

2.9. Human Comfort

2.9.1 Universal Thermal Climate Index (UTCI)

Project Name: UNaLab (Grant Agreement no. 730052)

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| Universal Thermal Climate Index (UTCI) | Climate Resilience Natural and Climate Hazards Health and Wellbeing |
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| Description and justification | UTCI index represents air temperature of the reference condition with the same physiological response as the actual condition. The UTCI provides a one-dimensional value that reflects the human physiological reaction to the multi-dimensional outdoor thermal environment (Bröde et al., 2012). It can predict both whole body thermal effects (hypothermia and hyperthermia; heat and cold discomfort), and local effects (facial, hands and feet cooling and frostbite). Applications of the UTCI include weather forecasts, bioclimatological assessments, bioclimatic mapping, urban design, engineering of outdoor spaces, outdoor recreation, epidemiology and climate impact research. |
| Definition | The UTCI is the air temperature that would produce under reference conditions the same thermal strain as the actual thermal environment. In other words, the UTCI is the reference environmental temperature causing strain. |
| Strengths and weaknesses | <ul style="list-style-type: none"> + Mathematical expression of a person's thermal comfort in the outdoors + The output is expressed in easily understandable temperature units, e.g., °C - Less reliable in areas with low wind speed - Requires a great deal of data for evaluation |

Measurement procedure and tool

The human body core temperature must be maintained within a narrow range around 37°C to ensure proper function of the body's inner organs and the brain, thus optimising human comfort, performance and health. In contrast, the temperature of the skin and extremities can vary widely, depending upon environmental conditions. This variation in the temperature of extremities is one of the mechanisms to equilibrate heat production and heat loss. The heat exchange between the human body and environment can be described in the form of the energy balance equation:

$$M + W + C + K + E + Q + Res \pm S = 0$$

where

- M=heat produced by metabolism;
- W=heat generated by muscular activity;
- C=sensible heat flux (heat transferred by convection);
- K=heat transferred through conduction contact with solid bodies);
- E=latent heat flux (evaporative heat flux);
- Q=radiative heat transfer;
- Res=heat transfer through respiration; and,
- S=heat content of the body.

The UTCI is derived from this mathematical model of thermoregulation with an integrated adaptive clothing model that also accounts for predicted votes of the dynamic thermal sensation based on core and skin temperature (Fiala et al., 1999, 2001, 2003; Havenith et al., 2011). The deviation of UTCI temperature from measured air temperature depends on measured values of air temperature (T_a) and mean radiant temperature (T_{mrt}), wind speed at a height of 10 m (v_a) and humidity expressed as water vapour pressure (p_a) or relative humidity (rH):

$$UTCI(T_a, T_{mrt}, v_a, p_a) = T_a + Offset(T_a, T_{mrt}, v_a, p_a)$$

The model reference condition is walking at 4 km/h (135 W/m²) with $T_{mrt}=T_a$, $v_a=0.5$ m/s, $rH=50\%$ ($T_a > 29^\circ\text{C}$) and $p_a=20$ hPa ($T_a > 29^\circ\text{C}$) (Bröde et al., 2012). The UTCI dynamic model response can be determined using the online calculator available from <http://utci.org>. The relationship between UTCI temperature (expressed in °C) and physiological stress is shown in the table below (adapted from Błażejczyk et al., 2010).

| UTCI (°C) range | Stress category |
|-----------------|---------------------|
| Above +46 | Extreme heat stress |

| | | |
|--|--|-------------------------|
| | +38 to +46 | Very strong heat stress |
| | +32 to +38 | Strong heat stress |
| | +26 to +32 | Moderate heat stress |
| | +9 to +26 | No thermal stress |
| | 0 to +9 | Slight cold stress |
| | -13 to 0 | Moderate cold stress |
| | -27 to -13 | Strong cold stress |
| | -40 to -27 | Very strong cold stress |
| | Below -40 | Extreme cold stress |
| Scale of measurement | Plot – street – neighbourhood – district | |
| Data source | | |
| Required data | Air temperature, T_a (°C) Mean radiant temperature, T_{mrt} (degrees Kelvin) Water vapour pressure (hPa) Relative humidity (%) Wind speed at a height of 10 m (m/s) | |
| Data input type | Quantitative | |
| Data collection frequency | Frequency as desired. UTCI can be calculated frequently with measurement intervals determined by (automated) weather data acquisition. | |
| Level of expertise required | Low-Moderate | |
| Synergies with other indicators | Direct relation to <i>Heatwave incidence</i> and <i>Number of combined tropical nights and hot days</i> indicators Similar to <i>Physiological equivalent temperature (PET)</i> | |
| Connection with SDGs | SDG 3 Good health and well-being, SDG 11 Sustainable cities and communities, SDG 13 Climate action | |
| Opportunities for participatory data collection | Participatory data collection is feasible through direct participation in weather data collection | |
| Additional information | | |
| References | Błażejczyk, K., Broede, P., Fiala, D., Havenith, G., Holmér, I., Jendritzky, G., Kampmann, B. & Kunert, A. (2010). Principles of the new Universal Thermal Climate Index (UTCI) and its application to bioclimatic research in European scale. <i>Miscellanea Geographica</i> , 14, 91-102. Bröde, P., Fiala, D., Błażejczyk, K., Holmér, I., Jendritzky, G., Kampmann, B., Tinz, B. & Havenith, G. (2012). <i>International Journal of Biometeorology</i> , 56, 481-494. | |

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2.9.2 Thermal Comfort Score (TCS)

Project Name: Nature4Cities (Grant agreement: No. 730468)

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| Thermal Comfort Score (TCS) | Climate Resilience |
|--------------------------------------|--|
| Description and justification | <p>The TCS (Thermal Comfort Score) is one out of five Key Performance Scores of the GREENPASS® system.</p> <p>It's based on the calculation of the frequency distribution of areas with thermo-physiological stress according to the PET classification. It describes the thermal comfort of humans in one single number for a selected area.</p> <p>The indicator describes the mean thermal comfort, which is the crucial parameter for humans (not air temperature). It allows to understand and compare the thermal comfort of any given area with ease.</p> |
| Definition | <p>The TCS (Thermal Comfort Score) gives a weighted information of the mean PET on face level.</p> |
| Strengths and weaknesses | <ul style="list-style-type: none"> + worldwide standardized key performance score regarding human thermal comfort + easy for communication, understanding and decision-making |