UNIVERSITÀ DEGLI STUDI FIRENZE
DIDA DIPARTIMENTO DI ARCHITETTURA

MAILAB
Multimedia Architecture Interaction

BRIEF | Comfort Modeling & Environmental Users' Requirements

G. RIDOLFI

Overview

Environmental Design Class

- 01. **BRIEF** Program & Environmental Report
- 02. **CONCEPT** Architectural Mass & Lay-out Optioneering
- 03. **SCHEME** Architectural Proposal
- 04. **DETAIL** Envelope Design & Conceptual Prototype
- 05. **FINAL** Project Communication

01 **BRIEF** | Program & Environmental Report

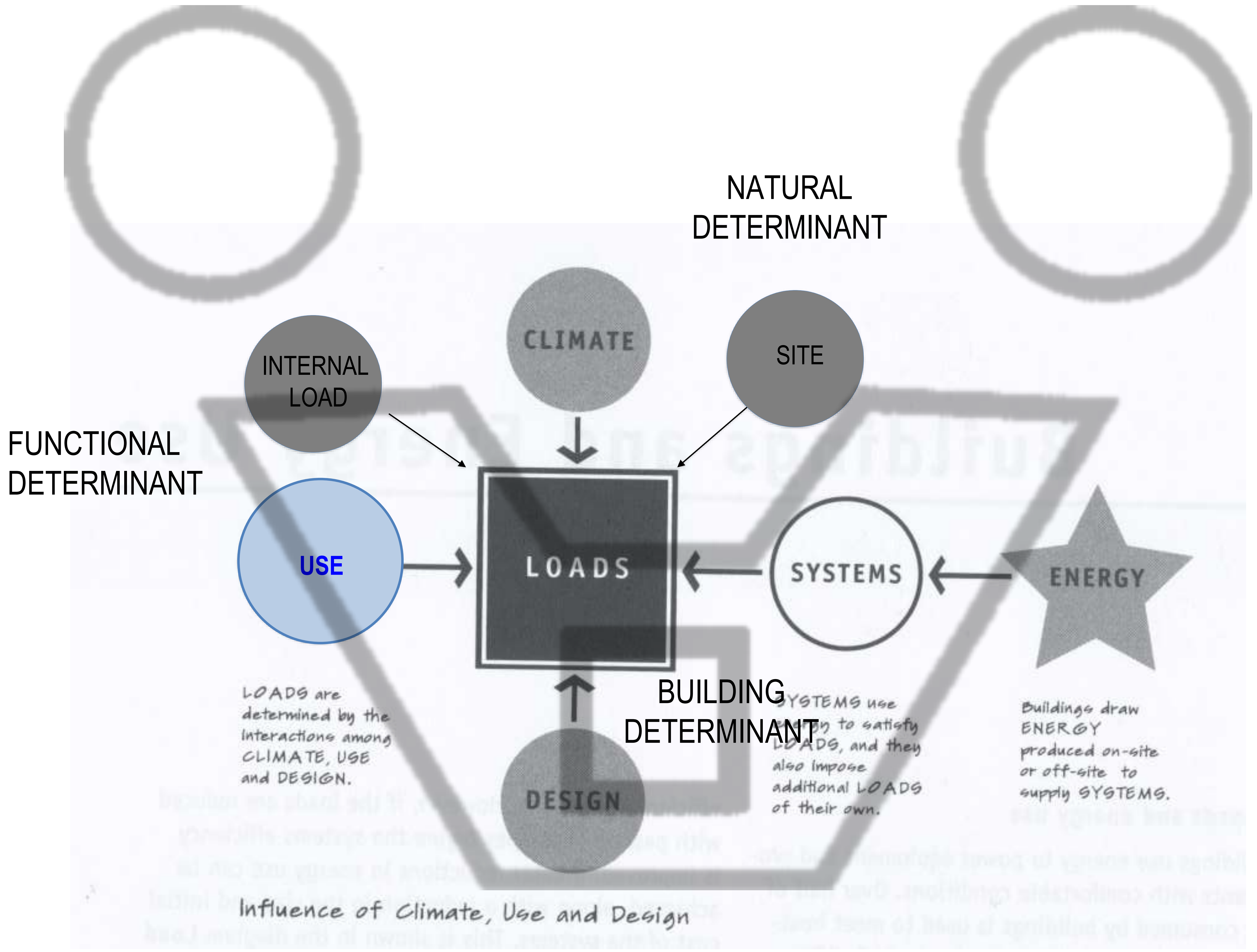
- 1.1. Project Mission & Space Program
- 1.2. Comfort Modeling & Environmental Users' Requirements
- 1.3. Climate based Design strategies
- 1.4. Site Assessment

Overview

part 1.2

BRIEF | Comfort Modeling & Environmental Users' Requirements

PROGRAM | Comfort Modeling & Environmental Users' Requirements



Standardized Comfort By Building Regulation

Indoor Design Conditions[3]

Type of Area	Summer DB[1]	Summer RH[2]	Winter DB[1]	Winter RH[2]
General Office	24 (75)		22 (72)	
ADP Rooms[9]	22 (72)	45[4]	22 (72)	
Corridors	24 (75)		22 (72)	
Building Lobbies[10]	24 (75)		22 (72)	
Toilets	24 (75)		22 (72)	
Locker Rooms	26 (78)		21 (70)	
Electrical Closets	26 (78)		13 (55)	
Mech. Spaces	35 (95)[5]		13 (55)[8]	
Elec. Switchgear	35 (95)[5]		13 (55)	
Elevator Mach. Room[10]	26 (78)[5]		13 (55)	
Emerg. Gen. Room	40 (104)[6]		18 (65)	
Transformer Vaults	40 (104)[5]			
Stairwells	(none)		18 (65)	
Comm./Tel. Frame Room[7]	24 (75)	45	22 (72)	30[12]
Storage Room	30 (85)		18 (65)	
Conference Room[11]	24 (75)		22 (72)	
Auditorium[10]	24 (75)		22 (72)	
Kitchen[10]	24 (75)		22 (72)	
Dining[10]	24 (75)		22 (72)	
Cafeteria[10]	24 (75)		22 (72)	
Courtrooms	24 (75)		22 (72)	454*

*Requires humidification in the winter.

Notes:

1 Temperatures are degrees Celsius (Fahrenheit), to be maintained at +/-1 °C (+/-2 °F).
2 Relative humidity is minimum permissible, stated in percent. Maximum permissible relative humidity is 60 percent in conditioned areas.
3 Dry bulb and relative humidity are to be maintained 150 mm (6 inches) to 1800 mm (6 feet) above the floor.
4 Relative humidity should be maintained at +/-5 percent in ADP spaces.
5 Maximum temperature. Space to be mechanically cooled if necessary.
6 Room must not exceed temperature with generator running.
7 Must comply with EIA/TIA Standard 569.
8 Minimum temperature in the building must be 13 °C (55 °F) even when unoccupied.
9 Confirm equipment manufacturer 's requirements as more stringent. Provide in-room display and monitor device (such as wall mounted temperature and humidity chart recorder).
10 System shall be designed for process cooling. Cooling system shall be a dedicated independent system.
11 Provide independent temperature control.
12 Minimum relative humidity requirements may be omitted in moderate southern climate zones upon approval of local GSA representatives.

Standardized Comfort By Building Regulation

Activity	Illumination (*lux, lumen/m*^{2})
Public areas with dark surroundings	20 - 50
Simple orientation for short visits	50 - 100
Working areas where visual tasks are only occasionally performed	100 - 150
Warehouses, Homes, Theaters, Archives	150
Easy Office Work, Classes	250
Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories	500
Supermarkets, Mechanical Workshops, Office Landscapes	750
Normal Drawing Work, Detailed Mechanical Workshops, Operation Theatres	1,000
Detailed Drawing Work, Very Detailed Mechanical Works	1500 - 2000
Performance of visual tasks of low contrast and very small size for prolonged periods of time	2000 - 5000
Performance of very prolonged and exacting visual tasks	5000 - 10000
Performance of very special visual tasks of extremely low contrast and small size	10000 - 20000

Standardized Comfort By Building Regulation

Source IESNA, 9th Edition Lighting Handbook, Reference and Applications, Chapter 10

I. INTERIOR LOCATIONS AND TASKS

Very Important | Important | Somewhat important | Blank = Not important or not applicable

Design Issues	Appearance of Space and Luminaires	Color Appearance (and Color Contrast)	Daylighting Integration and Control	Direct Glare	Flicker (and Strobe)	Light Distribution on Surfaces	Light Distribution on Task Plane (Uniformity)	Luminances of Room Surfaces	Modeling of Faces or Objects	Point(s) of Interest	Reflected Glare	Shadows	Source/Task/Eye Geometry	Sparkle/Desirable Reflected Highlights	Surface Characteristics	System Control and Flexibility	Special Considerations	Notes on Special Considerations	Illuminance (Horizontal)	Category or Value (lux)	Illuminance (Vertical)	Category or Value (lux)	Notes on Illuminance - see end of section	Reference Chapter(s)
Reading (16)																								Ch. 11, 12
Copied tasks																								
Microfiche reader																			A		A		
Photograph, moderate detail																			E				
Thermal copy, poor																			F				
Photocopies																			D				
Photocopies, 3rd generation																			E				
Data processing tasks																								
VDT screens																			A		A		
Impact printer																								
good ribbon																			D				
2nd carbon and greater																			E				
ink jet/laser printer																			D				
keyboard reading																			D				
Machine rooms																								
Active operations																			D				
Tape storage																			D		B		
Machine area																			C				
Equipment service																			E		C		
Thermal print																			E				
Handwritten tasks																								
#2 pencil and softer leads																			D				
#3 pencil																			E				
#4 pencil and harder leads																			F				
Ball-point pen																			D				
Felt-tip pen																			D				
Handwritten carbon copy																			E				
White boards																					B		
Chalk boards																					E		
Printed tasks																								
6-point type																			E				
8- and 10-point type																			D				
Glossy magazines																			D				
Maps																			E				
Newsprint																			D				
Typed originals																			D				
Telephone books																			E				

Standardized Comfort By Building Regulation

IES ILLUMINANCE CATEGORIES and VALUES – for GENERIC INDOOR ACTIVITIES

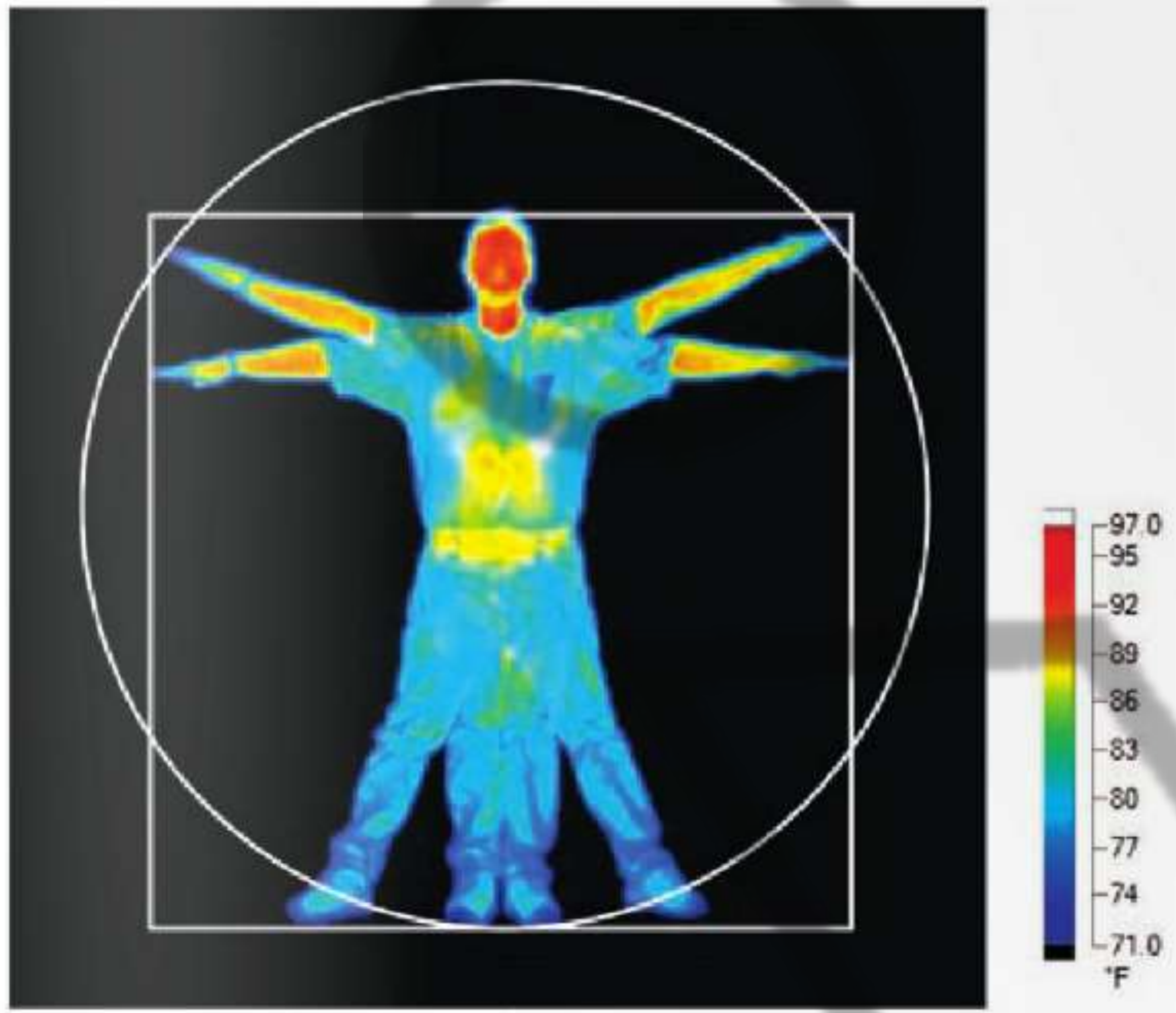
ACTIVITY	CATEGORY	LUX	FOOTCANDLES
Public spaces with dark surroundings	A	20-30-50	2-3-5
Simple orientation for short temporary visits	B	50-75-100	5-7.5-10
Working spaces where visual tasks are only occasionally performed	C	100-150-200	10-15-20
Performance of visual tasks of high contrast or large size	D	200-300-500	20-30-50
Performance of visual tasks of medium contrast or small size	E	500-750-1000	50-75-100
Performance of visual tasks of low contrast or very sm size	F	1000-1500-2000	100-150-200
Performance of visual tasks of low contrast or very sm size over a prolonged period	G	2000-3000-5000	200-300-500
Performance of very prolonged and exacting visual tasks	H	5000-7500-10000	500-750-1000
Performance of very special visual tasks of extremely low contrast	I	10000-15000-20000	1000-1500-2000

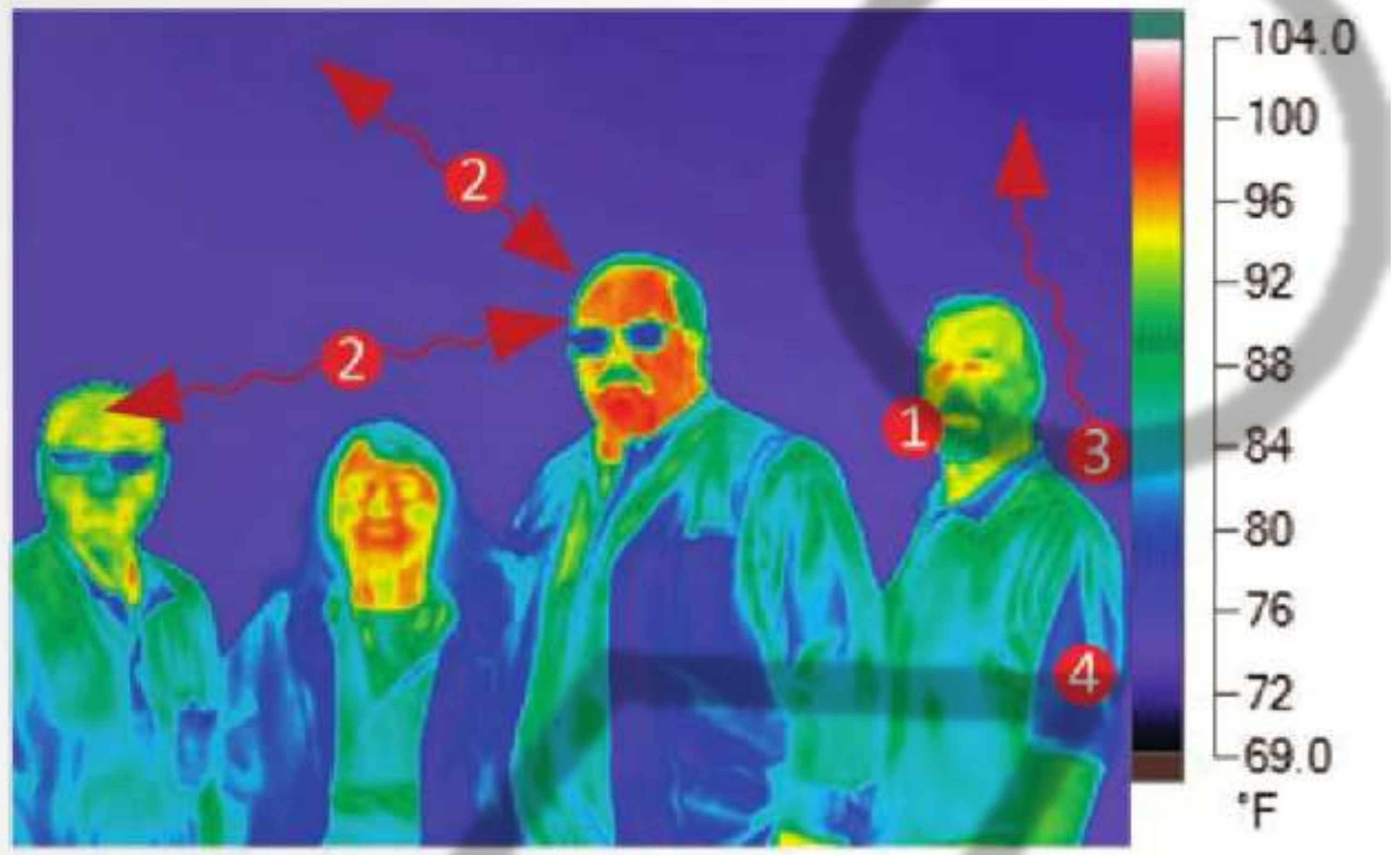
A-C for illuminances over a large area (ie lobby space)
D-F for localized tasks
G-I for extremely difficult visual tasks

Adaptive Comfort

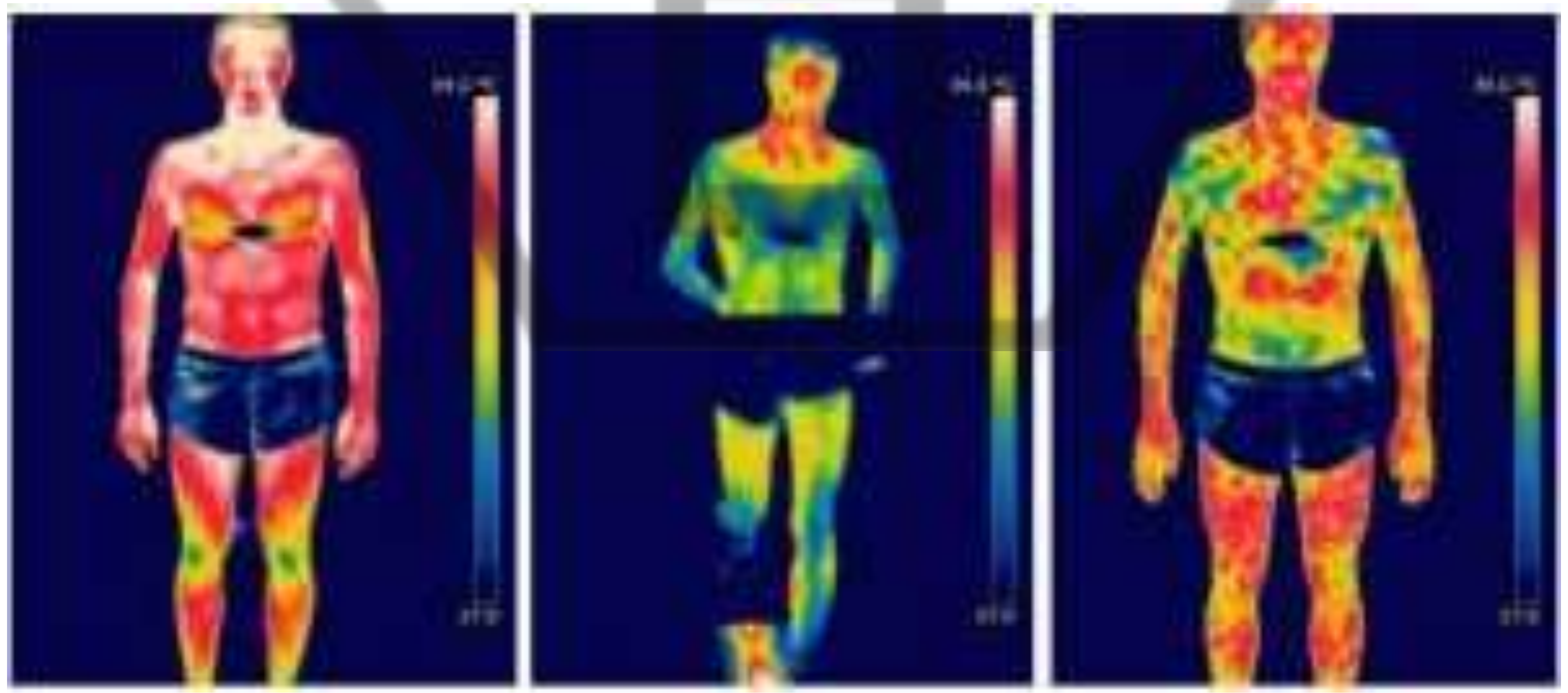
The thermohygrometric aspect

Thermal Adaptive Comfort. Human Body Behavior





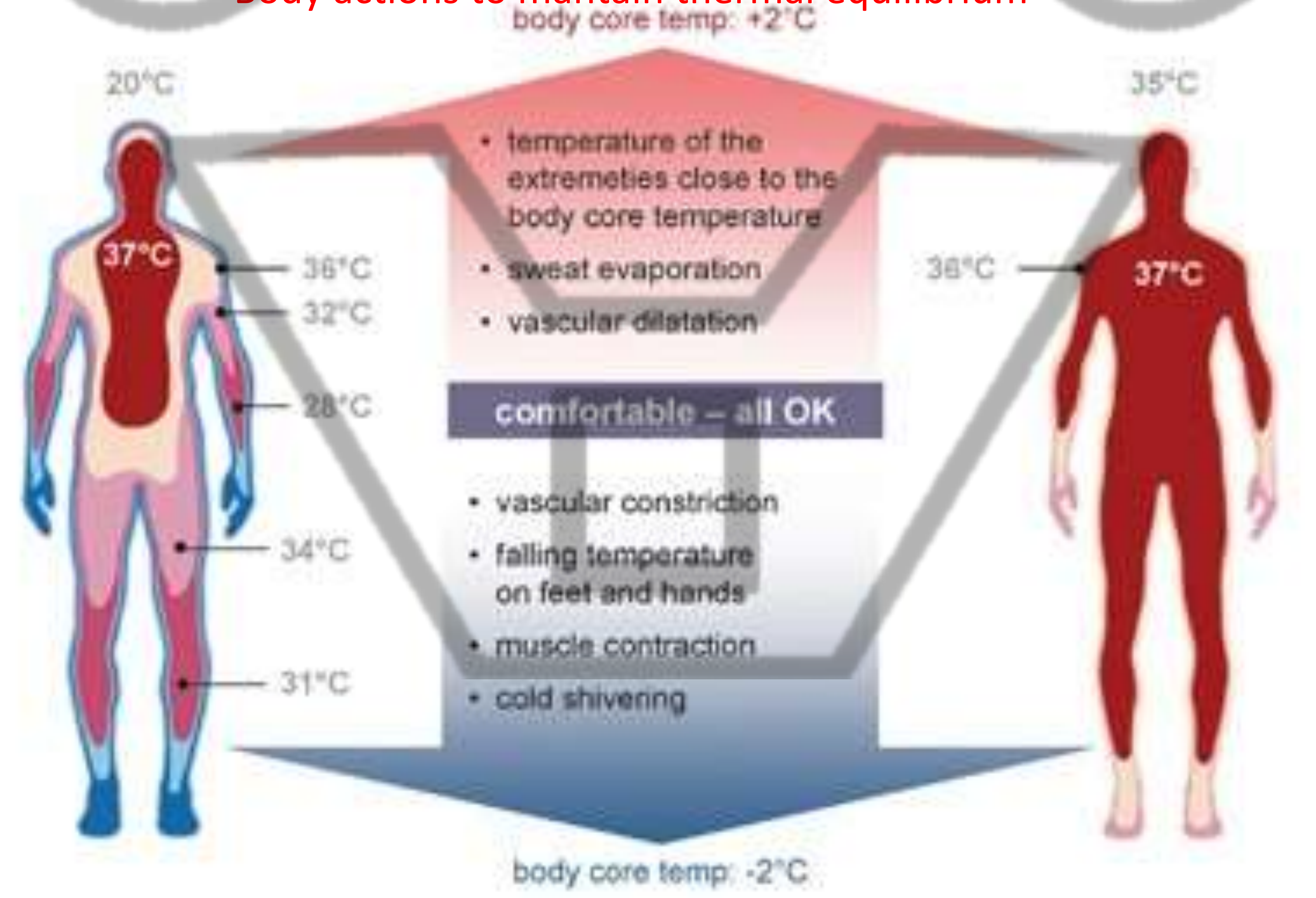
DIFFERENT HUMAN THERMAL ZONES



Thermal Adaptive Comfort. Human Body Behavior

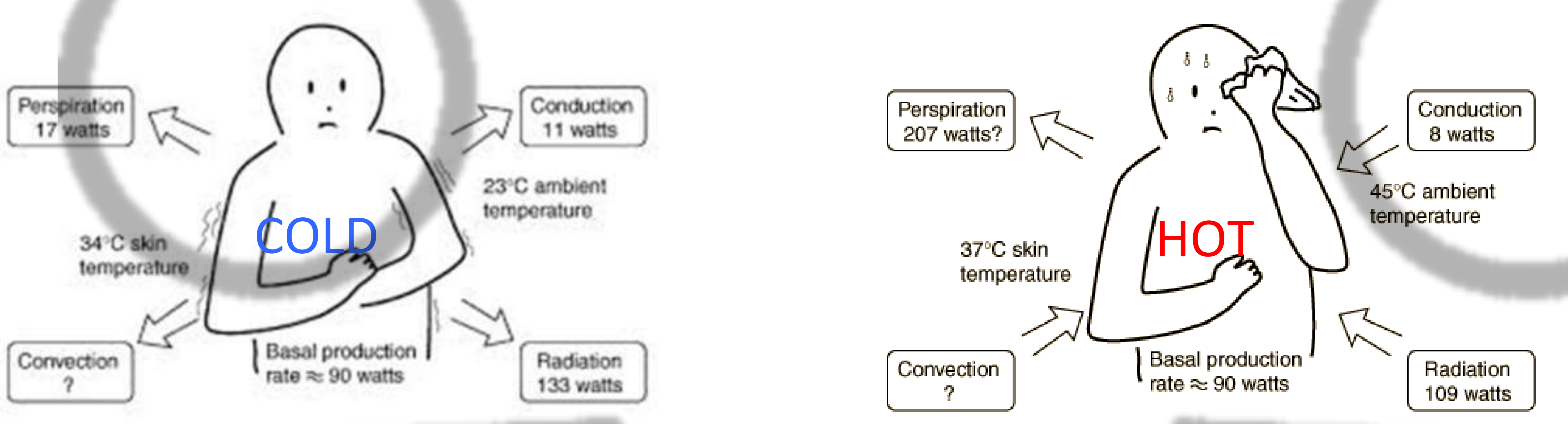
Thermal comfort= f (TEMPERATURE, WIND, HUMIDITY, METABOLIC RATE, DRESSING RATE)

