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Deep Energy Retrofits and IEQ; A European TAIL

Thermal, Acoustic, Indoor air, Luminous

Good Day and welcome to IAQ Radio+ Blog for episode 718 this week we welcomed: Dr. Pawel Wargocki, Dr. Wenjuan Wei and Dr. Corinne Mandin for a discussion about Deep Energy Retrofits and IEQ; A TAIL from Europe. With the large focus on making our building stock less energy intensive what will happen to indoor environmental quality? We discussed with a stellar group of academics about how to determine what deep energy retrofits will do to IEQ.

Pawel Wargocki is professor at the Technical University of Denmark. He graduated from the Warsaw University of Technology in Poland. He received his Ph.D. from the Technical University of Denmark in 1998, where he has been teaching and performing research ever since. He has more than 25 years of experience in research on human requirements in indoor environments. He is best known for his seminal work demonstrating that poor indoor environmental quality affects the performance of office work and learning. Other work influenced requirements for ventilation and air cleaning. Recent research includes studies on human emissions, sleep quality, the development of IEQ rating schemes, and the performance of green buildings. He has collaborated with leading research institutions, universities, and industrial partners worldwide, such as the National University of Singapore, Jiaotong University in Shanghai, Syracuse Center of Excellence, United Technologies, and Google. He was President and long-standing board member of the International Society of Indoor Air Quality and Climate (ISIAQ), President of the ISIAQ Academy of Fellows (previously Academy of Indoor Air Sciences), Vice President of the Indoor

Air 2008 conference, and Chair of ASHRAE committees. He has received several awards for his work, including the Rockwool Award for Young Researchers, ASHRAE Ralph Nevins Award, ISIAQ's Yaglou Award, and the Indoor Air Journal Best Paper Awards.

Dr. Wenjuan Wei is a research scientist at the Scientific and Technical Centre for Building (CSTB, France, since 2018). She received her Ph.D. in Civil Engineering from Tsinghua University (2009-2014). She was a guest researcher at the National Institute of Science and Technology (NIST, USA, 2011-2012), and a post-doctoral researcher at CSTB (2016-2018). During her post-doctoral appointment, she was Marie Skłodowska-Curie Fellow of the European Commission's Marie Skłodowska-Curie Actions and PRESTIGE Fellow of Campus France. Dr. Wei is a specialist in indoor environmental quality (IEQ). She received the Yaglou Award of the ISIAQ Academy in 2022 and is the co-chair of the ISIAQ Scientific and Technical Committee 32 addressing environmental/climate impacts. Her research interests include the emission and transport of (semi) volatile organic compounds (S)VOCs, indoor heat and pollutant exposures, and IEQ index. She has participated in several European and French research projects, such as Horizon-ALDREN and Horizon-PARC. She is co-supervising 2 PhD theses. She has published 43 peer-reviewed journal articles, and her h-index is 22.

Corinne Mandin earned her PhD in environmental chemistry from the University of Rennes, France. From 2013 to 2022, she coordinated the French Indoor Air Quality Observatory, a research program dedicated to indoor environmental quality created by the French government. In 2022, she joined the French institute for radiation protection and nuclear safety (IRSN) where she leads the epidemiology research group. Her research interests include human exposure to chemical and physical risk factors, both in living spaces and occupational settings, and related health effects. She is the Immediate Past President of the International Society for Indoor Air Quality and Climate (ISIAQ).

BACKGROUND INFORMATION & CONTEXT

To avoid health risks and discomfort, the European Energy Performance for Building Directive (EPBD) mandates that ‘‘Member States should support energy performance upgrades of existing buildings that contribute to achieving a healthy indoor environment.” There is, however, no widely accepted method for rating the

overall level of indoor environmental quality (IEQ), although several different approaches are proposed by standards, guidelines, and certification schemes. To fill this void, a new rating scheme called TAIL was developed to rate IEQ in offices and hotels undergoing deep energy renovation during their normal use; the scheme is a part of the energy certification method developed by the EU ALDREN project. The TAIL scheme standardizes rating of the quality of the thermal (T) environment, acoustic (A) environment, indoor air (I), and luminous (L) environment, and by using these ratings, it provides a rating of the overall level of IEQ. Twelve parameters are rated by measurements, modeling, or observation to provide the input to the overall rating of IEQ. Their quality levels are determined primarily using Standard EN-16798-1 and World Health Organization (WHO) air quality guidelines and expressed by colors and Roman numerals to improve communication. The TAIL rating was shown to discriminate IEQ levels when its feasibility was examined in eleven buildings across Europe to provide support for its applicability and input for further modifications. Opportunities for using the scheme in other types of buildings and for its further development and application are discussed.

