HOW TO INTEGRATE INDOOR ENVIRONMENTAL QUALITY WITHIN NATIONAL LONG-TERM RENOVATION STRATEGIES

POLICY PAPER

BPIE

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CONTEXT

A great number of scientific studies show that indoor environmental quality (IEQ) has a direct effect on health, comfort, wellbeing and productivity. Considering that people spend approximately 90% of their time indoors, it is crucial that building legislation ensures adequate levels of IEQ to promote healthy and comfortable indoor environments. Indoor air quality, thermal and acoustic comfort and sufficient levels of daylight are the major determinants of IEQ, and play an important role in ensuring the quality of life and general wellbeing of building occupants (Figure 1)[1] [1].

Figure 1 - Main elements and impacts of IEQ

- **Indoor air quality (IAQ)** refers to the air quality within buildings and structures. A space with good indoor air quality is low in contaminants and odours and has reasonable levels of CO_2 and moisture. The restriction and control of indoor air pollutant sources, in combination with adequate ventilation, are critical in ensuring good indoor air quality [2] [3].
- **Thermal comfort** refers to the individuals' perception of the thermal environment; they should feel neither too hot nor too cold [4].
- **Daylight and artificial lighting** should provide enough illumination to enable building users to do their tasks safely and comfortably, without interference from glare and shadows [5].
- **Acoustic comfort** includes the capacity to protect building occupants from noise and provide a suitable acoustic environment to fulfil the purposes that the building is designed for.

[1] Further details on IEQ and technical aspects can be found here: http://bpie.eu/publication/the-inner-value-of-a-building-linking-indoor-environmental-quality-and-energy-performance-in-building-regulation

About 2.2 million Europeans have asthma because of their living conditions and 110 million live in buildings with high concentrations of hazardous pollutants due to inadequate levels of ventilation [6]. Increasing indoor comfort and air quality can reduce illnesses and premature deaths associated with living in cold and damp homes. This in turn reduces pressure on healthcare and social services, with related benefits including fewer days of work missed, shorter hospital stays and improved educational performance.

Energy-efficient renovations can lead to a significant improvement of IEQ, resulting in substantial health benefits (Figure 1) [7] [8]. Better IEQ can have positive impacts on learning and working performance and can reduce absenteeism. Building legislation, and in particular the upcoming national long-term renovation strategies, is an obvious starting point.

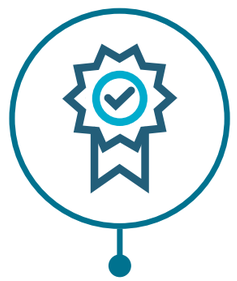
In buildings that are being retrofitted, failing to take IEQ into account can result, for example, in very airtight constructions with insufficient ventilation. This can lead to overheating or to the increase of indoor air pollutants, which also has implications on health and wellbeing. It is therefore important to set measures to ensure that renovation does not harm IEQ and does not compromise comfort, health and wellbeing.

IEQ parameters strongly depend on the type and use of the buildings. Office or educational buildings, like schools or kindergartens, are building types that require an intensive use over specific periods of time during the day, whereas dwellings might have less intensive use throughout the day and therefore have different thermal or lighting requirements. Consequently, IEQ requirements should be differentiated depending on the building type and use.

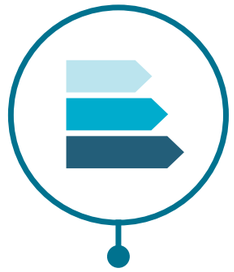
THE AMENDED EPBD IS AN OPPORTUNITY TO PROMOTE HEALTHY AND COMFORTABLE INDOOR ENVIRONMENTS