Body actions to mantain thermal equilibrium



Thermal Adaptive Comfort. Human Body Behavior

Body actions to mantain thermal equilibrium



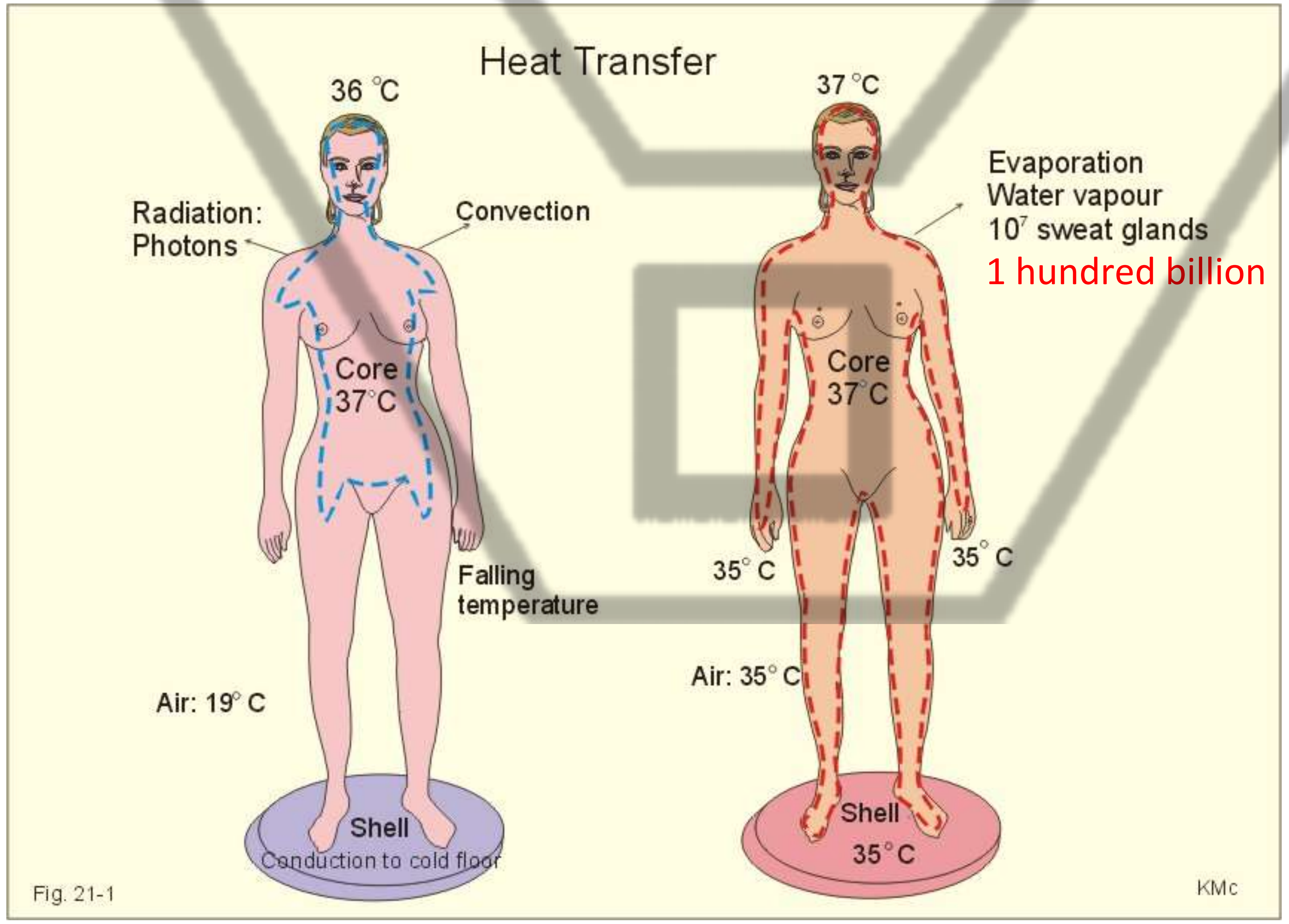
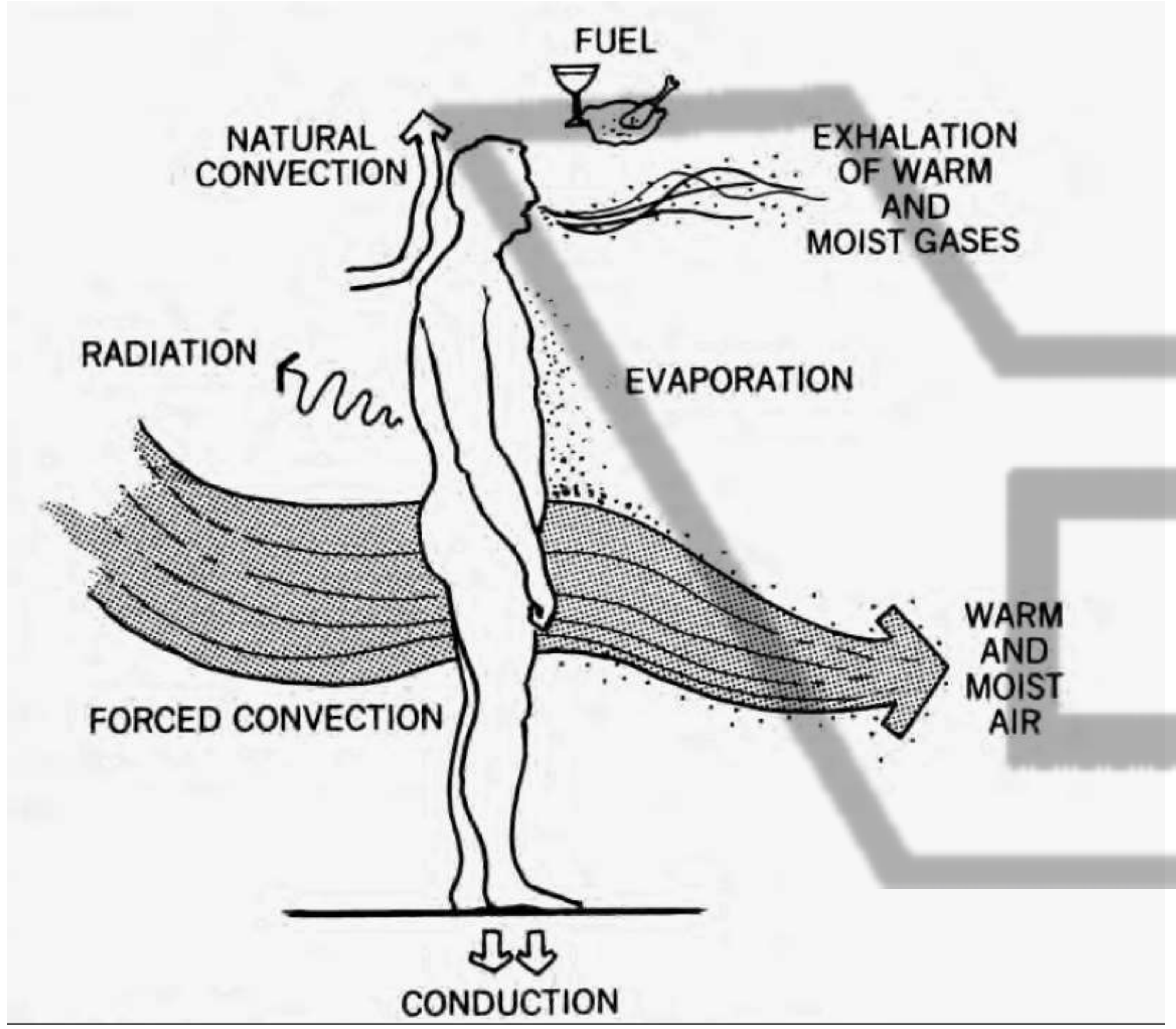
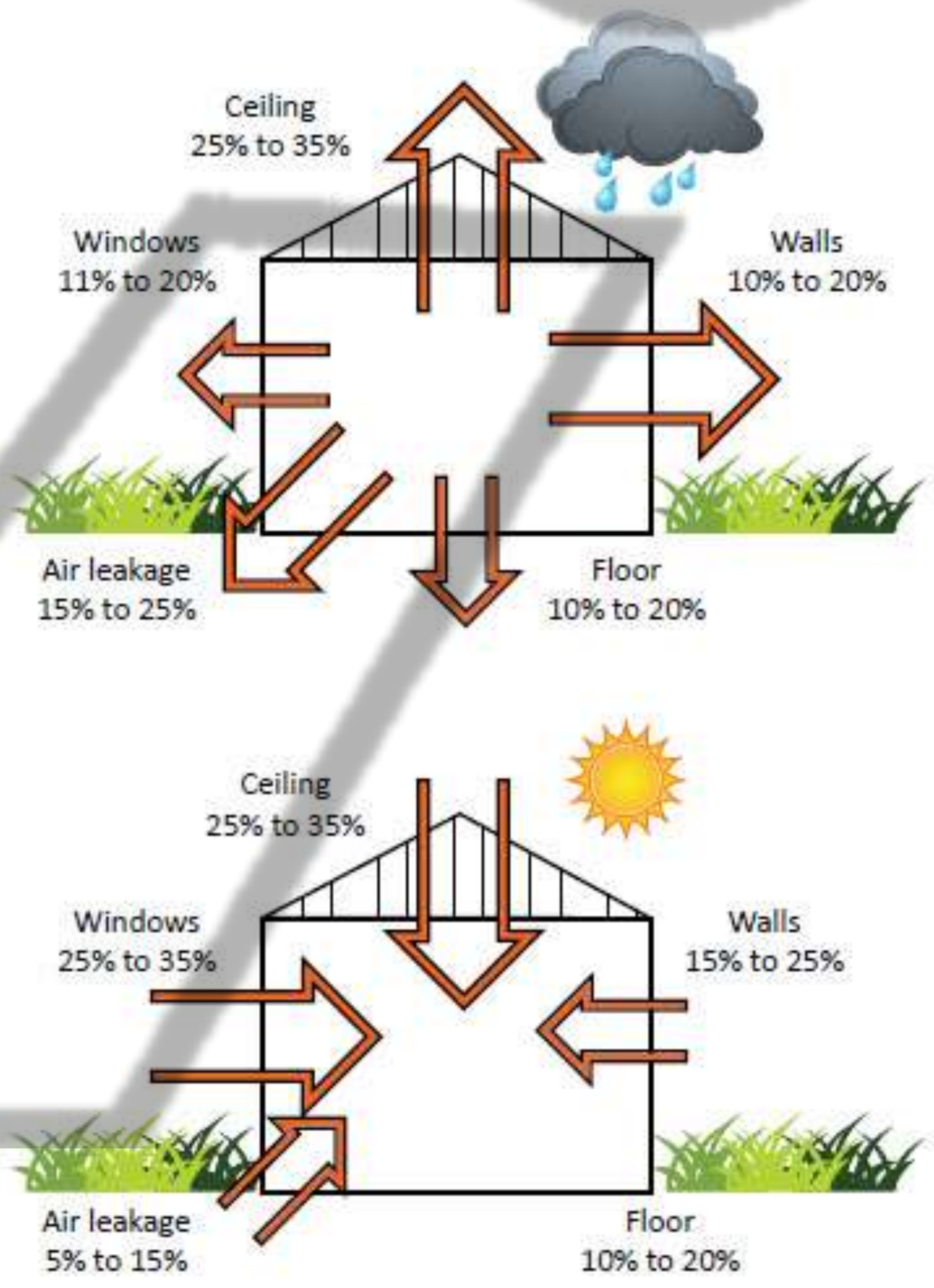


Fig. 21-1

Thermal Adaptive Comfort. Human Body Behavior

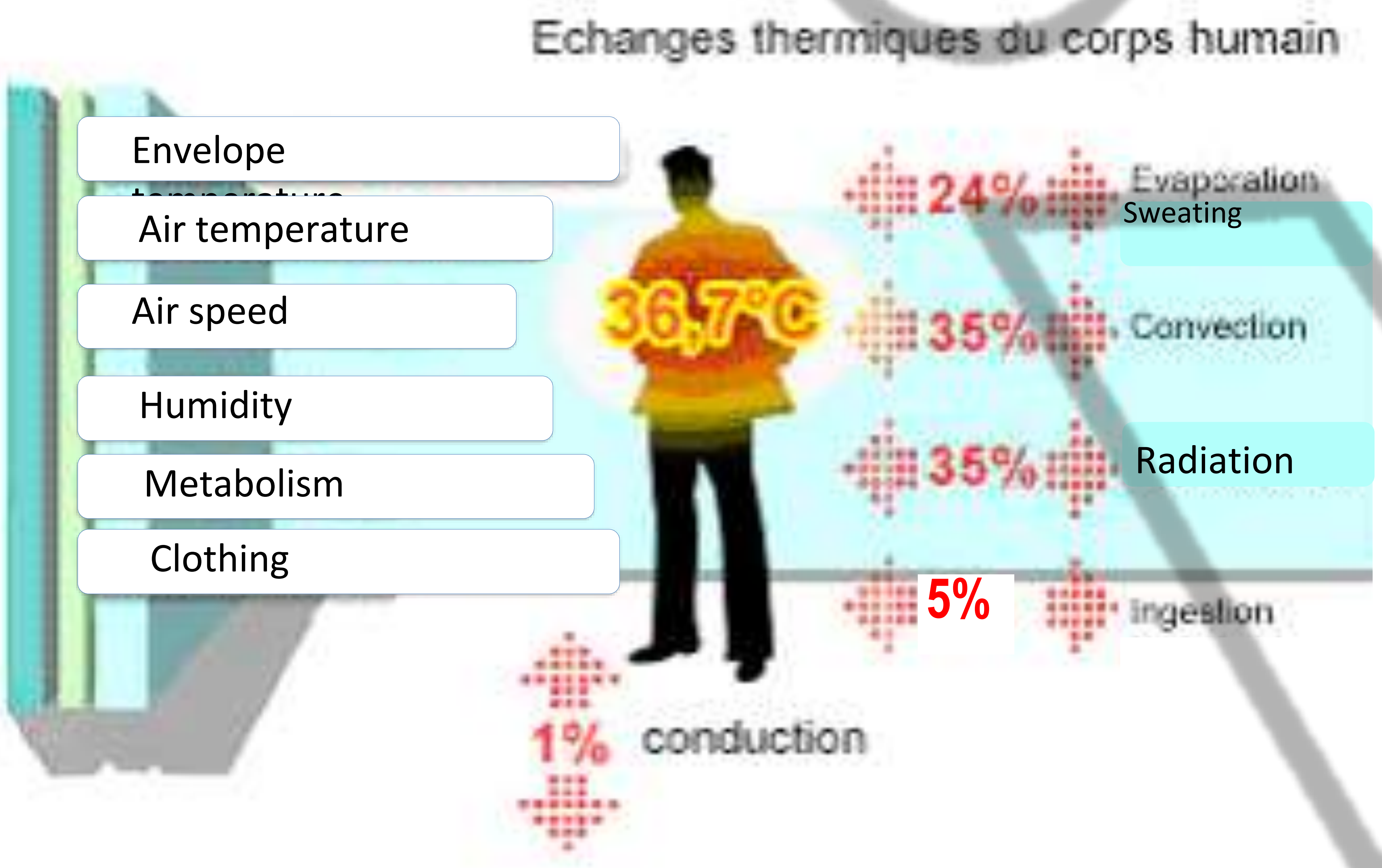
Energy mediator devices= Human skin & Building skin

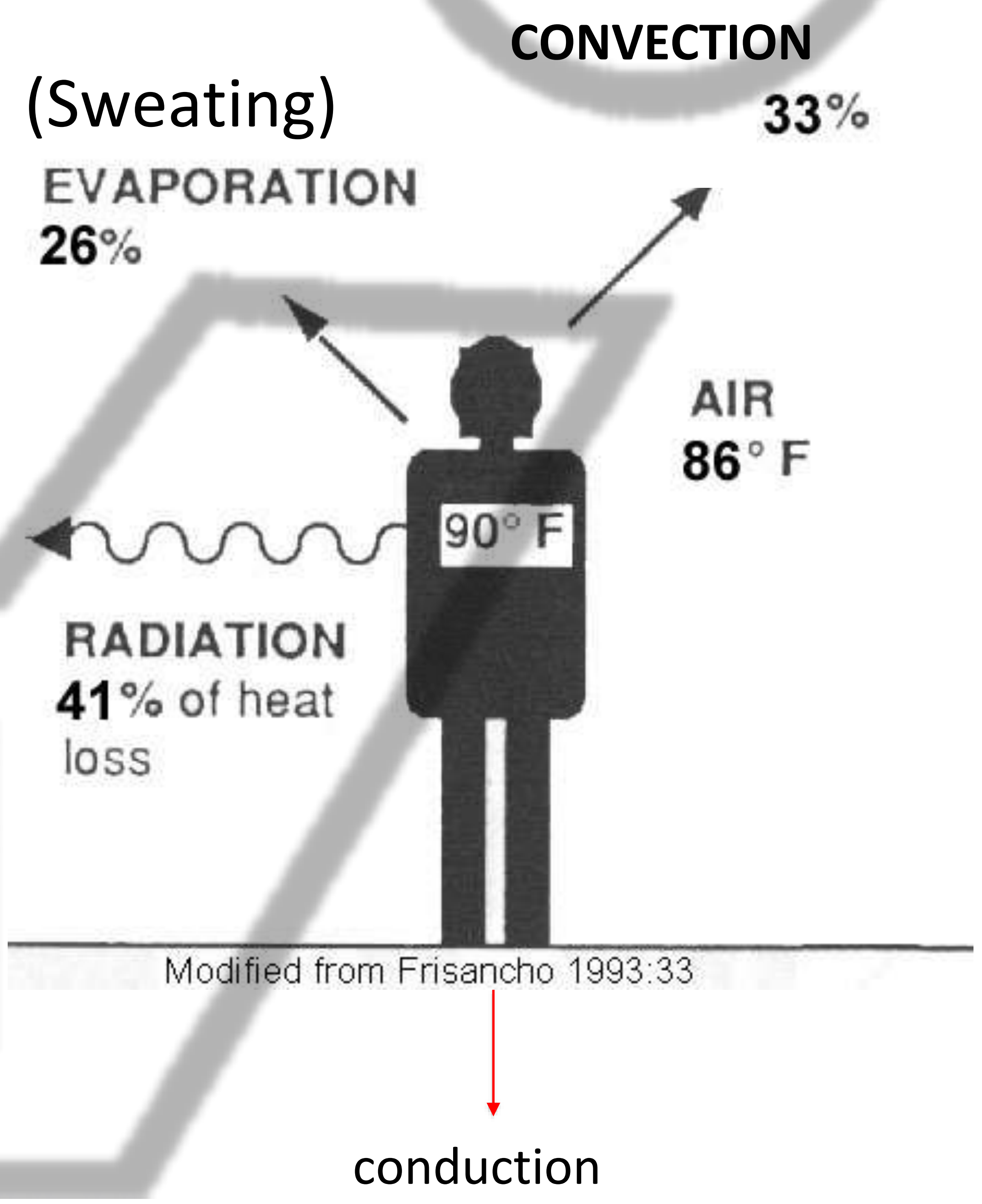




Thermal Adaptive Comfort. Human Body Behavior

HOW THE BODY EXCHANGE THERMAL ENERGY





The body exchanges:

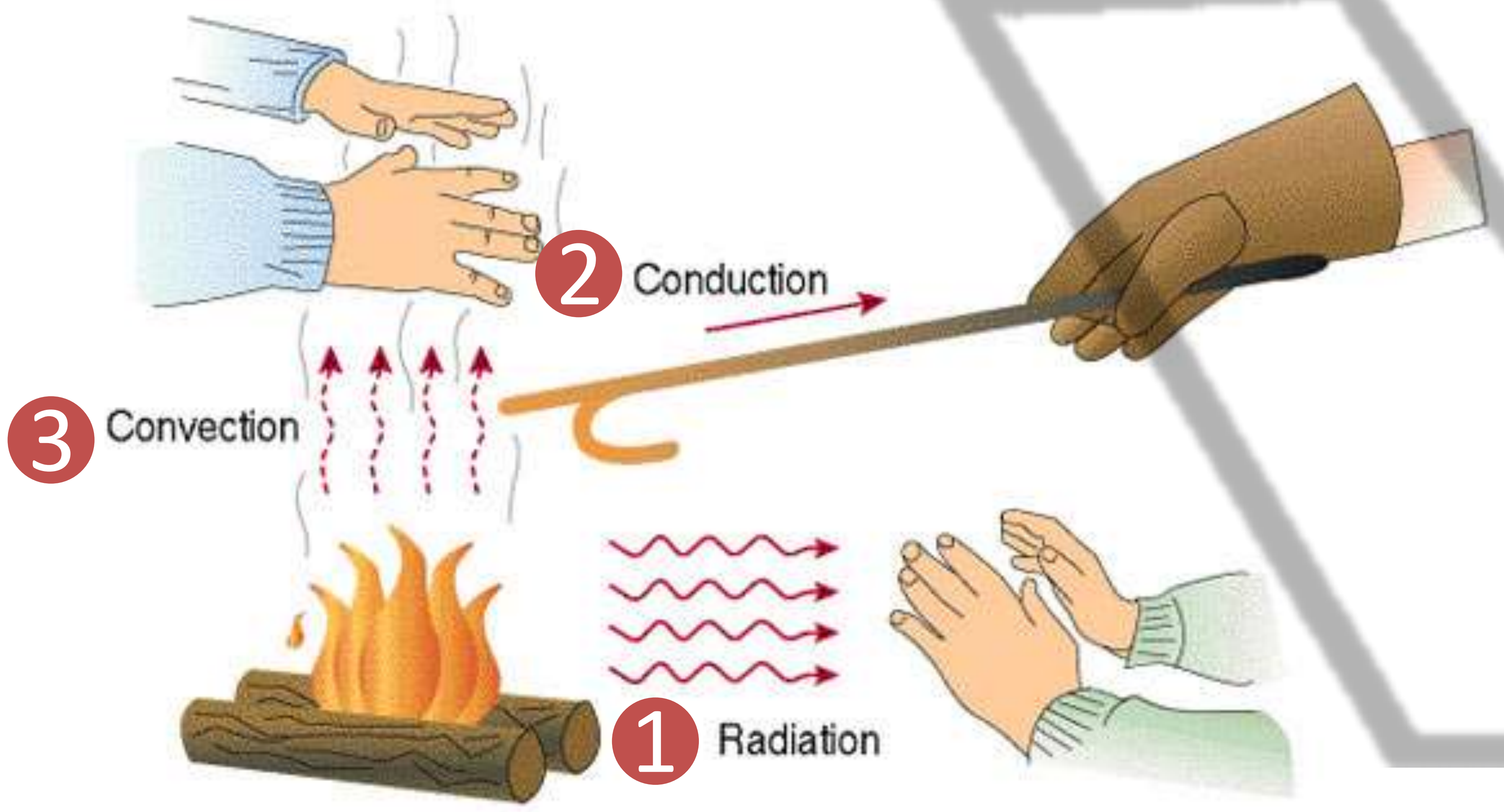
- 62% of this heat via radiation
- 15% by evaporation
- 10% by convection
- 10% by respiration
- 3% by conduction

http://www2.ecospecifier.org/

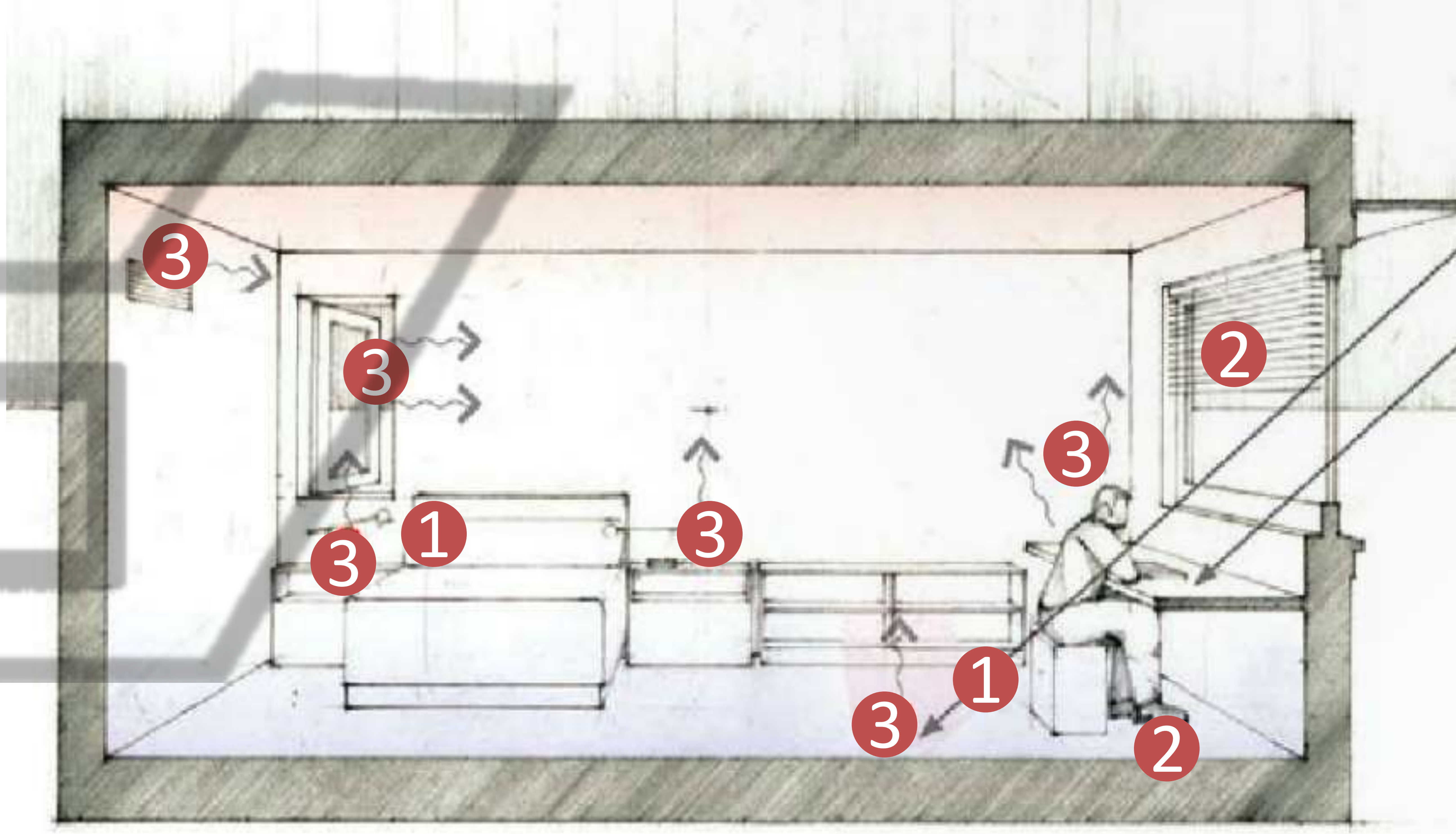
Adaptive Comfort. Thermohygrometric factors

