A Study of Daylight Metrics

Elucidating a basis for a common European approach

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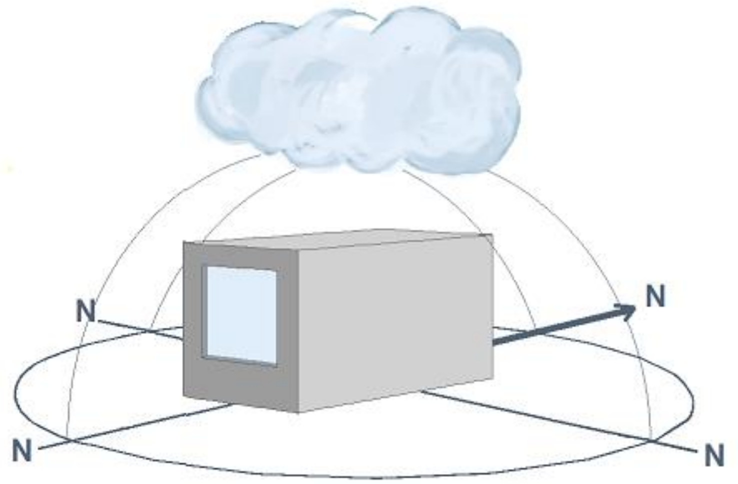
Daylight performance metrics investigated

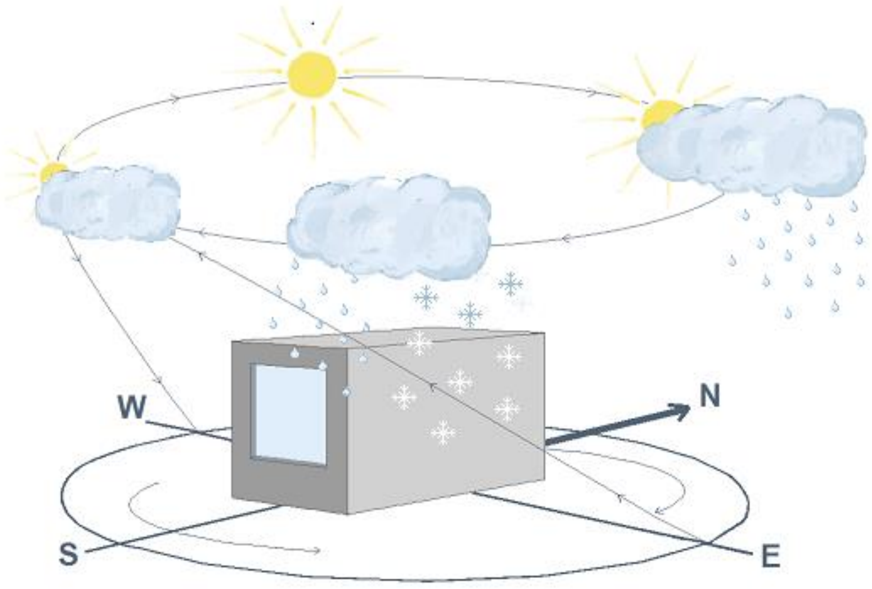
Static metrics

Static sky conditions
CIE overcast sky



Climate-based metrics

Dynamic sky conditions



Daylight performance metrics investigated

Static metrics

Static sky conditions
CIE overcast sky

Daylight Factor (DF):

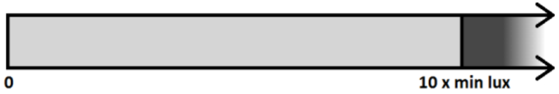
$$\frac{E_{interior}}{E_{exterior}} \%$$

Climate-based metrics

Dynamic sky conditions

Continuous Daylight Autonomy:

Maximum Daylight Autonomy:



Continuous Useful Daylight Illuminance:

Method

Parameters

Further more the study investigates the importance of varies design parameters of the window element. The following five window elements are investigated in the study:

