Indoor environmental quality as a mean to catalyse the acceptance and implementation of the major new EPBD provisions

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Abstract

Indoor Environmental Quality (IEQ) has a direct effect on health, comfort, wellbeing and productivity. Considering that people spend 90 % of their time indoors, it is crucial that building legislation ensures sufficient levels of IEQ which can lead to healthy and comfortable indoor environments. Not addressing these inadequacies will be a missed opportunity and come with huge societal costs. This study summarises the major opportunities to reflect the importance of IEQ in national and EU legal framework. The paper discusses how the aspects of IEQ, and indicators for the evaluation of the indoor environment can be integrated in relevant legislations. The current EU legislations disclose several weaknesses as they do not sufficiently provide concrete details on how to address and achieve acceptable IEQ. The real opportunity now lies at national level, and it is therefore critical to develop approaches for the integration of IEQ in national policy frameworks. To achieve this, four areas of opportunities are identified: (i) Long-term Renovation Strategies, (ii) Energy Performance Certificate (EPC), (iii) Smart readiness Indicator and (iv) Compliance and Quality control measures.

Introduction

A great number of scientific studies shows that the indoor environment has a significant influence on people's health and comfort [1] [2] [3] [4] [5]. Considering that people spend approximately 90 % of their time indoors [2], it is crucial that building legislation ensures sufficient levels of IEQ to promote healthy and comfortable indoor environments.

Indoor air quality, thermal and acoustic comfort and adequate levels of lighting are the major determinants of the indoor environmental quality (IEQ). Several scientific studies have indicated that several aspects of the IEQ (e.g. indoor air pollutants) have a direct effect on the health, comfort, wellbeing and productivity of the building's occupants [2].

Effective building regulation needs to sufficiently integrate the IEQ perspective. The building regulatory framework covering energy aspects is designed to continuously improve the energy performance of the building stock and reduce CO_2 emissions, while at the same time should ensure good IEQ. The recently revised Energy Performance of Buildings Directive (EPBD, 2018/844, Annex I), states that energy performance requirements should optimise health, indoor air quality and comfort levels [6]. However, the directive does not address how to ensure healthy and comfortable homes for EU citizens. Member States now need to adopt building regulations that reduce the climate footprint of the building stock and empower occupants with a healthy and prosperous environment.

This report defines an approach on how aspects of IEQ could be reflected in the implementation of the European regulatory framework on the energy performance of buildings. The main objective of this study is to identify opportunities to integrate IEQ in the implementation of the European legislative framework. The elements of the EPBD that are identified as oppor-

tunities for the integration of IEQ in national regulations are initially introduced. The potential options of including IEQ within these opportunities are then developed. Finally, the main recommendations are briefly listed.

Building regulations

While the EPBD (2010/31/EU, Art. 1, Art. 4, Annex I) acknowledged 'indoor climate' and clearly mentioned the interdependent relationship between energy efficiency and indoor climate, it did not include clear requirements and clarifications on indoor climate indicators, nor how they can be achieved. In the recently revised EPBD (2018/844, Art. 1, Art. 4, Art. 7, Annex I and IA), elements of health, comfort, indoor air quality and indoor climate conditions are present; however, still details related to their achievement are still not addressed.

For buildings undergoing major renovations, Member States are expected to address healthy indoor climate conditions, while energy needs should be calculated aiming to optimise health, indoor air quality and comfort levels (EPBD 2018/844, Art. 7). On the general framework for rating the smart readiness of buildings, the Commission will define a smart readiness indicator and develop a methodology which, amongst other things, will take into account benefits for the indoor climate conditions (EPBD 2018/844, Annex IA). One key aspect to be considered is the ability of the building to adapt its operational mode in response to occupant needs by maintaining healthy indoor climate conditions. The methodology of the EPBD (2018/844) should further consider the interoperability between systems including smart meters, self-regulating devices for indoor temperature, indoor air quality sensors and ventilation. Since the EU legislation falls short on information related to the achievement of a satisfactory IEQ, it is important to propose evidence-based future improvements.