RECOGNIZING ENERGY FORMS

FORMS of ENERGY EXCHANGE



INDOOR SPACE EXCHANGE WITH THE ENVIRONMENT

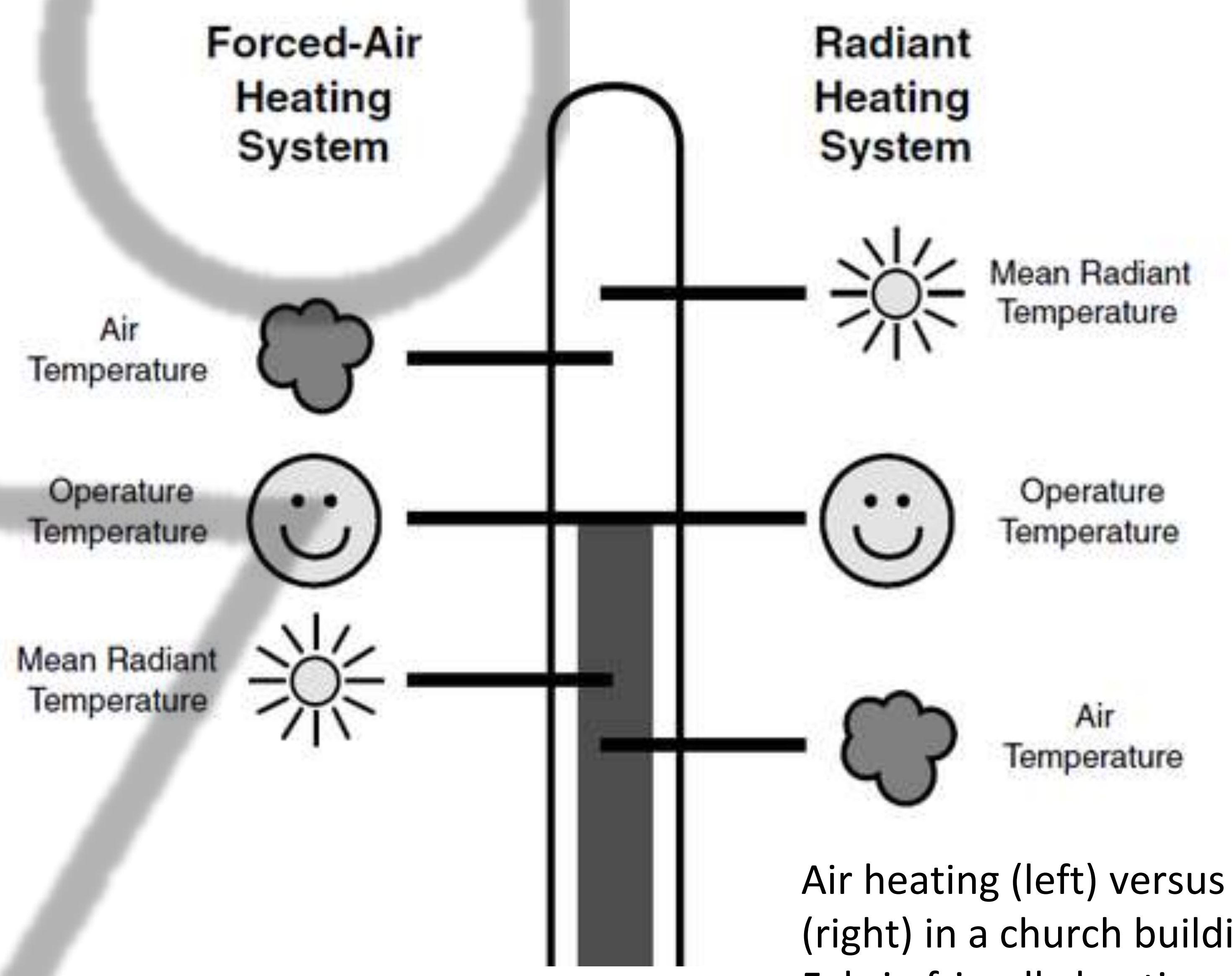


Adaptive Comfort. Thermohygrometric factors

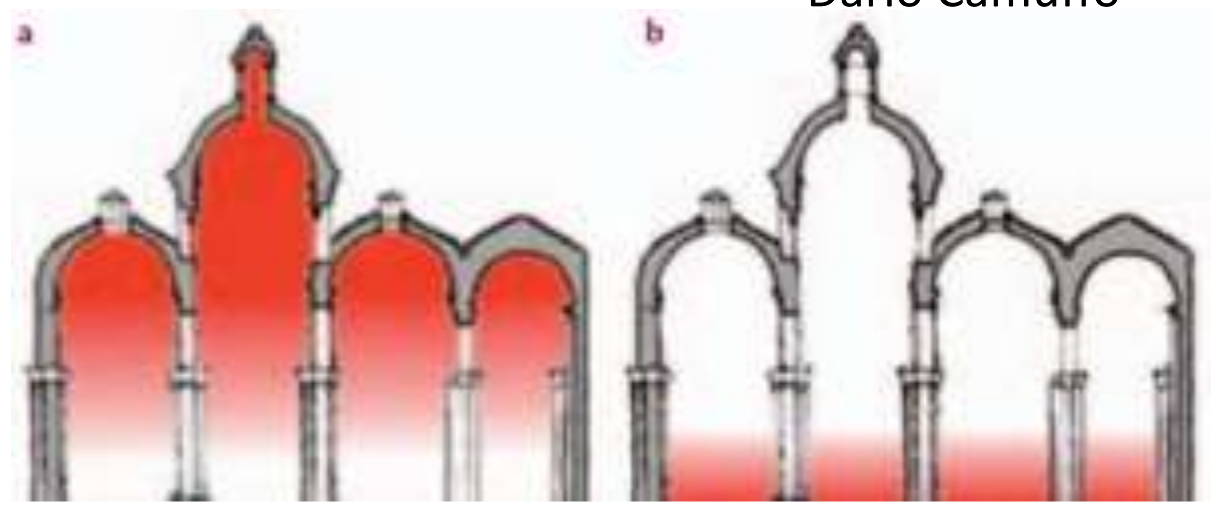
Environmental Temperature

Relatively small changes in mean radiant temperature have a far greater effect than similar changes in air temperatures (Ballinger 1992).
This gives rise to the importance of recognising the overall Environmental Temperature [T(env)], as opposed to just the dry bulb temperature.

T(env) = 2/3 Mean radiant surface temperature + 1/3 Air temperature



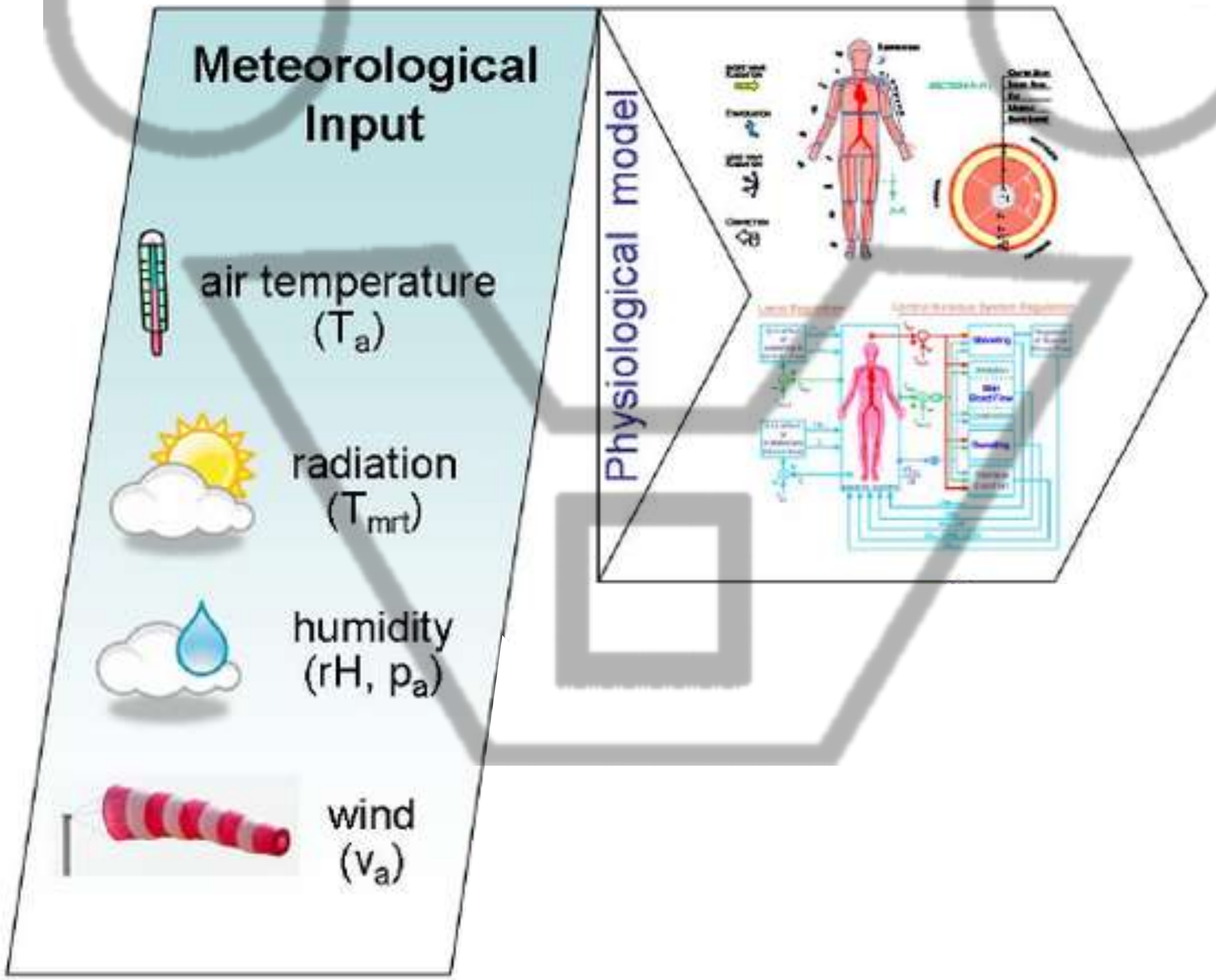
Air heating (left) versus radiant heating (right) in a church building. Source: Fabric-friendly heating Dario Camuffo



Radiant heating systems compensate a lower air temperature with a higher radiant temperature, while air heating systems compensate a lower radiant temperature with a higher air temperature. The operative temperature -- a weighted average of both -- can be the same. Source: *Radiant Heating & Cooling Handbook*, Richard Watson, 2008.

Adaptive Comfort. Effective Temperature and Thermohygrometric factors

Thermal comfort= f (TEMPERATURE, WIND, HUMIDITY)



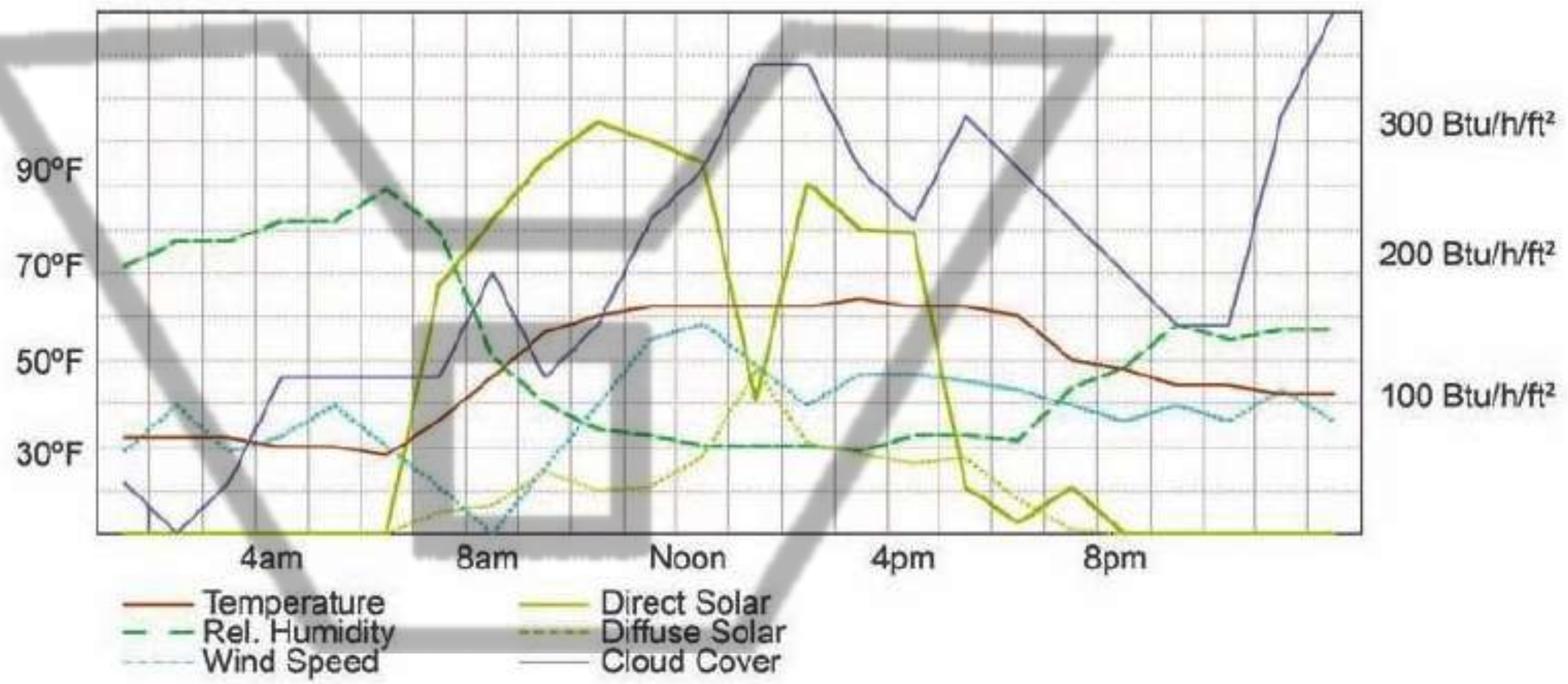
Adaptive Comfort. Effective Temperature and Thermohygrometric factors

HUMIDITY AGENT : COOLING vs HEATING A GENERAL ESTIMATION METHOD BASED ON **EFFECTIVE (Apparent) TEMPERATURE**

4.5

A 24-hour period set of data from a weather file shows the interaction of the dry bulb temperature, the relative humidity, the direct solar, diffuse solar, wind speed and cloud cover. Note the inverse relationship of temperature and humidity; direct and diffuse solar irradiation; and the inconsistent relationship between cloud cover and direct solar.

Source: Autodesk Ecotect Suite output of EnergyPlus weather data. Courtesy of Callison.

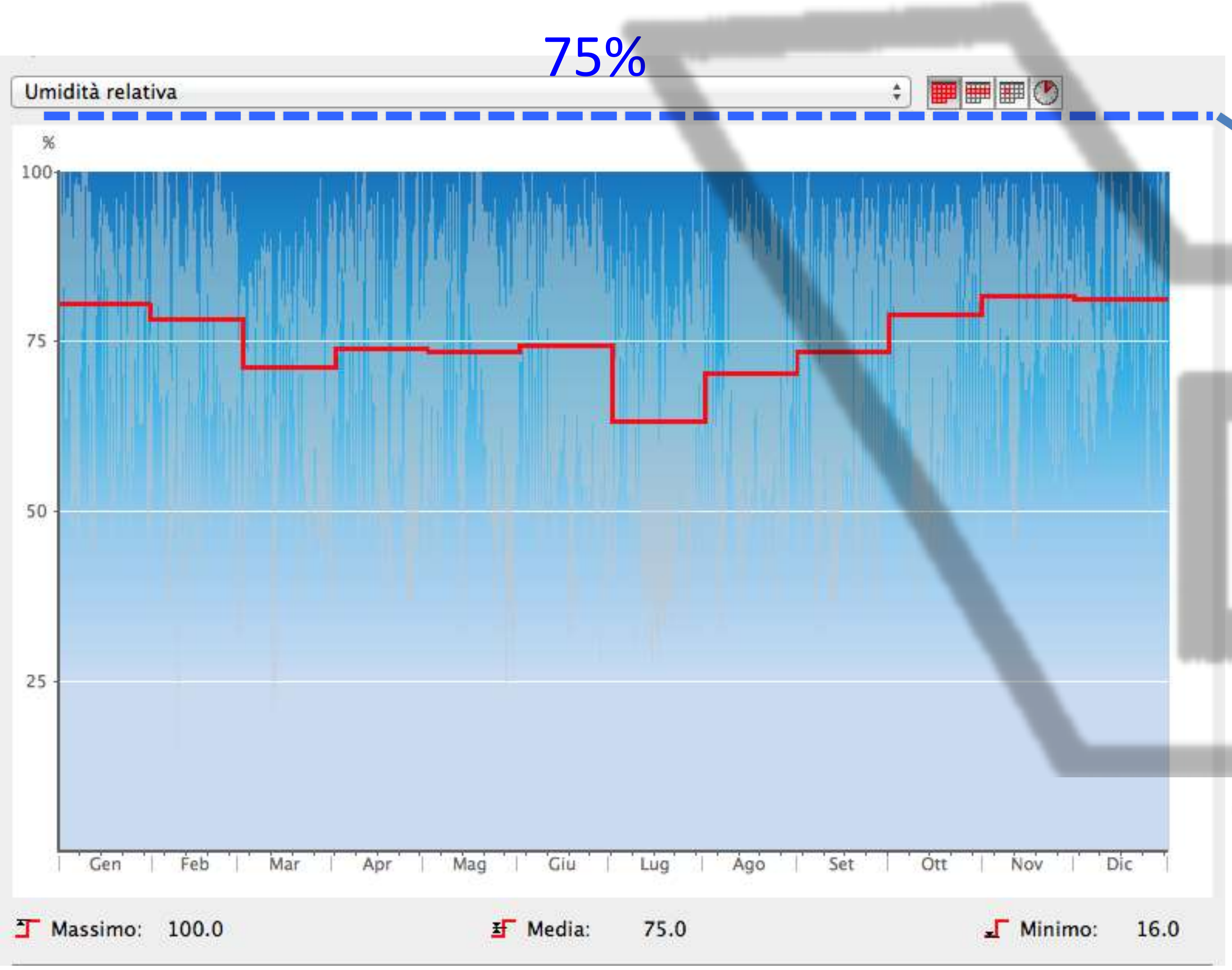


Inverse relationship between Temperature and Humidity

Adaptive Comfort. Effective Temperature and Thermohygrometric factors

HUMIDITY AGENT : COOLING vs HEATING A GENERAL ESTIMATION METHOD BASED ON APPARENT TEMPERATURE

The **AT** is defined as the temperature, at the reference humidity level, producing the same amount of discomfort as that experienced under the current ambient temperature and humidity.
Basically the **AT** is an adjustment to the *ambient temperature* (**T**) based on the level of humidity.



	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
42°	48	50	52	55	57	59	62	64	66	68	71	73	75	77	80	82
41°	46	48	51	53	55	57	59	61	64	66	68	70	72	74	76	79
40°	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75
39°	43	45	47	49	51	53	55	57	59	61	63	65	66	68	70	72
38°	42	44	45	47	49	51	53	55	56	58	60	62	64	66	67	69
37°	40	42	44	45	47	49	51	52	54	56	58	59	61	63	65	66
36°	39	40	42	44	45	47	49	50	52	54	55	57	59	60	62	63
35°	37	39	40	42	44	45	47	48	50	51	53	54	56	58	59	61
34°	36	37	39	40	42	43	45	46	48	49	51	52	54	55	57	58
33°	34	36	37	38	40	41	43	44	46	47	48	50	51	53	54	55
32°	33	34	36	37	38	40	41	42	44	45	46	48	49	50	52	53
31°	32	33	34	35	37	38	39	40	42	43	44	45	47	48	49	50
30°	30	32	33	34	35	36	37	39	40	41	42	43	45	46	47	48
29°	29	30	31	32	33	35	36	37	38	39	40	41	42	43	45	46
28°	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
27°	27	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
26°	26	26	27	28	29	30	31	32	33	34	34	35	36	37	38	39
25°	25	25	26	27	27	28	29	30	31	32	33	34	34	35	36	37
24°	24	24	24	25	26	27	28	28	29	30	31	32	33	33	34	35
23°	23	23	23	24	25	25	26	27	28	28	29	30	31	32	32	33
22°	22	22	22	22	23	24	25	25	26	27	27	28	29	30	30	31

Fino a 29 C°	Nessun disagio
Da 30 a 34 C°	Sensazione di disagio
Da 35 a 39 C°	Intenso disagio. Prudenza: limitare le attività fisiche più pesanti
Da 40 a 45 C°	Forte sensazione di malessere. Pericolo: evitare gli sforzi
Da 46 a 53 C°	Pericolo grave: interrompere tutte le attività fisiche
Oltre 54 C°	Pericolo di morte: colpo di calore imminente

Adaptive Comfort. Effective Temperature and Thermohygrometric factors

HUMIDITY AGENT : COOLING vs HEATING A GENERAL ESTIMATION METHOD BASED ON APPARENT TEMPERATURE

HUMIDEX- PERCEIVED TEMPERATURE
AND DISCOMFORT INDEX (range 20°C-34°C)

	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
42°	48	50	52	55	57	59	62	64	66	68	71	73	75	77	80	82
41°	46	48	51	53	55	57	59	61	64	66	68	70	72	74	76	79
40°	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75
39°	43	45	47	49	51	53	55	57	59	61	63	65	66	68	70	72
38°	42	44	45	47	49	51	53	55	56	58	60	62	64	66	67	69
37°	40	42	44	45	47	49	51	52	54	56	58	59	61	63	65	66
36°	39	40	42	44	45	47	49	50	52	54	55	57	59	60	62	63
35°	37	39	40	42	44	45	47	48	50	51	53	54	56	58	59	61
34°	36	37	39	40	42	43	45	46	48	49	51	52	54	55	57	58
33°	34	36	37	39	40	41	43	44	46	47	48	50	51	53	54	55
32°	33	34	36	37	38	40	41	42	44	45	46	48	49	50	52	53
31°	32	33	34	35	37	38	39	40	42	43	44	45	47	48	49	50
30°	30	32	33	34	35	36	37	39	40	41	42	43	45	46	47	48
29°	29	30	31	32	33	35	36	37	38	39	40	41	42	43	45	46
28°	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
27°	27	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
26°	26	26	27	28	29	30	31	32	33	34	34	35	36	37	38	39
25°	25	25	26	27	27	28	29	30	31	32	33	34	34	35	36	37
24°	24	24	24	25	26	27	28	28	29	30	31	32	33	33	34	35
23°	23	23	23	24	25	25	26	27	28	28	29	30	31	32	32	33
22°	22	22	22	22	23	24	25	25	26	27	27	28	29	30	30	31

