



ECEE Summer Study 2011

Energy efficiency first: The foundation of a low-carbon society

How the comfort requirements can be used to assess and design low energy buildings: testing the EN 15251 comfort evaluation procedure in 4 buildings

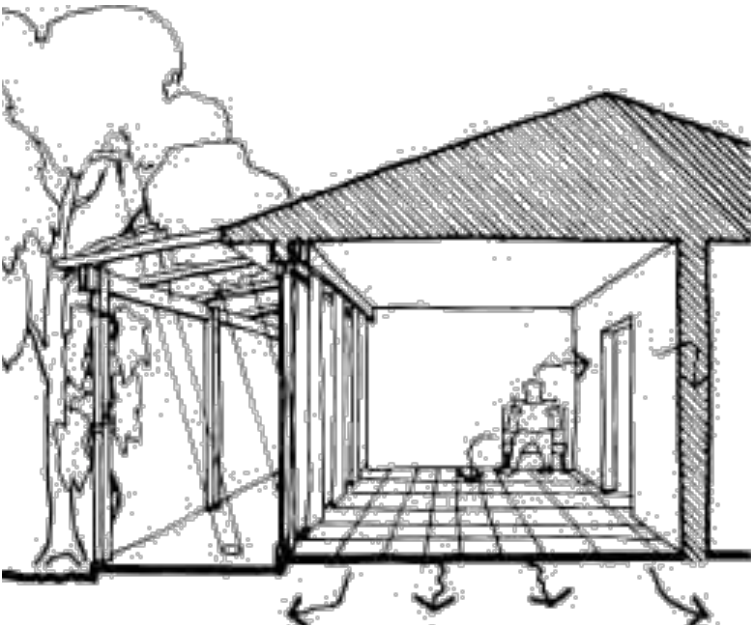
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EN 15251:2007

*Indoor environmental input parameters for **design** and **assessment** of energy performance of buildings addressing indoor air quality, **thermal environment**, lighting and acoustics*

- 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.
- An energy declaration without a declaration related to the indoor environment makes no sense.
- The Standard specifies methods for long term evaluation of the indoor environment obtained as a result of calculations or measurements.



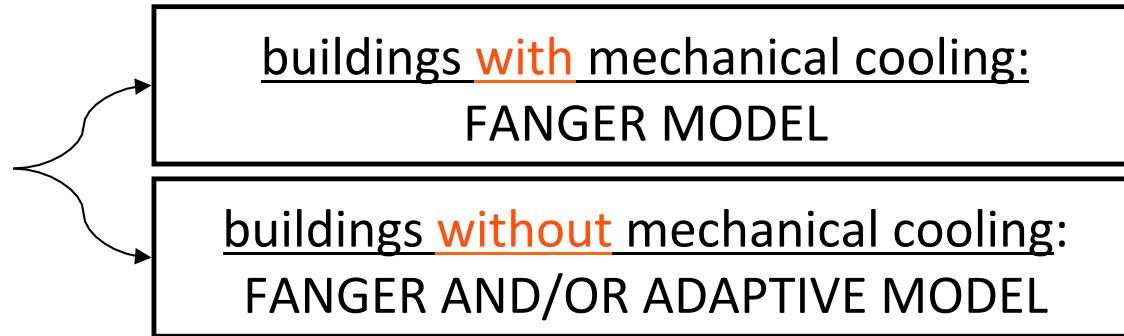


EN 15251:2007

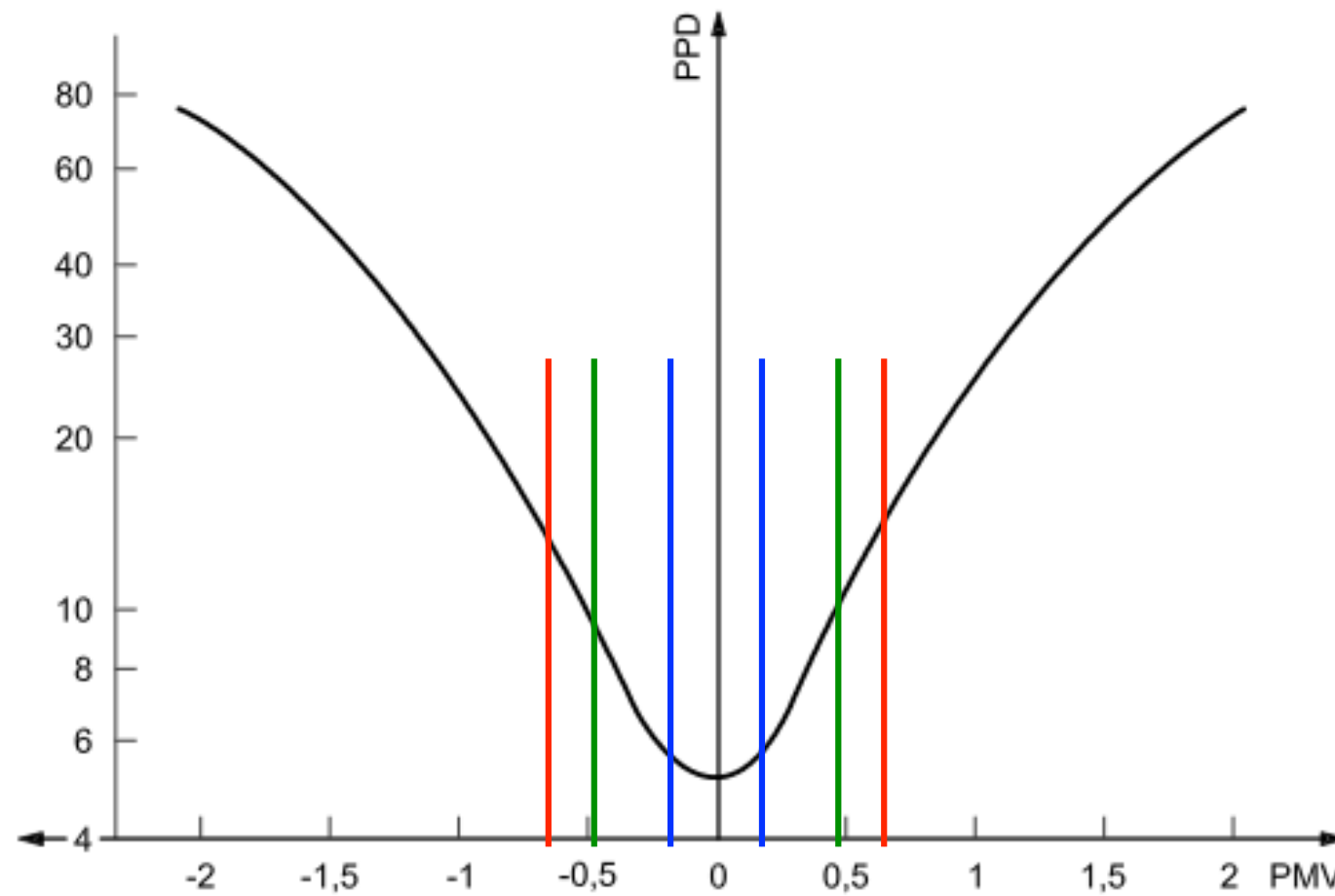
The **indoor environment** in a building **may be classified by**

