Evaluating Global Daylight Metrics within the Canadian Context: A Comparative Analysis

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Abstract

Daylight metrics' adaptability to the Canadian context remains underexplored. Canada's diverse geography and climate result in substantial variations in daylight availability, especially as one moves north. This study evaluates various global daylight metrics, including the European Daylighting Standard (EN-17037) and IES LM-83, within the Canadian context. Notably, EN-17037 defines its analysis period as the highest fifty percent (4380 hours) of the annual hourly values for diffuse illuminance, making it a climate-responsive benchmark. This contrasts with other metrics based on the percentage of a fixed occupied time when target illuminance is met. This research compares results under three building designs in four Canadian climates. The results will assess the capacity of metrics to respond to climate challenges.

Introduction

The optimization of natural daylight within buildings is essential for enhancing occupant comfort, reducing energy consumption, and ensuring well-being of individuals (Andersen, 2015). Daylighting standards and metrics have been developed to describe daylight performance. However, the application and effectiveness these standards and metrics are profoundly influenced by the specific geographical contexts in which they are applied (Fonseca et al., 2023).

Furthermore, the variation in daylight hours across different locations is significantly influenced by latitude which determines sunlight duration and elevation throughout the year. As locations move further away from the equator, they receive daylight at a more oblique angle and with shorter duration. Geography therefore results in variations in daylight availability that are directly attributable to 'northern-ness' of a Canadian climate (Naresh, 2023). As Canada spans a wide range of latitudes from 42°N to 83°N, it exhibits a significant difference in daylight availability, with northern regions experiencing more pronounced variations (Statistics Canada, 2011). Such geographic differences in daylight hours introduce complexities in applying daylighting standards uniformly across Canada. We therefore propose a consideration of latitude when evaluating the applicability of daylight metrics. While daylight metrics such as EN-17037 and LM-83 provide frameworks for evaluating daylight in buildings, they are grounded in assumptions that may not fully align with the diverse Canadian climates. For example, the suitability of LM-83's 8am to 6pm analysis period in Canadian climates where daylight is not available during those hours is fraught.

This study aims to investigate this gap by assessing the applicability of these daylight metrics specifically within the Canadian context. Through comparative analysis across three building designs situated in four distinct Canadian climates (Toronto, Edmonton, Yellowknife and Resolute), this research aims to assess the capacity of these metrics to address the unique challenges posed by Canada's geographical and climatic diversity. By doing so, it endeavours to provide insights into the suitability and adaptability of global daylighting standards for Canadian applications, aiming to contribute to the development of more inclusive, climate-responsive daylighting practices.

Methods

This study applies a scoping approach to evaluate the appropriateness of global daylight metrics in the Canadian context. The methodology is structured into several key components: daylight metrics, building designs, climate locations, simulation tools, and analysis process. Figure 1 illustrates the research flow where metrics and compliance are generated for three designs in four climates for two output types.

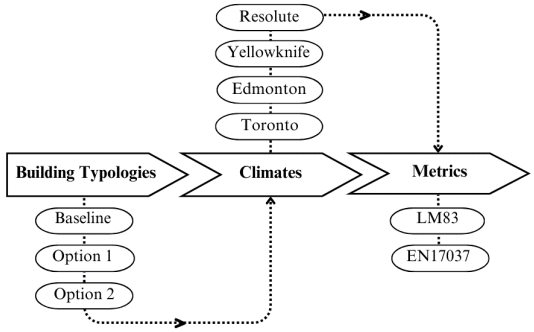

Figure 1: Branching diagram showing the relationship between building types, climates, and metrics.

Daylight Metrics

This study focuses on the analysis of two daylighting metrics: EN-17037 and LM-83. These metrics were selected for their international recognition and differing approaches to daylight evaluation. IES LM-83 assesses daylight adequacy through Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE). $sDA_{300/50\%}$ evaluates the percentage of a space achieving a minimum of 300 lux from daylight for at least 50% of the analysis period (8am to 6pm). Blinds and shades are operated hourly to block direct daylight (interior measurement of 1,000 lux or more) by window group. The daylight performance is categorized as "preferred" if 75% of the space meets $sDA_{300/50\%}$ and "nominally acceptable" at a 55% threshold. $ASE_{1000,250h}$

measures the potential for visual discomfort by identifying areas exposed to over 1,000 lux from direct sunlight for more than 250 hours annually, without factoring in the use of shades or blinds. Notably, it considers the same analysis period as sDA, covering 365 days of the year with a consistent 10-hour (8am to 6pm) duration per day. EN-17037 adapts its analysis period to climatic variations by selecting the 4,380 hours with the greatest diffuse horizontal illuminance in a climate file as its analysis period in contrast to LM-83. EN-17037 employs a tiered recommendation system for interior daylight levels, categorized into minimum, medium, and high levels. These categories are based on the percentage of an area achieving specific illuminance levels for at least 50% of daylight hours annually without the employment of shades and blinds:

- Minimum Recommendation: At least 50% of the area must achieve a target illuminance of 300 lux, with 95% of the area achieving at least 100 lux.
- Medium Recommendation: At least 50% of the area must achieve 500 lux, with 95% of the area reaching at least 300 lux.
- High Recommendation: At least 50% of the area should achieve 750 lux, with 95% of the area achieving no less than 500 lux.

