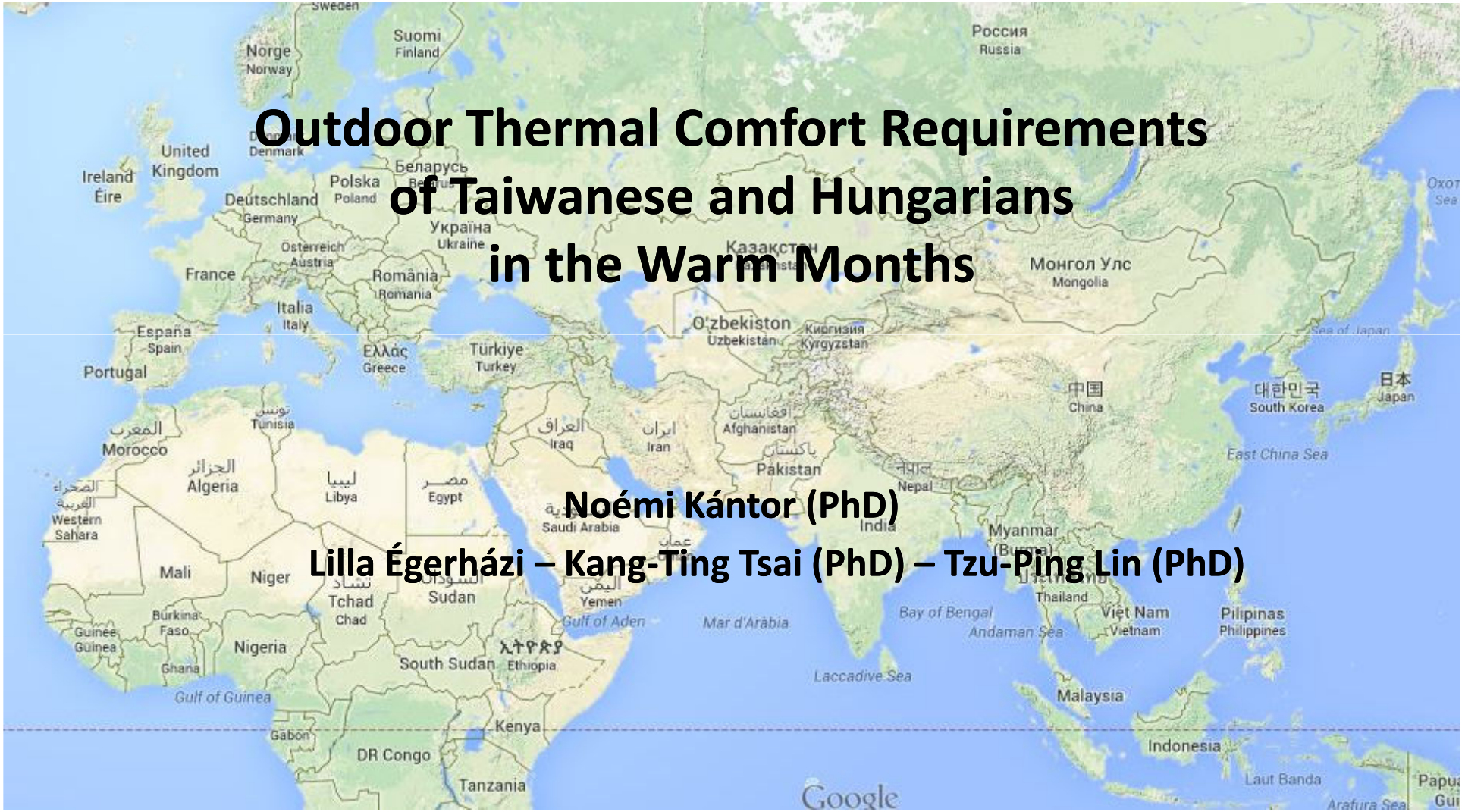
Outdoor Thermal Comfort Requirements of Taiwanese and Hungarians in the Warm Months



Noémi Kántor (PhD)

Lilla Égerházi – Kang-Ting Tsai (PhD) – Tzu-Ping Lin (PhD)

20th International Congress of Biometeorology 28 September - 1 October 2014

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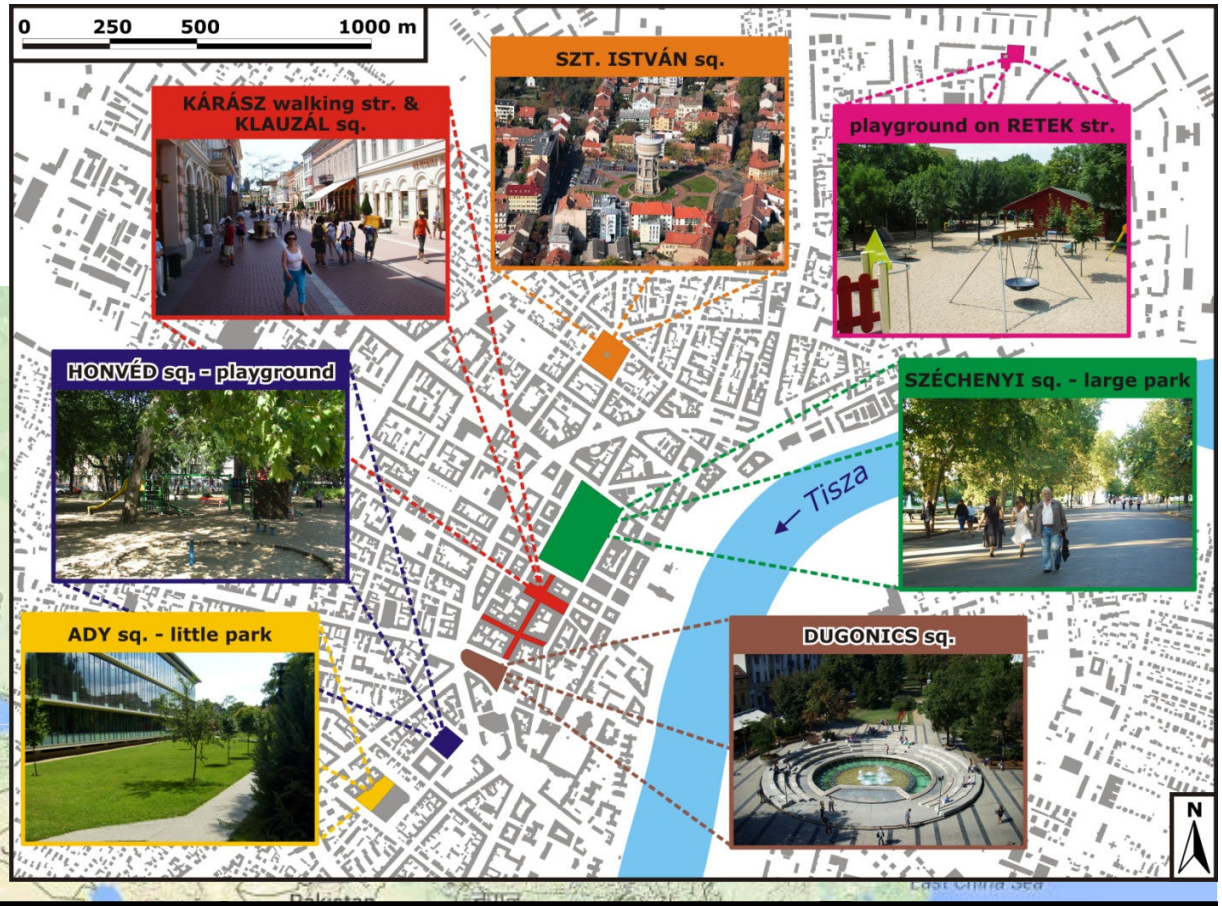
Landscape Ecology
University of Szeged,
Szeged, Hungary



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1st Hungarian questionnaire-project

- 2 recreational places
- 12 am – 3 pm
- spring & autumn

Kántor et al. 2012a
→Hungarian results

Kántor et al. 2012b
→ International comparison

Lin 2009

Location	*N*	PET range	Season	Regression equation	R^2	Neutral PET
Taichung City	22	24–45 °C	Hot season	TSV=0.1184·PET − 3.0253	0.96	25.6 °C
	10	16–26 °C	Cool season	TSV=0.1991·PET − 4.7229	0.89	23.7 °C
Szeged	33	7–39 °C	Transient seasons	$TSV=-0.004\cdot PET^2+0.278\cdot PET - 3.61$	0.91	16.8 °C

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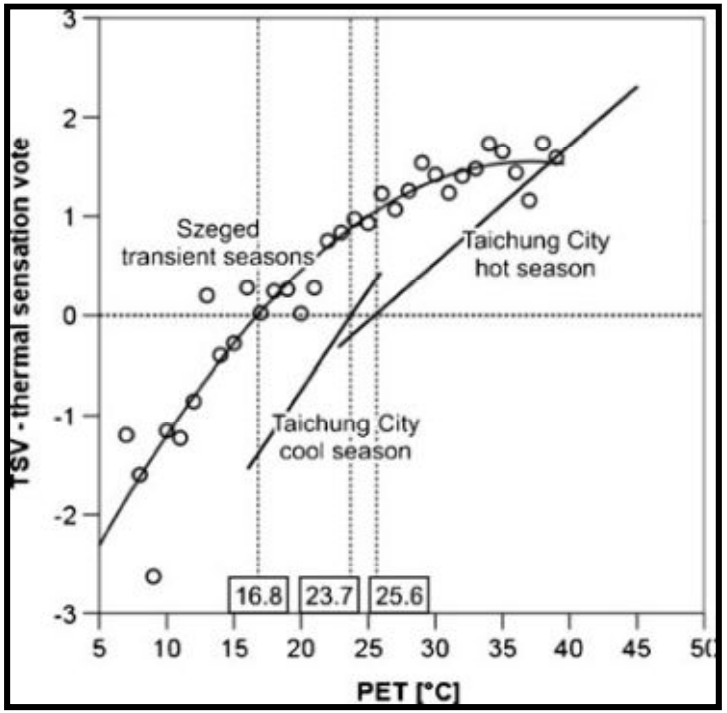
Differences which may influence the results:

- Different investigation times & seasons
  - Hungary: 12 am – 3 pm, transient seasons
  - Taiwan: 1 pm – 6 pm, all year

- Thermal Sensation Scale
  - Hungary: 9 degrees (very cold – very hot)
  - Taiwan: 7 degrees (cold – hot)

- Tmrt – different techniques
  - Hungary: 6-directional method
  - Taiwan: black globe technique



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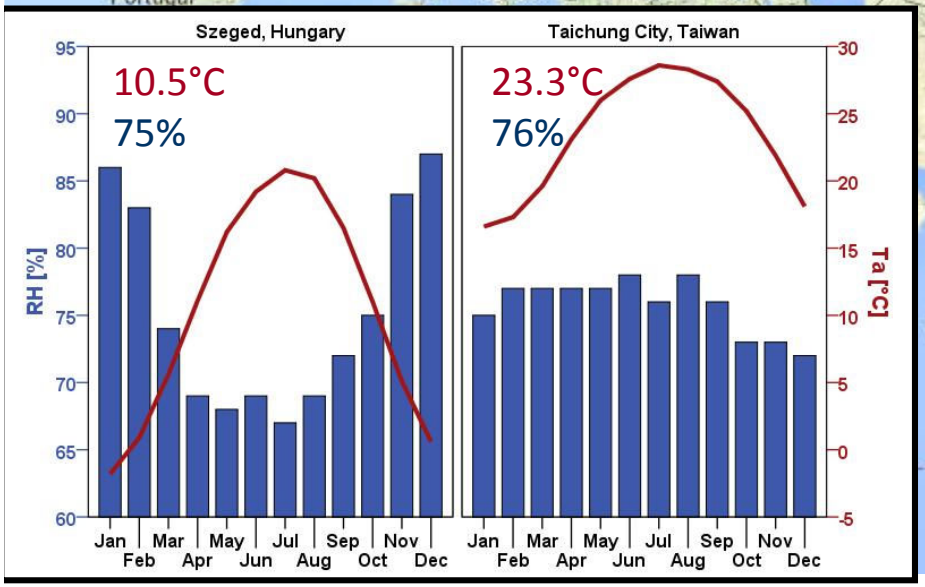
Research Center for the Humanities
& the Social Sciences
National Chung Hsing University,
Taichung, Taiwan

