D^2EPC Objectives on Human-Comfort & Wellbeing

- Extract the user behavioral profiles that influence the building's dynamic performance from the scope of occupant's comfort and wellbeing

- Incorporate a set of Human Comfort and Wellbeing indicators in the building assessment

- Examine the limitations of the defined KPIs in relation to the building's operation

- Provide information to the end-user for the indoor ambient conditions

D^2EPC Human-Comfort & Wellbeing Framework

- **Indoor Environmental Quality (I.E.Q.):**
  - **Thermal Comfort** is the condition of mind that expresses the level of satisfaction with the thermal environment and is assessed by subjective evaluation
  - **Visual Comfort** is the subjective reaction to the quantity and quality of light within any given space at a given time
  - **Indoor Air Quality (I.A.Q.)** makes reference to the right amount of fresh air provided according to occupation rate and type of activity

- **Comfort Profiles:**
  - A **measurement-based approach** is utilized to be performed on building data streams
  - The occupant's **personalized** boundaries are calculated based on the previous behavior (trends and patterns in precedent data) from a specialized Comfort Profiling Engine
  - The user profiles are calculated **dynamically** in a purely **data-driven** and **non-intrusive** way

- **Human Comfort & Wellbeing indicators:**
  - Based on well defined and measurable **environmental performance metrics** with relatively cheap and widely available IoT equipment
  - Stepping on **long-term evaluation methodologies**

Hybrid Approach on Profile Extraction

Hybrid Approach:

▪A **Personalized Comfort Profiling Engine** is utilized to calculate the **Thermal** and **Visual Comfort** profiles subject to data availability and quality

▪In any other case, recommended boundaries are extracted from European and national standard
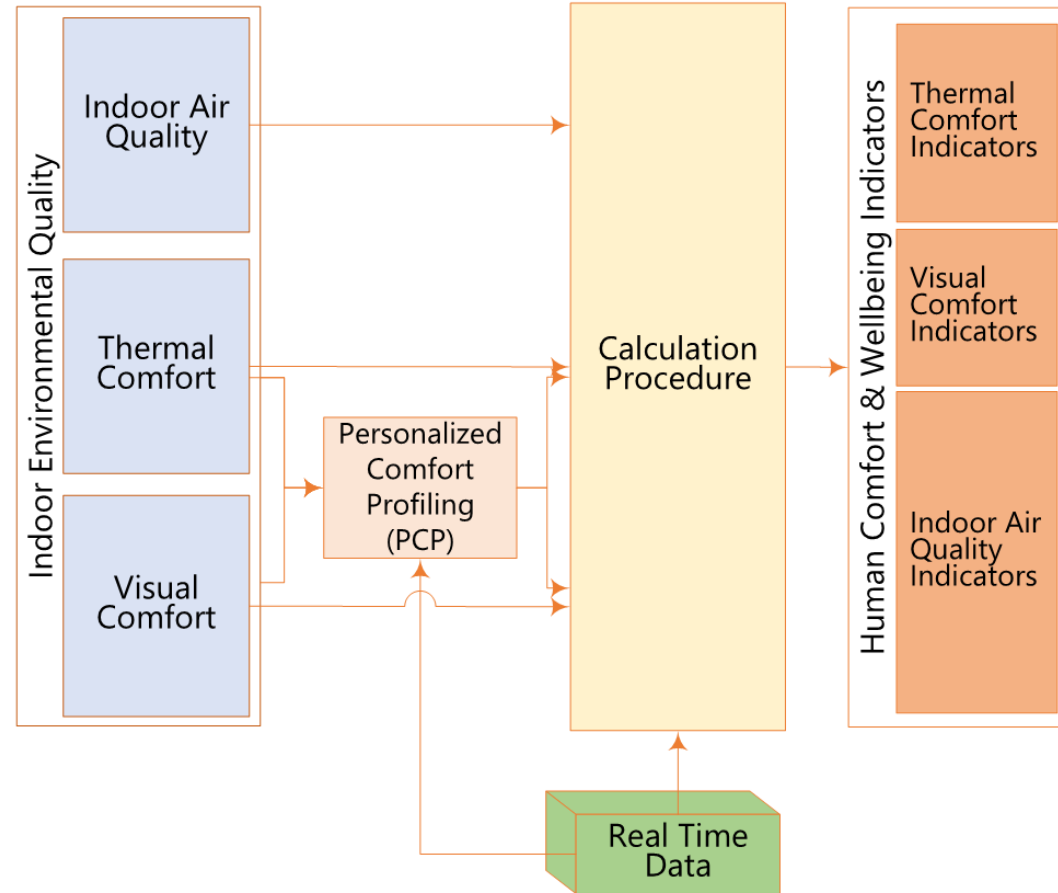
Literature Research – Relevant Standards

Level(s):
- 4.1. Indoor air quality (level 3)
- 4.2. Time outside of thermal comfort range (level 3)
- 4.3. Lighting and visual comfort (only specified with instructions for users at Level 1)