Table 1: Daylight Recommendations for EN-17037.

	Minimum	Medium	High
Target Illuminance (lx)	300	500	750
Fraction of space for target level (%)	50	50	50
Minimum target Illuminance (lx)	100	300	500
Fraction of space for minimum target level (%)	95	95	95
Fraction of daylight hours (%)	50	50	50

Building Typology and Materials

Figure 1 presents three architectural models evaluated for daylighting performance. These designs were selected to cover a wide range of common office building types in Canada, with a particular focus on façade design and its impact on daylighting. The selection reflects diverse façade designs of office building environments in response to both climatic and lighting needs. The base case model features a fully glazed façade or curtain wall system which is a prevalent design in modern office buildings. Despite its popularity, this design is known to present challenges related to daylight, such as the potential for glare and excessive closure of operable window shades. Full glazing is favored for maximizing natural light penetration but requires careful integration of light control strategies to manage issues like glare and thermal discomfort. Option 1 is designed with daylight optimization in mind. This model incorporates faceted recessed windows to enhance daylight diffusion and reduce glare potential. This approach represents a more careful engagement with daylighting principles in façade design. Option 2 reflects the characteristics of a typical office building from the 1980s, this model has a window-to-wall ratio of approximately 40%. It serves as a benchmark for assessing daylighting strategies in older office buildings that may not have been originally designed with modern daylighting standards in mind. Additionally, a light urban context surrounds the office building designs as shown in Figure 2. Material properties for lighting simulation are detailed in Table 2 as suggested by Jakubiec (2023).

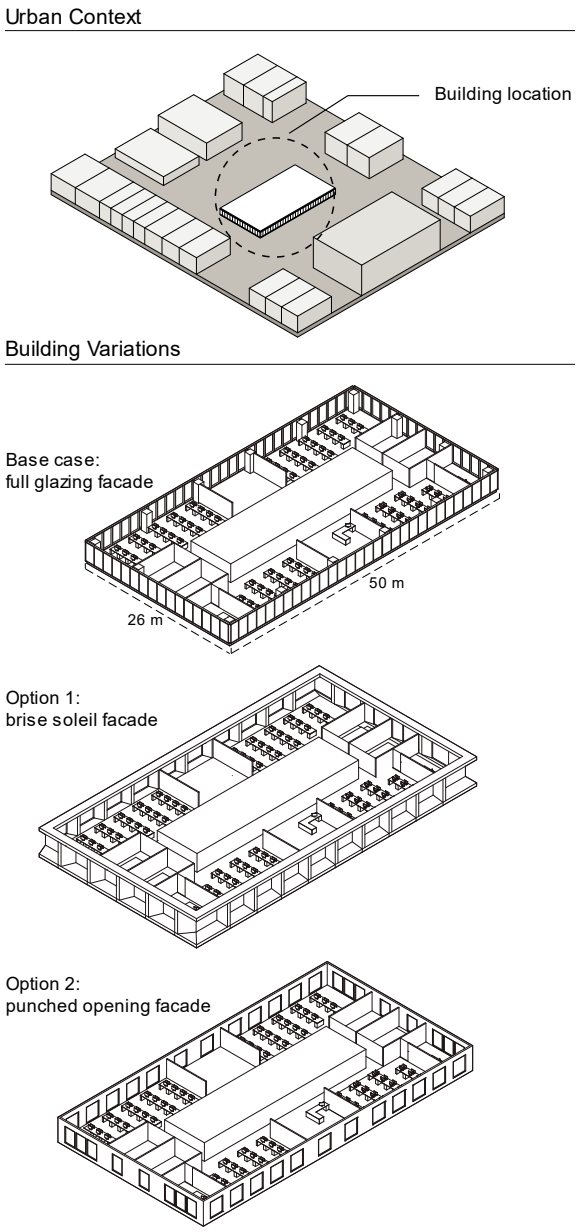

Figure 2: Diagram of modelled buildings.

Table 2: Material reflectance and transmission values used in daylight simulations.

