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Level(s) indicator 4.2: Time outside of thermal comfort range

User manual: overview, instructions and guidance

(Publication version 1.0)

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Title

Level(s) indicator 4.2: Time outside of thermal comfort range, User manual: overview, instructions and guidance (Publication version 1.0)

Abstract

Developed as a common EU framework of core indicators for the sustainability of office and residential buildings, Level(s) provides a set of indicators and common metrics for measuring the performance of buildings along their life cycle. As well as environmental performance, which is the main focus, it also enables other important related performance aspects to be assessed using indicators and tools for health and comfort, life cycle cost and potential future risks to performance.

Level(s) aims to provide a common language of sustainability for buildings. This common language should enable actions to be taken at building level that can make a clear contribution to broader European environmental policy objectives. It is structured as follows:

1. Macro-objectives: An overarching set of six macro-objectives for the Level(s) framework that contribute to EU and Member State policy objectives in areas such as energy, material use and waste, water and indoor air quality.
2. Core Indicators: A set of 16 common indicators, together with a simplified Life Cycle Assessment (LCA) methodology, that can be used to measure the performance of buildings and their contribution to each macro-objective.

In addition, the Level(s) framework aims to promote life cycle thinking. It guides users from an initial focus on individual aspects of building performance towards a more holistic perspective, with the aim of wider European use of Life Cycle Assessment (LCA) and Life Cycle Cost Assessment (LCCA) methods.

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How this indicator user manual works

Level(s) is a framework of core indicators of sustainability that can be applied to building projects in order to report on and improve their performance. The supporting documentation has been designed to be accessible to all the actors that may be involved in this process.

If you are new to the assessment of a building's sustainability, we recommend reading the **first part of the Level(s) user manual**. This will provide you with an introduction to the basic concepts behind Level(s) and how you can apply it to a building project.

If you haven't yet set up your building project to use Level(s), including completing the project plan and the building description, then we recommend reading the **second part of the Level(s) user manual**.

This indicator user manual forms the third part of the Level(s) user manual where you will find instructions on how to use the indicators themselves. It is designed to help you apply your chosen indicator to a building project. It will help you to do this in the following way:

- **Introductory briefing:** This section provides an overview of the indicator, including:
    - ✓ why you may wish to measure performance with it,
    - ✓ what it measures,
    - ✓ at which stages in a project it can be used,
    - ✓ the unit of measurement, and
    - ✓ the relevant calculation method and reference standards.
- **Instructions on how to use the indicators at each level**: This section provides:
    - ✓ step by step instructions for each level,
    - ✓ what is needed to make an assessment,
    - ✓ a design concept checklist (at Level 1), and
    - ✓ the reporting formats.

  The instructions often refer to the guidance and further information which can be found after the instructions.
- **Guidance and further information for using the indicator**: This section provides more background information and guidance to support you in following specific steps in the instructions, including the design concepts introduced at Level 1 and the practical steps to calculate or measure performance at Levels 2 and 3. They are all cross-referenced to specific instruction steps at either level 1,2 or 3.

This indicator user manual is structured so that once you are familiar with using the indicator and you know how to work with it, you may no longer need to refer to the guidance and background information, but only work directly with the instructions at the level of your choice.

Technical terms and definitions used

Adaptive condition	Physiological, psychological or behavioural adjustment of building occupants to the interior (and exterior) thermal environment in order to avoid discomfort.
Air-conditioning	A combination of the components required to provide a form of indoor air treatment, by which temperature is controlled or can be lowered.
Buildings without mechanical cooling	Buildings that rely on other techniques to reduce high indoor temperature during the cooling season like moderately-sized windows, adequate sun shielding, use of building mass, natural ventilation, control of internal gains, night time ventilation etc. to prevent overheating.
Handover	Step at which possession of the construction works is surrendered to the client upon completion with or without reservation.
Mechanical cooling	Cooling of the indoor environment by mechanical means used to provide cooling of supply air, fan coil units, cooled surfaces etc.
Predicted Mean Vote (PMV)	An index that predicts the mean value of the votes of a large group of persons on a 7 point thermal sensation scale based on the heat balance of the human body.
Predicted Percentage Dissatisfied (PPD)	An index that establishes a quantitative prediction of the percentage of thermally dissatisfied people (those who would vote hot, warm, cool or cold on the 7 point thermal scale) who feel too cool or warm.
Technical building system	Technical equipment for space heating, space cooling, ventilation, domestic hot water, built-in lighting, building automation and control, on-site electricity generation, or a combination thereof, including those systems using energy from renewable sources, of a building or building unit

Introductory briefing

Why measure performance with this indicator?

The control of thermal comfort and, in particular, solar gains in summer, is an important factor in all buildings. This is because, even in Northern European locations, uncontrolled gains from solar radiation can lead to uncomfortable conditions that may in turn require additional cooling energy.

