TOKYO METROPOLITAN UNIVERSITY
東京都立大学

# Survey Project on $CO_2$ Emission Reduction Effects of Buildings by ZEB in ASEAN Countries

April 12, 2022

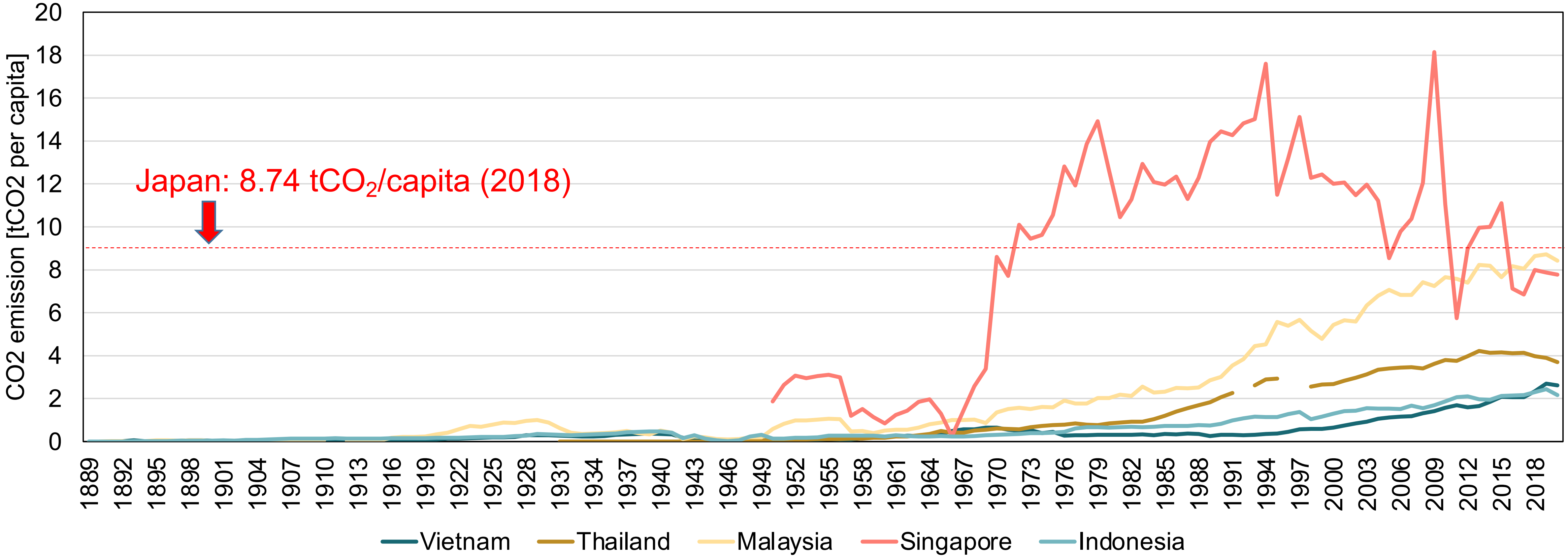
Ichinose Laboratory
Department of Architecture
Faculty of Urban Environmental Sciences
Tokyo Metropolitan University

# Contents

# Contents

1. $CO_2$ Emissions and Actual Energy Regulations of Buildings
2. Indoor Environment and Actual Energy Consumption of Buildings
3. Comparison of Climate Characteristics
4. Prediction of Reduced Environmental Load by Dissemination of ZEB Family
5. Summary

# 1. $CO_2$ Emissions and Actual Energy Regulations of Buildings

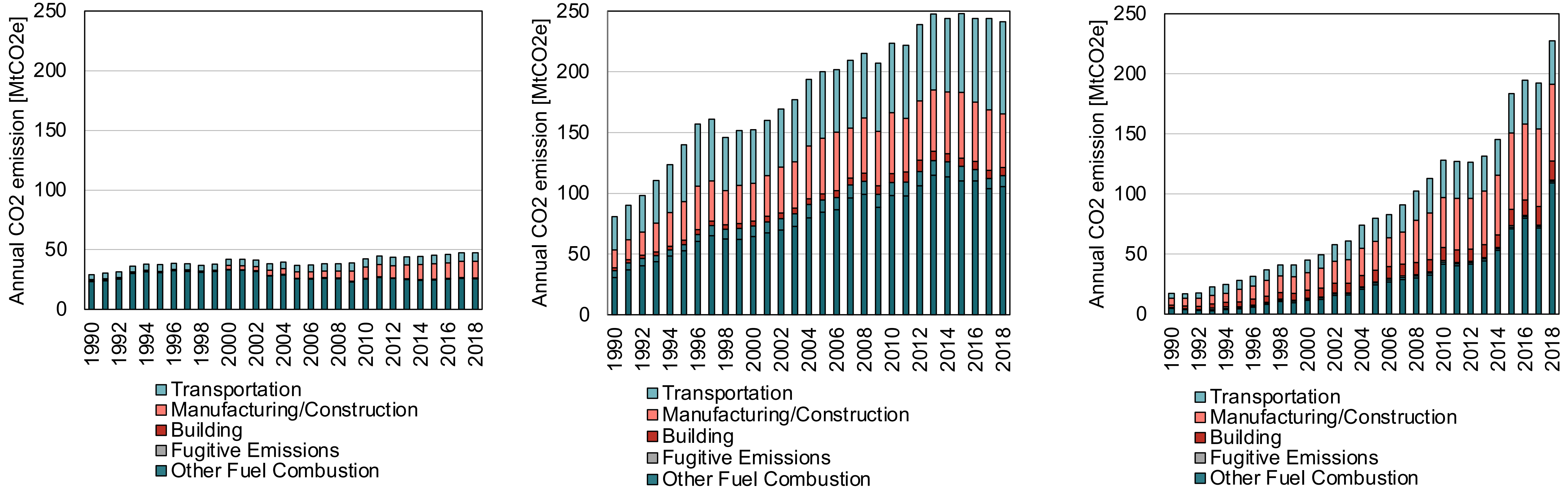



$CO_2$ emission per capita by country [1)]

Since the 1950s, $CO_2$ emission per capita has been increasing in the Southeast Asian Countries.

1) Climate Watch (CAIT): Country Greenhouse Gas Emission Data, World Resources Institute, https://www.wri.org/data/climate-watch-cait-country-greenhouse-gas-emissions-data, Accessed on 2022/2/24

# 1. $CO_2$ Emissions and Actual Energy Regulations of Buildings




(a) Singapore (b) Malaysia (c) Thailand

## $CO_2$ emission by sector [1)]

If $CO_2$ emissions in each country are classified by sector, those related to architecture account for about 30 to 40% of the total.

It is considered **contributive to establishing a sustainable society** to positively introduce **energy conservation technologies** into buildings.

1) Climate Watch (CAIT): Country Greenhouse Gas Emission Data, World Resources Institute, https://www.wri.org/data/climate-watch-cait-country-greenhouse-gas-emissions-data, Accessed on 2022/2/24

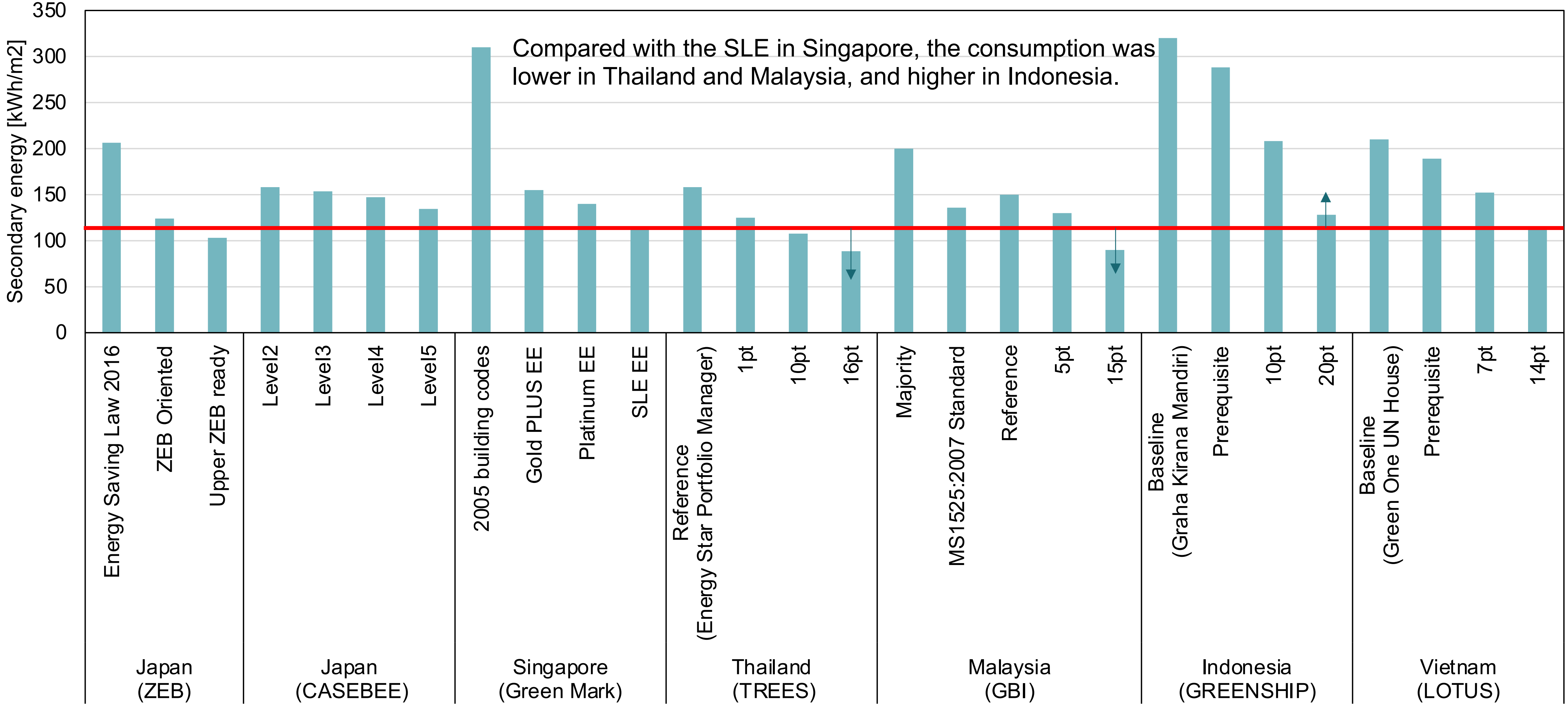
# 1. $CO_2$ Emissions and Actual Energy Regulations of Buildings

## Energy conservation countermeasure in each country

| Country | Energy conservation standards | Evaluation method |
|---|---|---|
| Japan | CASBEE [5)]<br>5) JSBC: CASBEE for Building (New Construction), 2016 edition | Evaluated by BEE = Environmental quality of building / Environmental load of building. Evaluated higher as BEE increases.<br>There are many evaluation items.<br>Energy consumption is evaluated in terms of **BPI** (ratio of standard PAL* to design PAL). |
| | ZEB [6)]<br>6) ZEB PORTAL, Ministry of the Environment: Definition of ZEB | Evaluated in terms of BEI (ratio of standard primary energy consumption to design primary energy consumption).<br>Evaluated higher as BEI decreases. |
| Singapore | Green Mark [7)]<br>7) Building and Construction Authority: GREEN MARK 2021 | Evaluated based on the score of 5 items related to an **energy consumption reduction rate compared with the energy conservation standard model enacted in 2005** and sustainability.<br>Achieve GoldPLUS at 50% reduction of energy consumption, Platinam at 55%, and SLE at 60%, respectively. |
| Thailand | TREES [8)]<br>8) TGBI: Thai's Rating of Energy and Environmental Sustainability (2017) | Evaluated with the total score of 8 items related to sustainability.<br>For energy consumption, points are added based on a **reduction rate compared with Energy Star Portfolio Manager**.<br>Energy Star Portfolio Manager is the U.S. standards. |
| Malaysia | Green Building Index [9)]<br>9) GREENBUILDINGINDEX SDN BHD: Green Building Index for NRNC (2009) | Evaluated based on the total score of 6 items related to sustainability.<br>For energy consumption, points are added every time **secondary energy consumption** is reduced by 10 $kWh/m^2$・year **on the basis of 150 $kWh/m^2$・year**. |
| Indonesia | GREENSHIP [10)]<br>10) GREEN BUILDING COUNCIL INDONESIA: GREENSHIP (2013) | Evaluated based on the total score of 6 items related to sustainability.<br>For energy consumption, one point is acquired at every 2.5% reduction from the baseline model, assuming 10% reduction therefrom as a minimum requirement.<br>**The baseline model shall be annual energy consumption of the model in line with the standards enacted by MoPW (Indonesian Ministry of Public Works)**. |
| Vietnam | LOTUS [11)]<br>11) VGBC: LOTUS New Construction V3 Technical Manual (2019) | Evaluated based on the total score of 6 items related to sustainability.<br>For energy consumption, one point is acquired at every 2.5% reduction from the baseline model, assuming 10% reduction therefrom as a minimum requirement.<br>The baseline model shall be **annual energy consumption of the model designed based on LOTUS Guideline**. |

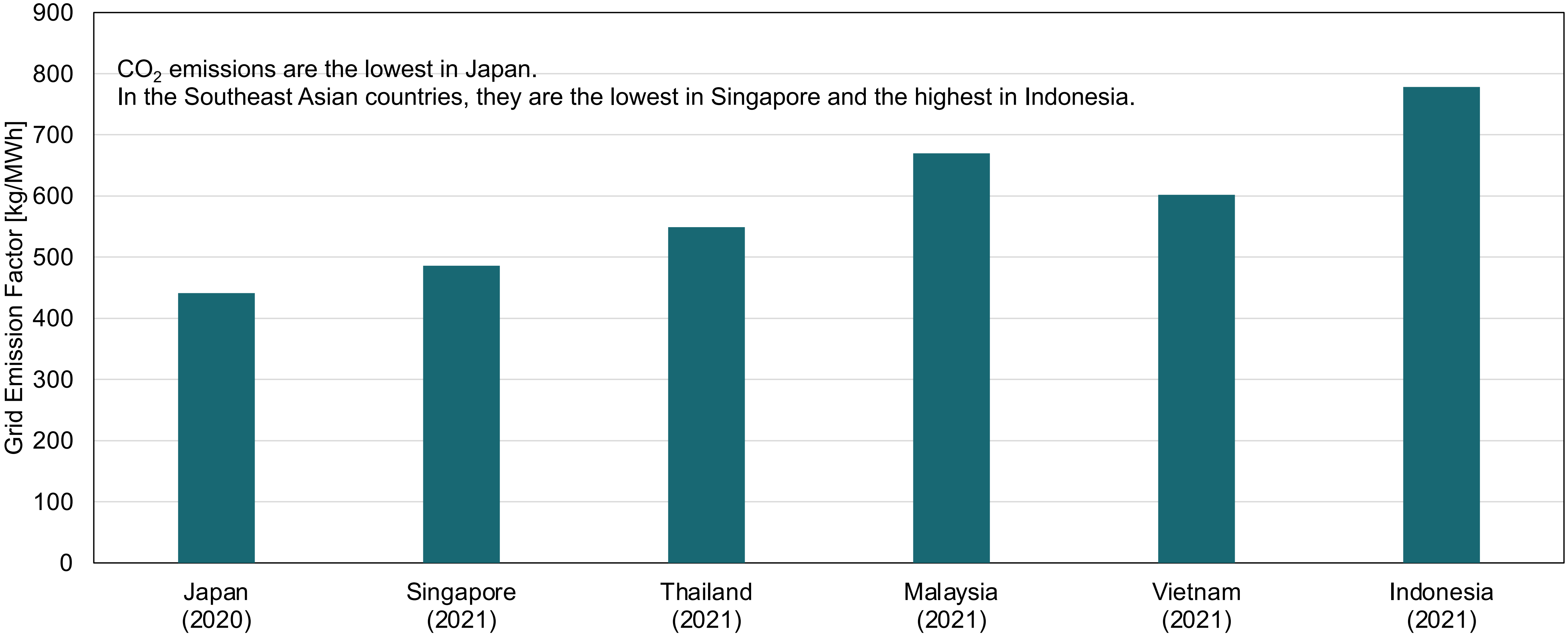
# 1. $CO_2$ Emissions and Actual Energy Regulations of Buildings

The following shows the energy conservation standards in each country converted into secondary energy consumption.




Targeted secondary energy in each Energy Conservation Countermeasure

The following shows $CO_2$ intensity in each country (volume of $CO_2$ emitted at every power generation of 1 kWh).