→ 2012

2013

Tzu-Ping Lin

Kang-Ting Tsai



46°N, 20°E
warm-temperate climate

24°N, 121°E
hot-humid subtropical

DATABASES

Hungary	Taiwan
Warm-temperate climate	Hot-humid climate
Szeged	**Yunlin, Huwei, Taichung**
6 outdoor places	5 outdoor places
10 am – 6 pm	8 am – 6 pm
2011 – 2012	2005 – 2006
Spring, summer, autumn	All year around

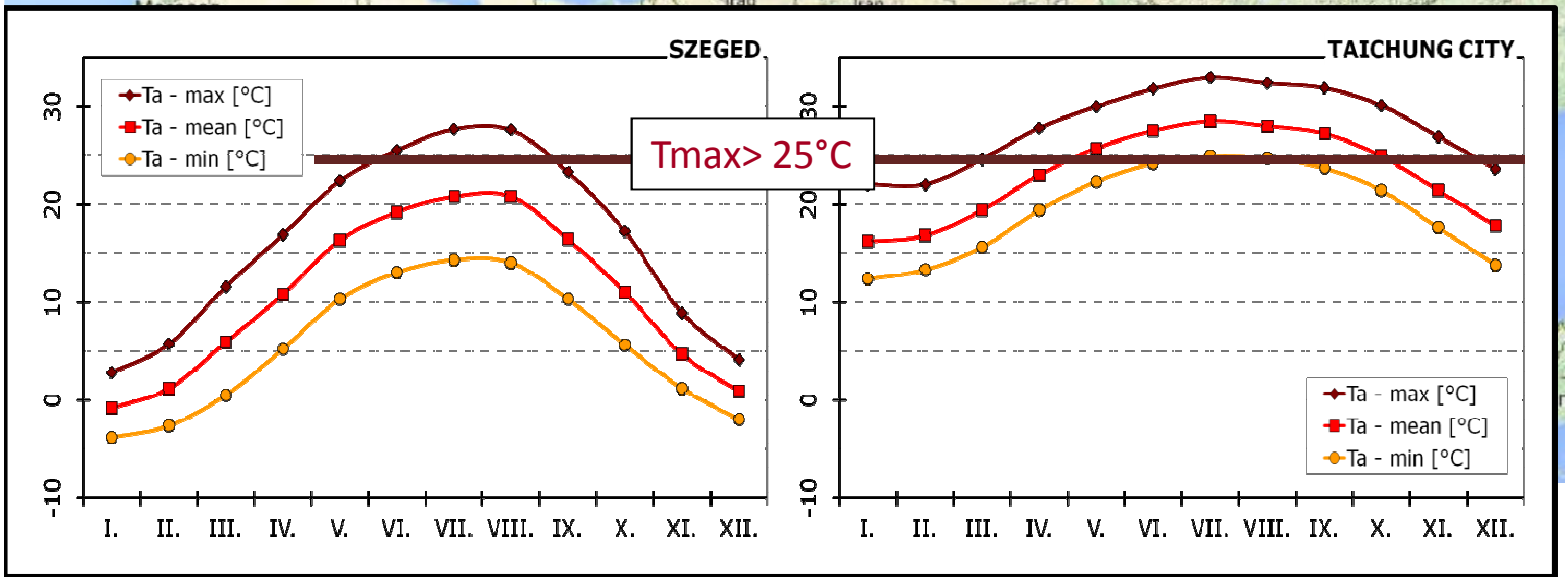
Lin et al. 2011

HUNGARY

TAIWAN

DATABASES

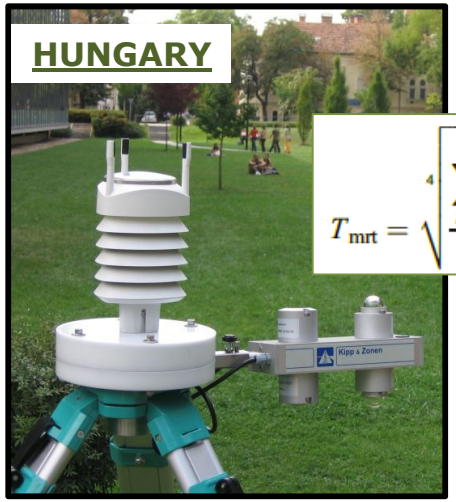
Hungary	Taiwan
Warm-temperate climate	Hot-humid climate
Szeged	**Yunlin, Huwei, Taichung**
6 outdoor places	5 outdoor places
10 am – 6 pm	8 am – 6 pm
2011 – 2012	2005 – 2006
~~Spring, summer, autumn~~	~~All year around~~
Summer (Jun – Aug)	**Hot season (Mar – Nov)**
14 – 50 year old subjects	
Only healthy subjects	
ca. 550 data in both nations	



MEASUREMENTS

Hungary	Taiwan
Ta [°C] – air temperature	
RH [%] – relative humidity	
v [m/s] – wind velocity	
Ki [W/m²] – Sw. rad. Li [W/m²] – Lw. rad.	Tg [°C] – globe temp.
Tmrt-6dir [°C] ←Ki, Li *Höppe 1992; VDI-3787*	**Tmrt-Tg [°C]** ←Tg, Ta, v *ISO -7726*
PET [°C] – Physiologically Equivalent Temperature *Mayer & Höppe 1987, Matzarakis et al.1999*	

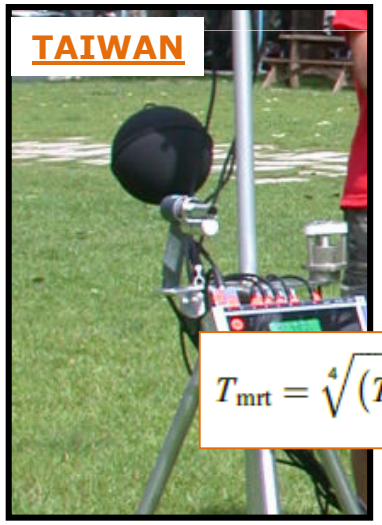
HUNGARY



$$T_{mrt} = \sqrt[4]{\frac{\sum_{i=1}^{6} W_i \cdot (a_k \cdot K_i + a_l \cdot L_i)}{a_l \cdot \sigma}} - 273.15$$

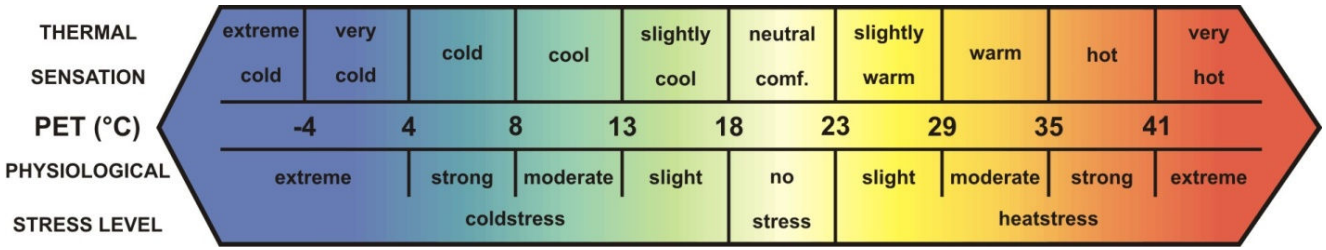
(Höppe 1992; VDI-3787 1998)

TAIWAN



$$T_{mrt} = \sqrt[4]{(T_g + 273.15)^4 + 2.498 \cdot 10^8 \cdot v^{0.6} \cdot (T_g - T_a)} - 273.15$$

(ISO-7726 1995)

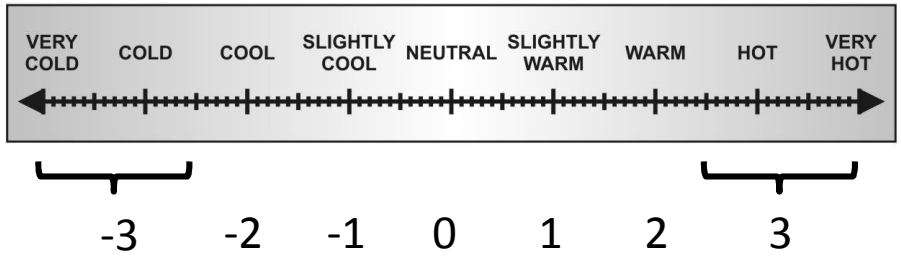


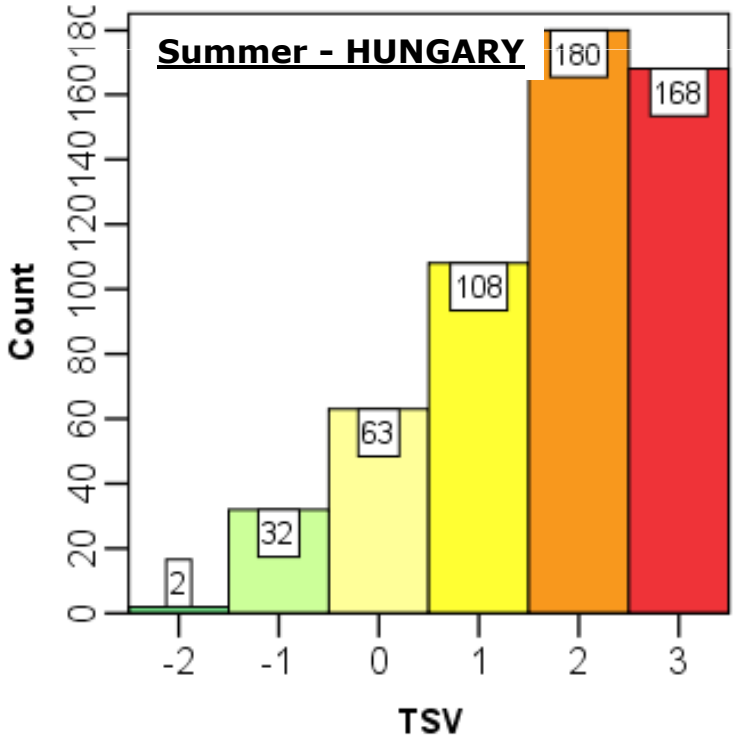
The Taiwanese Tmrt(Tg) data were recalculated to became comprehensible with the 6-dir. technique (The correction functions were derived using a Taiwanese parallel measurement series with the two techniques – *Kántor et al. 2014*)