The control of overheating is specifically addressed by the Energy Performance of Buildings Directive 2010/31/EU (EPBD) as amended by Directive (EU) 2018/844 [1] which states that:

> *'…there should be focus on measures which avoid overheating, such as shading and sufficient thermal capacity in the building construction, and further development and application of passive cooling techniques, primarily those that improve indoor climatic conditions and the microclimate around buildings.'*

Whilst the main focus of this indicator is on thermal comfort in summer, the ability of residents to keep homes warm in winter is also an important factor. A large proportion of the EU's housing stock cannot provide adequate levels of thermal comfort because of a combination of a lack of insulation, poor quality windows, cold bridging through the building fabric, high levels of air infiltration and inadequate or poorly maintained heating systems. This can lead to inadequate heating which can put more vulnerable residents at risk from seasonal illnesses. In relation to this the EPBD also states:

> *'The energy needs for space heating, space cooling, domestic hot water, ventilation, lighting and other technical building systems shall be calculated in order to optimise health, indoor air quality and comfort levels defined by Member States at national or regional level.'*

Adverse conditions due to climate change may exacerbate both of these problems in the future, and can be addressed by using the same indicator to calculate and report on future climatic scenarios under Macro Objective 5, indicator 5.1.

What does it measure?

This indicator measures the proportion of the year when building occupiers are comfortable with the thermal conditions inside a building. Thermal comfort has been described by Nicol et al (2013) [2] as:

> *'…..that condition of mind which expresses satisfaction with the thermal environment. Dissatisfaction can be caused by warm or cool discomfort of the [human] body as a whole….or by an unwanted cooling (or heating) of one particular part of the [human] body.'*

Linked to this it also seeks to measure the ability of a building (with and without building services) to maintain pre-defined thermal comfort conditions during the heating and cooling seasons [3].

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[1] Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency

[2] Nicol.F, Humphreys.M and Roaf.S (2013) *Adaptive thermal comfort – principles and practice*, Earthscan

[3] The EU Energy Poverty Observatory and the EU Building Stock Observatory provide more granular data and indicators in relation to the comfort conditions of Europe's building stock

At what stage of a project

Level	**Activities related to the use of indicator 4.2**
1. Conceptual design (following design principles)	✓ Thermal comfort risk assessment as part of the design of the building. ✓ Selection of tailored solutions for major renovation works.
2. Detailed design and construction (based on calculations, simulations and drawings)	✓ Calculated building permitting assessment - as part of an overheating assessment ✓ Consideration of different aspects of thermal comfort, including localised discomfort effects
3. As-built and in-use (based on commissioning, testing and metering)	✓ Measured EPB assessment sub types: climate corrected, use corrected or standard ✓ Commissioning: functional performance testing ✓ Comparison of estimated satisfaction levels with those obtained from occupier surveys.

The related additional heating and cooling consumption can also be reported in terms of primary energy demand using indicator 1.1 and life cycle costs using indicator 6.1

The unit of measurement

The unit of measurement is the **percentage of the time out of range from defined maximum and minimum temperatures** during the heating and cooling seasons. The reference temperature range shall be 18°C to 27°C.

The performance of a building should be assessed with and without mechanical cooling. The reported performance shall apply to those spaces or zones that account for >10% of the total useful floor area of the building.

If an occupier survey is to be carried out, the Predicted Percentage Dissatisfied (PPD) may also be reported on.

System boundary

The assessment boundary is the building. Heat losses and gains, both internal and external, that may affect the comfort conditions within the building, as well as the heating and cooling energy that may be required to maintain these conditions, are to be factored into calculations.

Scope

The scope of the indicator shall comprise the internal operating temperature and comfort condition of the occupiers within the building.

Those buildings which have full or mixed mode mechanical cooling shall additionally assess the performance of the building fabric without these mechanical systems operating. The same shall apply to buildings with central heating systems. This is intended to assess the inherent thermal resilience of the building envelope.

Calculation method and reference standards

Calculation of the reported performance shall be based on a dynamic energy simulation and in accordance with the method described in Annex A.2 of EN 16798-1. An overheating assessment that forms part of a National Calculation Method shall be accepted if it is based on a dynamic simulation method. If a more advanced calculation method is used, it shall be compliant with the ISO EN 52000-1 series.

If there is the intention to carry out post-occupancy evaluation of satisfaction/dissatisfaction with the thermal environment, the Predicted Percentage Dissatisfied (PPD) shall be estimated based on EN ISO 7730 (for mechanically cooled buildings) or the acceptable summer indoor temperature range (for buildings without mechanical cooling). The estimate PPD can then be compared with the results from an occupier survey.

Instructions on how to use the indicator at each level

Instructions for Level 1

L1.1 The purpose of this level

This level is for those users who would like to:

- Assess the risks of occupier thermal discomfort during the heating and cooling seasons for the building type being assessed.
- Understand measures that can be taken to create a comfortable thermal environment in the building types being assessed.

L1.2 Step-by-step instructions

These instructions should be read in conjunction with the accompanying guidance and supporting information which can be found from page 17 onwards.

1. Determine the required level of thermal comfort necessary/required for the spaces within the building, in line with national / regional building codes
2. Consult the checklist under L1.4 of thermal comfort design concepts and read the background descriptions in the Level 1 technical guidance
3. Within the design team, review and identify how the thermal comfort design concepts can be introduced into the design process.
4. Once the design concept is finalised with the client, record the thermal comfort design concepts that were taken into account using the L1 reporting format.

L1.3 Who should be involved and when

Actors involved at the conceptual design stage, led by the concept architect and engineers. The thermal comfort design concepts can be translated into detailed designs once professionals such as service engineers, energy auditors, energy/sustainability consultants and quantity surveyors become involved in the project.

L1.4 Checklist of thermal comfort design concepts

The following thermal comfort design concepts have been identified from best practice and literature reviewed by the Joint Research Centre as proxies for achieving better performance.

