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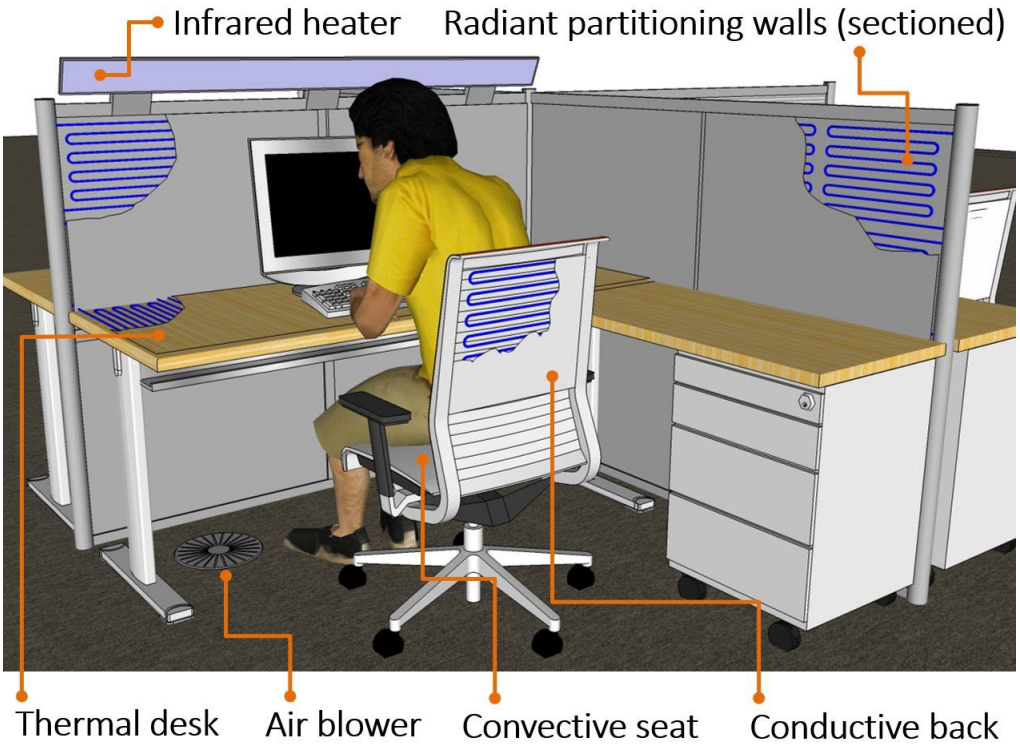
IEA EBC Annex 87

Scientific contribution of EPFL to IEA EBC Annex 87

Annual Report 2025



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Zusammenfassung

Dieser Jahresbericht beleuchtet die Beiträge des Laboratory of Integrated Comfort Engineering (ICE) der EPFL zum IEA EBC Annex 87 im Jahr 2025. Prof. Khovalyg und das ICE-Laborteam haben sich intensiv für die Förderung der Forschung zu personalisierten Umweltkontrollsystemen (PECS) durch wissenschaftliche redaktionelle Arbeit, umfangreiche Literaturrecherchen und mehrere Kooperationsinitiativen im Rahmen von Annex 87 engagiert. Ihre Beiträge umfassen die Leitung und Mitautorenschaft wichtiger systematischer Übersichtsarbeiten, die Teilnahme an laufenden Überprüfungen zu PECS-Steuerung, -Integration und -Umgebungsanforderungen sowie die Unterstützung internationaler Forschungsbemühungen zu thermischer Empfindungsmodellierung, manikinbasierter Leistungsbewertung und energiearmen Funktionskriterien für PECS. Parallel dazu entwickelt das Team methodische Rahmenwerke zur Bewertung der Energie- und Komfortleistung von PECS und führt ein vom SNF finanziertes Projekt zu energieeffizienten personalisierten Komfortsystemen durch. Dazu gehören die Festlegung von Testbedingungen, die Planung und Durchführung von Manikin-Experimenten sowie die Durchführung von Labormessungen zur Quantifizierung lokaler Effekte und des Energieverbrauchs repräsentativer PECS-Geräte. Prof. Khovalyg verbreitete die Aktivitäten von Annex 87 auch durch die Leitung von Workshops bei COBEE 2025 und CISBAT 2025, wo er Diskussionen über Benutzererfahrung, Bewertungsmethoden und die breitere Anwendbarkeit von PECS-Lösungen anregte.