- a) Criteria used for energy calculations (new buildings)
- b) Whole year computer simulations of the indoor environment and energy performance (new and existing buildings)
- c) Long term **measurement** of selected parameters for the indoor environment (existing buildings)
- d) **Subjective responses** from occupants (existing buildings)

BUILDING
TYPE:

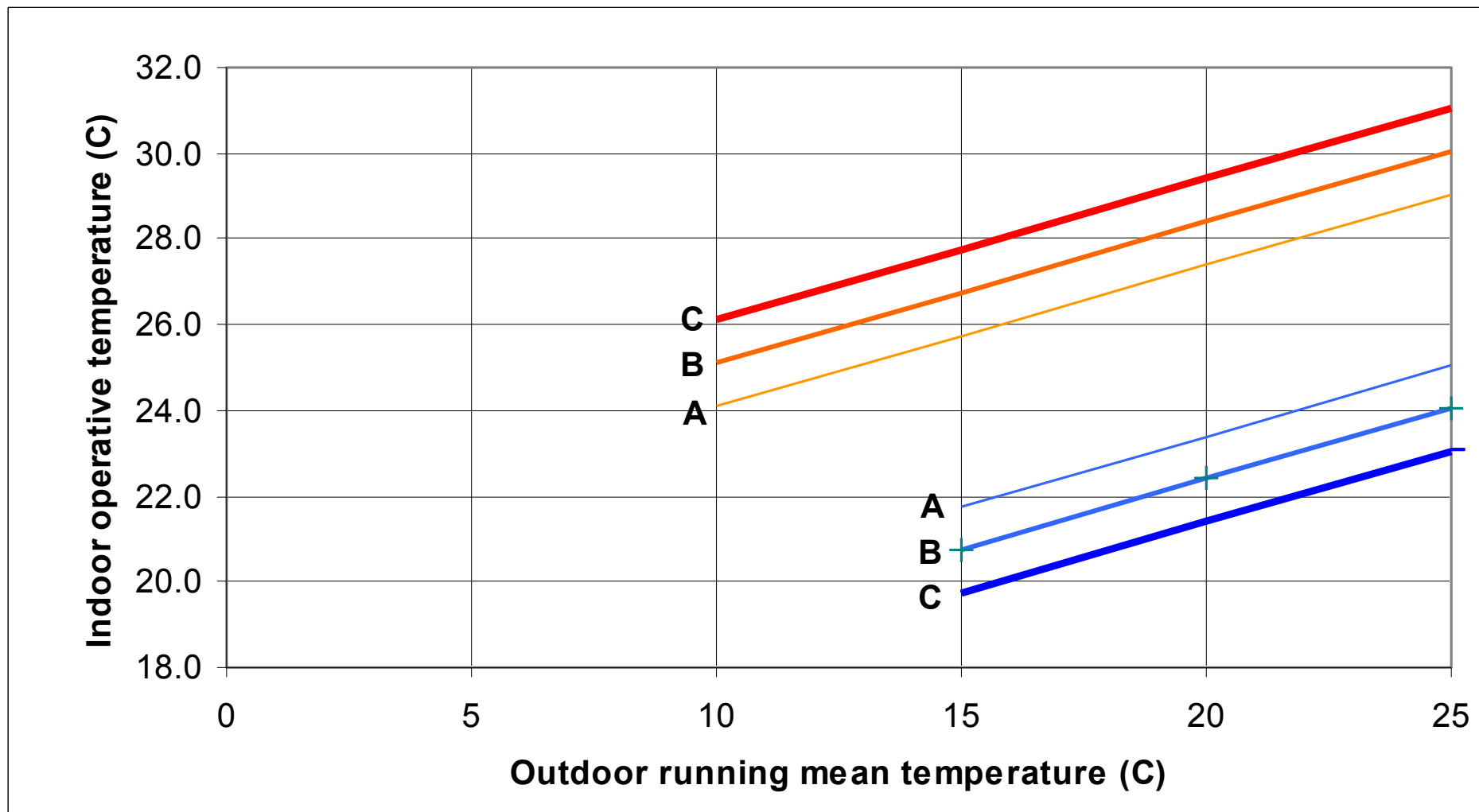


FANGER MODEL		Category	Explanation	ADAPTIVE MODEL
PMV	PPD [%]			T_C [°C]
$-0,2 < PMV < 0,2$	< 6	I	High level of expectation	$T_C - 2 \leq T_{op} \leq T_C + 2$
$-0,5 < PMV < 0,5$	< 10	II	Normal level of expectation	$T_C - 3 \leq T_{op} \leq T_C + 3$
$-0,7 < PMV < 0,7$	< 15	III	moderate level of expectation	$T_C - 4 \leq T_{op} \leq T_C + 4$
$PMV < -0,7$ and $PMV > 0,7$	> 15	IV	Values outside the above criteria	$T_{op} < T_C - 4$ and $T_{op} > T_C + 4$

