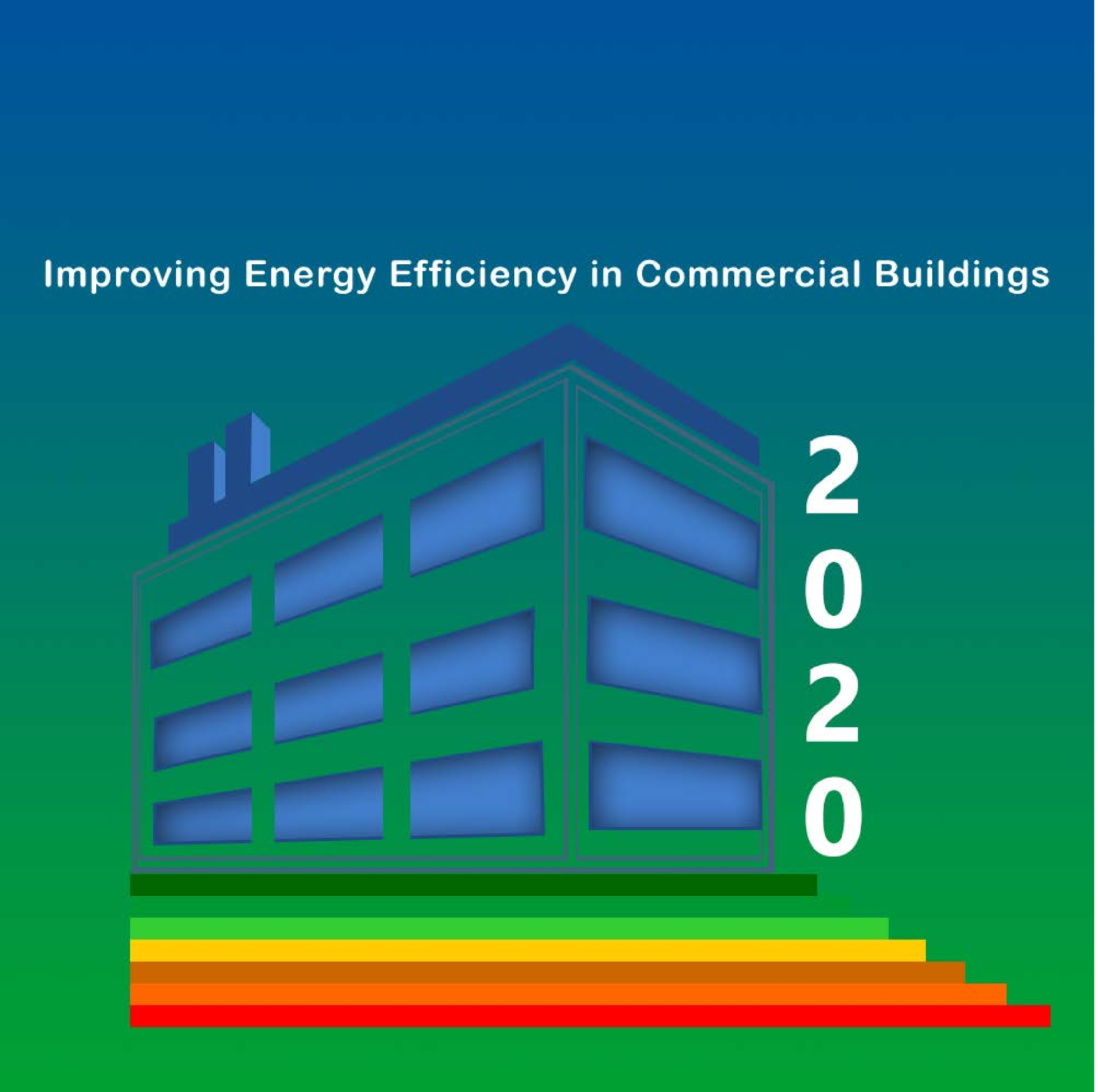

A new approach based on dynamic metric to assess daylighting potential in indoor environment

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Dynamic daylight simulations

The need to reduce energy consumptions has made unavoidable the use of renewable energy sources in buildings design. In this context daylighting, being a fundamental strategy to reduce energy costs and improve indoor comfort conditions, has gained a fundamental role in lighting design. This is true also thanks to the introduction of the dynamic daylight simulation techniques, allowing the indoor daylight availability to be calculated, accounting for its variability on time.

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Dynamic daylight simulations

Dynamic daylight simulations are based on the following phases:

a Collecting outdoor irradiance data from weather data file ➡

1st January - 10:00
.
.
.
3rd February - 16:00
.
.
.
5th March - 13:00
.
.
.
12th August - 13:00
.
.
.
10th October - 9:00
.
.
.
23rd December - 18:00

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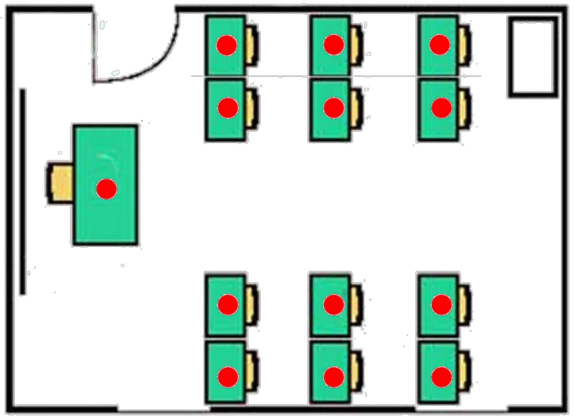
Dynamic daylight simulations

