The challenge of rating energy efficient IAQ management strategies: welcome to IEA-EBC Annex 86

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ABSTRACT

The energy performance of new and existing residential buildings needs to be radically improved to meet ambitious climate change goals and residential buildings are by far the largest component in the total building stock. A central boundary condition in constructing energy efficient buildings is doing so while maintaining a healthy, acceptable and desirable indoor environment. In its mission statement, the IEQ-Global alliance (IEQ_GA) states that Indoor Environmental Quality includes the thermal environment, the indoor air quality, lighting and the acoustic environment that occupants experience in buildings. While ventilation is the main strategy that is adopted for IAQ management, other technologies influencing IAQ (e.g. air filtration) are available as well and a large number of ventilation strategies exist. There is, however, no coherent assessment framework to rate and compare the performance of IAQ management strategies. IEA-EBC annex 86 is therefore developing a performance assessment method for maximizing energy savings while guaranteeing a high level of indoor air quality in terms of comfort and health for the occupants that works across different IAQ management strategies in new, renovated and existing residential buildings.

By mapping and gathering the existing work on the pollution sources in residential context (including occupant activities and the penetration of outdoor pollution), we are developing a consistent set of metrics that allows us to assess the performance of the various technologies. This includes extending the framework developed in Annex 68 with specific metrics for energy efficiency and particulate matter, explicitly including surface-room interations and HVAC component and controller modeling as well as creating a common methodology for IAQ data sharing among smart devices. By pooling and analyzing the data, the range of conditions in dwellings can be better understood and the most appropriate energy efficient IAQ management strategies can be identified. Ensuring performance over the lifetime of the system, however, requires continuous commissioning of the technical components of the system as well to prevent deterioration of the performance. The application of the assessment method on collected data over time will ensure that the predicted energy efficiency is actually maintained.

A useful rating method needs to be flexible enough to adapt to the continuously evolving knowledge about the impact of pollutants and the new pollutants 'du jour' that are discovered. The most relevant track that is explored to ensure this flexibility is monetising all impacts. Nevertheless, since monetisation depends on countless assumptions, we are focussing on a reporting guideline that should come with all publications using the method to ensure that the assumptions are clearly reported and the results can be reproduced and updated. This way, we hope to take performance based rating of IAQ strategies one step closer to meaningful day to day implementation.

KEYWORDS

IAQ; Rating; Residential; Performance

1 INTRODUCTION

The energy performance of new and existing residential buildings needs to be radically improved to meet ambitious climate change goals and residential buildings are by far the largest component in the total building stock. Since the introduction of the EPBD in Europe, the use of rating methods to compare different potential measures to achieve this improvement has become ubiquitous. A central boundary condition in constructing energy efficient buildings is doing so while maintaining a healthy, acceptable and desirable indoor environment. In its mission statement, the IEQ-Global alliance (IEQ_GA) states that Indoor Environmental Quality includes the thermal environment, the indoor air quality, lighting and the acoustic environment that occupants experience in buildings, thus immediately pointing to the inherently multifaceted character of IEQ, which complicates the use of rating compared to the relatively simple rating of energy expenditure or carbon emission. IAQ, as one component of IEQ, is in itself just as multifaceted, consisting of the exposure of occupants and buildings to a cocktail of often thousands of pollutants.

While ventilation is the main strategy that is adopted for IAQ management, other technologies influencing IAQ (e.g. air filtration and sorbing or catalytic surfaces) are available as well and even within the narrow use of ventilation as a strategy, a large number of different ventilation strategies exist. There is, however, no coherent assessment framework to rate and compare the performance of IAQ management strategies. Most standards related to ventilation and IAQ are prescriptive in nature and are therefore only applicable to a very specific IAQ management strategy (e.g. ventilation) and context for which they were developed and cannot be applied outside those limits or to compare potentially competing strategies. Slowly, performance based approaches are therefore replacing these prescriptive approaches. Ongoing work on the new prEN 15665 standard "Ventilation for buildings — Ventilation systems in residential buildings — Design" is a great step forward in creating a general framework for performance based rating, but it is deliberately vague in that it only provides a procedural scaffold for a performance based assessment that can accommodate any specific performance based rating method. Comparing and rating different IAQ management strategies requires actually filling in all the assumptions required to make a performance based assessment and, additionally, doing so in a way that is consistent for all the IAQ management strategies considered and, to come back to the point raised at the onset above, minimises energy expenditure.