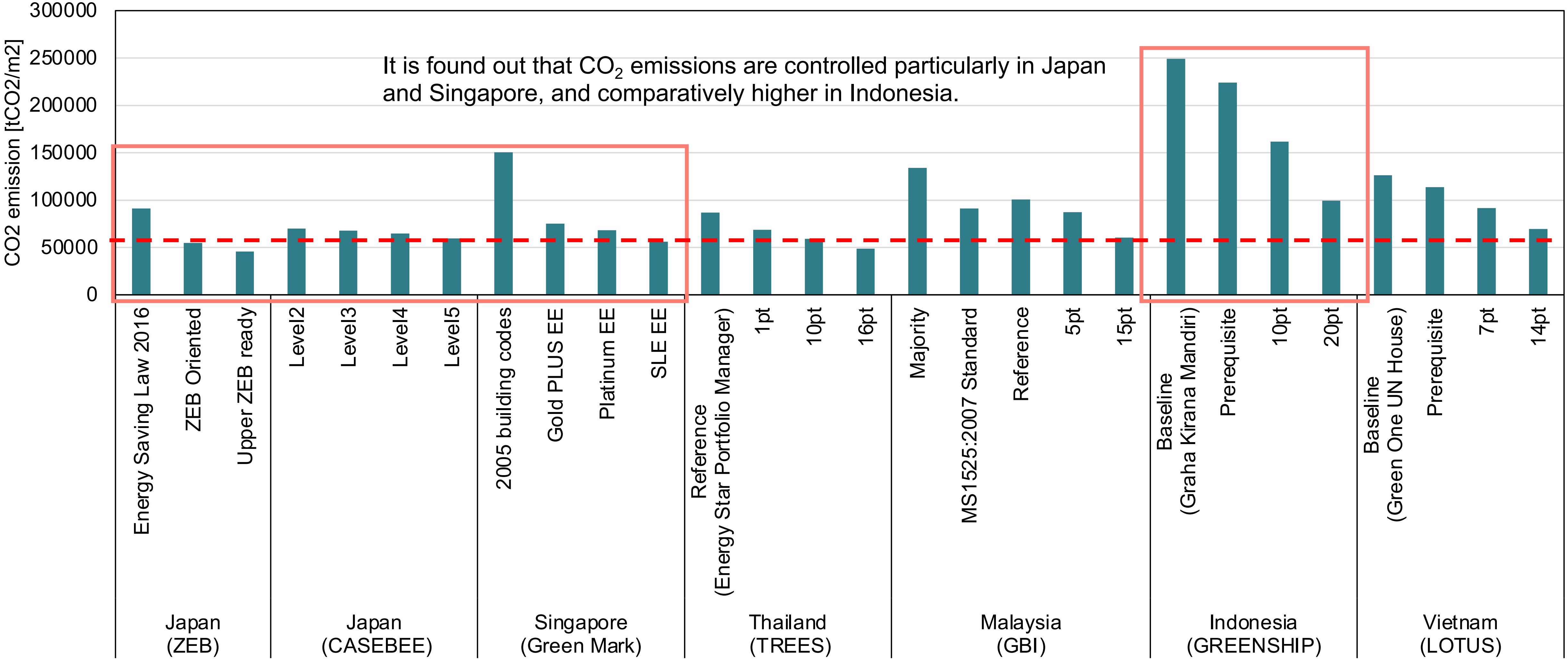

$CO_2$ emission from power generation in Asia [12) 13)]

12) Institute for Global Environmental Strategies: IGES List of Grid Emission Factors (2022)

13) Tokyo Electric Power Company Holdings, Inc.: CO2 emission, emission intensity and electricity sales https://www.tepco.co.jp/corporateinfo/illustrated/environment/emissions-co2-j.html (Accessed on 2022/3/14)

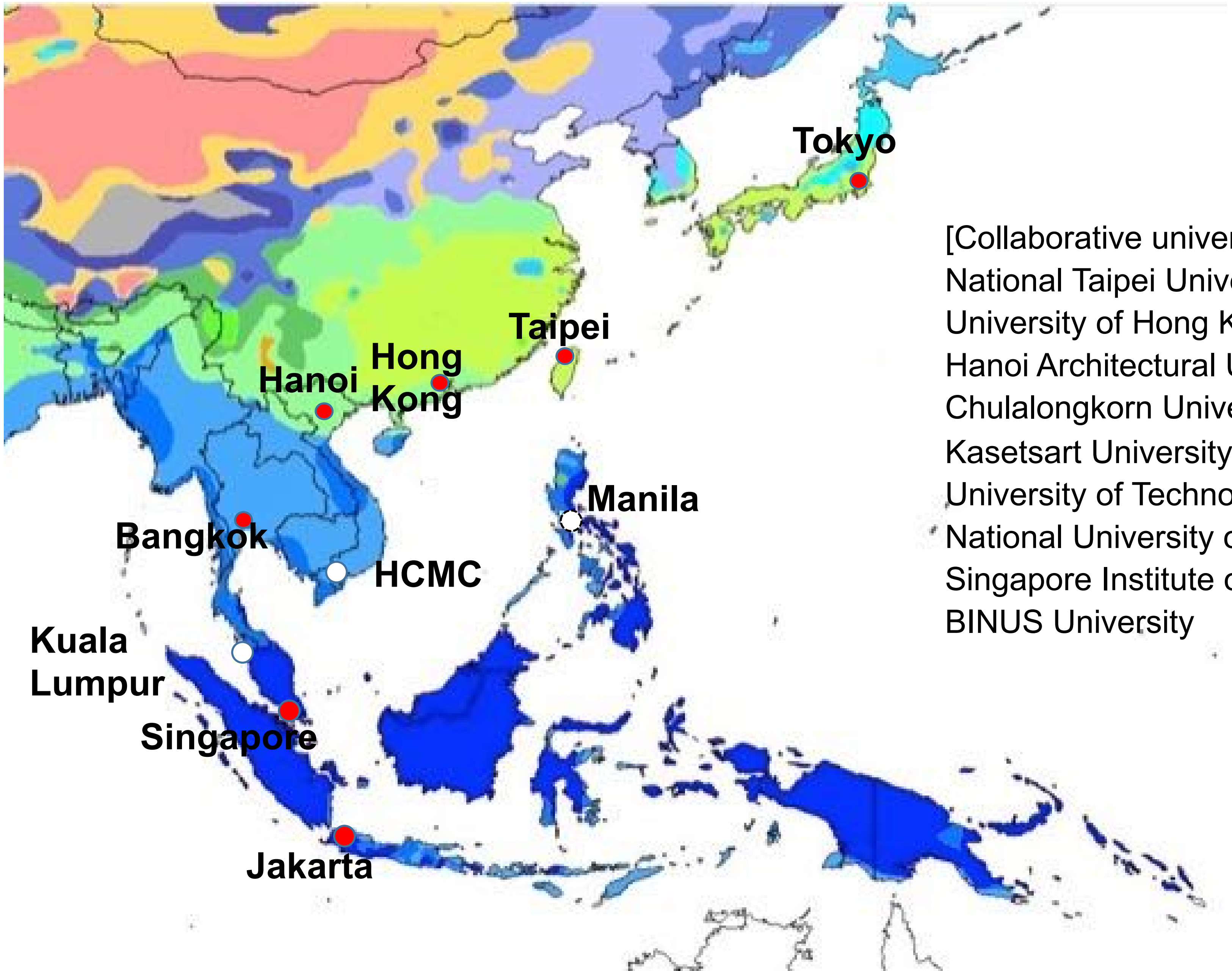
# 1. $CO_2$ Emissions and Actual Energy Regulations of Buildings

The following shows the energy conservation standards in each country converted into $CO_2$ emissions.
The energy conservation standards and $CO_2$ intensity mentioned on the previous pages are used for calculations.




Targeted CO2 emission in each Energy Conservation Countermeasure

# Contents

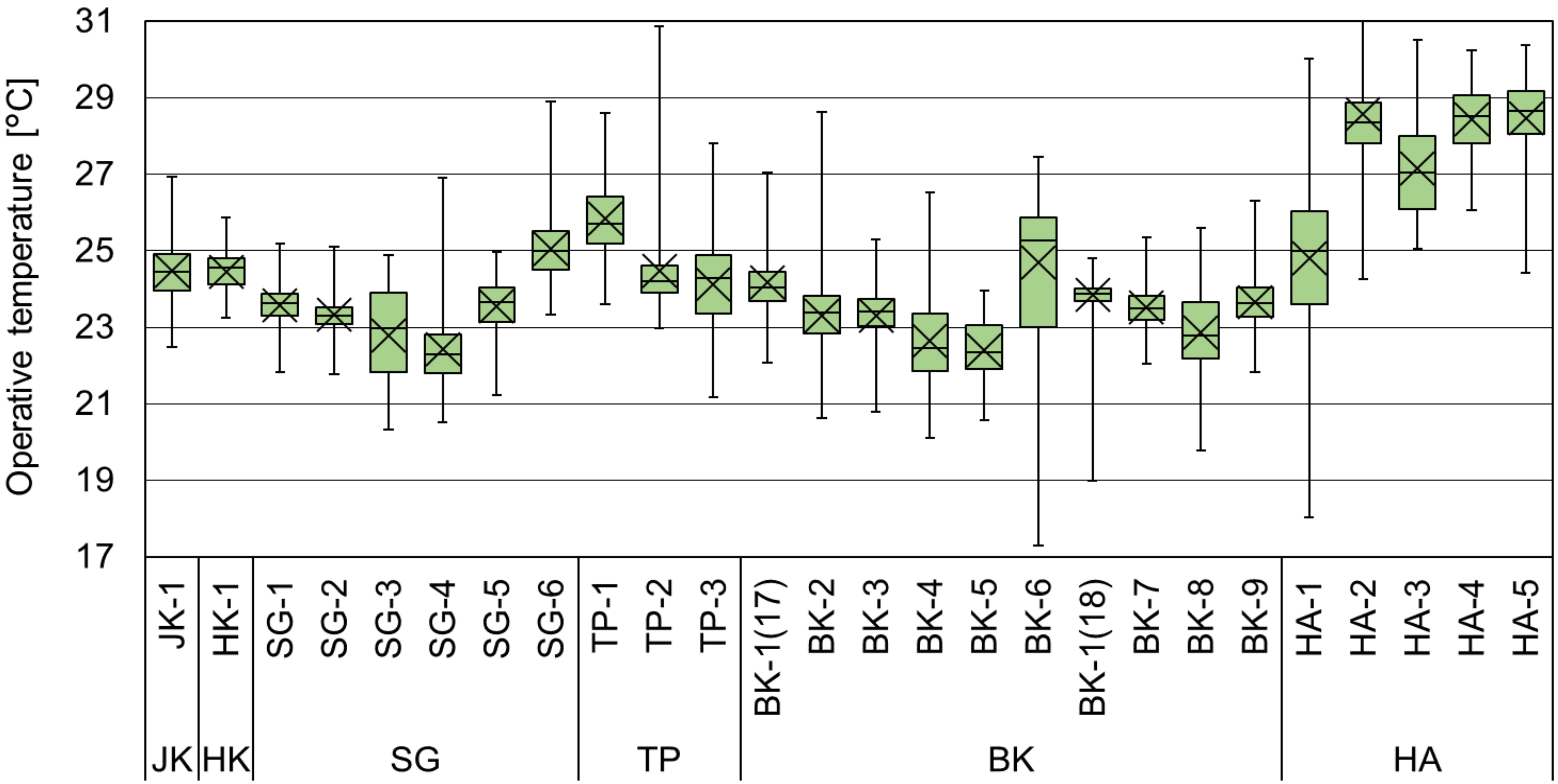



[Collaborative universities]
National Taipei University of Technology
University of Hong Kong
Hanoi Architectural University
Chulalongkorn University
Kasetsart University
University of Technology, Malaysia
National University of Singapore
Singapore Institute of Technology
BINUS University

# Target Office Building for Investigation

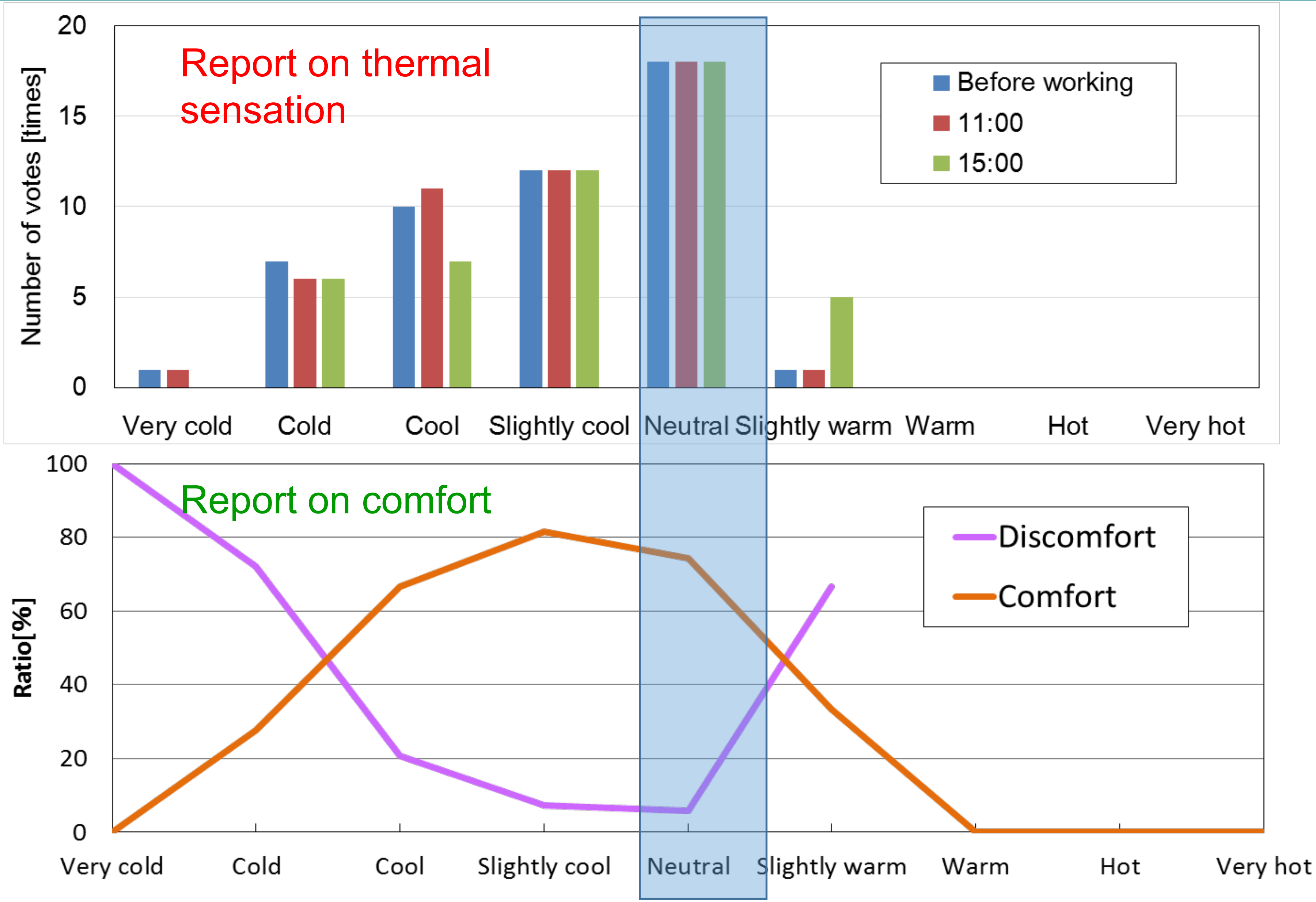
| City | Jakarta | Hong Kong | Singapore | | | | | | Hanoi | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Office | JK-1 | HK-1 | SG-1 | SG-2 | SG-3 | SG-4 | SG-5 | SG-6 | HA-1 | HA-2 | HA-3 | HA-4 | HA-5 |
| Age | 1993 | 2010 | 2014 | 1985 | 2014 | 2003 | 2014 | 2015 | 2010 | 2009 | 2002 | 2013 | 2009 |
| Total stories | 22 | 118 | 9 | 42 | 5 | 5 | 20 | 6 | 23 | 27 | 19 | 25 | 27 |
| Measured floor | 17 | 19 | 4 | 31 | 3 | 2 | 5 | 6 | 22 | 5 | 14 | 22 | 7 |
| A/C type | Cent | Cent | Cent | Cent | Cent | Cent | Cent | Cent | Indi | Cent | Both | Both | Indi |
| GFA [$m^2$] | 27000 | 260200 | 8667 | 81756 | - | 8408 | 31360 | 5516 | 28000 | 22518 | 34640 | 61400 | 40000 |
| Measured area | 843 | 484 | 550 | 879 | 360 | 1060 | 1761 | 565 | 981 | 436 | 1224.5 | 1684 | 840 |
| Number of the occupants | 74 | 41 | 31 | 88 | 22 | 38 | 186 | 51 | 36 | 40 | 54 | 152 | 35 |
| Business time | 9:00-17:00 | 9:00-18-00 | 8:30-17:00 | 8:30-17:30 | 8:30-17:30 | 8:30-17:30 | | | 8:00-18:00 | 8:00-18:00 | 8:00-18:00 | 8:00-18:00 | 8:00-18:00 |
| Investigation | Sep2017 | May2018 | Oct2017 | Nov2017 | Mar2018 | Mar2018 | May2018 | May2018 | May2015 | May2015 | May2015 | May2015 | May2015 |

| City | Taipei | | | Bangkok | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Office | TP-1 | TP-2 | TP-3 | BK-1(17) | BK-2 | BK-3 | BK-4 | BK-5 | BK-6 | BK-1(18) | BK-7 | BK-8 | BK-9 |
| Age | - | 2014 | 2014 | 2014 | 1992 | 2011 | 1985 | 1989 | 2016 | 2014 | 2011 | 2008 | 2015 |
| Total stories | 12 | 23 | 23 | 22 | 31 | 41 | 19 | 20 | 5 | 22 | 27 | 48 | 25 |
| Measured floor | 10 | 17 | 17 | 17 | 28 | 36 | 14 | 7 | 4 | 17 | 17 | 32 | 11 |
| A/C type | Indi | Indi | Indi | Cent | Cent | Cent | Cent | Cent | Cent | Cent | Indi | Cent | Cent |
| GFA [m2] | 9158 | 42712 | 42712 | 27720 | 194655 | 161285 | 24300 | 41500 | 6961 | 27720 | 64558 | 97094 | 56000 |
| Measured area | 544.7 | 967.7 | 1063 | 778 | 411 | 1090 | 1212 | 1100 | 1465 | 778 | 290 | 492 | 950 |
| Number of the occupants | 62 | 61 | 61 | 85 | 37 | 142 | 53 | 107 | 190 | 85 | 65 | 75 | 140 |
| Business time | 9:00-18:00 | | | 8:00-18:00 | 8:00-18:00 | 8:00-17:00 | 9.00-18.00 | 9.00-17.00 | 8:00-18:00 | 8:00-18:00 | 8:00-17:00 | 8:30-17:30 | 8.30-17.30 |
| Investigation | Sep2016 | Jun2018 | Jun2018 | Mar2017 | Mar2017 | Jul2017 | Jun2018 | Jun2018 | Sep2018 | Sep2018 | Mar2019 | Mar2019 | May2019 |