b Selecting calculation points ➡



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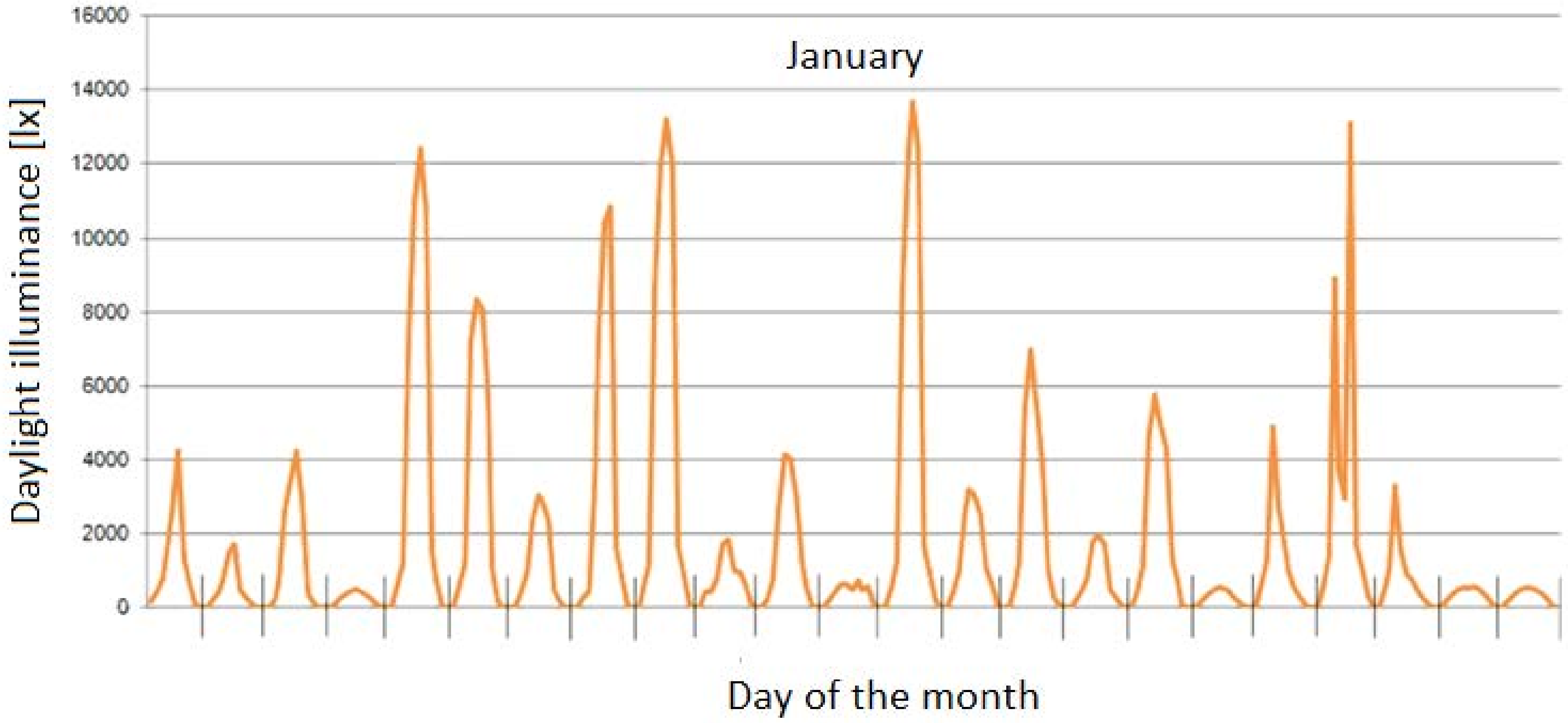
Dynamic daylight simulations

C Obtaining daylight illuminance trends for each calculation point



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d Interpreting obtained data by means of dynamic daylight performance metrics

- Daylight Autonomy (DA)
- Continuous Daylight Autonomy (Da_{con})
- Maximum Daylight Autonomy (Da_{max})
- Useful Daylight Illuminance (UDI)
- Annual Light Exposure
- Daylight Glare Probability (DGP)

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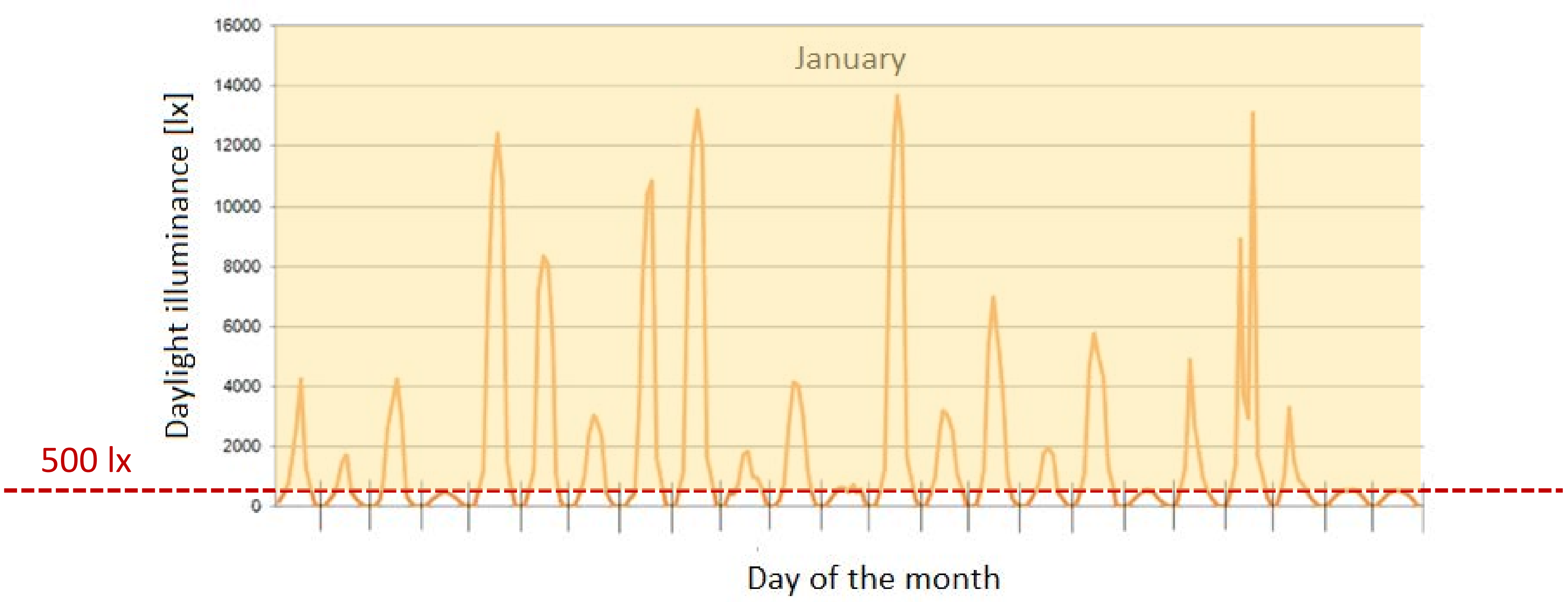
Daylight Autonomy

The Daylight Autonomy is the yearly percentage of time during which a specific illuminance level is achieved by daylight alone.



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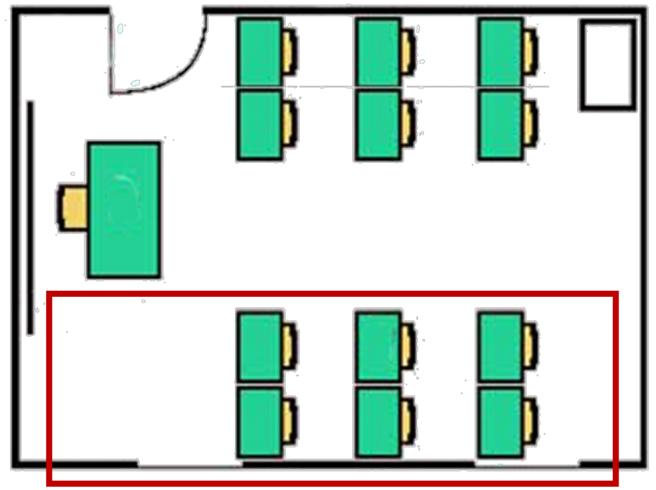
Daylight Autonomy

The necessity to have a unique parameter describing the entire space has driven to the introduction of the spatial Daylight Autonomy (sDA). It is the percentage of floor area characterized by a specific DA value (e.g. 50%) given a specific task illuminance (e.g. 300 lx).



Considering a target illuminance of 300 lx, the 45% of the considered points are characterized by a DA equal at least to 50%.

$sDA_{(50\%,300lx)}=45\%$

L. Heschong *et al.*, "Approved Method: IES Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE)," IES-Illuminating Engineering Society, 2012.