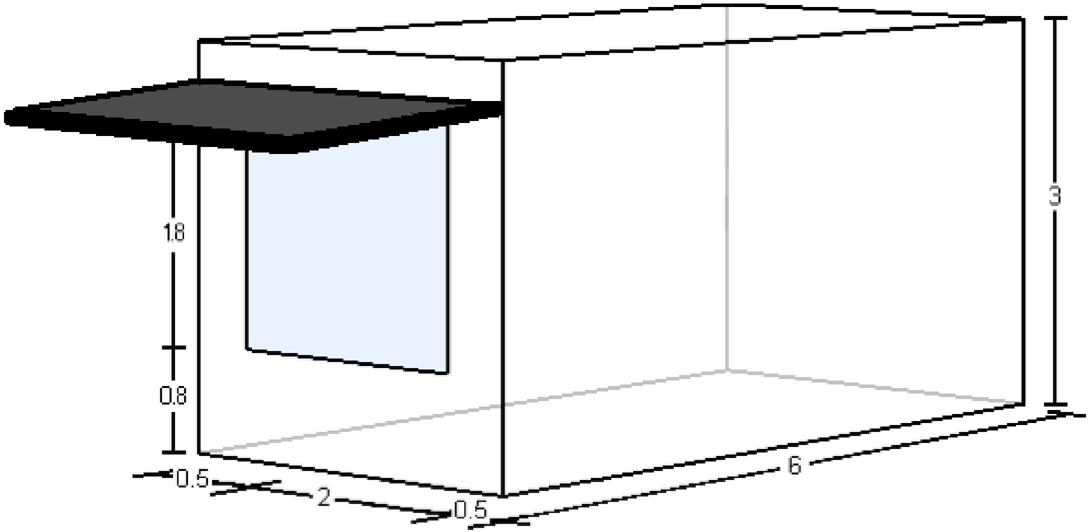
1) Clear glazing

2) Clear glazing + internal blinds

3) Clear glazing + External blinds

4) Solar coated glazing

5) Clear glazing + overhang



All simulations are carried out using IDbuild v. 2014a, see www.idbuild.dk

Method

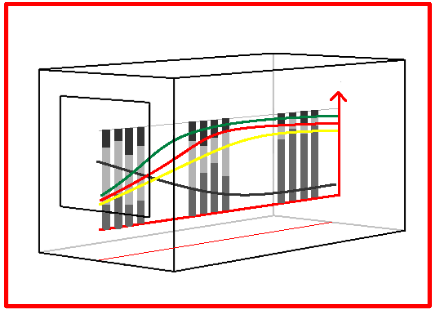
Parameters

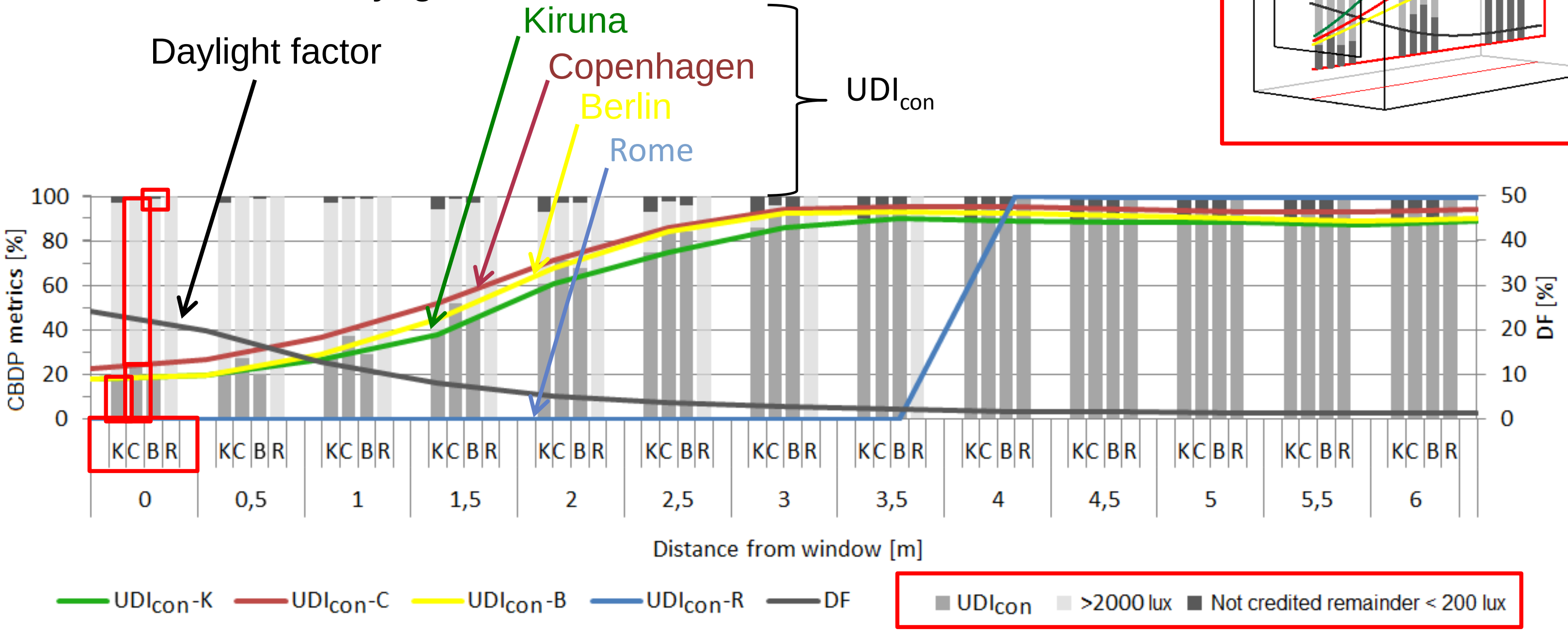
The sensitivity is investigated with respect to location and orientation, and to represent the European climate variety, the study focuses on the following four locations:

Results

Clear glazing – Oriented south

The underlying grey bar chart indicates the composition of the continuous useful daylight illuminance.



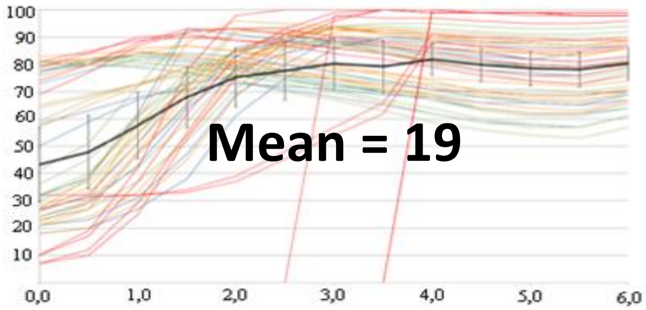


All results are displayed as the centreline value calculated at 0,8m above floor level.

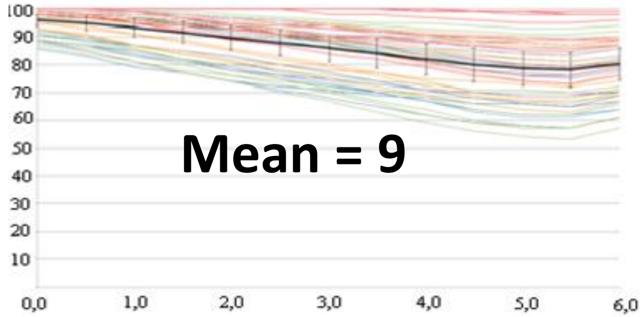
Results

Standard deviation – All parameters for each metric

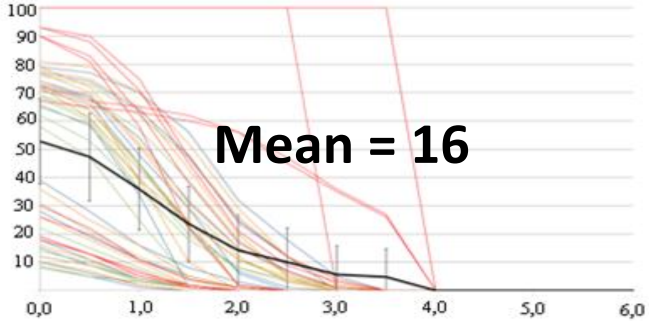
UDI_{con}



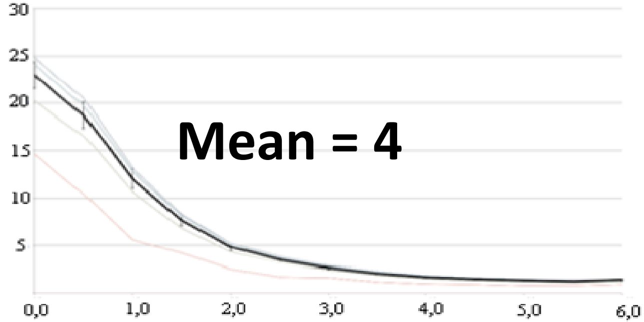
