Efforts on adaptation measures for urban heat island in Japan

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- List of adaptation measures for urban heat islands and their effects and associated evaluation indices
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- Extraction of hot spots based on urban block characteristics

Heat countermeasure guideline in the city by Japanese Ministry of Environment

Heat countermeasure guideline in the city by Japanese Ministry of Environment (2016)

- The guideline states that ‘by understanding the factors that make it hot and implementing appropriate adaptation measures for places we have to wait for or places we want to spend comfortably such as *bus stops* and *plazas*, we can promote a healthy and comfortable environment in the urban area’.

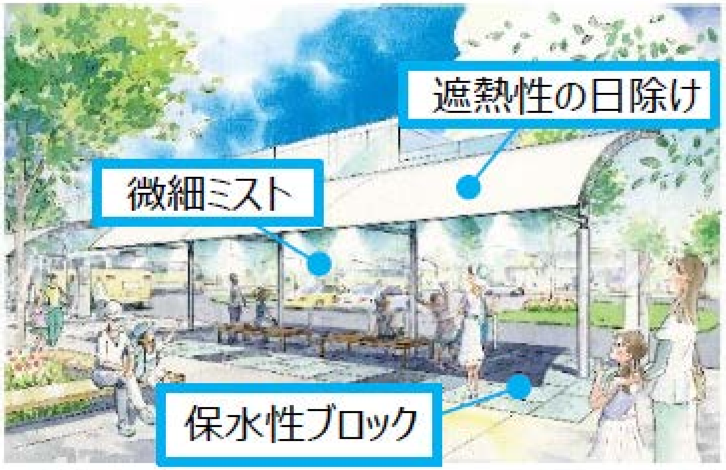
http://www.wbgt.env.go.jp/pdf/city_gline/city_guideline_full.pdf

Examples of adaptation measures by Ministry of Environment

adaptation measures for places we have to wait for such as bus stops

Fine mist spray

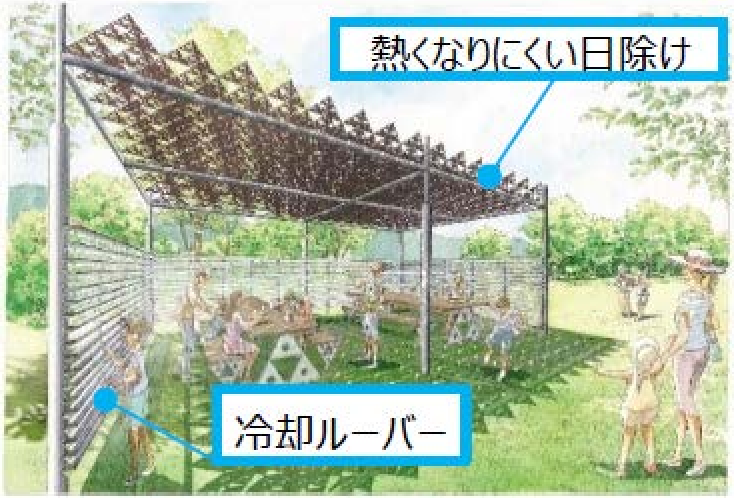
Water retentive pavement



Solar radiation shade

adaptation measures for places we want to spend comfortably such as plazas

Evaporative cooling louver



Fractal-shaped sunshade

Examples of adaptation measures by Ministry of Environment

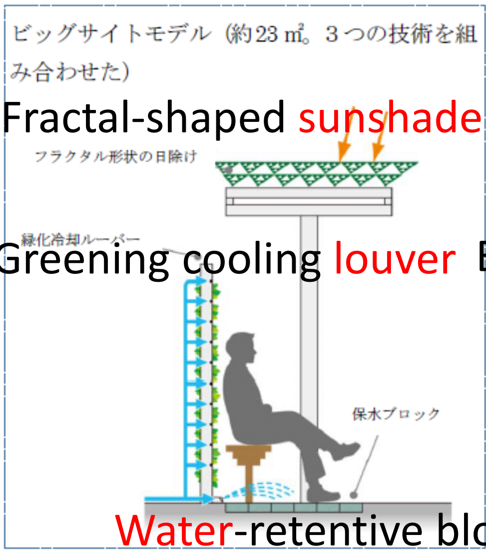
Automatically opening and closing awning at a bus stop
(a) whole view, (b) internal view, (c) closed state

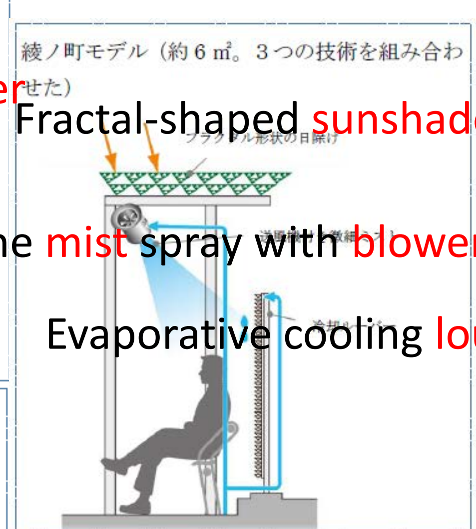
Fractal-shaped sunshade
(a) in a park, (b) at a tram stop

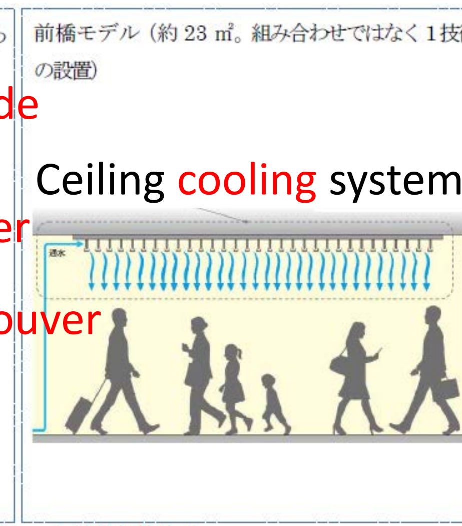
Evaporative cooling louver
(a) in a park, (b) at a tram stop

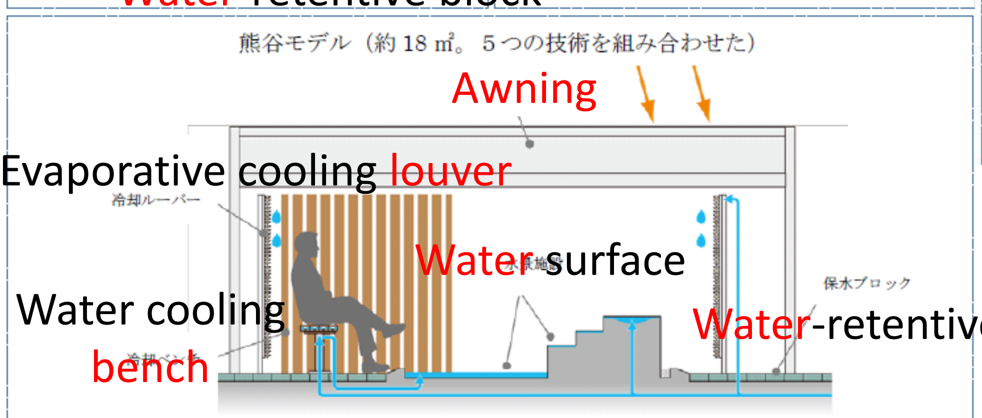
http://www.wbgt.env.go.jp/pdf/city_gline/city_guideline_full.pdf

Examples of adaptation measures by Ministry of Environment









List of adaptation measures for urban heat islands and their effects and associated evaluation indices

Adaptation measures for urban heat islands and their effects and associated evaluation indices

Menu	Evaluation Index	Main Effect Mechanism
from the heat countermeasure guidelines by the Japanese Ministry of Environment		
Green shade	Solar transmittance, Evaporative efficiency	Sun shade, Evaporative cooling
Solar radiation shade	Solar transmittance, Convection heat transfer coefficient	Sun shade, Convection heat transfer
Retroreflective surface	Downward solar reflectance	Solar reflection
Water retentive pavement	Evaporative efficiency	Evaporative cooling
Cool pavement	Solar reflectance	Solar reflection
Green pavement	Evaporative efficiency	Evaporative cooling
Green wall	Evaporative efficiency	Evaporative cooling
Water-retentive wall	Evaporative efficiency	Evaporative cooling
from the report by the Japanese Ministry of Environment		
Awning	Solar transmittance	Sun shade
Fractal-shaped sunshade	Solar transmittance, Convection heat transfer coefficient	Sun shade, Convection heat transfer
Mesh shade and water supply	Solar transmittance, Evaporative efficiency	Sun shade, Evaporative cooling
Evaporative cooling louver	Evaporative efficiency	Evaporative cooling
Greening cooling louver	Evaporative efficiency	Evaporative cooling
Tree pot	Solar transmittance, Evaporative efficiency	Sun shade, Evaporative cooling

http://www.wbgt.env.go.jp/pdf/city_gline/city_guideline_full.pdf

Adaptation measures for urban heat islands and their effects and associated evaluation indices

Menu	Evaluation Index	Main Effect Mechanism
Water-retentive block	Evaporative efficiency	Evaporative cooling
Water surface	Evaporative efficiency	Evaporative cooling
Fine mist spray with blower	Evaporation rate	Evaporative cooling
Ceiling cooling system	Surface temperature	Artificial cooling
Water cooling bench	Surface temperature	Artificial cooling
from town planning idea competition by Osaka Heat Island Countermeasure Technology Consortium		
Water surface	Evaporative efficiency	Evaporative cooling
Watering	Evaporative efficiency	Evaporative cooling
Fine mist spray	Evaporation rate	Evaporative cooling
Shading	Solar transmittance	Sun shade
Tree planting	Solar transmittance, Evaporative efficiency	Sun shade, Evaporative cooling
Roof and ground greening	Evaporative efficiency	Evaporative cooling
Wind use	Convection heat transfer coefficient	Convection heat transfer
Traffic mode control	Anthropogenic heat release	Reduction of anthropogenic heat release
Unused energy use, natural energy use	Anthropogenic heat release	Reduction of anthropogenic heat release
ICT use	Human body physiological amount	Reduction of human thermal load

http://osakahitec.com/active/news/news2018_01_vol14.pdf

A simple method to evaluate adaptation measures for urban heat island

Evaluation Method of Adaptation Measures

- The effect of adaptation measures is evaluated by outdoor human thermal comfort, which is strongly correlated to the outdoor thermal environment.
- As Nouri et al. pointed out, the selection of the index for the assessment of outdoor thermal comfort conditions is still a debated matter.

