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An overview of the European Standard EN 15251

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Abstract
The CEN Standard EN15251 has broken new ground in two major ways: firstly it attempts to bring together existing information about optimising thermal, air quality, acoustic and visual comfort so that designers can make energy calculations which embody all aspects of the environment which may impinge on energy use; secondly it recognises the different expectations occupants have of the thermal environment in mechanically and naturally ventilated buildings. Potentially this makes EN15251 a very powerful standard in the design of new buildings and the evaluation of existing buildings. For this reason it is important to be clear about the strengths and weaknesses of the Standard as written and to indicate ways in which future standards might improve on it and this is the aim of this paper.

Key Words: European Standard EN15251, Standards, Energy use in buildings, adaptive thermal comfort.

1. Introduction

This is a critique of the new CEN Standard EN15251 which has been developed as part of a series of new standards intended as a backup to the Energy Performance of Buildings Directive (EPBD). Standard EN15251 (CEN, 2007) was formulated by CEN/TC 156WG12. The title of the Standard is *Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustics.* EN15251sets up a series of indoor conditions to enable professionals and consultants to make calculations to predict energy use by buildings. The Standard sets out it's the purpose and scope. This paper looks at the requirements of the Standard and considers their applicability, inconsistencies and inherent assumptions.

This paper is part of the objectives of the project Comfort monitoring for CEN standard EN15251 linked to EPBD (Commoncense) deal principally with the thermal and lighting concerns of the Standard, though the sections of the Standard dealing with ventilation and acoustics will be mentioned where appropriate.

From EN15251

> Energy consumption of buildings depends significantly on the criteria used for the indoor environment (temperature, ventilation and lighting) and building (including

systems) design and operation. Indoor environment also affects health, productivity and comfort of the occupants.

Recent studies have shown that costs of poor indoor environment for the employer, the building owner and for society, as a whole are often considerable higher than the cost of the energy used in the same building. It has also been shown that good indoor environmental quality can improve overall work and learning performance and reduce absenteeism. In addition uncomfortable occupants are likely to take actions to make themselves comfortable which may have energy implications. An energy declaration without a declaration related to the indoor environment makes no sense. There is therefore a need for specifying criteria for the indoor environment for design, energy calculations, performance and operation of buildings

There exist national and international standards, and technical reports, which specify criteria for thermal comfort and indoor air quality (EN ISO 7730, CR 1752). These documents do specify different types and categories of criteria, which may have a significant influence on the energy demand. For the thermal environment criteria for the heating season (cold/winter) and cooling season (warm/summer) are listed. These criteria are, however, mainly for dimensioning of building, heating, cooling and ventilation systems. They may not be used directly for energy calculations and year-round evaluation of the indoor thermal environment. New results have shown that occupant expectations in natural ventilated buildings may differ from conditioned buildings. These issues are not dealt with in detail in the above mentioned documents.

The present standard specifies how design criteria can be established and used for dimensioning of systems. It defines how to establish and define the main parameters to be used as input for building energy calculation and long term evaluation of the indoor environment. Finally this standard will identify parameters to be used for monitoring and displaying of the indoor environment as recommended in the Energy Performance of Buildings Directive.

Different categories of criteria may be used depending on type of building, type of occupants, type of climate and national differences. The standard specifies several different categories of indoor environment which could be selected for the space to be conditioned. These different categories may also be used to give an overall, yearly evaluation of the indoor environment by evaluating the percentage of time in each category. The designer may also select other categories using the principles from this standard.

1.2 Scope

The scope of Standard EN15251 is extremely wide as is specified below. The aim if the authors of the Standard was to provide criteria for the calculation of building energy use which are consistent with the provision of an indoor environment which is consistent with their comfort and wellbeing. In workplaces this it is also considered that this needs to be consistent with the ability to work productively. The scope is set out in the standard as follows:

1. This European Standard specifies the indoor environmental parameters which have an impact on the energy performance of buildings.
2. The standard specifies how to establish indoor environmental input parameters for building system design and energy performance calculations.
3. The standard specifies methods for long term evaluation of the indoor environment obtained as a result of calculations or measurements.
4. The standard specifies criteria for measurements which can be used if required to measure compliance by inspection.
5. The standard identifies parameters to be used by monitoring and displaying the indoor environment in existing buildings.
6. This standard is applicable mainly in non-industrial buildings where the criteria for indoor environment are set by human occupancy and where the production or process does not have a major impact on indoor environment. The standard is thus applicable to the following building types: single family houses, apartment buildings, offices, educational buildings, hospitals, hotels and restaurants, sports facilities, wholesale and retail trade service buildings.
7. The standard specifies how different categories of criteria for the indoor environment can be used, but does not require certain criteria to be used. This is up to national regulations or individual project specifications.
8. The recommended criteria in this standard can also be used in national calculation methods, which may be different to the methods referred to here.
9. The standard does not prescribe design methods, but gives input parameters to the design of buildings, heating, cooling, ventilation and lighting systems.
10. The standard does not include criteria for local discomfort factors like draught, radiant temperature asymmetry, vertical air temperature differences and floor surface temperatures.

1.3 Comments to the Introduction and scope of EN15251

The introductory paragraphs of EN15251 are relatively non-controversial and reflect the thinking of many environmental engineers. In its early mention of employers and building owners the introduction does however indicate that the central concerns of the Standard will be buildings which are commercial workplaces.

This restriction in the concerns of the introductory section is probably justified in that the provision of comfortable and productive conditions in workplaces, and in particular offices, has been the central concern of much of the research on which this Standard is based. It should however be seen as a limitation of the Standard which is in contradiction to bullet 6 of the Scope which claims applicability of the recommendations of the Standard to “single family houses, apartment buildings, offices, educational buildings, hospitals, hotels and restaurants, sports facilities, wholesale and retail trade service buildings.”

This criticism of the range of applicability does not invalidate the Standard for use with other building types, but does suggest that caution should be used when applying it elsewhere and also indicates that the research which has been conducted in other buildings types should be closely inspected and any inconsistencies brought out in future updates of the Standard.

Another inconsistency between the way in which the scope of the Standard is worded and the later content of the Standard is the implication that energy is always involved in deciding the performance of any building. In fact the acoustic performance of buildings may have implications for the energy performance, but is not directly involved in any significant way in energy use. In addition this Standard incorporates ways of predicting under- or overheating of buildings which are free-running. Here the comfort and not the energy use is the key issue since such buildings are, by definition using only minimal energy to regulate indoor conditions.

2 Comments on the definitions in Standard

The Standard contains a number of definitions of terms used. Whilst in most cases there is little to disagree with in the wording of these definitions there are nonetheless underlying assumptions which can be discerned in the way some of the definitions are presented.

The most important of these underlying assumptions is that mechanical ventilation is the normal mode and that natural ventilation is in some way unusual or second rate.

> **Buildings without mechanical cooling**
> Buildings that do not have any mechanical cooling and rely on other techniques to reduce high indoor temperature during the warm season like moderately-sized windows, adequate sun shielding, use of building mass, natural ventilation, night time ventilation etc. for preventing overheating

The idea that a building which NEEDS mechanical cooling to remain comfortable might in many cases be inferior does not seem to occur to the drafting committee and this approach is confirmed by:

> **Cooling/heating season**
> Part of the year during which (at least parts of the day and part of the building, usually summer/winter) cooling/heating appliances are needed to keep the indoor temperatures at specified levels

Here again there is an assumption that the cooling season is a time where (mechanical) cooling is necessary and that temperature levels are specified (who by?). Whilst there is an acknowledgement that the heating/cooling are affected by the climate or weather the idea that the building itself may effect how long the season might be is not introduced

> **Demand controlled ventilation**

Ventilation system where the ventilation rate is controlled by air quality, moisture, occupancy or some other indicator for the need of ventilation

The demand is linked to a physical variable (AQ, Moisture etc) and not to the choice of the occupants. This militates against an NV/Passive solution where the physical parameters are variable and not easy to measure or control. The implication is that control and mechanical solutions give a superior outcome, whereas occupants may actually prefer to be given the means to control their own environment.