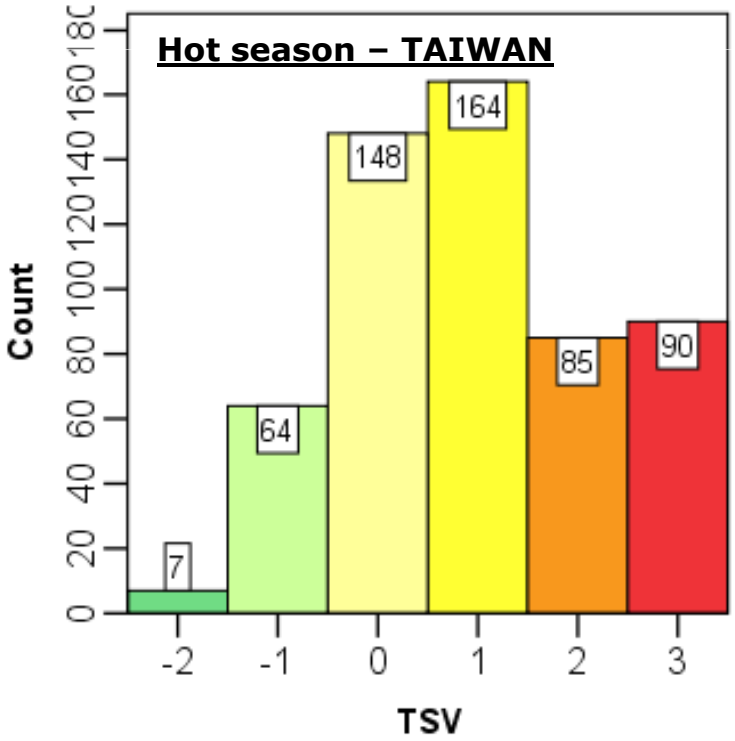
QUESTIONNAIRES

Thermal Sensation

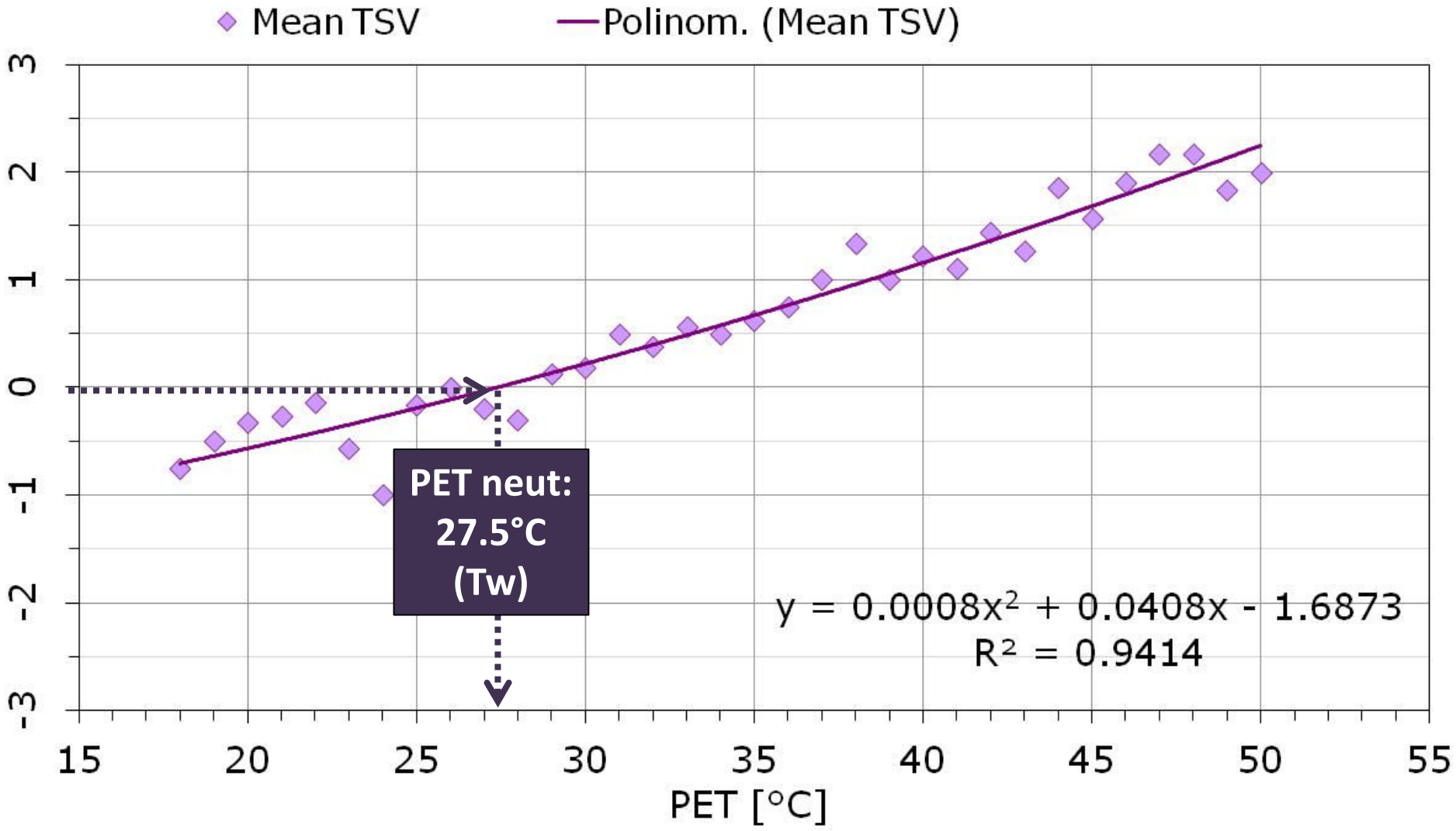
Hungary	Taiwan
Age, gender, etc.	
TSV – Thermal Sensation Vote	
9-degree (very cold → very hot)	**7-degree** (cold → hot)





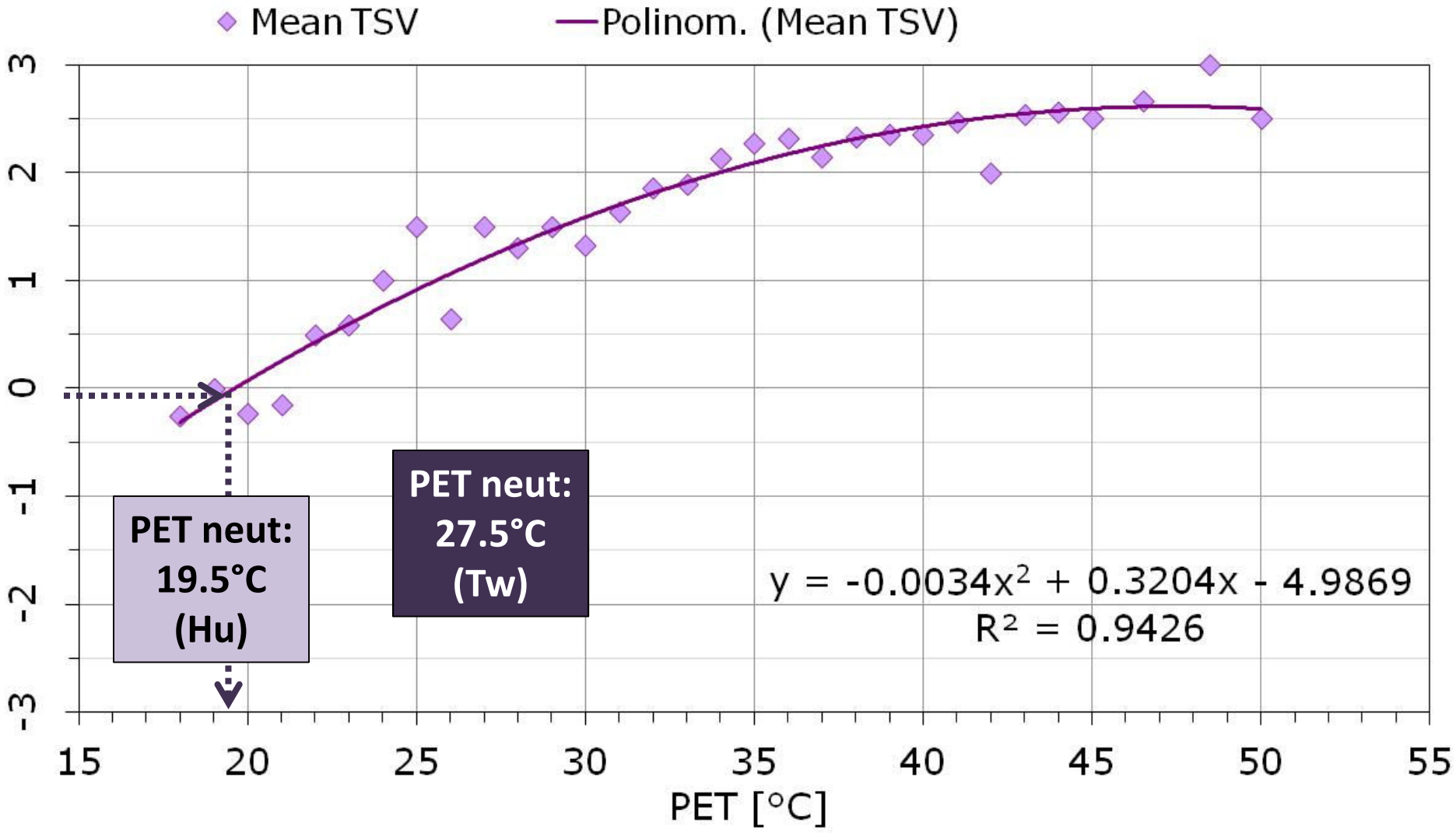


Hot season – TAIWAN



Mean TSV	the TSV-s were averaged according to 1°C wide PET intervals
Mean TSV vs. PET	regression curve
Neutral PET	where the mean TSV = 0