(i) Standard Effective Temperature (SET*)

(ii) Outdoor Standard Effective Temperature (OUT_SET*)

(iii) Perceived Temperature (PT)

(iv) Predicted Mean Vote (PMV)

(v) Index of Thermal Stress (ITS)

(vi) Predicted Percentage of Dissatisfied (PPD)

(vii) COMFA outdoor thermal comfort model

(viii) Universal Thermal Climate Index (UTCI)

(ix) Wet Bulb Globe Temperature (WBGT)

(x) Predicted Heat Strain (PHS)

Nouri, A.S.; Costa, J.P.; Santamouris, M.; Matzarakis, A. Approaches to Outdoor Thermal Comfort Thresholds through Public Space Design: A Review. Atmosphere **2018**, 9, 108.

Evaluation Method of Adaptation Measures

- Physiologically Equivalent Temperature (PET) is widely used in Europe; it is defined as the air temperature at which, in a typical indoor setting (without wind and solar radiation), the heat budget of the human body is balanced with the same core and skin temperature as under the complex outdoor conditions to be assessed.
- In Japan, SET* and WBGT are mainly used. WBGT, which is a stress index worldwide accepted as a preliminary tool for the assessment of hot thermal environments, is often used under more severe conditions to warn of the risk of heat stroke.
- SET* is defined as the equivalent dry bulb temperature of an isothermal environment at 50% RH in which a subject, while wearing clothing standardized for the activity concerned, would have the same heat stress and thermo-regulatory strain as in the actual test environment, is used to evaluate the thermal environment.

Höppe, P. The physiological equivalent temperature—A universal index for the biometeorological assessment of the thermal environment. Int. J. Biometeorol. **1999**, 43, 71–75.

Sensitivity analysis of SET*

Condition in typical summer

Air temperature: 34℃ (<u>20-40℃</u>),

Relative humidity: 50% (<u>30-80%</u>)

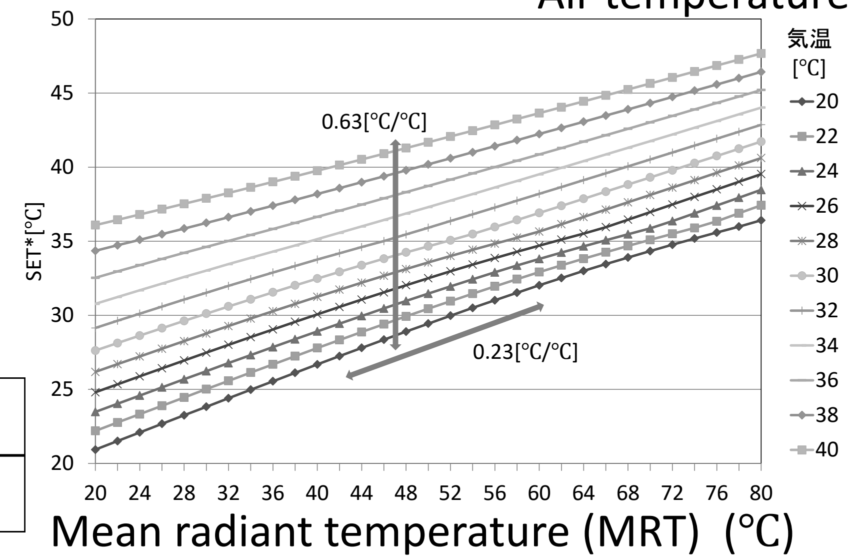
Wind velocity: 1m/s (<u>0.5-3.0m/s</u>),

MRT: 50℃ (sunny), 37℃ (shade) (<u>20-60℃</u>)

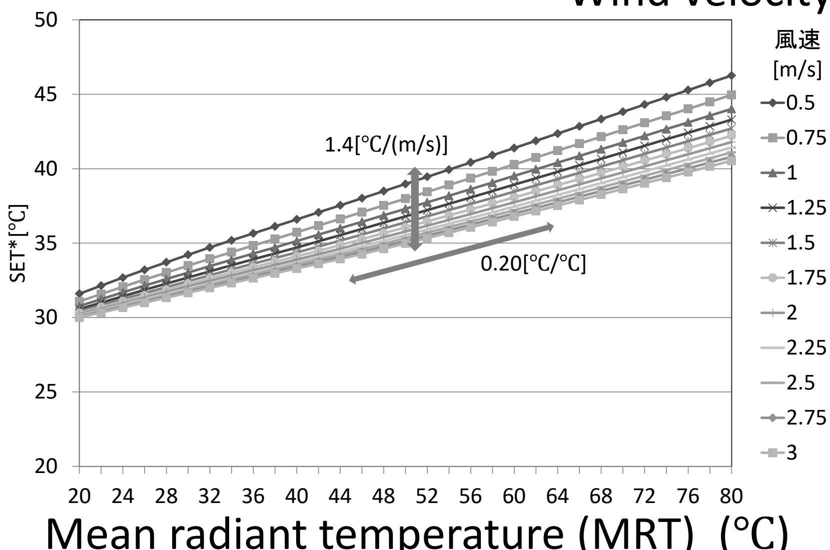
Clothing: 0.6clo, metabolism: 2Met

MRT	<u>0.21[°C/°C]</u>	Wind vel.	1.4[°C/(m/s)]
Air temp.	0.63[°C/°C]	Humid.	0.13[°C/%]

