From the Guest Editor

ENERGY EFFICIENCY IN BUILDINGS
Research Perspectives and Trends

by

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The 1st International Conference on Buildings, Energy, Systems, and Technology (BEST 2016), was held in Belgrade, Serbia, on November 2-4,2016.
This conference was an opportunity to bring together experts with different skills around the theme of building performance. It covered different aspects (technology, energy, environment, and economy), different scales (from the urban to the building level, including the built environment up to the single technical building systems), and different phases of the building process (from urban planning to building design, up to construction and management).
This Special issue contains extended versions of some selected papers presented at BEST 2016, which went through a blind peer review of international experts.
The present Editorial introduces the topics of the BEST 2016 and the contents of this Special issue. The focus of the Editorial is the theme of energy efficiency improvement in buildings; it provides an overview of state-of-the-art and of the legislation framework, and a discussion on research perspectives and trends.

Overview and legislation framework

According to IEA [1] the global buildings sector is responsible for 30% of final energy consumption and more than 55% of global electricity demand. Progress towards sustainable buildings is advancing, but improvements are still not keeping up with a growing buildings sector and rising demand for energy services. The buildings and building construction sectors are responsible together for 36% of global final energy consumption and nearly 40% of total direct and indirect CO_2 emissions, fig. 1. Energy demand from buildings and buildings construction continues to rise, driven by improved access to energy in developing countries, greater ownership and use of energy-consuming devices, and rapid growth in global buildings floor area, at nearly 3% per year.

Moving to the EU, buildings are responsible for approximately 40% of energy consumption and 36% of CO_2 emissions. Currently, about 35% of the EU's buildings are over 50 years old and almost 75% of the building stock is energy inefficient, while only 0.4-1.2% of the building stock is renovated each year. Therefore, more renovation of existing buildings has the

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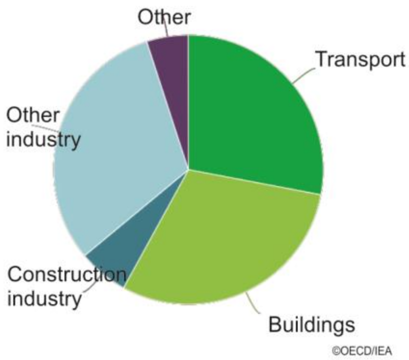

Figure 1. Global final energy consumption by sector (source: Energy Technology Perspectives, IEA, 2017)

potential to lead to significant energy savings – potentially reducing the EU's total energy consumption by 5-6% and lowering CO_2 emissions by about 5%.

The European Union is committed to developing a sustainable, competitive, secure and decarbonised energy system. The Energy Union and the Energy and Climate Policy Framework for 2030 establish ambitious Union commitments to reduce GHG emissions further by at least 40% by 2030 as compared with 1990, to increase the proportion of renewable energy consumed, to make energy savings in accordance with Union level ambitions, and to improve Europe's energy security, competitiveness and sustainability.

The 2010 Energy Performance of Buildings Directive (EPBD recast) [2] and the 2012 Energy Efficiency Directive [3] are the EU's main legislative instruments promoting the improvement of the energy performance of buildings within the EU and providing a stable environment for investment decisions. Directive 2018/844/EU [4], amending the Energy Performance of Buildings Directive, was published on June 19th, 2018. The revised provisions introduce targeted amendments aimed at accelerating the cost-effective renovation of existing buildings, with the vision of a decarbonised building stock by 2050 and the mobilisation of investments. The revision of the EPBD recast also supports electromobility infrastructure deployment in buildings' car parks and introduces new provisions to enhance smart technologies and technical building systems, including automation.

Discussion

Taking a cue from the overview presented above, we could ask ourselves the three following questions: Why is energy efficiency in buildings so important? How is it pursued and should be pursued in the future? Who should drive the process?

The answer to the first question is quite simple; there are over 7 billion people in world, and each of them lives or works in a built environment of some sort. Therefore, the researches and the outcomes concerning the energy efficiency of buildings can be profitable for an incredible number of beneficiaries. This obvious consideration is, on the other hand, supported by the aforementioned statistics according which for the developed countries the building sector represents 40% of the overall energy demand.