Fino a 29 C°	Nessun disagio
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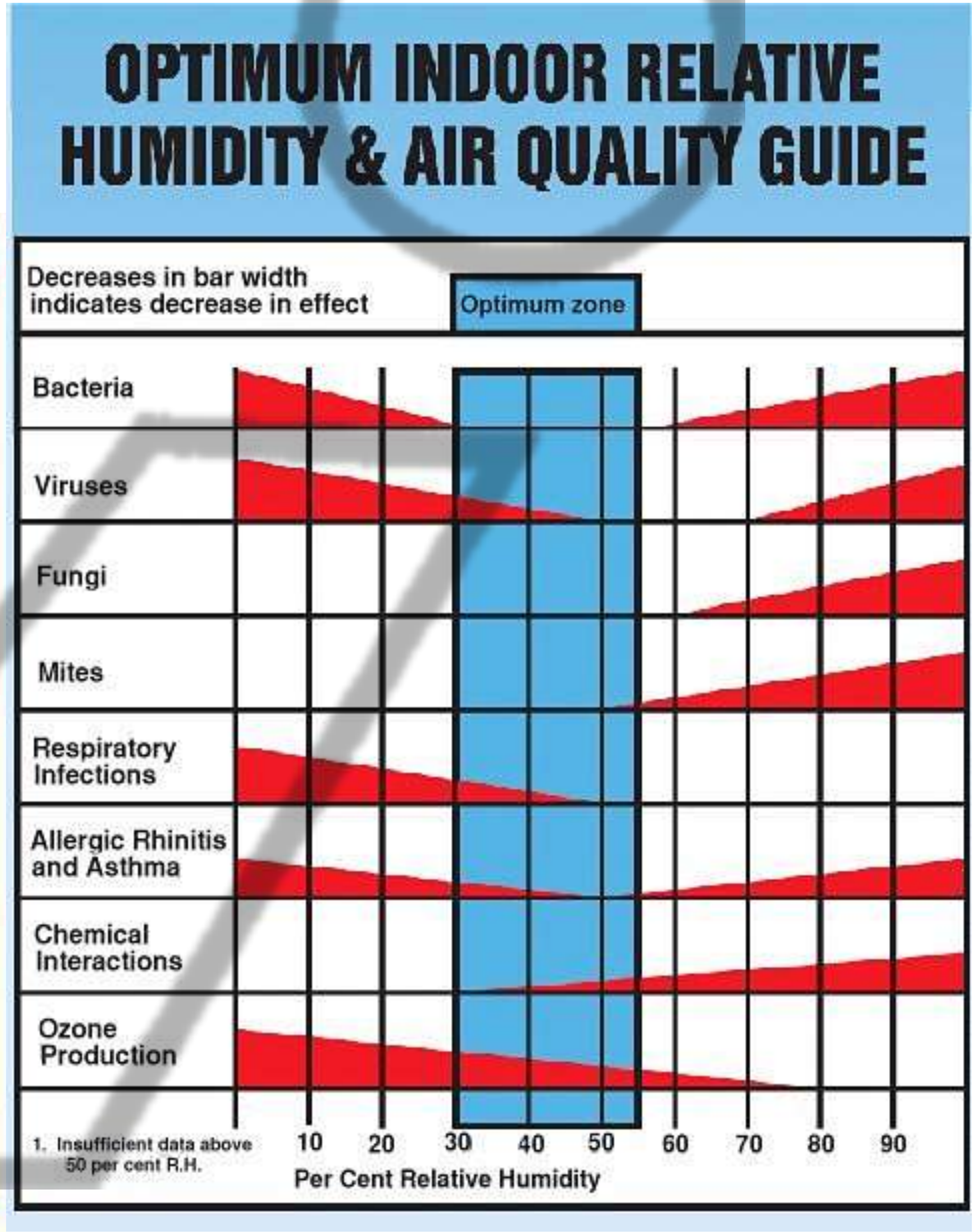
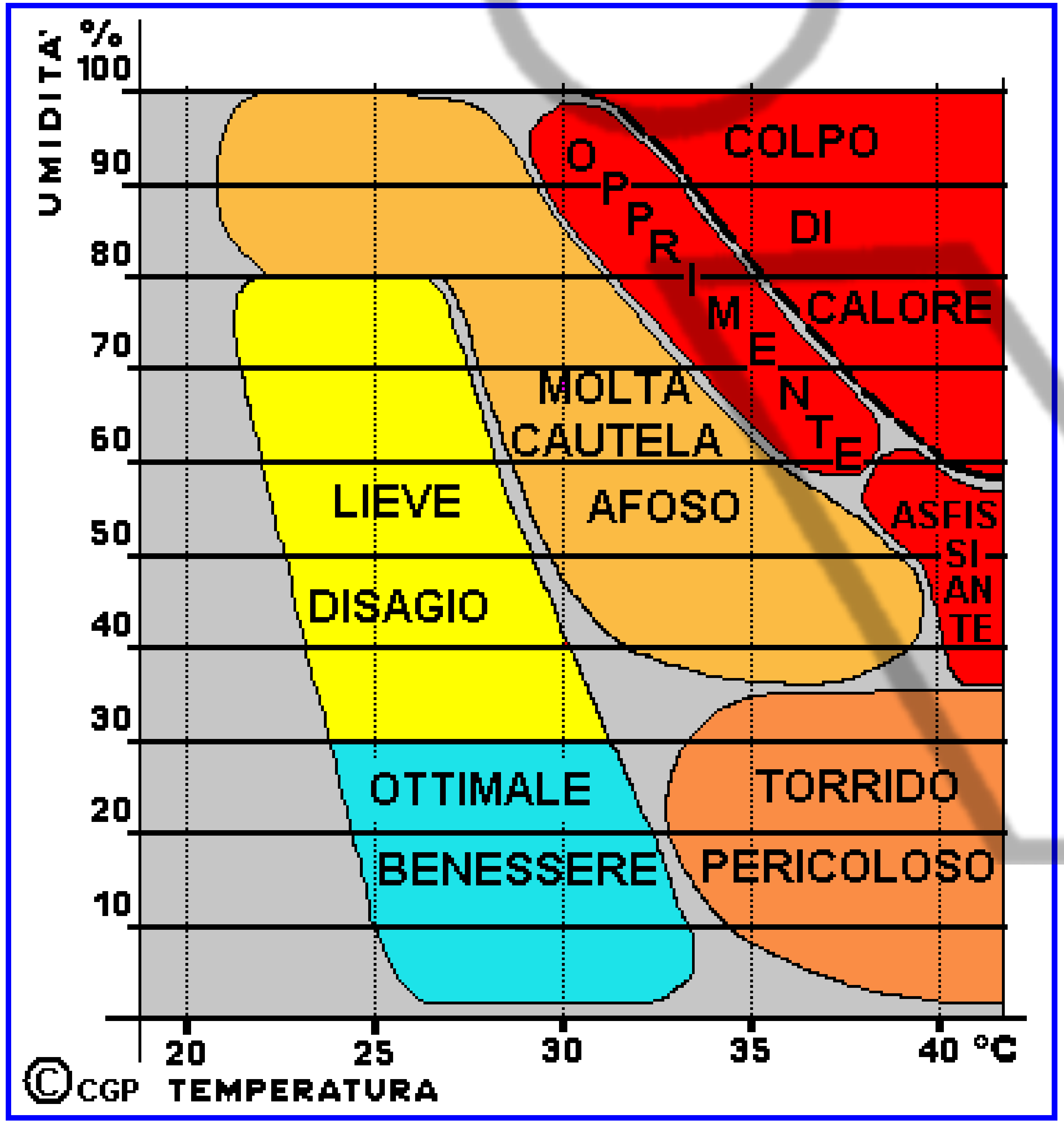
Oltre 54 C°	Pericolo di morte: colpo di calore imminente



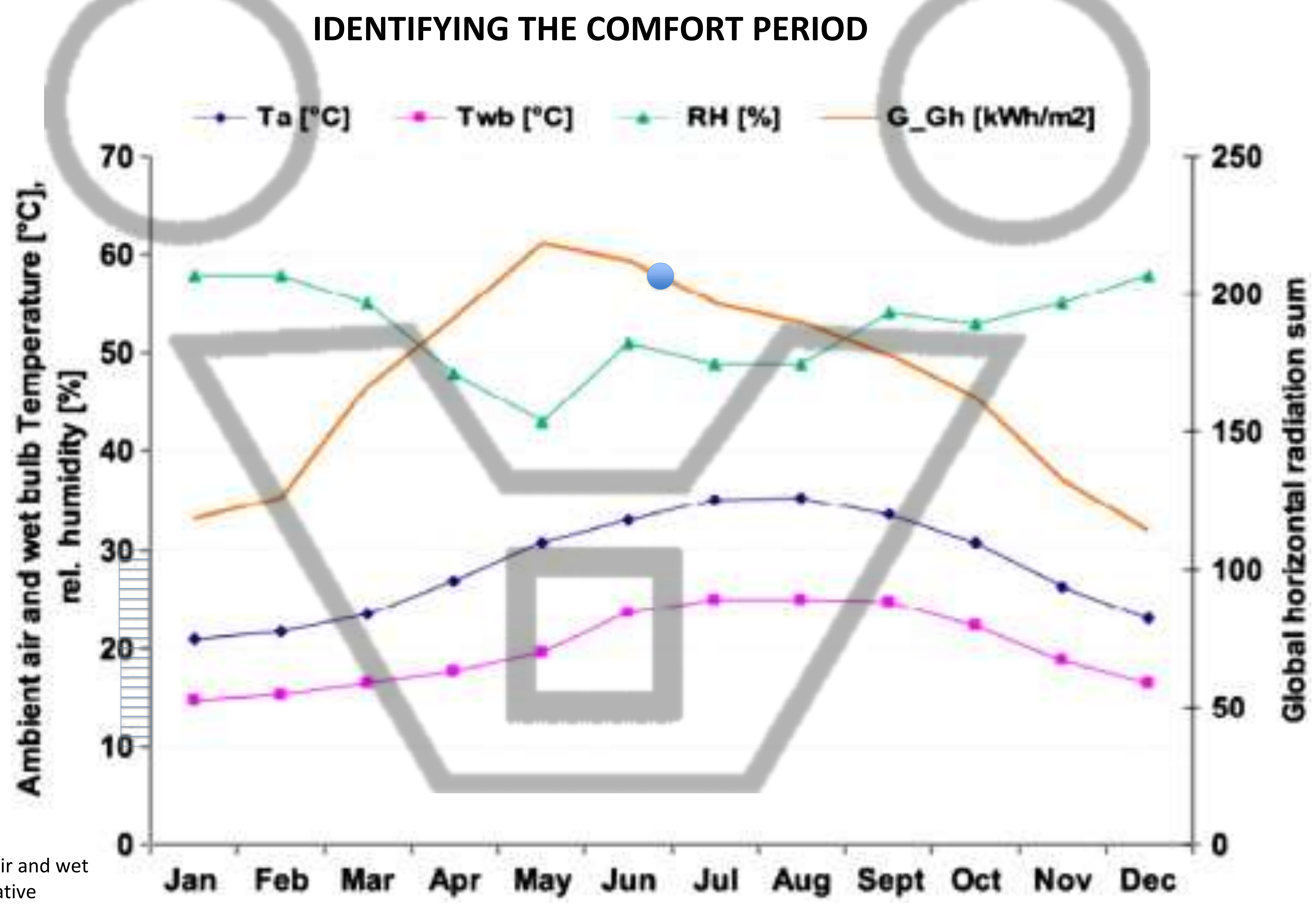
Adaptive Comfort. Effective Temperature and Thermohygrometric factors

HUMIDITY AGENT : COOLING vs HEATING A GENERAL ESTIMATION METHOD BASED ON APPARENT TEMPERATURE



HUMIDEX- PERCEIVED TEMPERATURE AND DISCOMFORT INDEX (range 20°C-55°C)

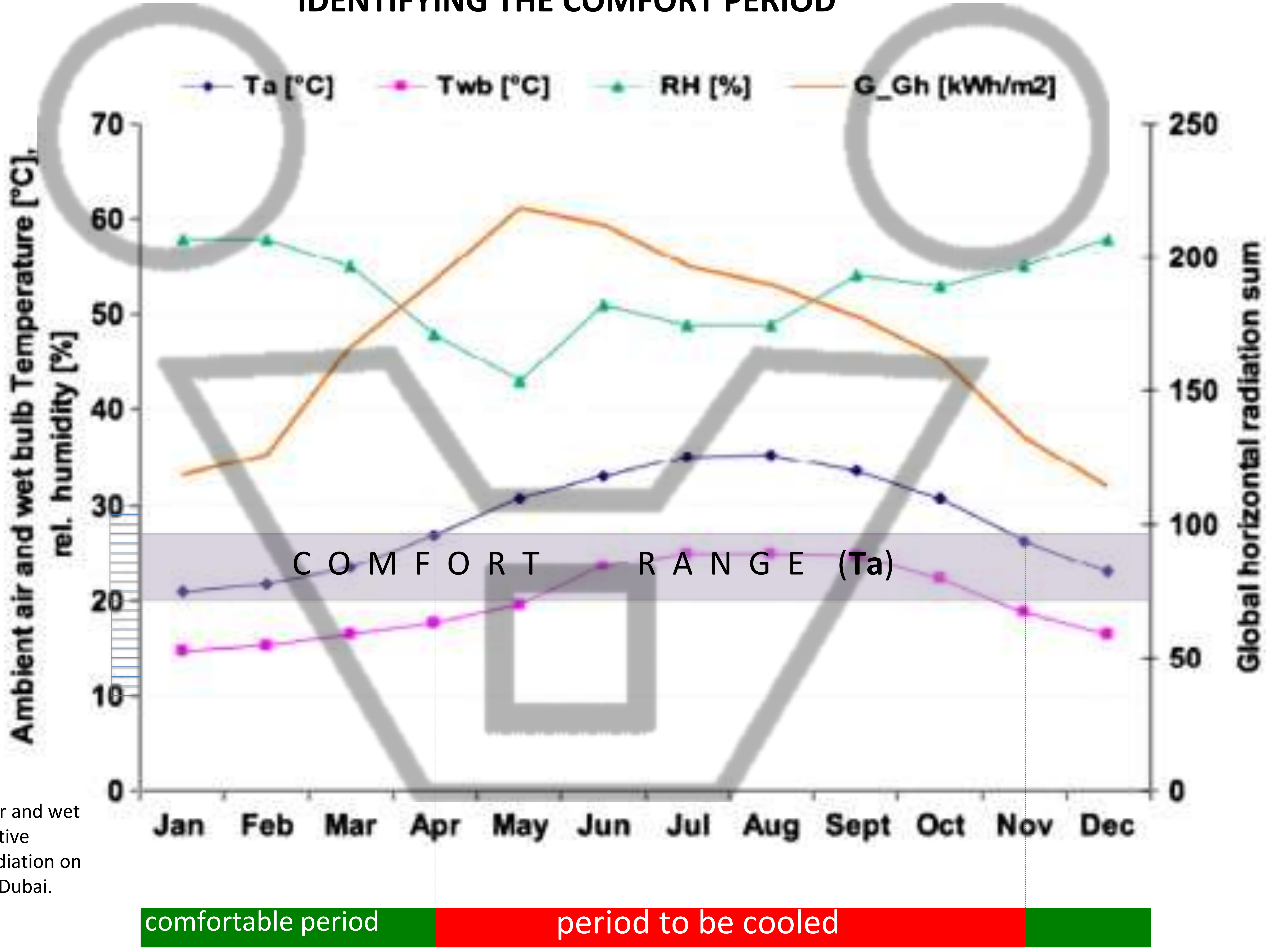
Project Mission. Goals and Philosophy



Monthly averages of air and wet bulb temperature, relative humidity and global radiation on a horizontal surface in Dubai.

Project Mission. Goals and Philosophy

IDENTIFYING THE COMFORT PERIOD



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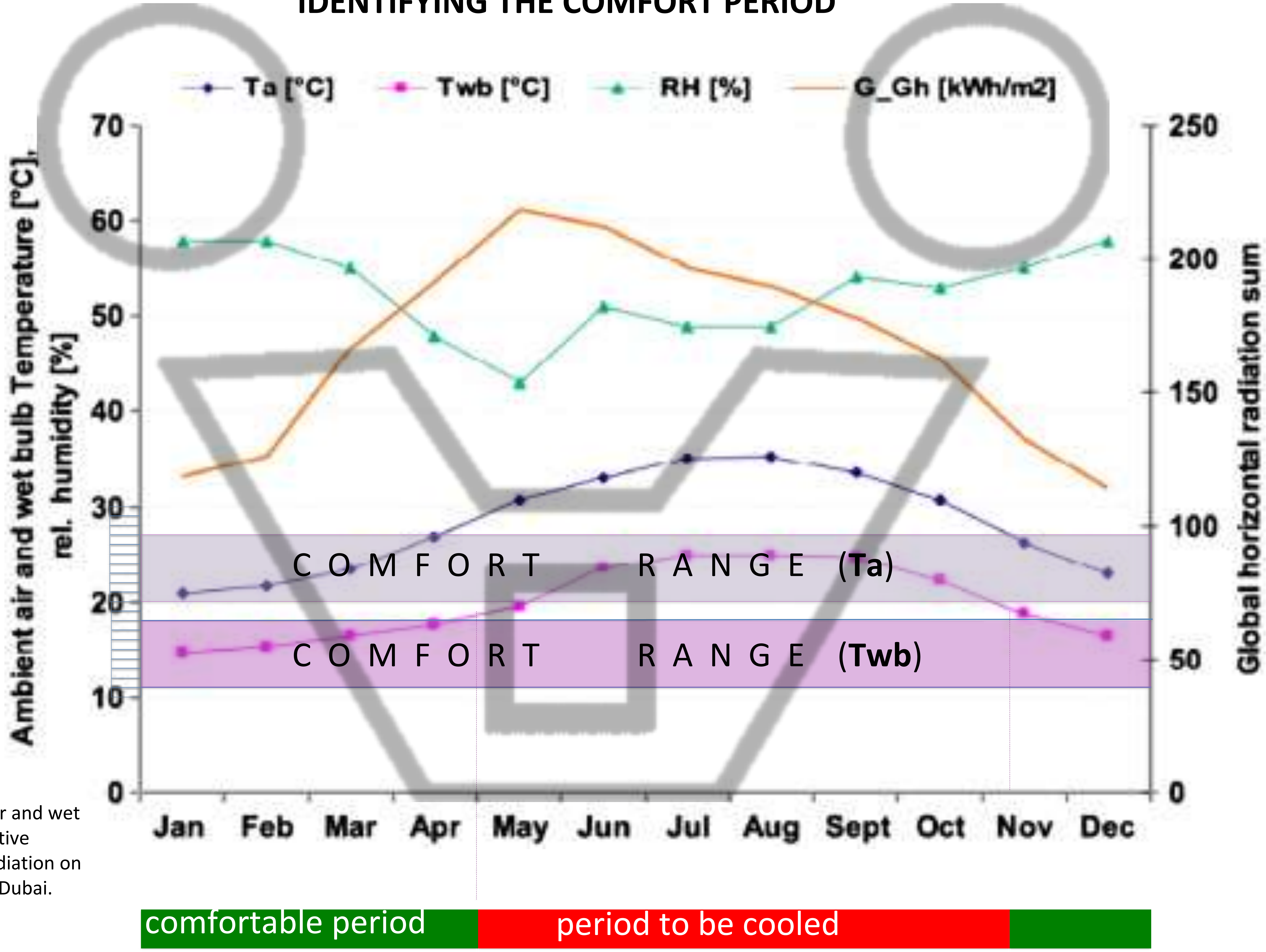

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Project Mission. Goals and Philosophy

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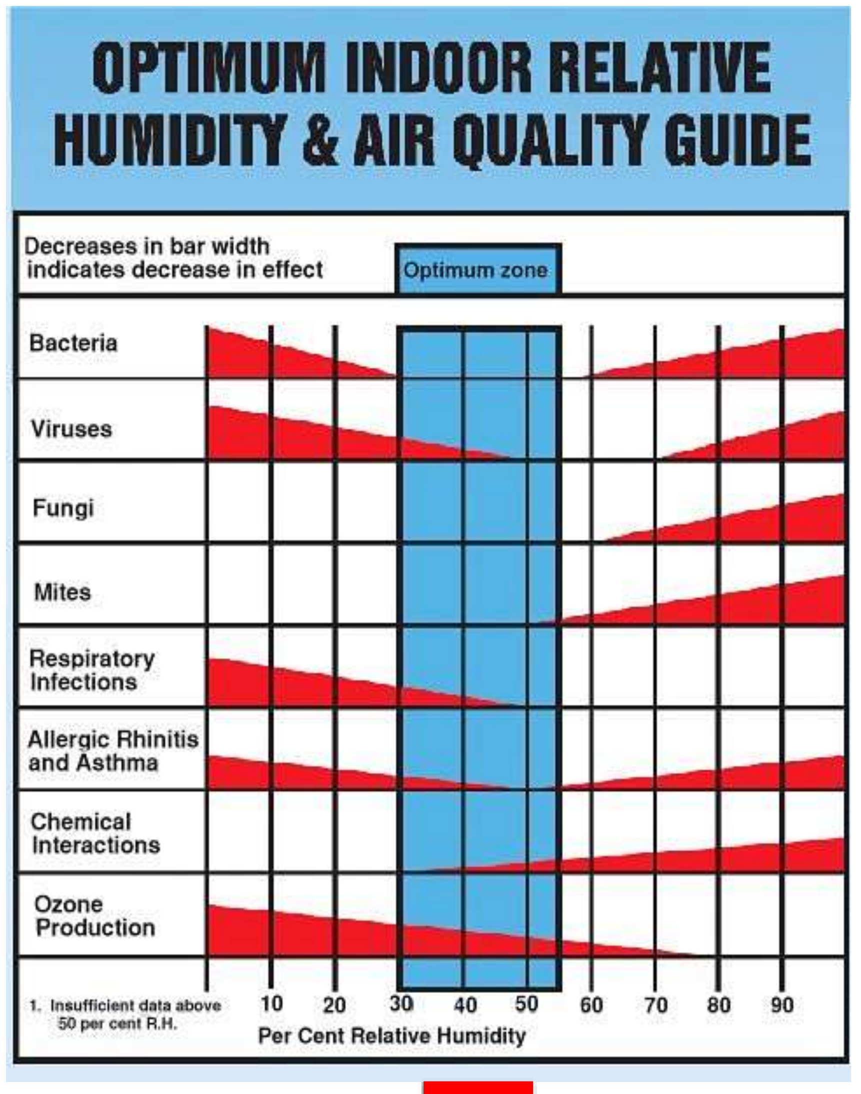

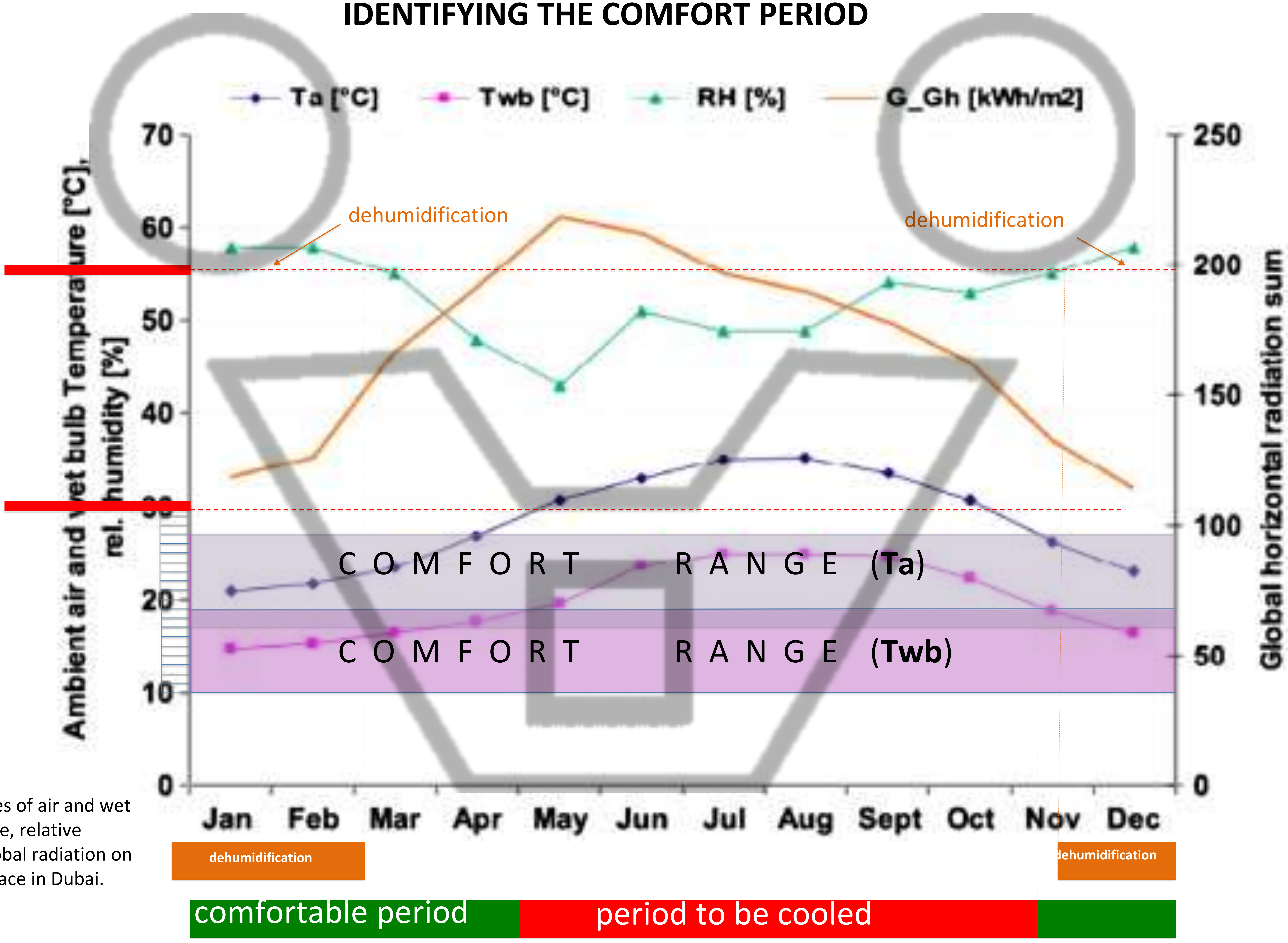

Monthly averages of air and wet bulb temperature, relative humidity and global radiation on a horizontal surface in Dubai.