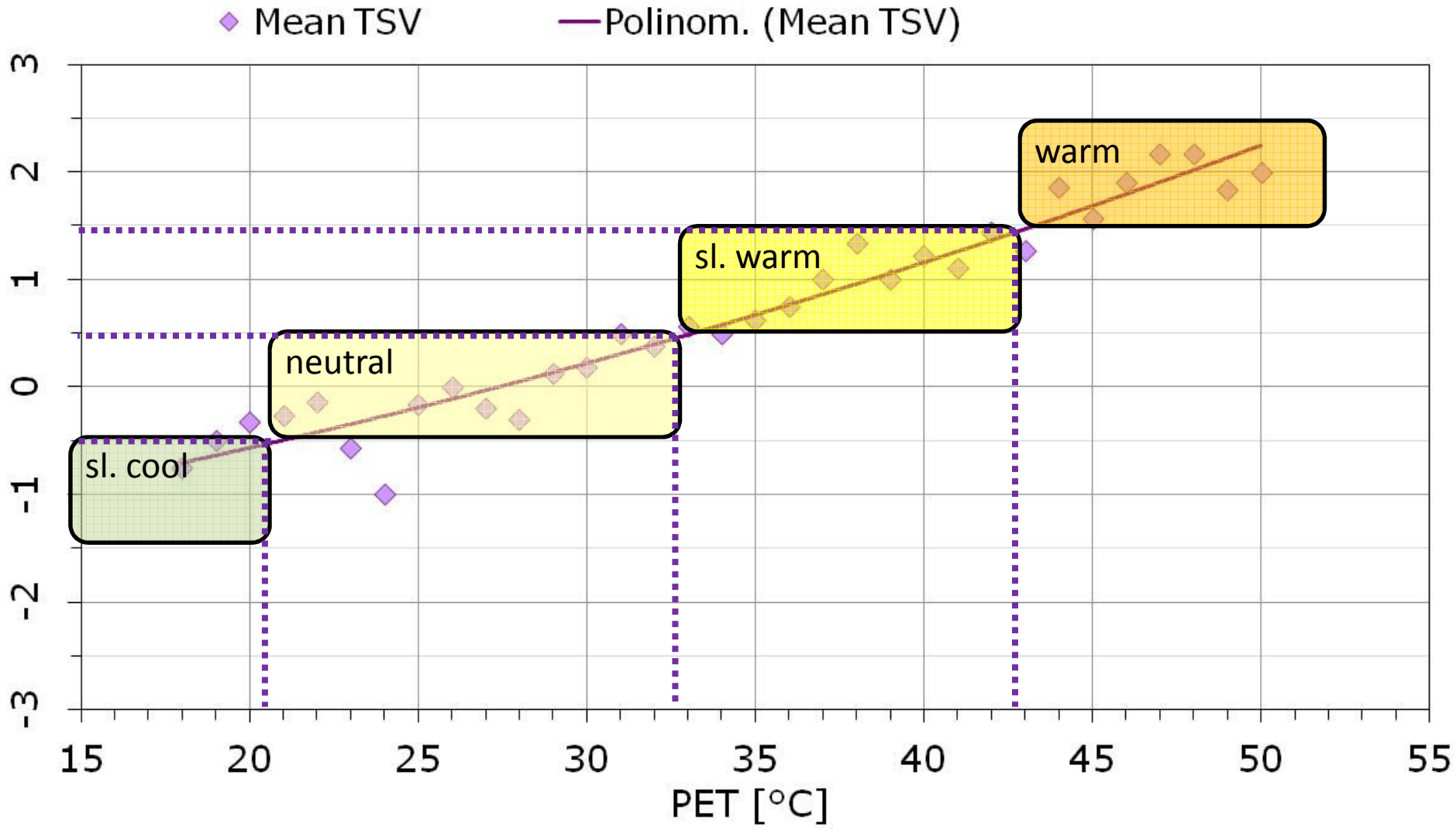
Summer – HUNGARY



The neutral temperature is higher in Taiwan

Taiwanese are better adapted to the warmer conditions

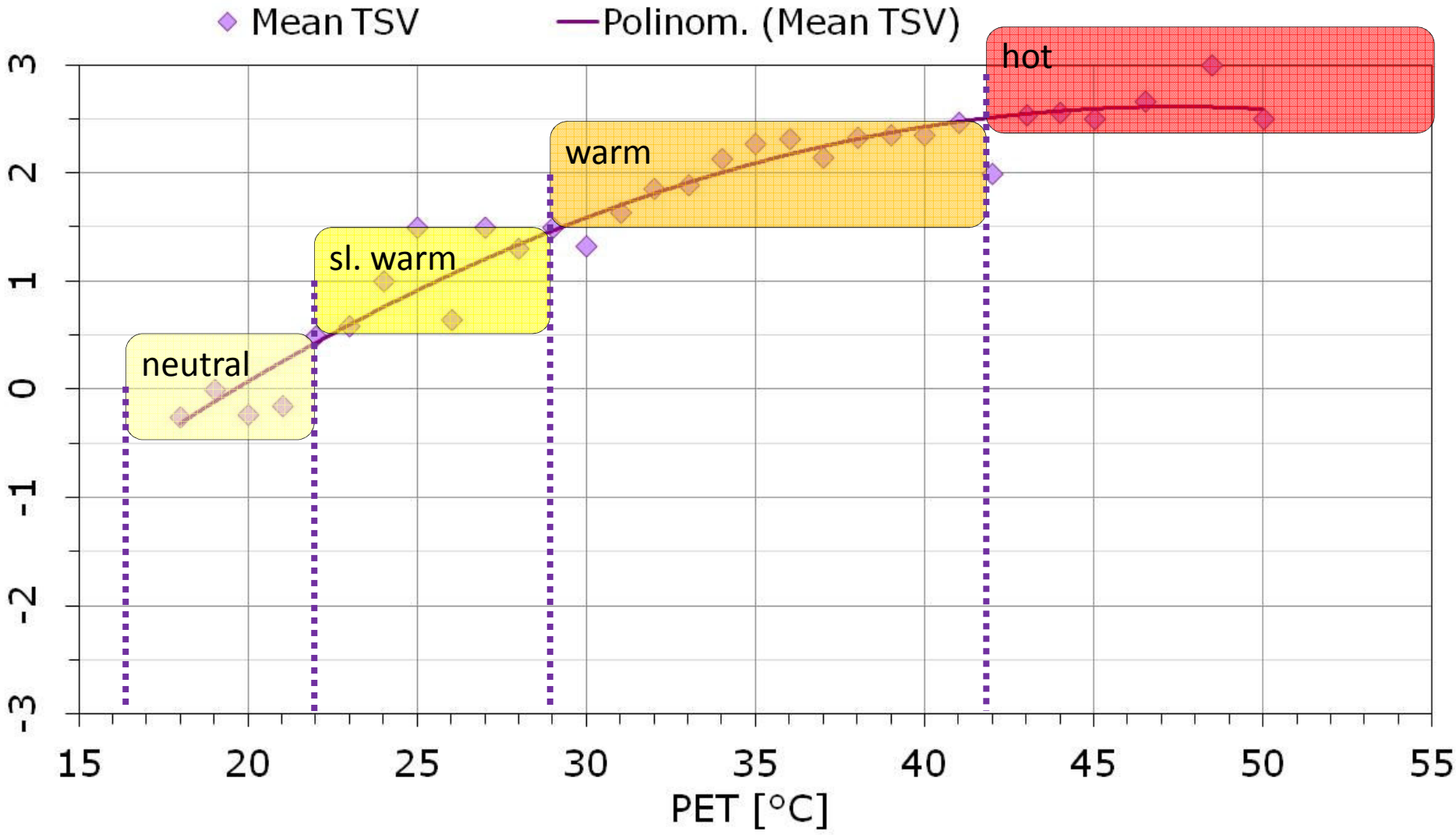
Hot season – TAIWAN



„Rescaling" the PET Projection of the TSV category boundaries (.5)

Taiwan: slightly cool – warm

Summer – HUNGARY

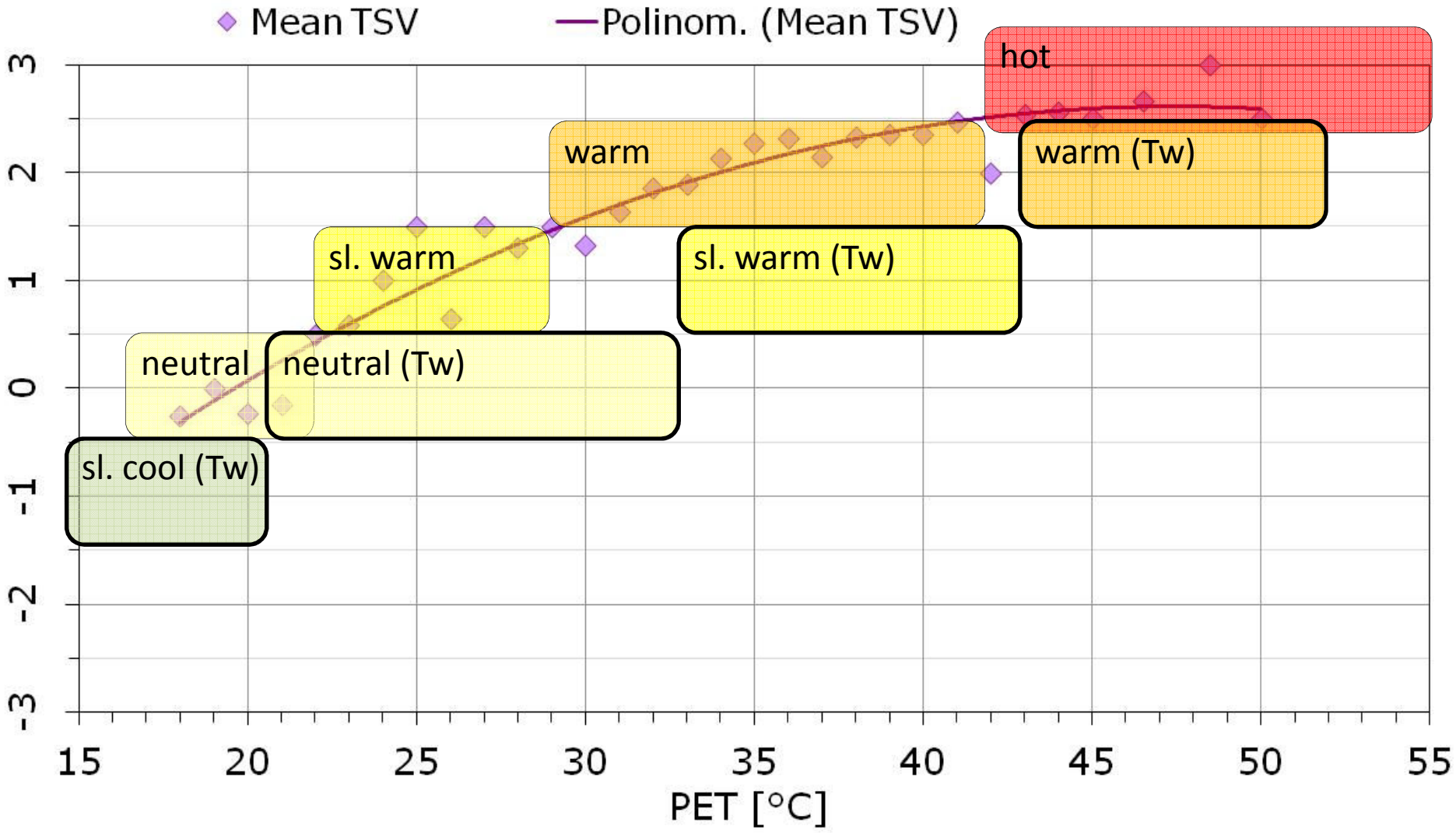


„Rescaling" the PET Projection of the TSV category boundaries (.5)

Taiwan: slightly cool – warm

Hungary: neutral – hot

Summer – HUNGARY



The neutral range (where TSV is between -0.5; 0.5) is wider in Taiwan

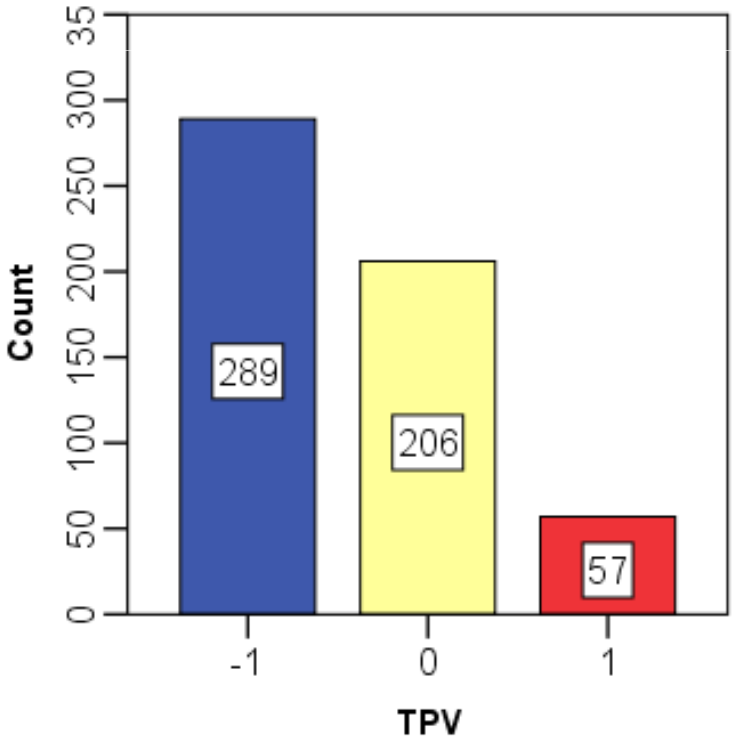
Taiwanese react not so intensively as the Hungarians

QUESTIONNAIRES

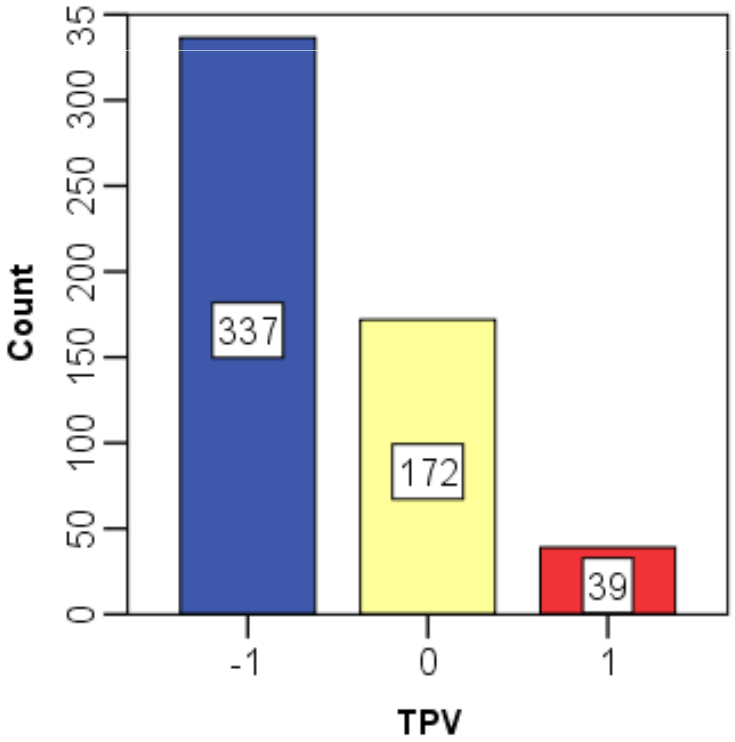
Thermal preferences

Hungary	Taiwan
Age, gender, etc.	
TSV – Thermal Sensation Vote	
9-degree (very cold → very hot)	**7-degree** (cold → hot)
TPV – Thermal Preference Vote (want cooler / want NO change / want warmer)	