Although many EU Member States require some form of overheating assessment in order to obtain a building permit, the checklist can be used to inform design concepts and to improve performance without necessarily having to make more advanced assessments of the building's thermal comfort conditions.

Table 1. Level(s) thermal comfort design concepts

Level 1 design concept	*Brief description*
1. Identify and assess risk factors	A number of risk factors can be identified that can contribute to the risk of thermal discomfort: • Site location: A number of factors should be taken into account: - Orientation will influence exposure to the sun in summer and prevailing winds in winter - Obstructions such as other buildings or nearby trees may limit solar gains during winter or summer - The urban microclimate may raise summer temperatures compared to data from local weather stations • Building design: A number of design factors can lead to excessive solar gain in summer or thermal losses in winter: - Glazing ratio: High glazing ratios on S/SE/SW facades can, without sufficient solar control, lead to overheating. - Insulation: Insufficient or poorly installed insulation with

	thermal bridging of the building envelope - Thermal mass: Insufficient thermal mass within the building envelope may result in significant temperature swings. - Aspect: Where the aspect of a residential dwelling does not allow for sufficient natural ventilation. - Shading: Where balconies, patios and shutters are not designed to provide adequate shading on S/SE/SW facades - Solar glass: Where the glazing is not specified to control infrared or ultraviolet radiation In some EU locations, an overheating assessment may be required and if carried out should be noted in the Level 1 reporting.
2. Design for comfortable thermal conditions	In designing a new building or major renovation, a range of decisions influence the thermal conditions in, on and around the building: • Building design: Design decisions in three key areas can be used to minimise seasonal swings in temperature and localised discomfort: - Envelope: A high performance, insulated building envelope with effective solar control measures will protect against outdoor conditions and minimise seasonal swings in internal temperatures. - Structure: Structural designs that provide natural ventilation and exposed thermal mass. - Servicing: Integration of heating and cooling design with the building structure and consideration of ventilation pathways. Localised indoor effects such as draughts and hot/cold spots should be avoided. • Landscape design: A number of nature-based design features can contribute to moderating the surrounding microclimate: - the presence of trees and vegetation in streets, courtyards, patios as well as on facades and roofs - The presence of water features such as ponds, drainage swales and fountains - Unsealed surfaces instead of hard, paved or dark surfaces
3. Take into account the site specific conditions	In designing the building or major renovation, take into account: • site specific conditions in order to better understand the microclimate. Steps that can be taken include: - Reference to local weather data in order to understand the distinct seasonal, monthly, weekly and daily conditions. - Reference to information about any localised microclimate conditions, such as prevailing winds, the urban heat island effect and air or noise pollution levels. In this way, the physical design, elevations and servicing can be designed to respond to the local climate, including the potential for passive heating/cooling, intelligent structures, high yield renewables and useful daylighting.

4. Take into account renovation specific conditions	In seeking to renovate a building, use information gathered in a baseline survey to adapt the improvements to the performance and conditions of the existing building location, fabric and landscaping, taking into account: • The orientation and exposure of facades and roofs • Existing floor layouts and ventilation pathways • Existing solar control features • The seasonal response of the building fabric to weather conditions, including structural thermal bridging • Existing technical services (if they are to be retained and upgraded) Information obtained from prior occupants may yield useful information about the buildings performance.

L1.5 Reporting format

To complete the reporting format for Level 1 you should answer yes or no for each of the design concepts that you have addressed and provide brief descriptions of the measures or decisions taken for each one.

Thermal comfort design concept	**Addressed?** *(yes/no)*	**How has it been incorporated into the building design concept?** *(provide a brief description)*
1. Identify and assess risk factors		
2. Design for comfortable thermal conditions		
3. Take into account the site specific conditions		
4. Take into account renovation specific conditions		

Instructions for Level 2

L2.1 The purpose of this level

This level is for those users who are at the stage of having to assess the energy requirements of a building and wish to make a quantitative assessment of the indoor thermal conditions according to the Category II temperature ranges stipulated in EN 16978-1 (or national equivalent). They may also need to make an overheating assessment of a building for the purpose of obtaining a building permit.

L2.2 Step-by-step instructions

These instructions should be read in conjunction with the accompanying technical guidance and supporting information.

1. Determine the required level of thermal comfort necessary/required for the spaces within the building, in line with national / regional building codes
2. With reference to indicator 1.1, identify whether the national/regional calculation method is dynamic and whether an overheating assessment is also required in order to obtain a building permit.
3. If the national/regional calculation method is dynamic, this may be used to calculate the time out of range. If not, a dynamic simulation method and software tool will need to be selected for use.
4. Complete the reporting table with the calculation method that will be used to calculate the time out of range
5. *Optional step:* Decide whether a post-occupancy evaluation of occupant satisfaction/dissatisfaction with the thermal environment will be carried out.
6. If yes, indicate in the reporting table that a post-occupant evaluation will be carried out and follow the instructions under L2.6.

