

RADIANCE WORKSHOP 2022 IN TORONTO, CANADA

# Effects of Model Geometries, Material Properties and Parameters on Calculation Accuracy in Simulations Using Radiance

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1. About us

2. Validation of optimal simulation settings for designers

## 1. About us

## 2. Validation of optimal simulation settings for designers

## Corporate profile, as a design and construction company



### Sales

# \$12.6B

### Staffs

# 7,757

### Architects (Licensed)

# 2,407

### Construction Mgrs (Licensed)

# 2,280

### History of Takenaka Corporation

## Takenaka, the Past and Future

Since its founding in 1610, Takenaka has specialized in architecture to produce a multitude of buildings that have become landmarks, and in this way, we have played a vital role in the development of our society. From the days of our founder Tobei-Masataka Takenaka, a master builder of shrines and temples, our philosophy of specializing in building construction lives on. Today this spirit is embodied in all of our work, which has spread beyond the framework of architecture to prosperous and secure urban creation, not only in Japan but all over the world.

### 1610

**1610**  
Tobei-Masataka Takenaka established a business in Nagoya to engage in shrine and temple construction.

### 1920

**1934**  
Meiji Seimeikan (Marunouchi, Tokyo) completed.

**1937**  
Takenaka Corporation established. Capital ¥1,500,000.

**1941**  
Takenaka Civil Engineering & Construction Co., Ltd. established.

**1957**  
Antarctic Exploration Research Facilities constructed. Patent acquired for Takenaka Caisson Process.

**1958**  
333-meter-high Tokyo Tower completed.

### 1975

**1978 West Germany**  
Deutsch-Japanisches Center completed.

**1979**  
Takenaka awarded Deming Application Prize.

**Ashiyahama Seaside Town**, proposed by the ASTM Group of which Takenaka was a member, completed.

**1981 Singapore**  
Changi International Airport Terminal 1 completed.

**1983 Tokyo**  
Ote Center Building completed and opened.

**1986**  
Takenaka awarded Best Design Prize in New National Theatre, Tokyo International Design Competition.

**1987**  
Yurakucho Mullion completed.

**1987 San Francisco**  
Hotel Nikko San Francisco completed and opened.

**1988**  
Chairman Renichi Takenaka awarded the Deming Prize.

**Tokyo Dome**, Japan's first multipurpose stadium with an air-supported membrane structure, completed.

### 1990

**1990 Osaka**  
Crystal Tower completed and opened.

**1990**  
Takenaka (Malaysia) Sdn. Bhd. established.

**1991 Hawaii**  
Grand Hyatt Kaula Resort and Spa completed and opened.

**1992**  
Takenaka awarded the Japan Quality Control Medal.

**1993**  
Fukuoka PayPay Dome, Japan's first multipurpose stadium with a retractable roof, completed.

**1993**  
PT. Takenaka Doboku Indonesia established.

**1995**  
ACROS Fukuoka, a pioneering work in environmental architecture, completed.

**1996 Thailand**  
Ayutaya Bank Main Office completed.

**1997**  
Nagoya Dome completed, one of the five major domes. (Vantelin Dome Nagoya)

### 2000

**2001**  
Takenaka Corporation (U.S.A.) established.

**2001**  
Oita Sports Park Showa Denko Dome Oita and Sapporo Dome completed.

**2003**  
Takenaka (China) Construction Co., Ltd. established.

**Germany**  
Hyundai Motor Europe R&D completed.

**2006**  
Superhigh-rise base isolation condominium City Tower Nishi-Umeda completed.

**2007**  
Chubu region's tallest skyscraper Midland Square completed. Large-scale integrated Tokyo Midtown and Shin-Marunouchi Building completed in central Tokyo.

**2008**  
World's first high-rise condominium comprising three interconnected skyscrapers, Island Tower Sky Club, completed.

**2009**  
Mitsubishi Ichigokan and Marunouchi Park Building completed.

### 2010

**2010**  
Takenaka India Private Ltd. established.

**2013**  
Osaka Timber Association Building, constructed in Moen-Wood, completed.

**2014**  
Abeno Harukas, the tallest building in Japan, completed.

Takenaka awarded Architectural Institute of Japan Award (Architectural Design) for Meiji Yasuda Life Insurance New Toyoko Building.

**2017**  
Global Gate complex opened to serve as the core of Sasashima Live 24, a redevelopment project.

**2017**  
Takenaka Vietnam Co., Ltd. established.

**Singapore**  
Changi International Airport Terminal 4 completed to handle the flow of people and economic activities as Southeast Asia's hub airport.

**Indonesia**  
Pacific Century Place Jakarta completed and distinguished for outstanding environmental features with LEED Platinum certification.

### 2018

**2018**  
Open community hub for academic and local exchanges Tokoha University, Shizuoka Kusanagi Campus completed.

First legacy utilization project FORMER MANKICHI YAMAGUCHI HOUSE/kudan house completed.

**2019 Kyoto**  
Kyoto Higashiyama Project (Kyoyamato & Park Hyatt Kyoto) opened.

**2019**  
Ariake Arena, a sports event venue, completed.

**Shibuya PARCO • HULIC building** completed as an urban and cultural development center.

**National Cerebral and Cardiovascular Center** completed as a center for leading-edge medical services.

### 2020

**2020 Tokyo**  
FLATS WOODS KIBA completed to accelerate the Forest, Grand Cycle.

**2020**  
Yokohama City Hall completed as a city hall open to citizens.

PACIFICO Yokohama North completed. PFI projects contribute to the Yokohama landscape.

Spatial configuration based on a 3D Voronoi model, "Steel Nest" Sanel Construction Steel Structure Division New Office, completed.

Office building embodying changes in the environment, River Holdings Ryogoku Office, completed.

MIYASHITA PARK completed by application of a vertical urban park system.

TAKENAKA Corporate Report 2022

## ■ Three Keywords to Understand the Origin of Japanese Major design contractors



### 棟梁 *Toryo* (master builder)

Master Temple and shrine carpenters, or *toryo*, lead groups of craftsmen with their spirit and skills

### 五意達者 *Goi-tassha*

Toryo mastered five different skills in one personality

- Building Design
- Estimation
- Carpentry Work
- Drawing
- Detailing(Carving)

### Design-Build

The one-step service for building lifecycle with the continuous concept being the most widely accepted project delivery system in Japan for over millennium

## ■ Major Works



Antarctic Expedition Base, 1<sup>st</sup> DfMA Project (1955)



Tokyo Dome, 1<sup>st</sup> air supported stadium (1988)



Abeno Harukas (2014)

## ■ Major Works



Changi Airport Terminal 4 (2017)



“Steel Nest” Sanei Construction Steel Structure Division New Office (2020)



Shibuya PARCO · HULIC building (2019)



Kyoyamato & Park Hyatt Kyoto (2019)

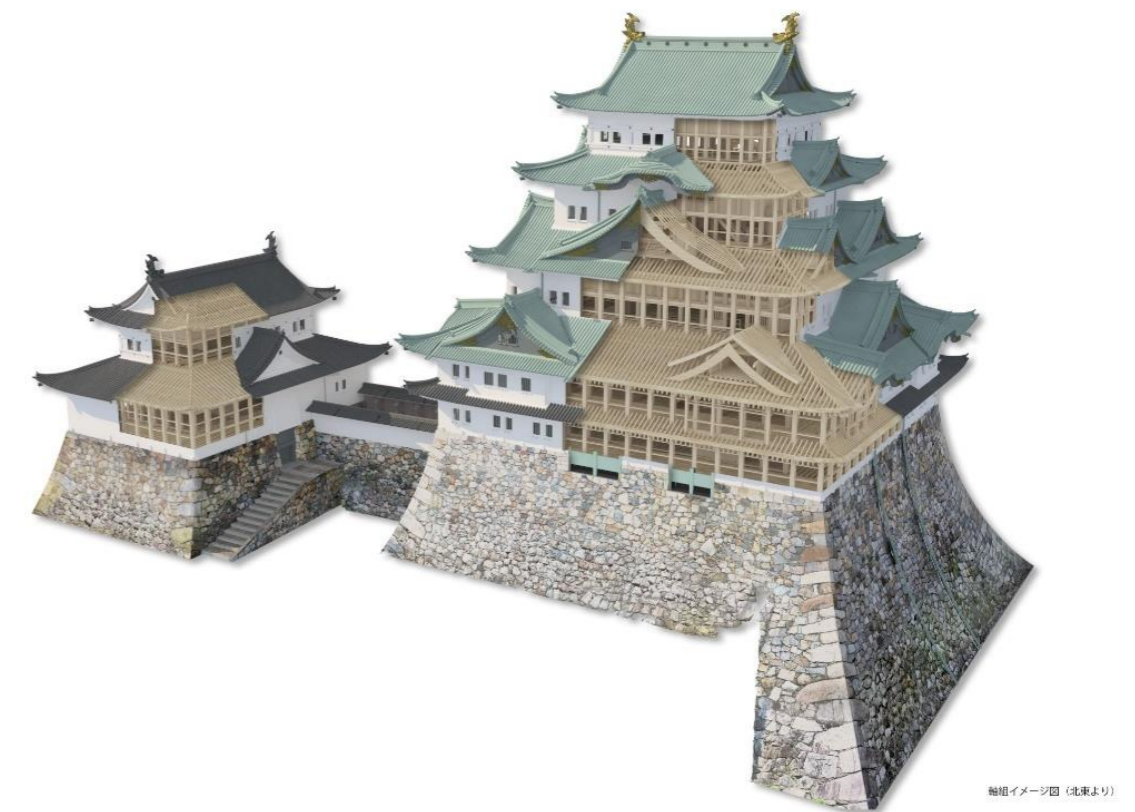
## Major Works



Suitengu Shrine(2016))



TAKENAKA CARPENTRY TOOLS MUSEUM(2014)



Nagoya Castle Reconstruction



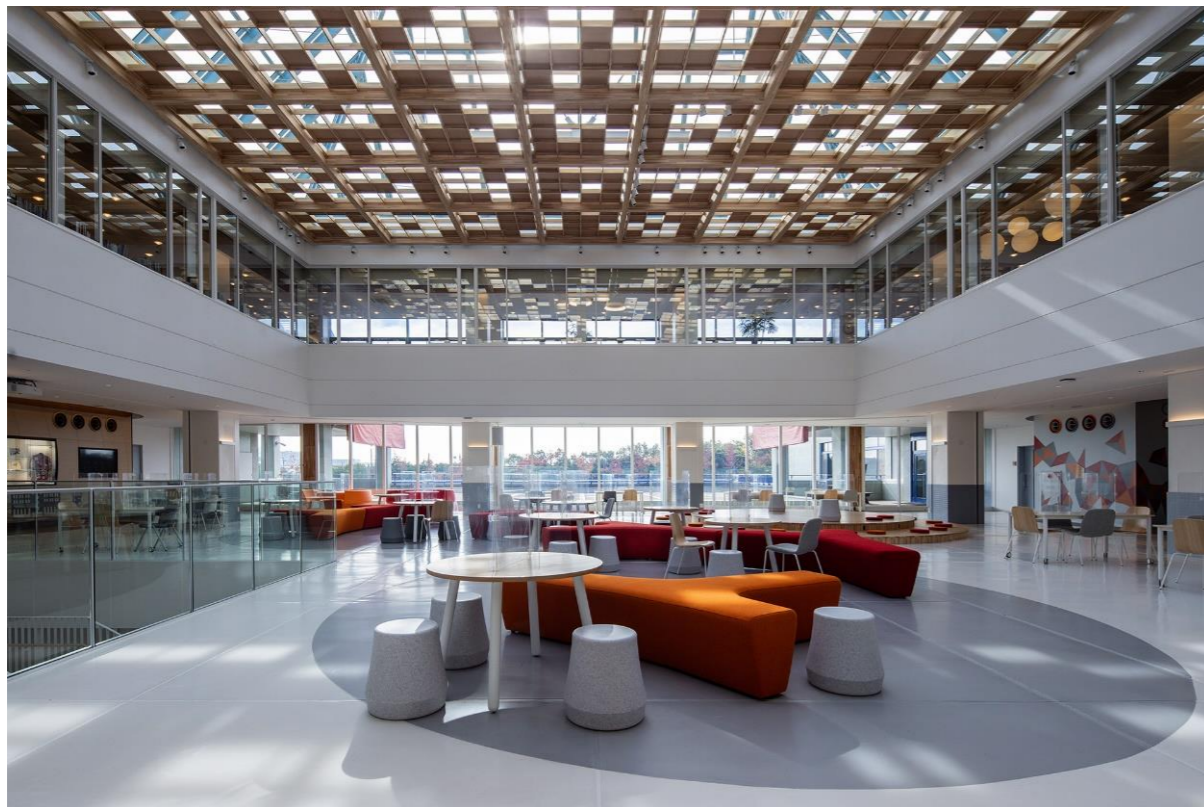
## ■ Sustainable Design Group, 2019~



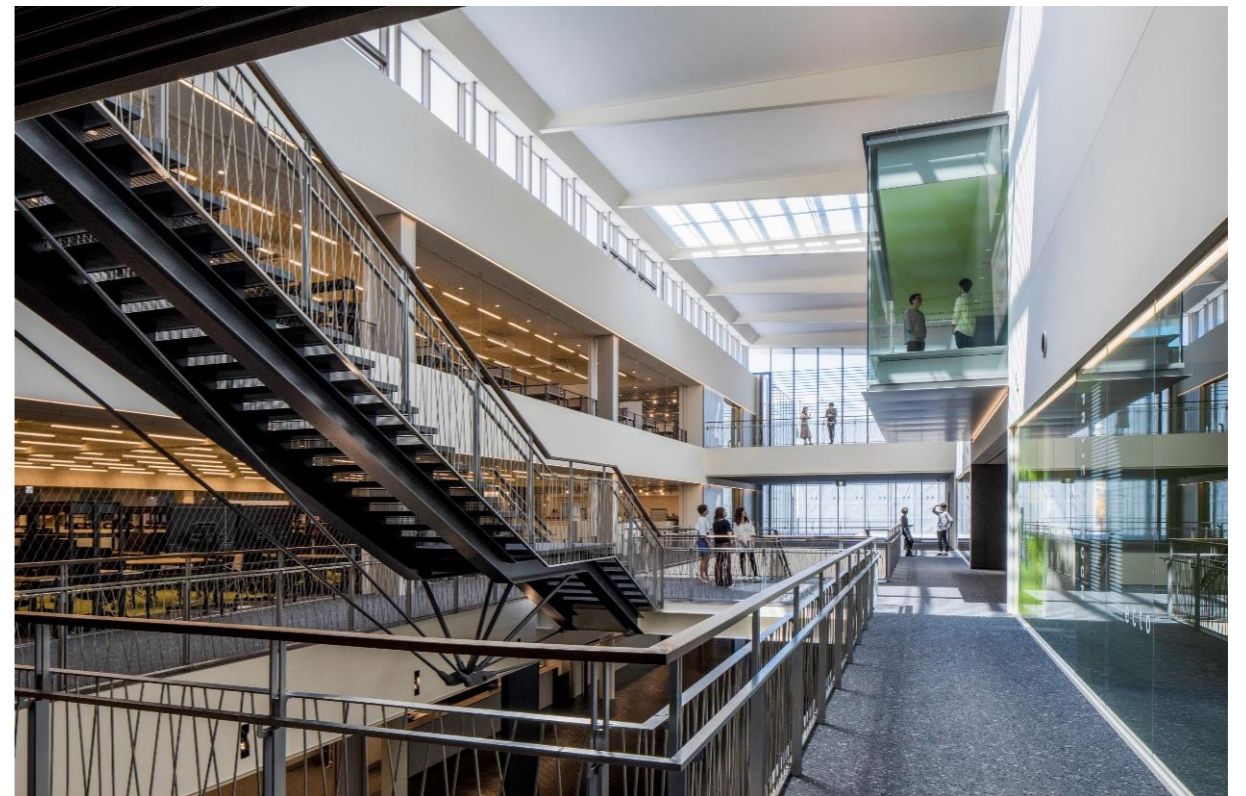
FM Center (2021)



Broadcasting Center (2024)

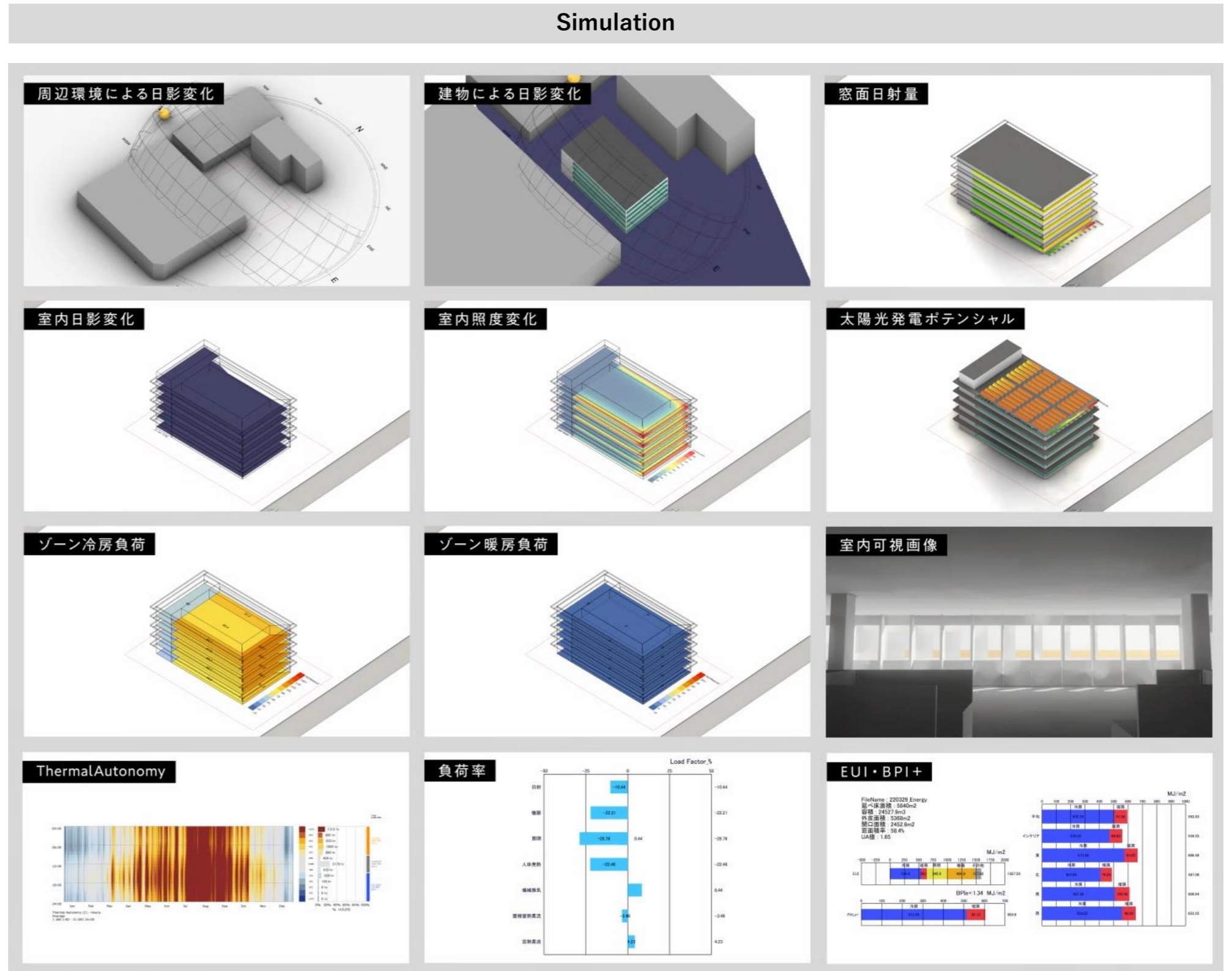
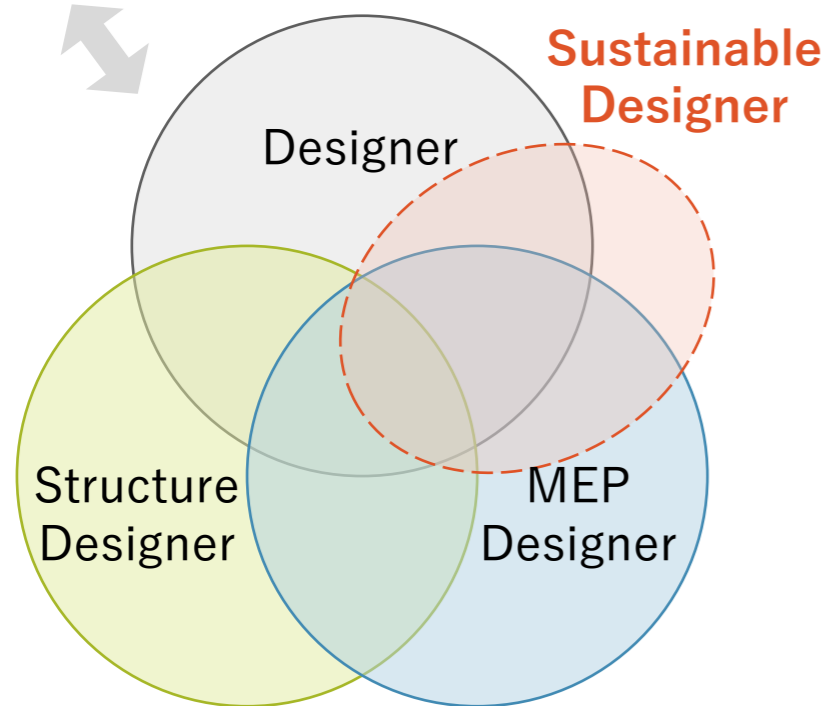
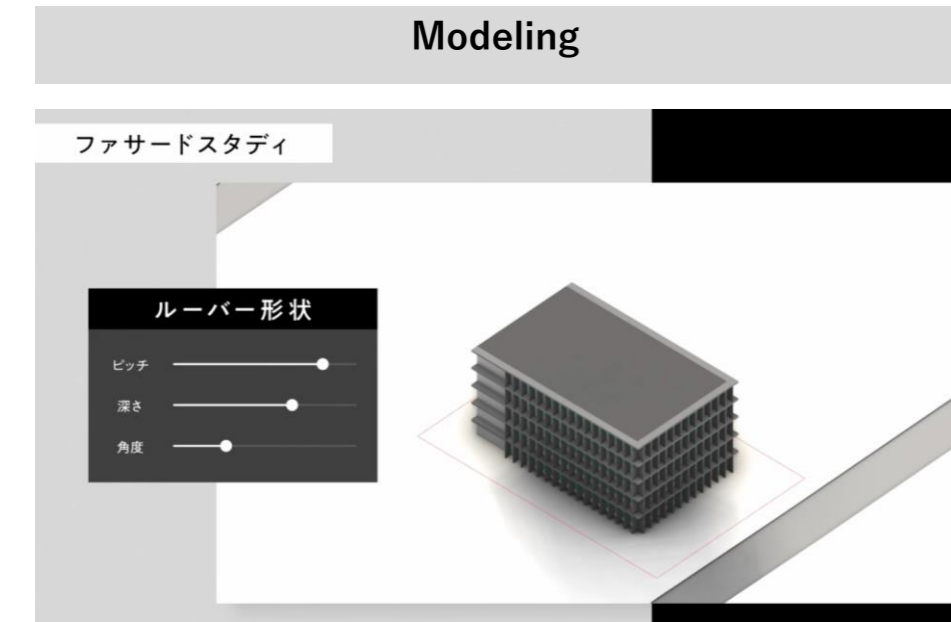