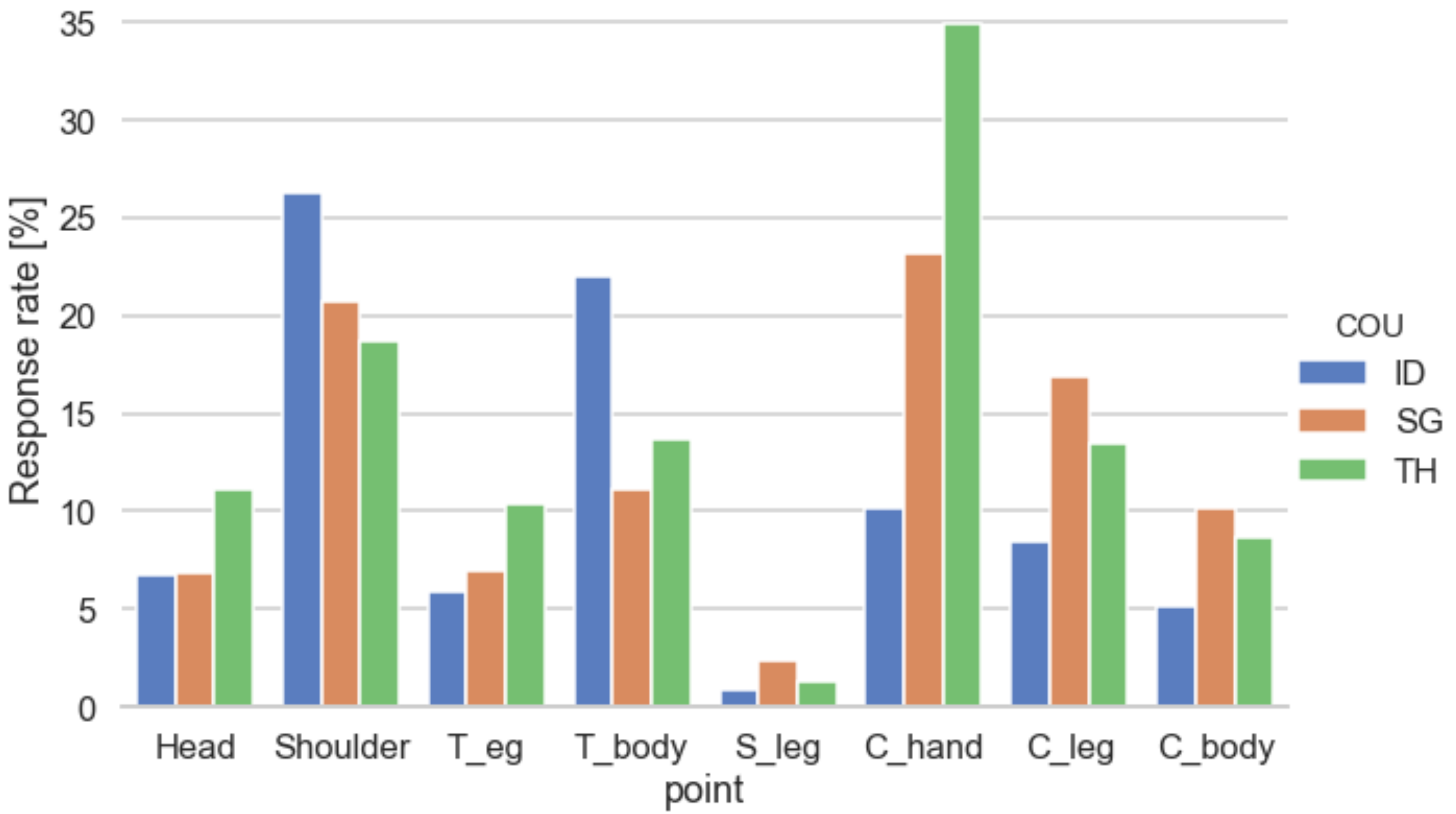



Operative Temperature Distribution in Actual Status

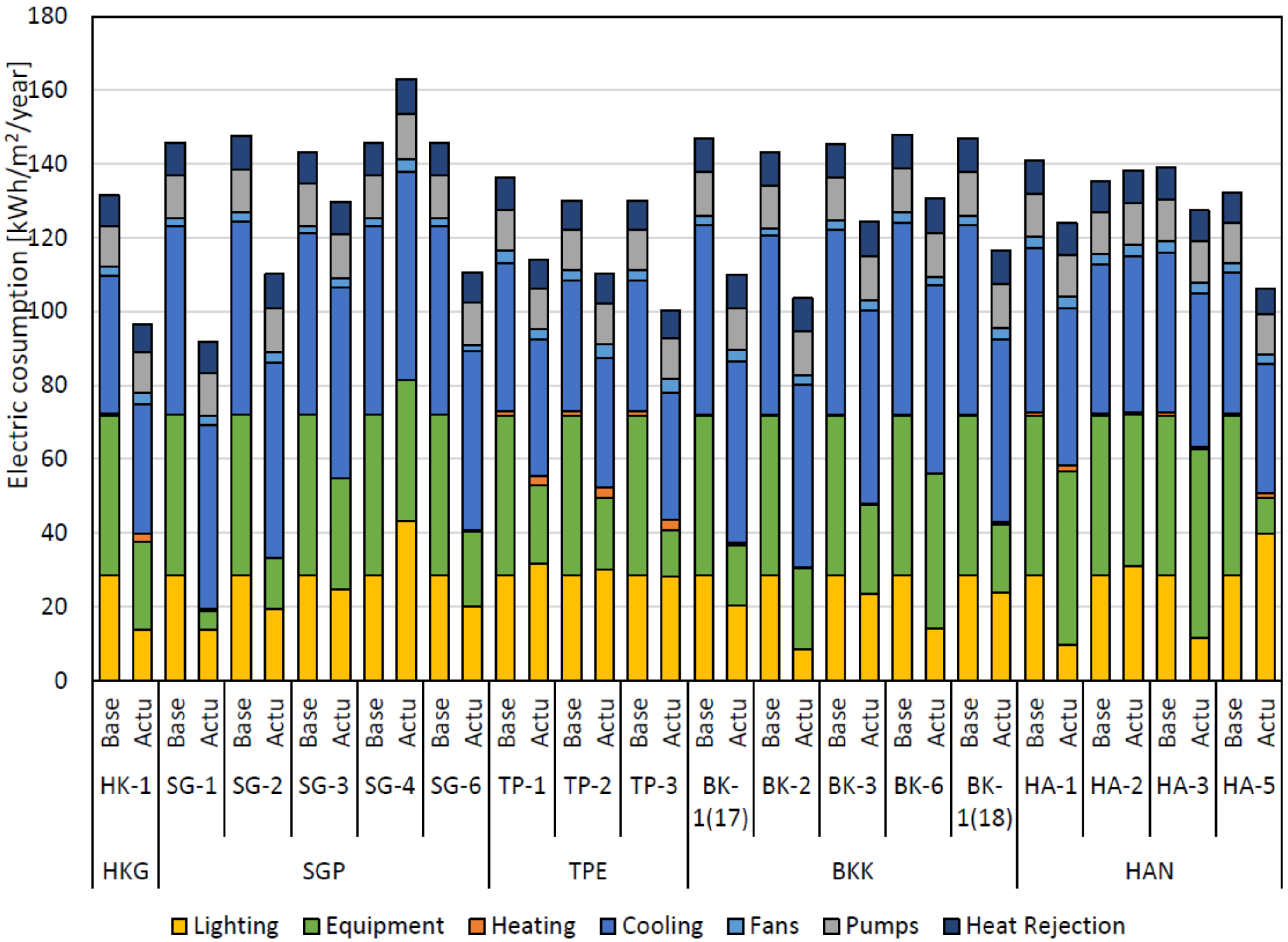
The indoor temperature tends to be low in Bangkok and Singapore, and slightly high in Hong Kong, Taipei and Hanoi.
It is likely to be subjected to climate characteristics and customs.




Relationship between Thermal Sensation and Comfort Vote

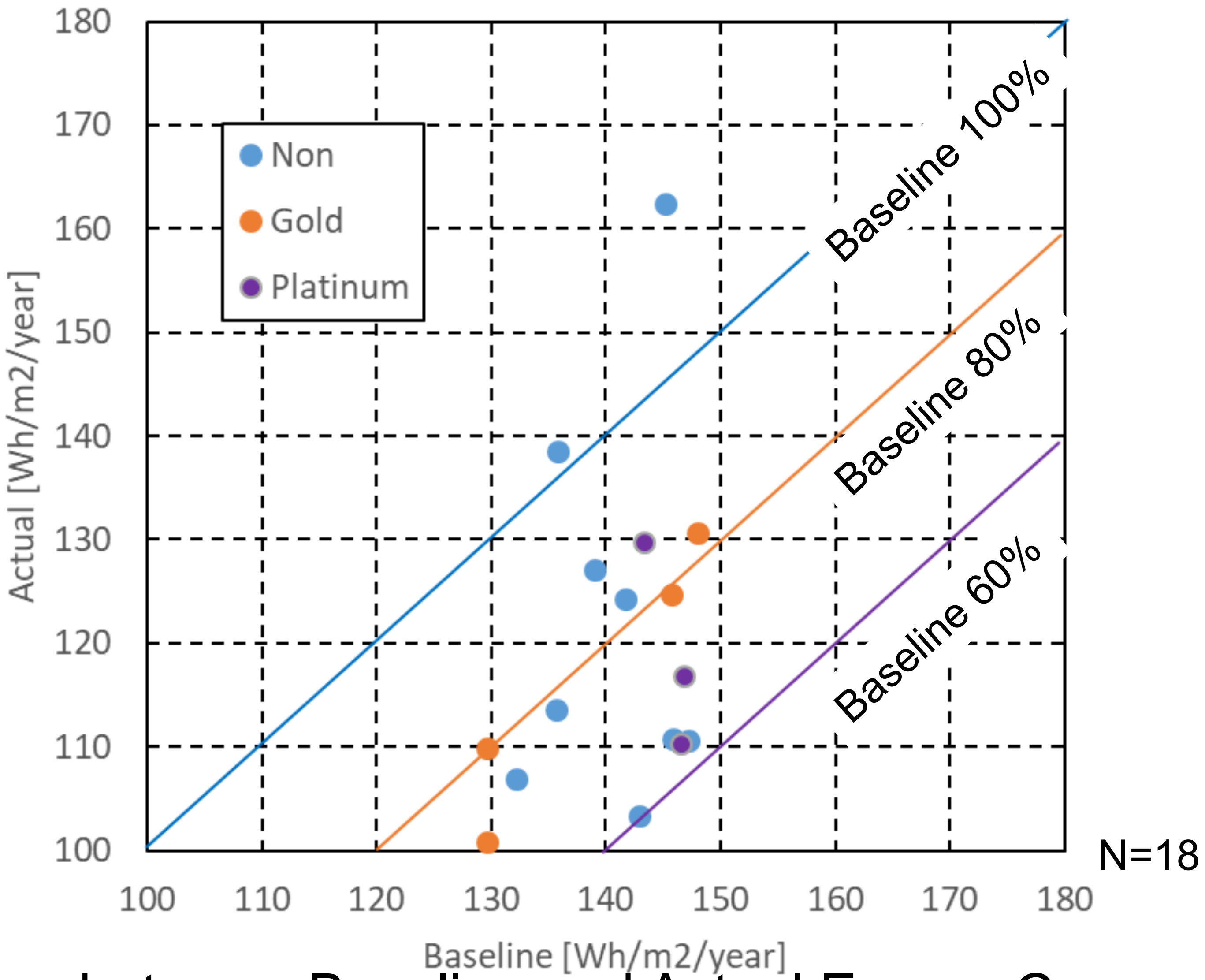



Frequency of Symptom Derived from Excessive Cooling




## Yearly Energy Consumption of Baseline and Actual

- An internal heat generation load is much lower than the European and U.S. standards.
- Although those certified as upper green buildings are included, there are actual cases exceeding a baseline.




Correlation between Baseline and Actual Energy Consumption

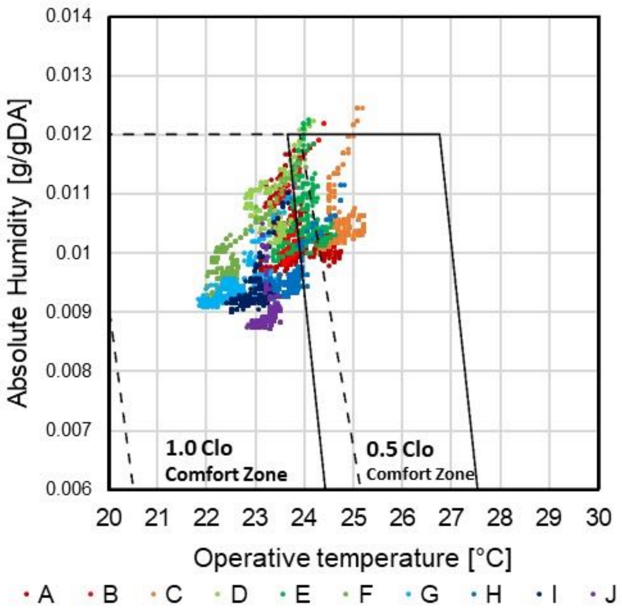
- Baseline vs. actual correlation is low.
- There is no actual energy control effect by raising and lowering the green building certification level.

# Reviewing the latent heat-sensible heat separate air conditioning in Bangkok

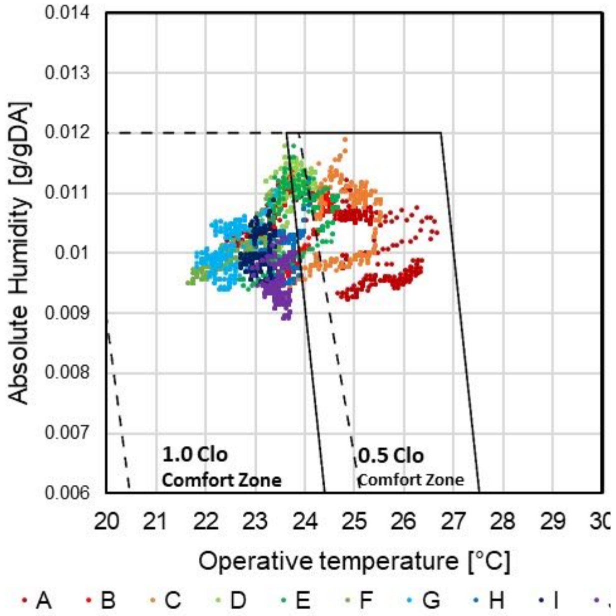
General air conditioning
56,000 m²
LEED Gold

Chilled beam air conditioning
22,000 m²
LEED Platinum

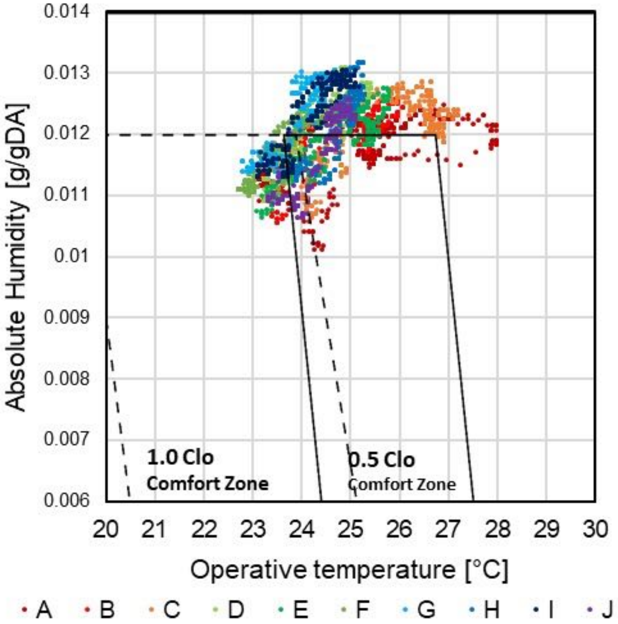
# Effect on indoor environment by setting temperature change
# General air-conditioned buildings