Mechanical cooling
Cooling of the indoor environment by mechanical means used to provide cooling of supply air, fan coil units, cooled surfaces, etc.
NOTE The definition is related to people's expectation regarding the internal temperature in warm seasons. Opening of windows during day and night time is <u>not regarded as mechanical cooling. Any mechanical assisted ventilation (fans) is regarded as mechanical cooling</u> *(emphasis in original).*

This definition assumes cooling wholly by mechanical means with no use of renewable energy sources (e.g. night cooling or heat pumps). This fits with the later definition of thermal comfort in terms of PMV but does not fit the spirit of the EPBD because it defines mechanical cooling as the outcome of highly energy intensive technologies. In addition the NOTE to this definition implies that any use of fans can constitute mechanical cooling. Taken literally this could mean that a building with fan extracts in the toilets needed to fulfil the Standards set out for fully air conditioned building. This will tend to work against the use of natural ventilation because buildings with NV cannot achieve the necessary close temperature limits.

Ventilation system
Combination of appliances designed to supply interior spaces with outdoor air and to extract polluted indoor air
NOTE: The system can consist of mechanical components (e.g. combination of air handling unit, ducts and terminal units). Ventilation system can also refer to natural ventilation systems making use of temperature differences and wind with facade grills in combination with exhaust (e.g. in corridors, toilets etc.). Both mechanical and natural ventilation can be combined with operable windows. A combination of mechanical and non-mechanical components is possible (hybrid systems).

Again natural ventilation is presented as the alternative and not as the 'equal' of mechanical ventilation. This gives one of the few references to hybrid systems

3 CATEGORIES AS PRESENTED IN THE STANDARD

A number of standards (ISO7730, ASHRAE 55) present categories for the buildings according to the closeness with which the indoor conditions are controlled. In these standards a close control is seen as denoting a superior building. Close control implies higher energy use and in this way buildings with high energy use are characterised as superior to those with lower energy use. In line with its connection with the EPBD, EN15251 does not categorise buildings in this way but rather in terms of the type of building and the expectations of the occupants (Table 1). Whilst the intention is clearly not to penalise buildings with less close control (many of which will be low-energy or passively controlled) there is widespread suspicion that the categories will nevertheless be used as indicators of ‘quality’, especially as ‘high expectation’ is associated with category 1.

Table 1. Suggested applicability of the categories and their associated acceptable temperature and PMV ranges (from Standard EN15251)

Category	Explanation
I	High level of expectation only used for spaces occupied by very sensitive and fragile persons
II	Normal expectation for new buildings and renovations
III	A moderate expectation (used for existing buildings)
IV	Values outside the criteria for the above categories (only acceptable for a limited periods)

The categories are associated with limitations as to PMV (mechanically cooled buildings) or temperature deviation from the adaptive comfort temperature (free-running buildings) as definitions for thermal comfort. These limitations are introduced and described in the informative annexes. Because close control is costly in energy this categorisation is at variance with the aims of the EPBD.

The standard goes on to address the ways in which input energy specification of buildings might be determined in order to comply with the EPBD given the appropriate categorisation. Category 2 is to be assumed as the ‘norm’ unless the building is clearly from a different category. It gives assumptions that can be used for the energy determination for heating/cooling, for ventilation rates, for lighting and for acoustics. Methods are also suggested for testing compliance with the Standard. This critique is concerned only with those parts of the Standard which deal with thermal and visual comfort and will concentrate on those concerns.

4. Thermal comfort and avoidance of overheating

4.1 Specification of design environment and range

In the case of mechanically cooled buildings (MCBs) the categories are associated with limits of PMV[i] (PMV ±0.2 for Category I, ±0.5 for II and ±0.7 for III) in line with categories A, B and C in EN ISO 7730 and ASHRAE 55 2004. This alignment with these standards in which categories A, B and C are specified in terms of quality of internal environment reinforces the notion expressed above that the EN15251 categories shown in Table 1 will in fact be interpreted by many practitioners as quality categories.

The range of PMV is specified, it is assumed that in a real situation the mean value will be zero using a given value for clothing. Though it is accepted that this value may be chosen to ‘take account of local custom or a desire for energy efficiency’ there is no guidance about how this will be achieved (e.g. conduct of surveys or guidance on appropriate clothing for reducing heating or cooling). Although PMV is used as a limiting index for MCBs, the range of allowable environments is nonetheless presented in the form of a temperature (Table A2 and A3 in Annexe A). These are presented for 'typical winter and summer clothing of 1.0 and 0.5 Clo' though no evidence is given that these are really typical values or how to deal with a situation where they are not. Because of this the standard risks encouraging the notion that these are recommended or standard values resulting in the unnecessary use of energy to achieve them.