Material	Reflectance (%)	Material	Reflectance (%)
Cladding	75%	Buildings	40%
Ceiling	85%	Ground	16%
Wall	84%		
Floor	85%		**Trans. (%)**
Desk	37%	Glazing	75%
Partition	84%	Roller Blinds	2.5%

Climate Locations

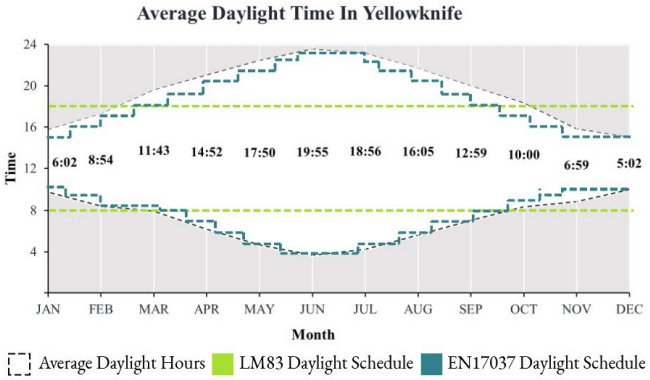

Figure 3: Comparison of average daylight time in Yellowknife against EN-17037 and LM-83 daylight schedules.

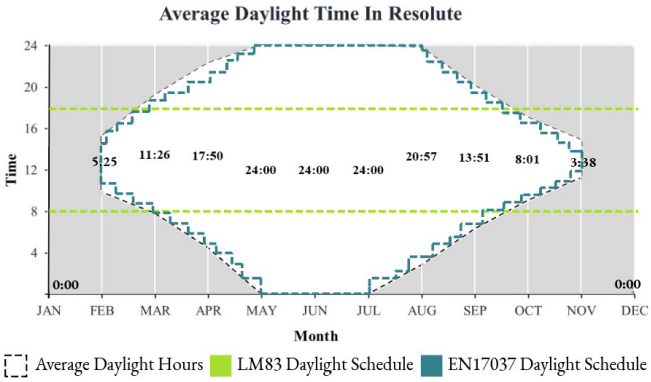

Figure 4: Comparison of average daylight time in Resolute against EN-17037 and LM-83 daylight schedules.

This study assesses daylighting across a spectrum of Canadian climates, specifically Toronto, Edmonton, Yellowknife and Resolute. These cities, with latitudes of 43.7°N, 53.5°N, 62.5°N and 74.6°N respectively, were chosen to illustrate Canada's latitude diversity. The selection emphasizes the challenges involved in applying daylighting standards consistently across the nation due to varying latitudes. Figures 3-4 depict the annual average daylight hours for extreme Canadian climates, Yellowknife and Resolute respectively. LM-83 and EN-17037 daylight schedules are highlighted in the figures to show how well the metrics align with actual daylight hours. Resolute differs considerably from LM-83's standard. Specifically, within LM-83's 8 am to 6 pm schedule, Toronto, Edmonton, Yellowknife, and Resolute experience 113, 243, 454, and 1192 hours of darkness, respectively. With its higher latitude, daylight hours fluctuate dramatically throughout the year, ranging from no daylight to 24 hours of daylight in Resolute (Government of Canada, 2024). This variability in daylight availability across different latitudes highlights the challenges of applying daylighting standards across Canada.

Simulation Tools

Daylighting simulations were performed using ClimateStudio, a climate-based daylight modeling (CBDM) interface that allows evaluation of luminous quantity using climate-based sun and sky conditions using Radiance (Ward, 1994). ClimateStudio's path-tracing method has been shown to produce low-error and consistent results (Santos et al., 2021). Simulations were performed using local airport climate data for each location, using typical meteorological year (TMYx, 2004-2018) datasets. A total of 2,358 sensors were placed in grids within each occupied area excepting the building core with a spacing of 0.60 m and a vertical floor offset of 0.76 m. Daylight was simulated using a six ambient bounce calculation in a method approximating the Radiance 5-phase annual calculation with 4,096 primary ray samples per sensor (Geisler-Moroder, Lee & Ward, 2016). The configuration of the modeling parameters adhered strictly to the guidelines established by the EN-17037 and LM-83 standards, as detailed in previous sections of this paper. For the LM-83 calculations, blinds were operated to avoid more than 2% of any space's floor area being covered with direct sunlight exceeding a 1,000 lx illuminance contribution from sunlight alone. The EN-17037 calculations were operated without blinds following common practice.

Results Processing

A Python script was developed to calculate the metrics for this research with the goal of adding additional daylight metrics to automate future analysis. Results per sensor, room, and building for compliance testing are output for analysis by the script.

Results

The evaluation of daylighting metrics EN-17037 and LM-83 within the Canadian context yielded four key sets of findings, each elucidating the adaptability and relevance of these metrics to diverse Canadian climates.