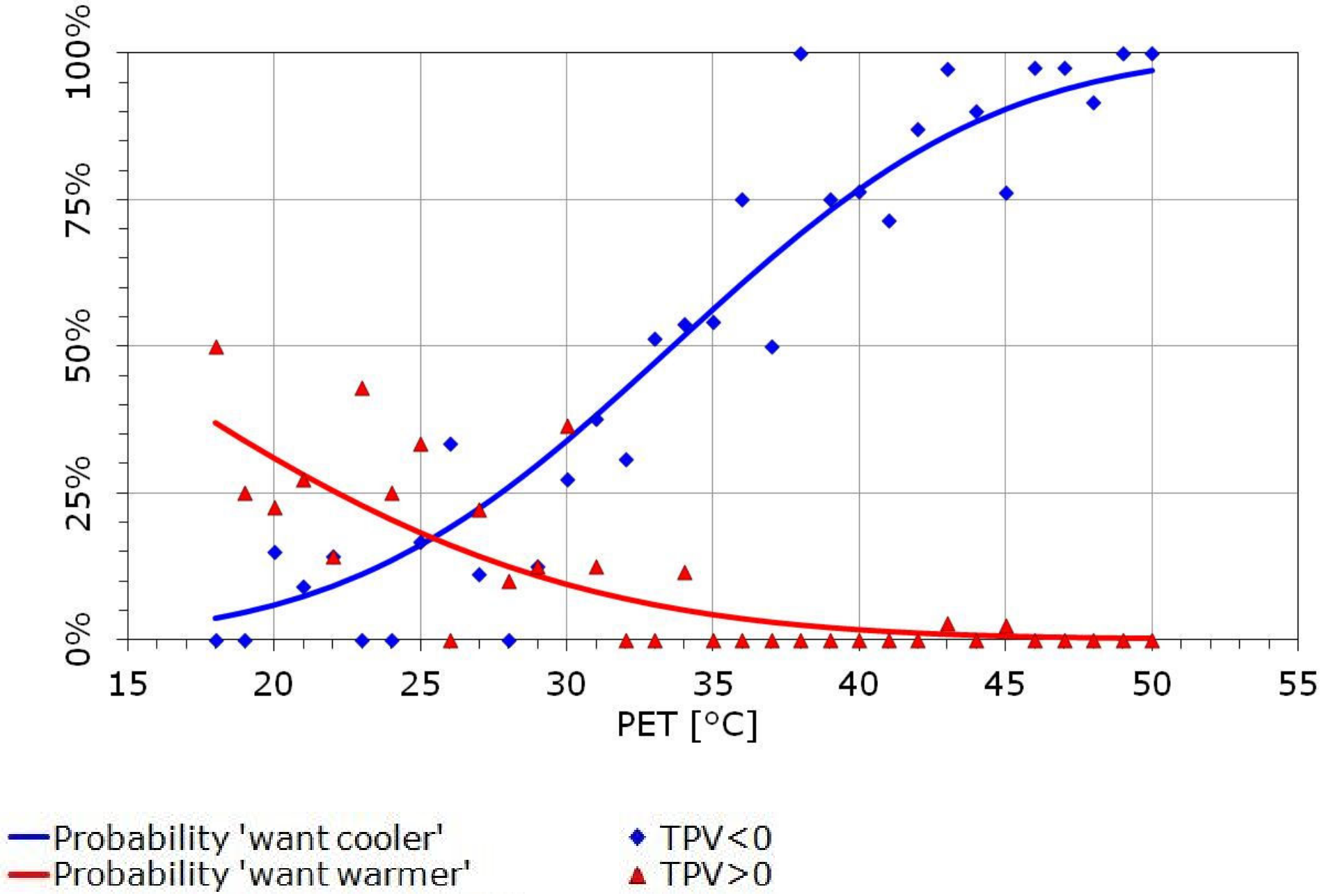
Summer - HUNGARY



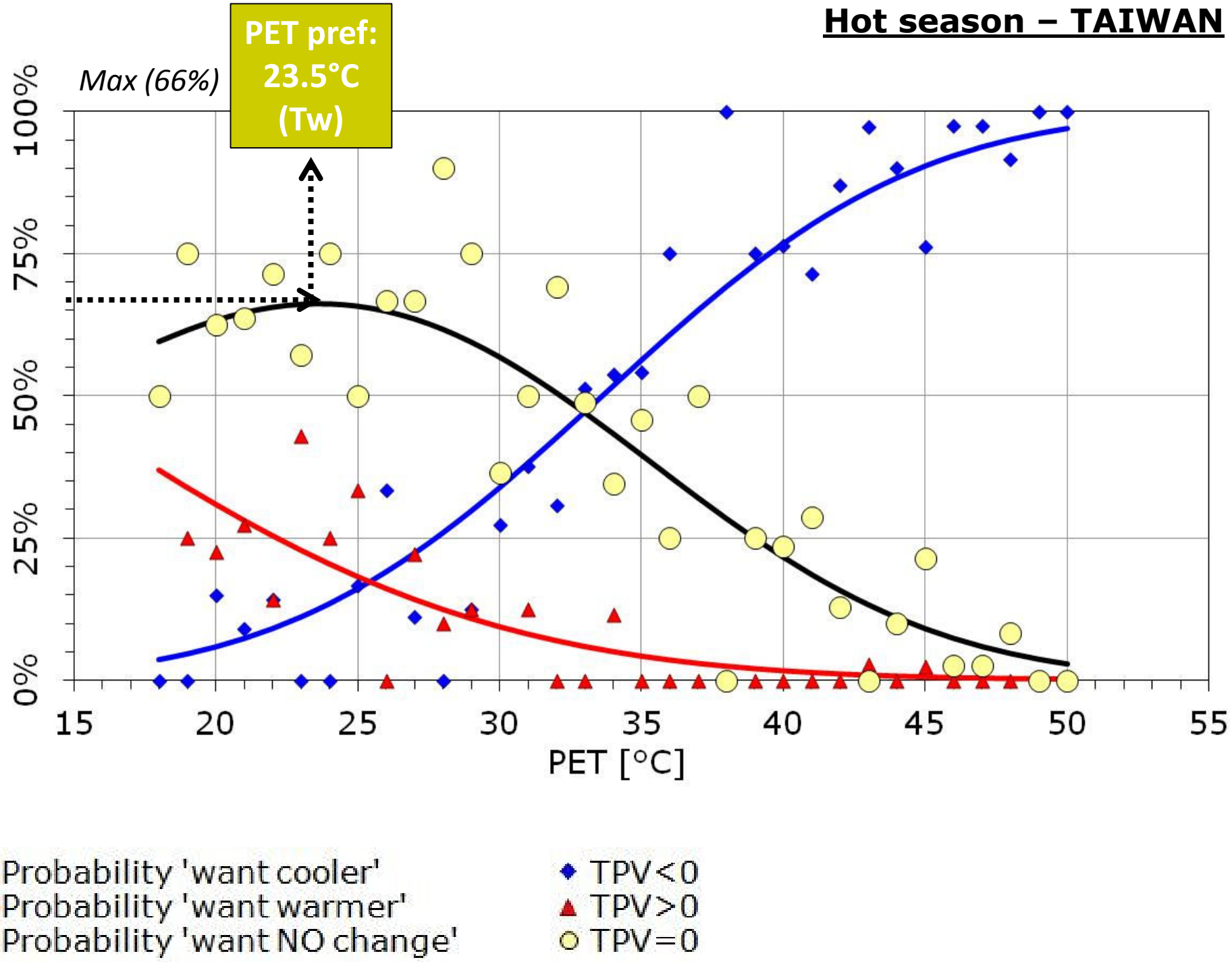
Hot season – TAIWAN



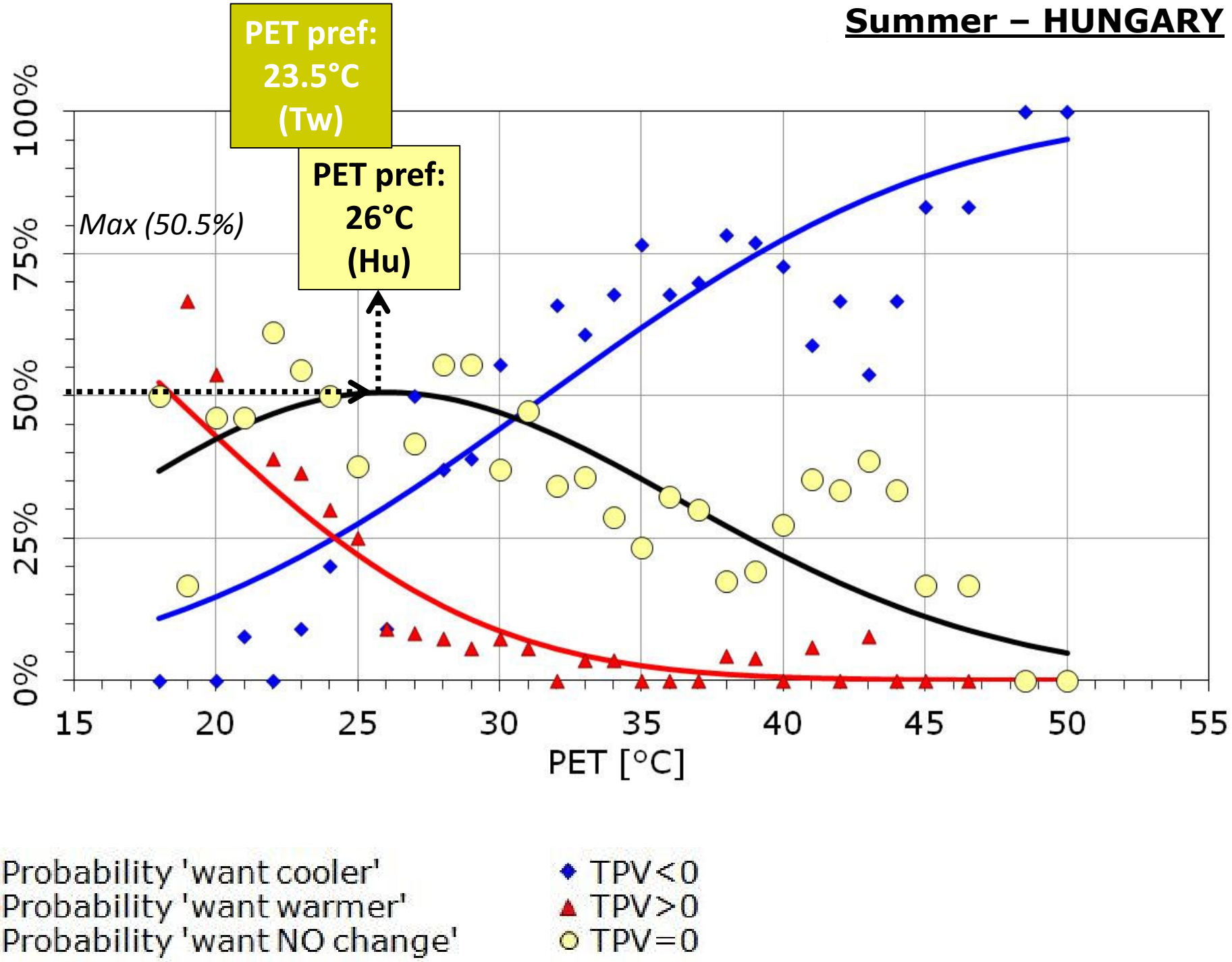
Hot season – TAIWAN



Hot season – TAIWAN



Summer – HUNGARY

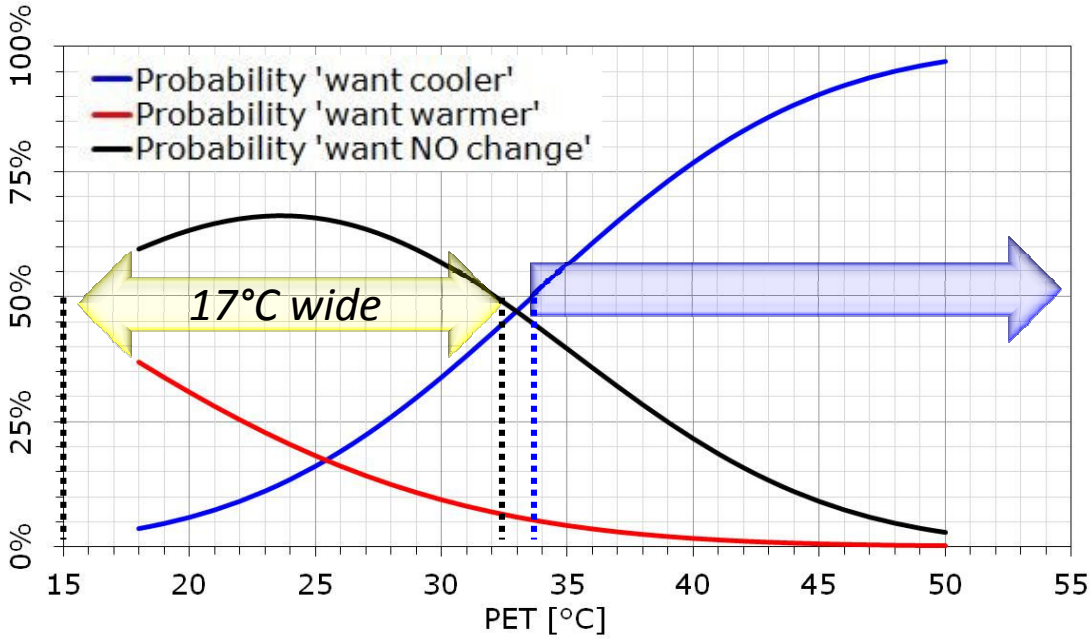


HOT DISCOMFORT At least 50% want cooler conditions (TPV<0)	
Taiwan	33.5°C →
Hungary	31.5°C →

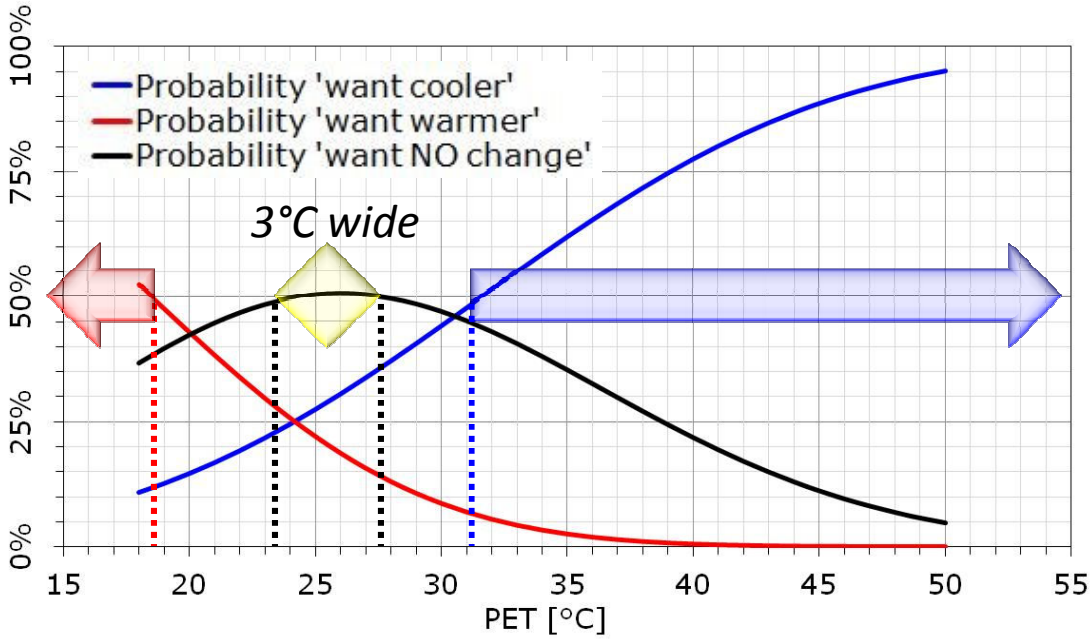
PREFERRED RANGE At least 50% want NO changes (TPV=0)	
Taiwan	ca. 15 – 32°C
Hungary	23.5 – 27.5°C

COLD DISCOMFORT At least 50% want warmer conditions (TPV>0)	
Taiwan	?
Hungary	← 18.5°C