Résumé

Ce rapport annuel met en lumière les contributions du Laboratoire d'ingénierie intégrée du confort (ICE) de l'EPFL à l'annexe 87 de l'IEA EBC en 2025. Le professeur Khovalyg et l'équipe du laboratoire ICE se sont fortement engagés dans l'avancement de la recherche sur les systèmes de contrôle environnemental personnalisés (PECS) à travers des travaux éditoriaux scientifiques, des revues bibliographiques approfondies et de multiples initiatives collaboratives au sein de l'annexe 87. Leurs contributions comprennent la direction et la co-rédaction d'importantes revues systématiques, la participation à des revues en cours sur le contrôle, l'intégration et les exigences environnementales des PECS, et le soutien aux efforts de recherche internationaux sur la modélisation de la sensation thermique, l'évaluation des performances à l'aide de mannequins et les critères fonctionnels à faible consommation d'énergie pour les PECS. Parallèlement, l'équipe développe des cadres méthodologiques pour évaluer les performances énergétiques et de confort des PECS et mène un projet financé par le FNS sur les systèmes de confort personnalisés à haute efficacité énergétique. Cela comprend la définition des conditions d'essai, la planification et la mise en œuvre d'expériences sur des mannequins, et le lancement de mesures en laboratoire pour quantifier les effets locaux et la consommation d'énergie des dispositifs PECS représentatifs. Le professeur Khovalyg a également diffusé les activités de l'annexe 87 en animant des ateliers lors des conférences COBEE 2025 et CISBAT 2025, favorisant les discussions sur l'expérience utilisateur, les méthodes d'évaluation et l'adoptabilité plus large des solutions PECS.

Summary

This annual report highlights the contributions of the Laboratory of Integrated Comfort Engineering (ICE) at EPFL to IEA EBC Annex 87 in 2025. Prof. Khovalyg and the ICE lab team have been deeply engaged in advancing research on Personalized Environmental Control Systems (PECS) through scientific editorial work, extensive literature reviews, and multiple collaborative initiatives within Annex 87. Their contributions span leading and co-authoring major systematic reviews, participating in ongoing reviews on PECS control, integration, and environmental requirements, and supporting international research efforts on thermal sensation modelling, manikin-based performance evaluation, and low-energy functional criteria for PECS. In parallel, the team is developing methodological frameworks for assessing PECS energy and comfort performance and is conducting an SNSF-funded project on energy-efficient personalized comfort systems. This includes defining testing conditions, planning and implementing manikin experiments, and launching laboratory measurements to quantify local effects and energy use of representative PECS devices. Prof. Khovalyg also disseminated Annex 87 activities by leading workshops at COBEE 2025 and CISBAT 2025, fostering discussions on user experience, evaluation methods, and the broader adoptability of PECS solutions

Contents

Abbreviations

IEA	International Energy Agency
EBC	Buildings and Communities Programme
ICE	Laboratory of Integrated Comfort Engineering
EPFL	École Polytechnique Fédérale de Lausanne
SFOE	Swiss Federal Office of Energy
PECS	Personalised Environmental Control Systems
HVAC	Heating, Ventilation, and Air-Conditioning
MET	Metabolic rate
TSV	Thermal sensation vote
TCV	Thermal comfort vote
IAQ	Indoor air quality
Empa	Swiss Laboratories of Materials Science and Technology

1 Introduction

1.1 Background information and current situation

A Personalised Environmental Control System (PECS) is defined as "*a system that can provide individually controlled thermal, air quality, acoustic or luminous environments in the immediate surroundings of an occupant, without affecting the entire space and other occupants' environment directly*". There has been growing interest in thermal PECS since as early as 1977 [1], as they can offer several benefits over traditional space conditioning in buildings using centralized HVAC (Heating, Ventilation, and Air-Conditioning) systems [2]. The primary benefit of PECS is higher satisfaction with the indoor environment, resulting from improvements in the immediate indoor environment experienced by occupants, enabled by the possibility of personalized local control of climate conditions [3–5]. Secondly, PECS offer the potential to reduce the operational energy of buildings due to (i) widening the range of temperature setpoints of the background environment and consequently reducing thermal energy provided by the centralized conditioning system or even avoiding any (e.g., in well-insulated buildings) [6], (ii) reducing supply air flow rates into the space as primary thermal conditioning is enabled by PECS and only the minimum required fresh air for ventilation purposes is needed [7], (iii) conditioning occupants only when they are present [7-8]. Finally, the well-being and productivity of occupants can be targeted when PECS are adequately applied [9-10]. Given that office personnel costs are high [11], an indoor environment that boosts work productivity can help reduce a business's total operational costs. Thus, PCSs represent a paradigm shift in how we climate our buildings, allowing targeted heating/cooling for people rather than spaces that are often unoccupied.

