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POSTGRADUATE PROGRAM OF THE FACULTY OF ARCHITECTURE AND URBANISM – PPG FAU UnB

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DAYLIGHT REQUIREMENTS:

an international overview and assessment of the feasibility of global harmonization

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Work presented to the University of Brasília (UnB) Examining Board as a requirement to obtain the title of Master in Architecture and Urbanism.

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“In a dark place we find ourselves, and a little more knowledge lights our way.”

"Em um lugar escuro estamos nós, e um pouco mais de conhecimento ilumina nosso caminho."

(Yoda, Star Wars)

Abstract

Daylight has always been part of the architectural practice, seen nowadays as key strategy for sustainability, energy efficiency and resilience in buildings. In this context, it is vital to verify how daylight is approached in reference documents — that base and guide practice, as Standards, Rating Systems, Building and Urban Codes, Regulations and Guidelines. Recommendations are made by daylight requirements, which are composed by metrics — a way to evaluate something through a combination of representative conditions — and parameters — a limit or numerical value. This research aims to investigate daylight requirements and their application in reference documents, to assess the feasibility of the requirements' harmonization at a global scale. For that, the steps fulfilled are: a systematic literature review; a collection of primary reference documents; a survey application to daylight specialists from different countries; analysis of primary documents; a categorization of the requirements and metrics found; and an analysis of the data with a climatic focus. Results show that mandatory documents are, in most of the countries, Building and Urban Codes and Regulations and in some cases also Standards. Non-geometric metrics are common within Standards and Rating Systems, while Building and Urban Codes and Regulations use more often the geometric/design metrics. In Guidelines, both types can be used, depending on the focus of the document. A categorization scheme was created for requirements and metrics, according to the subject: on one side, non-visual effects; on the other, visual effects were divided into daylight provision, sunlight access, glare control and assessment of views out. As for metrics, they are divided into non-geometric, with static and dynamic metrics; and geometric, with metrics related to building and urban forms. Among non-visual effects, metrics are divided into melanopic effects and melatonin suppression. Some of the most used metrics are Daylight Factor (DF), Window-to-Floor Ratio (WFR), Window sizes, Daylight Glare Probability (DGP). Non-visual metrics are not yet embodied in reference documents. Besides, further investigation is necessary to deepen the harmonization process and to connect better non-geometric and geometric metrics.

Keywords: Daylight requirements; Standards; Rating Systems; Building and urban codes; Regulations; Guidelines.

Requerimentos de iluminação natural: panorama internacional e avaliação da viabilidade de harmonização global

Resumo

A luz natural é parte da prática arquitetônica, vista atualmente como estratégia-chave para sustentabilidade, eficiência energética e resiliência em edificações. Nesse contexto, é essencial verificar como a luz natural é abordada em documentos de referência — que baseiam e guiam a prática, como Normas, Certificações, Códigos de Obras, Regulamentos e Manuais de Projeto. As recomendações são feitas pelos requerimentos de luz natural, compostos por métricas — que são uma forma de avaliação com base em condições representativas — e por parâmetros — limites ou valores numéricos. A pesquisa busca investigar os requerimentos de luz natural, de maneira a avaliar a viabilidade de harmonização a nível global. Para tal, as etapas realizadas foram: revisão sistemática de literatura; coleta de documentos de referência primários; aplicação de questionário com especialistas em luz natural de diferentes países; análise dos documentos primários; categorização dos requerimentos e métricas coletados; e análise dos dados segundo o contexto climático. Os resultados demonstram que, na maioria dos países, os documentos obrigatórios são os Códigos de Obras e os Regulamentos. As métricas não geométricas são comuns em Normas e Certificações, enquanto os Códigos de Obras e Regulamentos usam as métricas geométricas. Nos Manuais de Projeto podem aparecer ambos, a depender do foco do documento. Foi feita a categorização de requerimentos e métricas, dividida em: efeitos não visuais; e efeitos visuais, divididos entre provisão de luz natural, exposição à luz do sol, controle de ofuscamento e acesso a vistas externas. Já as métricas foram divididas entre não geométricas estáticas e dinâmicas; e geométricas, que se referem às formas urbanas e edilícias. Nos efeitos não visuais, as métricas se dividem entre sensibilidade melanópica e supressão de melatonina. Algumas das métricas mais usadas são Fator de Luz Diurna (DF), Percentual de abertura em relação ao piso (WFR), Dimensões de janelas, Probabilidade de Ofuscamento por Luz Natural (DGP). Métricas de efeitos não visuais ainda não foram incorporadas nos documentos, e é necessária maior investigação para aprofundar a harmonização, bem como para conectar métricas não geométricas às geométricas.

Palavras-chave: Requerimentos de luz natural; Normas; Certificações; Códigos de Edificações e Obras; Regulamentações; Manuais de projeto.

Figures

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Acronyms

ABNT

Associação Brasileira de Normas Técnicas (Brazilian Association for Technical Standards)

AQUA

Alta Qualidade Ambiental (High Environmental Quality)

ASHRAE

American Society of Heating, Refrigerating and Air-Conditioning Engineers

BCA

Building Construction Authority

BRE

Building Research Establishment

BREEAM

Building Research Establishment Environmental Assessment Method

CASBEE

Comprehensive Assessment System for Built Environment Efficiency

CEN

Comité Européen de Normalisation

CES

Certificación de Edificio Sustentable (Certification for Sustainable Buildings)

CIBSE

Chartered Institution of Building Services Engineers

CIE

Commission Internationale de l'Eclairage

CVS

Certificación de Vivienda Sustentable (Certification for Sustainable Housing)

CBDM

Climate-based Daylight Modelling

EN

European Norm

HQE

Haute Qualité Environnementale (High Environmental Quality)

IESNA

Illuminating Engineering Society of North America

IWBI

International WELL Building Institute

JSBC

Japan Sustainable Building Consortium

LEED

Leadership in Energy and Environmental Design

LM

Lighting Measurements

SLL

Society of Light and Lighting

TC

Technical Committee

USGBC

United States Green Building Council

Glossary

GHG

Greenhouse Gases

HVAC

Heating, ventilating and air conditioning

ipRGCs

Intrinsically photosensitive retinal ganglion cells

NIF

Non-image forming effects of light

Contents

1. Introduction

Daylight is essential in human life in many aspects (FATHY et al., 2020; TREGENZA; WILSON, 2011). As it has always been present during mankind development, exposure to daylight shaped human cycles along days, years and centuries (HRAŠKA; ČURPEK, 2024; KNOOP et al., 2020; TREGENZA; MARDALJEVIC, 2018; TREGENZA; WILSON, 2011). Daylight is the combination of direct sunlight with the diffuse radiation provided by skylight. Highly dynamic along days, different weather conditions, seasons and years, regular exposure to daylight provides humans visual and non-visual effects (KNOOP et al., 2020) that shape people's routines, reality comprehension and ways of life.

The visual effects of daylight refer to visibility itself: the human eye is stimulated by the spectrum of daylight, providing the perception of colour, textures, contrast, perspective, etc. Consequently, daylight is one of the main ways to perceive spaces, objects and reality itself (BELLIA; FRAGLIASSO, 2017; FATHY et al., 2020; KNOOP et al., 2020; LI et al., 2017). Insufficient daylight also has consequences: during children's and teenagers' growth, low exposure to daylight may cause myopia and other visual issues, while a richer exposure can reduce visual impairments (KNOOP et al., 2020; MARDALJEVIC, 2021).

Since the 2000s, when a third photoreceptor responsible for non-image forming (NIF) effects of light have been discovered in human eye — the intrinsically photosensitive retinal ganglion cells (ipRGCs) — research about non-visual effects of daylight has increased. The ipRGCs are capable of "converting" light stimuli into neural and chemical reactions important to human metabolism, with influence over production of hormones, improvement of physical and mental health, well-being maintenance, regulation of sleep routine, alertness, productivity, etc (FIGUEIRO; GONZALES; PEDLER, 2016; HOUSER et al., 2021; TREGENZA; WILSON, 2011). Today, there are plenty of evidence within scientific research in medical, biological and architectural areas of the benefits of daylight for health, psychological and physiological wellbeing (HRAŠKA; ČURPEK, 2024; SEPÚLVEDA et al., 2020).

Daylight and daylighting are different. Daylight is the phenomenon of sun rays providing visibility through reflection in surfaces to human eyes (TREGENZA; WILSON, 2011), while daylighting is the act to design spaces considering the behaviour of daylight through openings, glazed or not, that allow daylight indoors. Daylighting was always part of architecture, as it allows architects to define spaces with different sensorial experiences, interesting angles, highlight different objects and details (HRAŠKA; ČURPEK, 2024; TREGENZA; WILSON, 2011).

After almost two centuries where electric light was developed really quickly, the consequences of low exposure due to unavailability of daylight in buildings became evident (MARDALJEVIC; CHRISTOFFERSEN, 2017). Moreover, despite the ease of access to electric light, evidence shows that daylight has a better quality and spectrum; the same visual task can be developed with much less daylight, when compared to electric light; the occupants prefer daylight in indoor spaces; and that the use of the newest technologies, alone, is not enough to guarantee good visual quality, well-being of occupants and energy efficiency (BOUBEKRI, 2008; GENTILE et al., 2022; KNOOP et al., 2020; TURAN et al., 2020). Thus, with the increasing attention over sustainability and energy efficiency in buildings, daylight presence has been more and more considered a key strategy to reduce greenhouse gases (GHG) emissions and promote healthier spaces (KRUISSELBRINK; DANGOL; ROSEMANN, 2018; LO VERSO et al., 2021a; MARDALJEVIC; CHRISTOFFERSEN, 2017; TURAN et al., 2020).

However, design considering daylight is a complex activity. In order to capture daylight indoors, there has to be available natural light, which depends on how much the climate, the site and the surroundings allow access to sky dome and penetration of sunlight rays (BOUBEKRI, 2008; MARDALJEVIC; CHRISTOFFERSEN, 2017). Beyond that, designing with daylight requires a wide comprehension of how daylight strategies affect occupants, which is not always clear, neither during professional education in architecture courses, nor in practical experience (KRUISSELBRINK; DANGOL; ROSEMANN, 2018; LO VERSO et al., 2021a, 2021b; SOKÓŁ, 2019). Also, few building construction legislations have mandatory daylight demands (BOUBEKRI, 2008).

In architectural activities, there is a series of documents that guide practitioners. Generally, these documents contain goals and objectives to be complied in buildings and urban spaces, according to the local culture, climate, social reality, economic feasibility, as well as occupants' and spaces' demands (BOUBEKRI, 2008). There is an enormous quantity of possible reference documents for practitioners in each region, country, district, or city.

As it is really hard to embrace absolutely all existing documents that may concern daylight in built environment, in this research, were chosen as focus the standards, the rating systems, the building and urban codes, the regulations, and the guidelines (CIE; TC 3-61, 2021). These reference documents are used by architects, urban planners, professional's associations, company managers, government policy makers and the building construction industry — which are some of the many actors involved in building design and construction. In that context, the requirements started to figure in reference documents as way to embrace the demands linked to daylight in the built environment.

Even though there were significant progresses and well-developed proposals about daylight requirements in reference documents, there is still a lack of consistency in recommendations and problems in comprehension of concepts (LO VERSO et al., 2021a, 2021b; TREGENZA; MARDALJEVIC, 2018). This lack of consensus evidences a theoretical flaw, defying professionals to work with many diverse criteria and hindering the embodying of daylight into projects in a consistent way (TREGENZA; MARDALJEVIC, 2018). Ultimately, this induces professionals to rely mostly on previous works experiences and on an average knowledge about simulation tools in order to design buildings with proper daylight levels, or even to assess the benefits sought (SOKÓŁ, 2019).

Hence, it is paramount to acknowledge the application of daylight requirements in reference documents, in order to verify the possibility to harmonize their use in an international level (CIE; TC 3-61, 2021). Requirements, in this context, are composed by parameters and metrics, that must be accurate enough to evaluate the behaviour of the project's features (SOKÓŁ, 2019).

A possible harmonization of daylight requirements could provide greater coordination and diffusion of design techniques and goals related to daylight in the built environment. This comprehends environmental, social and technological benefits that can answer the difficulties of both researchers and professionals about how to use daylight more efficiently through the right tools, looking for the better results according to human needs and promoting eco-friendly daylight focused solutions for buildings (CIE; TC 3-61, 2021).

The main stakeholders involved and who could benefit from the harmonization are the professionals involved in building and urban design (architects, urbanists, designers, engineers, lighting designers), the industry through the right products (glazing, façade components, shadowing devices), policy makers that elaborate reference documents for professional practice (standards, local codes, laws and regulations, rating systems and other certification schemes) as well as researchers, scientists and students, whose focus regarding daylighting could be better targeted and the daylighting education better-founded (CIE; TC 3-61, 2021).

This dissertation is part with the research developed by the *Commission Internationale de l'Eclairage* – CIE, Division 3, "Interior environment and lighting design". Specifically, this work is developed within the CIE Technical Committee 3-61 (CIE; TC 3-61, 2021), which aims to assess the feasibility of global harmonization of daylight requirements.

1.1.Aim of the Study

The aim of this research is to investigate daylight requirements and their application in reference documents — standards, rating systems, regulations, building and urban codes, and guidelines — as a global overview to assess the feasibility of the requirements' harmonization.

1.2. Specific aims

a. Explore the types of daylight requirements and metrics found in literature and reference documents collected from different countries worldwide;

b. Analyse the documents collected as to their type, the kind of requirements found, the metrics used and application aspects;

c. Investigate if the use of daylight requirements and metrics in documents follows any criteria related to climatic features;

d. Develop recommendations and pathways towards the harmonization of daylight requirements.

2. Daylight requirements: definitions and history

The major part of decisions about daylight quantity and quality, visual comfort, energy savings, outside views, heat loads, and human satisfaction are made in the beginning of the design process (SOKÓŁ, 2019). Both quantity and quality of lighting can be assessed or recommended by several indicators and, according to the goals of the design, those indicators can be independent or not (MONTEOLIVA; VILLALBA; PATTINI, 2018).

The indicators that can guide the design process are considered the requirements. “Requirement” is something demanded or obligatory, a need or necessity (DICTIONARY LLC, 2023). In this context, it is something indispensable for the building adequate performance — e.g., daylight. The “metric” is a way to measure or evaluate something, with the use of figures or statistics (DICTIONARY LLC, 2023). “Metric” also refers to a mathematical combination of quantities, dimensions, and representative conditions in a scale. The best metrics are the ones with an intuitive meaning to designers (MARDALJEVIC; HESCHONG; LEE, 2009; TREGENZA; WILSON, 2011). A “parameter” is a limit, or a boundary, that acts as guideline for an activity or a policy; therefore, it is a factor that enables judgement or evaluation of something (DICTIONARY LLC, 2023) — e.g., a numerical value.

Regarding building performance, the definitions of requirements, metrics and parameters are similar, since they allow to evaluate buildings, define performance levels, and serve as a foundation for decision-making (BIAN; MA, 2017; MARDALJEVIC; HESCHONG; LEE, 2009). Requirements influence directly on building and urban design features, strategies and decisions, since those are important references for practitioners and should always be part of the building design practice and educational curricula (SOKÓŁ, 2019). Nevertheless, for their use to be effective in architectural practice, requirements have to be objective, simple, testable, consistent and replicable, able to give robust and reliable results (TREGENZA; WILSON, 2011). Also, requirements must be present in reference documents and legislations, in order to avoid poor design decisions and to demand good performance of architecture features.

Even considering the discussions, it is not clear how these requirements could lead to adjustments in design practice, or if daylight metrics incorporation in standards, rating systems, building and urban codes, regulations and guidelines would really have the sought result — i.e., the criteria compliance in projects focused on daylight quality indoors, and not only to achieve points in certification (TREGENZA; MARDALJEVIC, 2018).

As a consequence of the lack of harmonization of daylight requirements, there are a lot of systems, indicators and rankings proposed. Each one has its own organization, using metrics and parameters in different ways (MONTEOLIVA; VILLALBA; PATTINI, 2018; SOKÓŁ, 2019). According to some authors, overviews about daylight legislations show that there are several possible requirements. According to literature analysis, the following requirements are the most frequently found (BOUBEKRI, 2008; CZACHURA et al., 2022; SOKÓŁ, 2019; TREGENZA; WILSON, 2011):

- provision and distribution of daylight;
- availability of sunlight indoors;
- quality of views out;
- prevention of glare; and
- non-visual effects.

Metrics basically combine a series of features: a presentation (with a visual or numerical representation), a function (comparative, conforming or quantifying) and characterization (through values, time constraints or normalisation) (CZACHURA et al., 2022). However, this classification can vary according to different authors, so, it is not yet fully consolidated.

In literature, daylight metrics are the main focus of recent studies, with the aim to inform, integrate and evaluate daylighting in the built environment, through calculations, simulations and measurements since the earlier design stages (DIAS et al., 2018; KRUISSELBRINK; DANGOL; ROSEMANN, 2018; MARDALJEVIC; HESCHONG; LEE, 2009; SOKÓŁ, 2019; WEI et al., 2020). Over the years, there has been a clear and important evolution of metrics, their concepts, calculations and measurement techniques. In that time, new metrics have been created, with increasing complexity, especially with the multiple possibilities of computer-based calculations.

2.1. A panorama of static and dynamic daylight metrics

Tregenza and Mardaljevic (2018) describe the way daylighting was perceived historically. According to the authors, one of the first recommendations concerning daylight occurred in Ancient Greece, with Socrates. Four centuries later, Vitruvius recommends proper daylight in built spaces, according to the visible sky portion through façade openings.

Further on, in Justinian Era (about 529-565 A.D.), discussions emerged about daylight rights: The Justinian Code had recommendations about sunlight potential, skylight provision and, for the first time, there was a distinction between illumination and external views — where the view out could be achieved from a low opening, while daylight needed openings that could capture some portion of sky dome (HRAŠKA; ČURPEK, 2024; TREGENZA; MARDALJEVIC, 2018). That was only the beginning of daylight requirements. Later, daylight became more and more a vital part of the design practice, turning into a tradition and intrinsic knowledge within each region, its' climate, and its' traditional architecture (TREGENZA; MARDALJEVIC, 2018).

Later on, the 1832 Prescription Act in the UK settled the notions of *Right to Light* (TREGENZA; MARDALJEVIC, 2018). A Right to Light was established to an owner of a building when one or more windows have enjoyed provision of daylighting for 20 years or more, without interruptions (MARDALJEVIC, 2021). That means that any form of "threat" to those daylighting conditions could result on an injunction to eventually prevent a new construction or other modifications that could reduce the daylight provision to that building and its' owner (MARDALJEVIC, 2021). This rule remains on application in the UK, given the existence of Right to Light recommendations until nowadays (GREAT BRITAIN LAW COMMISSION, 2014).

For the Right to Light Law, the main metric remains to be the Sky Factor (SF), which is defined as the ratio of the illumination on a horizontal surface at a point in space, to the unobstructed external horizontal illumination, usually expressed as a percentage, and it was the main basis to "Right to Light" regulations in the UK, which aimed to guarantee daylighting indoors and prevent excessively dull spaces by controlling the interactions between buildings and their surroundings (MARDALJEVIC, 2021; TREGENZA; MARDALJEVIC, 2018).

In the 20th century, more daylight metrics were created, after many scientific studies (AYOUB, 2019; BELLIA; FRAGLIASSO; STEFANIZZI, 2017). Daylight Factor (DF) was the main metric, defined as the ratio of the internal horizontal illuminance to the unobstructed external horizontal illuminance (AYOUB, 2019; MARDALJEVIC, 2021; TREGENZA; MARDALJEVIC, 2018). In literature, there are some inconsistencies about which one was the first static daylight metric: Daylight Factor (DF) or Sky Factor (SF) (AYOUB, 2019; MARDALJEVIC, 2021). Regardless of the chronological imprecisions, SF and DF have similarities and differences that commonly lead to the conclusion that DF is an evolution of SF (MARDALJEVIC, 2021).

DF and SF are considered the first *static metrics*[1]. Static metrics take into account point-in-time illuminances under a single sky condition, despise seasonal, geographical and building geometry constraints and were traditionally calculated by tables and two-dimensional drawings (AYOUB, 2019; MARDALJEVIC, 2021; REINHART; MARDALJEVIC; ROGERS, 2006; SOKÓŁ, 2019).

Both SF and DF consider only diffuse daylight, without influence of the geographical orientation of openings, and of regional and climatic differences (MARDALJEVIC, 2021). The two metrics have also their differences: opposite to SF, DF admits as components the external and internal luminance values (i.e., the light reflections of external and internal surfaces) and possible reductions in external illuminance caused by surfaces and shading (MARDALJEVIC, 2021; REINHART; MARDALJEVIC; ROGERS, 2006; TREGENZA; MARDALJEVIC, 2018). As other example of static metric, there is Skyview Factor (SVF), used in assessments of urban canyons or as a component of DF (AYOUB, 2019; MARDALJEVIC, 2021; SHAFAVI; TAHSILDOOST; ZOMORODIAN, 2020).

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[1] Static metrics capture only instantaneous illumination scenarios, with fixed and particular sky conditions (MARDALJEVIC, 2006; REINHART; MARDALJEVIC; ROGERS, 2006).

The major limitations involved in calculations of DF and other static metrics are the too general recommendations — which do not embody façade orientations, location, time of day and year, and weather variance. Also, static metrics do not evaluate variables associated with sunlight and, consequently, with glare[2] and how to avoid it (MARDALJEVIC; HESCHONG; LEE, 2009; REINHART; MARDALJEVIC; ROGERS, 2006). However, there are also static metrics regarding glare: CIE Glare Index (CGI), Daylight Glare Index (DGI), and Visual Comfort Probability (VCP) (MAHIĆ et al., 2017; TZEMPELIKOS; CHAN, 2016), which are identified with the same limitations of DF (AYOUB, 2019).

In 1983, Daylight Coefficient (DC) was developed and expressed the ratio between the external luminance of a sky patch and the internal illuminance, under diverse sky conditions (AYOUB, 2019). Nonetheless, calculations were still based on point-in-time measurements (MARDALJEVIC, 2021; MIRI; ASHTARI, 2019).

The late 1990s and early 2000s gave way to a significant development of modelling and simulation softwares, that were increasingly embodied in architectural and engineering practice, leading to Climate Based Daylight Modelling (CBDM). CBDM, by its turn, gave origin to *dynamic metrics*[3], based on detailed weather files with about 8,760h/year of local climate information (MARDALJEVIC, 2021; MIRI; ASHTARI, 2019). Those weather files are, until today, developed for a continuously increasing number of cities. The diffusion of CBDM led to a great development of dynamic daylight metrics, since they accelerated the calculation process and provided more realistic and accurate results. As technology is always evolving, simulation tools are continuously upgraded in applicability and precision until this day (MARDALJEVIC, 2021; MARDALJEVIC; ANDERSEN, 2012; REINHART; MARDALJEVIC; ROGERS, 2006; SOKÓŁ, 2019).

[2] Glare is the discomfort provoked by daylight that can — or not — impair visibility (PIERSON et al., 2022).

[3] Dynamic metrics capture the site-specific features, based on realistic sun and sky conditions of that climate on an annual basis (MARDALJEVIC, 2021; REINHART; MARDALJEVIC; ROGERS, 2006).

As examples of dynamic metrics, there are Daylight Autonomy (DA) (REINHART; MARDALJEVIC; ROGERS, 2006), Useful Daylight Illuminance (UDI) (NABIL; MARDALJEVIC, 2005), as well as Annual Sunlight Exposure (ASE) (MARDALJEVIC; ANDERSEN, 2012; NABIL; MARDALJEVIC, 2005; REINHART; MARDALJEVIC; ROGERS, 2006). Some dynamic metrics regarding glare are Sunlight Duration (SD) and Daylight Glare Probability (DGP) (AYOUB, 2019; KRUISSELBRINK; DANGOL; ROSEMANN, 2018; PIERSON et al., 2022; SHAFAVI; TAHSILDOOST; ZOMORODIAN, 2020).

Daylight Autonomy (DA) expresses the ratio of occupied hours, throughout the year, in which a minimum illuminance range is attended on the work plane only with daylight. With the aim of incorporating the different ways daylight behaves in space, authors later subdivided DA (BELLIA; FRAGLIASSO, 2018; GONZÁLEZ; FIORITO, 2015; REINHART; MARDALJEVIC; ROGERS, 2006), as follows:

- Continuous Daylight Autonomy (DA_{con}): illuminance values slightly below ideal are considered, which means there are benefits coming from daylight even if the illuminance is below 500 lux;
- Maximum Daylight Autonomy (DA_{max}): regards the excessive incidence of sunlight, with the possibility of glare occurrence, since it is calculated as ten times the ideal illuminance (5000 lux); and
- Spatial Daylight Autonomy ($sDA_{lx/h\%}$): ratio of the total area that meets an ideal quantity of illuminance in the work plane along the year, meaning that activities can be performed only with daylight. Usually, sDA is fixed in 300 lux for 50% of occupied hours in a given percentual area ($sDA_{300/50\%}$).

Some authors consider subcategories of sDA: Preferred Daylight Sufficiency, in which daylight must reach $sDA_{300/50\%}$ at a minimum of 75% of the space's area, and Nominally Accepted Daylight Sufficiency, where at least 55% of the space's area need to meet $sDA_{300/50\%}$. In the most recent version of LM 83, released in 2023, a new parameter for sDA is now allowed: $sDA_{150/50\%}$, where 150 lux per 50% of occupied hours are admitted in spaces with less critical visual tasks (IESNA, 2012, 2023; MARCONDES CAVALERI et al., 2018).

Useful Daylight Illuminance (UDI) corresponds to the percentual of hours, per year, where useful illuminances occur in a space, that is, neither too dark (< 100 lux) nor too bright

(> 2000 lux) (NABIL; MARDALJEVIC, 2005, 2006). The UDI ranges are considered useful to perform various visual tasks and were obtained from field studies, based on occupants' behaviour and preferences in buildings entirely daylit (MARCONDES CAVALERI et al., 2018). Values above the maximum threshold, even though eventually bring beneficial non-visual effects, denote the possible occurrence of visual or thermal discomfort (DIAS et al., 2018). Nabil and Mardaljevic (2005) proposed three ranges:

- UDI fell-short: illuminance below 100 lux, considered insufficient;
- UDI: illuminance from 100 to 2000 lux, considered enough to perform different kinds of tasks, according to task requirements;
- UDI exceeded: illuminance above the threshold of 2000 lux, which may cause visual/thermal discomfort.

Later, it was suggested to split UDI into two more categories, to comprehend the eventual necessity of complementary artificial light and express total autonomy. Respectively, the new categories were called UDI supplementary (UDI-s, from 100-200 lux) and UDI autonomous (UDI-a, from 200-2000 lux) (REINHART; MARDALJEVIC; ROGERS, 2006). In the 2010s, UDI ranges were modified (MARCONDES CAVALERI; CUNHA; GONÇALVES, 2018; SOKÓŁ, 2019):

- UDI fell-short (UDI-f): insufficient illuminance, below 100 lux;
- UDI supplementary (UDI-s): illuminance between 100-300 lux, which requires artificial light complementation;
- UDI autonomous (UDI-a): illuminance from 300-3000 lux, level considered capable of fulfil daylight in spaces without electric light; and
- UDI exceeded (UDI-e): illuminance above 3000 lux, the maximum threshold that indicates visual and/or thermal discomfort.

Those changes in UDI were due to the great availability of daylight in some locations, associated with the preference of occupants for greater illuminance levels, as well as the health benefits connected to larger levels of natural illuminance (MARCONDES CAVALERI; CUNHA; GONÇALVES, 2018; SOKÓŁ, 2019). Similarly to UDI, Reinhart and Wienold (2011) proposed Daylight Availability (DAv) to represent spaces supplied by daylight, also with ranges — divided into complete, partial, excessive, or unlit.

There are also metrics regarding access to sunlight indoors and outdoors. ASE is a relative value that determines the possible occurrence of visual discomfort by sunlight (IES, 2012, 2023a; REINHART; MARDALJEVIC; ROGERS, 2006), frequently used to assess spaces sensible to sunlight, whether it is pleasant — in hospitals or educational facilities — or unwanted — as in art museums (LO VERSO et al., 2021a). Its parameter value is commonly adopted as the percentage of the area of a space that exceeds 1000 lux in more than 250 occupied hours in a year ($ASE_{1000/250h}$) (IESNA, 2012, 2023; MARCONDES CAVALERI et al., 2018). Among the dynamic metrics, only ASE doesn't have threshold values, since it expresses an annual cumulative amount of sunlight in a space (REINHART; WIENOLD, 2011).

Ayoub (2019) found also dynamic metrics related to solar access: Annual Light Exposure (ALE) is the cumulative amount of visible light in a space over a year, as a proxy mainly for places with light-sensitive art pieces. ASE can also be used as a method to comprehend the possibilities of excessive heat and glare indoors. By its turn, the Sunlight Beam Index (SBI) measures the cross-sectional area of sunlight that passes through a glazing surface, considering all sun path during a whole year (AYOUB, 2019; DERVISHAJ; GUDMUNDSSON, 2024). "Exposure to Sunlight" is a metric used to guarantee a quantity of sunlight indoors to provide healthier spaces in schools, hospitals, nurseries, and at least one permanently occupied room in residences; to reduce heating energy consumption during cold seasons and overall energy used to lighting (DERVISHAJ; GUDMUNDSSON, 2024).

As dynamic metrics provide more realistic results, their evaluation of glare occurrence is often considered more reliable. The dynamic metrics specific to the assessment of glare are Sunlight Duration (SD) and Daylight Glare Probability (DGP) (AYOUB, 2019). SD was elaborated to measure the entrance of sunlight whether it is direct or relative, in hours, from sunrise to sunset. DGP, on the other hand, assesses the probability of discomfort by glare, based on the vertical luminance of surfaces and illuminance of the source (AYOUB, 2019). One of the variances of DGP is Enhanced Simplified Daylight Glare Probability (eDGPs), a metric that simplifies and accelerates the calculations when there are strong contrasts components that cannot be removed, due to the presence of intense sunlight in a dark space (AYOUB, 2019).

DGP does not indicate the spatial or temporal distribution of sunlight, which means it is strongly related to the occupant's perception (AYOUB, 2019). Ayoub (2019) also points out that the lack of a more precise evaluation of glare hinders architects and designers to integrate effective solutions to avoid it. Hence, considering also the study conducted by Pierson et al. (2022), not all variables can be measured by DGP alone, as it's not very clear if and how much cultural and socioenvironmental factors influence occupants' perceptions.

Nevertheless, authors claim that glare metrics are important to measure the possibility of discomfort by glare, always according to occupants' perception (PIERSON et al., 2022). However, when calculations are made with standard climate data, which is the case of static metrics, there is a considerable risk of inaccurate results (TZEMPELIKOS; CHAN, 2016). Despite that, simplified analyses are relevant due to the rapidness to obtain results based on simple illuminance data.

Even though some studies claim there were no differences in perception of visual comfort *versus* glare in building occupants of different cultural backgrounds (PIERSON et al., 2022), authors clarify that some issues in the research may have influenced results, such as: translation mistakes, issues during interviews and short breaks for a minimum visual adaptation. That said, the differences between cultural, geographical, physiological, and environmental contexts may still shape the tolerance of occupants regarding the variance of daylight and glare perception (PIERSON et al., 2022; SHAFAVI et al., 2020).

Nowadays, there are numerous softwares that allow designers to assess daylight's contribution, energy efficiency, compliance with requirements, and daylighting design in general. Nevertheless, the diffusion of dynamic metrics is still below its potential in architectural practice, possibly due to difficulties in the comprehension of concepts during the lighting education and in further professional activities, as authors found in recent research (LO VERSO et al., 2021a, 2021b; SOKÓŁ, 2019). Other author identified as possible reasons the various metrics that convey the same information in different ways, the lack of mandatory requirements in reference documents and the few or non-existent overlays between documents (BOUBEKRI, 2008; CZACHURA et al., 2022).

As for the non-visual effects of daylight, it is now known their essential role in human health, by regulating the circadian system (LO VERSO et al., 2021b). The most used metrics nowadays are Equivalent Melanopic Lux (EML), Melanopic Equivalent Daylight Illuminance (mEDI or M-EDI) and Circadian Stimulus (CS). All of those metrics relate daylight and electric light to the human metabolism, measuring the impact those can have of health. In the case of electric light, EML and mEDI use calculators to set parameters to reach the benefits of daylight with various sources of electric light, for example (KOLBERG et al., 2022; SIMS, 2022; YUN; JEONG; CHOI, 2021). CS also has an online calculator and expresses more specifically the impact of daylight on the suppression of melatonin on human organism, which is a way to comprehend the health state of a person, considering hormones, sleep routine, etc (LIGHTING RESEARCH CENTER, 2023a, 2023b; REA et al., 2012).

From EN 17037:2018+A1, Target Illuminance (E_T) and Minimum Target Illuminance (E_{Tmin}) relate temporal and spatial distribution of light (CEN, 2018), representing similar concepts with Spatial Daylight Autonomy (sDA). Exposure to Sunlight, in EN 17037, looks similar to LM's ASE in a first look; however, Exposure to Sunlight evaluates the sunlight access in cold weather, while ASE is focused on the possible visual discomfort caused by excessive sunlight indoors (CEN, 2018; IES, 2012, 2023a; MARDALJEVIC, 2021; PAULE; FLOURENTZOU, 2019; SOLVANG et al., 2020). Considering the literature findings, there is a clear evolution in the complexity of metrics, from static to dynamic, especially after CBDM. Table 1 summarizes the definitions of static and dynamic metrics approached in this section. Right after, Figure 1 displays a synthetic timeline of the main daylight metrics found.

Table 1 Definitions of main static and dynamic metrics found in the Systematic Literature Review.

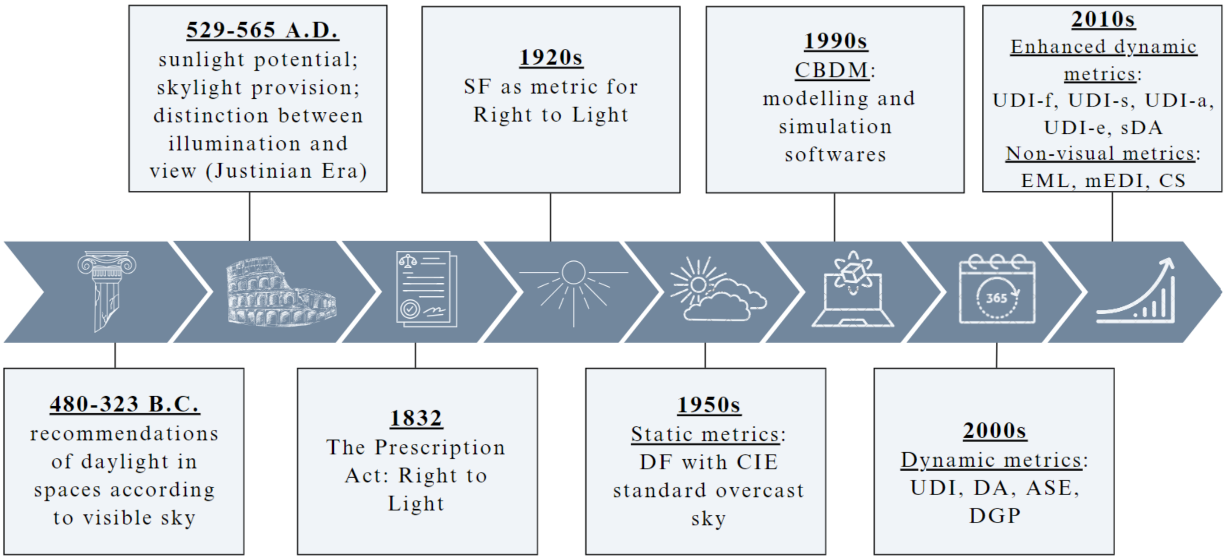
TYPE	METRICS	DEFINITION
STATIC	Sky Factor (SF)	ratio of the illuminance on a horizontal surface, to the unobstructed overcast sky (AYOUB, 2019; TREGENZA; MARDALJEVIC, 2018)
	Daylight Factor (DF)	ratio of the illuminance on a horizontal surface to the unobstructed overcast sky, considering internal and external reflections (BELLIA et al., 2017; TREGENZA; MARDALJEVIC, 2018; AYOUB, 2019)
	Average Daylight Factor (ADF/DF_{avg})	ratio of the illuminance on a horizontal surface to the unobstructed overcast sky, considering reflections, across a grid of points (AYOUB, 2019; TREGENZA; MARDALJEVIC, 2018)
	Daylight Glare Index (DGI)	subjective rating based on the summation of several glare sources (AYOUB, 2019)
DYNAMIC	Daylight Autonomy (DA)	ratio of occupied hours in a year in which a minimum illuminance range is attended only by daylight (NABIL; MARDALJEVIC, 2006; REINHART et al., 2006; DIAS et al., 2018)
	Continuous DA (DA_{con})	DA with daylight illuminance values below ideal (500 lux) (BELLIA et al., 2017; DIAS et al., 2018; AYOUB, 2019)
	Maximum DA (DA_{max})	DA with illuminance 10 times above the ideal value (5,000 lux), with possible glare (BELLIA et al., 2017, DIAS et al., 2018)

(Cont. Table 1) Definitions of main static and dynamic metrics found in the Systematic Literature Review.

TYPE	METRICS	DEFINITION
DYNAMIC	Spatial DA (sDA)	area of work plane that meets an ideal value of illuminance, usually 300 lux for 50% of occupied hours ($sDA_{300/50\%}$) (AYOUB, 2019; MONTEOLIVA et al., 2020)
	Target Illuminance (E_T)	illuminance level achieved across a fraction of the reference plane within a space for at least half of the daylight hours (CEN, 2018; MARDALJEVIC; CHRISTOFFERSEN, 2017)
	Minimum Target Illuminance (E_{Tmin})	minimum illuminance level achieved across a fraction of the reference plane within a space for at least half of the daylight hours (CEN, 2018; MARDALJEVIC; CHRISTOFFERSEN, 2017)
	Useful Daylight Illuminance (UDI)	range of illuminances across the work plane that fall between minimum and maximum values along the year (NABIL; MARDALJEVIC, 2005, 2006)
	UDI fell-short (UDI-f)	insufficient daylight, with levels below 100 lux (GONZÁLEZ; FIORITO, 2015; NABIL; MARDALJEVIC, 2005, 2006)
	UDI supplementary (UDI-s)	illuminances between 100-300 lux, requiring electric light complement (GONZÁLEZ; FIORITO, 2015; MARDALJEVIC; ANDERSEN, 2012; NABIL; MARDALJEVIC, 2006)
	UDI autonomous (UDI-a)	illuminance levels from 300-3,000 lux, considered sufficient for different visual tasks (GONZÁLEZ; FIORITO, 2015; MARDALJEVIC; ANDERSEN, 2012; NABIL; MARDALJEVIC, 2006)
	UDI exceeded (UDI-e)	levels above 3,000 lux, with possible visual/thermal discomfort (MARDALJEVIC; ANDERSEN, 2012, GONZÁLEZ; FIORITO, 2015, BELLIA et al., 2017)
	Exposure to Sunlight/ Sunlight Exposure	achieved through the expression of the minimum number of hours during which this space receives direct sunlight, for a clear cloudless reference day in the year (CEN, 2018)
	Sunlight Duration (SD)	duration of sunlight penetration, expressed in hours or simple dimensionless units (AYOUB, 2019)
	Annual Sunlight Exposure (ASE)	annual cumulative amount of sunlight; area that meets 1,000 lx in 250 occupied hours ($ASE_{1000/250h}$) (BELLIA et al., 2017, MARCONDES CAVALERI et al., 2018, MONTEOLIVA et al., 2020)
	Annual Light Exposure (ALE)	cumulative amount of visible light in a space over a year (AYOUB, 2019; DERVISHAJ; GUDMUNDSSON, 2024)
	Sunlight Beam Index (SBI)	cross-sectional area of sunlight that passes through a glazing surface, considering all sun path during a whole year (AYOUB, 2019; DERVISHAJ; GUDMUNDSSON, 2024)
	Daylight Glare Probability (DGP)	probability of discomfort by glare, based on vertical luminance of surfaces and illuminance of source (KRUISSELBRINK et al., 2018; AYOUB, 2019; PIERSON et al., 2022)
	Annual Probable Sunlight Hours (APSH)	a percentage of the unobstructed annual total number of hours in the year that the sun is expected to shine (LITTLEFAIR et al., 2022)
NON-VISUAL	Melanopic Equivalent Daylight Illuminance (mEDI or M-EDI)	equivalent illuminance for the melanopic photoreceptor in the human eye (CIE, 2018; IWBI, 2023)
	Circadian Stimulus (CS)	characterizes a light stimulus as it affects human melatonin suppression and the human circadian system (FIGUEIRO; GONZALES; PEDLER, 2016; LIGHTING RESEARCH CENTER, 2023a, 2023b)
	Equivalent Melanopic Lux (EML)	measures the biological stimulation of the photoreceptors involved in the non-visual effects of light (ipRGCs) compared to the traditional vision ones (cones) (IWBI, 2023; SIMS, 2022; YUN; JEONG; CHOI, 2021)
	Photopic Illuminance	irradiance measured according to perceived brightness for an observer (KOLBERG et al., 2022; REA et al., 2012)

Source: Author (2024).

Figure 1 Timeline of daylight requirements and metrics.



Source: Author (2023).

2.2.Context of International and National authorities

The elaboration of reference documents is commonly a responsibility of several types of organizations and institutions, with different action levels inside countries, with great impact on the built environment (IMRIE; STREET, 2009). These organizations and institutions can be autonomous or part of Governmental structures, and create documents based on the demands of the society — whether for environmental responsibility, socio-political and spatial issues, cultural aspects, among others. The articulations among the various actors and institutions involved in urban and building construction compose the Governance of cities and countries (CABE, 2011; IMRIE; STREET, 2009).

The focus of documents varies on different aspects of professional practice: some of them guide regulations on urban space and interactions between urban fabric and construction of buildings, while others focus on the elaboration of documents to guide building design specifically, regarding many types of requirements (IMRIE; STREET, 2009). All types of reference documents in architecture and urbanism, then, can work as mechanisms and instruments of governance that can answer, absorb or perpetuate socio-political, spatial, environmental problems found in cities, since those are not only a technical package, but also a way to represent interests from different stakeholders and part of a wide panorama that influences architecture and professionals (CABE, 2011; IMRIE; STREET, 2009).

Some of the main autonomous organizations that elaborate Standards researched in this work are American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), *Comité Européen de Normalisation* (CEN), Chartered Institution of Building Services Engineers (CIBSE), *Commission Internationale de l'Eclairage* (CIE), Illuminating Engineering Society of North America (IESNA), Society of Light and Lighting (SLL), among others. These institutions gather specialists in themes engaged in architectural practice and can be equally or even more influential than their government counterparts (IMRIE; STREET, 2009), such as lighting and daylighting; heating, ventilating and air conditioning (HVAC); building construction engineering services; architecture and engineering education; the pursue of excellence in professional practice; and the promotion of research topics linked to construction activities. The majority of mentioned organizations are originally each from a country, instead of being supranational. However, some have an international influence, since Standards sometimes are applied by practitioners in more countries other than the original ones.

The organizations that create Rating Systems are more internationalized than professional organizations: United States Green Building Council (USGBC), Building Research Establishment (BRE), Japan Sustainable Building Consortium (JSBC), Building Construction Authority (BCA), International WELL Building Institute (IWBI), *Haute Qualité Environnementale* (HQE). However, some of those organizations have national headquarters in countries where the Rating System is applied — as is Green Building Council Brazil (GBC Brasil) and *Alta Qualidade Ambiental-Haute Qualité Environnementale* (AQUA-HQE, Brazil).

On the other hand, institutions that elaborate Building and Urban Codes and Regulations are directly linked to the Government, like City Halls, Secretariats, Commissions, Ministries, Federal Agencies — and those Codes have been used at least since the Renaissance Era, or even earlier (CABE, 2011). These documents are usually the ones mandatory to follow, since they are legally binding and an important aspect of cities' administration. Guidelines, by their turn, as forms of supplementary guidance, are adopted by local authorities in order to have further considerations about a specific theme, even though a Code could normally go further (CABE, 2011). More details of the application of the reference documents are explained in section 2.3.

2.3.Architectural reference documents

This section discusses the reference documents chosen for analysis in this work, their definitions, applications and coverage within architecture research and practice.

a. **Standards**: official publication with technical specifications, requirements and recommendations about quality, safety, design, construction methods, performance, operation, maintenance, symbols or other characteristics of a product — in architecture, buildings and urban constructions are the products. Standards can be developed by international and national organizations, professional and industry organizations, and others institutions (GRIFFITH UNIVERSITY LIBRARY GUIDES, 2023). In the case of buildings, standards provide guidance about the conditions regarding light, acoustic, thermal comfort, performance of materials, etc., to which buildings must comply, in order to be safe and comfortable to occupants (TREGENZA; MARDALJEVIC, 2018).

Tregenza and Mardaljevic (2018) defend also that in order to be effective and to guarantee good results, the conditions or levels defined by standards must be "few, obviously related to the purpose, testable within a realistic time and at a reasonable cost, capable of giving consistent results when repeated or reproduced by different assessors and capable of being used by all relevant parties" (TREGENZA; MARDALJEVIC, 2018, p. 64–65).

The application of standards usually varies according to the legislations of the country, i.e., a standard becomes mandatory when a law or decree refers to that standard or a specific law defines it as mandatory (BATTAGIN, 2014; BELLIA et al., 2017). Whether compliance is mandatory or not, it is always necessary to verify if the standards tend to distort the design process towards specific solutions that may not be suitable for all places, or even to observe which interests there are behind those standards. That is, unless the standard is very carefully written and applied, the results could be completely different from the originally intentions — e.g., instead of providing comfort and good lighting, provoking excessive heat loads, glare or other problems (TREGENZA; MARDALJEVIC, 2018).

According to literature, some of the most influential standards are "LM 83" and "EN 17037", due to the influence those standards have over documents from another countries (AGHEMO et al., 2016; SEPÚLVEDA et al., 2020).

b. **Rating systems**: also called certifications, rating systems measure levels of performance, with specific aims and various types and levels of requirements. Commonly, architectural rating systems were created and evolved focusing on the creation of projects environmentally responsible and on the sustainable use of natural resources throughout the project lifecycle (DESIGNING BUILDINGS, 2022). Even though, more recently, rating systems have been accounting the importance of daylight indoors as a way to improve productivity and mental health of building occupants, as well as its great contribution to the circadian rhythm, the approach of most systems refer mostly to the energy savings aspect, rather than the other dimensions that daylight reaches — including wellbeing, mental health, visual accuracy and awareness of the surroundings (MCARTHUR; POWELL, 2020).

Rating systems are, nowadays, seen as key drivers of well-being and sustainability, strong evaluation methods along time (BELLIA et al., 2017). After decades and numerous buildings certificated, the criteria used on these systems became targets to design teams — as a starting point, if they don't intend to apply for any rating system, or as main objective, if they intend to (KEELER; BURKE, 2010; MCARTHUR; POWELL, 2020; TREGENZA; MARDALJEVIC, 2018). As for daylighting, it has become a key aspect in those systems (AYOUB, 2019; MARDALJEVIC; HESCHONG; LEE, 2009; REINHART; MARDALJEVIC; ROGERS, 2006).

Rating Systems are not mandatory, but instead, they have a significant commercial appeal — i.e., the buildings best classified have greater commercial value for stakeholders, while projects that reach lower-level classification in these schemes can be enhanced, in order to reach a higher level. Nevertheless, it is necessary to question whether what is considered "good daylighting" in these systems is properly effective for visual quality and not only for energy savings (REINHART; MARDALJEVIC; ROGERS, 2006).

In literature, the most known rating systems are common research objects. BREEAM is the first rating system created, in the 1990s, in Great Britain. Beyond the original version, many countries made their own versions of BREEAM (BELLIA et al., 2017). LEED, originally inspired on BREEAM, is nowadays the most diffused rating system worldwide (BELLIA et al., 2017; KIM; HAN, 2022; OBRECHT et al., 2017), available in many countries other than USA — Italy, Brazil, Japan, Germany, etc, which also adapted LEED to each local reality. "WELL" is the only rating system, so far, that approaches non-visual effects of daylight, approaching three metrics: Equivalent Melanopic Lux (EML), Circadian Stimulus (CS) and Melanopic Equivalent Daylight Illuminance (mEDI or M-EDI) (IWBI, 2023).

c. **Building and urban codes:** official documents, elaborated by local governments and authorities, focused on guidance of design, regulation and construction in cities, defining rules about the relations between buildings and the urban fabric, with the aim to achieve higher quality spaces according to technical, economic and social principles. The existing urban fabric can and should also be enhanced by the rules defined in codes, as they are expected to assure sustainability, social and ecofriendly development, nature-based solutions, etc (CABE, 2011; NIST, 2022).

As building and urban codes are primarily concerned with the actions of private and public actors in the enterprise of cities and buildings, they usually do not address daylight metrics, but are focused on parameters that, indirectly or directly, influence over the capture of daylight in interior spaces. In some contexts, instead of being legally binding, codes are seen as "models" for legal jurisdictions to develop statutes and regulations (CHOY, 2023; NIST, 2022). In this analysis, building and urban codes are defined as the mandatory documents to which practitioners’ resort during the elaboration of projects.

d. **Building regulations:** documents that apply to all buildings, to guarantee they are secure for people in or around them. Usually, Regulations are elaborated by the state or local government, containing a series of approved requirements, rules of conduct in the urban and building environments, and goals, covering the technical aspects of construction, as well as shaping design and development in cities. Their application is usually mandatory to building construction activities and to compose the governance of a city (IMRIE; STREET, 2009; URBANIST ARCHITECTURE, 2021).

Historically, regulations are legally binding and state-controlled, which made them highly influential to architectural practice and, at the same time, influenced by the evolution of architecture and cities over time (IMRIE; STREET, 2009). Nevertheless, some practitioners commonly claim that regulations can constraint architectural practice, due to the presence of the “prescription” style of recommendations (IMRIE; STREET, 2009; URBANIST ARCHITECTURE, 2021).

e. **Guidelines:** in architecture, refer to the set of policies, rules and procedures promulgated and/or amended by the developer or the local architectural control authority, which shall act as a guide for architectural activities, as well as control and review processes (LAW INSIDER, 2023). Guidelines can also help to preserve the long-term vision and property value of a community, by outlining requirements regarding styles and exterior features, as well as provide a set of good design practices (LAW INSIDER, 2023).

In the international context, guidelines and manuals are common within architecture and engineering organizations in many countries. Often, they also clarify the rules and recommendations given by other reference documents. Hence, guidelines are not mandatory, but instead, can be a reference for practitioners. Table 2 below summarizes reference documents, each definition and application in architectural practice.

Table 2 Definitions and application of reference documents for architectural practice.

DOCUMENT	DEFINITION	APPLICATION
Standards	Publications with technical specifications, requirements and recommendations, developed by international/national organizations, professional and industry associations (DESIGNING BUILDINGS, 2022)	Depends on the country
Rating systems	Systems that measure levels of performance, in order to create ecofriendly projects (GRIFFITH UNIVERSITY LIBRARY GUIDES, 2023)	Non-mandatory
Building and urban codes	Requirements for how architecture and urban planning should be designed and constructed, under the view of state and local governments, coordinating the actions of private and public stakeholders (CHOY, 2023; NIST, 2022)	Mandatory
Building regulations	Guarantee buildings' safety for people in or around them, covering technical aspects of construction (URBANIST ARCHITECTURE, 2021)	Mandatory
Guidelines	Set of policies, rules and procedures amended by the local architectural control authority, acting as a guidance for architectural activity and use of building and urban codes and regulations (LAW INSIDER, 2023)	Non-mandatory

Source: Author (2023).

2.4.Harmonization of requirements and metrics

Information is harmonized in many fields of science, from data analysis to satellite images and biological data. In this context, to harmonize is to coordinate types, levels and sources of information in compatible and comparable categories, in order to allow better comprehension of the gathered data, as well as better analysis and decision-making (CHENG et al., 2024).

As in other fields of study, in daylighting, the lack of consensus and harmonization makes it difficult to communicate and compare the parameters and goals of daylighting projects. Even if the aim is not to prescribe exactly the best parameter values internationally — since the climatic differences make impossible to have a single recommendation — harmonized requirements and metrics could optimize the use of those criteria in a global scale, reducing the number of different criteria used and the uncertainties of which requirements and metrics to use during architectural practice (SIMAIKA et al., 2024). In the same way, with daylight requirements, the harmonization could then lead to a greater diffusion of requirements, favouring favour its coherent and cohesive incorporation into reference documents, as well as provide better guidance to the elaboration of design strategies — bringing benefits for designers, policymakers, and managers in the built space and design practice.

There are various ways to harmonize data. Harmonization can be done after the information is collected — called retrospective, ex-post or output harmonization — or previously to the data collection — prospective, ex-ante or input harmonization (CHENG et al., 2024). Harmonization procedures can be applied not only to group similar terminologies and concepts with the same results or meanings, but also to show that different methods can provide measures, ranges and parameters regarding the same variables, for example (BAKX et al., 2019; CHENG et al., 2024). Still according to Cheng et al. (2024), at least three dimensions can be involved in harmonizing information:

- Syntax: where the information to be harmonized come in very diverse technical formats, as .csv, HTML and others. This type requires more processing before the harmonization action itself;

- Structure: where the variables can relate with each other among a certain amount of information collected, whether this information is organized (through tables, data sheets, boards) or not (analysis of primary documents, images);
- Semantics: where it is necessary a closer evaluation of the meanings of words, in order to group different names and terms that express the same concepts — even though those concepts may suffer variation in parameter values, for example.