International School (2021)



University (2022)

## ■ Sustainable Design Tool

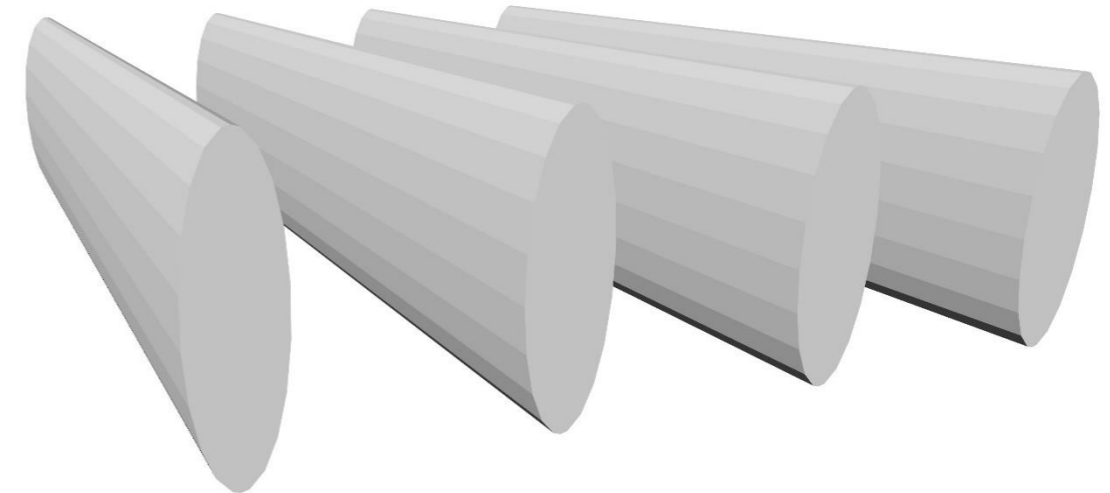
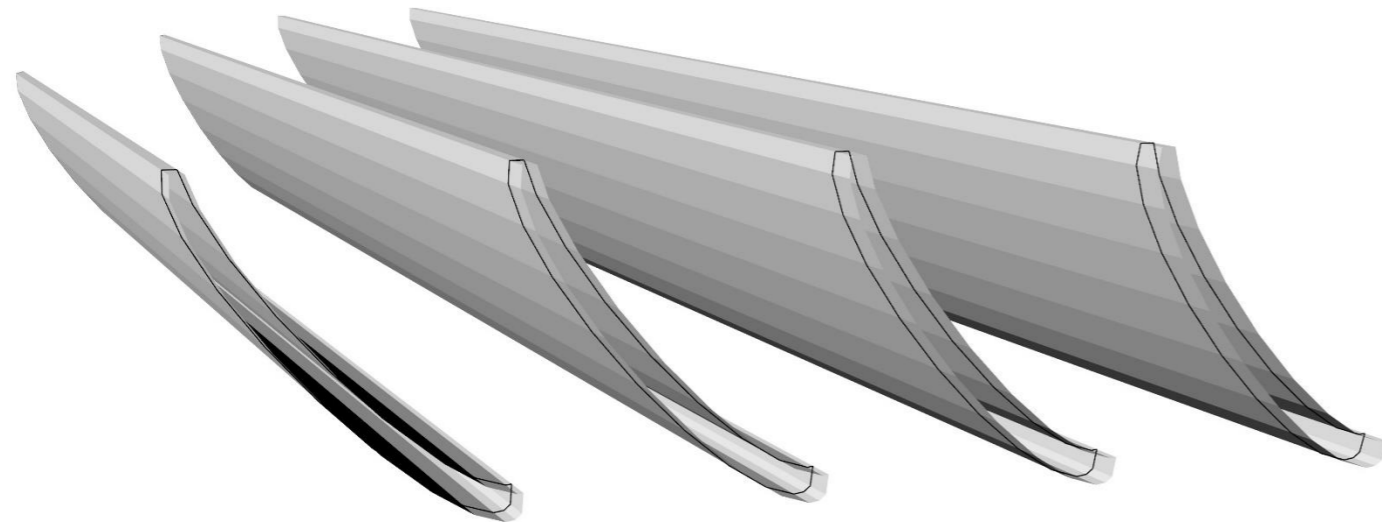


■ What shape transmits the maximum amount of light while avoiding direct light exposure?

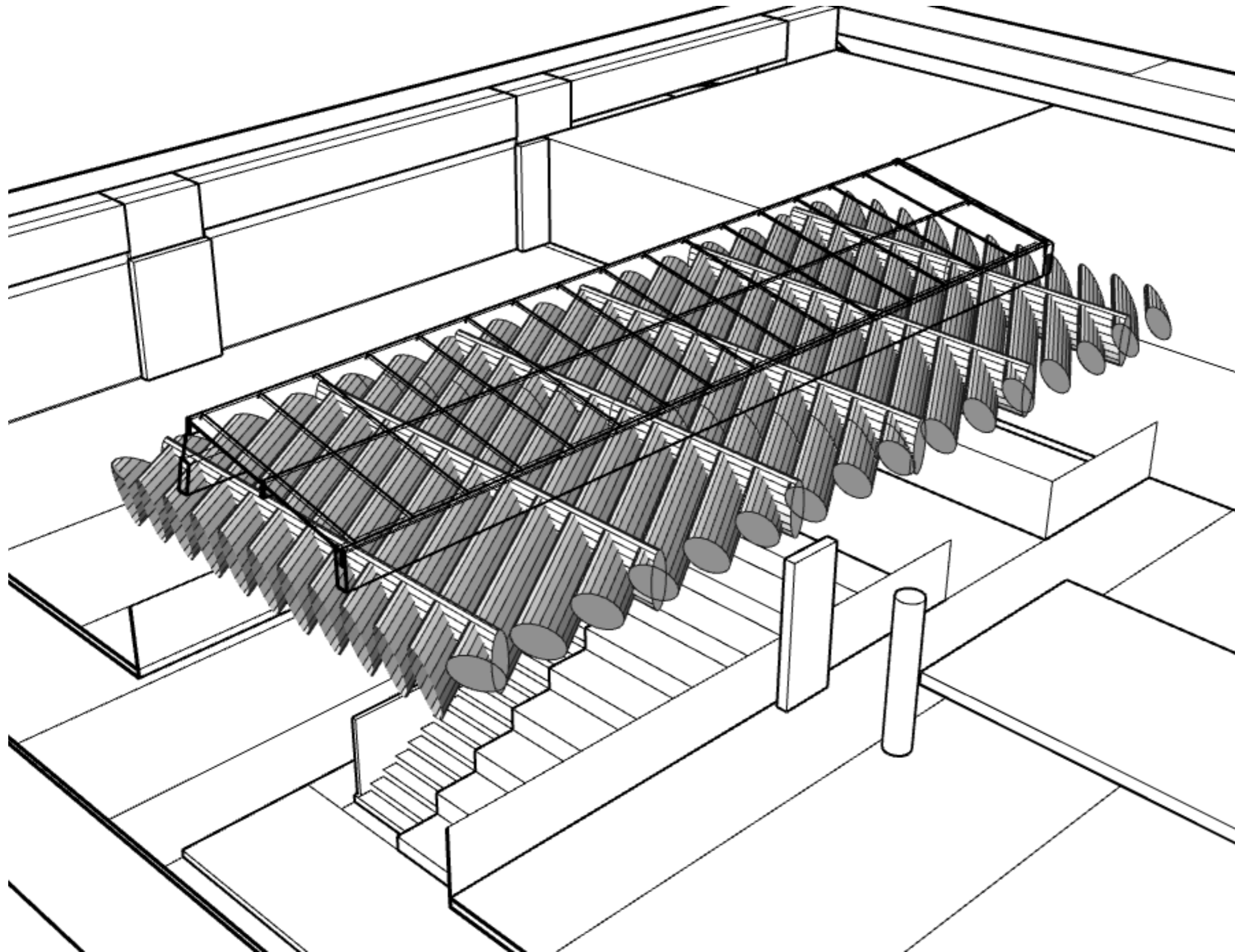
Arched shape

VS

Elliptical shape



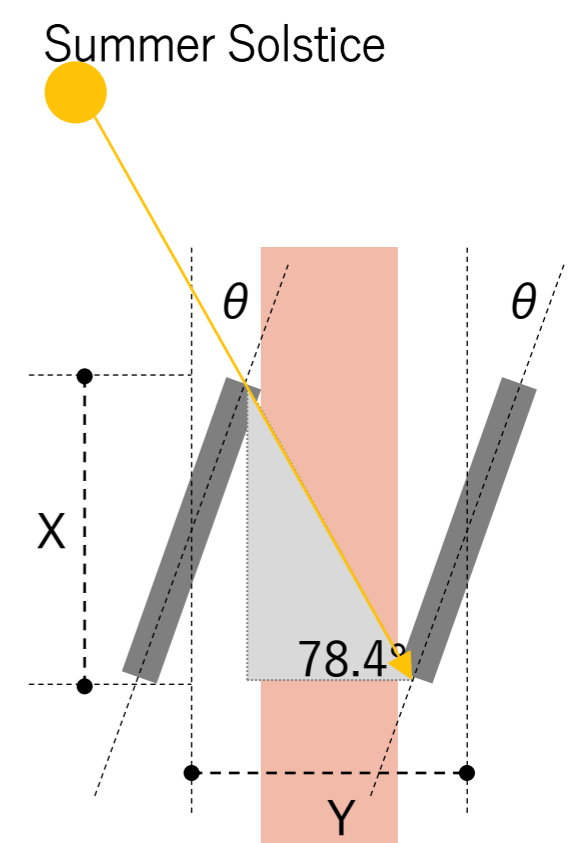
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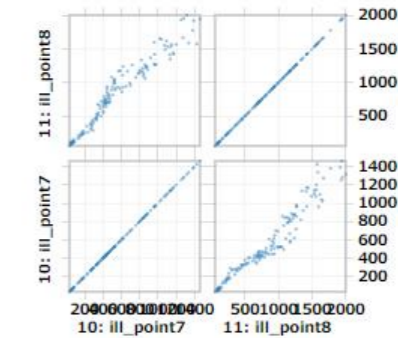
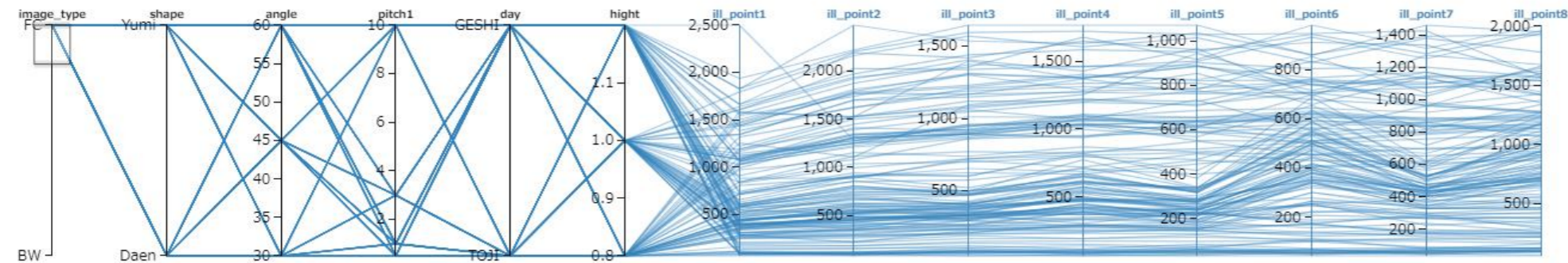
$3*3*2*4*2=144\text{Case}$

**Angle (3Case)**  
30,45,60 degree  
**Height (3Case)**  
0.8m,1m,1.2m  
**Shape (2Case)**  
Elipsed, Arched

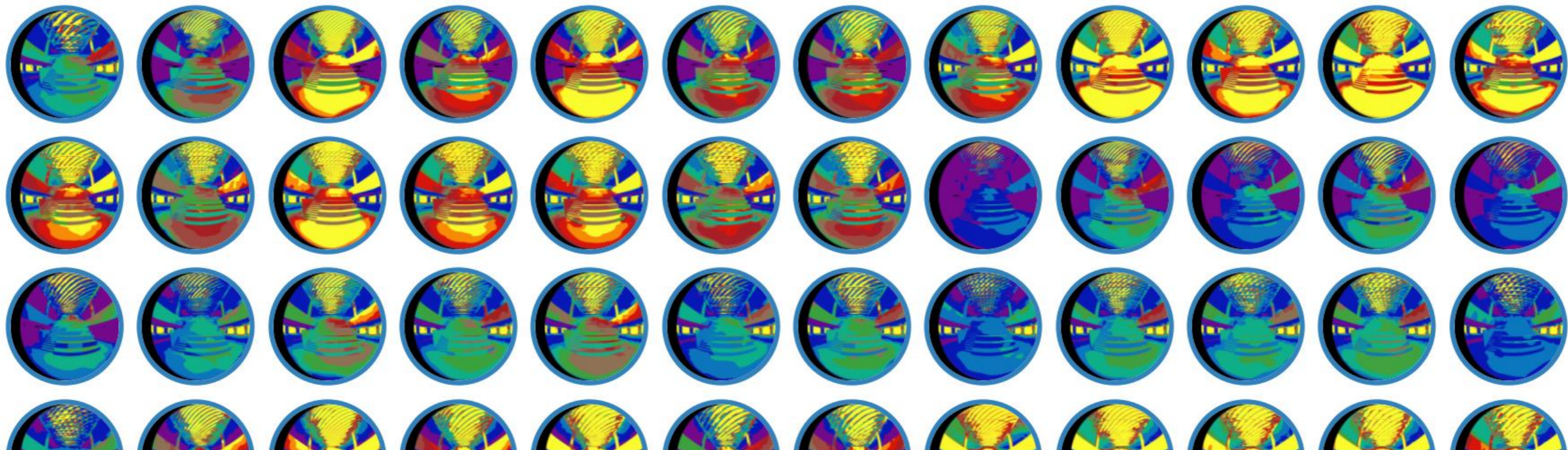
**Pitch (4Case)**  
Non,3m,1m,0.5m



## ■ What shape transmits the maximum amount of light while avoiding direct light exposure?

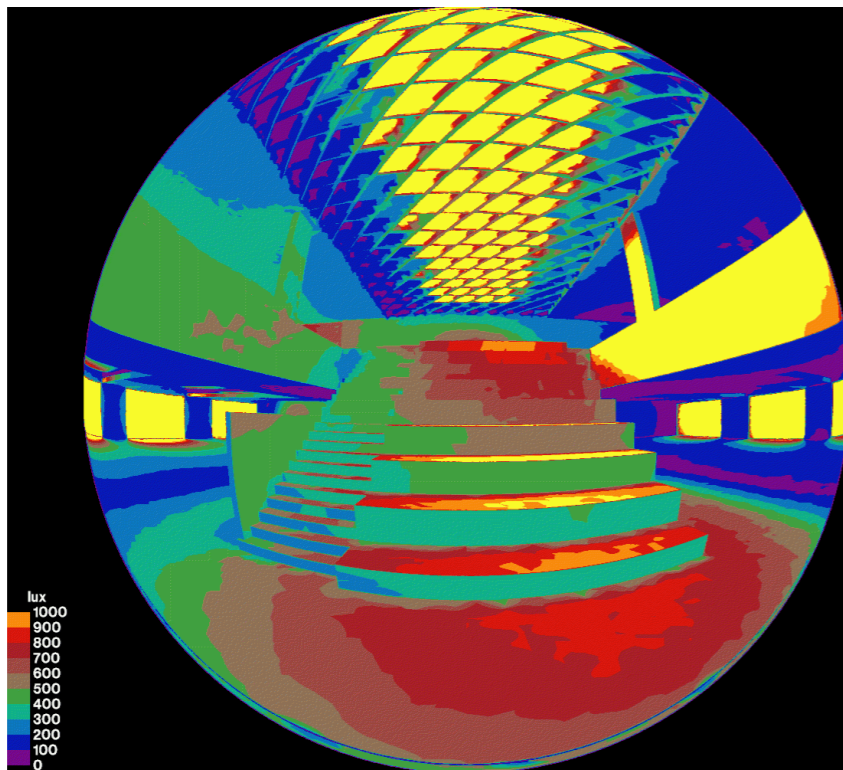


Sort by:



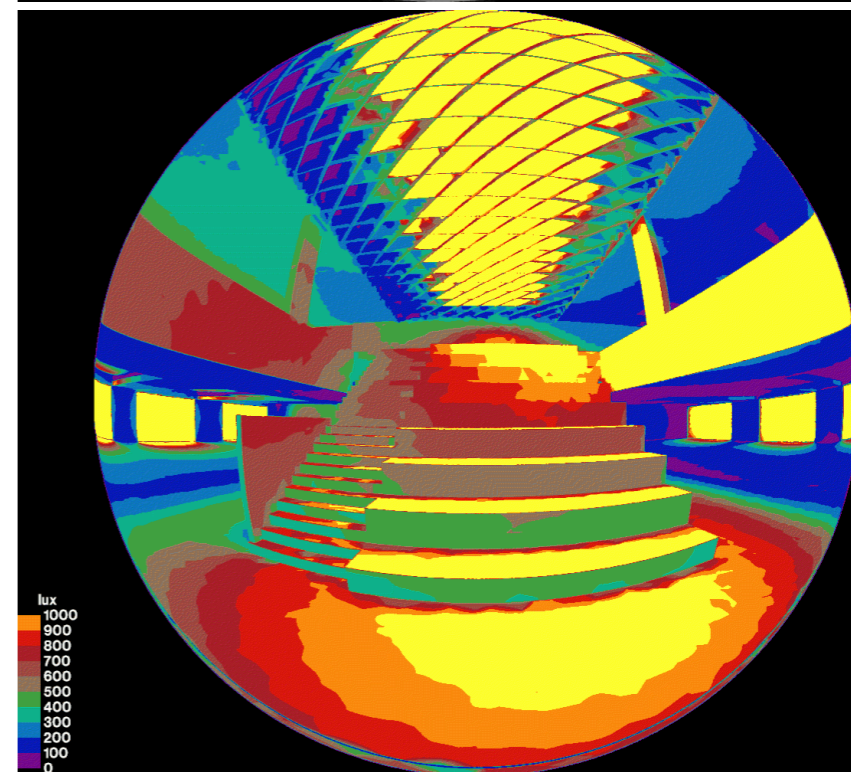
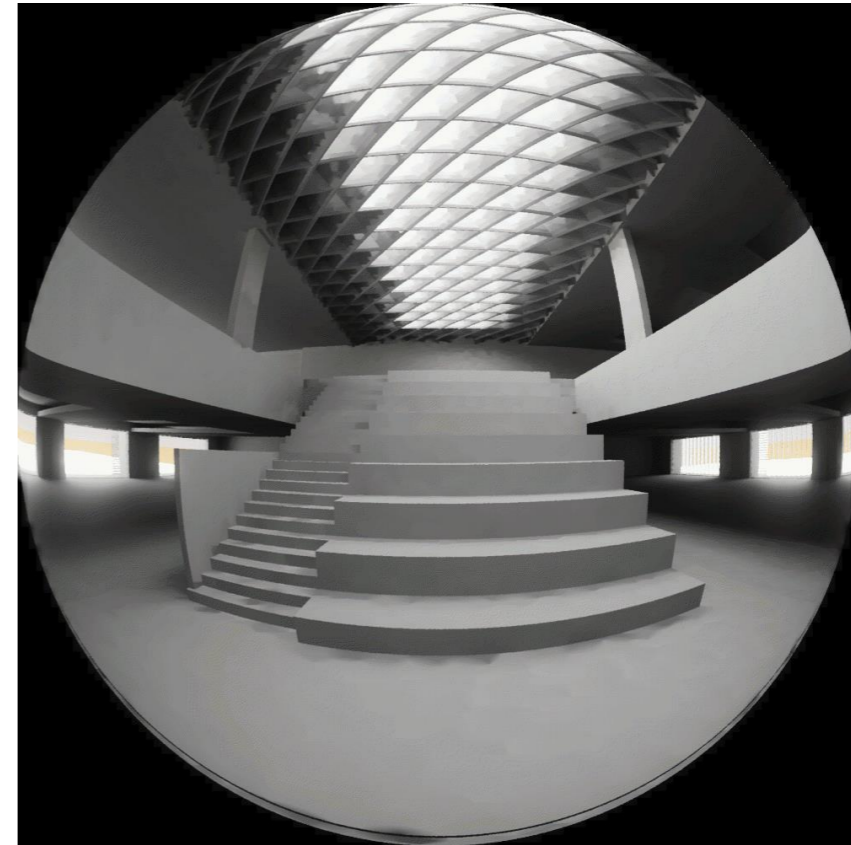
■ What shape transmits the maximum amount of light while avoiding direct light exposure?