Thermal Comfort
- EN 15251
- ASHRAE 55 – 2017
- ISO 7243:2017

Visual Comfort
- EN 17037
- EN 12464-1

Indoor Air Quality
- EN 16798-1/2:2019
- ASHRAE 62.1/2-2019
- WHO guidance (2010)

Long-term evaluation Methodologies

- **Time out of range** (EN 15251. Level(s) 4.2), calculates the % of hours during which the occupants are out of comfort for a specific period of interest (e.g., heating/cooling periods in a yearly basis). The comfort boundaries in the D^2EPC approach are substituted with the personalized boundaries extracted from the comfort profiling engine (where feasible)

- **Degree Hours** (EN 15251) which integrates tailored weights to the "time out of range" calculation addressing how much the indoor ambient conditions deviated from the recommended conditions. The weights are defined based on the absolute difference between the measured value and the personalized/recommended upper or bottom limit.

- **Footprint of Indoor Environment** (CEN/TR 16798-2) reports the % of hours of each level compared to the total hours of the period of interest

Quality of indoor environment in % of time of occupancy in four categories				
Percentage	5	7	68	20
Thermal Environment	IV	III	II	I
Percentage	7	7	76	10
Indoor Air Quality	IV	III	II	I

D^2EPC Thermal Comfort Indicators

Indicator Name	I.E.Q. Domain	Environmental Parameter	Evaluation Methodology	Recommended Boundaries / Categories	Building Typologies
Deviation from the temperature range	Thermal Comfort	Indoor Dry-bulb (Air) Temperature	Time out of Range	Profiling Engine / ASHRAE 55 Indoor temperature limits	Residential/Commercial (Regularly occupied spaces by the same occupants)
Thermal Degree Hours	Thermal Comfort	Indoor Dry-bulb (Air) Temperature	Degree Hours	Profiling Engine / ASHRAE 55 Indoor temperature limits	Residential/Commercial (Regularly occupied spaces by the same occupants)
Deviation from the humidity range	Thermal Comfort / I.A.Q.	Indoor Relative Humidity	Time out of Range	Relative humidity range (Level(s) 4.3)	Residential/Commercial
Deviation from the acceptable WBGT levels	Thermal Comfort	Indoor Wet-bulb Globe Temperature (Indirectly calculated with Air Temperature and Relative Humidity)	Footprint of Indoor Environment	WBGT levels (ISO 7243:2017)	Common areas within Commercial buildings / Industrial Buildings
Humidex levels	Thermal Comfort	Indoor Humidex (Indirectly calculated with Air Temperature and Relative Humidity)	Footprint of Indoor Environment	Humidex levels	Residential/Commercial (Occupied spaces)

D^2EPC Visual Comfort Indicators

| Indicator Name	I.E.Q. Domain	Environmental Parameter	Evaluation Methodology	Recommended Boundaries / Categories	Building Typology
Deviation from the set Illuminance boundary	Visual Comfort	Indoor Illuminance	Time out of Range	Profiling Engine	Residential/Commercial (Regularly occupied spaces by the same occupants)
Deviation from the standard Illuminance levels	Visual Comfort	Indoor Illuminance	Time out of Range	Illuminance Levels (EN 12464)	Residential/Commercial (based on space typology)
Set Visual Degree Hours	Visual Comfort	Indoor Illuminance	Degree Hours	Profiling Engine	Residential/Commercial (Regularly occupied spaces by the same occupants)
Standard Visual Degree Hours	Visual Comfort	Indoor Illuminance	Degree Hours	Illuminance Levels (EN 12464)	Residential/Commercial (based on space typology)

D^2EPC Air Quality Indicators

Indicator Name	I.E.Q. Domain	Environmental Parameter	Evaluation Methodology	Recommended Boundaries / Categories
CO2 Indoors	I.A.Q. (Main)	Difference between indoor and outdoor carbon dioxide concentrations	Footprint of Indoor Environment	CO2 Categories (CEN/TR 16798-1/2:2019)
TVOCs	I.A.Q. (Main)	Total Volatile Organic Compounds concentration in the indoor air	Footprint of Indoor Environment	TVOCs limits (CEN/TR 16798-1:2019)
PM2.5	I.A.Q. (Main)	Particulate Matter (2.5 µm diameter) concentration in the indoor air	Footprint of Indoor Environment	PM2.5 limits (CEN/TR 16798-1:2019)
Benzene	I.A.Q. (Complimentary)	Benzene concentration in the Indoor air	Footprint of Indoor Environment	Benzene limits (CEN/TR 16798-1:2019)
Formaldehyde	I.A.Q. (Complimentary)	Formaldehyde concentration in the Indoor air	Footprint of Indoor Environment	Formaldehyde limits (CEN/TR 16798-1:2019)
Radon	I.A.Q. (Complimentary)	Radon concentration in the Indoor air	Footprint of Indoor Environment	Radon limit (WHO Guidelines)
PM10	I.A.Q. (Complimentary)	Particulate Matter (10 µm diameter) concentration in the indoor air	Footprint of Indoor Environment	PM10 limits (CEN/TR 16798-1:2019)
Ventilation Rate	I.A.Q. (Complimentary)	Roughly estimated based on indoor hourly CO2 concentrations	Footprint of Indoor Environment	Ventilation Rate categories (CEN/TR 16798-1:2019)