The EU's main legislation in this area, the amended Energy Performance of Buildings Directive (EPBD, 2018/844), mentions that energy performance requirements defined by governments in all EU countries should optimise health, indoor air quality and comfort levels. The Directive doesn't specify how to achieve satisfactory IEQ and harmonise indoor comfort requirements across Member States, but it provides a great opportunity to integrate IEQ and energy performance. Now that the Directive must be transposed into national legislation (by March 2020), there are great opportunities to increase the importance of IEQ. EU Member States should ensure they:

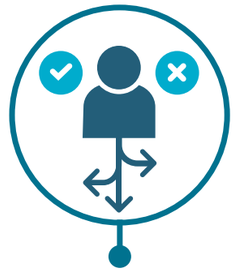
INCLUDE MEASURES PROMOTING IEQ IN LONG-TERM RENOVATION STRATEGIES



INTEGRATE IEQ IN ENERGY PERFORMANCE CERTIFICATES (EPCs)



ENSURE COMPREHENSIVE QUALITY CONTROL MEASURES TO HELP ACHIEVE A SATISFACTORY IEQ



REFORM THE COST-OPTIMAL METHODOLOGY AND INCLUDE PARAMETERS TO EVALUATE THE IMPACTS ON IEQ

PROMOTE IEQ IN LONG-TERM RENOVATION STRATEGIES
(ARTICLE 2A)

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 [9].

Governments should facilitate the cost-effective transformation of existing buildings into nearly zero-energy buildings (nZEBs) and include in their strategy an estimate of expected energy savings and wider benefits, such as those related to health and air quality. Long-term renovation strategies give Member States the flexibility to decide which segment of the building sector they want to tackle first and how. This is an opportunity to raise awareness about the importance and benefits of good IEQ and use it as a trigger for renovation.

Investing in the renovation of unhealthy homes is also an investment towards a healthier population with fewer sick building syndrome (SBS) symptoms and building-related illnesses.

Neglecting IEQ when planning a renovation could 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 small windows. The resulting inadequate ventilation and insufficient daylight led to poor quality indoor environments which had implications on health and wellbeing.

Renovation is 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. When defining renovation strategies, the objective should be to reduce the energy consumption of buildings while improving the comfort, health and wellbeing of people using them, in a way that optimises both building and societal costs [10].

HOW CAN HEALTH AND IEQ BE INTEGRATED IN NATIONAL LONG-TERM RENOVATION STRATEGIES?

Long-term renovation strategies refer to the renovation of the national building stock covering all building types including public and private, residential and non-residential buildings. It is up to Member States to decide which building types to prioritise and make relevant adjustments.

Strategy development

- Strategies should recognise increased comfort, health and productivity as drivers for energy renovation. Policies and measures should ensure adequate levels of natural lighting, acoustic comfort, ventilation, thermal comfort and indoor air quality. Incentives for renovation should include IEQ parameters as well as energy savings to promote projects that also aim to improve health and wellbeing.
- Renovation strategies should report on issues beyond energy efficiency, such as IEQ. Currently few do so.

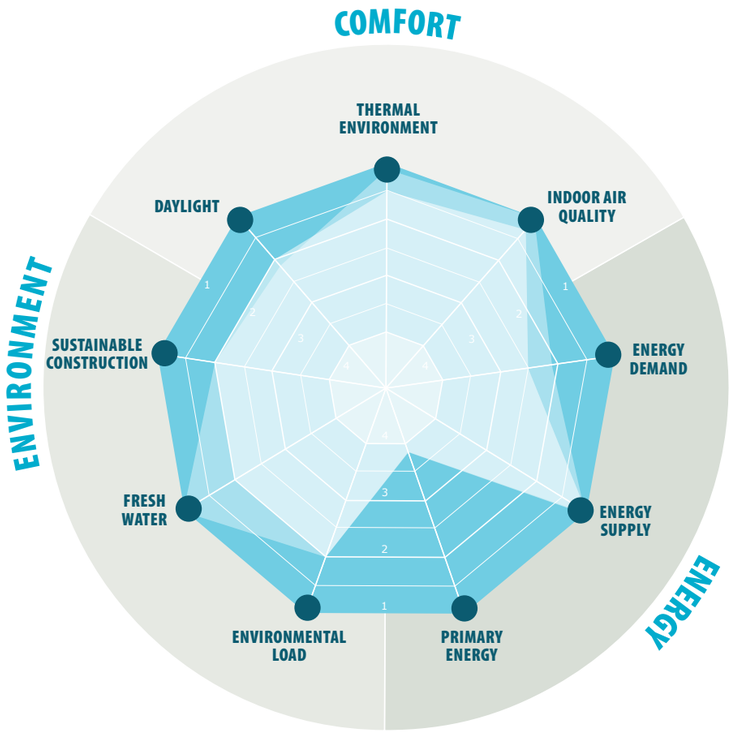
Denmark introduced renovation classes in its building regulation (BR2018) requiring renovated buildings to meet the same level as new builds on certain IEQ parameters in order to be classified in the best class [11].