Arched shape



VS

Elliptical shape

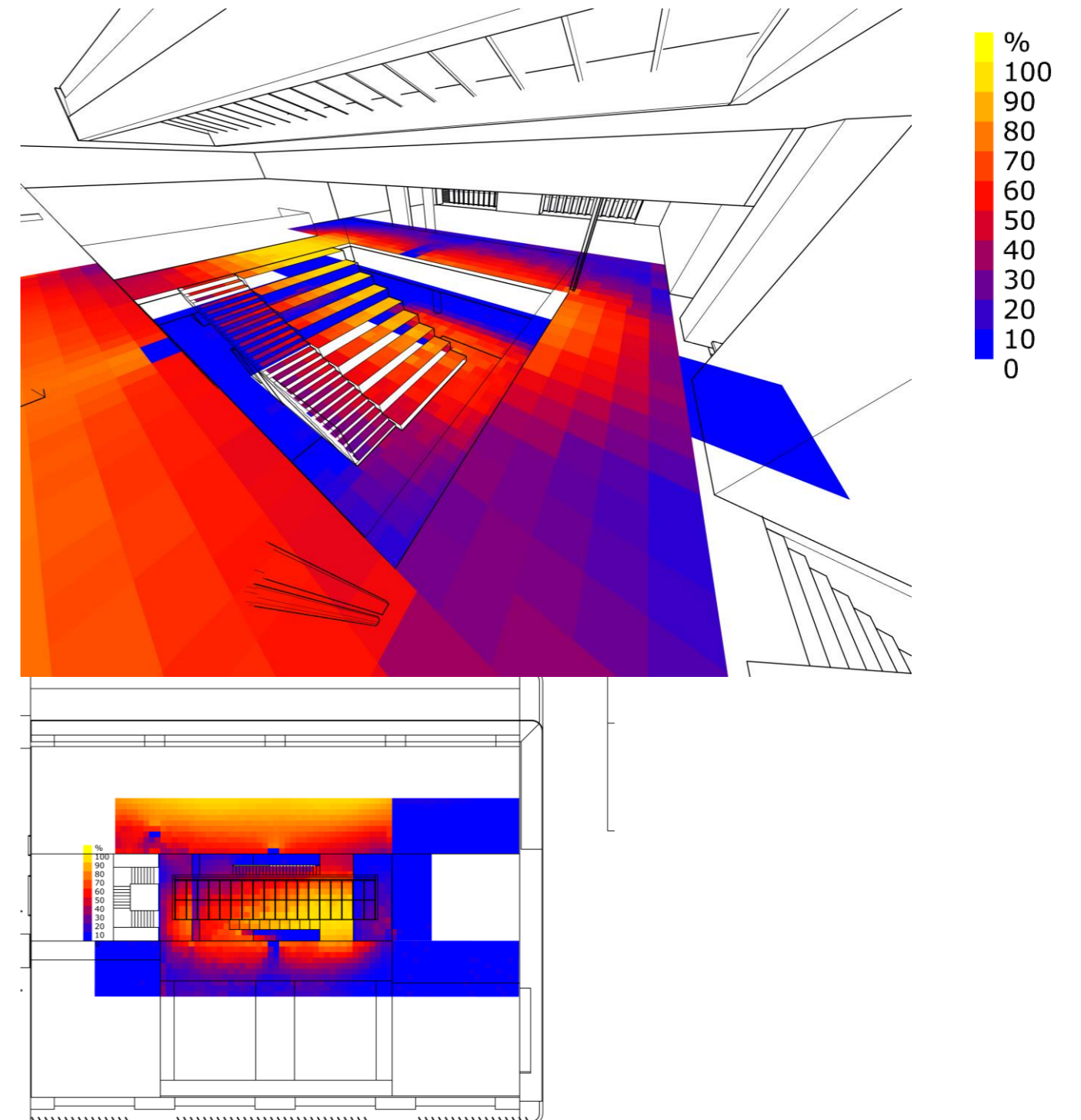
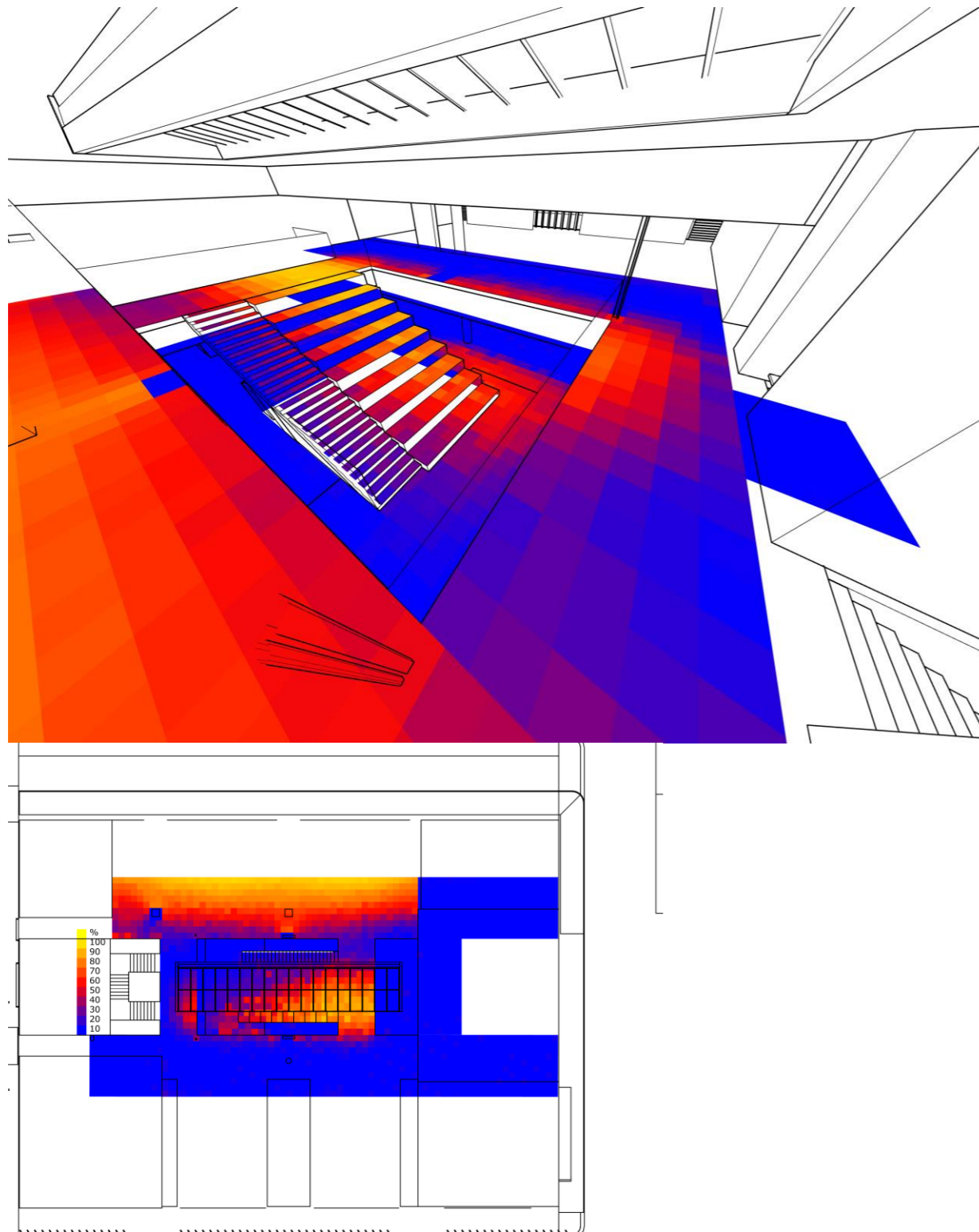


■ What shape transmits the maximum amount of light while avoiding direct light exposure?

Arched shape

VS

Elliptical shape

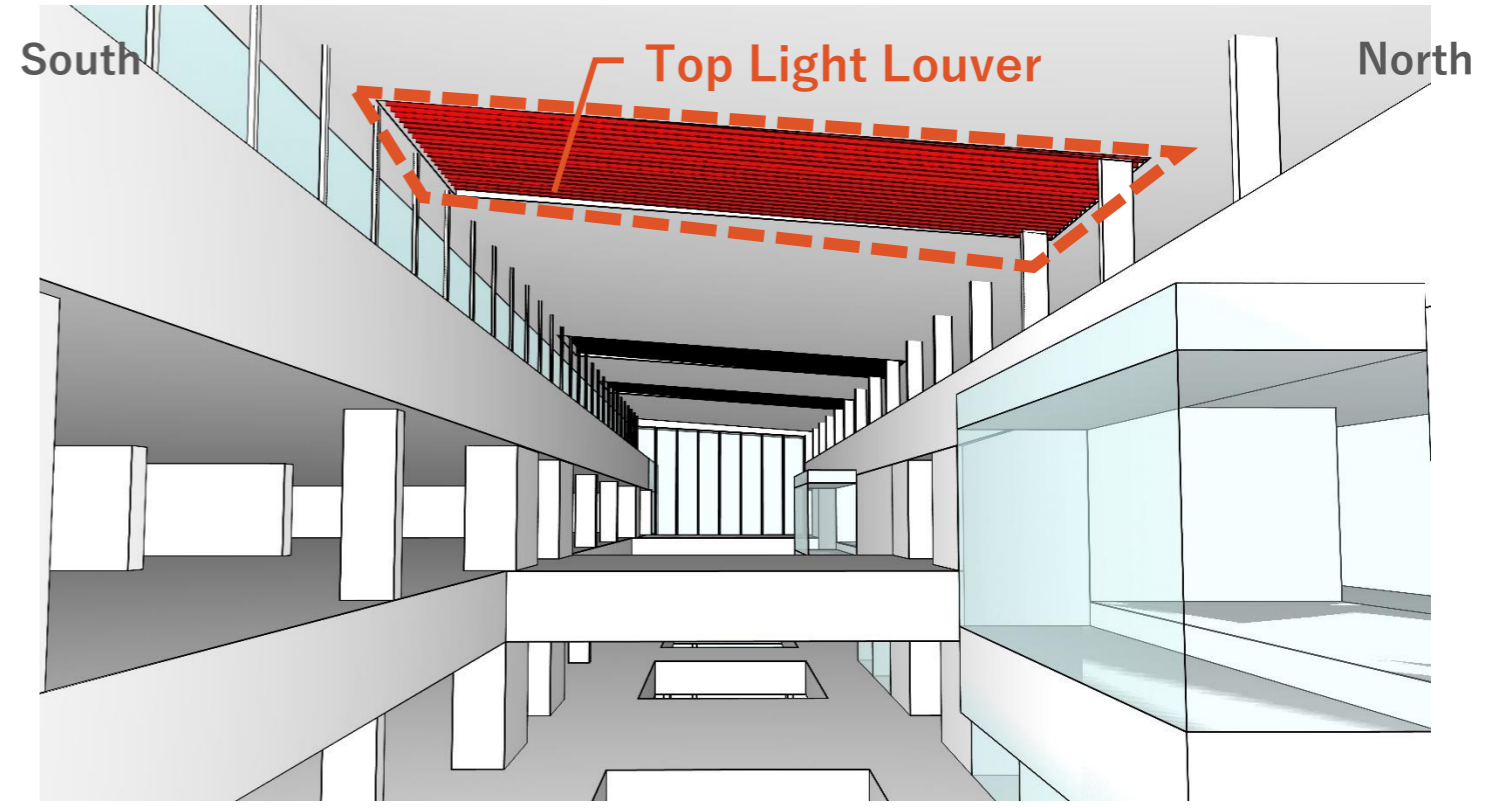
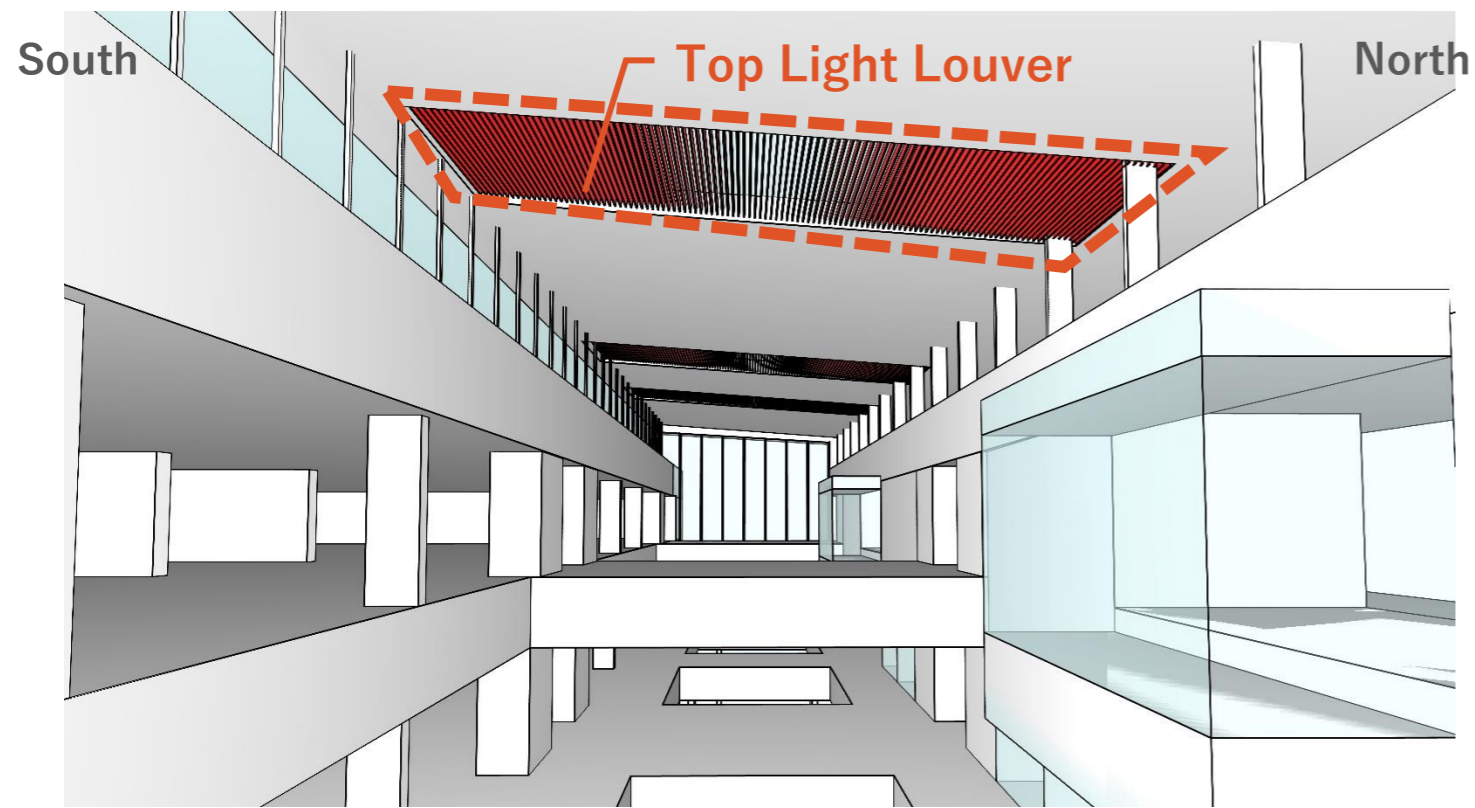


■ Which direction of the top light louvers is better for shading from the sun?

East-West

VS

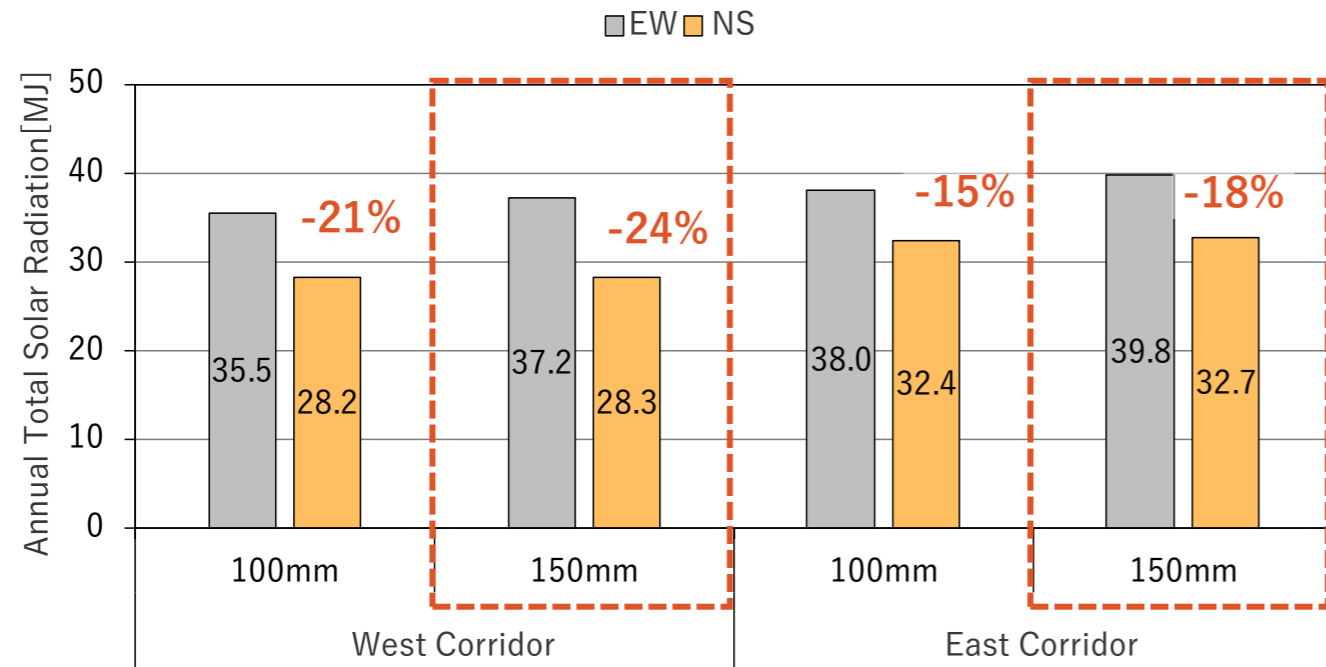
North-South





## Which direction of the top light louvers is better for shading from the sun?

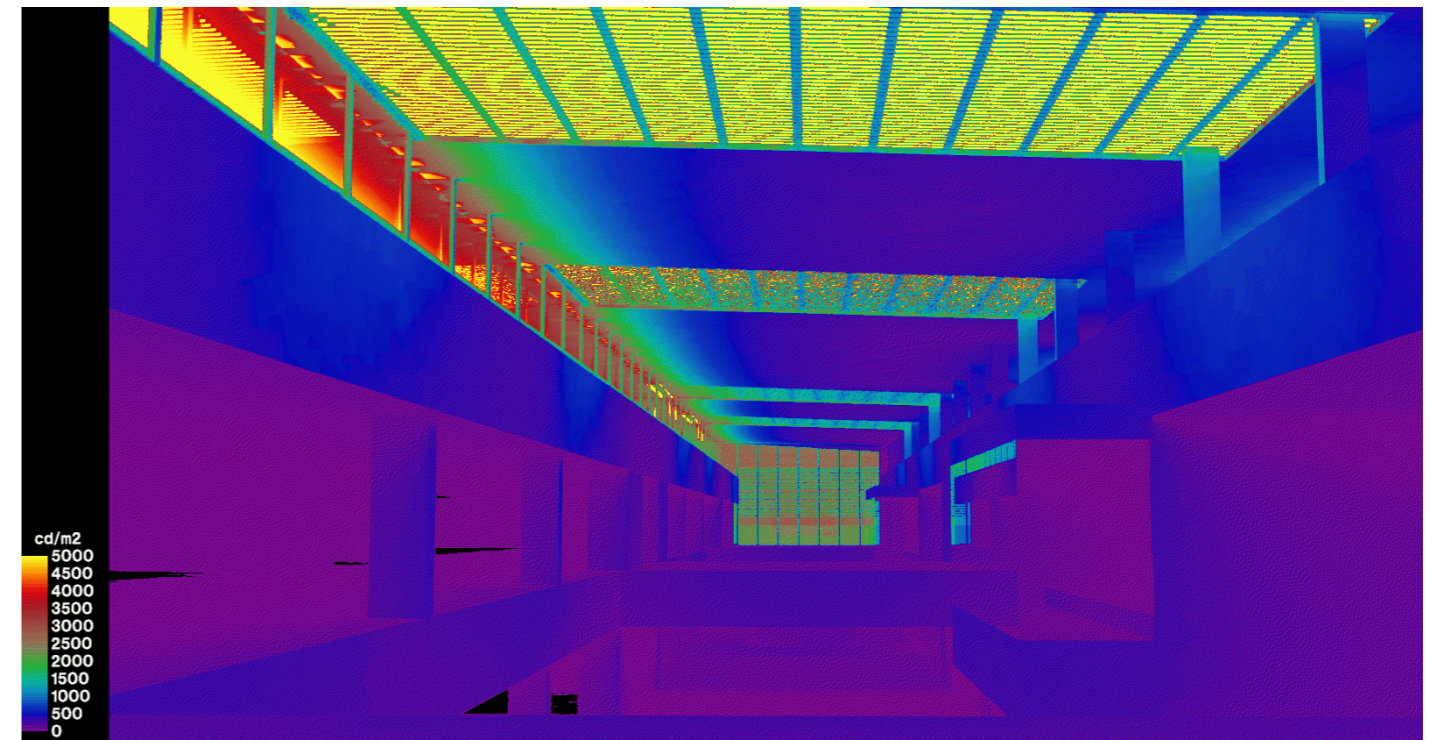
• Solar Radiation Reduction



• Rendering image (June 21, 10:00)