Among the main gains involved in the harmonization process are the robustness of the combined data available for further analysis, the wider application of certain information or results, the possible increase the reliability in the use of methods and metrics grouped by similarity, the improvement in information quality, as well as allow access to general information that would not be available otherwise (CHENG et al., 2024).

As possible losses, sometimes the harmonization may make researchers lose sight of what it is indeed being evaluated, cause the loss of conceptual diversity, less comparability inside the grouping, low visibility of social contexts and cultural backgrounds (CHENG et al., 2024). Thus, harmonization systems and classifications can be more strict — where only identical concepts or words are grouped — or more flexible — when some variation is allowed (CHENG et al., 2024). This, essentially, depends on the variables under evaluation and on the goals of the research.

Due to their specificity, the act to harmonize information regarding a single subject is relatively easier, since this process includes using terms most widely known or that describe more accurately the topics, concerning the mathematical or methodological approach (BAKX et al., 2019; CHENG et al., 2024), as well as architectural or urban meaning, for example. This is the particular case of this work, that approaches the feasibility and possibilities of harmonization of daylight requirements. The goal is to find a way to group and classify requirements and metrics based on the similarity of their application and meanings, which makes it a harmonization based on *semantics*, with a retrospective process, as proposed by Cheng et al. (2024).

Considering the positive and negative points, on the contrary to what it may seem initially, harmonization processes do not mean that groups, classification or datasets are complete or totally homogenic. The harmonized data has its flaws and limits, and needs constant evaluation and reviewing. That is, as a product of a wider set of information, harmonized data are a simplified version of those originally collected. This demands, from further researchers or professionals that intend to work with the harmonized data a careful analysis, in order not to have superficial or inaccurate results (CHENG et al., 2024).

It is not the goal of this research to fully exhaust the theme of harmonization of daylight requirements and metrics, since there are many possible points of view and categories that could be explored. Nevertheless, it will be a significant contribution in order to organize a collection of the available information about daylight requirements and metrics in a global scale, as well as provide recommendations and pathways to harmonization strategies.

3. Method

3.1.Methodological path

In order to comply with the aims of this research, the following steps will be fulfilled in this work.

a. **Systematic literature review**: analysis of scientific about daylight requirements, to deepen the comprehension of their evolution and use;
b. **Collection of primary documents**: collection of Standards, Rating Systems, Regulations, Building and Urban Codes, Guidelines from various countries, to verify how and which daylight requirements are used, their commonalities, overlaps, and gaps;
c. **Survey application**: survey sent to practitioners and specialists to collect information about most used daylight metrics, requirements and reference documents;
d. **Analysis and discussion of results**: cross analysis of the literature findings and the collected documents, through a climatic point of view;
e. **Identification of possible strategies for harmonization**: identification of opportunities and recommendations to support future harmonization of daylight requirements in different types of reference documents.

3.2.Systematic Literature Review

The first step to support the theoretical framework for this research was a Systematic Literature Review (SLR). SLRs are commonly "used to map, find, critically evaluate, consolidate and assemble the results of relevant primary studies (…), as well as identify gaps to be filled, leading to a coherent report or a summary" (DRESCH; LACERDA; ANTUNES JR, 2015, p. 141–142). The method follows a strict replicable structure, in search of information free of biases (DRESCH; LACERDA; ANTUNES JR, 2015). Hence, searches were carried out through databases to find relevant papers to the scope of this research. Furthermore, authors advise that is also effective to a systematic review to search the bibliography of the found papers (KUGLEY et al., 2017). Thus, this step was also done in this research. In the following items, search steps and selection of results are detailed.

The search was conducted through three main databases: Scopus, Web of Science and Google Scholar, choosing mainly articles published in scientific journals from 2015 to 2022. Search strategies were defined according to guidelines from Kugley et al. (2015). The first criterion to select papers was free access, whether it was open or the institutional access. Only in Google Scholar, keywords were translated to Brazilian Portuguese, in order to find related articles in this language.

Beyond the 41 papers found in the search databases, 16 articles were added to this SLR: 6 were recommended as references by CIE TC 3-61 members, and the remaining 10 were found through a search in found articles' references. Several of the 16 new papers were published before the estimated time frame, nevertheless, there were included due to their great relevance to the theme. Therefore, 57 papers were selected (Table 3).

Table 3 Summary of search strings and databases.

STRINGS	DATABASES/KEYWORDS	RESULTS	SELECTED
1st	Scopus/Web of Science (TITLE-ABS-KEY) "daylight metrics" AND "standards"	21	14
2nd	Scopus/Web of Science (TITLE-ABS-KEY) "daylight metrics" AND "rating systems"	0	0
3rd	Scopus/Web of Science (TITLE-ABS-KEY) "daylight metrics" AND "certification systems"	1	1
4th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight" AND "building certifications"	11	8
5th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight" AND "building guidelines"	2	1
6th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight criteria"	6	6
7th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight metrics" AND "urban codes"	0	0
8th	Google Scholar "métricas de iluminação natural"	11	2
9th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight requirements" AND "urban codes"	2	1
10th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight requirements" AND "standards"	10	5
11th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight requirements" AND "building certifications"	0	0
12th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight requirements" AND "rating systems"	0	0
13th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight requirements" AND "building guidelines"	0	0
14th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight requirements" AND "building regulations"	3	2
15th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight metrics" AND "building regulations"	2	1
	PAPERS FOUND IN DATABASES	69	41
	REFERENCES/RECOMMENDED BY TC 3-61	16	16
	TOTAL		57

Source: Author (2023).

Then, the 57 articles' abstracts and keywords were read for a second filtering. Based on that, articles were classified according to their adhesion to the theme: low adhesion were those focused on case studies, that barely touch the main theme; medium adhesion were the articles that address the theoretical basis of daylight metrics, although they do not focus on them in the main analysis; at last, the high adhesion articles were those discussing metrics in theoretical basis as well as in method, discussion, and results. After the second filtering, 36 articles with medium and high adhesion were selected for full reading (Table 4).

Table 4 Adhesion of selected papers to the defined theme.

ADHESION TO THEME	QUANTITY
High	**23**
Medium	**13**
Low	21
TOTAL	57
FULL READING TOTAL (SRL)	**36**

Source: Author (2023).

After the SRL, more articles were gradually added to the consulted literature. The articles were found through further references, recommendations of specialists and non-systematized searches. That way, 36 other articles were added, reaching the total of 7**2 articles** consulted in this research.

3.3. Collection of primary documents

The first primary documents collection was made through CIE TC 3-61 collaboration platform, in CIE's website, sent by TC 3-61 members from December/2022 to April/2023. The documents received (full or summaries) approach daylight requirements mostly known and used, but also requirements related with lighting in general, energy efficiency, architecture, urbanism, that in some way mention or have any requirement for daylight and daylighting. Also, were collected some reference documents approaching the non-visual effects of daylight — even though it is a very new research field, it is important to register and follow up the evolution of non-visual effects metrics and parameters in reference documents. The First Results Report was produced in May 2023.

The second collection campaign started in May/2023 and went until July/2024, through a survey sent to specialists in daylight. The survey, properly described on a following topic, aided to widen the representation of different climates and countries.

In both campaigns, 137 documents were found and received from 36 countries: from Europe (22 countries, 73 documents), North America (2 countries, 17 documents), South America (4 countries, 28 documents), Asia (4 countries, 9 documents), Oceania (2 countries, 5 documents), Africa (2 countries, 4 documents) and 1 International Rating System. Regarding non-visual effects, were found 3 Standards (1 European, 1 Brazilian and 1 American), 2 Rating Systems (1 from USA and 1 from Singapore) and 1 Guideline (USA). Table 5 summarizes the documents received from December 2022 to June 2024.

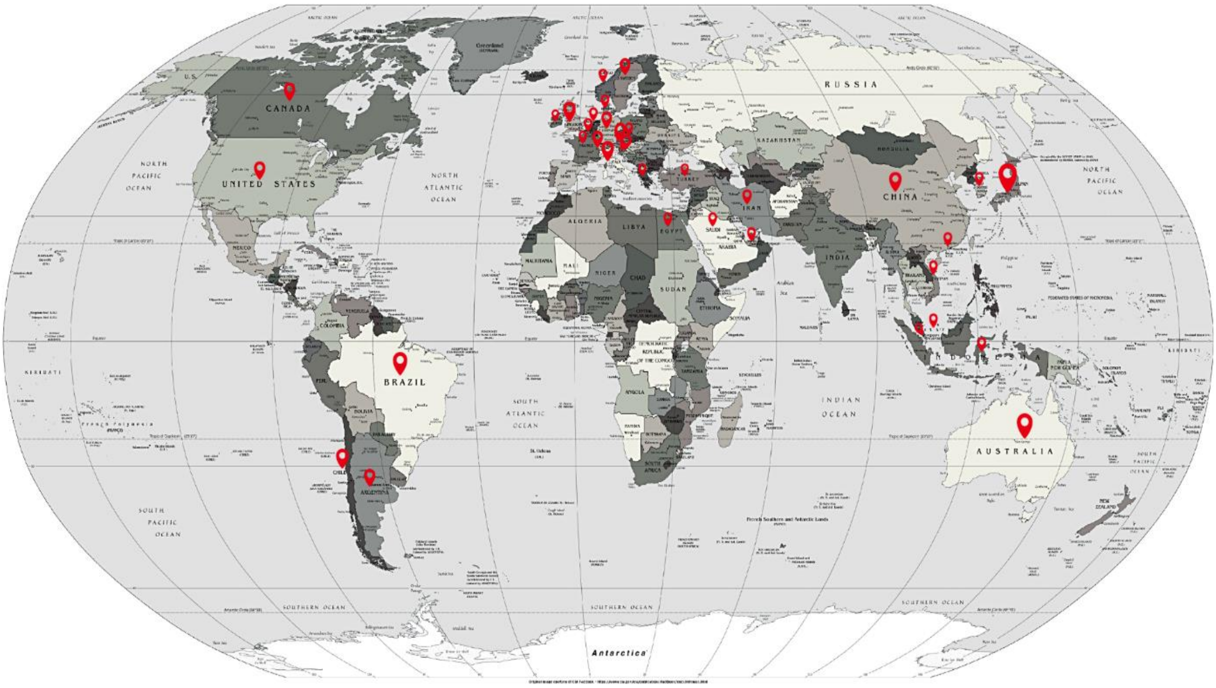
Table 5 Primary documents collected from Dec/2022 to Jul/2024.

VISUAL EFFECTS	
TYPE OF DOCUMENT	**QUANTITY**
Standards	39
Guidelines	12
Rating systems	24
Building and Urban Codes/Regulations	62
TOTAL	**137**
NON-VISUAL EFFECTS	
TYPE OF DOCUMENT	**QUANTITY**
Standards	3
Guidelines	1
Rating systems	2
Building and Urban Codes/Regulations	0
TOTAL	**6**

Source: Author (2023).

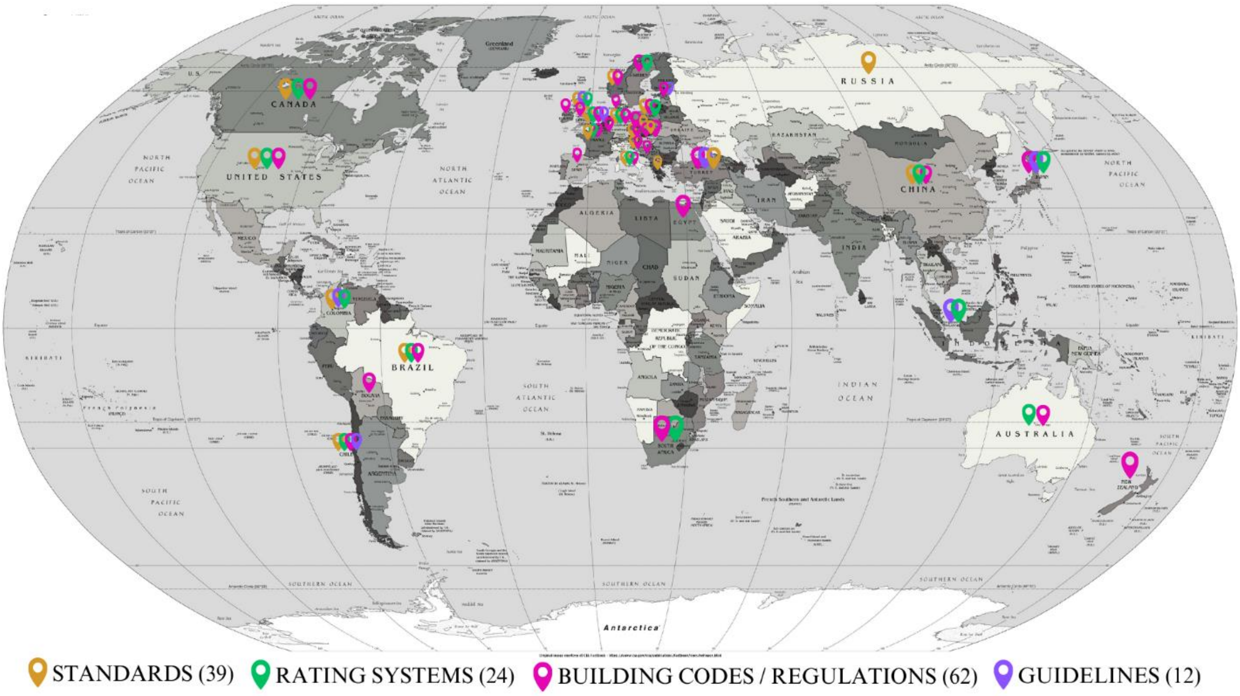
The following figures display the geographical distribution of the found articles (Figure 2) and primary documents found (Figure 3). In the SLR, noticeably, there is a concentration in Europe (24), Asia (12) and North America (7). Only 12 papers were found in Latin America (4), Africa (4) and Oceania (2). Researchers from different countries developed articles about daylight requirements together in some cases; hence, numbers overlap. The European great representativity remains, while Nort and South America, Asia and Oceania have also documents found. Africa keeps under represented, as there were only two documents received from a single African country. From Figures 2 and 3, it is possible to infer that the results of the SLR and the primary documents from the first collection campaign mostly overlap, even though the articles have more representativity than the primary documents. The second collection, though, provided better representativity from other continents: after that, all continents are represented by at least two countries.

Figure 2 Geographical distribution of the found articles during the systematic literature review.



Source: Author (2022).

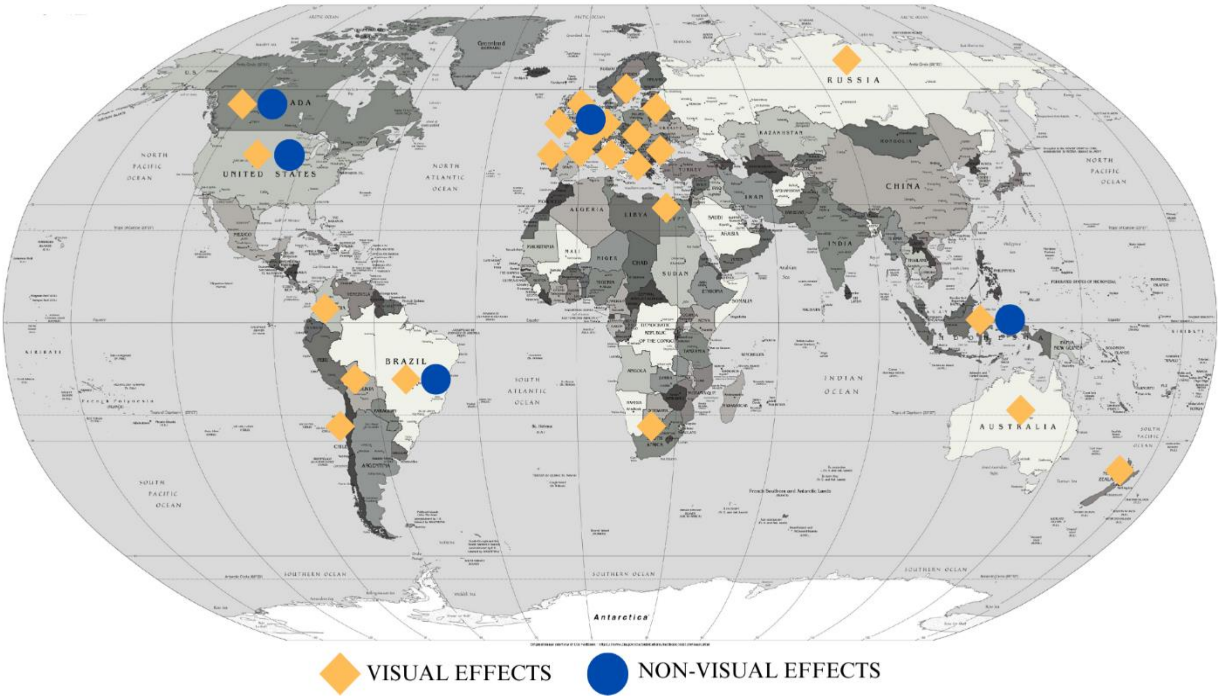
Figure 3 Geographical distribution of the 137 primary documents collected, per type of documents.



Source: Author (2024).

Figure 4 displays the distribution of documents according to visual and non-visual effects. The documents that have recommendations about non-visual effects are non-mandatory and come from North American (USA/Canada), South American (Brazil), European and Asian (Singapore).

Figure 4 Distribution of found documents regarding visual and non-visual effects of daylight.



Source: Author (2024).

3.4.Survey with CIE specialists

The survey was elaborated with the aim to gather information about reference documents to comprehend which are the ones mostly used by practitioners in their countries, how many and which of those are mandatory, and how they concern daylight directly or indirectly, as well as other architectural parameters, in order to find possible pathways to the harmonization of requirements in a worldwide scale. The questions had as basis the first collection of documents made on the context of TC 3-61 (CIE; TC 3-61, 2021), whose analysis left gaps about the reference documents, specially concerning their obligatoriness and representation from more countries outside Europe.

Additionally, the survey allowed responders to send the documents they understand being essential during architectural practice — as a brief summary or the entire document. The possibility to send documents provides more representativity — since there was a significant gap during systematic literature review and the first document collection campaign. In both cases, European documents were the most well represented, with some representation from Asia, Americas, and Oceania. Africa was under represented in both situations, with only a few articles and documents found from African countries.

Before the questions of the survey, the basic definitions of each document considered in this research were presented, in order to clarify the questions and to make understandable which reference documents should be considered by the respondents. The definitions were given such as in Table 2. The questions were structured as follows (CIE; TC 3-61, 2023) and the complete survey can be seen in Annex I.

> *1. Are there Daylighting Standards in your country? What are the daylight requirements in it/them? Could you share some of these documents? If not, please describe briefly.*
>
> *2. What is/are the most used Rating System(s) in your country? What are the daylight requirements in it/them? Could you share some of these documents? If not, please describe briefly.*
>
> *3. What are daylight requirements in Building and urban Codes and Regulations in your country? (examples are window wall ratio WWR, window floor ratio WFR, sky view factor, height to width/aspect ratio, street width or average building height). Could you share some of these documents? If not, please describe briefly.*
>
> *4. Are there Guidelines for daylight in your country? What are the requirements in it/them?*
>
> *5. Which of these documents are mandatory for architectural and urbanism practice in your country?*
>
> ( ) *Standards*
> ( ) *Building and urban Codes/Regulations*
> ( ) *Rating Systems*
> ( ) *Guidelines*
> ( ) *Others. Please specify.*

The survey was sent to CIE Division 3 members through the official Commission Platform and answers were sent by respondents by e-mail. Also, in order to reach more representation from different countries, the survey was also sent to PLEA (Passive and Low

Energy Architecture) specialists and fellow researchers within partner Universities. Even though there are 35 Division 3 National Representatives of CIE, from various countries, the survey has received 15 answers, including those from specialists outside of TC 3-61. This evidences a participation rate of about 42% on the survey.

3.5.Analysis of primary documents

The primary documents collected for this research will be analysed according to several criteria:

- type of documents and their obligatoriness: mandatory, non-mandatory, partially mandatory (when for some situations or specific typologies the document is mandatory);
- the kind of requirement each document presents: daylight provision, views, glare, sunlight, non-visual effects;
- the occurrence (number) of metrics in each document: for each document, each metric was counted once, in order to register the occurrence — not the repetition. This was necessary because some of the metrics are repeated many times in the same document, for different building typologies, for example;
- types of metrics: as in static, dynamic, geometric, etc;

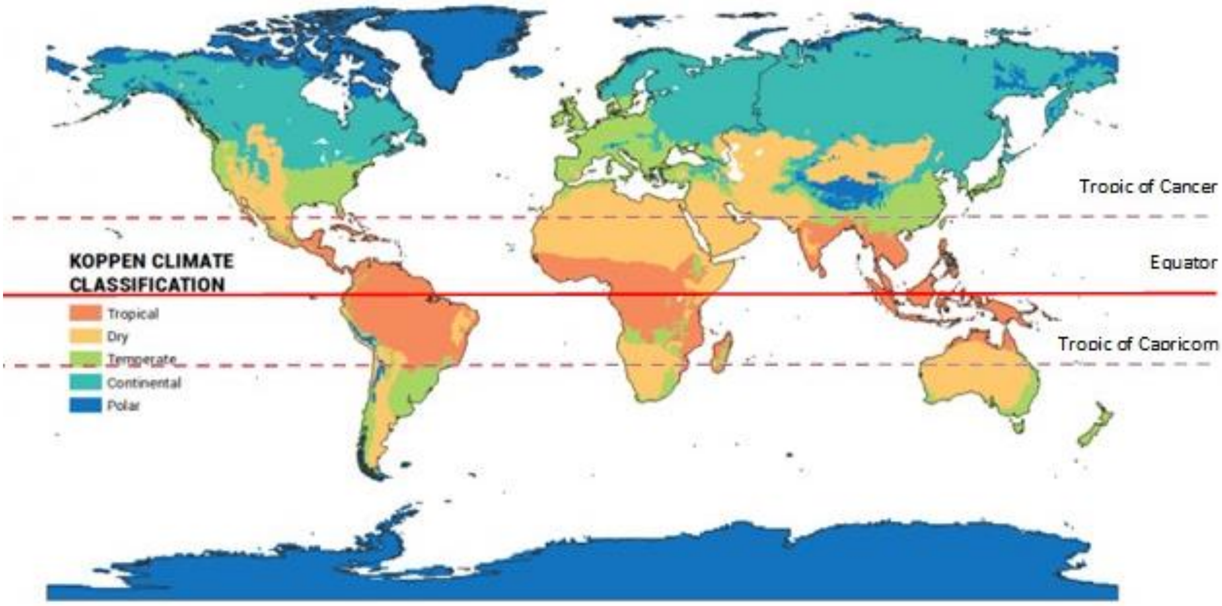
Firstly, in chapter 4, the total amount of documents found are summarized and quantified. Then, in section 4.1, there is an overview of the documents found, their application in the countries of origin, followed by comments on the requirements found in each type of document. Each section has a table summarizing all requirements found, with metrics and parameters, also quantifying the occurrence — i.e., the main metrics found — according to the aims and the types of documents. In section 4.2, there is a crossover of results, which combines the overview provided by the literature review, with the information found in reference documents.

In topic 4.3, daylight requirements are assessed from the climatic point of view, in an attempt to identify which ones are most suitable for different climates and why, possibly along with the parameters (AMORIM; PINHEIRO, 2024). The analyses complement each other in the comprehension of the various “layers” involved in daylighting, how the climate differences, as well as the obligatoriness and forms of application of reference documents in the daily activities, influence requirements.

The climatic focus considers the occurrence of metrics based on Koppen climate classification and geographical location — according to the Tropics of Cancer and Capricorn. For this division, the five categories of Koppen are considered: Temperate, Continental and Polar were grouped in the "predominantly cold climates", while Tropical and Dry were grouped as "predominantly warm climates" (EARTHHOW, 2023).

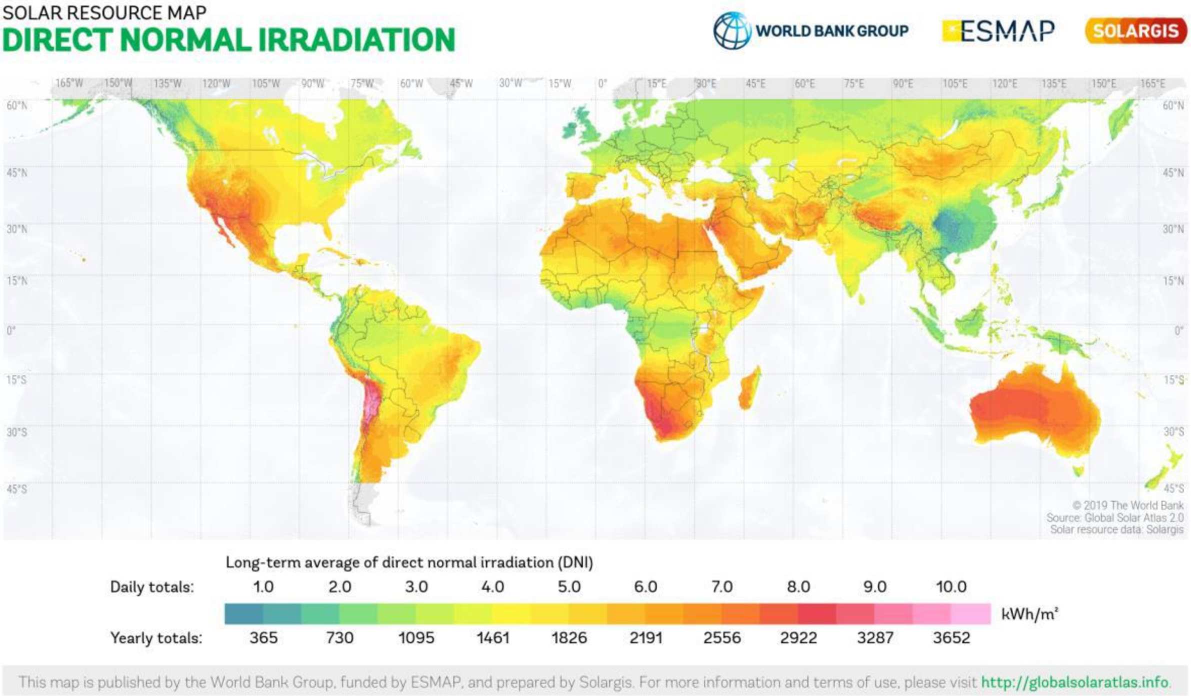
Also, the classification of Sunbelt Regions is considered, defined as the countries within the latitudes 40°N and 40°S, which have the highest levels of solar radiation per year on the planet. In these regions, the climates are hot-humid and hot-arid. So, in this approach, all regions between the Tropic lines are considered "predominantly warm" (DEVINENI et al., 2015; EARTHHOW, 2023; GURTNER et al., 2023a; JAKOB, 2020). The Koppen climate classification used in this research is illustrated by Figure 5, while Figure 6 shows the Sunbelt regions, with the direct normal sunlight irradiation.

Figure 5 Koppen climate classification, showing "predominantly warm" climates — tropical and dry, which are the ones within and close to the Tropics.



Source: EARTHHOW, 2023.

Figure 6 Sunbelt regions, defining the areas of the globe with higher levels of solar irradiation, mainly within tropical and dry climates.

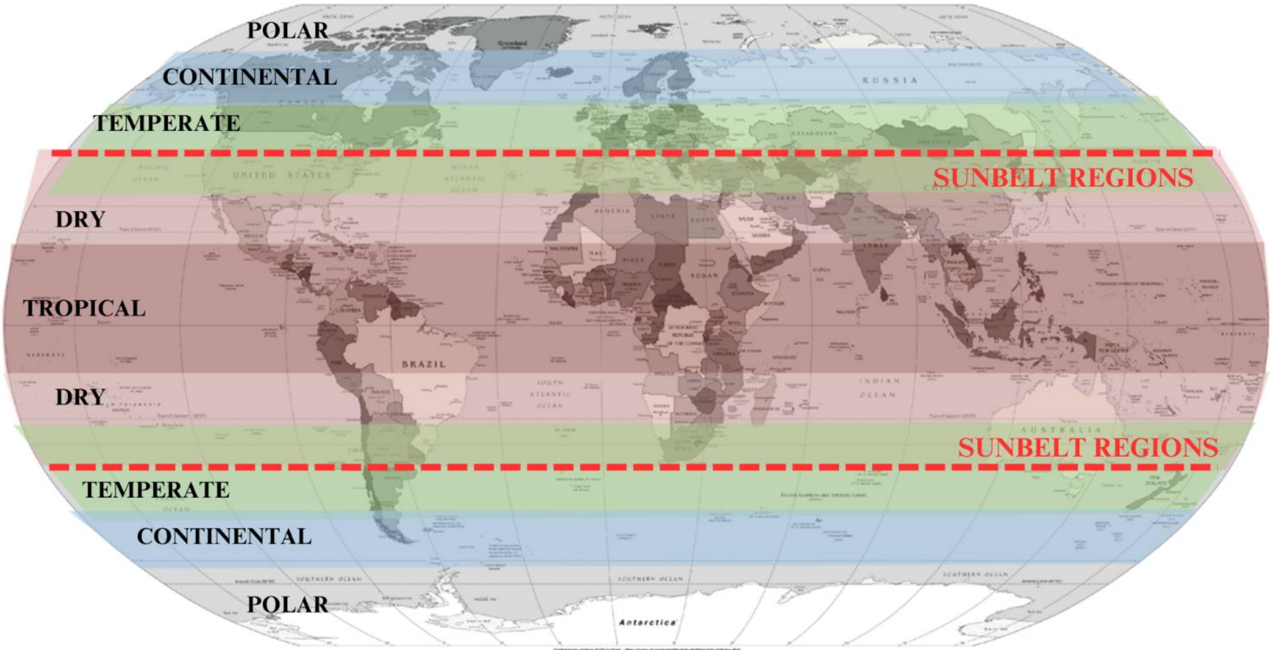


Source: (GURTNER et al., 2023b).

Based on Figures 5 and 6, it is possible to comprehend that both Koppen and Sunbelt Regions classifications demonstrate basically the same regions as hot-humid and hot-arid with the higher solar incidence, on global scale. Thus, a combination of these two classifications is used in this research (Figure 7), to allow a further understanding of how daylight requirements and metrics are used, according to climates and the solar incidence, in different places and find occasional patterns that match those climatic specificities. The climate distribution and the sunbelt regions are rather simplified, since those divisions are rather irregular in literature.

The darker red hatch on the map of Figure 7 highlights the higher solar incidence in tropical climates near the Equator Line, where warmer climates on the globe are found. The clearer red hatches contiguous to the darker one highlight the dry and temperate climates, also with a high solar incidence — even though less than the central region of the globe. The green areas on the map are the Temperate climates, with an intermediate solar radiation amount; the blue hatches express the Continental climate and the grey areas are the Polar climates, both receiving the less amount of solar incidence on the planet.

Figure 7 Koppen climate classification and Sunbelt Regions reunited, in a simplified scheme.



Source: Author, adapted from EarthHow (2020) and Gurtner et al. (2023b).

Further on, topic 4.4 has the analysis combining the results of the SLR, documents collection and survey. The aim is to verify which requirements and metrics appear in literature, which are most frequent in documents and if these groups present similar or different tendencies. These tendencies will be important to verify possible pathways to harmonization. The crossed analysis takes into account a wide worksheet with all documents collected, specifying the occurrence of metrics, as well as the representation of documents by countries and continents.

3.6. Harmonization strategies

In order to verify the feasibility of harmonization of requirements and metrics, all the criteria found in documents will be listed, accounted according to occurrence in documents and grouped following the main aspect of the requirement. Requirements will be explored in each document, including concepts, metrics and their parameter values. That way, the intention is to elaborate a scheme to subsidize harmonization based on semantics, which guarantees a rather flexible classification, since it allows some variations in concepts or methods, but with the same core meaning to requirements and metrics (BAKX et al., 2019; CHENG et al., 2024).

The goal is to facilitate a conceptual and technical interpretation of daylight requirements and metrics, with a categorization scheme based on which aspects of daylight performance are measured or to which architectural/urban element they are related to — i.e., building or urban aspects, design, performance, etc (AMORIM; PINHEIRO, 2024). As the demand for harmonization is taken in this research as a premise to help professionals to design using daylight, all methodological steps are focused on a classification that gives some contouring to a harmonized system. Also, a careful classification process is necessary for better comprehension of daylight aspects by professionals, government institutions and stakeholders of building construction (BAKX et al., 2019; CHENG et al., 2024).

That way, daylight requirements and metrics will be categorized in groups that combine their semantics (CHENG et al., 2024), which facilitates the understanding of daylighting aspects involved, while demonstrates directions to make daylight concepts closer to daily architectural practice (AMORIM; PINHEIRO, 2024).

4. Documents collected: analysis and discussion

The collected documents — standards, rating systems, guidelines, regulations, building and urban codes — are analysed in this section, approaching their contents regarding daylight and application in each country. Document received were from 22 countries in Europe, 2 in North America, 4 in South America, 4 in Asia, 2 from Oceania and 2 from Africa, with a total of 137 documents, as summarized in Table 6.

Table 6 Primary documents collected, distributed by country/continent of origin.

DOCUMENT	COUNTRY	QUANTITY
STANDARDS	Europe	11
	Italy	3
	UK	2
	Germany	1
	Netherlands	1
	Slovenia	1
	Czech Republic	2
	Austria	1
	France	1
	Slovakia	1
	Estonia	1
	Brazil	3
	Chile	1
	Colombia	2
	USA	4
	China	1
	Russia	2
	South Africa	1
GUIDELINES	UK	3
	Netherlands	1
	Estonia	1
	Turkey	1
	Singapore	1
	Japan	1
	USA	1
	Chile	2
	Colombia	1
RATING SYSTEMS	International	1
	UK	2
	Italy	1
	Sweden	1
	Germany	1

(Cont. Table 6) Primary documents collected, distributed by country/continent of origin.

DOCUMENT (cont.)	COUNTRY (cont.)	QUANTITY (cont.)
RATING SYSTEMS	France	3
	Spain	1
	USA	3
	Canada	1
	Australia	1
	Colombia	1
	Brazil	3
	Chile	2
	Japan	1
	China	1
	South Africa	1
BUILDING AND URBAN CODES/ REGULATIONS	Italy	9
	UK	2
	Netherlands	1
	Norway	1
	Poland	1
	Austria	1
	Belgium	1
	Croatia	1
	Hungary	1
	Denmark	1
	France	4
	Germany	1
	Slovenia	1
	Sweden	1
	Czech Republic	1
	Estonia	1
	Slovakia	2
	Spain	1
	Ireland	1
	Turkey	1
	USA	5
	Canada	3
	Brazil	10
	Chile	1
	Bolivia	2
	Australia	1
	New Zealand	3
	China	1
	Japan	1
	Egypt	2
TOTAL		**137**

Source: AMORIM; PINHEIRO (2024).

The highest quantity of documents is on the category of Building and Urban Codes/Regulations. Some countries, as Italy and Brazil, have a large representation with numerous documents, portraying different regional situations. France and USA also have documents from different regions and with recommendations to various building typologies. Standards is the second larger category, followed by Rating Systems and lastly, Guidelines.

4.1. Use and evolution of daylight requirements in primary documents

The primary documents analysed were received in their original versions or in summaries, and are divided as the beforementioned standards, guidelines, rating systems, regulations, and building and urban codes. Then, each document was analysed approaching the daylight requirements.

4.1.1. Standards

Standards analysed came from Europe (19), with representativity from Asia (3), North America (5) and South America (6) and Africa (1). The standards analysed were the ones listed in Table 7, and a description of each one follows.

Table 7 Standards received and analysed in this research.

TITLE / COUNTRY	REFERENCE
UNI 10840:2007 – Light and lighting – Educational buildings (Italy)	(UNI, 2007)
UNI/PdR 13.1:2019 Environmental sustainability of construction works (Italy)	(UNI, 2019)
UNI/PdR 77:2020 – Guidelines for computerized calculation for the determination of LENI (Italy)	(UNI, 2020)
BS 8206-2/2008: Code of practice for daylighting (UK)	(BSI, 2008)
TSG-1-004:2010 – Efficient use of energy (Slovenia)	(REPUBLIKE SLOVENIJE, 2022)
CIE S 026/E:2018: system for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light (Europe)	(CIE, 2018)
ISO/CIE DIS 8995-1:2023 – Light and Lighting – Lighting for Workplaces. Part 1: Indoors	(ISO; CIE, 2023)
LM 83-2012: Approved Method - IES Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE) (USA, Canada)	(IES, 2012)
LM 83-2023: Approved Method - IES Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE) (USA, Canada)	(IES, 2023a)
IES RP-46-2023: Supporting the Physiological and Behavioral Effects of Lighting in Interior Daytime Environments (USA)	(IES, 2023b)
ANSI/IES LP-3-20/2020: Lighting Practice – Designing and Specifying Daylighting for Buildings (USA)	(IES, 2020)

(Cont. Table 7) Standards received and analysed in this research.

TITLE / COUNTRY (cont.)	REFERENCE (cont).
ANSI/ASHRAE/IES Standard 90.1-2022: Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings (USA)	(ANSI; ASHRAE; IES, 2022)
EN 15193-1/2017: Energy Performance of Buildings – Energy Requirements for Lighting (Europe)	(CEN, 2017)
EN 17037/2018: Daylight of Buildings (Europe)	(CEN, 2018)
BS ISO 19454:2019 – Building Environment Design – Indoor Environment – Daylight opening design for sustainability principles in visual environment (Europe)	(BSI; ISO, 2019)
The Hague sunlight norm (The Netherlands)	(THE NETHERLANDS, [s.d.])
EN 12464-1: Light and Lighting - Lighting of Indoor Work Places (Europe)	(CEN, 2011a)
EN 410 – Glass in buildings – Determination of luminous and solar characteristics of glazing (Europe)	(CEN, 2011b)
EN 14500 and EN 14501 – Blinds and shutters – Thermal and visual comfort – Performance characteristics and classification (Europe)	(CEN, 2021a)
EN 16798-1 & CEN 16798-2 – Energy performance of buildings – Ventilation for buildings (Europe)	(CEN, 2019)
NF X35-103 – Ergonomics – Ergonomic Principles for Workplace Lighting (France)	(CEN, 2013)
ČSN 73 4301:2004 – Residential buildings (Residential Buildings) (Czech Republic)	(DARULA; CHRISTOFFERSEN; MALIKOVA, 2015)
EVS 894:2008+A1:2010 – Lighting for residential and office premises (Estonia)	(DARULA; CHRISTOFFERSEN; MALIKOVA, 2015)
STN 73 4301:2005 Dwellings buildings (Slovakia)	(DARULA; CHRISTOFFERSEN; MALIKOVA, 2015)
Technical Regulation of Lighting and Public Lighting (RETILAP) (Colombia)	(REPUBLICA DE COLOMBIA, 2010)
Colombian Technical Standard (NTC) 4595 - Planning and design of school facilities and environments (Colombia)	(REPUBLICA DE COLOMBIA, 2020)
ABNT NBR 15.215:2023 – Daylighting (Brazil)	(ABNT, 2024)
ABNT NBR 15.575:2013 – Building Performance Standard (under revision) (Brazil)	(ABNT, 2013a)
NBR ISO CIE 8995:2013 – Lighting in office spaces" (Brazil)	(ABNT, 2013b)
Standardized terms of reference with energy efficiency parameters and environmental comfort (…) – TDRe (Chile)	(GOBIERNO DE CHILE, 2016)
Standard for daylighting design of buildings GB 50033 (China)	(MOHURD, 2013)
SP 23.102.2003 – Natural Lighting of Residential and Public Buildings (Russia)	(NIISF RAASN; FSUE CNS, 2003)
SP 52.13330.2016 – Daylighting and Artificial Lighting (Russia)	(NIISF RAASN; LLC CERES-EXPERT, 2016)
South African National Standard - The application of the National Building Regulations Part O: Lighting and ventilation (SANS10400-O) (South Africa)	(SOUTH AFRICAN BUREAU OF STANDARDS, 2011a)

Source: AMORIM; PINHEIRO (2024).

"UNI 10840:2007 – Light and lighting – Educational buildings" (**Italy**) approaches specifically educational facilities, proposing the use of Daylight Factor (DF) as metric, similar to the "Circolare Ministeriale Lavori pubblici n. 3151, May 22 1967", an Italian law (UNI, 2007). "UNI/PdR 13.1:2019 – Environmental sustainability of construction works", also **Italian**, specifies criteria for the assessment of the environmental sustainability of non-residential buildings and their external relevant areas, with a view to their classification through the award of a performance score. The document calculates the performance score of non-residential buildings, newly built or undergoing major renovations, involving not the individual unit, but the entire building (UNI, 2019).

"BS 8206-2/2008: Code of practice for daylighting" (**United Kingdom**) uses Average Daylight Factor (DF_{avg}) as main daylight requirement. In some domestic interiors, DF_{avg} values vary (BSI, 2008). Also current in **UK** and all **Europe**, "ISO 19454:2019 – Building Environment Design – Indoor Environment – Daylight opening design for sustainability principles in visual environment" does not display requirements as usually found in this research. Instead, it sets a range of design criteria that favours daylighting in built environment, with no metrics or value parameters recommended. In this case, the requirements are "Extent of Sunlight", "View to exterior", "Daylight Opening to the Wall/Floor Area", "Appropriate level of indoor daylight" and "Daylight control systems". Depending on the building type, the criteria of each requirement vary (BSI; ISO, 2019).

"TSG-1-004:2010 – Efficient use of energy" (**Slovenia**), which states that the "collecting area' (the roof and the facade) of a building is exposed to sun's rays 1m above the ground should provide a quantity of hours of exposure of at least 2h on December 21st; at least 4h on the equinoxes; and at least 6h on June 21st — similar to a common requirement called Exposure to Sunlight (REPUBLIKE SLOVENIJE, 2022).

"LM 83" in a standard from the **United States of America** (USA) that originally developed back in 2012 the method to calculate and assess spaces through Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE) (IES, 2012). LM 83 has been revised, and the new version was recently published by the Illumination Engineering Society of North America (IESNA). Comparing both versions, LM 83:2023 included a new parameter: in spaces where are performed less critical visual tasks, sDA can reach lower a lower value. ASE, in LM 83:2023 version, is reported through gross ASE, that considers all image-preserving glazing; and net ASE, which considers only the image-preserving glazing areas that do not apply an automated daylight management. The threshold value of ASE, though, is still the same as in the 2012 version (IES, 2023a). In **Canada**, LM 83 in adopted, just as in the United States.

Also from the **USA**, “ANSI/IES LP-3-20/2020: Lighting Practice – Designing and Specifying Daylighting for Buildings” has as requirements several static and dynamic metrics, as well as geometry-based metrics: DF, DA, sDA, UDI, DGP, DGI, ASE, WWR, WFR, shadowing angles, VLT. The recommendations aim to guide professionals through the project phases (IES, 2020). “ANSI/ASHRAE/IES Standard 90.1-2022: Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings” focus on metrics regarding fenestration in buildings, such as WWR, skylight fenestration areas and VLT of glazing (ANSI; ASHRAE; IES, 2022).

“EN 15193-1/2017” is also a standard adopted by **European** countries in general. LENI takes into account the daylight contribution through DF, Daylight Supply Factor ($F_{D,S}$) and Daylight Dependency Factor (F_D). $F_{D,S}$ and F_D depend on location, latitude, sky conditions, building geometry and façade/openings orientation (UNI, 2017). Hence, as both are also linked to DF, do not have a single recommended value, but instead EN 15193-1/2017 displays a series of values in tables to enable LENI calculations.

Also adopted by mostly of **European** countries, “ISO/CIE DIS 8995-1:2023 Light and Lighting – Lighting for Workplaces. Part 1: Indoors” (ISO; CIE, 2023)specifies lighting requirements for humans in indoor work places, focusing on visual comfort, performance and safety on work spaces. As metrics, ISO/CIE 8995-1:2023 establishes surface reflectances, maintained illuminances, DGP and colour rendering (Ra).

“EN 17037:2018” is a standard that applies to all **European** countries (CEN, 2018). Daylight Provision, Assessment of views out, Exposure to Sunlight and Glare are the requirements on EN 17037. As metrics, Target Illuminance (E_T) regards the illuminance level achieved across a fraction of the reference plane within a space for at least half of the daylit hours, from a vertical or an inclined opening. Minimum Target Illuminance (E_{Tmin}) refers to minimum visibility and uniformity of daylight in spaces. Regarding Assessment of Views Out, the metrics — Horizontal Sight Angle, Layers, Distance — have the aim to evaluate the permanent interactions between occupants and external environment. Exposure to Sunlight is important in winter seasons of cold climates, while Glare Control assesses, through DGP, the occurrence and tolerance of possible glare within occupants of a room.

“EN 12464-1: Light and Lighting – Lighting of Indoor Work Places” is also a **European** Standard, that has DF as the only requirement regarding daylight, defining as parameter at least 1% (CEN, 2011a). Other several standards valid for **Europe** were received, such as: “EN 410 – Glass in building – Determination of luminous and solar characteristics of glazing” (CEN, 2011b); “EN 14500 and EN 14501 – Blinds and shutters – Thermal and visual comfort – Performance characteristics and classification” (CEN, 2021a); “EN 16798-1 & CEN 16798-2 – Energy performance of buildings – Ventilation for buildings” (CEN, 2019). Most of these standards require daylight indoors, but do not set minimum or maximum values to comply. “EN 16798-1 & CEN 16798-2” uses DF values, calculated according to geometric and glazing properties of the openings.

European “ISO 19454:2019 – Building Environment Design – Indoor Environment – Daylight Opening Design” (BSI; ISO, 2019) is focused on openings, defining a series of requirements to guide design, such as: Daylight opening ratio to the wall area of a habitable room; Levels of indoor daylight based on human visual needs and the extent of sunlight; Control of glare caused by daylight, etc. However, the standard does not use any particular metric, which makes the requirements too vague.

Another document from **The Netherlands** is “Haagse bezonningsnorm” (The Hague sunlight norm), which describes Target DF, that predicts a parameter of daylight distribution by time and space; other requirement is the sunlight exposure, defining the minimum sunlight hours a facade must be able to receive in a given period of the year, recommending a quantity of hours per day (THE NETHERLANDS, [s.d.]).

From **France**, “NF X35-103 – Ergonomics – Ergonomic Principles for Workplace Lighting” (CEN, 2013). As some of the European standards, NF X35-103 demands for daylight indoors, without making specific exigences on how to achieve it.

From **Czech Republic**, “ČSN 73 4301:2004 – Obytné budovy (Residential Buildings)” establishes Sunlight Duration as metric to measure the exposure to sunlight in spaces, as well as **Estonian** “EVS 894:2008+A1:2010 – Lighting for residential and office premises” and “STN 73 4301:2005 – Dwellings buildings”, from **Slovakia** (DARULA; CHRISTOFFERSEN; MALIKOVA, 2015).

RETILAP (2010), from **Colombia**, contains as requirements several DF values, which vary according to the type of room/building. “NTC 4595” (2020), also from **Colombia**, is a standard focused of educational facilities and has as requirements: DF, referring to values of RETILAP; WFR, according to local climates; and minimum setbacks between openings and plot’s boundaries, in order to guarantee access to daylight by not obstructing openings from the outside (REPUBLICA DE COLOMBIA, 2010, 2020).

The new version of “ABNT NBR 15.215:2023 – Daylighting” (**Brazil**) (ABNT, 2024), has similar requirements to EN 17037:2018 – Daylight Provision, Assessment of views out, Exposure to Sunlight and Glare. The parameter values change, though, given the great differences between European and Brazilian climates. “ABNT NBR 15.575:2024 – Building Performance” (**Brazil**) (ABNT, 2013a), also under revision, recommends as requirements the Daylight Target Illuminance — as a metric of daylight provision — and Minimum Illuminance — to provide daylight uniformity to rooms. Both target illuminance and minimum illuminance should be achieved for at least 50% of daylit hours, considering 10 h/day of daylight. These levels have a similar logic to ABNT NBR 15.215:2024 on purpose, due to the intention to harmonize both standards in the best way possible. “NBR ISO CIE 8995:2013 – Lighting in office spaces” (**Brazil**) (ABNT, 2013b), uses DF as metric for daylight in offices.

From **Chile**, “Términos de Referencia Estandarizados con Parámetros de Eficiencia Energética y Confort Ambiental (…) – TDRe” uses both static and dynamic metrics as daylight requirements: there are parameters for DF, DA, sDA, UDI, DGP and luminance levels for different tasks, considering minimum and acceptable levels, as well as energy savings due to the use of daylight indoors (GOBIERNO DE CHILE, 2016).

The **Chinese** “Standard for daylighting design of buildings GB 50033 (2013)” uses as requirements DF, WFR, and Daylight Glare Index (DGI). As for DF, there are several values, corresponding to the various building typologies, from offices to residential, industry, hotels, healthcare, etc. WFR connects the openings’ areas to the depth that lighting reaches inside the rooms, by side and roof windows. DGI is a metric related to glare, not common in documents. Similarly to DGP, DGI classifies glare perception from imperceptible to intolerable (MOHURD, 2013).

From **Russia**, “SP 23.102.2003 – Natural Lighting of Residential and Public Buildings” and “SP 52.13330.2016 – Daylighting and Artificial Lighting” use as requirements target DF and WFR, which are interdependent, since WFR values depend directly on the parameters of DF and the illuminance target level (NGUYEN; KORKINA, 2021; NIISF RAASN; FSUE CNS, 2003; NIISF RAASN; LLC CERES-EXPERT, 2016).

The **South African** National Regulations (SANS10400-O) (2011/2012) uses as requirements the minimum light transmittance of glazed areas, even though there are no parameters defined, but instead it recommends that “glazing material or sealant that permits light to pass through but with a degree of obscuration and diffusion”. Also, SANS10400-O states WFR parameters, as well as “zones of space” — which are different values of linear distances to allow and estimate the influence of vertical obstructions over windows (SOUTH AFRICAN BUREAU OF STANDARDS, 2011b, 2011a, 2012).

Regarding non-visual effects, the **European** “CIE S 026/E:2018: system for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light” recommends Melanopic Equivalent Daylight Illuminance (mEDI or M-EDI) as main metric, but as it is (CIE, 2018). The **Brazilian** “NBR 15.215-3: Daylighting” defines parameters for three metrics of non-visual effects: Circadian Stimulus (CS), Equivalent Melanopic Lux (EML) and Melanopic Equivalent Daylight Illuminance (mEDI or M-EDI) (ABNT, 2024). The last Standard with recommendations about non-visual effects is the **American** “IES RP-46:2023 – Supporting the physiological and behavioral effects of lighting in interior daytime environments”, which uses Melanopic Equivalent Daylight Illuminance (mEDI or M-EDI) as metric (IES, 2023b). The following Table 8 summarizes findings about daylight requirements in the standards received.

Table 8 Daylight requirements present in the standards received.

CONTINENT	COUNTRY	REQUIREMENTS	METRICS	DOCUMENT
Europe	Europe	Daylight Provision	E_T	EN 17037: 2018
			E_{Tmin}	
		Assessment of views out	Horizontal Sight Angle Layers Outside distance view	
		Exposure to Sunlight	Exposure to Sunlight	
		Glare	DGP	
		Energy for illumination	DF	EN 15193: 2017
			$F_{D,S}$	
			F_D	

(Cont. Table 8) Daylight requirements present in the standards received.

CONTINENT (cont.)	COUNTRY (cont.)	REQUIREMENTS (cont.)	METRICS (cont.)	DOCUMENT (cont.)
Europe	**Europe**	Non-visual effects	mEDI	CIE S 026/E:2018
		—	VLT	EN 410:2011
		Glazing properties	—	EN 14500 / 14501
		Access to daylight	DF	EN 16798-1 CEN 16798-2:2019
		Outside views	—	
		—	DF	EN 12464-1:2011
		Luminance distribution	Wall, floor and ceiling reflectance and mantained illuminance	ISO/CIE DIS 8995-1:2023
		Illuminance	$\bar{E}m$	
		Glare	DGP	
		Colour rendering	Ra	
		Daylight	—	
	Italy	General criteria for electric lighting and daylighting	DF	UNI 10840:2007
		Energy for illumination	$F_{D,S}$	UNI/PdR 77:2020
			F_D	
	The Netherlands	Daylight Provision	Target DF	NEN-EN 17037:2022
			Target DF	
		Sunlight exposure	Target daily sunlight hours on a façade	The Hague sunlight norm
	UK	Daylight Provision	DF_{avg}	BS 8206-2: 2008
		Daylight opening ratio to wall area	—	BS ISO 19454:2019
		Daylight opening ratio to floor area	—	
		Levels of indoor daylight	—	
		Quality of views to exterior	—	
		Control of glare caused by daylight	—	
		Daylight control systems	—	
	France	Access to daylight	—	NF X35-103:2013
		Outside views	—	
	Slovenia	Energy efficiency of buildings	FDS_T (DFavg)	TSG-1-004: 2010
		Exposure to sunlight	Exposure to sunlight	
	Czech Republic	Sunlight Duration	SD	ČSN 73 4301:2004
	Estonia	Sunlight Duration	SD	EVS 894:2008+ A1:2010
	Slovakia	Sunlight Duration	SD	STN 73 4301:2005
South America	Colombia	Exploitation of daylight	CLD / DF	RETILAP (2010)
		Visual Comfort	CLD / DF	NTC 4595 (2020)
			WFR	
			Minimum setback	
	Brazil	Daylight Provision	E_T	ABNT NBR 15.215:2023
			E_{Tmin}	

(Cont. Table 8) Daylight requirements present in the standards received.