23ºC

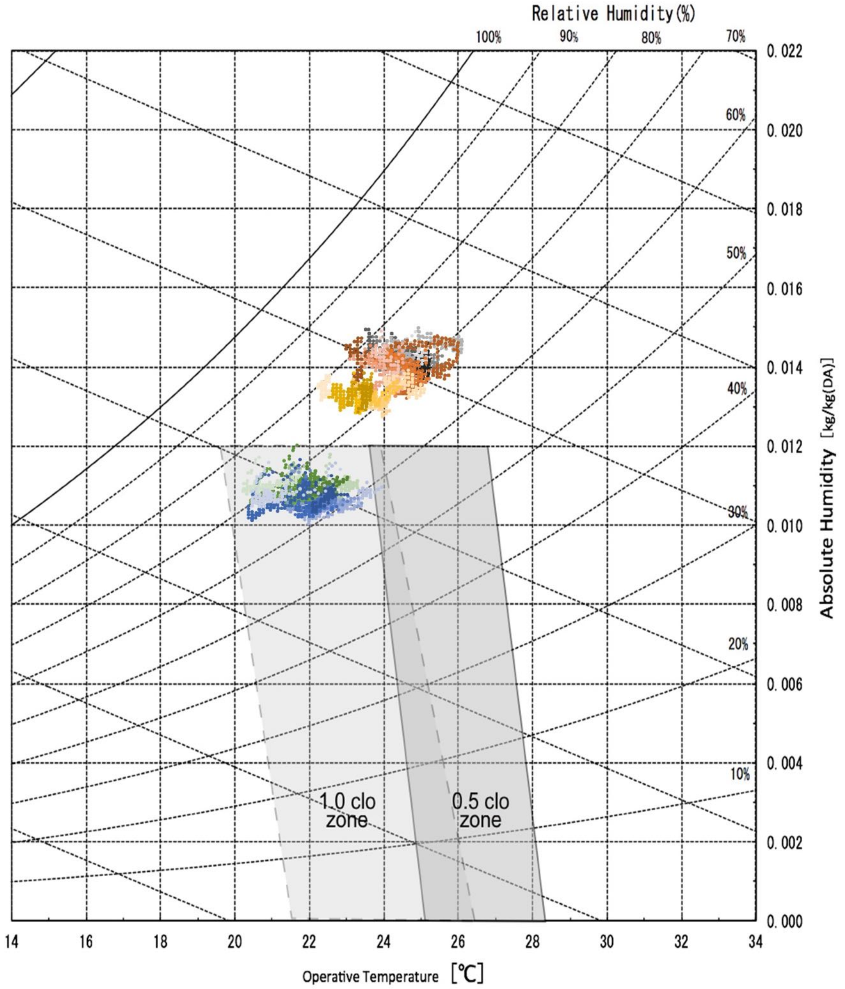



24ºC

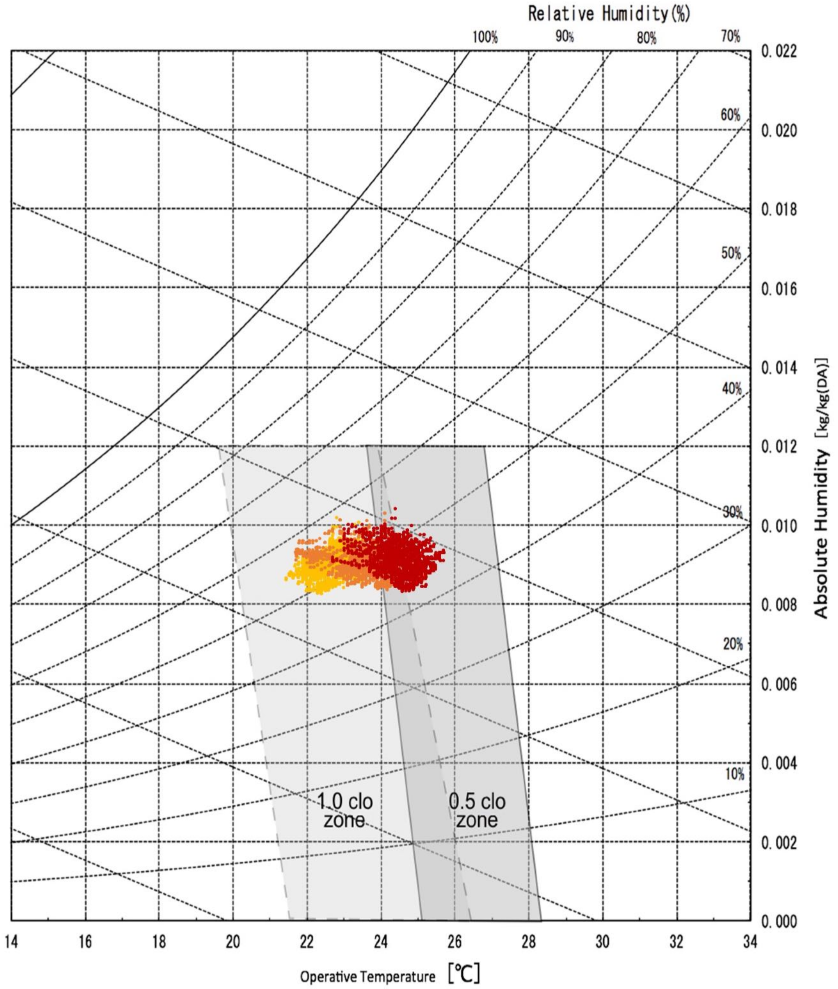



25ºC

# Increase of indoor temperature setting by chilled beam

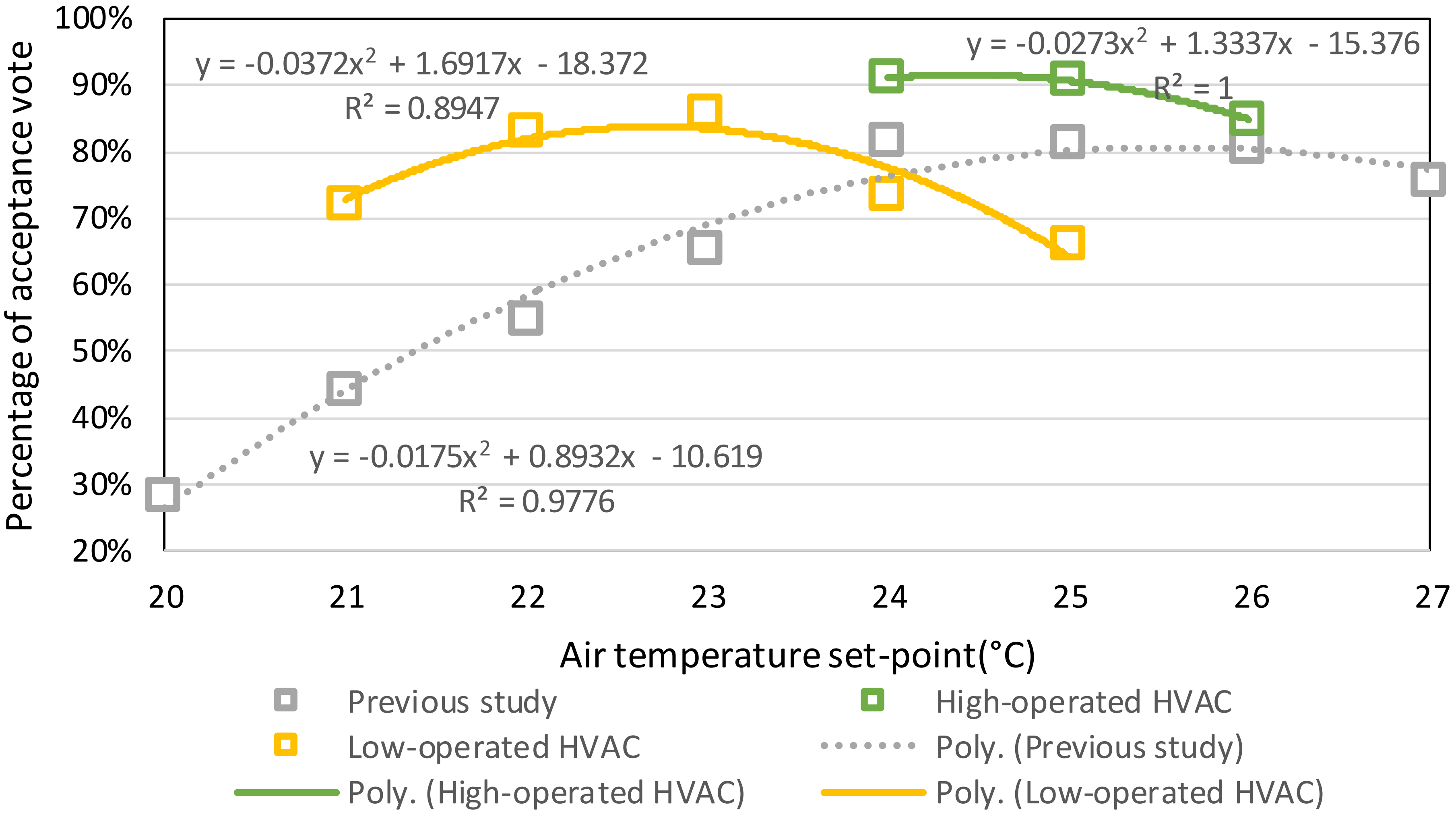



General air conditioning

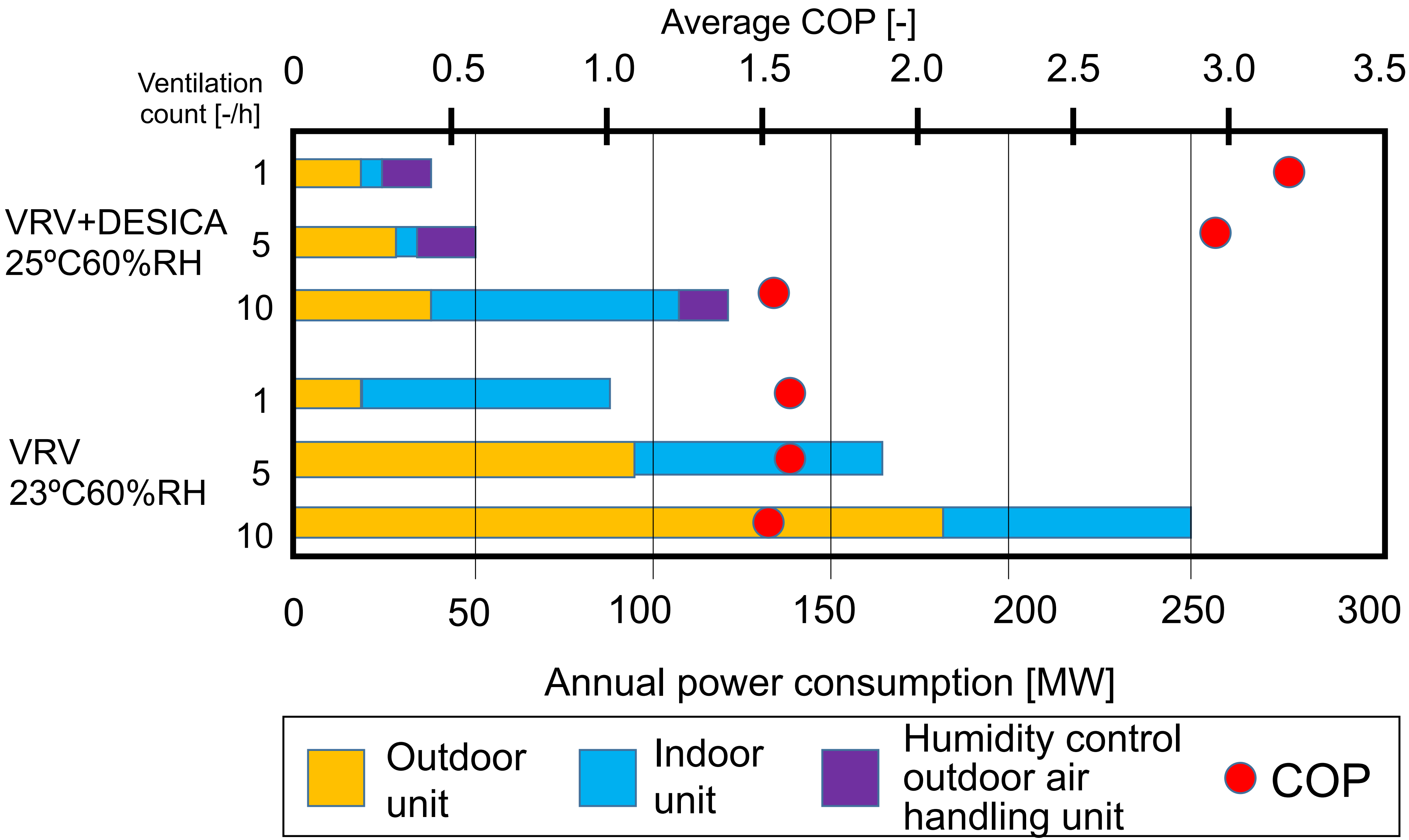



Chilled beam

# Increase of satisfaction of office workers by chilled beam



# Energy conservation potential by desiccant outside air processing



# Contents

1. $CO_2$ Emissions and Actual Energy Regulations of Buildings
2. Indoor Environment and Actual Energy Consumption of Buildings
3. Comparison of Climate Characteristics
4. Prediction of Reduced Environmental Load by Dissemination of ZEB Family
5. Summary

# 3. Comparison of Climate Characteristics

The weather conditions at each location in Southeast Asia were summarized for this analysis.
The following was referenced as meteorological data.

- EnergyPlus Weather Data (EPW) [2)]
- DOE2 BIN data [3)]

Table 3-1 Summary of weather data

| Location | Format | Latitude | Longitude |
|---|---|---|---|
| Singapore | EPW | 1.37 | 103.98 |
| Kuala Lumpur | EPW | 3.12 | 101.55 |
| Jakarta | BIN | -6.20 | 106.80 |
| Bangkok | EPW | 13.92 | 100.60 |
| Hanoi | EPW | 21.02 | 105.80 |
| Kagoshima | EPW | 31.57 | 130.55 |
| Tokyo | EPW | 36.18 | 140.42 |


Fig. 3-1 Positional relationship of target points [4)]

2) EnergyPlus: https://energyplus.net
3) DOE2: https://doe2.com
4) World map designed by and available for PowerPoint. Blank map downloaded free of charge: https://power-point-design.com/ppt-design/world-map-for-powerpoint/

# Comparison of temperature, humidity and solar radiation by box plots

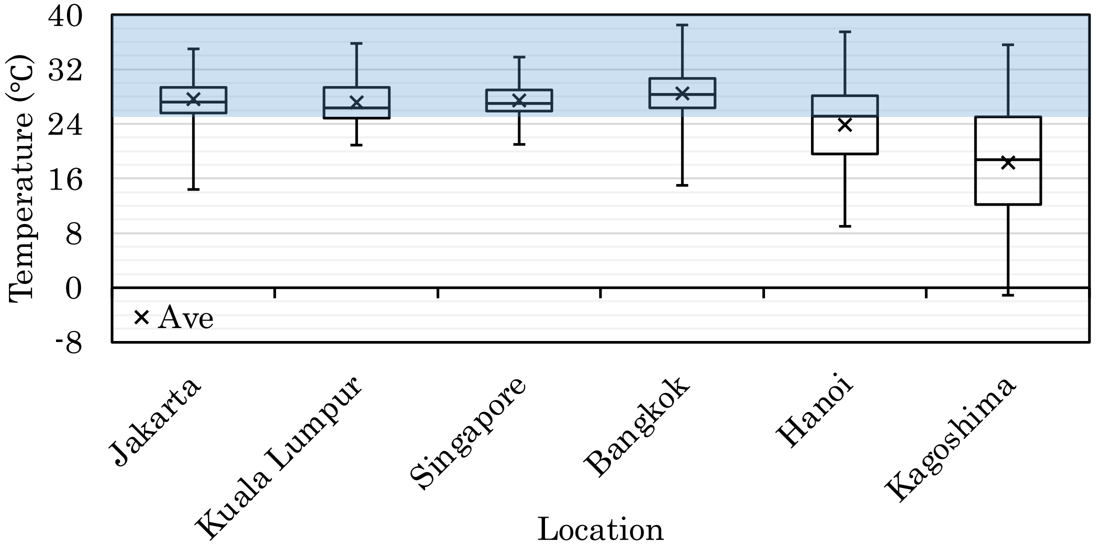



Fig. 3-2 Comparison of temperature

- The temperature is lower in Hanoi and Kagoshima than in other locations.
- Other than Kagoshima, the lowest temperature is 8ºC or higher.
- The lowest temperature is particularly high in Kuala Lumpur and Singapore.
- The highest temperature in Bangkok and Hanoi is particularly high.

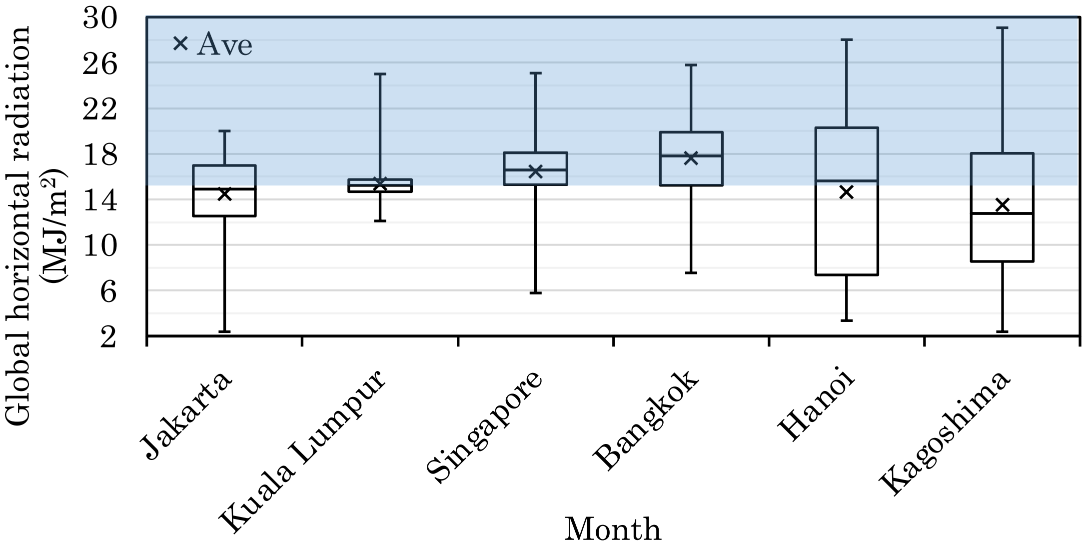



Fig. 3-3 Comparison of daily total global horizontal radiation

- In Kuala Lumpur, the minimum global horizontal radiation value is higher than in other locations.
- In Jakarta, the maximum global horizontal radiation value is lower than in other locations.
- In Singapore and Bangkok, the global horizontal radiation tends to be higher than in other locations.

# Comparison of temperature, humidity and solar radiation by box plots

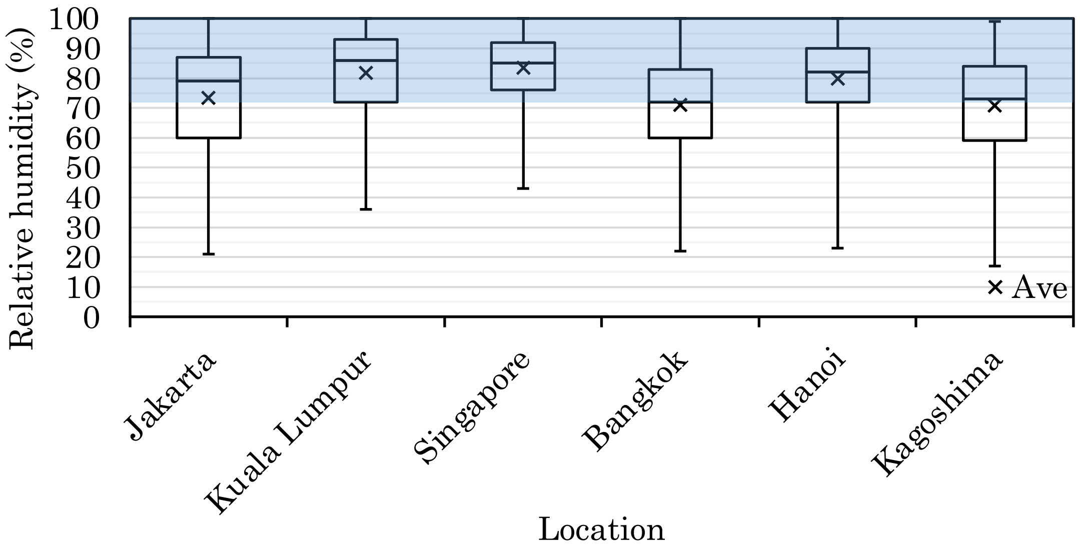



Fig. 3-4 Comparison of relative humidity

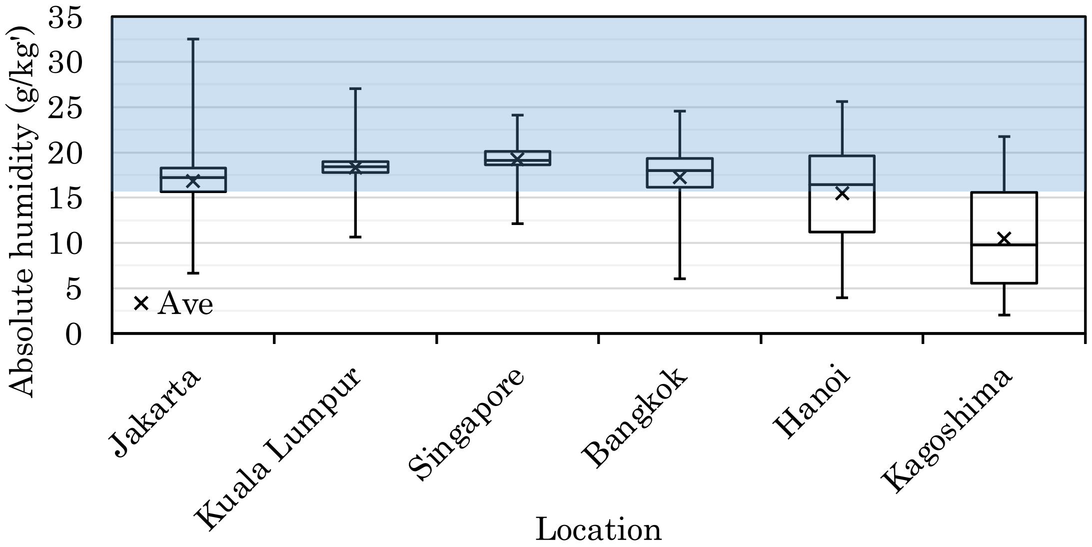



Fig. 3-5 Comparison of absolute humidity

- The relative humidity tends to be higher in Kuala Lumpur, Singapore and Hanoi than in other locations.
- The lowest humidity in Kuala Lumpur and Singapore is higher than in other locations.

- The absolute humidity in Kagoshima tends to be lower than in other locations.
- In Jakarta, the maximum absolute humidity value is particularly high.
- In Singapore, the minimum absolute humidity value is particularly high.