**Key**

PMV predicted mean vote

PPD predicted percentage dissatisfied, %



✓ LONG-TERM ASSESSMENT OF INDOOR ENVIRONMENTS:

1) Measurements of indoor climatic variables

→ Long-term indicators:

Foot-print classification: percentage of time in 4 categories; eg to be in category 2 a building should be for 97 (or 97)% of the time in category 2

Percentage	x %	y %	w %	z %
Category	IV	III	II	I

Degree hours & PPD weighted criteria:

- Cumulative Indexes able to weight the discomfort level (as a function of the distance from the comfort range)
- But they do not have a reference threshold, so are not linked to categories

2) Occupant interview through questionnaires

Seasonal statistics:

- on sensation and preference of occupants
- on metabolic activity, clothing resistance and building control

✓ MEASUREMENTS:

- The measurement instrumentation used for evaluation of the thermal environment shall meet the requirements given in **EN ISO 7726**.
- Comply with the recommendations given in EN ISO 7726 as far as the location of measurement instrumentation within the spaces is concerned.
- Measurements shall be made **where occupants are known to spend most of their time** and **under representative weather condition** of cold and warm season. For the winter measurements at or below mean outside temperatures for the 3 coldest months of the year, and for the summer measurements at or above statistic average outside temperatures for the 3 warmest months of the year with clear sky.
- The **measurement period** for all measured parameters should be long enough to be representative, for example 10 days.

Locations of the sensors	Weighting coefficients for measurements for calculation mean values				Recommended heights (for guidance only)	
	Homogeneous environment Class C Class S		Heterogeneous environment Class C Class S		Sitting	Standing
Head level			1	1	1,1 m	1,7 m
Abdomen level	1	1	1	2	0,6 m	1,1 m
Ankle level			1	1	0,1 m	0,1 m

✓ MEASUREMENTS:

- **Class I:** Field experiments in which all sensors and procedures are in 100% compliance with the specifications set out in ASHRAE Standard 55 (1992) and ISO 7730 (1984). **Three heights of measurement with laboratory-grade instrumentation** including omnidirectional **anemometry** capable of **turbulence intensity** assessments.
- **Class II:** Field experiments in which **all** indoor physical environmental **variables** (t_a , t_r , v , rh , clo , met) necessary for the calculation of PMV/PPD indices are collected **at the same time and place** as the thermal questionnaires are administered. Measurements **may not have been made at the three heights** above floor level as specified in ASHRAE (1992) and ISO (1994) standards (0.1, 0.6 and 1.2m). Humidity measurements were taken by aspirated psychrometer or solid state hygrometer sensors. Air speeds are measured by hot wire (or sphere) probes with thresholds above 0.1 ms⁻¹.
- **Class III:** Field studies based on simple measurements of indoor **temperature** and possibly humidity. One level of measurement above the floor. **Possibly asynchronous and non-contiguous physical** (temperature etc.) **and subjective (questionnaire)** measurements.

About thermal comfort assessment, we selected 4 different approaches:

- M1 – Detailed measurement:** following the specifications of ISO 7726 and ASHRAE RP-884 (**Class I or II**), to measure all the physical variables defining indoor microclimate in a representative room of the building, continuously for **3-4 weeks in winter** and **3-4 weeks in summer**. For the definition of the measurement periods we will consider the statistics of the building climatic context and we will choose the most critical days.
- M2 – Simplified Measurements:** to measure only the principal indoor parameters (we propose air temperature and relative humidity) in 2-3 representative points of the building, continuously for larger periods: **2 months in winter** (December and January or January and February) and **2 months in summer** (June and July).
- Q1 – Detailed Questionnaire:** to present subjective questionnaires to the occupants concerning Temperature, Air movement, Humidity, Lighting, Noise, Air quality, Overall comfort, Clothing Resistance, Metabolic Activity and Building Control.
- Q2 – Simplified Questionnaire:** to present subjective questionnaires to the occupants concerning Temperature, Clothing Resistance, Metabolic Activity and Building Control.

Methodology

*Testing of the Methodology
for compliance of existing buildings to EN15251*

Code	Type	Description	Instrument	When/Duration	Where/Who	Calculation / Analysis
M1	Measurement (ASHRAE Class I or Class II)	Following the specifications of ISO 7726 and ASHRAE RP-884 (Class I or II), to measure all the physical variables defining indoor microclimate.	Mobile Measurement System (MMS)	During periods probably more critical: 2-3 weeks in winter and 2-3 weeks in summer. Frequency: 10-20 min (if possible max, min, average and standard deviation values for each time step).	Installation and removal days: point measures in large part of the building. Other days: continuous measures in a representative room.	PMV, PPD indicators PPD weighted, Percentage outside the range (Fanger) indicators Foot-print (Fanger) classification
M2	Measurement (ASHRAE Class III)	To measure the principal indoor and outdoor parameters (air temp and relative humidity). (Plus CO2 concentration, if possible)	Temp-RH Dataloggers	3 months in winter (December, January, February) and 3 months in summer (June, July, August). Frequency: 10-20 min.	continuous measures in 2-3 representative points of the building, in 1-2 critical points of the building and in 1 outdoor point.	Contextualization of M1 Degree hours (Adaptive), Percentage outside the range (Adaptive) indicators Foot-print (Adaptive) classification
Q1	Interview	Direct interview with Mobile Measurement System. Questions about all sensations-preferences, clo, met and control.	Questionnaire Q1	During the days of installation and removal of MMS. 2-3 interviews for each measurement point	To the larger number of occupants: at least the 50% of total occupants, better if more than 20.	Clo and met statistics Evaluation of lighting, noise and IAQ Correlation with measurement elaborations
Q2	Interview	Indirect interview without Mobile measurement System. Simplified questions about thermal sensations, preferences, clo, met and control.	Questionnaire Q2	During the days when the MMS is installed. 2-4 interviews a day with each occupant	Where the MMS is installed and to the larger number of occupants: at least the 50% of total occupants, better if more than 20.	Clo and met statistics Correlation with measurement elaborations