CONTINENT (cont.)	COUNTRY (cont.)	REQUIREMENTS (cont.)	METRICS (cont.)	DOCUMENT (cont.)
		Assessment of views out	Horizontal Sight Angle Layers Outside distance of the view	
		Exposure to Sunlight	Exposure to Sunlight	
		Glare	DGP	
		Daylight as a non-visual stimulus	CS	
			EML	
			mEDI	
		Daylight Provision	Target Illuminance	ABNT NBR 15.575:2013
			Minimum Illuminance	
		Daylight Provision	DF	NBR ISO CIE 8995:2013
	Chile	Visual Comfort: Daylight	DF	TDRe v2016
			DA	
			sDA	
			UDI	
			DGP	
			Luminance	
North America	USA, Canada	Sufficiency of Daylight Illuminance	sDA $_{300/50\%}$	LM 83:2012/ 2023
			sDA $_{150/50\%}$	
		Potential Risk of Excessive Sunlight Penetration	ASE $_{1000/250h}$	
		Windows and Skylight Details	VLT	
	USA	Daylighting Design	DF	ANSI/IES LP-3-20/2020
			DA	
			DA_{con} / cDA	
			DA_{max} / mDA	
			sDA	
			UDI	
			UDI-e	
			ASH	
			ADE	
			ASE $_{1000/250h}$	
			DGI	
			DGP	
		Design Parameters	a_P	
			WWR	
			VLT	
			WFR	
		—	mEDI	IES RP-46:2020
Asia	China	Standard Value for Daylight	DF	GB 50033 (2013)
		—	DGI	
		—	WFR	
	Russia	—	DF_T	SP 23.102.2003
		—	WFR	
		—	DF	SP 52.13330.2016

(Cont. Table 8) Daylight requirements present in the standards received.

CONTINENT (cont.)	COUNTRY (cont.)	REQUIREMENTS (cont.)	METRICS (cont.)	DOCUMENT (cont.)
Africa	South Africa	Natural Lighting: general	minimum light transmittance	SANS10400 (2011/12)
		Opening’s area	WFR	
		—	WFR of combined areas	
		Zone of space	Minimum setbacks from outside obstacles	
		Length of zone	Length of zone	
		Coverings over openings	—	

Source: AMORIM; PINHEIRO (2024).

The primary documents’ analysis shows that the influence of LM 83 is regional: USA and Canada use frequently LM in their calculations and the standard also influenced rating systems like LEED, WELL, and Living Building Challenge. In Europe, the EN standards are adopted by most of the countries. The beforementioned worldwide influence of these standards stands, actually, in the documents that are used outside their original regions. Some examples are the Brazilian versions of LEED and ABNT NBR 15.215, and Chilean TDRe.

In Standards, as it is possible to understand from Table 8, some requirements are very well defined, since some of them appear in various documents: “daylight provision”, “exposure to sunlight”, “sunlight duration”, “glare assessment”, “assessment for views out”. The other requirements can have similar names to those, like “sufficiency of daylight”, “daylight”, “access to daylight”, “visual comfort”, “outside views”. The metrics are frequently the same, also: Daylight Factor (DF), Target Illuminance (E_T), Minimum Target Illuminance (E_{Tmin}), Spatial Daylight Autonomy (sDA), Daylight Glare Probability (DGP), Window-to-Floor Ratio (WFR), Window-to-Wall Ratio (WWR). This indicates some groups that can be combined towards a harmonization considering the daylight aspect and the metrics used, regardless of the countries and climates — since this harmonization process does not consider the parameter values.

4.1.2. Rating systems

Rating Systems schemes collected during the research were from Europe (6), Asia (2), Oceania (1), North America (6) and South America (8). Specifically, the Rating Systems analysed during the collection campaigns are listed in Table 9 and described further on.

Table 9 Rating Systems received and analysed in this research.

TITLE / COUNTRY	REFERENCE
WELL v 2.1 (USA)	(IWBI, 2023)
LEED v 4.1 (USA)	(USGBC, 2022)
Living Building Challenge (LBC) (USA, Canada)	(LIVING FUTURE ORG., 2019)
Protocollo ITACA (Italy)	(ITACA, 2022)
BREEAM (UK)	(BRE, 2022)
German Society for Sustainable Building (DGNB) (Germany)	(DGNB SYSTEM, 2023)
Svanen scheme 089 (Sweden)	(NORDIC COUNCIL OF MINISTERS, 2016)
HQE B v1.0 and BD v4.0 (France)	(CERTIVEA, 2024a)
NF Habitat HQE certification – House & Collective Residential buildings; Construction & Renovation (France)	(CERTIVEA, 2024b)
OsmoZ certification (France)	(CERTIVEA, 2024c)
Certificación VERDE (Spain)	(HRASKA, 2011)
LEED GBC CASA v 2 (Brazil)	(GBC BRASIL, 2017)
LEED v 4 (2014) (Brazil)	(GBC BRASIL, 2014)
Inmetro Normative Instruction for the Energy Efficiency Classification of Commercial, Services and Public Buildings (INI-C) (Brazil)	(INMETRO, 2022)
Selo Azul Caixa (Brazil)	(CAIXA, 2010)
AQUA-HQE (Brazil)	(FUNDAÇÃO VANZOLINI; CERTIVEA, 2021)
HQE (France)	(CERTIVEA, 2024a)
NF HQE Habitat (France)	(CERTIVEA, 2024b)
CASA Colombia v3.0 (Colombia)	(CCCS, 2023)
Certificación de Edificio Sustentable (CES) (Chile)	(GOBIERNO DE CHILE, 2022)
Certificación de Vivienda Sustentable (CVS) (Chile)	(GOBIERNO DE CHILE, 2021)
Green Star (Australia)	(GREEN BUILDING COUNCIL AUSTRALIA, 2022)
Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) (Japan)	(CASBEE, 2014)
BCA Green Mark (Singapore)	(BCA GREEN MARK, 2021)
Green Building Evaluation Standard GB/T 50378 (China)	(MOHURD, 2019)
Green Star Rating (South Africa)	(GREEN BUILDING COUNCIL OF SOUTH AFRICA, [s.d.])

Source: AMORIM; PINHEIRO (2024).

“LEED” is also an **American** rating system, highly diffused worldwide, that applies for many different types of buildings. The daylight requirements most commonly used in LEED v 4.1 are sDA and ASE determined by simulations, with the alternatives of illuminance calculation by simulations and by local measurements; and quality views, specifying the criteria to which views must comply (USGBC, 2022). **Canada** applies LEED v 4.1 as main rating system in the country in North America. Also, LEED is the most popular certification scheme worldwide.

“WELL” is an **American** rating system mostly focused on the health aspects of buildings, in order to provide restorative spaces and suitable places for work or rest. Regarding visual effects, the requirements are sDA and Point-in-time Illuminance of ASE (IWBI, 2023). WELL is also used in **Canada** for specific evaluations regarding health in buildings. “Living Building Challenge (LBC)” is also an **American and Canadian** system, developed in partnership by both countries. LBC is focused on the relation between impact versus efforts, establishing goals that cause positive and specific impacts to the place, the community and the culture where the project is located. LBC is organized into seven performance categories that encourage self-sufficient, positive, regenerative buildings regarding light, air, food, nature and community. Daylight in LBC is evaluated through the provision of daylight and views out in indoor spaces, which must be available for 75% or 90% of permanently occupied rooms’ areas, earning more points according to the level complied (LIVING FUTURE ORG., 2019).

“Protocollo ITACA” is the **Italian** rating system. Regarding daylight, ITACA uses as requirement the Mean Daylight Factor (DF_m) to evaluate daylight availability indoors (ITACA, 2022).

BREEM has an **international** version that includes as metrics DF_{avg}, Average daylight illuminance and Minimum daylight illuminance, whose values vary according to latitude and climates where the System is to be applied (BRE, 2021). The **UK** version of “BREEAM” uses mainly Average Daylight Factor (DF_{avg}) (BRE, 2023). The BREEAM version used in **The Netherlands**, instead, uses the Target Daylight Factor, that refers to the DF achieved across a fraction of the reference plane (80%), within an occupied space, for at least half of the daylight hours, establishing target parameters for spaces according, to the function and type of building (BRE, 2022).

The “Svanen scheme 089” (**Sweden**), is a Nordic certification that requires daylight with the same metrics and parameters as those found in EN 17037 (NORDIC COUNCIL OF MINISTERS, 2016).

The “**German** Society for Sustainable Building (DGNB)” accounts daylight in different interior spaces through several metrics, such as DF, E_T, windows’ sizes, exposure to sunlight, DGP and views out (DGNB SYSTEM, 2023).

From **Spain**, “Certificación VERDE”, focused on sustainability of buildings in various aspects, uses DF as main daylight metric (HRASKA, 2011).

The **Brazilian** version of LEED also uses sDA and ASE, as well as their alternative methods of illuminance calculation through simulations or local measurements; also evaluates quality views. The parameter values and scores are basically the same in both versions (GBC BRASIL, 2014). Also **Brazilian**, “Instrução Normativa Inmetro para a Classificação de Eficiência Energética de Edificações Comerciais, de Serviços e Públicas (INI-C)” is a system that classifies buildings according mainly to energy efficiency parameters. INI-C refers to commercial and public buildings, where the ranking goes from E, for worse performance, to A, for the best performance. In this system, there is the possibility to comply the demand for integration between daylight and electric light by computer simulation using DA (INMETRO, 2022).

Selo Azul Caixa is another **Brazilian** rating system focused on providing indicators and parameters for the construction of social housing. Those indicators enable better conditions in terms of sustainability, energy efficiency and comfort to occupants. Regarding daylight, though, it only specifies the demand for natural light in common areas and in bathrooms (CAIXA, 2010).

“Alta Qualidade Ambiental (AQUA-HQE)” (2021) is the latest **Brazilian** adaptation of the **French** “Haute Qualité Environnementale (HQE)”, focused on non-residential buildings. It uses basically DF as main requirement in a wide diversity of spaces. Also, AQUA-HQE considers WWR, views out and general access to daylight, with different parameters, according to tasks executed in the various types of buildings (FUNDAÇÃO VANZOLINI; CERTIVEA, 2021).

From **France**, “High Environmental Quality (HQE)” has as requirements for tertiary buildings DA, DGP, outside views according to EN 17037 (CERTIVEA, 2024a). The residential version of HQE, “NF Habitat HQE” requires access to daylight in all rooms, VLT >60%, WFR parameters for minimum and better scores, and outside views (CERTIVEA, 2024b). Also French, “OsmoZ Certification” is focused on quality of life at work environments. As for the daylight requirements, OsmoZ considers DF, DA and guarantees of access to daylight for 50% of meeting rooms and 80% of offices (CERTIVEA, 2024c).

The **Colombian** “CASA Colombia v 3.0” (2023) has requirements applicable to social and non-social housing. It requires DF values according to RETILAP standard, as well as an average value of WFR, visible light transmittance (VLT) of glazing, a minimum illuminance of 100 lux in 90% of rooms’ areas — similar to Minimum Target Illuminance —, adequate daylight access, which is very similar in concept to UDI, and a requirement focused on access to views out (CCCS, 2023).

From **Chile**, “Certificación de Edificio Sustentable (CES)” evaluates office, commercial and institutional buildings, while “Certificación de Vivienda Sustentable (CVS)” assesses residential buildings. In both schemes, there are static and dynamic metrics, as well as views out as requirements. The main difference is that CES has more detailed parameters, with prerequisites and higher compliance levels for each requirement. In CES, requirements used are DF, $sDA_{300/50\%}$, UDI, views out and DGP. In CVS, the requirements have simpler compliance for DF, UDI and views out (GOBIERNO DE CHILE, 2021, 2022).

“Green Star” is the **Australian** national certification scheme, focused on the promotion of ecofriendly buildings. As daylight requirements, it brings visual light transmittance (VLT) of glazing, views out, DF — with slightly different values of DF for floor areas and work planes’ areas — and overshadowing angle to openings by surrounding buildings (GREEN BUILDING COUNCIL AUSTRALIA, 2022).

“Comprehensive Assessment System for Building Environmental Efficiency (CASBEE)” is the **Japanese** rating system. It evaluates the seismic capacity, the reliability and comfort of buildings, being recognized as an important policy throughout Japan. Since its first version, CASBEE has been continuously improved, including requirements regarding energy, embodied CO_2, the use of ecofriendly materials, improvement of buildings’ life cycle, among others. About daylighting, CASBEE has DF as requirement, with varying parameters for different types of buildings (CASBEE, 2014).

In **Singapore**, the Building Construction Authority (BCA) created “Green Mark” as the national rating system. “BCA Green Mark” is a green building system, focused on the particularities of the tropical climate, with the aim to encourage sustainable design solutions, energy efficiency, reducing embodied carbon, the use of smart technologies, enhance resilience to climate change and the creation of healthier environments. As daylight requirements, BCA Green Mark considers the provision of views out, daylight provision indoors through DA, as well as building morphology metrics, such as WWR, obstruction angles, average urban obstruction, etc (BCA GREEN MARK, 2021).

From **China**, the "Assessment standard for green buildings GB/T 50378" (2019) uses the same requirements for daylight as the defined in "Standard for daylighting design of buildings GB 50033:2013" (MOHURD, 2013, 2019).

The **South African** "Green Star Rating" (GBC South Africa) (n.d.) has as daylight requirements DF and Daylight Illuminance — which is a minimum illuminance that spaces must reach (GREEN BUILDING COUNCIL OF SOUTH AFRICA, [s.d.]). Table 10 below show the requirements found in Rating Systems analysed.

The Rating Systems that mention non-visual effects metrics are the **American** "WELL v 2", which defines parameters using EML, CS and mEDI (IWBI, 2023); and "BCA Green Mark" from **Singapore**, using as main metrics EML and mEDI (BCA GREEN MARK, 2021). Table 10 shows daylight requirements found in the analysis of rating systems.

Table 10 Daylight requirements present in the rating systems researched.

CONTINENT	COUNTRY	REQUIREMENTS	METRICS	DOCUMENT
Europe	UK	Visual comfort – Daylighting	DF_{avg}	BREEAM UK (2023)
			Average daylight illuminance	
			Minimum daylight illuminance	
		View Out	Distance	
			window % of surrounding wall area	
	International	Visual comfort – Daylighting	DF_{avg}	BREEAM International (2024)
			Average daylight illuminance	
			Minimum daylight illuminance	
	Germany	Daylight Availability	DF	DGBN (2023)
			E_T	
			Translucent skylight portion of roof	
		Visual contact to the outside	Angle Layers Distance Window sizes	
		Absence of glare in daylight	DGP	
		Exposure to daylight	Exposure to sunlight	

(Cont. Table 10) Daylight requirements present in the rating systems researched.

CONTINENT (cont.)	COUNTRY (cont.)	REQUIREMENTS (cont.)	METRICS (cont.)	DOCUMENT (cont.)
Europe	Italy	Daylighting	DFm	Protocollo ITACA (2022)
	Sweden	Daylight provision	E_T E_{Tmin}	Svanen scheme 089 (2016)
		Assessment for views out	Horizontal Sight Angle Layers Outside distance of view	
		Glare	DGP	
		Exposure to Sunlight	Exposure to Sunlight	
	Spain	—	DF	VERDE (2011)
	France	Access to daylight	daylight illuminance	HQE B v1.0 and BD v4.0 (2024)
			DA	
		Outside Views	Horizontal Sight Angle Layers Outside distance of view	
		—	DGP	
		Access to daylight	VLT	NF Habitat HQE certification (2024)
			WFR	
		Outside views	—	
		Access to daylight	DF	OsmoZ Certification (2024)
			DA	
		Outside views	—	
North America	USA/ Canada	Light Exposure	sDA $_{300/50\%}$	WELL v 2.0 (2022)
			E_T	
			envelope glazing area	
		Daylight Design Strategies	VLT	
			Vertical envelope glazing	
		Circadian Light Design	EML	
			CS	
			mEDI	
		Daylight	sDA $_{300/50\%}$	LEED v 4.1 (USGBC)
			Point-in-time illuminances	
			Illuminances	
			ASE $_{1000/250h}$	
		Quality views	Layers and distance from windows	
			VLT	
	USA/ Canada	Healthy interior environment	Access to daylight	Living Building Challenge (2023)
			Access to views	
		Healthy interior performance	Access to daylight	
			Access to views	
South America	Brazil	Minimum performance of indoor space	DF	LEED GBC CASA v 2 (2017)

(Cont. Table 10) Daylight requirements present in the rating systems researched.

CONTINENT (cont.)	COUNTRY (cont.)	REQUIREMENTS (cont.)	METRICS (cont.)	DOCUMENT (cont.)
		Daylight	sDA $_{300/50\%}$	LEED v 4 (2014)
			Point-in-time illuminances	
			Measured illuminances	
			ASE $_{1000/250h}$	
		Quality views	Layers	
			Distance from windows	
			Angles	
			Distance to windows	
			VLT	
		Potential Integration of Lighting System with Available Daylight	DA	INI-C (2022)
		Lighting Comfort and Performance	—	Selo Casa Azul Caixa (2022)
		Relation with the surroundings	—	
		Natural ventilation and daylighting in bathrooms	WFR	
		Daylight Optimization	DF	AQUA-HQE (2021)
			WWR	
			VLT	
		Access to views	—	
	Colombia	Visual Comfort	CLD / DF	CASA Colombia v3.0 (2023)
			WFR	
			VLT	
			Minimum illuminance	
			Illuminance levels in space	
			Layers	
	Chile	Passive Visual Comfort: Daylight	DF	Certificación CES (2022)
			sDA $_{300/50\%}$	
			UDI	
			DGP	
		Passive Visual Comfort: Visual access to exterior	Access to views	
			Layers	
			Distance from windows	
		Daylighting	DF	Certificación CVS (2021)
			UDI	
			Light Transmittance	
		Views Out	Layers	
Oceania	Australia	Daylight	VLT	Green Star (2015)
			DF	
			Overshadowing angle	
		Views	Angles	
			Distance	
			External obstruction	
			Window sizes	

(Cont. Table 10) Daylight requirements present in the rating systems researched.

CONTINENT (cont.)	COUNTRY (cont.)	REQUIREMENTS (cont.)	METRICS (cont.)	DOCUMENT (cont.)
Asia	Japan	Light and Illumination – Daylight	DF	CASBEE (2014)
	Singapore	Circadian Rhythm – Views to outside	Occupied area	BCA Green Mark (2021)
			distance to external objects	
			WWR	
		Energy Efficiency – Effective Daylighting	DA	
			Daylighting provision	
			Floor to ceiling height	
			WWR	
			VLT	
			AUOA	
			UDI-e $_{3000lx,10\%}$	
			OOA (possible values)	
		Circadian Lighting System	EML	
			mEDI	
	China	—	DF	Assessment standard for green buildings GB/T 50378 (2019)
		—	DGI	
		—	WFR	
Africa	South Africa	Indoor Environmental Quality	DF	Green Star Rating (GBC South Africa) (n.d.)
			Daylight Illuminance	

Source: AMORIM; PINHEIRO (2024).

Similarly to Standards, Rating Systems define well the daylight requirements. In this case, they are even more detailed, since Rating Systems clearly divide the aspects of building performance that are analysed and ranked. As some examples of requirements, there are “Visual comfort – Daylighting”, “Daylight Availability”, “Daylight Provision”, “Daylight”, “Quality Views”, “Outside Views”. Some of the requirements are too vague, though, without specifying known metrics to an objective evaluation — like in “Healthy interior environment”, “Healthy interior performance”, “Lighting Comfort and Performance”. Without proper definitions of requirements and explicitly recommended metrics, it is not clear how to group these criteria, which makes the harmonization process more difficult and imprecise, even considering the semantics aspect.

The requirements that refer to non-visual effects in Rating Systems usually are named by circadian effects, like in “Circadian Light Design”, “Circadian Rhythm – Views to outside” and “Circadian Lighting System”.

4.1.3. Regulations, Building and urban codes

Building and urban Codes and Regulations received are European (32), North American (2), South American (12), Asian (2), African (1) and Oceanian (3). The documents are summarized in Table 11 described further.

Table 11 Building and Urban Codes and Regulations received and analysed in this research.

TITLE / COUNTRY	REFERENCE
Circolare Ministeriale Lavori pubblici n. 3151	(MINISTERO DEI LAVORI PUBBLICI, 1967)
Circolare Ministeriale n. 13011 (Italy)	(MINISTERO DEI LAVORI PUBBLICI, 1974)
Decreto Ministeriale July 5th, 1975, Modificazioni alle istruzioni ministeriali (June 20 1896) (Italy)	(MINISTERO DELLA SANITÀ, 1975)
Decreto Legislativo n 8 (Italy)	(MINISTERO DEL LAVORO E DELLE POLITICHE SOCIALI, 2008)
Building regulation, D.C.R. n. 247-45856 (Turin, Italy)	(CONSIGLIO REGIONALE DEL PIEMONTE, 2017)
Energy Code Annex to Building Regulations (Turin, Italy)	(CITTÀ DI TORINO, 2006)
Building code of Campania (Italy)	(REGIONE DI CAMPANIA, [s.d.])
Minimum Environmental Criteria – Buildings (CAM – EDILIZIA) (Italy)	(MITE), 2022)
Building Regulations 2010 – March/2023 compilation of individual approved documents	(MINISTRY OF HOUSING COMMUNITIES AND LOCAL GOVERNMENT, 2023)
Right to Light Law (UK)	(GREAT BRITAIN LAW COMMISSION, 2014)
NEN 2057:2011: Building Code 2012 (The Netherlands)	(DUTCH GOVERNMENT, 2012)
Regulation of the Minister of Infrastructure on the technical conditions to meet by building and their location (Poland)	(MINISTER OF INFRASTRUCTURE, 2018)
Executive order on building regulations 2018 (BR18) (Denmark)	(MINISTRY OF TRANSPORT BUILDING AND HOUSING - DENMARK, 2018)
Construction and Housing Code (France)	(MINISTÈRES ÉCOLOGIE ÉNERGIE TERRITOIRES, 2021)
Articles R4213-1 à 4 Créé par Décret n°2008244 - Labor Code - Obligations of the Building Owner (France)	(RÉPUBLIQUE FRANÇAISE, 2008a)
Article R4223-1 à 12 Créé par Décret n°2008244- Labor Code - Obligations of the Employer (France)	(RÉPUBLIQUE FRANÇAISE, 2008b)
Environmental regulation of new buildings re 2020 Th-BCE 2020 and Thbat rule (France)	(RÉPUBLIQUE FRANÇAISE, 2020)
Rules on Minimum Technical Requirements for the Construction of Apartement Buildings and Apartments (Slovenia)	(REPUBLIC OF SLOVENIA, 2011)
Swedish Building Code Boverket's building rules (BBR 29) (Sweden)	(SWEDISH CONSTRUCTION SERVICE, 2020)
Código Técnico de la Edificación (CTE) (Spain)	(MINISTERIO DE VIVIENDA Y AGENDA URBANA, 2019)
Ireland Building Regulations – Technical Guidance Document, Department of Housing, Planning and Local Government (Ireland)	(IRISH DEPARTMENT OF HOUSING, 2020)
Workplace directive - ASR A3.4 Lighting (Germany)	(BAUA, 2023)

(Cont. Table 11) Building and Urban Codes and Regulations received and analysed in this research.

TITLE / COUNTRY (cont.)	REFERENCE (cont.)
OIB guideline 3: hygiene, health and environmental protection (Austria)	(BREGAR et al., 2022, 2023)
Elementary requirements in terms of safety, health and equipment of housing RRU Title II (Regulations Region of Town Planning) (Belgium)	(BREGAR et al., 2022, 2023)
Rulebook of minimal technical conditions for design and construction of apartments from the Socially Establishment Program (Croatia)	(BREGAR et al., 2022, 2023)
Government decree 253/1997. (XII. 20) on the national settlement planning and construction requirements (Hungary)	(BREGAR et al., 2022, 2023)
Building Technical Regulations (TEK17) with guidance (Norway)	(NORWEGIAN BUILDING AUTHORITY, 2017)
Regulation No. 268/2009 about technical requirements for buildings (Czech Republic)	(DARULA; CHRISTOFFERSEN; MALIKOVA, 2015)
RT I: 2002 – Building Code (Estonia)	(DARULA; CHRISTOFFERSEN; MALIKOVA, 2015)
Regulation No. 259/2008 of the Ministry of Health of the Slovak Republic (Slovakia)	(DARULA; CHRISTOFFERSEN; MALIKOVA, 2015)
Regulation No. 532/2002 of the Ministry of Environment of the Slovak Republic (Slovakia)	(DARULA; CHRISTOFFERSEN; MALIKOVA, 2015)
Building Standards Act (Japan)	(BUILDING CENTER OF JAPAN, 2013)
Turkish National Building Regulation (Turkey)	(MOEU, 2023)
Energy Performance Regulation in Buildings (Turkey)	(TURKISH ENVIRONMENT AGENCY, 2017)
G7 Natural Light Acceptable Solution G7/AS1 (New Zealand)	(NEW ZEALAND GOVERNMENT, 2021a)
G7 Natural Light Acceptable Solution G7/AS2 (New Zealand)	(NEW ZEALAND GOVERNMENT, 2021b)
G7 Natural Light Verification Method G7/VM1(New Zealand)	(NEW ZEALAND GOVERNMENT, 2021c)
National Construction Code (NCC) (Australia)	(AUSTRALIAN BUILDING CODES BOARD, 2022a, 2022b)
International Building Code (IBC) (USA)	(ICC, 2024)
Energy Conservation Construction Code of New York State – ECCCNYS (USA)	(NEW YORK STATE, 2020)
Arizona Manufactured Home Construction and Safety Act (USA)	(ARIZONA DEPARTMENT OF HOUSING, 2021)
California Code of Regulations – Building Energy Efficiency Standards (USA)	(ENERGY CODE ACE, 2022)
California Building Code – Title 24, vols. 1 & 2 (USA)	(INTERNATIONAL BUILDING COUNCIL; CALIFORNIA BUILDING STANDARDS COMMISSION, 2022)
British Columbia Building Code (Canada)	(BRITISH COLUMBIA MINISTRY OF HOUSING, 2024)
National Energy Code of Canada for Buildings	(CANADIAN COMMISSION ON BUILDING AND FIRE CODES, 2020)
National Electric Code (Canada)	(CSA, 2021)
Belém's Law of Land Use and Control (LCCU 1999) (Brazil)	(BELÉM, 1999)
Brasília’s Building Construction Code (Lei n.6138/2018) and the Annex IV of Decree n.39272/2018 (Brazil)	(BRASÍLIA, 2018, 2022)
Curitiba's Law of Land Use and Decree n. 1001 (Brazil)	(CURITIBA, 2019, 2020)

(Cont. Table 11) Building and Urban Codes and Regulations received and analysed in this research.

TITLE / COUNTRY (cont.)	REFERENCE (cont.)
Maceió's Urbanism and Building Code (Brazil)	(MACEIÓ, 2006)
Recife's Law of Land Use (Brazil)	(RECIFE, 2016, 2020)
Rio de Janeiro's Building Construction Code (Lei Complementar n.198/2019) and LUOS n.57/2018 (Brazil)	(RIO DE JANEIRO, 2018, 2019)
São Paulo's Building Construction Code (COE) (Lei nº 16.642/2017; decreto nº 57.776/2017) (Brazil)	(SÃO PAULO, 2017)
Guía Boliviana de Construcción de Edificaciones (Bolivia)	(ESTADO PLURINACIONAL DE BOLIVIA, 2015)
Código de Urbanismo y Obras – Gobierno Autónomo de Santa Cruz de La Sierra – TOMO III (Bolivia)	(GOBIERNO AUTÓNOMO MUNICIPAL DE SANTA CRUZ DE LA SIERRA, 2020)
General Urban Planning and Construction Ordinance – OGUC (Chile)	(GOBIERNO DE CHILE, 2020)
Unified Building Law n.119/2008 and Ministerial Decree no.114/ 2009 (Egypt)	(MINISTRY OF HOUSING UTILITIES AND URBAN DEVELOPMENT, 2008, 2009)

Source: AMORIM; PINHEIRO (2024).

Among the building and urban codes received in the 1st collection of documents, there is a series of **Italian** legislations that approach daylight. Three of them, "Circolare Ministeriale Lavori pubblici n. 3151 (Public works ministerial circular)", "Circolare Ministeriale n. 13011 (Ministerial circular n.13011)" and "Decreto Ministeriale July 5th, 1975, Modificazioni alle istruzioni ministeriali June 20 1896 (Ministerial Decree July 5th, 1975, modifications to ministerial instructions June 20 1896)" use as requirements the Average Daylight Factor (DFm) and the openable surface of windows (WFR), with different values considered adequate for different types and functions of buildings.

Also, "Decreto Ministeriale December 18, 1975. Norme tecniche aggiornate relative all'edilizia scolastica (Ministerial Decree December 18, 1975. Updated technical standards relating to school buildings)" gives Average Daylight Factor (DFm) values for several types of school rooms — the same parameters of the previous "Ministerial Decree July 5th, 1975". "Decreto Legislativo n 81 9 aprile 2008 (Legislative Decree No. 81 April 9th 2008)" states rules to have safe work spaces, with sufficient daylight combined to electric light. Were also received "Building Regulation D.C.R. n. 247-45856" and "Energy Code Annex to Building Regulations" (both from **Turin**), "Building Code of **Campania**" and "Minimum Environmental Criteria – Buildings (CAM – EDILIZIA 2022)". The documents from **Turin** and from **Campania** use DFm as main daylight requirement. The exception is CAM-EDILIZIA 2022, that has as general recommendation that the openings must be oriented from east to west, passing through south; and minimum illuminance values for different types of spaces (new construction, urban renovations, demolitions, reconstructions; elementary and junior/high schools; and nursery schools/kindergartens), similar to de concepts of target illuminance and spatial daylight autonomy (CITTÀ DI TORINO, 2006; CONSIGLIO REGIONALE DEL PIEMONTE, 2017; MINISTERO DEI LAVORI PUBBLICI, 1967, 1974, 2008; MINISTERO DELLA SANITÀ, 1975; MINISTERO DELLA TRANSIZIONE ENERGETICA (MITE), 2022; REGIONE DI CAMPANIA, [s.d.]).

The **British** "Building Regulations 2010 – March/2023 compilation of individual approved documents" is the general document for building construction. As metrics, this Regulation brings window sizes, WFR, Minimum Light Transmittance, Daylight Dependency Factor (as component of a metric related to energy efficiency — LENI) and Overhang Obstruction Angle (MINISTRY OF HOUSING COMMUNITIES AND LOCAL GOVERNMENT, 2023). Also from **UK**, one of the most historically important documents regarding daylight is Right to Light Law, which bring Sky Factor as main metric to measure the access to daylight in buildings (GREAT BRITAIN LAW COMMISSION, 2014).

The "NEN 2057:2011: Building Code 2012" (**The Netherlands**) recommends as daylight requirements the minimum equivalent aperture surface area — describes a percentage of how much aperture surface area is required for any occupied space, with different values according to type and functions of spaces — and the minimum aperture surface area — determines the minimum area of openings per occupied space, in any type of space (except penitentiary cells) (DUTCH GOVERNMENT, 2012).

In **Poland**, the "Regulation of the Minister of Infrastructure on the technical conditions to meet by building and their location" defines as main parameters the window-to-floor ratios for permanently occupied rooms (at least 1/8) and for any other rooms (at least 1/12). Also, the code recommends at least 3h of direct sunlight in residential rooms, during equinox days between 7 a.m. and 5 p.m; and in children's facilities as nurseries, schools etc, at least 4h from 8 a.m. to 4 p.m. The Polish Regulation brings also Height to width, a requirement that relates to the urban scale, since refers to the ratio between buildings' height and street width, in order to not hinder urban access to sunlight (MINISTER OF INFRASTRUCTURE, 2018).

The “Executive order on Building Regulations 2018 (BR 18)”, used in **Denmark** is similar to EN 17037:2018, since it analyses daylight sufficiency and view of the surroundings as main daylight requirements. To reach daylight sufficiency, openings areas are sized in comparison to the relevant floor area (Window-to-Floor Ratio – WFR); alternatively, projects should demonstrate that lighting intensity from daylight is 300 lux or by, for at least 50% of the relevant floor area for a minimum of 50% of the daylight hours (the same parameters found for sDA in many documents). BR 18 also defines maximum height of buildings, distances from site’s boundaries, and building’s ratio, which is defined as the floor area as a percentage of the site area, and it serves to ensure that the plot is developed in accordance with the use stated in the application. The general orientations approach the necessity to avoid excessive energy consumption destined to daylight, stating that daylight must be used as a main source to the extent it is possible; also, nuisance from glare and direct sunlight must be avoided, as well as excessive heat load gains (MINISTRY OF TRANSPORT BUILDING AND HOUSING - DENMARK, 2018).

The “Code de la construction et de l'habitation” (Construction and Housing Code) (2014), from **France**, determines WFR value for rooms, which must have an opening of 1/6 of floor area. Also, the Code defines Target Illuminance and Minimum Target Illuminance values, as well as the necessity of views out in at least one residential space with two layers visible: sky and horizon (MINISTÈRES ÉCOLOGIE ÉNERGIE TERRITOIRES, 2021). Also from **France**, “Articles R4213-1 à 4 Créé par Décret n°2008244 – Labor Code – Obligations of the Building Owner” and “Article R4223-1 à 12 Créé par Décret n°2008244 – Labor Code – Obligations of the Employer” (RÉPUBLIQUE FRANÇAISE, 2008a, 2008b) are regulations that have as requirement the access to daylight, which is mandatory, unless not compatible with the activities. Another regulation French regulation is “Environmental regulation of new buildings re 2020 Th-BCE 2020 and Thbat rule” (RÉPUBLIQUE FRANÇAISE, 2020), with DF, VLT and WFR as daylight requirements.

In **Austria**, the “OIB guideline 3: hygiene, health and environmental protection” (2019) defines WFR values, as well as horizontal and vertical obstruction angles, that interfere in daylighting the building analysed and the views out (BREGAR et al., 2022, 2023).

From **Belgium**, “Elementary requirements in terms of safety, health and equipment of housing RRU Title II” states WFR parameters, as well as distances from obstructions in the surroundings to guarantee pleasant views out (BREGAR et al., 2022, 2023).

The “Rulebook of minimal technical conditions for design and construction of apartments from the Socially Establishment Program”, from **Croatia**, establishes WFR values for openings in residential buildings (BREGAR et al., 2022, 2023).

The **Hungarian** “Government decree 253/1997 (XII. 20.) on the national settlement planning and construction requirements” determines WFR for different types of rooms and requires exposure to sunlight in residences (BREGAR et al., 2022, 2023).

From **Slovenia**, the “Rules on Minimum Technical Requirements for the Construction of Apartement Buildings and Apartments (2011)”, which defines WFR value to guarantee minimum natural lighting to be achieved through the openings of a room of 20% of floor area (REPUBLIC OF SLOVENIA, 2011).

The “**Swedish** Housing Agency's building rules – BBR 29” (2020) defines a WFR of at least 10% of floor area to reach DF of 1% and recommends, even if the opening does not comply to the WFR beforementioned, DF must still be 1% (SWEDISH CONSTRUCTION SERVICE, 2020).

From **Norway**, “Byggteknisk forskrift med veiledning (TEK17)” (Building technical regulations with guidance — TEK17) defines that rooms permanently occupied by people must have adequate access to daylight and specifies minimum height, width and sum of height and width of windows. This standard uses Average Daylight Factor (ADF) as metric for permanently occupied rooms, defining a general minimum value, which should be complied through computer simulations, according to NS-EN 12464-1:2011. Also, TEK17 states that all rooms of permanent occupancy, whether residential, work or public, must have at least 1 window with a satisfying view out for sitting and standing occupants, placed minimally 1.0m above the floor. In densely build-up areas, it is sufficient to have a view of rows of houses, streets, and backyards (NORWEGIAN BUILDING AUTHORITY, 2017).

Sunlight Duration is the metric used in “Regulation No. 268/2009 about technical requirements for buildings”, from **Czech Republic**; “RT I: 2002 – Ehitusseadus (Building

Code)”, from **Estonia**; as well as in “Regulation No. 259/2008 of the Ministry of Health of the Slovak Republic” and “Regulation No. 532/2002 of the Ministry of Environment of the Slovak Republic”, from **Slovakia**. All those regulations present recommendations according to type of building, location, season and time of year (DARULA; CHRISTOFFERSEN; MALIKOVA, 2015).

The **Spanish** “Código Técnico de la Edificación – CTE” (Building Technical Code) is a mandatory building code for all Spain that reunites requirements and guidelines for building construction, focused on energy efficiency and environmental quality (MINISTERIO DE VIVIENDA Y AGENDA URBANA, 2019). Given its focus on energy use in Spain, CTE only demands electric lighting systems to incorporate daylight in indoor spaces, regulating the electric lighting use through dimmers or on/off drivers. CTE does not present any particular daylight criterion, parameter, requirement or metric. **Spain** does not have a unified regulation or code with daylight requirements. Instead, each region has its own recommendations of Window-to-Floor Ratio (WFR), varying from 1/8 to 1/12 (BREGAR et al., 2022, 2023).

Ireland’s “Building Regulations – Technical Guidance Document, Department of Housing, Planning and Local Government” define WFR values: at least 10% for vertical windows and 7% for roof windows. Also, for the space to be considered with adequate daylighting conditions, DF must be of 2% (IRISH DEPARTMENT OF HOUSING, 2020).

“Arbeitsstättenrichtlinie – ASR A3.4 Beleuchtung” (Workplace directive – ASR A3.4 Lighting) is a **German** code that indicates as requirements the visual connections to the outside — even though there are no classification criteria —, uses DF as metric for daylight provision indoors, with 2% as parameter, and recommends measures to prevent or limit glare occurrence, although it does not evaluate glare itself through any metrics (BAUA, 2023).

The **Japanese** “Building Standards Act” is mandatory; it has a section called Natural Lighting Regulation. The Act states that all habitable rooms of houses, schools, hospitals, clinics, dormitories, boarding houses, and other buildings should have openings (windows) for daylighting; also, defines as parameters to provide access to daylight in indoor spaces the openings areas related to the floor areas (window-to-floor areas), according to the type of building and task developed within the rooms: in the newest version, it should be at least 1/7 of floor area in living rooms, dormitories, bedrooms, hospitals or up to 1/10 of floor area if measures are taken to ensure the installation of lighting equipment or efficient methods to provide daylight; not less than 1/5 of floor area in classrooms of compulsory education facilities; and not less than 1/10 of floor area in classrooms of other types of schools (BUILDING CENTER OF JAPAN, 2013).

In **Turkey**, “Turkish National Building Regulation (2023)” is mandatory and defines that the openings must comply with the Energy Performance Regulation in Buildings and Turkish Standards Institution (TSE) standards. By its turn, the “Energy Performance Regulation in Buildings” define that the WWR values should vary according to HVAC systems (MOEU, 2023).

From **New Zealand**, 3 documents were analysed: “G7 Natural Light Acceptable Solution G7/AS1”, “G7 Natural Light Acceptable Solution G7/AS2” and “G7 Natural Light Verification Method G7/VM1”. The first two define acceptable solutions to apply in projects, in order to obtain daylight in indoor spaces. The parameters used are the level of illuminance in habitable spaces, glazing area, light transmittance of the glass, obstruction angles and awareness of the exterior, which is the provision of outside views. The last document also has illuminance of habitable spaces as parameter, defining 30 lux as minimum daylight illuminance in indoor spaces; the same parameter also uses DF as metric, presenting target DF values for some main cities of the country as reference. The other parameter of the last document is awareness of the outside, through the providence of exterior views (NEW ZEALAND GOVERNMENT, 2021a, 2021b, 2021c).

“National Construction Code, vols. 1 & 2” (AUSTRALIAN BUILDING CODES BOARD, 2022a, 2022b) are the main building codes and regulations in **Australia**. Among the instructions for building construction in the documents, the daylight metrics used are DFavg, WFR, window dimensions and setbacks.

The “International Building Code (IBC)” (2024) released by the International Construction Council, is the main Code used by **United States**. IBC works as an important model for all States to unify building construction recommendations. As requirements that influence daylight, IBC has WFR, exterior openings criteria, minimum frontage distances and area increase factors (ICC, 2024). **New York State** has its own Energy Conservation

Construction Code of New York State – ECCCNYS (2020), which brings as recommendation WWR, VLT and minimum window area (NEW YORK STATE, 2020). In **Arizona** (**USA**), the Arizona Manufactured Home Construction and Safety Act (2021) recommends WFR parameters for a single room or for combined rooms in order to capture daylight indoors (ARIZONA DEPARTMENT OF HOUSING, 2021). Also from the **USA**, "California Code of Regulations" and "California Building Code – Title 24"(ENERGY CODE ACE, 2022; INTERNATIONAL BUILDING COUNCIL; CALIFORNIA BUILDING STANDARDS COMMISSION, 2022) set the mandatory criteria for buildings in the State. The daylight metrics used are WFR, WWR, window dimensions and VLT.

From **Canada**, the "British Columbia Building Code" (2024) states minimum area for openings, a maximum height value for fire scaping and a maximum glazed area, according to setbacks between buildings or buildings and plot's boundaries (BRITISH COLUMBIA MINISTRY OF HOUSING, 2024). Also from **Canada**, "National Energy Code of Canada for Buildings" (CANADIAN COMMISSION ON BUILDING AND FIRE CODES, 2020) refer as metrics window sizes, Factor for Daylight Harvesting, Daylight Supply Factor, Installed Interior Lighting Energy (IILE), Interior Lighting Energy Allowance (ILEA) and effective luminous transmittance (similar to VLT). The last **Canadian** document was "National Electric Code", which defines window sizes that influence daylighting (CSA, 2021).

Regarding **Brazilian** codes, 6 cities were chosen, representing macro regions in Brazil — Belém (North), Recife and Maceió (Northeast), Brasília (Midwest), Rio de Janeiro (Southeast) and Curitiba (South). Codes from Belém, Curitiba, Maceió and Recife are urban laws that determine policies regarding urban systems, zoning, dwelling, land use, environment and social care, etc. Even though documents from Belém, Curitiba, Maceió and Recife have details about all these parameters, they do not approach specifically daylighting in buildings. Consequently, they only give parameters that influence daylight indirectly, such as front, floor area ratio, side and rear setbacks of buildings to sites' boundaries and in between buildings and their surroundings (BELÉM, 1999, 2008; CURITIBA, 2019, 2020; MACEIÓ, 2006; RECIFE, 2016, 2020).

Rio de Janeiro's (**Brazil**) "Building Construction Code" (Lei Complementar n.198/2019), on the other hand, has some parameters regarding openings for natural lighting and ventilation, setting minimum WFR of different percentages, according to the function of rooms. This law also defines that all spaces of extended permanence must have openings that communicate with the exterior of the buildings through the envelope itself or through balconies. Spaces of transitory permanence, instead, can have openings for natural light and ventilation through other internal spaces. The law also determines that daylight should be captured by the entire opening area. However, to residential bathrooms or restrooms, natural light is not mandatory (RIO DE JANEIRO, 2018, 2019).

In **Bolivia**, "Guía Boliviana de Construcción de Edificaciones" (Bolivian Building Construction Guide) (2015), unify recommendations about building construction, and serve as basis for documents elaborated by each autonomous city government. It gives orientations of side setbacks between buildings, WFR values and establishes a minimum distance for proper views out. "Código de Urbanismo Y Obras – Gobierno Autónomo de Santa Cruz de La Sierra – TOMO III (2018)" (Code of Urban Planning and Works – Autonomous Government of Santa Cruz de la Sierra – Volume III) gives as main requirement WFR, with specific values for different types of rooms and occupation standards (ESTADO PLURINACIONAL DE BOLIVIA, 2015; GOBIERNO AUTÓNOMO MUNICIPAL DE SANTA CRUZ DE LA SIERRA, 2020).

Brasília's (**Brazil**) "Building Construction Code (Lei n.6138/2018)" and the "Annex IV of Decree 39272/2018 (Decreto n.39.272/2018)" defines WFR for room's openings and minimum daylighting and ventilation prisms rays[4] (BRASÍLIA, 2018, 2022). Still from **Brazil**, São Paulo's Building Construction Code (Código de Obras e Edificações – COE São Paulo) defines setbacks specifically focused on openings and setbacks considering the building's height. Also, there are definitions of lightwells for natural ventilation and insolation, both for buildings under 10m or higher (SÃO PAULO, 2017).

[4] Daylighting and ventilation prism: a free space within a building, in all its' height, that guarantees daylighting and natural ventilation to rooms that communicate with it.

From **Chile**, “General Urban Planning and Construction Ordinance – OGUC (2020)” is the mandatory building code that guides architectural activities. As requirements, OGUC has essentially geometry-based metrics, such as Height of building x Distance to the offset, Grazing angle, distance from windows and WFR (GOBIERNO DE CHILE, 2020).

In **Egypt**, the “Unified Building Law n.119/2008” and “Ministerial Decree no.114/ 2009” (AYYAD; GABR, 2012; MINISTRY OF HOUSING UTILITIES AND URBAN DEVELOPMENT, 2008, 2009) are the Regulations that set the rules for building construction, and daylighting has WFR as criterium.

By their own nature, as defined in previous topics, regulations and building and urban codes do not contain daylight requirements related to non-visual effects, since those documents mostly relate to buildings’ geometry, systems, and their interactions with the urban fabric. Table 12 summarizes daylight requirements found in the regulations and building and urban codes received.

Table 12 Daylight requirements found in regulations, and building and urban codes.

CONTINENT (cont.)	**COUNTRY (cont.)**	**REQUIREMENTS (cont.)**	**METRICS (cont.)**	**DOCUMENT (cont.)**
Europe	Italy	—	DFm	Circolare Min. Lavori pubblici n. 3151 (1967)
		—	DFm	Circolare Ministeriale n. 13011 (1974)
		—	DFm	Building regulation, D.C.R. 28 November 2017 n. 247-45856
		—	WFR	
		—	DFm	Energy Code Annex to Building Regulations
		—	DFm	Decreto Ministeriale July 5th, 1975, Modificazioni alle istruzioni ministeriali 20 giugno 1896
		—	WFR	
		—	DFm	Decreto Ministeriale December 18, 1975 Norme tecniche aggiornate relative all’edilizia scolastica
		—	DFm	Building regulation, D.C.R. 28 November 2017 n. 247-45856
		—	WFR	
		Daylighting	DFm	Energy Code Annex to Building Regulations (Turin, Italy) (under review)
		—	DFm	Campania (Law)
		—	WFR	

(Cont. Table 12) Daylight requirements found in regulations, and building and urban codes.

CONTINENT (cont.)	COUNTRY (cont.)	REQUIREMENTS (cont.)	METRICS (cont.)	DOCUMENT (cont.)
Europe	Italy	Daylighting	DFm	Minimum Environmental Criteria – Buildings (CAM – EDILIZIA 2022)
			Illuminance in space and time	
	The Netherlands	—	A_e	NEN 2057:2011: Building Code 2012
		—	A_{min}	
	Norway	Light	DF	Building technical regulations (TEK17)
			Minimum sizes of windows	
		View out	Layers	
			Sill height	
	Poland	Lighting and insolation	WFR	The Regulation of the Minister of Infrastructure on the technical conditions to meet by building and their location (2015)
			Exposure to Sunlight	
		—	Setbacks from plot's boundaries	
			Obstruction angles	
			Height to width	
	UK	Thickness of walls in certain small buildings	Window sizes	The Building Regulations 2010
		New elements in existing dwellings, including extensions	opening areas	
			area of windows	
		Limiting solar gains	Minimum Light Transmittance	
			Overhang obstruction angle	
		Lighting	Daylight Dependency Factor (F_D)	
		—	SF	Right to Light Law (2014)
	Denmark	View of surroundings	—	BR18: 2018
		Sufficient access to daylight	WFR	
			Minimum illuminance by area by time	
			Maximum heights	
			Setbacks	
		Building Right	Building's ratio	
	France	—	WFR	Construction and Housing Code (2014)
		—	E_T	
		—	E_{Tmin}	
		—	Layers	
		Access to daylight	—	Articles R4213-1 à 4 Créé par Décret n°2008244 – Labor Code – Obligations of the Building Owner (2008)
		Access to daylight	—	Article R4223-1 à 12 Créé par Décret n°2008244- Labor Code – Obligations of the Employer (2008)

(Cont. Table 12) Daylight requirements found in regulations, and building and urban codes.

CONTINENT (cont.)	COUNTRY (cont.)	REQUIREMENTS (cont.)	METRICS (cont.)	DOCUMENT (cont.)
Europe	France		VLT	RE 2020 Règle TH-BCE 2020 et ThBat (2020)
			WFR	
			DF	
	Austria	—	WFR	OIB-Richtlinie 3 (2019)
		—	Angle of visible sky	
		—	Obstruction angle	
		—	Distance from windows	
		—	Distance to windows	
	Belgium	—	WFR	RRU Titre II (2021)
		—	Distance from windows	
	Germany	Visual connection to the outside	Window sizes	ASR A3.4 (2023)
		Sufficient daylight	DF	
		Measures to limit glare	—	
	Croatia	—	WFR	Rulebook of minimal technical conditions for design and construction of apartments from the Socially Establishment Program (2017)
	Hungary	—	WFR	253/1997. (XII. 20.) Government decree on the national settlement planning and construction requirements (1997)
		—	Exposure to sunlight	
	Slovenia	—	WFR	Rules on Minimum Technical Requirements for the Construction of Apartement Buildings and Apartments (2011)
	Sweden	—	WFR	BBR 29 (2020)
		—	DF	
	Spain	—	Demands to incorporate daylight in indoor spaces	CTE (2019)
		—	WFR	Regional requirements [s.d.]
	Ireland	—	WFR	Ireland Building Regulations (2020)
		—	DF	
	Czech Republic	—	Sunlight Duration	Regulation No. 268/2009 about technical requirements for buildings
	Estonia	—	Sunlight Duration	RT I: 2002 Building Code
	Slovakia	—	Sunlight Duration	Regulation No. 259/2008 & Regulation No. 532/2002

(Cont. Table 12) Daylight requirements found in regulations, and building and urban codes.

CONTINENT (cont.)	COUNTRY (cont.)	REQUIREMENTS (cont.)	METRICS (cont.)	DOCUMENT (cont.)
Europe	Turkey	—	WWR	Turkish National Building Regulation (2023) / Energy Performance Regulation in Buildings
North America	USA	Exterior openings	Opening percentage	International Building Code, International Code Council (2024)
			Window sizes	
		Lighting – Natural Light	Minimum frontage distance	
			WFR	
			Area increase factor	
		Fenestration	Fenestration area	2020 Energy Conservation Construction Code of New York State (ECCCNYS)
			VT	
		Sidelit zone	Minimum window area	
		Light and ventilation	WFR	Arizona Manufactured Home Construction and Safety Act (2021)
		Light and ventilation	WFR	California Code of Regulations – Building Energy Efficiency Standards (USA) (2022)
			VLT	
			Window sizes	
			WWR	
			SRR	
		Lighting	WFR	California Building Code – Title 24, vols. 1 & 2 (2022) (USA)
	Canada	Egress Windows or Doors for Bedrooms	Minimum opening area	British Columbia Building Code (2024)
			Maximum height of openings	
			Maximum glazed area	
		—	Window area	National Energy Code of Canada for Buildings (2020)
		—	IILE	
		—	ILEA	
		—	Factor for Daylight Harvesting	
		—	Daylight Supply Factor	
		—	Effective luminous transmittance	
		Lighting	head height	National Electric Code (2021)
South America	Brazil	Spaces' ventilation and lighting	WFR	Rio de Janeiro’s Building Construction Code (Lei Complementar n.198/2019)
			Windows connected with exterior	
		Occupancy Control	front, side and rear setbacks	Rio de Janeiro's Law of Land Use (LUOS n.57/2018)
			lightwells	

(Cont. Table 12) Daylight requirements found in regulations, and building and urban codes.

CONTINENT (cont.)	COUNTRY (cont.)	REQUIREMENTS (cont.)	METRICS (cont.)	DOCUMENT (cont.)
South America		Lighting and Ventilation	lightwells	Brasília's Building Construction Code (Lei n.6138/2018) and Annex IV of Decree 39272/2018 (Decreto n.39.272/2018)
			WFR	
		Occupancy	front, side and rear setbacks	Belém's Law of Land Use (LCCU 1999)
		Land Usage and Occupancy Control	front, side and rear setbacks	Curitiba's Law of Land Use (2019) and Decree n. 1001 (2020)
		Residential Use	front, side and rear setbacks	Maceió's Urbanism and Building Code (2006)
			setbacks between buildings	
		Land Occupancy	front, side and rear setbacks	Recife's Law of Land Use (2019)
		Technical Provisions – Implementation	setbacks from plot's boundaries	COE São Paulo (2017)
		Ventilation and Insolation Provisions	lightwells	
			front, side and rear setbacks	
	Bolivia	Environmental Conditioning	WFR	Guía Boliviana de Construcción de Edificaciones (2015)
			lightwells	
			Distance from windows	
		Lighting and Ventilation of Indoor Spaces	WFR	Código de Urbanismo Y Obras – Gobierno Autónomo de Santa Cruz de La Sierra – TOMO III (2018)
	Chile	Of the grouping of the buildings and their relationship with the ground	Height of building x Distance to the offset	General Urban Planning and Construction Ordinance – OGUC (2020)
			Grazing angle	
		habitability conditions	Distance to windows	
			Maximum window area	
		Health assistance buildings	total minimum windows area	
		Schools and Student households	% of floor area - daylighting	
Oceania	New Zealand	Illuminance of habitable spaces	Emin	G7 Natural Light Acceptable Solution G7/AS1 (2021)
			Area of glazing	
			VLT	
			head height	
		Awareness of the outside environment	Area of glazing	
			Window sizes	
		Illuminance of habitable spaces	Emin	G7 Natural Light Acceptable Solution G7/AS2 (2021)
			GW	
			VLT	
			OOA	
			AEOA	
		Awareness of the outside environment	Area of glazing	
			Window sizes	

(Cont. Table 132) Daylight requirements found in regulations, and building and urban codes.

