

# TAIL: Open-source rating scheme to evaluate the quality of the indoor environment



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She has been involved in various European and international projects and expert committees, including those at the World Health Organization and the European Joint Research Centre. She currently chairs the expert committee dedicated to outdoor and indoor air quality at the French Agency for Food, Environmental and Occupational Health and Safety. She was president of the International Society for Indoor Air Quality and Climate (ISIAQ) from 2020 to 2022, and is now vice-president of the ISIAQ Academy of Fellows from 2024 to 2026. In 2025, she was appointed a member of the French Academy of Pharmacy.



**Pawel Wargocki** is a professor at the Technical University of Denmark. He is an academic teacher, scientist, industry consultant, and IAQ expert. He is a mechanical engineer by education. He has expertise in environmental psychology, physiology, and exposure monitoring, with over 30 years of experience in research on human requirements in indoor environments. He is a Fellow of ISIAQ, REHVA, and ASHRAE. He graduated from the Warsaw University of Technology in Poland and received his Ph.D. from the Technical University of Denmark, where he has been teaching and performing research ever since. He is known for his seminal work demonstrating that poor indoor environmental quality affects the performance of office work and learning. His research significantly influenced the requirements for indoor air quality, ventilation, and air

cleaning. His research has recently focused on studies of human emissions, sleep quality, the development of IEQ rating schemes, the performance of green buildings, solutions for reducing infection risk and air cleaning, as well as interactions between different indoor environmental domains. He has trained and educated numerous students and scholars. He has collaborated with leading research institutions, universities, and industrial partners worldwide, including the National University of Singapore, Jiao Tong University in Shanghai, Waseda University in Tokyo, the Syracuse Center of Excellence, United Technologies, Velux, Boeing, and Google. He was the President and a long-standing board member of the International Society of Indoor Air Quality and Climate (ISIAQ), President of the ISIAQ Academy of Fellows (previously the Academy of Indoor Air Sciences), Vice President of the Indoor Air 2008 conference, and Chair of several ASHRAE committees. He has been invited to many conferences as a keynote speaker and received several awards for his work and papers. He published extensively.

**LHC: In previous RJ # 1/2026, your article about TAIL was published [1], but let's start from the beginning. What is TAIL, and why did you develop it?**

**PW:** It is a method for assessing the quality of the indoor environment (IEQ), its four key components, and the overall IEQ. The main motivation for developing this rating scheme was to fill a gap: no such method existed, and also, among other reasons, to create a reliable way to quantify the non-energy benefits of deep energy renovations (DER) in the context of the EPBD (version 2018). Although several attempts to rate IEQ have been made in the past, none have been widely accepted or used; of course, this does not include commercial certification schemes, which may not be affordable to all building owners and users.

**CM:** At that time, when we started developing TAIL, some studies highlighted a critical issue: building retrofits that focused solely on energy savings frequently overlooked ventilation and indoor air quality. As a result, some renovated buildings experienced increased radon levels, elevated humidity, or other unintended consequences. Renovations were primarily driven by energy savings to reduce greenhouse gas emissions. This is crucial to mitigating climate change, but it sometimes comes at the expense of indoor environmental quality. And it can have a negative impact on the occupant's health.

**LHC: Why did you decide to evaluate offices and hotels within the same rating framework, given that people work in offices but sleep in hotels?**

**CM:** This was decided at the outset of the ALDREN project (Alliance for Deep RENovation in buildings), during which we developed the TAIL rating. We felt that office and hotel building owners and managers had more resources to implement IEQ-related initiatives and that IEQ could be a commercial lever in such buildings. Overall, the rating framework is similar for both types of building, but some measurements and guidelines for defining the quality categories differ between offices and hotels to account for their different uses.

**PW:** There was a missing link in all energy renovations to the indoor environment, which is why a rating scheme, such as TAIL, was needed. We felt that office and hotel building owners and managers had more resources to implement IEQ-related initiatives, and that that getting involved in achieving good IEQ could be used as a selling point for such buildings. We did not want to include all buildings as it would be too difficult task.