Case Studies


*Testing of the Methodology
for compliance of existing buildings to EN15251*


	IT1		IT2		IT3		IT4	
	S	W	S	W	S	W	S	W
M1	✓	✓	✓	✓	✓	✓	✓	✓
M2	✓	✓	✓	✓	✓	✓	✓	✓
Q1	✓	✓	✓	✓	✓	✓	□	□
Q2	✓	✓	✓	✓	✓	□	□	□



Case Studies


Testing of the Methodology
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ID:	IT1	
Location:	Lodi, Italy (urban)	
Destination:	Office (and social housing)	
Age:	2006	
Size:	600 m ²	
Heating strategies:	Air conditioning with fan coils.	
Cooling strategies:	Natural ventilation, air conditioning with fancoils.	
Enabled controls:	Windows, fancoils.	

ID:	IT2	
Location:	Varese, Italy (urban)	
Destination:	Office and laboratory	
Age:	2002	
Size:	3 000 m ²	
Heating strategies:	Heterogeneous: HVAC or fan coils or radiators	
Cooling strategies:	Heterogeneous: HVAC or fan coils or natural ventilation	
Enabled controls:	Windows, internal blind, local fan.	

Case Studies

*Testing of the Methodology
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ID:	IT3	
Location:	Imola, Italy (urban)	
Destination:	School and administrative offices	
Age:	2008	
Size:	4 500 m2	
Heating strategies:	Heat recovery, district heating with radiant panels.	
Cooling strategies:	External solar blinds, natural night ventilation, ground exchanger, solar cooling with radiant panels.	
Enabled controls:	-	

ID:	IT4	
Location:	Cherasco (CN), Italy (rural)	
Destination:	Residential with home office	
Age:	2005	
Size:	200 m2	
Heating strategies:	Heat recovery, air-to-air heat pump, biomass stove.	
Cooling strategies:	External solar blinds, natural night ventilation, ground exchanger	
Enabled controls:	Windows, blinds, mechanical air flow	

Collected Data

*Testing of the Methodology
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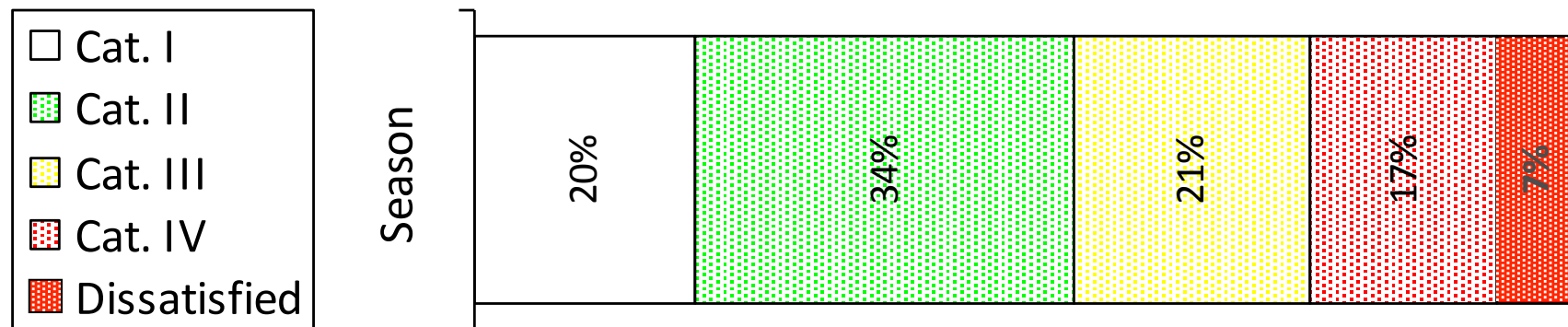
	IT1	IT2	IT3	IT4
M1	12370	7457	17005	2281
M2	64 298	71145	79256	32412
Q1	82	140	61	-
Q2	502	1309	80	-



SUMMARY REPORT OF COMFORT ASSESSMENT

Main calculations /analysis:

- ✓ Questionnaire (Q1 and Q2) → Percentage **distribution of sensation** vote, **aggregating -1, 0 and 1 votes** (not thermally dissatisfied people, according to ISO 7730);
- ✓ Detailed measurements (M1) → Calculate **PMV** → percentage of time in the 4 comfort categories (**Foot-print**), with the **addition of category D** (“Dissatisfied”) aggregating time intervals with $PMV < -1$ and $PMV > 1$, according to the comfort model of Fanger (PMV-PPD);
- ✓ Simplified measurements (M2) → percentage of time in the 4 comfort categories (**Foot-print**), according to the **adaptive** comfort model of EN 15251.



SUMMARY REPORT OF COMFORT ASSESSMENT

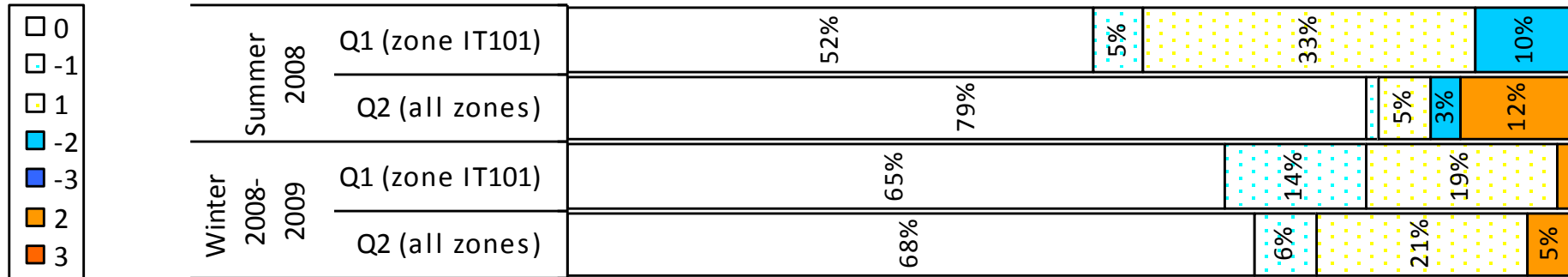
Additional information:

- ✓ General: qualitative notes about the survey experiences; assessment about the occupant response and the **representativeness** of the M1+Q1 period respect the wider M2+Q2 period;
- ✓ Questionnaire (Q1 and Q2):
 - ✓ number of collected questionnaires;
 - ✓ **% of votes** finding **air movement**, humidity, lighting, noise and indoor air quality **acceptable**;
 - ✓ distribution of **temperature preference**;
 - ✓ questionnaire statistics (**clo, met, building controls**);
- ✓ Detailed measurements (M1):
 - ✓ homogeneity of the environment (in case of Class I measurements);
 - ✓ **cause of discomfort** (information not obtainable from the foot-print view);
- ✓ Simplified measurements (M2):
 - ✓ indoor temperature distribution in 2-4 zones of building.

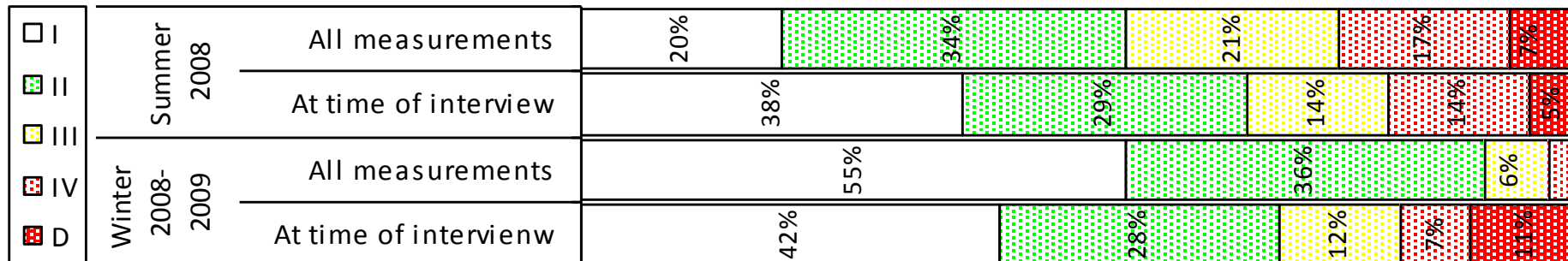
Results (IT1)

Testing of the Methodology
for compliance of existing buildings to EN15251

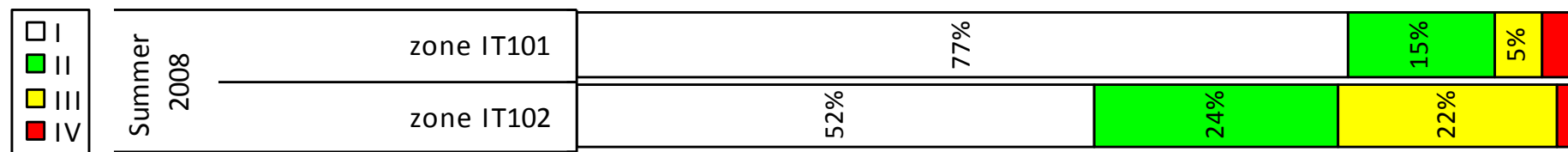
Percentage distribution on sensation vote (From Q1, Q2):



Foot-print FANGER (From M1):



Foot-print ADAPTIVE (From M2):



Results (IT1)

Testing of the Methodology
for compliance of existing buildings to EN15251

Notes	Assessment of responses:	Good											
	Representativeness of the M1+Q1 period:	fair			fair			-					
Q1 (Q2)	Season	Summer 2008			Winter 2008-2009			Summer 2009					
	Number of questionnaires	21 (373)			57 (66)			- (63)					
	Temperature acceptable (%)	90% (85%)			98% (95%)			- (97%)					
	Air movement acceptable (%)	100%			98%			-					
	Humidity acceptable (%)	86%			88%			-					
	Lighting level acceptable (%)	90%			88%			-					
	Noise level acceptable (%)	90%			60%			-					
	IAQ acceptable (%)	100%			91%			-					
	Distribution of temperature preference (%)	Colder	Unch.	Warmer	Colder	Unch.	Warmer	Colder	Unch.	Warmer			
		43% (23%)	43% (73%)	14% (3%)	12% (26%)	74% (68%)	14% (6%)	- (10%)	- (67%)	- (24%)			
	Distribution on thermal sensation votes:												
	<div><div><div>□ 0</div><div>□ -1</div><div>□ 1</div><div>■ -2</div><div>■ -3</div><div>■ 2</div><div>■ 3</div></div></div>	Summer 2008	Q1 (zone IT101)	<div><div>52%</div><div>5%</div><div>33%</div><div>10%</div></div>									
			Q2 (all zones)	<div><div>79%</div><div>5%</div><div>3%</div><div>12%</div></div>									
		Winter 2008-2009	Q1 (zone IT101)	<div><div>65%</div><div>14%</div><div>19%</div><div></div></div>									
			Q2 (all zones)	<div><div>68%</div><div>6%</div><div>21%</div><div>5%</div></div>									
		Summer 2009	Q2 (all zones)	<div><div>70%</div><div>19%</div><div>8%</div><div></div></div>									
Statistics		Mean		SD		Mean		SD		Mean		SD	
Clo		0.56 (0.32)		0.14 (0.07)		0.88 (0.54)		0.12 (0.13)		- (0.44)		- (0.13)	
Met		1.21 (1.21)		0.13 (0.17)		1.26 (1.14)		0.15 (0.09)		- (1.06)		- (0.09)	
Typical controls		door-windows, AC, blind				Heating, door				door-windows, AC, blind			