Within IEA-EBC Annex 86 'Energy Efficient Indoor Air Quality Management in Residential Buildings', we are therefore working on a performance based rating method suitable for maximizing energy savings while guaranteeing a high level of indoor air quality in terms of comfort and health for the occupants that works across different IAQ management strategies in new, renovated and existing residential buildings. By mapping and gathering the existing work on the pollution sources in residential context (including occupant activities and the penetration of outdoor pollution) in subtask 2, we are developing a consistent set of metrics that allows us to assess the performance of the various technologies (subtask 1). This includes extending the framework developed in Annex 68 with specific metrics for energy efficiency and particulate matter, explicitly surface-room interactions such as moisture and VOC buffering (subtask 3) and HVAC component and controller modelling such as moisture or VOC controlled demand controlled ventilation (DCV) (subtask 4) as well as creating a common methodology for IAQ data sharing among smart devices (subtask 5).

In this paper, we will propose some open questions and problems that need to be addressed to achieve a working and relevant rating method and discuss the solutions for them that are being explored in the annex. More specifically, in the sections below, we will discuss different use cases for the rating method and their implications for the implementation, the ranking of potential IAQ management strategies and the availability of an ecosystem that supports the rating method.

2 USE CASES FOR A RATING METHOD AND THEIR IMPLICATIONS

Although the introduction sets up a specific context, namely lowering the energy expenditure of a dwelling, within this context, a number of different use cases for the rating method remain and these have different implications for the requirements of the rating method.

The first and most straightforward application is comparing the merits of 2 or more different IAQ management strategies for a specific dwelling. Here, only the relative performance of each of the selected IAQ management strategies on the desired performance indicators needs to be assessed. In this use case, the rating method therefore only needs to select the desired performance indicators and provide sufficiently detailed methods to be able to perform a performance based assessment and output the selected performance criteria in order to compare the selected IAQ management strategies.

A particular application of this use case is comparing theperformance of an IAQ management strategy to absolute reference values. An example of this is given below for the comparison to ELV values as proposed within IEA-EBC Annex 86.