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Daylight Autonomy expresses daylight potential of a space referring to a specific task illuminance, so referring to a specific visual task.

If the task is not defined?

- Analysis of multitasking spaces;
- Preliminary analysis before complete definition of spaces functions;
- Retrofit interventions for functional recovery.

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Inverting Daylight Autonomy paradigm

Daylight Autonomy

Percentage of time during which

a specific illuminance level is achieved by daylight alone

Median Daylight Illuminance

Daylight illuminance achieved

for a significant percentage of time (i.e. 50% of the year).

Improving Energy Efficiency in Commercial I

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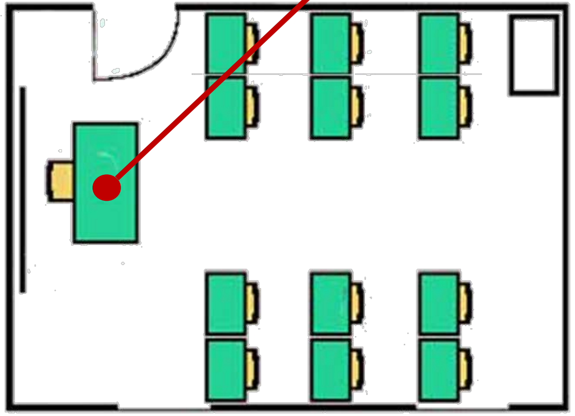
Median Daylight Illuminance - MDI



Date	Time	Daylight Illuminance	Ordered series
1st Jan	9:00	69	0
1st Jan	10:00	210	0
1st Jan	11:00	388	9
1st Jan	12:00	1041	19
1st Jan	13:00	1051	69
1st Jan	14:00	906	69
1st Jan	15:00	660	99
1st Jan	16:00	318	157
1st Jan	17:00	19	210

In statistics and probability theory, a median is a value separating the higher half from the lower half of a data sample, a population or a probability distribution.

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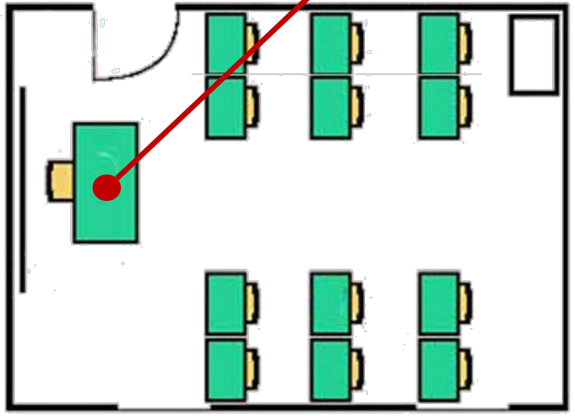
Median Daylight Illuminance - MDI



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For half of the year daylight illuminance is higher or equal to the Median Daylight Illuminance

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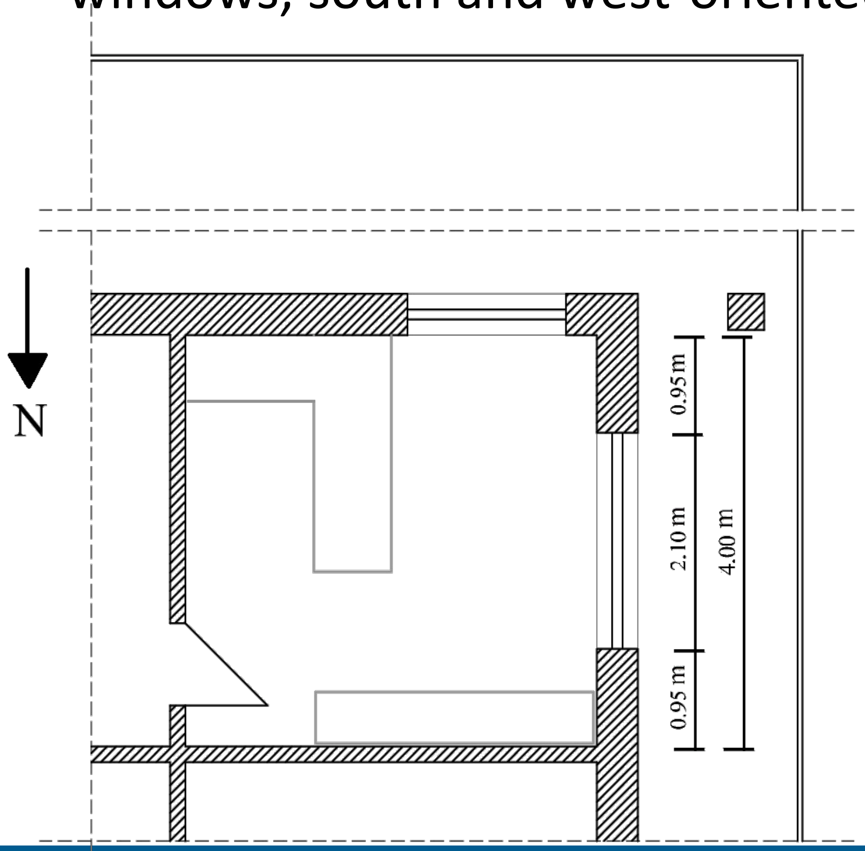
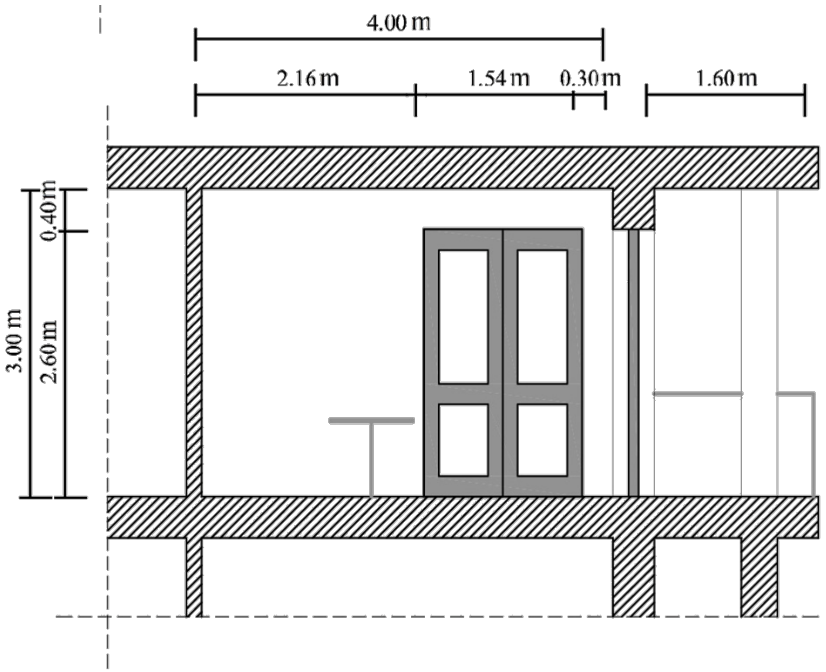
Application of the MDI

Case study: an office located in Naples equipped with two French windows, south and west-oriented respectively.