Steps to calculate the heating and cooling season time out of range

7. For residential developments with many house or apartment typologies, make a representative selection of the designs to be modelled.
8. Determine whether default values for the building occupancy and conditions of use patterns shall be used, as stipulated in a national calculation method, or whether real-life assumptions can be made. Determine also whether the weather files are stipulated.
9. If a dynamic simulation was not already setup for the purposes of reporting on indicator 1.1, identify and gather the input data that will be required to make the calculations.
10. Setup the dynamic simulation, inputting the temperature set points stipulated in the Level(s) guidance.
11. *Going a step further:* If there is access to historical data an analysis can be made of heat wave duration and intensity.
12. If the simulation does not automatically calculate the time out of range, identify the output from the calculation routine that can be used to interrogate the internal temperature per hour.
13. Establish two models for each building or property typology – one with mechanical heating/cooling systems and one without.
14. Run the simulation for each model in order to obtain the internal temperatures per hour for a year.
15. If the simulation does not automatically calculate the time out of range, the result shall be analysed in order to derive the percentages for the upper and lower temperature bands.
16. Complete the main reporting table for each building or property typology with the times out or range obtained.

L2.3 What do you need to make an assessment?

The main items needed are as follows:

- An appropriate calculation software tool that can run a dynamic simulation and which is compliant with the national/regional calculation method for the relevant Member State and/or EN ISO 52000-1
- A building design sufficiently advanced to provide the input data required to make the calculations using the compliant calculation software tool.
- *Optional for going a step further:* the appropriate input data and assumptions to make calculations according to the method described in EN ISO 16798-1 (see L2.6)

L2.4 Who should be involved and when?

Those actors involved at the detailed design stage, led by the architect or engineer. Input data may need to be obtained from, amongst others, the architect, service engineers, energy auditor and quantity surveyor. Simulations may be carried out by the service engineers or energy/sustainability consultants.

L2.5 Ensuring the comparability of results

Comparative performance assessments shall be made on the basis of:

- Use of standard input data for the thermal simulation: Default input data provided as part of national / regional calculation methods or the default data provided in Annex G of EN ISO 13790 (or EN ISO 52016-1) shall be used. This shall include the use of standard occupancy and conditions of use data for the building type (see Annex G.8).
- PPD thermal parameter input data: For the six parameters identified in EN ISO 7730, the default or reference national or regional data for the building type shall be used.
- Weather data: The design reference year stipulated by the national or regional calculation method for overheating shall be used. If an equivalent is not provided for heating then the typical meteorological year shall be used.
- Heating and cooling seasons: The heating and cooling seasons defined in the relevant national calculation method shall be used.
- Temperature ranges: The Category II temperature ranges, as stipulated in EN 15251 and EN 16978-1 (or national equivalent), shall be used in all cases.

L2.6 Going a step further – Optimisation steps to improve the assessment and building performance

The following step can be taken in order to optimise the thermal simulations:

- Building occupancy and condition of use data: Real-life assumptions and values for the building shall be used instead of the default values established by national calculation methods or laid down in EN 16798-1.
- Site specific weather data: The use of weather files that are as representative as possible of the location of the building. This could include for the use of data sets that have been adjusted to reflect the Urban Heat Island effect in a specific urban location.
- Heat wave intensity: Simulation and analyse of the frequency of intense heat wave events during which 27°C or an upper temperature of 31°C are exceeded.

The following step can be taken to allow for a comparison of the design satisfaction/dissatisfaction with thermal comfort conditions and the results of a post-occupancy survey:

- Determination of the thermal performance category in accordance with the method described in Annex F of EN 15251. The thermal comfort category can then be read across to the estimated dissatisfaction arising from the survey.

L2.7 Format for reporting the results of an assessment

Supporting information

Level 2 reporting item	**Information to provide** **(select/delete as appropriate)**
Calculation method	*Specify the Member State and the specific method used*
	The specific dynamic method used if it is not a national calculation method
Post-occupancy survey	*Indicate whether the design stage thermal comfort category will be calculated for later comparison*

Performance assessment results

Performance aspect	**Heating season**	**Cooling season**
Operative temperature range (°C)	*Lower/upper limits*	*Lower/upper limits*
Time out of range (%) - without mechanical heating/cooling	*Proportion of time*	*Proportion of time*
Time out of range (%) - with mechanical heating/cooling	*Proportion of time*	*Proportion of time*

Optional reporting for comparison with post-occupancy assessment results [4]

Performance aspect	**Heating season**	**Cooling season**
Thermal environment categories - without mechanical cooling	*EN 15251, Annex F comfort category*	*EN 15251, Annex F comfort category*
Time out of range (%) - with mechanical cooling	*EN 15251, Annex F comfort category*	*EN 15251, Annex F comfort category*

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[4] These categories are based on estimation of the occupant dissatisfaction with the comfort conditions, providing the basis for comparison of design and occupied dissatisfaction levels.

Instructions for Level 3

L3.1 The purpose of this level

This level is for those users who would like to:

1. Collect monitoring data on the thermal conditions in a building in order to compare the performance with design simulations, and
2. Carry out a post-occupancy survey of occupants in order to determine the level of dissatisfaction with the thermal comfort conditions and compare the results with the design estimates.

L3.2 Step-by-step instructions

These instructions should be read in conjunction with the accompanying technical guidance and supporting information.

Monitoring and metering strategy

1. The procedure will depend on the building type:
   - For office buildings (new and renovated): prior to handover, the setting up of temperature sensors shall be completed. This shall include their location, correct calibration and link to the data logging system.
   - For residential buildings (new and renovated): this step is likely to require a monitoring period to be agreed with residents and the temporary installation of sensors at a later point in time.
2. For office buildings (new and renovated): Following handover and prior to occupation, responsibility shall be assigned for obtaining and compiling the data provided by the installed probes.

