

# Vitality HUB Perceived Thermal Comfort | Requirements

Thermal Comfort-as-a-Service (CaaS) IoT system

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Project: Perceived thermal comfort - VitalityHub

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## Version History

Change	Author	Date	Version
Set up document	Bartosz Kaszuba	15-11-2025	1
Review and updates	Artur Kraskov	28/11/2025	1.1

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# Introduction

This document is complementary to Vitality HUB Perceived Thermal Comfort Project Plan. It covers user stories, functional and non-functional for initial V-model phases.

## Background

The project plan was compiled and covered scope, milestones, development plan and other important details [1].

# Research question

How do we make a system that would satisfy the needs:

- of office workers for sufficient thermal comfort,
- thermal comfort researchers need for a tool that collects and analyzes data,
- and infrastructure owners need to make workers feel comfortable

while achieving the least electrical waste, such that every group participating in the project has is alleviated from their prime concerns.

## Sub questions

1. Which sensors must be used?
2. Which data users must provide through the app?
3. Which weather or building API data do we need to get?
4. Do we need to use wearables and get data like wrist skin temperature?
5. How to develop an accurate sensing and predicting algorithm/model?

# User stories & use cases

This section structures user stories for workers and visitors stakeholder groups. It sketches a few core use cases for the Living Lab and later client deployments. Stories use the “As a ... I want ... so that ...” pattern and focus on perceived thermal comfort, feedback, experimentation, and low-maintenance sensing. Other stakeholder groups such as researchers and infrastructure owners are out of scope for this semester. First we aim to develop a user-oriented solution. And then will make it available for research purposes.

## Workers and visitors (occupants)

Across large surveys and field studies, office workers repeatedly report that being too hot or too cold is one of the most common complaints and that this affects comfort, well-being, and productivity. Research on occupant-centric control and personal comfort models shows that individuals differ systematically in their preferences and that simple feedback mechanisms (“too hot/too cold” votes) are effective inputs to adaptive control strategies. Work on comfort maps in hot-desking offices, thermostat “wars” in shared spaces, and gender or individual inequities in comfort provides concrete patterns that your stories generalize.

Table 1: User stories, evidence and reference

User story	Evidence / key findings from literature	Reference
1. “As an office worker, I want my workspace to stay within a comfortable range throughout the day so that I can focus on my tasks without feeling too hot or too cold.”	Large multi-building studies (e.g. OFFICAIR) show that “too hot” and “too cold” are among the most frequent complaints in European modern offices and are strongly associated with lower overall comfort and satisfaction. Systematic reviews and experimental studies link thermal discomfort to reduced self-reported and measured productivity, supporting the need to maintain a stable comfortable range for office work.	OFFICAIR post-occupancy evaluation of European offices: <a href="https://www.mdpi.com/1660-4601/13/5/444">https://www.mdpi.com/1660-4601/13/5/444</a>  Systematic review on thermal comfort & productivity: <a href="https://www.mdpi.com/2075-5309/11/6/244">https://www.mdpi.com/2075-5309/11/6/244</a>  Office thermal environment vs. workers’ comfort: <a href="https://www.sciencedirect.com/science/article/abs/pii/S0360132322000981">https://www.sciencedirect.com/science/article/abs/pii/S0360132322000981</a>

<p>2. “As a hot-desking employee, I want to see which zones in the building are likely to feel comfortable for me right now so that I can choose a suitable place to work.”</p>	<p>The “Comfort Map” concept was developed specifically for open-plan and shared offices to visualize spatial comfort differences, so occupants—especially in desk-sharing/hot-desking setups—can choose workstations whose conditions match their preferences. Studies on adaptive thermal comfort and modern office layouts report that workers naturally migrate to more comfortable micro-zones, and that tools which expose such information can support better space choice and satisfaction.</p>	<p>Comfort Map for office workplaces:  <a href="https://www.mdpi.com/2075-5309/11/6/233">https://www.mdpi.com/2075-5309/11/6/233</a></p> <p>Adaptive thermal comfort for energy-saving office design:  <a href="https://www.e3s-conferences.org/articles/e3sconf/pdf/2023/33/e3sconf_iaqvec2023_01083.pdf">https://www.e3s-conferences.org/articles/e3sconf/pdf/2023/33/e3sconf_iaqvec2023_01083.pdf</a></p> <p>Hot-desking and zone choice context:  <a href="https://floorplanmapper.com/hot-desking/">https://floorplanmapper.com/hot-desking/</a></p>
<p>3. “As a meeting participant, I want the room to adjust automatically to occupancy and avoid stuffy or freezing meetings so that I don’t have to search for or argue over thermostats.”</p>	<p>Research and practice describe recurring “thermostat wars” in shared spaces, where meeting rooms and open offices swing between too hot and too cold, leading to frequent manual setpoint changes and conflicts. Occupant-centric HVAC controllers such as HVACLearn use occupancy data and simple thermal votes to automatically adjust thermostat setpoints, reducing uncomfortable episodes and manual interactions. This supports the need for automatic, occupancy-aware adjustment rather than ad-hoc thermostat battles.</p>	<p>Personal Office Air / “thermostat wars” in shared offices:  <a href="https://global.ctbuh.org/resources/papers/4225-Peschiera_PersonalOfficeAir.pdf">https://global.ctbuh.org/resources/papers/4225-Peschiera_PersonalOfficeAir.pdf</a></p> <p>Popular summary of office temperature conflicts:  <a href="https://www.businessnewsdaily.com/10964-office-temperature-debate.html">https://www.businessnewsdaily.com/10964-office-temperature-debate.html</a></p> <p>HVACLearn occupant-centric thermostat control:  <a href="https://dl.acm.org/doi/10.1145/3396851.3402364">https://dl.acm.org/doi/10.1145/3396851.3402364</a></p>