Comparison of Daylight Hours to Metric Schedules

Figures 3 and 4 compare the average daylight hours available in Yellowknife and Resolute with the daylight schedules recommended by EN-17037 and LM-83. It is evident from this comparison that EN-17037 offers a more realistic and adaptable schedule, aligning more closely with the actual daylight hours experienced across the four studied climates. Notably, EN-17037 accounts for significantly

fewer dark hours within its occupied hours within its occupied daylight schedule, as detailed below:

- Toronto: 2 dark hours
- Edmonton: 22 dark hours
- Yellowknife: 0 dark hours
- Resolute: 0 dark hours

The earliest and latest hour that falls in the EN-17037 analysis is:

- Toronto: 6 am and 9 pm
- Edmonton: 5 am and 10 pm
- Yellowknife: 4 am and 12 am
- Resolute: 12 am and 12 am

In contrast, LM-83's schedule reveals a distinctly higher incidence of dark hours during the analysis period schedule:

- Toronto: 113 hours
- Edmonton: 243 hours
- Yellowknife: 454 hours
- Resolute: 1192 hours

These findings suggest that EN-17037's scheduling encompasses a greater percentage of daylight hours in its assessment. LM-83's fixed schedule is less adaptable to extreme northern climates, particularly in cases like Resolute, where over 1000 hours of darkness are factored into daylight evaluations. This is a significant misalignment with actual daylight availability in Northern climates making the maximum achievable $sDA_{300/50\%}$ value 67.3% in Resolute while it is 96.9% in Toronto. In addition, a crucial aspect of LM-83's daylight evaluation is the operation of blinds and shades, designed to mitigate direct daylight exceeding an interior measurement of 1,000 lx due to direct sunlight alone. The metric's consideration of average closed shades hours reveals another layer of difference between climates:

- Toronto: 963 hours
- Edmonton: 995 hours
- Yellowknife: 721 hours
- Resolute: 371 hours

The closed shades hours reflect the metric's attempt to address glare but also illustrate a significant interaction between daylight availability and the necessity for shading, which varies considerably across different climates. The disparity in dark hours and the management of shades closed hours across climates emphasize the critical need for daylighting metrics that are both responsive and adaptable to the geographical and seasonal peculiarities of a location. EN-17037's performance indicates a closer approximation to real-world daylight conditions. However, the accuracy of EN-17037's assessment schedule compared to a realistic occupancy schedule is a separate matter. This is particularly evident when considering its ability to account for night lighting in places like Yellowknife and Resolute, which may not be relevant unless it involves shift work or other activities requiring nighttime operation. Conversely, the fixed schedule and the high number of closed shades hours in LM-83, especially in climates with extreme daylight variations like Canada, implies the limitations of a universal approach to daylight assessment.

Compliance with EN-17037 and LM-83 across Climates and Building Designs

Figures 5 through 7 depict the compliance rates of the three building designs under the EN-17037 and LM-83 standards across the selected climates. The results indicate a significant variability in the spaces meeting LM-83 compliance criteria across different climates and building types. The variability in sDA compliance highlights a noticeable decrease as one moves northward. Similarly, ASE compliance exhibits a decrease in glare issues as one moves north, attributed to the reduced daylight in sDA compliance.

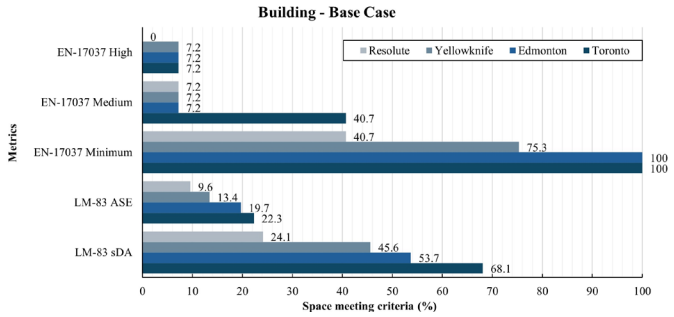

Figure 5: Comparison of results for base case building.

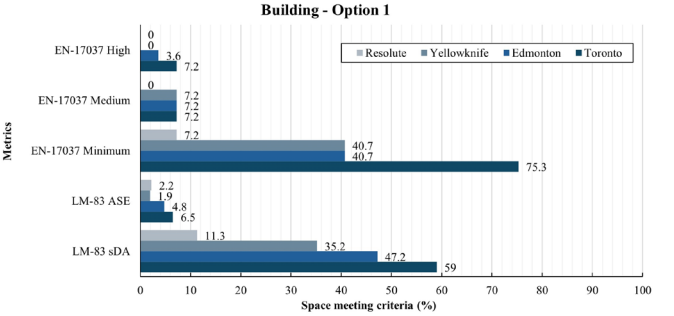

Figure 6: Comparison of results for option 1 building.