The recently developed TAIL rating scheme enables assessment of the changes in the indoor environmental quality (IEQ) associated with a building's deep energy renovation (DER) and classification of the resulting quality levels of the thermal (T), acoustic (A), and luminous (visual) (L) environments and indoor air quality (I). Since the TAIL rating is primarily based on measurements, it cannot be determined prior to renovation operations to help design the IEQ. To fill this gap, the PredicTAIL method was developed to predict the changes in ten of the twelve TAIL parameters as a result of DER.

The parameters included in PredicTAIL are indoor air temperature, relative humidity, sound pressure level, daylight factor, illuminance, and concentrations of carbon dioxide, formaldehyde, benzene, radon, and PM2.5; no prediction is made for ventilation rate or mold. To examine the feasibility of the PredicTAIL method and the sensitivity of the existing models for quantifying changes in the TAIL parameters corresponding to different renovation strategies, simulations were performed in a hotel and an office building using different software: TRNSYS, IDA ICE, ACOUBAT, MATHIS-QAI, and PHANIE; other existing models can be used as well. These modeling tools were first benchmarked against the TAIL parameters measured in the buildings before renovation. Once the agreement between

measurements and modeling was considered acceptable, four pragmatic renovation scenarios were applied, and their impact on the IEQ parameters was quantitatively modeled. The simulations showed that the quality levels of the IEQ parameters were improved or unchanged for some parameters but degraded for other parameters after DER. The changes in the IEQ parameters and the TAIL rating depended on the renovation scenarios, suggesting that the PredicTAIL method is sufficiently sensitive to guide renovation design.

The choice of the TAIL parameters is a compromise between a large number of measurement-based IEQ parameters that have been proposed in scientific publications and Green Building certification schemes, including HQE, BREEAM, and LEED, and the feasibility and affordability to implement TAIL rating scheme.

The quality level of each parameter is assessed in accordance with the EN 16798-1 standard and the World Health Organization (WHO) air quality guidelines.

The PredicTAIL method is not a new simulation model, but it establishes the principles for integrating the existing thermal, acoustic, IAQ and lighting models to enable the prediction of the TAIL parameters under a holistic modeling framework.

Nuggets mined from today's episode:

Why are IEQ standards an important topic? Pawel- KPIs (Key Performance Indicators) are quantifiable measurements used to measure performance. For IEQ there has been a lack of KPIs. Lack of IEQ KPIs results in an inability to compare resulting in setbacks in innovation. Our team sought to start the process of standards quantification and rating. Retrofitting buildings can change IEQ in either direction. The EU seeks to improve energy efficiency and reduce CO_2 emissions. One of our goals is to find and identify economic benefits for retrofitting. The ability to measure and quantify IEQ performance provides opportunities to intensify incentives for retrofitting hotels and office buildings through a rating scheme with metrics.

Rather than reconstruct the wheel, we sought to find existing standards and metrics. We found that 90 different parameters are currently being measured without a standard approach which should be measured; so our team decided to create our own set of necessary measurements/parameters to rate IEQ. We first defined our working principles and objectives.

Corinne- European buildings often lack ventilation. In 2012, mold and radon were identified as potential problems in both new and retrofitted tight buildings. Lack of ventilation allows radon to accumulate and mold to grow in the case of building up RH. But we must not only focus on IAQ but also on IEQ.

The Energy Performance of Buildings Directive (EPBD) introduces a set of standards that play a key role to support the Energy Performance of Buildings Directive (EPBD) of the EU. Any energy retrofit should not aggravate the health and comfort of the occupants.

Pawel- TAIL is an abbreviation of 4 primary building metrics: Thermal Acoustic Indoor air and Luminous. For Thermal, TAIL uses dry bulb measurements. TAIL was developed to be applicable and adaptable by the industry. It can also be used by research but we were more focusing on ensuring that IEQ is considered by industry and attainable. TAIL metrics include: Dry Bulb, Air Velocity, Humidity, Wet Bulb. TAIL was created with simplicity is mind. Purposefully, narrowed the number of parameters rather than widening them. The simpler TAIL is to use, the wider the potential for acceptance.