<p>4. “As someone with a strong personal preference (always cold / always warm), I want the system to learn my pattern over time so that local adjustments (e.g. airflow, setpoint, micro-actuation) better match my comfort without disturbing others.”</p>	<p>Personal Comfort Model research explicitly targets individual-level prediction, showing that people exhibit consistent personal thermal preferences (“always cold” / “always warm”) that differ from population averages, and that models learned from each person’s own feedback outperform standard PMV/adaptive models. Studies on overcooling and gender inequity in offices demonstrate systematic differences (e.g. many women report being too cold at typical setpoints), reinforcing the need for systems that recognize and respect individual patterns rather than a single “neutral” setpoint. Personalized or local comfort systems (e.g. personal fans, radiant panels) coupled with such models can improve satisfaction without changing conditions for everyone.</p>	<p>“Personal Comfort Models – A New Paradigm in Thermal Comfort for Occupant-Centric Environments”:  <a href="https://escholarship.org/uc/item/18d174zs">https://escholarship.org/uc/item/18d174zs</a></p> <p>Building-specific occupant-centric thermal comfort models:  <a href="https://www.sciencedirect.com/science/article/pii/S2352710224018497">https://www.sciencedirect.com/science/article/pii/S2352710224018497</a></p> <p>Overcooling and gender inequity in office comfort:  <a href="https://www.nature.com/articles/s41598-021-03121-1">https://www.nature.com/articles/s41598-021-03121-1</a></p>
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<p>5. “As an occupant, I want a simple way (one or two clicks on web/mobile) to report ‘too cold / too warm / fine’ so that I feel heard and the environment can improve over time.”</p>	<p>Occupant-centric control frameworks and predictive building energy management methods routinely use very simple feedback scales (e.g. “too cold / comfortable / too warm” buttons or quick web forms) as input to comfort and energy optimization, because low-effort interactions drive higher participation and usable datasets.</p> <p>“Humans-as-a-sensor” and intensive longitudinal comfort studies emphasize minimal-burden, high-frequency self-reports via apps or mobile tools to link subjective perception with environmental measurements, which aligns directly with a 1–2 click reporting interface. Such feedback loops have been shown to support both improved comfort control and occupants’ sense of being heard and involved.</p>	<p>Occupant votes in RL-based thermostat control (HVACLearn):  <a href="https://dl.acm.org/doi/10.1145/396851.3402364">https://dl.acm.org/doi/10.1145/396851.3402364</a></p> <p>Predictive building energy management with user feedback:  <a href="https://www.sciencedirect.com/science/article/pii/S2666955224000340">https://www.sciencedirect.com/science/article/pii/S2666955224000340</a></p> <p>“Humans-as-a-sensor for buildings” (intensive longitudinal comfort models):  <a href="https://www.mdpi.com/2075-5309/10/10/174">https://www.mdpi.com/2075-5309/10/10/174</a></p> <p>Systematic review of adaptive behavior &amp; comfort self-reports:  <a href="https://pmc.ncbi.nlm.nih.gov/articles/PMC10287772/">https://pmc.ncbi.nlm.nih.gov/articles/PMC10287772/</a></p>
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# Core use cases

## 1. **Living Lab: Everyday comfort companion**

Workers and visitors in the Vitality HUB use a simple web/mobile interface to report “too cold / OK / too warm” and see at a glance how comfortable different zones are right now. Behind the scenes, the system fuses IEQ sensors, occupancy and weather data to keep each zone within a comfortable range over the day, so people can focus on their tasks instead of fighting the temperature.

## 2. **Living Lab: Smart meetings without thermostat wars**

When people enter a meeting room, the system uses presence detection and recent feedback to adjust conditions automatically and avoid stuffy or freezing meetings. Participants can still give quick input via the app if they feel uncomfortable, but in most cases the room quietly stays “in the green” without anyone hunting for a thermostat.

## 3. **Living Lab / client pilot: Comfort-as-a-Service with research sandbox**

In the Living Lab and later at a client pilot site, occupants use the same feedback app and comfort views to understand and influence their environment, while an expert interface lets researchers choose different comfort models, tweak parameters (e.g. features, thresholds, update frequency), and compare their performance over time, so the system can gradually converge on models that work best for real users in real buildings.