Data collection and reporting

3. Data shall be collected after the minimum period of occupation time has passed following completion of the building and then for the minimum duration of time.
4. If the data is to be used to compare with other buildings, the performance shall be corrected in relation to the conditions of use and the test reference year for the local area or region, following the national method or the method in EN ISO 52000-1.
5. The data obtained shall be analysed in order to derive the percentages for the upper and lower temperature bands for the defined heating and cooling seasons.
6. Complete the main reporting table for each building or property typology with the times out or range obtained.
7. *Optional step:* Identify and attempt to diagnose the reason for any significant deviations from the calculated figures reported at Level 2.

L3.3 What do you need to make an assessment?

A monitoring strategy to enable the collection of hourly temperature data from thermal probes installed at sampling locations inside the building or each representative residential property type.

L3.4 Who should be involved and when?

Those actors involved in handover of the building and in the subsequent facility management. Analysis may be carried out by the same service engineers or energy/sustainability consultants who made the design assessment, or by consultants appointed by the building owner/operator.

L3.5 Ensuring the comparability of results

For the post-occupancy evaluation of satisfaction/dissatisfaction, ISO 10551 provides a reference evaluation method and survey format for thermal comfort.

L3.6 Format for reporting the results of an assessment

Performance assessment results

Performance aspect	**Heading season**	**Cooling season**
Operative temperature range (°C) *if different from the reference values*	*Lower/upper limits*	*Lower/upper limits*
Time out of range (%) - without mechanical heating/cooling	*Proportion of time*	*Proportion of time*
Time out of range (%) - with mechanical heating/cooling	*Proportion of time*	*Proportion of time*

Optional reporting for comparison with post-occupancy assessment results [5]

Performance aspect	**Heating season**	**Cooling season**
Thermal environment categories - without mechanical cooling	*EN 16798-1, Annex A.2 comfort category*	*EN 16798-1, Annex A.2 comfort category*
Time out of range (%) - with mechanical cooling	*EN 16798-1, Annex A.2 comfort category*	*EN 16798-1, Annex A.2 comfort category*

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[5] These categories are based on estimation of the occupant dissatisfaction with the comfort conditions, providing the basis for comparison of design and occupied dissatisfaction levels.

Guidance and further information for using the indicator

Instructions for using level 1

In this part of the guidance, additional bacground guidance and explanations are provided for a number of the key concepts introduced in the Level 1 thermal comfort design concept checklist, namely:

- L2.4 – Checklist item 1: Building design for inherent thermal resilience
- L2.4 – Checklist item 2: Factors that can cause localised indoor thermal discomfort
- L2.4 – Checklist item 3: The shading and microclimate benefits of nature-based solutions

For each concept, the implications for building design, landscape design and thermal modelling are identified.

L2.4 – Checklist item 1: Building design for inherent thermal resilience

A building's structure, fabric and ventilation systems can be designed in a way that provides inherent resilience to overheating events. There are three main areas of potential focus for resilient design and engineering to manage the thermal energy balance of a building:

- Thermally massive building structures: In buildings with thermal massive structures the inherent thermal inertia can be used to delay swings in temperature, thereby moderating internal comfort conditions (see figure 1). In new buildings there is the potential to go further by designing a thermally activate structure in which the heating and cooling is routed through the building structure.. These can, even in the present climate, allow for a significant reduction in the size of HVAC plant because of its inherent thermal inertia over a 24 hour operating period.
- Thermally resilient envelope and façade: The materials can be selected for both their albedo effect (solar reflectance) and their thermal resistance (insulation value), thereby reducing absorption and transmission of solar radiation to the interior of the building.
- Thermally resilient air intake systems: The design of fresh air intake pathways so that air is brought into buildings through shaded external spaces and through underground systems can minimise air intake temperatures

Dynamic thermal simulation is required to more accurately quantify the benefits of inherently resilient design features. It can also be used to optimise the design of facades and structures, as well as the operation of ventilation and cooling systems, in order to utilise this capacity.

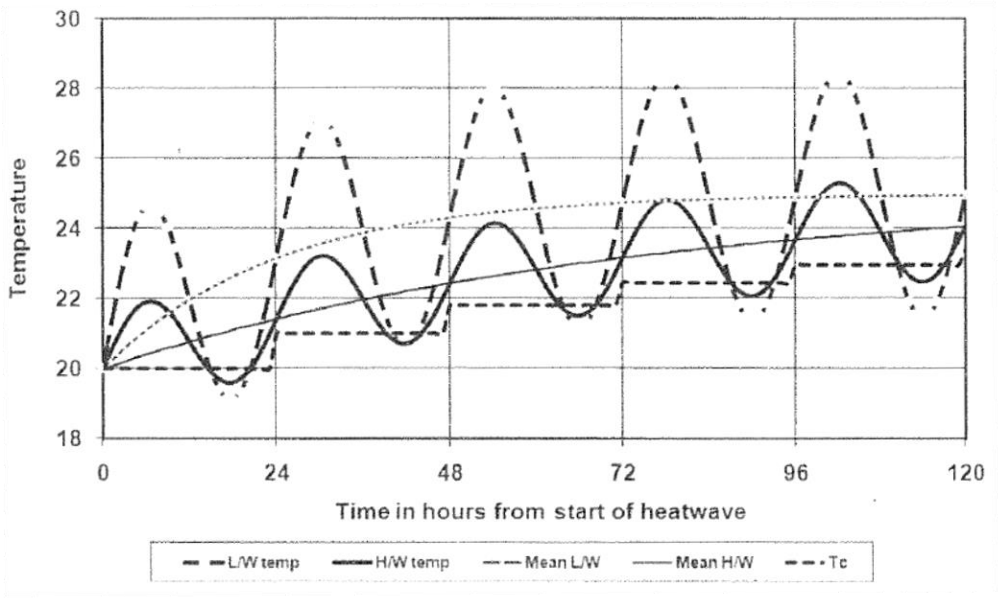

Figure 1 Comparison of indoor thermal variation of light weight (L/W) and heavy weight (H/W) buildings