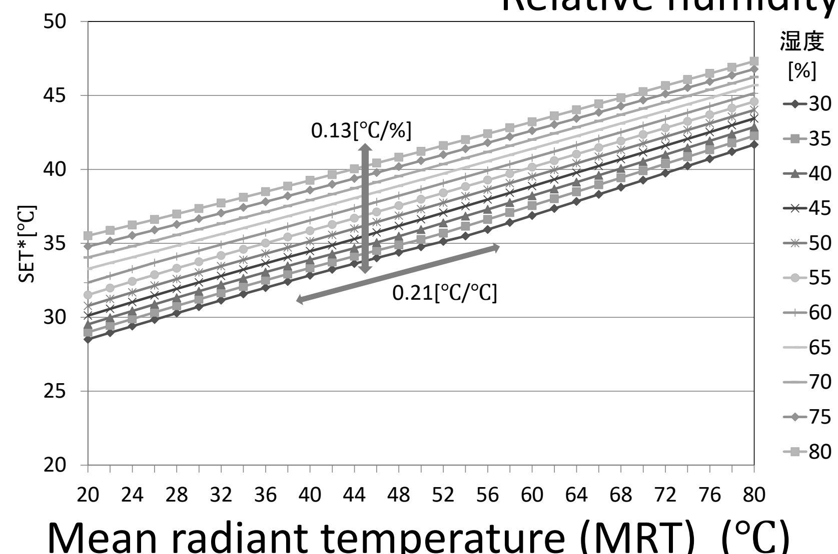
Air temperature



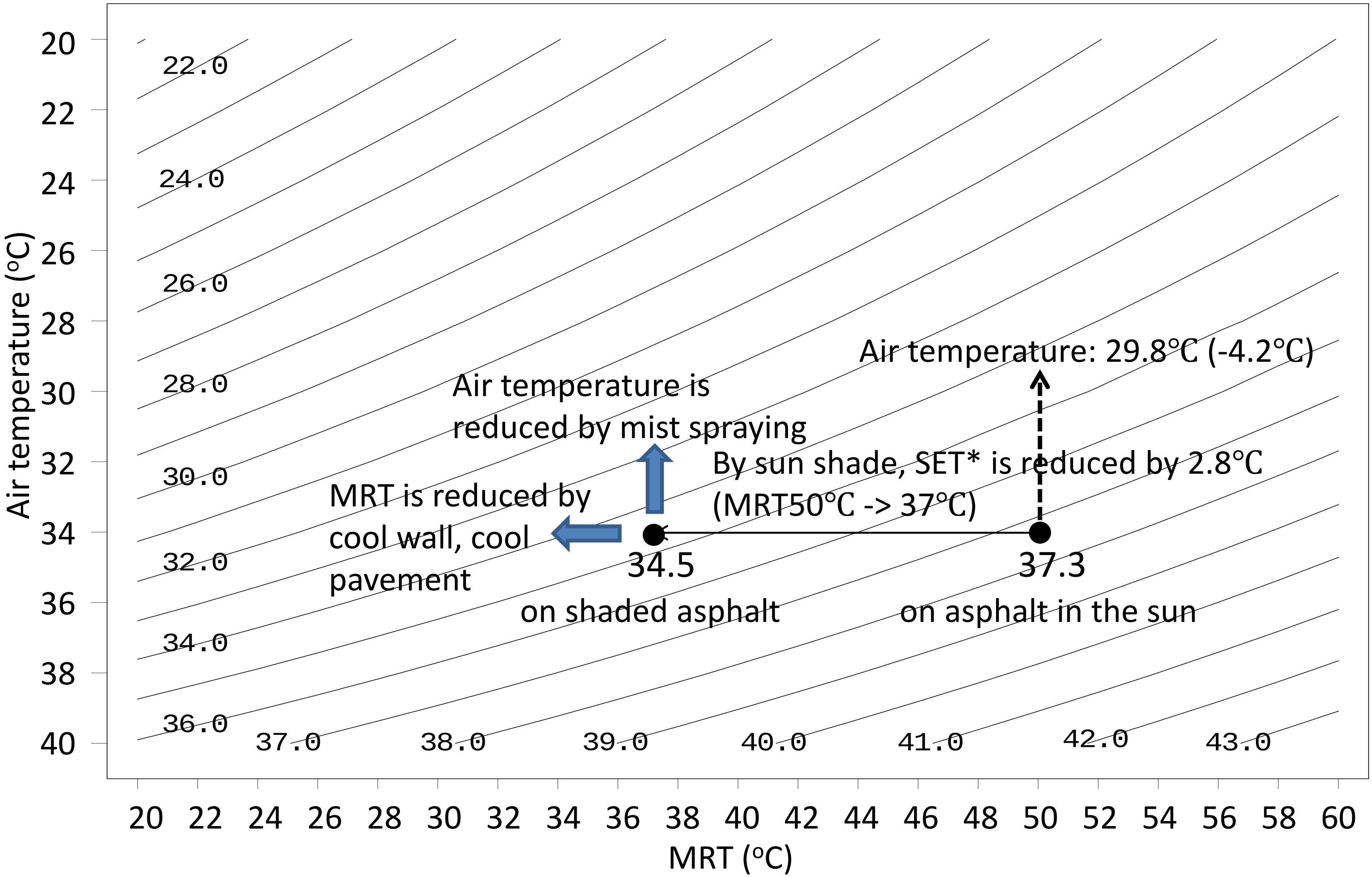
Wind velocity



Relative humidity

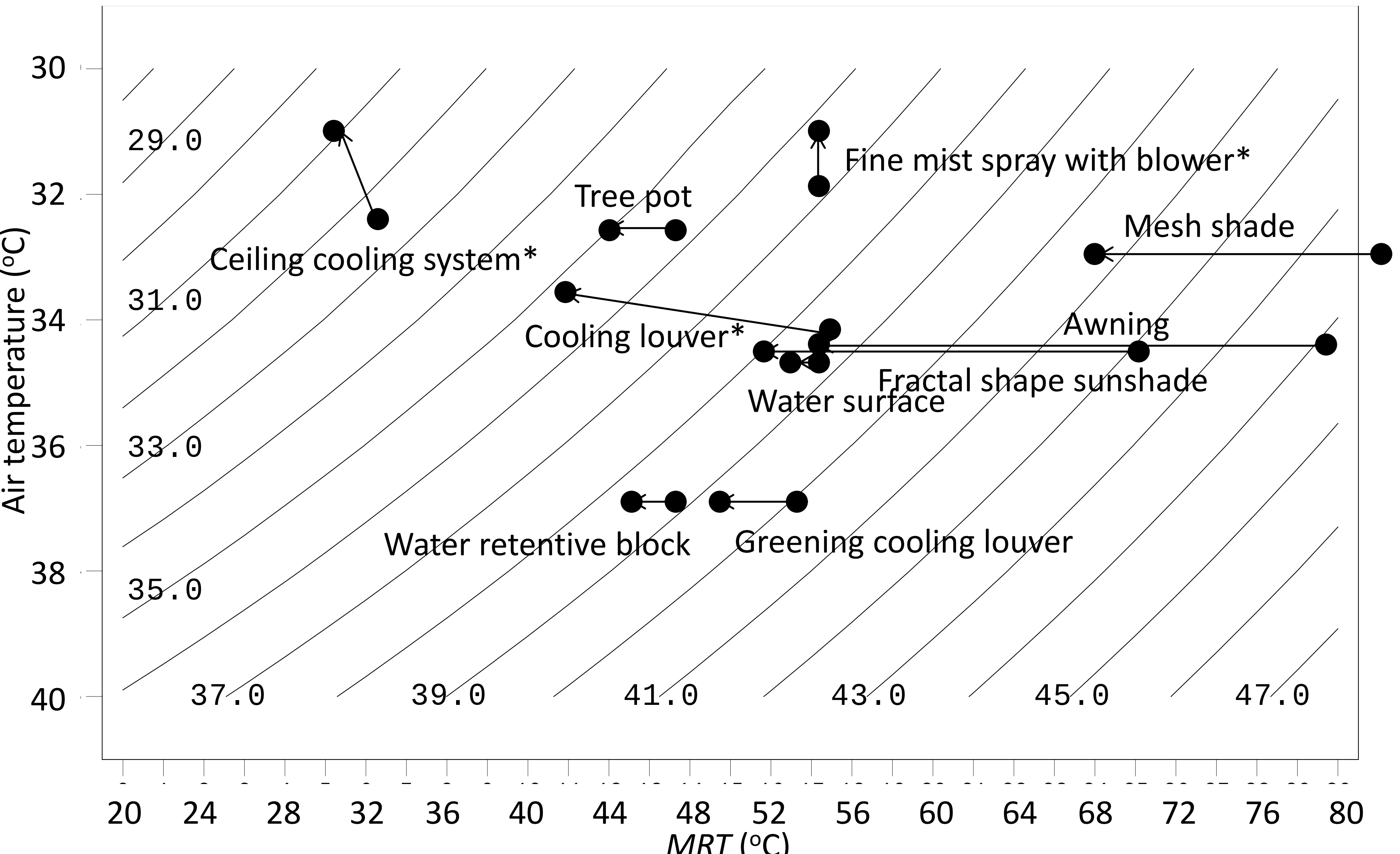


Air temperature, MRT and SET*



Air temperature, MRT and SET*

By the report Entrusted by the Ministry of the Environment in 2016 Fiscal Year



*: change in wind velocity and relative humidity have been reported

Calculation results of reduction of MRT

- Assuming that human body is a sphere,
  MRT can be calculated from

$$MRT = \left(a_h Q/\sigma + \sum_{i=1} \Phi_i T_i^4 \right)^{\frac{1}{4}}$$

a_h is solar absorptance of human body (assumed 0.5).

Q is incident solar radiation on human body (W/m^2).

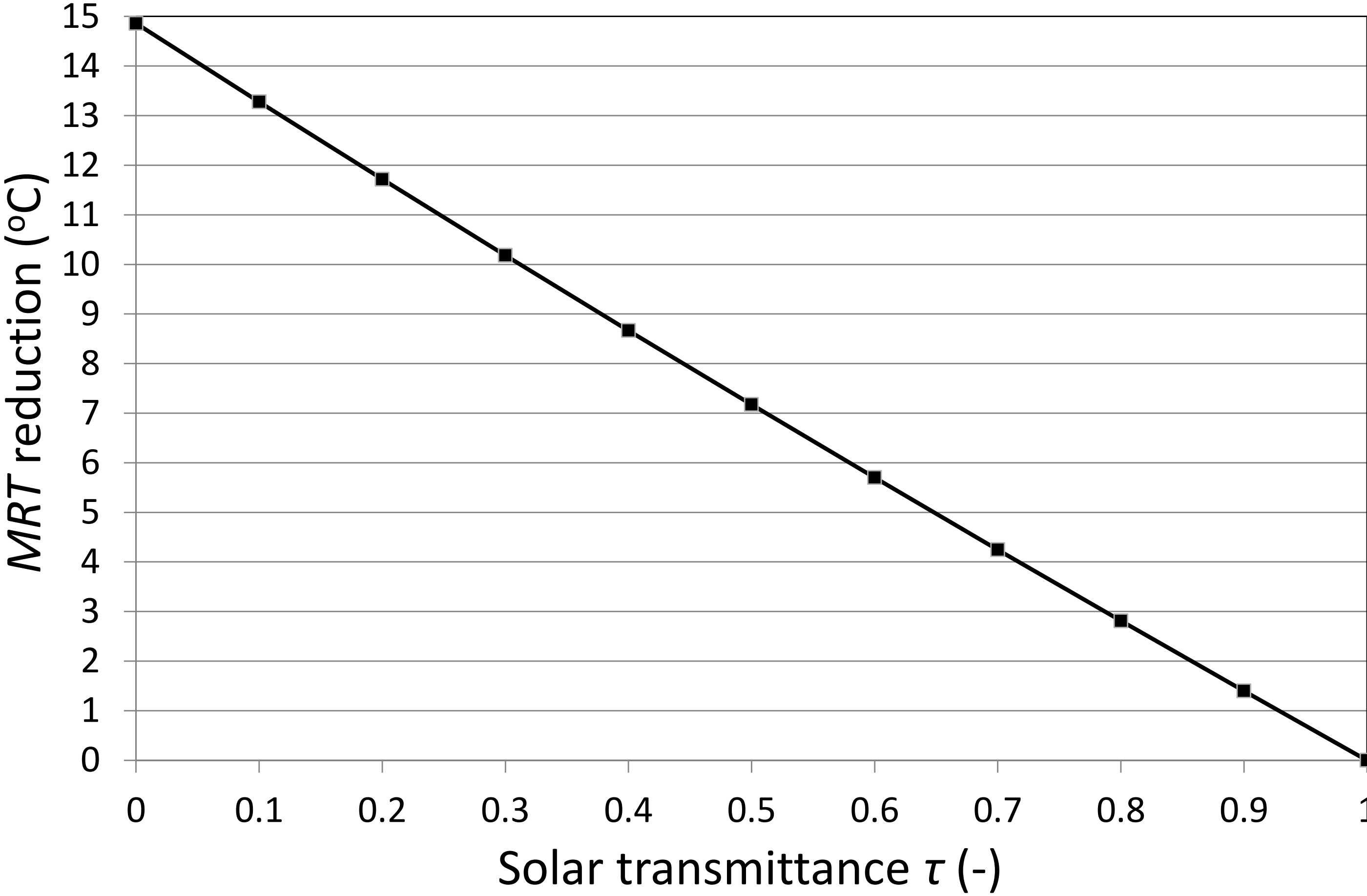
σ is Stefan–Boltzmann constant (=5.67*10^{-8} W/(m^{2}K^4)).