Hot season – TAIWAN



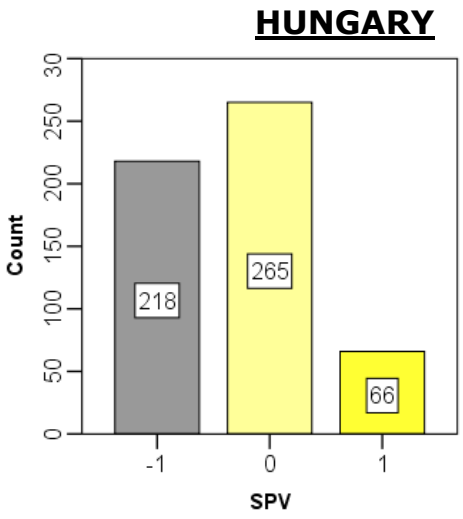
Summer – HUNGARY

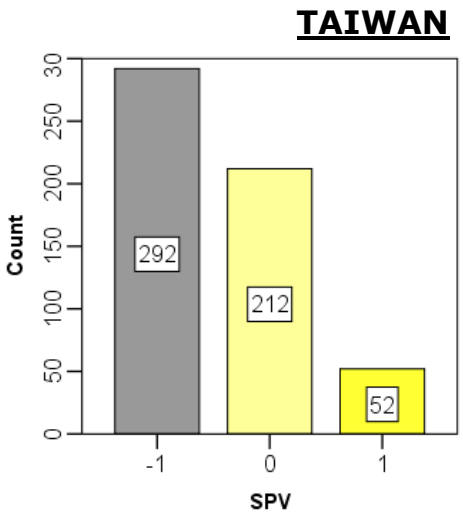


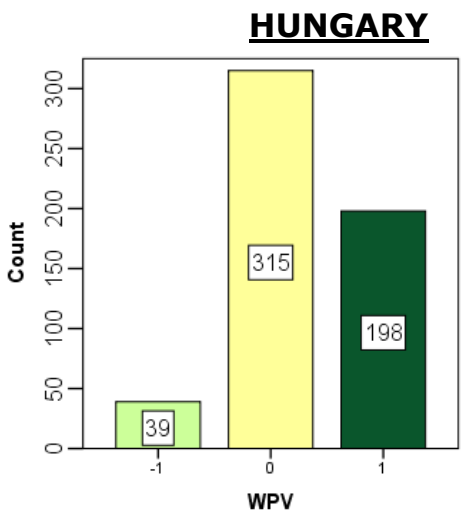
QUESTIONNAIRES

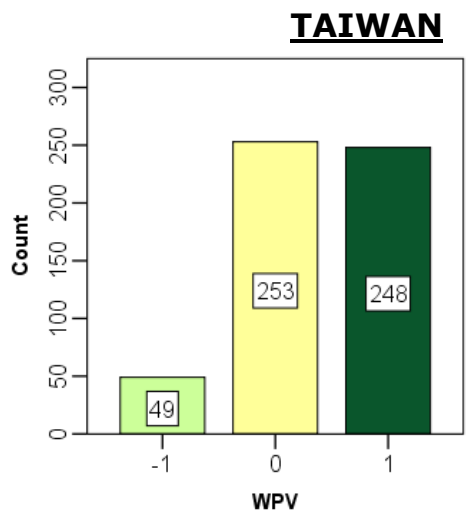
Other preferences

Hungary	Taiwan
Age, gender, etc.	
TSV – Thermal Sensation Vote	
9-degree (very cold → very hot)	**7-degree** (cold → hot)
TPV – Thermal Preference Vote (want cooler / want NO change / want warmer)	
SPV – Thermal Preference Vote (want less sun / want NO change / want more sun)	
WPV – Thermal Preference Vote (want slighter wind / want NO change / want stronger wind)	