CONTINENT (cont.)	COUNTRY (cont.)	REQUIREMENTS (cont.)	METRICS (cont.)	DOCUMENT (cont.)
		Illuminance of habitable spaces	DF	G7 Natural Light Verification Method G7/VM1 (2021)
		Awareness of the outside environment	Area of glazing	
			Window sizes	
	Australia	Natural Lighting	DF_{avg}	National Construction Code (NCC) (2022)
		Methods and extent of natural light	WFR	
			setbacks	
			Window sizes	
Asia	Japan	—	WFR	Natural Lighting Regulation – Building Standards Act (2023)
	China	—	DF	GB 55016:2021 – General code for building environment
Africa	Egypt	—	WFR	Unified Building Law n.119/2008 and Ministerial Decree no.114/ 2009

Source: AMORIM; PINHEIRO (2024).

Building and Urban Codes and Regulations are the documents with less definitions of requirements. Most of the documents, as shown in Table 12, do not even have clear requirements about daylight. When requirements are defined, as those refer to an enormous quantity of different aspects, the names are too generic: “Spaces' ventilation and lighting”, “Occupancy”, “Residential Use”, “Habitability Conditions”, “Technical Provisions – Implementation”, “Environmental Conditioning”, among others. Even though there are some similar requirements, the Codes and Regulations group is the less homogenic and, hence, the most difficult to harmonize.

However, the metrics frequently repeat, which indicates some pathways to harmonization, considering the aspects they refer to — openings’ percentage related to floor or wall areas, setbacks, obstruction and shadowing angles, etc.

4.1.4. Guidelines

In the international context, guidelines are not very common in many countries. This may justify why only a few documents were found — from Europe (5), South American (3) and Asian (2) countries. The building guidelines accessed through the primary documents collection and the survey are in Table 13.

Table 13 Guidelines received and analysed in this research.

TITLE / COUNTRY	REFERENCE
SLL Lighting Guide: Lighting for the Built Environment – LG 10/2014: A guide for designers (UK)	(SLL; CIBSE, 2014)
Daylighting in older people's housing (UK)	(POCKLINGTON FOR PROFESSIONALS, 2015)
Site layout planning for daylight and sunlight: a guide to good practice ("BRE daylight and sunlight")	(LITTLEFAIR et al., 2022)
TNO Sunlighting 2018 (The Netherlands)	(HBA, 2018)
Guidelines for calculating the duration of direct sunlight (Estonia)	(ESTONIAN GOVERNMENT, [s.d.])
Regulation on Green certificate regulation for buildings and settlements (Turkey)	(TURKISH ENVIRONMENT AGENCY, 2017)
Underwriters Laboratories DG 24480: Design Guideline for Promoting Circadian Entrainment with Light for Day-Active People (USA)	(UL LLC, 2020)
Resolución 0549 de 2015 Anexo I – Guía de Construcción Sostenible para el ahorro de agua y energía em las edificaciones (Colombia)	(REPUBLICA DE COLOMBIA, 2013)
Manual of Passive Design and Energy Efficiency in Public Buildings, DA MOP (Chile)	(INNOVA CHILE, 2012)
Energy efficiency guide for social housing, AChEE (Chile)	(BUSTAMANTE et al., 2009)
Standards for Design and Maintenance of Windows and Openings on Interior Lighting and Visual Environment (Japan)	(ARCHITECTURAL INSTITUTE OF JAPAN, 2010)
Daylight Reflectance Design Guide (Singapore)	(BCA GREEN MARK, 2022)

Source: AMORIM; PINHEIRO (2024).

From **United Kingdom**, "SLL Lighting Guide: Lighting for the Built Environment – LG 10/2014: A guide for designers" works mostly with the DF_{ave}, describing values in order to ensure a well daylit room in work or residential spaces. DA is mentioned, but no target value is recommended, instead, a simulated calculus aims at a target value of 300 lux, using a formula that involves DA. Also, UDI is mentioned, but only with two ranges. SLL also defines four classification levels of outside views, stating their importance to mental health and metabolism regulation. Also from **UK**, "Daylighting in older people's housing" is a guideline specific for the design of housing for the elderly. Some of the requirements found in it are DF_{ave}, exposure to sunlight, views out, setbacks between buildings, angle of visible sky and angle of obstruction (SLL; CIBSE, 2014).

The last guideline from the **UK** is "Site layout planning for daylight and sunlight: a guide to good practice" (LITTLEFAIR et al., 2022), which displays requirements and metrics directly related to Right to Light Regulation evaluations and British version of EN 17037. The document is also known as "BRE Daylight and Sunlight" and presents as metrics Annual Probable Sunlight Hours (APSH), Vertical Sky Component (VSC), Target Illuminance (ET), obstruction angles, spacing-to-height ratio, sunlight for open spaces and views out.

By its turn, “TNO Sunlighting 2018” (**The Netherlands**) describes the minimum sunlight hours a window must be able to receive, through “target daily sunlight hours”, which can be set in two different ways: the light norm and the strict norm (HBA, 2018).

The **Estonian** “Guidelines for calculating the duration of direct sunlight” is a guideline focused on the exposure to sunlight in permanent living spaces, schools and healthcare institutions, being mandatory for these buildings, and not mandatory for temporary accommodations. This guide allows variation of the amount of exposure to sunlight, taking into account if the duration is continuous or interrupted, as well as the percentual of the areas or quantity of rooms that meet the requirements (ESTONIAN GOVERNMENT, [n.d.]).

In **Turkey**, “Green certificate regulation for buildings and settlements” states that daylight provision and views out should be complied according to EN 17037, while illuminance uniformity and Mean DF must follow “British Standard BS 8206 Part 2”. Regarding glare, the Certificate recommends that openings should have solar shading systems to avoid glare occurrence (TURKISH ENVIRONMENT AGENCY, 2017).

The Resolución 0549 de 2015, from **Colombia**, in the “Annex I” (Guía de Construcción Sostenible para el ahorro de agua y energía em las edificaciones) focus on the energy and water savings in buildings. Annex I brings several metrics, such as the compliance of DF values from RETILAP, WWR values, as well as vertical and horizontal obstruction angles of solar protections for openings (REPUBLICA DE COLOMBIA, 2013).

In **Chile**, “Manual of Passive Design and Energy Efficiency in Public Buildings (2012)” and “Energy efficiency guide for social housing (2009)” are important guidelines to architecture professionals that have daylight requirements, both with static metrics and geometric metrics: DF and WFR (BUSTAMANTE et al., 2009; INNOVA CHILE, 2012).

The “Standards for Design and Maintenance of Windows and Openings on Interior Lighting and Visual Environment” (**Japan**) provides recommendations for work and residential spaces. Currently, the main metric is still DF. However, the newest revision, scheduled for 2024, will take into account as requirements: for work spaces, the views out, daylight provision through vertical illuminance, glare evaluation through the metrics Predicted Glare Sensation Vote (PGSV); for residential spaces, both the overall daylight provision and the views out will be evaluated through WFR (ARCHITECTURAL INSTITUTE OF JAPAN, 2010).

From **Singapore**, the “Daylight Reflectance Design Guide” is a document with orientations specific to buildings with a high reflective envelope. It addresses the distance between buildings to estimate the influence of reflected glare on the surroundings, as well as the WWR — as it is one of the main features that allows the occurrence of glare through the penetration of reflected sunlight rays — and simulations to evaluate DGP. DGP values are the same found in EN 17037 (BCA GREEN MARK, 2022).

Some guidelines, in the same way as standards, already contain some requirements about non-visual effects of daylight. In primary documents collection campaign, only one guideline approached non-visual effects: The **American** “Underwriters Laboratories DG 24480: Design Guideline for Promoting Circadian Entrainment with Light for Day-Active People”. UL DG 24480 approaches non-visual effects of light through the metric Circadian Stimulus (CS), which characterizes a light stimulus as it affects human melatonin suppression and the human circadian system more broadly. CS helps to comprehend the level of alertness the human metabolism reaches, according to the level of illuminance from daylight or from other sources (UL LLC, 2020). The following Table 14 summarizes the daylight requirements found in the guidelines analysed.

Table 14 Daylight requirements found in guidelines.

CONTINENT	COUNTRY	REQUIREMENTS	METRICS	DOCUMENT
Europe	UK	Daylight calculations	DF_{avg}	SLL Lighting Guide 10:2014
			DA	
			UDI	
		Internal space planning	AVS	
			head height	
		Initial design considerations – Building positioning and obstructions	Obstruction angle	
			VSC	
			APSH	
			Light transmittance of glazing	
		Views in and out	Horizontal Sight Angle	
			Layers	
			Distance from windows	

(Cont. Table 14) Daylight requirements found in guidelines.

CONTINENT (cont.)	COUNTRY (cont.)	REQUIREMENTS (cont.)	METRICS (cont.)	DOCUMENT (cont.)
Europe	UK	Light from the sky	DF_{avg}	Daylighting in older people's housing (2015)
			area of glazing	
			setbacks between buildings	
			AVS	
			AO	
		Sunlight Availability	APSH	
		Window design: aspects	Sill height	
			Layers	
		Sunlighting	APSH	BRE daylight and sunlight (2022)
		Light from the sky	VSC	
			Obstruction angle γ	
		Interior daylighting recommendations	E_T	
			E_{TM}	
			D (50%)	
			D (95%)	
		Alternative to skylight and sunlight access	Spacing-to-height ratio	
		View	Horizontal sight angle	
			Layers	
			Outside distance of the view	
	The Netherlands	—	Target daily sunlight hours	TNO Sunlighting (2018)
	Estonia	Insolation	Duration of Insolation	Guidelines for calculating the duration of direct sunlight [n.d.]
	Turkey	Daylight provision	DF	Green certificate regulation for buildings and settlements (2017)
			DFm	
			Spatial daylight illuminance	
			Illuminance uniformity	
		Assessment for views out	Horizontal Sight Angle	
			Layers	
			Distance	
		Glare	DGP	
		Exposure to sunlight	Exposure to Sunlight	
Asia	Japan	Daylight	DF	Standards for Design and Maintenance of Windows and Openings on Interior Lighting and Visual Environment (2024)
			Vertical illuminance	
		View	Solid angle of windows	
			Distance to the outside obstacles	
			Overall visible volume	
		Glare	Predicted Glare Sensible Vote (PGSV)	

(Cont. Table 14) Daylight requirements found in guidelines.

CONTINENT (cont.)	COUNTRY (cont.)	REQUIREMENTS (cont.)	METRICS (cont.)	DOCUMENT (cont.)
Asia	Japan	Daylight/View	Area of windows	Standards for Design and Maintenance of Windows and Openings on Interior Lighting and Visual Environment (2024)
			WFR	
	Singapore	Site analysis	Setbacks between buildings	Daylight Reflectance Design Guide (2022)
			Height ratio	
			WWR	
		Glare evaluation	DGP	
North America	USA	Circadian entrainment – calculation procedures	CS	Underwriters Laboratories DG 24480 (2020)
South America	Colombia	Good practices – Daylight	DF	Resolution 0549/2015, Annex I
		Energy – Passive Strategies	WWR	
			VSA	
			HSA	
	Chile	Daylighting Strategies	DF	Manual of Passive Design and Energy Efficiency in Public Buildings (2012)
			WFR	
			TL	
		Lighting Comfort	WFR	Energy efficiency guide for social housing (2009)
		Daylighting Strategies	DF	

Source: AMORIM; PINHEIRO (2024).

In Guidelines, requirements also have very different nomenclatures. That is possibly due to the specificity of the documents, which are dedicated to particular aspects of building construction. Some examples are: “Internal space planning”, “Initial design considerations – Building positioning and obstructions”, “Alternative to skylight and sunlight access”, “Lighting Comfort” — even though the metrics mostly repeat among them. However, some requirements names are not that different, and the use of the same metrics supports the harmonization process: “Daylight calculations”, “Light from the sky”, “Daylight”, “Good practices – Daylight”, “Daylighting Strategies”.

4.2. Classification of requirements and metrics

Daylight requirements have improved rapidly, with multiple discussions that often result in various metrics and system proposals. This defies designers to work with metrics and reference documents with little or no overlaps. Consequently, it is common that professionals end up relying mostly on personal experience.

The worksheet elaborated through the research has three main goals: to list all documents analysed, to account for the requirements found — along with their metrics and parameter values — and comprehend the representation of countries and continents. These indicators allow to understand how requirements and metrics found distribute by type of document, countries, climates.

The analysis of the documents unfolded a variety of possible requirements, with different names and concepts — some more specific and detailed, others too vague or without clear definitions. Some examples of documents with clear definitions of requirements are among Standards and Rating Systems. Some Rating Systems tend to have different, more original names for requirements — "Healthy interior environment" (LIVING FUTURE ORG., 2019), "Passive Visual Comfort" (GOBIERNO DE CHILE, 2022), etc. — but mostly, the requirements are not different from those found traditionally in Standards.

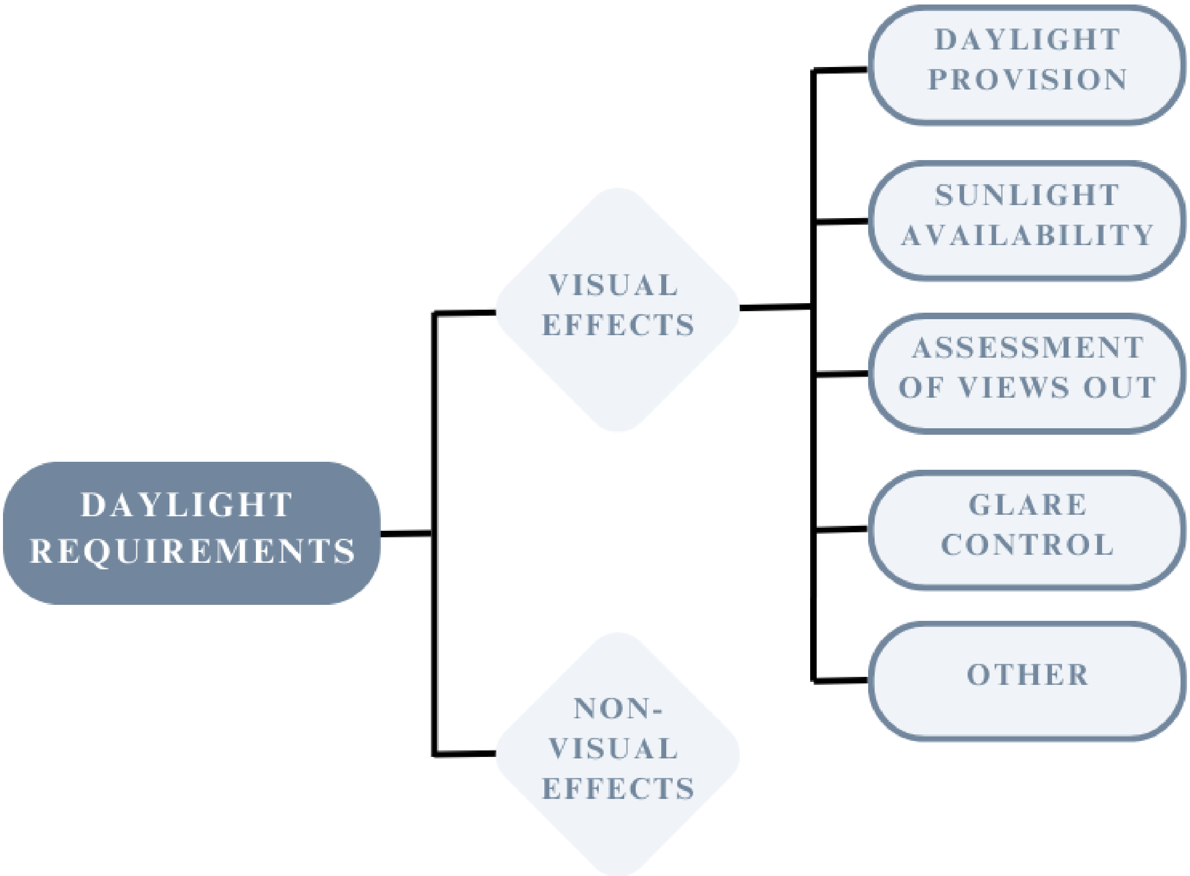
On the other hand, a great number of Building and Urban Codes and Regulations do not present requirements or, when presented, the concepts are not clearly defined or do not inform precisely the scope of coverage. A reason for that could be that historically, only the metrics are presented without defining the aims, while requirements are intuitive, in a certain way. Nonetheless, some themes were common within the analysis of requirements:

- **daylight provision**, like in Daylight Provision (ABNT, 2024; CEN, 2021b), Sufficiency of Daylight Illuminance (IES, 2012, 2023a), Daylight Sufficiency (ABNT, 2013a), Daylight Calculations (SLL; CIBSE, 2014), Light Exposure (IWBI, 2023), Light and Illumination (CASBEE, 2014);
- **sunlight availability,** as in Exposure to Sunlight (ABNT, 2024; CEN, 2021b), Potential Risk of Excessive Sunlight Penetration (IES, 2012, 2023a), Sunlighting (POCKLINGTON FOR PROFESSIONALS, 2015), Insolation (ESTONIAN GOVERNMENT, [s.d.]);
- **assessment of views out,** like on assessment of views out (ABNT, 2024; CEN, 2021b), windows and view (BSI, 2008), views in and out (SLL; CIBSE, 2014), quality views (GBC BRASIL, 2014; USGBC, 2022), view out (BRE, 2021, 2023);

- **glare control,** as in protection from glare (ABNT, 2024; CEN, 2021b), glare evaluation (BCA GREEN MARK, 2022), Absence of glare in daylight (DGNB SYSTEM, 2023); and
- **non-visual effects,** like Daylight as a non-visual stimulus (ABNT, 2024), ipRGC-influenced responses to light (ISO; CIE, 2023), Circadian Light Design (IWBI, 2023), Circadian entrainment (UL LLC, 2020).

There are also the specific cases. The Energy related requirement normally refers to minimum daylight quantities to be provided in order to replace electrical light and improve energy efficiency in buildings, so this was grouped into the "Daylight provision" category. In a similar way, "Assessment for Views Out" is a requirement that has both geometric and non-geometric metrics. By semantics, the requirements were grouped approaching similar aspects into macro themes: visual effects — with daylight provision, sunlight availability, glare control, assessment of views out — and non-visual effects (Figure 8).

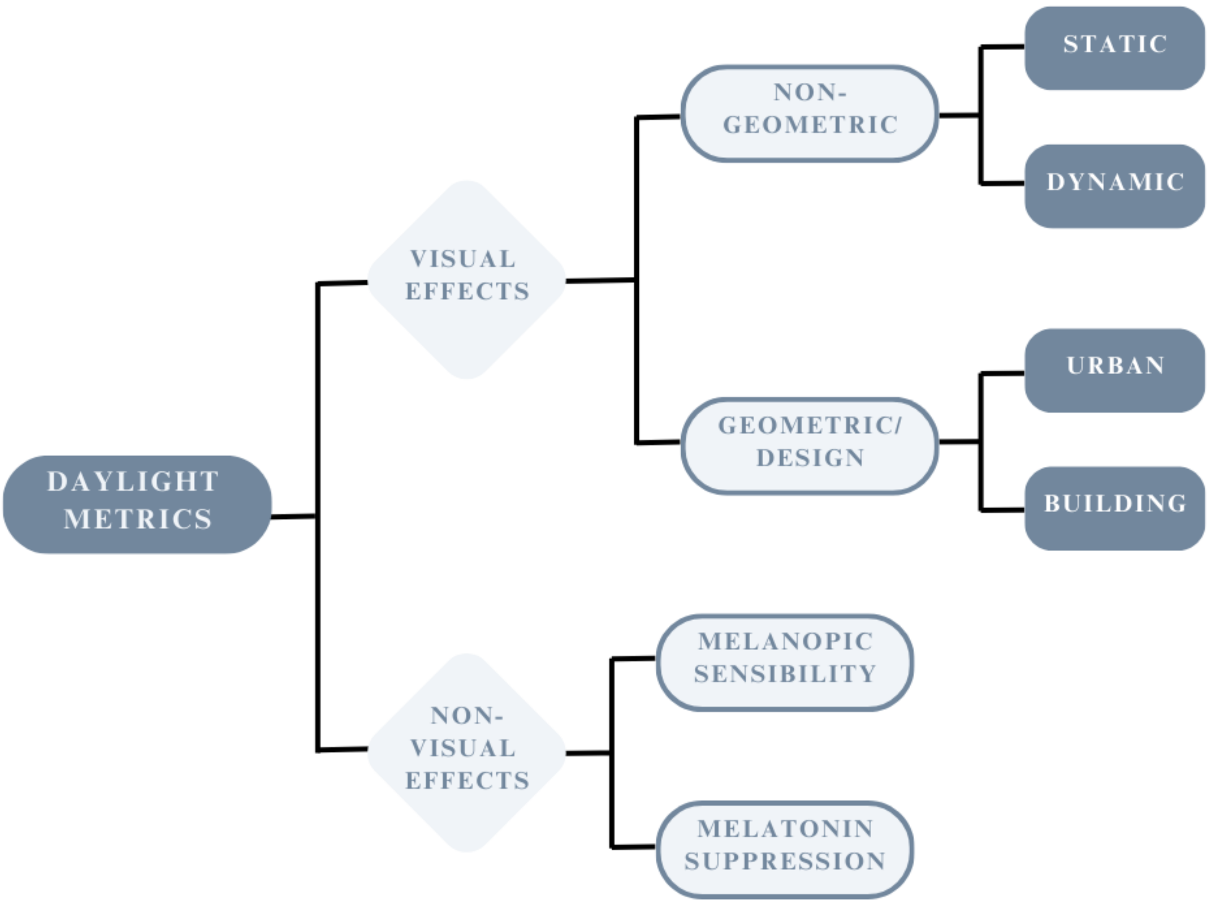
Figure 8 Classification of Daylight Requirements found in documents analyzed.



Source: Author (2024).

The related imprecisions in requirements, whether regarding their meanings, clear concepts or even the existence of requirements in documents caused the harmonization process to converge towards the classification of metrics. 120 metrics were found on documents collected. They are classified in **non-geometric**, **geometric/design** (for visual effects) and **melanopic sensibility**, **melatonin suppression** (for the non-visual effects). Among the non-geometric metrics, there are the static and the dynamic metrics — where DF, DA, sDA, UDI, etc are found — focused on the daylighting performance itself, even though not mentioning how to achieve the results through building design. Geometric/Design metrics are the largest category found, composed by metrics regarding the urban and the building levels — with criteria like setbacks, land occupancy, angles of obstruction and shadowing, among others. At the building level, window features are the most mentioned aspects — e.g. dimensions, proportion of openings by wall or floor area, light transmission properties, among others (Figure 9). The occurrence of metrics in documents can be seen in Table 15 and the specificities regarding non-geometric and geometric/design metrics are discussed on following topics.

Figure 9 Classification of daylight metrics found in this research.



Source: Author (2024).

Table 15 Occurrence of daylight metrics in documents found in this research.

REQUIREMENT	**CLASSIFI CATION**	**ASPECT**	**METRICS**	**TOTAL**	**STANDARDS**	**RATING SYSTEMS**	**GUIDELINES**	**BUILDING AND URBAN CODES / REGULATIONS**
DAYLIGHT PROVISION	NON-GEOMETRIC	STATIC	Maintained illuminance	1	**1**			
			Standard Illuminance	1	**1**			
			Vertical Illuminance	1			**1**	
			Illuminance uniformity	1			**1**	
			Illuminances	1		**1**		
			Average Daylight Illuminance	2		**2**		
			Minimum Daylight Illuminance	1		**1**		
			Daylight Illuminance	1		**1**		
			Minimum Illuminance	2	**1**	**1**		
			Illuminance	2				**2**
			Sky Factor	1				**1**
			Vertical Sky Component	2			**2**	
			Daylight Factor	40	**15**	**13**	**5**	**7**
			Average Daylight Factor	17	**2**	**4**	**2**	**9**
			Target Daylight Factor	4	**2**	**1**	**1**	
			Mean Daylight Factor	1			**1**	
		DYNAMIC	Target Illuminance	9	**4**	**3**	**1**	**1**
			Minimum Target Illuminance	4	**3**			**1**
			Spatial Daylight Autonomy	9	**3**	**6**		
			Useful Daylight Illuminance	4	**2**	**1**	**1**	
			Continuous Daylight Autonomy	1	**1**			
			Maximum Daylight Autonomy	1	**1**			
			Annual Daylight Exposure	1	**1**			
			Basic Daylight Autonomy	1			**1**	

(Cont. Table 15) Occurrence of daylight metrics in documents found in this research.

REQUIREMENT (cont.)	CLASSIFI CATION (cont.)	ASPECT (cont.)	METRICS (cont.)	TOTAL (cont.)	STANDARDS	RATING SYSTEMS	GUIDELINES	BUILDING AND URBAN CODES / REGULATIONS
			Daylight Autonomy	5	**2**	**3**		
			Useful Daylight Illuminance Exceeded	1		**1**		
			Minimum illuminance by area by time	1				**1**
			Illuminance in space and time	2		**1**		**1**
		DAYLIGHT + ENERGY	Daylight Supply Factor	3	**2**			**1**
			Daylight Dependency Factor	3	**2**			**1**
			Factor for daylight harvesting	1				**1**
SUNLIGHT AVAILABILITY	NON-GEOMETRIC	DYNAMIC	Sunlight Exposure	2	**2**			
			Exposure to sunlight	6	**2**	**2**		**2**
			Sunlight Duration	6	**3**			**3**
			Target daily sunlight hours on a façade	1	**1**			
			Annual Sunlight Exposure	6	**3**	**3**		
			Annual probable sunlight hours	3			**3**	
			Sunlight to open amenity spaces	1			**1**	
			Duration of insolation	1			**1**	
			Annual Sunlight Hours / Direct Sunlight Hours (ASH)	1	**1**			
GLARE CONTROL	NON-GEOMETRIC	DYNAMIC	Daylight Glare Probability	10	**6**	**3**	**1**	
			Predicted Glare Sensation Vote (PGSV)	1			**1**	
		STATIC	Daylight Glare Index	3	**2**	**1**		
ASSESSMENT OF VIEWS OUT	GEOMETRIC/ DESIGN	STATIC	Horizontal sight angle	5	**3**		**2**	

(Cont. Table 15) Occurrence of daylight metrics in documents found in this research.

REQUIREMENT (cont.)	CLASSIFI CATION (cont.)	ASPECT (cont.)	METRICS (cont.)	TOTAL (cont.)	STANDARDS	RATING SYSTEMS	GUIDELINES	BUILDING AND URBAN CODES / REGULATIONS
ASSESSMENT OF VIEWS OUT	GEOMETRIC/ DESIGN	STATIC	Layers	19	**4**	**9**	**4**	**2**
			Outside distance of the view	4	**3**		**1**	
			occupied area	2		**2**		
			Distance to windows	3		**1**		**2**
			Solid angle of windows	1			**1**	
			Distance to the outside obstacles	1			**1**	
			Overall visible volume	1			**1**	
			External Obstruction	1		**1**		
			Distance from windows	9		**5**	**1**	**3**
SIZES / PROPORTIONS	GEOMETRIC/ DESIGN	STATIC	Window-to-floor ratio (WFR)	36	**4**	**4**	**2**	**26**
			Window-to-floor ratio of combined areas	1	**1**			
			Window-to-wall Ratio (WWR)	9	**1**	**3**	**3**	**2**
			Glazing-to-wall ratio (GWR)	1				**1**
			Minimum sizes of windows	1				**1**
			Maximum glazed area	1				**1**
			Maximum window area	1				**1**
			Minimum window area	2				**2**
			Minimum 'equivalent aperture surface area'	1				**1**
			Minimum aperture surface area	1				**1**
			Minimum opening area	1				**1**
			Window sizes	13		**4**		**9**
			Area of glazing	4			**1**	**3**
			Area of windows	2			**1**	**1**
			Opening areas	1				**1**

(Cont. Table 15) Occurrence of daylight metrics in documents found in this research.

REQUIREMENT (cont.)	CLASSIFICATION (cont.)	ASPECT (cont.)	METRICS (cont.)	TOTAL (cont.)	STANDARDS	RATING SYSTEMS	GUIDELINES	BUILDING AND URBAN CODES / REGULATIONS
SIZES / PROPORTIONS	GEOMETRIC/ DESIGN	STATIC	Fenestration area	1				**1**
			Envelope glazing area	1		**1**		
			Vertical envelope glazing	1		**1**		
			Opening percentage	1				**1**
			Window % of surrounding wall area (related to view)	1		**1**		
			Head height	3			**1**	**2**
			Sill height	2			**1**	**1**
			Maximum height of openings	1				**1**
			Lightwells	3				**3**
			Skylight area	1	**1**			
			Translucent skylight portion of roof surface	2		**2**		
			Fenestration area (skylight)	1	**1**			
			Skylight Roof Ratio	1				**1**
SETBACKS / DISTANCES / HEIGHTS	GEOMETRIC/ DESIGN	BUILDING	Minimum setbacks from window to outside obstacles	2	**2**			
			Setbacks from plots' boundaries	3				**3**
			Front, side and rear setbacks	5				**5**
			Minimum frontage distance	1				**1**
			Maximum height of openings	1				**1**
			Floor to ceiling height	1		**1**		
			Length of zone	1	**1**			
		URBAN	Setbacks between buildings	3			**2**	**1**

(Cont. Table 15) Occurrence of daylight metrics in documents found in this research.

REQUIREMENT (cont.)	CLASSIFICATION (cont.)	ASPECT (cont.)	METRICS (cont.)	TOTAL (cont.)	STANDARDS	RATING SYSTEMS	GUIDELINES	BUILDING AND URBAN CODES / REGULATIONS
SETBACKS / DISTANCES / HEIGHTS	GEOMETRIC/ DESIGN	URBAN	Minimum setbacks from outside obstacles	2	**2**			
			Setbacks	1				**1**
			Building's ratio	1				**1**
			Maximum height	1				**1**
			Height ratio	1			**1**	
			Spacing-to-height ratio	1			**1**	
			Height of Building x distance of the offset	1				**1**
			Height to width	1				**1**
ANGLES	GEOMETRIC/ DESIGN	BUILDING	Obstruction angle	4			**2**	**2**
			Vertical shadowing angle	1			**1**	
			Horizontal shadowing angle	1			**1**	
			Overhang Obstruction Angle	3		**1**		**2**
			Average exterior obstruction angle	1				**1**
		URBAN	Vertical shadow angle / profile angle	1	**1**			
			Angle of visible sky	3			**2**	**1**
			Angle of obstruction	1			**1**	
			Overshadowing angle	1		**1**		
			Average urban obstruction angles	1		**1**		
			Grazing angle	1				**1**
GLAZING PROPERTIES	GEOMETRIC/ DESIGN	PHYSICAL PROPERTIES	Minimum light transmittance	2	**1**			**1**
			Visible light transmittance	15	**3**	**9**		**3**

(Cont. Table 15) Occurrence of daylight metrics in documents found in this research.

REQUIREMENT (cont.)	CLASSIFICATION (cont.)	ASPECT (cont.)	METRICS (cont.)	TOTAL (cont.)	STANDARDS	RATING SYSTEMS	GUIDELINES	BUILDING AND URBAN CODES / REGULATIONS
GLAZING PROPERTIES	GEOMETRIC/ DESIGN	PHYSICAL PROPERTIES	Visible light transmittance/ solar heat gain coefficient	1	**1**			
			Effective luminous transmittance	1				**1**
			Obstruction or distortion	1		**1**		
OTHERS	GEOMETRIC/ DESIGN AND NON-GEOMETRIC	OTHER	Luminance levels in space	1			**1**	
			Colour rendering index	1	**1**			
			Ceiling, walls and floor reflectance	1	**1**			
NON-VISUAL EFFECTS	NON-GEOMETRIC	MELANOPIC SENSIBILITY	Melanopic Equivalent Daylight Illuminance	6	**4**	**2**		
			Equivalent Melanopic Lux	2	**1**	**1**		
		MELATONIN SUPPRESSION	Circadian Stimulus	3	**1**	**1**	**1**	
		OTHER	Photopic Illuminance	1	**1**			

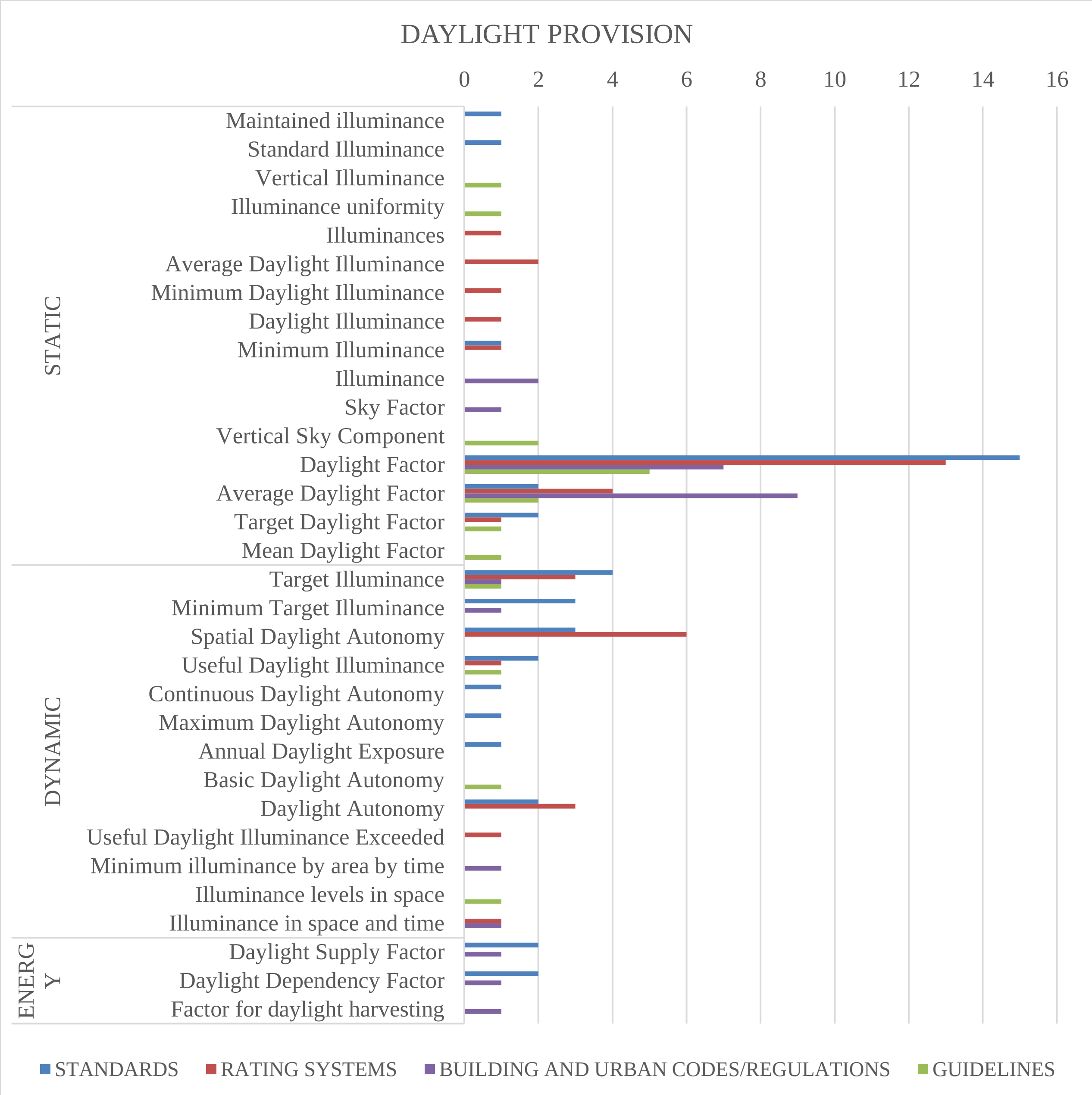
Source: Author (2024).

4.2.1. Visual effects: non-geometric metrics

A significant part of found metrics are non-geometric, with numerical parameters for an aimed performance in terms of the respective requirements. In that way, metrics can be related to Daylight Provision, Views Out, Sunlight Availability, Glare Control and Non-visual Effects. Non-geometric metrics provide an information that is already a criterium in itself, since it allows comparison and a way of evaluation. They measure, express and evaluate daylight according to different variables. Most of metrics that account for the amount of daylight inside rooms take into account basic criteria like illuminance and luminance (BOUBEKRI, 2008). Illuminance is the variable that describes the measurement of the amount of illuminating a given surface, while luminance is the amount of light reflected from surfaces to human eyes (TREGENZA; WILSON, 2011).

Most metrics involving daylight provision measure illuminance: according to exterior sky, to the combination of sunlight and skylight, to the changes in visibility and the measured illuminance due to reflections, etc. Although illuminance has predominated for a long time as an indicator for metrics, both visual and non-visual effects, in the last few years, luminance has been accounted also, due to the changes in visual tasks, the increments of technology and the creation of metrics focused on the vertical plane. However, non-geometric metrics do not provide input for building and urban design, since those cannot provide enough information about configuration and properties of buildings.

Figure 10 Non-geometric metrics regarding the Daylight Provision requirement.



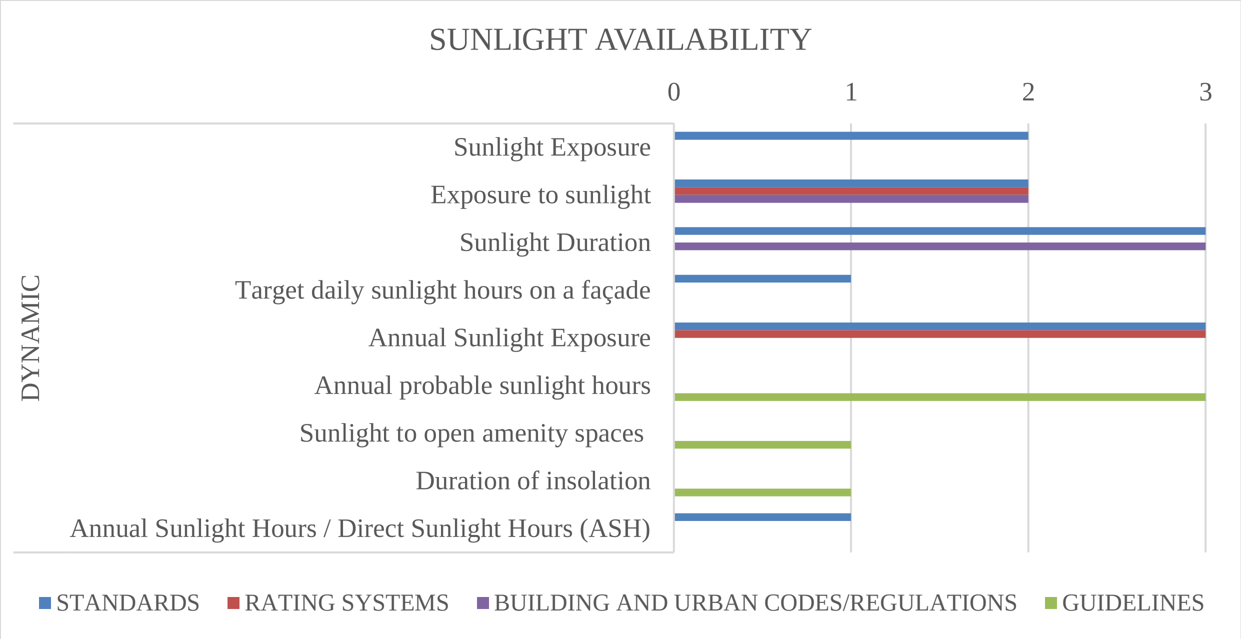
Source: Elaborated from Amorim; Pinheiro (2024).

As Figure 10 Shows, Daylight Factor — and its variations, like DF_{avg}, Mean DF, etc — remain the most used metrics in all documents, especially on Standards and Rating Systems. This is partly explained by the wide use of this metric since the first half of the 20th century. As CBDM metrics only emerged in the 1990s, although scientific research encourages their use due the multiple benefits and advantages regarding climatic features, are not still widely used in documents and in professional practice. Also, the use of DF is simpler to calculate or estimate, which secures DF being the most known and used metric. In a European context, this is a smaller issue, since DF is focused on diffuse illuminance given by overcast skies. In sunny climates like Brazil, Singapore, Colombia and others, though, DF distorts the results by the lack of accountability of sunlight in calculations. That way, openings for daylighting can be overestimated, causing problems like excessive heat load gains, glare occurrence and even the increase in energy consumption due to the use of air conditioning.

The dynamic metrics mostly used are Target Illuminance and Spatial Daylight Autonomy. E_T and sDA are especially used in Standards and Rating Systems, as well, but on the contrary of DF, have very few applications on building and urban codes and regulations. The other found metrics are similar to the most popular ones, but with slightly different names — like this related to daylight illuminance, and those on the Daylight Autonomy and Useful Daylight Illuminance spectrum. They could have been considered under the same names, but this could have caused the loss of important information, like the applications and variations within the concepts.

Regarding sunlight, the main metrics mentioned are Exposure to Sunlight, Sunlight Duration and Annual Sunlight Exposure (ASE) (Figure 11). Mostly, the metrics regarding sunlight try to embody direct sunlight inside rooms, especially in places with winter seasons, when sunlight is most wanted. Besides the thermal aspect, sunlight is welcome in healthcare and education facilities due to its psychological benefits to learning process and to the recovery from diseases. Exposure to Sunlight and Sunlight Duration request a minimum solar incidence indoors due to thermal reasons, commonly expressed in a number of hours — i.e., 1,5h, 3h or 4h of sunlight indoors. On the other hand, ASE account for the maximum threshold of solar incidence, and incidence above those levels may result in thermal discomfort and glare occurrence — the usual parameter is a maximum of 1000 lux of solar incidence in 250h in a year.

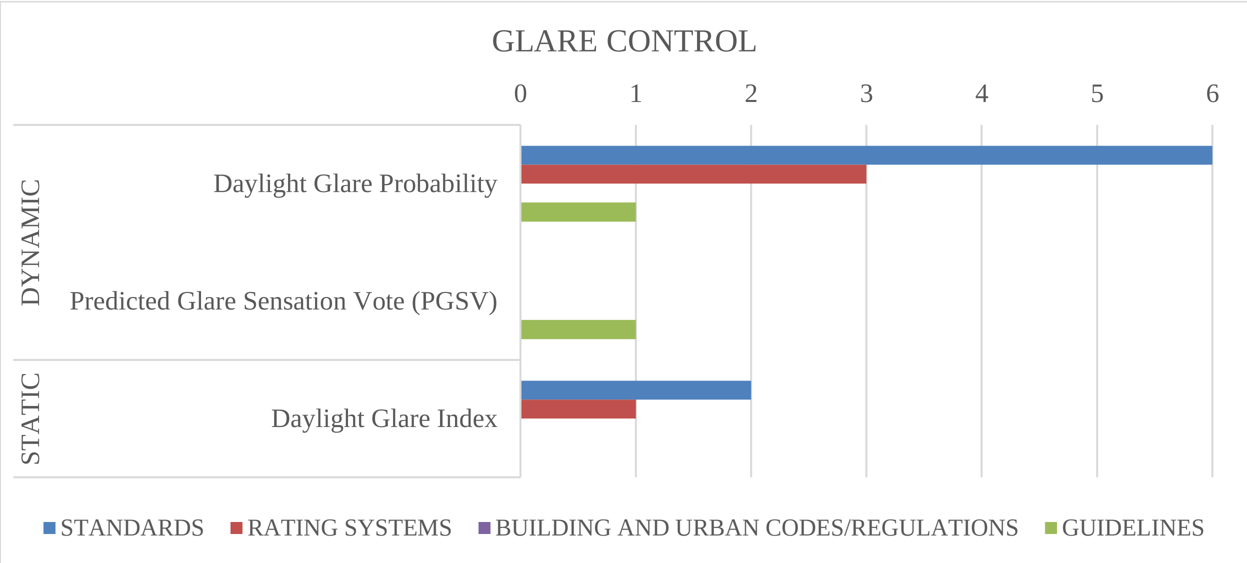
Figure 11 Sunlight availability non-geometric metrics.



Source: Elaborated from Amorim; Pinheiro (2024).

Glare occurrence is mostly estimated in documents through DGP, since it is a dynamic metric. DGI, instead, is a static metric and, even though it is used in some documents, DGP is acknowledged as the most trustable metric to understand users' perception about discomfort by glare due to daylight. Predicted Glare Sensation Vote (PGSV) is based on the average luminance of the whole window plane, whether it does not differentiate between uniform and non-uniform glare sources. The same happens to Daylight Glare Index (DGI), according to authors (KIM; AHN; KIM, 2008) (Figure 12).

Figure 12 Occurrence of non-geometric metrics concerning glare control.



Source: Elaborated from Amorim; Pinheiro (2024).

4.2.2. Visual effects: geometric/design metrics

The geometric/design metrics are composed by those metrics related to the zoning of the urban fabric and the building design, also referring to physical characteristics of the building and urban surroundings that influence daylight indoors (TREGENZA; WILSON, 2011). These metrics — shading or obstruction angles, setbacks between the buildings and the sites' boundaries, windows' sizes according to indoor floor or wall area, etc (BOUBEKRI, 2008; DERVISHAJ; GUDMUNDSSON, 2024; TREGENZA; WILSON, 2011) — have been part of the architectural activities for a long time, since the conditions of each location always shaped buildings and their relation with the external environment. That way, geometric metrics directly support architectural activities.

The requirements related with the building and urban geometry have a different complexity than the ones related to other properties related to daylight, like illuminance and luminance (BOUBEKRI, 2008; CZACHURA et al., 2022). Usually, they were used as ways to calculate how daylight would behave indoors in buildings constructed before the computer-aided design (CAD) existed. Later, computer softwares made the calculations easier, but until nowadays there is no consensus on the way to evaluate sunlight access in the urban scale (DERVISHAJ; GUDMUNDSSON, 2024).

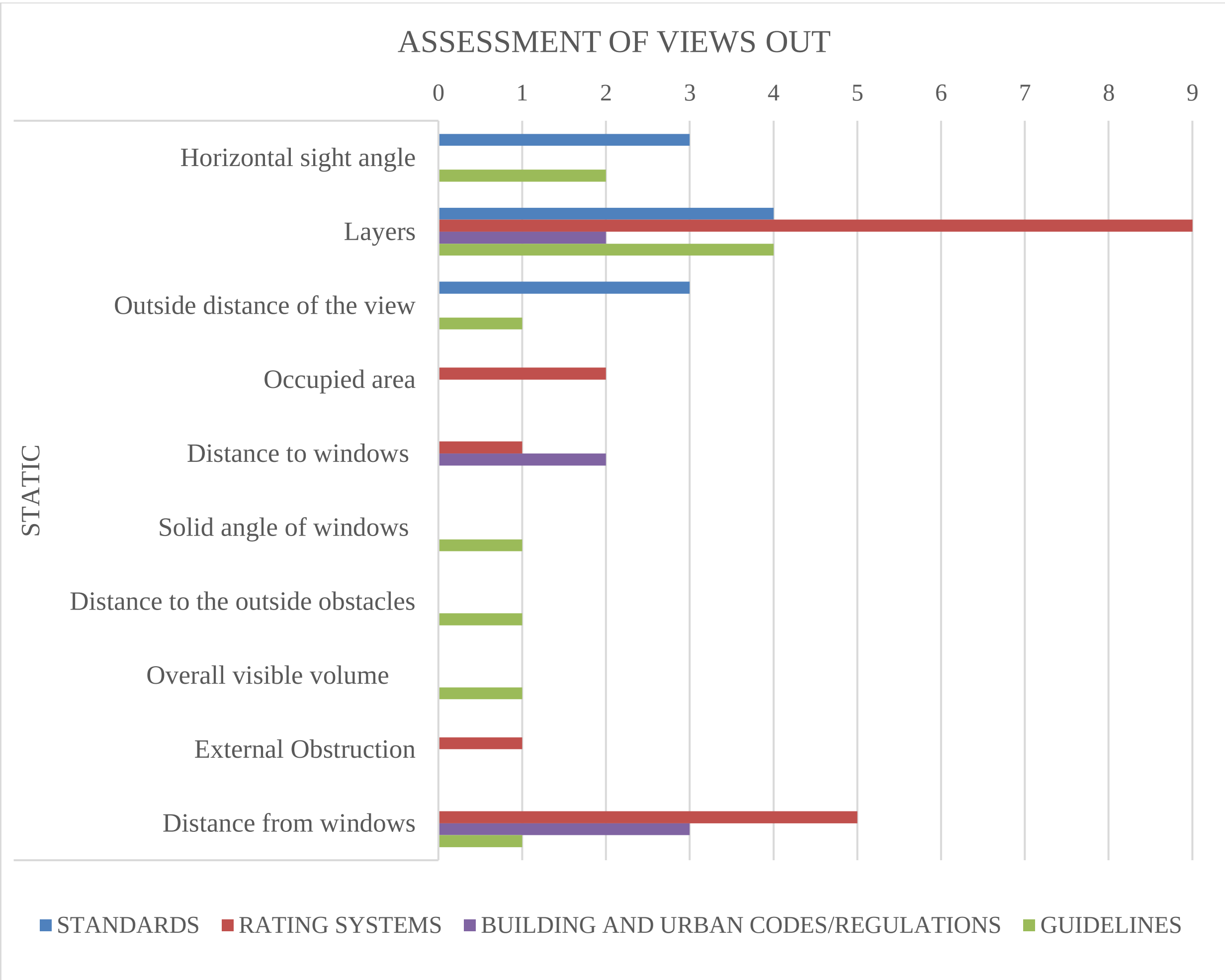
According to Czachura et al. (2022), even though there are plenty of metrics that evaluate daylighting inside rooms, there is still no consensus as to which ones are most suitable to evaluate solar access in building and in urban spaces. This fact, combined to the low expertise of professionals and the lack of simulation softwares dedicated to urban planning make the urban design assessments still scarce, for daylighting and for other topics as well. For that reason, many practitioners have been advocating easy and efficient evaluation metrics to the urban design activities (CZACHURA et al., 2022).

Even considering this gap, daylight and sunlight evaluations in the urban scale are usually made through geometric/design metrics. That is, they allow measuring the influence of the outdoor environment in daylighting indoors, as well as the effects of buildings on sites, over each other, and in surroundings in the provision of daylight (CZACHURA et al., 2022).

Figure 13 displays the metrics that assess views out. Within the analysis, usually, documents evaluate the content of the view, the width of the windows and the distance from the openings to the contents in sight. Respectively, the metrics for those criteria are layers, horizontal sight angle and distance from windows to view, all of those considered static metrics, since the conditions are fixed once the building is ready for use.

Even with these existing metrics, not all documents that require views out to their spaces make such an objective evaluation. That is, in various documents, “views out” only appear as requirements, establishing that spaces should “provide visual contact with the outside” (BSI; ISO, 2019; CEN, 2013, 2021a), ensure “access to views in habitable spaces” (CERTIVEA, 2024b, 2024c; FUNDAÇÃO VANZOLINI; CERTIVEA, 2021), or “spaces should have openings that provide view of the surroundings” (MINISTRY OF TRANSPORT BUILDING AND HOUSING - DENMARK, 2018). Therefore, frequently views out are evaluated too subjectively and this fact hinders the definitions of what elements a view out should have to be considered pleasant and proper to occupants.

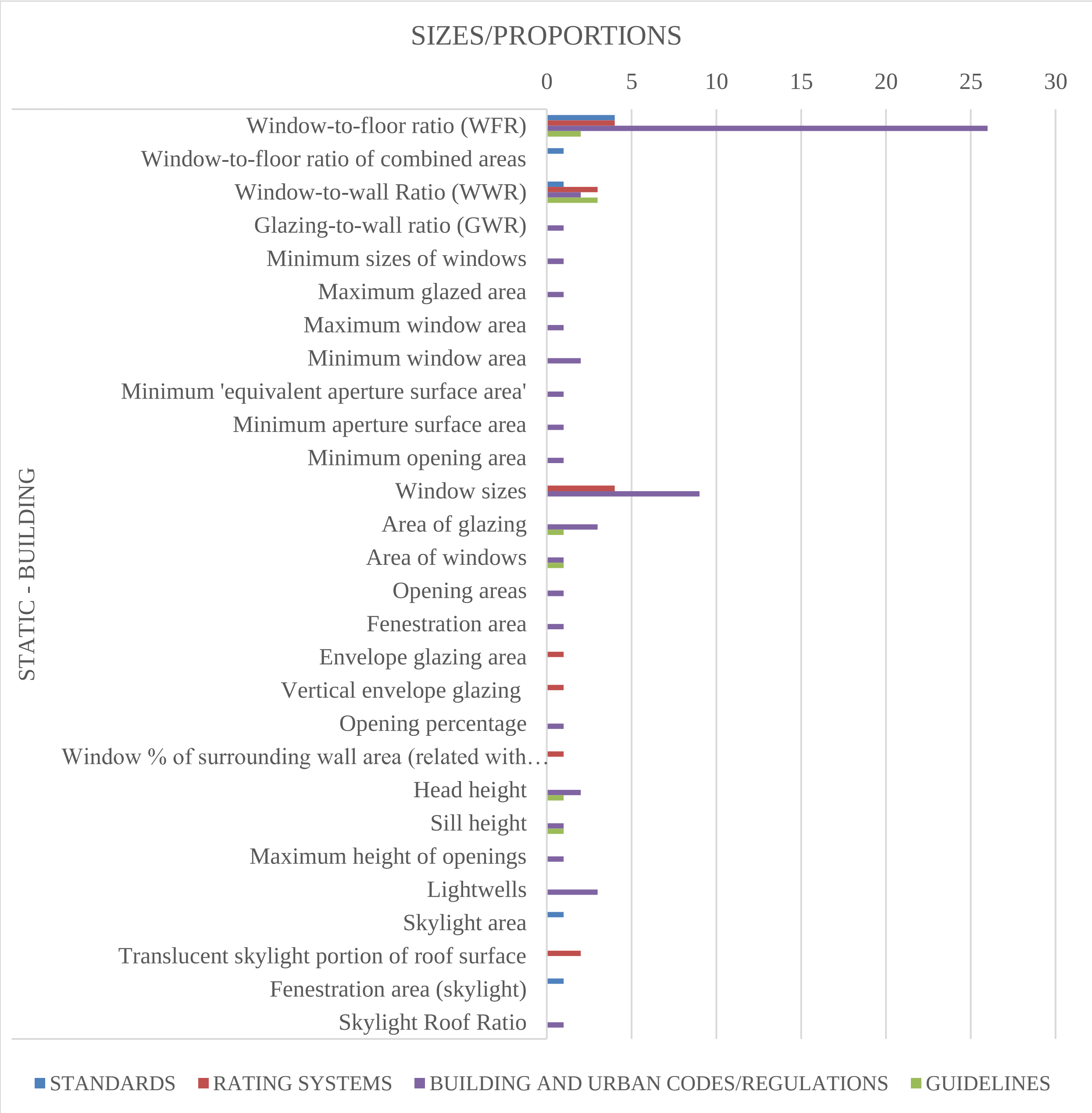
Figure 13 Assessment of views out metrics found in documents.