Adaptive Comfort. Effective Temperature and Thermohygrometric factors

WIND AGENT : A GENERAL ESTIMATION METHOD BASED ON APPARENT TEMPERATURE

EFFECT OF WIND ON TEMPERATURE (Apparent Temperature)

	Wind Speed (mph)					
Temp (˚C)	**10**	**20**	**30**	**40**	**50**	**60**
20	17	15	14	13	12	11
15	12	9	7	6	5	4
10	7	3	1	0	-2	-3
5	2	-3	-5	-7	-9	-10
0	-4	-9	-11	-14	-16	-17
-5	-9	-15	-18	-21	-23	-24
-10	-15	-21	-25	-28	-30	-32
-15	-21	-27	-32	-35	-37	-39
-20	-27	-33	-38	-42	-45	-47
		Significant	Severe	Extreme		

Wind chill equivalent temperatures from Steadman

Adaptive Comfort. Effective Temperature and Thermohygrometric factors

WIND AGENT : A GENERAL ESTIMATION METHOD BASED ON APPARENT TEMPERATURE

Apparent temperature (AT) as a Wind Chill - after Steadman 1994

Temperature (°C)

Wind Speed (km/h)	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0	-8	-7	-6	-5	-4	-3	-2	-1	1	2	3	4	5	6	8	9	10	11	12	14	15	16	17	19	20	21
2	-9	-8	-6	-5	-4	-3	-2	-1	0	1	2	4	5	6	7	8	10	11	12	13	15	16	17	18	20	21
4	-9	-8	-7	-6	-5	-4	-2	-1	0	1	2	3	4	6	7	8	9	10	12	13	14	15	17	18	19	21
6	-9	-8	-7	-6	-5	-4	-3	-2	-1	1	2	3	4	5	6	8	9	10	11	12	14	15	16	18	19	20
8	-10	-9	-8	-7	-5	-4	-3	-2	-1	0	1	2	4	5	6	7	8	10	11	12	13	15	16	17	19	20
10	-10	-9	-8	-7	-6	-5	-4	-2	-1	0	1	2	3	4	6	7	8	9	10	12	13	14	16	17	18	20
12	-11	-9	-8	-7	-6	-5	-4	-3	-2	-1	1	2	3	4	5	6	8	9	10	11	13	14	15	16	18	19
14	-11	-10	-9	-8	-7	-5	-4	-3	-2	-1	0	1	2	4	5	6	7	8	10	11	12	13	15	16	17	19
16	-11	-10	-9	-8	-7	-6	-5	-4	-3	-1	0	1	2	3	4	6	7	8	9	11	12	13	14	16	17	18
18	-12	-11	-10	-8	-7	-6	-5	-4	-3	-2	-1	1	2	3	4	5	6	8	9	10	11	13	14	15	17	18
20	-12	-11	-10	-9	-8	-7	-6	-4	-3	-2	-1	0	1	2	4	5	6	7	9	10	11	12	14	15	16	18
22	-13	-11	-10	-9	-8	-7	-6	-5	-4	-3	-1	0	1	2	3	4	6	7	8	9	11	12	13	15	16	17
24	-13	-12	-11	-10	-9	-7	-6	-5	-4	-3	-2	-1	1	2	3	4	5	6	8	9	10	12	13	14	15	17
26	-13	-12	-11	-10	-9	-8	-7	-6	-4	-3	-2	-1	0	1	2	4	5	6	7	9	10	11	12	14	15	16
28	-14	-13	-12	-10	-9	-8	-7	-6	-5	-4	-3	-1	0	1	2	3	5	6	7	8	9	11	12	13	15	16
30	-14	-13	-12	-11	-10	-9	-7	-6	-5	-4	-3	-2	-1	1	2	3	4	5	7	8	9	10	12	13	14	16
32	-14	-13	-12	-11	-10	-9	-8	-7	-6	-4	-3	-2	-1	0	1	3	4	5	6	7	9	10	11	13	14	15
34	-15	-14	-13	-12	-10	-9	-8	-7	-6	-5	-4	-3	-1	0	1	2	3	5	6	7	8	10	11	12	13	15
36	-15	-14	-13	-12	-11	-10	-9	-8	-6	-5	-4	-3	-2	-1	1	2	3	4	5	7	8	9	10	12	13	14
38	-16	-15	-13	-12	-11	-10	-9	-8	-7	-6	-5	-3	-2	-1	0	1	3	4	5	6	8	9	10	11	13	14
40	-16	-15	-14	-13	-12	-11	-9	-8	-7	-6	-5	-4	-3	-1	0	1	2	3	5	6	7	8	10	11	12	14
42	-16	-15	-14	-13	-12	-11	-10	-9	-8	-6	-5	-4	-3	-2	-1	1	2	3	4	5	7	8	9	11	12	13
44	-17	-16	-15	-14	-12	-11	-10	-9	-8	-7	-6	-5	-3	-2	-1	0	1	3	4	5	6	8	9	10	12	13
46	-17	-16	-15	-14	-13	-12	-11	-9	-8	-7	-6	-5	-4	-3	-1	0	1	2	3	5	6	7	9	10	11	13
48	-18	-16	-15	-14	-13	-12	-11	-10	-9	-8	-6	-5	-4	-3	-2	-1	1	2	3	4	6	7	8	9	11	12
50	-18	-17	-16	-15	-14	-12	-11	-10	-9	-8	-7	-6	-5	-3	-2	-1	0	1	3	4	5	6	8	9	10	12
52	-18	-17	-16	-15	-14	-13	-12	-11	-10	-8	-7	-6	-5	-4	-3	-1	0	1	2	4	5	6	7	9	10	11
54	-19	-18	-17	-15	-14	-13	-12	-11	-10	-9	-8	-6	-5	-4	-3	-2	-1	1	2	3	4	6	7	8	10	11
56	-19	-18	-17	-16	-15	-14	-13	-11	-10	-9	-8	-7	-6	-5	-3	-2	-1	0	2	3	4	5	7	8	9	11
58	-20	-18	-17	-16	-15	-14	-13	-12	-11	-10	-8	-7	-6	-5	-4	-3	-1	0	1	2	4	5	6	8	9	10
60	-20	-19	-18	-17	-16	-14	-13	-12	-11	-10	-9	-8	-6	-5	-4	-3	-2	-1	1	2	3	5	6	7	8	10
62	-20	-19	-18	-17	-16	-15	-14	-13	-11	-10	-9	-8	-7	-6	-5	-3	-2	-1	0	2	3	4	5	7	8	9
64	-21	-20	-19	-17	-16	-15	-14	-13	-12	-11	-10	-8	-7	-6	-5	-4	-2	-1	0	1	2	4	5	6	8	9
66	-21	-20	-19	-18	-17	-16	-14	-13	-12	-11	-10	-9	-8	-6	-5	-4	-3	-2	0	1	2	3	5	6	7	9
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70	-22	-21	-20	-19	-17	-16	-15	-14	-13	-12	-11	-10	-8	-7	-6	-5	-4	-2	-1	0	1	3	4	5	6	8
72	-22	-21	-20	-19	-18	-17	-16	-15	-13	-12	-11	-10	-9	-8	-6	-5	-4	-3	-2	0	1	2	3	5	6	7
74	-23	-22	-20	-19	-18	-17	-16	-15	-14	-13	-12	-10	-9	-8	-7	-6	-4	-3	-2	-1	1	2	3	4	6	7
76	-23	-22	-21	-20	-19	-18	-16	-15	-14	-13	-12	-11	-10	-8	-7	-6	-5	-4	-2	-1	0	1	3	4	5	7
78	-23	-22	-21	-20	-19	-18	-17	-16	-15	-13	-12	-11	-10	-9	-8	-6	-5	-4	-3	-2	0	1	2	4	5	6
80	-24	-23	-22	-21	-19	-18	-17	-16	-15	-14	-13	-12	-10	-9	-8	-7	-6	-4	-3	-2	-1	1	2	3	5	6

Apparent temperature with no radiational heating and relative humidity fixed at 70%

Formula from *Norms of apparent temperature in Australia*, **Aust. Met. Mag**, Vol 43, 1994, 1-16.

Adaptive Comfort. Effective Temperature and Thermohygrometric factors

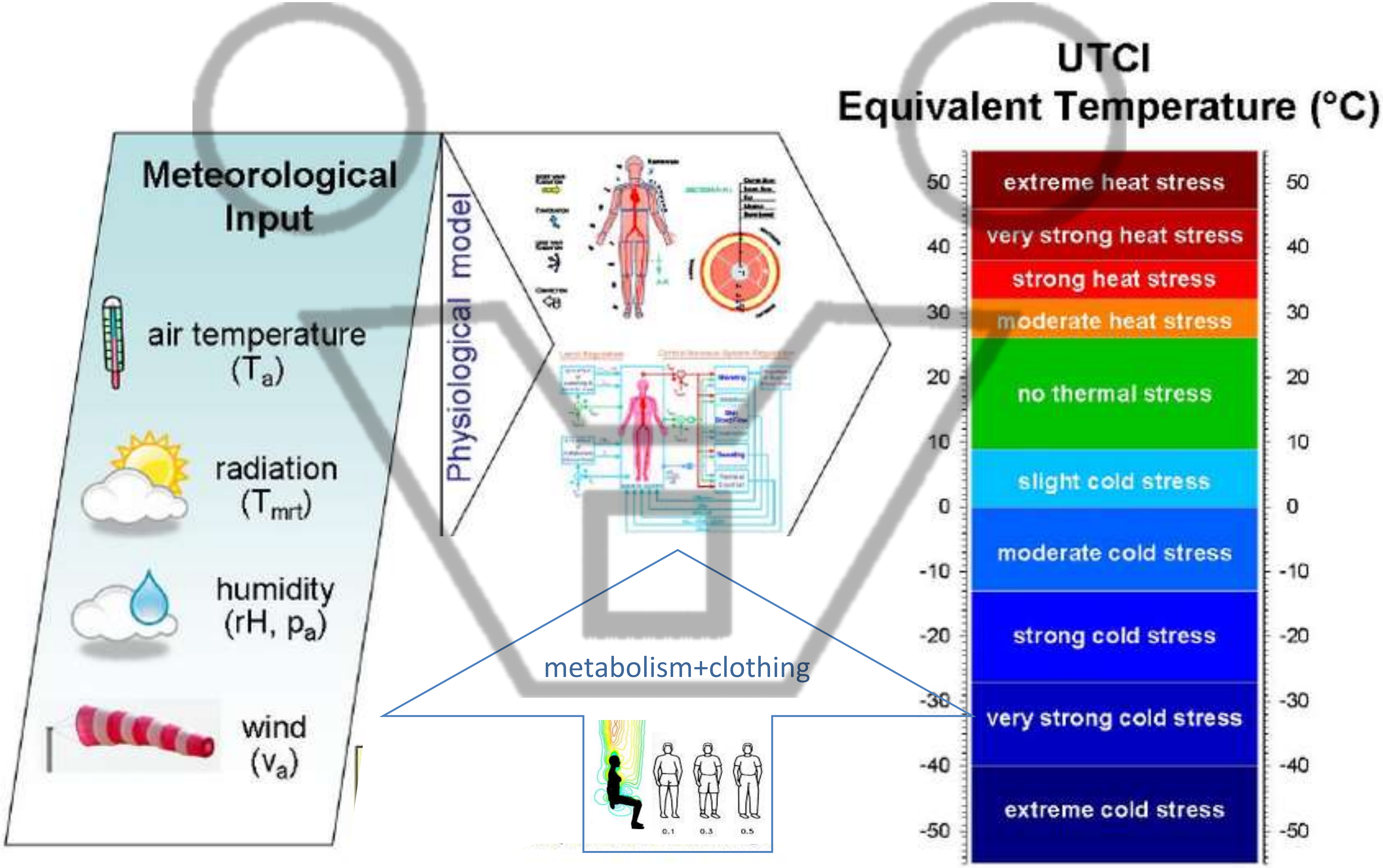
WIND AGENT : A GENERAL ESTIMATION METHOD BASED ON APPARENT TEMPERATURE

Wind Speed (km/hr)	Air Temperature (Celsius)																
	0	-1	-2	-3	-4	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-60
6	-2	-3	-4	-5	-7	-8	-14	-19	-25	-31	-37	-42	-48	-54	-60	-65	-71
8	-3	-4	-5	-6	-7	-9	-14	-20	-26	-32	-38	-44	-50	-56	-61	-67	-73
10	-3	-5	-6	-7	-8	-9	-15	-21	-27	-33	-39	-45	-51	-57	-63	-69	-75
15	-4	-6	-7	-8	-9	-11	-17	-23	-29	-35	-41	-48	-54	-60	-66	-72	-78
20	-5	-7	-8	-9	-10	-12	-18	-24	-30	-37	-43	-49	-56	-62	-68	-75	-81
25	-6	-7	-8	-10	-11	-12	-19	-25	-32	-38	-44	-51	-57	-64	-70	-77	-83
30	-6	-8	-9	-10	-12	-13	-20	-26	-33	-39	-46	-52	-59	-65	-72	-78	-85
35	-7	-8	-10	-11	-12	-14	-20	-27	-33	-40	-47	-53	-60	-66	-73	-80	-86
40	-7	-9	-10	-11	-13	-14	-21	-27	-34	-41	-48	-54	-61	-68	-74	-81	-88
45	-8	-9	-10	-12	-13	-15	-21	-28	-35	-42	-48	-55	-62	-69	-75	-82	-89
50	-8	-10	-11	-12	-14	-15	-22	-29	-35	-42	-49	-56	-63	-69	-76	-83	-90
55	-8	-10	-11	-13	-14	-15	-22	-29	-36	-43	-50	-57	-63	-70	-77	-84	-91
60	-9	-10	-12	-13	-14	-16	-23	-30	-36	-43	-50	-57	-64	-71	-78	-85	-92
65	-9	-10	-12	-13	-15	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
70	-9	-11	-12	-14	-15	-16	-23	-30	-37	-44	-51	-58	-65	-72	-80	-87	-94
75	-10	-11	-12	-14	-15	-17	-24	-31	-38	-45	-52	-59	-66	-73	-80	-87	-94
80	-10	-11	-13	-14	-15	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
85	-10	-11	-13	-14	-16	-17	-24	-31	-39	-46	-53	-60	-67	-74	-81	-89	-96
90	-10	-12	-13	-15	-16	-17	-25	-32	-39	-46	-53	-61	-68	-75	-82	-89	-96
95	-10	-12	-13	-15	-16	-18	-25	-32	-39	-47	-54	-61	-68	-75	-83	-90	-97
100	-11	-12	-14	-15	-16	-18	-25	-32	-40	-47	-54	-61	-69	-76	-83	-90	-98
105	-11	-12	-14	-15	-17	-18	-25	-33	-40	-47	-55	-62	-69	-76	-84	-91	-98
110	-11	-12	-14	-15	-17	-18	-26	-33	-40	-48	-55	-62	-70	-77	-84	-91	-99

0 to -10 Low | -10 to -25 Moderate | -25 to - 45 Cold | -45 to -59 Extreme | -60 Plus very Extreme

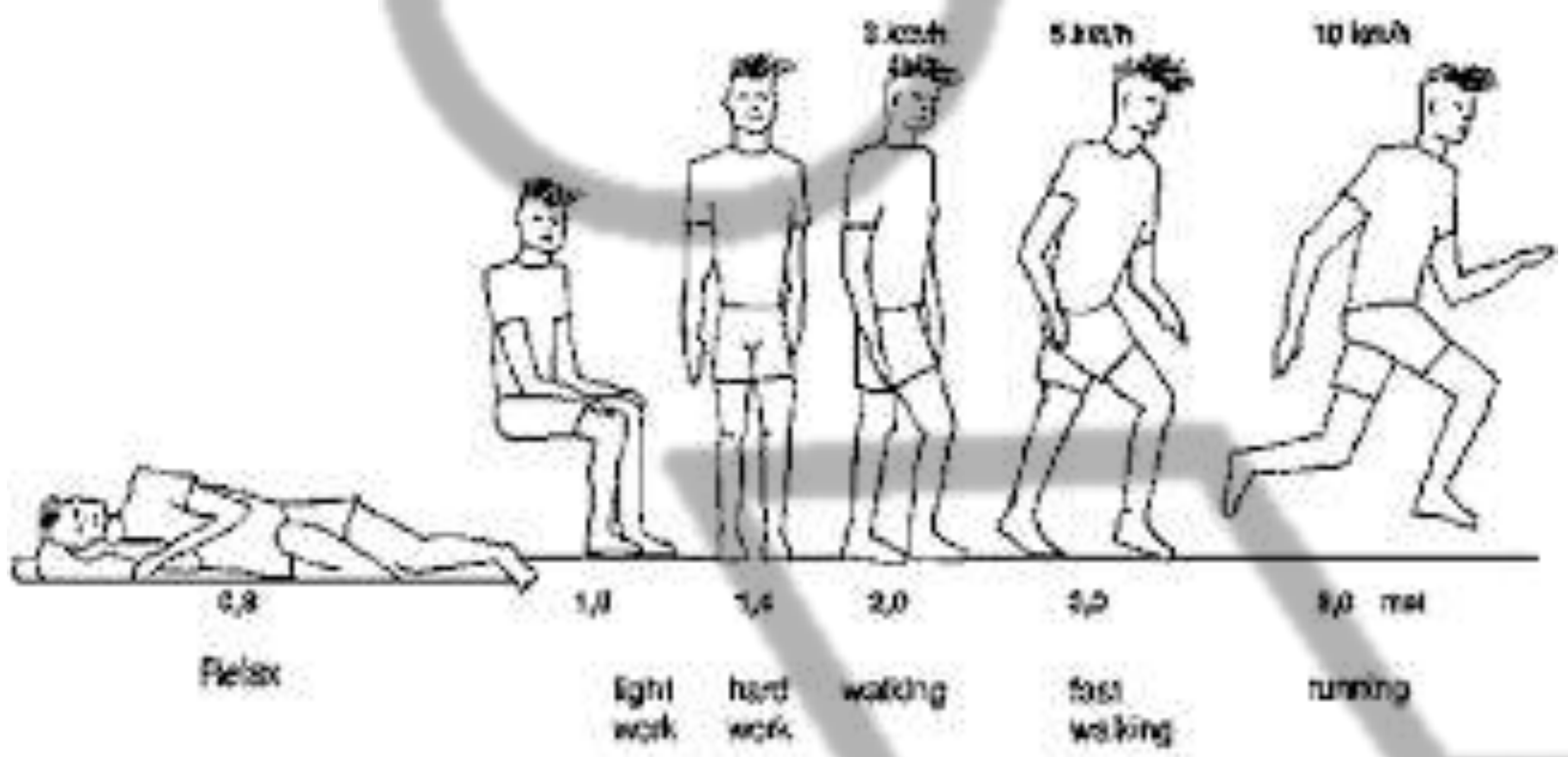
WIND CHILL- Siple e Passel del 1945 reviewed in 2001

Adaptive Comfort. Metabolism and Clothing



Adaptive Comfort. Metabolism and Clothing

MET - The Metabolic Rate



1met = 50kcal/hm²=0,05815Kw/hsqm

1 kcal = 4.190 J = 1.164 Wh.

1 BTU/h ft2= 5,6783 w/h mq
1 w/h mq= 0,17610904672173 BTU/h ft2
http://www.the-engineering-page.com/conv/u.html

1 BTU = 252 cal
1 BTU = 1,055056 kJ
1 W= 3,412 BTU/h = 1J/s
1 Kcal= 0,00116 Kw/h
http://www.convertworld.com

Table 4 Typical Metabolic Heat Generation for Various Activities

	$Btu/h \cdot ft^2$	met*
Resting		
Sleeping	13	0.7
Reclining	15	0.8
Seated, quiet	18	1.0
Standing, relaxed	22	1.2
Walking (on level surface)		
2.9 fps (2 mph)	37	2.0
4.4 fps (3 mph)	48	2.6
5.9 fps (4 mph)	70	3.8
Office Activities		
Reading, seated	18	1.0
Writing	18	1.0
Typing	20	1.1
Filing, seated	22	1.2
Filing, standing	26	1.4
Walking about	31	1.7
Lifting/packing	39	2.1
Driving/Flying		
Car	18 to 37	1.0 to 2.0
Aircraft, routine	22	1.2
Aircraft, instrument landing	33	1.8
Aircraft, combat	44	2.4
Heavy vehicle	59	3.2
Miscellaneous Occupational Activities		
Cooking	29 to 37	1.6 to 2.0
Housecleaning	37 to 63	2.0 to 3.4
Seated, heavy limb movement	41	2.2
Machine work		
sawing (table saw)	33	1.8
light (electrical industry)	37 to 44	2.0 to 2.4
heavy	74	4.0
Handling 110 lb bags	74	4.0
Pick and shovel work	74 to 88	4.0 to 4.8
Miscellaneous Leisure Activities		
Dancing, social	44 to 81	2.4 to 4.4
Calisthenics/exercise	55 to 74	3.0 to 4.0
Tennis, singles	66 to 74	3.6 to 4.0
Basketball	90 to 140	5.0 to 7.6
Wrestling, competitive	130 to 160	7.0 to 8.7

Sources: Compiled from various sources. For additional information, see Buskirk (1960), Passmore and Durnin (1967), and Webb (1964).
*1 met = 18.4 $Btu/h \cdot ft^2$

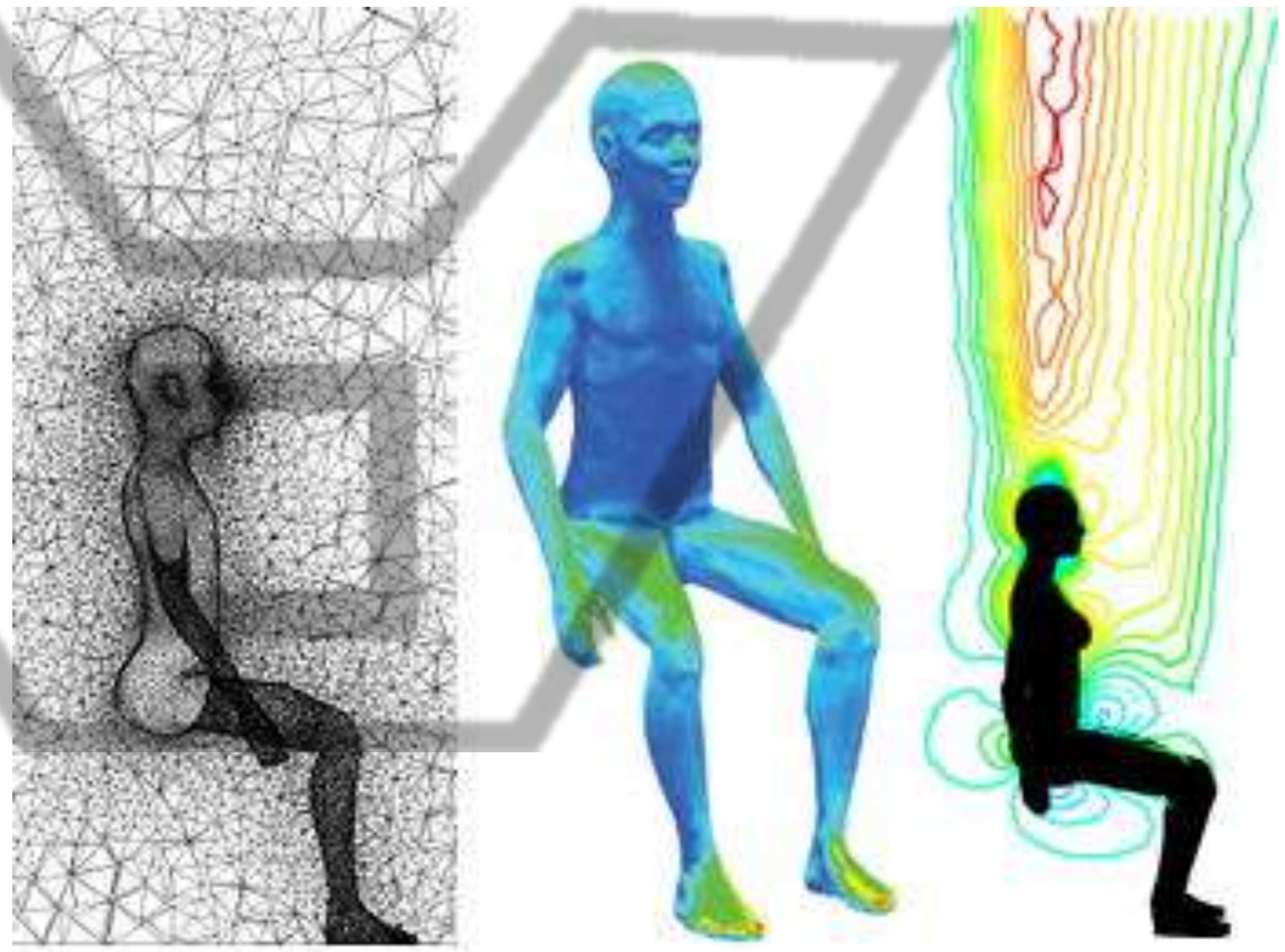
Adaptive Comfort. Metabolism and Clothing

MET - The Metabolic Rate

Sitting Activity Met = 1
= 50kcal/hsqm=0,05815Kw/hsqm

Average body surface
Male= 2 mq
Female= 1,75

100 watt/h



100 watt/h

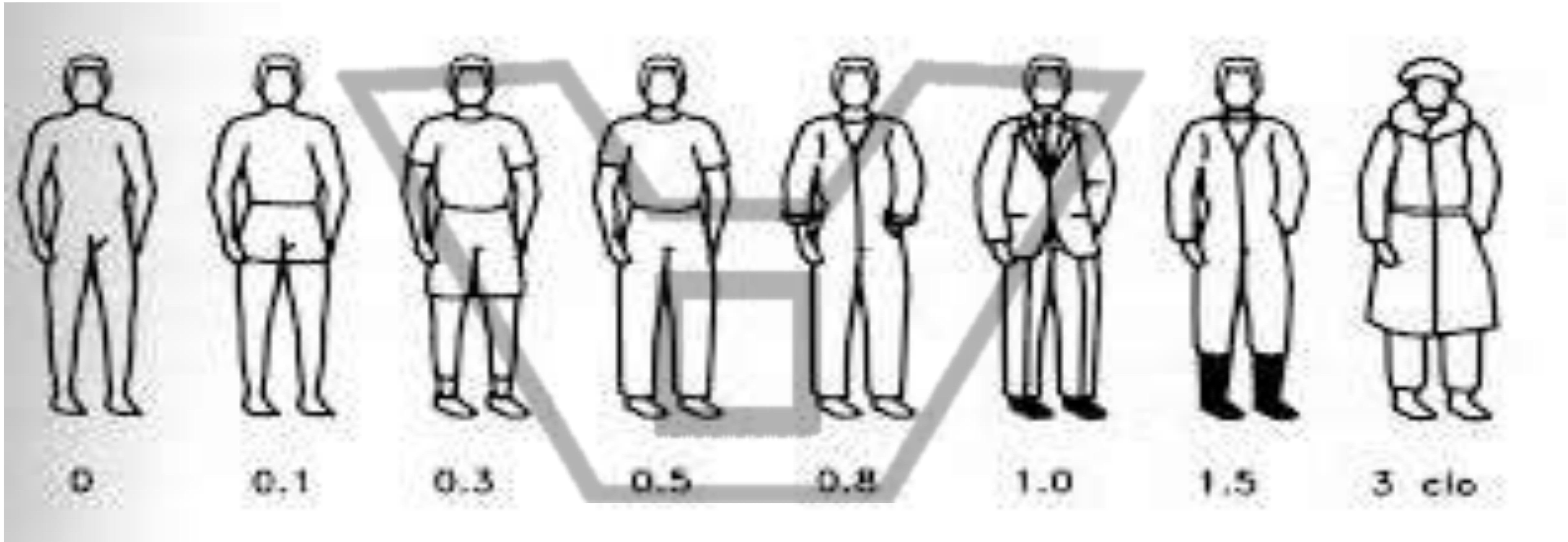
Adaptive Comfort. Metabolism and Clothing

MET - The Metabolic Rate

Converting the excess heat generated by the Stockholm Central Station's 2500 daily users to hot water and pump it to the nearby Kungsbrohuset office block.