DA_{con}



DA_{max}



DF



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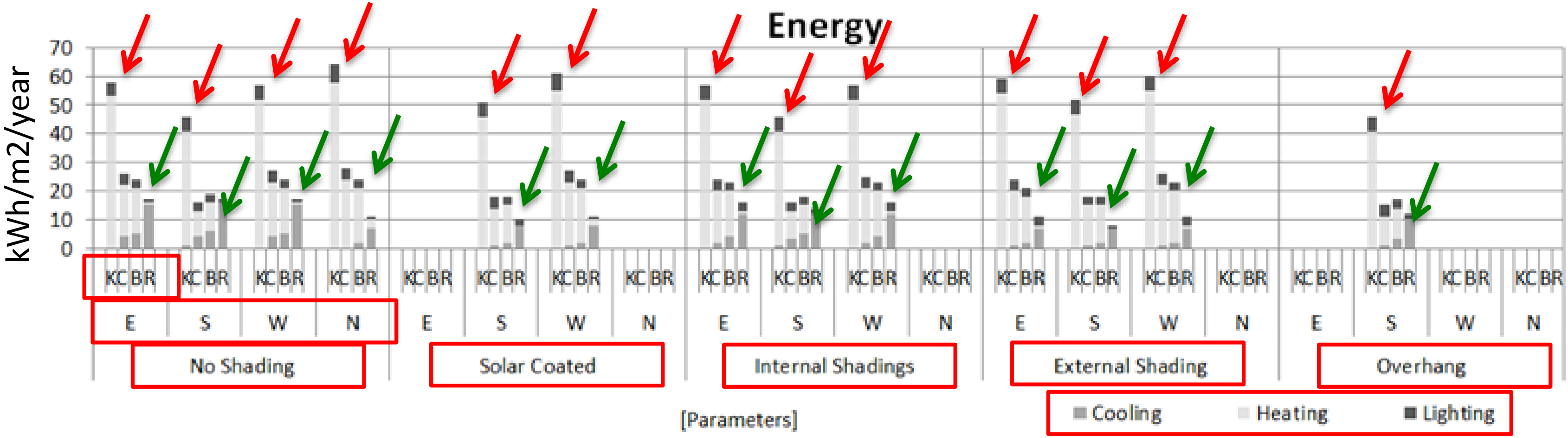
Results

Energy consumption



- Important to include the energy use composition (heating, cooling, lighting)
- Highest energy consumption in Kiruna, lowest in Rome
- Energy use for lighting according to window properties is mainly affected in Rome

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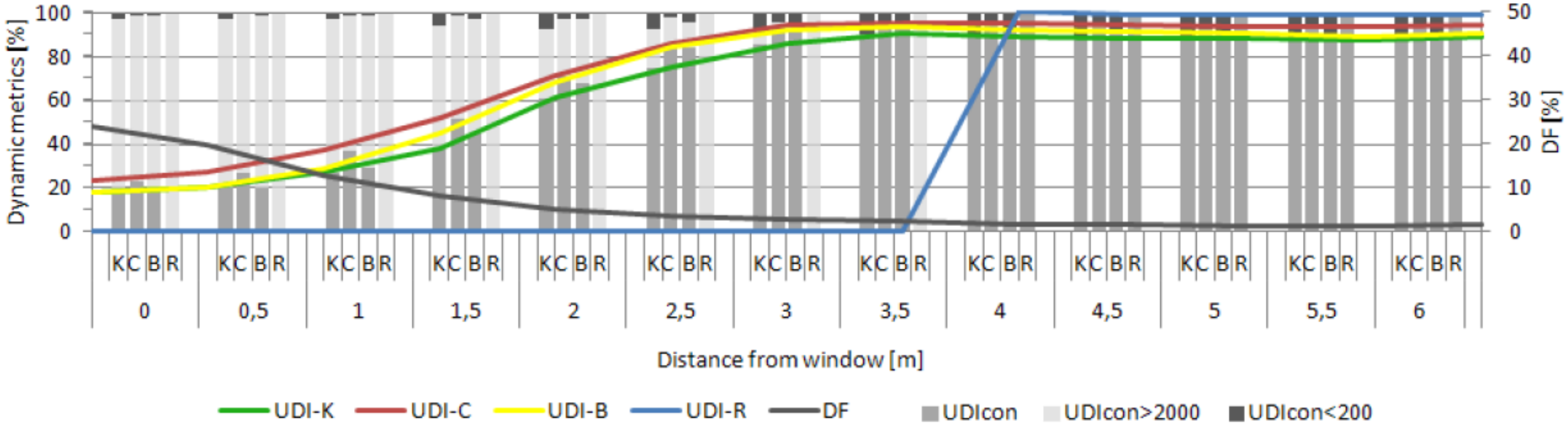
Results