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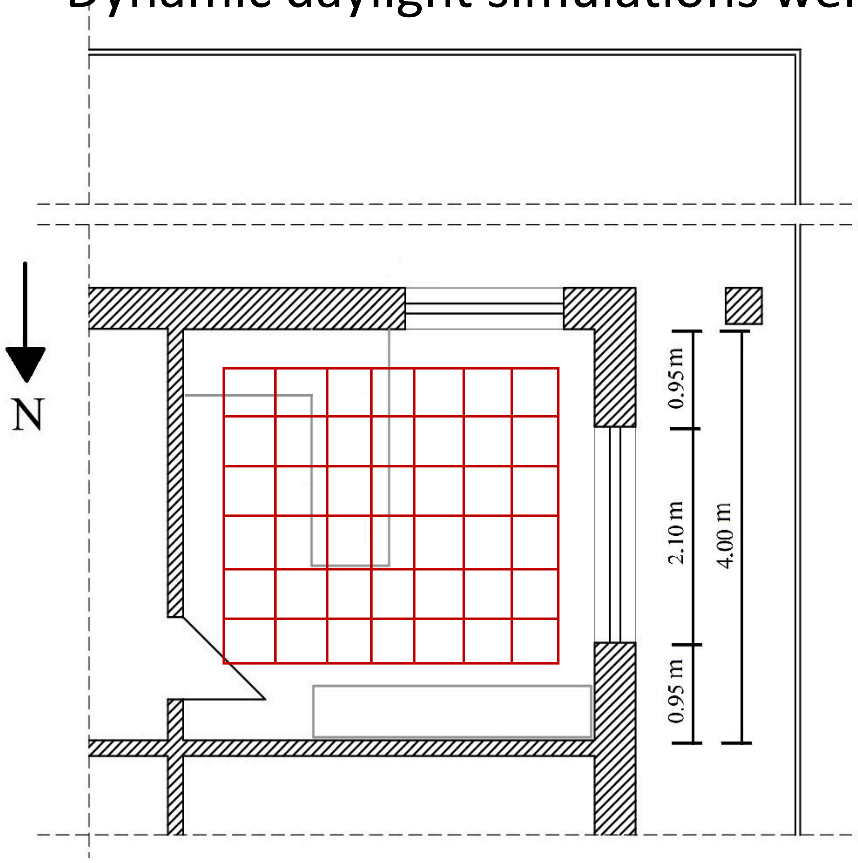
Dynamic daylight simulations were performed by means of DIVA for Rhinoceros.



Calculation points: daylight Illuminances were calculated for a calculation grids 7·8 points (distance among points around 0.4 m) and at the eye level of a men seated at the desk.

Weather data file: Naples IWEC

Time schedule: The room was occupied from Monday to Friday, from 9:00 to 18:00. Daylight saving time ranged from April the 1st to October the 31st.

Analyzed configurations: two windows, only south window, only west window.

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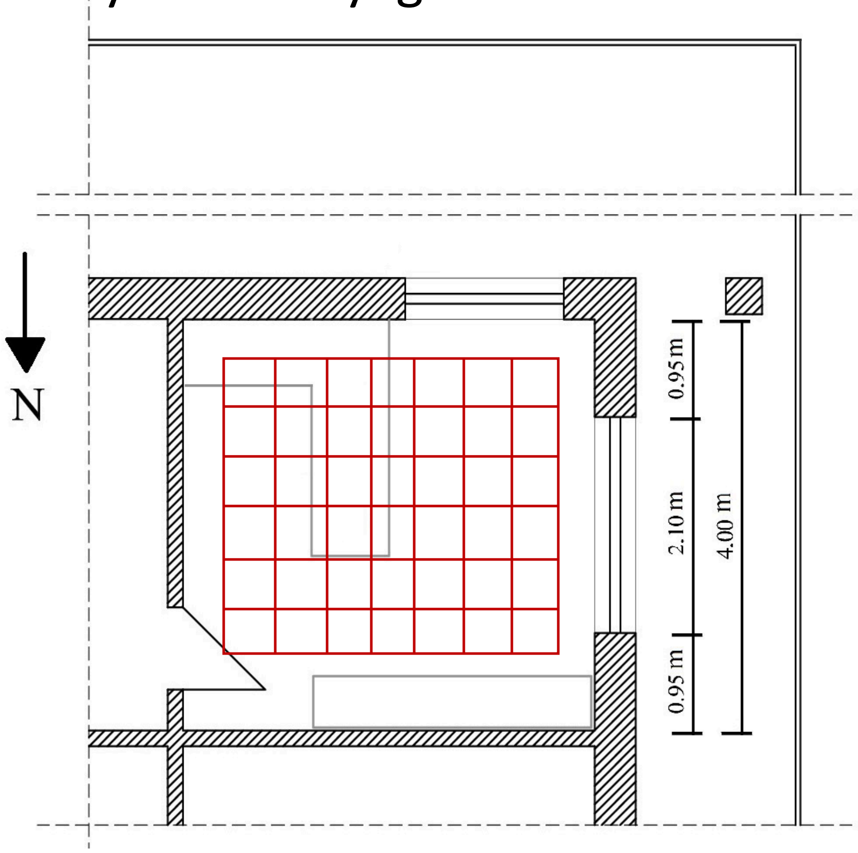
Dynamic daylight simulations were performed by means of DIVA for Rhinoceros.



Ambient bounces	Ambient division	Ambient sampling	Ambient resolution	Ambient Accuracy
7	1500	100	300	0.05

	Visual reflectance
Ceiling	0.8
Floor	0.3
Interior walls	0.5
Desk top	0.5
Window frame	0.2

Visual transmittance of the glazing: 87%

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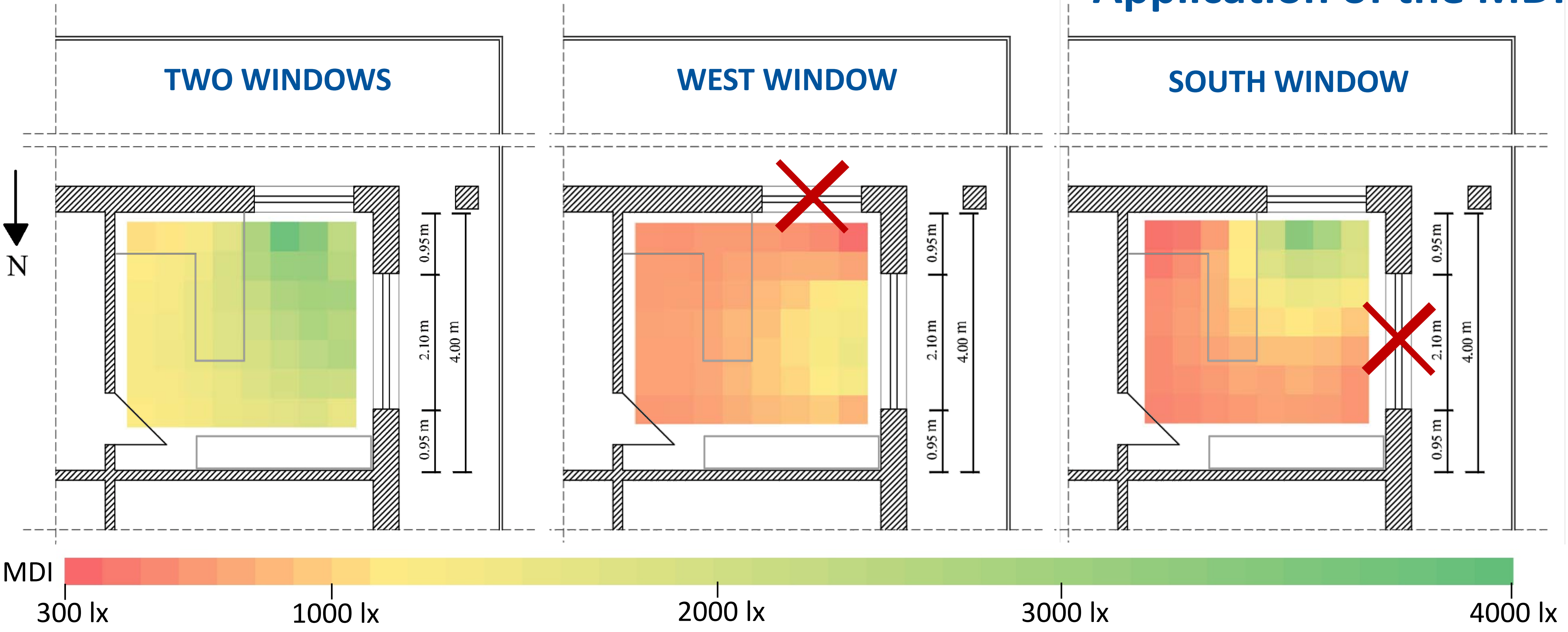
Application of the MDI