Reflecting IEQ in EU and national policies

OPPORTUNITIES FOR THE INTEGRATION OF IEQ IN NATIONAL REGULATIONS

Considering the gaps in the existing European building regulations, there are more opportunities at national level, so it is necessary to develop approaches for the integration of IEQ in national policy frameworks. To do so, four main opportunities are identified: (i) long-term renovation strategies (EPBD 2018/844: Art. 2a (g), (c)); (ii) Energy Performance Certificates (EPCs) (EPBD 2018/844: Art. 19, Art. 20, 2); (iii) smart readiness indicator (EPBD 2018/844: Annex IA); and (iv) compliance and quality control measures (EPBD 2018/844: Art. 14 and Art. 15) (Figure 1).

Long-term renovation strategies

The objective of a long-term renovation strategy is 'to support the renovation of the national stock of residential and non-residential buildings, both public and private, into a highly energy efficient and decarbonised building stock by 2050, facilitating the cost-effective transformation of existing buildings into nearly-zero energy buildings' [6]. This is an obligation that governments shall follow and require a national adaptation (e.g. overview of the national building stock, identification of cost-effective ways of renovation based on climate etc.).

In new or retrofitted buildings, not taking IEQ into account can result, for example, in very airtight constructions with insufficient ventilation. This can lead to reduced amounts of 'fresh' air entering a building or to the increase of indoor air pollutants, which also has implications on health and wellbeing. Therefore, when defining renovation strategies, the objective should be to reduce the energy consumption of buildings without compromising comfort, health and wellbeing of people living inside them, in a way that optimises both building and societal costs [7]. It should however be pointed out that a building's main purpose is to provide good IEQ and this has to be managed with Paris-compatible amounts of energy/emissions.

Energy Performance Certificates

Energy Performance Certificates (EPCs) are an integral part of the EPBD and constitute an important instrument to enhance energy performance of buildings, which Article 19 of the recently revised EPBD says should be further improved [8]. The main objective of the EPC is to serve as an information tool for future building owners, tenants, occupiers and real estate actors (Art. 20, 2). Therefore, EPCs can be a powerful market tool to create demand for energy efficiency in buildings by targeting improvements such as a decision-making criterion in real-estate transactions, and by providing recommendations for the cost-effective or cost-optimal upgrading of the energy performance [8]. EPCs are adopted by member states and adjusted at national level based on the national legislation context (e.g. standardised vs tailor made recommendations).

In order not to compromise the health and wellbeing of building occupants, these recommendations on renovation opportunities should go side by side with IEQ aspects. EPCs are among the most important sources of information on the

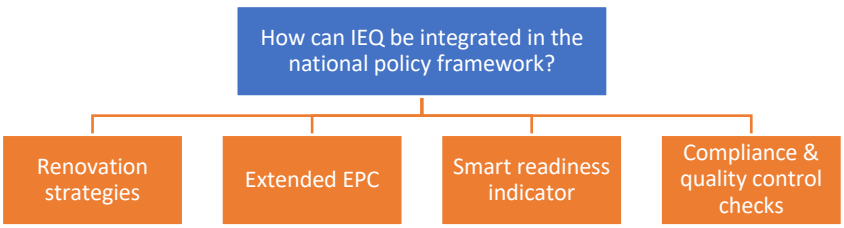

Figure 1. Opportunities for the integration of IEQ in national regulations.

energy performance of the EU's building stock and have the potential to become effective instruments to track buildings' energy performance and an overall characterisation of the IEQ.

Smart readiness indicator

According to a definition by the Buildings Performance Institute Europe (BPIE) a smart building is very energy efficient and covers its low energy demand to a large extent by onsite or district-level renewable energy sources [9]. A smart building (i) stabilises and drives a faster decarbonisation of the energy system through energy storage and demand-side flexibility; (ii) empowers its users and occupants with control over the energy flows; and (iii) recognises and reacts to users' and occupants' needs in terms of comfort, health, indoor air quality and safety as well as operational requirements [9]. As part of the revised EPBD in Annex Ia, the European Commission will define a smart readiness indicator and establish a methodology which, among other things, takes into account benefits for the indoor climate conditions. To give value to smart buildings, the indicator must pull the market in the direction of smarter buildings, while also providing meaningful information on the potential of the building to prospective new tenants or buyers [9].