Source: Elaborated from Amorim; Pinheiro (2024).

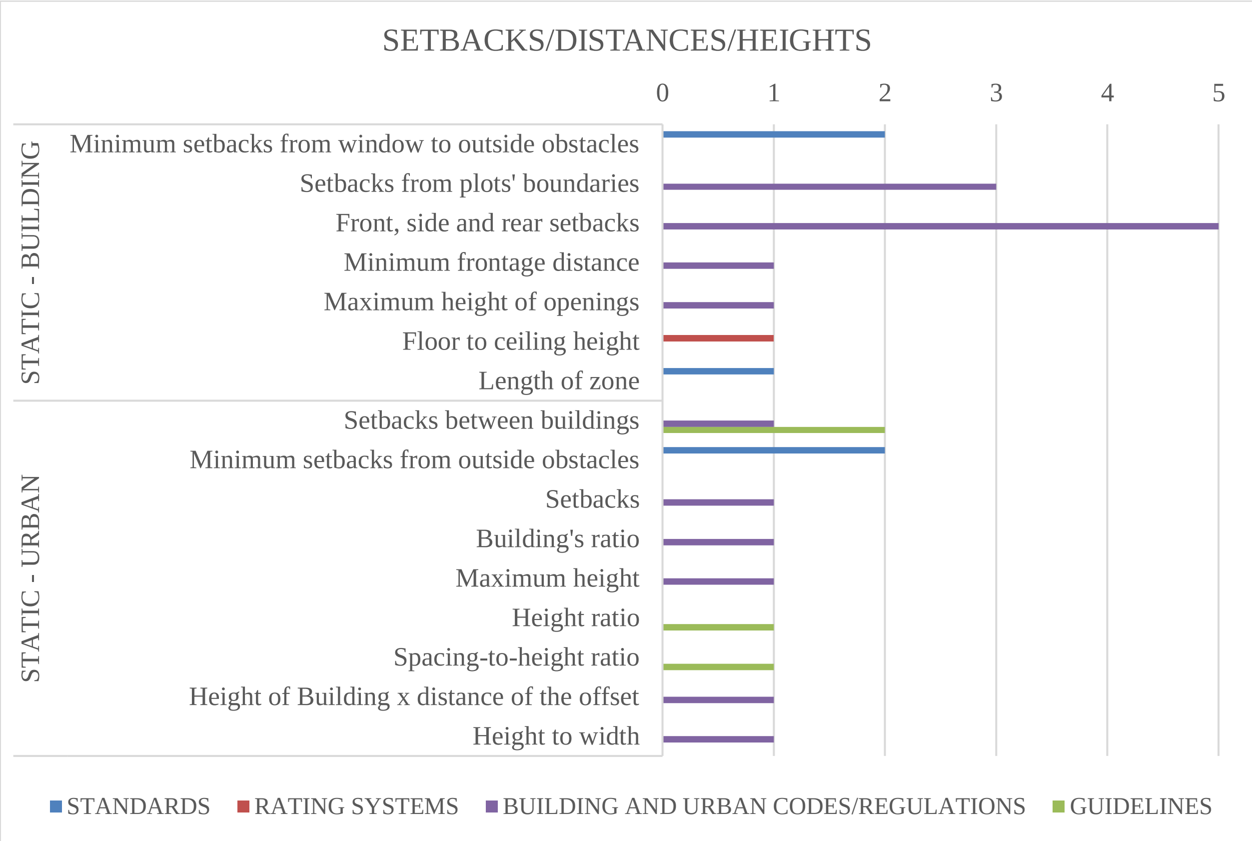
Figures 14 and 15 below display the use of geometric/design metrics in documents analysed. Clearly there is a predominance of this kind of metrics in building and urban codes and regulations, with a wide application of WFR. The second most used metrics refer to window sizes and WWR. All of those account for the dimensions of windows and their proportions according to floor areas and facade areas. Regarding setbacks, distances and heights, metrics are found mostly in building and urban codes and regulations, being used mainly to design buildings and mediate their relations with the surrounding urban fabric.

Figure 14 Building level geometric/design metrics, regarding sizes/proportions openings, commonly found in documents.



Source: Elaborated from Amorim; Pinheiro (2024).

Figure 15 Geometric/design metrics about setbacks, distances, heights and ratios in building and urban levels.

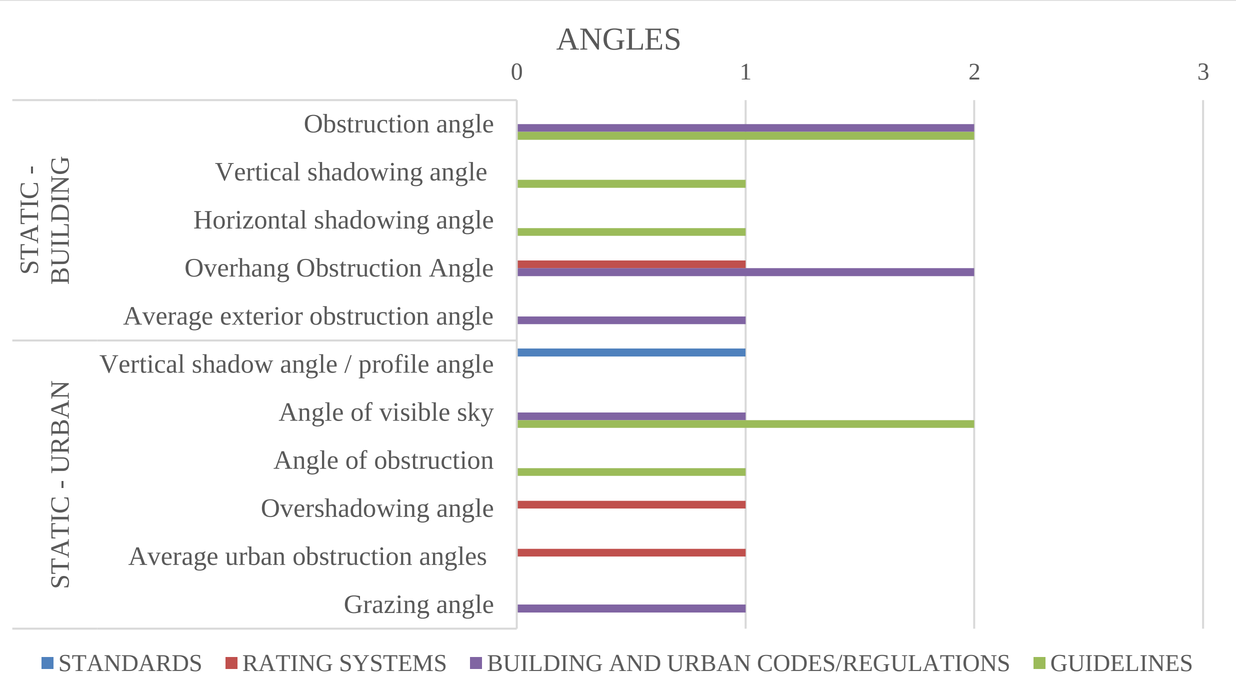


Source: Elaborated from Amorim; Pinheiro (2024).

The metrics regarding angles can be both from the building and the urban levels. In the building level, those commonly express the shadowing and obstructions from elements on the façade or caused by buildings over themselves. Often, the shadowing devices — vertical and horizontal shadowing, overhangs, exterior obstruction — are focused on the thermal aspect, protecting openings against excessive sunlight and heat loads. Nevertheless, those influence direct and diffuse daylight indoors, no-skyline view and even the views out, which means that they also require analysis under the daylighting point-of-view.

On the other hand, angles in the urban level express the influence of buildings among themselves and with other elements — that is, shadowing and obstructions caused by other constructions, sometimes indicating the occurrence of urban canyons, low or no access to daylight in the first floorplans, etc. Even though these metrics are used originally to comprehend how building influence and are influenced by the surroundings, shadowing and obstructions also impact daylighting indirectly. For that reason, angles are used mostly on guidelines and in building and urban codes and regulations (Figure 16).

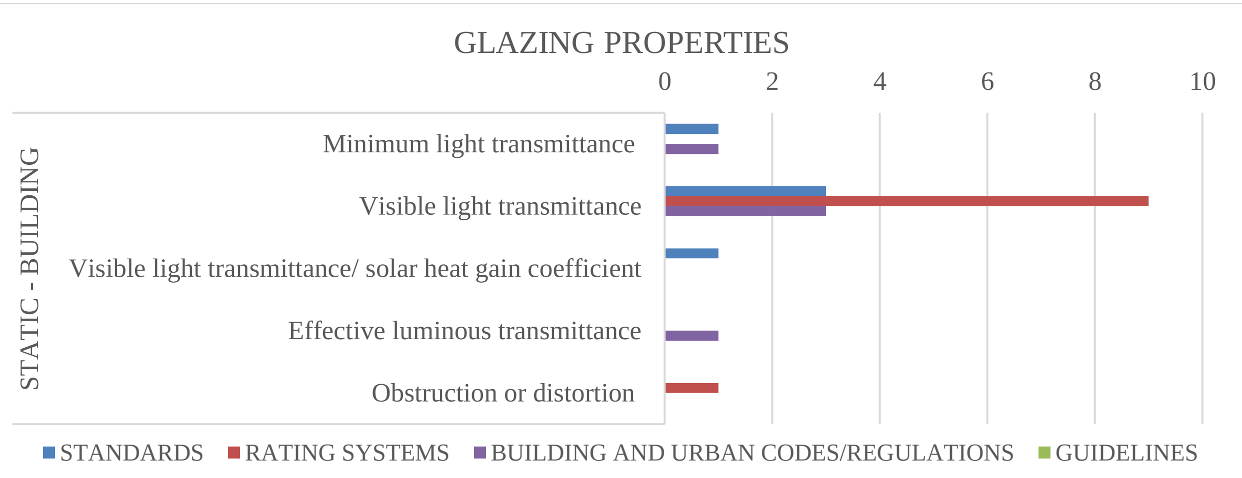
Figure 16 Building and urban metrics regarding shadowing and obstruction angles.



Source: Elaborated from Amorim; Pinheiro (2024).

Another type of metrics frequently found are those related to physical properties of glazing, which influence not only the quantity but also the quality of daylighting. Thus, as those are too specific features that are not usually part of the design practice, they receive special focus on rating systems. The reason is that the rating systems indeed encourage the best possible performance, and this aim involves directly the physical properties of materials, like the visible transmittance of glazing, minimum light transmittance, U-value, among others, in order to receive the best performance ranking possible (Figure 17).

Figure 17 Glazing physical properties metrics found in documents.



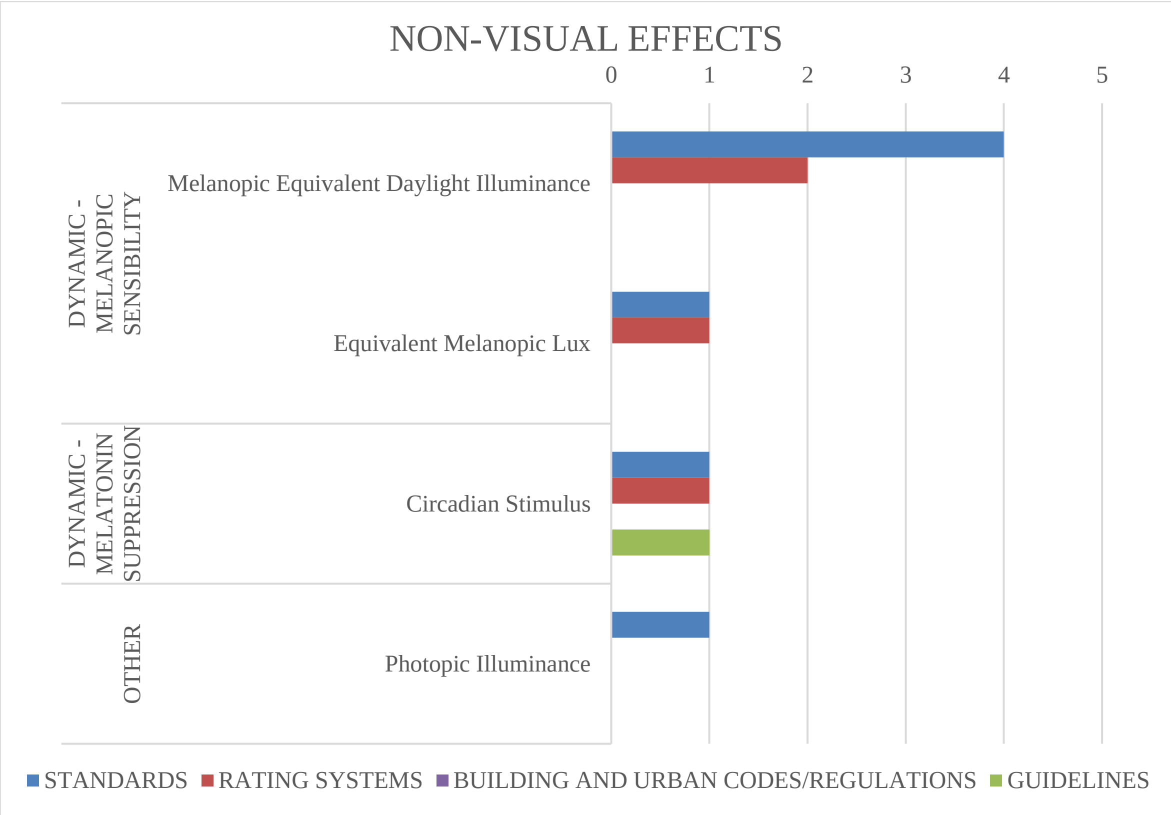
Source: Elaborated from Amorim; Pinheiro (2024).

4.2.3. Non-visual effects

Regarding non-visual effects, the main metrics found are Melanopic Equivalent Daylight Illuminance (mEDI), Equivalent Melanopic Lux (EML), Circadian Stimulus (CS) and Photopic Illuminance. The first two measure the effects of different lighting sources over through melanopic sensibility of light received by the ipRGCs. CS quantifies the melatonin suppression along the day, while Photopic Illuminance evaluates the vision of the human eye in well-lit conditions — which can be an input for the other non-visual effects metrics.

Metrics of non-visual effects are not found in building and urban codes and regulations, as Figure 18 shows — which demonstrates that the mandatory documents do not follow the most recent advances in daylighting. Consequently, professionals, decision-makers and other stakeholders are not yet beware of how physiological and psychological needs of occupants should influence building design, in order to provide the best visual and non-visual conditions. Thus, despite visual conditions may be sufficiently treated during design phases to assure that tasks can be properly developed indoors, that does not imply that those are the best conditions to provide the physiological benefits of lighting.

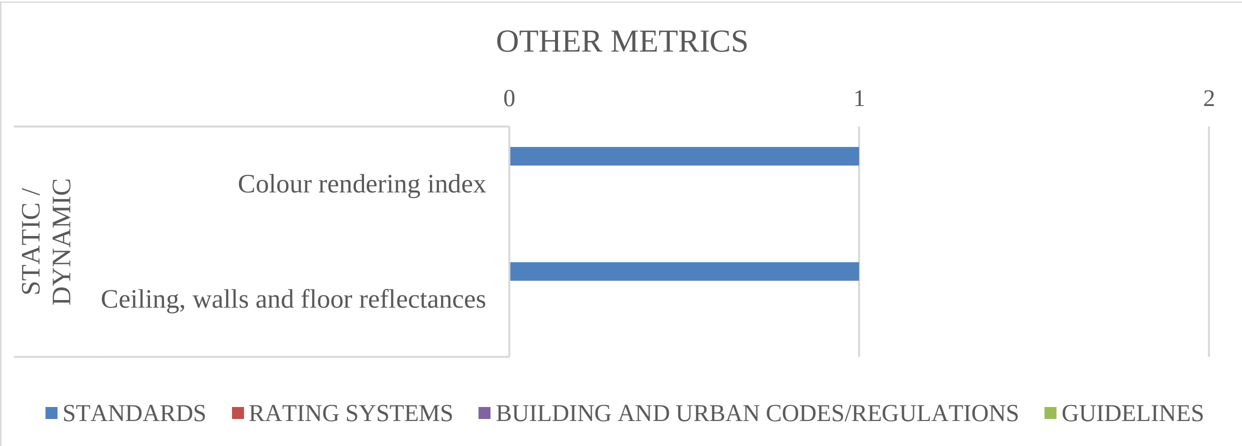
Figure 18 Non-visual effects metrics occurrence in documents.



Source: Elaborated from Amorim; Pinheiro (2024).

Other metrics found during the analysis of documents are expressed in Figure 18. About Colour rendering index (Ra) and Ceiling, walls and floor reflectances, mentioned in one standard, refer to the "indication of the colour rendering properties of a light source" and "the minimum requirements for the average luminance can be calculated from the recommended minimum illuminance multiplied by the recommended value of the wall, floor and ceiling reflectance", respectively (ISO; CIE, 2023). These metrics do not account daylight directly, though daylighting is a component of the lighting analysis (Figure 19).

Figure 19 Other metrics found in documents analysed.



Source: Elaborated from Amorim; Pinheiro (2024).

4.3. Climate-based analysis

The climatic analysis of the requirements and metrics aims to visualize the use of metrics in documents and countries, in order to find out if climatic features interfere in the choice of daylighting criteria. As metrics were more deeply analysed during the documents collection, these are the focus of the climate-based analysis. The only requirement expressed on this analysis is "outside views", in order to reunite the components of views into a single term, for better visualization.

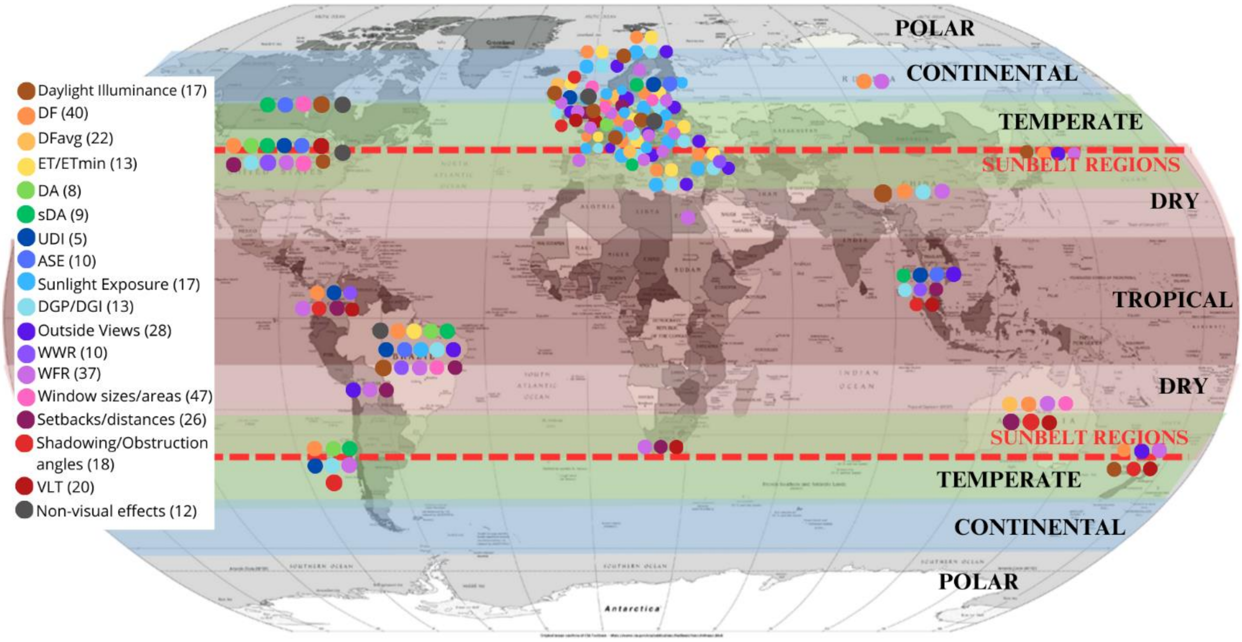
In the following Figures 20, 21 and 22, metrics were simplified to the most representative, meaning that the ones in the maps summarize similar concepts. That way, the 120 metrics found are expressed in maps through a total of 18:

- Metrics such as DF, DF_{avg}, sDA, UDI, WFR, WWR, are shown separately, due to their greater representativity, as well as unique concepts;

- "Daylight Illuminance" gathers Standard Illuminance, Average Daylight Illuminance, Minimum Daylight Illuminance, Minimum Illuminance, Illuminance and others;
- "Daylight Autonomy" summarizes DA itself, Basic Daylight Autonomy, Continuous Daylight Autonomy and Maximum Daylight Autonomy;
- Target Illuminance (E_T) is summed up with Minimum Target Illuminance (E_{Tmin});
- "Outside views" sums up Horizontal sight angle, Layers and Distance of view;
- "Sunlight Exposure" reunites Exposure to Sunlight, Sunlight Duration, Target daily sunlight hours on a façade, Sunlight to open amenity spaces, Duration of Insolation;
- "Annual Sunlight Exposure" (ASE) gathers ASE itself, with Annual Probable Sunlight Hours (APSH) and Annual Sunlight Hours (ASH);
- "Daylight Glare Probability" (DGP), Daylight Glare Index (DGI) and Predicted Glare Sensation Vote (PGSV) are represented together, under the subtitle "DGP/DGI";
- "Shadowing/Obstruction angles" summarize the variety of metrics about angles, such as Obstruction angle, Vertical and Horizontal Shadowing Angle, Overhang Obstruction Angle, etc;
- "Setbacks/distances" summarize nomenclatures such as Setbacks from plots' boundaries, Front, side and rear setbacks, Setbacks between buildings, Floor to ceiling height, Height of Building x distance of the offset, and others;
- "Window sizes/areas" refer to metrics that define linear sizes and areas of windows with no related percentual to floor or façade areas;
- "Visual Light Transmittance" (VLT) summarizes metrics like Minimum light transmittance, Effective luminous transmittance, and Visible light transmittance/ solar heat gain coefficient;
- "Non-visual effects" summarizes Melanopic Equivalent Daylight Illuminance, Equivalent Melanopic Lux, Circadian Stimulus and Photopic Illuminance.

Figure 20 shows a geographical distribution of metrics in all documents analysed. Under the climatic point of view, metrics found in documents were crossed with the classification proposed. Consequently, it is possible to infer that most metrics are applied regardless climatic features, since the same ones can be found in regions with substantial climatic differences. As an example, DF can be found in documents from Europe, from North and South America, from Asia and from Oceania. Even if the parameter values are different, DF is more efficient in climates with predominance of overcast sky, which is not the case in tropical regions. Nevertheless, this presence of DF in all regions can be explained by its grater familiarity to professionals, even if calculations are not properly made — that is, DF is applied based on interpretations of the usual value parameters, for example.

Figure 20 Metrics used in all documents, distributed within Koppen climates and Sunbelt regions.

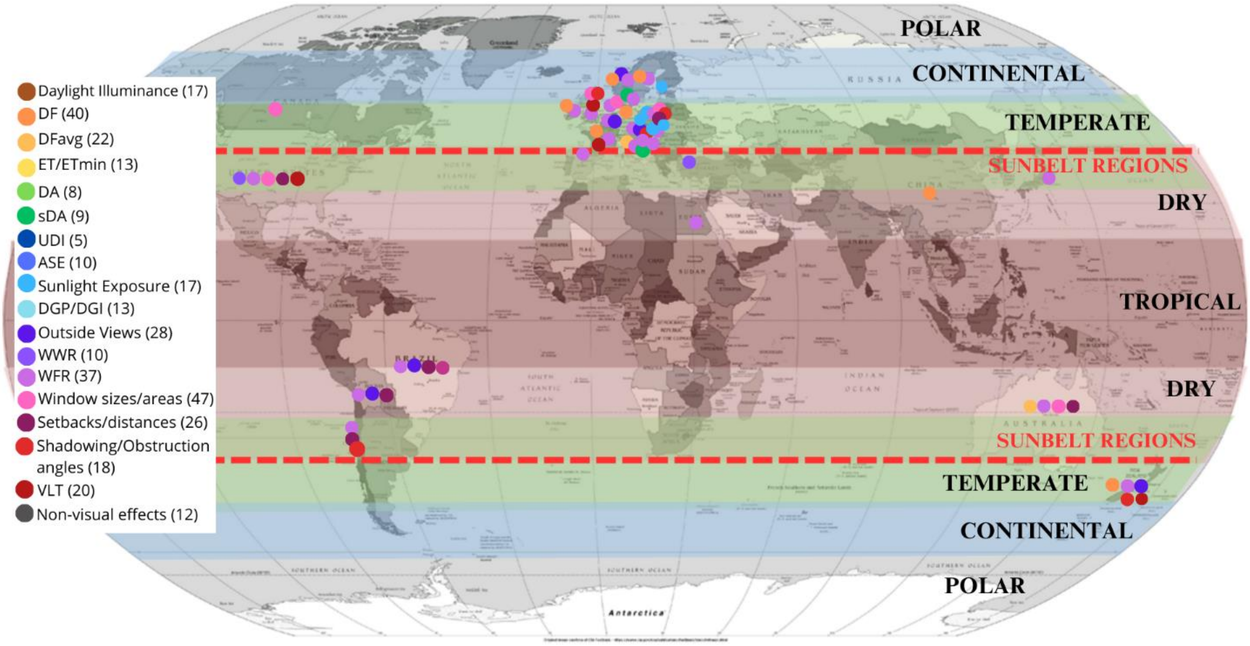


Source: Author (2024).

Static geometric metrics are also found in all regions, mainly in Building and Urban Codes and Regulations. Besides, as shown in Figure 21 below, dynamic metrics are not commonly used in mandatory documents, even though static non-geometric metrics as DF are used. Nevertheless, some countries in Europe, Oceania and North America are starting to incorporate dynamic metrics — such as sDA, UDI, E_T.

As for dynamic metrics, Exposure to Sunlight and Sunlight Duration are often applied in climates with stricter winter seasons, where sunlight is welcome due the thermal and psychological benefits, e.g. in northern Europe. In tropical regions, Sunlight Exposure and Sunlight Duration are uncommon. Instead, ASE is more used, due to concerns about an excessive amount of sunlight — and consequently higher heat loads; and DGP, since glare control is essential due to the great incidence of sun rays all year.

Figure 21 Metrics used in mandatory documents, overlapped with Koppen climates and Sunbelt regions.

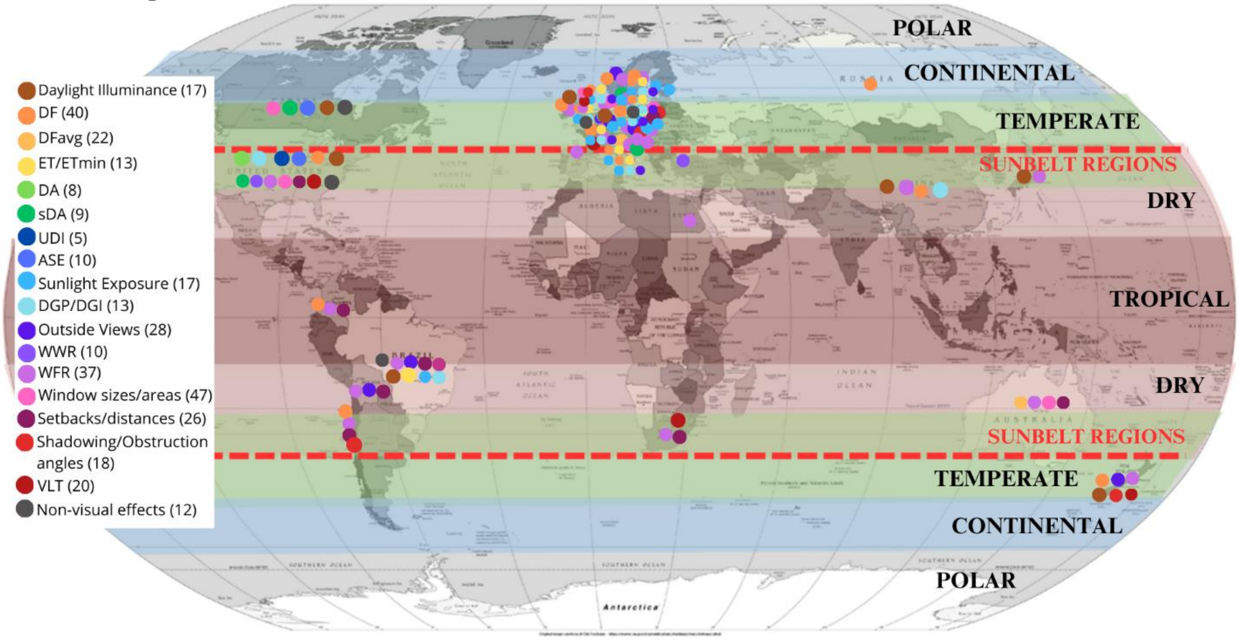


Source: Author (2024).

Putting together mandatory documents and Standards (Figure 22), it is noticeable that Window-to-Floor Ratio (WFR), Window sizes, Setbacks and Daylight Factor (DF) are the most frequent, independently of the climatic features. The wide use of DF is the most problematic practice, because the parameter values are frequently similar, even when climates are completely different. This makes DF an unreliable metric in many places, especially those within the tropics and near Equator line, since those are frequently the warmest weathers and clearest sky patterns, in which the possible distortions caused by DF could cause great impairments to buildings and occupants. The other metrics usually adapt better to each climate conditions, but those still do not necessarily guarantee proper levels of daylight, neither avoid glare occurrence.

This group of documents expresses the tendency of Building and Urban Codes and Regulations to refer to Standards when regulating certain requirements — which makes Standards mandatory — at the same time that evidences that even Standards being mentioned in them, Codes and Regulations have not yet embodied dynamic metrics among recommendations. This keeps the scientific progress of daylighting disconnected from the mandatory demands and, consequently, from daily professional practice.

Figure 22 Metrics in Building and Urban Codes, Regulations and Standards, within Koppen climates and Sunbelt regions.



Source: Author (2024).

This first approach of climatic analysis is limited to the conceptual definitions of metrics, since the variables considered and the calculation methods are crucial to evaluate if a metric can be suitable, or not, for a certain climatic region. The parameter values, instead, are probably impossible to harmonize due to great variations — i.e., each location should have recommended values considering climatic patterns, cultural background and user preferences. Table 16 below shows the distribution of metrics among the Koppen climatic classification.

Table 16 Occurrence of metrics in different climates.

CLASSIFICATION	METRICS	CLIMATE			
		TROPICAL	DRY	TEMPERATE	CONTINENTAL
NON-GEOMETRIC (STATIC)	Maintained illuminance			1	
	Standard Illuminance			1	
	Vertical Illuminance			1	
	Illuminance uniformity			1	
	Illuminances			1	
	Average Daylight Illuminance			2	
	Minimum Daylight Illuminance			1	
	Daylight Illuminance			1	
	Minimum Illuminance	2			
	Illuminance			2	
	Sky Factor			1	
	Vertical Sky Component			2	

(Cont. Table 16) Occurrence of metrics in different climates.

CLASSIFICATION (cont.)	METRICS (cont.)	CLIMATE (cont.)			
		TROPICAL	DRY	TEMPERATE	CONTINENTAL
NON-GEOMETRIC (STATIC)	Daylight Factor	7	3	27	3
	Average Daylight Factor		1	16	
	Target Daylight Factor			3	1
	Mean Daylight Factor			1	
NON-GEOMETRIC (DYNAMIC)	Target Illuminance	2	1	5	2
	Minimum Target Illuminance	1	1	2	
	Spatial Daylight Autonomy	2		5	3
	Useful Daylight Illuminance			4	
	Continuous Daylight Autonomy			1	
	Maximum Daylight Autonomy			1	
	Annual Daylight Exposure			1	
	Basic Daylight Autonomy			1	
	Daylight Autonomy	1	1	3	
	Useful Daylight Illuminance Exceeded	1			
	Minimum illuminance by area by time			1	
	Illuminance levels in space	1			
	Illuminance in space and time			1	1
	Daylight Supply Factor			3	
	Daylight Dependency Factor			3	
	Factor for daylight harvesting				1
	Sunlight Exposure			2	
	Exposure to sunlight		1	5	
	Sunlight Duration			6	
	Target daily sunlight hours on a façade			1	
	Annual Sunlight Exposure	6		4	2
	Annual probable sunlight hours			3	
	Sunlight to open amenity spaces			1	
	Duration of insolation			1	
	Annual Sunlight Hours / Direct Sunlight Hours (ASH)		1	1	
NON-GEOMETRIC (STATIC/ DYNAMIC)	Daylight Glare Probability	2	1	7	
	Predicted Glare Sensation Vote (PGSV)			1	
	Daylight Glare Index		1	2	
GEOMETRIC/ DESIGN	Horizontal sight angle	1	1	3	
	Layers	3	1	13	2
	Outside distance of the view	1	1	2	

(Cont. Table 16) Occurrence of metrics in different climates.

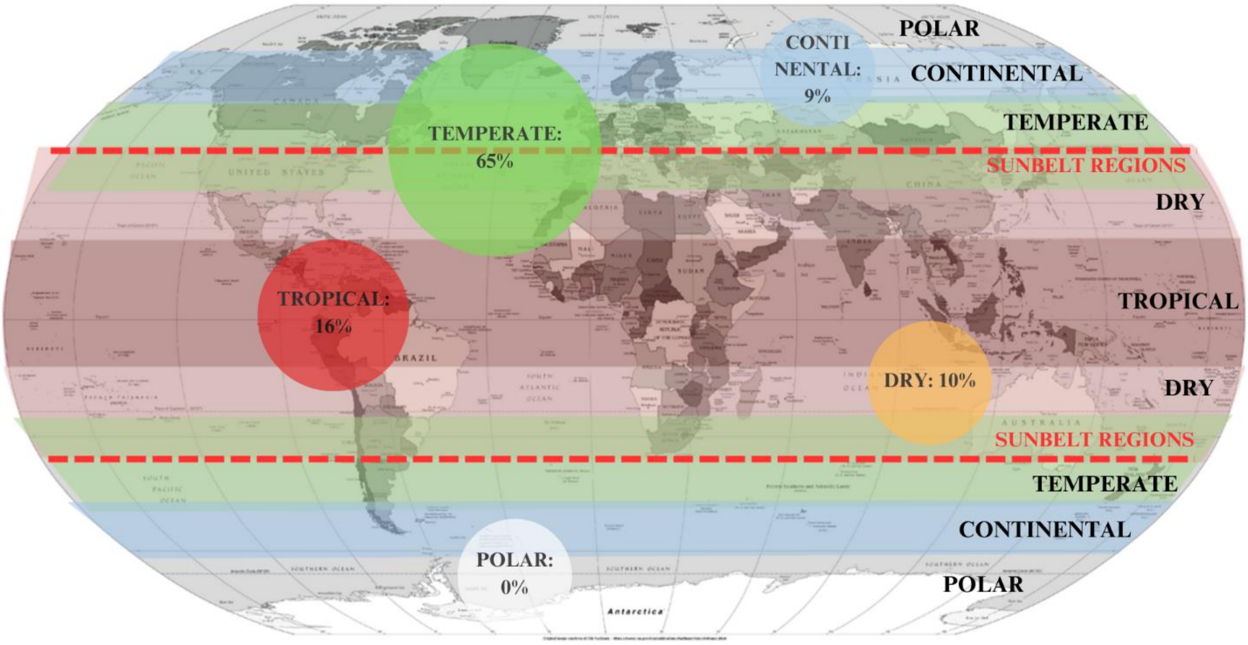
CLASSIFICATION (cont.)	METRICS (cont.)	CLIMATE (cont.)			
		TROPICAL	DRY	TEMPERATE	CONTINENTAL
GEOMETRIC/ DESIGN	Occupied area	2			
	Distance to windows	1	1	1	
	Solid angle of windows			1	
	Distance to the outside obstacles			1	
	Overall visible volume			1	
	External Obstruction		1		
	Distance from windows	3		6	2
	Window-to-floor ratio (WFR)	7	3	24	2
	Window-to-floor ratio of combined areas		1		
	Window-to-wall Ratio (WWR)	4		4	1
	Glazing-to-wall ratio (GWR)			1	
	Minimum sizes of windows				1
	Maximum glazed area				1
	Maximum window area			1	
	Minimum window area			2	
	Minimum 'equivalent aperture surface area'			1	
	Minimum aperture surface area			1	
	Minimum opening area				1
	Window sizes		2	10	1
	Area of glazing			4	
	Area of windows			2	
	Opening areas			1	
	Fenestration area			1	1
	Envelope glazing area			1	1
	Vertical envelope glazing			1	1
	Opening percentage			1	
	Window % of surrounding wall area (related with view)			1	
	Head height			2	1
	Sill height			1	1
	Maximum height of openings				1
	Lightwells	2	1		
	Skylight area	1			
	Translucent skylight portion of roof surface			2	
	Fenestration area (skylight)			1	1
	Skylight Roof Ratio			1	

(Cont. Table 16) Occurrence of metrics in different climates.

CLASSIFICATION (cont.)	METRICS (cont.)	CLIMATE (cont.)			
		TROPICAL	DRY	TEMPERATE	CONTINENTAL
GEOMETRIC/ DESIGN	Minimum setbacks from window to outside obstacles	2			
	Setbacks from plots' boundaries	1	1	1	
	Front, side and rear setbacks	3	2		
	Minimum frontage distance			1	
	Maximum height of openings				1
	Floor to ceiling height	1			
	Length of zone		1		
	Setbacks between buildings	1	1	1	
	Minimum setbacks from outside obstacles		2		
	Setbacks		1	1	
	Building's ratio			1	
	Maximum height			1	
	Height ratio	1			
	Spacing-to-height ratio			1	
	Height of Building x distance of the offset		1	1	
	Height to width			1	
	Obstruction angle	1		3	
	Vertical shadowing angle	1			
	Horizontal shadowing angle	1			
	Overhang Obstruction Angle	1		2	
	Average exterior obstruction angle			1	
	Vertical shadow angle / profile angle			1	
	Angle of visible sky			3	
	Angle of obstruction			1	
	Overshadowing angle		1		
	Average urban obstruction angles	1			
	Grazing angle		1	1	
	Minimum light transmittance		2		
	Visible light transmittance	3	1	11	2
	Visible light transmittance/ solar heat gain coefficient			1	
	Effective luminous transmittance				1
	Obstruction or distortion			1	
OTHERS	Colour rendering index			1	
	Ceiling, walls and floor reflectances			1	
NON-VISUAL EFFECTS	Melanopic Equivalent Daylight Illuminance			6	
	Equivalent Melanopic Lux	1		1	
	Circadian Stimulus	1	1	1	
	Photopic Illuminance	1			

Source: Elaborated from Amorim; Pinheiro (2024).

Figure 23 Climatic distribution of metrics found, according to Koppen classification.



Source: Elaborated from Amorim; Pinheiro (2024).

Figure 23 demonstrates that the metrics found are adapted mostly for temperate climates, even though Table 16 shows that many metrics occur in almost all climates. Some examples are the geometric metrics more used, like Window-to-Floor Ratio (WFR) and Window-to-Wall Ratio (WWR), Setbacks between buildings, Visible Light Transmittance (VLT). Among static and dynamic non-geometric metrics, Daylight Factor (DF), Target Illuminance (E_T), Spatial Daylight Autonomy (sDA), Useful Daylight Illuminance (UDI) can be highlighted as metrics that occur in all climates and global regions.

4.4. Discussion of results

During the research, a total of 120 metrics were found, among all types. The geometric/design group is the largest, with 72 metrics, then followed by 44 non-geometric metrics and 4 non-visual metrics. Geometric/design metrics are the group mostly used on mandatory documents — Building and Urban Codes and Regulations. The group that has a wider quantity of metrics is Codes and Regulations. In fact, all categories mix geometric and non-geometric metrics, but Codes and Regulations have a predominance of geometric metrics (58%, against only 32% non-geometric metrics), as well as Guidelines (only 38% are non-geometric). On the opposite, Standards have a predominance of non-geometric metrics (56% versus 44% geometric/design metrics), and also Rating Systems, 23 are non-geometric (54%).

Window-to-Floor Ratio (WFR) is the most frequent geometric/design metric, mentioned 36 times in all documents, with special attention to the 26 mentions in Codes and Regulations. Window sizes is the second most mentioned — 13 times in all documents, 9 of those in Codes and Regulations. Third, Window-to-Wall Ratio (WWR) was mentioned 9 times in documents, distributed into 3 times each in Rating Systems and Guidelines, 2 times in Codes and Regulations, and 1 time in Standards.

There is also the distinction between metrics related to buildings and those related to urban spaces. From the 72 metrics in this group, 45 concern building features, while only 27 refer to the urban interactions. This demonstrates the lack of attention given to sunlight in urban spaces during design steps, which can reduce access to daylight indoors.

Even though geometric/design group is the most common in mandatory documents — 42 geometric/design metrics (76%), against 13 non-geometric (24%) — and, consequently, in daily professional practice, those are too generic and do not guarantee the aimed daylighting results. Nevertheless, those remain very usual to professionals due to the direct influence over the building design.

Beyond that, many studies demonstrate that DF and DF_{avg} can induce the design of large glazed areas, which may cause thermal, energetic, and luminous damage to environments, such as increased heat load or glare occurrence. So, static metrics require more attention when used, as they are admitted reliable to evaluate daylight performance in several cases, whether it's not reliable the use of overcast sky standards in evaluations of places where the clear sky is most common. That is one case where the results would overestimate daylight levels, causing excessive heat loads and glare. However, it is noticeable that DF recommended values varies greatly from one document to another.

As metrics evolved, though, reference documents started to adopt dynamic metrics, in order to obtain more precise and realistic results. Dynamic metrics, then, capture daylight considering latitude, time, season, building geometry, orientation, etc., variables that change substantially according to project, location and the intentions of the designer. So, even though there is no way to predict or recommend with absolute precision how a design that embraces daylight should be, dynamic metrics can guide and measure the expression of daylight in architectural practice.

The 44 non-geometric metrics are composed by 20 static and 24 dynamic. Daylight Factor (DF) and Average Daylight Factor (DF_{avg}) are the static metrics frequently used in documents — 57 times, 17 in Standards and Rating Systems each, 16 times in Codes/Regulations and 7 times in Guidelines. Regarding dynamic metrics, Daylight Glare Probability (DGP) is mentioned 10 times, followed by Target Illuminance (E_T) and Spatial Daylight Autonomy (sDA), mentioned 9 times each in all documents. DGP is more frequent in Standards (6 times), also mentioned in Rating Systems (3 times) and Guidelines (1 time). E_T more common in Standards (4 times) and Rating Systems (3 mentions), also being used 1 time each in Codes/Regulations and Guidelines. sDA is mentioned 3 times in Standards and 6 times in Rating Systems.

Despite dynamic metrics are the most found metrics in literature, the architectural practice does not reflect such a wide use of those on building design steps. This could be justified by several reasons: the gaps in comprehension of definitions, of calculation and simulation methods, as well as how unclear the parameters are translated into design variables. That way, dynamic metrics and Climate-Based Daylight Modelling (CBDM) remain restricted to scientific research and in documents focused on higher performance, such as Rating Systems and some Standards.

That evolution can be observed when exploring the daylight requirements within the reference documents for architectural practice. Clearly, the first documents with recommendations about daylight used static metrics — mostly DF. Nonetheless, dynamic metrics now are more common: together, those metrics are found in all types of documents, even though they are not that common in professional practice.

Assessment for Views Out appear all documents and is important not only for residential buildings, but also for offices and healthcare spaces. Although there are several metrics to classify views out, this requirement is still considered very subjective, since depending also from cultural and social contexts. Nevertheless, Views Out are an important requirement not only to daylight indoors, but to the internal environmental and psychological quality to occupants — even though environmental and psychological quality of spaces is not a direct topic of this research.

An important tendency to observe is that Standards and Rating Systems use more frequently static and dynamic daylight metrics as defined by scientific research, since those types of documents evolved along time in parallel with evolution of metrics — from static to dynamic. The parameters of several metrics are also similar.

Standards frequently replicate the requirements in between themselves — e.g., the European standards that apply to countries of the continent, and some of them serve as reference for countries outside Europe to create their own requirements or adopt similar metrics and parameters. Standards use, nowadays, mostly dynamic metrics — 28 non-geometric, 17 geometric, where 68% (19) of them are dynamic — and computer simulations to show compliance to requirements.

Despite standards being a good reference for professionals, though, they do not necessarily provide good lighting, since the parameters are established as the minimum acceptable. EN 17037:2018+A1:2021 is a very important example of international standard, since it served as basis not only for European countries to apply, but also as a model for the reviews of standards worldwide, like the Brazilian cases — ABNT NBR 15.215, NBR 15.575. LM 83 had a great impact as the standard that consolidated sDA and ASE, a metric widely used not only in other standards, but also in rating systems, for example.

In the case of Rating Systems, most of them also use non-geometric metrics — 24 non-geometric (57%) with 12 static and 12 dynamic, and 18 (43%) geometric/design. However, Rating Systems focus on higher performance and innovation, when compared to Standards. That way, it is common that the requirements of certification schemes have minimum, medium and higher levels and, linked to that, a certain number of points — i.e., the better performance earns more points and reaches better overall classifications. This stimulates stakeholders and architecture teams to pursue better performance levels, even though rating systems are non-mandatory — instead, have a great commercial value due to the sustainability argument and the economic gains for real estate deals (sales, rent, etc).

LEED is used worldwide, with little differences between the daylight requirements. For example, USA's and Brazilian's versions are basically the same. Yet, there are profound differences between the climates of each country. So, the use of similar values can lead to design mistakes or overestimations of daylight that, in a tropical country like Brazil, incurs in higher heat loads, glare nuisance and other issues. BREEAM, by its turn, works mostly with DF or Average DF. Some other rating systems started to have a wider application, like WELL (American, focused on health aspects) and HQE (French). Brazil and Italy, beyond their versions of LEED and BREEAM, have also their own systems: respectively, Selo Azul Caixa and Protocollo ITACA. Other rating systems analysed in this research were CASA Colombia, DNGB (Germany), Living Building Challenge (USA/Canada), CASBEE (Japan), BCA Green Mark (Singapore), Green Star (Australia), AQUA-HQE (Brazilian adaptation of the French HQE), CES and CVS (Chile) and GB/T 50378-2019 (China).

Regarding the geometric/design metrics, it is possible to observe that those are found more frequently in Regulations, as in Building and Urban Codes, where: 13 are non-geometric (24%), against 42 geometric (76%). As stated before, these metrics commonly are focused on the building shape and geometry, as well as with its' relation with plots, other surrounding buildings, possible obstructions, etc. However, they have a decisive influence on the possibilities of daylight provision indoors. That way, Building and Urban Codes and Regulations offer a different direction to designers, focusing not only onto guaranteeing access to daylight, but also to intermediate the interactions between buildings and the urban space. As those are the most common mandatory documents, professionals in building construction follow Codes and Regulations strictly, since inconsistencies with the requirements demanded by these documents might even withhold building and urban sites construction and cause legal issues.

Guidelines' requirements are in between those groups. There are Guidelines dedicated to help professionals to apply mandatory documents, focused on the building and urban criteria; and there are others, focused on better architectural practice with advanced recommendations, which apply static and dynamic metrics, referenced by the international Standards and Rating Systems, possibly in an attempt to encourage a wider use of requirements. In Guidelines, 17 metrics are non-geometric (45%) and 21 geometric (55%), demonstrating a rather equal distribution.

The climatic analysis of metrics found demonstrate that 65% of metrics are used on temperate climates, against 16% on tropical climates, 10% metrics on dry climates, 9% on continental climates and none on polar climates — the absence of metrics on polar climates is due to the absence of documents of countries with this particular climate. Considering the occurrence of most metrics in almost all climates, it is possible to infer that there are no direct correlations between the metrics chosen for reference documents and their different climates. Moreover, most metrics were initially developed for temperate climates, which is demonstrated by the higher incidence of metrics in this climatic classification.

The reduced results from literature review about daylight requirements in Regulations, Building and Urban Codes and Guidelines indicate that these documents are not usually research objects. This evidences a gap between academic research — that reflects more on standards and rating systems — and the daily architectural practice — more influenced by building and urban codes, regulations and guidelines.

This approach demonstrates the different ways that reference documents can address daylight and guide practitioners in the design process. The analysis unveils, on one hand, that the greater acceptance and usage of dynamic daylight metrics depend directly on the comprehension of those definitions and the tools necessary during architectural education. On the other hand, the application of dynamic metrics as requirements in mandatory reference documents is also crucial, since those are the most used documents due to their obligatoriness.

5. Conclusions

This chapter presents the findings and conclusions of the research, as well as the limitations found during the process and the future research suggestions.

5.1. Main findings and conclusions

The wide research about daylight requirements in architecture reference documents provided an international overview to understand how daylight is treated and embodied during building design. The steps fulfilled — Systematic Literature Review, Collection of Documents, Survey, Analysis of Findings — were put together to integrate the comprehension about daylighting in the various layers within architecture practice.

During the SRL, many metrics are found, from the first approaches of daylighting in architecture, to enhanced dynamic metrics in the 2010s. In this scenario, dynamic metrics nowadays prevail in scientific research, since there are numerous case studies using them to evaluate a high variety of spaces. Even further, studies from 2023 and 2024 are developing more precise and complex dynamic metrics, considering luminance data, for example. As those are not fully consolidated, they are not yet used in any reference documents.

In spite of the findings from the SRL, the analysis of the reference documents reveals that geometric and non-geometric static metrics still are the most used in daily practice: WFR, WWR, setbacks, angles, DF, DF_{avg}, etc. This is evidenced mainly by the difference in quantity of geometric/design metrics: from the 120 metrics found, 60% (72) of them are geometric/design related, 20% (24) are dynamic, 17% (20) are static and 3% (4) are non-visual. The reason may be that static metrics were historically the ones used before the wide use of computers and softwares and, even after CBDM was possible, static metrics prevailed in mandatory reference documents — Building and Urban Codes, Regulations — through tables with standard value parameters and bidimensional calculations. Yet, the use of non-geometric metrics remains providing limited results in daily architectural practice.

Dynamic metrics, even though bring more precise and reliable results, demand deeper knowledge, conceptual maturity and methodological domain, as well as advanced technology and proper tools, which usually are not clearly explained in the documents. In some countries, that might be a significant issue, making even more difficult the use of dynamic metrics. Besides, in some documents, the absence of proper daylight recommendations was noted, even through the geometric/design metrics. Without these criteria, the opening design becomes intuitive and with no basic parameters to comply, compromising the daylight and sunlight access in buildings and in urban spaces.

The documents collected can be grouped into three main types: Standards and Rating Systems, where non-geometric metrics are usually consolidated, aligned with the most recent recommendations from scientific research; Building and Urban Codes and Regulations, where geometry/design metrics prevail; and Guidelines, a group on its own due to the applications these documents can have — i.e., focused on specific kind of buildings of functions, to help the application of mandatory documents, recommendations for a particular aspect of the buildings. Thus, Guidelines have geometric/design or non-geometric metrics.

One of the central conclusions is that non-visual effects are a requirement not commonly present in many documents. This happens despite the increase in research regarding the non-visual effects in human health, comfort and overall wellbeing. Only 6 out of all documents collected have metrics and parameters regarding the non-visual effects of daylight. Among those, 3 Standards, 1 Guideline, 2 Rating Systems and no Building and Urban Codes or Regulations. Hence, most documents do not follow the evolution of scientific research regarding requirements of non-visual effects.

Both dynamic and non-visual effects metrics are applied by some Standards, Rating Systems and Guidelines, documents with voluntary application. This voluntary application implies in orientations towards better practices, but without the widespread of the knowledge in mandatory documents, recommendations that could provide occupants good environmental quality are not fulfilled. Thus, this indicates that building design and professionals are focused on promoting wellbeing based only on visual effects, which does not translate fully the user experience during building occupation.

Another bottom-line fact is that the use of some reference documents, as the Rating Systems diffused internationally, without adaptations to each location, can cause distortions and design mistakes. As an example, the absence of specific methods concerning the application of sDA in each climate: even if the usual parameter value (300 lux per 50% of work plane per 50% of daylit hours in a year) is considered generally adequate, the solar incidence and other climatic features combined can cause uncomfortable spaces due to excessive daylight and heat load gains.