- Deep renovation of existing buildings could include IEQ requirements equal to those for new buildings.
- Healthier buildings reduce pressure on healthcare and social services. These cost savings should be considered in the estimation of wider benefits (as mentioned in Article 2a, 1 (g)) and when designing policies for the building stock. Methodologies have been already developed that quantify the expected reductions in building-related illnesses and estimate the associated healthcare [12].
- In order to have a reference level for renovation, Member States could develop different renovation classes based on the age of the building stock and include minimum levels for IEQ for the individual classes. In other words, a classification system for IEQ could be introduced in national long-term renovation strategies.

The renovation classes in Denmark, for example, are energy frames for existing buildings (for domestic buildings, the best performing class is around 60 kWh/m^2, while the worst performing class is around 80-90 kWh/m^2). They are primarily intended for building owners making thorough energy renovations who would like a more holistic approach to energy renovation and include requirements for the indoor climate covering lighting, thermal comfort, ventilation and CO_2 levels [11]. These classes could be similar to the energy performance levels within a label scale.

Another example is the Active House, a worldwide quality stamp for comfortable and sustainable buildings. Active House advises on elements important to people's lives and living in their home, and issues its label for buildings that meet three specified requirements for indoor comfort, energy efficiency and the environment. The level of ambition for each of the three main principles of the Active House (Comfort, Energy, Environment) is plotted on a radar (Figure 2) showing how 'active' the building has become [13].

Figure 2 - Radar showing how the parameters included in each of the three principles are balanced against each other (Source: Active House)



- Smart buildings[2] can lead to lighter (and cheaper) and more accurate certification and commissioning processes on aspects of both energy performance and IEQ. Member States should introduce measures to link smart buildings with their long-term renovation strategies; a good reference point for this is the smart readiness indicator[3].

[2] A smart building is highly energy efficient and covers its very low energy demand to a large extent by on-site or district system-driven renewable energy sources. 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; (iii) recognises and reacts to users' and occupants' needs in terms of comfort, health, indoor air quality, safety as well as operational requirements.

[3] 'The Commission shall establish the definition of the smart readiness indicator and a methodology by which it is to be calculated, in order to assess the capabilities of a building or building unit to adapt its operation to the needs of the occupant and of the grid and to improve its energy efficiency and overall performance', EBPD 2018/844

Smart buildings could motivate building owners to renovate through, for example, digital messages based on monitoring data: e.g. 'your indoor air has been poor for x days, you should open your windows more regularly' or 'replace your manual windows by automatically-operated ones' [14]. Smart monitoring of energy performance and IEQ can make building occupants, owners and commissioners aware of the prevailing indoor conditions, for example through messages (e.g. 'for x% of the occupied time, there was a risk of overheating') and therefore nudge them to take actions. On issues related to the 'needs of the occupants', the smart readiness indicator will have a major role in shifting from asset-based to actual energy and IEQ performance of the building by, for example, quantifying the impact of IEQ on the energy performance of the building. This can improve the way energy performance is evaluated within EPCs [15].