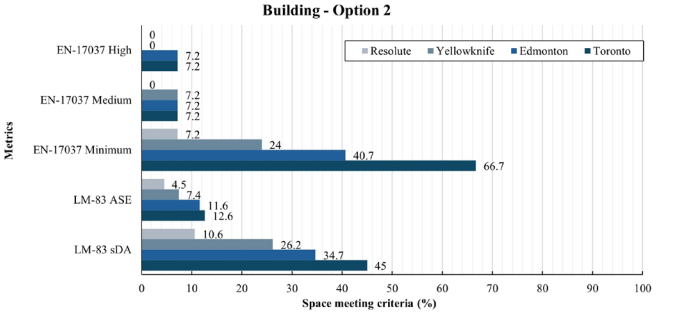

Figure 7: Comparison of results for option 2 building.

Recall from earlier discussions, LM-83 identifies the daylight performance "preferred" if 75% of the space meets $sDA_{300/50\%}$ and "nominally acceptable" at a 55% threshold. Even the fully glazed base case building did not meet the

"preferred" criterion in any climate, achieving only "nominally acceptable" status in Toronto for the base case and option 1 buildings.

The integration of LM-83 within the Leadership in Energy and Environmental Design (LEED) Standard's lighting criteria indicates the practical implications of these findings for design professionals seeking a building daylight certification. Under LEED version 4.1, daylighting performance contributes to LEED points based on the percentage of qualifying areas meeting the $sDA_{300/50\%}$ criteria as shown below:

- 1 point: ≥ 40% $sDA_{300/50\%}$
- 2 points: ≥ 55% $sDA_{300/50\%}$
- 3 points: ≥ 75% $sDA_{300/50\%}$

The same building type achieves varying LEED points based on its geographic location, as demonstrated in Table 3. In northern climates like Yellowknife and Resolute, it is challenging to achieve a high daylight performance according to LEED.

Table 3: LEED points achieved in different building types and climates.

	Base Case	Option 1	Option 2
Toronto	2 points	2 points	0 points
Edmonton	1 point	0 points	0 points
Yellowknife	1 point	0 points	0 points
Resolute	0 points	0 points	0 points

Conversely, EN-17037 is more consistent in achieving its minimum, medium, and high daylighting criteria compared to LM-83. This uniformity is particularly evident in the medium and high categories, where an identical percentage of the building space fulfils the daylighting criteria across the varied climates. This phenomenon can be attributed to EN-17037's climate-responsive scheduling, which enables a more equitable assessment of buildings in diverse climatic conditions and its rigid daylight classification of rooms. Similarly to findings under the LM-83 method, a downward trend in compliance with the minimum recommendation is still observed as one progresses northward. This pattern aligns with expectations due to both metrics requiring 300 lux across 50% of the space for their respective daylight recommendations. Furthermore, it becomes evident that EN-17037's minimum recommendations were met in three climates (Toronto, Edmonton, and Yellowknife) in the base case scenario, which features a fully glazed design. This suggests two possible interpretations: firstly, the criteria for medium and high recommendations may be excessively stringent for northern climates; secondly, EN-17037's assessment methods—predicated on a binary evaluation of daylight presence over a 50% time threshold—imposes a rigid spatial unit of compliance where each room is either fully daylit or not. In contrast, LM-83 adopts a more granular approach by assessing daylight on an area or sensor basis, considering the proportion of each room and the entire building that meets the criteria (visualized in Figure 8). This methodological divergence renders EN-17037's standards comparatively more difficult, as it designates spaces as either daylit or not based solely on the time-based threshold, without the partial room analysis permitted by LM-83. Such a stringent approach to defining compliance highlights the inherent challenges and potential limitations of EN-17037 in accommodating the nuanced dynamics of daylight performance across spaces in varying architectural and climatic contexts.

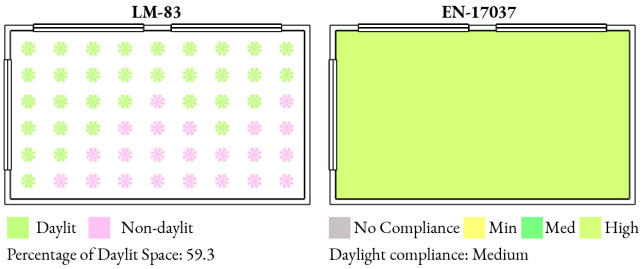

Figure 8: Conceptual diagram showing the different analysis methods in LM-83 and EN-17037.

Spatial Daylight Analysis in the Base Case Building

Figure 9 illustrates the spatial daylight performance within the base case across four Canadian climates, contrasting the results against the LM-83 and EN-17037 standards. The choice to focus on the base case is due to its full glazing properties, which amplifies daylighting effects and thus serves as a more discernible subject for evaluating the data. The spatial diagrams from LM-83 indicate a notable reduction in both sunlight exposure and mean illuminance as one proceeds from Toronto to Resolute. This gradient reveals a consistent decrease in spaces meeting the daylight autonomy criteria towards higher latitudes, in line with the predicted decline in daylight hours. This latitudinal dependency highlights the potential challenges in LM-83's application to geographically diverse conditions as previously discussed. In contrast, EN-17037's assessment across the daylight autonomy levels of 300 lux, 500 lux, and 750 lux demonstrates a less pronounced decline in compliance as latitude increases. All four cities exhibit a relatively higher compliance at the 300-lux level, but higher thresholds witness a decline. Intriguingly, this diminishment is milder compared to the more marked falloff observed in LM-83's spatial daylight autonomy. Such a pattern suggests that EN-17037 may present a more stable performance benchmark in environments with substantial latitudinal daylight variation.