A similar case happens to the use of EN 17037:2018+A1:2021 in Europe, without specifying adaptations and recommending the correct weather files for calculations in each country. If in Europe these incomplete recommendations can cause distortions in building design, as well as unexpected results, the consequences can be even worse outside Europe. An example is Brazilian NBR 15.215:2023, that apply the same metrics as EN 17037:2018+A1:2021, with some adaptations in parameters. The direct impact of this issue is that the positive benefits of better practices in daylighting remain distant from the usual practice of architecture and are overall lost for occupants.

As it was also possible to conclude from the analysis, the requirements — daylight provision and sufficiency, sunlight availability, views out, glare control and non-visual effects — have a wide spectrum of metrics each. Those metrics application vary greatly according to an assortment of reasons: some of them include familiarity with the concepts and calculation methods, historical focus on daylighting and its metrics in architecture, technical and conceptual maturity of professionals, hesitant use of simulation softwares, legal demands for daylight in the country, among others.

Likewise, another outcome of the climatic analysis is that, even with the relevant impact of daylight on architecture, the application of criteria according to each climate is rare. There innovative documents, such as the Chilean example (TDRe), which divides the recommendations according to regions north, centre and south, due to the geography of the country. Another example is Brazilian NBR 15.215, that presents a latitude 3-region division of Brazil, whose differences incorporate mostly sky pattern and available sunlight. Even though the geographical differences are evidenced on these particular documents, respectively on sophisticated and basic ways, the majority of reference documents apply metrics with few or none climatic criteria. The Colombian NTC 4595 also distinguishes WFR values for different climates, reducing the proportional opening areas as the climate is warmer. Nonetheless, this is not a division common to documents. These examples above are exceptions. Hence, the climatic distribution of metrics done in this research evidences that, despite non-geometric dynamic metrics are supposed to connect to climates, the paths to assure that climatic conditions are truly taken into account remain unclear.

Regarding the harmonization steps fulfilled, this work elaborated not only a semantic classification as initially proposed, but also a structure harmonization. That happened because, besides taking into account the meanings of requirements and metrics, the data found was not entirely organized in tables or data sheets. So, an extensive search throughout primary documents necessary and further an organization of data in a Table composed by documents found, requirements names and definitions, metrics names and definitions, parameters (when found) and other details, as units, symbols and acronyms (Annex II).

Emblematic examples emerged about the harmonization of metrics. sDA, E_T and E_{Tmin} have similar concepts, as well as Annual Sunlight Exposure (ASE) and "Exposure to Sunlight". ASE and Exposure to Sunlight express slightly differently the interactions with sunlight — while ASE indicates excessive glare and even heat gains, Exposure to Sunlight suggests a good level of sunlight indoors in cold climates (thermal aspects). In an international context, these are some of the most used metrics, which indicates a pathway to harmonization. However, even the metrics providing the information of a certain daylight level reached in a percentual area and for part of the daylit hours in a year — sDA, E_T and E_{Tmin} — those do not comprehend or display the daylight levels below and above the considered ideal. UDI, instead, has its subcategories, based on ranges of daylight levels. Therefore, UDI could possibly be an alternative for daylight provision requirement.

Geometric/design metrics guide building and urban design, but are not the results themselves, since those cannot alone guarantee results that comply to aimed daylight performance goals. The greatest advantage of geometric metrics is the familiarity with the architectural and urban design practice, since they are used by professionals during the whole design process. Hence, those will certainly remain in use by professionals, but the demand for integration between geometry/design and non-geometric becomes more evident, in an attempt to understand more clearly how the two kinds of metrics interfere in each other.

Due to the lack of use of metrics in some mandatory documents, both geometric and non-geometric, it is still possible that not all countries have the necessary cultural and technological maturity to embody detailed daylight criteria in the daily professional practice. Therefore, to those places, the harmonization of requirements and metrics may still be too distant from the "market" reality, where professionals would be able to truly comprehend and include those methods in architecture and design decisions.

To sum up, the most promising pathways to deepen and make mor feasible the harmonization process of requirements and metrics include:

- The choice of representative metrics according to each requirement, according to semantic (terms' meanings), structure similarities (as in the framing of metrics in same or similar requirements in most documents), as well as considering how many mentions were detected;
- Among representative metrics, give preference to dynamic metrics, since those are the ones originally most connected to climatic features;
- Highlight the importance of Building and Urban Codes and Regulations mentioning Standards for specific daylighting criteria, making mandatory documents more focused on performance;
- The recommendations in Building and Urban Codes and Regulations could also be improved through the use of dynamic metrics together with geometric/design metrics;
- The translation of dynamic metrics into geometric/design metrics would be very significant to make parameters easier to be complied by professionals that do not have the best scientific or technological possibilities, or even the best knowledge and market maturity.

5.2. Research limitations

This section is dedicated to identify and explain several limitations found during the research. The main limitations found were: low feedback received on the survey sent to specialists; limited comprehension about how the documents found indeed portray the reality of each country, regarding the use of the documents themselves and the requirements and metrics in them; some metrics that might have been missed; the significant subjectivity that some requirements are evaluated; the impossibility to find regional documents from all countries that represent the local architectural practice; the fact that some rating systems can be used in many countries and not all of them make local adaptations; the choice to not include guidelines about energy efficiency and shading for openings; and the "hidden" stakeholders that influence the use and elaboration of reference documents.

The low feedback received on the survey sent to specialists was probably due to the national representatives might not be daylight specialists and could have had difficulties to redirection the survey to the correct specialists. Hence, during the collection of answers the participation rate was too low — only 15 answers. It is not clear how this participation rate could have been raised, but some ways that could have narrowed the results and information found were the inclusion of questions regarding the value parameters, the other possible stakeholders involving building construction in the country, the common practices of professionals regarding the use of reference documents.

This low feedback on the survey also led to a reduced comprehension of how much or if the documents received indeed represent daylighting in architectural practice in the countries. Along with the difficulties to find regional representative documents from some countries with great territories and climate variations, e.g. Brazil, this can cause distortions. As examples, the gap in metrics or other criteria that influence daylighting and are only present in documents elaborated and applied for a city or a district, with no jurisdictions in surrounding areas; and the inaccurate data of the obligatoriness of the documents and how much they influence each other in the daily practice.

In this process, some metrics that have components regarding daylight, or other types of metrics that influence daylight and sunlight in buildings and urban spaces might have been missed. That was due to the lack of definitions and proper information regarding the measuring and calculation methods, rules-of-thumb that are commonly known, or other criteria particularly applicable to a certain locations or uncommon cases.

Beyond the inaccurate information these issues may have caused to the research, they also perform as obstacles for professionals to deeply comprehend how to apply the metrics and comply to the requirements. Consequently, these circumstances hinder the comprehension of daylight requirements by professionals and the real criteria that influence all requirements — daylight sufficiency, access to views out, glare avoidance and sunlight availability — in architecture projects.

Subjective evaluation is also an issue. The main requirement that suffers with it is the quality of views out, since from the many documents that display this as a requirement, very few of them have objective metrics to assess the available views, such as proximity to openings, angle of vision, layers within the view, distance to surrounding obstructions. LEED, EN 17037 and NBR 15.215 are examples with these metrics to evaluate views out. However, many other documents, bring only the mandatory provision of views out with good quality, but with no specific metrics to analyse. Some of them require only an opening with a view out for a certain percentage of the rooms in the building, others only specify that the view should be visible from a percentage of the rooms' areas. Thus, even though the permanent access with the exterior environment is very important to human health and circadian entrainment, this is yet a flaw in many documents that do not provide enough evidence and methods to classify views.

As for the use of Rating Systems internationally, even though they promote sustainable architecture — at certain level —, not all of them are really adapted to each climatic reality of the countries they are applied. That way, although the metrics can be used, some cautious is necessary with the parameters. If not adapted, the buildings are under the risk of only complying to the requirements to get the certification, but with no real benefits to health, comfort and well-being of users, and not even getting the possible benefits of energy efficiency, high performance of buildings and ecofriendly solutions.

Concerning the absence of documents focused on energy efficiency and shading, those were not included due to the enormous variety of shading device types in each geographical orientation and latitudes and the differences from one region to another in electricity production and energy matrix, for example. These local features demand evaluations linked to energetic management in buildings, which is not the scope of this research.

In some scenarios, there are non-explicit stakeholders involved in buildings construction that influence documents use in some countries, like the United Kingdom and United States. In these cases, insurance companies, for example, demand the fulfilment of Guidelines to provide policies. That way, even if the document is not defined as mandatory by the legal framework, in practice they are used as mandatory by designers. Nonetheless, these are very specific cases, that could not be evaluated in all countries in behalf of the lack of information concerning this kind of situation.

5.3. Suggestions for future research

Some topics for future research can be foreseen, such as: how do geometric/design metrics and non-geometric metrics connect and truly influence each other; possibilities to harmonize the parameters of each metric according to latitude and climatic features; the feasibility for practitioners to adopt metrics on daily practice; how to consider maturity level and scientific advances, considering technological and educational maturity in countries; the other dimensions of harmonization process.

The influence of geometric/design and non-geometric metrics between each other could be best comprehended through simulations and a deeper investigation of how variables connect in building design. The same strategy could be used to find out if the parameters of metrics could be harmonized according to latitudes with similar climatic patterns. Even further, the development of a method that could "translate" non-geometric into geometric/design metrics would be significant to professionals, making daylight requirements and metrics closer to the criteria that define building and urban forms.

Study cases might be the best strategy to understand the feasibility of professionals using more daylight requirements and metrics in daily practice, since it would be necessary to investigate the reasons why they are not broadly used nowadays. This includes even the investigation about the technological, educational and scientific possibilities for professionals and students. Moreover, there is also the need to connect dynamic metrics to local climates, with parameter values and detailed weather files to use — still not standardized regarding the correct origin, amount of information within the files, extensions, etc. These are complicating factors that induce professionals to keep working mostly with geometry-based metrics.

In this research, the semantics and the structure dimensions of harmonization were explored. In future research, syntax harmonization could also be investigated, or a deeper analysis of mathematical and methodological approaches of calculation and simulations, for example.

6. Scientific production and contribution

The scientific production related to this research is composed, until this moment, by a survey model to be sent for another similar research; a full table with all reference documents, with the requirements and metrics found; and two published articles presented on international conferences, as follows:

- Annex I – Complete text of the Survey sent to daylight specialists, to collect documents and information of their application in each country;
- Annex II – Full Table with reference documents, requirements, metrics, their definitions and parameter values from all the collected information.
- Annex III – Article presented and published in the Proceedings of the 30th CIE Session: “Daylight requirements: an overview of definitions, progress and gaps” (PINHEIRO; AMORIM, 2023), the article contains the method, discussions and results of the systematic literature review of this research;
- Annex IV – Article presented and published in the Proceedings of 37th PLEA 2024 Conference: “Daylight metrics and requirements: a review of reference documents for architectural practice” (PINHEIRO et al., 2024). The paper sent approaches method, discussions and results of the primary documents collection and the survey answered by specialists;

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ANNEX I: SURVEY

On behalf of CIE TC 3-61 “Review of regional daylight requirements to assess the feasibility of global harmonization” we kind ask you to answer this survey, which aims to gather information about the use of reference documents and daylight requirements in order to find possible pathways to the harmonization of requirements in a worldwide scale. It is very important to have a global representative collection, so the participation of your country is very important.

Please answer and attach documents directly on the following emails: clamorim.unb@gmail.com and aparquiteturas@gmail.com.

Thank you very much for your collaboration.

Cláudia Amorim
CIE TC 3-61 Chair, Division 3 Secretary

Nozomu Yoshizawa
Division 3 Director

SURVEY

Please consider the following definition of DAYLIGHT REQUIREMENTS:

DAYLIGHT REQUIREMENTS: in our context can be defined as something demanded or obligatory for building performance. Regarding daylight, some examples can be mentioned: daylight provision-> illuminance levels, daylight factor (DF), daylight autonomy (DA), useful daylight illuminance (UDI) and others; daylight distribution -> uniformity, spatial daylight autonomy (sDA), and so on; glare -> daylight glare probability (DGP) is an example; view out -> existence and quality of outside views; provision of sunlight-> sunlight exposure (SE), ecc. We are also looking to building and urban design requirements present specially in documents like building and urban codes and regulations. Some examples of these are window wall ratio (WWR), window floor ratio (WFR), sky view factor, height-to-width (or aspect ratio), street width (or distance between buildings), average building height, and so on.

Please consider the following definitions for the REFERENCE DOCUMENTS we are searching:

TYPE OF DOCUMENT	DEFINITION	APPLICATION
Rating systems	Systems that measure levels of performance to create ecofriendly projects (DESIGNING BUILDINGS, 2022)	Non-mandatory
Standards	Publications with technical specifications, requirements and recommendations about quality, safety, design, construction etc. of a product; developed by international/ national organizations, professional and industry associations (GRIFFITH UNIVERSITY LIBRARY GUIDES, 2023)	Depends on the country

Guidelines	Set of policies, rules and procedures amended by the local architectural control authority, which shall act as a guidance for architectural activity (LAW INSIDER, 2023)	Non-mandatory
Building and urban codes	Set minimum requirements for how architecture and urban planning should be designed and constructed, under the purview of state and local governments, coordinating the actions of private and public, to create meaningful places and to formulate development following technical, economic and social principles (NIST, 2022, CHOY, 2023)	Mandatory
Building regulations	Guarantee buildings' safety for people in or around them, covering technical aspects of construction (URBANIST ARCHITECTURE, 2021)	Mandatory

1. Are there **Daylighting Standards** in your country? What are the daylight requirements in it/them? Could you share some of these documents? If not, please describe briefly.

2. What is/are the most used **Rating System(s)** in your country? What are the daylight requirements in it/them? Could you share some of these documents? If not, please describe briefly.

3. What are daylight requirements in **Building and urban Codes and Regulations** in your country? (examples are window wall ratio WWR, window floor ratio WFR, sky view factor, height to width/aspect ratio, street width or average building height). Could you share some of these documents? If not, please describe briefly.

4. Are there **Guidelines** for daylight in your country? What are the requirements in it/them?

5. Which of these documents are mandatory for architectural and urbanism practice in your country?

( ) Standards

( ) Building and urban Codes/Regulations

( ) Rating Systems

( ) Guidelines

( ) Others. Please specify.

ANNEX II: FULL TABLE FROM DOCUMENTS COLLECTION

DAYLIGHT REQUIREMENTS (VISUAL EFFECTS)							
DOCUMENT	**REQUIREMENT'S CATEGORY**	**REQUIREMENT DEFINITION**	**METRIC**	**SYMBOL**	**METRIC DEFINITION OR APPLICATION**	**PARAMETERS**	**APPLICATION**
EN 17037:2018 - Daylight of Buildings (Europe) *"This document specifies elements for achieving, by means of natural light, an adequate subjective impression of lightness indoors, and for providing an adequate view out. In addition, reccomendations for the duration of sunshine exposure within occupied rooms are given" "This document gives information...on how to limit glare."*	Daylight provision	A space is considered to provide adequate daylight if a target illuminance level is achieved across a fraction of the reference plane within a space for at least half of the daylit hours. *Methods apply the availability of external illuminance as determined from climate data suitable for the site of evaluation.*	Target Illuminance (vertical and inclined openings)	E_T	Illuminance level achieved across a fraction of the reference plane (50%) within a space for at least half of the daylit hours, from a vertical/inclined opening.	Min.: 300 lux; Mid.: 500 lux; Max.: 750 lux.	**NON MANDATORY**
			Minimum Target Illuminance vertical and inclined openings)	E_{Tmin}	Minimum illuminance level achieved across a fraction of the reference plane (95%) within a space for at least half of the daylit hours, from a vertical/inclined opening.	Min.: 100 lux; Mid.: 300 lux; Max.: 500 lux.	
			Target Illuminance (horizontal openings)	E_T	Illuminance level achieved across a fraction of the reference plane (95%) within a space for at least half of the daylit hours, from a horizontal opening.	Min.: 300 lux; Mid.: 500 lux; Max.: 750 lux.	
			Daylight Factor	D	This standard provides the corresponding Daylight Factor (D) relative to recommended Target Illuminance (Et) and Target Minimum Illuminance (Etm) for 33 capitals of CEN national members, using data of Median External Diffuse Illuminance (Ev,d,med)	D (%) to exceed minimum 100, 300, 500 or 750 lux , according to median external global illuminance.	
	Assessment for view out	View opening(s) should provide a sufficient view. In addition to rating parameters horizontal sight angle, outside distance of the view and number of layers, the aesthetical value of objects and the composition of the view must be included	Horizontal sight angle		width of the view opening. should be sufficiently large to ensure a wide and distant view.	Minimum: ≥ 14° Medium:≥ 28° High: ≥ 54°	
			Layers		Layers that view out should comprise. Number of layers to be seen from at least 75% of utilized area, including sky, landscape (urban and/or nature), ground.	Min.: landscape; Med.: landscape + other layer; High: all 3 layers.	
			Outside distance of the view		distance from the inner surface of view opening to opposite major obstructions located in front of the opening	Min: ≥ 6,0m Med: ≥ 20,0m High: ≥ 50,0m	
	Exposure to Sunlight	Sunlight provision is essencial for any interior space and depending on the fucntion it is generally desirable, except during hot climatic conditions	Sunlight Exposure	SE	Minimum exposure to sunlight should be provided in at least one habitable space in dwellings, patient rooms in hospitals, play rooms in nurseries. This is achieved through the expression of the minimum number of hours during which this space receives direct sunlight, for a clear cloudless reference day in the year.	Sunlight Exposure levels: Min.: 1,5h; Med.: 3h; High: 4h.	
	Protection from Glare	Glare is produced when too bright areas are located within the visual field or when the contrast ratio is reduced due to veiling reflections. To acess glare from daylight, the complex luminance distribution within the field of view and the size, intensity and location of the glare source(s) in regard to the line of sight have to be taken into account.	Daylight Glare Probability	DGPe	DGP is an approach to consider both the illuminance at eye level and individual glare sources of high luminance to estimate the fraction of dissatisfyed persons. The DGP assessment can be applied to a space with vertical or inclined daylight openings, but is not applicable for a space with horizontal daylight openings.	DGP should not exceed fraction FDGP,exceed = 5 % of the usage time of the space. Glare perception: DGP ≤ 0,35 (not noticed); 0,35 < DGP ≤ 0,40 (noticed w/out discomfort); 0,4 < DGP ≤ 0,45 (noticed w/ discomfort); DGP ≥ 0,45 (intolerable).	
ISO/CIE DIS 8995-1:2023 Light and Lighting - Lighting for Workplaces. Part 1: Indoors (Europe) *This document specifies lighting requirements for humans in indoor work places, which meet the needs for visual comfort, performance and safety of people having normal, or corrected to normal ophthalmic (visual) capacity and response to light. This document specifies requirements for lighting solutions for typical indoor*	Luminance distribution	The requirements for the specific tasks and activities are given by Ēm, Uo, Ra and RUGL. The requirements for the space in which the task(s) or activities are carried out are given by Ēm, c for the perception ofobjects and people within this space and Ēm, wall and Ēm, ceiling for room brightness. In the case of spaces illuminated by daylight, DGP is the reccomended metric for glare For task and activity areas, colours shall be rendered with sufficient fidelity to support visual performance, the feeling of comfort and well-being, accurate rendering of colours in the environment, of objects and of human skin	Wall, floor and ceiling reflectance and mantained illuminance		The minimum requirements for the average luminance can be calculated from the recommended minimu illuminance multiplied by the recommended value of the wall, floor and ceiling reflectance	— ceiling: 0,7 to 0,9; — walls: 0,5 to 0,8; — floor: 0,2 to 0,6.	
	Illuminance		Maintained illuminances	Ēm	Areas to be lit are task and activity areas, the immediate surrounding area and background area, walls,ceiling, and objects in the space. The illuminance and its distribution on the task area and on its immediate surrounding area have a great impact on how quickly, safely, and comfortably a person perceives and carries out the visual task. Maintained illuminances are specified to fulfil visualc omfort and performance needs of people having normal or corrected to normal visual capacity and response to light, for 53 different task	Depends on the activity	
	Glare		Daylight Glare Probability	DGP		Refer to EN 17037	
	Colour rendering		Colour rendering index	Ra	To provide an objective indication of the colour rendering properties of a light source the general colour rendering index Ra	Depends on the activity	

work places and their associated areas in terms of quantity and quality of illumination. The illumination can be provided by daylight, electric light, or a combination of both.	Daylight	Daylight can be provided through daylight openings including windows, skylights, or other innovative fenestration technologies such as light guidance systems (e.g., light shelves, louvres, mirror shafts) and light transport systems (e.g., light pipes, core sunlighting systems, light guides).					
DIN 5034-1:2011-07 - Daylight in interiors - part 1: general requirements (Germany)	Energy requirements for lighting	Daylighting can make artificial lighting unnecessary when there is sufficient daylight and can reduce it when daylight alone is not enough. This can significantly reduce the energy consumption of artificial lighting.	Daylight Factor	DF	windows 0.85m above the floor and in 1m distance to walls in the middle of the room	average 0.9%; at least 0.75% at the most unfavourable place	**NON MANDATORY**
UNI 10840:2007 - Light and lighting - Educational buildings (Italy)	General criteria for electric lighting and daylighting	(no definition)	Daylight Factor	DF	proposes a method for the calculation of **DF,** in analogy to the one reported in the "Circolare Ministeriale Lavori pubblici n. 3151, May 22 1967"		**NON MANDATORY**
			Visible Transmittance		Reference values for glasses' visible transmittance and for the calculation of daylight coefficients are reported in form of tables and diagrams		
UNI/PdR 13.1:2019 Environmental sustainability of construction works (Italy) *"The document applies for the purpose of calculating the performance score of non-residential buildings, newly built or undergoing major renovations involving not the individual real estate unit but the entire building"*	---	(no definition)			specifies the criteria on which the multi-criteria analysis system for the assessment of the environmental sustainability of non-residential buildings is based, with a view to their classification through the award of a performance score (for non-residential buildings newly built or through major renovations)		**NON MANDATORY**
UNI/PdR 77:2020 - Guidelines for computerized calculation for the determination of LENI (Italy) *"This UNI/PdR supports the use of the program LENICALC for the calculation of LENI according to method 2 (complete calculation) of the UNI EN 15193-1:2017 standard. Neither the standard (UNI EN 15193-1:2017), nor this UNI/PdR and the software are concerned with lighting requirements"*	---	(no definition)	Daylight Factor	DF	Ratio of the illuminance at a point on a given plane due to the light received directly or indirectly from a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky, excluding the contribution of direct sunlight to both illuminances.	Depends on transparency index, space depth and shading index, as defined in item F.3.1. EN 15193-1	**NON MANDATORY**
			Daylight Supply Factor	$F_{D,S}$	Related to the Daylight Factor (D), expresses the distribution of external illuminance through space and time, in accordance to façade and openings. Two façade status must be considered: sunlight/glare protection non activated; or protection activated (with occurrance of sunlight/glare over the façade).	Depend on location, latitude, sky conditions, building geometry and façade/openings orientation	
			Daylight Dependency Factor	F_D	Gathers the contribution of daylight (FD,S) and responsive control of artificial light (FD,C). FD,S is calculated as in Annex F or ISO 10916. Uses as main parameter the DF obtained from the openings (vertical and horizontal).		
EN 15193-1:2017 - Energy Performance of Buildings - Energy Requirements for Lighting (Europe) **UNI EN 15193-1/2:2017, Prestazione energetica degli edifici (Italy)**	Energy for illumination	(no definition)	Daylight Factor	DF	Ratio of the illuminance at a point on a given plane due to the light received directly or indirectly from a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky, excluding the contribution of direct sunlight to both illuminances.	Depends on transparency index, space depth and shading index, as defined in item F.3.1. EN 15193-1	**MANDATORY**
			Daylight Supply Factor	$F_{D,S}$	Related to the Daylight Factor (D), expresses the distribution of external illuminance through space and time, in accordance to façade and openings. Two façade status must be considered: sunlight/glare protection non activated; or protection activated (with occurrance of sunlight/glare over the façade).	Depend on location, latitude, sky conditions, building geometry and façade/openings orientation	
			Daylight Dependency Factor	F_D	Gathers the contribution of daylight (FD,S) and responsive control of artificial light (FD,C). FD,S is calculated as in Annex F or ISO 10916. Uses as main parameter the DF obtained from the openings (vertical and horizontal).		

BS 8206-2:2008 - Code of practice for daylighting (UK)	Daylight and room brightness		Average daylight factor	DF_{avg}	ratio of total daylight flux incident on a referencearea to the total area of the reference area, expressed as a percentage of outdoor illuminance on a horizontal plane due to an unobstructed sky of assumed or known luminance distribution	bedrooms - ADF at least 1%; living rooms - ADF at least 1.5%; kitchens - ADF at least 2%	**NON MANDATORY**
					across the office floor area for the space to appear predominantly daylit	> 2%	
					For spaces with an average daylight factor **> 5%** then electric lighting **will not normally be needed** during the daytime	> 5%	
			Mean Daylight Factor		(no definition)	Mean of DF values measured over a horizontal working plane to calculate DFavg	
	Daylight for task lighting		Uniformity		Over the task area of na individual worker, the uniformity in illuminance should be that recommended for electric lighting in clause 5 of BS 8206:1985.	Should not fall below 0.8 of average illuminance	
	Windows and View	All occupants of a building should have the opportunity for the refreshment and relaxation afforded by a change of scene and focus. Even a limited view to the outside can be valuable. If an external view cannot be provided, occupants should have an internal view possessing some of the qualities of a view out-of-doors, for example, into an atrium.	Layers		Views including all three "layers" are the most completely satisfying.	1) upper (distant), being the sky and its boundary with the natural or man-made scene; 2) middle, being the natural or man-made objects themselves; 3) lower (close), being the groundscape forming the foreground of the view.	
TSG-1-004:2010 - Efficient use of energy (Slovenia)	Energy efficiency of buildings	FDS_T account for the daylight contribution to the energy use in buildings	Average Daylight Factor	FDS_T		Table 8.21	
	Exposure to Sunlight	(no definition)	Exposure to Sunlight		the "collecting area" (the roof and the facade) of a building is exposed to sun's rays 1m above the ground should provide a quantity of hours of exposure	at least 2h on December 21st; at least 4h on the equinoxes; and at least 6h on June 21st	
NEN-EN 17037:2022: Besluit Bouw en Leefomgeving (The Netherlands)			Target daylight factor (vertical and inclined openings)	DF	Daylight factor achieved **across a fraction of the reference plane (50%) within an occupied space for at least half of the daylit hours**.	1,0% for residential functions; 0,5% for children daycare; 0,4% for penitentiary functions; 0,5% for healthcare; 0,4% for offices; 0,5% for educational functions. All surface areas reduced by obstruction.	**NON MANDATORY**
			Target daylight factor (vertical and inclined openings)	DF	Daylight factor achieved **across a fraction of the reference plane (50%) within an occupied area for at least half of the daylit hours**.	0,8% for residential functions; 0,4% for children daycare; 0,4% for penitentiary functions; 0,4% for healthcare; 0,3% for offices; 0,4% for educational functions. All surface areas reduced by obstruction.	
ČSN 73 4301:2004 - Obytné budovy (Residential Buildings) (Czech Republic)		(no definition)	Sunlight duration		based on the determination of period when reference point is exposed to direct sunlight	At least 1,5 hour on March 1st or balance of sunlight duration in the period from February 10th to March 21st is at least 1,5 hour ; solar altitude is at least 5°	
EVS 894:2008+A1:2010 - Lighting for residential and office premises (Estonia)		(no definition)	Sunlight duration			3 hours of sunlight during the summer months, i.e. April 22nd to August 22nd.	
STN 73 4301:2005 - Dwellings buildings (Slovakia)		(no definition)	Sunlight duration			At least 1.5 hour in low densely area and at least 1 hour in high densely area in the period of March 1st to October 13th, (3 hours is recommended); Insolation between 10:00 - 15:00 in the play rooms in building for child care; Solar altitude is at least 5°.	
Haagse bezonningsnorm (The Hague sunlight norm, the Netherlands)		(no definition)	Target daily sunlight hours on a façade		Describes the minimum sunlight hours a facade must be able to receive on any day between 19-feb and 21-oct. A minimum of 50% of a façade must fulfil the requirement. This code is only applicable on new construction and large renovations in The Hague. Also needs to be determined for surrounding buildings if applicable (similar to Right to light in the UK?)	2 hours per day, for 50% of the façade.	**NON MANDATORY**

NBR 15.215 - Daylighting (Brazil)	Daylight Availability Indoors	Daylight can contribute significantly for lighting needs for tasks in any building. This means that openings to daylighting must have proper areas to provide enough daylight throughout the year.	Target Illuminance (vertical and inclined openings)	E_T	Illuminance level achieved across a fraction of the reference plane within a space for at least half of the daylit hours, from a vertical/inclined opening.	Level 1: 250 lux for 40% of reference plane; Level 2: 250 lux for 55% of reference plane; Level 3: 250 lux for 70% of reference plane	**NON MANDATORY**
			Minimum Target Illuminance vertical and inclined openings)	E_{Tmin}	Minimum illuminance level achieved across a fraction of the reference plane within a space for at least half of the daylit hours, from a vertical/inclined opening.	Level 1: 100 lux for 60% of reference plane; Level 2: 100 lux for 75% of reference plane; Level 3: 100 lux for 90% of reference plane	
	Assessment for view out	External views allow visual connection to the outside, providing information about about the surroundings and weather conditions along the day. These information can relieve fatigue related to long permanence indoors.All occupants of a space must have the opportunity of relaxation provided by a change of	horizontal sight angle			level 1: ≥ 14° level 2: ≥ 28° level 3: ≥ 54°	
			layers			level 1: landscape; level 2: landscape + other layer; level 3: all 3 layers.	
			Outside distance of the view			level 1: ≥ 6,0m level 2: ≥ 20,0m level 3: ≥ 50,0m	
	Minimum exposure to direct sunlight	Direct sunlight exposure is na important quality criteria in indoor spaces and can contribute to human's wellbeing. Sunlight is desirable to any indoor space in the cold season and essential to some spaces, depending on their function.	Exposure to Sunlight		Recommended exposure in the winter months of the year (where there is winter in Brazil) and in buildings with healthcare and education as main functions, in at least 1 permanently occupied room	Level 1: 1.5 h; Level 2: 3h; Level 3: 4h	
	Protection from Glare	Glare is a negative visual sensation to the observer coused by areas with luminance brightness higher than what eyes are adapted, producing discomfort or loss of visual performance and visibility.	Daylight Glare Probability	DGP	The DGP assessment can be applied to a space with vertical or inclined daylight openings, but is not applicable for a space with horizontal daylight openings.	DGP should not exceed fraction FDGP, exceed = 5 % of the usage time of the space. Glare perception: DGP ≤ 0,35 (not noticed); 0,35 < DGP ≤ 0,40 (noticed w/out discomfort); 0,4 < DGP ≤ 0,45 (noticed w/ discomfort); DGP ≥ 0,45 (intolerable).	
	Maximum Annual Exposure to direct sunlight	Allows another dimension to the sunlight analysis, approaching na eventual source of visual discomfort and complements the analysis of Daylight Availability.	Annual Sunlight Exposure	$ASE_{1000/250h}$	sum of the time (hours) (e.g. on a given day) within a given period during which the sun is above the actual horizon with a cloudless sky, which may be limited by permanent obstructions like mountains, buildings, etc.	Threshold of 1000 lux in 250h/year (admits 10 h/day of sunlight)	
NBR 15.575 - Building Performance Satndard (residential) (Brazil)	Daylight Sufficiency	(no definition)	Target Illuminance	E_{ALVO}	Illuminance level achieved across a fraction of the reference plane within a space for at least half of the daylit hours (10 h/day), from a vertical/inclined opening.	Min.: 200lx in 40% plane; Med.: 200lx in 55% plane; Max.: 200lx in 70% plane	**NON MANDATORY**
			Minimum Illuminance	$E_{MÍN}$	Minimum illuminance level to reach uniformity in a room for at least half of the daylit hours (10 h/day)	60 lx in 75% plane	
ISO CIE NBR 8995 - Lighting in work spaces (Brazil)	Daylight	(no definition)	Daylight Factor	DF	recommended for offices with one side windows	must not be under 1% in work planes 3m away from windows and 1m distant from side walls	**NON MANDATORY**
LM 83-12/23: Approved Method - IES Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE) (IESNA) (USA, Canada)	Sufficiency of Daylight Illuminance	To report a percentage of floor area that exceeds a specified illuminance level for a specified amount of annual hours.	Spatial Daylight Autonomy	$sDA_{300/50\%}$	Describes annual sufficiency of ambient daylight levels in interior environments: percent of analysis area (the area where calculations are performed typically across an entire space) that meets a minimum daylight illuminance level for a specified fraction of the operating hours per year.	Preferrable: 300 lux/50% in 75% of area; Acceptable: 300 lux/50% in 55% of area.	**NON MANDATORY**
			Spatial Daylight Autonomy	$sDA_{150/50\%}$		150 lux/50% in 50% of area in spaces with less critical visual tasks	
	Potential Risk of Excessive Sunlight Penetration	Looks at one potential source of visual discomfort: direct sunlight.	Annual Sunlight Exposure	$ASE_{1000/250h}$	Expresses the potential for visual discomfort in interior work environments. Percent of an analysis area that exceeds a specified direct sunlight illuminance level more than a specified number of hours per year.	Threshold of 1000 lux in 250h/year (admits 10 h/day of sunlight)	
	Windows and Skylight Details	Factors that influence daylight transmission	visible light transmittance	VLT	consider a minimum dirt depreciation factor	5% in regular side windows 10% if glass is sloped from 20-85° and 15% for skylights	
Reglamento Técnico de Iluminación y Alumbrado Público (RETILAP) (Colombia)	Exploitation of daylight	To reduce the consumption of energy associated with lighting, in any construction that requires lighting to develop any type of activity, the natural light provided by the radiant energy of the sun must be used, which is available throughout the day directly or through the celestial vault.	Coeficiente de Luz Diurna (Daylight Factor)	CLD / DF	industries	5%	**PARTIALLY MANDATORY** (light can be complemented with electrical)
					offices	2%	
					classrooms	2%	
					healthcare	1%	
					Bedrooms/dormitories	0.5% (in 75% of space area)	
					Kitchens	2% (50% of space area)	
					living rooms	1% (50% of space area)	

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NTC 4595 - Planning and design of school environments and facilities (2020) (Colombia)	Comodidad Visual (Visual Comfort)	To provide environmental conditions to ensure a proper visibility for the distinct visual tasks. The focus on daylight is to guarantee that the greatest part of school journey has lighting requirements fulfilled without the use of electric light.	Factor Luz Día (Daylight Factor)	FLD / DF	classrooms	no less than 2%	**MANDATORY**
			window-to-floor ratio	WFR	in temperate/cold climates	1/3	
					in warm/dry climates	1/4	
					in warm/humid climates	1/5	
					openings with translucent glass	increase of 20% of area	
			Minimum setbacks from window to outside obstacles		distance from window to obstacles to ensure access to daylight	3m	
GB 50033:2013 - Standard for daylighting design of buildings (China)	Standard Value for Daylight	Specified exterior natural light design illuminance value and the illuminance value for reference planes with the standard value for appropriate daylighting efficiency.	Daylight Factor	DF	offices, according to each type of workplace	4% (600lx) 3% (450 lx) 2% (300lx) 1% (150 lx)	**NON MANDATORY**
					residential spaces	bedrooms, living rooms: 2% bathrooms, corridors, restaurants, stairs: 1%	
					educational facilities	classrooms, laboratories: 3% circulations, bathrooms: 1%	
					healthcare	clinics, pharmacies, laboratories: 3% lobby, waiting rooms, offices: 2% circulations, bathrooms: 1%	
			Standard Illuminance		for interior natural illuminance	kitchens: 300lx toilets, passages, staircases: 150lx classrooms: 450lx	
			Daylight Glare Index	DGI	evaluates glare from windows	20: imperceptible; 23: slightly perceptible; 25: acceptable; 27: discomfort; 28: intolerable.	
			window-to-floor ratio	WFR	to reach each DF value (side windows)	I: 1/3 (lighting depth: 1.8) II: 1/4 (lighting depth: 2.0) III:1/5 (lighting depth: 2.5) IV:1/6 (lighting depth: 3.0) V: 1/9 (lighting depth: 4.0)	
			window-to-floor ratio	WFR	to reach each DF value (roof windows)	I: 1/6 (lighting depth: 1.8) II: 1/8 (lighting depth: 2.0) III:1/10 (lighting depth: 2.5) IV:1/13 (lighting depth: 3.0) V: 1/23 (lighting depth: 4.0)	
Términos de Referencia Estandarizados con Parámetros de Eficiencia Energética y Confort Ambiental (…) - TDReMOP v2016 (Chile)	Confort Visual: Luz Natural (Visual Comfort: Daylight)	(no definition)	Factor de Luz Día (Daylight Factor)	DF		< 1% insufficient = 2% minimum required ideal value: 2 < DF < 5 % space is essentially daylit: between 5% - 10% >10% possible glare occurrence	**MANDATORY**
			Spatial Daylight Autonomy	sDA	schools and offices	300 lux / 50% occupied hours in >55% room area (good); and >75% (very good)	
					hospitals	300 lux / 50% occupied hours >75% (good); and >90% (very good)	
			Daylight Autonomy	DA	daylight contribution in spaces throughout the year	< 50%: low economy 50% ≤ DA < 80%: medium economy ≥ 80%: high economy	
			Useful Daylight Illuminance	UDI	useful levels of illuminance for occupants	≥ 80% of the year w/ UDI 200 - 3,000 lux (acceptable) > 50 - < 80% of the year UDI 200 - 3,000 lux (minimum)	
			Daylight Glare Probability	DGP		DGP > 0.35 % (imperceptible) DGP ≤ 40 % (perceptible) DGP ≤ 0.35 % (no glare occurrence)	

						for visual tasks	> 2000 cd/m² too bright for any tasks > 1000 cd/m² bright to visual field < 500 cd/m² acceptable < 30 cd/m² unacceptable (too dark)	
	SOUTH AFRICAN NATIONAL STANDARD - The application of the National Building Regulations Part O: Lighting and ventilation (SANS10400-O) *This part of SANS 10400 provides deemed-to-satisfy requirements for compliance with part O (Lighting and Ventilation) of the National Building Regulations. Developed by the South African Bureau of Standards (SABS), SANS 10400 is a series of regulations that set the standards for building construction across the nation. These regulations are more than just recommendations; adhering to them is mandatory by law.*	Natural Lighting: general	Where, for the purposes of natural lighting, a room is provided with one or more openings, such opening or openings shall be situated in an external wall, or in a suitable position in the roof of the building, and shall be provided with a zone of space					
			Where such opening is glazed, it shall be glazed with transparent or approved translucent glazing material, in accordance with the requirements of SANS 10400-N.	minimum light transmittance	VLT	Openings can be glazed with transparent or approved translucent glazing material, in accordance with the requirements of SANS 10400-N. SANS 10137 3.48 – "translucent descriptive of a glazing material or sealant that permits light to pass through but with a degree of obscuration and diffusion"	No stated minimum light transmittance values found.	
		Opening´s area	Opening´s area for Low cost construction for 'poorer communities'	window-to-floor ratio	WFR	Category 1 buildings – F2 (small shop), H3 (domestic residence consisting of two or more dwelling units on a single site) or H4 (dwelling house – dwelling unit on its own site)	No less than 5% of the total area of such openings	
			Opening´s area for Standard construction	window-to-floor ratio	WFR	Standard constructions; The openings to a room which opens onto a roofed and enclosed balcony, a gallery or a veranda;	No less than 10% or 0,2sqm of the total area of such openings; At least 10% of the combined room areas	
			The openings which opens onto a roofed and enclosed space	window-to-floor ratio of combined areas	WFR	Opening´s area in relation to the combined floor area of the room concerned and the balcony,gallery or veranda	shall be at least 10 % of the combined floor area of the room concerned and the balcony, gallery or veranda	
		Zone of space	This considers potential obstructions that would influence amount of light entering rooms in plan	Minimum setbacks from outside obstacles		Zone of space outside the opening – this can be divided into portions. Parallel planes. This considers potential obstructions that would influence amount of light entering rooms in plan.	0,5m boundary line on either side of a boundary (minimum practical zone of space = minimum of 1m)	
						a building line, where present, are within a property, therefore the length of zone to the boundary zone should be greater that the length of zone to the building line	Min 1m length of zone to building line	**MANDATORY**
						there is a converse restriction on building height to 24m of a habitable room	Max 8m length of zone	
		Length of zone	in relation to vertical obstruction for habitable room	length of zone		Ratio of distance to obstruction in relation to height of obstruction. For habitable rooms in residential/institutional buildings	1/3 the distance from the top of the opening to the top of the obstruction, minimum of 1m	
						Ratio of distance to obstruction in relation to height of obstruction. EXCEPT residential/institutional buildings	1/5 the distance from the top of the opening to the top of the obstruction, minimum of 1m	
						Length of zone in relation to vertical obstruction. For bathrooms, shower, restrooms	1/10 the distance from the top of the opening to the top of the obstruction, minimum of 1m	
		Coverings over openings	If any projections are likely to significantly reduce the amount of light reaching such openings, at least two-thirds of the plan area of the zone of space shall have an unrestricted shaft.			any projections that are likely to significantly reduce the amount of light reaching such openings (sizes of shadowing devices)	at least 2/3 of the plan area of the zone of space shall have na unrestricted shaft	
				Daylight Factor	DF	the ratio of interior horizontal illuminance at an especific point to the exterior horizontal illuminance from a CIE standard overcast sky that provides this illuminance to a space	varies according to sky models and climates	
				Daylight Autonomy	DA	Percentage or fraction of the occupied time throughout the year when a target illuminance value is met or exceeded at a specific point by daylight alone	300 lux (DA_{300})	
				Continuous Daylight Autonomy	DA_{con} / cDA	An extension of DA that gives credit for any fraction of the daylight target illuminance	150lux, 300 lux (cDA_{300} as 300 lux is the target)	

ANSI IES LP-3-20-Lighting Practice_Designing and Specifying Daylighting for Buildings (2020) (USA) *"This document provides detailed discussions and guidelins on the design and performance of building systems."*	Daylighting Design	Aimed at meeting targets for desired performance through careful decisions on multiple key design parameters, given specific context.	Maximum Daylight Autonomy	DA_{max} / mDA	An extension of DA that expresses the period in which daylight levels exceed na upper limit	3,000 lux ($mDA_{3,000}$)	**NON MANDATORY**
			Spatial Daylight Autonomy	sDA	percentage of are in a room or building that meets a given DA value for a set analysis period	300 lux for 50% space 50% occupied hours; tends to increase satisfaction when in 75% of area	
			Useful Daylight Illuminance	UDI	Composed by three ranges including the percentage of occupied hours of the year when daylight illuminance at an interior point of interest is judged to be at "useful" levels, very low levels or high levels	UDI supplementary: below 100lx UDI useful: 100 to 3,000 lx UDI exceeded: above 3,000 lux	
			Annual Sunlight Hours / Direct Sunlight Hours	ASH	number of hours when a particular point in analysis is likely to receive direct sunlight (to evaluate exterior shading; operable shading devices; other design solutions)	number of hours that exceed 1,000 lux	
			Annual Daylight Exposure	ADE	Cumulative amount of visible light incident on a point of interest, measured in lux.hours/year (applied to spaces with light-sensitive artwork)	different parameters for each type of artwork	
			Annual Sunlight Exposure	$ASE_{1000/250h}$	Addresses how much direct sunlight a space receives, using a single value (standardized by LM 83)	exceeds 1,000 lux in 250h	
			Daylight Glare Index	DGI	Numerical value based on the window and space static luminance conditions under a specified daylight condition	14 = imperceptible 16 = just perceptible 18 = perceptible 20 = just acceptable 22 = unacceptable 24 = just uncomfortable 26 = uncomfortable 28 = just intolerable 30 = intolerable	
			Daylight Glare Probability	DGP	Attempts to compute the fraction of the population who might consider a daylight condition to be uncomfortable	DGP ≤ 0.35: imperceptible 0.35 ≤ DGP ≤ 0.40: perceptible 0.40 ≤ DGP ≤ 0.45: disturbing	
	Design Parameters	Those that designers have control over (...) Each decision turns design parameters into context parameters for the decisions to follow.	Vertical shadow angle / profile angle	a_P	apparent altitude of the sun relative to a vertical surface of interest to evaluate sunlight penetration distance for the shading impact of an overhang of light	calculated by Equation A-10 in Annex A; varies according to latitude and season	
					Minimum acceptable window size	25-30%	
			visible light transmittance	VLT	espectrally neutral	35-40%	
			Skylight area			4-6%	
EN 12464-1: Light and Lighting - Lighting of Indoor Work Places (2011) (Poland, Denmark)			Daylight Factor	DF	In rooms with side windows, in the workplace located at a distance of 3 meters from the outer wall and 1 meter from the side wall	not less than 1%	**MANDATORY**
SP 23.102.2003 - Natural Lighting of Residential and Public Buildings (Russia)		(no definition)	Target Daylight Factor	DF_T	residential, schools	0.4% to 1.7% (Table 4 in the document)	
			Target Daylight Factor	DF_T	Work spaces	0.3% to 1.4% (Table 6 in the document)	
		(no definition)	window-to-floor ratio	WFR	defined according to calculation formulas, graphs and the DF parameters	defined according to calculation formulas, graphs and the DF parameters	
SP 52.13330.2016 - Daylighting and Artificial Lighting (Russia)		(no definition)	Daylight Factor	DF (KEO)	According to visual accuracy/category work levels, to <u>overhead or combined</u> lighting	from 2% to 4%	
			Daylight Factor	DF (KEO)	According to visual accuracy/category work levels, to <u>side</u> openings	from 0.5% to 1.5%	
EN 410 - Glass in building - Determination of luminous and solar characteristics of glazing (2011) (Europe)		(no definition)	Luminous transmission of glazing		test method and calculation		
EN 14500 and EN 14501 - Blinds and shutters - Thermal		(no definition)	visible light transmittance	VLT	Performance of the solar protection: glare class (depends on luminous transmitances normal-normal and normal-hemispherical)		

and visual comfort - Performance characteristics and classification (2021) (Europe)		(no definition)	visible light transmittance	VLT	Performance of the solar protection: diffuse transmittance		
	"outside views"	(no definition)			Performance of the **solar protection**: class of visual contact with outside	(no values)	
NF X35-103 - Ergonomics - Ergonomic Principles for Workplace Lighting (2013) (France)	Access to daylight	(no definition)			required for all workplaces	(no values)	
	outside views	(no definition)			considered for all workplaces	(no values)	
EN 16798-1 & CEN 16798-2 - Energy performance of buildings - Ventilation for buildings (2019) (Europe)	Access to daylight	considered for all buildings	Daylight Factor	DF	Min and max requirements for DF of each daylight opening of a space. Specific calculation formulas for DF from geometric parameters and glazing parameters. Daylight supply factor is calculated from DF weighted by duration of solar protection activation. This is used for computing the electric lighting energy	Specific calculation formulas for DF from geometric parameters and glazing parameters	
	outside views	considered for all buildings				(no values)	
Standard 90.1-2022 (SI Edition) - Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings (USA, Canada)	Lighting	(no definition)	Window-to-Wall Ratio	WWR	for vertical fenestration	max. 40% of wall area	
			fenestration area (skylight)		for skylights	max. 3% of roof area	
			Visible Transmittance/solar heat gain coefficient	Assembly min. VT/SHGC	ratio of VT/SHGC for all types of vertical fenestration (fixed, operable, entrance door) (Ratio Visible Transmittance/Solar Heat Gain Coefficient)	min. 1.10	
ISO 19454/2019: Building Environment Design - Indoor Environment - Daylight Opening Design (Europe, UK)	Daylight opening ratio to the wall area of a habitable room	Minimum daylight opening should be secured for the health management of te building environment					
	Daylight opening ratio to the floor area of a habitable room	Minimum daylight opening should be secured for the health management of te building environment. Should be noted that the ratio alone is not enough to get na acceptable indoor visual environment, as a minimum ratio induce small rooms to have small openings					
	Levels of indoor daylight based on human visual needs and the extent of sunlight	The extent of sunlight into the habitable rooms should be determined in the project information. Sunlight is undesirable from the viewpoint of glare, excessive luminance contrast and overheating. However, it can create pleasing patterns of light and shadows on surfaces in interiors and make the space vivid and cheerful. Exposure to sunlight in the morning is essential to maintain good circadian rhythms					
	Quality of views to exterior	The views to the exterior are defined as the views out of the windows and/or rooflights.It is essential to get openness and quality views to ensure occupants' visual comfort and connection to the exterior through daylight openings					
	Control of glare caused by daylight	The larger the daylight opening is, the more important the glazing selection and shading effectiveness are to control glare and heat gain by users.					
	Daylight control systems						
	Daylight calculations	The absolute levels of illuminance that are needed for any particular task depend on the visual acuity required for the task and, to a lesser	Average Daylight Factor	DF_{avg}	can provide a quick overview of the overall level of daylight within a room, and can be useful when comparing different design solutions; is sometimes considered an index of the porousness of a building, i.e. how much of the envelope is open to skylight (only applicable to diffuse light, never for sunlight)	If a room is not too deep or obstructed, ADF = 5% or more ensures daylit space; DFavg < 2% makes a room too dull. For domestic interiors, DFavg = 2% can be enough, although some tasks require more	

SLL Lighting Guide: Lighting for the Built Environment - LG 10/2014: A guide for designers (UK) *"This guide will take the reader through the process of daylight design, from background and theory through to initial design and then detailed design. A section about visualisation techniques then follows, although the use of visualisation tools can be usefully employed at any stage of the process. For each of these stages in the process, this guide will highlight the key considerations to be made and explain the design techniques that can be used."*	Daylight calculations	required for the task and, to a lesser degree, the nature of the environment in which the task is to be carried out.	Basic Daylight Autonomy	DA	Eint = (ADF × Eext × fo) / 100; where Eint is the average internal (horizontal) illuminance (lux), DFave is the average daylight factor (%), Eext is the external horizontal diffuse illuminance (lux) and fo is the orientation factor (table 3.2)	No value directly recommended; Estimations of Eext to obtain Eint = 300 lux	**<u>NON MANDATORY</u>**
			Useful Daylight Illuminance	UDI	annual occurrence of illuminances across the work plane that are within a range considered 'useful' by occupants	UDI = 100-300 lux (supplementary); UDI = 300-3000 lux (autonomous)	
	Internal space planning	Daylight is extremely desirable in some spaces, whereas in others it is less important, and indeed may need to be excluded depending on the function of the space (e.g. control rooms). Thus, different functions should lead to spaces that relate to daylight in different ways, as appropriate. This is why space planning and interior layout is an important stage of daylight design.	angle of visible sky	AVS	measured from the centre of the window to the top of external obstruction	θ > 65° , reasonable results. 45° < θ < 65°, larger windows and/or changes to room layout are usually needed. 25° < θ < 45°, it is very difficult to provide adequate daylight unless very large windows are used. θ < 25°, it is often impossible to achieve reasonable daylight, even if the whole window wall is glazed.	
			head height		window head height above floor level	Table 2.1	
	Initial design considerations - Building positioning and obstructions	Effective daylight design must start at the site layout stage, before windows are considered in detail. The orientation of building faces, and hence the windows within them, has an important bearing on the environment within a building, determining how much sunlight it receives and affecting views out.	obstruction angle		the angle the obstruction makes from the centre of the window, measured from the horizontal	OA < 25°, good daylighting; 25° < OA < 45°, large windows and/or changes to room layout; 45° < OA < 65°, very large windows; OA > 65°, impossible to achieve reasonable daylight	
			Vertical Sky Component	VSC		VSC at least 27%, good daylighting; 15% < VSC < 27%, large windows and/or changes to room layout; 5% < VSC < 15%, very large windows; VSC < 5%, impossible to achieve reasonable daylight	
			Annual Probable Sunlight Hours	APSH	criterium for good daylighting	min. 25% sunlight hours and at least 5% during winter (Sep. 21 - Mar. 21)	
			Light Trasmittance of glazing		diffuse transmittance according to glass type	0.3 - 0.8 (Appendix I)	
	Views in and out	A view out from a window enhances the experience of the building for all users. Views provide a connection to the external landscape, which can reveal seasonal and diurnal variation, and could include human activity or wildlife. In addition, a view comprising elements at some distance from the occupant can facilitate relaxation of the eye muscles by allowing occupants to take visual breaks from their work, for example by gazing into the	Horizontal sight angles		Views provide a connection to the external landscape, which can reveal seasonal and diurnal variation, and could include human activity or wildlife. A window view can provide significant benefits to the health and wellbeing of building occupants. View is also believed to have a mitigating effect on perceived daylight glare.	Insufficient: <14°; Sufficient: >14°; Good: >28°; Excellent: >54°.	
			Layers			Insufficient: only sky or ground; Sufficient: landscape +1 layer; Good: landscape +1 layer; Excellent: all layers.	
			distance from windows			Insufficient: <6m from view; Sufficient: >6m from view; Good: > 20m from view; Excellent: >50m from view.	
	Light from the sky	In site layout planning, it is important to ensure that a sufficient area of sky will be visible at each window so that good internal lighting can be provided from windows of a reasonable size. This is largely determined by the window's proximity to obstructions, such as neighbouring buildings or large overhangs.	Average Daylight Factor	DF_{avg}	criterium for good daylighting	min. 1%	
					room is gloomy, electric light is required during the day	< 2%	
					room will seem good daylit, but electric light might be needed for some tasks	2% - 5%	
					room is brightly lit and electric light is rarely needed	> 5%	
			area of glazing		including the combined surface area of the floor, ceiling, walls and glazing	1/25th total surface area of room	
			setbacks between buildings		to maintain privacy	at least 22m away	
			angle of visible sky	AVS	measured perpendicular to the window from the window's centre	> 65°, good daylighting; 45°-65°, should have larger windows; 25°-45°, very large windows; < 25° not possible to get good daylighting	
					measured from the centre of the window, with the angle measured between the	< 25°, free from obstruction	

