# Wepop Newsletter

## February 2026

## Final Project Newsletter – An Interview Looking Back at Innovation and Impact

### Introduction

In recent years, the concept of comfort in buildings has evolved towards a truly **human-centric approach**, where personalization and user control are central. By leveraging data collected directly from users through wearables and environmental sensors, it is now possible to move beyond one-size-fits-all solutions and design environments that adapt to individual needs and preferences. **WEPOP is the result of a strong collaborative effort among four academic partners—UniEcampus, UNIVPM, UNIPG and UNIPA—each contributing complementary expertise** in sensing technologies, data analysis, comfort modelling and experimental validation. In this final newsletter, we meet the project partners, Figure 1, to explore the key innovations developed throughout the project, before concluding with insights from the **Principal Investigator**, who reflects on the overall outcomes achieved and the impact of WEPOP's human-centric vision.


Figure 1. First project meeting in Rome at eCampus.

## Interview – From Technology Development to Real-World Impact

### 1. Environmental sensors and data analysis (UNIVPM)

*Questions to project partner working on environmental sensors and data analysis - Università Politecnica delle Marche*

**What was the main innovation introduced in environmental sensing and data analysis during the project?**

In the WEPoP project, a core innovation was the deployment of a network of non-invasive ultrasonic sensors for indoor human activity monitoring that does not require subjects to wear any device, enabling completely free movement while preserving privacy. The ultrasonic sensors provide high-resolution distance data, which are pre-processed to extract meaningful motion features. A multi-stage classification strategy combining machine learning and deep learning algorithms was developed to distinguish between activity classes (e.g., static vs. dynamic tasks) and refine specific activity recognition with high accuracy. These AI-driven analyses allow the system to infer individual activity levels such as MET (Metabolic Equivalent of Task), linking environmental sensing directly with human behavioural metrics.

**How do these solutions improve the way environmental data are collected and understood?**

The integration of ultrasonic sensing with advanced data analytics enhances both the quality and interpretability of collected environmental data. By accurately classifying occupant activities and estimating MET, the system supports activity-aware evaluation of indoor comfort conditions, moving beyond static or aggregate assumptions. This enables personalised comfort assessment tailored to real occupant behaviour. Furthermore, the scalable AI framework allows the fusion of activity metrics into comfort and energy models, offering a richer dataset for informed control of environmental systems. Future developments envisioned by the consortium include the use of larger ultrasonic arrays and refined measurement techniques to further improve spatial resolution and classification robustness.

### 2. Physiological sensing for a human-centric approach

*Questions to partner working on physiological monitoring and data interpretation – Università eCampus*

**Why is monitoring physiological signals essential to better understand personal comfort from a human-centric perspective?**

Monitoring physiological signals is essential because thermal comfort is ultimately a human perception, not a purely environmental condition. Traditional comfort models rely on averaged environmental variables and assume uniform responses, whereas the human body reacts to thermal stimuli through physiological homeostasis mechanisms. Signals such as skin temperature, galvanic skin response, heart activity and brain activity directly reflect how individuals regulate heat, experience discomfort or adapt to changing conditions. By capturing these responses, physiological monitoring enables a direct and objective measurement of personal thermal perception, accounting for inter-individual variability and dynamic responses that cannot be represented by environment-centric models alone.

**How did physiological data, combined with environmental measurements, help capture individual responses and support personalized comfort models?**

In the WEPOP project, physiological data were systematically combined with environmental measurements to build Personal Comfort Models (PCMs). Environmental variables describe the external thermal stimulus, while physiological signals capture the individual response to that stimulus.

This multimodal approach enabled the development of data-driven models that predict thermal sensation at the individual level rather than relying on population averages. Wearable sensing allowed continuous and non-invasive data acquisition, while machine learning techniques exploited the combined dataset to identify personalized patterns. The integration of physiological, environmental and contextual data proved crucial for capturing individual differences and supporting adaptive, human-centric comfort modeling, acting also on the building management system and, hence, contributing to optimizing the overall comfort.

## 3. The wearable sensor developed within the project

### *Questions to the partner responsible for the wearable device – Università degli Studi di Palermo*

**What makes the wearable sensor developed in the project innovative compared to existing solutions?**

Wearable solutions are becoming increasingly widespread as systems capable of offering a variety of physiological parameters at any time. This could bring immense benefits in terms of preventing adverse health conditions or, more generally, improving quality of life. However, currently available devices do not guarantee adequate measurement accuracy, making the information unusable or misleading. This is particularly true for wearable devices based on photoplethysmographic (PPG) sensors, which are affected by several influencing parameters (such as contact pressure), limiting the reliability of the measurements.