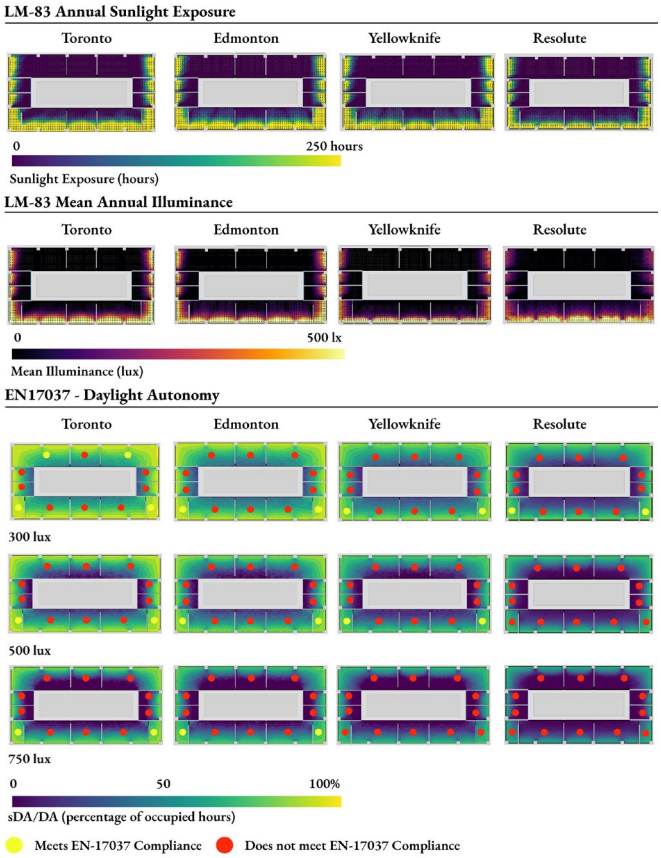

Figure 9: Comparison of spatial results for LM- 83 and EN-17037 across four climates.

Orientation Analysis in the Base Case Building

Figures 10 and 11 compare the building orientation results against the LM-83 and EN-17037 standards in the two extreme climates studied: the northernmost and southernmost locations. As mentioned before, the focus on the base case is deliberate to amplify daylighting effects, making it a more discernible subject for evaluation. The results indicate a notable reduction in compliance levels for both metrics as the location shifts from Toronto to Resolute. This trend reflects a consistent decrease in spaces meeting daylight criteria at higher latitudes, aligning with the predicted decline in daylight hours caused by more pronounced seasonal variations in northern regions. For LM-83, the North and East orientations demonstrate the highest compliance levels, whereas for EN-17037, the North and South orientations exhibit the highest compliance levels. The disparity highlights differences in how the two metrics assess daylight performance. This difference can be attributed to LM-83's misalignment with actual daylight availability in northern climates. As previously noted, the maximum achievable $sDA_{300/50\%}$ value 67.3% in Resolute, compared to 96.9% in Toronto. Furthermore, a key factor is the inclusion of blinds in LM-83's analysis, which contrasts with EN-17037 that does not consider blind usage. This difference is evident in the reduced compliance percentages on the southern façade in LM-83's $sDA_{300/50\%}$ results, where blinds are used to mitigate excessive daylight. For example, in both climates, the percentage of space meeting $ASE_{1000,250h}$ is higher than $sDA_{300/50\%}$, particularly in Resolute, where a zero percent $sDA_{300/50\%}$ value corresponds to over twenty percent in $ASE_{1000,250h}$. This variation occurs because $ASE_{1000,250h}$ does not account for the use of blinds and shades, resulting in higher values due to the direct exposure to daylight. Specifically, in Resolute's Southern room, the mean $sDA_{300/50\%}$, and mean DA_{300} are 21.3 lx and 52.9 lx respectively, with DA_{300} assessed without blinds. This significant difference highlights the impact of blinds or shades on daylight quality assessment. The implication of this operational difference is profound; it accentuates the role of dynamic shading in achieving daylighting benchmarks and highlights a limitation in LM-83's approach where the use of blinds can lead to a considerable portion of the space not meeting the set criteria.