Φ_i is shape factor of human body and each surface.

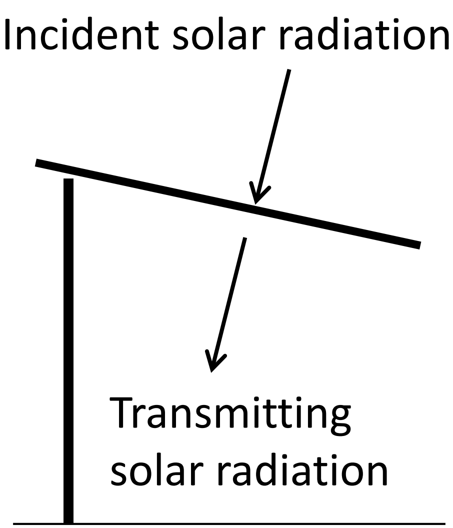
T_i is surface temperature of each surface (K).

Solar transmittance τ and MRT reduction by adaptation measures

when Q = 900/4 + 100 W/m^2, each surface temperature T_i = T_a = 34 ^{o}C)
(Direct solar radiation: 900 W/m^2, diffuse solar radiation: 100 W/m^2)



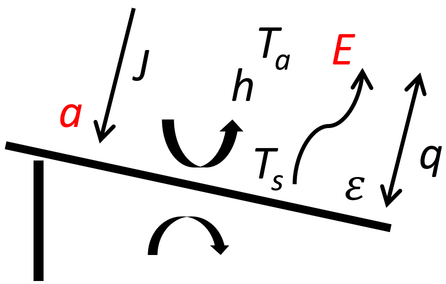
τ = Transmitting / Incident



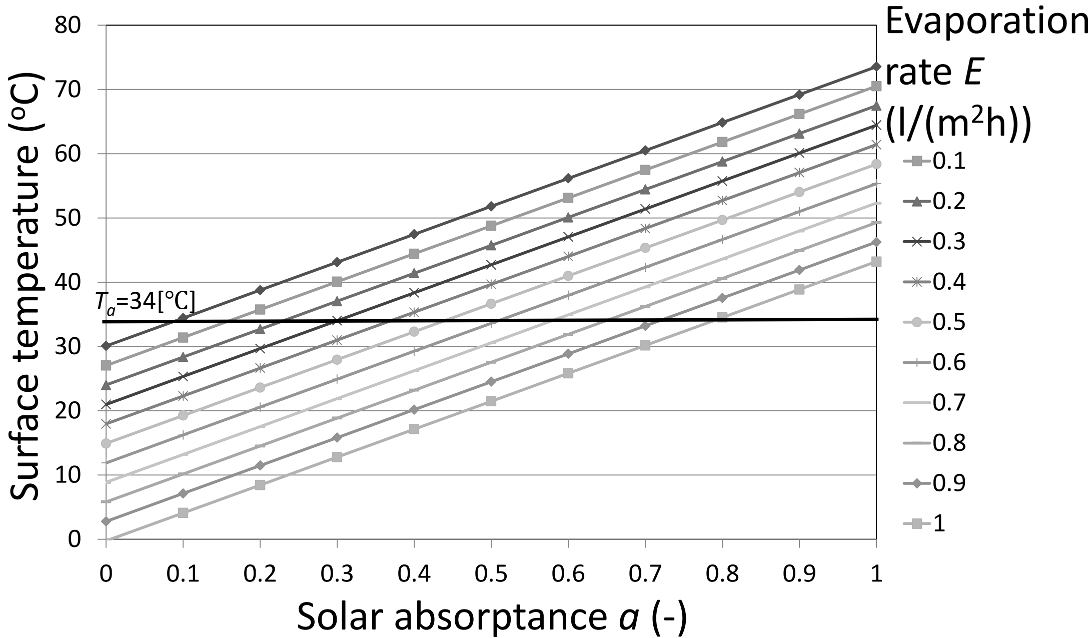
Surface temperature T_s of adaptation measures and solar absorptance a

- Surface temperature T_s of adaptation measures is calculated from

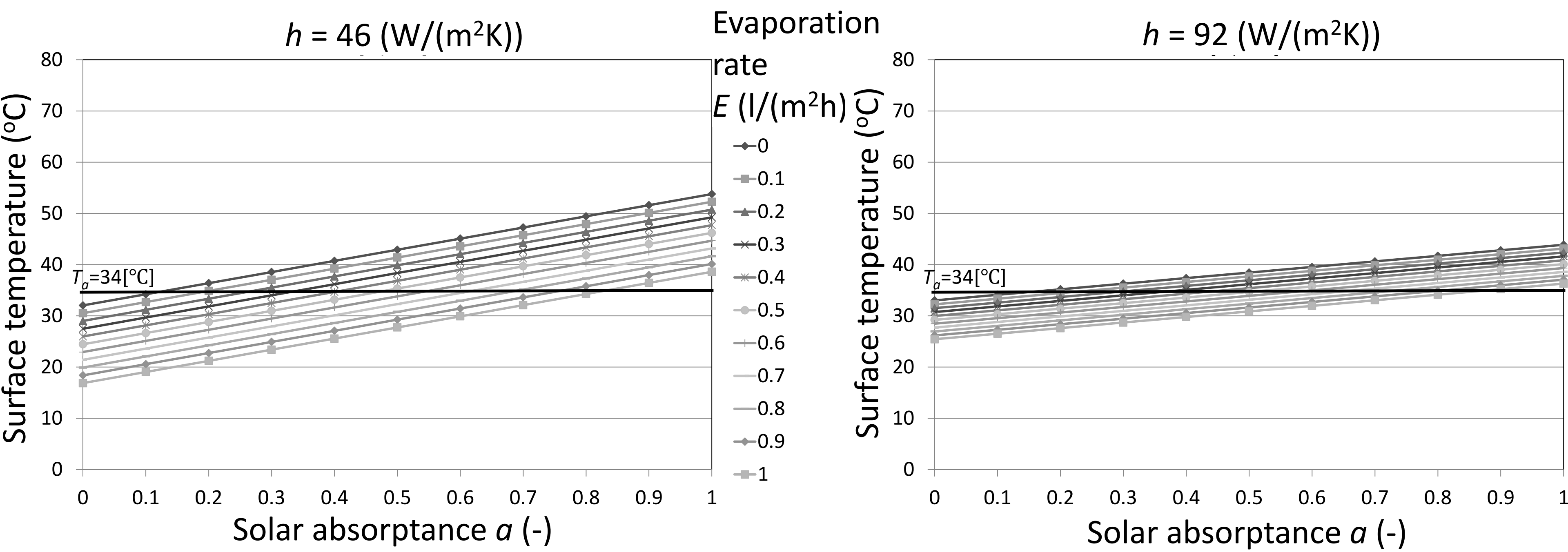
$$T_s = \frac{1}{h}(aJ + \varepsilon q - lE) + T_a$$

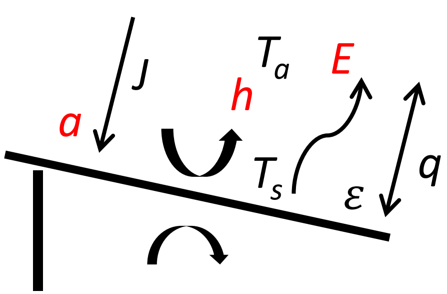


Heat transfer coefficient h is 23 W/(m^{2}K), emissivity ε is 0.97, net infrared radiation q is −93 W/m^2 for different values of evaporation rate E (l/m^{2}h)



Surface temperature T_s when heat transfer coefficient h is 46, 92 W/(m^{2}K)