The measurement device developed within the WEPOP project is based on photoplethysmographic sensors and it has an innovative system which automatically adjusts the contact pressure based on each specific subject. The final goal is to increase the quality of PPG signal and ensure that the information is always reliable, even during normal daily activities. This represents a major step forward in the effectiveness of these devices, making them suitable for a wide range of applications.

**How does it complement environmental measurements and contribute to a more complete picture?**

As mentioned, improving signal quality opens up new possibilities for using the acquired information. This is particularly true for photoplethysmographic signals as their morphology is rich in cardiovascular information that goes beyond heart rate alone and also reflects the mechanical properties of the blood vessels.

Specifically, a PPG system capable of extracting high-quality signals would allow for the identification of vasoconstriction and vasodilation phenomena, thereby enabling the extraction of information related to environmental comfort even before the subject perceives sensations of cold or heat.

Such a system would therefore allow for early intervention through adjustments to the air-conditioning system, based not on fixed thresholds but on the actual needs of the occupants.

This would result in reduced energy consumption and a significant improvement in environmental comfort.

## 4. Measurement campaigns and real-world validation

### *Questions to partner involved in the campaigns – Università degli Studi di Perugia*

**Where and how were the measurement campaigns carried out, and why were these settings important?**

Both the summer and winter measurement campaigns were carried out in the NEXT.ROOM, a climate-controlled test room located at CIRIAF, the Interuniversity Research Centre on Pollution and Environment “Mauro Felli”, within the Engineering campus of the University of Perugia (Italy). The facility is designed to support research across different domains, allowing environmental conditions and human responses to be studied together in a controlled but realistic setting.

Within the WEPOP project, the experiments focused on understanding how people's bodies respond to different environmental and cognitive conditions. Each session lasted 90 minutes and involved two participants performing common office tasks such as writing, reading, discussing with a colleague, and making phone calls. During the sessions, key physiological signals were continuously monitored, including brain activity (i.e., electroencephalogram, EEG), electrodermal activity, heart rate, and skin temperature.

At the same time, the indoor environment was fully monitored in terms of thermal, visual, and air quality conditions. Participants also reported their perceived comfort, acceptability, and preferences for each environmental aspect using a dedicated online platform. Additional contextual data were collected through nearby ultrasound sensors and video information from laptop webcams.

All data were stored in a privacy-preserving format. This experimental setup was chosen to capture, in an integrated way, the conditions and stimuli typically experienced during office work and to support human-centred studies of comfort, preferences, and performance across different tasks.

**What did the campaigns reveal about the performance and potential of the project technologies?**

The campaigns confirmed the robustness and relevance of the project technologies for investigating human comfort, highlighting the increasing role of physiological signals in human-centred indoor environment research. The integrated sensing framework successfully embedded wearable physiological monitoring within a realistic indoor setting. A key outcome is the initial integration of environmental sensing, physiological responses, and participant feedback with the operational HVAC system of the NEXT.ROOM. This coupling allows occupant responses to be analysed in direct relation to real-time climate control, supporting future applications in adaptive and intelligent building operation.

Initial results already demonstrate the potential of this approach. Moderate changes in indoor air temperature produced clear physiological reactions, such as increases in skin temperature and electrodermal activity, while participants' reported comfort, air quality, and perceived productivity remained largely unchanged. This suggests that physiological responses do not always directly reflect how comfortable people say they feel, highlighting the value of combining objective and subjective data.

Building on these findings, the next phases of the project will further analyse the relationships between physiological signals, environmental preferences, and the activities performed by occupants. This integrated perspective will support the development of personalised comfort models tailored to specific tasks and contexts, enabling future indoor climate-control strategies that adapt to individual needs while maintaining energy efficiency.

## 5. Project outcomes and overall impact

### *Final questions to the Principal Investigator – Prof. Marco Arnesano*

**What are the main outcomes and achievements of the project as a whole?**

The WEPOP project achieved several significant outcomes across sensing, modeling and real-time application:

**Multi-domain data platform:** Development of a comprehensive digital platform integrating environment sensors, wearable devices and machine learning algorithms for synchronized data acquisition, processing and modeling, Figure 2.