The positive impacts of PECS are broad (i.e., higher occupant satisfaction, enhanced well-being and productivity, and reduced building energy use) and warrant investigation, especially in light of the built environment's transition toward occupant-centric solutions and the energy crisis that urges reductions in building energy use. An increasing body of research has advanced various aspects of thermal PECS over the past few decades [2, 12-13]. However, there are still so few PECS commercially available and deployed in actual buildings. The main issue is that it is difficult to compare the performance of different PECS, as prior studies primarily explore a single device type rather than multiple devices. Studies also used different instances as their reference cases. Therefore, comparing the results of different studies is unrealistic. To increase PECS market presence and deployment in actual buildings, standardized methods for PECS design and integration with the centralized HVAC system should be developed, along with a selection guide. In addition, the interaction between different PECS (e.g., combinations of thermal and ventilation) should be better understood. For these reasons, a global scientific initiative, Annex 87, "Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems (PECS)," was launched in 2022 and supported by the Buildings and Communities Programme (EBC) of the International Energy Agency (IEA). The main objectives of Annex 87 are (i) to optimize PECS for energy use, human comfort, and productivity, (ii) to develop guidelines on integrating PECS in already existing buildings, (iii) to define standardized performance evaluation of PECS, (iv) to address current barriers for a wide implementation of PECS in buildings, and, finally, (v) to provide input to standards about proper application of PECS. Among numerous international participants of Annex 87, the Laboratory of Integrated Comfort Engineering (ICE) at EPFL, headed by Assist. Prof. Dolaana Khovalyg contributes to international efforts to advance global knowledge of the energy effectiveness of thermal PECS through its fundamental and applied research. In addition, Assist. Prof. Khovalyg, one of the leading experts in the field, co-leads Subtask A,"**Fundamentals**," and is actively involved in cross-subtask activities.

1.2 Purpose of the project

The purpose of the ICE lab's (EPFL) participation in Annex 87 is to advance knowledge in the design and operation of thermal PECS and their application through research involving human experimentation (controlled studies and field tests), modeling of human thermophysiological responses, and building energy simulations.

1.3 Objectives

The objectives of the ICE lab (EPFL) activities contributing to Annex 87 are:

- Establish scientific evidence for the need for the personalized climatization approach
- Develop methods for personalized sensing to enable the use of PECS
- Development and testing of PECS in terms of effect on human comfort and energy reduction in buildings

2 Procedures and methodology

The ICE lab contributes to Annex 87 through two main efforts:

1. **Collaborative activities within Annex 87:**
   - *Contribution to comprehensive literature review activities*: participation in an extensive literature review activities to establish a state-of-the-art, focusing on thermal and ventilation Personal Environmental Control Systems (PECS), encompassing the work of Subtasks A through D.
   - *Contribution to collaborative research projects*: engagement in collaborative research tasks within activities in Subtasks A-D (e.g., international Round Robin test on manikin-based PECS evaluation, conducting simulation studies to define low-energy functional criteria and power requirements for energy-efficient PECS
2. **Generation of Original Research Findings**: Original research results on Personalized Environmental Control Systems and personalized comfort from own research projects that leverage the lab's unique experimental resources, such as *the ICE climatic chamber*, a highly advanced facility designed for controlled studies on thermal and ventilation performance (details: https://www.epfl.ch/labs/ice/research-facilities/).

3 Activities and results

3.1 Participation in expert meetings of Annex 87

The 5th expert meeting of the working phase of IEA EBC Annex 87 took place in Stuttgart (Germany) on April 3-4, 2025, and the 6th expert meeting was held in Montreal (Canada) on September 22-23, 2025 (Figure 1). Prof. Khovalyg, the head of the ICE lab, participated in both in-person meetings and led the updates on Subtask A "*Fundamentals*."

Figure 1. Annex 87 expert meeting attendees in 2025, only in-person participants are captured: (left) in Stuttgart, April 3-4, (right) in Montreal, September 22-23.