# Functional requirements

Table 2: Functional requirements

#	Description
FR1	The system shall collect occupant thermal feedback (e.g. sensation, comfort, preference) with no more than two interactions per entry via a web/mobile application, and timestamp and link each entry to the user's current zone/location and context.
FR2	The system shall acquire, timestamp, and store environmental and contextual data from all configured sensors (Senseca microclimate logger, Zigbee IEQ nodes, mmWave presence, door/window contacts, smart plugs, building and weather APIs) into a unified data model suitable for comfort analysis.
FR3	The system shall compute standard thermal comfort indices (e.g. PMV/PPD and adaptive comfort) for selected reference locations using the microclimate logger and context data, providing a baseline for comparison with data-driven models.
FR3.1	The model must adapt to a number of inputs. Be able to work with more inputs or less inputs. Have MVP and be able to expand.
FR4	The system shall provide zone-level thermal comfort predictions at regular intervals (e.g. every 5 minutes) by applying building-specific occupant-centric models that fuse environmental, contextual, and feedback data.
FR5	Where sufficient data are available, the system shall support personal or cohort-level comfort models that can generate individualized preference predictions and compare their performance with baseline models.
FR6	The system shall expose comfort indicators, predictions, and simple explanations to occupants through the feedback app (e.g. current status, likely sensation band, suggested comfortable zones) without requiring technical knowledge.
FR7	The system shall provide researchers with configuration interfaces to define experiments (e.g. model variants, feature sets, sampling strategies), tag data with experiment identifiers, and retrieve datasets for offline analysis.
FR8	The system shall provide facility managers and infrastructure owners with dashboards that present aggregated comfort metrics, occupant feedback statistics, key environmental variables, and basic energy indicators per zone and over time.
FR9	The system shall support limited control or advisory actions, such as adjusting non-critical setpoints via building APIs, toggling smart plugs connected to local comfort devices, or issuing recommended actions to facility staff, subject to safety and governance constraints.

FR10	The system shall log all configuration changes, model deployments, and control or advisory actions to enable traceability and post-hoc analysis of comfort and energy outcomes.
FR11	Sensors must be installed in the kit. The kit must be mobile, easy to move between rooms. It must be upgradable - allow to add new sensors.

## Non-functional requirements

Table 3: Non-functional requirements

#	Description
NFR1	The system shall be designed to operate reliably under continuous use in the Living Lab, with high data availability (target $\geq 95\%$ uptime for core sensing and data pipelines) and graceful degradation if individual sensors fail.
NFR2	The architecture shall be modular and technology-agnostic, allowing replacement or addition of sensors, gateways, and models without redesigning the entire system (e.g. by using standardized interfaces and message formats).
NFR3	Data storage and processing shall comply with applicable EU data protection regulations, ensuring that personally identifiable information is minimized, separated from raw sensor data where feasible, and protected via appropriate access controls and pseudonymization.
NFR4	The occupant app and dashboards shall prioritize usability and low interaction cost, following established human-in-the-loop and occupant-centric design principles to encourage regular feedback without causing survey fatigue.
NFR5	The system shall be interoperable with existing smart-building and BMS infrastructures via open or well-documented APIs and protocols, facilitating future integration into other buildings beyond the Living Lab.
NFR6	The sensing network shall support retrofittability, meaning that additional wireless sensors can be installed without major building works and can be logically integrated into the platform through configuration rather than code changes.
NFR7	For current battery-powered nodes, the system shall minimize communication overhead and allow configuration of reporting intervals and payload sizes to extend battery life, while remaining compatible with future long-life or energy-harvested devices in the LoLiPoP-IoT project context.
NFR8	The platform shall expose clear interfaces and performance metrics (e.g. power budgets, duty cycles, data quality requirements) so that LoLiPoP-IoT partners

	can design and evaluate their energy-harvesting/micro-power solutions against realistic comfort-monitoring demands.
NFR9	The solution shall be designed for maintainability, with configuration as code where possible, documentation of deployment and integration steps, and monitoring/alerting to support long-term operation by non-research staff.
NFR10	The initial deployment shall be scoped as a research-grade, Living-Lab system that is robust enough for real occupants but explicitly positioned as a pilot, allowing iterative refinement before any large-scale commercialization or productization.

## Expert Feedback

Date: 27/11/25

Expert: Bernard Grundlehner

Thanks for the summary! I think it is going to be a very nice project which clearly goes beyond state-of-the-art, mainly because of:


- Flexibility to utilize multiple data inputs, with the option to use (or augment with) standard IoT sensors through Home Assistant
- Personalized advice towards choosing optimal room

These are to me the main differentiators.

# Conclusion

The document reports user stories and system requirements for Comfort-as-a-Service IoT kit with sensors and feedback dashboard. User stories were compiled based on literature study and discussed with the stakeholder. Following V-model system requirements were compiled. This clarifies what the solution should be and how it must behave. Validation of the results will be conducted in accordance with the best practices for research and user testing after an initial prototype and the model are ready.

# Reference

1. Kraskov A., Kaszuba B., (2025), Vitality HUB Perceived Thermal Comfort | Project Plan: Thermal Comfort-as-a-Service (CaaS) IoT system, [Online] Available:  
 Vitality HUB Perceived Thermal Comfort \_ Project Plan.pdf