GUIDELINES	**Daylighting in older people's housing 2015 (UK)**			angle of obstruction	AO	measured from the centre of the window, with the angle measured between the top of the obstruction and the horizon line	≥ 25°, should have no overhangs to obtain 65° sky angle
		Window design: aspect	As many older occupants might have impaired mobility or be affected by long term illness, views should be visible to people who are seated or lying down.	sill height		height between finished floor level and lower point of window	800mm allowed floor-to-ceiling glazing in case of balconies and ground pavement
				layers			should have natural features; spaces w/ human activities; near and distant features of interest; external reference points, free from obstructions
		Sunlight Availability	most people like to have some direct sunlight, provided they have some control over it. Sunlight can also be important for health, particularly in the winter months. Exposure to direct sunlight can be particularly important for people who are largely housebound.	Annual Probable Sunlight Hours	APSH	the dwelling receives sunlight for a proportion of the total number of hours that sunlight would, in the course of an average year, fall on unobstructed ground at the same location	min. 25% sunlight hours and at least 5% during winter (Sep. 21 - Mar. 21)
	Site layout planning for daylight and sunlight: a guide to good practice ("BRE daylight and sunlight") (UK) (2022)	Sunlighting	People like sunlight.(...) The sun is seen as providing light and warmth, making rooms look bright and cheerful and also having a therapeutic, health-giving effect.	Annual Probable Sunlight Hours	APSH	This considers only the hours of sunlight a window will receive over a 12 month period. Because the test relates only to sunlight, only windows facing within 90 degrees of due south are considered under the methodology	APSH = 1/4 of total daylit hours, including at least 5% of APSH in the winter months (21 Sep. to 21 Mar.) if APSH ≤ 4%, the loss of sunlight is small; If APSH > 5%, reduction is noticed
		Light from the sky	The quantity and quality of daylight inside a room will be impaired if obstructing buildings are large in relation to their distance away. The distribution of light in the room will be affected as well as the total amount received	Vertical Sky Component	VSC	This takes no account of direct sunlight and assesses only the amount of diffuse light within a room related to an affected window. this is a measure of the amount of sky visible from the window of an affected room	the window must have a view of 27% of the 'dome of the sky'
				Obstruction angle γ		building-to-building angles	values in Table F1
		Interior daylighting recommendations	(no definition)	Target Illuminance	E_T	ET (lx) for half of assessment grid	Min.: 300 lx Med.: 500 lx Max.: 750 lx
				Target Illuminance	E_{TM}	ETM (lx) for 95% of assessment grid	Min.: 100 lx Med.: 300 lx Max.: 500 lx
				Target Daylight Factor	D	Target daylight factor D for half of assessment grid	Min.: 2.1% Med.: 3.5% Max.: 5.3%
				Target Daylight Factor	D	Target daylight factor D for 95% of assessment grid	Min.: 0.7% Med.: 2.1% Max.: 3.5%
		Alternative to skylight and sunlight access	(no definition)	Spacing-to-height ratio		(spacing of obstruction)/ (height above reference point)	values in Table F1
		Site layout planning: Gardens and open spaces	Good site layout planning for daylight and sunlight should not limit itself to providing good natural lighting inside buildings. Sunlight in the spaces between and around buildings has an important impact on the overall appearance and ambience of a development.	Sunlight to open amenity spaces and gardens		Suggests that consideration of sunlight to external areas should normally include: Gardens, usually the main back garden of a house, and allotments; Parks and playing fields; Children's playgrounds; Outdoor swimming pools and paddling pools; Sitting-out areas, such as those between non-domestic buildings and in public spaces; Focal points for views, such as a group of monuments or fountains.	at least half of the garden/amenity area should receive at least two hours of direct sunlight on 21 March.
			Views out through daylight openings can help building occupants to feel more connected to the outside	Horizontal sight angles		as recommended by BS EN 17037, views out include three distinct layers: sky, landscape, and ground. Generally, a view of nature is preferred to a view of a built environment, as is a wide and distant view to a narrow and near view, and a	min.: ≥ 14° med.: ≥ 28° max.: ≥ 54°

	View	more connected to the outside world and less trapped, and thus have a therapeutic or relaxing effect. This is all the more important where people have to be indoors for long periods.	layers		diverse and dynamic view to a monotonous view. Glazing materials should provide a clear, undistorted, and neutrally coloured view out. the landscape layer is visible from not less than 75% of the reference points in the living or working area; the view should provide environmental information on location, time, and weather.	Min.: landscape; Med.: landscape + other layer; Max.: all 3 layers.	
			Outside distance of the view			Min: ≥ 6,0m Med: ≥ 20,0m Max: ≥ 50,0m	
TNO sunlighting (The Netherlands)		(no definition)	Target daily sunlight hours		Describes the minimum sunlight hours a window sill must be able to receive on any day between 19-feb and 21-oct. Time is measured horizontally in the middle of any window sill.	light norm: 2 hours possible per day; strict norm: 3 hours possible per day.	**NON MANDATORY**
Standards for Design and Maintenance of Windows and Openings on Interior Lighting and Visual Environment (Japan)	Daylight		Daylight Factor	DF	Work spaces		**NON MANDATORY**
		the intensity of daylight in interior spaces will be evaluated to reduce energy-consumption by electric lighting	**Vertical Illuminance**			(no values)	
	View	the size and configuration of windows will be regulated mainly to satisfy the view quality	Solid angle of windows		related to size and configuration of windows	(no values)	
			Distance to the outside obstacles			(no values)	
			Overall visible volume			(no values)	
	Glare	(no definition)	**(Predicted Glare Sensation Vote)**	**PGSV**	using vertical illuminance (work spaces)	(no values)	
	Daylight/View	Overall visual environment including view and daylight will be regulated by the area of windows (residential spaces)	**area of windows**			(no values)	
			window-to-floor ratio	WFR			
Daylight Reflectance Design Guide (BCA) (Singapore)	Site analysis	New buildings	Setbacks between buildings		Spaces between buildings must be considered during the planning and design stages to minimise reflected glare occurrence	from 10-50m: affects level 23 and above	**NON MANDATORY**
						from 30-70m: affects levels from 13-21	
						from 50-70m: affects level 13 and lower	
			Height ratio		The height ratio is derived by comparing the height of the building with that of a surroundin building. A heigher ratio means the evaluated building is comparatively taller than the neighbouring building.	(no values)	
			Window-to-wall Ratio	WWR	increases occurrence of reflected daylight glare	0.5 and higher	
	Glare evaluation	Useful and scientific method to study the probability of reflected glare and its impact on neighbouring buildings.	Daylight Glare Probability	DGP	most robust metric that generates the most reliable results under daylighting conditions; evaluated through simulations; to meet the requirement, DGP must be under 0.40	imperceptible: DGP < 0.35	
						perceptible: 0.35 < DGP < 0.40	
						disturbing: 0.40 <DGP < 0.45	
						intolerable: DGP > 0.40	
Guidelines for calculating the duration of direct sunlight (Estonia)	Insolation	direct solar radiation is considered insolation as the angle at which the sun rises are at least 6 degrees and the angle between the azimuth of the sun and the façade under consideration is at least 10 degrees	Duration of insolation		must be guaranteed between 22 April and 22 August; in apartments up to 3 rooms, at least 1 room must comply; in apartments w/ 4 or more rooms, at least 2	2.5 h (continuous) or 3 h (interrupted)	**PARTIALLY MANDATORY (for permanent living places, schools, healthcare)**
					must be guaranteed between 22 April and 22 August; in apartments up to 3 rooms, at least 2 rooms must comply; in apartments w/ 4 or more rooms, at least 3	2 h (uninterrupted)	
					in densely built-up areas	0.5 h	
					in playrooms of pre-school	3 h	
					healthcare institutions	3 h in at least 60% of living quarters of rooms	
					fields of pre-school, healthcare, welfare institutions	3 h in at least 50% of the area	
Green certificate regulation for buildings and settlements (2017) (Turkey)	Daylight provision and View	(no definition)	Daylight factor, spatial daylight illuminance		CEN standard TS EN 17037+A1 should be considered		**MANDATORY**
			Mean Daylight Factor	DFm	British Standard BS 8206 Part 2 (Code of practice for daylighting) should be used		
			Uniformity				
			angles		**CEN standard TS EN 17037+A1 should be considered**		
			layers				
			distance				

Resolución 0549 de 2015, Anexo I - Guía de Construcción Sostenible para el ahorro de agua y energía em las edificaciones (Colombia) *"A reference document for the design of new building, efficient in water and energy use. The goal is to provide a tool for the implementation of sustainable construction strategies to be applied in all country's cities. The Guide aims to promote energy efficiency and water conservation during building occupation."*	Buenas Prácticas - Luz del día (Good practices - Daylight)	Advanced systems and control devices offer better daylighting conditions, pleasant to users and energy efficient in buildings. Those systems need to be connected to general architectural strategies in buildings.	Coeficiente de Luz Diurna (Daylight Factor)	CLD (DF)		values defined by RETILAP	**NON MANDATORY**
	Energía - Medidas Pasivas (Energy - Passive Strategies)	The energy saving passive strategies are those embodied in building design, and take advantage of the climatic conditions of the surroundings, maximizing natural thermal control sources, ventilation and energy reduction to provide comfort for occupants.	Relacción Ventana-Pared (Window-to-wall Ratio)	RVP (WWR)		max. 40%	
			ángulo de sombra vertical (Vertical shadowing angle)	VSA	provides a vertical shadowing for openings	no more than 70°	
			ángulos de sombra horizontal (Horizontal shadowing angle)	HSA	provides a horizontal shadowing for openings	no more than 70°	
Manual de Diseño Pasivo y Eficiencia Energética en Edificios Públicos (Chile)	Estrategias de Iluminación Natural (Daylighting Strategies)	Integration of aylighting and electric lighting to achieve a good lighting project and comfortable conditions to space occupants.	Factor Luz Día (Daylight Factor)	FLD (DF)		too dark: DF < 2% adequate: 2% < DF < 5% ideal: 5% < DF < 10% too high: DF > 10%	**NON MANDATORY**
			Porcentaje de la pared de la ventana (window-to-wall ratio)	(WWR)	according to room width	< 8 m: 20 % from 8 m to 11 m: 25 % from 11 m to 14 m :30 % longer than 14 m: 35 %	
			Transmisión Luminosa (Light Transmittance)	TL	To balance the choice of a glass based on the highest light transmittance and lowest heating transmittance possible	Table 5.3	
Guía de Diseño para la Eficiencia Energética en la Vivienda Social (Chile)	Comfort Lumínico (Lighting Comfort)	To obtain a good level of light comfort, natural lighting is recommended, both for the quality of light itself, as for the need to achieve energy efficiency. In general, natural lighting is appropriate both psychologically and physiologically, but in the absence of it from certain hours of the day, a complementary or permanent contribution of artificial light is necessary.	% Superfície Vidriada (ventanas) (window-to-floor ratio)	WFR	Window surface with respect to the space area	north and east - living: 27% south - bedroom: 10%	**NON MANDATORY**
	Estrategias de Iluminación Natural (Daylighting Strategies)	Another element that must be present inside the complex balance of design and efficiency.	Factor de Luz Diurna (Daylight Factor)	DF	residential spaces	living rooms: 1.5% (med.), 0.5% (min.) bedrooms: 1% (med.), 0.3% (min.) kitchens: 2% (med.), 0.6% (min.)	
						w/out electric light: med. DF ≥ 5% w/ electric light: med. DF ≥ 2%	
	Light Exposure	Provide indoor light exposure through daylight and electric light strategies	Spatial Daylight Autonomy	$sDA_{200/40\%}$	Describes minimum levels of natural lighting in spaces during occupied hours. All spaces except dwellings and guest rooms. Calculated according to LM 83.	at least 40% of the space receives at least 200 lux of sunlight for at least 30% of operating hours each year	
			Spatial Daylight Autonomy	$sDA_{300/50\%}$	Describes minimum levels of natural lighting in spaces during occupied hours. All spaces except dwellings and guest rooms. Calculated according to LM 83.	at least 50% of the space receives at least 300 lux of sunlight for at least 50% of operating hours each year	
			Target Illuminance	E_T	Describes minimum levels of natural lighting in spaces during occupied hours. All spaces except dwellings and guest rooms. Calculated according to CEN 17037.	19 fc is achieved for >30% of floor area throughout 50% of daylit hours of the year	

Well v 2.0 (USA/Canada) (2024)		strategies.	Target Illuminance	E_T	Describes minimum levels of natural lighting in spaces during occupied hours. All spaces except dwellings and guest rooms. Calculated according to CEN 17037.	28 fc is achieved for >30% of floor area and average illuminance 9 fc is achieved for >95% of floor area throughout 50% of daylit hours of the year	**NON MANDATORY**
			envelope glazing area		ratio to the regularly occupied floor area of all spaces, including dwelling units and guest rooms	no less than 7% of the regularly occupied floor area	
	Daylight Design Strategies	Provide daylight exposure indoors through design strategies.	Visible light transmittance	VLT	for all spaces, including dwellings units and guest rooms	greater than 40%	
			Vertical envelope glazing		ratio to the regularly occupied floor area of each dwelling unit	no less than 15% - 1 point no less than 25% - 2 points	
LEED v 4.1 (USA/Canada) (2023)	Daylight	To connect building occupants with the outdoors, reinforce circadian rhythms, and reduce the use of electrical lighting by introducing daylight into the space.	Spatial Daylight Autonomy	$sDA_{300/50\%}$	Percent of analysis area that meets a minimum daylight illuminance level for a specified fraction of the operating hours per year.	Min: 300 lux / 50% in 40% occupied area; med: 300 lux / 50% in 55% occupied area; high: 300 lux / 50% in 75% occupied area; each regularly occupied space achieves sDA 300/50% in at least 55% occupied area.	**NON MANDATORY**
			Point- in- time illuminances		perform computer simulations for illuminance at 9 a.m. and 3 p.m. on a clear-sky day at the equinox for each regularly occupied space. Demonstrate illuminance levels are between 300 lux and 3,000 lux at both 9 a.m. and 3 p.m.	55% occupied area: 1 point; 75% occupied area: 2 points; 90% occupied area: 3 points.	
			Illuminances		measured illuminances in each regularly occupied space. Achieve illuminance levels between 300 lux and 3,000 lux.	55% occupied area 1x/year: 1 point; 75% occupied area 2x/year: 2 points; 90% occupied area 2x/year: 3 points.	
			Annual Sunlight Exposure	$ASE_{1000/250h}$	Percent of an analysis area that exceeds a specified direct sunlight illuminance level more than a specified number of hours per year.	1000 lux in 250h/year for a maximum of 10% of the area (10 h/day of sunlight)	
	Quality Views	To give building occupants a connection to the natural outdoor environment by providing quality views.	Layers and distance from windows		Provide occupants in the building with a view to the outdoor natural or urban environment for 75% of all regularly occupied floor area. Views must be through glass with a visible light transmittance (VLT) above 40%. If the glazing has frits, patterns, or tints the view must be preserved. Neutral gray, bronze, and blue-green tints are acceptable.	nature, urban landmarks, or art;	
						objects at least 25 feet (7.5 meters) from the exterior of the glazing	
						Occupants must have direct access to the view and be within three times the head height of the glazing	
			visible light transmittance	VLT		min. 40%	
LEED BD+C (USA/Canada) (2023)	Minimum acess to daylight	To connect building occupants with the outdoors, reinforce circadian rhythms, and reduce the use of electrical lighting by introducing daylight and views into the space.	Illuminance in space and time		Demonstrate through computer modeling or daylight measurements that illuminance levels comply with minimum daylight in regularly occupied space and adequate levels in the entire building	minimum in spaces: 10 lux in 90% occupied area; adequate levels in the building: between 150-5000 lux for at least 50% occupied area.	
			obstruction or distortion		For at least 50% of the regularly occupied spaces in each residential unit, have one window, unosbtructed by frits, fibers, patterned glazing, or added tints that distort color balance.	flora, fauna, or sky;	
			Distance from windows			objects at least 25 feet from the exterior of the window.	
LEED GBC CASA v 2 (2017) (Brazil)	Minimum performance of indoor space	Design buildings in a way to provide a proper amount of daylight indoors, with no harm to the thermal performance.	Fator de Luz Diurna / Daylight Factor	FLD / DF	FLD/DF must be locally measured, according to the method present in the standard NBR 15.575. Spaces are classified between intermediary or high performance, according to their main function, taking into account the DF values measured.	Living rooms, bedrooms, kitchens, laundries: intermediary ≥ 0,65; High ≥ 0,75. Bathrooms, garages, internal or common circulations: intermediary ≥ 0,25; high 0,35.	**NON MANDATORY**
LEED v 4 (2014) (Brazil)	Luz Natural (Daylight)	To connect building occupants with the outdoors, reinforce circadian rhythms, and reduce the use of electrical lighting by introducing daylight into the space.	Autonomia Espacial de Luz Diurna | Spatial Daylight Autonomy	$sDA_{300/50\%}$	Demonstrate through computer modeling or daylight measurements that illuminance levels comply with minimum sDA 300/50% in the regularly occupied floor area	sDA 300/50% of 55% (2 pts) or 75% (3 pts) (occupied area); 75% (1 pt) or 90% (2 pts) in healthcare	**NON MANDATORY**
			Point- in- time illuminances		perform computer simulations for illuminance at 9 a.m. and 3 p.m. on a clear-sky day at the equinox for each regularly occupied space. Demonstrate illuminance levels are between 300 lux and 3000 lux at both 9 a.m. and 3 p.m.	75% occupied area: 1 pt; 90% occupied area: 2 pts	
			Measured illuminances		measures illuminance in each regularly occupied space. Achieve illuminance levels between 300 lux and 3000 lux.	75% occupied area: 2 pts; 90% occupied area: 3 pts	
			Annual Sunlight Exposure	$ASE_{1000/250h}$	Percent of an analysis area that exceeds a specified direct sunlight illuminance level more than a specified number of hours per year.	1000 lux in 250h/year for a maximum of 10% of the area (10 h/day of sunlight)	

	Vistas de Qualidade (Quality views)	To give building occupants a connection to the natural outdoor environment by providing quality views.	visible light transmittance	VLT		min. 40%	
			layers		Provide occupants in the building with a view to the outdoor natural or urban environment for 75% of all regularly occupied floor area. Views must be through glass with a visible light transmittance (VLT) above 40%. If the glazing has frits, patterns, or tints the view must be preserved. Neutral gray, bronze, and blue-green tints are acceptable.	flora, fauna, or sky;	
			distance from windows			objects at least 7.5 meters from the exterior of the glazing	
			angles			Multiple vision lines in different directions	
			distance to windows			unobstructed views with distance minor to 3x window heights	
INI-C (Brazil)	Potential Integration of Lighting System with Available Daylight	(no definition)	Spatial Daylight Autonomy	sDA	In order to obtain level A (best performance) in energy efficiency, buildings must inform the potential of daylight integration with electric lighting systems; there is no minimum of daylight integration or DA required	DA = 300 lux at least 50% of daylight hours	**PARTIALLY MANDATORY for public buildings**
BREEAM (International) (2024)	Visual comfort - Daylighting	To ensure daylighting, artificial lighting and occupant controls are considered at the design stage to ensure best practice in visual performance and comfort for building occupants.	Average Daylight Factor	ADF / DF_{avg}	required by latitude (degrees), according to Table 10	min. 1.5% for educational facilities ≤ 40° min. 1.2% for dwellings ≤ 40° min. 1.5% retail buildings ≤ 40° min. 1.5% industrial, offices etc ≤ 40°	**NON MANDATORY**
			Average daylight illuminance		averaged over entire space	Table 12 (varies according to % area and type of space/building)	
			Minimum daylight illuminance		at worst lit point		
BREEAM (UK) (2024)	Visual comfort - Daylighting	To encourage best practice in visual performance and comfort by ensuring daylighting, artificial lighting and occupant controls are considered.	Average Daylight Factor	ADF / DF_{avg}	for 80% of space area	at least 2% (Table 5.1)	**NON MANDATORY**
			Average daylight illuminance		averaged over entire space	At least 300 lux for 2000 hours per year or more (Table 5.3)	
			Minimum daylight illuminance		at worst lit point	At least 90 lux for 2000 hours per year or more (Table 5.3)	
	View out	95% of the floor area in 95% of spaces for each relevant building area provides na adequate view out	Distance		of external objects	Table 5.6: View out building-specific requirements	
			window % of surrounding wall area		similar to "WWR"		
BREEAM (Poland)		(no definition)	Average Daylight Factor	ADF / DF_{avg}			**NON MANDATORY**
VERDE (Spain)		(no definition)	Daylight Factor	DF		DF ≥ 1% of general value	
LEED (Poland)	Daylight	To connect building occupants with the outdoors, reinforce circadian rhythms, and reduce the use of electrical lighting by introducing daylight and views into the space.	Spatial Daylight Autonomy	$sDA_{300/50\%}$		300 lux in 50% occupied area in 50% daylit hours	**NON MANDATORY**
			Annual Sunlight Exposure	$ASE_{1000/250h}$		amount of 1000lux in 250h/year	
	Quality Views	To give building occupants a connection to the natural outdoor environment by providing quality views.	visible light transmittance	VLT	Provide occupants in the building with a view to the outdoor natural or urban environment for 75% of all regularly occupied floor area. Views must be through glass with a visible light transmittance (VLT) above 40%. If the glazing has frits, patterns, or tints the view must be preserved. Neutral gray, bronze, and blue-green tints are acceptable.	above 40%	
			layers			nature, urban landmarks, or art;	
			distance from windows			objects at least 25 feet (7.5 meters) from the exterior of the glazing	
			distances to windows (from occupants)			Occupants must have direct access to the view and be within three times the head height of the glazing.	

AQUA-HQE (Brazil) (2021)	Otimização da Iluminação Natural (Daylight Optimization)	(no definition)	Fator de Luz do Dia / Daylight Factor	FLD / DF	Offices, classrooms exposed to external walls	DF ≥ 1.2% for 80% of area in 80% of rooms; DF ≥ 2% in 80% of area in 80% of rooms AND DF ≥ 1.5% in 20% remaining rooms; DF ≥ 2.5% in 80% rooms AND DF ≥ 1.5% in 20% remaining rooms AND DF ≥ 0.7% in rooms not next to external walls DFmin ≥ 1.5% in 80% area (hotel rooms and eating spaces);	**NON MANDATORY**
			Fator de Luz do Dia / Daylight Factor	FLD / DF	offices, classrooms NOT exposed to external walls	DF ≥ 0.7% in 90% room area	
			Fator de Luz do Dia / Daylight Factor	FLD / DF	circulation spaces, exhibition halls	DFmin ≥ 0.5% in all rooms, DFm ≥ 1%; OR DFmin ≥ 0.5% in all rooms; DFm ≥ 1% and DFmin ≥ 0.5% in all rooms	
			Fator de Luz Diurna / Daylight Factor	FLD / DF	all kinds of buildings	DFmin ≥ 1% in 70% area of sensible spaces	
			Window-to-wall Ratio	WWR	openings on external walls to assure access to daylight - exhibition halls	20% or 30%	
			visible light transmittance	VLT		at least 50%	
	Access to views	(no definition)	(no metrics/criteria clearly defined)		habitable spaces	100% of rooms (offices, classrooms, private and eating rooms in hotels); at least 50% in commercial spaces; 60% or 100% in hotels' saloons;	
					circulation spaces, exhibition halls	at least 30%, 50% OR 75% of points in a room; 100% in common spaces	
HQE B v1.0 and BD v4.0 (France)	Access to daylight	(no definition)	Daylight Illuminance		threshold for rooms	aligned with NF EN 12464-1 Lighting of indoor workplaces	**NON MANDATORY**
			Daylight Autonomy	DA	% of hours compared to reference period (8am-6pm; or 9am-7pm; or 24h)	illuminance threshold is met in 80% of the area	
			Daylight Illuminance		threshold for rooms	Generally aligned with NF EN 12464-1 Lighting of indoor workplaces (electric lighting)	
	outside views	(no definition)	window sizes		required for all tertiary buildings	(no values)	
			angle			min.: ≥ 14° med.: ≥ 28° max.: ≥ 54°	
			layers			Min.: landscape; Med.: landscape + other layer; Max.: all 3 layers.	
			distance			Min: ≥ 6,0m Med: ≥ 20,0m Max: ≥ 50,0m	
		(no definition)	Daylight Glare Probability	DGP	Calculating DGP is mandatory when there is no solar protection.	calculated hour by hour at 11 different times	
NF Habitat HQE certification House & Collective Residential buildings; Construction & Renovation (France)	Access to daylight		visible light transmittance	VLT		> 60% required	**NON MANDATORY**
			window-to-floor ratio	WFR		1/6 or 1/5 (better score) required	
	outside views		(no metrics/criteria clearly defined)			required	
OsmoZ certification (France)	Access to daylight	in 80% of the offices at less than 7m or 4m of facades in 50% of meeting rooms have direct access to daylight	Daylight Factor	DF	or equivalent DA parameters	DF > 0.7% (1 pt) DF > 1.5% (2 pts) DF > 2% (3 pts)	
			Daylight Autonomy	DA	or equivalent DF parameters	10% < DA < 45% (1 point) 45% < DA < 65% (2 points) 65% < DA < 100% (3 points)	

RATING SYSTEMS

	outside views	(no definition)	(no metrics/criteria clearly defined)		required	in 25%, 50%, or 75% of common spaces	
GREEN Star (2022) (Australia)	Daylight	(no definition)	Visible Light Transmittance	VLT	VLT glazing must have a visible light transmittance equal to, or greater than, 40%. Typical values/ranges for various glazing types	Clear single glazing: 70 - 90% Tinted single glazing (green): 70% Tinted single glazing (grey): 20% Clear double glazing: 70 - 80% Double glazing with a low emissivity coating: 40 - 70% (but can be as low as 10%)	**<u>NON MANDATORY</u>**
			Overshadowing angle		External shading includes: buildings, cliffs, and any other solid structure. External shading does not include trees.	above 25° does not overshadows	
			Daylight Factor	DF	for offices, educational facilities, public buildings in spaces' nominal area	min. 2%	
			Daylight Factor	DF	for offices' workplanes	min. 2.5%	
	Views	(no definition)	angle		The **Line of Sight** is determined by drawing a line from the qualifying view (window, atrium or high quality internal view depending on the rating tool) to the eye of the building occupant. The occupant is expected to be seated or standing at a work setting or mobile within a retail, industrial or another space.	A line at 45° can be used at the corners of high quality views	
			distance			within 8 meters of a qualifying view is found to be compliant	
			external obstruction		The view must extend from the perimeter of the building and be unblocked by any permanent solid structure	there must not be another building within 8m	
			window sizes		there is no minimum dimension for glazing prescribed within this guide, however project teams are encouraged to consider the intent of the credit in the context of their building to establish whether the glazing provided within their project will have the capacity to provide views to occupants	Glazing which is below 720mm or above 2,400mm cannot contribute to external views	
CASBEE (Japan) (2014)	Light and Illumination - Daylight	(no definition)	Daylight Factor	DF	Entire buildings and common properties (vertical openings)	Level 1: DF < 1%; Level 2: 1% ≤ DF < 1.5%; Level 3: 1.5% ≤ DF < 2%; Level 4: 2% ≤ DF < 2.5%; Level 5: DF ≥ 2.5%	**<u>NON MANDATORY</u>**
			Daylight Factor	DF	Hotel and residential accomodations (roof openings)	Level 1: DF < 0.5%; Level 2: 0.5% ≤ DF < 1.0%; Level 3: 1.0% ≤ DF < 1.5%; Level 4: 1.5% ≤ DF < 2.0%; Level 5: DF ≥ 2.0 %	
			Daylight Factor	DF	Hospital accomodations (roof openings)	Level 1: DF < 0.5%; Level 2: 0.5% ≤ DF < 0.75%; Level 3: 0.75% ≤ DF < 1.0%; Level 4: 1.0% ≤ DF < 1.25%; Level 5: DF ≥ 1.25 %	
Deutshe Gesellschaft für Nachhaltinges Bauen - DGNB (Germany)	Daylight Availability	To ensure a sufficient and trouble-free supply of daylight and artificial lighting in all permanently used interiors. Visual comfort forms the basis for general well-being and efficient and performance-enhancing work. Natural light has a positive effect on people’s mental and physical health. In addition, good use of daylight offers a high energy-saving potential with regard to artificial lighting.	Daylight Factor	D	Daylight supply at 50% of the usable area for more than 50% of daylight hours (Office; Education; Assembly buildings; Residential; Healthcare buildings; Hotel)	≥ 1% (less pts); ≥ 1.5 % (+pts); ≥ 2 % (++pts)	**<u>NON MANDATORY</u>**
			Target Illuminance	E_T	Daylight supply at 50% of the usable area for more than 50% of daylight hours (Office; Education; Assembly buildings; Residential; Healthcare buildings; Hotel)	≥ 150 lux	
			Daylight Factor	D	For consumer markets, commercial buildings	side windows: DF ≥ 1%; roof windows: DF ≥ 2%	
			Daylight Factor	D	For shopping centres	≥ 2%	
			Translucent skylight portion of roof		assembly buildings	≥0.5% (min.); ≥2% (+pts); ≥4% (++pts)	
	Visual contact with the outside	Availability of line of sight to the outside (according to DIN **EN 17037**)	angle			min.: ≥ 14° med.: ≥ 28° max.: ≥ 54°	
			layers			Min.: landscape; Med.: landscape + other layer; Max.: all 3 layers.	
			distance			Min: ≥ 6,0m Med: ≥ 20,0m Max: ≥ 50,0m	

			Window sizes		height, area, width, sill, lintel dimensions	max. sill height is 0.95 m; min. lintel height is at least 2.2 m; min. width of the windows is at least 55% of the room width	
	Absence of glare in daylight	(according to DIN **EN 17037**)	Daylight Glare Probability	DGP	Absence of glare due to solar/glare protection system. An excess of <5% during the utilisation period is permissible.	DGP ≤ 0.45	
						DGP ≤ 0.40	
						DGP ≤ 0.35	
	Exposure to daylight	(according to DIN **EN 17037**)	Exposure to Sunlight		Duration of exposure to daylight in at least 1 living space in residential units	Level 1: 1.5 h; Level 2: 2.0h; Level 3: 3.0h	
					Duration of exposure to daylight in at least 1 living space in of 100% guest rental units (hotel) or patient rooms (healthcare buildings)	≥1.5 h.	
					Duration of exposure to daylight in at least 1 living space in of 50% guest rental units (hotel) or patient rooms (healthcare buildings)	≥2.0 h.	
					Duration of exposure to daylight in at least 1 living space in of 60% guest rental units (hotel) or patient rooms (healthcare buildings)	≥2.0 h.	
					Duration of exposure to daylight in at least 1 living space in of 60% guest rental units (hotel) or patient rooms (healthcare buildings)	≥3.0 h and ≥ 1.5 h for the remaining 40% spaces	
Deutshe Gesellschaft für Nachhaltinges Bauen - DGNB (2023) (Poland)	Daylight Availability		Daylight Factor	D			**NON MANDATORY**
			Target Illuminance	E_T			
			Translucent skylight portion of roof surface				
	Visual contact with the outside	(according to DIN **EN 17037**)	angle			min.: ≥ 14° med.: ≥ 28° max.: ≥ 54°	
			layers			Min.: landscape; Med.: landscape + other layer; Max.: all 3 layers.	
			distance			Min: ≥ 6,0m Med: ≥ 20,0m Max: ≥ 50,0m	
			Window sizes				
	Absence of glare in daylight	(according to DIN **EN 17037**)	Glare	DGP		DGP ≤ 0.45 DGP ≤ 0.40 DGP ≤ 0.35	
	Exposure to Sunlight	(according to DIN **EN 17037**)	Exposure to Sunlight				
Living Building Challenge (2019) (USA/Canada)	Healthy interior environment	to promote good indoor air quality and a healthy interior environment for project occupants.	access to daylight		from 75% of regularly occupied spaces and opportunities for those occupants in the remaining five percent of regularly occupied spaces to move to compliant spaces for a portion of their day	for 75% of regularly occupied spaces	**NON MANDATORY**
			access to views				
	Healthy interior performance	to create healthy spaces that allow all species to thrive by connecting people to nature and ensuring that our indoor spaces have healthy air and natural daylight.	access to daylight		from 95% of regularly occupied spaces and opportunities for those occupants in the remaining five percent of regularly occupied spaces to move to compliant spaces for a portion of their day	for 95% of regularly occupied spaces	
			access to views				
	Circadian Rhythm - Views to outside	Humans and animals have internal clocks that synchronise physiological functions (the circadian rhythm). In buildings this natural rhythm can be disturbed if we are exposed to light at certain hours of the day (e.g., at night time). The Circadian Rhythm has a major role in sleep, cognitive performance, and the immune system.	occupied area		**Window views** provide a connection to the outside, giving us information about ongoing changes that occur outside (passage of time and weather). Distant views refocus our visual gaze from nearby content (computer displays) onto far away content. This helps minimise eyestrain.	75% of the floor area of all regularly occupied spaces is within 8m of windows, with unobstructed views	
			occupied area			95% of the floor area of all regularly occupied spaces is within 12m of windows, with unobstructed views	
			distance to external objects			sufficient distance gap of at least 10m to allow sufficient view to the sky and surroundings.	
			Window-to-wall Ratio	WWR	Window(s) shall be sufficiently sized at an appropriate height	at least 25% of each facade	
			Daylight Autonomy	DA	Office, Institutional spaces where lux requirement is 500 lux	DA 500lx,50%	
					Industrial, sports facilities, retail areas where lux requirement is 300 lux	DA 300lx,50%	

BCA Green Mark (Singapore) (2021)	Energy Efficiency - Effective Daylighting	Encourage design that optimises the use of natural lighting to improve visual comfort and reduce energy use associated with artificial lighting.	Daylight Autonomy	DA	Hotel, resort-like and service apartment where lux requirement is 200 lux; residential units	DA 200lx,50%	**NON MANDATORY**
			Daylighting provision		minimum coverage of the total normally occupied spaces	15%	
					minimum coverage in at least two (2) of the following areas: lift lobbies, corridors, staircases, car parks, atriums, toilets	80%	
			Floor to ceiling height		Spaces with typical room floor-to-ceiling heights	2.5 m to 3.1 m	
			Window-to-wall Ratio	WWR	10 values to choose from during calculations	10%, 20%, 26%, 32%, 39%, 43%, 52%, 60%, 70%, and 87%	
			Glazing type (Visible Light Transmittance)	VLT	six (6) options of Visible Light Transmittance (Tvis), obtained from glazing specification	25%, 35%, 45%, 55%, 65% and 75%	
			Average urban obstruction angles	AUOA	average portion of the sky blocked by surrounding obstructions such as neighbouring buildings	less than 57.25°	
			Useful Daylight Illuminance Exceeded	UDIe 3000lx,10 %	daylight illuminance threshold for all cases	3000 lux for more than 10% of occupied hours in a year	
			Overhang Obstruction Angle	OOA	angle describing the portion of the sky blocked by a horizontal overhang	0°	
						15°	
						30°	
Svanen scheme 089 (Nordic Ecolabel) (Sweden)	Daylight provision; Assessment for view out; Exposure to sunlight; Protection from glare.	(same requirements as **EN 17037**)					
PROTOCOLLO ITACA (Italy) (2022)	Illuminazione Naturale (Daylighting)	Assure adequate levels of daylight in all primary occupancy spaces	Average Daylight Factor	DFm	assumes the average Daylight Factor of all the primary spaces in the buildings as criteria to evaluate the indoor environmental quality related to daylight availability. The method to calculate the parameter follows the approach defined in the Standard EN 15193-1	The ratings are: Average DF < 2% = -1 Average DF = 2% = 0 Average DF = 2.6% = 3 Average DF = 3% = 5	**NON MANDATORY**
BREEAM (The Netherlands)			Target daylight factor	DF	Daylight factor achieved across a fraction of the reference plane (80%) within an occupied space for at least half of the daylit hours.	2% for offices, 5% for educational functions, 2% for commercial spaces, 2% for hotel rooms, 5% for children daycare, 2% for industrial functions, 2% for laboratoria, 2% for swimming pools, 3% for atriums.	**NON MANDATORY**
Selo Azul Caixa (Brazil) (2022)	Lighting Comfort and Performance	Encourage the use of daylighting with quality to offer healthy conditions, comfortable lighting, electric lighting reduction during the day and consequent reduction in energy use			Mandatory Report of compliance to requirements of NBR 15575:2021		**PARTIALLY MANDATORY**
	Relation with the surroundings	Preserve wellbeing, safety and health of occupants, considering possible negative impacts of the surroundings may cause to the building			recommends provision of outside views for occupants to mantain permanent access to the exterior of buildings, balancing daylighting and heat gains	(no direct analysis criteria)	
	Natural ventilation and daylighting in bathrooms	Improve bathroom's salubrity and reduce energy use.	window-to-floor ratio	WFR	recommends daylight in common areas of residential complexes, as well as in home's bathrooms	minimum 12.5% of floor area (bathrooms)	
CASA Colombia v.3 (Colombia)	Confort Visual (Visual Comfort)	To provide visual comfort in housing spaces, favouring the circadian rhythm of occupants, from a good quality lighting, daylight and access to outside views.	Coeficiente de Luz Diurna (Daylight Factor)	CLD / DF	bedrooms, living room, kitchen, dining room	values defined by RETILAP	**NON MANDATORY**
			layers		habitable spaces with direct access to outside views, from a seated position, in 90% of room area	views to nature, movement or sky	
			Minimum Illuminance		minimum daylight access in each habitable space	100 lux in 90% of room area	
			Illuminance levels in space		illuminance levels reached inside the range	150-5,000 lux in at least 50% room area	
			window-to-floor ratio	WFR	area of window related to floor area	15%	
			visible light transmittance	VLT	light transmittance of glazing	min. 40%	

GB/T 50378:2019 - Assessment standard for green buildings (China)	—	(no definition)	Daylight Factor	DF	offices, according to each type of workplace	4% (600lx) 3% (450 lx) 2% (300lx) 1% (150 lx)	**NON MANDATORY**
			Daylight Factor	DF	residential spaces	bedrooms, living rooms: 2% bathrooms, corridors, restaurants, stairs: 1%	
			Daylight Factor	DF	educational facilities	classrooms, laboratories: 3% circulations, bathrooms: 1%	
			Daylight Factor	DF	healthcare	clinics, pharmacies, laboratories: 3% lobby, waiting rooms, offices: 2% circulations, bathrooms: 1%	
	—	(no definition)	Daylight Glare Index	DGI	evaluates glare from windows	20: imperceptible; 23: slightly perceptible; 25: acceptable; 27: discomfort; 28: intolerable.	
	—	(no definition)	window-to-floor ratio	WFR	to reach each DF value (side windows)	I: 1/3 (lighting depth: 1.8) II: 1/4 (lighting depth: 2.0) III:1/5 (lighting depth: 2.5) IV:1/6 (lighting depth: 3.0) V: 1/9 (lighting depth: 4.0)	
			window-to-floor ratio	WFR	to reach each DF value (roof windows)	I: 1/6 (lighting depth: 1.8) II: 1/8 (lighting depth: 2.0) III:1/10 (lighting depth: 2.5) IV:1/13 (lighting depth: 3.0) V: 1/23 (lighting depth: 4.0)	
Certificación CES (2021) (Chile)	Confort visual pasivo: luz natural (Passive Visual Comfort: Daylight)	Visual comfort is the subjetive manifestation of compliance of satisfaction with the indoor lighting conditions, in a way that allows people to fulfill their work and health needs. Must be in accordance with space's function.	Factor Luz Día / Daylight Factor	FLD / DF	for rooms regularly occupied (offices)	≥ 2% in at least 75% of the area	**PARTIALLY MANDATORY for public buildings**
					for rooms regularly occupied (educational, healthcare)	good: 5 ≤ DF ≤ 10 in 75% room area acceptable: 2≤ DF ≤ 5 in 75% room area	
			Spatial Daylight Autonomy	$sDA_{300/50\%}$	for rooms regularly occupied (offices)	sDA 300 lux/50% in 75% floor area in at least the following percentage of spaces: north: 50% center: 45% south:30-40%	
					for rooms regularly occupied, according to climatic zones (educational, healthcare)	sDA 300 lux/50% in 75% floor area in at least the following percentage of spaces: north: ≥ 95% (very good); ≥80% (good); ≥60% (acceptable); center: ≥ 90% (very good); ≥75% (good); ≥55% (acceptable); south:≥ 80-85% (very good); ≥65-70% (good); ≥45-50% (acceptable).	
			Useful daylight Illuminance		for rooms regularly occupied, according to climatic zones (offices)	UDI 100-2,000 lux in 75% floor area in at least the following percentage of spaces: north: 50% center: 40% south:20 - 30%	
					for rooms regularly occupied, according to climatic zones (educational, healthcare)	UDI 100-2,000 lux in 75% floor area in at least the following percentage of spaces: north: ≥ 80% (very good); ≥70% (good); ≥60% (acceptable); center: ≥70% (very good); ≥60% (good); ≥50% (acceptable); south:≥50-60% (very good); ≥40-50% (good); ≥30-40% (acceptable)	
			Daylight Glare Probability	DGP	for all climatic zones	≤ 40%	
	Confort Visual Pasivo: Acceso visual al	Establish a minimum percentage of	access to views			> 75% of regularly occupied areas must access views out	

	Exterior (Passive Visual Comfort: Visual access to exterior)	Establish a minimum percentage of access to views out to building's occupants	layers		windows must allow views out with a ledge < 1.2m, then demonstrate the percentage of area of enclosures that have access to 2 of three factors	nature/sky views, movement, other objects	
			distance from windows			objects distanced > 7.5m	
Certificación CVS, for homes (2021) (Chile)	Iluminación Natural (Daylighting)	(no definition)	Daylight Factor	DF	for residential spaces	≥ 2%	**NON MANDATORY**
			Useful Illuminance		for residential spaces	UDI 100 - 2,000 lux in 75% room area	
			Light Transmittance	TL		consider glass specifications in modelling	
	Vista al Exterior (Views Out)	(no definition)	layers		75% of regularly occupied areas must access views out	sky or green area	
Green Star Rating (Green Building Council South Africa) (n.d.) *"This is a voluntary certification of buildings by the Green Building Council South Africa on application related primarily to Energy Consumption"*	Indoor Environmental Quality	(no definition)	Daylight Factor	DF		no less than 1.5%	**NON MANDATORY**
			Daylight Illuminance			no less than 150 lux	
Circolare Ministeriale Lavori pubblici n. 3151, May 22 1967 (Italy)		(no definition)	Average Daylight Factor	DF_{avg}	the area of glass surfaces must not exceed the value in order that the average daylight factor	DFm must be greater or equal than 6%	**MANDATORY**
Circolare Ministeriale n. 13011, November 22, 1974 (Italy)		(no definition)	Average Daylight Factor	DFavg	For healthcare buildings	at least 0,03 in rooms for hospitalization, 0,02 in canteens and gyms and 0,01 in offices, distribution spaces ans stairs	**MANDATORY**
Decreto Ministeriale July 5th, 1975, Modificazioni alle istruzioni ministeriali 20 giugno 1896 (Italy)		(no definition)	Average Daylight Factor	DFavg	For scholar buildings	3% in classrooms for lessons, study, reading, laboratories, drawing, etc; 2% in gym and canteen; 1% in offices, corridors, stairs, toilets, connecting spaces	**MANDATORY**
			window-to-floor ratio	WFR	Openable surface of windows in the case of premises (shops, stores…) not intended for residential use	1/8 of the useful area if the room area ≤ 100m²	
						1/10 of the useful area, with a minimum of 12,5m², if the area 100 ≤ x ≤ 1000 m²	
						1/12 of the useful area of the room, with a minimum of 100m², if the area is ≥ 1000m²	
Decreto Ministeriale December 18, 1975. Norme tecniche aggiornate relative all'edilizia (Italy)		(no definition)	Average Daylight Factor	DFavg	in classrooms for lessons, study, reading, laboratories, drawing, etc	3%	**MANDATORY**
					in gym and canteen	2%	
					in offices, corridors, stairs, toilets, connecting spaces	1%	
Decreto Legislativo 9 aprile 2008, n 81 (Italy)		(no definition)	-	-	measures to be adopted to preserve safety in working places; unless required for the working activities or in case of underground spaces, the working places must have sufficient daylight. And in any cases, all working places must have fixtures to provide adequate electric lighting for safety, health and well-being of workers.		**MANDATORY**
Building regulation, D.C.R. 28 November 2017 n. 247-45856 (Turin, Italy)		In residential buildings, all rooms, with the exception of bathrooms, access rooms, corridors, storage rooms, and stairwells, must directly receive air and daylight.	Average Daylight Factor	DFavg	In residential buildings, all rooms, with the exception of bathrooms, access rooms, corridors, storage rooms, and stairwells, must directly receive air and daylight	window size has to be defined to ensure an DFm not below 2%	**MANDATORY**
			window-to-floor ratio	WFR	opening window surface	≥ 1/8 of the floor surface	

Energy Code Annex to Building Regulations (Turin, Italy) *(under review)*	Daylighting	In order to reduce the energy consumption and the environmental impacts of buildings and to improve indoor environmental comfort.	Average Daylight Factor	DFavg	average Daylight Factor ≥ 3% for all main spaces (with the exception of service spaces such as bathrooms, corridors, storage rooms, cellars....) and it is considered achieved only if the requirement for transparent surfaces summer shading is at the same time respected	The assigned rating is: DFm ≥ 3% = 3 points DFm ≥ 4% = 5 points	**MANDATORY**
Campania, Italy		In residential buildings, all rooms, with the exception of bathrooms, access rooms, corridors, storage rooms, and stairwells, must directly receive air and daylight.	Average Daylight Factor	DFavg	In residential buildings, all rooms, with the exception of bathrooms, access rooms, corridors, storage rooms, and stairwells, must directly receive air and daylight.	DFm not below 2%	**MANDATORY**
			window-to-floor ratio	WFR	opening area of windows	≥ 1/8 of the floor surface	
Minimum Environmental Criteria – Buildings (CAM – EDILIZIA 2022) (Italy)	Daylighting	As regards residential destinations, the illuminating surfaces of the living area (living rooms, dining rooms, living kitchens and similar rooms) must be oriented from EAST to WEST, passing through SOUTH.	Average Daylight Factor	DFm	must be guaranteed in renovations/ restoration/ conservative projects	> 2%	**MANDATORY**
			Illuminance in space and time		projects of urban renovation, new construction and demolition and reconstruction, for any intended use (excluding those for which sector-specific rules and reference levels of natural lighting exist such as operating theatres, radiological rooms, etc. excluding nursery schools, kindergarten, elementary and junior/high schools)	at least 300 lux in at least 50% of measuring points in the room; minimum of 100 lux in 95% of measuring points inside the room for 50% of daylight hours	
					For elementary and junior/high schools	at least 500 lux in at least 50% of measuring point in the room; minimum of 300 lux in 95% of measuring points inside the room for 50% of daylight hours	
					For nursery schools and kindergartens	at least 750 lux in at least 50% of measuring point in the room; minimum of 500 lux in 95% of measuring points inside the room for 50% of daylight hours	
Regulation No. 268/2009 about technical requirements for buildings (Czech Republic)		(no definition)	Sunlight duration			At least 1.5 hour on March 1st or balance of sunlight duration in the period from February 10th to March 21st is at least 1,5 hour ; solar altitude is at least 5°	**MANDATORY**
RT I: 2002 - Ehitusseadus (Building Code) (Estonia)		(no definition)	Sunlight duration			3 hours of sunlight during the summer months, i.e. April 22nd to August 22nd	**MANDATORY**
Regulation No. 259/2008 of the Ministry of Health of the Slovak Republic; Regulation No. 532/2002 of the Ministry of Environment of the Slovak Republic (Slovakia)		(no definition)	Sunlight duration			At least 1.5 hour in low densely area and at least 1 hour in high densely area in the period March 1st to October 13th, (3 hours is recommended); Insolation between 10:00 - 15:00 in the play rooms in building for child care; Solar altitude is at least 5°.	**MANDATORY**
The Building Regulations 2010 - March 2023 compilation of individual approved documents (UK)	Thickness of walls in certain small buildings	(no definition)	Window sizes		one or two major openings	not higher than 2.1m and total width (one or two combined openings) should not exceed 5m	**MANDATORY**
			Window sizes		standard window	1.23m wide × 1.48m high	
	New elements in existing dwellings, including extensions	(no definition)	opening areas		sum of windows, roof windows, rooflights and doors areas for a dwelling	should not exceed 25% of total floor area of the dwelling	
			area of windows		Newly constructed dwellings	should not exceed 25% of total floor area of the dwelling	
	Limiting solar gains	(no definition)	minimum light transmittance			0.7	

	Limiting solar gains	(no definition)	overhang obstruction angle		cut-off on due south-facing façades only	50° altitude	
	Lighting	(no definition)	Daylight Dependency Factor	F_D	LENI component	If no daylight-linked dimming system is used, then Fd = 1. If the electric lighting dims in response to daylight being available, then in areas with adequate daylight Fd = 0.8.	
Right to Light Law (UK) (2014)		(no definition)	Sky Factor	SF	The ratio of the illuminance directly received from a uniform sky at the point indoors, to the illuminance outdoors under an unobstructed hemisphere of this sky. No allowance is made for glass losses or light blocked by glazed bars and (usually) window frames; nor is reflected light included, either from interior surfaces or obstructions outside	If more than half a room has a sky factor of less than 0.2%, then the room as a whole is inadequately lit	**MANDATORY**
NEN 2057:2011: Building Code 2012 (The Netherlands)		(no definition)	minimum 'equivalent aperture surface area'	A_e / WFR	The Ae describes a percentage of how much aperture surface area is required for any occupied space: the initial requirement varies per function. If there are obstructions (i.e. overhangs) the 'equivalent aperture surface area' is reduced by a given factor. NEN 2057:2011 describes the methodology including the reductions factors per obstruction type.	10% for residential functions, 5% for children daycare, 3% for penitentiary functions, 5% for healthcare, 2,5% for offices, 5% for educational functions. All surface areas reduced by obstruction.	**MANDATORY**
			Minimum aperture surface area	A_{min}	The minimum aperture surface area per occupied space (not reduced).	0,5 for all functions, except penitentiary cells (0,15)	
G7 Natural Light Acceptable Solution G7/AS1 (New Zealand)	Illuminance of habitable spaces	(no definition)	Illuminance		For habitable spaces of housing, old people's homes, and early childhood centres, natural light shall provide an illuminance	no less than 30 lux at floor level for 75% of the standard year.	**MANDATORY**
			area of glazing		Input parameter for opening on external walls	no less than 10% of floor area	
			visual light transmittance	VLT	Input parameter for openings on external walls	no less than 70%	
			head height		Input parameter for openings on external walls	1/2 (one side window) or 1/4 (both sides) of room width	
	Awareness of the outside environment	(no definition)	area of glazing		For habitable spaces of housing, old people's homes, and early childhood centres, openings to the outside shall have an area of transparent glazing suitable to give awareness of the outside.	At least 50% of the area of glazing provided for natural light in habitable spaces shall be transparent glazing	
			Window sizes			Shall be located in the zone between the levels 90cm and 200cm from floor	
G7 Natural Light Acceptable Solution G7/AS2 (New Zealand)	Illuminance of habitable spaces	(no definition)	Illuminance		For habitable spaces of housing, old people's homes, and early childhood centres	no less than 30 lux at floor level for 75% of the standard year	**MANDATORY**
			glazing-to-wall ratio	GWR	Input parameter to the maximum permitted room depth table. There are nine glazing-to-wall ratios (GWRs) included in the maximum room depth table (2.1.4.1)	10%, to 90%. The closest GWR value to the actual room GWR from this list shall be chosen for utilizing the table 2.1.4.1.	
			visible light transmittance	VLT	Input parameter to the maximum permitted room depth table. Five visible light transmittance (VLT) values are represented in the maximum permitted room depth table. VLT values shall be derived from the actual glazing specifications for the building	40%, 50%, 60%, 70, and 80% for different glazing types	
			overhang obstruction angle	OOA	Input parameter to the maximum permitted room depth table. Three overhang obstruction angles (OOAs) are included in the maximum permitted room depth table. The closest value to the actual building OOA value shall be used	0°, 15°, and 30°	
			average exterior obstruction angle	AEOA	Input parameter to the maximum permitted room depth table. There are three ranges of average exterior obstruction angle (AEOA) values in the maximum permitted room depth table. AEOA can be determined from the average urban construction height in metres, the height of the building floor level above ground, and the distance between neighbouring buildings.	For ≥ 0° to < 20°, and For ≥ 20° to < 40°, and For ≥ 40° to ≤ 60°.	
	Awareness of the outside environment	(no definition)	area of glazing		For habitable spaces of housing, old people's homes, and early childhood centres, openings to the outside shall have an area of transparent glazing suitable to give awareness of the outside.	At least 50% of the area of glazing provided for natural light in habitable spaces shall be transparent glazing	
			Window sizes			Shall be located in the zone between the levels 90cm and 200cm from floor	
	Illuminance of habitable spaces	(no definition)	Daylight Factor	**DF**	For habitable spaces of housing, old people's homes, and early childhood centres, natural light shall provide an illuminance of no less than 30 lux at floor level for 75% of the standard year	Auckland - DF 0.26 Wellington - DF 0.32 Christchurch - DF 0.27 Invercargill - DF 0.34	