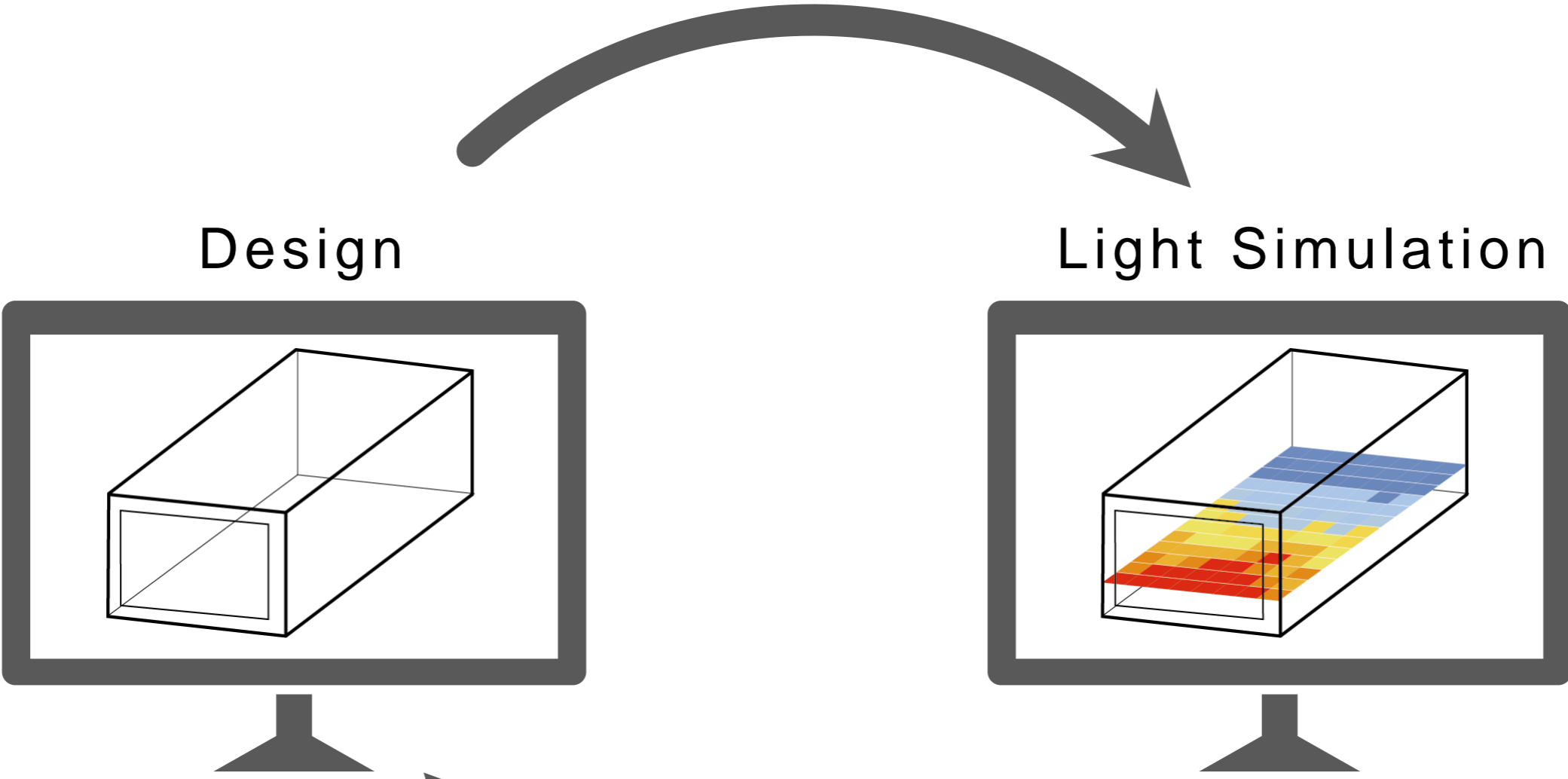


• luminance image (June 21, 10:00)

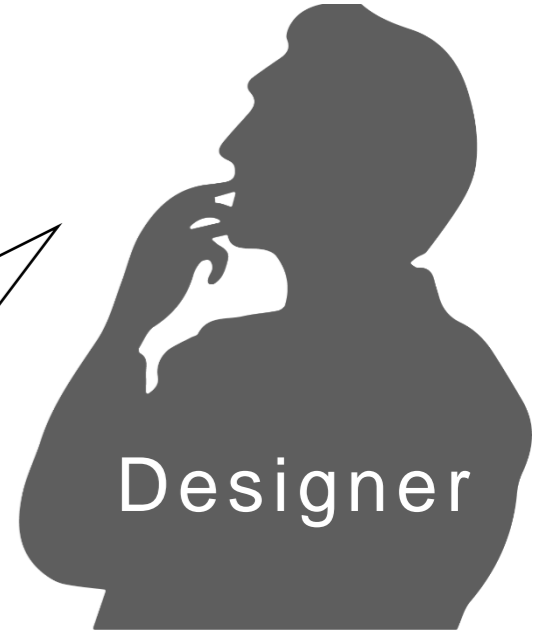


1. About us

**2. Validation of optimal simulation settings for designers**



It is Important to balance the **calculation accuracy** and **calculation load...**



# Background

			Predesign	Schematic Design	Design Development
			1PH	2PH	3PH
Study Model	Design Study		Zoning & Programming	Floor plan, Section and Elevation Study	Detail Design
	Model		Volume Model Skin Pattern	Pre Plan Design Skin Pattern (Variety)	Plan Adjustment Skin Detail
	Material	Inside	×	△	○
		Opening	○	○	○
		Outside	△	○	○
	Light	Daylight	○	○	○
Electric Light		×	△	○	
Required Accuracy	Simulation (Annual)	Envelope Solar Irradiance	Accuracy ±10%		
		Illuminance (sDA, ASE, UDI)	Accuracy ±20%	Accuracy ±10%	
	Simulation (One-time)	Envelope Solar Irradiance	Accuracy ±10%		
		Illuminance	Accuracy ±20%	Accuracy ±10%	
		Luminance		Accuracy ±20%	Accuracy ±10%
		Glare (DGP, PGSV)		Accuracy ±20%	Accuracy ±10%
		Rendering Image	Accuracy ±25%	Accuracy ±20%	Accuracy ±10%
		View	Accuracy ±25%	Accuracy ±20%	Accuracy ±10%
		Illuminance (Electric Light)		Accuracy ±20%	Accuracy ±10%
		NB Value			Accuracy ±10%

Building Features **6** Elem.

- Type of shading
- Type of window
- Floor height
- Surrounding buildings
- One's gaze
- Season
- Time

Simulation Setting **7** Elem.

- Reflectance properties
- Analysis model detail
- Parameter setting
- Calculation Methods
- Number of sky divisions
- How to calculate DGP/PGSV
- Computation program



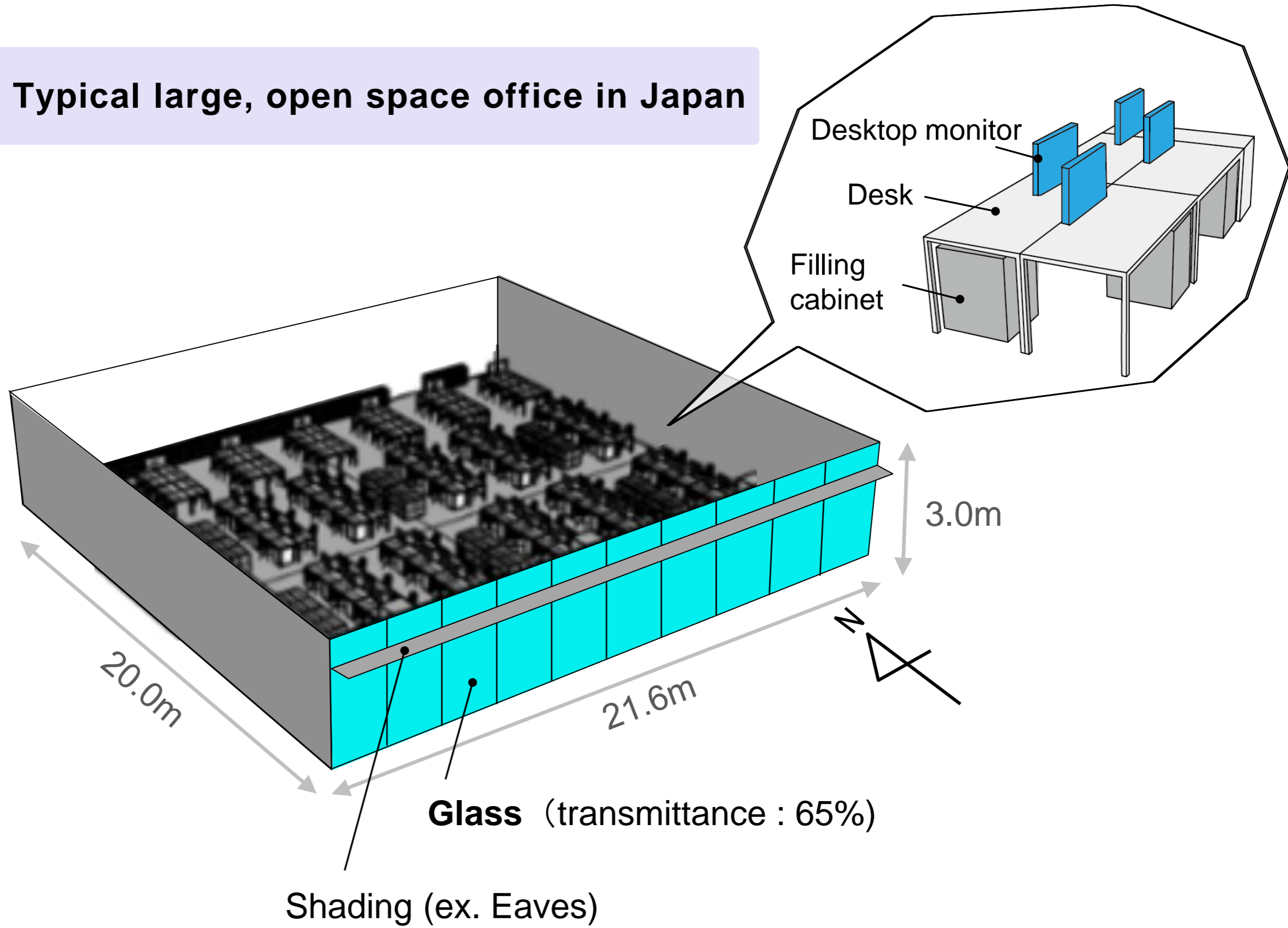
Indicator Accuracy **5** Elem.

- sDA
- ASE
- DGP, DGPs
- PGSV, PGSV/sat
- Annual DGP

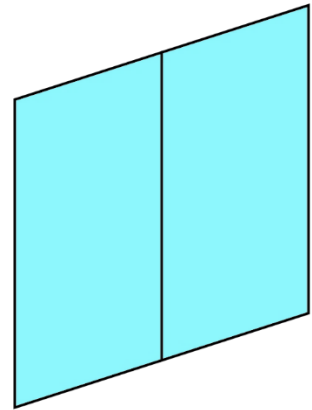


**Objective : To create guidelines for simulation settings for designers**

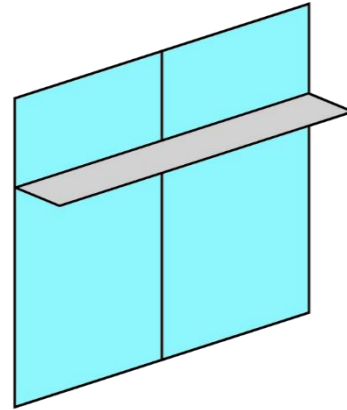
## Typical large, open space office in Japan



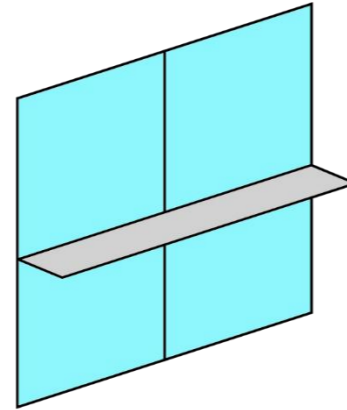
## ■ Type of Shading : 6 types



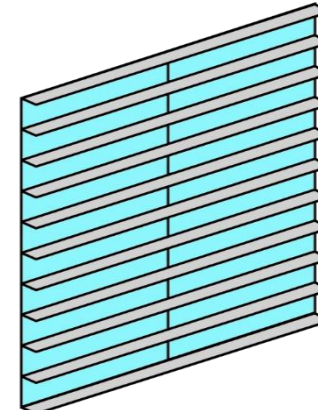
None



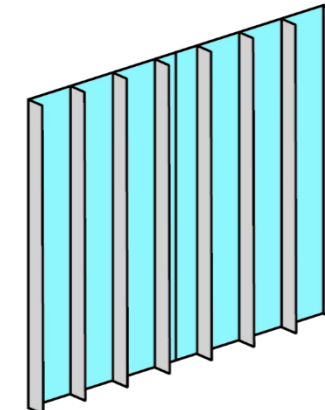
Eave



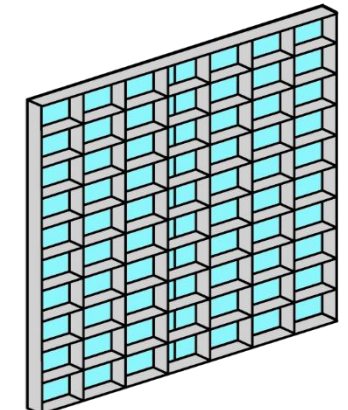
Light Shelf  
(LS)



Horizontal  
Louver  
(HL)

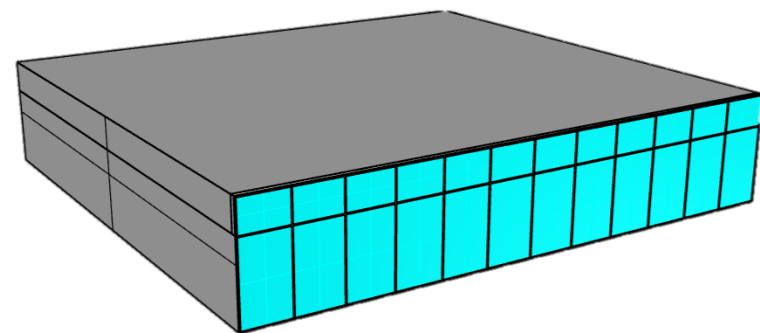


Vertical  
Louver  
(VL)

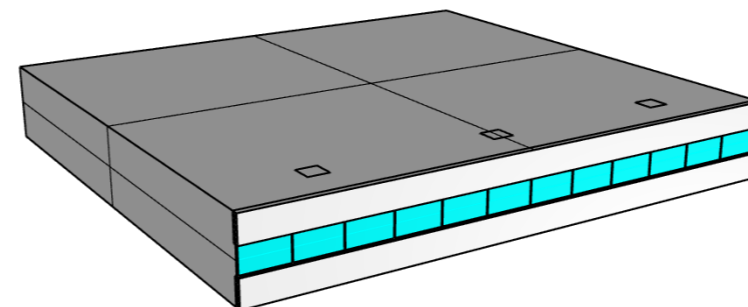


Lattice  
Louver  
(LL)

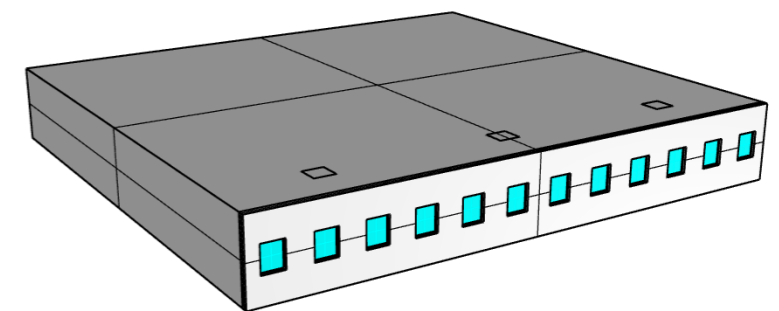
## ■ Type of Window : 3 types



Curtain Wall



Horizontal Window



Small Window

## Building Features **6** Elem.

- Type of shading
- Type of window
- Floor height
- Surrounding buildings
- One's gaze
- Season
- Time



## Simulation Setting **7** Elem.

- Reflectance properties
- Analysis model detail
- Parameter setting
- Calculation Methods
- Number of sky divisions
- How to calculate DGP/PGSV
- Computation program