**LHC: In [2], you mention that TAIL determines the overall indoor environment quality based on four individually rated components. How is this overall rating determined?**

**PW:** We ultimately decided that the lowest-performing component of IEQ should determine the overall quality

level of a building. In practice, this means that even if three components perform exceptionally well, a single parameter performing very poorly will pull the overall rating down. It may seem strict, but the logic is similar to how we assess water quality: one contaminant above the limit is enough to classify the water as undrinkable. We applied the same principle here. We simply did not want to open up to compromises or tradeoffs (Fig.1).



**Fig. 1.** The TAIL rating scheme with four colours representing the quality levels of each IEQ component and the overall IEQ level; the colours are just examples of the quality levels, and each of the TAIL components can have any of the four quality levels represented by four colours. The Roman numeral in the centre shows the integrated overall quality level determined based on the quality level of the four components of TAIL.

Furthermore, we do not have strong evidence of how the different parameters interact or whether, for example, noise should be weighed more heavily than lighting. Consequently, we chose not to allow tradeoffs. Instead, we wanted to create an incentive to improve all aspects of the indoor environment.

We are still working on determining the overall rating to ensure it is inclusive and encourages action rather than penalizing, but again, we do not want to create situations in which one IEQ component is valued more than the others.

**LHC: All four aspects/components of the indoor environment are weighed equally in TAIL. But you assess 12 parameters, with only one representing thermal comfort and eight representing indoor air quality. How is that equal?**

**CM:** Our development of TAIL began with an extensive literature review to identify which parameters meaningfully describe the indoor environment - those linked to health, comfort, and well-being, that are practical to measure, affordable, and easy for both occupants and building managers to understand.

From the roughly 90 parameters identified in the literature, we applied clear selection criteria: affordability, clarity, the existence of established guidelines, and consistency with existing building certification frameworks. Using this process, we narrowed the list down to 12 parameters. Indoor air quality is inherently diverse. It includes particulate matter (such as PM<sub>2.5</sub>), gaseous pollutants (such as benzene and formaldehyde), biological contaminants (such as mold), and even radioactive elements (such as radon). We also use CO<sub>2</sub> as a proxy for ventilation. So yes, there

are 8 parameters related to indoor air quality that reflect the scientific literature and align with other green building certification systems. Finally, each IEQ component (thermal environment, acoustics, indoor air, light) carries the same weight, so in the end, they contribute equally.

**LHC: Typically, thermal comfort is characterized by using four parameters: air temperature, mean radiant temperature, air velocity, and relative humidity. Why does TAIL use only a single parameter to represent the thermal aspect?**

**PW:** You are absolutely right. We had to take a pragmatic approach. Our aim was to create a rating scheme that people could realistically use and parameters that could be measured without high cost or complexity. It is simply not feasible to measure all the parameters reported in the scientific literature that may be used to characterize the indoor environment.

For the thermal aspect, we decided to focus solely on air temperature. Relative humidity is typically within an acceptable range in most buildings (and is rather integrated into the ‘indoor air’ component), and adding operative temperature (which combines air temperature with mean radiation temperature) would have made the measurement significantly more complex and difficult to measure. So, we opted for a balance between scientific completeness and practical applicability. Additionally, in the new energy-retrofitted buildings, it has been observed that the air temperature is close to the operative temperature. Using air temperature is not expected to result in a flawed rating.

**LHC: Did you validate your rating scheme? I mean, did you check if these 12 parameters are sufficient?**

**PW:** Yes, we conducted several measurements to verify whether the scheme could meaningfully distinguish buildings by their IEQ and to ensure that not all buildings would simply fall into, for example, Category 4. The results showed that the selected 12 parameters are sufficient to capture real differences in performance, while still keeping the scheme practical and usable in everyday practice. Some measurements have been published in [2]. We intend to publish the others this year.