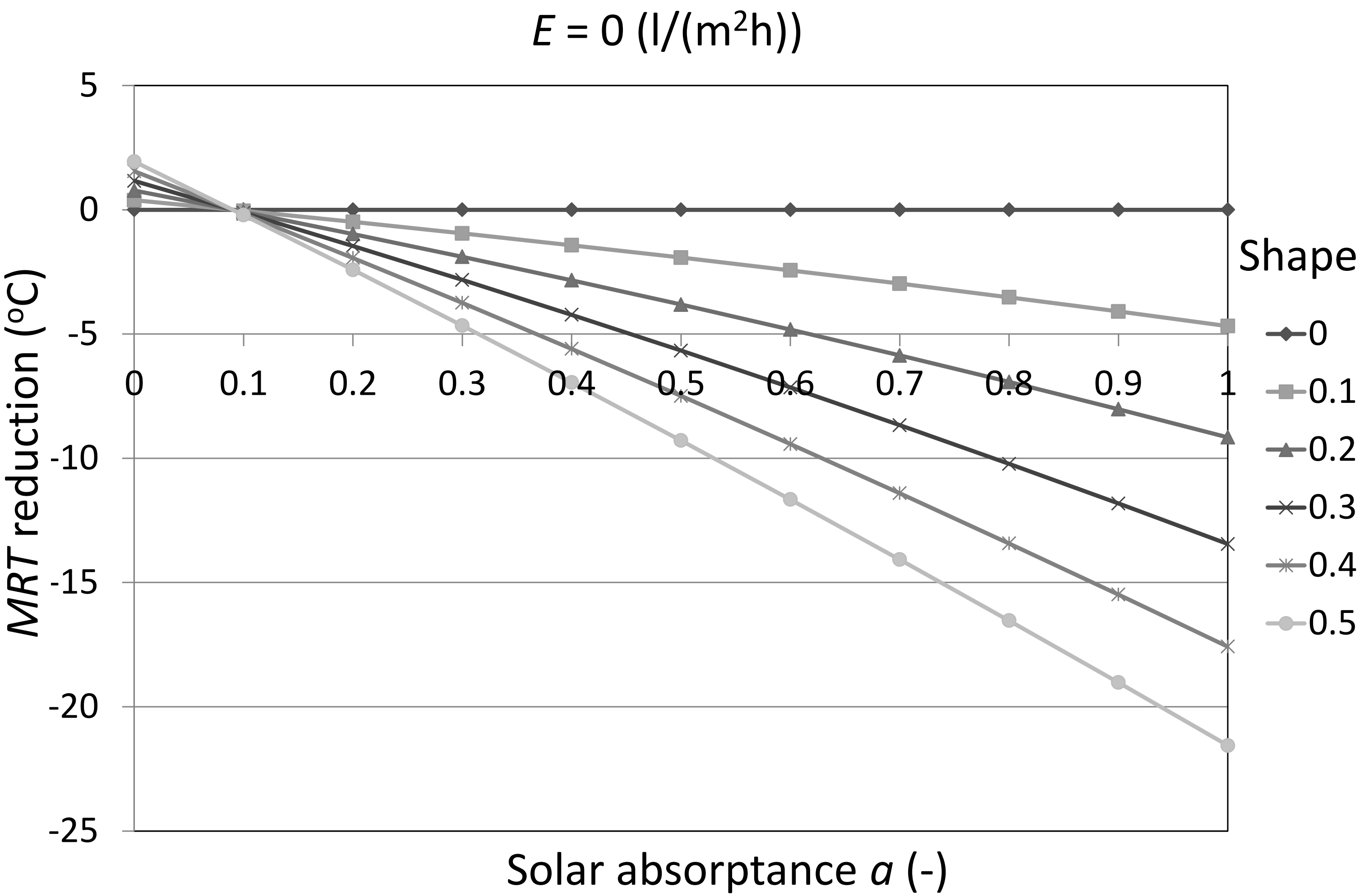


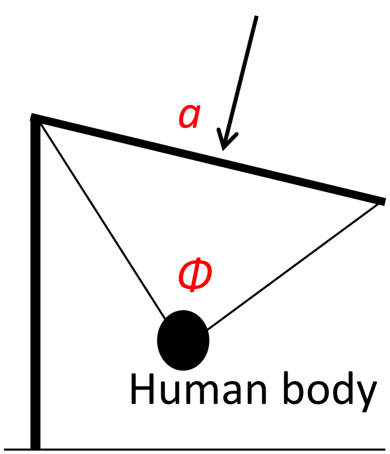


MRT reduction and solar absorptance *a*

when evaporation rate *E* is 0 l/(m^2h)

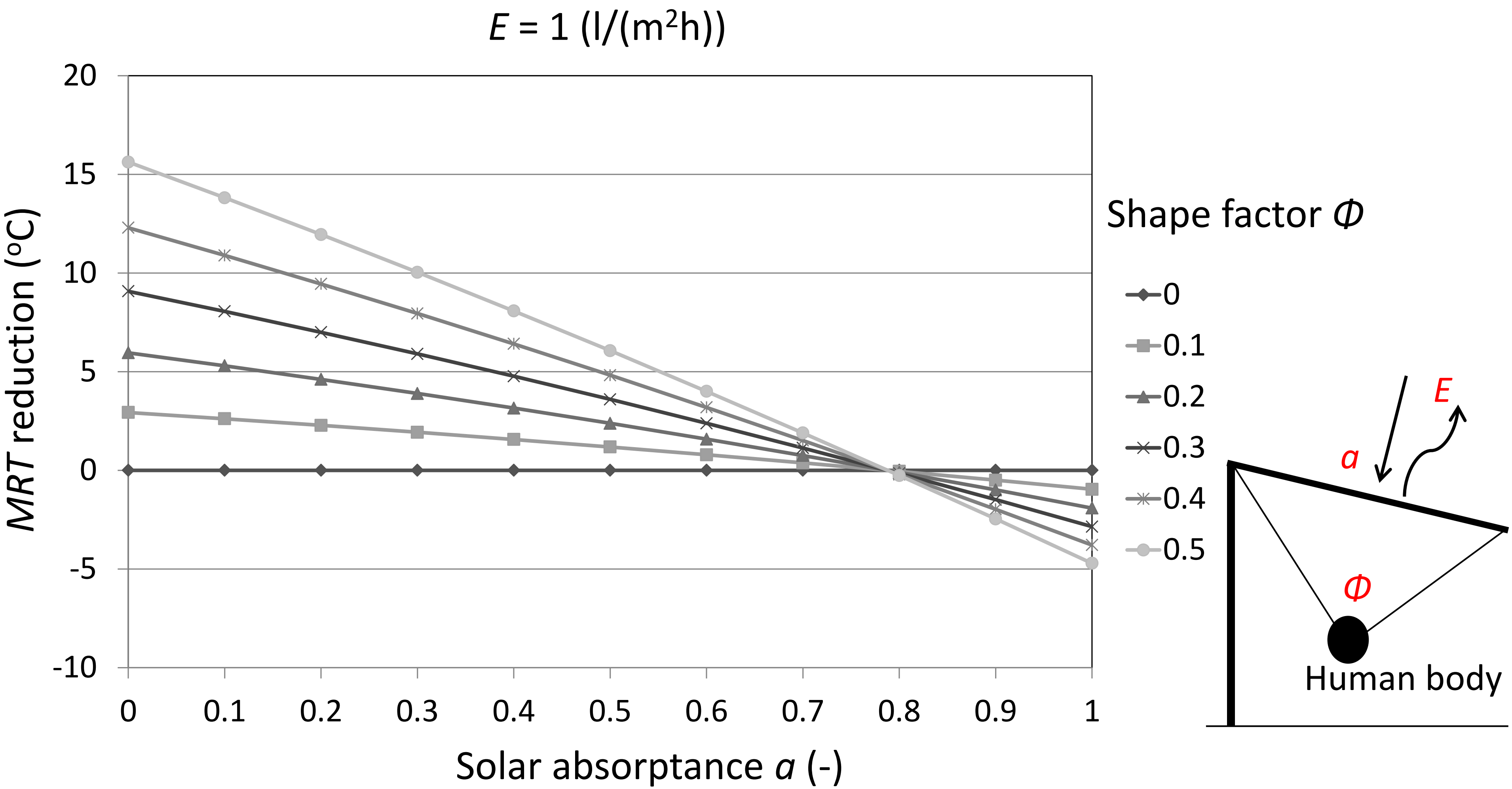
for different values of shape factor *Φ* of human body