## Indicator Accuracy **5** Elem.

- **sDA**
- **ASE**
- DGP, DGPs
- PGSV, PGSV/sat
- Annual DGP

	<b>Low</b>	<b>Med</b>	<b>High</b>
Accuracy	×	△	○
Load	○	△	×

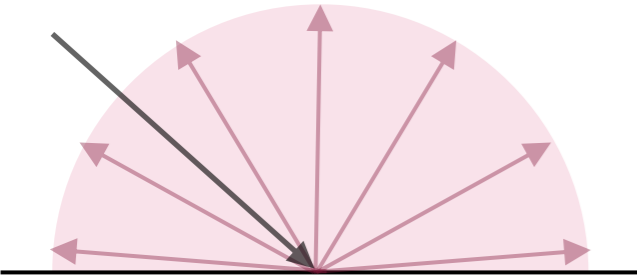


## Low

plastic

All

Equal diffusion surface



## Med

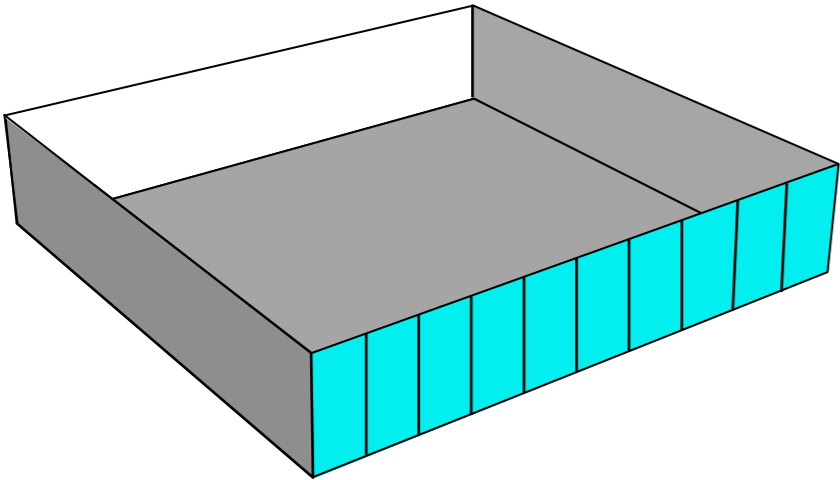
mirror

Equal diffusion surface  
+  
Specular reflective surface

## High

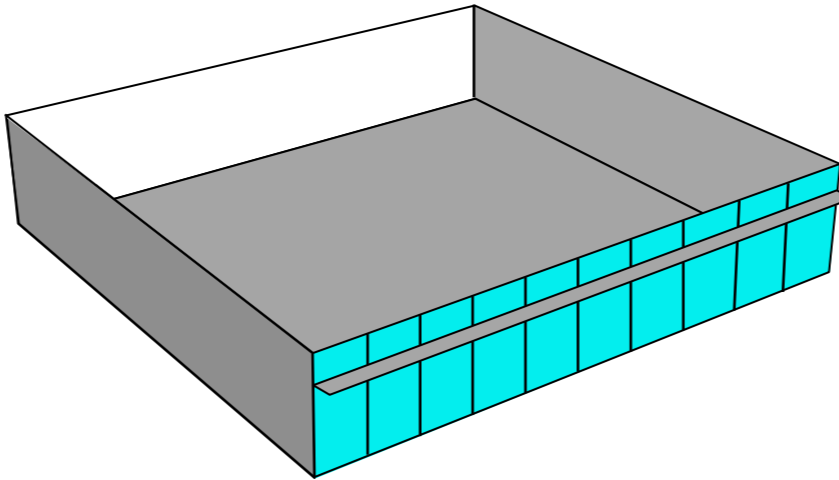
BSDF

**Low**



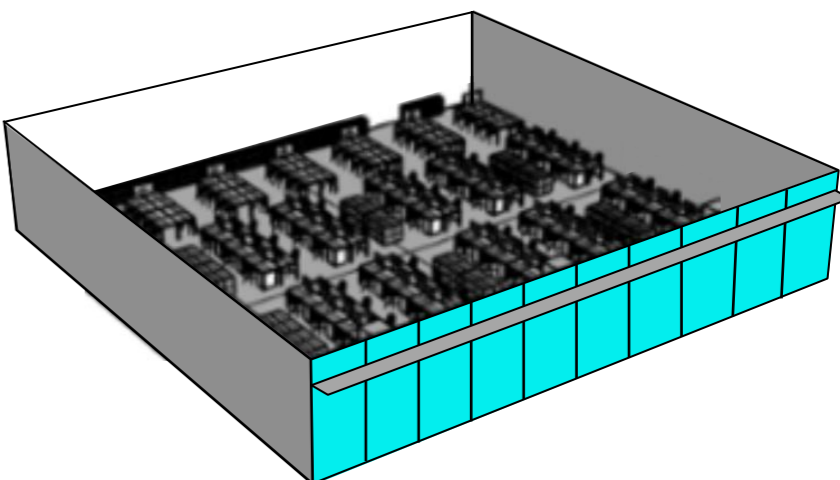
None

**Med**

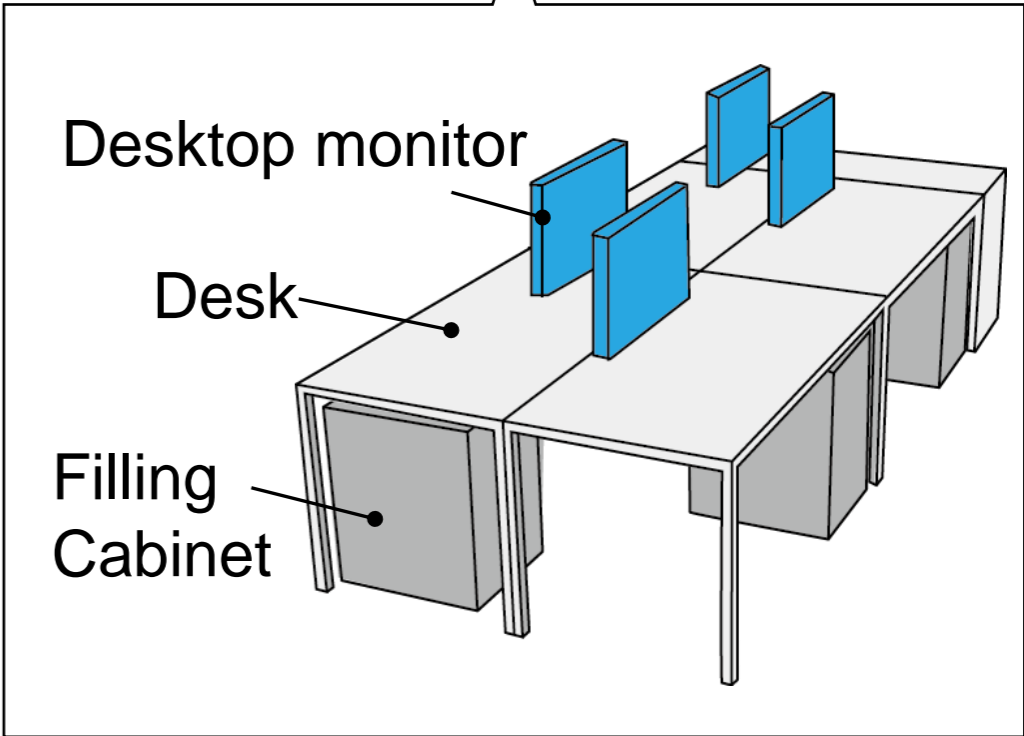


Shading

**High**



Shading  
Fixtures



Three levels to match Honeybee Plus component,  
 [HB Plus Radiance Parameters Grid-based] default settings in 2020.

	<b>Low</b>	<b>Med</b>	<b>High</b>
aa	0.25	0.2	0.1
ab	3	5	6
ad	5000	15000	25000
ar	16	64	128
as	128	2048	4096
lw	2.0E-06	6.7E-06	5.0E-03
lr	4	6	8
dc	0.25	0.5	0.75
dj	0	0.5	1
dp	64	256	512
ds	0.5	0.25	0.05
dr	0	1	3
dt	0.5	0.25	0.15
ss	0	0.7	1
st	0.8	0.5	0.15
c	1	1	1

におけるDC法のデフォルト値3

By 2PH Method

By rtrace

$$\varepsilon = \frac{M - T}{T} \times 100 [\%]$$

$\varepsilon$  : Relative Error

M : Examined value

T : True value

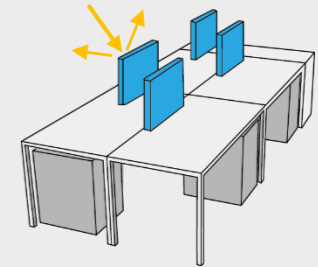
# Result – Errors due to different grades of models and calculation parameters

Legend	
Model	Parameter
Low	Low
	Med
	High
Med	Low
	Med
	High
High	Low
	Med
	High

High model Condition : Minimum value of sDA / ASE

↳ Fixtures blocked light and lowered desk surface illumination.

**Fear of overestimating desk surface illumination if the low grade model is used.**



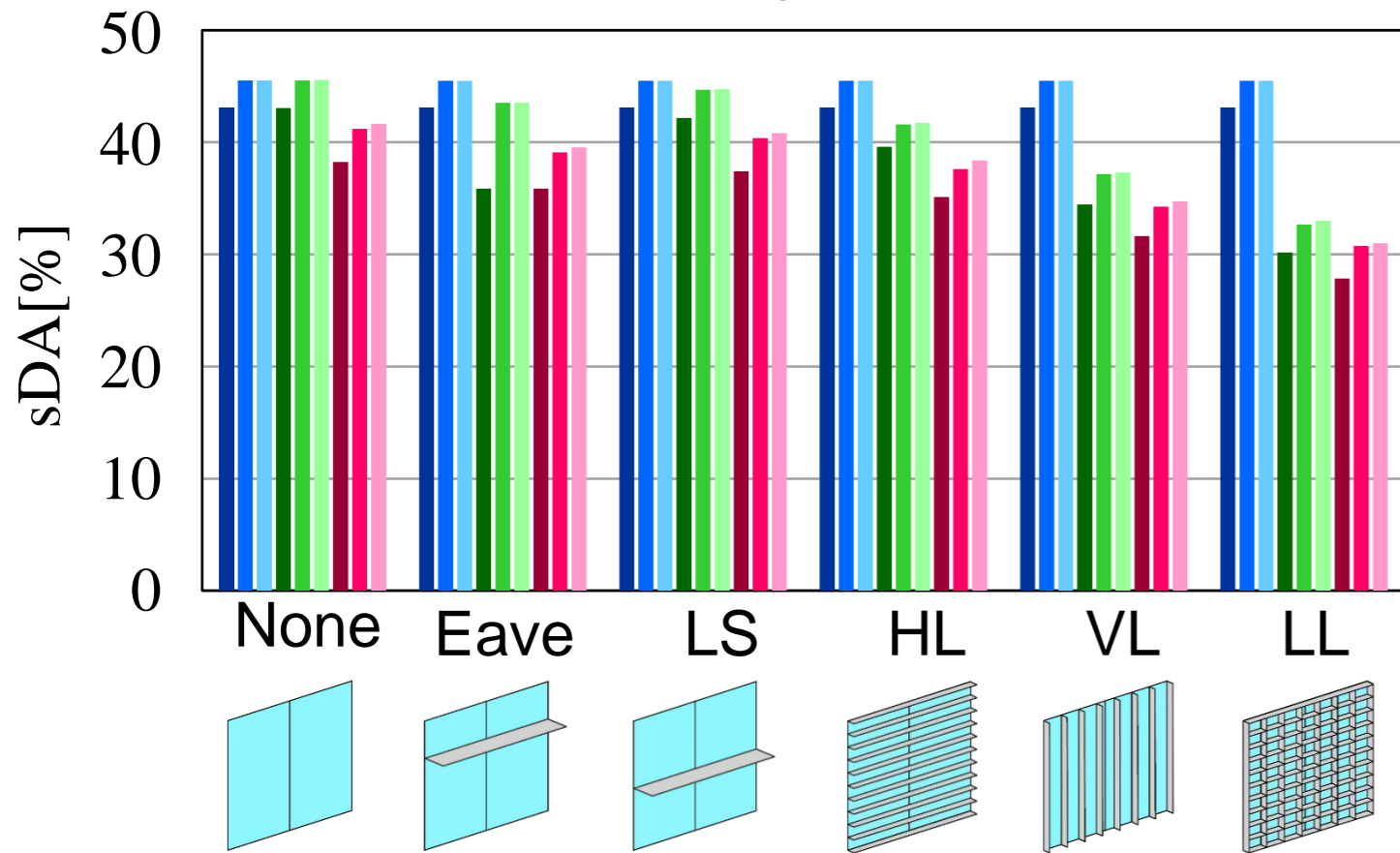
sDA : Minimum with parameter Low condition

ASE: No difference between parameter grades

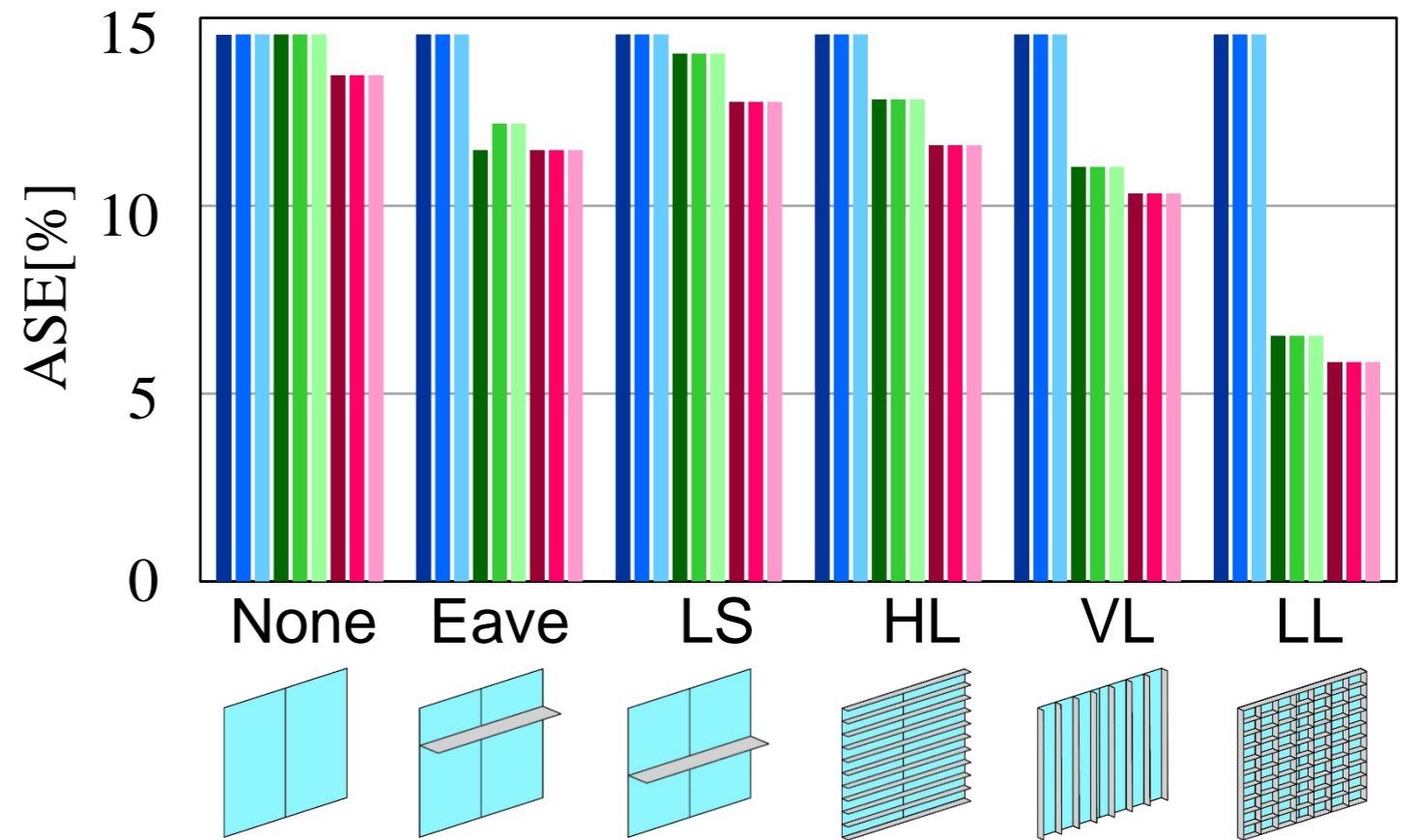
↳ ASE is strongly affected by the direct radiation component.

**Be careful with parameters when evaluating with sDA.**

sDA in Curtain wall



ASE in Curtain wall



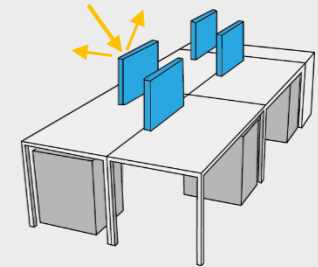
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Legend	
Model	Parameter
Low	Low
	Med
	High
Med	Low
	Med
	High
High	Low
	Med
	High

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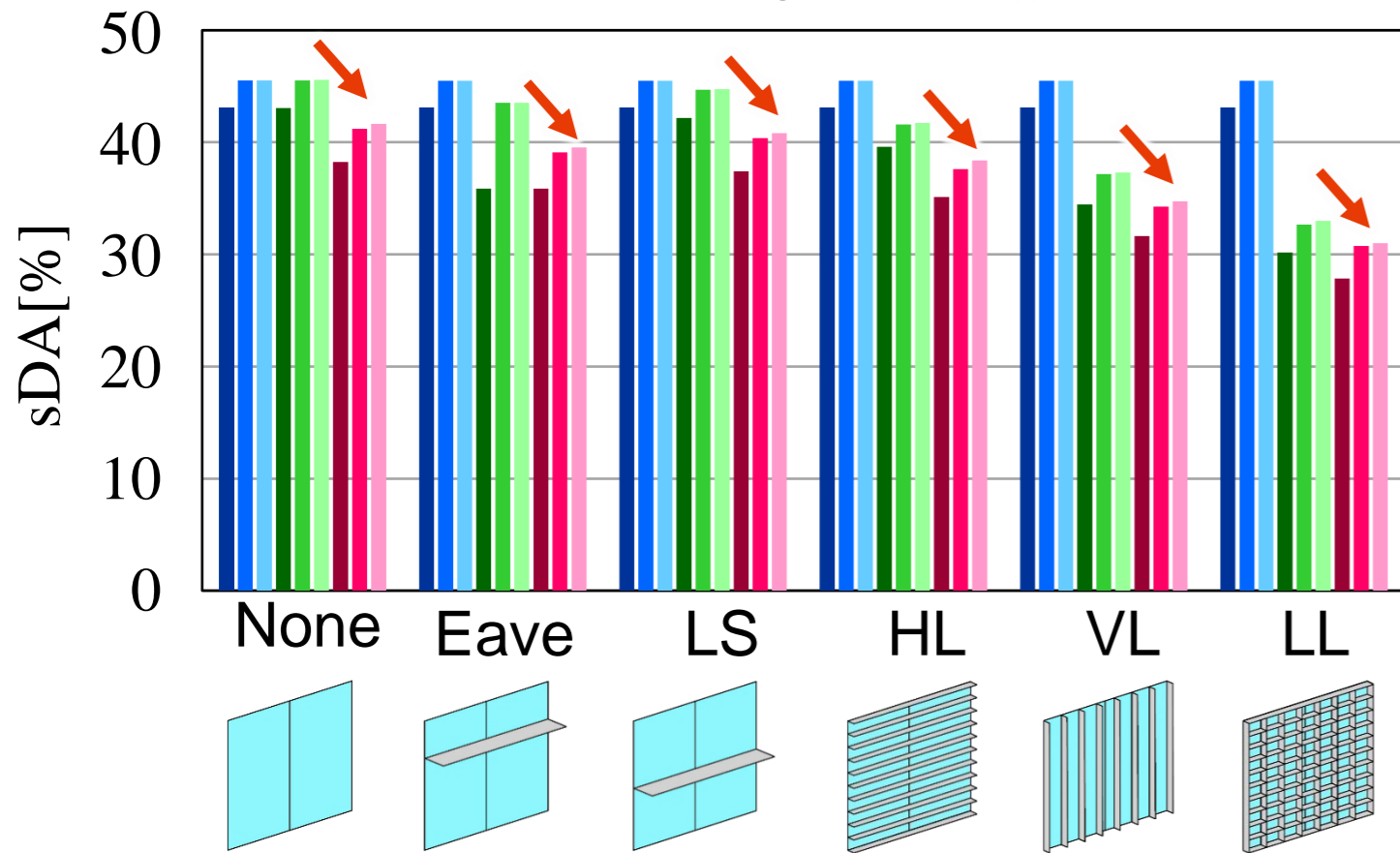
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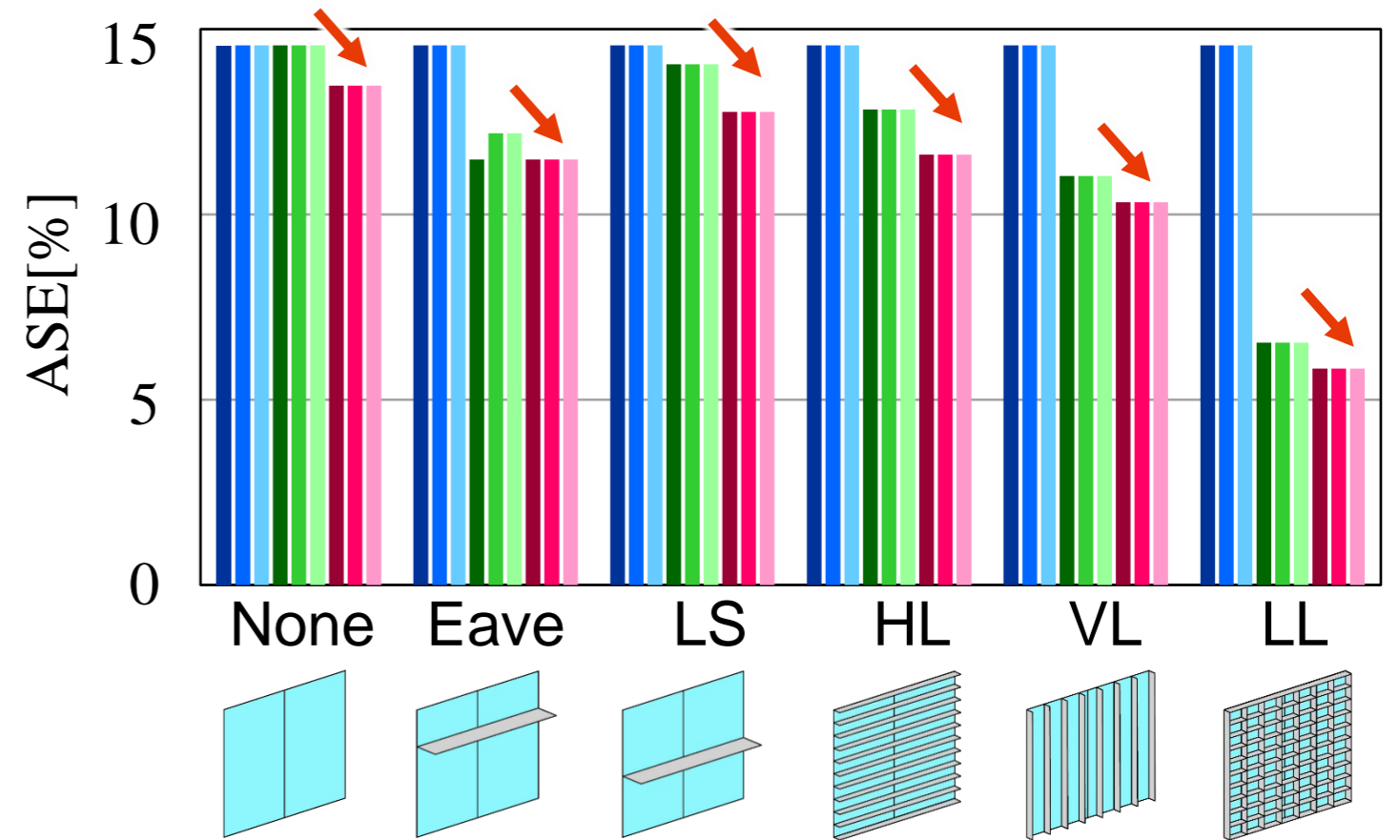
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sDA in Curtain wall