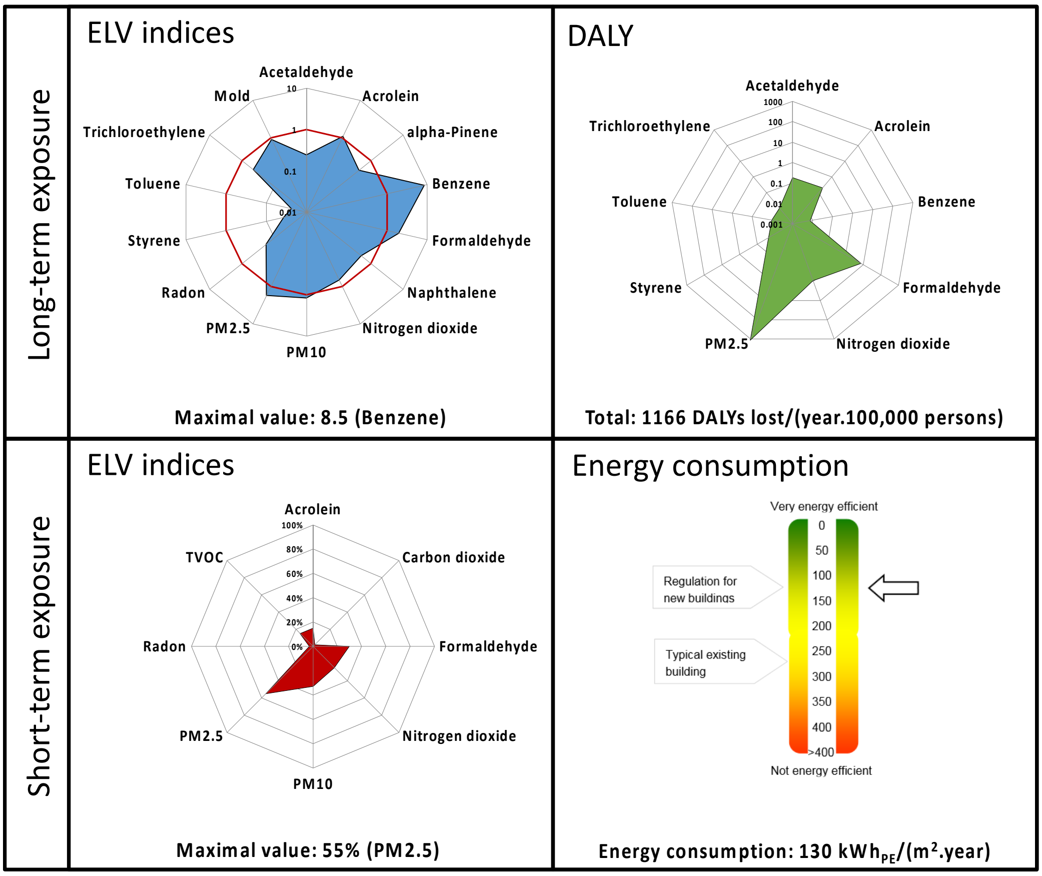

Figure 1: An example of IAQ/Energy signature for low-energy residential buildings as proposed in IEA-EBC Annex 68 (data represented here are just for display and do not represent actual situation), from AIVC Contributed Report 17 (Abadie, 2017).

Since it relies on monitoring and post-hoc analysis, the application of this first use case is relatively rare, except in research settings and in case of complaints. A more common use case is the one where this comparison needs to be made in order to select an option that will be realised. This use case can be called the ‘engineering’ use case and introduces the need for the rating method to rank the selected IAQ management strategies (select 1 above the other(s)).

The selection of appropriate performance indicators and the complexities entailed by the need for ranking are discussed in section 3 below.

Since in the ‘engineering’ use case the IAQ management strategy will only be implemented after the selection, this use case can only rely on simulation to predict the performance as a basis for the rating method. With the existing state of knowledge in Building Energy Simulation (BES), Coupled Heat, Air, Moisture and Pollutants Simulation (CHAMPS), Multi-Zone Airflow Simulation and Computational Fluid Dynamics (CFD) such an assessment is in principle always possible, provides sufficient data about the specific dwelling. That this is not always the case in the design stage is almost self-evident. In any case, the amount of work required to collect or decide on all relevant data may be prohibitive.

A different dimension is introduced when the performance of an IAQ management strategy needs to be benchmarked against other buildings, other building design options or when the benefits of a generic strategy are to be assessed. In these cases, the rating method also needs to provide a set of clear reference conditions that assure that the assumptions for the assessment are consistent and robust across the considered cases.

A relevant and applicable rating method therefore, in addition to a clear description of the methods, requires an ecology of relevant data and reference conditions that will be discussed in section 4 below.

3 GENERAL RANKING METHODS FOR IAQ MANAGEMENT STRATEGIES

A considerable amount of research has been devoted to the selection of the priority pollutants, both from a population level, burden of disease based and from an discrete occupant, acute health impact based perspective (Logue, 2013; Abadie, 2017; Ghijsels, 2022).

By focusing on health, the indicators and ranking methods proposed are often not fully equipped to address the use cases discussed above. For example, it is an open question what cut-off value to use based on the estimated burden of disease and whether that cut-of should apply to the expected value or a certain probability. The aggregation method proposed by Abadie (2017) masks the relative benefits of a system on the non-dominant pollutants. If this indicator is used as a cost function in design or control optimisation problems, due to the trade-off between operating costs and benefits of the IAQ management strategy, the exposure of these non-dominant exposures will be maximised within the envelope provided by the exposure to the dominant pollutant. On the other hand, an aggregation based on averaging will mask the effect of the dominant pollutant and are therefore not suited to identify failure to comply with minimum.