MRT reduction and solar absorptance *a*

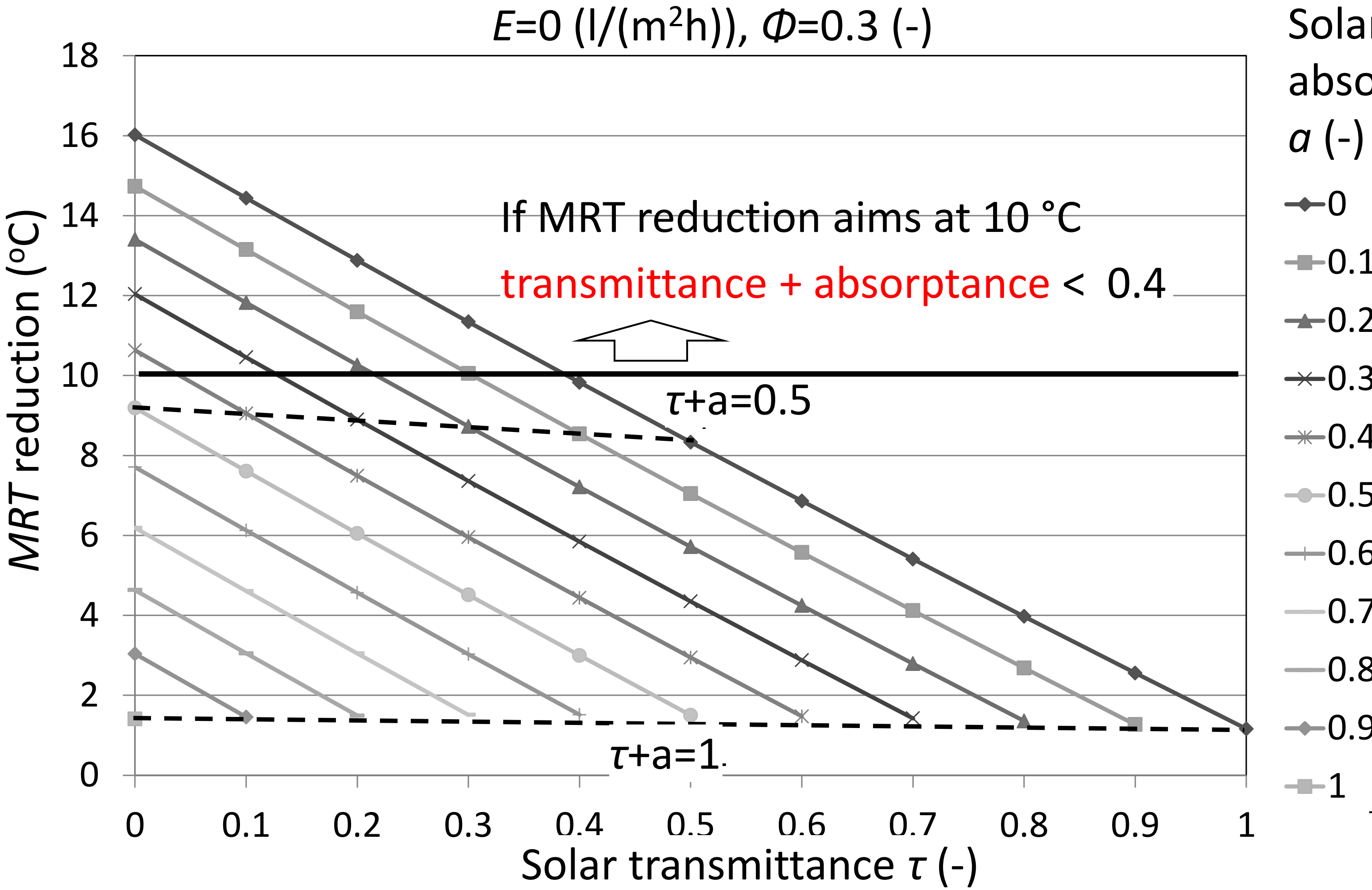
when the evaporation rate <u>*E* is 1 l/(m²h)</u>
for different values of shape factor *Φ* of human body

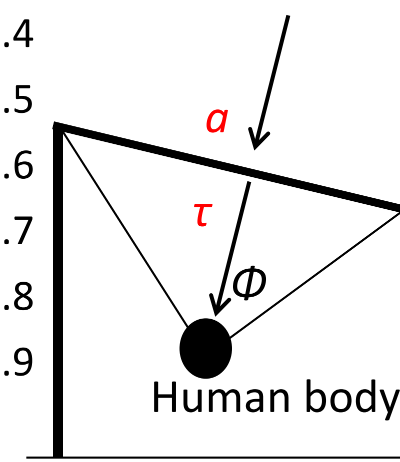


MRT reduction and solar transmittance τ

when the evaporation rate *E* is 0 l/(m²h)