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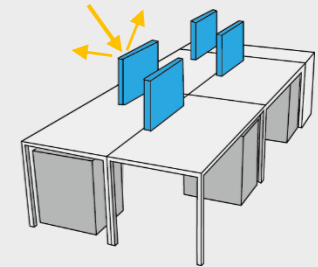
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	Med
	High
Med	Low
	Med
	High
High	Low
	Med
	High

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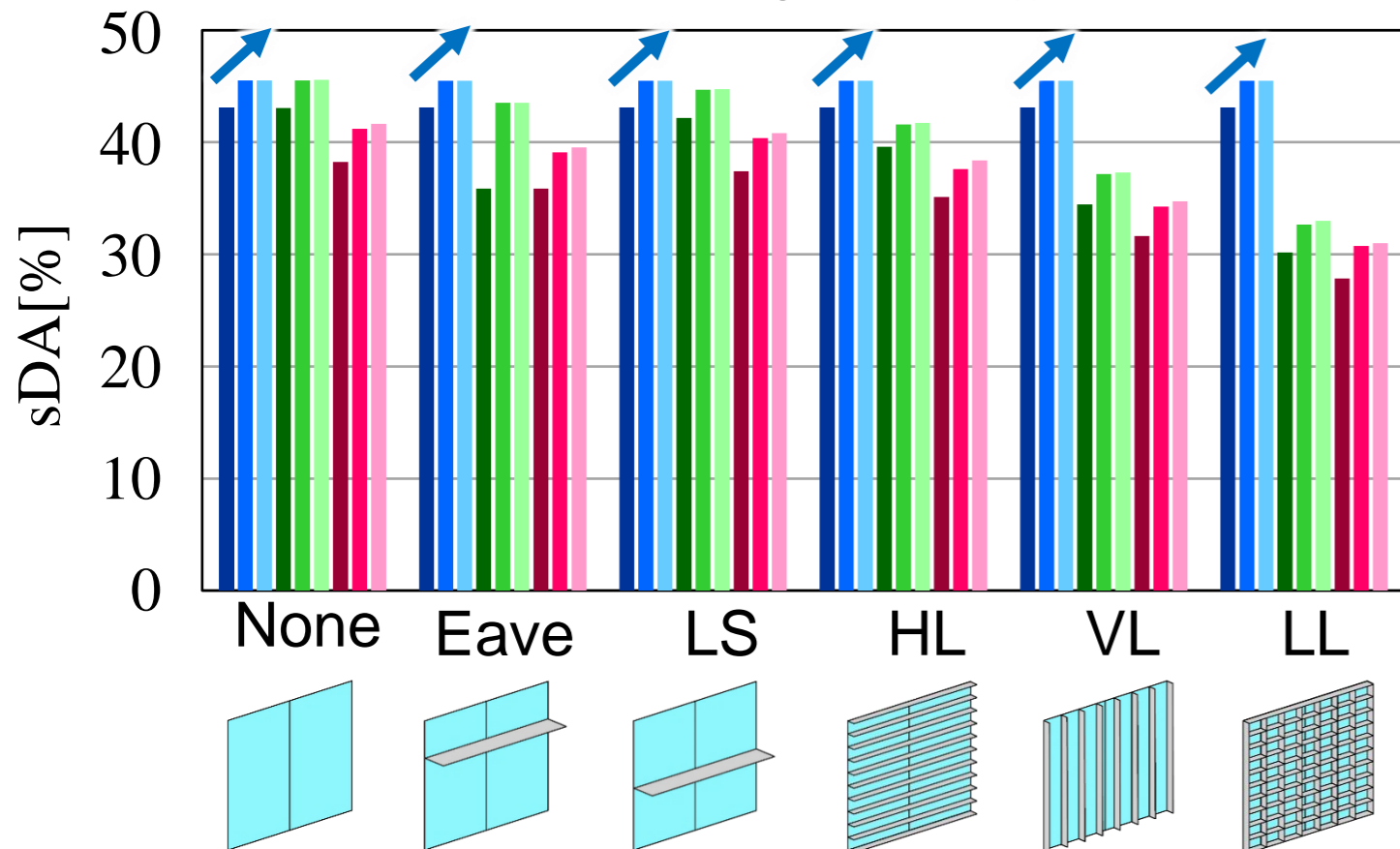
sDA : Minimum with parameter Low condition

ASE: No difference between parameter grades

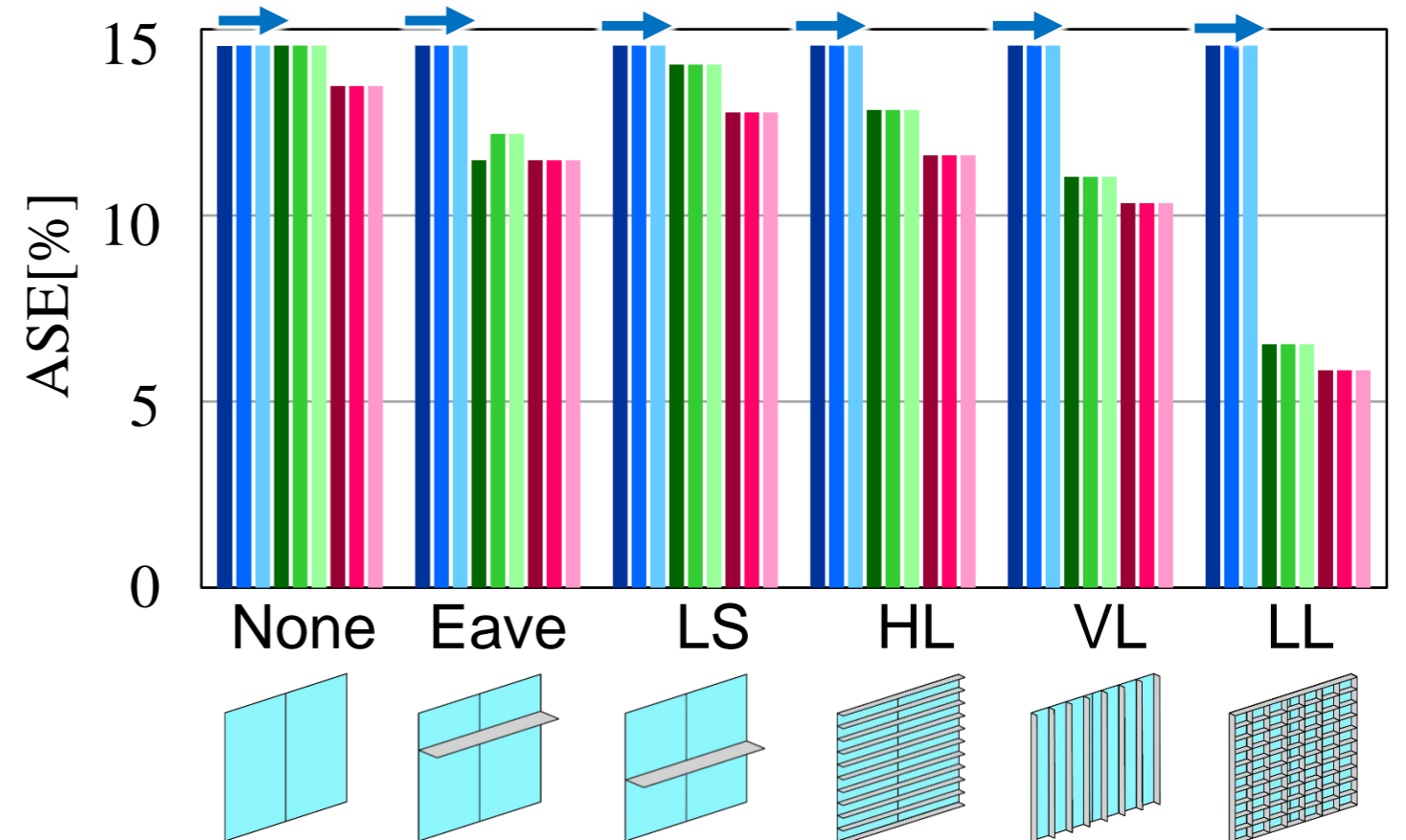
↳ ASE is strongly affected by the direct radiation component.

**Be careful with parameters when evaluating with sDA.**

sDA in Curtain wall



ASE in Curtain wall



# Result – Errors due to different grades of model and calculation parameters

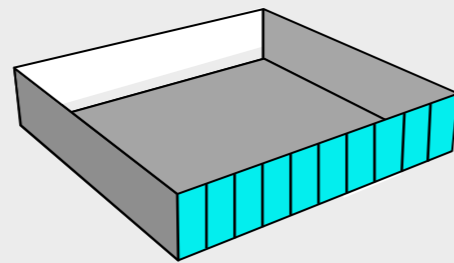
Legend	
Model	Parameter
Low	Low
	Med
	High
Med	Low
	Med
	High
High	Low
	Med
	High

Calculate the error rate using the High-High condition for each shading as the true value.

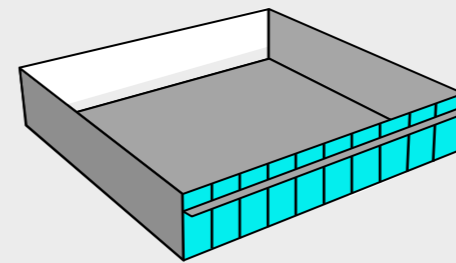
When the model was Low, the error rate was larger for some types of shading.

The larger the solar shading effect of the shades, the larger the error rate.

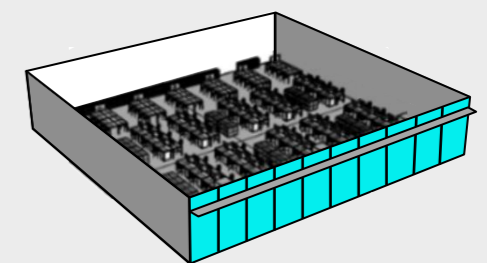
It is important to analyze the shading geometry from the early design stage.



Model : Low

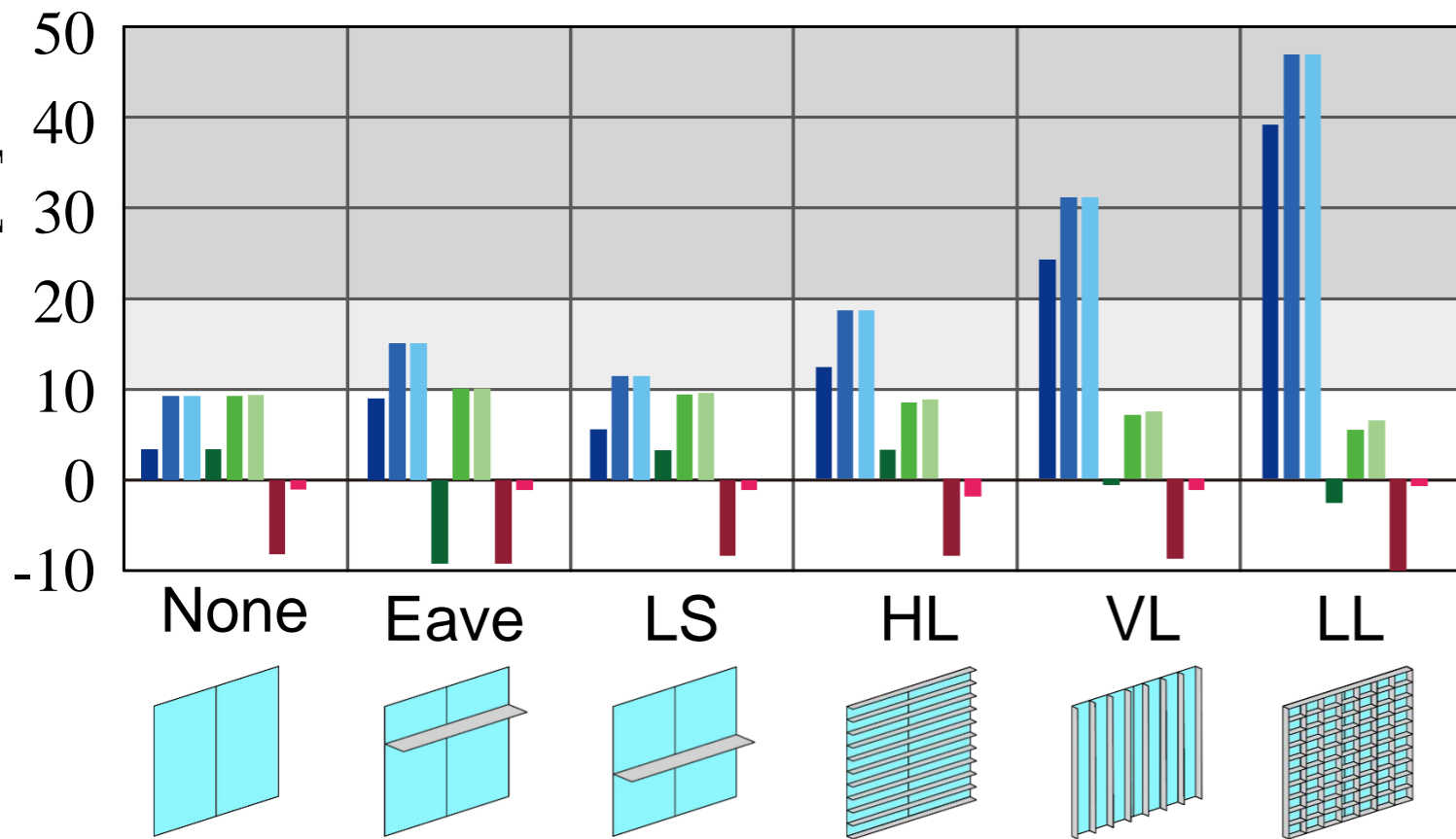


Med

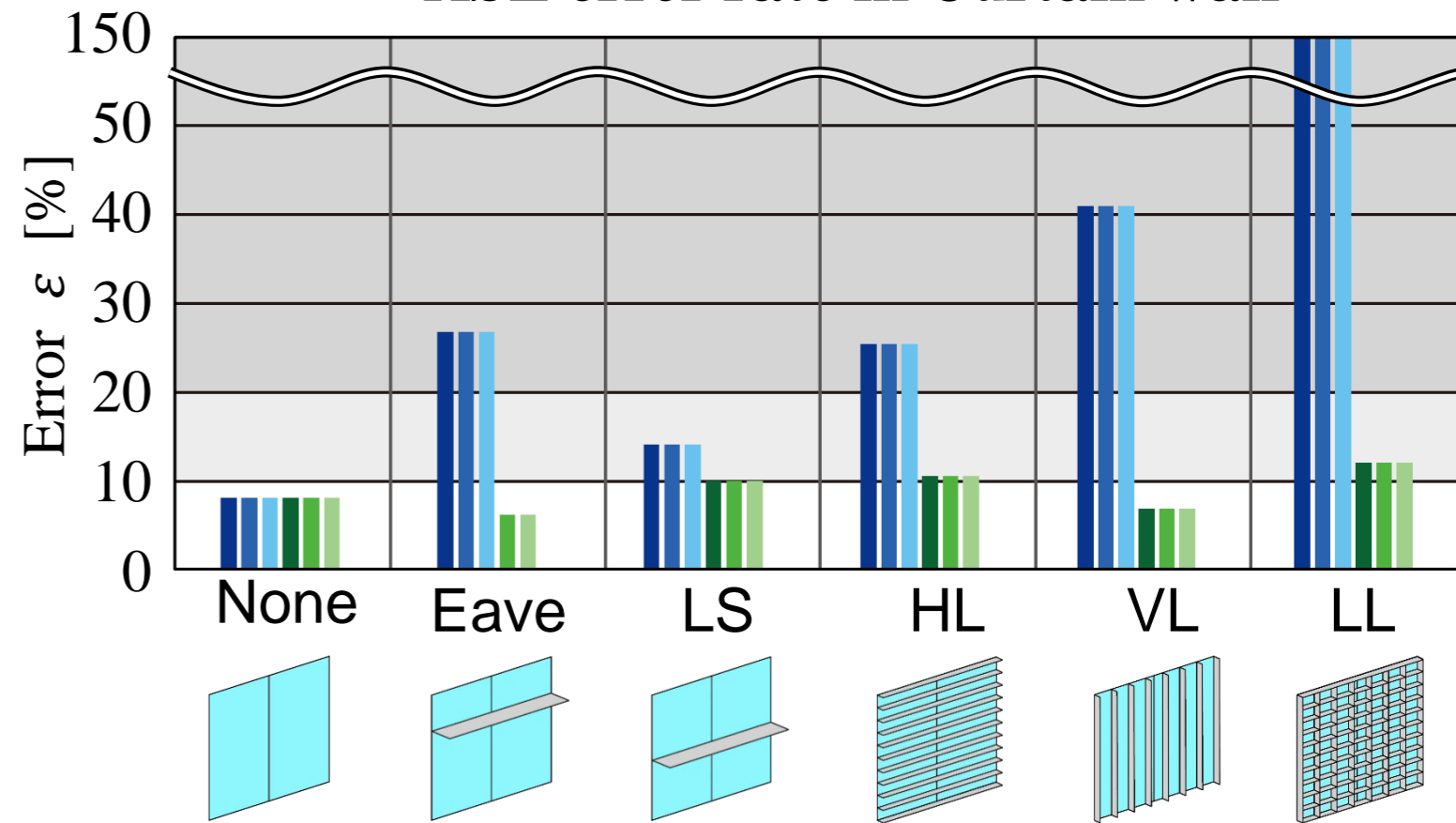


High

sDA error rate in Curtain wall



ASE error rate in Curtain wall

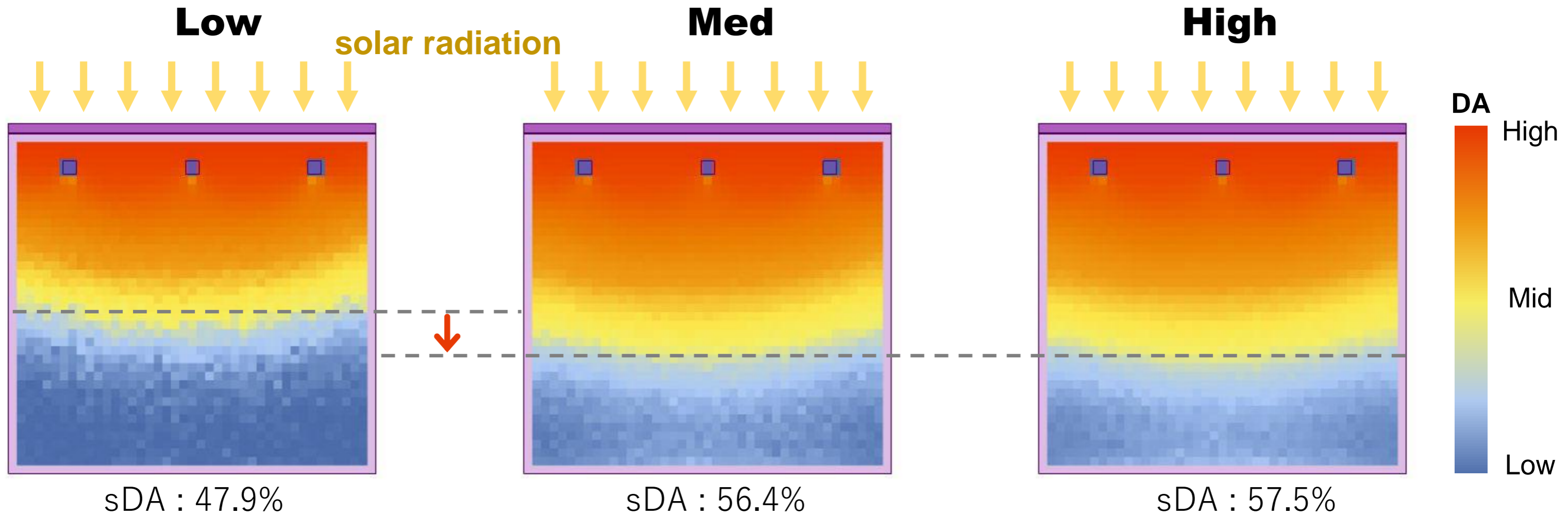




# Need to evaluate daylight distribution

In large Japanese-style, open-spaces offices, the "difference in DA distribution" becomes too large to ignore.