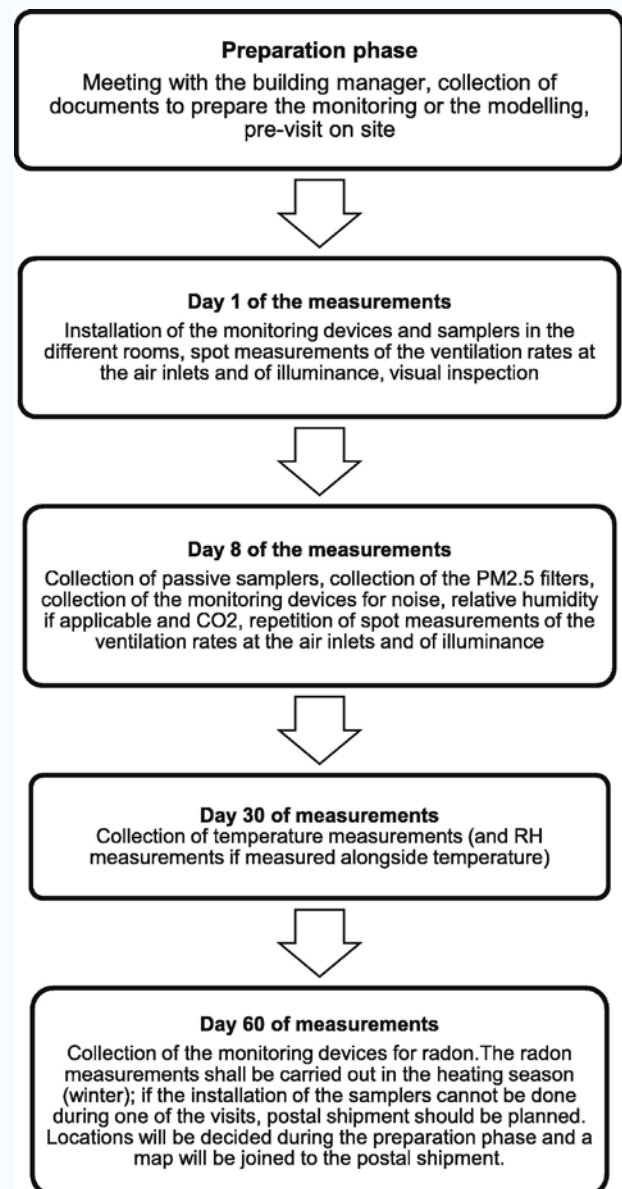
**LHC: Let’s talk about practical use. Can anybody apply this rating scheme, or is some form of accreditation required?**

**CM:** Anyone can use it. TAIL is an opensource rating scheme, and the full protocol is described in [2]. The protocol explains how to select representative rooms, since it’s not feasible to measure every space in a building. For example, in an office building, you must include both individual offices and openplan areas, while in hotels, you focus on different types of guest rooms. No measurements are needed in restaurants or other daytime spaces.

It’s not a simple ‘plugandplay’ tool, but it is relatively affordable and accessible for anyone familiar with indoor environmental measurements. To support users, we also developed an Excel-based calculation tool. It is not included directly in the original publication, but it can be provided upon request.

**LHC: So, if I carry out all the measurements in the office building where I work and obtain an overall indoor environment quality rating, will anyone verify it, similar to how assessors operate in other certification schemes?**

**PW:** As we said, anyone can use it. Of course, you need some skills and experience, but most building facility managers, technicians, and engineers can perform and interpret measurements (Fig.2). We intend to prepare a train-