# Relationship of temperature, humidity and solar radiation with latitude

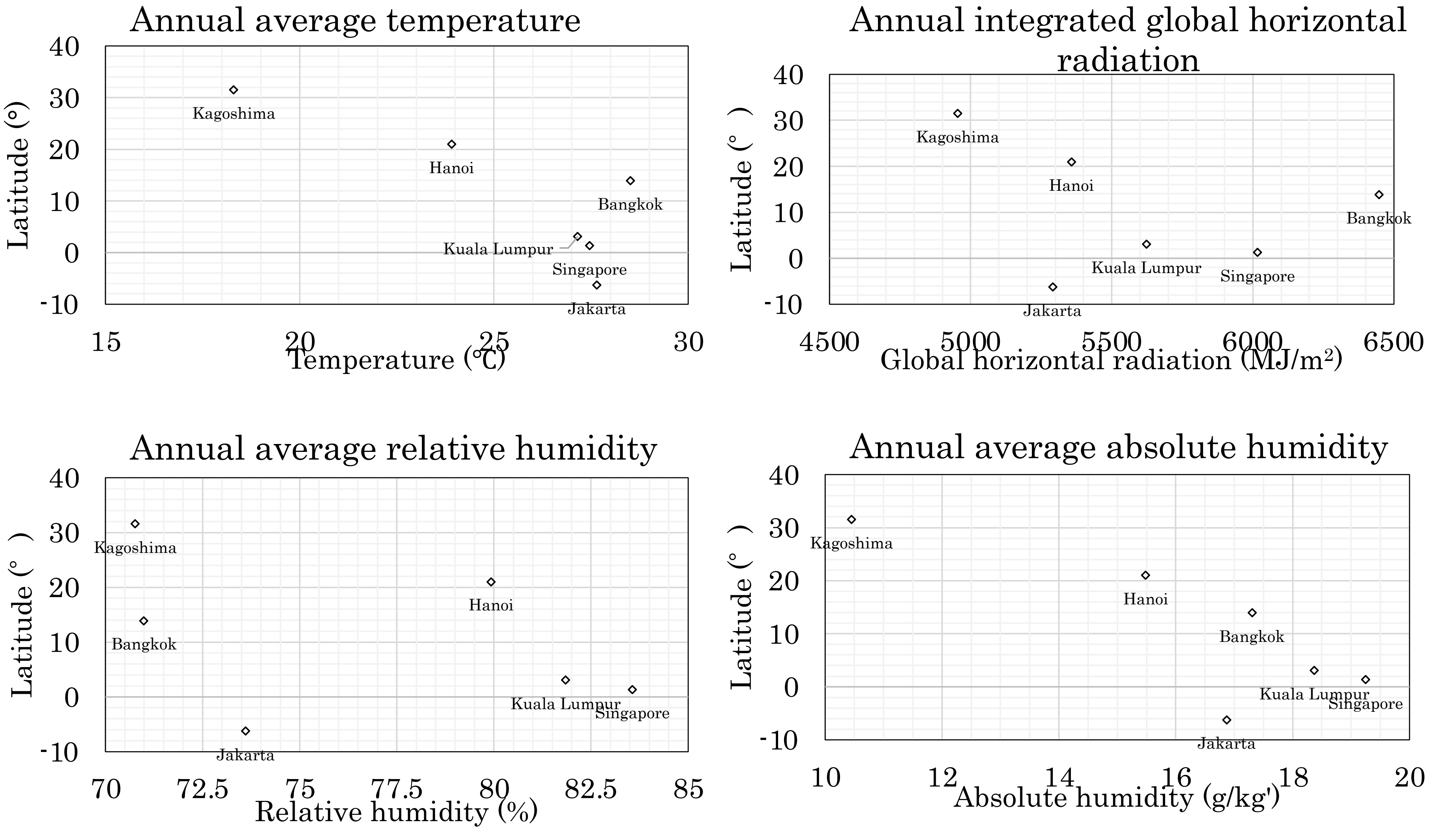



Fig. 3-6 Relationship between annual average/integrated value of meteorological factors and latitude

# Relationship of temperature, humidity and solar radiation with latitude

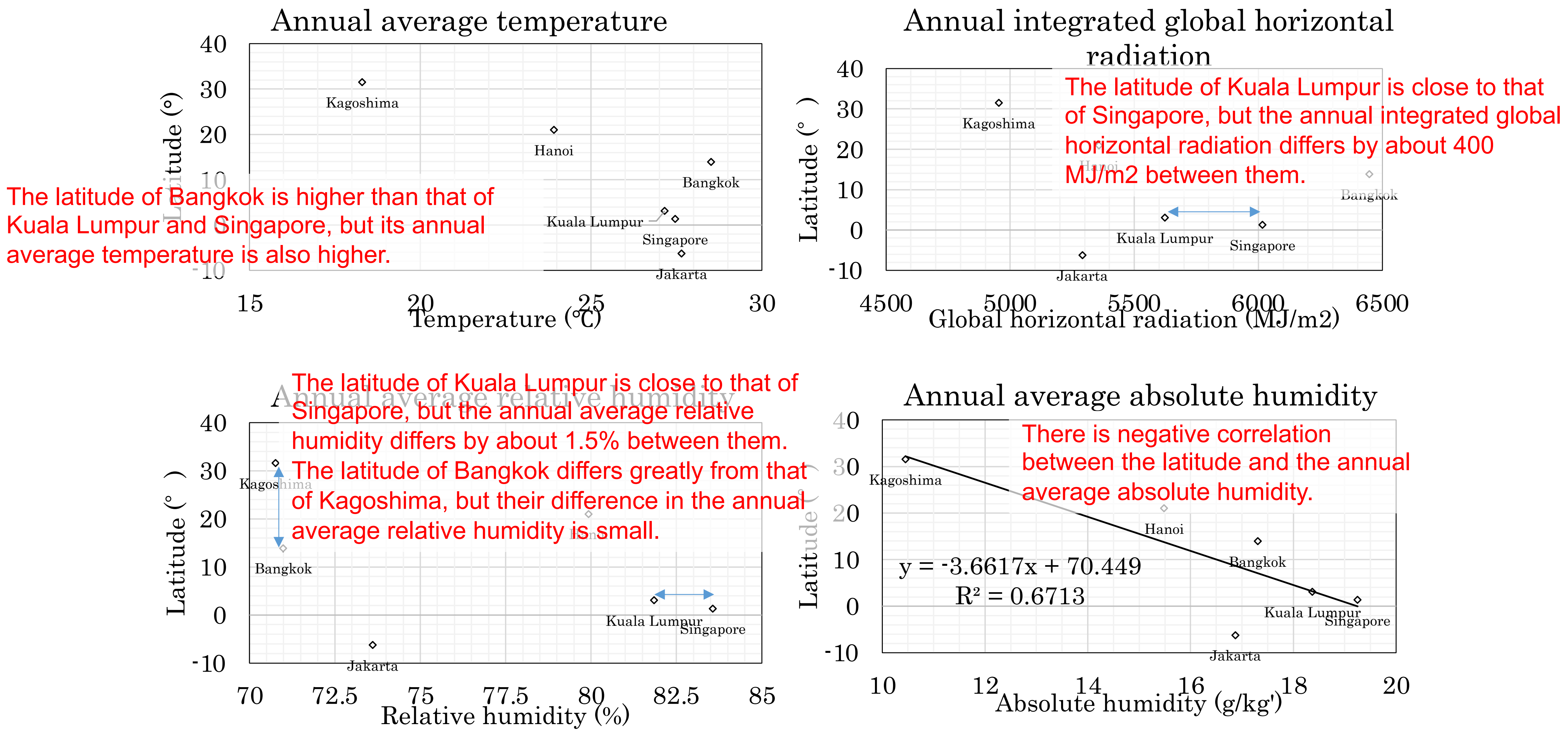



Fig. 2-5 Relationship between annual average/integrated value of meteorological factors and latitude

# Comparison of transition of monthly average temperature

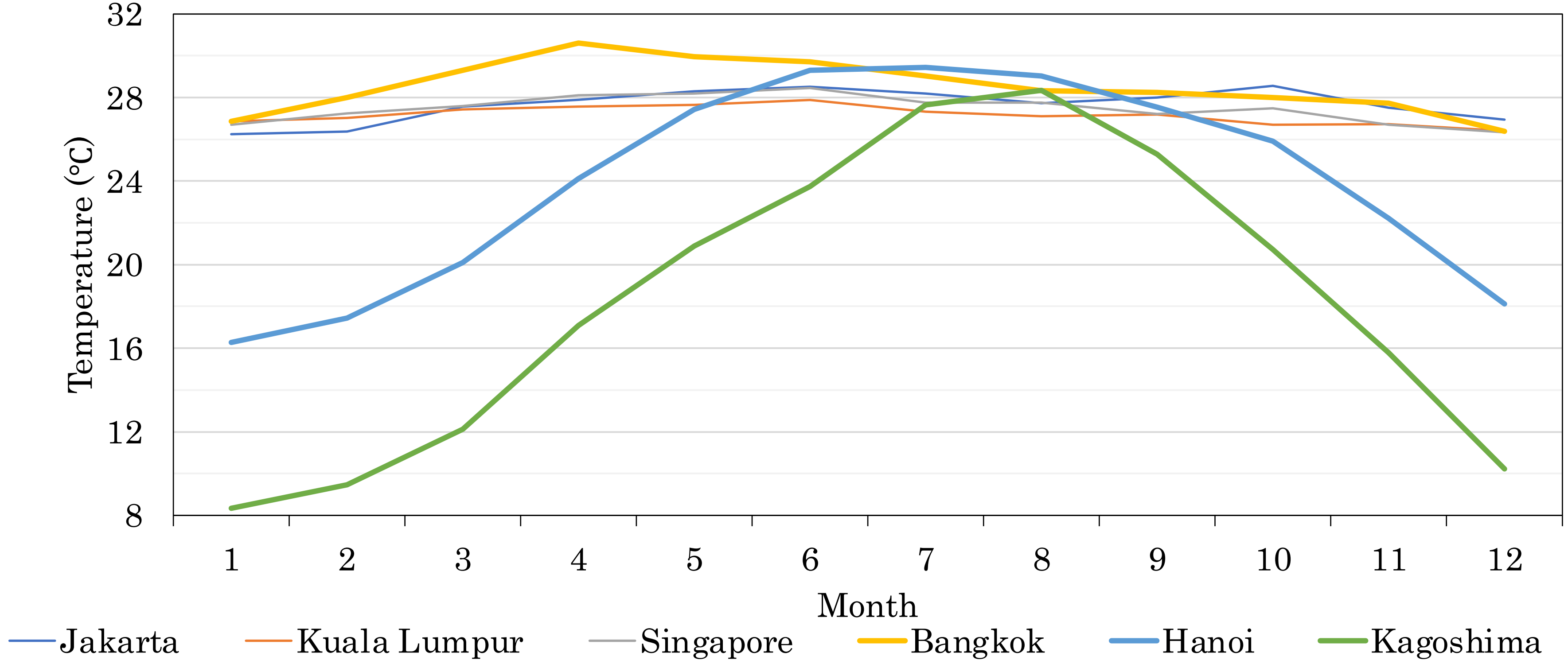



Fig. 2-6 Monthly average temperature

- There is a temperature difference in Hanoi and Kagoshima from one month to another. In Hanoi, the temperature becomes higher than in other locations in July and August, and the temperature in Kagoshima also gets closer to other locations.
- The temperature in Jakarta, Kuala Lumpur and Singapore almost levels off, transitioning in a range of 26 to 29ºC.
- In Bangkok, the temperature becomes higher in April, exceeding 30ºC.

# Comparison of transition of monthly average humidity

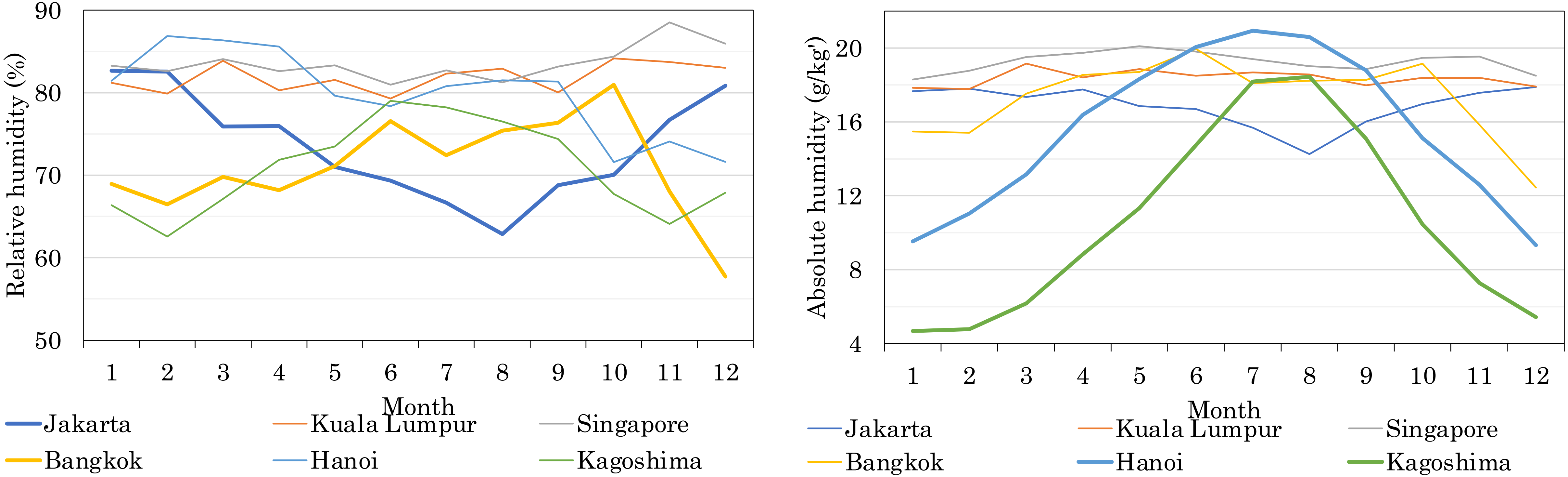



Fig. 2-7 Monthly average relative humidity and absolute humidity

- In Jakarta, both the relative humidity and absolute humidity become the lowest in August.
- In Bangkok, both the relative humidity and absolute humidity become the lowest in December.
- The absolute humidity almost levels off in Kuala Lumpur and Singapore.
- In Kagoshima, both the relative humidity and absolute humidity transition in the shape of an arch.
  In Hanoi, only the absolute humidity transitions in the shape of an arch.

# Comparison of transition of monthly integrated solar radiation

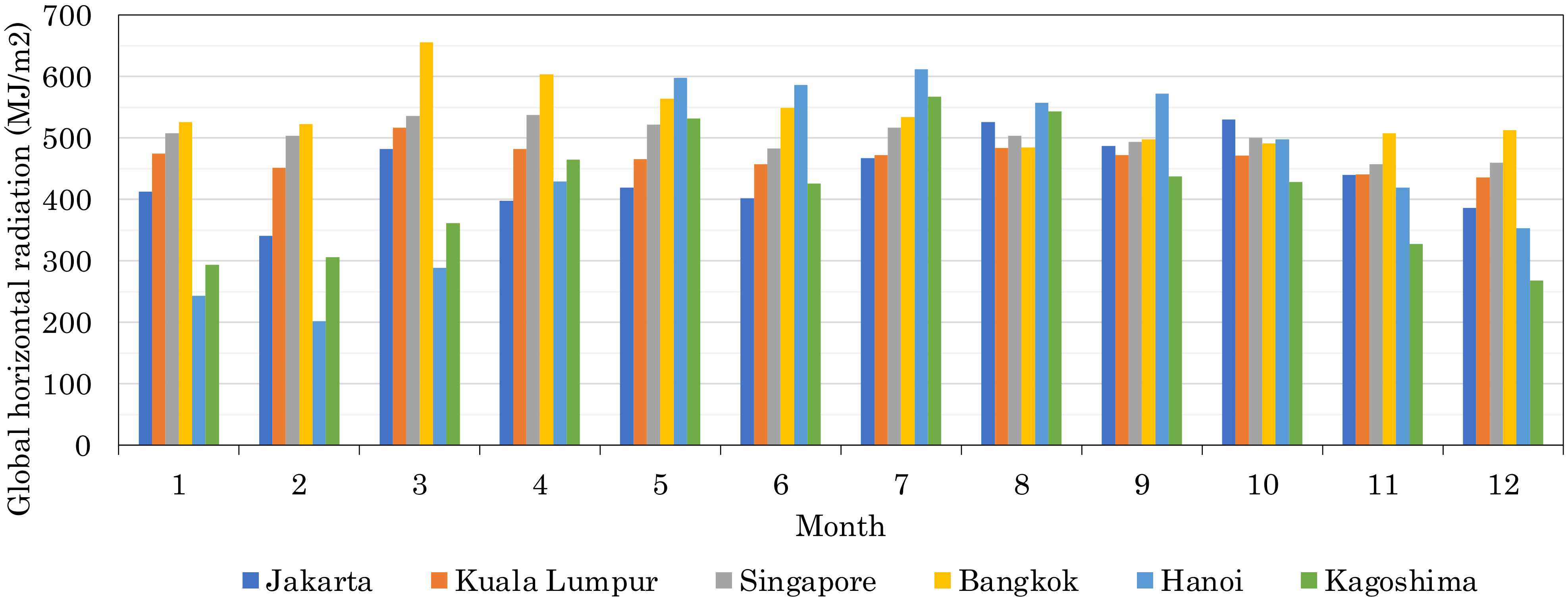



Fig. 2-7 Monthly integrated solar radiation

- In Hanoi and Kagoshima, global horizontal radiation transitions lower than in other locations from November to March, but higher than in other locations from July to August.
- In Bangkok, global horizontal radiation stands out from the rest in March.

# Comparison of transition of monthly integrated solar radiation

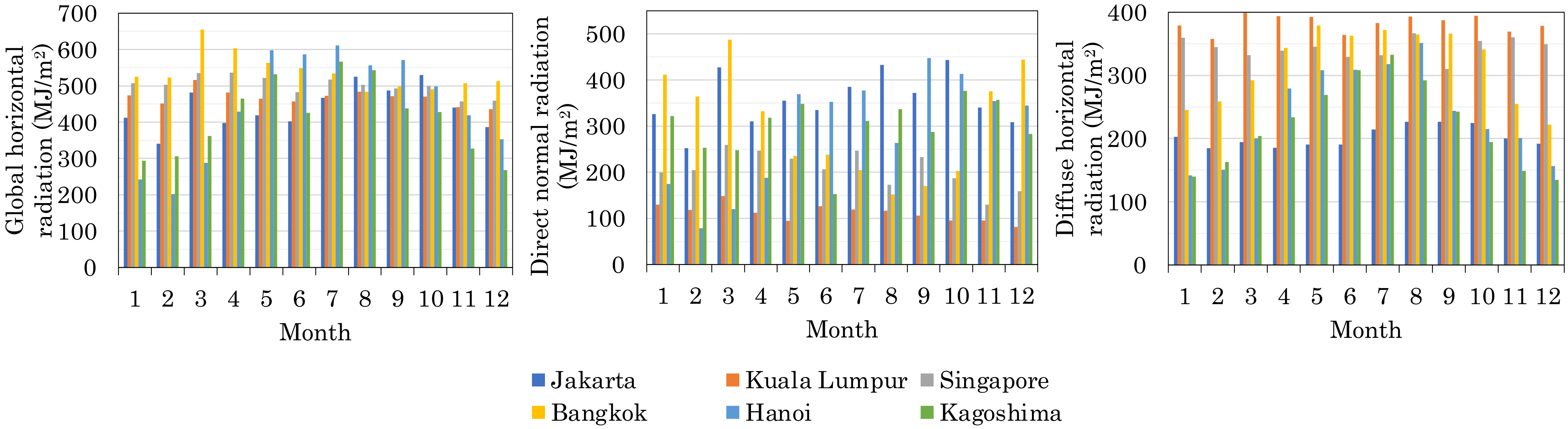



Fig. 3-9 Monthly integrated solar radiation

- In Hanoi and Kagoshima, global horizontal radiation transitions lower than in other locations from November to March, but higher than in other locations from July to August.
- In Bangkok, global horizontal radiation stands out from the rest in March.
- In Kuala Lumpur and Singapore, direct normal radiation transitions lower than in other locations, but diffuse horizontal radiation transitions higher than in other locations.
- In Jakarta, direct normal radiation transitions lower than in other locations.