Energy consumption

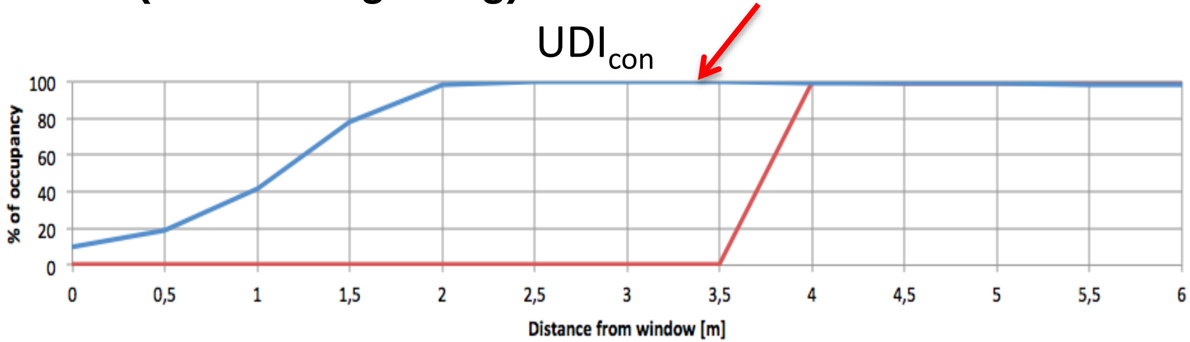
Clear glazing – Oriented south

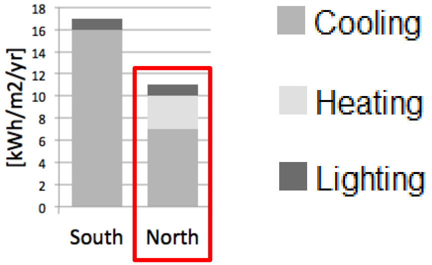


Results

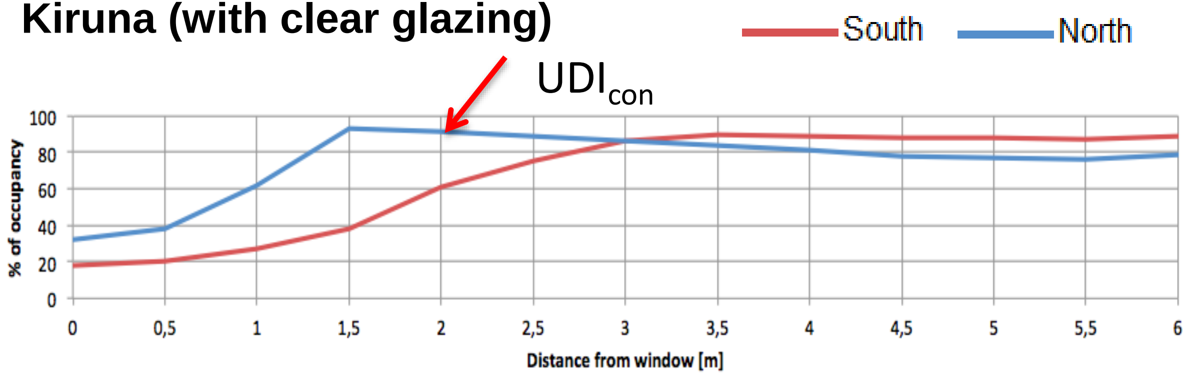
Energy consumption

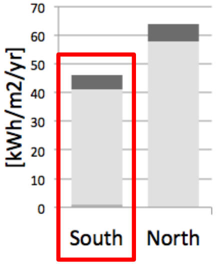
Rome (with clear glazing)





Kiruna (with clear glazing)





The study showed that...