Coming to the second question, about how has been energy efficiency pursued and how should it be pursued in the future, it is evident that a paradigm shift is taking place.

In the last decades, energy crises, increasing price of energy, concerns about air pollutions and the global warming forced to a stricter control of the energy performance of the built environment. All measures and the innovation have been mainly based on the so-called *energy conservation approach*, focusing on the energy demand for space heating, aiming at limiting the thermal losses through the envelope and maximizing the solar gains.

The paradigm shift requires overcoming the dogma for which the building components are something static, *i. e.* not changing its features, behaviour and functions. It is necessary to start working *with the climate* and not *against it*, in order to exploit the natural resources and the opportunities offered by local climate in an effective way. Moreover, it is necessary to include, involve, share, and systematize buildings and people. The emerging notions of *re-*

generative/integrative design and *net-positive development* overcome the traditional green building theories based on the mitigation of the global and local depletion, and environmental degradation. The emerging trends for future development include adaptability, multi-functionality, and integration of the building elements, fig. 2, a holistic approach, inclusion, involvement and sharing between buildings and users, and working at various scales, from component to systems, buildings, districts, cities, territory.

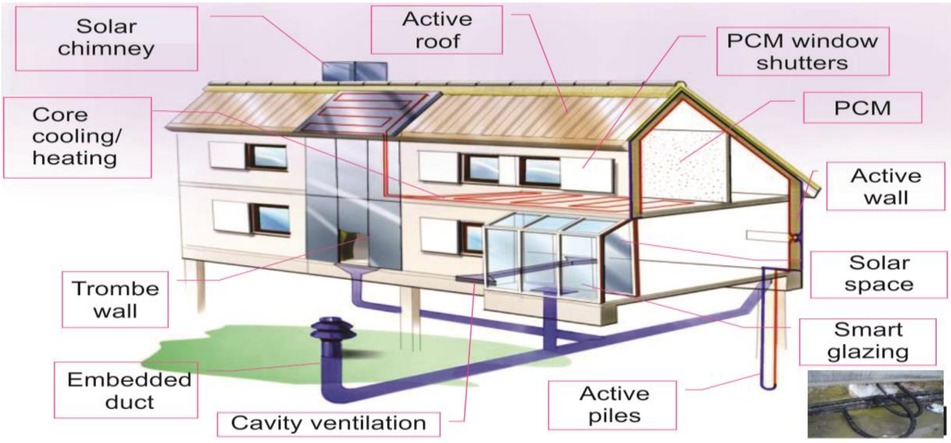

Figure 2. Example of adaptability, multi-functionality and integration in buildings (source: IEA, Annex 44 – *Integrating Environmentally Responsive Elements in Buildings*)

A high efficiency process is realised when all the stages of the process are approached in a holistic way, not only during the concept and the design phases, but also during construction and operation, fig. 3.

Figure 3. Holistic approach (source: M. Filippi, "Building Physics Challenges in Construction, Industry and Education", IBPC 2015)

During the design phase it becomes important a *collaborative and integrative approach*, including a *common language* for sharing information, innovative practices and tools, and user-friendly graphical representations to facilitate the comprehension and discussion within the design team. There is need of developing common tools and practices for integrated performance evaluation, for technical information storage, economic evaluation, *etc*. A multi-criteria optimization approach allows meeting all design constraints (comfort, health and wellbeing, acoustics, air quality, *etc*.) without resorting to energy consuming building services installations.

During the construction phase, the key point is guaranteeing an actual performance as expected in the design phase; that implies the execution of measurements and the calibration of predicting models as to close the gap between expected and actual performance.

During the operation phase, the post occupancy evaluation (POE) allows to evaluate the building quality in operation, meanwhile allowing multiple feedback loops on quality of design and construction between final users, designers and builders. The POE draw on an extensive use of qualitative and quantitative tools and methods, including audit (power acoustics, daylighting …), long-term monitoring (energy, thermal environment …), and occupant surveys (indoor environmental quality, space layout …). Involvement of the user through energy labels and peer comparison feedbacks appears as an effective way for improving the building performance. A conscious behavior can yield a significant reduction of energy consumption.