**Large-scale experimental campaigns:** Execution of systematic experimental campaigns involving more than 100 participants in controlled yet realistic conditions. The resulting datasets have been curated and made available to the scientific community, enabling continued investigation, benchmarking and methodological development beyond the duration of the WEPOP project.

**Advanced physiological signal processing:** Validated methodologies for acquiring, cleaning and extracting features from physiological signals, including temperature, galvanic skin response and cardiac activity.

**Personalized comfort models:** Development and validation of AI-based Personal Comfort Models (PCMs) that combine physiological, environmental and contextual data to predict thermal sensation at the individual level, demonstrating improved accuracy compared to traditional approaches, Figure 3.

**Real-time monitoring and control:** Demonstration of the feasibility of real-time comfort assessment and the integration of comfort models with control strategies for HVAC, lighting and personal comfort systems.

**Enhanced wearable sensing hardware:** A key technical achievement is the prototyping and testing of a PPG-based wearable with an auto-tightening mechanism, designed to significantly improve sensor–skin contact and reduce motion artifacts in real-world usage. This innovation enhances the reliability and accuracy of cardiac and related physiological measurements in mobile, non-controlled environments — a major step toward practical wearable comfort sensing.

Overall, WEPOP demonstrated that physiological and environmental measurements, integrated sensing, and AI-driven modeling can be combined into a comprehensive human-centric comfort management system.

**How can these results contribute to future research, innovation or real-world applications?**

The results of the WEPOP project provide a **solid foundation for future human-centric building technologies**. From a research perspective, they enable the development of standardized procedures for physiological-based PCMs and foster further investigation into multimodal comfort perception. From an innovation standpoint, the platform and methods support the **transition toward deployable, real-time comfort management systems**, including integration with HVAC and smart building infrastructures. In real-world applications, these results pave the way for buildings that adapt to occupants rather than forcing occupants to adapt to buildings, contributing to improved well-being, productivity and energy efficiency. Ultimately, WEPOP helps bridge the gap between experimental research and scalable, real-life human-centric building solutions.

In addition, two datasets have been published in Open Access:

- The Human Experience in Regulated Offices (HERO) dataset, link: https://zenodo.org/records/16980698
- The Human Experience in Regulated offices Extended (HEROx) dataset, link: https://zenodo.org/records/18598884