For non-mechanically cooled buildings (NCBs) in free-running mode the comfort temperature is defined according to the running mean of the outdoor temperature using the formula

$$T_{comf} = 0.33\ T_{rm} + 18.8. \qquad (1)$$

The allowable maximum difference between this comfort temperature and the actual indoor operative temperature (T_{diff}) is given in terms of the categories (T_{diff} ±2K for Category I, ±3K for II and ±4K for III). This means that the limiting temperatures vary with the running mean of the outdoor temperature (figure 1).

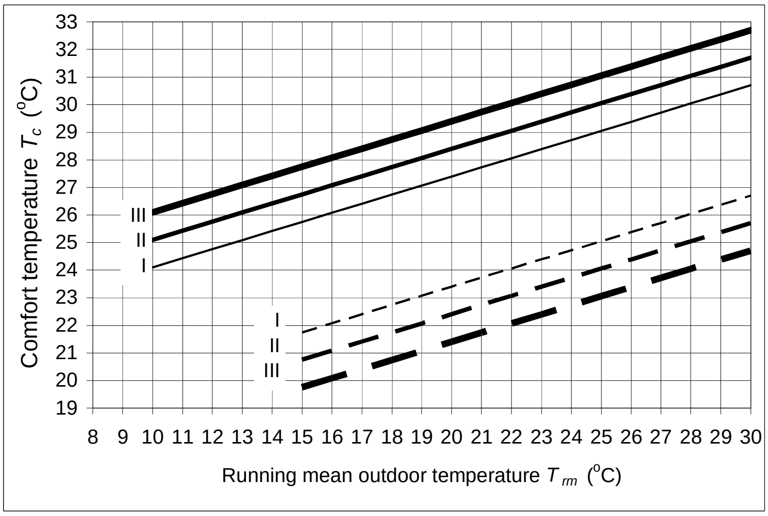

Figure 1 temperature limits for NMV buildings in free-running mode (after EN15251)

Above these temperature bands the building is assumed to be overheating (as in the MCBs buildings they are above the specified upper value of PMV) and below they are in compliance. Overheating in buildings is currently a critical source of concern in the building industry particularly with the threat of global warming and the increased incidence of overheating it implies.

There are a number of such overheating criteria, an example is that specified by CIBSE (2006) which specifies overheating as exceeding 28°C for more than 1% of occupied hours. This type of criterion can be criticised on a number of counts:

1. The introduction of the 'adaptive approach to thermal comfort' showed that the temperature at which the majority of people are comfortable varies with the running-mean of the external temperature (this is dealt with in EN15251 for NCBs by the use of an adaptive comfort temperature).
2. While it provides a measure of the occurrence of overheating, it does not provide a measure of its severity. This problem is dealt with in EN15251 using weighting factor: a) a cooling degree hours measure, which takes discomfort to be linearly proportional to the difference from the discomfort threshold temperature, and a weighted measure based on the Predicted Percentage Dissatisfied (PPD) (Table 3) which takes discomfort to be non-linearly proportional to the difference from the discomfort threshold temperature (whether this criterion is appropriate in NCBs is questionable). But the Standard still assumes zero overheating where the environment is within the specified limits. In fact complaints of overheating occur even within the 'comfort zones' (figure 2)
3. The 'hours over' criterion and any criterion which has a sharp threshold temperature will be very sensitive to the nature of the assessment method for internal temperatures. It is also very sensitive to the shape of the distribution of indoor temperatures. Discomfort is assumed to occur at the edge of this distribution and in the nature of such distributions this part of the distribution is imprecise. Thus in the case of a modelling study, different assumptions (e.g. in the weather files) or software might put the design on one side or the other of the threshold and in a monitoring exercise the result will be very dependent on the weather at the time. There is also potential to alter the 'occupied hours' so as to achieve a different percentage of occupied hours above the threshold temperatures.