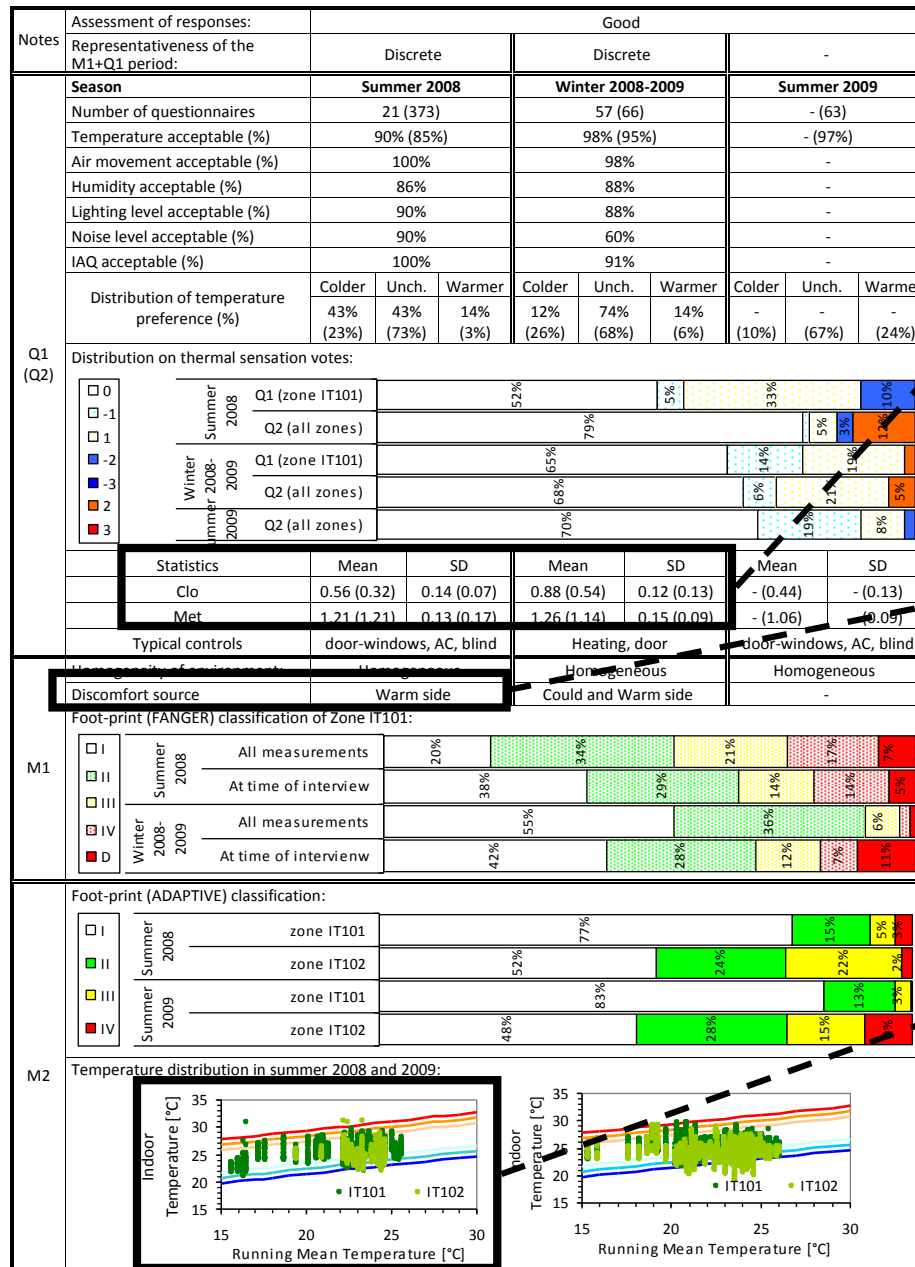
Results (IT1)

Testing of the Methodology
for compliance of existing buildings to EN15251

Notes	Assessment of responses:	Good								
	Representativeness of the M1+Q1 period:	Discrete			Discrete			-		
Q1 (Q2)	Season	Summer 2008			Winter 2008-2009			Summer 2009		
	Number of questionnaires	21 (373)			57 (66)			- (63)		
	Temperature acceptable (%)	90% (85%)			98% (95%)			- (97%)		
	Air movement acceptable (%)	100%			98%			-		
	Humidity acceptable (%)	86%			88%			-		
	Lighting level acceptable (%)	90%			88%			-		
	Noise level acceptable (%)	90%			60%			-		
	IAQ acceptable (%)	100%			91%			-		
	Distribution of temperature preference (%)	Colder	Unch.	Warmer	Colder	Unch.	Warmer	Colder	Unch.	Warmer
		43% (23%)	43% (73%)	14% (3%)	12% (26%)	74% (68%)	14% (6%)	- (10%)	- (67%)	- (24%)
	Distribution on thermal sensation votes:									
	<div><div><div>□ 0</div><div>□ -1</div><div>□ 1</div><div>■ -2</div><div>■ -3</div><div>■ 2</div><div>■ 3</div></div></div>	Summer 2008	Q1 (zone IT101)	<div><div>52%</div><div>5%</div><div>33%</div><div>10%</div></div>						
			Q2 (all zones)	<div><div>79%</div><div>5%</div><div>3%</div><div>12%</div></div>						
		Winter 2008-2009	Q1 (zone IT101)	<div><div>65%</div><div>14%</div><div>19%</div><div></div></div>						
			Q2 (all zones)	<div><div>68%</div><div>6%</div><div>21%</div><div>5%</div></div>						
			Q2 (all zones)	<div><div>70%</div><div>19%</div><div>8%</div><div></div></div>						
		Statistics		Mean	SD	Mean	SD	Mean	SD	
Clo		0.56 (0.32)	0.14 (0.07)	0.88 (0.54)	0.12 (0.13)	- (0.44)	- (0.13)			
Met		1.21 (1.21)	0.13 (0.17)	1.26 (1.14)	0.15 (0.09)	- (1.06)	- (0.09)			
Typical controls		door-windows, AC, blind		Heating, door		door-windows, AC, blind				

Results (IT1)