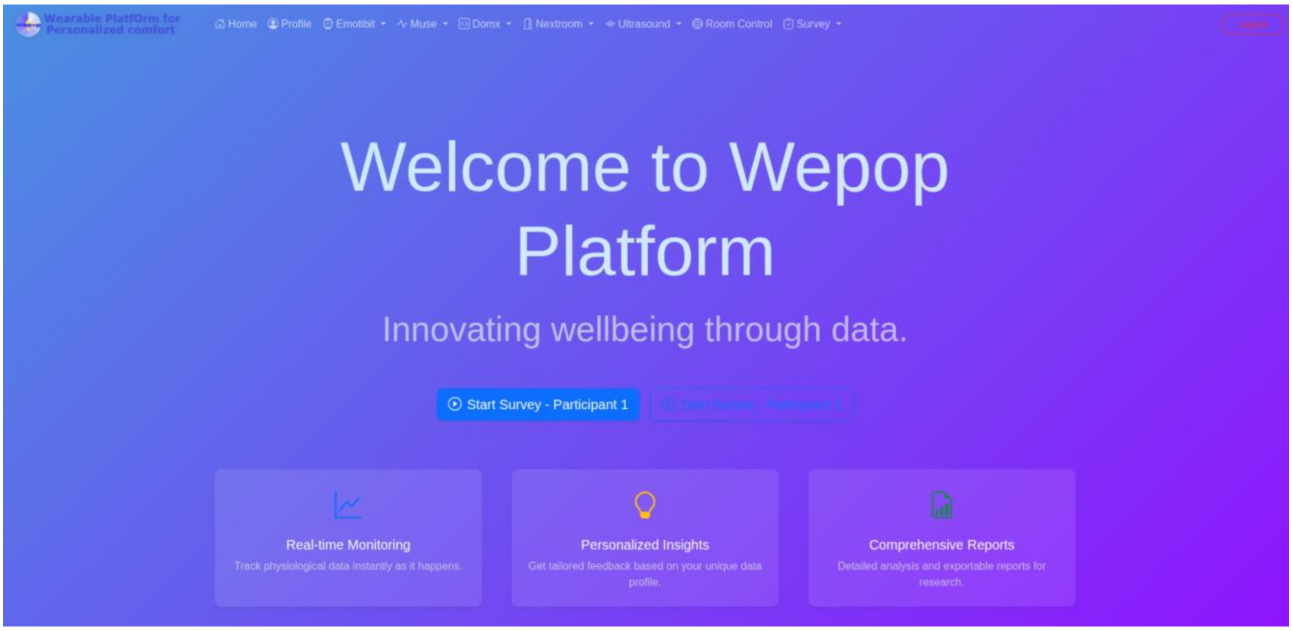


Figure 2. Initial dashboard screenshot

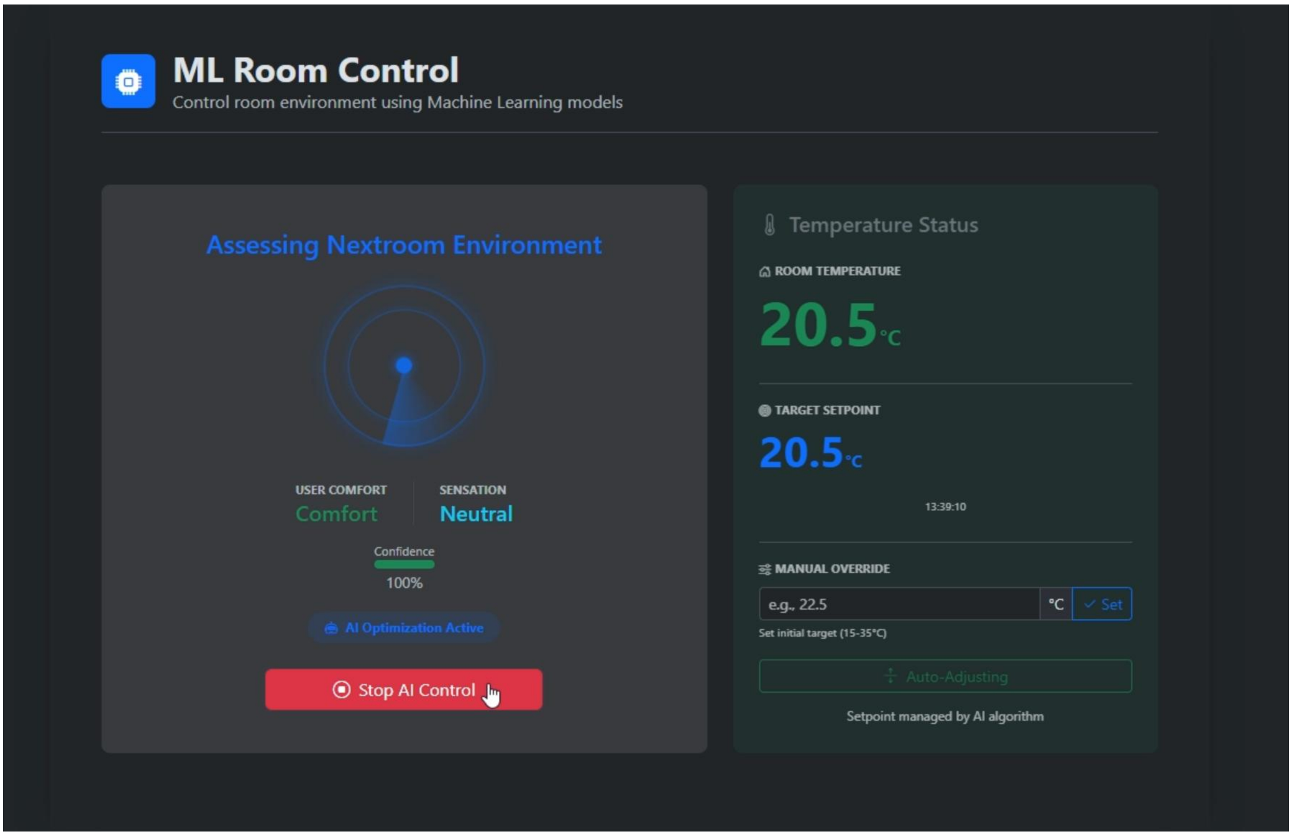


Figure 3. PCM/AI Room Control

Platform demo [Registrazione dello schermo 2026-01-27 133943.mp4]

Partners:

The research has been founded by European Union, next Generation EU, Mission 1 Component 2, through the WEPOP (Prot.2022RKLB3J) ''WEarable Platform for OptImised Personal comfort'' project, within the PRIN 2022 program.