Policy adaptation and supporting legislative tools

- Policies and measures should promote deep renovation that ensures good IEQ and generates benefits for society in terms of local jobs, economic growth, lower health bills and overall better living standards. Deep renovation can increase indoor comfort, wellbeing and productivity, and lead to a reduction in absenteeism from work and healthcare costs.
- Supporting instruments like building renovation passports and one-stop-shops should also promote IEQ. A building renovation passport is a step-by-step renovation roadmap that guides a building owner to achieving a highly efficient building. It provides comprehensive information on relevant indicators such as energy performance and CO_2 emissions and recommends improvements in a detailed and dynamic way. This can stimulate deep or staged deep renovations. IEQ aspects should be incorporated among the indicators, and comfort and wellbeing should be included in the information delivered to the building owner.
- Renovation policies should integrate cost-effective solutions to deliver good IEQ and properly consider all benefits and measures of renovation, like thermal performance improvements.

Awareness raising/training

- Training, education and experience of professionals issuing certification documents, installers and commissioners should be expanded beyond energy efficiency matters to cover IEQ.

INTEGRATE IEQ IN ENERGY PERFORMANCE CERTIFICATES (EPCs)

(ARTICLES 11, 19, 19A AND 20 (2))

EPCs are among the most important sources of information on the energy performance of the EU's building stock. They have the potential to become effective instruments to track buildings' energy performance and their overall IEQ status, as energy efficiency and IEQ improvements are inter-related and can be achieved simultaneously. Currently most EPCs don't cover IEQ. In order not to compromise the health and wellbeing of building occupants, recommendations for cost-effective or cost-optimal upgrading of energy performance should also incorporate IEQ aspects.

HOW CAN IEQ BE INTEGRATED IN EPCs?

Strategy development

- EPCs have the potential to become effective instruments to track not only a building's energy performance but also its overall IEQ by providing evidence-based information (e.g. measurements, building occupant surveys, dynamic computer simulations).
- Member States can adjust EPCs to ensure IEQ is considered. New measures to adapt EPCs and incorporate IEQ can also be included in national long-term renovation strategies.
- A further upgrading of the certification process could be the evolution of the EPC to a more comprehensive certificate (e.g. EPC+ in Flanders), involving aspects beyond energy such as health, comfort, smartness, etc. The Active House[4], the German Sustainable Building Council certification system (DGNB)[5] and the WELL Building Standard[6] are inspiring initiatives that include sociocultural aspects, performance verification and health.
- The behaviour of building occupants is a crucial aspect of maintaining good IEQ. Article 20 (2) of the EPBD says Member States shall provide information to owners and tenants through accessible and transparent tools, including EPCs.

Policy adaptation and supporting legislative tools

- To support deep renovation, EPCs should be complemented by building renovation passports including aspects of health, indoor climate and comfort (art. 19a).

[4] www.activehouse.info/about/about-active-house
[5] www.dgnb-system.de/en/system/certification_system
[6] www.wellcertified.com/en/explore-standard

Awareness raising/ training

- Campaigns to raise the awareness of building occupants of the importance of IEQ and its effects on health, comfort and wellbeing should be also considered. For example, gathering occupants' perceptions of the indoor environment through structured surveys would build their participation and have positive effects on their behaviour.
- It is crucial that qualified professionals issuing extended EPCs or their equivalent (also including IEQ aspects) have relevant experience and training beyond energy-related aspects to cover all elements of IEQ, wellbeing and cost-effectiveness.

WHICH IEQ INDICATORS CAN BE INTEGRATED IN EPCs?