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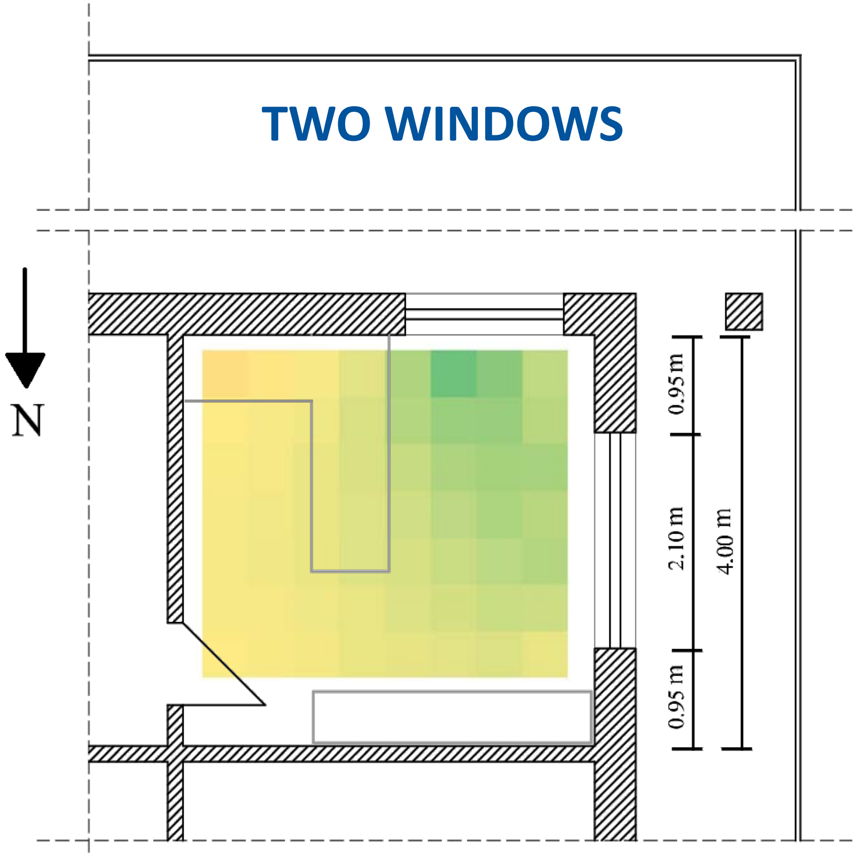

How to transform the MDI in a spatial parameter

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Characteristic Daylight Illuminance (CDI)

At this purpose, the concept of Characteristic Daylight Illuminance (CDI) was introduced based on the definition of the $\bar{E}_{task}$ set. The $\bar{E}_{task}$ set includes the most recurring illuminance thresholds indicated by the current standard plus the zero value.

$$\bar{E}_{task} = \{0\ lx, 50\ lx, 100\ lx, 200\ lx, 300\ lx, 500\ lx, 750\ lx, 1000\ lx, 2000\ lx\}$$

Given the $\bar{E}_{task}$ set, knowing MDI, it is possible to define the $\bar{E}_{task,MDI}$ subset, composed of all the elements belonging to the $\bar{E}_{task}$ set and lower or equal to the MDI. At this point, the CDI [lx] can be defined as:

$$CDI = max\{\bar{E}_{task,MDI}\}$$

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Characteristic Daylight Illuminance (CDI)

For example if MDI= 354 lx

$$\bar{E}_{task} = \{0\ lx, 50\ lx, 100\ lx, 200\ lx, 300\ lx, 500\ lx, 750\ lx, 1000\ lx, 2000\ lx\}$$

$$\bar{E}_{task,MDI} = \{0\ lx, 50\ lx, 100\ lx, 200\ lx, 300\ lx\}$$

$$CDI = max\{\bar{E}_{task,MDI}\} \longrightarrow$$ CDI = 300 lx

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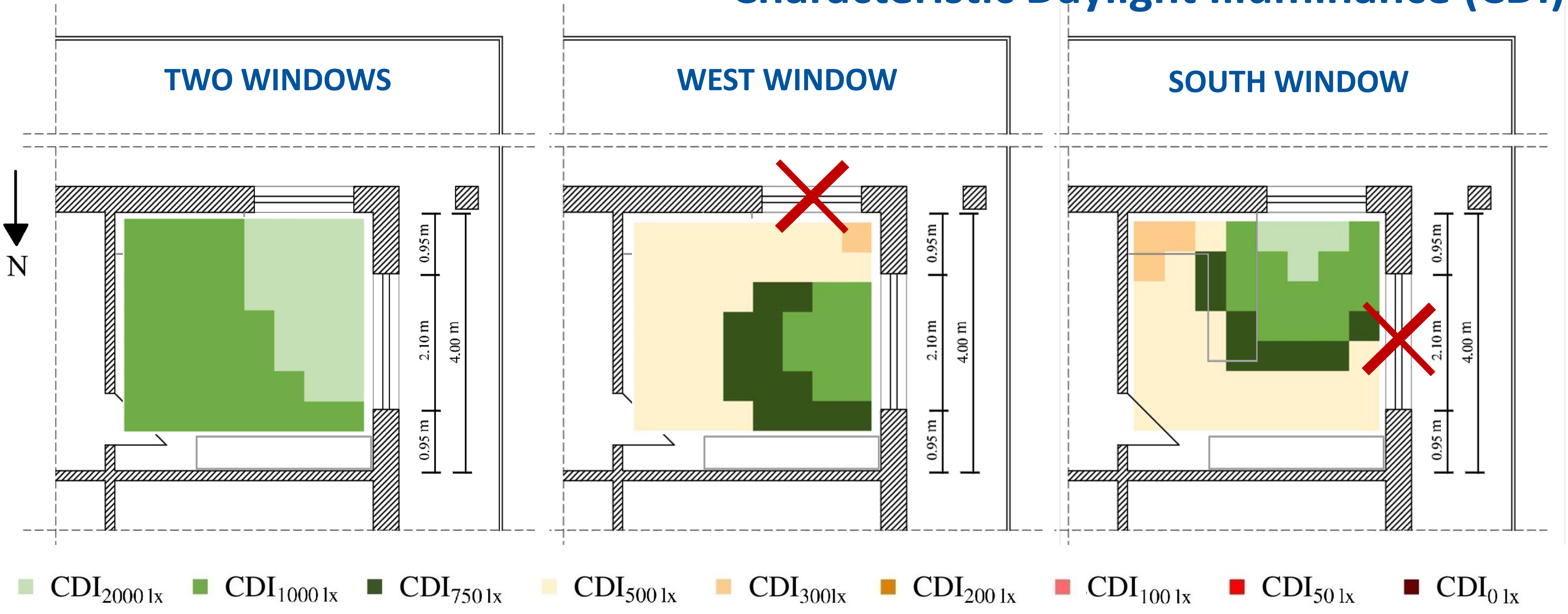
Characteristic Daylight Illuminance (CDI)