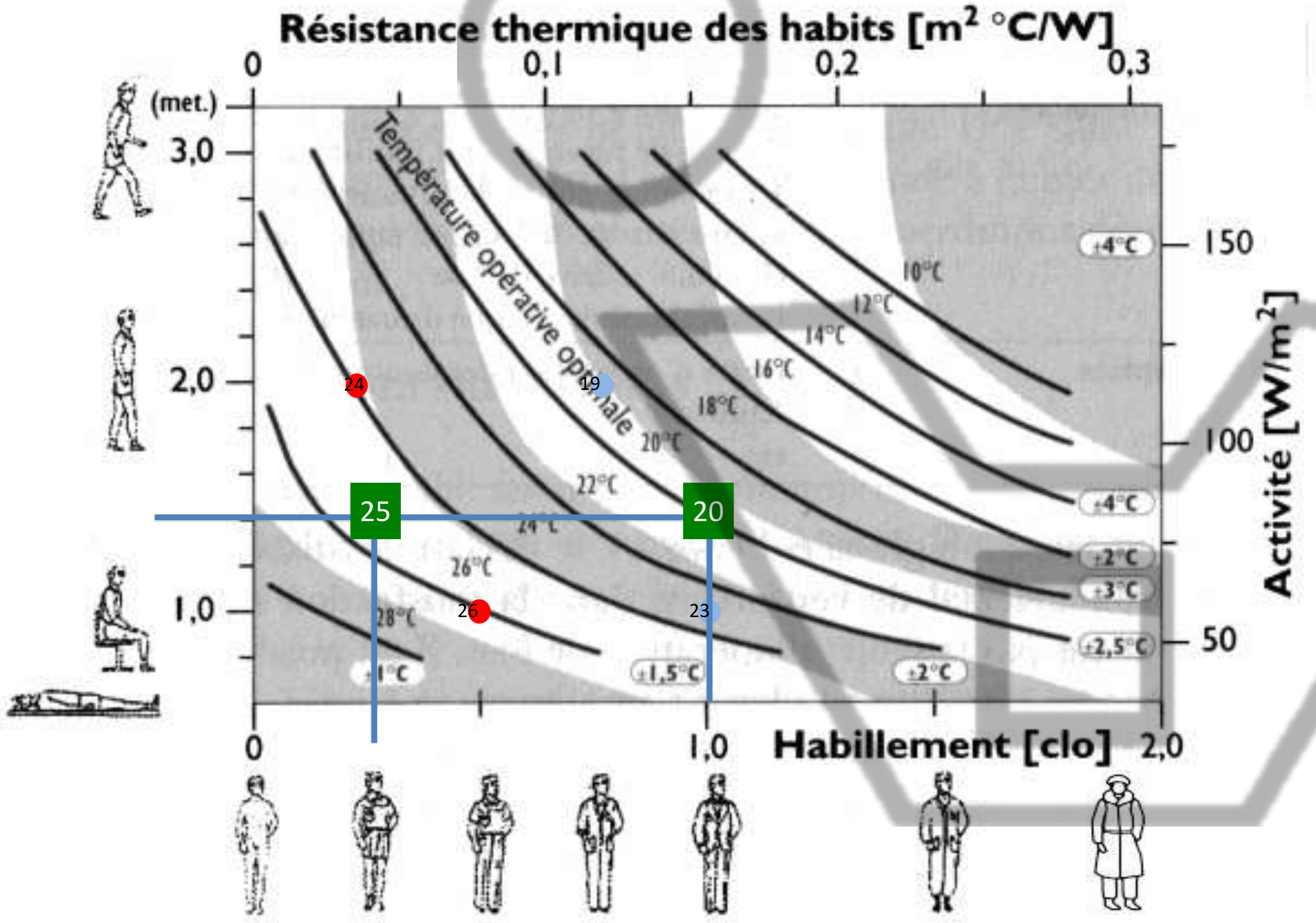
Adaptive Comfort. Metabolism and Clothing

CLO - The Clothing Rate



Adaptive Comfort. Metabolism and Clothing

Controlling thermal comfort by means of clothing



■ Comfort Temperature

Ideal Environmental temperature

Winter 19°-21°C
Summer 25°-26°C

Adaptive Comfort. Methods

ESTIMATING ACCETABLE INDOOR THERMAL COMFORT OVER STANDARDIZED VALUES USING AULICIEMS METHOD (1981)

Standard code

20 °C ± 2 C°

Auliciems A. et al, 2007, Thermal Comfort [pdf] Passive and Low Energy Architecture International in association with the Department of Architecture, The University of Queensland Brisbane

$$Tc=13{,}5+0{,}54To$$

Tc = comfort temperature
To = outdoor temperature

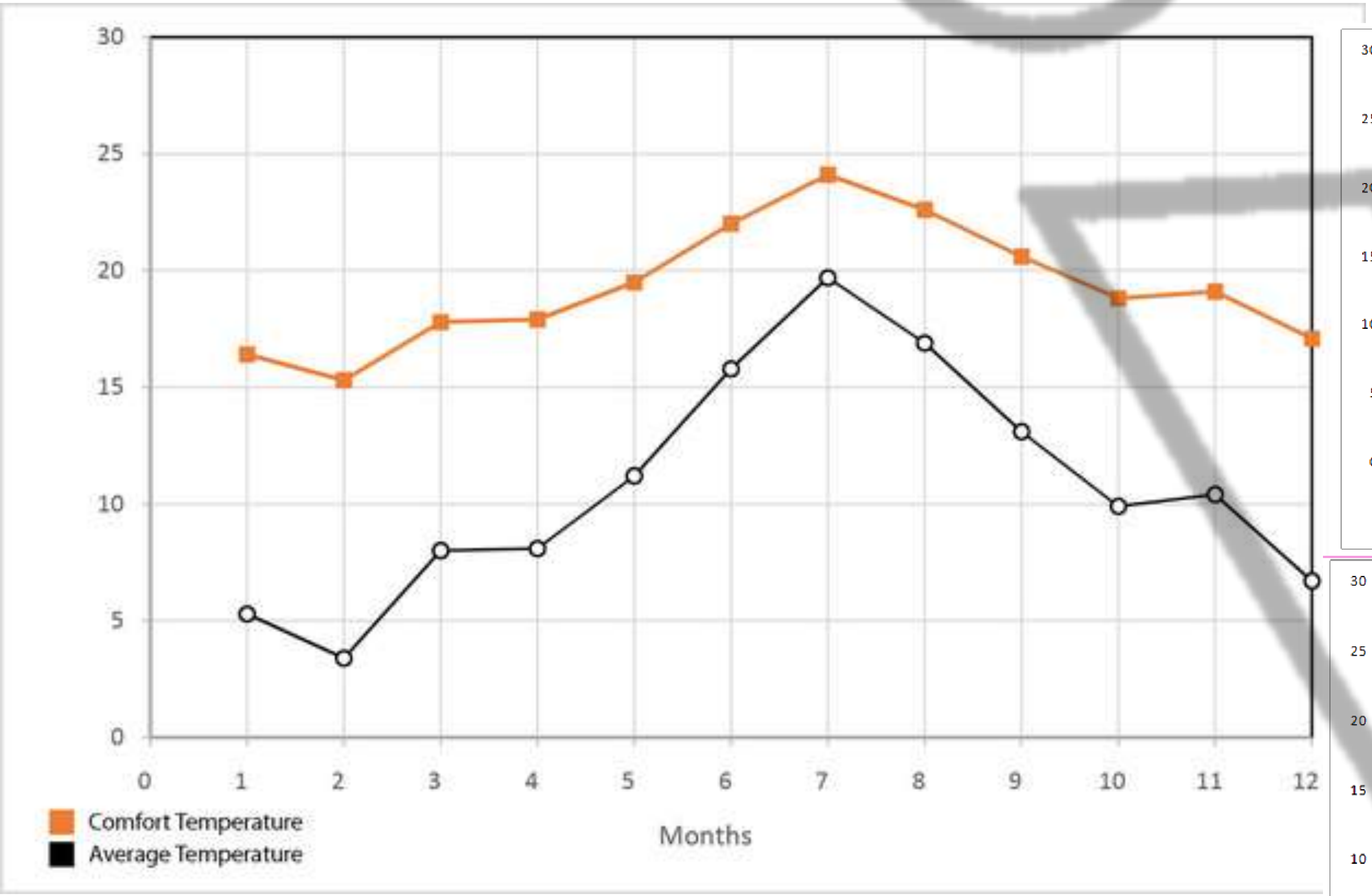
Month	Avg Temp (To)(°C)	Comfort Temp (Tc) (°C)	Temperature Difference	
January	5.3	16.4	11.1	WINTER
February	3.4	15.3	11.9	
March	8	17.8	9.8	SPRING
April	8.1	17.9	9.8	
May	11.2	19.5	8.3	
June	15.8	22	6.2	AUTUMN
July	19.7	24.1	4.4	
August	16.9	22.6	5.7	
September	13.1	20.6	7.5	SUMMER
October	9.9	18.8	8.9	
November	10.4	19.1	8.7	
December	6.7	17.1	10.4	WINTER

Temperature needed to achieve comfort

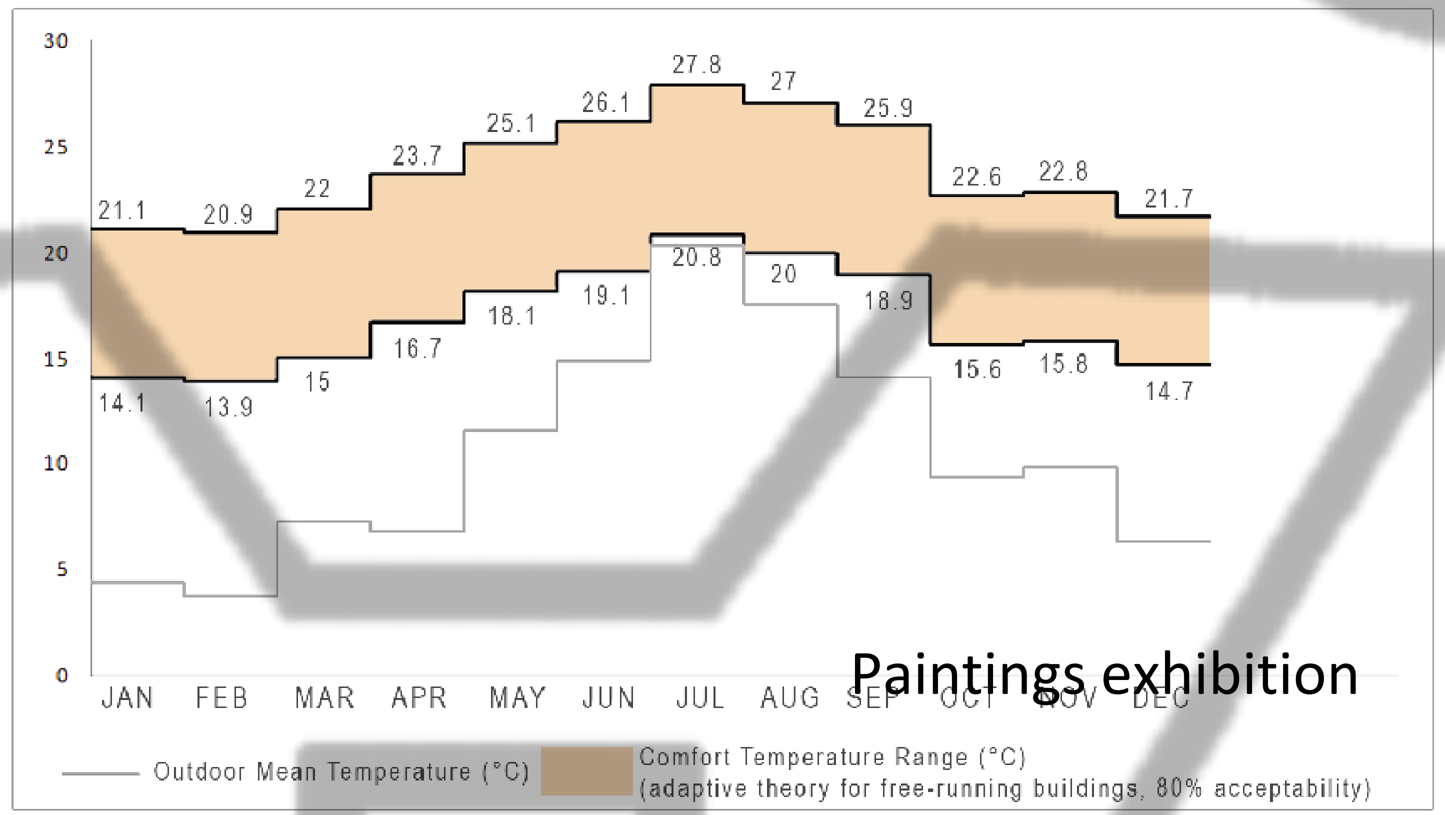
https://edplondon.weebly.com/comfort/estimating-the-comfort-temperature-using-the-equation-tc135054to-where-tc-is-the-comfort-temperature-and-to-is-the-outdoor-temperature

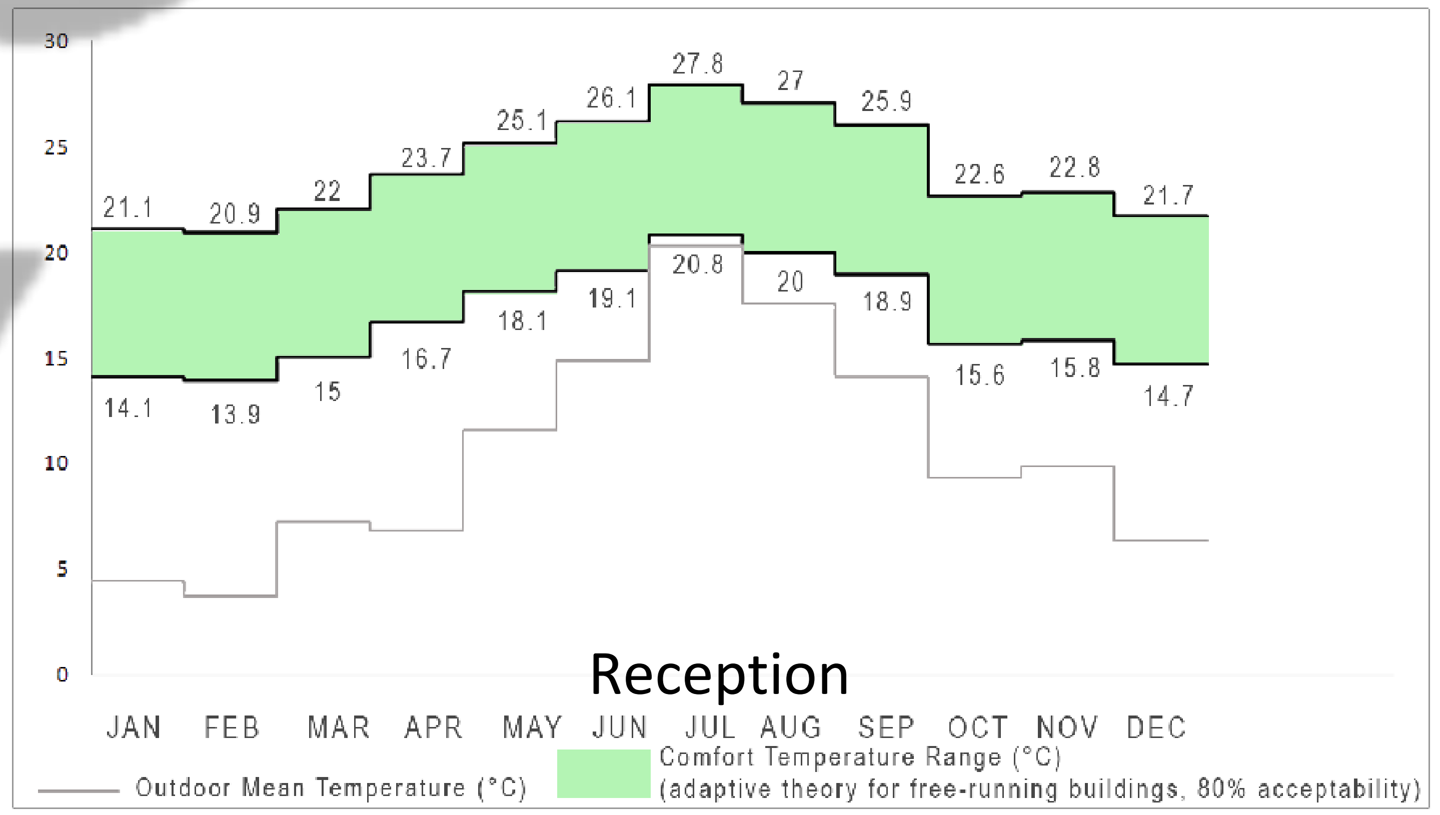
Adaptive Comfort. Methods

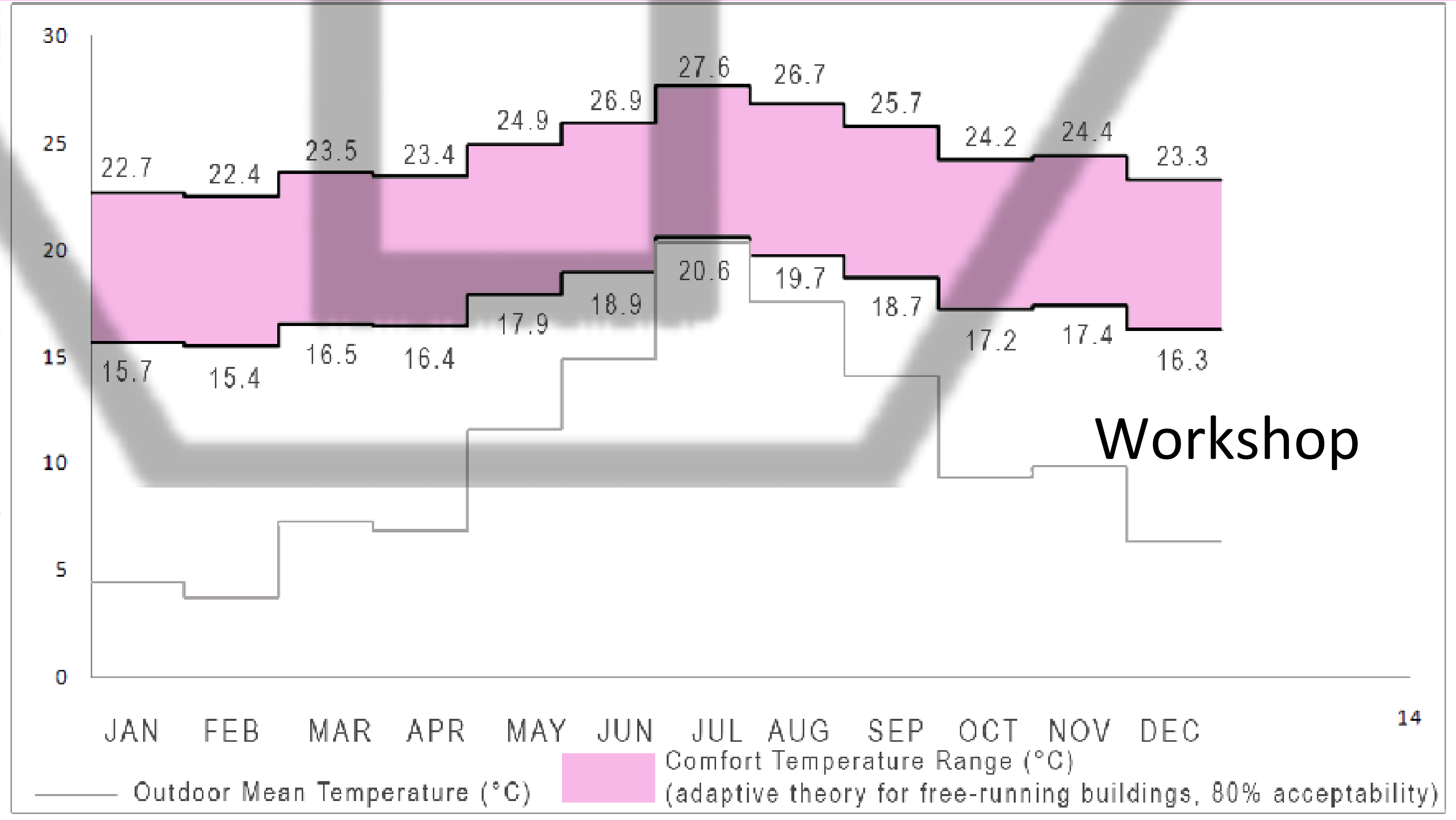
ESTIMATING ACCETABLE INDOOR THERMAL COMFORT OVER STANDARDIZED VALUES USING AULICIEMS METHOD (1981)

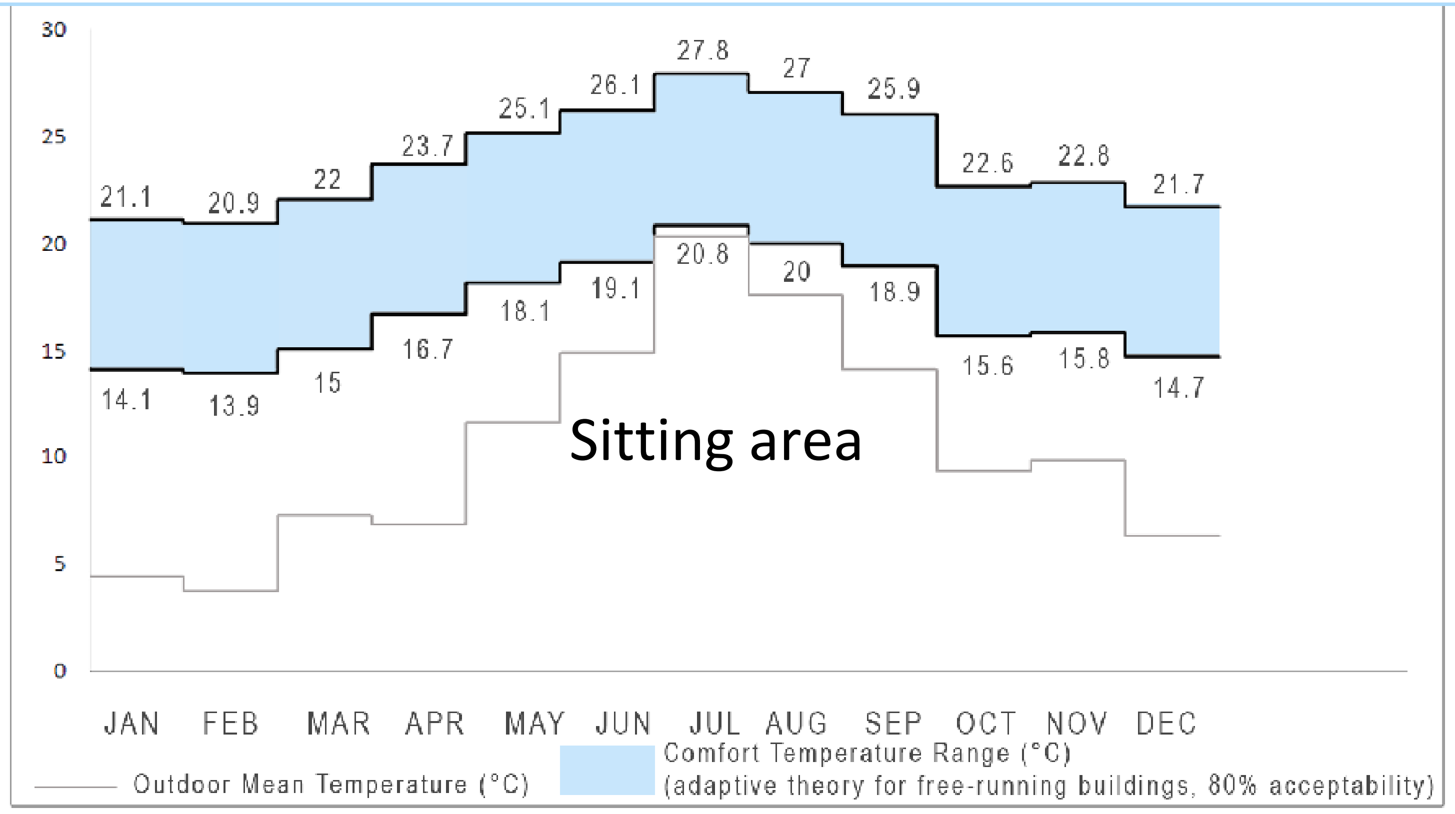


Linear relationship between outdoor temperature and comfort temperature (which is the basic principle of adaptive comfort)









https://edplondon.weebly.com/comfort/estimating-the-comfort-temperature-using-the-equation-tc135054to-where-tc-is-the-comfort-temperature-and-to-is-the-outdoor-temperature

Adaptive Comfort. Methods

OUTDOOR COMFORT METHODS

- Universal Thermal Comfort Index (**UTCI**)

UTCI follows the concept of an equivalent temperature.
This method summarises the interaction of environmental agents such as: **temperature, wind speed, and humidity, and radiation** (long- wave and short-wave radiant heat fluxes).