Since there is no single performance indicator for IEQ, EPCs should evaluate and set levels for the main categories described in this paper: indoor air quality, thermal comfort, daylight and acoustic comfort[16]. This evaluation can be grounded in evidence-based indicators that can originate from: a) comparing actual IEQ values to recommended guidelines (design criteria), b) calculations, c) measurements and d) questionnaire surveys (EN15251:2007)[7].

a) **Recommended guidelines and limit values (design criteria)** should aim at minimising the level of dissatisfaction among individuals. For indoor air quality, this could involve indicators on compliance with recommended limits of indoor air contaminants such as CO_2. For thermal comfort, it could include the percentage of time that temperatures are within acceptable recommended comfort ranges for summer and winter. Indicators on daylight could include light levels, view to the outside, access to daylight, and glare protection.

b) **Calculations:** performance against elements of IEQ can be analysed through modelling and simulations. Several software tools are available to simulate the thermal environment, indoor air quality, daylight and acoustics, the results of which could be integrated in EPCs as an indicator of the indoor environment.

c) **Measurements** are a quantitative indicator for the evaluation of IEQ parameters (e.g. CO_2, temperature, light levels, etc.), the results of which can be included in EPCs (Figure 3). Moving towards a digital society in which sensors are widely deployed, IEQ monitoring is becoming mainstream and can be more simply and easily encompassed within EPCs.

d) **Qualitative evaluations:** scientific studies have shown that job satisfaction and health are greatly affected by the level of comfort offered by the working environment [17]. For this reason, surveys of building occupants are a crucial qualitative indicator for ensuring the satisfactory operation of a building. EPCs could give an indication of these subjective evaluations.

[7] EN 15251: 2007, Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics

Figure 3 - Necessary steps to be considered during the measurement phase

EPCs could be complemented by the smart readiness indicator. This can identify the building potential to maintain performance levels, and help shape a clear vision about the role of digitization and more advanced technical systems for increased efficiency and flexibility, which may not be reflected in simple measures of the uptake of cost-efficient renovation. Improved indoor comfort is an expected advantage from smart buildings [15].

Considering the low price for issuing EPCs in some countries, evidence-based IEQ aspects could even be collected through simplified checklists. For indoor air quality, these could involve checklists of installed systems and materials and their performance and maintenance (e.g. the ventilation system) and the operability of windows. For daylight, they could contain simplified evaluations of daylight conditions (e.g. Daylight Factor based on EN 17037[8]) based on available blueprints or drawings. Thermal comfort could be assessed with a checklist of construction elements (e.g. insulation, thermal mass, solar shading devices including operability and automation).

[8] En 17037, Daylight in buildings

ENSURE COMPREHENSIVE COMPLIANCE AND QUALITY CONTROL (ARTICLES 14 AND 15)

Heating, ventilating and air-conditioning systems are critical to providing a healthy indoor environment, and are also significant energy users. Optimising their operational performance increases both energy efficiency and IEQ.

HOW CAN MEMBER STATES INTEGRATE IEQ IN INSPECTIONS, COMMISSIONING AND PERFORMANCE ASSESSMENTS?

Member States should implement mandatory regular inspections and commissioning of the heating and air-conditioning systems, as seen in Articles 14 and 15 of the amended EPBD, and performance assessments of IEQ requirements.