- CBDP metrics are significantly more sensitive to various design parameters than DF
- UDI_{con} has the highest sensitivity of the CBDP metrics due to both upper and lower illuminance limits
- changes in UDI_{con} do not indicate whether they are caused by too high or too low illuminances
- relation between UDI_{con} and energy performance is location specific
- only an integrated daylight and thermal analysis shows if an increased/decreased UDI_{con} is beneficial for the overall energy performance

Thank you for your attention

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Keywords: *Climate-Based Daylight Performance Metrics, Daylight Factor, Energy Performance, Parameter Analysis*

Abstract

This paper describes a study of climate-based daylight performance metrics in comparison with the static metric of the Daylight Factor (DF): Continuous Useful Daylight Illuminance (UDI_{con}), Continuous Daylight Autonomy (DA_{con}) and Maximum Daylight Autonomy (DA_{max}) (Mardaljevic et al., 2009; SBI, 2008; Reinhardt et al., 2006; Nabil & Mardaljevich, 2005). The study features systematic variations of design parameters important for the daylight availability in a room for four different European locations with significantly different climate characteristics. The aim of the study is to provide a basis for recommending a suitable common daylight metric for the upcoming European Daylighting Standard.

The study shows that the climate-based daylight performance metrics are significantly more sensitive to variations of design parameters important to the daylight availability in the room than the Daylight Factor. The climate-based daylight performance metrics provide a much more representative picture on how different parameters influence the daylight conditions in a room. The climate-based daylight performance metrics could easily be calculated using the simulation program iDbuild (Petersen & Svendsen, 2010). Calculation time was almost identical to that for the calculation of the Daylight Factor. DA_{con} has the lowest sensitivity of the climate-based daylight performance metrics, since it has no upper illuminance limit, while UDI_{con} was the most sensitive. UDI_{con} however lacks information on its range composition, since changes can be caused by either too high or too low illuminances. Due to this limitation in UDI_{con}, it is recommended to evaluate the daylight conditions in a space through a combination of UDI_{con} and DA_{max}. The combined calculations indicate the percentage of time for which the illuminance values in the room will exceed the specified maximum levels.

None of the daylight metrics reflects how the parameter variations will affect total energy consumption of the room. Furthermore no clear link was found between sensitivity of daylight metrics and the impact of daylighting strategies on the overall energy consumption of the room. It is therefore recommended to evaluate the daylight conditions together with the energy consumption of the room, when different façade design options need to be assessed.

Investigation method

A simple room as depicted in fig. 1was used for daylighting and energy simulations. The analysis involved five different design parameters for the window element: clear glazing, clear glazing with external blinds, clear glazing with internal blinds, clear glazing with overhang and solar coated glazing. To elucidate a basis for a common European daylight metric, the analysis involved four different European locations: Kiruna (Sweden), Copenhagen (Denmark), Berlin (Germany) and Rome (Italy) as well as all four orientations. The parametric analysis was performed using iDbuild, which offers a rapid, yet dynamic and relatively precise algorithm capable of making integrated daylight and thermal simulations using hourly weather data (Nielsen, 2005; Hviid et al., 2008; Petersen & Svendsen, 2010; Petersen et al., 2014). The simulation results were evaluated using the following metrics (Fig. 1).

Static metric
- The daylight factor (DF)

Climate-based daylight performance metrics
- The continuous Useful Daylight Illuminance (UDI_{con})
- The continuous Daylight Autonomy (DA_{con})
- The maximum Daylight Autonomy (DA_{max})

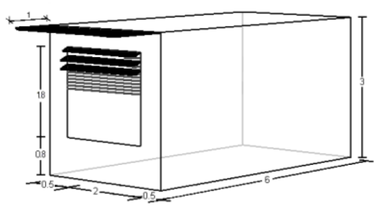

Figure 1. Illustrations of some of the different façade design, with focus on different shading devices

Results and discussion

The simulation results confirm that the climate-based daylight performance metrics are sensitive to changes in orientation, location and façade design, and that there are differences in sensitivity for the various climate-based daylight metrics. The metrics' sensitivity along the room centreline is illustrated in figure 2 which displays all parametric variations for each of the four metrics along with the average and standard deviation.