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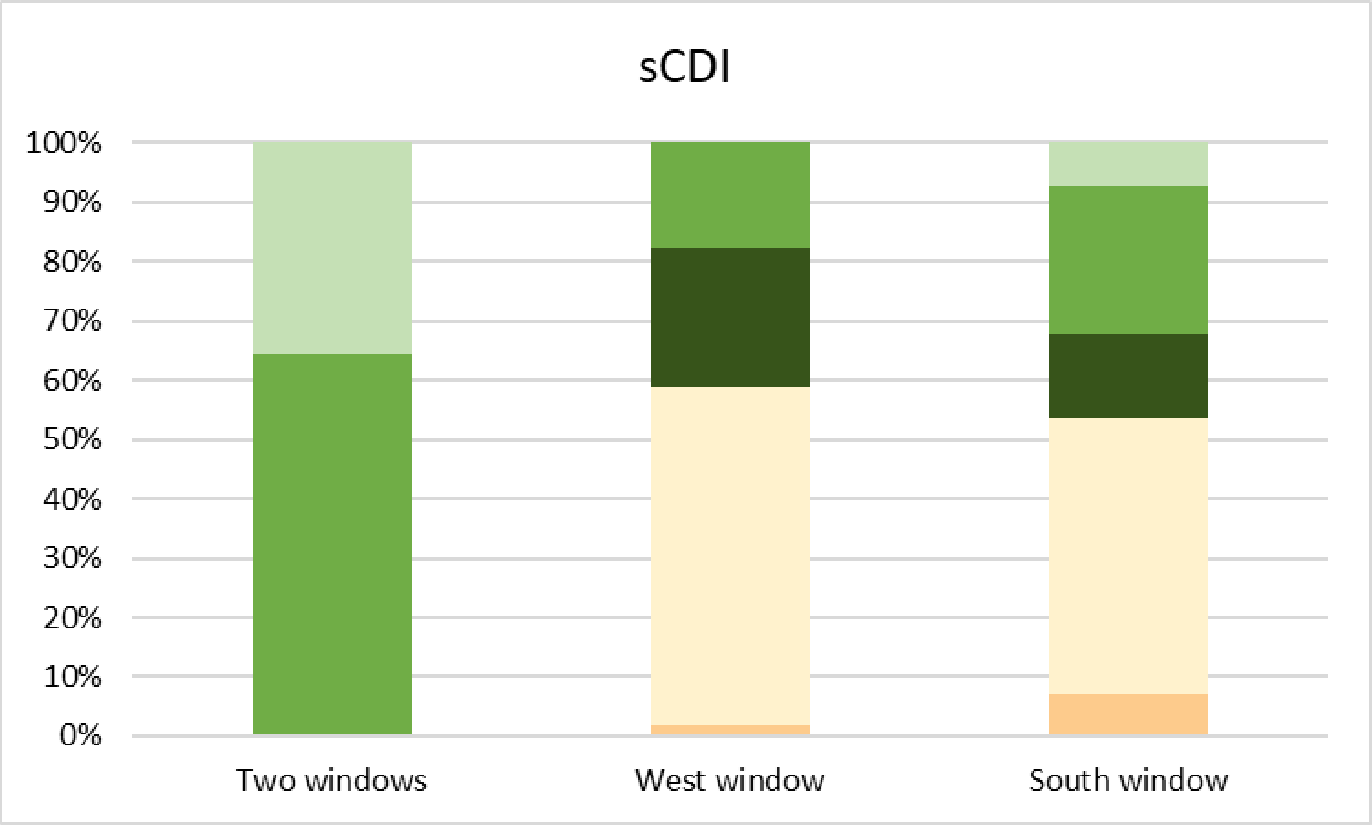
Spatial Characteristic Daylight Illuminance (sCDI)



$sCDI_{2000\,lx}$ $sCDI_{1000\,lx}$ $sCDI_{750\,lx}$ $sCDI_{500\,lx}$ $sCDI_{300lx}$ $sCDI_{200\,lx}$ $sCDI_{100\,lx}$ $sCDI_{50\,lx}$ $sCDI_{0\,lx}$

The spatial CDI is the percentage of the floor area for which CDI is equal to each given task illuminance belonging to the $\bar{E}_{task}$ set.

