFETY ACTUATORS FOR FIRE DAMPERS

- Maximum safety through reliable closing and holding of the damper in the safety position.
- Possibility to control scenarios by means of intelligent controls and connection of sensors.
- Infrastructure protection in the event of a power failure by automatic closing of the fire damper using the spring energy of the actuator.
- Reduced maintenance and operating costs.

BENEFITS AND ADVANTAGES OF BELIMO MOTORISED SMOKE CONTROL DAMPERS

- Smoke control dampers are brought into the defined safety position in case of fire and maintain it reliably.
- Escape and emergency routes remain low smoke areas.
- The flashover is delayed or even prevented.
- Fire fighting and rescue work is made significantly easier.
- The building structure and tangible assets are protected.

All inclusive.

Belimo as a global market leader develops innovative solutions for the controlling of heating, ventilation and air-conditioning systems. Actuators, valves and sensors represent our core business.

Always focusing on customer added value, we deliver more than only products. We offer you the complete product range for the regulation and control of HVAC systems from a single source. At the same time, we rely on tested Swiss quality with a five-year warranty. Our worldwide representatives in over 80 countries guarantee short delivery times and comprehensive support through the entire product life. Belimo does indeed include everything.

The “small” Belimo devices have a big impact on comfort, energy efficiency, safety, installation and maintenance.
In short: Small devices, big impact.

- 5-year warranty
- On site around the globe
- Complete product range
- Tested quality
- Short delivery times
- Comprehensive support

BELIMO Automation AG
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Fon + 41 43 843 62 63, info@belimo.ch, www.belimo.com

EN – 12.2019 – Subject to technical modifications

REHVA

Federation of European Heating, Ventilation and Air Conditioning Associations

MEMBERS

Network of 27 European HVAC Associations joining 120 000 professionals

REHVA Office: Rue Washington 40, 1050 Brussels - Belgium

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

Send information of your event to Ms Giulia Marenghi gm@rehva.eu

Exhibitions, Conferences and Seminars in 2020 & 2021

Exhibitions 2020

27-29 February 2020	ACREX	New Delhi, India	http://acrex.in/home
8-13 March 2020	Light+Building 2020	Frankfurt, Germany	https://light-building.messefrankfurt.com/frankfurt/en.html
10-13 March 2020	SHK Essen	Essen,Germany	https://www.shkessen.de/branchentreff/
17-20 March 2020	MCE - Mostra Convegno Expocomfort	Milan, Italy	https://www.mcexpocomfort.it/

Conferences and Seminars 2020

1-5 Feb 2020	2020 ASHRAE Winter Conference and AHR Expo	Orlando, Florida	https://www.ashrae.org/conferences/2020-winter-conference-orlando
4-6 March 2020	World Sustainable Energy Days	Wels, Austria	https://www.wsed.at/en/world-sustainable-energy-days.html
12 March 2020	REHVA Seminar at Light+Building	Frankfurt, Germany	https://www.rehva.eu/events/details/rehva-seminar-at-light-building
20 March 2020	REHVA-AiCARR Seminar on Buildings Digitalization	Milan, Italy	https://www.rehva.eu/events/details/rehva-aicarr-seminar-on-buildings-digitalization
1 April 2020	Danvak Dagen 2020	Copenhagen, Denmark	https://danvak.dk/produkt/danvakdagen2020/
1-3 April 2020	14th TTMD Symposium	Istanbul, Turkey	http://www.ttmd.org.tr/en/activities/international-symposium-on-installation-in-construction
16-17 April 2020	CIBSE Symposium	Glasgow, UK	https://www.cibse.org/technical-symposium-2020
12-14 May 2020	13th IEA Heat Pump Conference	Jeju, Korea	http://hpc2020.org/
15-19 May 2020	REHVA Annual Meeting + ClimaMed 2020	Lisbon , Portugal	http://www.climamed.org/en
14-17 June 2020	NSB 2020 Building Physics Conference	Tallinn, Estonia	www.nsb2020.org/
14-17 June 2020	Roomvent 2020	Torino, Italy	http://roomvent2020.org/
20-24 July 2020	Indoor Air 2020	Seoul, Korea	www.indoorair2020.org
14-16 Sept 2020	AIVC Conference	Athens, Greece	https://www.aivc.org/event/14-16-september-2020-conference-athens-41st-aivc-conference
13-14 October 2020	BuildSim Nordic 2020	Oslo, Norway	https://buildsimnordic2020.ibpsa-nordic.org/our-travels/
13-15 October 2020	Chillventa 2020	Nurnberg, Germany	https://www.chillventa.de/en
29-31 October 2020	Refcold	Delhi, India	https://www.refcoldindia.com/home

Conferences and Seminars 2021

17-21 April 2021	Cold Climate	Tallin, Estonia	https://www.scanvac.eu/events.html
29 Sept-2 Oct 2021	ISK Sodex 2021	Istanbul, Turkey	http://www.sodex.com.tr/

Light + Building 2020 – all set for success with the latest topics and 2,700 exhibitors

'Connecting. Pioneering. Fascinating'*. Such is the tagline of the upcoming Light + Building in Frankfurt am Main, providing the central theme that runs through this leading world trade fair, to be launched from 08 to 13 March 2020. All the market leaders have signed up and we are currently expecting some 2,700 exhibitors, who will be presenting their world firsts in the fields of lighting, electrical and electronic engineering, home and building automation and security technology.