Aiming to provide technical support on the definition and provision of a smart readiness indicator for buildings, a study was recently conducted by a consortium of VITO, Waide Strategic Efficiency, Ecofys and OFFIS and was commissioned and supervised by DG Energy. The proposed methodology is based on the inspection of 'smart ready services' that are present in a building. A functionality that has been taken into account when defining the smart ready services relevant to IEQ, is 'The ability to adapt its operation mode in response to the needs of the occupant paying due attention to the availability of user-friendliness, maintaining healthy indoor climate conditions and ability to report on energy use' [10]. The report further mentions that a smart ready service can provide to users and the grid, several impacts of services such as the ones on well-being and health of occupants. For example, smarter controls can deliver a better IEQ compared to traditional controls, and therefore raise occupant's well-being [10]. A second technical study was launched at the end of December 2018 aiming to provide further technical input for the development of the smart readiness indicator scheme.

Taking into account the first technical study for the smart readiness indicator, it seems that there will not be significant modifications on national level. However, considering the impact criterion on well-being and health referring to strict basic requirements on the impacts of services on the health and well-being of occupants, these requirements could require a national adaptation.

Compliance and quality control

Mandatory inspections, as seen in Articles 14 and 15 of the revised EPBD should be implemented by Member States. Compliance should be regularly assessed during the design stage, pre- and post-occupancy and pre- and post-renovation of the building, while quality control checks of the heating, cooling and ventilation systems should take place to ensure the long-term operating performance of buildings in relation to the IEQ requirements.

HOW CAN IEQ BE INTEGRATED IN THE IDENTIFIED OPPORTUNITIES?

Long-term renovation strategies

Policies within the building renovation strategies should ensure that IEQ is taken into account by also considering supporting instruments (e.g. Building Renovation Passports) which give Member States the flexibility to decide on which segment of the building sector they want to tackle first and how [7]. In addition, while supporting some renovation strategies, Member States should highlight the impact that specific renovation measures should have on both the energy performance of the building and the IEQ. Within this lies also a challenge in raising awareness of the importance and benefits of good IEQ.

The long-term renovation strategies developed by Member States are an opportunity to improve the quality of life of citizens by integrating IEQ aspects [11]. In the last decade, there has been an increasing trend of scientific studies showing that energy-efficiency retrofits which ensure IEQ (indoor air quality, thermal comfort etc.) can have significant health benefits. In support of this, article 2a 1 (f) of the revised EPBD mentions that long-term renovation strategies should encompass 'wider benefits related to health, safety and air quality'. IEQ should therefore be integrated in national implementation of long-term renovation, recognizing that deep renovation has far-reaching benefits for society and public spending. Increasing indoor comfort and air quality can lead to a reduction of illnesses and premature deaths associated with living in cold and damp homes, and this in turn reduces pressure on healthcare and social services [11]. These cost savings should be taken into account in the estimation of wider benefits (as mentioned in Art. 2a 1 (g) of the revised EPBD) and when designing policies for the building stock. In addition, there is a need for procedures to better value these benefits and for them to be more widely disseminated and communicated.

The majority of renovation strategies do not report topics beyond energy efficiency such as IEQ, although IEQ and energy efficiency can be achieved simultaneously [12]. Neglecting IEQ when planning a renovation can result in the building's degradation. For example, in Denmark and Sweden, in response to the oil crises in the 1970s, dwellings were constructed to be airtight with inadequate ventilation, as well as having small windows and insufficient daylight. This often lead to poor quality indoor environments. Rather, renovation should be viewed as an opportunity to improve the indoor air quality and the comfort and quality of life for building occupants, while at the same time achieving a high energy performance [7]. Although thermal comfort, indoor air quality, adequate levels of natural lighting and acoustics are among the most important drivers and benefits of renovation, energy retrofits are often applied without considering requirements for the assessment of their impact on the overall IEQ.

EPCs

Although increased thermal comfort and air quality, higher levels of natural lighting and improved health of occupants are among the most important benefits and drivers for renovation, they are mostly not currently covered by EPCs. As a result, the relevance of EPCs for owners (including potential owners) and their ability to stimulate the renovation of buildings is limited. Along with the Building Renovation Passport (EBPD

Figure 2. Indicative stages that could be part of the smart readiness indicator.