- Physiological Equivalent Temperature (**PET**)

PET is one of the most commonly used indices for measuring heat stress in outdoor spaces. It is the output of Munich Energy Balance Model for Individuals (MEM

INDOOR COMFORT METHODS

- Adaptive Method (**AM**)

proposed for spaces where occupants can control their thermal environment by means of clothing, operable windows, fans, personal heathers, and sun shaders

- Predicted Mean Vote (**PMV**)

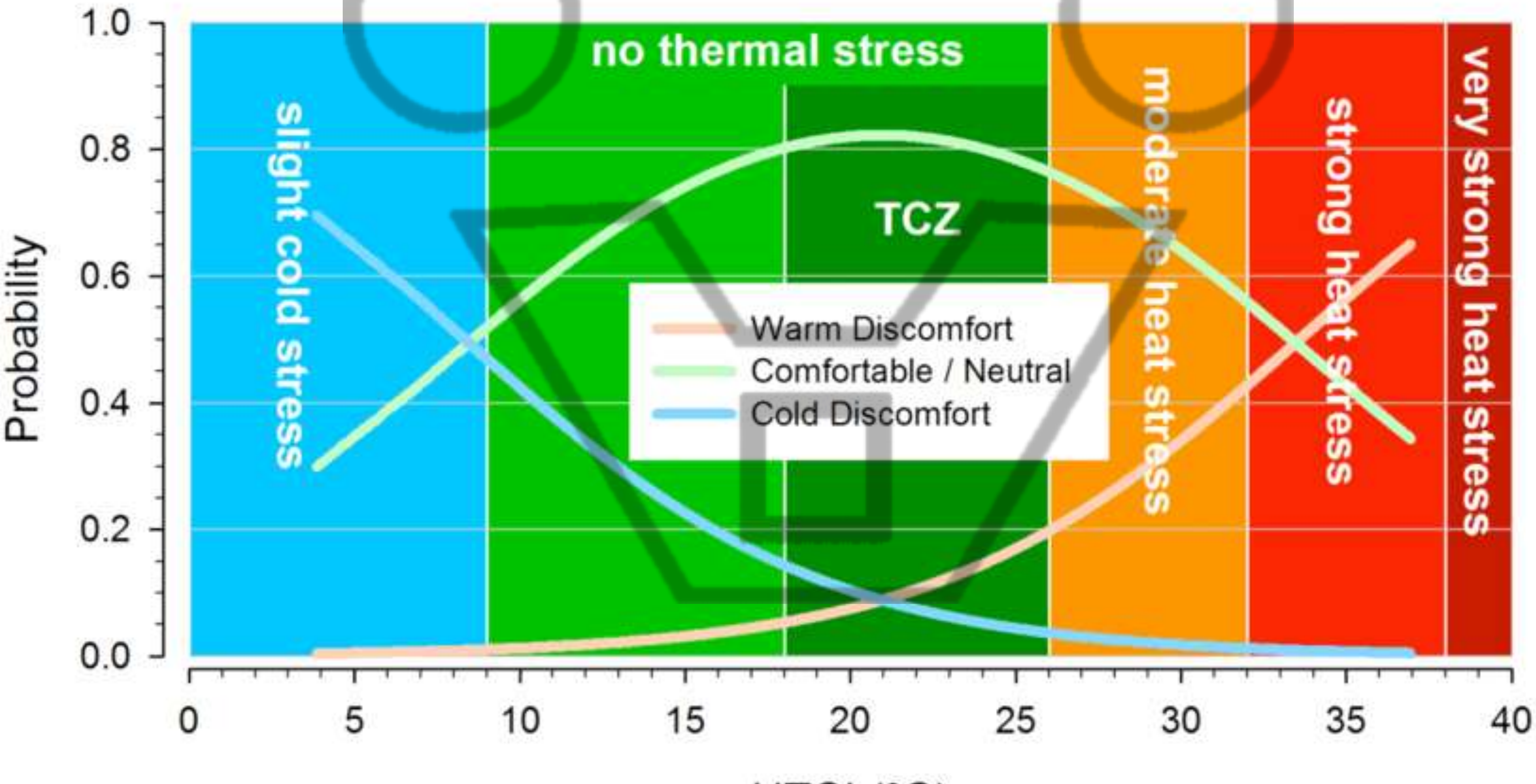
**Proposed by Fanger for controlled chamber under steady state conditions.
It uses four environmental parameters (including dry temperature, radiation temperature, wind speed, and relative humidity) and two human parameters (clothing insulation and metabolic rate).
It's range goes from -5 to +5. It's Benchmark should be around 0**

- Predicted Percentage Dissatisfied (**PPD**)

It's based on PMV and its value ranges goes from 0 to 100. It's Benchmark should be <20%

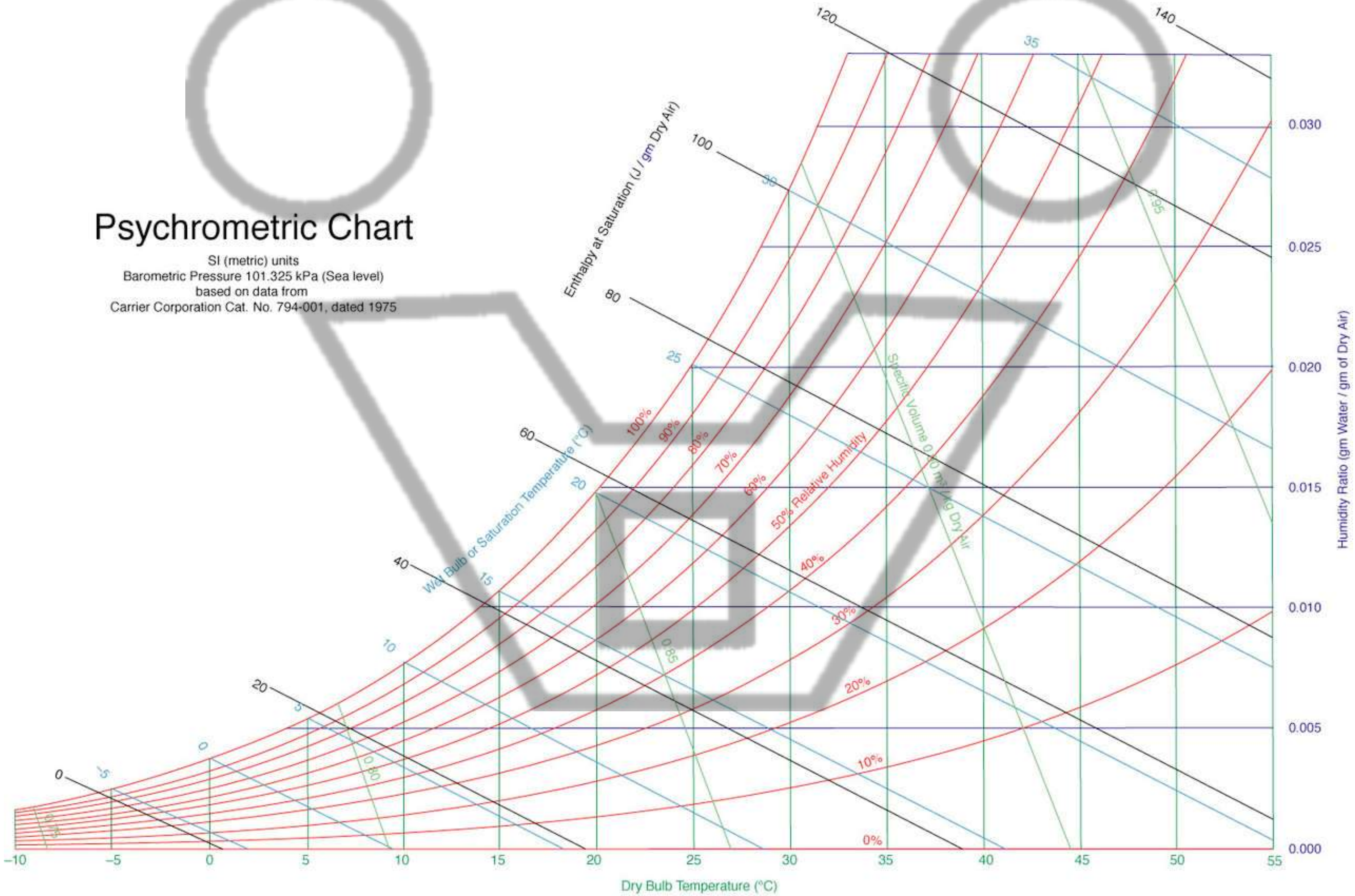
Adaptive Comfort. Methods

OUTDOOR COMFORT: UNIVERSAL THERMAL COMFORT INDEX



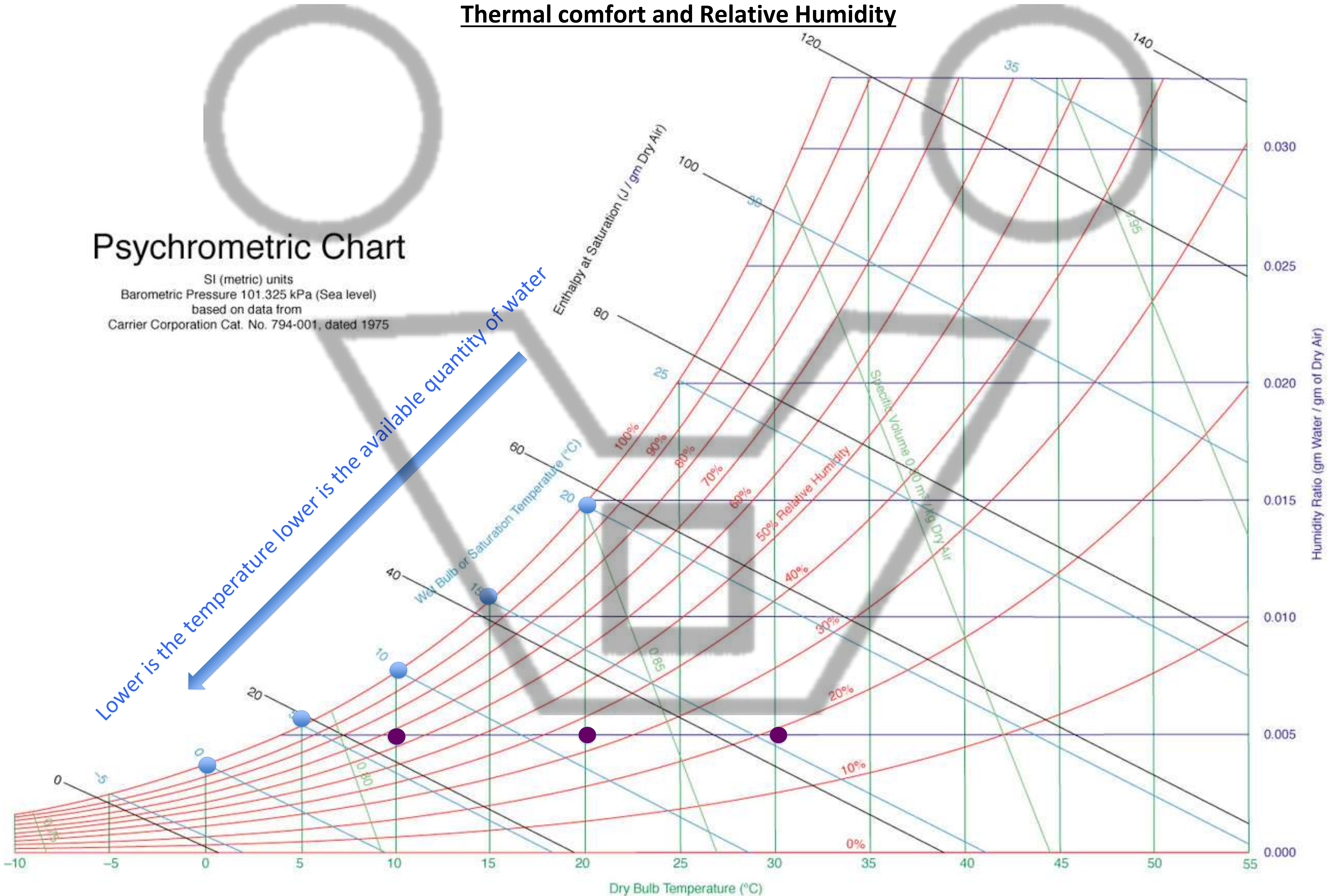
Adaptive Comfort. The Psychrometric Chart Tool

Thermal comfort and Relative Humidity



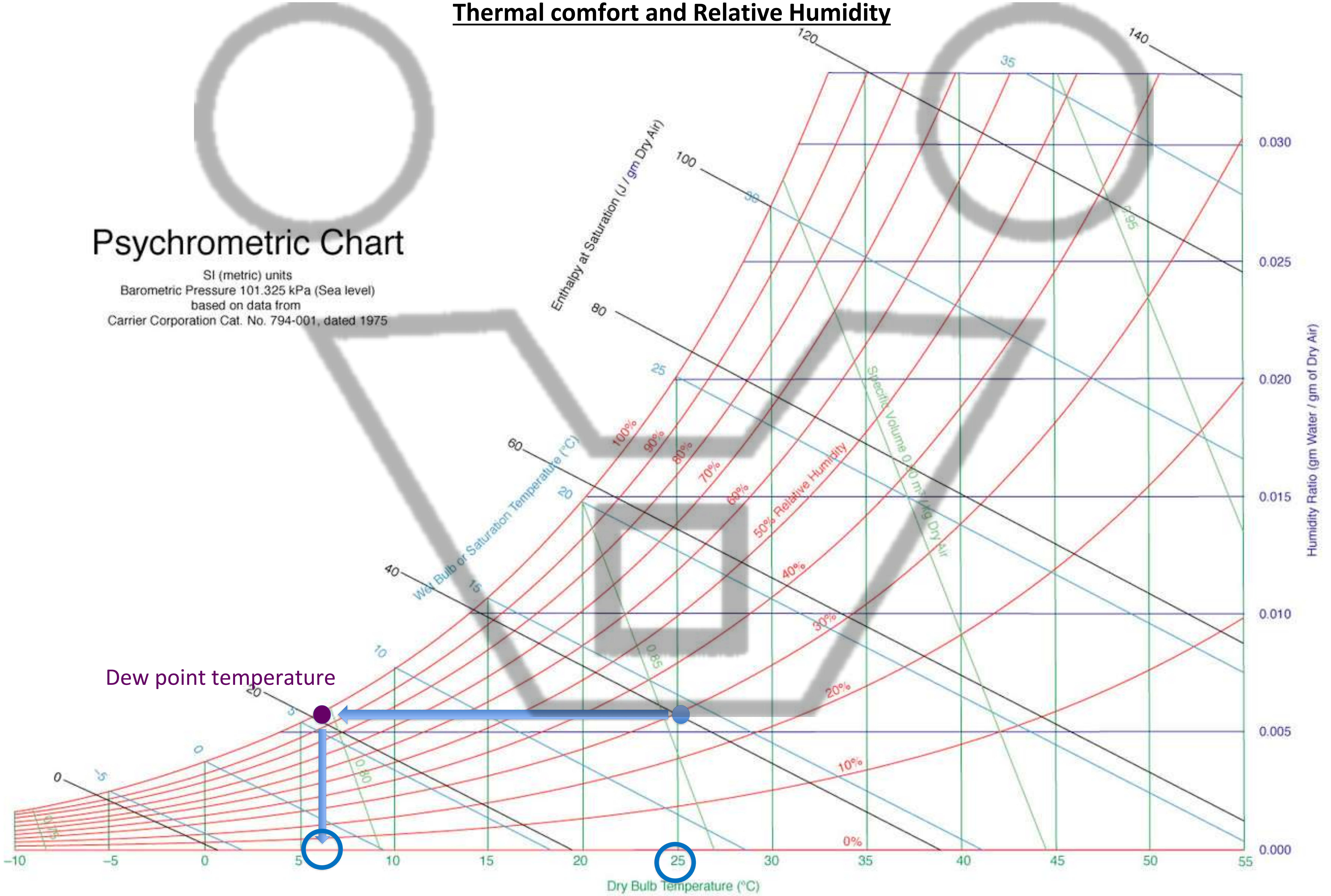
Adaptive Comfort. The Psychrometric Chart Tool

Thermal comfort and Relative Humidity



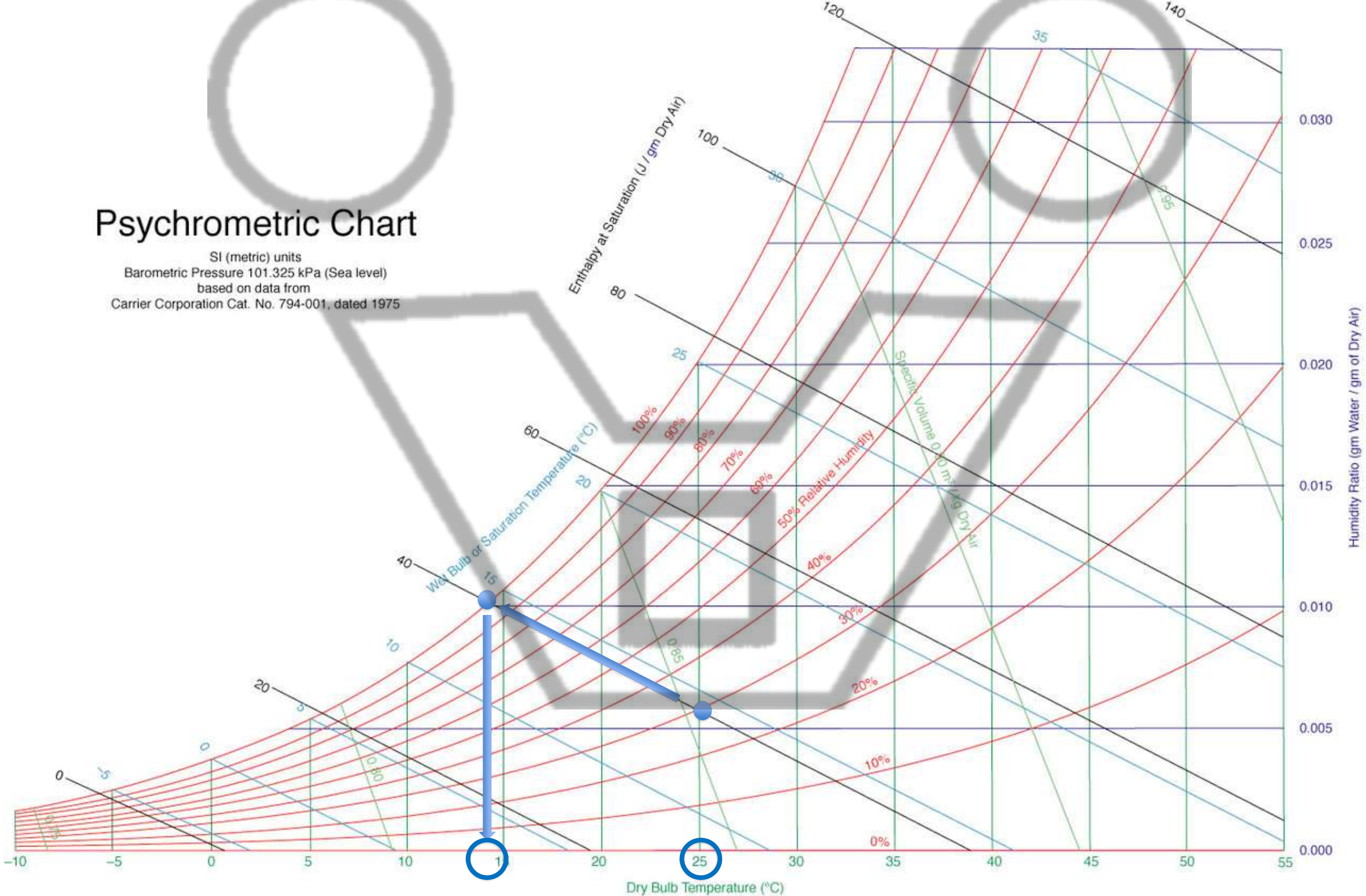
Adaptive Comfort. The Psychrometric Chart Tool

Thermal comfort and Relative Humidity

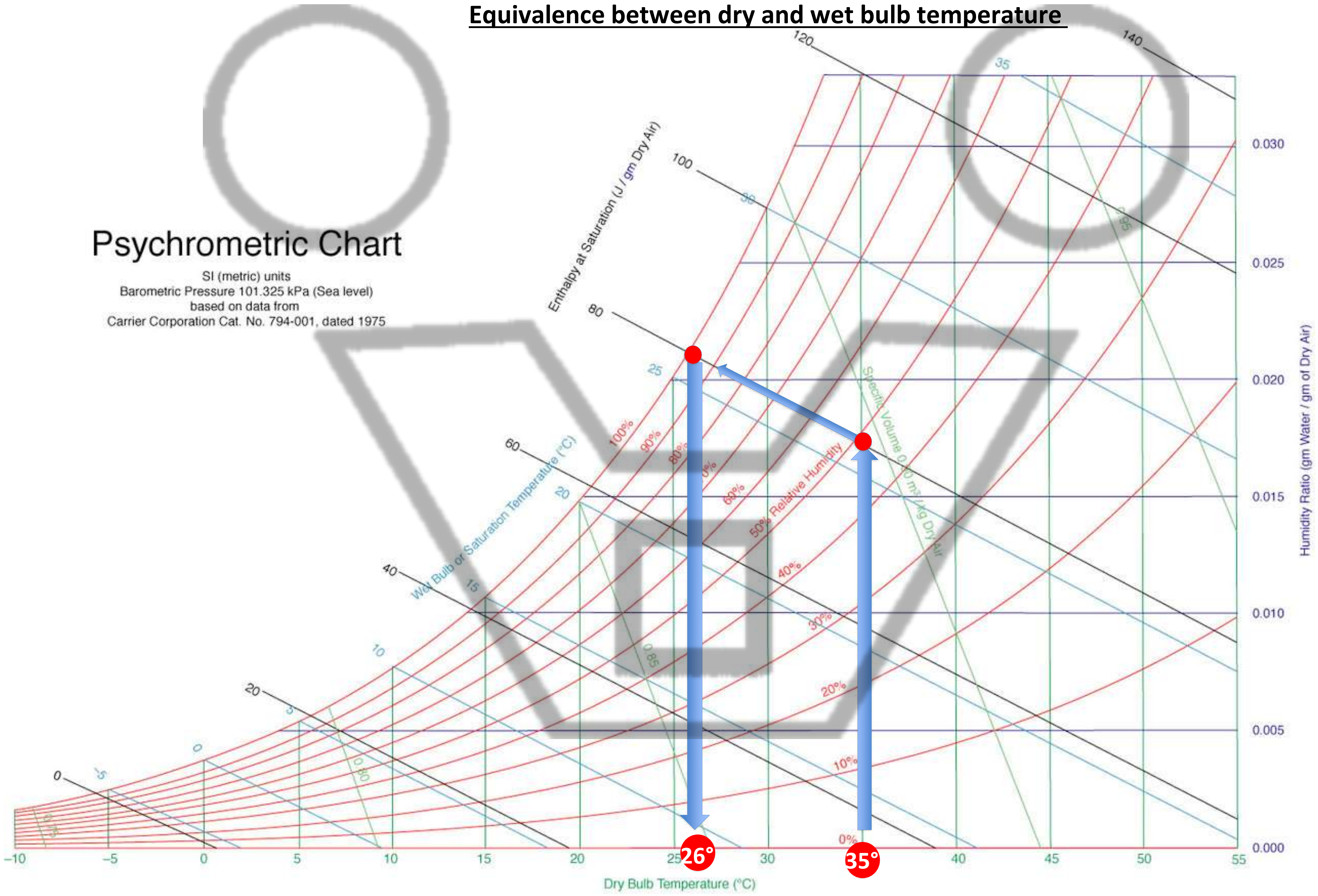


Adaptive Comfort. The Psychrometric Chart Tool

Equivalence between dry and wet bulb temperature



Adaptive Comfort. The Psychrometric Chart Tool

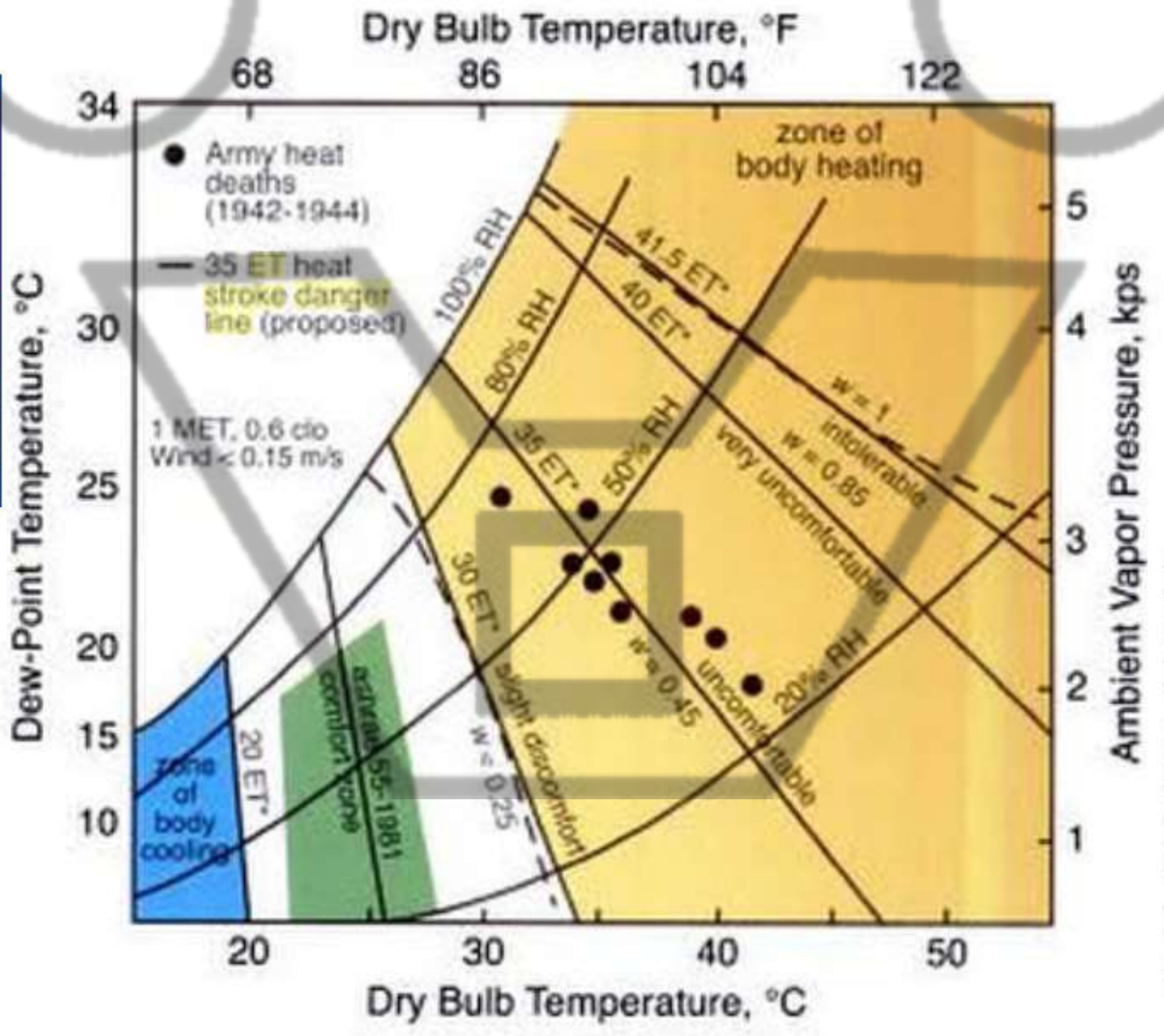


Adaptive Comfort. The Psychrometric Chart Tool

NOMOGRAM INTEGRATING EFFECTIVE TEMPERATURE

	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
42°	48	50	52	55	57	59	62	64	66	68	71	73	75	77	80	82
41°	46	48	51	53	55	57	59	61	64	66	68	70	72	74	76	79
40°	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75
39°	43	45	47	49	51	53	55	57	59	61	63	65	66	68	70	72
38°	42	44	45	47	49	51	53	55	56	58	60	62	64	66	67	69
37°	40	42	44	45	47	49	51	52	54	56	58	59	61	63	65	66
36°	39	40	42	44	45	47	49	50	52	54	55	57	59	60	62	63
35°	37	39	40	42	44	45	47	48	50	51	53	54	56	58	59	61
34°	36	37	39	40	42	43	45	46	48	49	51	52	54	55	57	58
33°	34	36	37	39	40	41	43	44	46	47	48	50	51	53	54	55
32°	33	34	36	37	38	40	41	42	44	45	46	48	49	50	52	53
31°	32	33	34	35	37	38	39	40	42	43	44	45	47	48	49	50
30°	30	32	33	34	35	36	37	39	40	41	42	43	45	46	47	48
29°	29	30	31	32	33	35	36	37	38	39	40	41	42	43	45	46
28°	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
27°	27	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
26°	26	26	27	28	29	30	31	32	33	34	34	35	36	37	38	39
25°	25	25	26	27	27	28	29	30	31	32	33	34	34	35	36	37
24°	24	24	24	25	26	27	28	28	29	30	31	32	33	33	34	35
23°	23	23	23	24	25	25	26	27	28	28	29	30	31	32	32	33
22°	22	22	22	22	23	24	25	25	26	27	27	28	29	30	30	31