Testing of the Methodology
for compliance of existing buildings to EN15251

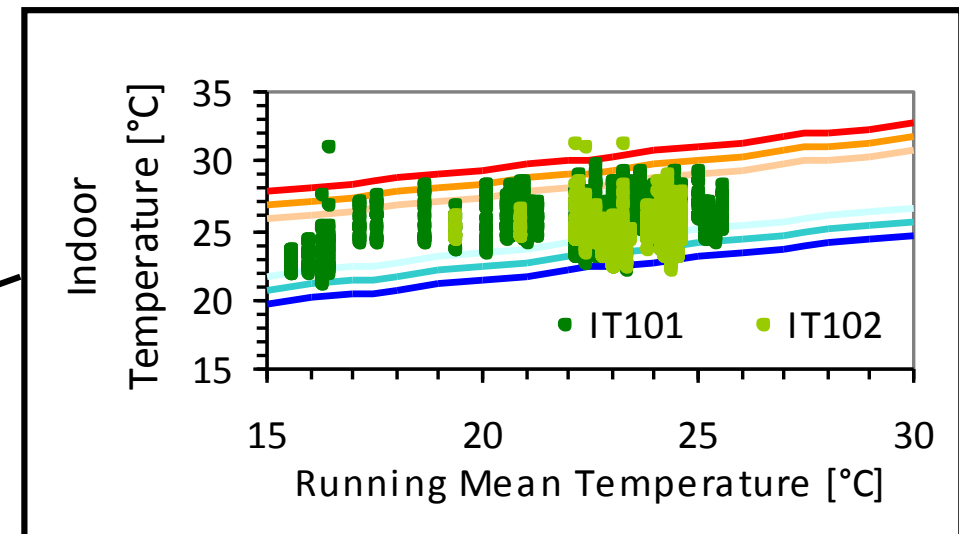


Main collateral information:

	Summer 2008		Winter 2008-2009	
Statistics	Mean	DS	Mean	DS
Clo	0.56	0.14	0.88	0.12
Met	1.21	0.13	1.26	0.15

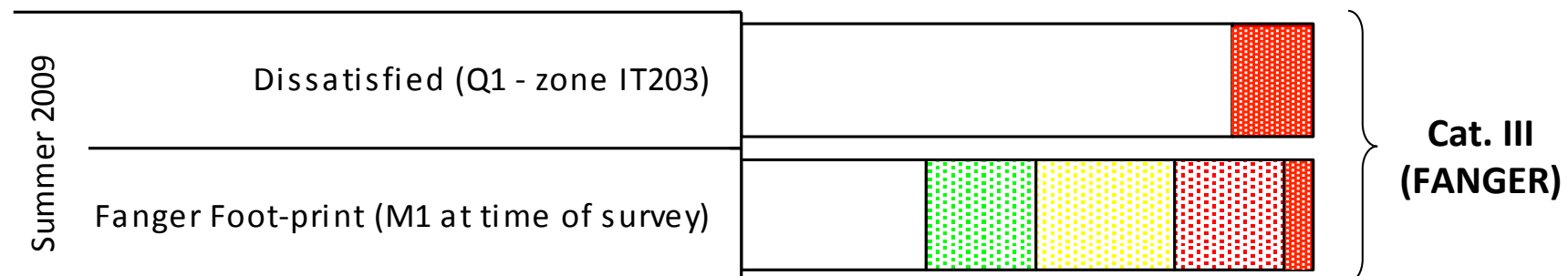
Discomfort source in summer:

warm side



About the coherence of comfort categories and occupant sensation votes

- ✓ “Is it possible to evaluate the coherence of categories with respect to the responses of the occupants of a building?” this might be difficult to achieve using present procedures.
- ✓ A direct comparison is limited for semantic reasons – we should be able to formulate questionnaires able to discriminate between categories and occupants should be able to understand the semantic differences
- ✓ A way to conduct these assessments indirectly – as is done in our investigations – is to compare the seasonal distribution on thermal sensation votes with the relative footprint classification. This makes it possible to qualitatively identify the comfort category that best describes the occupant response:



Procedure issues to be improved

- ✓ especially in large buildings, it is to be expected that **different zones/rooms provide different comfort levels**, but it is complicated to assess it a priori and, for economic reasons, to investigate a building in the 100% of its spaces (especially with detailed measurements);
- ✓ the comfort assessments depend on the **occupant's behavior and on the contingent climatic conditions**, and as a result it can change as a function of them; it would be advantageous to find a way to normalize these factors;
- ✓ **considering all the uncertainties** related to the data acquisition (representativeness of the monitored environment, accuracy of instruments , clo and met identification, etc.), we reckon **the proposed value of acceptable deviation (3-5%) to be too restrictive**;
- ✓ most of activities concerning the check and the elaboration of collected data are left to the professional 'common sense' of the evaluator; on one hand they should be **standardized** in order to ensure consistency of results and to allow their comparison, on the other hand qualifying criteria for building professionals should be proposed (many competences are needed).
- ✓ **Reducing a comfort assessment to the indication of a category can be insufficient** and it can misrepresent the comfort demand of occupants and stakeholders; we propose the adopted format of our report (with the addition of the category "Dissatisfied") for further assessment in order to clarify the results.