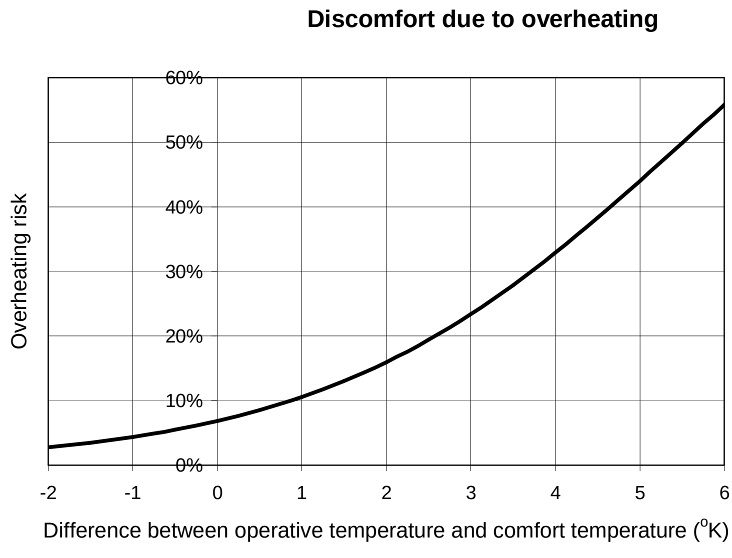

Figure 2 showing the actual increase in discomfort with values of T_{diff} (see above) showing that discomfort occurs even at the design temperature and that there is no sharp cut-off (from Nicol et al 2008)

Table 3 from EN15251 showing example weighting factors for time in discomfort using the two weighting systems (but assuming no discomfort when within the band of ‘comfort’ temperature).

Temperature °C		Weighting factors	
		wf(°C)	wf(PPD)
Cool	20	3	4,7
	21	2	3,1
	22	1	1,9
Neutral	23	0	0
	24	0	0
	25	0	0
	26	0	0
Warm	27	1	1,9
	28	2	3,1
	29	3	4,7

There is a need for a more robust approach to defining overheating. Such an approach will be of interest to Standards and professional bodies (CIBSE, for instance has a overheating task-force looking at the problem) and whilst a solution to the problem will require fresh research and is therefore outside the scope of the Commoncense project we will need to keep an eye out for relevant papers and reports.

4.2 Compliance methodologies

The whole methodology of the Standard is based on the specification of design environments (and ranges around them) which theory suggests will be found comfortable by building occupants. Such an approach has been normal in the environmental specification by standards such as EN ISO 7730 and ASHRAE 55. Such an approach is driven by the need of the HVAC industry in particular and the building industry is general to specify ‘comfort’ which is the product they are selling as part of the building. The alternative approach, that comfort is a goal which occupants should be enabled to seek (Shove, 2003), is not acknowledged in this standard.

The approach taken in EN15251 requires that the environments are accurately measured or reliably calculated to test compliance with the Standard. In particular the prediction of the PMV index to within say 0.1 (a meaningless amount in terms of comfort but a very important one if we are controlling our indoor environment to ±0.2 PMV). Since errors in the measurement of the 6 appropriate input parameters (Air temperature, radiant temperature, humidity, air velocity, clothing insulation and metabolic rate – see ISO 7730, 2007) are additive within the final value of PMV, then each parameter must be measured with great accuracy. This poses a problem for compliance measurements or calculations since the cost of instrumentation to measure the variables to the required accuracy is high. In the case of the ‘personal’ variables - clothing insulation and metabolic rate it is probably impossible to measure the value with the necessary accuracy. The complexity and costliness of the necessary measurement will militate against any occupant undertaking a compliance check.

In the case of the free-running NCBs the measurement of the single defining variable – operative temperature – is relatively easy using a globe thermometer as an appropriate instrument. The calculation of operative temperature is also commonly available in simulation tools. But the problem of finding realistic periods for measurements or appropriate weather files for simulation are not addressed except to say they should be 'typical' for summer and winter periods (in many parts of Europe the only predictable thing about the weather is that it is unpredictable!). Measurement periods even of 10 days or more in length (the suggested period) can be misleading and open to misinterpretation.

One further type of compliance check is recognised, which is to perform a comfort survey in the building. This seems the most direct and straightforward way to test compliance and has the advantage that is can by done in any building, whether MCB or NCB. The problems with this approach are:

1. similar to those of the NCBs – it may be hard to find a representative period for doing the survey
2. Interpreting the results – what proportion of people feeling unacceptably hot, for instance, amounts to overheating (The only hint of advice in this is the limiting value of PPD of 10% for category II and 15% for category III but this may not be the same as the proportion of discomfort in a field survey)?
3. What questions to ask? The questions included in the Standard are typical questions for a thermal comfort study, where the focus is the individual rather than the building. Questions such as 'how often does this building get too hot in summer?' might be more appropriate.
4. Again the cost of such a survey in time and energy of the occupants and analysis and interpretation of the results can be considerable and may discourage compliance checks.