Fino a 29 C°	Nessun disagio
Da 30 a 34 C°	Sensazione di disagio
Da 35 a 39 C°	Intenso disagio. Prudenza: limitare le attività fisiche più pesanti
Da 40 a 45 C°	Forte sensazione di malessere. Pericolo: evitare gli sforzi
Da 46 a 53 C°	Pericolo grave: interrompere tutte le attività fisiche
Oltre 54 C°	Pericolo di morte: colpo di calore imminente

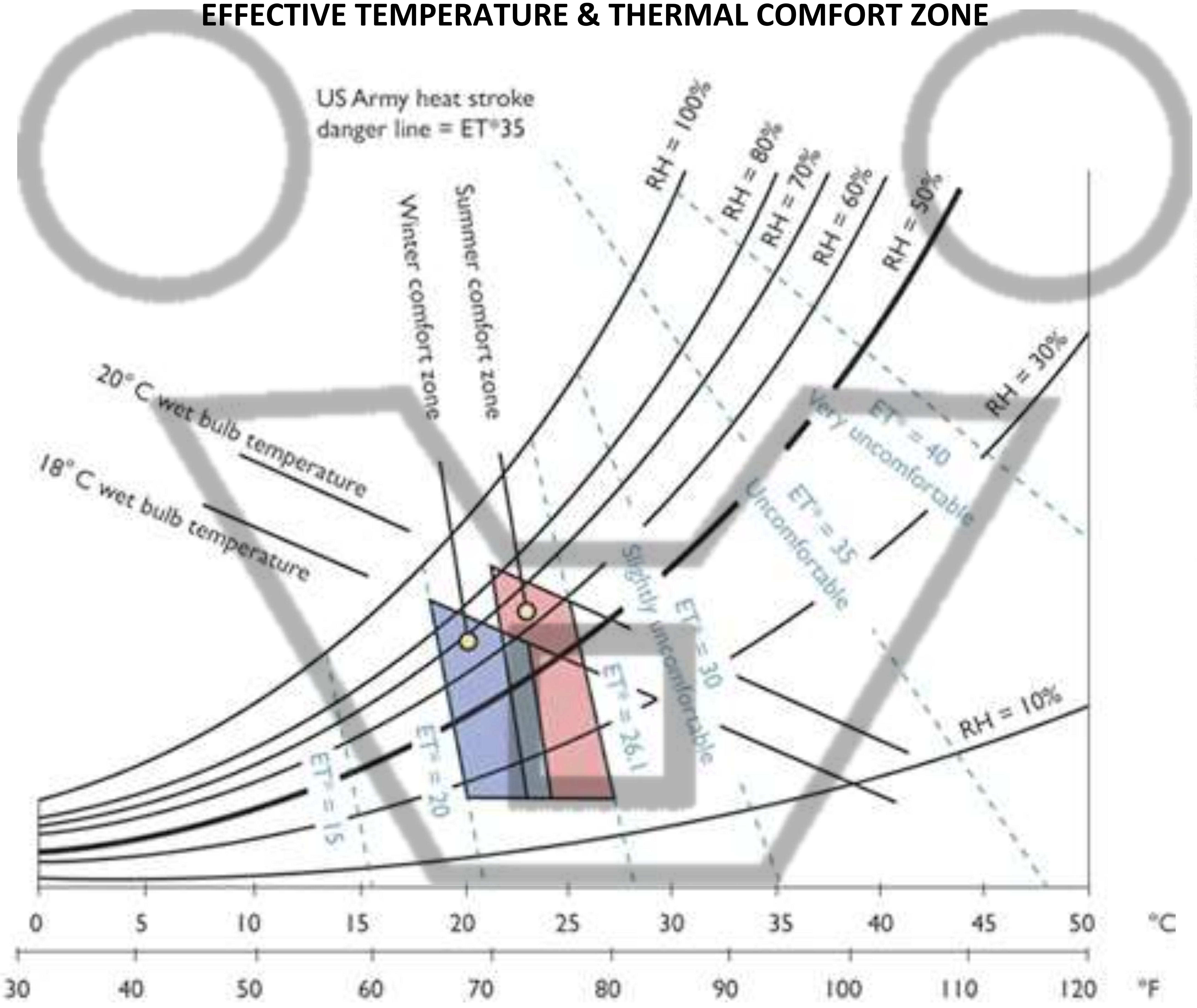


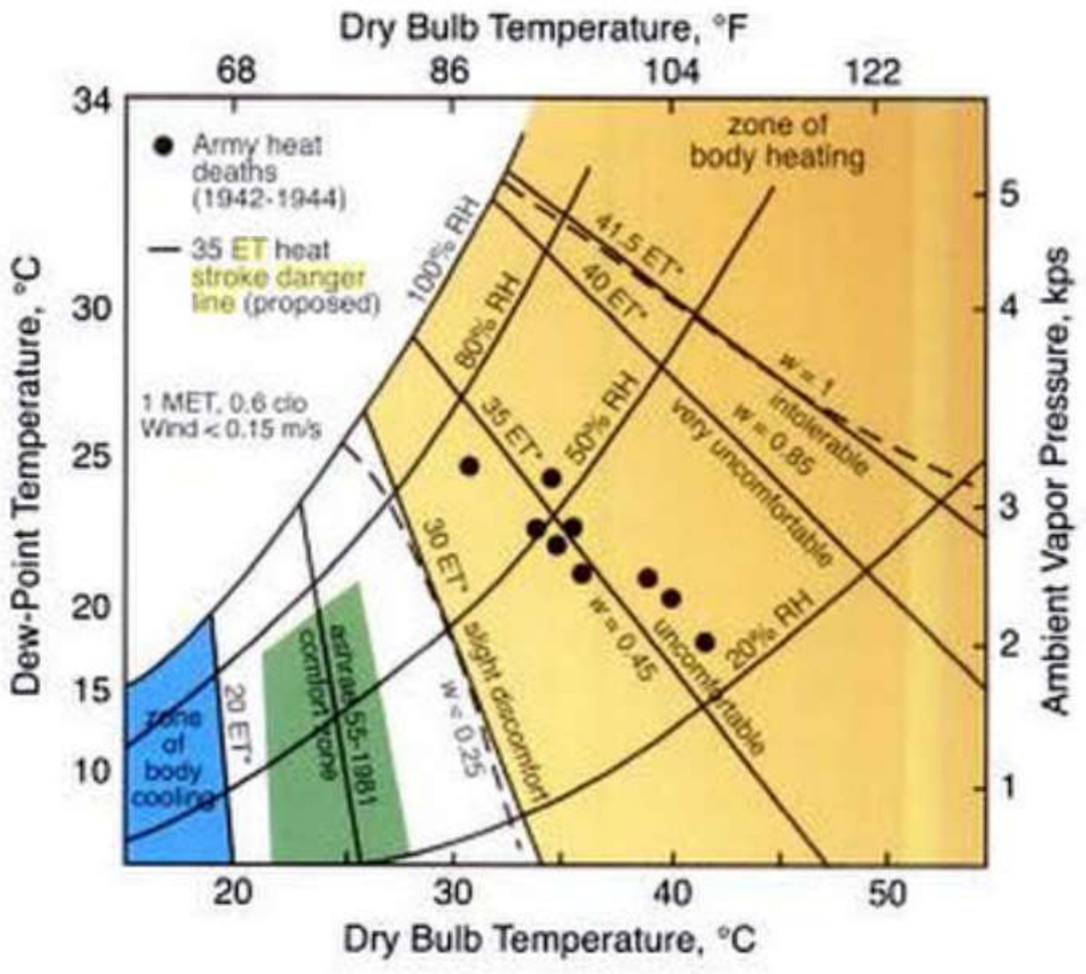
Condition:
MET: 1
CLO: 1

Fig. 8-8. Nomogram for the "new," effective temperature (ET*), including data points for US Army heat deaths provided by Hardy. ashrae: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc; clo: unit of clothing insulation, 1 clo = 0.155 m^2 K/W; MET: unit of metabolism, 1 MET = 58.15 W/m^2. RH: relative humidity. Illustration: Adapted with permission from ASHRAE. Copyright 2005 © American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc (www.ashrae.org). Reprinted with permission from the 2005 *ASHRAE Handbook—Fundamentals.* (This text may not be copied nor distributed in either paper or digital form without ASHRAE's permission.) Data source: Hardy JD. Thermal comfort and health. *ASHRAE J.* 1971;13:43.

Adaptive Comfort. The Psychrometric Chart Tool

EFFECTIVE TEMPERATURE & THERMAL COMFORT ZONE





Thermal comfort= f (TEMPERATURE, WIND, HUMIDITY, METABOLIC RATE, DRE

Adaptive Comfort. Computational Tool

INDOOR COMFORT

CBE CENTER FOR THE BUILT ENVIRONMENT

THERMAL COMFORT TOOL

>to access the tool: http://comfort.cbe.berkeley.edu/EN

INDOOR COMFORT METHODS

- Adaptive Method (AM)

proposed for spaces where occupants can control their thermal environment
by means of clothing, operable windows, fans, personal heathers, and sun shaders

- Predicted Mean Vote (PMV)

Proposed by Fanger for controlled chamber under steady state conditions.
It uses four environmental parameters (including dry temperature, radiation temperature, wind speed, and relative humidity) and two human parameters (clothing insulation and metabolic rate).
It's range goes from -5 to +5. It's Benchmark should be around 0

- Predicted Percentage Dissatisfied (PPD)

It's based on PMV and its value ranges goes from 0 to 100. It's Benchmark should be <20%

Adaptive Comfort. Hygrothermic Computational Tool

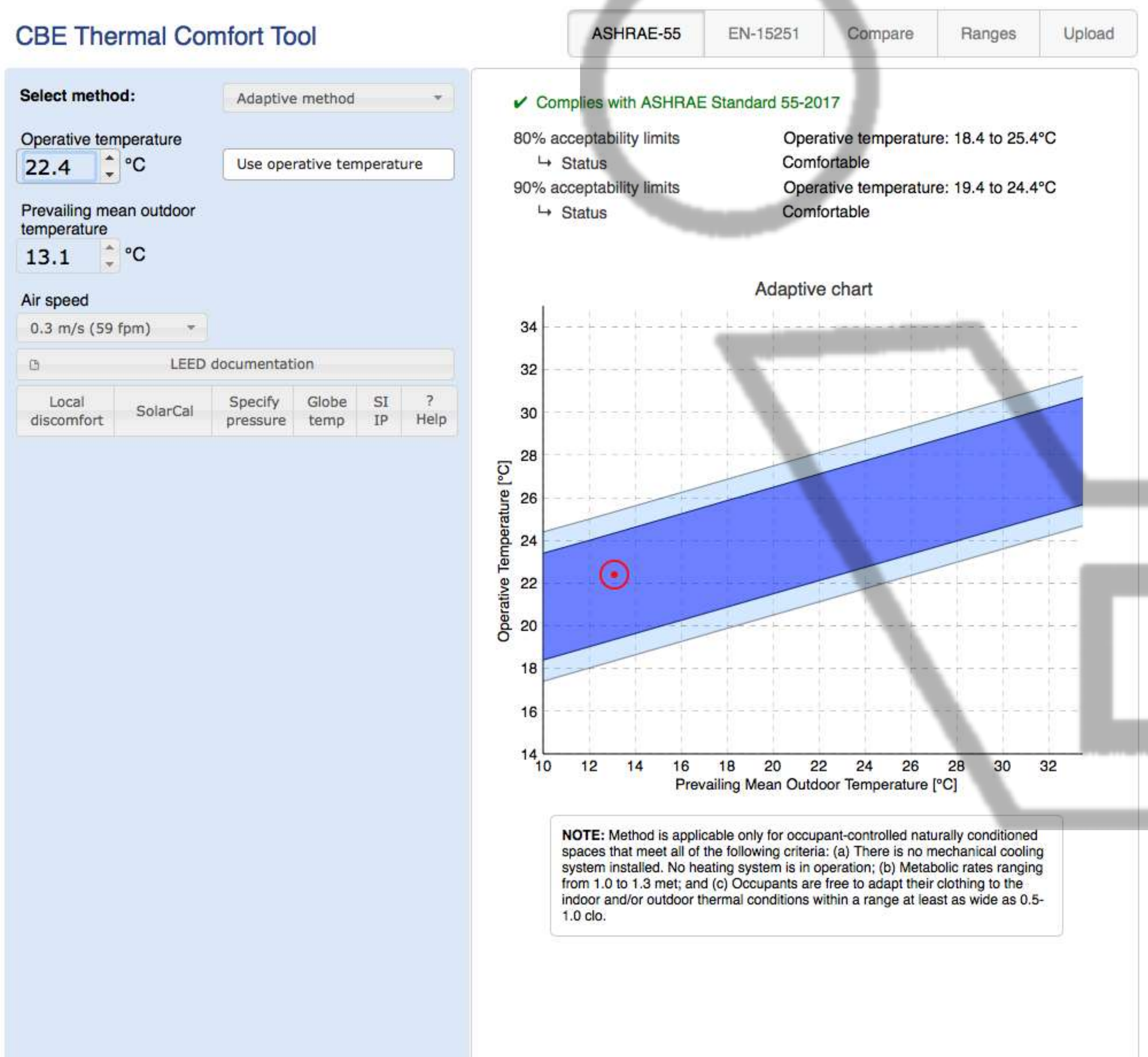
INDOOR COMFORT

CBE CENTER FOR THE BUILT ENVIRONMENT THERMAL COMFORT TOOL

>to access the tool: http://comfort.cbe.berkeley.edu/EN

Adaptive Comfort. Hygrothermic Computational Tool

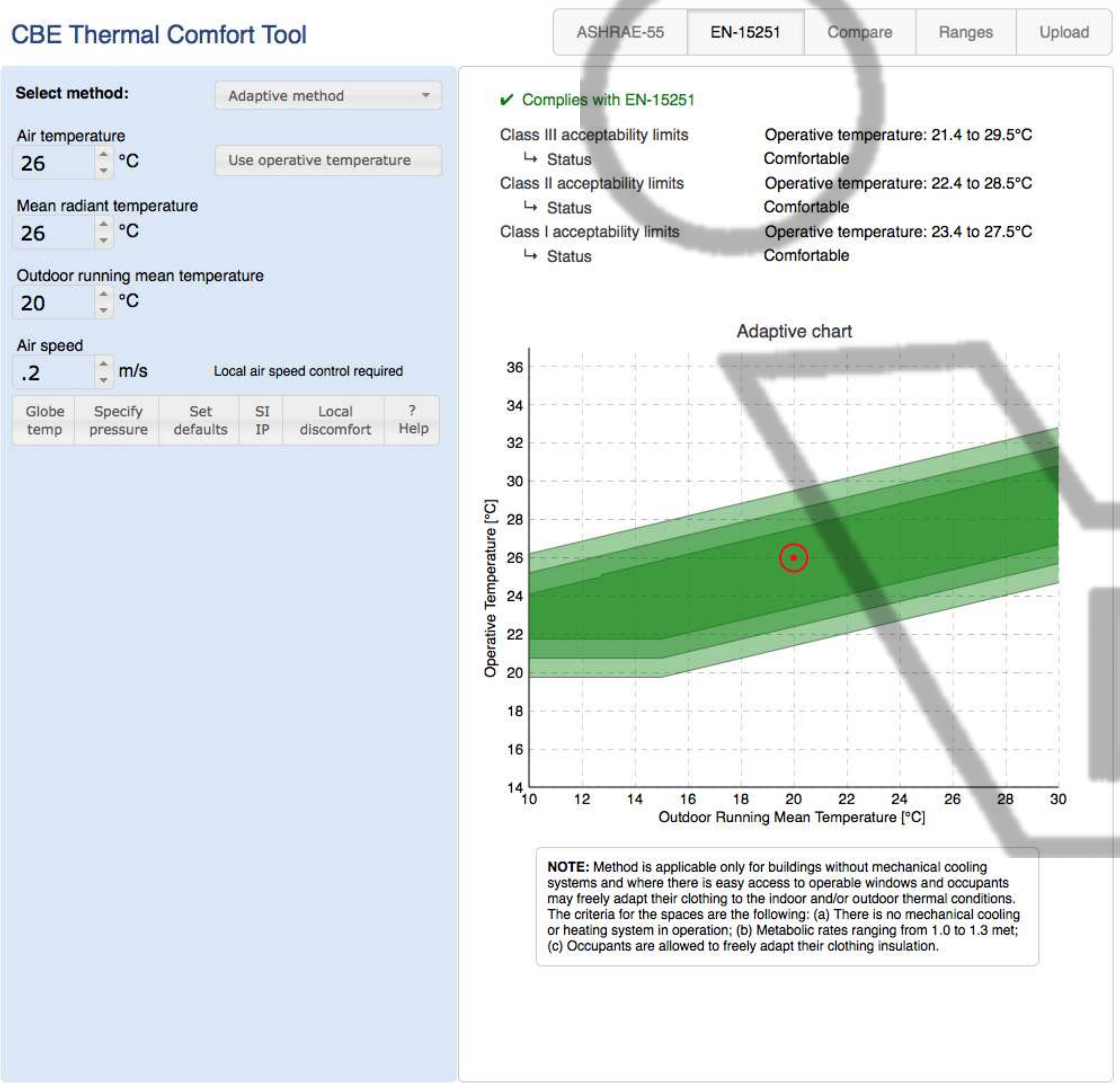
INDOOR THERMAL COMFORT USING ADAPTIVE METHOD (ASHRAE 55-2017)



NOTE: Method is applicable only for occupant-controlled naturally conditioned spaces that meet all of the following criteria: (a) There is no mechanical cooling system installed. No heating system is in operation; (b) Metabolic rates ranging from 1.0 to 1.3 met; and (c) Occupants are free to adapt their clothing to the indoor and/or outdoor thermal conditions within a range at least as wide as 0.5-1.0 clo.

Adaptive Comfort. Hygrothermic Computational Tool

INDOOR THERMAL COMFORT USING ADAPTIVE METHOD (EN-15251)



NOTE: Method is applicable only for buildings without mechanical cooling systems and where there is easy access to operable windows and occupants may freely adapt their clothing to the indoor and/or outdoor thermal conditions. The criteria for the spaces are the following: (a) There is no mechanical cooling or heating system in operation; (b) Metabolic rates ranging from 1.0 to 1.3 met; (c) Occupants are allowed to freely adapt their clothing insulation.

Through this tool is possible to visualize the range of comfort when people are able to adapt their clothes, metabolism and… windows

Adaptive Comfort. Hygrothermic Computational Tool

INDOOR THERMAL COMFORT USING ADAPTIVE METHOD (ASHRAE 55-2017)

>> TO BE USED FOR ASSIGNMENT <<

0. Set ASHRAE-55. Set EN-15251 for EU context

1. Set PMV method

5. Adjust Air & Main radiant temperature (same value) unitll the red dot is on the middle of the graph. **That is the raccomended value for that functional activity and space**

2. Set Air speed 0.1

3. Set Humidity 40% *

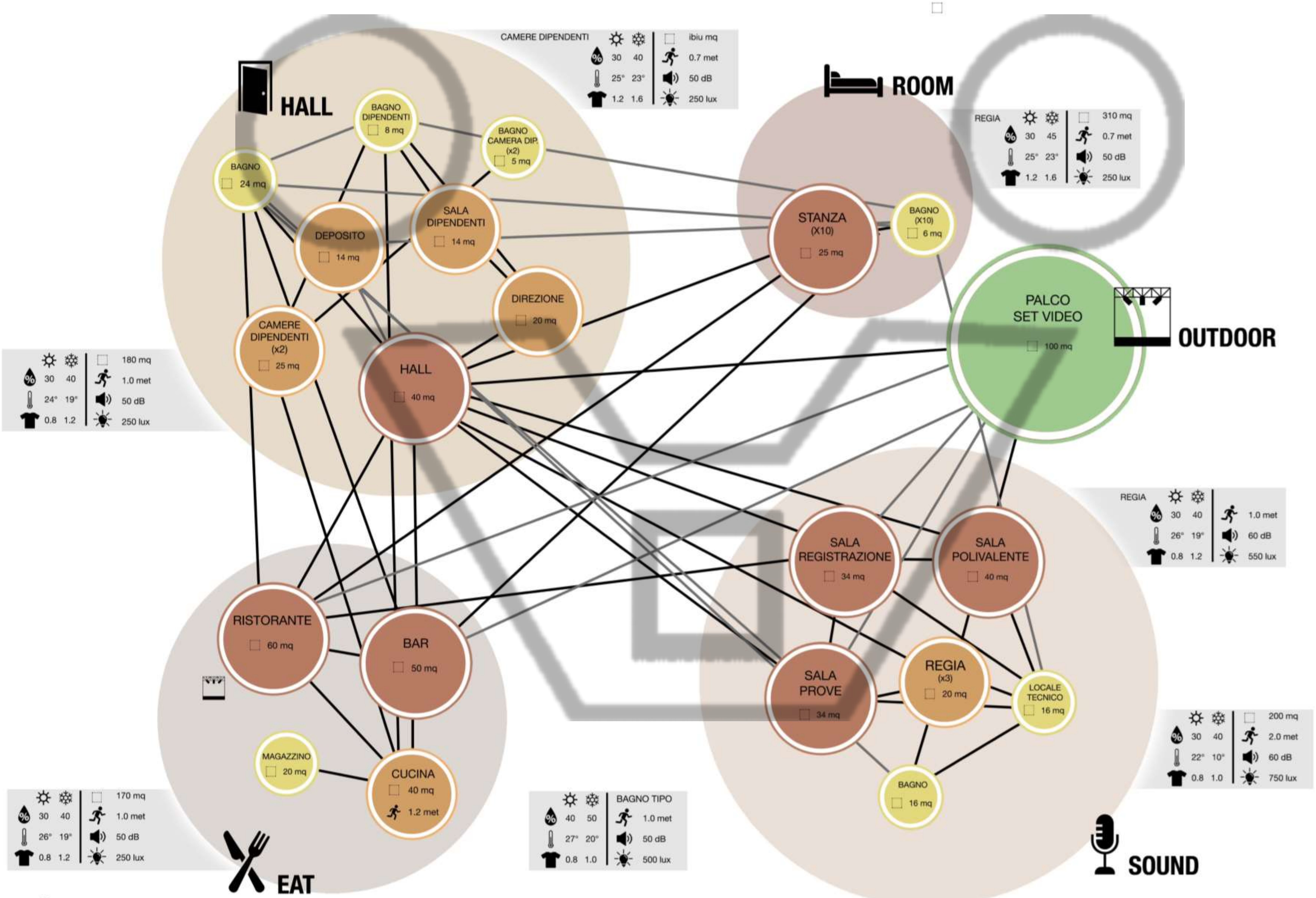
4. Set Methabolic rate & Clothing Rate according to the analyzed activity

* Alternatives temperatures values for each functional values can be checked modifying Humidity (30-55%)

...and compare results with temperature values established by national codes

In this psychrometric chart the abscissa is the dry-bulb temperature, and the mean radiant temperature (MRT) is fixed, controlled by the inputbox. Each point on the chart has the same MRT, which defines the comfort zone boundary. In this way you can see how changes in MRT affect thermal comfort. You can also still use the operative temperature button, yet each point will have the same MRT

Adaptive Comfort. Thermal Environmental Cluster



Adaptive Comfort. Thermal Environmental Cluster