Centre stage at Light + Building will be some of the major drivers in the sector: topics such as 'Smart Urban' and 'Functional Aesthetics in Lighting and Luminaire Design'. 'Smart Urban' encompasses topics relating to intelligent infrastructure in urban districts. At the same time, a key element in this headline theme is the interlinking of home and work, as the smallest unit of space that people inhabit in their private and working lives, on the one hand, and the city as the largest unit on the other. This includes things like the location of production sites, digital charging infrastructure to provide for e-mobility and dynamic street lighting, as well as surveillance networks and intelligent parking systems.

A key area in the 'Lighting' product group is the presentation of the latest trends in design and technology on the lighting market. Digitalisation in the lighting sector continues to throw the focus ever more closely on human beings themselves and their individual needs. For that reason, too, 'Functional Aesthetics' is one of the beacon issues of the current season. This is all about the deliberate avoidance of ornamental design features and a focus on the specific requirements for lighting in each individual case. Subtly designed lamps, which emit variable light spectra for various, different scenarios – controlled, in part, by the smart building itself, are increasingly being employed in educational, work and leisure contexts. Thus, for example, windowless rooms are transformed into spaces that are flooded with light. Adaptive light wavelengths serve to excite or dampen natural biorhythms - depending on requirements.

At this, the world's largest trade fair for lighting and building services engineering, the industry will be showcasing its intelligent and networked solutions, ground-breaking technologies and up-to-the-minute design trends, which all contribute to improving both the economic efficiency of buildings and the comfort, convenience and security requirements of the users.

Light + Building is a trade fair of innovation and encompasses all the electronically controlled building services; with the unique breadth and depth of its product spectrum, it promotes integrated building planning – from the 'smart home' to the 'smart building' and the 'smart city'.

Electrical engineering, together with disciplines relating to home and building automation, all have a key role to play in the construction and operation of the intelligent, networked building. The crucial factor is the interoperability of the systems involved. So that, at Light + Building, you find electro-technical solutions in the context of other fields such as lighting, home and building automation and security technology. Here, the industry will be exhibiting solutions and technologies aimed as much at low energy usage and modern safety and security requirements as at opportunities for individual design and high levels of convenience and comfort.

In addition to the broad range of exhibitors' products on offer, Light + Building scores highly with its varied complementary programme, which is grouped under the headings of 'Emotion', 'Skills', 'Career' and 'Selection'. There are specific topics on offer for the entire spectrum of trade visitors, including architects, engineers, planners, interior architects, designers, tradespeople, retailers and representatives from industry – ranging from special exhibitions and demonstrations to specialist lectures and trend presentations.

Further up-to-date information relating to Light + Building and its complementary programme, as well as travel arrangements and tickets can be found at: www.light-building.com.

Visit Light + Building on the following social networks, too:

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www.light-building.com/youtube

* https://light-building.messefrankfurt.com/frankfurt/de/themen-events/top-themen.html

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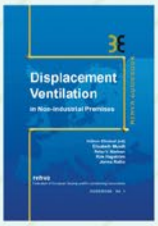
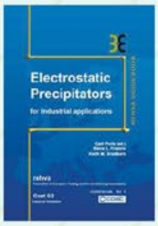
EUROPEAN GUIDEBOOKS



No.01: DISPLACEMENT VENTILATION IN NON-INDUSTRIAL PREMISES

No.02: VENTILATION EFFECTIVENESS



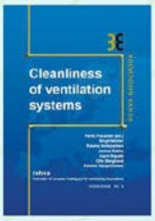
No.03: ELECTROSTATIC PRECIPITATORS FOR INDUSTRIAL APPLICATIONS

No.04: VENTILATION AND SMOKING

No.05: CHILLED BEAM APPLICATION GUIDEBOOK

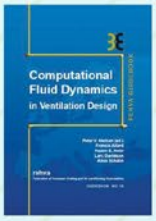
No.06: INDOOR CLIMATE AND PRODUCTIVITY IN OFFICES

No.07: LOW TEMPERATURE HEATING AND HIGH TEMPERATURE COOLING

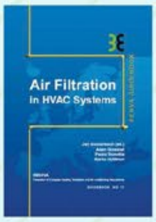


No.08: CLEANLINESS OF VENTILATION SYSTEM

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



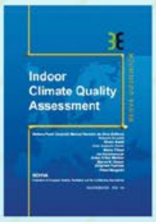
No.10: COMPUTATIONAL FLUID DYNAMICS IN VENTILATION DESIGN



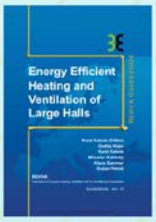
No.11: AIR FILTRATION IN HVAC SYSTEMS

No.12: SOLAR SHADING

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

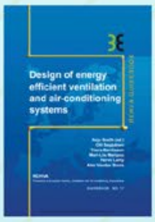


No.14: INDOOR CLIMATE QUALITY ASSESSMENT

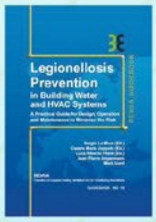


No.15: ENERGY EFFICIENT HEATING AND VENTILATION OF LARGE HALLS

No.16: HVAC IN SUSTAINABLE OFFICE BUILDINGS



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



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

No.19: MIXING VENTILATION

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

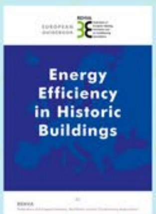
No.21: ACTIVE AND PASSIVE BEAM APPLICATION DESIGN GUIDE

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

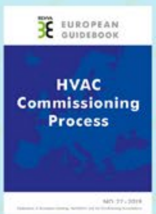
No.23: DISPLACEMENT VENTILATION

No.24: FIRE SAFETY IN BUILDINGS

No.25: RESIDENTIAL HEAT RECOVERY VENTILATION



No.26: ENERGY EFFICIENCY IN HISTORIC BUILDINGS



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

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

No.29: QUALITY MANAGEMENT FOR BUILDINGS