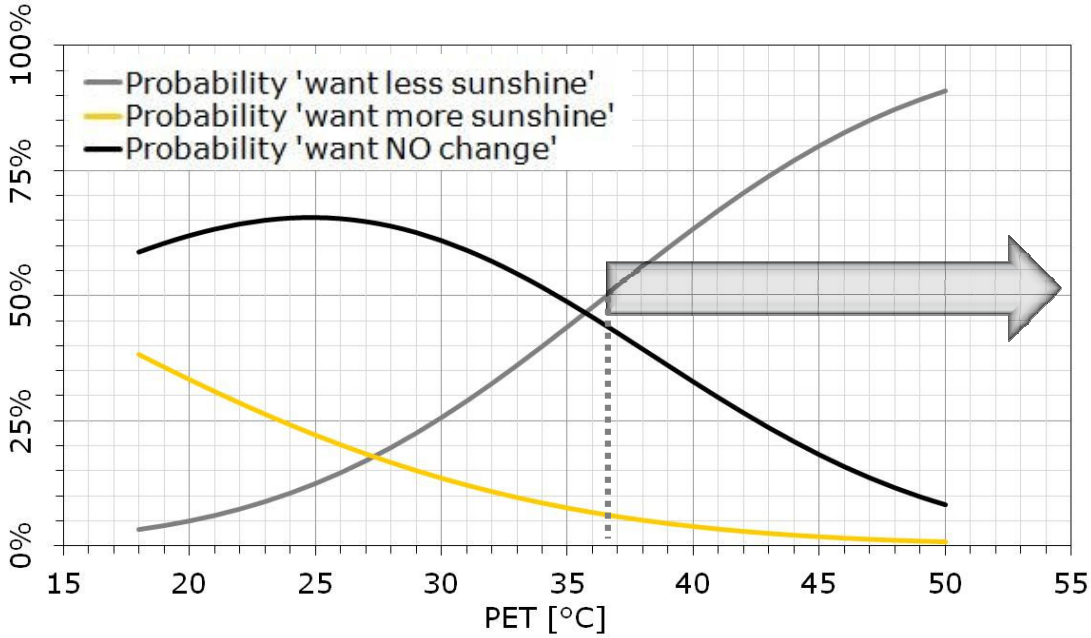




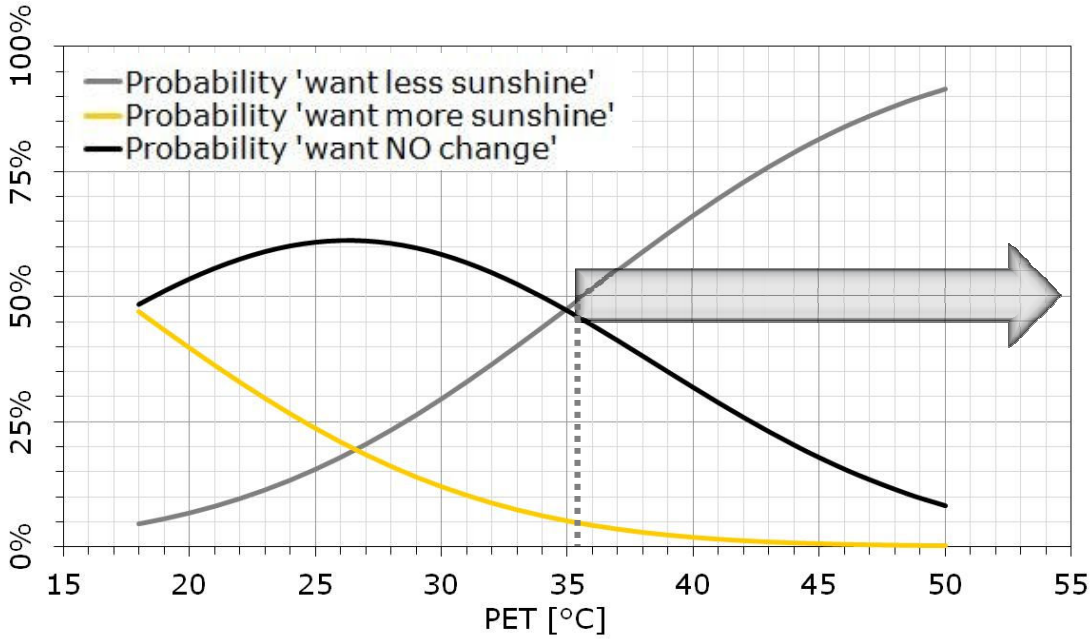


At least 50% want less sunshine (SPV<0)	
Taiwan	36.5°C →
Hungary	35.5°C →

Hot season – TAIWAN

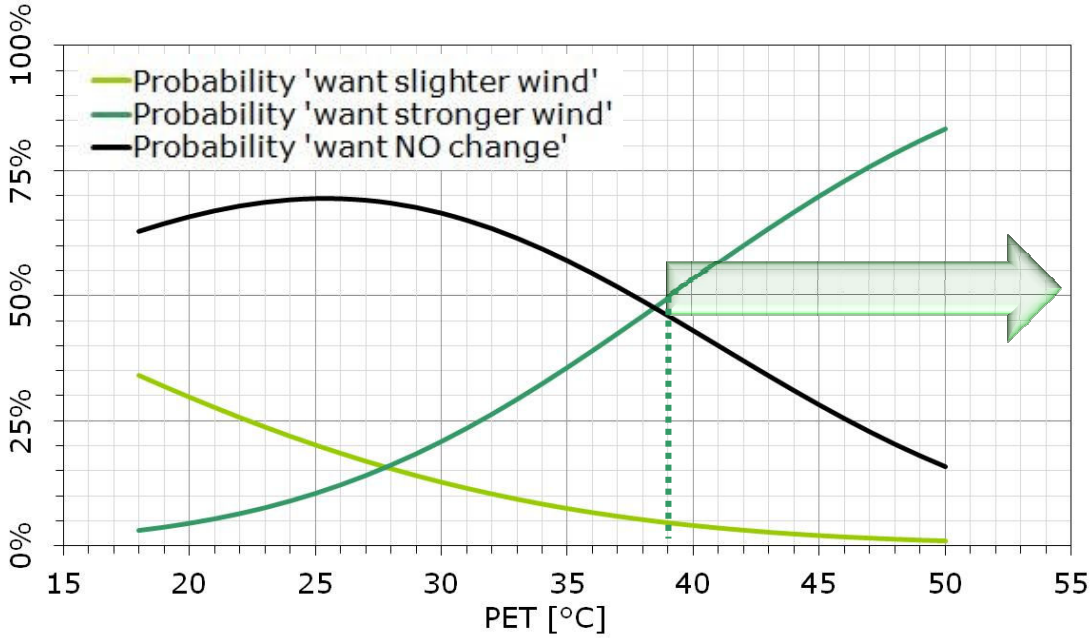


Summer – HUNGARY

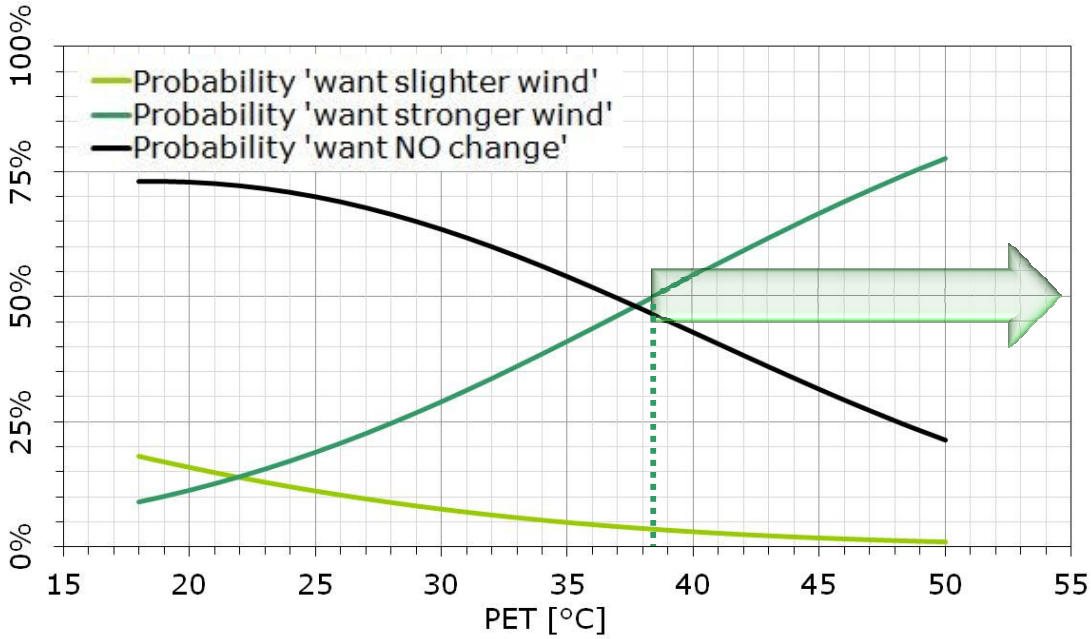


At least 50% want stronger wind (WPV>0)	
Taiwan	39°C →
Hungary	38.5°C →

Hot season – TAIWAN



Summer – HUNGARY



SUMMARY

The warm discomfort benchmarks (min 50% of subjects want changes) are closer to each other in Taiwan and start at a bit higher PET values

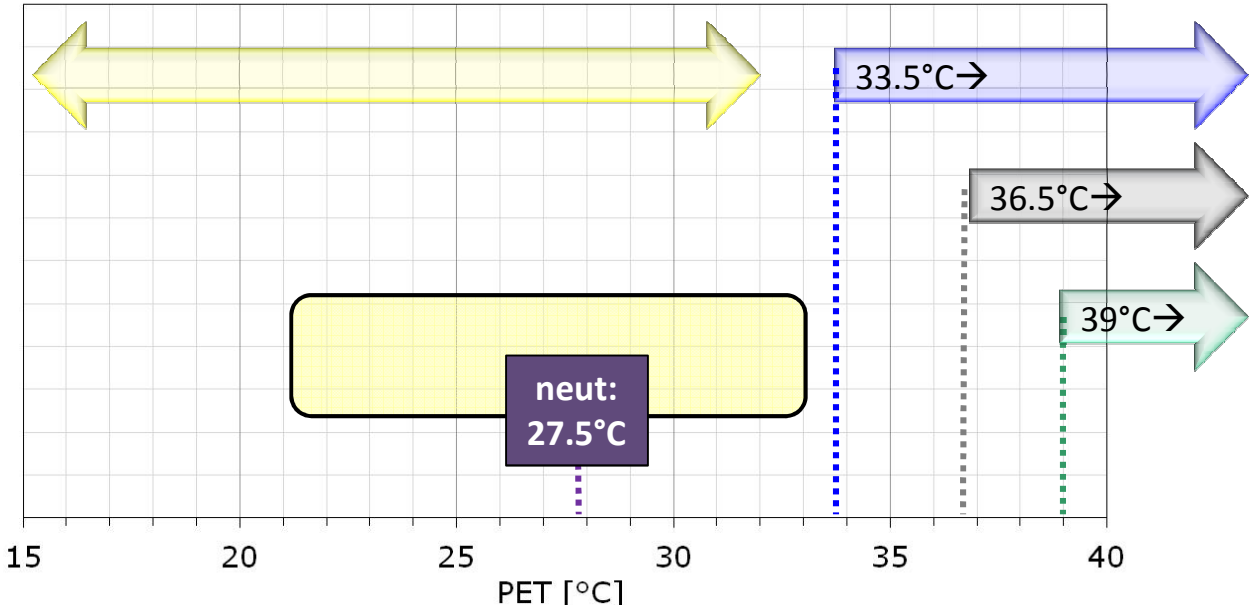
The preferred/ comfortable domain (min. 50% of subjects want NO changes in temperature), and the neutral range (mean TSV [-0.5; 0.5]) are much wider in Taiwan

Taiwanese people are more tolerant against the changes of the thermal environment

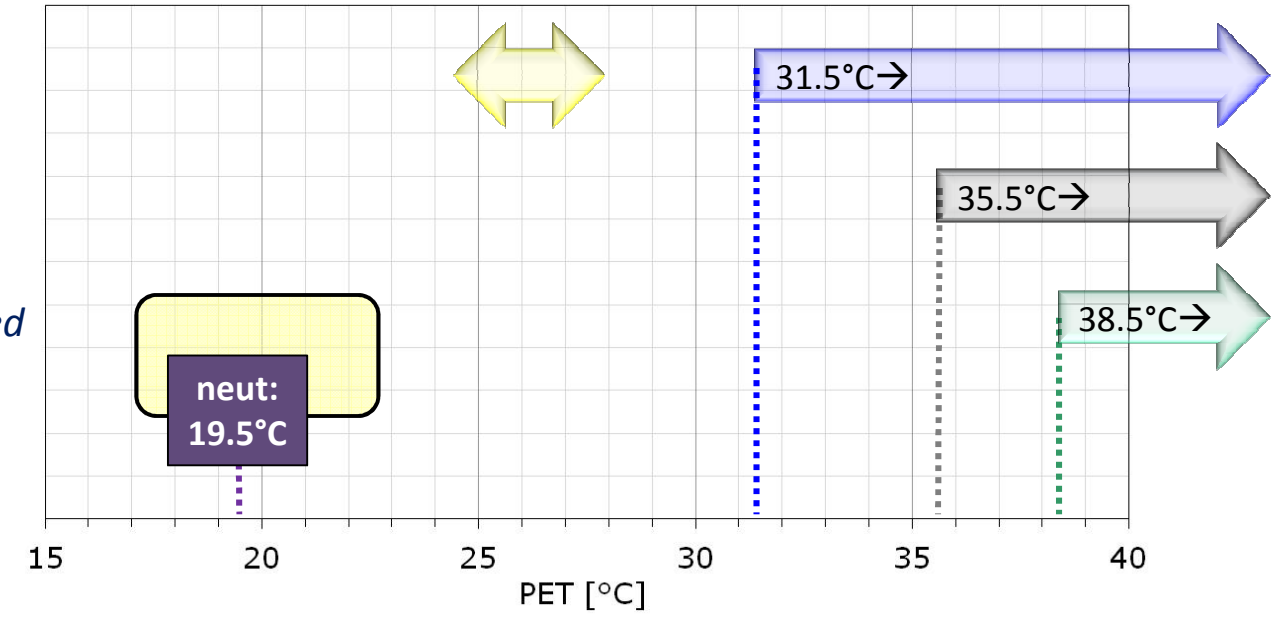
The neutral PET temperature (the PET at which the mean TSV=0) is 8°C higher in Taiwan than in Hungary

Taiwanese people are better adapted (physiologically & mentally) to the hot climate