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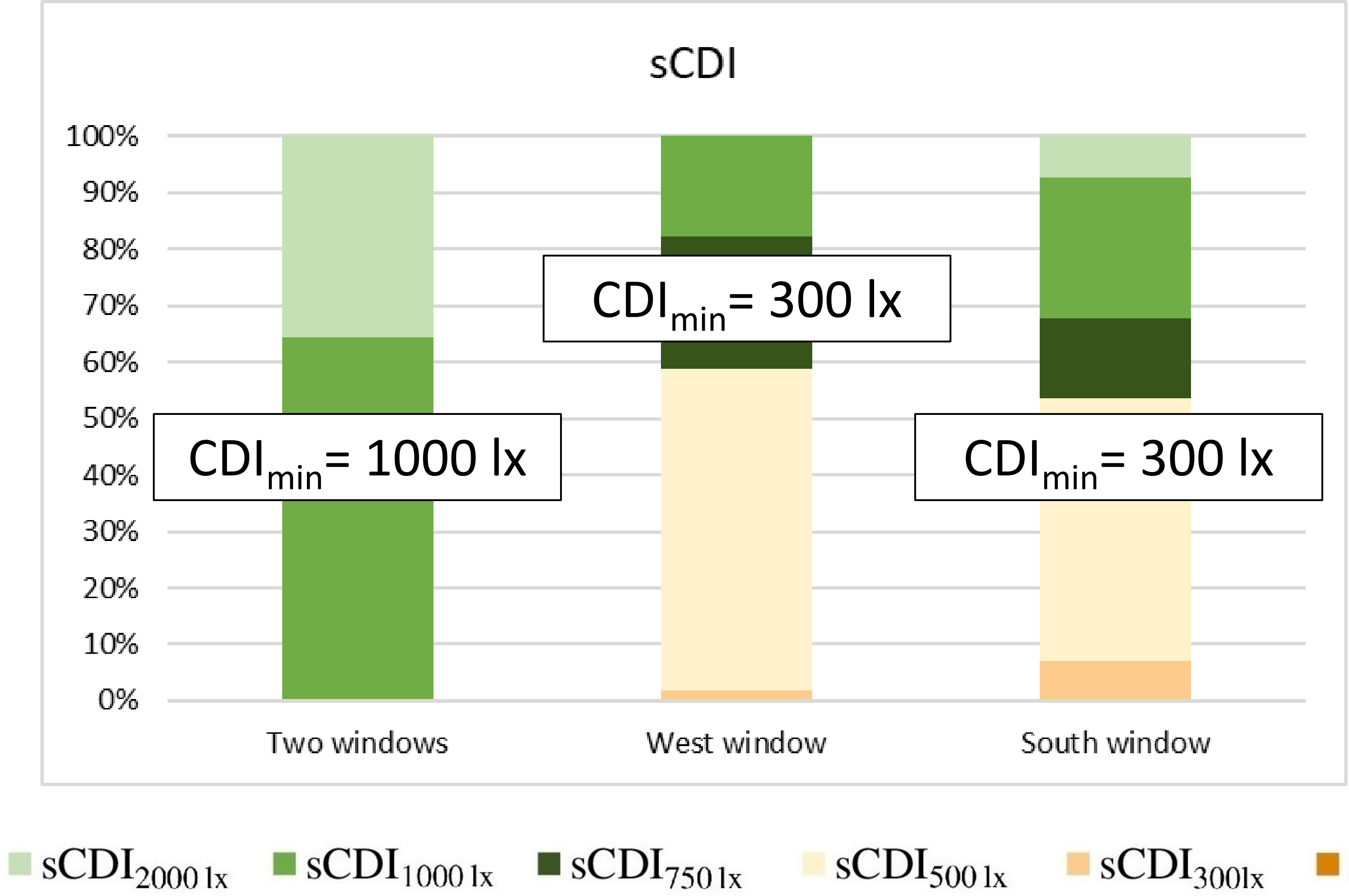
Minimum Characteristic Daylight Illuminance (CDI_{min})



To describe the entire space with only one parameter the minimum CDI can be used.

Indeed, the minimum observed CDI corresponds to the task illuminance that can be fulfilled for 50% of the year by daylight alone in the entire space.

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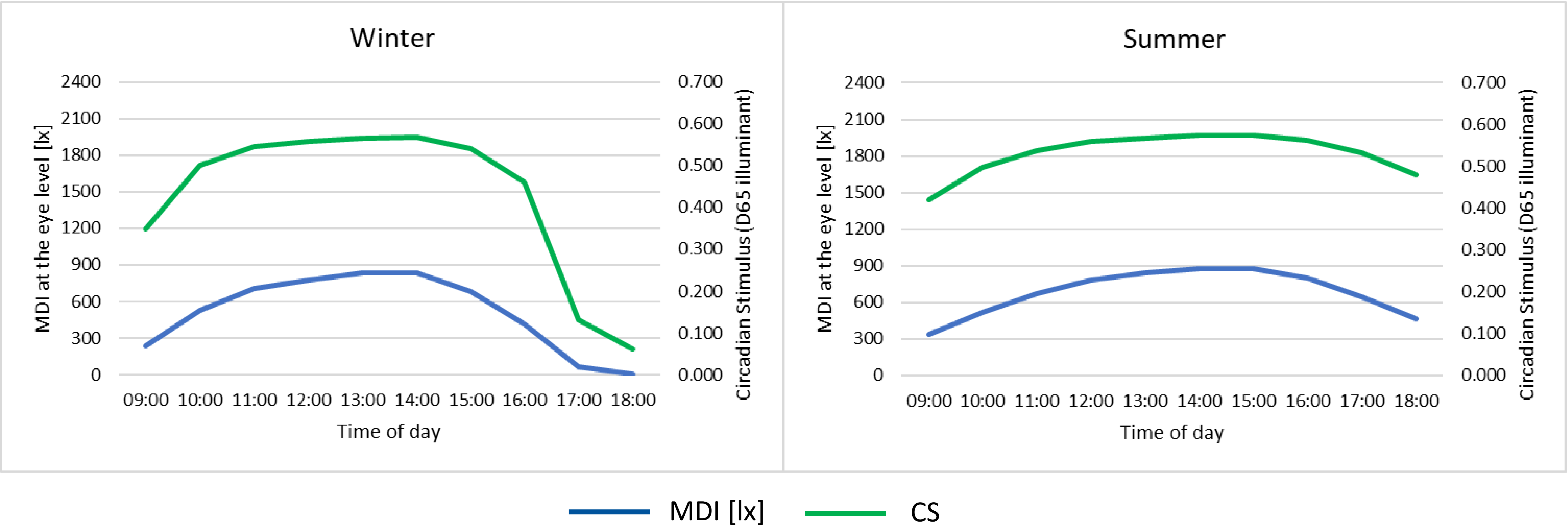
Application examples: Circadian analysis

South window



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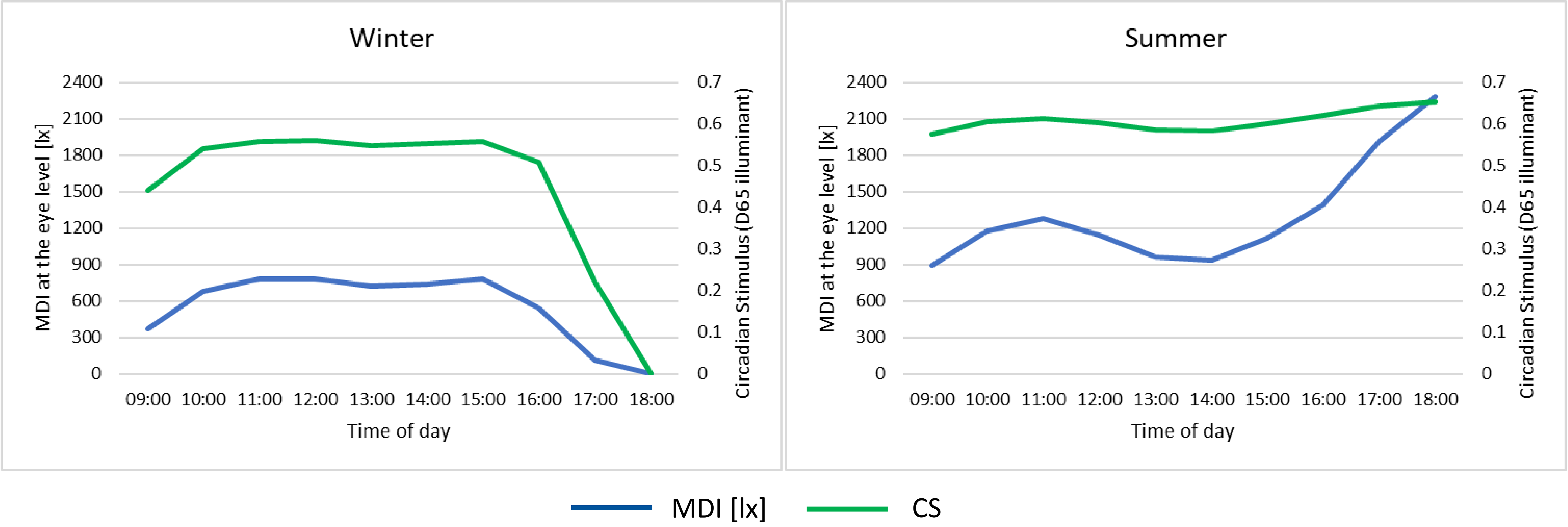
Application examples: Circadian analysis

West window



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Application examples: Historical buildings analysis

Monteoliva, J. M., Bellia, L., Fragliasso, F., & Pattini, A. (2020). Ancient Romans and daylighting: the case of Villa of the mysteries in Pompeii. Journal of Cultural Heritage.