More importantly, focusing solely on health impacts negates the other expectations that occupants have about a high quality indoor environment and therefore need to complemented with impacts on other aspects of IEQ such as noise or odour nuissance. Cony et al. (2022)

therefore proposed a monetisation method that allows to account for all impacts, costs and benefits of an IAQ management strategy.

The assumptions behind the monetisation of each impact should be the subject of a lot of further research and debate, and the ranking of particular proposed IAQ management methods based on it should still always check a set of minimum performance criteria to avoid critical conditions. Nevertheless, the monetisation provides additional methodological benefits. It can take the temporal asynchronicity of impacts into account by discounting them for their distance in time. Additionally it can deal with probability of unlikely events or uncertainty in general by including the expected cost for insurance, allowing to incorporate notions or resilience (Al-Assaad, 2022) and, if formulated as a rate of accrual as proposed by De Jonge (2022), it can be used in gradient based design and control optimisation.

4 AN IAQ RATING ECOLOGY

As mentioned in section 2, the application of a rating method is not only dependent on the sufficient documentation of the applicable assessment methods such as measurement protocols, applicable models and indicators and ranking methods. Especially if simulations or benchmarks across different implementations are used, a set of input or meta data and boundary conditions needs to be consistently defined and available.

Currently, both of these conditions are rarely met simultaneously. Existing performance based assessment methods are usually developed for a specific use case and therefore the data and conditions selected for them cannot easily be applied in other use cases. For example, rating methods for the assessment of generic demand controlled ventilation (DCV) systems typically only include data and boundary conditions for the pollutants that are measured by the DCV's sensors (Guyot, 2019). On the other hand, although the DALY or monetisation based methods referenced in section 3 are flexible enough to accommodate the assessment of any IAQ management strategy, all data and boundary conditions for their application to a specific (set of) case(s) is typically not available at the required level of detail. If the labour of constructing this consistent (at least for the case at hand) and available set of data and conditions needs to be started from scratch with every application of the rating method, the cost of applying it will be prohibitive outside a pure research context.

The broad application of a rating method therefore requires the existence of an ecology of additional components feeding that rating method. This requires the rating method to be open-ended, in the sense that the interdependencies of inputs and conditions are clearly defined and, whenever possible, reduced to first principles. A second condition is the accumulation of data and conditions in an accessible form that allows future work to build on the existing information.

Within subtasks 2 and 5 of Annex 86, we are putting forward 2 elements to help realise this ecology. On the one hand, we are putting together a database of existing source strength data and monitoring data for IAQ assessments based on the Pandora database (Abadie, 2011), accompanied by a series of scripts that allow to convert and analyse the stored monitoring data. On the other hand, we are preparing a reporting guideline that should come with all publications using the method to ensure that the assumptions are clearly reported and the results can be reproduced and updated, similar to those proposed for adjacent fields (Nägeli, 2022; Stevens, 2016; Grimm, 2010; equator-network, 2022).

5 CONCLUSIONS

A useful IAQ rating method needs to be flexible enough to adapt to the continuously evolving knowledge about the impact of pollutants and the new pollutants 'du jour' that are discovered. In this paper, we proposed some open questions and problems that need to be addressed to achieve a working and relevant rating method and discuss the solutions for them that are being explored in IEA-EBC annex 86. We have discussed different use cases within which a general IAQ rating method could be applied and based on that analysis discerned a need for general ranking methods for IAQ management strategies and an IAQ rating ecology to support the rating method. The most promising track that is explored for the general ranking method is monetising all impacts. The building of the IAQ rating ecology is supported by a database for input data and boundary conditions. Additionally, since modeling and monetisation depend on countless assumptions, we are focussing on a reporting guideline that should come with all publications using the method to ensure that the assumptions are clearly reported and the results can be reproduced and updated. This way, we hope to take performance based rating of IAQ strategies one step closer to meaningful day to day implementation.

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