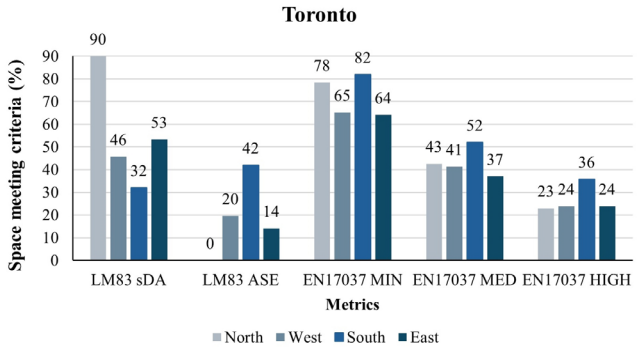

Figure 10: Comparison of orientation results for LM- 83 and EN-17037 for Toronto.

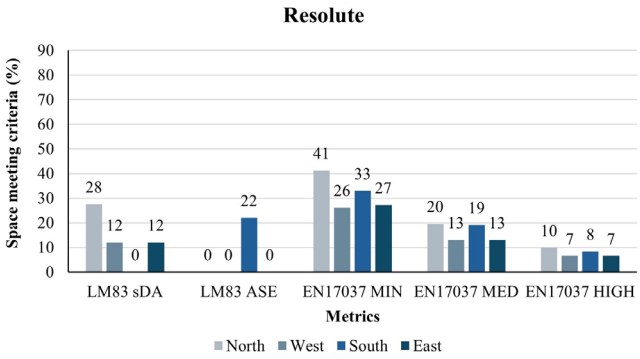

Figure 11: Comparison of orientation results for LM- 83 and EN-17037 for Resolute.

Discussion

The comparative analysis of daylight metrics within the Canadian context has yielded helpful insights into the suitability of EN-17037 and LM-83, particularly when juxtaposed with the diverse geographic and climatic conditions of Canada. The evidence suggests that EN-17037's schedule aligns more closely with the actual daylight hours, reducing the number of dark hours within its operational period. This responsiveness renders it a more

adaptable standard, especially in climates with extended periods of daylight typical of northern latitudes. However, the study also uncovers a paradox within EN-17037's approach. While it successfully accounts for longer daylight hours, it inadvertently includes hours that occur during the biological night in places like Yellowknife. This is particularly significant as daylight is not typically harnessed for occupational activities during periods when people are regularly asleep. This leads one to question the practicality of such a schedule in northern contexts where, despite the abundance of light, the 'useful' daylight hours may not coincide with standard working hours. While LM-83's fixed schedule may not accurately reflect the true daylight hours, it could be argued that it holds greater significance and utility as it aligns with the hours when occupants are typically present. Furthermore, LM-83's methodology, with its strict requirement on blinds, delves into the idea of the occupant experience. The absence of blinds in EN-17037's assessment may overlook the practical aspect of daylight utilization and visual comfort within spaces. This divergence raises critical questions about the role and operationalization of shading in daylight metrics and whether a balance can be struck that more accurately reflects true occupant experiences.

Another significant finding from this study is the challenge of meeting EN-17037's and LM-83's higher daylight recommendations. The stringent nature of these criteria, as demonstrated even by fully glazed buildings in Toronto, prompts a re-evaluation of the standard's applicability to North American climates. EN-17037's binary assessment of room daylight compliance stands in contrast to LM-83's area-based evaluation, offering a partial room analysis. This strict dichotomy may not adequately capture the nuanced daylighting needs of diverse spaces, suggesting that the EN-17037 standard might benefit from incorporating more granularity in its compliance criteria.

These reflections culminate in the imperative to develop an improved daylighting metric that can harmonize daylight availability with actual occupancy. A prospective metric should ideally consider both daylight hours and occupancy periods, ensuring that the assessment of daylight performance is relevant to when spaces are actively in use, and it is possible to daylight them depending on climate-specific outdoor light availability. Such a metric could integrate aspects from both LM-83 and EN-17037, combining EN-17037's adaptability to geographic conditions with LM-83's practical user occupancy schedule considerations. For instance, an adaptive metric might employ a flexible schedule that adjusts to both seasonal daylight variations and typical occupancy patterns, ensuring the assessment is sensitive to the times when daylight can be most beneficial. This could involve a dynamic schedule that responds to both the intensity of daylight and the specific requirements of occupancy. Figure 10 illustrates such a schedule that responds to both the occupancy schedule of a typical office set by LM-83 and the most daylight hours defined by EN-17037. In effect, Figure 11 illustrates a Boolean union of the LM-83 and EN-17037 schedules which eliminates dark hours from being included in occupancy schedules. This resulting schedule for Toronto includes 3537 daylit hours, for Edmonton 3410 daylit hours, for Yellowknife 3184 daylit hours and for Resolute 2443 hours. Figure 11 illustrates the variance in DA_{300} results across the four studied climates, comparing the new proposed schedule with the schedule defined by LM-83. Evidently, the new combined daylight schedule produced more consistent results across the four different climates. While these schedules are different, they represent the potential for daylighting in a fair manner across the four climates.