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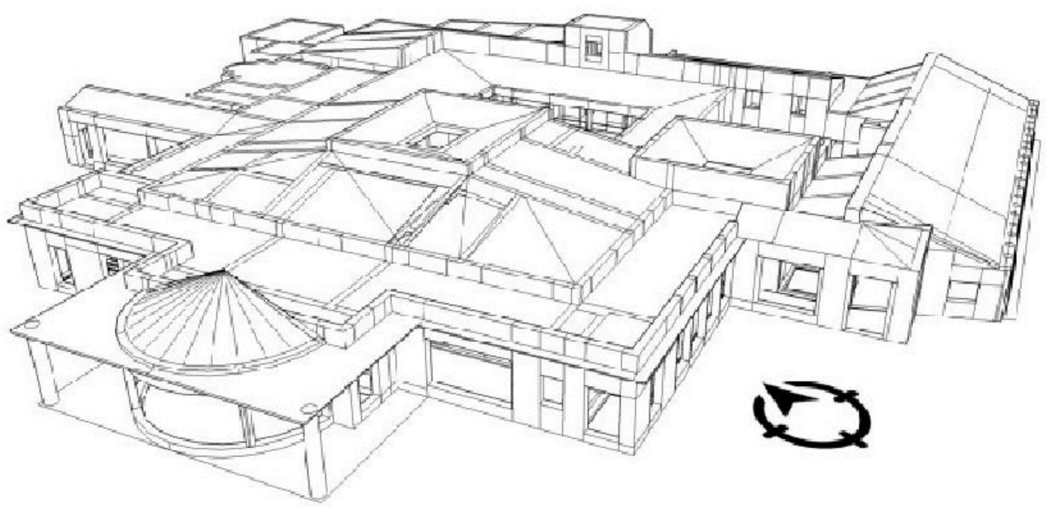
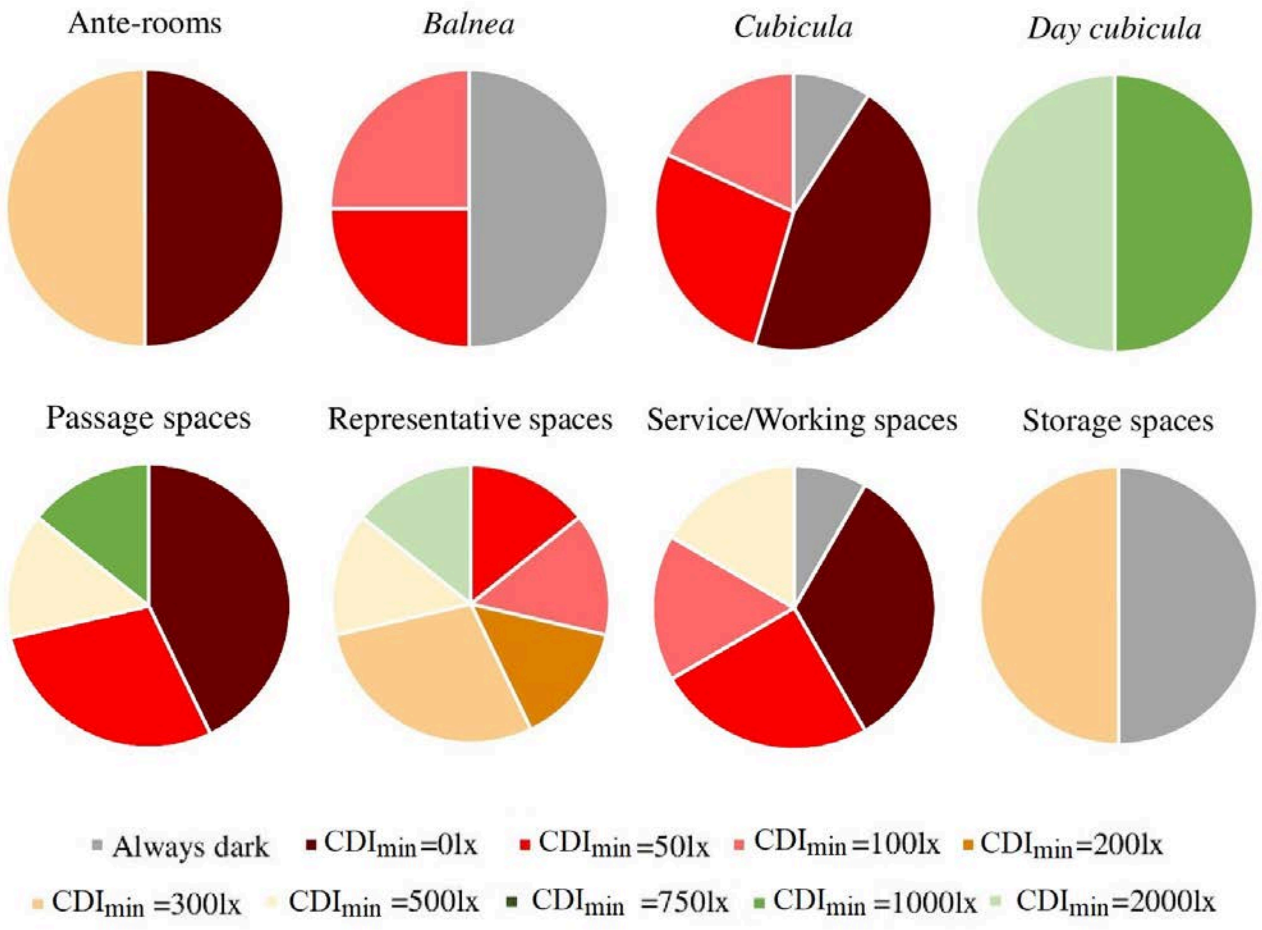
Application examples: Historical buildings analysis





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Conclusions

- The Median Daylight Illuminance (MDI) calculated at a point informs about the daylight illuminance achieved at least for half of the year at the point.

- The Characteristic Daylight Illuminance (CDI) can be used to approximate the MDI and making simpler the comparisons between results.

- The analysis of the spatial CDI (sCDI) provides an idea about the typical daylight distribution of indoor daylight illuminances.

- The minimum CDI (CDI_{min}) represents the illuminance value that is surely achieved in the entire space for half of the year.

- The use of the proposed parameters can be a useful integration to DA and sDA analysis for specific applications since they express daylight potential not referring to a specific visual task.

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Thank you for the attention

Questions?

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