Source: Nicol et al (2012)

L2.4 – Checklist item 2: Factors that can cause localised indoor thermal discomfort

The sensation of thermal comfort or discomfort is in practice more complex than defining an upper and lower temperature range, or considering the human body as a whole. Evidence from the study of low energy and passive buildings has shown that the following localised aspects are important to consider:

- Draughts,
- Vertical air temperature differences,
- Floor temperature, and
- Radiant temperature asymmetry.
- Activity levels

Assessments of the relationship between occupant discomfort and the potential variation in the thermal sensation caused by these aspects are individually provided in EN ISO 7730. Indicative performance categories for each of these aspects are also provided in EN 15251 and EN 16978.

L2.4 – Checklist item 3: The shading and microclimate benefits of nature-based solutions

The presence of vegetation on buildings (e.g. green roofs) or between/within buildings (e.g. trees) can provide shading and can moderate external air and surface temperatures around a building. This is because it shades materials with a low albedo and a high thermal capacity, such as paving and building envelope materials, thereby minimising the re-radiation of heat. The use of soil instead of hard 'sealed' surfacing on and around a building can further moderate external temperatures.

The guidance note below provides some further information on the options available to factor the shading and cooling action of vegetation and soil into building designs.

Learn more

Options for modelling and assessing the performance improvements of nature-based features

Two main options exist for factoring the shading and cooling function of vegetation and soil into a building design:

1. Change building thermal simulation inputs: Some dynamic and quasi steady-state building simulations allow for the input of vegetation shading. However, the potential to do this is not currently well developed and representative input data is difficult to obtain.
2. Use of a ‘green factor’ scoring system: This can be used as a proxy for the ecosystem services provided by green infrastructure. It works by scoring the shading and cooling potential of green features on, in or around a building (e.g. trees according to their leaf area, evapotranspiration rate, soil water retention). This approach has been applied in cities such as Berlin, Stockholm and Southampton.

The second option can only be considered to provide a useful proxy if the potential ecosystem services that can be provided are weighted to reflect the shading and cooling potential of vegetation, soil or combinations of both. The maturity and extent of the vegetation in 2030 and 2050 should also be estimated.

To take two examples of the second option, Malmö's ‘Green Space Factor’ (GSF) provides a simplified weighting system for green infrastructure[6]. The GSF is weighted as follows to take into account the extent of soil sealing, the depth of soil and the extent of vegetation (e.g. mature trees have a greater weighting).

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[6] Kruuse.A, *the green space factor and the green points system*, GRaBs Expert paper 6, EU INTERREG project, TCPA, April 2001

$$GSF = \frac{(area\ A\ x\ factor\ A)+(area\ B\ x\ factor\ B)+(area\ C\ x\ factor\ C)+etc.}{total\ courtyard\ area}$$

In Berlin, a 'Biotope Area Factor' (BAF) is used to reduce soil sealing and increase green cover in higher density urban areas 7. It is applied as a planning requirement to all buildings in specific inner urban areas. The Berlin factor is largely determined based on the proportion of building and space where there is soil sealing (see formula 1). It does not account for the extent of vegetation that may be planted in the soil i.e. it does not reflect leaf transpiration cooling capacity.

$$BAF = \frac{ecologically\ effective\ area\ (m^2)}{area\ of\ the\ public\ land}$$

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[7] Climate ADAPT (2014) *Berlin biotope area factor – implementation of guidelines helping to control temperature and runoff*, European Environment Agency.

Instructions for level 2

In this part of the guidance, further background is provided on:

- L2.2 – Steps 7-15: The calculation methodology
- L2.2 – Step 8: Data requirements and recommended sources
- L2.2 – Step 10-11: The selection of weather data sets,
- L2.2 – Step 16: Post-occupancy evaluation of comfort.

In addition, further guidance is provided on setting up the assessment to cover the post-occupancy evaluation of comfort.

L2.2 – Steps 7-15: The calculation methodology

The thermal simulation shall be conducted for the building both with and without mechanical cooling and heating. This is intended in order to ensure that the inherent thermal characteristics of the building envelope and structure are assessed.

Calculation of the reported performance shall be carried out using a dynamic simulation model and in accordance with the methods described in Annex F of EN 15251. In some Member States, the national calculation method for energy assessments is based on a dynamic method. Results from such a method may be used. A guidance note is provided to help getting started if a dynamic simulation has not been used before.

Guidance note

Getting started with dynamic building energy simulations

Setting up such a model can be time consuming and requires experience and expertise, as it requires a great number of input parameters to reflect the specific detail about a building and its likely operating conditions. It is also unlikely that the national calculation method will be dynamic.

