Politecnico di Torino

Doctoral Dissertation

Doctoral Program in Energetics (37th cycle)

# Design and in-field application of a monitoring system for indoor environmental quality and occupants' comfort assessment

Virginia Isabella Fissore

**Supervisors**

Prof. Arianna Astolfi, Supervisor

Prof. Anna Pellegrino, Co-supervisor

Ph.D. Giuseppina Emma Puglisi, Co-supervisor

## Summary

The building sector is responsible for about 30% of global final energy consumption and nearly 26% of global energy related emissions. The revised Energy Performance of Buildings Directive (EPBD) contributes to the goal of achieving a decarbonized, zero-emission building stock by 2050, promoting the employment of Building Automation and Control Systems (BACS), to further provide comfortable and healthy environments. Indoor Environmental Quality (IEQ), which accounts for thermal, acoustic, visual and indoor air quality domains, and energy monitoring sensors can be exploited to support the implementation of such systems.
Standards and building certification schemes propose a different number of IEQ parameters to be monitored, and although numerous studies have proposed methods for developing IEQ monitoring systems and defining an overall IEQ index able to describe the building conditions, a standardized solution has yet to emerge. Nowadays, it is possible to deepen the research by continuously and simultaneously monitoring thermal, acoustic, lighting and air quality parameters thanks to the use of low-cost sensors within the IoT framework. Nevertheless, many critical design challenges, both at the hardware and software levels, have yet to be fully explored in the pursuit of an integrated IEQ monitoring platform. Moreover, although low-cost sensors offer a cost-effective solution for driving automated or human-informed control actions within BACS, they still suffer from issues in sensitivity, accuracy and response time and lack harmonized calibration standards.
Since IEQ drives energy consumption and affects occupants' comfort, well-being, health and productivity, post-occupancy evaluation surveys, based on questionnaires administered to the building end-users, were introduced to assess IEQ and comfort. However, the proper methodology, device to be used, adequate frequency of feedback request and questions to administer are still under investigation. The reliability of subjective responses may also be altered by factors that could influence occupants' comfort, i.e., contextual, personal and behavioural factors. Studies have shown that even when IEQ meets established standards thresholds, occupants can still experience discomfort, revealing a critical gap between objective measurements and subjective perception.
Within this context, this Ph.D. research aimed at developing the PROMET&O (PROactive Monitoring for indoor EnvironmenTal quality & cOmfort) system, made up of a low-cost multi-sensor that monitors parameters across the four IEQ domains, and a questionnaire that collects feedback on occupants' comfort.

The data monitored during occupancy hours are used by the PROMET&O system to compute quality indexes of each domain (i.e., percentages of compliance in time of each parameter with predefined thresholds), which are then averaged into an overall IEQ index. Specifically conceived calibration procedures were tailored to the requirements of each monitored parameter to ensure the metrological traceability of the multi-sensor measurements. Meanwhile, subjective comfort percentages are calculated from questionnaire responses. All the collected and processed data are displayed on an interactive dashboard to enhance building end-users awareness on IEQ topic. In this way, comprehensive information is provided that could allow facility managers to implement building systems control strategies tailored to each environment, based on monitored IEQ conditions, contextual factors and subjective feedback, ultimately enhancing occupants' well-being and energy efficiency.

The in-field application of this system enabled (i) the comparative analysis of objective monitored data and subjective comfort feedback, (ii) the refinement of single-domain index calculations, (iii) the assessment of the effects of personal, behavioural, and contextual factors on IEQ and occupants' comfort, and (iv) the empirical confirmation of the value of collecting subjective feedback.