# Comparison of transition of solar radiation by country

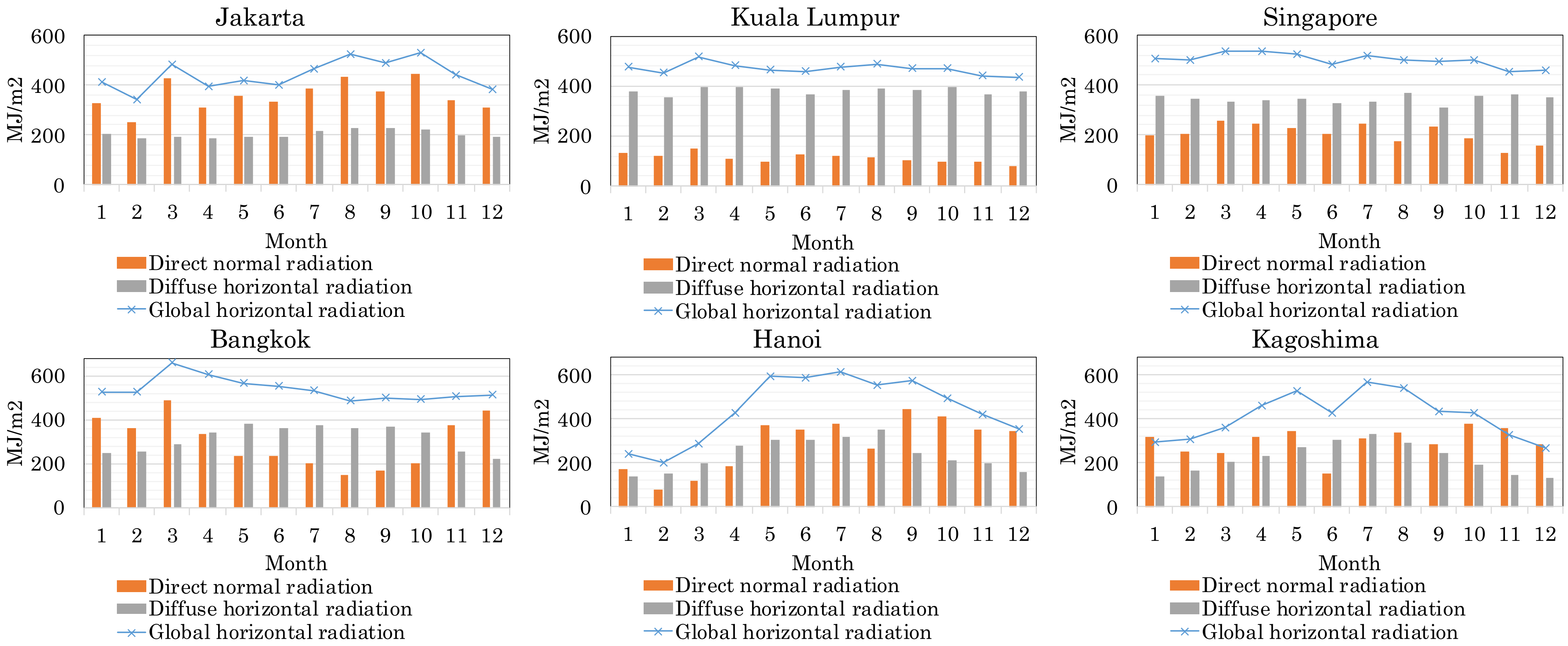



Fig. 2-8 Monthly integrated solar radiation by country

- In Jakarta, direct normal radiation is higher than diffuse solar radiation throughout the year.
- In Kuala Lumpur and Singapore, diffuse solar radiation is higher than direct normal radiation throughout the year, but global horizontal radiation almost levels off.
- In Bangkok, diffuse solar radiation is higher than direct normal radiation from May to October, and global horizontal radiation stands out at 655 MJ/m2 in March.
- In Hanoi, global horizontal radiation is low from January to February and direct normal radiation becomes high from September to October.
- In Kagoshima, global horizontal radiation and direct normal radiation become low in June, but global horizontal radiation becomes the highest in July.

# Contents

The following outlines the input conditions for the reference model (Base).
With this reference model, calculate the changes of $CO_2$ emissions and heat load resulting from the ZEB measures.

List of main parameters of reference model Base [14)]

| Model summary | |
|---|---|
| Weather data | Singapore (EPW) |
| People | 0.2person/m$^2$ |
| People load | 132W/person |
| Light | 9.68W/m$^2$ |
| Equipment | 9.68W/m$^2$ |
| Ventilation | 1.5/h |
| Area | 1000m$^2$ |
| Rentable floor area ratio | 0.7 |
| Ceiling height | 4m |
| WWR | 0.7 |

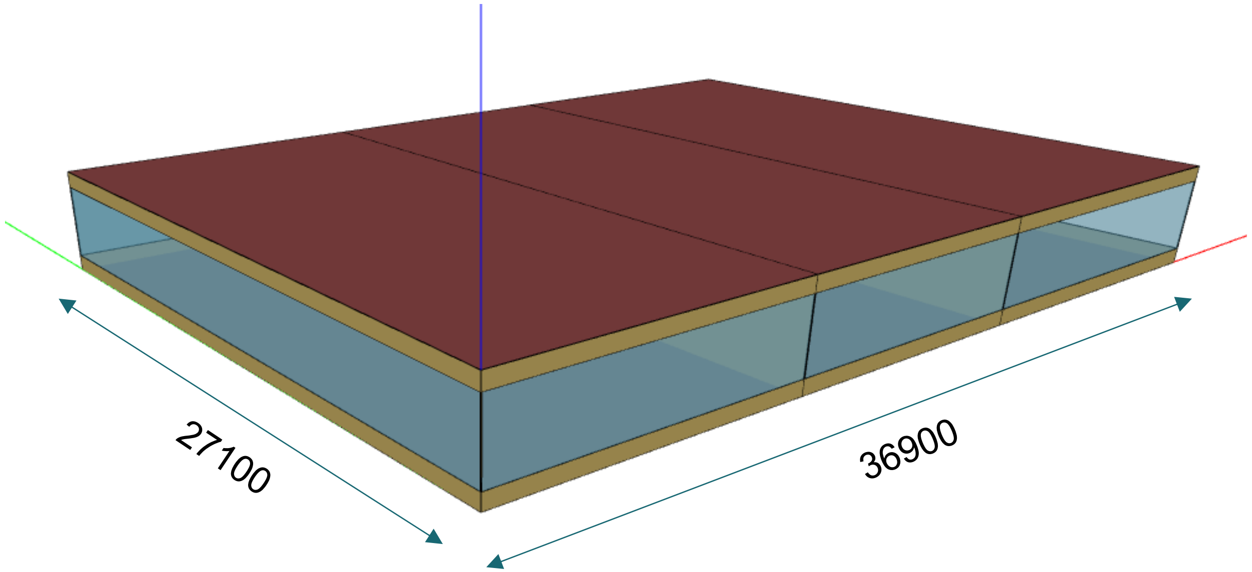


Fig.5-1 Appearance of Base

14) Yukiko MABUCHI, Masayuki ICHINOSE, Nobuki MATSUI, Masayuki OGATA, Alkhalaf Haitham
"Proposal of air conditioning method based on actual usage at office buildings in Tropic Asia"
Convention (Fukushima) of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, Technical Papers of Annual Meeting, Pages 241 to 244. (Sep. 2021)

# List of specifications for building frame

Construction

| | Ceiling | mm | Roof | mm | Ext. wall | mm | Floor | mm | Int. wall | mm |
|---|---|---|---|---|---|---|---|---|---|---|
| Outside | Carpet | 7 | Virtual Insulation | - | Tile | 8 | Virtual Insulation | - | Gypsum board | 12 |
| | Concrete25 | 25 | Roof membrane | 9.5 | Mortar | 20 | Rock wool | 15 | Air gap | - |
| | Air gap | - | Roof insulation | 169.3 | Concrete150 | 150 | Air gap | - | Gypsum board | 12 |
| | Concrete245 | 245 | Metal decking | 1.5 | Sprayed rigid urethane foam | 25 | Concrete245 | 245 | | |
| | Air gap | - | | | Air gap | - | Air gap | - | | |
| | Rock wool | 15 | | | Gypsum board | 12 | Concrete25 | 25 | | |
| Inside | | | | | | | Carpet | 7 | | |

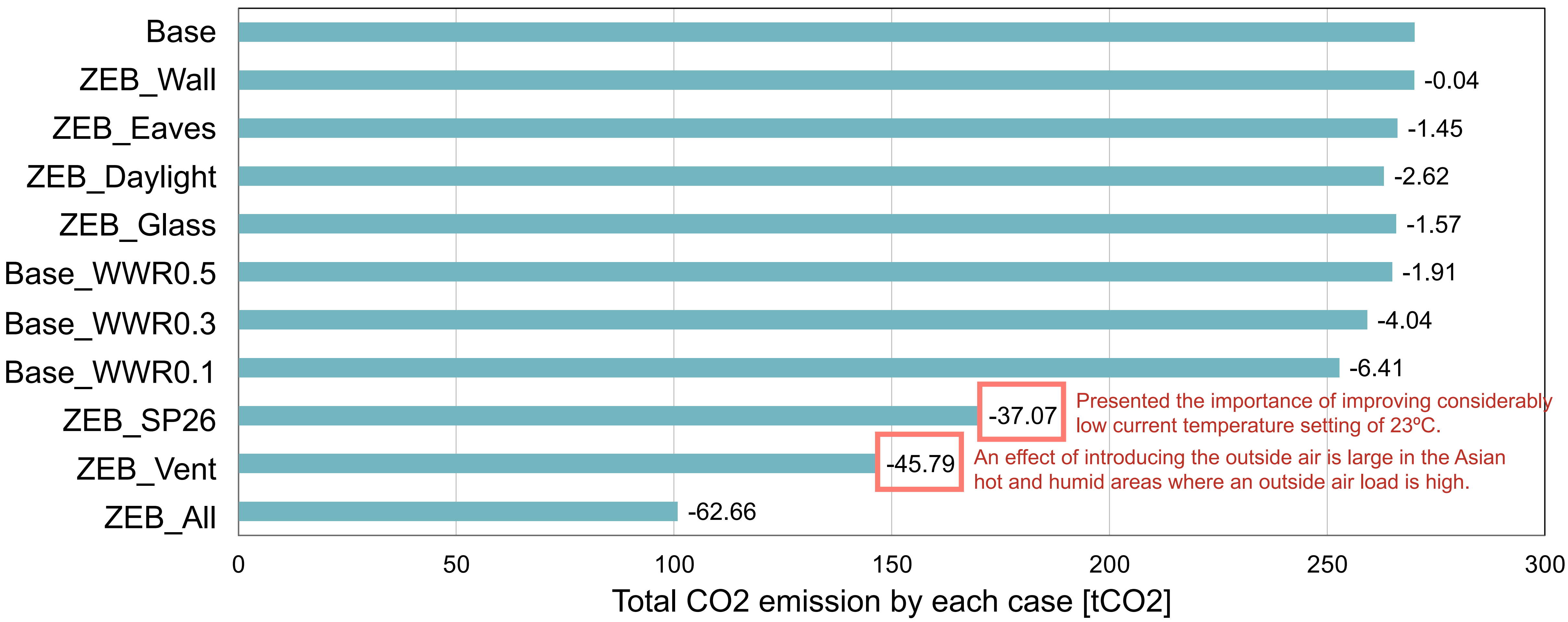
Sprayed rigid urethane foam was designed 50 mm thick for “ZEB wall”, a model with improved outer wall overall coefficient.

The following 6 types of ZEB measures were considered.

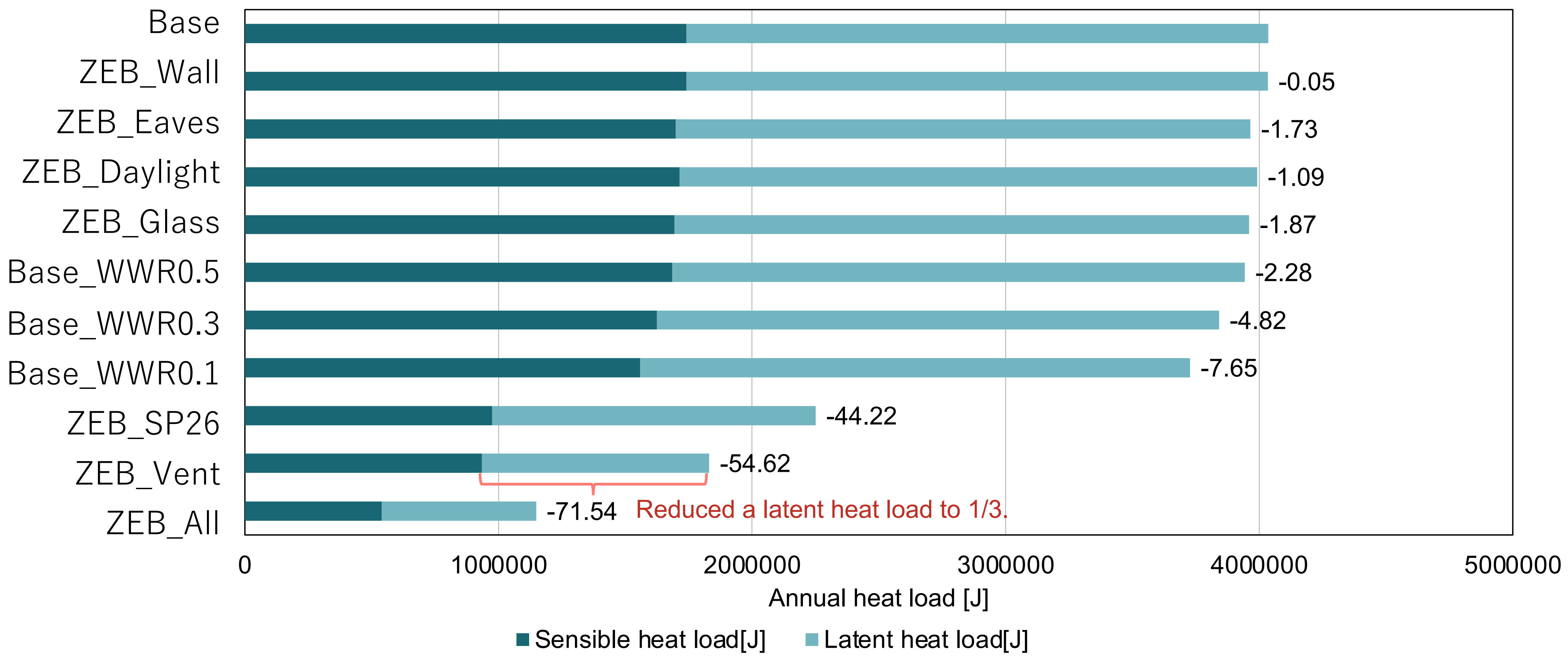
## List of main parameters of ZEB reference model and ZEB measures applied model

| Energy conservation policy | Reference model (Base) | ZEB measures applied model (ZEB) |
|---|---|---|
| Utilization of daylight (Daylight) | No | Yes (500 lx) |
| Overall coefficient of glass (Glass) | 5.0 W/(m$^2$･K) (High-performance heat reflecting glass) [15)] | 1.5 W/(m$^2$･K) (Low-e double-glazed glass) [15)] |
| Depth of eaves (Eaves) | 0 mm | 800 mm |
| Air conditioning setting temperature (SP26) | 23ºC | 26ºC |
| Outer wall overall coefficient (Wall) | 0.83 W/(m$^2$･K) | 0.5 W/(m$^2$･K) |
| Airtightness/ventilation (Vent) | 8/h | 1/h |

15) Central Glass, Optical Performance and Thermal Performance of Sheet Glasses
https://www.asahiglassplaza.net/catalogue/sougou_gijutsu/0004a.pdf, Accessed on 2022/2/24

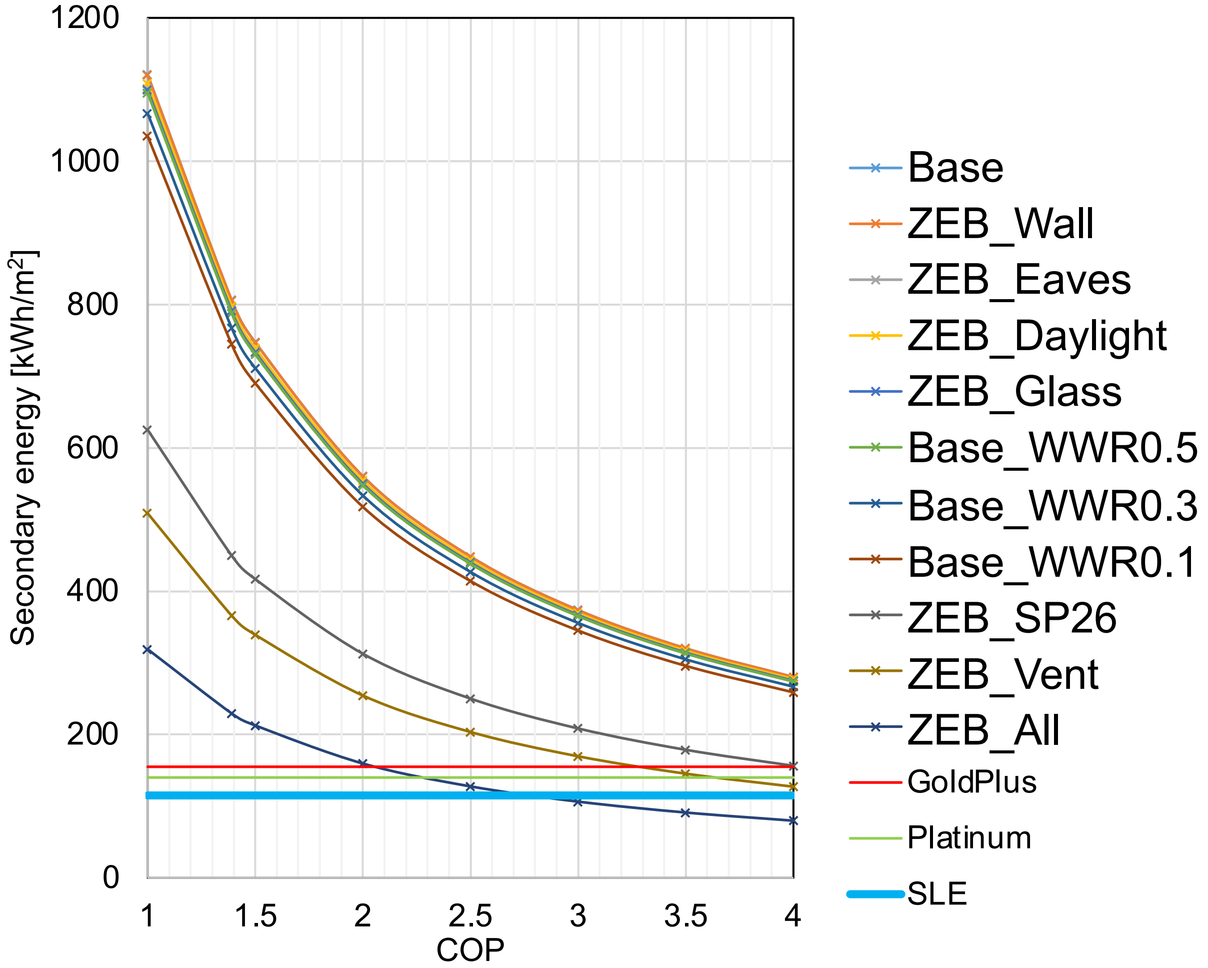



$CO_2$ emission reduction effects by single and full introduction of ZEB measures




# Heat load reduction effects by single and full introduction of ZEB measures

## (3) SLE achievement rate for each case




Effect on energy consumption by ZEB measures for each air conditioning system COP and comparison with SLE

- Secondary energy consumption cannot be greatly reduced by simply changing a window area ratio.
- A reduction of secondary energy consumption by changing the air-conditioning setting temperature and outside air control is greater than that by other measures, but the SLE level cannot be reached even by improving the COP.

→ There is a limit to a single measure.

Secondary energy consumption of the model (ZEB_All) subjected to all measures can reach the SLE level at COP ≥ 2.8.

Targeting 5 locations in Southeast Asia plus Kagoshima and Tokyo, calculate the changes of $CO_2$ emissions and heat load resulting from the post-measure model (ZEB_All).