Figure 2 shows that UDI_{con} has the highest sensitivity throughout the cross-section of the room. DA_{max} is mainly sensitive in the front of the room and DA_{con} is the least sensitive of the climate-based daylight performance metrics.

More detailed analysis demonstrates that the sensitivity of a certain parameter is not the same at all locations. For example, the sensitivity towards orientation shifts with the location, indicating that the orientation influences the daylight performance more in some locations than in others. The Daylight Factor, on the other hand, is inherently insensitive to location and orientation. Furthermore, the Daylight Factor only shows a minor sensitivity to changes in the façade design compared to the climate-based daylight performance metrics.

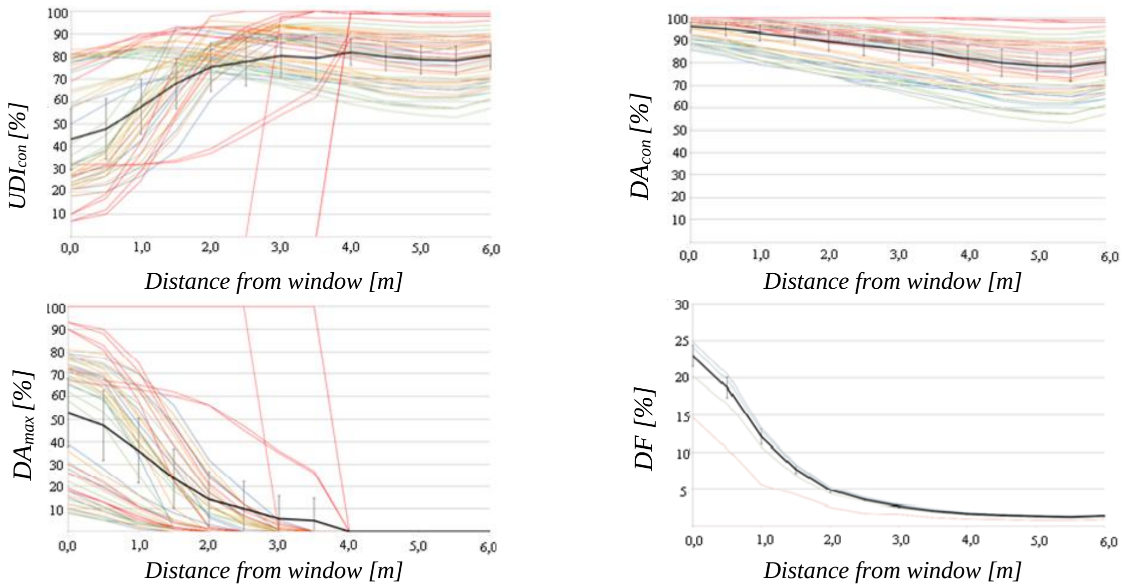

Figure 2: Illustration of all parametric variations for each of the four metrics; UDI_{con}, DA_{con}, DA_{max} and DF, calculated along the room's centerline at a height of 0.8m. Colour-labeled by location; Blue (Kiruna), Green (Copenhagen), Orange (Berlin), Red (Rome). The black line identifies the mean values and standard deviation.

Daylight performance and location

The study shows that daylight performance is sensitive to locations when using climate-based daylight performance metrics. A differentiation of location is therefore an important factor when establishing a common European daylight metric.

This can be derived from figure 3 where the distribution of the daylight at the different locations according to the various metrics throughout the room is depicted. The shown distribution is in the centreline of the room at 0,8m height for a façade design with clear glazing. This graph also shows that the climate-based daylight performance metrics is taking the different weather and sky conditions into account while the DF is the same towards the different locations.