Strategy development

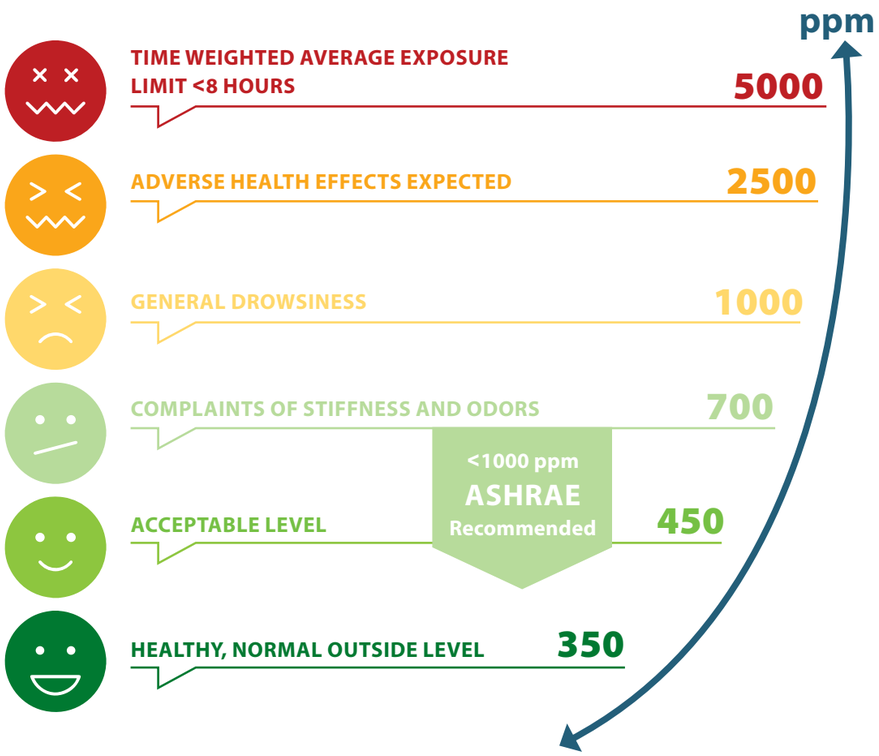
- Compliance with relevant requirements should be regularly assessed during the design stage, pre- and post-occupancy and pre- and post-renovation of the building (Figure 4).
- Quality control checks of the heating, cooling and ventilation systems should take place to ensure the long-term operating performance of buildings in relation to the IEQ requirements.

Figure 4 - Stages at which compliance and quality control checks should take place (Source: "Promoting healthy and energy efficient buildings in the European Union," European Commission, JRC 2016 adapted by BPIE)

Awareness raising/training

- Post-occupancy evaluations, post-installation/construction commissioning (e.g. for ventilation systems), user's behaviour verification, audits and inspections should also be regularly performed to ensure effective operation of buildings. Through monitoring of IEQ parameters over time (by analysing past readings, observing present conditions, forecasting future environment), pre-and post-renovation quality control can ensure that building occupants have access to healthier buildings (Figure 5 shows an example for carbon dioxide levels).

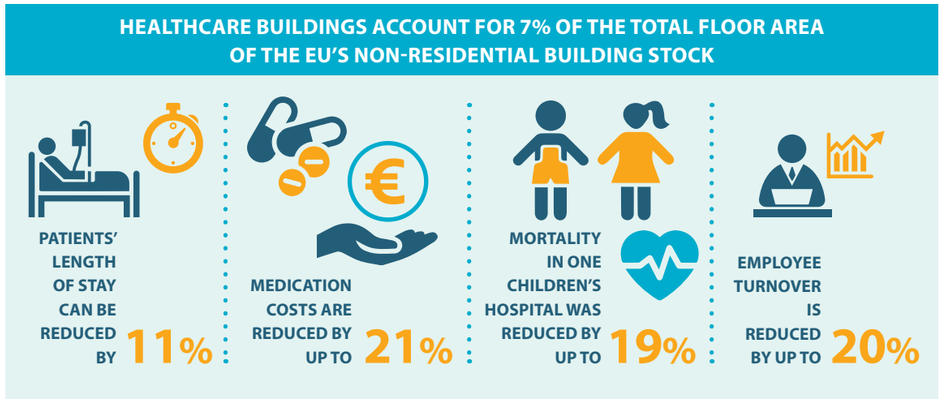
Figure 5 - Link between CO_2 levels and wellbeing (Source: IOT Factory [18] adapted by BPIE)



REFORM THE COST-OPTIMAL METHODOLOGY
(ARTICLES 4 AND 5)

The EPBD has left the cost-optimal methodology untouched. The current methodology overlooks many of the societal gains and the healthcare cost reduction of getting healthier nearly zero-energy buildings (Figure 6) [19]. Integrating these gains could boost the renovation rate across the EU and accelerate the transformation of unhealthy, uncomfortable and energy-inefficient buildings into healthy, comfortable nearly zero-energy buildings.