DA distribution by analysis parameter  
( Window type : Curtain Wall, Shading type : Eave)

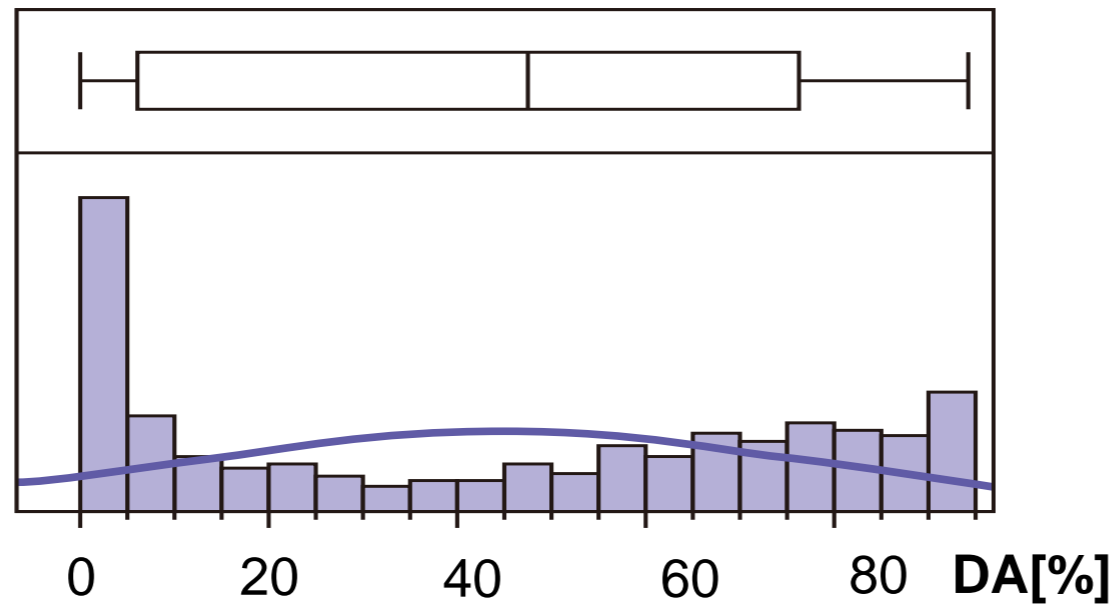
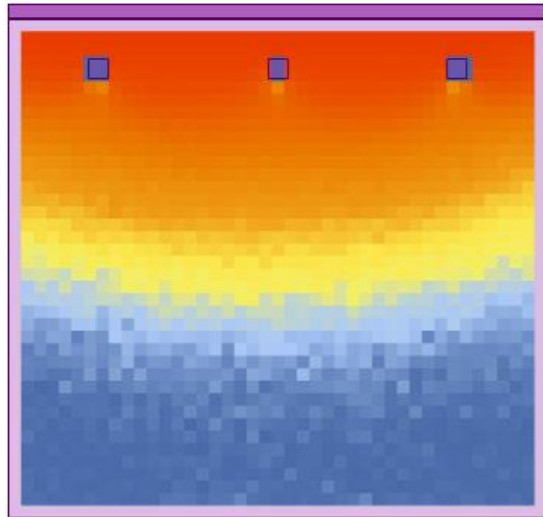


Even though the error rate for sDA is clear –there was a 16% error between Low and High). Low has insufficient indirect calculation, and the distribution of DA is different from Med and High.

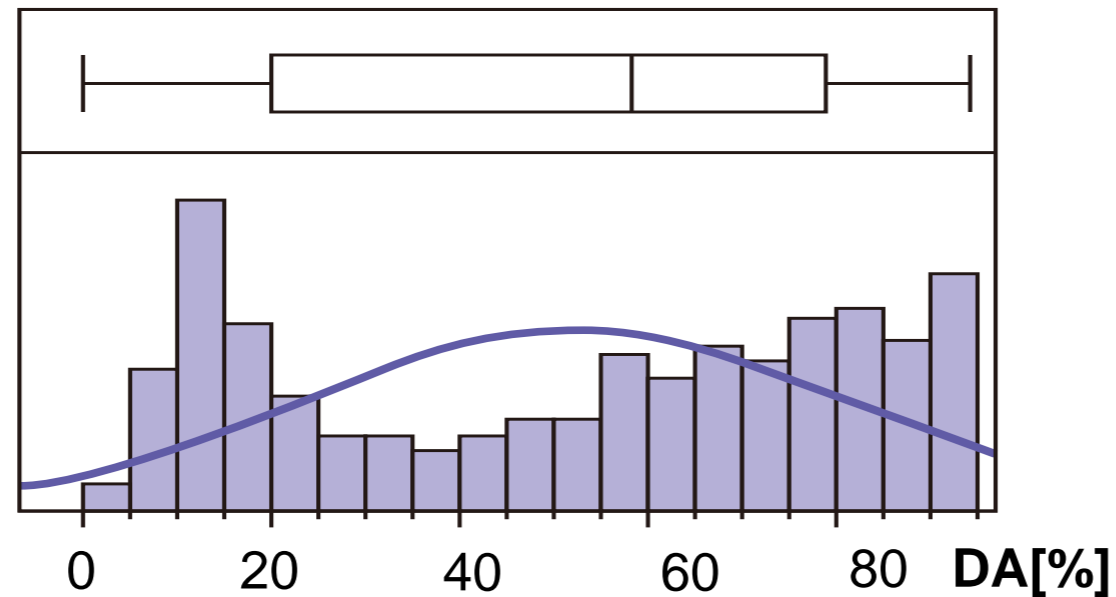
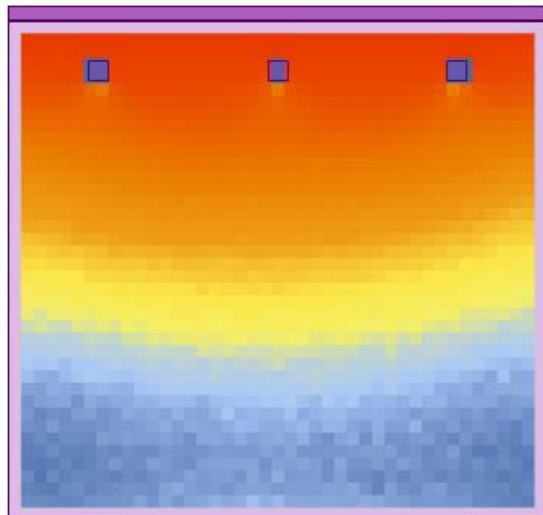
Indicators used to quantitatively assess differences in distribution should also be considered.

# Histogram of DA by grade of analysis

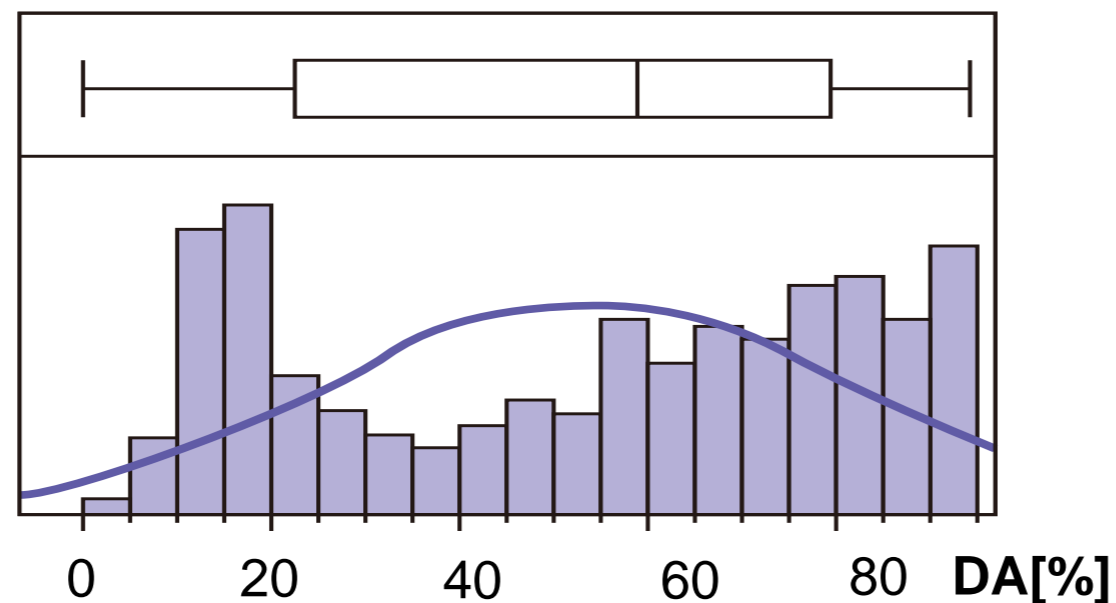
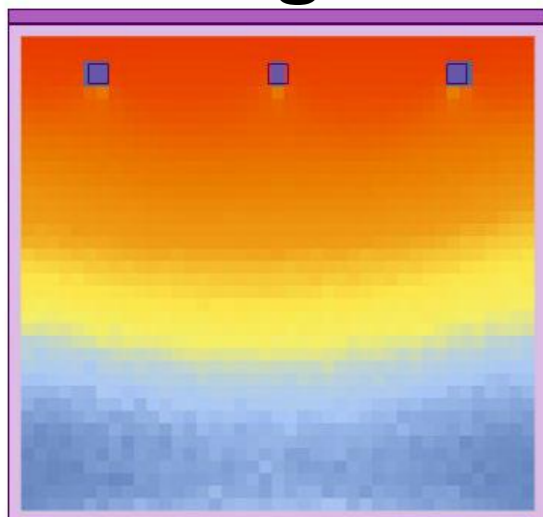
**Low**



**Med**



**High**



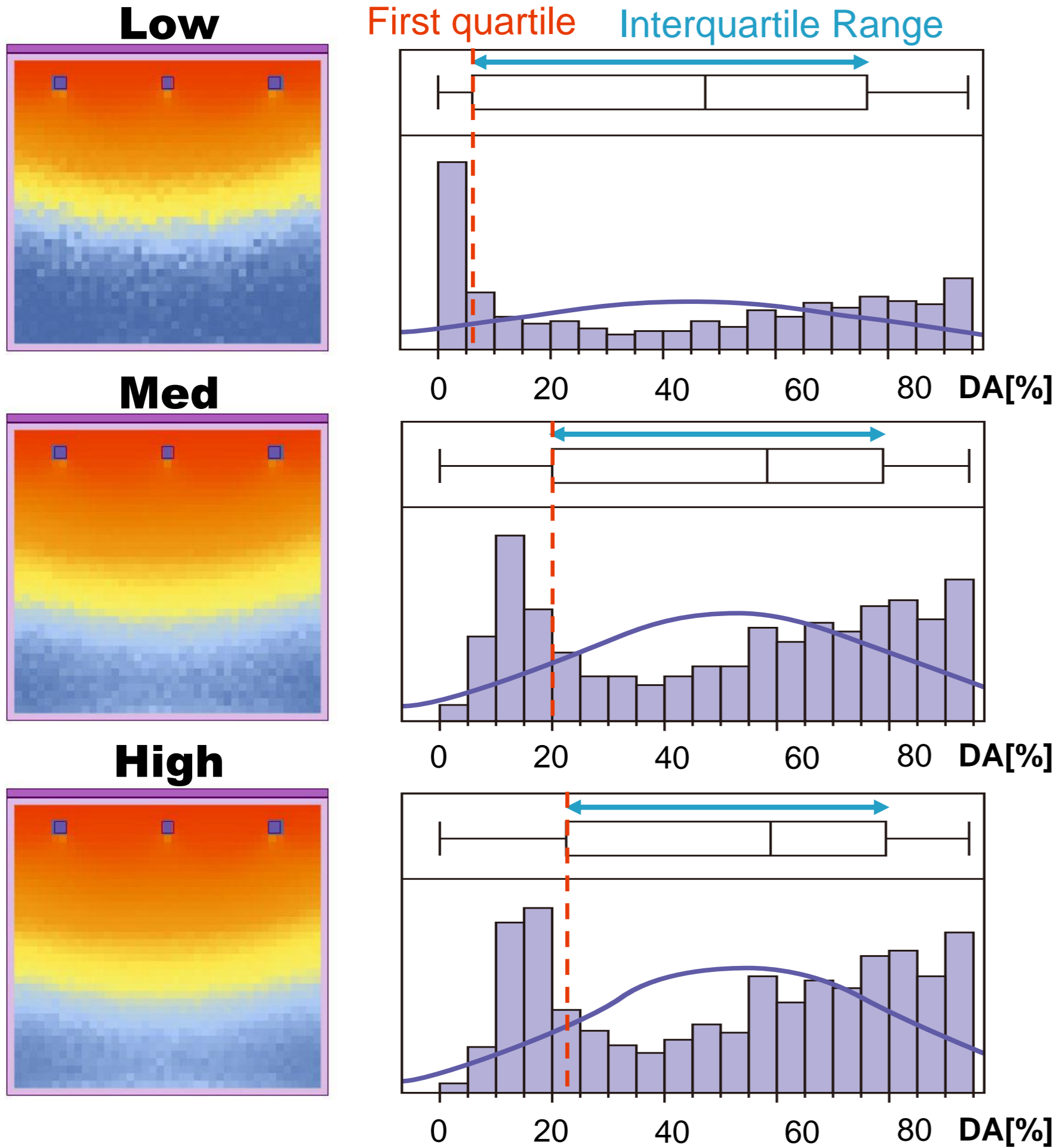
Creating a DA Histogram

Differences in appearance of  
DA distribution

1. Interquartile Range
2. first quartile

By comparing the above two,  
it may be possible to  
quantitatively evaluate the  
distribution accuracy.

# Histogram of DA by grade of analysis



Creating a DA Histogram

Differences in appearance of DA distribution

1. Interquartile Range
2. first quartile

By comparing the above two, it may be possible to quantitatively evaluate the distribution accuracy.

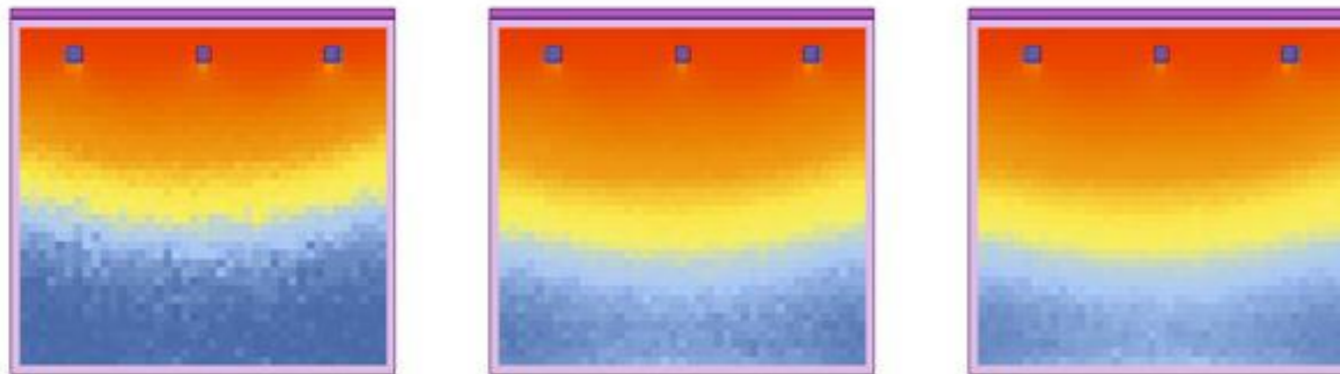
# Evaluation of distributional differences

**The first quartile / interquartile range for each condition and the error rate for each High condition as the true value were calculated.**

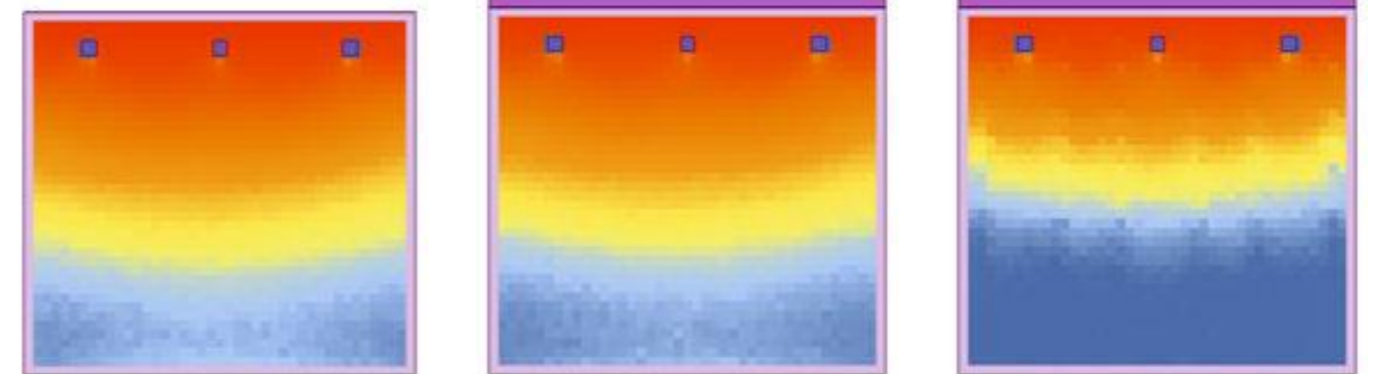
When appearance difference are visible, the error rate was more than 10%.

Distribution error could be evaluated using first quartile count/ interquartile range error with a threshold of  $\pm 10\%$ .

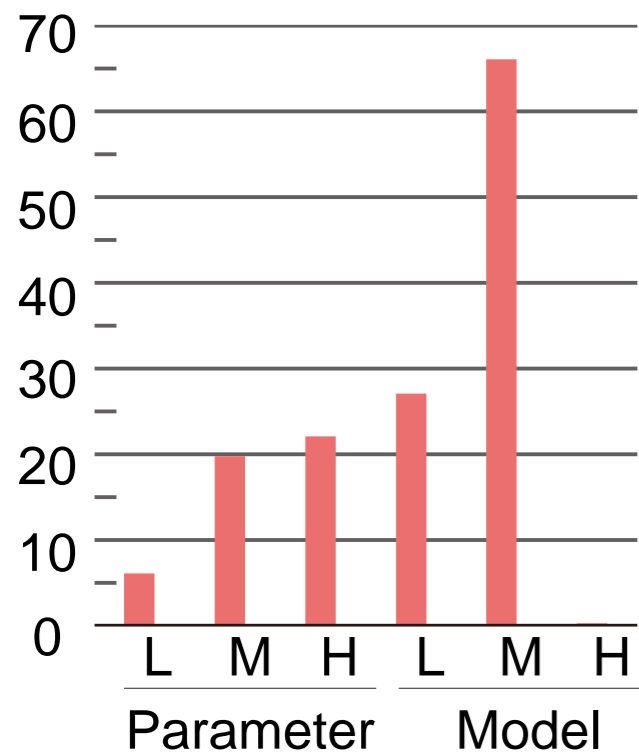
Calculation Parameter Grade  
Low Med High



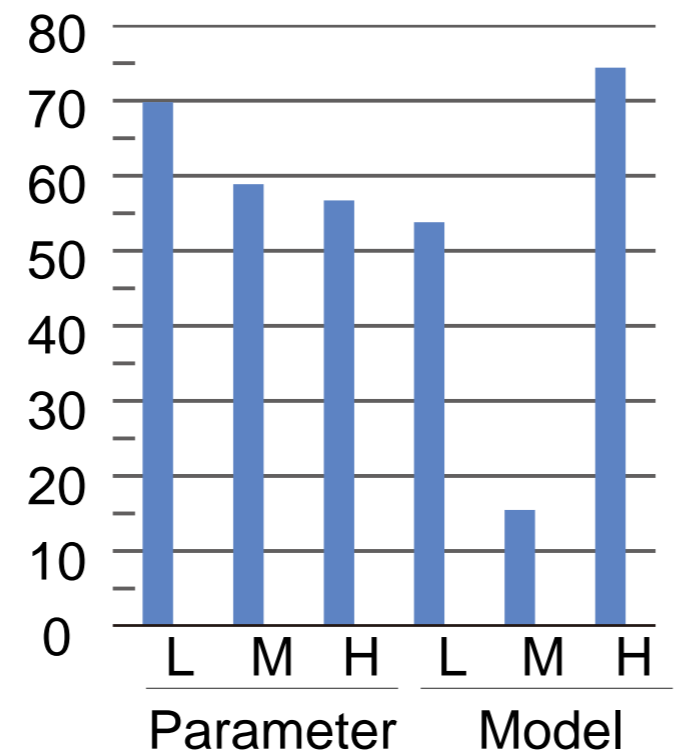
Calculation Model Grade  
Low Med High



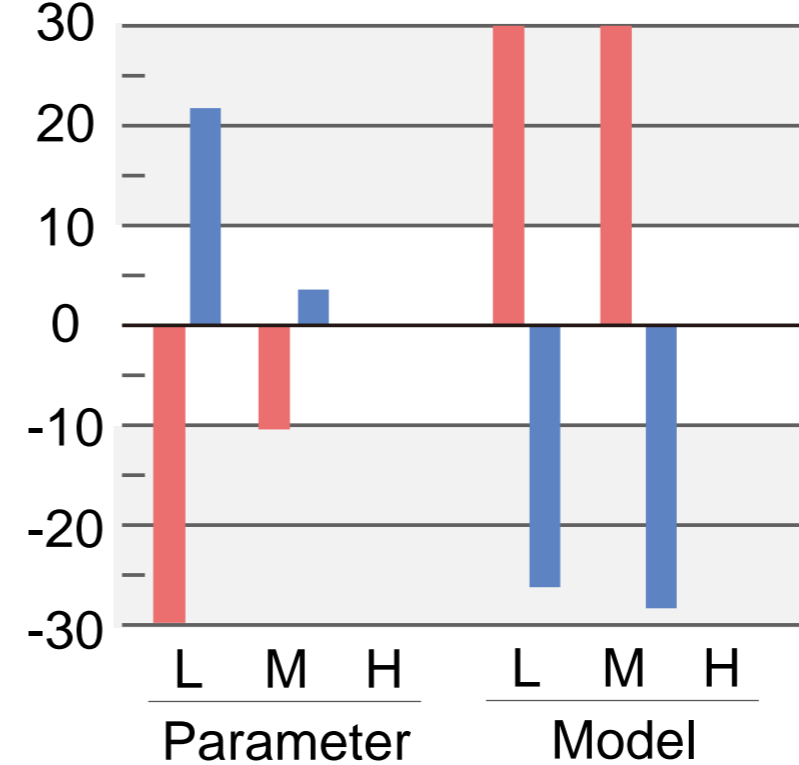
1<sup>st</sup> quartile [%]