Personalised Comfort Profiling Engine

- The PCP analyses the collected data from the pilot infrastructure and identifies the occupant's comfort boundaries (implying that the optimal visual/thermal conditions for the occupant are dictated by her/himself)

- Extracts insight exclusively from preceding timeseries data with no other sources of information required. All separate user profiles must refer to regularly occupied spaces by the same users

- Applied for the calculation of Thermal and Visual Comfort Profiles (subject to data availability and quality)

- The engine comprises of state-of-the art classification algorithms (i.e., SAX algorithm) for the definition of comfort boundaries

Preliminary Results

Aggregated (hourly) T / RH measurements from an occupied living room
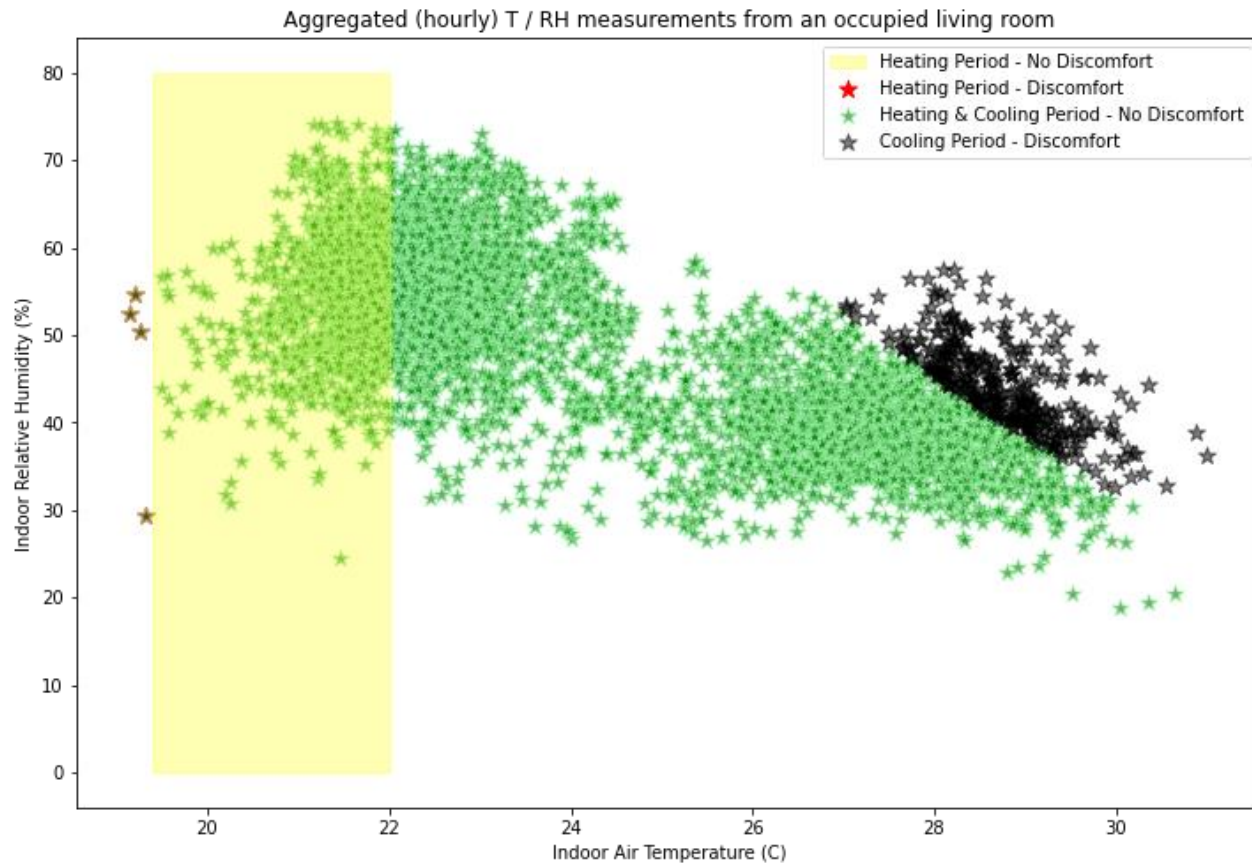
Indicator Name	Result
Deviation from the Temperature Range	19%
Thermal Degree Hours	1964,9
Deviation from the Humidity Range	2,45%
Humidex Levels	No Discomfort - 91,85% Some Discomfort – 8,15%