Hot season – TAIWAN



Summer – HUNGARY



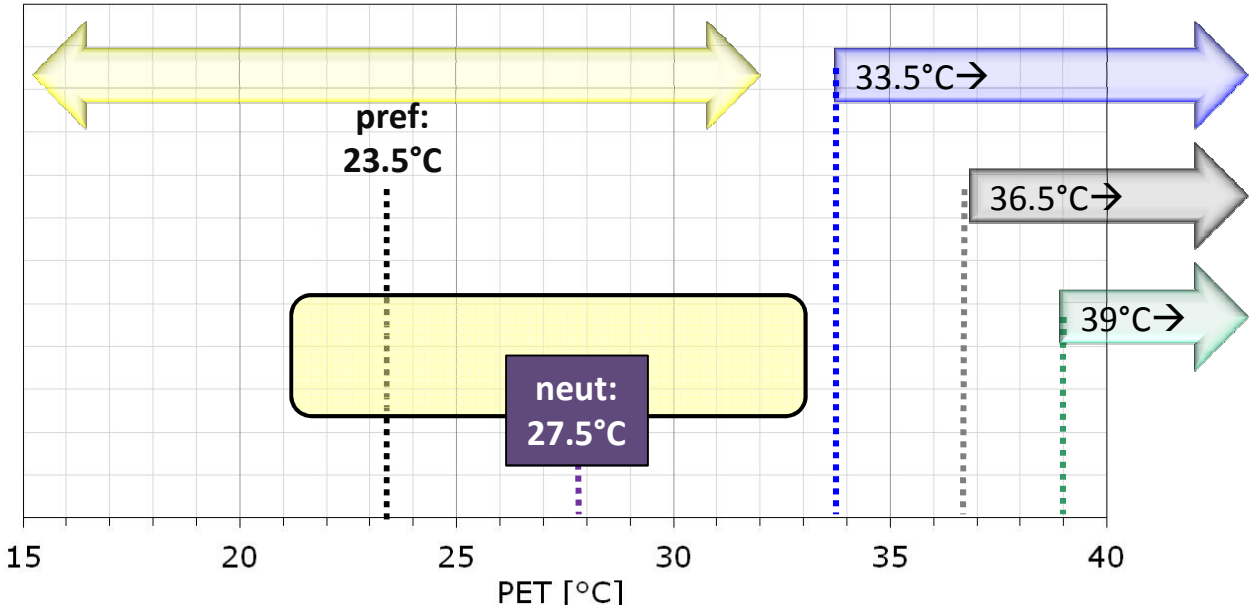
SUMMARY

The preferred temperature
(the PET at which the probability of 'want NO change' vote is maximal)
is 2.5°C lower in Taiwan than in Hungary
and in Taiwan it is below the neutral temp.

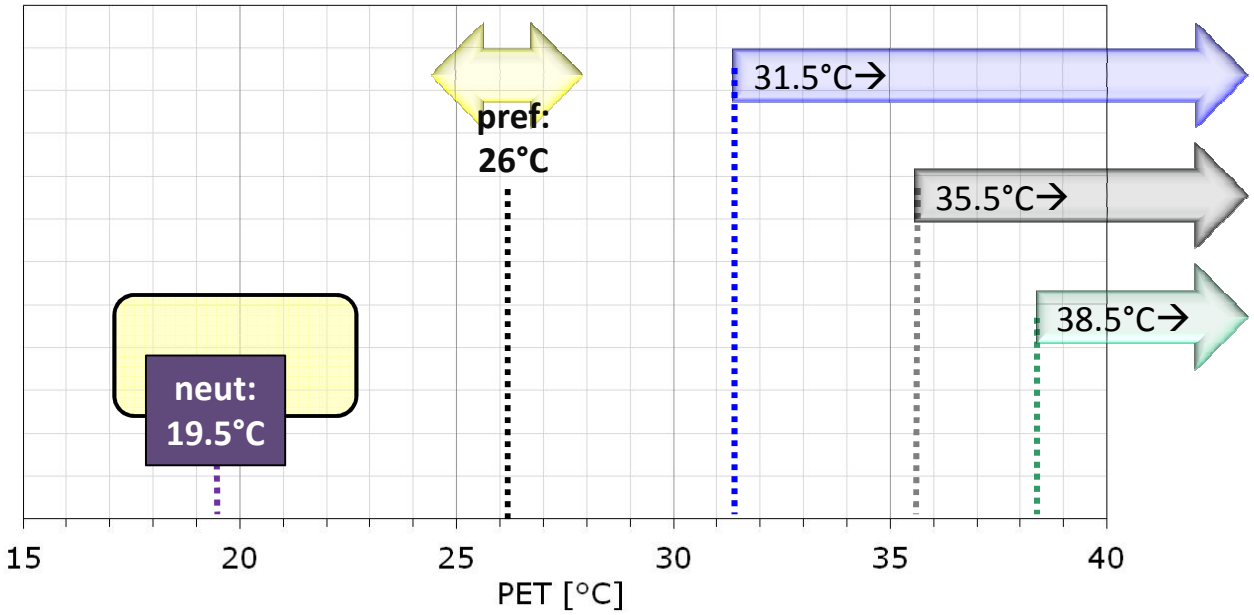
Taiwanese got accustumed to the heat stress, BUT prefer somewhat cooler conditions

Hungarians assess as comfortable clearly warmer thermal conditions than that they perceive neutral

Hot season – TAIWAN



Summer – HUNGARY



SUMMARY

The preferred temperature
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and in Taiwan it is below the neutral temp.

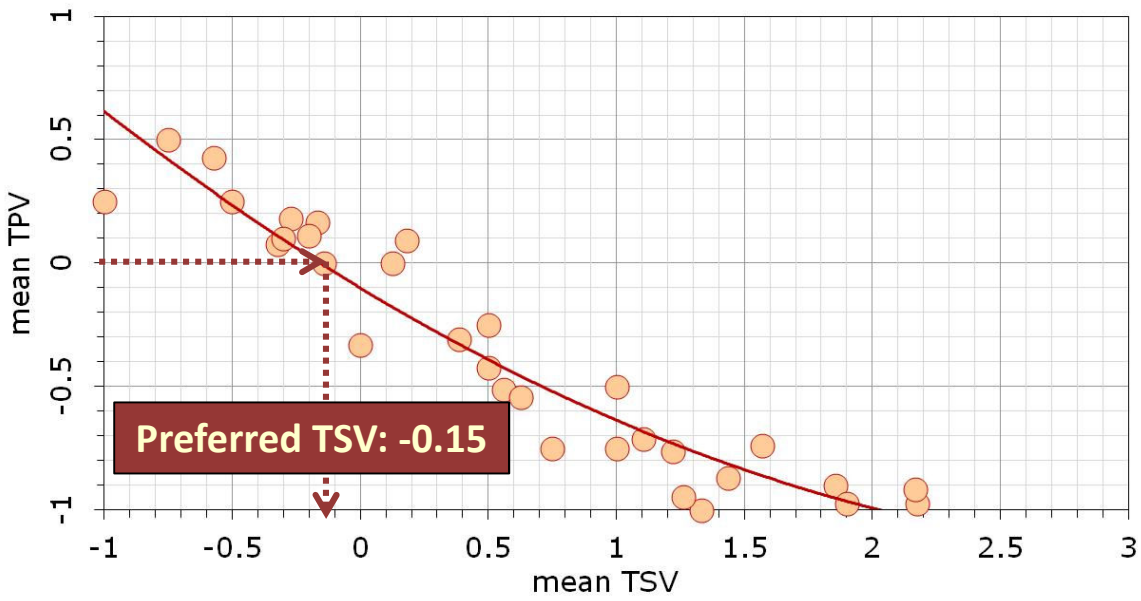
Taiwanese got accostumed to the heat stress, BUT prefer somewhat cooler conditions

Hungarians assess comfortable clearly warmer thermal conditions than that they perceive neutral

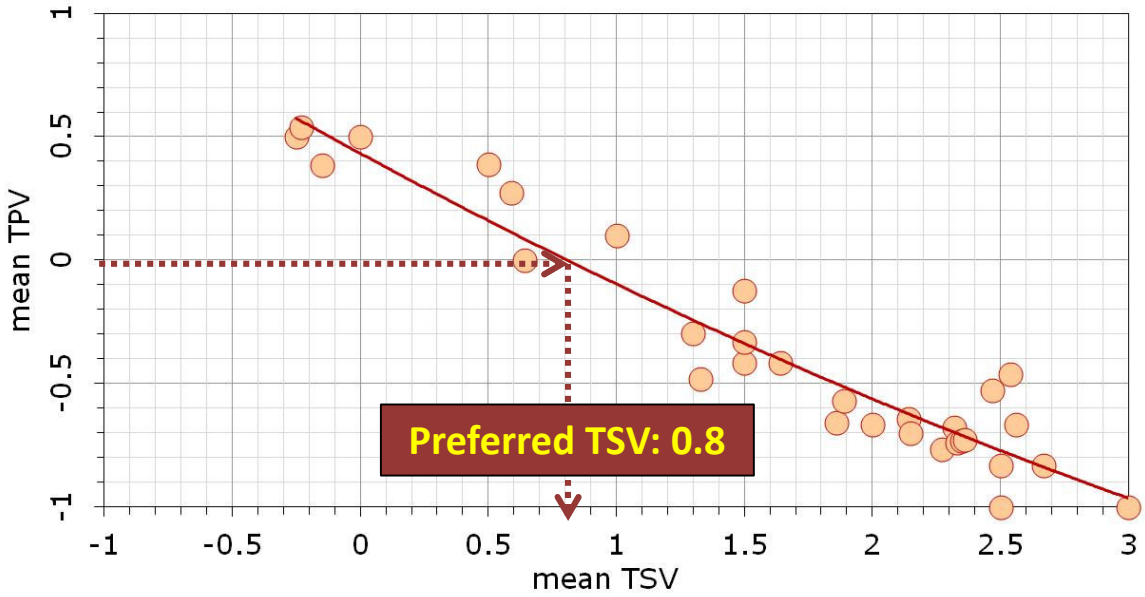
Thermal neutrality ≠ preference

The preferred thermal sensation
(the TSV where the mean TPV=0)
in the warm months is
NEUTRAL (-0.15) in Taiwan
SLIGHTLY WARM (0.8) in Hungary

Hot season – TAIWAN



Summer – HUNGARY



Thank you very much for your attention!

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For the international comparison, special thank for the sponsorship of the Research Center for the Humanities and Social Sciences at the National Chung Hsing University.
Thanks for the Conference Participation Support by The Hungary Initiatives Foundation.

Previous publications in the topic

Lin TP (2009): Thermal perception, adaptation and attendance in a public square in hot and humid regions. Build Environ 44, 2017-2026

Lin TP, de Dear R, Hwang RL (2011): Effect of thermal adaptation on seasonal outdoor thermal comfort. Int J Climatol 31, 302-312

Kántor N, Égerházi L, Unger J (2012a): Subjective estimation of thermal environment in recreational urban spaces - Part 1: investigations in Szeged, Hungary. Int J Biometeorol 56, 1075-1088

Kántor N, Unger J, Gulyás Á (2012b): Subjective estimations of thermal environment in recreational urban spaces - Part 2: international comparison. Int J Biometeorol 56, 1089-1101

Kántor N, Kovács A, Lin TP (2014): Looking for simple correction functions between the mean radiant temperature from the "standard black globe" and the "six-directional" techniques in Taiwan. Theor Appl Climatol, DOI 10.1007/s00704-014-1211-2

Other cited publications

Mayer H, Höppe P (1987): Thermal comfort of man in different urban environments. Theor Appl Climatol 38, 43-49

Höppe P (1992): Ein neues Verfahren zur Bestimmung der mittleren Strahlungstemperatur in Freien. Wetter und Leben 44, 147-151

VDI (1998): Methods for the human-biometeorological assessment of climate and air hygiene for urban and regional planning. Part I: Climate. VDI 3787, Part 2. Beuth, Berlin, 29 p

ISO (1998) ISO Standard 7726. Ergonomics of the thermal environments – Instruments for measuring physical quantities.

Matzarakis A, Mayer H, Izomon MG (1999): Application of a universal thermal index: physiological equivalent temperature. Int J Biometeorol 43, 76-84