It is recommendable to by making an assessment of the local climate and relate this to case studies of buildings of the same type with a validated performance in the same climate. A good example in this case is the tool *Climate Consultant*[8].

Once users have gained more experience, they can move on to use the full simulation capabilities. It is recommended to start with a dynamic tool that works on the basis of a limited number of inputs. Good examples are Example File Generator[9] (EnergyPlus) and eQuest[10] (DOE2.2).

In some Member States, the simulation model that supports the national calculation method is dynamic – for example, CALENER/HULC in Spain. Training and support in the use of the tool is therefore available.

Where a dynamic simulation tool is not available nationally, a number of international tools are available, some of which are free to obtain – for example, EnergyPlus. Suitable dynamic simulation tools shall have been validated according to the procedures of EN ISO 52016-1, EN 15265 or ASHRAE 140 (the latter two being based on the BESTEST method). Tools that are known to already have been validated accordingly include DOE2, BLAST, ESP, SRES/SUN (SERIRES/SUNCODE), SERIRES, S3PAS (LIDER/CALENER), TAS, TRNSYS and EnergyPlus.

The methods described in EN 15251 cover buildings with and without mechanical cooling. For the modelling of a building without mechanical cooling, the assumptions described in Annex F of EN 15251 that relate to adaptive conditions shall be followed (referred to as *'Acceptable indoor temperatures for design of buildings without mechanical cooling systems'*).

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[8] University of California, *Climate Consultant*, http://www.energy-design-tools.aud.ucla.edu/climate-consultant/

[9] EnergyPlus Example File Generator, https://buildingdata.energy.gov/cbrd/resource/704

[10] eQuest, http://doe2.com/equest/index.html

Adaptive conditions is an important concept for naturally cooled buildings. Evidence shows that people's perception of thermal comfort is strongly influenced by the mean temperature outside, to such an extent that during the heating and cooling seasons the maximum and minimum temperature range can be increased.

L2.2 – Step 8: Data requirements and recommended sources

The data sources for the thermal simulation shall be the same as those identified for indicator 1.1. Reference values provided at national level may be used or, alternatively, bespoke values can be identified. The assumptions shall however be reported.

The Predicted Percentage Dissatisfied (PPD) design stage estimate requires input data for six thermal parameters - clothing, activity, air and mean radiant temperature, air velocity and humidity.

Table 2. Data requirements and sources for indicator 4.2

Data item	**Potential source**	
	Default EU values	**National, regional or locally specific values**
Thermal simulation	*See indicator 1.1*	*See indicator 1.1*
PPD thermal parameters	ISO 8996, ISO 9920 EN ISO 7730 Annexes B/C EN ISO 7730 Annex E (overall estimate of PPD)	National or regional calculation method (overheating assessment) Building permitting requirements
Weather data	Three climate zones (EN 15265 test cases)	National or regional calculation method Member State Meteorological Offices

L2.2 – Step 10-11: The selection of weather data sets

It is recommended to use a typical meteorological year (TMR) derived from a medium term (20 or 30 year) time series for a standard local weather station, although some Member States stipulate a Design Reference Year for overheating calculations. The length of this time series will ensure that the TMR is representative of climatic variations in the short to medium term. If access to hourly local weather files is not possible then the Joint Research Centre's open access weather file database may be used across the EU [11].

<u>The Urban Heat Island (UHI) effect</u>

As highlighted under Level 1, it is important to take into account, where possible, the Urban Heat Island (UHI) effect, as this can have a significant effect on localised external temperature. In some EU towns and cities, work has been done to interpolate weather datasets to take into account the UHI effect. This is particularly important in major cities and locations where the urban design, commuting patterns and topography can exacerbate winter or summer conditions.

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[11] Joint Research Centre, Photovoltaic Geographical Information System (PVGIS) – TMY generator https://ec.europa.eu/jrc/en/PVGIS/tools/tmy

Learn more

Determining the extent of the urban heat island effect

The Urban Heat Island (UHI) effect is an additional factor to take into account when modelling the external air and radiative temperatures around a building. This is because the temperature in an urban area can be elevated compared to rural areas due to a combination of:

- vehicle exhaust,
- building air conditioning heat rejection,
- street canyon geometry,
- reduced evapotranspiration by vegetation and,
- absorption and re-radiation of heat by roads, paving and structures.

The effect can be generalized across an urban area or, where there are combinations of factors, it can be very localised within a district or at specific points.

Recognising the significance of this effect, a number of cities have put in place initiatives to support designers to better take it into account. Examples include London[12], Stuttgart[13] and Zaragoza[14].

Taking into account extreme weather events

Whilst an estimation of the time out of a thermal comfort range will provide a broad indication of the tolerance of the building, it will not provide information on persistent periods of temperature stress that may reduce occupants tolerance to 'out of range' conditions. As a result, their willingness to adapt to higher temperatures may progressively reduce during these events, thereby affecting discomfort levels and cooling energy use.

Data on the duration and intensity of heat waves in a locality or region can provide the basis for a more detailed risk assessment[15]. Figure 1 illustrates how, during a seven day period, an example building's operative temperature exceeded a set temperature limit four consecutive days in a row for a total of 31 hours.