**Fig. 2.** The process of assessment of the parameters used to derive the level of TAIL.

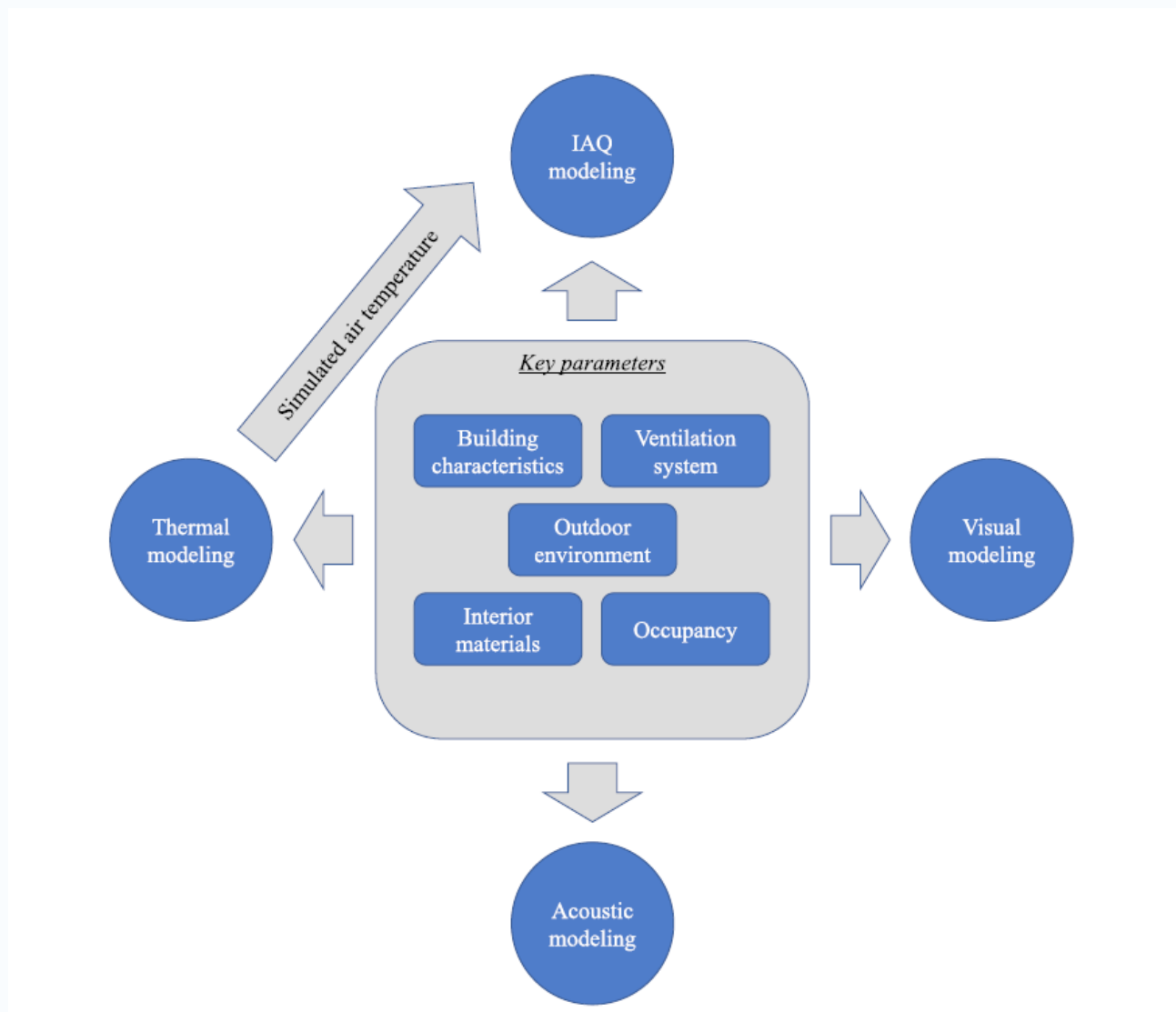
ing module on performing measurements using TAIL and place it online. The scheme is voluntary and fully open-source. The idea is to have a single, shared framework that can be applied across different buildings, so that measurements are comparable and allow meaningful benchmarking using the same set of metrics. Hopefully, the scheme will be included in future standards and guidelines. TAIL has been mentioned in the EC documents supporting the application of the new EPBD [3].

**CM:** Yes, that's certainly the direction we hope to move toward in the future. But our first and most important objective is to give building owners a clear way to identify potential issues in their buildings - especially after renovation - so they can address them and improve IEQ.