Interquartile Range [%]



Error [%]



■ : 1<sup>st</sup> quartile  
■ : Interquartile Range

Considerations up to this point

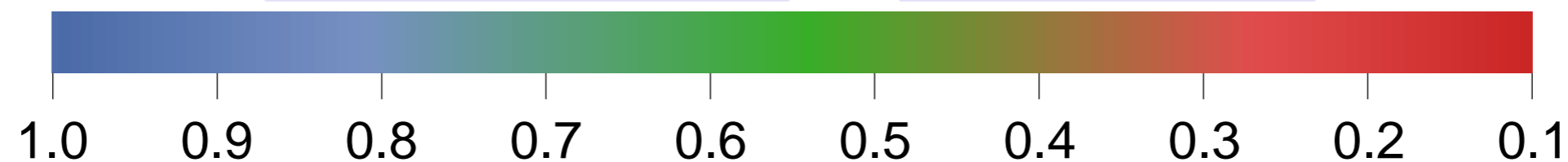


Continuous examination

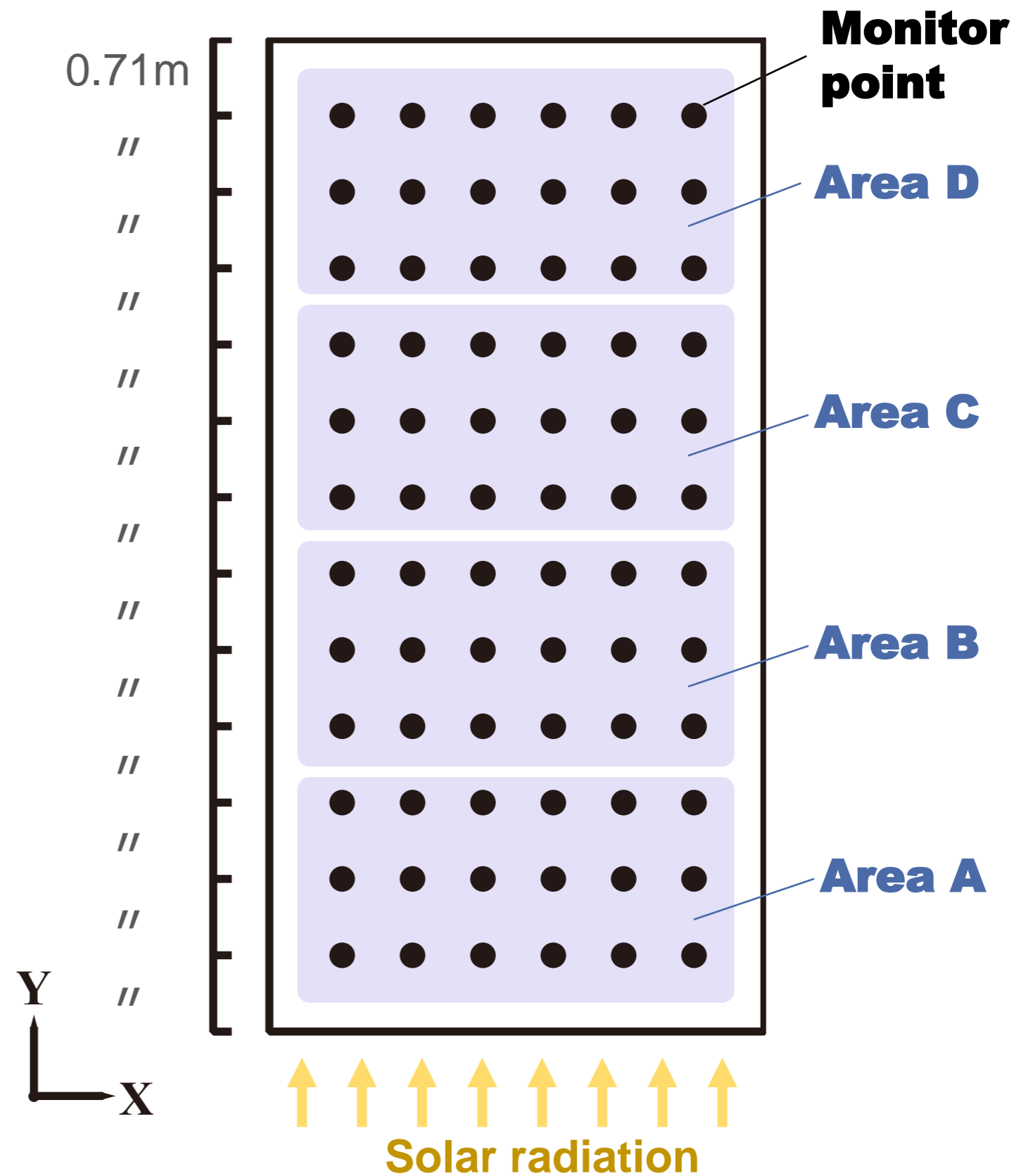
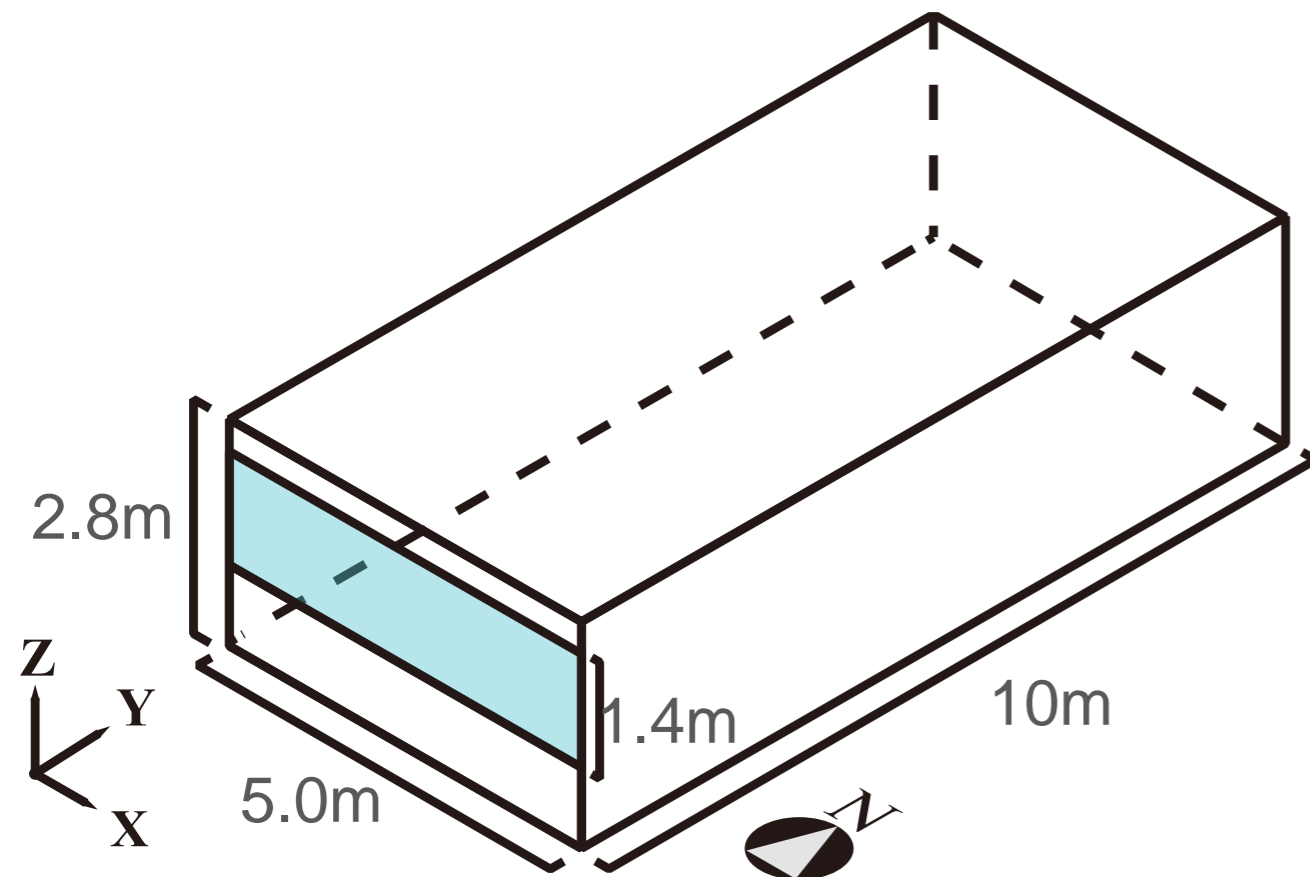


Study the effect of **-aa** parameters on

calculation accuracy and calculation load.



## Simple analytical model for benchmarking <sup>1)</sup>



1) Christoph F. Reinhart, Oliver Walkenhorst; Validation of dynamic RADIANCE-based daylight simulations for a test office with external blinds, Energy and Buildings 33 (2001) 683-697

	<b>For Examined value</b>	<b>For True value</b>
aa	(Variable)	0.1
ab	6	6
ad	4096	4096
ar	128	128
as	4096	4096
lw	5.0E-03	5.0E-03
lr	8	8
dc	0.75	0.75
dj	1	1
dp	512	512
ds	0.05	0.05
dr	3	3
dt	0.15	0.15
st	0.15	0.15

## Root Mean Square Relative Error

$$RMSRE = \sqrt{\frac{1}{n} \sum_{i=0}^{n-1} \left( \frac{E_{ai} - E_{ti}}{E_{ti}} \right)^2}$$

$n$  : Number of all monitors

$i$  :  $i$ -th monitor point

$E_{ai}$  : Result of calculation at the  $i$ -th monitor point

$E_{ti}$  : True value at the  $i$ -th monitor point



## Calculation Time Ratio

$$CTR = \frac{T}{T_{true}}$$

$T$  : Calculation time when using parameters for examined values

$T_{true}$  : Calculation time when using parameters for true values

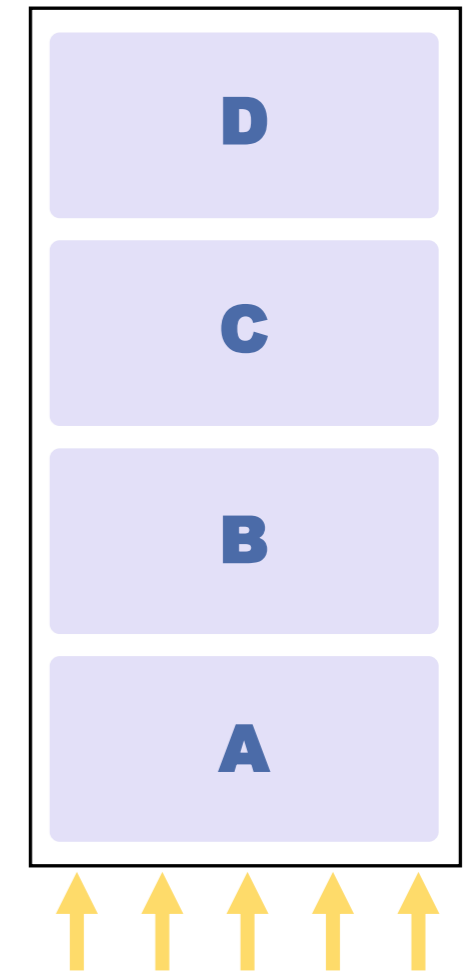
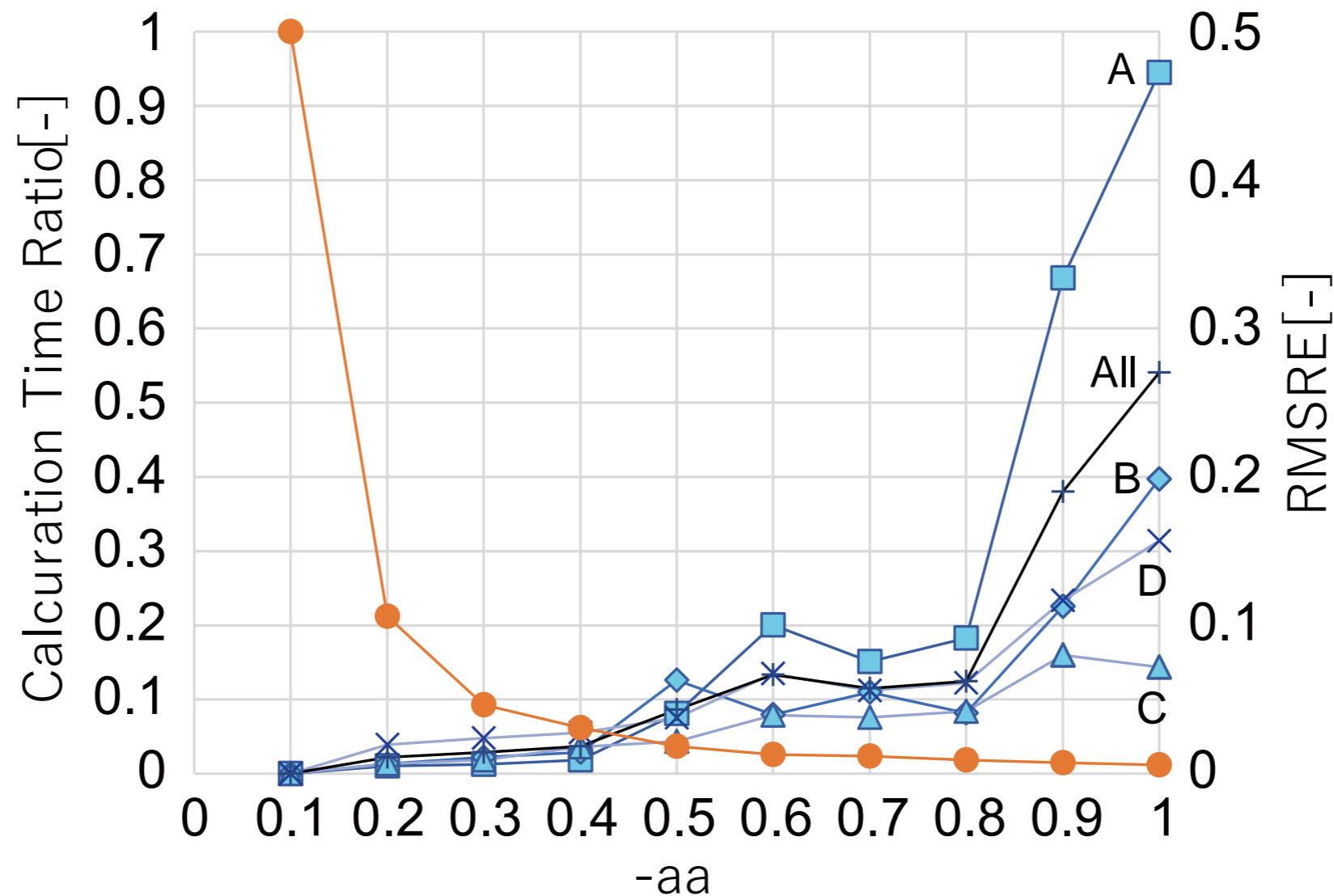
# The Effect of Calculation Parameters on Accuracy - Results

When  $-aa$  is small ( $-aa \leq 0.4$ ), there is no difference in error for each area.

When  $-aa$  is large ( $-aa > 0.4$ ), the accuracy is poor in the order of  $A > B > D > C$ .

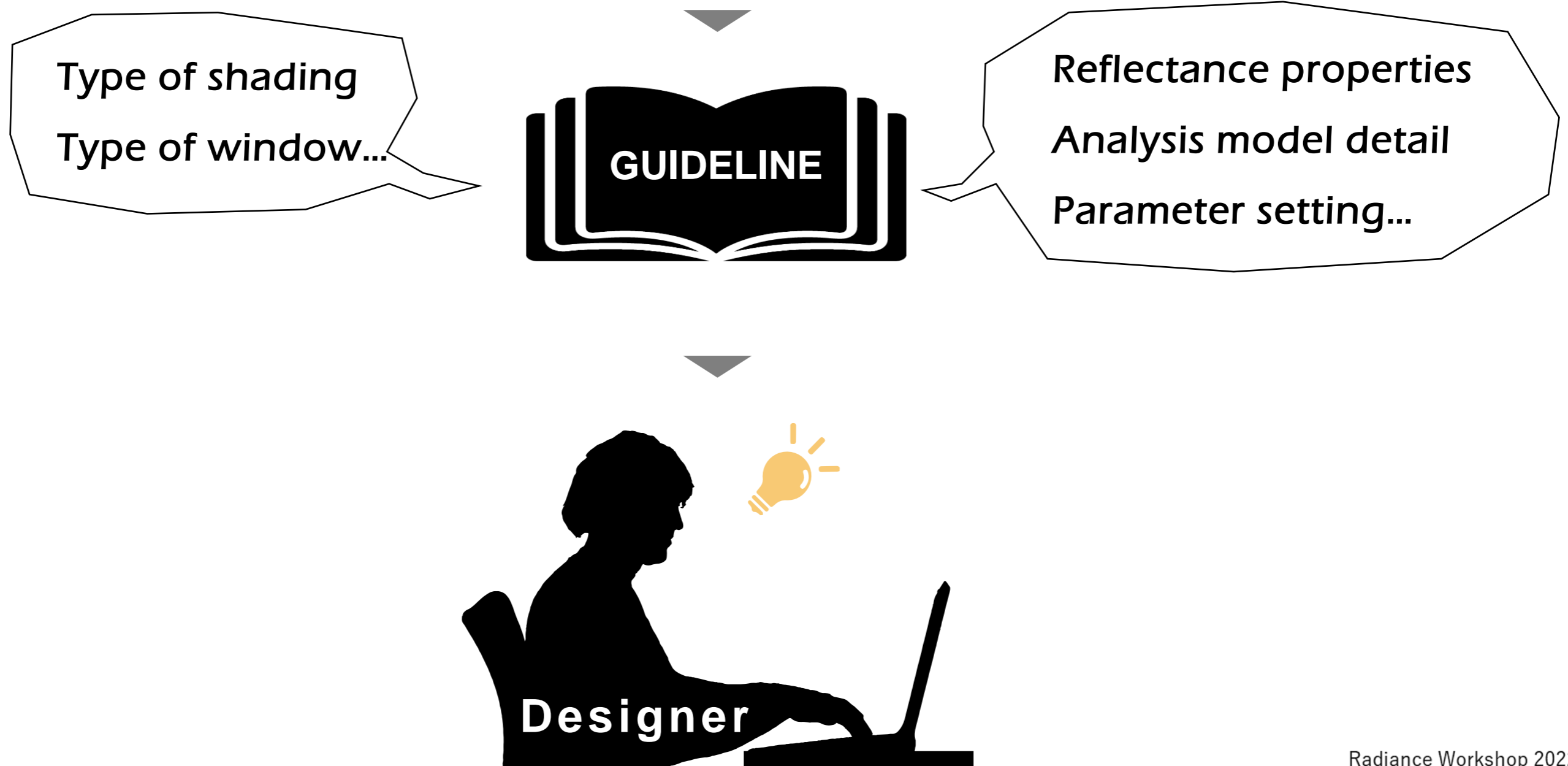
When  $-aa \leq 0.4$ , the error is sufficiently small, but the CTR is significantly reduced compared to  $-aa = 0.1$ .

↳ **Setting  $aa=0.1$  is too much and inefficient!**



# Summary

		1PH	2PH	3PH
Study Model	Design Study	Zoning & Programming	Floor plan, Section and Elevation Study	Detail Design
	Model	Volume Model Skin Pattern	Pre Plan Design Skin Pattern (Variety)	Plan Adjustment Skin Detail
Required Accuracy	Simulation (Annual) Envelope Solar Irradiance			
	Simulation (Annual) Illuminance (sDA, ASE, UDI)			



What do you think about the **ACCURACY** and **LOAD** of simulation in the design field?

**Thank you for listening!**

**Question?**

**Please use simple English...**