5 Lighting in EN15251

The Standard makes no attempt consider the visual environment and its impact on the health and wellbeing of the building occupants. Instead it refers to two other standards:

1. Standard EN15193 is a little-known and little-used standard that primarily provides a calculation technique to estimate the potential energy savings from the use of the occupancy controls and daylight linked controls in buildings. It is unlikely at this time that any energy savings are being achieved. A study in the UK found that 12 out of 15 systems are not working and those that are required greater scrutiny. Similar problems have been reported from Greece and Germany. A study of the problem is vital but beyond the scope of this project.
2. Standard EN 12464 provides basic data primarily for the design of artificial lighting systems. However with illuminance as the primary definition (along with other such as glare) there is no guidance on real lighting design.

What is primarily missing from EN15251 and by implication in EN12464 is a discussion of the merits and drawbacks (usually relative to solar ingression) of daylight.

Some National Standards (e.g. BS8206 pt 2 2008) are much more developed. The health aspects of daylighting and sunlight are increasingly emphasised (issues relating to SAD for northern Europe is an example). Minimum daylight levels are specified particularly for residential buildings. Loss of daylight during development is also considered ensuring access to sunlight – important for the elderly and disabled is demanded.

Environmental assessment methods now consider daylight requirements for educational and office buildings. In that sense, though they were developed earlier than EN15251, they are more advanced.

The complete absence of such criteria in EN15251 will be the main focus of workpackage 6 in the Commoncense project.

6. Other considerations

In this paper we have limited our main discussion to the thermal and visual aspects of EN15251 but there are two items in the other sections which concern us because they seem to be in contradiction to the aims of the EPBD.

6.1 Ventilation

The Standard suggests values for the calculation of ventilation rate which applies to the dissipation of pollution from persons and that from the building. These two rates are then added together to obtain the total ventilation rate. This would only seem necessary if the pollution was of the same type, otherwise simply using the maximum of the two would seem to reduce pollution levels to the required level or less, and at the same tome help to conserve heating/cooling energy.

6.2 Acoustics

The noise levels considered necessary for various environments are very low and will encourage the use of MV in buildings to reduce external noise particularly in urban settings. Whilst the values given are in line with current standards they are low compared to those in offices where the noise level was not considered excessive in field surveys (Wilson and Nicol 2003).

6.3 EN15251 and the EPBD does it (should it) encourage low-energy solutions?

EN 15251 is written to augment the Energy Performance of Buildings Directive of the EU. It is not obliged to encourage low energy solutions and seeks merely to provide the information necessary to make energy calculations. However since the directive is designed to encourage the energy policies of the EU it should be possible that where two possibilities for solving a problem are available, that the one which represents lower energy use should be encouraged (Nicol and Humphreys, 2002 Nicol and Humphreys 2009). This does not seem to be among the aims of the drafting committee.

6.4 Can it be written with NV as 'natural'?

At a number of points in this discussion we have pointed out a bias towards the use of mechanical cooling or heating. This bias seems to be deeply embedded in the 'mentality' of the standards committees, maybe because the Standards are often intended to serve the needs of the HVAC industry in defining comfort. New standards which put forward passive low energy solutions are therefore unlikely, and could initially result in contradictions between different Standards but might eventually result in more synergy and transparency in the writing and application of standards. Nicol and Humphreys (2009) and Boerstra (2010) among other who have addressed this problem and suggested approaches which could act as a catalyst for this process.

7 Conclusions

EN15251 contains many new ideas about the Standardisation of indoor environments to ensure comfort and to enable the calculation of building energy use. This brief paper cannot deal extensively with the strengths and weaknesses of the definitions, approaches and methodologies involved, for instance the applicability of the allowance for air movement caused by fans to the 'adaptive' parts of the Standard. There are however a number of problems with the Standard with regard to the specification of a comfortable indoor thermal environment and it is a necessary part of the work of the Commoncense project to suggest ways in which the existing Standard can be improved upon. This can be approached in two ways:

1. to carry out the procedures involved in the Standard and to test whether they are practical to use and compatible with the aims and objectives of the EPBD which they are intended to support
2. to suggest new and maybe more robust approaches to setting standards for the thermal environment in buildings

Acknowledgements

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