2018/844: Art. 19a), a document outlining a long-term step-by-step renovation roadmap to achieve deep renovation for a specific building, EPCs could include evidence-based IEQ aspects. Building Renovation Passports provide a comprehensive set of relevant indicators (e.g. energy consumption, CO_2 emissions) and include a dynamic dimension by delivering information about recommended improvement steps in a detailed way and, by doing so, stimulate deep or staged deep renovations [13]. Evidence-based IEQ aspects could originate from measurements, building occupant questionnaire survey outcomes and/or computer simulations [14]. Structured and standardised measurements and surveys should take place both before and after renovations to ensure that energy efficiency upgrades (renovations) did not compromise the quality of the indoor environment. Certain measurements such as the airtightness of the building's construction could be integrated in the EPC (IEQ status of building). Considering the low price for issuing EPCs is come countries, evidence-based IEQ aspects could even be collected through simplified checklists of installed systems and materials. This list could also contain information of the performance and maintenance of the ventilation systems and building materials.

Numerous researchers have stressed the need for a metric/index of the overall indoor environment that would consist of most physical parameters to be presented alongside the energy certification [12]. Several studies are recommending methods for the evaluation of the IEQ using rating/scoring systems. For example, the 'Dwelling Environmental Quality Index' (DEQI) aims to improve energy efficiency based on human behaviour in social housing. DEQI should assist households and property managers to identify potential faults related to the indoor environment, while ensuring that IEQ is not compromised during energy-saving processes [12]. The index reflects the IEQ in a single value and is based on three major parameters of the indoor environment (temperature, relative humidity and CO_2 concentrations) and is in compliance with the EU standard EN 15251:2007.

Smart readiness indicator

Capturing and promoting the benefits of smart buildings for building users and occupants (e.g. cost savings, an optimal IEQ), the energy system (e.g. reduced pressure on the energy markets), the economy (e.g. creation of local jobs) and society as a whole (e.g. tackling climate change, reducing air pollution) must be the underlying purpose of introducing a smart readiness indicator [9]. In addition, the implementation of the general framework methodology for the smart readiness indicator should fulfil its foremost task of providing a decent living space for occupants by integrating IEQ aspects such as indoor air quality and meeting GHG targets. This can ensure buildings are able to adapt to the essential needs of occupants for health, wellbeing and productivity in their operation.

Smart buildings need to go beyond being energy efficient and healthy, and also recognise and react to users' and occupants' needs to optimise comfort, indoor air quality, wellbeing and operational requirements [9]. The smart readiness indicator should characterise the ability of a building or its systems to sense, interpret, communicate, interact with the occupants and contribute to an optimal operation of energy-connected assets. The smart readiness indicator should aim at improving the quality of life of building occupants and also ensure the efficient operation of buildings, for example through reducing inspections by giving notice when a problem is detected. The current proposal of BPIE is to develop a user-friendly and performance-based IEQ indicator that would be integrated in the framework methodology of the smart readiness indicator. The smart readiness indicator, apart from ensuring the building's effective operation and helping improve its energy performance, would further respect occupants' needs towards a healthy, comfortable and productive indoor environment. This indicator could include an index or metric (e.g. DEQI) which would consider the most important physical parameters of IEQ. By using mature and interactive ICT, it could be displayed on screens in buildings, providing real-time information on IEQ-related aspects based on real-time measurements [15]. Based on the monitored information it would then provide the building occupants with tailored advice – for example, when the CO_2 levels are high, to open windows or turn the ventilation system on [16]. Possible stages that could be part of the smart readiness indicator are shown in Figure 2.

Compliance and quality control

Across the Member States, compliance and quality control checks of EPCs are of crucial importance for the effective implementation of the building regulations. According to Article 18 of the EPBD, Member States must establish an independent control system of the issued EPCs aiming to ensure compliance. To achieve compliance on the EPCs, the EU-funded project QUALICHeCK, identified a three-step approach including [17]: (1) a Clear procedures on determining EPC input data;

(2) a Clear legal procedures on decision-making on non-compliance and associated actions; (3) In case of non-compliance effective control and sanctioning mechanisms should be applied.

To support the integration of IEQ within the regulatory framework through the previously mentioned 'boosting tools' (renovation strategies, EPCs, smart readiness indicator) adequate enforcement of implementation, compliance and control mechanisms must be in place to ensure they are adhered to. A similar three-step approach to the QUALICHeCK project recommendations above could be applied to ensure quality control of IEQ requirements.