Figure 6 - Quantified benefits of improved IEQ in hospitals (Source: BPIE 2018, [20])



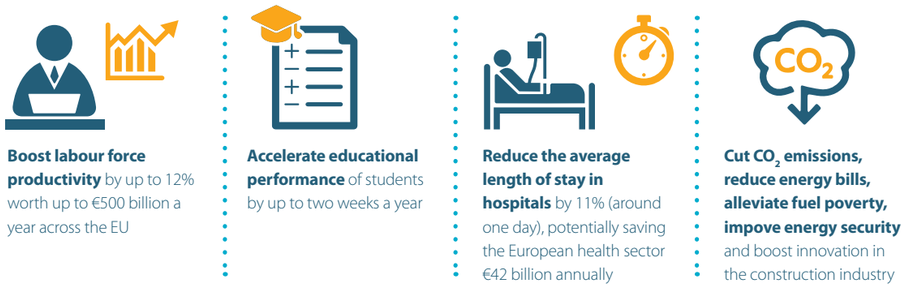
HOW CAN IEQ BE INTEGRATED IN THE COST-OPTIMAL METHODOLOGY?

Strategy development

- The cost-optimal methodology should include parameters to evaluate the impacts on health, comfort, productivity and IEQ.
- In addition to cost savings from the application of energy-efficiency technologies, a revised methodology should include benefits such as reduced costs in the healthcare sector due to an improved indoor environment, increased productivity and wellbeing, and lower absenteeism [6].

Buildings with good IEQ can lead to a reduction in healthcare costs and help tackle energy poverty (Figure 7) [21] [22].

Figure 7 - Quantified impacts of improved IEQ in schools, offices and hospitals (Source: BPIE 2018, [21])



Boost labour force productivity by up to 12% worth up to €500 billion a year across the EU

Accelerate educational performance of students by up to two weeks a year

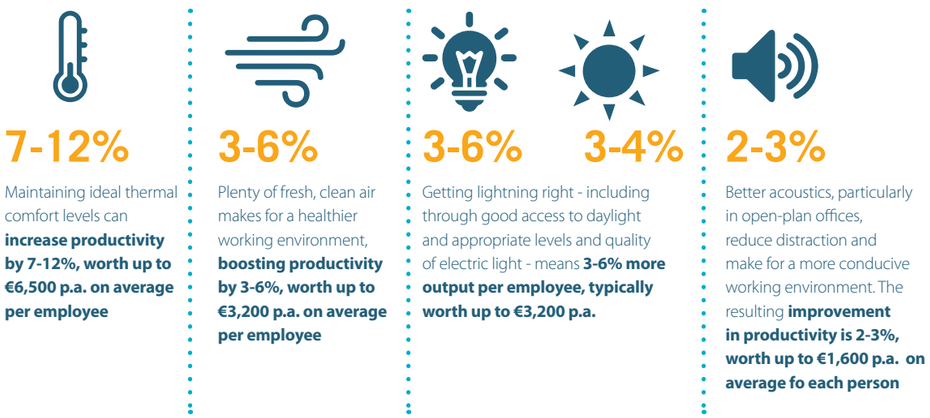
Reduce the average length of stay in hospitals by 11% (around one day), potentially saving the European health sector €42 billion annually

Cut CO_2 emissions, reduce energy bills, alleviate fuel poverty, impove energy security and boost innovation in the construction industry

An increasing number of studies show significant health benefits when highly efficient new or renovated buildings ensure good indoor air quality. A report published by the Joint Research Centre (JRC) on 'Promoting healthy and energy efficient buildings in the European Union' shows that various studies in Europe have quantified the benefits in terms of improved life quality, absenteeism reduction, public spending and improved conductivity, but not in a systematic way or under a common framework:

- The savings in costs from the health-based benefits are estimated to be comparable to the energy savings alone [6].
- 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 rarely include requirements to assess the impact on the overall IEQ (Figure 8) [20] [23] [24].