**LHC: Is the use of TAIL also applicable to new buildings?**

**CM:** Yes, it can also be applied to new buildings, because the underlying parameters are the same. However, TAIL was originally developed with retrofitted buildings in mind, given the specific risk that energy renovations can unintentionally degrade indoor environmental quality.

Let me also mention that we developed a modeling tool for use during the design process. It is called predicTAIL and allows the modeling of the TAIL quality category for each parameter in a future building (new or retrofitted). It guides the designer on which decisions should be made to ensure the overall IEQ is not compromised [3] and (Fig.3).



**Fig. 3.** Diagram of the PredicTAIL method.

**LHC: Have you compared TAIL with systems like the WELL Standard or BREEAM to see how they align?**

**CM:** We have not carried out any comparison. Our aim is not to position TAIL against existing certification schemes. TAIL is simply another tool - an open-source one - that anyone can use.

**PW:** In practice, most of the measurements required for TAIL are also needed in many other certification systems. Our view is that a building's performance should be assessed not only from an energy perspective but also from the standpoint of indoor environmental quality, and that is precisely what TAIL provides.

Because it is open-source and grounded in established standards and WHO guidelines, it has a strong and transparent reference base. These references were not created by us; they come from widely recognized scientific and regulatory sources and bodies.

**LHC: TAIL was developed between 2019 and 2021. Are there any new developments?**

**PW:** At the moment, we do not have an active project dedicated specifically to TAIL, but TAIL is an element of the EU Breeze project and a new PhD project in France. There may be other groups that use TAIL, but we are not aware of them; we hereby request contact with them. We would like to build more visibility - ideally through a stronger communication campaign and a dedicated website - but for now, one of the most important next steps is to develop a sensor or monitoring device tailored to TAIL. That would make the measurement process much easier and more accessible.

The new EPBD requires all office buildings to monitor indoor-environment quality, but it does not specify how this should be done. The European Commission has published a guideline [4] for implementing the EPBD; TAIL is included among the possible methods for characterizing indoor environmental quality.

**CM:** We recently adapted TAIL for use in school buildings [5]. It has already been applied in 308 schools across France, and the experience so far has been very positive. The method has proven highly feasible, helped prioritize IEQ improvements where needed, and enabled comparisons across different school buildings. We also plan to have the TAIL for residential buildings.

**LHC: If you would have to simplify TAIL, do you see any possibility to reduce these 12 parameters?**

**CM:** I would not reduce the number of parameters. What we really need is a monitoring device that can easily and affordably measure all 12 parameters. The market is evolving quickly, and there are already promising developments.

**PW:** The device alone is not enough. It needs to be part of a broader infrastructure. We need companies that can offer these measurements as a service. And this is not

unique to TAIL- any rating scheme requires an ecosystem around it. So rather than simplifying the method or making compromises, we should focus on building that infrastructure. The TAIL scheme has already been made simple but credible.

**LHC: What are your hopes for the future of the TAIL rating scheme?**

**CM:** My hope is that TAIL will be widely adopted by managers of office buildings and schools, and that it will eventually expand to other building types as well. We are also considering adding an occupant rating component in the future.

**PW:** Nowadays, we still characterize buildings primarily through their energy performance. We should also be characterizing them based on how well they perform in terms of indoor environmental quality. The latest version of the EPBD moves us in that direction by requiring buildings to be both energy-efficient and healthy. That is an important step forward. And we already have a validated tool, TAIL, to reach that goal. It is grounded in existing standards and WHO guidelines that can support this shift. So why not use it? We must start somewhere.

Occupant feedback is important, of course, because sensitivity varies from one building population to another. But we have not yet included post-occupancy evaluation in TAIL, as it would make the scheme more complex and harder to apply in practice. Though there are plans to do it.

Of course, it would be great to valorize TAIL and attach economic values to different categories. This may sometimes be difficult to do, but we are also working on how to make it happen, as it would create an additional incentive to ensure that IEQ in buildings is high.

## References

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