Wenjuan- There are both similarities and differences between American, European and Asian buildings. TAIL's main focus is alignment with European climate and building standards. Yet, TAIL is adaptable to buildings located in a wide range of geographies.

Corinne- We reviewed existing knowledge rather than rebuild the wheel. The team decided to refer to Green Building Certifications and existing standards to choose the parameters to be included in TAIL rating scheme. The 90 parameters reviewed were reduced to 12, and those were divided into 4 categories defining IEQ. Energy retrofits should not result in deterioration of interior parameters. There should be affordable and accessible guidelines to classify good or poor quality.

Wenjuan- The IAQ in TAIL are: Ventilation Rate, Relative Humidity, CO_2 concentration, Formaldehyde, Benzene, PM2.5, Visible Mold and Radon.

Pawel- IAQ is an important issue. We couldn't reduce the parameters down to only 1 or 2; so we decided to use some that exist; CO_2 (because it is commonly used)

and Ventilation Rate (because it can be measured). The WHO has indoor air quality guidelines for chemical substances and mold. We followed them.

Corinne- There are diverse pollutants indoors: biological (bacteria, fungi, virus), physical (radon), chemical (particles such as PM2.5 and organic gases).

Pawel- The ventilation rate indoors can be hard to measure. TAIL did not want to enforce these measurements but ventilation is a proxy of IAQ and generally prescribed in IAQ standards such as EN 16798. CO_2 alone doesn't provide information on ventilation as you need to know occupation and activity as a minimum.

Corinne- It's costly to measure ventilation rates. It can be done at ventilation supply grilles and air ducts. In a building, for TAIL assessment, you need to carry out the measurements in 2 to 10 rooms depending on the size of the building. If people cannot afford measuring all the twelve parameters, measuring fewer parameters is better than measuring none. Some schools and IEQ consultants in France are currently using TAIL. IEQ consultants and others with the equipment and expertise can take the measurements.

Pawel- The TAIL papers were published during the pandemic and were not widely circulated. We envision that each country using TAIL will decide upon their own metrics. TAIL is designed for both research and practical use developers are focused more on the practical.

Wenjuan- TAIL can be used in conjunction with standardized instruments and low-cost sensors. The so-called low-cost sensors need to be benchmarked prior to use. Within the EU U-CERT project (https://u-certproject.eu/)it is planned to develop a toolkit and program to calculate TAIL online.

Pawel- Ambition to develop a TAIL meter that anyone can make measurements. Low-cost sensor can also be used. TAIL defines the quality of measurements in the published papers.

Corinne- Formaldehyde and benzene, known carcinogens are included in TAIL rating scheme measurement. Benzene is regulated in outdoor air and is a tracer for

vehicle combustion. More generally, benzene is emitted by combustion processes, e.g., smoking, wood and incense burning.

Wenjuan- TAIL measures the actual. PredicTAIL is based on predicted TAIL levels before completion of retrofitting. Capturing seasonal changes for a minimum of 1 season preferably 2 seasons over span of 7-30 days.

ROUNDUP-

Where is TAIL going next?

Corinne- The adoption process of TAIL can be slow. TAIL should be part of the regulations because retrofitting is a massive plan due to energy saving needs. Moreover, people expect easy to understand information. The French government wants to add benefits of IEQ in new buildings as a new label in 2030. Optimistic!

Wenjuan- We have an ALDREN PhD student committed to a 3 year long program to adapt TAIL to French Schools, test and gather data. We are thinking about other projects.

Pawel- Ongoing development of TAIL with the hopes of having it included in a European Standard. Our objective is including TAIL in the revision of EN 16798.

What is your major concern related to building energy retrofit?

Pawel- The most common concern during retrofitting is IAQ. Thermal overheating is another concern.

Wenjuan- I agree with Pawel. We saw preliminary results that temperature can be a concern in some buildings. CO_2 is also a concern.

Corinne- Mold, radon, and rising temperatures due to climate change are concerns.

Guests lasts words:

Pawel- We want to place an economic value on the benefits provided by TAIL (through estimation of benefits from improved occupant health and productivity/learning).

Wenjuan- Try Tail, use TAIL and give us your feedback.

Corinne - We need to look at buildings holistically. While energy performance is important occupant health is also highly important.

Z-Man signing off

Trivia:
What is EN 1990-EN 1999?

Answer: EN codes EN 1990-EN 1999 are a series of 10 European codes standards providing a common approach for the design of buildings and other civil engineering works and construction projects. They are the recommended reference for technical specifications in public contracts.

Answered by:
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