More detailed analysis of duration and intensity could also have implications for how, for example, an excess of heat is managed over a 24 hour period or over several days. This is important because, during continuous overheated periods, the urban environment may re-radiate more heat at night, thereby maintaining ambient air temperatures. The effects of heat stress on the human body may also be compounded over time, reducing occupant's willingness to adapt to higher temperatures in interior environments.

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[12] London's urban heat island, https://data.london.gov.uk/dataset/london-s-urban-heat-island---average-summer

[13] Climate ADAPT case study of Stuttgart,http://climate-adapt.eea.europa.eu/metadata/case-studies/stuttgart-combating-the-heat-island-effect-and-poor-air-quality-with-green-ventilation-corridors

[14] José M. Cuadrat Prats, Sergio M. Vicente-Serrano y Miguel A. Saz Sánchez, *Los efectos de la urbanizacion en el clima de Zaragoza (España): La isla de calor y sus factores condictiontes*, Boletín de la A.G.E. N.º 40 - 2005, págs. 311-327

[15] W. Victoria Lee & Koen Steemers (2017) *Exposure duration in overheating assessments: a retrofit modelling study*, Building Research & Information, 45:1-2, 60-82

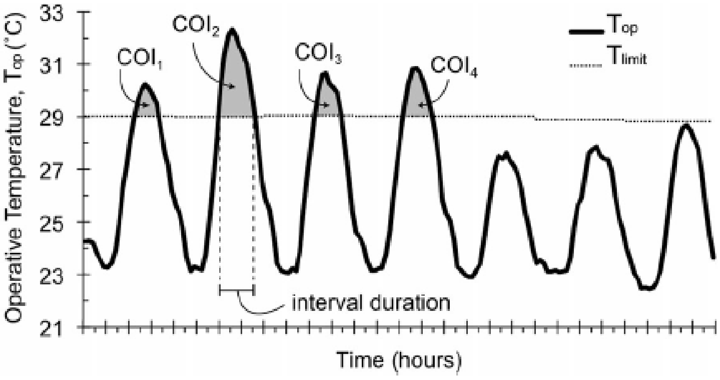

Figure 2 Example of Continuously Overheated Intervals (COIs) over a seven day period

Source: Lee and Steemers (2017)

L2.2 – Step 16: Post-occupancy evaluation of comfort

If there is the intention to carry out post-occupancy evaluation of satisfaction/dissatisfaction with the thermal environment and, depending on whether mechanical cooling is to be used in the building, a design prediction can first be made. The recommended method is based on the EN 15251 indoor thermal comfort categories and how the building is cooled:

- Mechanically cooled buildings: Predicted Percentage Dissatisfied (PPD) shall be estimated based on EN ISO 7730
- Buildings without mechanical cooling: the acceptable summer indoor temperature range shall be used.

The findings from occupant survey methods are usually expressed in terms of Predicted Percentage Dissatisfied (PPD) and Predicted Mean Vote (PMV). These results can be read across to the EN 15251 thermal comfort categories as shown in table 2. I represents the best performance and IV the worst.

Table 3. The read across between indoor thermal environment categories, Predicted Percentage Dissatisfied (PPD) and acceptable (adaptive) indoor summer temperatures

EN 15251 category	Fanger method		Adaptive method (Nicol et al)
	PPD (%)	PMV	Operative temperature variance (oC)
I	≤ 6	-0.2 ≤ PMV ≤ +0.2	± 2
II	≤ 10	-0.5 ≤ PMV ≤ +0.5	± 3
III	≤ 15	-0.7 ≤ PMV ≤ +0.7	± 4
IV	>15	PMV < -0.7 and PMV > 0.7	

Source: Athienitis and O'Brien (2015)

Instructions for level 3

In this part of the guidance, the sampling protocol for internal spaces for monitoring purposes is detailed, together with the standardised basis for reporting on the results of a post-occupancy evaluation.

L3.2 – Steps 1-2: Sampling protocol for room thermal comfort

The sampling protocol for determining the floor space and rooms to be monitored post-occupancy shall be as follows:

- Office buildings: All room configurations within the total useful floor area that are used for office-related work and which account for more than 10% of the total useful floor area.
- Residential buildings: The main living rooms and all bedrooms within a home. In the case of assessment of multiple homes within an apartment block of residential development, each distinctive configuration and orientation shall be assessed.

Additional step: Post-occupancy evaluation of comfort

The survey method set out in ISO 10551 shall form the basis for the post-occupancy evaluation. The findings from occupant survey methods are usually expressed in terms of Predicted Percentage Dissatisfied (PPD) and Predicted Mean Vote (PMV). These results can be read across to the EN 15251 thermal comfort categories, for which a result may have been reported at Level 2, and as shown in table 3. I represents the best performance and IV the worst.

Table 4. The read across between indoor thermal environment categories, PPD and acceptable (adaptive) indoor summer temperatures

EN 15251 category	Fanger method		Adaptive method (Nicol et al)
	PPD (%)	PMV	Operative temperature variance (oC)
I	≤ 6	-0.2 ≤ PMV ≤ +0.2	± 2
II	≤ 10	-0.5 ≤ PMV ≤ +0.5	± 3
III	≤ 15	-0.7 ≤ PMV ≤ +0.7	± 4
IV	>15	PMV < -0.7 and PMV > 0.7	

Source: Athienitis and O'Brien (2015)

The overall thermal simulation of the building shall be according to the CEN standards that support the Energy Performance of Buildings Directive. This shall be as described in indicator 1.1.