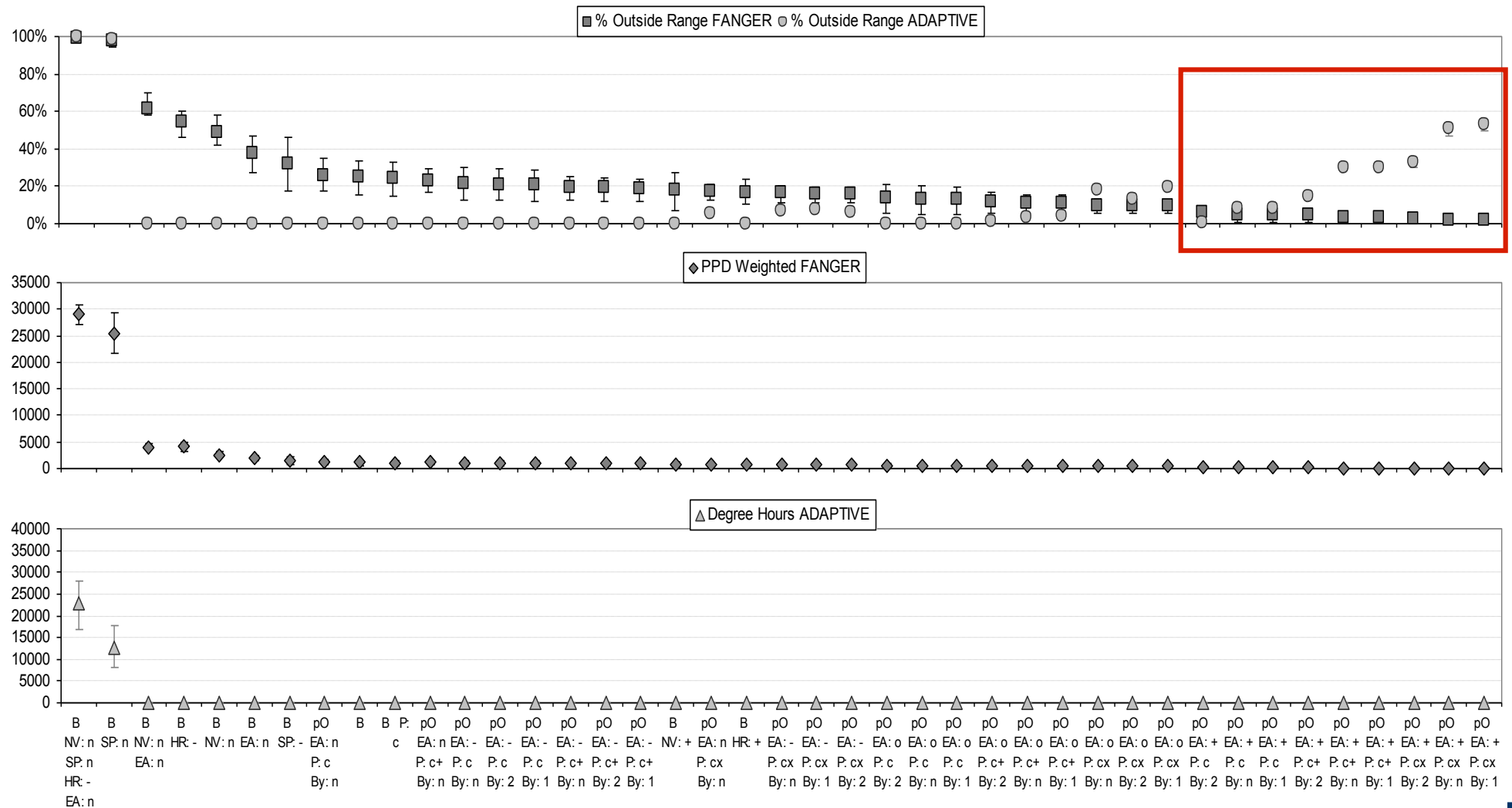
About the relationship with the energy certification

- ✓ A long-term objective of the EN 15251 procedure is to place the foundations for accompanying the energy certification of a building with an assessment of its indoor comfort. But at the moment, while energy certification has begun in much of Europe (in application of the EPBD Directive), comfort evaluation is in its infancy.
- ✓ To assess the energy needs or primary consumption of a building, in the framework of **energy certification** procedures, **standardized calculations** (through steady-state or semi-dynamic software) were undertaken for existing buildings and in this context – the steady state approach standardizes the indoor conditions (e.g. indoor temperature equal to 20°C in winter and 26°C in summer) – the comfort assessment can only be done in a second phase, by **monitoring or interviews**.
- ✓ To equate and integrate them, there are two main possibilities:
 - ✓ **de-normalising the energy certification** (e.g. monitoring the real energy consumption of a building or using the energy bills)
 - ✓ **normalizing the comfort assessment** (e.g. adopting dynamic simulation approaches for existing buildings as well).

Alternatives to be tested

- ✓ The possibility of evaluating the indoor comfort through Dynamic Simulation should also be tested in existing buildings. Certainly it would reduce costs and it would evaluate the entire building. But this may mean a loss of precision, especially through using unsuitable software or unskilled modelling techniques. The constant improvement of these tools (for example in dealing with radiative aspects and exact operative temperature calculation) can only benefit this approach.
- ✓ Another possible alternative is the use of Building Energy Management (BEMs) in the collection of data. In recent years a large number of buildings have adopted these systems which can ensure an extended monitoring (maybe for more seasons), without extra cost. An improvement of the sensors presently used would be advisable.

Cherasco (CN) (5% category II, asimmetry DH, different optimum)



Design of low/zero-energy buildings

- ✓ The **discontinuities between the two variants (Fanger and adaptive)** arising in the optimization procedure with the use of long-term indexes **may be reduced** when considering the large influence that certain variables such as **clothing** (and total) insulation and **air velocities** have on the calculated values of PMV.
- ✓ In order to conceive a design process for low/zero-energy buildings, based on the comfort optimization, a suitable long-term comfort (or discomfort) index is needed. It should consider:
 - ✓ the distance in degrees outside a specific comfort range (defined according a specified comfort model),
 - ✓ the percentage of time outside the comfort range,
 - ✓ both overheating and overcooling.
- ✓ At the moment these considerations are being discussed within the IEA Task 40-Annex 52 (NZEB).

Conclusions

*Testing of the Methodology
for compliance of existing buildings to EN15251*

- ✓ As part of the Commoncense project, some existing buildings (4 in Italy) analysed to assess their level of thermal comfort. The methodology proposed by the standard EN 15251 was tested to identify its critical issues and to investigate the possibility of its application on a large scale.
- ✓ The analysis we have performed has allowed us to recognize parts of the procedures proposed by EN 15251 as premature and incomplete. For its extension on large-scale it is necessary to bridge basic gaps and confront different criticisms.
- ✓ The work done has identified some of them and has allowed us to propose possible solutions.



CommonCense

Thanks for your attention!

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