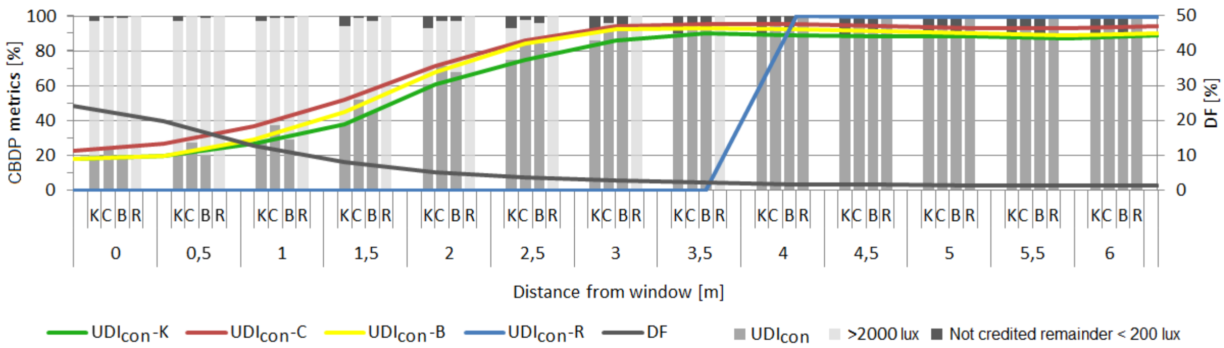

Figure 3: Illustration of the different daylight metrics for a southern orientation in four different European climates; Kiruna (K), Copenhagen ©, Berlin (B) and Rome ®. The colored lines show UDI_{con}, the black line DF, and the underlying grey bars represent UDI_{con} (200-2000 lux plus partial credit below 200 lux), DA_{max} (>2000 lux) and the remainder of the illuminance range below 200 lux for which supplementary electric light is needed

Energy

Climate-based daylight performance calculations can be used to evaluate the energy needed for electric lighting and for determining the need for solar shading. This information can be integrated with dynamic thermal simulations for evaluation of energy use for heating and cooling. Figure 4 shows the impact of the parameter variations' in terms of energy performance varies with location, climate and orientation.

For example, a high UDI_{con} (no shading) for a southern orientation results in an increased total energy use in Rome due to a higher cooling demand, while the total energy use in Kiruna is decreased due to a lower heating demand when compared to the other daylighting strategies investigated. This suggests that climate-based daylight performance metrics such as UDI_{con} are suitable inputs for the prediction of the energy use for electric lighting, but that only an integrated daylight and thermal analysis at the specific location can assess whether an increased/decreased UDI_{con} is a benefit for the overall energy performance of a space.

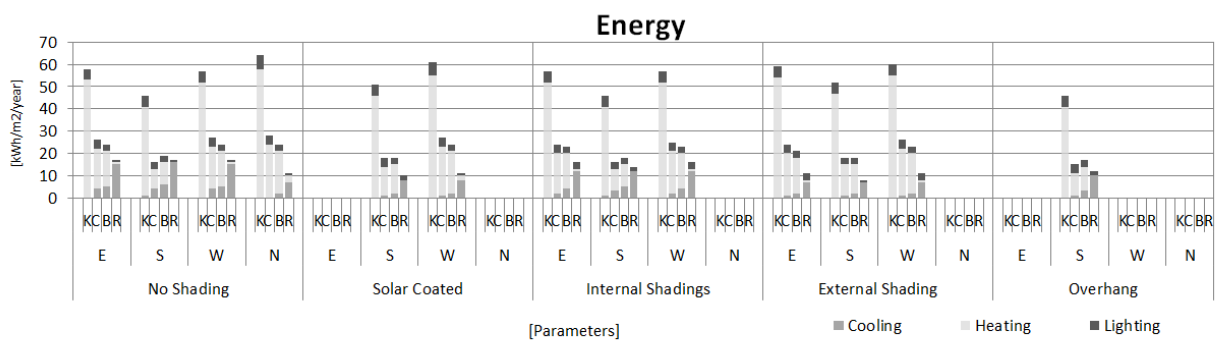

Figure 4: Energy use for heating, cooling and electrical lighting for parameter variations of window properties at the different locations (Kiruna (K), Copenhagen ©, Berlin (B) and Rome ®) and orientations (East (E), South (S), West (W) and North (N)). If no bars are shown, the simulation has not been carried out for the specific orientation.

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