Finally, sharing the needs besides the resources brings to a building which can been seen either as a consumer or as a producer, depending on the balance between energy need and energy production; that brings to the new concept of energy prosumer.

Coming to the third question about the drivers of the process, we could ask ourselves which is the best profile for a researcher in the field of energy efficiency and from which pathway this professional figure should come. It is necessary to take into account the complexity and the multiplicity of factors, systems and processes that come into play, such as new materials and technologies, system analysis, building simulation, optimization, data analysis, socio-economic and psychological aspects, big-data, monitoring, and so on. The conclusion is that a multidisciplinary approach is the potentially optimal and promising pathway to achieve the desired goals.

Research perspectives

The EU's energy strategy is strongly oriented towards the improvement of energy efficiency and CO_2 emissions reduction. The refurbishment of the existing building stock is considered as an important opportunity.

In this context, recent international research activities have been oriented to the development of new methods and tools for planners, designers and managers, and to foster the market penetration of the most advanced technologies.

The challenges in EU construction industry go through concepts like deep renovation, nearly zero-energy buildings, sustainable buildings, renewable energy, fig. 4. These concepts reflect in many research programs financed by the European Commission.

Figure 4. Challenges in the construction industry

Under the Energy-efficient Buildings (EeB), a partnership between the European Commission and the private sector, it is published the multiannual EeB roadmap [5], which is the document containing the research and innovation priorities of the private sector. The Roadmap 2014-20 established the following key research areas: Technologies for acceleration of building stock renovation, Interactive and sustainable buildings embedded at district and city scale, and Ensuring energy performance during service life. Specific objectives concern development, integration and demonstration of new technologies in the following aspects.

– *Innovative construction* (*e. g*. building envelope, multi-target design, materials and pre-fabrication methods, approaches adapted to public buildings or commercial/private-housing ones).
– Systemic, cost-effective, mass-customized, high-performing, and minimally invasive *building-retrofitting solutions* integrating innovative energy equipment and storage.
– *Interactive sustainable buildings* for energy neutrality/positivity in a block of buildings.
– *Performance monitoring tools* to ensure energy efficiency during the service life, by providing the full performance predicted at the design phase and long-lasting quality to the end-user, in combination with durable components.

As regards the International Energy Agency, it is worthwhile to mention the Energy in Buildings and Communities Programme, which enables international collaborative R&D projects on high priority themes such as: integrated planning and building design, building energy systems, building envelope, community scale methods, and real building energy use.

Contents of the Special issue

The contents of this Special Issue reflect the multiplicity of research themes, scales and approaches, as previously described. It includes 26 articles, besides the present Editorial; these articles are structured in four main sections: *Sustainable buildings*, *urban climate and environment*, *Energy performance assessment of buildings*, *Operational performance and management of buildings*, and *Economics, financing and smart buildings*.

In the section on *Sustainable buildings, urban climate and environment*, some papers deal with criteria for environmental, sustainable and resilient design in different climates and at different scales. The issues of urban heat island and of solar radiation are also addressed. Other papers focus on specific technologies, such as green façades.

The second section on *Energy performance assessment of buildings* mainly focuses on the use and validation of simplified methods to predict solar gains, indoor temperature and energy demand. The potentialities of use of daylight and thermal mass are also discussed.

The third section on *Operational performance and management of buildings* investigates the design and actual operation of different kinds of technical building systems, ranging from photovoltaic systems to district heating, from green roofs to thermal collectors. Decarbonisation scenarios and large scale potentialities of various technologies are also addressed.

The last section on *Economics, financing and smart buildings* is focused on the operational assessment of building stocks with a view to development strategies and to public buildings refurbishment.

References

[1] ***, International Energy Agency website, www.iea.org/buildings/
[2] ***, Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)

[3] ***, Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC
[4] ***, Directive 2018/844/EU of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency
[5] ***, Multi-annual roadmap for the contractual PPP on Energy efficient Buildings under Horizon 2020, December 2013.

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