Figure 8 - Improved productivity and cost savings due to improved IEQ (Source: BPIE 2018, [20])



7-12%

Maintaining ideal thermal comfort levels can **increase productivity by 7-12%, worth up to €6,500 p.a. on average per employee**

3-6%

Plenty of fresh, clean air makes for a healthier working environment, **boosting productivity by 3-6%, worth up to €3,200 p.a. on average per employee**

3-6% **3-4%**

Getting lightning right - including through good access to daylight and appropriate levels and quality of electric light - means **3-6% more output per employee, typically worth up to €3,200 p.a.**

2-3%

Better acoustics, particularly in open-plan offices, reduce distraction and make for a more conducive working environment. The resulting **improvement in productivity is 2-3%, worth up to €1,600 p.a. on average fo each person**

HARMONISE CALCULATION METHODOLOGIES AND IEQ REQUIREMENTS AT EU LEVEL

Beyond ensuring that IEQ is properly addressed when transposing the EPBD, there is a need to harmonise calculation methodologies and IEQ requirements across the EU. Several Member States have introduced national requirements on IEQ, but they're often expressed in different units, not legally binding and below comfort levels [6]. This non-homogenised approach exists even when European standards are available (e.g. EN 16798-1)[9] and makes comparing different regulations very difficult. Harmonising requirements and methodologies would address inconsistencies between different calculation methodologies, IEQ requirements and design criteria, and avoid unequal protection of building occupants across Europe. Combined with a continuous assessment and regular review, harmonisation would ensure that good, reliable and comparable data is collected. It would allow a systematic approach for defining indices and metrics to compare outcomes across all Member States.

HOW CAN CALCULATION METHODOLOGIES AND IEQ REQUIREMENTS BE HARMONISED?

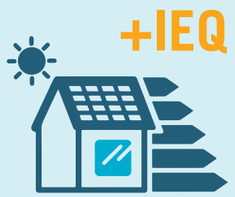
- Where available, existing EU standards should be used in all Member States to allow a transparent comparison and evaluation, which could help further improve IEQ across the EU.
- Long-term renovation strategies should include measures to apply EU standards and promote their harmonisation.
- Member States should also envisage synergies between building and health policies to ensure that all citizens have access to decent levels of IEQ. The same approach should be adopted across EU policies: the European Commission should encourage synergies between working groups on public health, construction and EPBD to ensure that all relevant legislation promotes a healthy indoor environment.

[9] EN 16798-1: Energy Performance of Buildings – Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics

CONCLUSIONS

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 needs 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, which in turn triggers the need towards a cost-optimal methodology. The amendments to the EPBD (2018/844) have sparked a change in the right direction, but strong action and implementation is needed at Member State level. To increase the recognition of IEQ in EU and national policy, BPIE recommends the following actions:

Ensure that **measures improving indoor environmental quality are included in energy-efficiency retrofits,** as a trigger to drive renovation and achieve significant health benefits.



Revise and expand EPCs into reliable, compliant and user-friendly 'next-generation EPCs' by also including non-energy aspects such as IEQ.

Require regular compliance and quality control checks of heating, cooling and ventilation systems to ensure the long-term operating performance of buildings in relation to IEQ requirements.

Update the cost-optimal methodology to integrate societal gains, promote the transition toward healthy, comfortable nearly zero-energy buildings and boost the renovation rate.

Member States should set a clear strategy for developing and implementing these actions and explore supportive legislative tools and policy adaptation at national level. Lastly, adequate training of professionals involved and raising of awareness of end-beneficiaries can have a significant positive impact on the successful integration of IEQ within these actions.

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