3.2 Scientific activities and results

Guest editor for the special issue on PECS in the journal "Building and Environment":
Assist. Prof. Khovalyg served as a guest editor of the special issue "*Advancements in Personalized Environmental Control Systems (PECS)*" throughout 2024-2025, and 22 original research works were accepted for publication.

Literature review:

A series of literature review activities to understand the state of the art and define the research gaps related to PECS in the domains of Thermo and IAQ was initiated across Annex 87 Subtasks A-D.

Prof. Khovalyg contributed to the following published reviews:

- Leading author of the review work "**Personalized Environmental Control Systems (PECS): Systematic review of benefits for thermal comfort, air quality, health, and human performance**" published in the *Building and Environment* journal, DOI: 10.1016/j.buildenv.2025.113541
- Co-author of the review work "**Personalized environmental control systems (PECS): A systematic review of performance evaluation methods for thermal comfort, air quality and energy**" published in the *Building and Environment* journal, DOI: 10.1016/j.buildenv.2025.113471

Prof. Khovalyg contributes to the following ongoing review works:

- **Literature review on the control and integration of Personalized Environmental Control Systems (PECS)** – activity within Subtask C, publication is for 2026
- **Definition and identification of the requirements of PECS in terms of localized and background thermal environment and air quality** – activity within Subtask A, publication is for 2026

Annex 87 collaborative research activities:

The ICE lab team, led by Prof. Khovalyg, contributes to the following ongoing research activities:

- **Validation and improvement of local thermal sensation models** (lead – Agnes Psikuta, Empa)
- **Round Robin Test to evaluate the PECS performance using manikins** (lead – Kai Rewitz, RWTH-Aachen)

- Simulation-based research on **outlining the basic low-energy functional criteria for PECS** and **identification of generic power requirements for PECS** to **achieve energy savings** compared to ambient conditioning systems (lead – Douaa Al-Assaad, KU Leuven, and Dolaana Khovalyg, EPFL)

ICE lab's ongoing research projects:

- Development of **a methodological framework** for evaluating **the potential energy savings achievable through PECS** and definition of **metrics and assessment methods to quantify PECS performance** in terms of both *comfort* and *energy indicators* (in collaboration with Politecnico di Torino, TEBE Group).
- The ICE lab was awarded SNSF funding (grant number 10000212) to conduct a research project titled "**Personalized Comfort Systems (PCSs): Minimizing energy use in buildings while maximizing thermal comfort**" in collaboration with Empa. Details of the funding are available here: https://data.snf.ch/grants/grant/10000212. The project launched in November 2024, with 2 PhD students joining the team (Yan Liang and Maitreyee Saini, supervised by Prof. Khovalyg). The following activities have been performed in 2025:
  - Identifying testing conditions for a range of PECS (conductive, conductive, and radiative), methods for testing the local environmental exposure, and measuring the energy effectiveness of PECS
  - Planning of the experiments to measure the performance of PECS using thermal manikins from Empa in the ICE climatic chamber, and purchase of the PECS devices for testing.
  - Setup of the experiments in the ICE climatic chamber, as shown in Figure 2, to measure the performance of 3 types of PECS (desk fans, radiant panels, and heating chairs). The objective of measurements is to quantify: (i) the local effect of PECS using the HVAC thermal manikin; (ii) measure energy used by the PECS and the background HVAC system, and verify the methodology to determine the energy effectiveness of PECS. These experiments started in November 2025 and will continue until mid-January 2026.

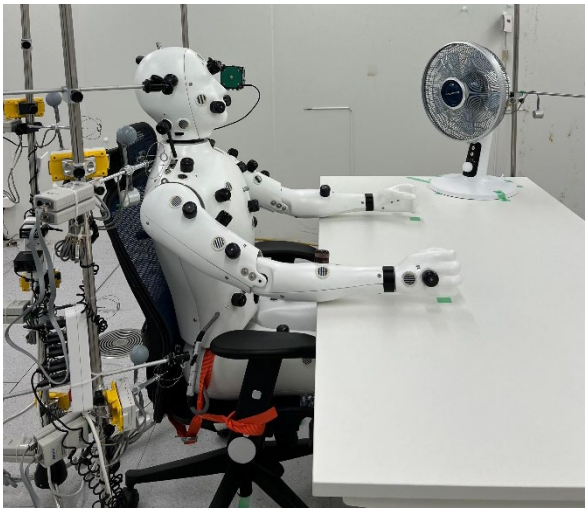

Figure 2. Overview of the experimental setup for testing the desk fan using the HVAC thermal manikin with 46 sensor sets (including air temperature, air speed, radiative heat flux, and relative humidity)