List of main parameters of ZEB measures applied model (ZEB_All) [14)]

| Model summary | |
|---|---|
| Weather data | 7 points |
| People | 0.2person/m$^2$ |
| People load | 132W/person |
| Light | 9.68W/m$^2$ |
| Equipment | 9.68W/m$^2$ |
| Ventilation | 1.5/h |
| Area | 1000m$^2$ |
| Rentable floor area ratio | 0.7 |
| Ceiling height | 4m |
| WWR | 0.7 |

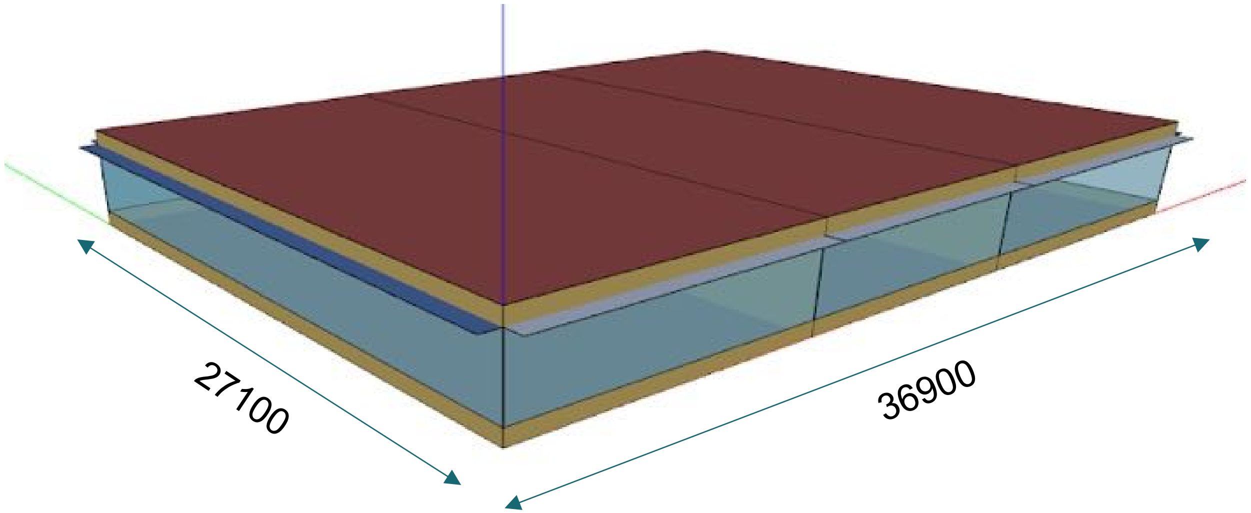
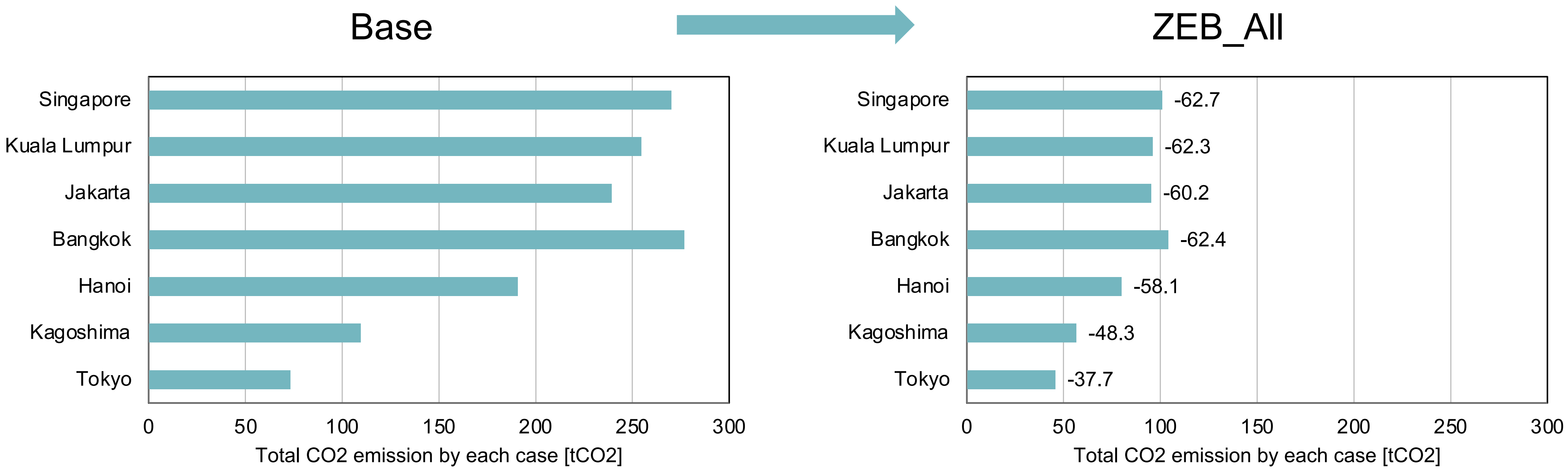



Fig. 5-5 Appearance of ZEB

14) Yukiko MABUCHI, Masayuki ICHINOSE, Nobuki MATSUI, Masayuki OGATA, Alkhalaf Haitham
"Proposal of air conditioning method based on actual usage at office buildings in Tropic Asia"
Convention (Fukushima) of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, Technical Papers of Annual Meeting, Pages 241 to 244. (Sep. 2021)

## (1) Change of $CO_2$ emissions

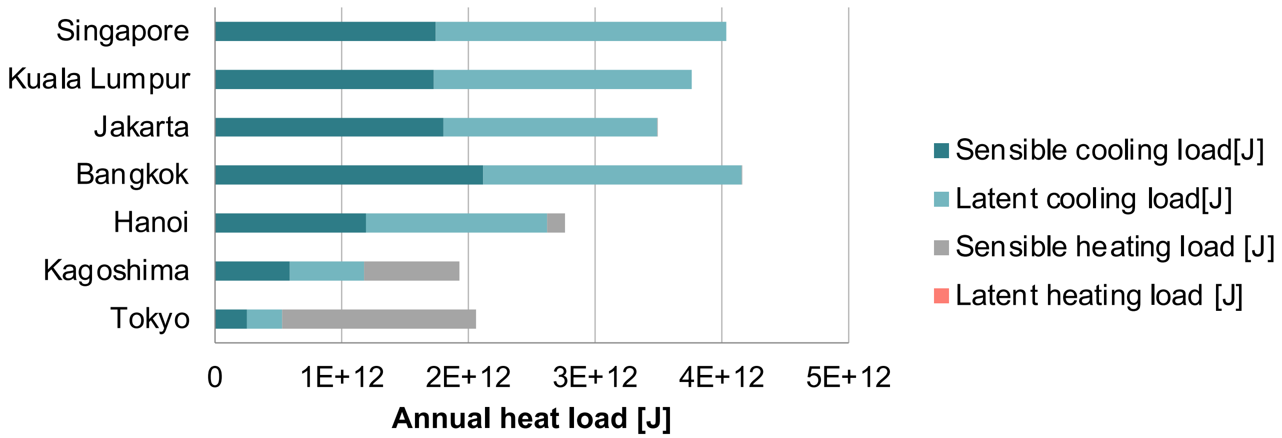



# $CO_2$ emission reduction effect by ZEB measures for Base model by city

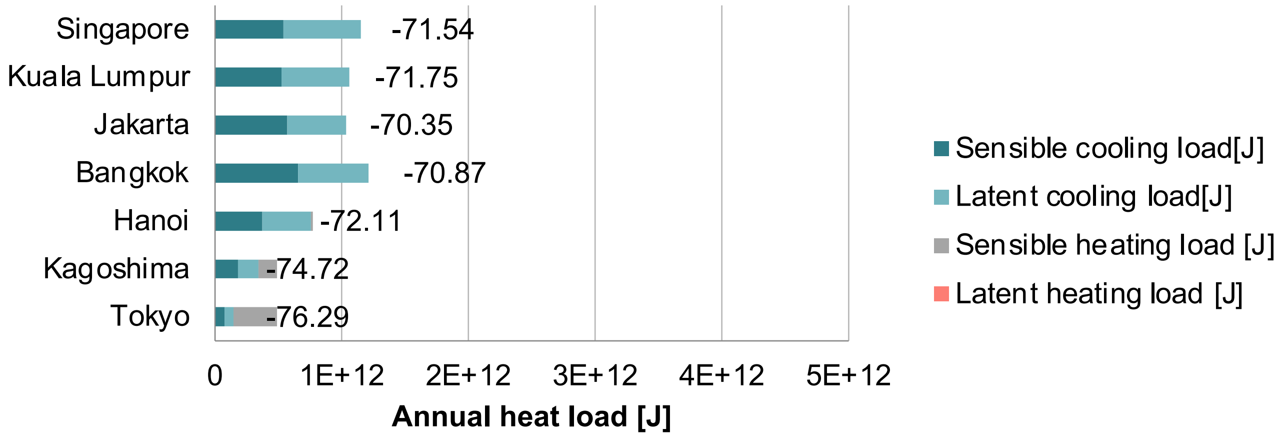
In case the energy conservation measures are taken, $CO_2$ emissions are expected to be reduced by about 58.1% to 62.7% from when they are not taken.

## (2) Change of heat load

Ref_model



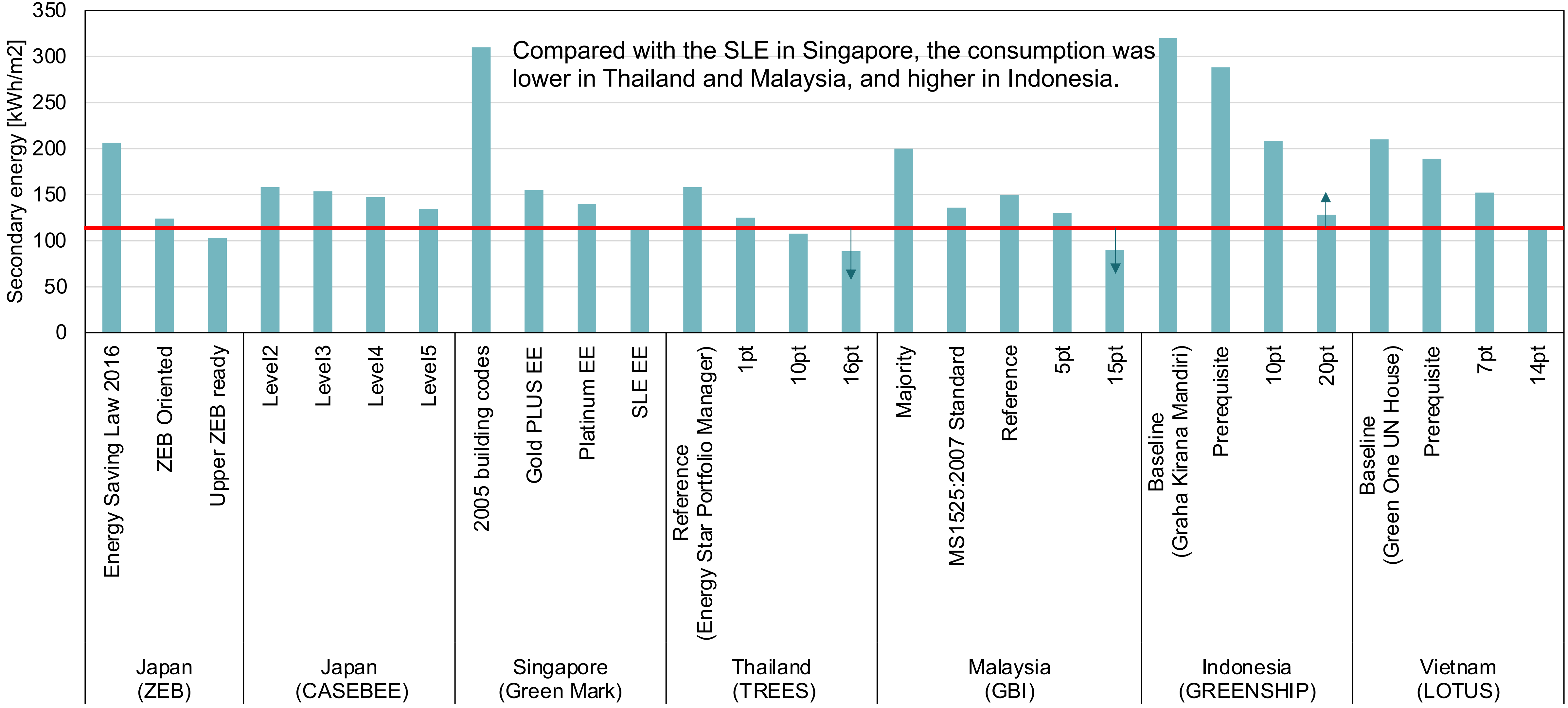

Imp_model_All




# Heat load reduction effect by ZEB measures for Base mode by city

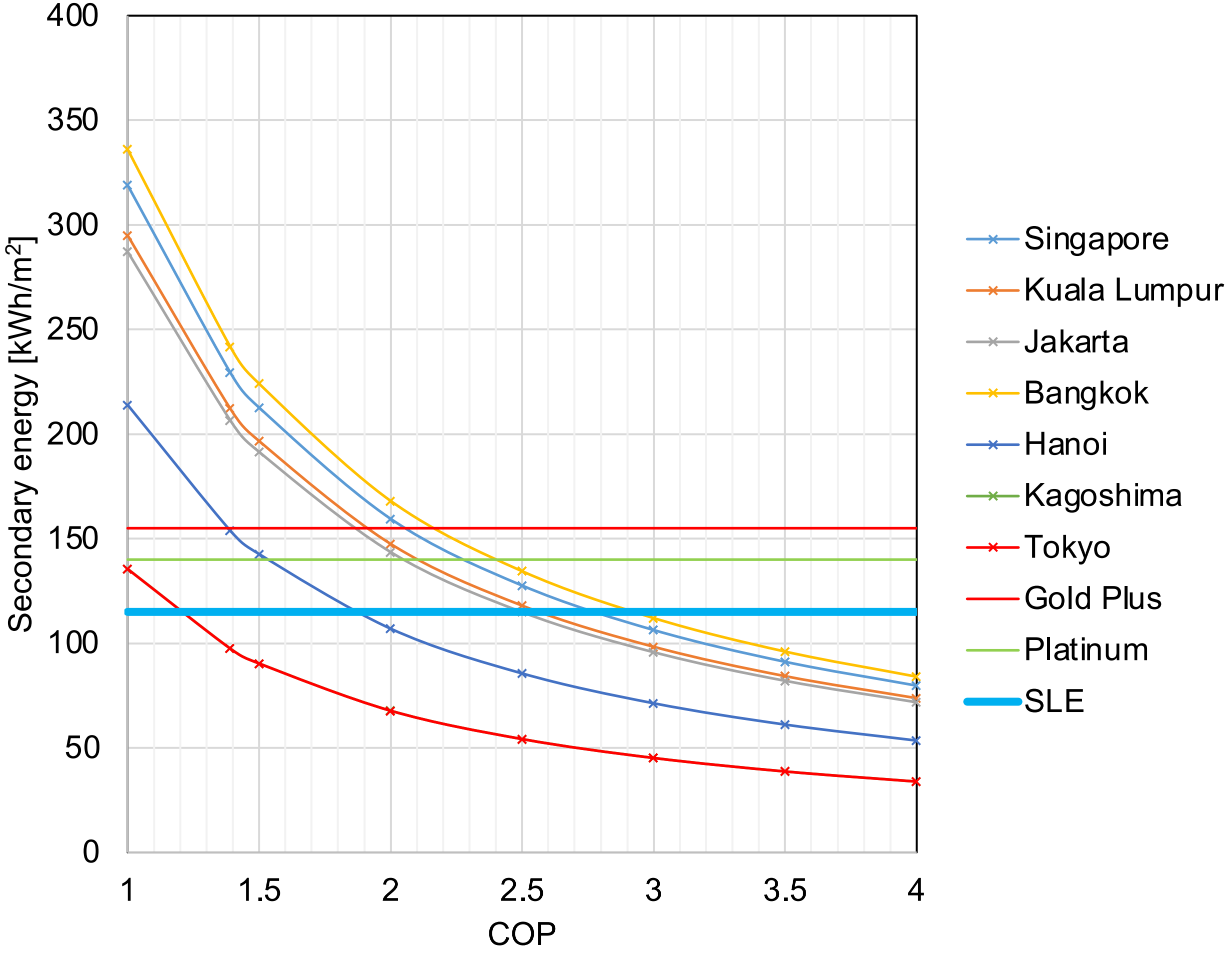
In Hanoi, a sensible heat load by heating was noticed.
In case the energy conservation measures are taken, the heat load is expected to be reduced by about 70.4% to 72.1% from when they are not taken.

The following shows the energy conservation standards in each country converted into secondary energy consumption.




# Targeted secondary energy in each Energy Conservation Countermeasure

## (3) SLE achievement rate for each case




Effect on energy consumption by ZEB measures by city and air conditioning system COP and comparison with SLE

- Secondary energy consumption in Kagoshima and Tokyo are always at the Plutinum level.
- Not reaching even the Gold Plus level at COP < 1.85.
- Achieved the Gold Plus level at COP ≥ 2.16.
- Achieved the Plutinum level at COP ≥ 2.40.
- Achieved the SLE level at COP ≥ 2.93.

Targeting 5 locations in Southeast Asia plus Kagoshima and Tokyo, calculate the changes of $CO_2$ emissions and heat load when the window area ratio of ZEB measures applied model (ZEB_All) is changed.