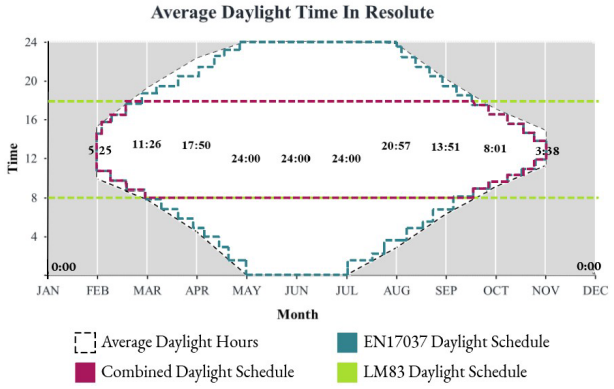

Figure 10: Comparison of proposed and LM-83 daylight schedules in Resolute.

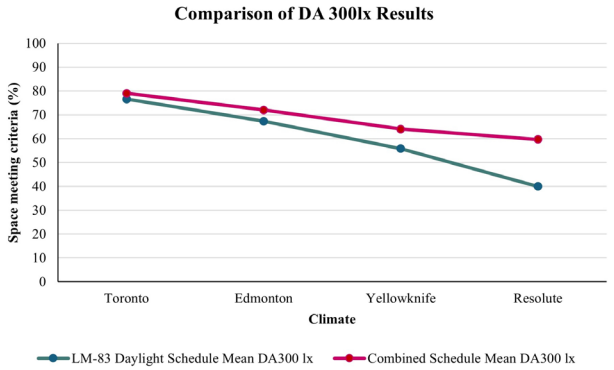

Figure 11: Comparison of proposed and LM-83 daylight schedules for DA_{300} results in Resolute.

The proposed daylighting schedule aims to address the limitations of occupancy schedules that do not account for climate-induced daylight variations. The inherent challenge in applying these standard schedules is their inclusion of dark hours in the assessment. This has led to the realization that no architectural design, irrespective of its ingenuity, can compensate for the disadvantage imposed by a high incidence of dark hours within the daylighting evaluation period. Consequently, the development of a responsive schedule that adapts to both occupancy patterns and the actual quantity of daylight becomes critical. By integrating these two factors, the schedule can accurately reflect the

usable daylight within occupied spaces and ensure that the assessment of daylight performance is relevant and practical.

Conclusion

This study highlights the complexities of applying global daylighting standards to a country as climatically varied as Canada. This research systematically assessed the suitability of these metrics through a comparative analysis of three building designs in Toronto, Edmonton, Yellowknife and Resolute, uncovering that EN-17037 offers a more adaptable framework, closely aligning with the actual daylight hours experienced across these diverse climates. Conversely, LM-83's standard analysis period fails to accommodate the extensive dark hours inherent to far northern latitudes, casting doubt on its effectiveness in such unique conditions. This study brought to light the implications of EN-17037's inclusivity of nighttime hours, a non-utilitarian aspect in conventional daylighting practices, and LM-83's more practical analysis period. The latter opens a discourse on how metric schedules can align with the hours when occupants are typically present and simultaneously respond to climate challenges. The findings also emphasized the rigorousness of EN-17037's compliance thresholds, with even fully glazed buildings in sunnier climates struggling to meet more than the minimum requirements. This prompts a re-evaluation of the medium and high recommendations within North American climates and suggests the potential for refining EN-17037 to reflect a more nuanced understanding of daylight utility. Reflecting upon these findings, it becomes clear that there is an imperative for a more adaptive metric—one that bridges the gap between daylight availability and occupancy. A metric that is attuned not only to the quantity of daylight but also to its quality and relevance to the occupants' schedules. The envisioned metric would dynamically integrate both occupancy schedules of LM-83 and top daylight hours of EN-17037. In conclusion, this investigation highlights the need for further innovation in daylighting metrics, advocating for the development of standards that are responsive to the intricate tapestry of geographic and climatic conditions.

Future Work / Limitations

- Model Specificity: The simulations relied on specific architectural models and material properties, which may not capture the full range of building types and materials present across Canada. The findings may thus be limited in their generalizability to other designs and material compositions.
- Blinds: The study has identified the operational frequency of blinds as a potential variable in daylighting assessments, particularly in northern urban contexts. The impact of this variable on daylighting metrics represents a subject for future research.
- Different programs: The research highlighted the standard daylight analysis period, which may not adequately represent the complexity of shift work and seasonal occupations, especially in northern climates with greater daylight variability. Future research should investigate how daylighting standards could be adapted to account for these diverse programmatic needs.

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