Summarised recommendations to integrate IEQ in EU and national policies

Good IEQ is a cornerstone of ensuring health, comfort, wellbeing and productivity in buildings, while reducing the building stock's climate impact is essential to the EU's commitments under the Paris agreement. A balance must be ensured between the different expectations of building occupants, such as energy savings, comfortable temperature, sufficient daylight and good indoor air quality. IEQ can become a driving force for energy renovation and proper implementation across Europe. The recently revised EPBD (2018/844) has sparked a change in the right direction, but strong action and implementation is needed at EU and Member State level.

- *EU level: Harmonize calculation methodologies and IEQ requirements at EU level.* Harmonising requirements and methodologies at European level would address inconsistencies between different calculation methodologies, IEQ requirements and design criteria, and between countries. This will allow a systematic approach for defining indexes and metrics for comparison of outcomes across all Member States. European standards specifying calculation methodologies and IEQ requirements do exist, however they are not consistent across Member States (e.g. requirements are expressed in different units). In addition, since EU standards are not mandatory, there is no legal obligation for Member States to apply them, therefore there is a strong differentiation across EU countries. The EU should also encourage a continuous assessment and review framework, which ensures good, reliable and comparable data.
- *National level: Use long-term national renovation strategies to boost improvements in IEQ.* Requirements and guidance are needed on how to ensure that building renovation not only results in significant energy savings, but also improves the quality of life, health and wellbeing of the people living and working within these buildings. During implementation Member States should design policies that improve indoor air quality and have a positive impact on comfort, health and productivity, as drivers for energy renovation.
- *National level: Address IEQ in major energy renovations.* Major energy renovations drastically reduce the energy needs of a building. However, without considering IEQ, renovation might have adverse effects on the indoor environment. Major renovation should reduce energy bills and increase comfort while ensuring proper air quality. In every major energy renovation project, there should be a plan to ensure energy, comfort and air quality needs are met.
- *National: Use the new Building Renovation Passport concept to ensure effective IEQ improvements.* A Building Renovation Passport should provide comprehensive information on relevant indicators such as energy performance, CO_2 emissions and IEQ aspects.
- *National level: Make Energy Performance Certificates more useful for owners.* EPCs should be revised and further expanded into reliable, compliant and user-friendly 'next-generation EPCs' by also including non-energy aspects such as comfort and IEQ and should be complemented by Building Renovation Passports.
- *National level: Integrate IEQ aspects in the smart readiness indicator.* The smart readiness indicator should aim to improve the quality of life of building occupants and continuously ensure the effective operation of buildings. Integrating IEQ aspects into the general framework methodology of the smart readiness indicator will ensure a building can adapt to occupants' essential needs in terms of health, wellbeing and productivity in its operation.
- *National level: Ensure comprehensive compliance and quality control.* Post-occupancy evaluations, post-installation/construction commissioning (e.g. for ventilation systems), user's behaviour verification, audits (Art. 10 and 19a of the revised EPBD) and regular inspections (Art. 14 and 15 of the EPBD) are crucial to ensure effective operation of buildings. Compliance and quality control checks of heating, cooling and ventilation systems should be regularly carried out to ensure the long-term operating performance of buildings in relation to IEQ requirements.
- *National level: Expand the training of energy experts.* Across Europe, energy experts in the construction sector should be properly trained and educated (Art. 2a 1 (f) of the revised EPBD). Training, education and experience of people issuing certification documents (e.g. EPCs, linked to extended EPCs, Figure 1), installers and commissioners (involved in renovations, linked to long-term renovation strategies, Figure 1) should be expanded to go beyond energy efficiency matters and also cover IEQ, health, comfort and wellbeing.
- *National level: Raise awareness of building occupants on IEQ aspects.* The behaviour of the building occupants is a crucial aspect of maintaining good IEQ. As referred to in Art. 20 (2) of the revised EPBD, Member States 'shall provide information to owners and tenants through accessible and transparent tools'. Campaigns to raise the awareness of building occupants of the importance of IEQ and its effects on health, comfort and wellbeing should be considered. Also, gathering occupants' perceptions of the indoor environment through structured surveys (that could be part of the evidence-based IEQ aspects of the extended EPCs or used as drivers of renovation, Figure 1) will build their participatory involvement which may have positive effects on their behaviour regarding the indoor climate.

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