List of main parameters of ZEB measures applied model (ZEB_All) [14)]

| Model summary | |
|---|---|
| Weather data | 7 points |
| People | 0.2person/m$^2$ |
| People load | 132W/person |
| Light | 9.68W/m$^2$ |
| Equipment | 9.68W/m$^2$ |
| Ventilation | 1.5/h |
| Area | 1000m$^2$ |
| Rentable floor area ratio | 0.7 |
| Ceiling height | 4m |
| WWR | 0.1~0.7 |

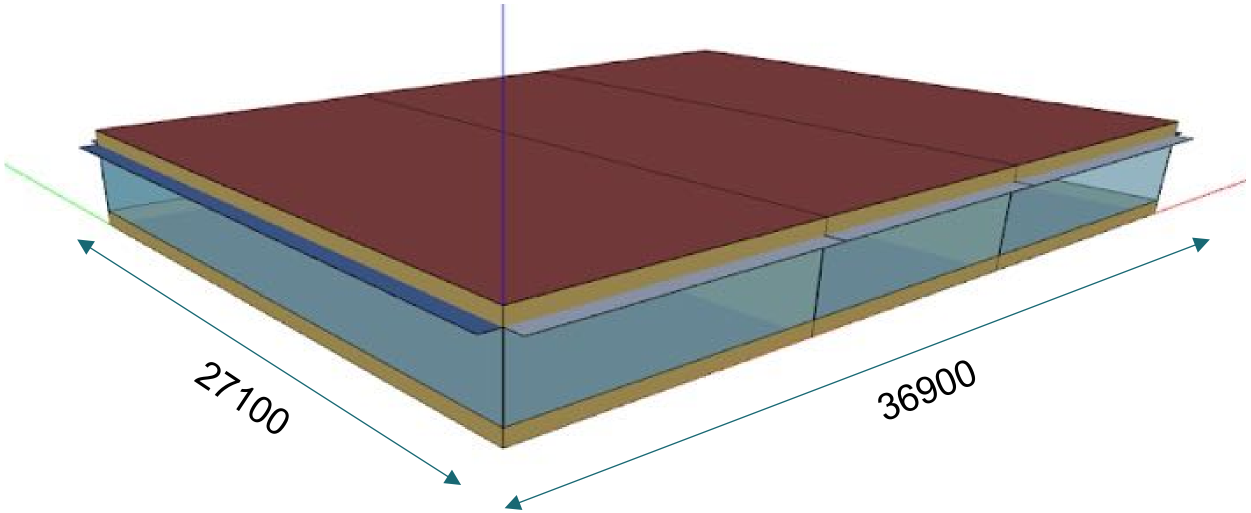
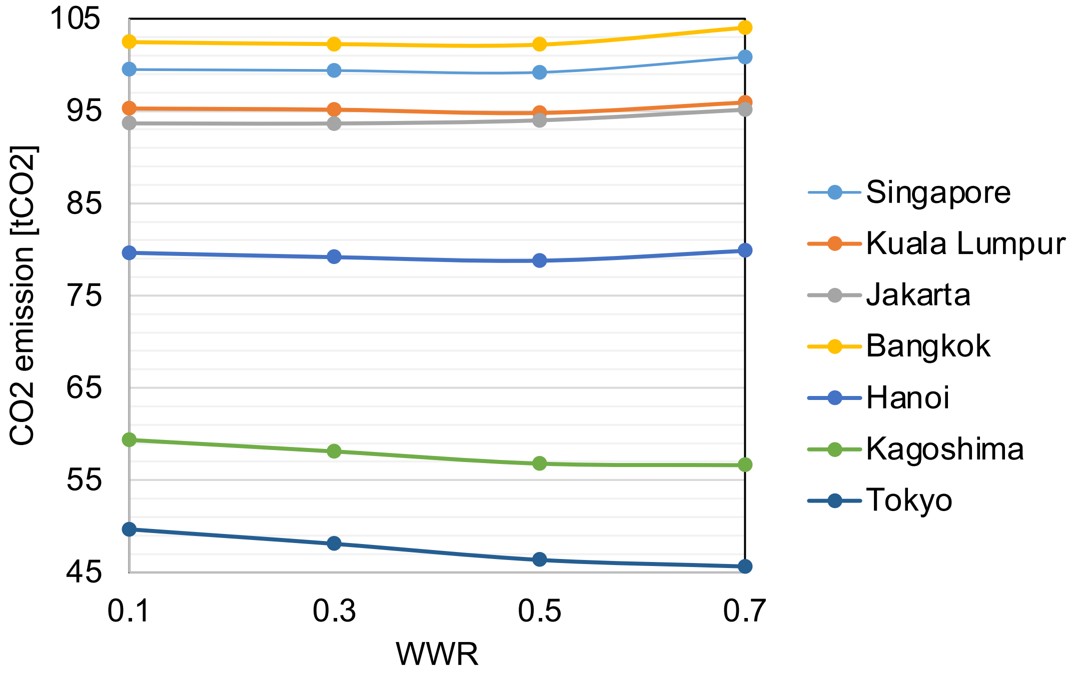
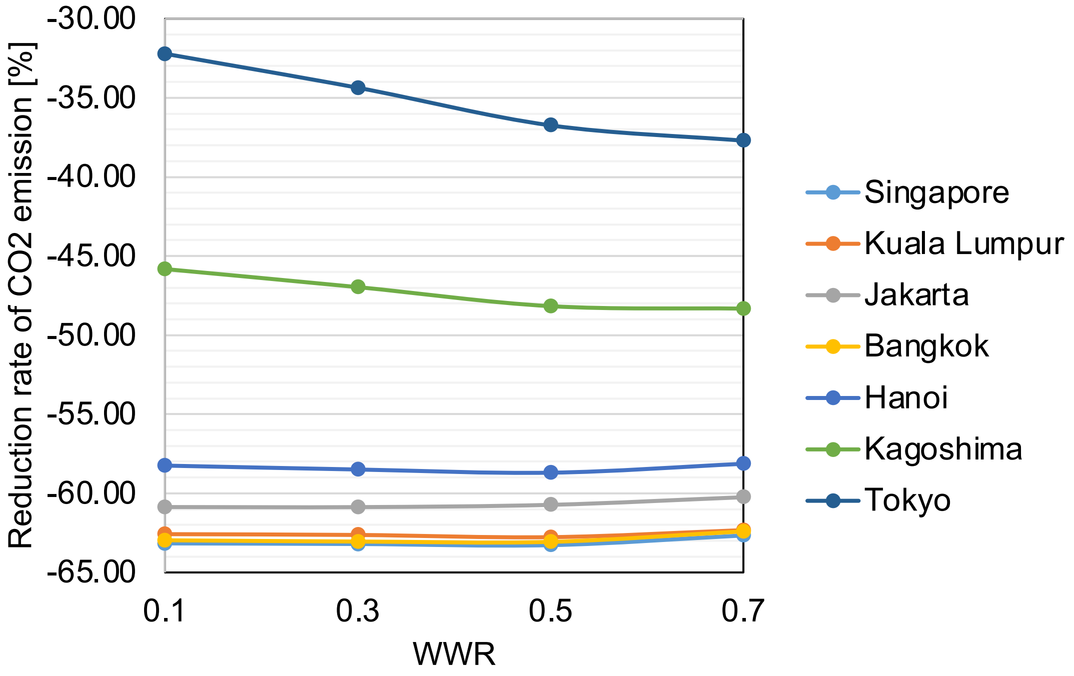


Fig. 5-5 Appearance of ZEB

14) Yukiko MABUCHI, Masayuki ICHINOSE, Nobuki MATSUI, Masayuki OGATA, Alkhalaf Haitham
"Proposal of air conditioning method based on actual usage at office buildings in Tropic Asia"
Convention (Fukushima) of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, Technical Papers of Annual Meeting, Pages 241 to 244. (Sep. 2021)

## (1) Change of $CO_2$ emissions

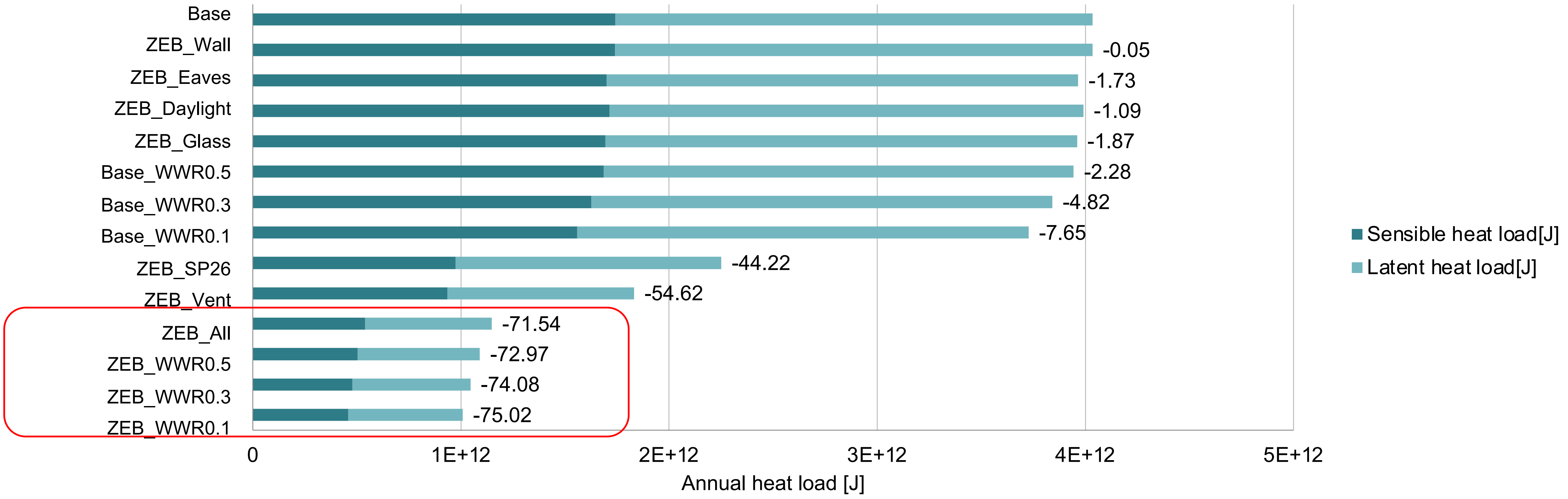



$CO_2$ emission reduction effect based on WWR by city

- A $CO_2$ emission reduction volume does not change greatly, even if the window area ratio is reduced for the ZEB measures applied model (ZEB_All).
- In Kagoshima and Tokyo, the smaller window area ratio lowers a $CO_2$ emission reduction rate.

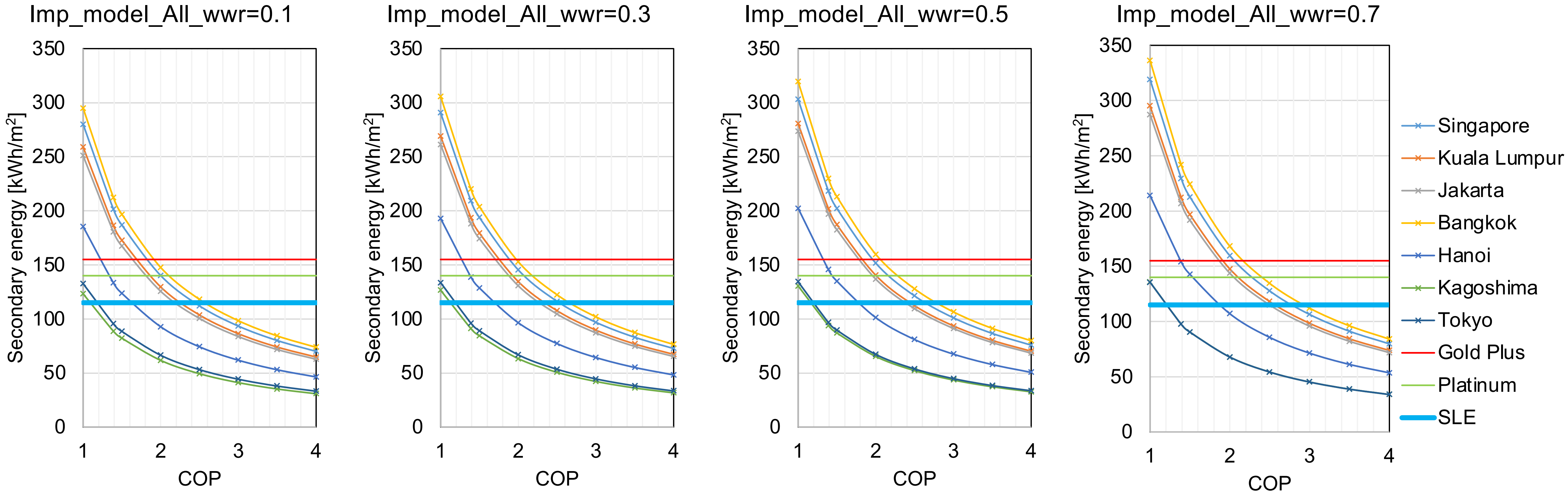
## (2) Change of heat load




Heat load reduction effect by ZEB measures for Base model by city

- Even if the window area ratio is reduced for the ZEB measures applied model (ZEB_All), the heat load is not lowered greatly.

## (3) SLE achievement rate for each case




Energy consumption reduction effect based on WWR by city

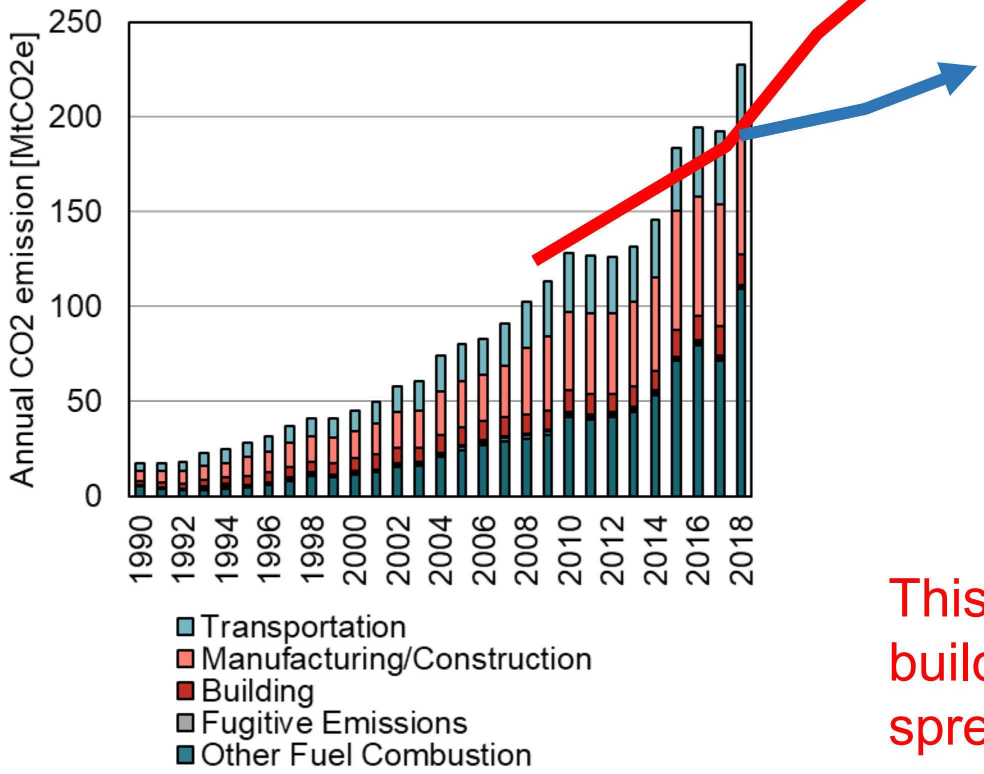
SLE achieved at COP ≥ 2.59

SLE achieved at COP ≥ 2.69

SLE achieved at COP ≥ 2.79

SLE achieved at COP ≥ 2.93

# Prediction method for future $CO_2$ emissions

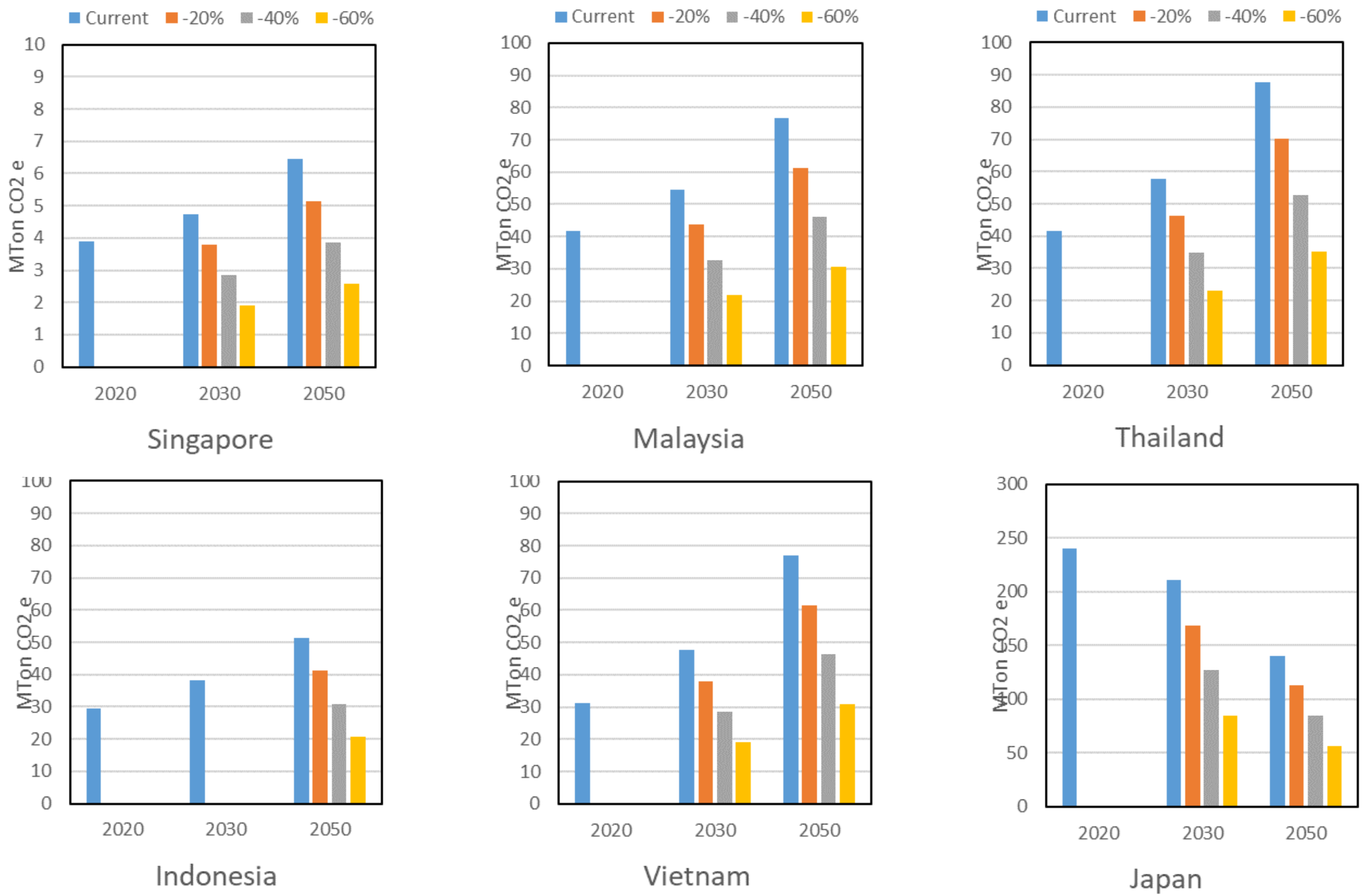



Future prediction based on past to current statistics

Future prediction expecting reduction effects in construction field
0%
20% reduction
40% reduction
60% reduction

This study evaluates only reduction effects of single buildings; it does not consider the factors such as spread of renewable energy and improvement of power generation efficiency.

# 4. Prediction of Reduced Environmental Load by Dissemination of ZEB Family



# Contents

# 5. Summary

■ $CO_2$ emission trends

- $CO_2$ emissions seem to have peaked in Singapore, Malaysia and Thailand, but they are still high in the rest of ASEAN countries.
- $CO_2$ emissions are expected to continuously increase in Indonesia and Vietnam.
- Equivalent to Japan, $CO_2$ emission per capita is high in Singapore and Malaysia, followed by Thailand, Vietnam and Indonesia, where per-capita emission is below the half that level, but its increase rate is high.
- Currently, total $CO_2$ emissions in Japan are close to 5 to 10 times higher than in the ASEAN countries. If they transition down the road as is now, $CO_2$ emissions in Japan will remain high even in 2030 and 2050.
- Once ZEB is disseminated, $CO_2$ emissions in Japan may be reduced to as low as in the ASEAN countries in around 2030.

# 5. Summary

■ Meteorological characteristics

- Meteorological characteristics differ even in Southeast Asia. A cooling load is the highest in Bangkok.

■ Energy conservation standards

- In the secondary energy standards, the highest-level settings are equivalent to those in Japan, but the lowest-level ones differ greatly.
- The $CO_2$ emission standards are the strictest in Japan. The emission setting in Indonesia stands out from the rest of the ASEAN countries.

■ Effects of ZEB measures

- The effects are low even if the window area ratio is greatly regulated.
- In case the single ZEB measures are taken, high effects are noticed in air conditioning setting temperature, optimization of outside air load processing and improvement of air conditioning system COP.
- To reach the SLE level, it is essential to apply composite measures. $CO_2$ emissions can be reduced by 60% in the ASEAN countries (40% reduction in Tokyo).
- $CO_2$ reduction potential by ZEB is very high.
- Energy conservation alone is not enough to realize carbon neutrality. Introduction of renewable energy and synergy with other industries are essential.