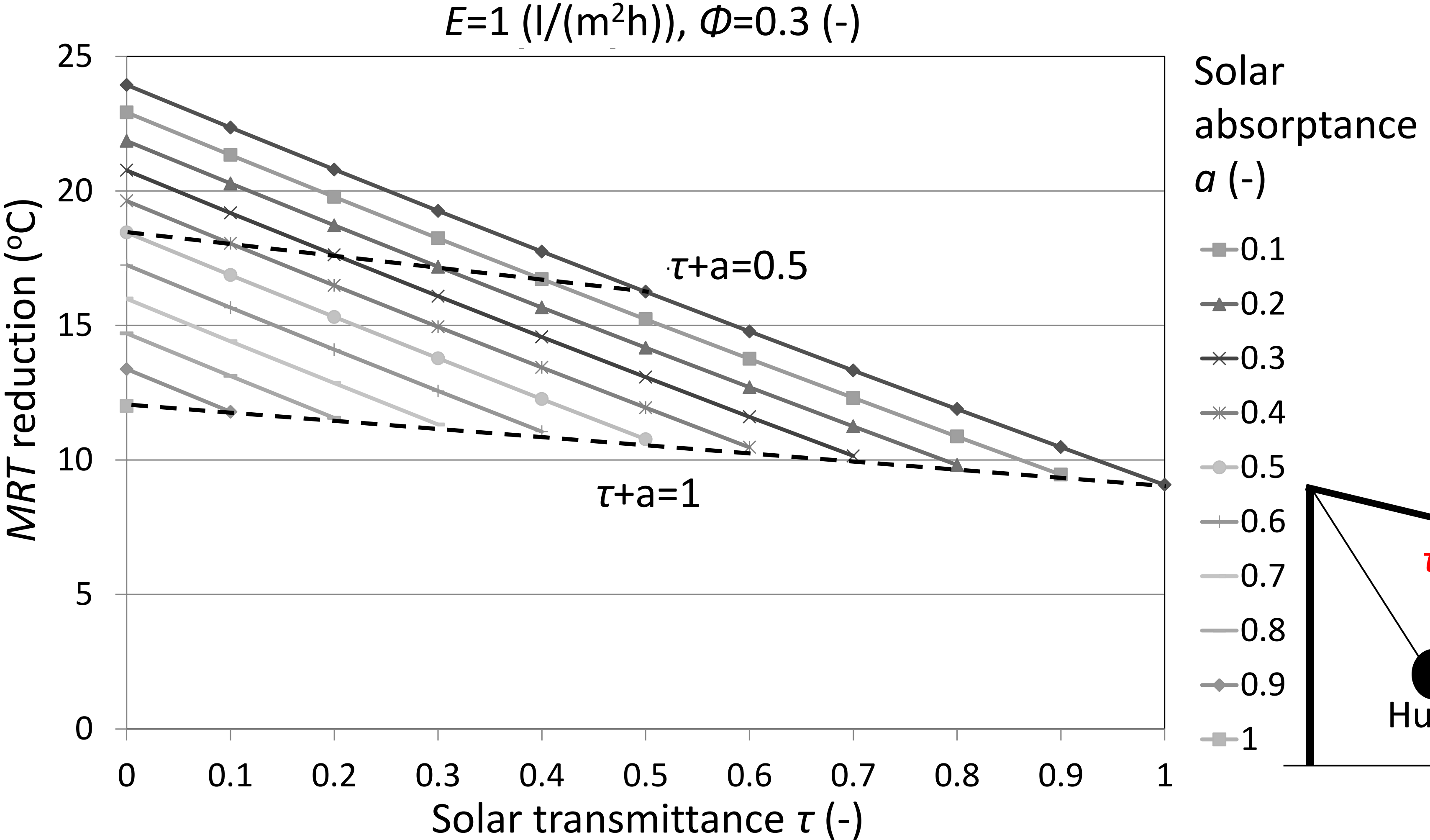
shape factor *Φ* of human body is 0.3

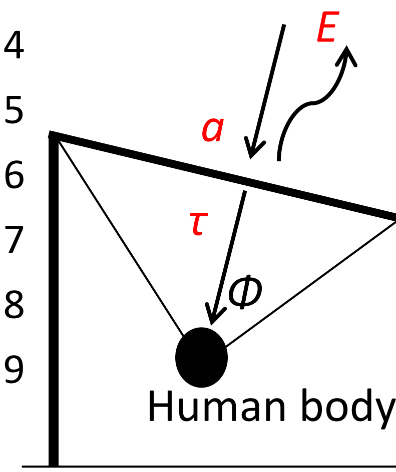




MRT reduction and solar transmittance τ

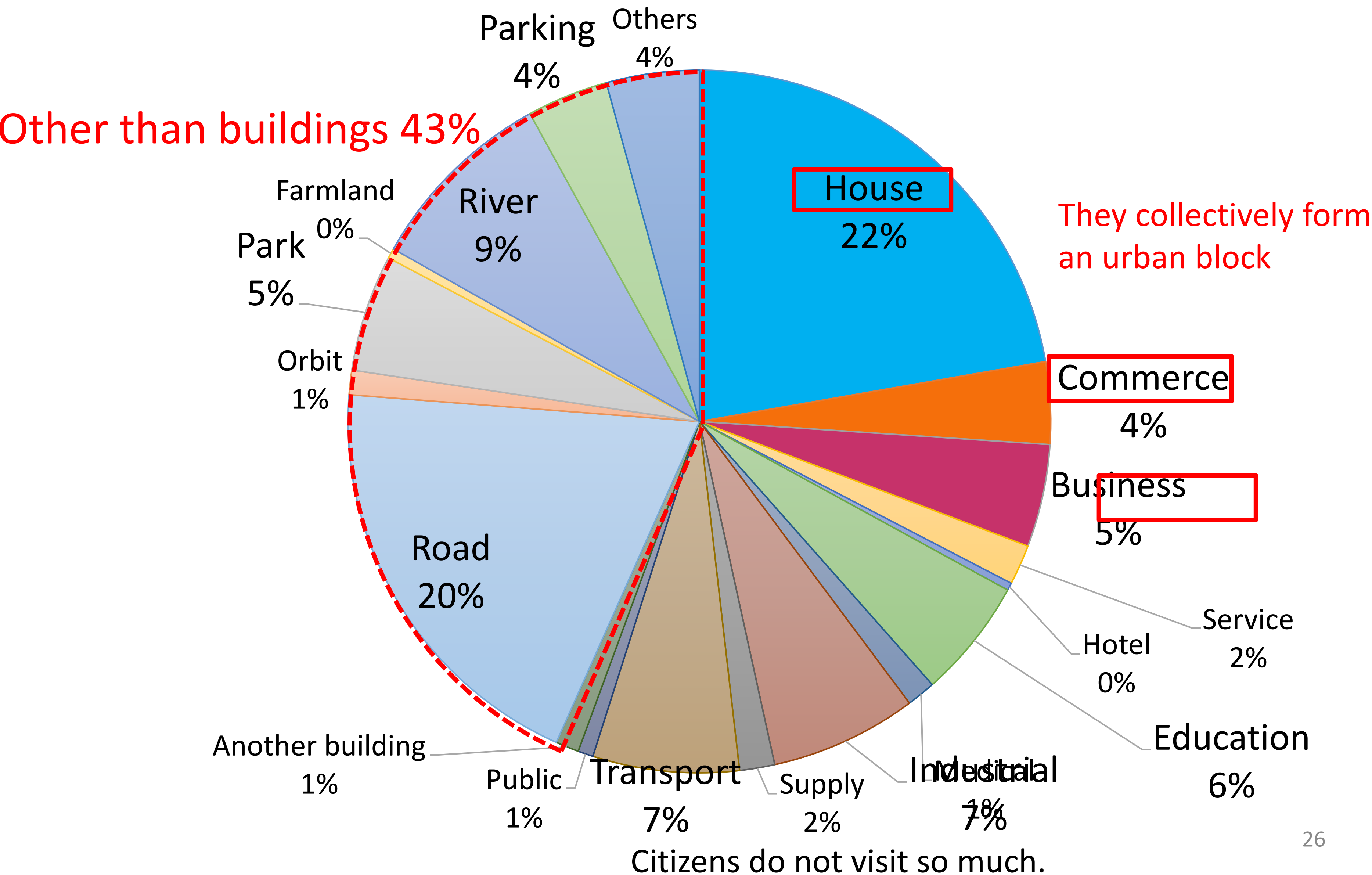
when the evaporation rate <u>E is 1 l/(m^{2}h)</u>
shape factor <u>Φ</u> of human body <u>is 0.3</u>



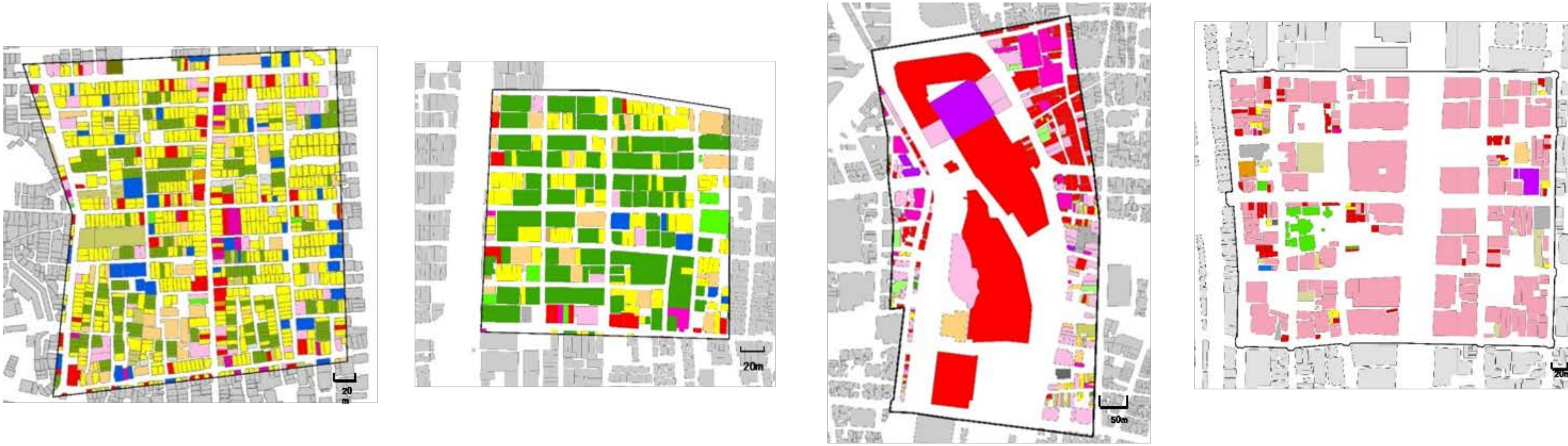


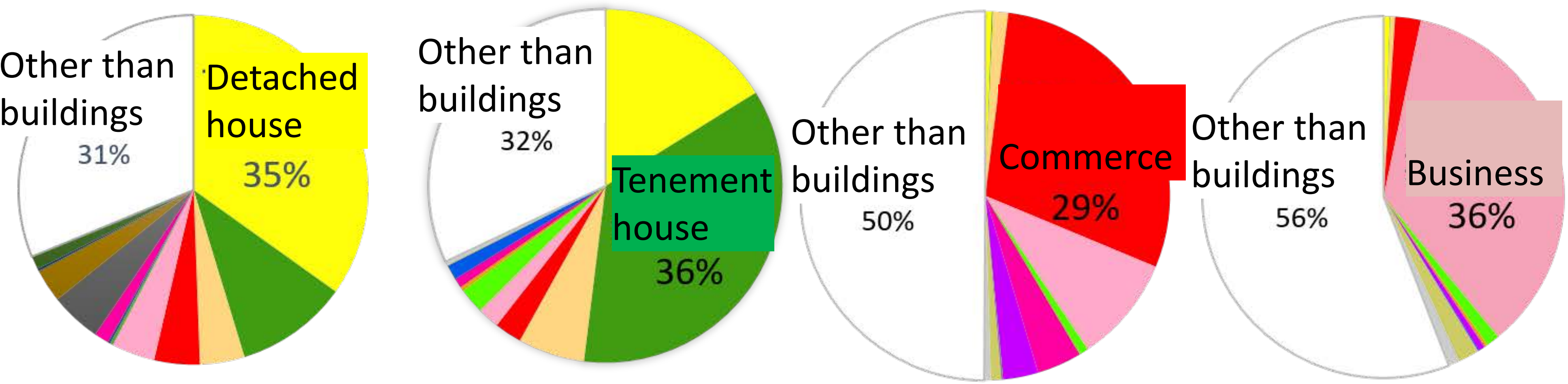
Extraction of hot spots based on urban block characteristics

Land use ratio in Osaka city



Objective urban blocks

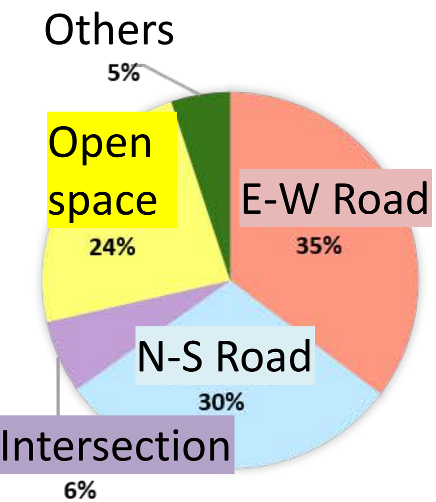




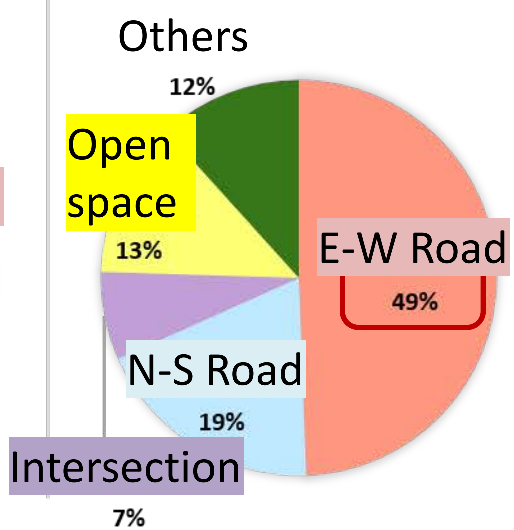
一戸建て住宅　長屋住宅　共同住宅　販売商業施設
業務施設　文教施設　医療厚生施設　遊興・娯楽・サービス施設
工業施設　運輸通信施設　その他施設　建物以外

E-W road, N-S road, Intersection, Open space, Others in <u>other than buildings</u>