3.3 Participation in Annex 87 activities dissemination

Prof. Khovalyg led two workshops at COBEE2025 and CISBAT 2025 conferences (see Fig. 3):

- The Symposium on PECS was held on July 8, 2025, as part of the COBEE 2025 conference (Eindhoven University, the Netherlands), led by *Dolaana Khovalyg*, *Douaa Al-Assaad*, *Michele Zinzi*, and *Jianlei Niu*. The session brought together attendees from different fields and opened with an overview of SBT A, which focused on the benefits of PECS, and SBT D, which addressed methodological approaches to studying PECS. The participants were then divided into two groups for discussion: Group 1 focused on **user experience**, while Group 2 focused on **objective evaluation methods.**

  As a contribution to the symposium, Prof. Khovalyg led the submission of a conference paper titled "***Personalized Environmental Control Systems (PECS): Novel classification of devices enhancing thermal comfort***".

- The Workshop on PECS took place on September 3, 2025, during the CISBAT 2025 conference (Lausanne, Switzerland), and was led by *Dolaana Khovalyg* and *Alireza Afshari*. The session gathered participants from academia and industry and began with an overview of ongoing Annex 87 activities. Following the introduction, the discussion focused on three key themes: **user acceptability of PECS**, the **adoptability of PECS solutions**, and the **adaptability of users** when interacting with these systems.

Figure 3. Leading team of the workshop activities in 2025: (left) COBEE 2025, (right) CISBAT 2025.

4 Evaluation of results to date

The results obtained to date are satisfactory and have direct input to the activities held in Annex 87.

5 Next steps

- **Dissemination activities:**
  - Workshop on PECS at the IAQVEC 2026 conference (18-22 May 2026)
  - Conference presentations at ROOMVENT 2026 conference (15-18 September 2026)
    - "*An experimental framework to quantify the energy transfer pathways in personal environmental control systems*" (led by Maitreyee Saini, EPFL)
    - "*Manikin-based evaluation method for PECS of the heat exchange between the body and the environment*" (led by Yan Liang, Empa)

- Publish Annex 87 remaining literature review papers:
  - "*Literature Review on the Control and Integration of PECS*" (tentative title), led by Meng Kong, GTI Energy**.**
  - "*Requirements of PECS in terms of localized and background thermal environment and air quality*" (tentative title), led by Jun Shinoda, DTU.
- Publish the research paper, in collaboration with Politecnico di Torino, on the methodological framework for evaluating metrics and assessment methods to quantify PECS performance (led by Matteo Bilardo, POLITO)

Annex 87 collaborative research activities:

- Advance and complete the simulation activity between Subtask A and D.
- Advance and complete the Round Robin test with manikins

ICE research activities: Progress into the 2nd year of the project **SNSF-PCS** that will focus on extensive experimental testing of a wide range of PECS performance using two types of thermal manikins (HVAC and ANDY). The methodology for evaluating the energy efficiency of the different kinds of PECS is planned for validation.

6 National and international cooperation

***National collaboration*:** The ICE lab collaborates with Empa (Switzerland) within the SNSF-funded project that focuses on developing a holistic methodology for energy effectiveness of thermal PECS.

International collaboration:

- A collaboration within the *Round Robin Test for PECS performance using manikins* with German and Canadian national teams represented by contributors from RWHT, Concordia University, and Waterloo University.
- A collaboration with Politecnico di Torino (TEBE Group – Prof. Marco Perino, Prof. Enrico Fabrizio, Dr. Matteo Bilardo) in the development of the methodological framework for evaluating metrics and assessment methods to quantify PECS performance.
- In further contributions to the Annex 87 collaborative activities listed in section 3.2, the ICE lab collaborates with many other research entities (e.g., KU Leuven, DTU, UNIPIG, etc.).

7 Publications

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3. Khovalyg D., Shinoda J., Bivolarova M.P. (2025) ***Personalized Environmental Control Systems (PECS): Novel classification of devices enhancing thermal comfort***, Proceedings of the 6th International Conference on Building Energy and Environment (COBEE 2025), Eindhoven University of Technology, The Netherlands, 6–10 July 2025.

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