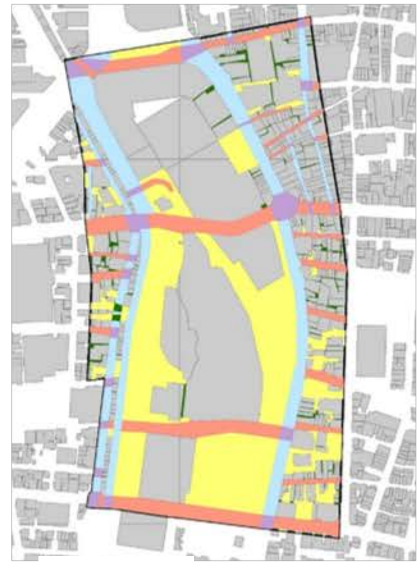
Detached house district

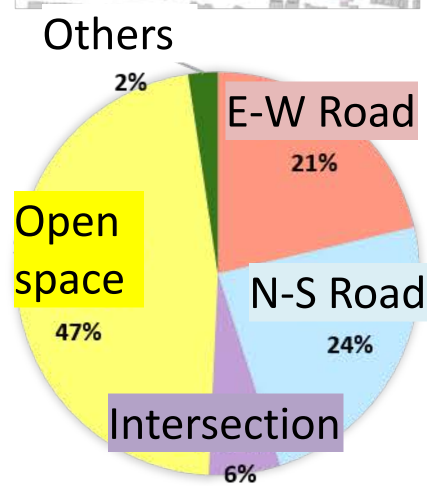


Tenement house district

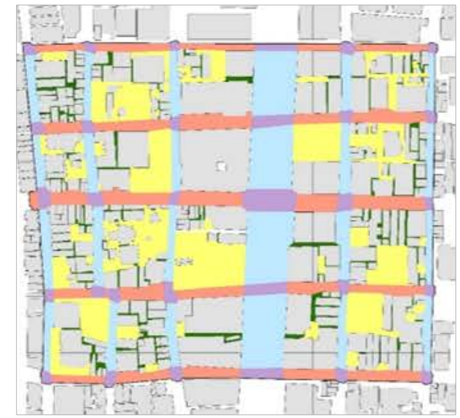


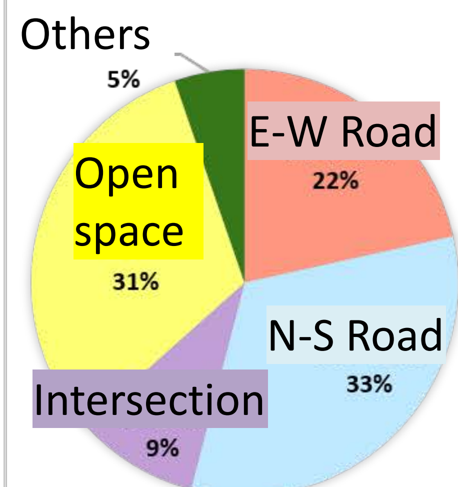
Commerce district





Business district

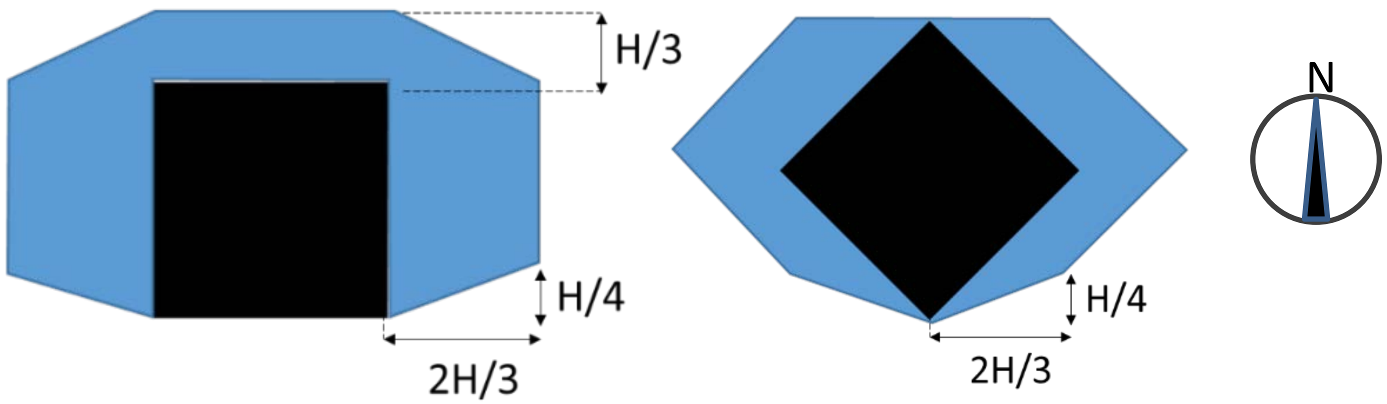




Sunshine condition

Places hard to be shadowed by buildings

If the building height is H, the blue part is 80% or less of the daily integrated solar radiation gain. The other spaces are hard to be shadowed by buildings.



Weak wind condition

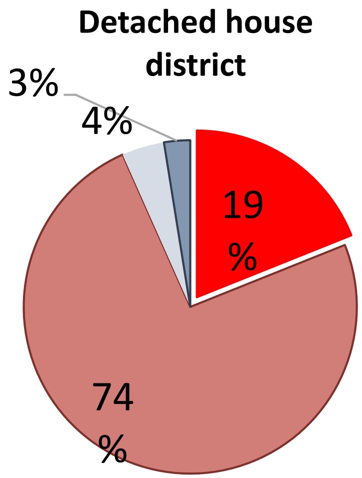
Ventilation is poor in narrow street

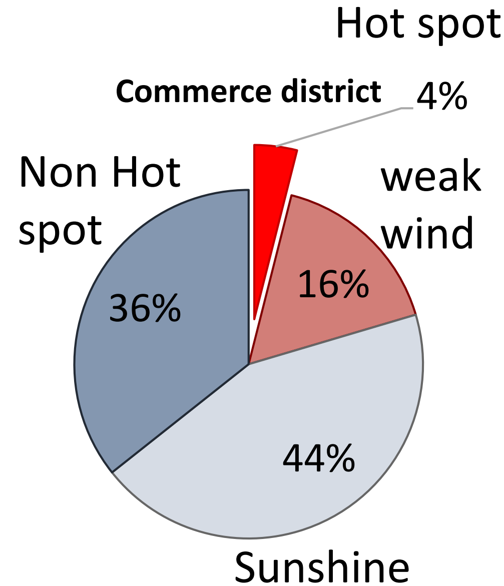
If the road width is W and the building height is H, a weak wind risk of 70% or more occurs in a narrow street.

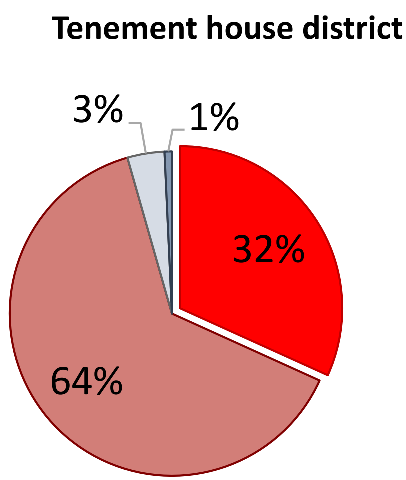
Selection criteria of hot spot by wind environment (high priority area)

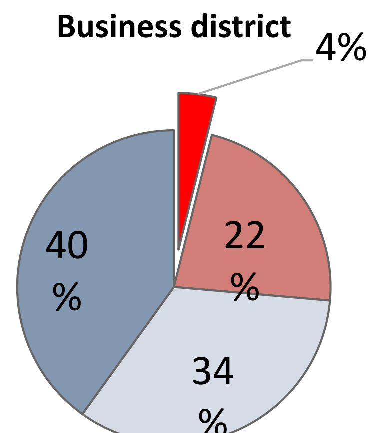
<table>
<tr><th>W</th><th>road parallel to main wind direction</th><th>road perpendicular to main wind direction</th></tr>
<tr><td>0 - 5 m</td><td colspan="2">regardless of H</td></tr>
<tr><td>5 - 10 m</td><td rowspan="2">H < 30 m</td><td>H < 30 m</td></tr>
<tr><td>10 -15 m</td><td>H < 40 m</td></tr>
</table>

Hotspots: weak wind and sunshine









Hot spot (weak wind and sunshine) ホweak wind
Sunshine 乱×日射遮蔽〇 Non Hot spot

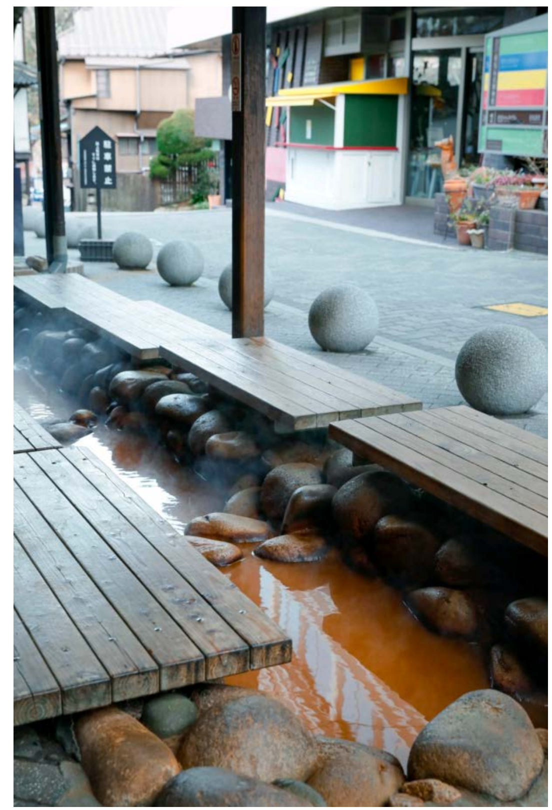
Summary

In Japan, the study of adaptation city has already started.

We expect to exchange information with Italians and the world.

Thank you for your attention.

Kobe Harbor



Hot spring town in Kobe suburb