G7 Natural Light Verification Methoc G7/VM1 (New Zealand)	Awareness of the outside environment	(no definition)	area of glazing			a) 5% of the floor area of the space, (where there is no habitable space borrowing light); or b) 5% of the total floor area of the space and the floor area of any adjacent habitable space that is borrowing natural light via the space;	**MANDATORY**
			Window sizes		For habitable spaces of housing, old people's homes, and early childhood centres, openings to the outside shall have an area of transparent glazing suitable to give awareness of the outside	shall be located in the zone between the levels 90cm and 200cm from floor level	
Natural Lighting Regulation - Building Standards Act (Japan)		(no definition)	Window-to-floor Ratio		the ratio of the opening area effective for daylighting to the floor area in houses, sickrooms of hospitals and clinics, bedrooms or dormitories and boarding houses;	shall not be less than 1/7	
					area of windows necessary for a living room in a house that is effective for daylighting	**at least 1/7**	
					if measures are taken to ensure the installation of lighting equipment or effective daylighting methods	**can be up to 1/10**	
					... In classrooms of kindergartens and elementary-, junior-high-, high-, and other compulsory education schools	shall not be less than 1/5	
					... In classrooms of other types of schools	shall not be less than 1/10	
Building Technical Regulations (TEK17) with guidance (Norway)	Light	The lighting conditions are of great importance for human health and well-being and is crucial for how fast and safely we can carry out a work	Minimum sizes of windows	linear size	minimum height	0.6 m	**MANDATORY**
				linear size	minimum width	0.5 m	
					minimum sum of height and width	1.50 m	
			Daylight Factor	DF	rooms permanently occupied by people must have adequate access to daylight; simulations should be performed with the assumptions from NS-EN 12464-1:2011	2%	
	View out	View is important and sought-after quality with great importance for how the indoor environment is experienced.	layers		In densely build-up areas	it is sufficient to have a view of rows of houses, streets, backyards and the like	
			sill height		Room for permanent stay must have a window that gives satisfactory view out; in residential, work and public buildings, all rooms of permanent occupation must have at least 1 window w/ satisfactory view	min. 1m above floor	
The Regulation of the Minister of Infrastructure on the technical conditions to meet by building and their location (2002) (Poland)	Lighting and insolation	Rooms intended for human occupation should be lit by the daylight illumination, adjusted for its intended use, shape and size, considering the requirements in § 13 as well as general health and safety rules.	window-to-floor ratio	WFR	in permanently occupied rooms	WFR at least 1/8	**MANDATORY**
			window-to-floor ratio	WFR	in any other rooms where daylight is required	WFR at least 1/12	
			Exposure to Sunlight		in rooms for children, nurseries, schools, during equinox days between 8am and 4pm	at least 4h	
					residential rooms, in equinox days from 7am to 5pm	at least 3h	
					in the city centre development	no shorter than 2h	
			Setbacks from plot's boundaries		a distance from the border to a neighbouring building plot	4.0m (façades with windows) 3.0m (façades without windows)	
			obstruction angle			max 40° (60° free of obstructions)	
			Height to width		ratio between the building height and the width of the distance between buildings	§ Art.13 of specifies the conditions for distances between buildings to guarantee access to daylight: D ≥ H for obstructing objects no higher than 35m; D ≥ 35 m for obstructing objects higher than 35m. For downtown infill buildings, the distance (D) can be decreased by half. Where: H is the obstructing height and is counted from: the lower edge of the lowest windows in the obstructed building to the level of the highest edge of the obstructing object.	
OIB-Richtlinie 3: Hygiene,			window-to-floor ratio	WFR		min. 12,5%, 15% with obstruction; +1% more at each 1m past 5m of room width	
			angle of visible sky		vertical angle	max 30°	

health and environmental protection (2019) (Austria)		(no definition)	obstruction angle		horizontal angle	max 45° of obstruction	**MANDATORY**
			distance to windows			2m distant from obstructions in all rooms	
			distance from windows		unobstructed views from openings	**6m at least 1 flat's window**	
Elementary requirements in terms of safety, health and equipment of housing RRU Title II (Regulations Region of Town Planning) (2021) (Belgium)		(no definition)	window-to-floor ratio	WFR	for bedrooms	min. 1/12; min. Area 1m²	**MANDATORY**
			distance from windows		unobstructed views from openings	distant 3m from obstructions	
Rulebook of minimal technical conditions for design and construction of apartments from the Socially Establishment Program (2011) (Croatia)		(no definition)	window-to-floor ratio	WFR	residential buildings	min. 1/7 floor area	**MANDATORY**
253/1997. (XII. 20.) Government decree on the national settlement planning and construction requirements (Hungary)		(no definition)	window-to-floor ratio	WFR		1/6 for schools; 1/10 in permanent occupied rooms ; 1/12 in rooms w/ roof openings	**MANDATORY**
			Exposure to Sunlight		at least 1 residential space in february 15	1h	
Ireland Building Regulations 2020 – Technical Guidance Document, Department of Housing, Planning and Local Government (Ireland)		(no definition)	window-to-floor ratio	WFR	In rooms intended for work, the appropriate amount of daylight is defined as the ratio of the window area to the floor area	at least 10% for standard windows	**MANDATORY**
						7% for roof windows	
			Daylight Factor	DF	for rooms to be be considered that the lighting conditions are adequate	2%	
Executive order on building regulations 2018 (BR18) (Denmark)	View of the surroundings	(no definition)			Working rooms, living rooms, teaching rooms, etc must be equipped with windows which provide a view of the surroundings. Windows and sun screening must be planned and implemented to ensure a view to the surroundings for a satisfactory part of the usage time.	(no angles, layers or distances)	
	Sufficient access to daylight	Access to daylight to an extent which ensures sufficient lighting of the rooms.	window-to-floor ratio	WFR	Work rooms, living spaces in institutions, teaching rooms, dining rooms, in the following referred to as working rooms, etc. and living rooms and kitchens must have access to daylight to an extent which ensures sufficient lighting of the rooms.	**minimum 10% of the relevant floor area**	
			Minimum illuminance by area by time			proof that lighting intensity from daylight is 300 lux or by for minimum half to the relevant floor area for minimum half of the daylight hours	
						Windows must be established, placed and possibly shielded to ensure that direct **sunlight does not cause overheating of the rooms and to prevent nuisance** from direct sun radiation	
			Maximum height		For detached single-family houses, two-family houses with horizontal separation lines and semidetached houses with vertical separation lines	1.40 metres x the distance to boundaries to neighbouring plots and paths	
			Setbacks		from plots' boundaries to neighbours, roads and paths	min.: 2.50 m	

BUIDING AND URBAN CODES / REGULATIONS

	Building Right	Right to erect buildings on a plot	Building's ratio		The buildings ratio is defined as the floor area as a percentage of the plot area, and it serves to ensure that the plot is developed in accordance with the use stated in the application.	1) 60% for multi-storey buildings; 2) 40% per cent for fully or partly integrated single family houses, including semi-detached houses, terraced houses, houses attached via outbuildings, etc. and similar low, adjacent buildings; 3) 30% for detached single- and two-family houses with horizontal separation lines located in an area comprised of detached family houses; 4) 15% for holiday homes; 5) 45% for other buildings, including buildings covered by para (1) - (4) and multi-storey buildings in areas not zoned for that purpose.	
Code de la construction et de l'habitation (2021) (France)		(no definition)	window-to-floor ratio	WFR	window surface/floor area; rooms must have na opening area and transparent surface to the exterior	1/6	**MANDATORY**
			Target Illuminance	E_T		300 lx 50% area 50% daylight hours	
			Minimum Target Illuminance	E_{Tmin}		100 lx 95% area 50% daylight hours	
			layers		at least 1 residential space	sky and horizon view in at least 1 residencial space	
Articles R4213-1 à 4 Créé par Décret n°2008244 - Labor Code - Obligations of the Building Owner (2008) (France)		(no definition)	Access to daylight		mandatory for workplaces		**MANDATORY**
Article R4223-1 à 12 Créé par Décret n°2008244- Labor Code - Obligations of the Employer (2008) (France)		(no definition)	Access to daylight		mandatory for workplaces unless not compatible with the activities		
Réglementation environnementale des bâtiments neufs RE 2020 Règle TH-BCE 2020 et ThBat (2020) (France)		(no definition)	visible light transmittance	VLT		Used in calculation of electric lighting energy use	
			window-to-floor ratio	WFR		1/6 is mandatory for residential buildings (appartments and houses)	
			Daylight Factor	DF		calculated in each space, according to a modified CIBSE formula from geometric parameters and optical parameters of glazings	
Rules on Minimum Technical Requirements for the Construction of Apartement Buildings and Apartments (2011) (Slovenia)		(no definition)	window-to-floor ratio	WFR	Minimum area of the openings of a room	homes, schools, kindergartens: 20% offices: 12,5%	**MANDATORY**
Boverkets byggregler (BBR 29) (Sweden) (2020)		(no definition)	window-to-floor ratio	WFR	General window area through simplified method	at least 10% of floor area to reach DF 1%	**MANDATORY**
			Daylight Factor	DF	Reached by windows according to the specified method, as well as other types of openings, even though not design according to the method	1%	
Código Tecnico de la Edificación (CTE) (Spain) (2019)		(no definition)			Demands systems to incorporate daylight in indoor spaces, regulating the electric lighting use through dimmers or on/off drivers		**MANDATORY**
Spain: regional requirements		(no definition)	window-to-floor ratio	WFR		from 1/12 to 1/8	**MANDATORY**
Rio de Janeiro's Building	Ventilação e Iluminação dos	Spaces will be daylit and naturally ventilated through openings and	window-to-floor ratio	WFR	living rooms, bedrooms, offices, shops and other extended permanence rooms	1/8	

Construction Code (Lei Complementar n.198/2019) (Brazil)	Iluminação dos Compartimentos (Spaces' ventilation and lighting)	windows, whose areas must guarantee environmental comfot conditions, according to their function.	window-to-floor ratio	WFR	kitchens, locker rooms, dining halls	1/10	**MANDATORY**
					all spaces of extended permanence must have openings that communicate with the exterior of the buildings through windows, lightwells or balconies	all spaces of extended permanence must have views out	
Rio de Janeiro’s Law of Land Use (LUOS n.57/2018) (Brazil)	Do Controle de Ocupação (Occupancy Control)		lightwells				
			front, side and rear setbacks		Distances between the building's facade plans and the respective front, side and funds of the lots, and will have their minimum dimensions defined by the Building Construction Code.	front: min. 3.0m; lateral and rear: varying according to n. of floors	**MANDATORY**
Brasília's Building Construction Code (Lei n.6138/2018) and Annex IV of Decree 39272/2018 (Decreto n.39.272/2018)	Dos Parâmetros Edilícios Gerais e dos Usos da Edificação (General building parameters and building uses)	(no definition)			all non-residential premises must have a extended permanence rooms with daylighting and ventilation opening to the exterior		**MANDATORY**
					residential's extended permanence rooms must have daylighting and ventilation openings to the public places, mandatory leaves of daylighting/ventilation lightwells		
	Iluminação e Ventilação (Lighting and Ventilation)	(no definition)	Lightwell for daylighting and ventilation - plot area ≤ 600 m2		rooms of extended permanence, according to height of building (a)	a ≤ 8.50 = 1.50m; 8.50 < a ≤ 12.00 = 3.00m; 12.00 < a ≤ 35.00 = 5.00m; 35.00 < a ≤ 55.00 = 7.50m; a > 55.00 = 10.00 m	
					rooms of transitory permanence, according to height of building (a)	a ≤ 8.50 = 1.50m; 8.50 < a ≤ 12.00 = 1.50m; 12.00 < a ≤ 35.00 = 2.50m; 35.00 < a ≤ 55.00 = 4.00m; a > 55.00 = 5.00 m	
			Lightwell for daylighting and ventilation - plot area > 600 m2		rooms of extended permanence, according to height of building (a)	a ≤ 8.50 = 1.50m; 8.50 < a ≤ 12.00 = 3.00m; 12.00 < a ≤ 25.00 = 5.00m; 25.00 < a ≤ 40.00 = 7.50m; 40,00 < a ≤ 60,00 = 10.00m; a > 60,00 = 11.00m.	
					rooms of transitory permanence, according to height of building (a)	a ≤ 8.50 = 1.50m; 8.50 < a ≤ 12.00 = 1.50m; 12.00 < a ≤ 25.00 = 2.50m; 25.00 < a ≤ 40.00 = 4.00m; 40,00 < a ≤ 60,00 = 5.00m; a > 60,00 = 6.00m.	
			window-to-floor ratio	WFR	for residential spaces	living rooms, bedrooms, kitchens and reversible spaces: 1/8; laundries, bathrooms and restrooms: 1/10	
			window-to-floor ratio	WFR	for common areas of residential spaces	halls, circulations, stairs, ramps, bathrooms, restrooms, hospitality bathrooms: 1/10; Staff room, classrooms, offices, shops, hospitality bedrooms: 1/8; garages: 1/20	
Lei Complementar de Controle e Uso do Solo (LCCU) de Belém/PA (1999) (Brazil)	Ocupação (Occupancy)	(no definition)	front, side and rear setbacks		dimensions and distance relations between the building and the divisions of land	front: min 5.0m, in residential, commericla and service buildings; min. From 5. to 10.0 m in industrial buildings	**MANDATORY**
						lateral: min. 1.5 to 2.5m in residential, commercial and service buildings; min. 1.5 to 3.0 m to industial buildings	
						rear: 3.0 to 5.0 in residential, commercial and service buildings; min. 3.0 to 10.0 m to industial buildings	
Lei n.15511 de Zoneamento, uso e ocupação do solo de Curitiba/PR (2019) e Decreto n. 1001 (2020) (Brazil)	Do Aproveitamento e da Ocupação do Solo (Land Usage and Occupancy Control)	(no definition)	setbacks from plot's boundaries		defined by urban construction models, according to building function, plot area, lot utilization coefficient, occupancy rates	regular construction zones: up to 2 floors, optional; from 2 floors on, min. 2.50m	**MANDATORY**
						in central, educational and military zones: min. 5.0 m	
Lei n. 191104 de Parcelamento, Uso e Ocupação do Solo do Recife/PE (2019) (Brazil)	Da Ocupação do Solo (Land Occupancy)	(no definition)	front, side and rear setbacks		defined by urban construction models, according to building function, plot area, lot utilization coefficient, occupancy rates — buildings up to 8 floors	front: min. 3.0 to 5.0m; lateral: min. 1.5 to 3.0m; depending on building use. Rear: formula	**MANDATORY**
					defined by urban construction models, according to building function, plot area, lot utilization coefficient, occupancy rates — buildings up to 20 floors	front: min. 7.0m; lateral: min. 3.0 to 4.0 m, depending on building use. Rear: min. 5.0m	

					defined by urban construction models, according to building function, plot area, lot utilization coefficient, occupancy rates — buildings beyond 20 floors	front: min. 7.0m; lateral: min. 5.0 m. Rear: min. 5.0m	
Código de Urbanismo e Edificações de Maceió/AL (2006) (Brazil)	Do Uso Residencial (Residential Use)	(no definition)	front, side and rear setbacks		minimum front, side and rear setbacks	front: 5.0 m; sides: 3.5 m; rear: 3.0 m	**MANDATORY**
			setbacks between buildings		for buildings up to 4 floors	5.0 m, in case there are openings in both buildings; 4.0 m in case only 1 building has openings; 3.0 m in case at least 1 building has openings only for bathrooms or both have no openings	**MANDATORY**
					buildings with 5 to 10 floors	8.0 m between buildings	
					buildings above 10 floors	double the lateral setback through formula, minus 30%	
Código de Obras e Edificações de São Paulo (COE São Paulo) (2017) (Brazil)	Disposições Técnicas - Da Implantação (Technical Provisions - Implementation)	(no definition)	setbacks from plot's boundaries		minimum distance between plot's boundaries and openings on building façade, independently of the external plot walls	min. 1.5m for openings facing boundaries min. 0.7m for openings perpendicular to boundaries	**MANDATORY**
	Das disposições de Aeração e Insolação (Ventilation and Insolation Provisions)	(no definition)	lightwells		internal uncovered free area for ventilation and insolation (área livre descoberta interna - poço interno descoberto)	If building's height H ≤ 10m, min. Lightwell area: 5m²; min. Width: 1.5m If building's height H > 10m, lightwells should correspond to a rectangle 2A x 3A (where A = setbacks dimensions)	
			front, side and rear setbacks		Setbacks for buildings higher than 10m, which may be stepped and calculated through the formula A = (H - 6)÷10	min. 3.0m	
Guía Boliviana de Construcción de Edificaciones (2015) (Bolivia)	Acondicionamento Ambiental (Environmental Conditioning)	In buildings for housing, the architectural project will consider that the habitable environments receive sunlight through vains, to provide the user with well-being and comfort.	lightwells (pozos aire - luz)		open spaces (air-light wells) to achieve good natural lighting and ventilation; These spaces should not be partially or totally roofed with ruffles, stairs, corridors or corridors.	up to 4 floors: 2m; above 4 floors: 3m (service spaces: kitchens, bathrooms, etc) up to 4 floors: 3m; above 4 floors: 4m (spaces of permanent occupancy: bedrooms, offices, stores)	**MANDATORY**
			window-to-floor ratio	WFR	free of obstacles	20%	
			distance from windows		direct views must be distant from the windows	min. 2m	
Código de Urbanismo Y Obras - Gobierno Autónomo de Santa Cruz de La Sierra - TOMO III (2018) (Bolivia)	Iluminación y Ventilación de los Espacios Internos (Lighting and Ventilation of Indoor Spaces)	Regardless of their category of architecture typology, indoor spaces should have direct and natural lighting and ventilation.	window-to-floor ratio	WFR	for "first category" openings free of coverings destined to daylighting and ventilation (bedrooms, living/dining rooms, offices, commercial rooms, etc)	1/6	**MANDATORY**
			window-to-floor ratio	WFR	for "second category" openings free of coverings destined to daylighting and ventilation (kitchens, service rooms, etc)	1/8	
			window-to-floor ratio	WFR	for "third category" openings free of coverings destined to daylighting and ventilation (bathrooms, restrooms, stairs, indoor corridors, laundries,hallways, technical rooms, patios, etc)	1/10	
			window-to-floor ratio	WFR	for underground rooms	at least 5% of floor area for daylighting; each additional underground floor must increase 5% to the previous opening area	
			window-to-floor ratio	WFR	restaurants	10%	
			window-to-floor ratio	WFR	for side and roof openings in offices	1/5	
Workplace directive - ASR A3.4 Lighting (2023) (Germany)	Visual connection to the outside	(no definition)	Window sizes		size, position and characteristics of windows	(no values)	**NON MANDATORY**
	Sufficient daylight	(no definition)	Daylight Factor	DF	Sufficient daylight at the workplace	2%	
	Measures to limit glare	(no definition)			"glare needs to be prevented or minimised"		
Turkish National Building Regulation (2023)		(no definition)	Window-to-wall Ratio	WWR	should vary according to HVAC systems	(no values)	**MANDATORY**
GB 55016:2021 - General code for building environment (China)		(no definition)	Daylight Factor	DF		(no values)	**MANDATORY**

General Urban Planning and Construction Ordinance - OGUC (Chile) (2020)	Del agrupamiento de los edificios y su relación con el suelo (Of the grouping of the buildings and their relationship with the ground)	(no definition)	Height of building x Distance to the offset (Altura de la Edificación x Distanciamiento)		distances according to the existence, or not, of openings	Buildings' height... ≤ 3.5m: w/ window 3m; w/out window 1.4m 3.5m < H < 7m: w/ wind. 3m; w/out wind. 2.5m ≥ 7m: w/ wind. 4m; w/out wind. 4m	MANDATORY
			Grazing angle (Angulo de las Rasantes)		distance to the offset and grade of the building; the grazing angle considered with respect to the horizontal plane and distinguished by region / climatic zone	no less than 45° north 80°, center 70°, south 60°	
	De las condiciones de habitabilidad (habitability conditions)	(no definition)	Distance to windows		specially in bedrooms	1.5m	
			superficie máxima de ventanas (maximum window area)		considers zone of construction and glass properties (U value)	zone 1: 50% zone 2: 40% zone 3: 25% zone 4: 21% zone 5: 18% zone 6: 14% zone 7: 12%	
	Edificios de Asistencia Hospitalaria (Health assistance buildings)	(no definition)	total minimum windows area (superficie total minima de ventanas)		hospitals	1/5	
	Locales Escolares y Hogares Estudiantiles (Schools and Student households)	(no definition)	% of floor area - daylighting (% superficie del recinto - iluminación)		educational facilities, according to climatic zone	north (14%) center (17%) south (20%)	
	Exterior openings		Window sizes			height of not less than 2134 mm;	
International Building Code, International Code Council (2024) (USA)			opening percentage			longer side at least 65 percent open and unobstructed	
	Lighting - Natural Light	(no definition)	Window-to-floor ratio	WFR	minimum net glazed area	no less than 8% of floor area	
			Minimum frontage distance		open space adjacent to the building perimeter	min. 6096 mm (20ft)	
			area factor increase		based on frontage distance	up to 25% perimeter: no increase; 25 to 50%: 0.17-0.25 area increase; 50 to 75%: 0.33-0.50 area increase; 75 to 100%: 0.50-0.75 area increase;	
2020 Energy Conservation Construction Code of New York State (ECCCNYS) (USA)	Fenestration		fenestration area		fenestration area, not including opaque doors and spandrel panels	not greater than 30% of gross wall area for skylight, not more than 3% of gross roof area	MANDATORY
			visible transmittance	VT		minimum: 0.2 clear glass: 0.6 tinted glass: 0.3 glazed block: 0.6	
	Sidelit zone		Minimum window area		minimum fenestration area	no less than 2.23m^2	
Arizona Manufactured Home Construction and Safety Act (USA) (2021)	Light and ventilation	(no definition)	Window-to-floor ratio	WFR	to a simple space	no less than 8% of floor area	MANDATORY
			Window-to-floor ratio	WFR	to a combination of spaces for daylighting purposes	no less than 10% of floor area OR 25 ft^2	
California Code of Regulations - Building Energy Efficiency Standards (USA) (2022)	Light and ventilation		Window-to-floor ratio	WFR	to skylights in non-residential spaces	at least 3%	MANDATORY
			visible light transmittance	VLT	to skylights in non-residential spaces	no less than the applicable value required by Section 140.3(a)6D	
			Window sizes		To qualify for a Power Adjustment Factor (PAF) (clerestory fenestration)	at least 10 feet above the finished floor	
			Window-to-wall Ratio	WWR	To qualify for a Power Adjustment Factor (PAF) (for windows with Interior and Exterior Horizontal Slats)	20-30%	
			Window-to-wall Ratio	WWR	Interior and Exterior Light Shelves, to qualify for a PAF	greater than 30%	
			Window-to-wall Ratio	WWR	to west-facing exterior areas	no more than 40%	

			visible light transmittance	VLT	Vertical fenestration minimum VLT, for non-residential buildings, climate zones from 1-16	Fixed windows: 42% Curtainwall or Storefront: 46% Operable Window: 32% Glazed Doors: 17%	
			Skylight Roof Ratio	SRR	Skylights areas related to roof area	no greater than 5%	
National Energy Code of Canada for Buildings (2020)			Window sizes	area	for skylights	shall be less than 2% of the gross roof area	**MANDATORY**
			Window sizes	area	head height impacts on the calculation of the ***sidelighted*** areas of rooms		
			Installed Interior Lighting Energy	IILE	total annual energy consumption of interior lighting in all spaces of the proposed building; account the daylit area of rooms		
			Interior Lighting Energy Allowance	ILEA	the maximum allowed annual energy consumption of all interior lighting complying with the		
			Factor for Daylight Harvesting	$F_{DL,i}$	a combination of "daylight supply factor", "daylight system control factor" and "daylight-dependent control factor for electric lighting" (component of IILE and	values of each component given by Tables 4.3.2.7.-A; 4.3.2.7.-B; 4.3.2.8.; 4.3.2.9.-A	
			Daylight Supply Factor	$C_{DL,sup,i}$	contribution of daylight in the calculations of IILE and ILEA	defined by Table 4.3.2.8. for the four cardinal directions only	
			effective luminous transmittance	$\tau_{eff,i}$	effective luminous transmittance of the fenestration providing sidelighting		
California Building Code - Title 24, vols. 1 & 2 (2022) (USA) (ICC)	Lighting	Every space intended for human occupancy shall be provided with natural light by means of exterior glazed openings (...)	Window-to-floor ratio	WFR	minimum net glazed area	no less than 8% of floor area	**MANDATORY**
			Window-to-floor ratio	WFR	to adjoining spaces with half of common area opened and unobstructed	min. 10% or 25sq ft or 2.32m² (whichever is greater)	
			Window-to-floor ratio	WFR	windows open to a sunroom	min. 10% or 20 sq ft or 1.86m² (whichever is greater)	
National Electric Code 2021 (Canada)	Lighting	(no definition)	head height		influences daylighting control for certain space uses		**MANDATORY**
British Columbia Building Code (2024) (Canada)	Egress Windows or Doors for Bedrooms	(no definition)	Minimum opening area		for rooms combinated for lighting and ventilation	2 m²	**MANDATORY**
			Maximum height of openings		for fire escaping	not higher than 1.5m	
			Maximum glazed area		according to Exposed Building Face (EBF) exposed to outside façade portions with setbacks from plot's boundaries	setback ≤ 2m: max. Glazed area = 10% setback ≤ 6m: max. Glazed area = 57% setback ≤ 8m: max. Gazed area = 100%	
National Construction Code (NCC) (Australia) (2022)	Natural Lighting	Sufficient openings must be provided and distributed in a building, appropriate to the function or use of that part of the building	Average Daylight Factor	DFavg		not less than 2%	**MANDATORY**
			Average Daylight Factor	DFavg	also calculated through the formula: DFavg = W/A . To/(1 - R²); for habitable residential rooms, childcare	depends on WWR (W/A), VLT, visible sky angle	
	Methods and extent of natural light	(no definition)	Window-to-floor ratio	WFR	side windows without obstructions	min. 10%	
			Window-to-floor ratio	WFR	rooflights without obstructions	min. 3%	
			setbacks		for windows opened to walls of the same or another building	no less than 1m	
			setbacks		for windows opened to walls of the same or another building, for patient care spaces	no less than 3m	
			setbacks		in habitable spaces	50% of the square root of the exterior height of the wall in which the window is located, measured in metres from its sill.	
			window sizes		window sill in aged care building	not more than 1 m above the floor level	
			window sizes		window sills in early childhood care spaces	not higher than 500mm above floor	
			window-to-floor ratio	WFR	for spaces with natural light borrowed from adjoining room (windows)	not less than 10%	
			window-to-floor ratio	WFR	for spaces with natural light borrowed from adjoining room (roof openings)	not less than 3%	
Unified Building Law n.119/2008 and Ministerial Decree no.114/2009 (Egypt)		(no definition)	window-to-floor ratio	WFR	for dwelling rooms	8%	**MANDATORY**
			window-to-floor ratio	WFR	service spaces (toilets, kitchens, bathrooms, stairwell)	10%	
DAYLIGHT REQUIREMENTS (NON VISUAL EFFECTS)							

STANDARDS	**CIE S 026/E:2018: system for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light (Europe)**		(no definition)	Melanopic Equivalent Daylight Illuminance	mEDI or M-EDI	Equivalent illuminance for the melanopic photoreceptor in the human eye		
	NBR 15.215-3 (2024) (Brazil)	Luz como estímulo não visual (Daylight as a non-visual stimulus)	Non-visual stimuli are those related to the circadian potential, mediated by the capacity of optical radiation to stimulate photoreceptors of photosensitive cells containing melanopsin (ipRGCs) in humans.	Circadian Stimulus	CS	Characterizes a light stimulus as it affects human melatonin suppression and the human circadian system more broadly	≥ 0,30 (if only electric light) (WELL v 2.1); ≥ 0,30 (min. 2h mornings), ≥ 0,20 (5 to 7pm), ≥ 0,10 (after 8pm) (UL 24480)	
				Equivalent Melanopic Lux	EML	Measures the stimulation of the photoreceptors involved in the non-visual effects of light (the ipRGCs, with a maximum at 490nm) compared to the traditional vision ones (the cones, maximum at 555nm).	Minimum 150 EML / Optimal 240 EML (if only electric light); Minimum 120 EML / Optimal 180 EML (electric light if daylight driteria are complied) (WELL v 2.1 and UL 24480); ≥ 250 (6am to 7pm); ≤ 10 (3h before sleep from 7pm to 10pm); ≤ 1 (after 10pm)	
				Melanopic Equivalent Daylight Illuminance	mEDI or M-EDI	Equivalent illuminance for the melanopic photoreceptor in the human eye	≥136 (minimum) to 218 (optimal) if only electric light; ≥109 (minimum) to 163 (optimal) with electric light if given daylight criteria are complied; ≥ 218 (min.) if only electric light; ≥ 163 with electric ligh if daylight criteria are complied; (WELL v 2.1) ≥ 250 (6am to 7pm); ≤ 10 (3h before sleep from 7pm to 10pm); ≤ 1 (after 10pm) (UL 24480)	
				Photopic Illuminance			≥ 500 from 7am to 4pm (UL 24480);	
	IES RP-46, Supporting the Physiological and Behavioral Effects of Lighting in Interior Daytime Environments (2023) (USA)		(no definition)	Melanopic Equivalent Daylight Illuminance	mEDI or M-EDI	for daytime illuminance	250 lux	
	ISO/CIE DIS 8995-1:2023 Light and Lighting - Lighting for Workplaces. Part 1: Indoors	ipRGC-influenced responses to light	The stimulation of the ipRGCs shall be quantified using the melanopic Equivalent Daylight Illuminance (melanopic EDI or mel EDI)	Melanopic Equivalent Daylight Illuminance	mEDI or M-EDI	The melanopic EDI resulting from a light source shall be calculated by multiplying the melanopic DER of the light source by the photopic illuminance as produced by the light source on the eye of the occupant or by correcting the luminous flux of the light source/luminaire to reflect the melanopic DER of the light source/luminaire for a calculation which directly outputs the melanopic EDI	Throughout the daytime, the recommended minimum melanopic EDI is 250 lx at the eye measured in the vertical plane6). If available, daylight should be used in the first instance to meet these levels.	
			The melanopic efficacy of the luminous radiation from a light source or lighting installation, shall be quantified using the melanopic Daylight Efficacy Ratio (melanopic DER or mel DER)	Melanopic Daylight Efficacy Ratio	melanopic DER or mel DER			
RATING SYSTEMS	**Well v 2.1 (2024)**	Circadian Light Design	Support circadian and psychological health through indoor daylight exposure and outdoor views.	Equivalent Melanopic Lux	EML	Measures the stimulation of the photoreceptors involved in the non-visual effects of light (the ipRGCs, with a maximum at 490nm) compared to the traditional vision ones (the cones, maximum at 555nm).	At least 150 EML - 1 point At least 275 EML - 3 points	
				Circadian Stimulus	CS	Characterizes a light stimulus as it affects human melatonin suppression and the human circadian system more broadly	≥ 0,30 (if only electric light)	
				Melanopic Equivalent Daylight Illuminance	mEDI or M-EDI	defines how many lux of light of a given source are needed to obtain the same melanopic response as if it was from daylight	At least 136 M-EDI - 1 point At least 250 M-EDI - 3 points	
	BCA Green Mark (Singapore) (2021)	Circadian Lighting System	Dynamic 'circadian' lighting uses dimmable, colour-tuning LEDs to give brighter and blue-enriched light in the morning middle of the day, while providing dimmer and blue depleted light later in the day.	Equivalent Melanopic Lux	EML	Recommended Colour Temperature Range during the day, using electric light. At least 3 colour shifts could be considered during the day. A recommended programme is below for a building with normal daytime occupancy. Note that the colour changes shall be gradual and recommended to be over a 1-hour period.	7am to 10am: 3500-4000K 10am to 2pm: 5000K-6500K 2pm to 5pm: 3500K-4000K 5pm onwards: 2700 -3000K	
				Melanopic Equivalent Daylight Illuminance	mEDI or M-EDI			

GUIDELINES	**Underwriters Laboratories DG 24480 (US): Design Guideline for Promoting Circadian Entrainment with Light for Day-Active People (2019)**	Circadian entrainment - calculation procedures	(no definition)	Circadian Stimulus	CS	Characterizes a light stimulus as it affects human melatonin suppression and the human circadian system more broadly. The calculated effectiveness of the spectrally weighted irradiance at the cornea from threshold (0.1) to saturation (0.7), assuming a fixed duration of exposure of one hour	≥ 0,3 for at least 2 hours, from 07 a.m. to 4 p.m. ≤ 0,2 from 05 p.m. - 07 p.m. ≤ 0,1 after 08 p.m.	

ANNEX III: ARTICLE PUBLISHED IN CIE 30TH SESSION

DAYLIGHT REQUIREMENTS: AN OVERVIEW OF DEFINITIONS, PROGRESS AND GAPS

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Abstract

Daylight is fundamental in the built environment. Requirements define, describe, and measure the behavior of daylight. This article conducts a systematic literature review that aims to investigate daylight metrics and requirements in documents regarding buildings, such as standards, regulations, rating systems, guidelines, and building and urban codes to track their progress over time and the remaining gaps. The results show a lack of studies approaching daylight requirements in building and urban codes, regulations and guidelines, showing a gap between research and design practice. There is an evolution on time from static to dynamic metrics as requirements found in international standards and rating systems. Static metrics are still present on some of these documents, but dynamic metrics provide more accurate evaluations. Finally, Spatial Daylight Autonomy and Target Illuminance have similar concepts, as well as Annual Sunlight Exposure and Exposure to Sunlight, which suggests a possible harmonisation in an international context.

Keywords: Daylight requirements, Rating systems, Standards, Regulations, Guidelines, Regulations, Building and urban codes.

1 Introduction

Daylight is essential to human life for many reasons (Fathy et al., 2020). Basically, it's effects are divided between visual and non-visual, where visual effects refer to visibility itself (Bellia and Fragliasso, 2017, Li et al., 2017, Fathy et al., 2020, Knoop et al., 2020), and to non-visual effects, which concern circadian cycle regulation, as well as physical and mental health (Kruisselbrink et al., 2018; Mardaljevic 2021). In the built environment, daylight's importance is evidenced by the capacity to achieve energy efficiency, reduce costs and emissions of greenhouse gases, and promote healthier buildings (Mantzourani et al., 2020). However, design embodying daylight is complex: it requires a wide comprehension of how it affect spaces, which is not always clear, neither during education, nor in practical experience (Bellia and Fragliasso, 2017, Kruisselbrink et al., 2018, Lo Verso et al., 2021, Mardaljevic, 2021).

Daylight requirements embrace the necessities linked to natural light in the built environment, whether to develop specific visual tasks or to obtain non-visual effects. The word "metric" refers to a mathematical combination of quantities, dimensions, and representative conditions in a continuous scale that, at times, may not be directly measured on field (Mardaljevic et al., 2009). Daylight metrics, a type of requirement, aim to scale and evaluate daylight in the built environment, in order to guide building design (Mardaljevic et al., 2009, Dias et al., 2018, Kruisselbrink et al., 2018, Wei et al., 2020). According to Mardaljevic et al. (2009), the best metrics have an intuitive meaning and are easily validated through field measurements.

In this context, approaches metrics and requirements regarding only visual effects of daylight, given the fact that visual and non-visual effects have very different requirements. The aim of the research is to understand which requirements are mostly used in building design, their progress along time, the remaining gaps, and their application in reference documents — such as rating systems, standards, building and urban codes, regulations and guidelines. The definitions and obligatoriness of each document used in this article are found in Table 1.

Table 1 – Reference documents searched and definitions

DOCUMENT	DEFINITION	APPLICATION
Rating systems	Systems that measure levels of performance to create ecofriendly projects (Designing buildings, 2022)	Non-mandatory
Standards	Publications with technical specifications, requirements and recommendations about quality, safety, design, construction etc. of a product; developed by international/ national organizations, professional and industry associations (Griffith University Library Guides, 2023)	Depends on the country
Guidelines	Set of policies, rules and procedures amended by the local architectural control authority, which shall act as a guidance for architectural activity (Law Insider, 2023)	Non-mandatory
Building and urban codes	Set minimum requirements for how architecture and urban planning should be designed and constructed, under the purview of state and local governments, coordinating the actions of private and public, to create meaningful places and to formulate development following technical, economic and social principles (NIST, 2022, Choy, 2023)	Mandatory
Building regulations	Guarantee buildings' safety for people in or around them, covering technical aspects of construction (Bahar, 2021)	Mandatory

This article is aligned with the Commission Internationale de l'Eclairage (CIE), Division 3 – Interior Environment and Lighting Design. Specifically, this paper was developed within the work of CIE Technical Committee 3-61 (TC 3-61): Review of regional daylight requirement to assess the feasibility of global harmonisation, which aims to assess the feasibility of global harmonization of daylight requirements in reference documents.

2 Method

The used method is a systematic literature review (SLR). SLRs are commonly "used to map, find, critically evaluate, consolidate and assemble the results of relevant primary studies (...), as well as identify gaps to be filled" (Dresch et al., 2015 pp. 141–142) . The method follows a replicable structure, free of biases, in which search strings are carried out through databases to find relevant articles (Dresch et al., 2015; Kugley et al. 2017).The search used three main databases: Scopus, Web of Science (WoS) and Google Scholar, choosing papers published in journals from 2015 to 2022. The results found in WoS were the same as those found in Scopus. Only in Google Scholar, keywords were translated to Brazilian Portuguese, in an attempt to verify the existence of any specificities within a familiar context to researchers. The first criterion to select articles was open access, since not all articles found were freely available.

Beyond the 41 selected papers in the databases, 16 other articles were added to this SLR: 6 were recommended by members of CIE TC 3-61, and the remaining 10 were found through search in other articles' references — which were considered even though were published before the defined time frame, due to the relevance to the theme. Those articles were the ones that first introduced and discussed many of the today's most known daylight metrics, climate-based analysis and simulations. The search strings and the first selection of articles, defined according to Kugley et al. (2015), are summarized in Table 2.

Table 2 – Summary of search strings in databases

STRINGS	DATABASES/KEYWORDS	RESULTS	SELECTED
1st	Scopus/Web of Science (TITLE-ABS-KEY) "daylight metrics" AND "standards"	21	14
2nd	Scopus/Web of Science (TITLE-ABS-KEY) "daylight metrics" AND "rating systems"	0	0
3rd	Scopus/Web of Science (TITLE-ABS-KEY) "daylight metrics" AND "certification systems"	1	1
4th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight" AND "building certifications"	11	8

5th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight" AND "building guidelines"	2	1
6th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight criteria"	6	6
7th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight metrics" AND "urban codes"	0	0
8th	Google Scholar "métricas de iluminação natural"	11	2
9th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight requirements" AND "urban codes"	2	1
10th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight requirements" AND "standards"	10	5
11th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight requirements" AND "building certifications"	0	0
12th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight requirements" AND "rating systems"	0	0
13th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight requirements" AND "building guidelines"	0	0
14th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight requirements" AND "building regulations"	3	2
15th	Scopus/Web of Science (TITLE-ABS-KEY) "daylight metrics" AND "building regulations"	2	1
PAPERS FOUND IN DATABASES		69	41
PAPERS FROM REFERENCES/RECOMMENDED BY TC 3-61		16	16
TOTAL			57

Next, the 57 articles went through a second filtering. This classification divided the articles found into three great groups, based on adhesion to the theme: low adhesion applies daylight requirements on case studies; medium adhesion approach briefly the requirements, but focus on other parameters; high adhesion discuss requirements in the entire study. Finally, considering only high and medium adhesion, 36 articles were selected for full reading.

3 Results and discussion

3.1 Geographical distribution of found papers

Figure 1 below displays the geographical distribution of the found papers. Noticeably, there is a concentration in Europe (24 – 50%), Asia (10) and North America (7). Only 12 papers were found in Latin America (4), Africa (4), Middle East (2) and Oceania (2). These quantities consider the authors' institutions; thus, some numbers overlap and exceed the number of selected articles, since authors from different institutions work together frequently.

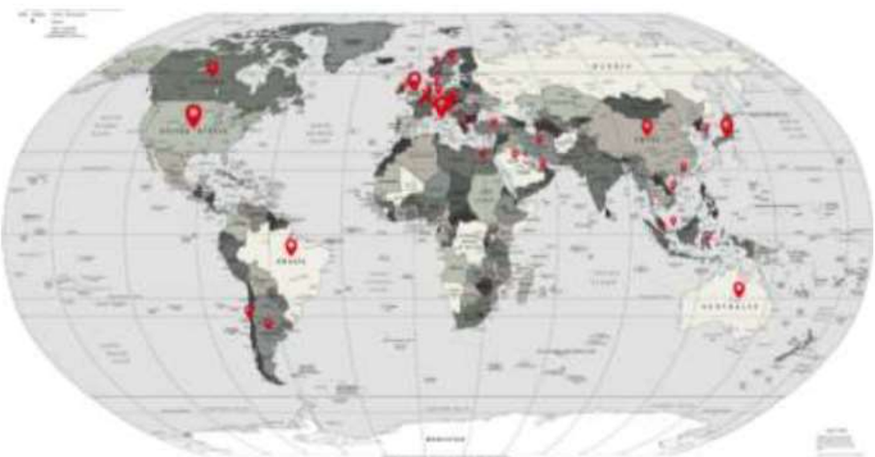

Figure 1 – Geographical distribution of research about daylight requirements

3.2 A brief timeline

According to Tregenza & Mardaljevic (2018), daylight has been acknowledged and used in architectural practice since Ancient Greece, with discussions about daylight rights and distinctions between necessities for daylighting, that required bigger openings with vision of the sky and outside views. Along the centuries, daylight became a vital part of the building design and an intrinsic knowledge within each region, its climate, and its traditional architecture (Tregenza and Mardaljevic, 2018).

Regarding daylight metrics, the nowadays called static metrics were calculated by tables and two-dimensional drawings, with standard and uniform weather conditions (Ayoub, 2019). In literature, some authors state that Daylight Factor (DF) came first, while others defend that it was Sky Factor (SF) that came before (Tregenza and Mardaljevic, 2018, Ayoub, 2019). Regardless of the chronological imprecisions, the most common vision is DF as an enhanced SF. Until now, DF remains widely used, although it is considered a limited parameter, once standard conditions hardly correspond to the real nuances of daylight (Reinhart et al., 2006, Bian and Ma, 2017, Knoop et al., 2020, Mardaljevic, 2021).

In the early 2000s, the significant development of simulation softwares led to Climate Based Daylight Modelling (CBDM) and new dynamic daylight metrics, which adopted weather files with 8,760 h/year of climate information. Those softwares became part of architectural and engineering practice and led to a greater application of dynamic metrics, since they accelerated calculations and provided realistic results, enhancing the assessment of daylight (Reinhart et al., 2006; Mardaljevic and Andersen, 2012; Mardaljevic, 2021). Until this day, CBDM is still expanding, as weather files keep being developed for an increasing number of cities (Mardaljevic, 2021). According Ayoub (2019), two main stages stand out: one in the early 1990s, with the widespread of computers, validation datasets, weather files and test cases; the other occurred in the first years of the 2010s, when the new technologies accelerated and enhanced even more daylight evaluations, including spatiotemporal assessments of daylight and their effects on visual tasks (Ayoub, 2019).

Nowadays, there are numerous softwares that allow designers to assess daylight's contribution in terms of energy efficiency, compliance with standards, and design in general. Nevertheless, the diffusion of dynamic metrics is still below its potential, possibly due to difficulties in the comprehension of concepts (Lo Verso et al., 2021). Figure 2 shows a brief timeline of daylight requirements and metrics. All metrics definitions are given in Table 4.

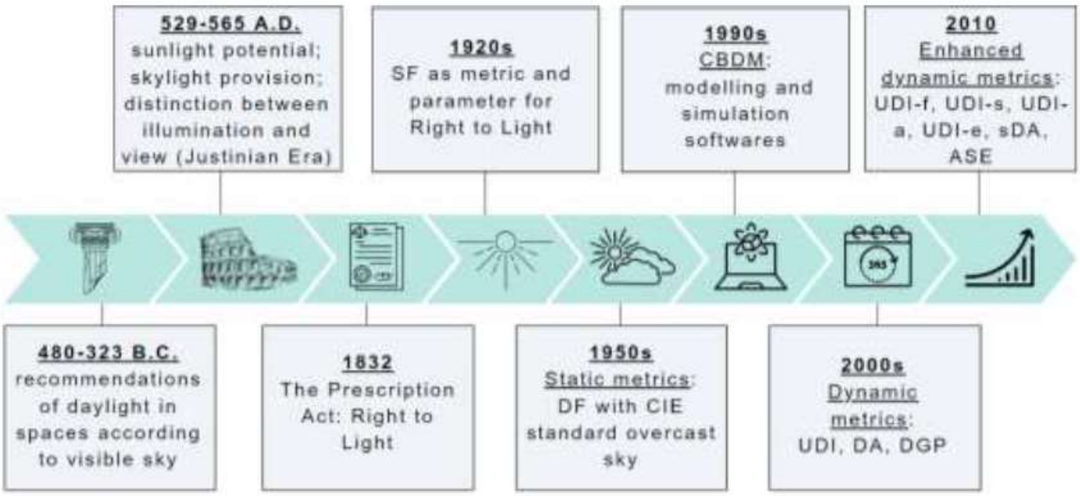

Figure 1 – Timeline of daylight requirements and metrics

It is noticeable the evolution from static to dynamic metrics along time (e.g., from Daylight Factor – DF to Daylight Autonomy – DA), as well as the embodying of more sophisticated metrics that evaluate daylight availability, the possible glare occurrence specific for daylight and excessive heat load gains (Daylight Glare Probability – DGP, Useful Daylight Illuminance

– UDI). After 2010, were found some proposals to unfold the main metrics, in order to provide detailed evaluations of daylight availability through space (Spatial Daylight Autonomy – sDA) (IESNA, 2012, 2023) and more specific metrics for glare, insufficient daylight e sunlight occurrence (variations of UDI and Annual Sunlight Exposure – ASE) (IESNA, 2012, 2023, Mardaljevic and Andersen, 2012, Mardaljevic et al., 2012).

3.3 Static and dynamic daylight metrics

Static and dynamic metrics consider different weather data and time periods (Bellia et al., 2017; Ayoub, 2019): static metrics deal with standard overcast sky standards and point-in-time illuminances. Dynamic metrics, instead, use 8,760 h/year weather files, embodying natural climate variance (Reinhart et al., 2006; Ayoub, 2019; Mardaljevic, 2021). The major limitations involved in static metrics are the generalized parameters, as well as the impossibility to predict variables associated with sunlight and glare (Reinhart et al., 2006; Mardaljevic et al., 2009). The diffusion of CBDM allowed a wider application of dynamic metrics, since they accelerated calculations and provided more realistic results (Reinhart et al., 2006; Mardaljevic, 2021).

In the research conducted by Ayoub (2019), the approach was focused on the metrics most used in calculation methods and simulation tools during 100 years of architectural practice. Based on this, Ayoub (2019) found a much wider range of static and dynamic metrics, from the first versions of DF until the latest unfolding of dynamic metrics, showing their growing complexities in methods and definitions. However, this SLR focused on the analysis of metrics and requirements among the chosen reference documents. So, according to the findings, the metrics in Table 3 are the most recurrent — for they are mentioned in at least two articles.

Table 3 – Most significant static and dynamic metrics found in this SLR

TYPE	METRICS	DEFINITION
STATIC	Sky Factor (SF)	ratio of the illuminance on a horizontal surface, to the unobstructed overcast sky (Tregenza and Mardaljevic, 2018, Ayoub, 2019)
	Daylight Factor (DF)	ratio of the illuminance on a horizontal surface to the unobstructed overcast sky, considering internal and external reflections (Bellia et al., 2017; Tregenza and Mardaljevic, 2018; Ayoub, 2019)
	Average Daylight Factor (ADF)	ratio of the illuminance on a horizontal surface to the unobstructed overcast sky, considering reflections, across a grid of points (Tregenza and Mardaljevic, 2018, Ayoub, 2019)
DYNAMIC	Daylight Autonomy (DA)	ratio of occupied hours in a year in which a minimum illuminance range is attended only by daylight (Nabil and Mardaljevic, 2006; Reinhart et al., 2006; Dias et al., 2018)
	Continuous DA (DA_{con})	DA with daylight illuminance values below ideal (500 lux) (Bellia et al., 2017; Dias et al., 2018; Ayoub, 2019)
	Maximum DA (DA_{max})	DA with illuminance 10 times above the ideal value (5,000 lux), with possible glare (Bellia et al., 2017, Dias et al., 2018)
	Spatial DA (sDA)	area of work plane that meets an ideal value of illuminance, usually 300 lux for 50% of occupied hours ($sDA_{300/50\%}$) (Ayoub, 2019, Monteoliva et al., 2020)
	Useful Daylight Illuminance (UDI)	range of illuminances across the work plane that fall between minimum and maximum values along the year (Nabil and Mardaljevic, 2005, 2006)
	UDI fell-short (UDI-f)	insufficient daylight, with levels below 100 lux (Nabil and Mardaljevic, 2005, 2006, González and Fiorito, 2015)
	UDI supplementary (UDI-s)	Illuminances between 100-300 lux, requiring electric light complement (Nabil and Mardaljevic, 2006, Mardaljevic and Andersen, 2012, González and Fiorito, 2015)
	UDI autonomous (UDI-a)	Illuminance levels from 300-3,000 lux, considered sufficient for different visual tasks (Nabil and Mardaljevic, 2006, Mardaljevic and Andersen, 2012, González and Fiorito, 2015)

	UDI exceeded (UDI-e)	levels above 3,000 lux, with possible visual/thermal discomfort (Mardaljevic and Andersen, 2012, González and Fiorito, 2015, Bellia et al., 2017)
	Annual Sunlight Exposure (ASE)	annual cumulative amount of sunlight; area that meets 1,000 lx in 250 occupied hours (ASE $_{1000/250h}$) (Bellia et al., 2017, Marcondes Cavaleri et al., 2018, Monteoliva et al., 2020)
	Daylight Glare Probability (DGP)	probability of discomfort by glare, based on vertical luminance of surfaces and illuminance of source (Kruisselbrink et al., 2018; Ayoub, 2019; Pierson et al., 2022)

Dynamic metrics about daylight provision (DA, sDA, UDI, ASE and variations) express the performance and the goals in daylighting, taking work planes as reference, and serving as good basis for design process and evaluations. Also, UDI ranges take into account the higher availability of daylight in some locations and the preference of occupants for greater illuminance levels (Marcondes Cavaleri et al., 2018). Among dynamic metrics, only ASE doesn't have threshold values, because it expresses an annual cumulative amount of sunlight in a space that determines the possible occurrence of discomfort (Reinhart et al., 2006). ASE is frequently used to assess spaces sensible to sunlight, whether it is pleasant or unwanted (Lo Verso et al., 2021). Yet, some dynamic metrics are seen as too unfamiliar and hard to use by practitioners, even if are more reliable due to the embodying of local features (Bian and Ma, 2017).

Concerning glare, a negative point is that DGP does not indicate the spatial or temporal distribution of sunlight, meaning it is strongly related to the occupant's perception. The lack of a more technical precise evaluation of glare hinders practitioners to design precise solutions (Ayoub, 2019). Moreover, according to Pierson et al. (2022), not all variables can be measured by DGP, as it's not clear if and how much cultural and socioenvironmental factors influence occupants' glare perception. Even so, authors claim that metrics like DGP are relevant to measure the possibility of discomfort by glare from daylight (Pierson et al., 2022).

3.4 Daylight requirements in reference documents

3.4.1 Rating systems

Rating systems (or certifications) are key drivers of sustainability in buildings and have become strong evaluation methods along time (Bellia et al., 2017). Even though certifications have emerged specifically to assess building performance, they became design references to practitioners (Reinhart et al., 2006; Mardaljevic et al., 2009), and daylight was included as a key aspect in those systems (Reinhart et al., 2006; Ayoub, 2019).

BREEAM is the first rating system created, in the 1990s, in Great Britain. Beyond the original version, The Netherlands, Spain and other countries made their own versions of BREEAM (Bellia et al., 2017). LEED, created originally inspired on BREEAM, is nowadays the most diffused certification worldwide (Bellia et al., 2017, Obrecht et al., 2017, Kim and Han, 2022), available in many countries other than the USA — Italy, Brazil, Japan, Germany, etc, which also adapted LEED to each local reality. ITACA Protocol, a rating system entirely Italian, was created in 2000s and can be applied to many types of buildings (Bellia et al., 2017). Table 4 summarizes daylight requirements found in the described rating systems.

Table 4 – Daylight requirements found in main used rating systems worldwide

RATING SYSTEM	REQUIREMENTS
BREEAM	Average daylight illuminance, minimum daylight illuminance (point-in-time measurements); quality of view out, measures against glare, window wall ratio (WWR) (Bellia et al., 2017, Obrecht et al., 2017)
LEED	includes DF, sDA, ASE, UDI; evaluations through simulations or measurements; quality of view out (Ayoub, 2019, Kim and Han, 2022)
ITACA Protocol	Average DF (Bellia et al., 2017)

Noticeably, LEED includes both static and dynamic metrics as requirements. On BREEAM and ITACA Protocol, instead, static metrics still prevail.

3.4.2 Standards

Some building construction standards are focused on daylight requirements. As an example, LM 83 – Approved Method: IES Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE) is an American standard, released firstly in 2012 by the International Engineering Society (IES), to develop a metric able to describe daylight in built spaces. LM 83 used sDA and ASE in a series of simulations and provided guidelines for projects (IESNA, 2012, 2023).

In Europe, EN 15193-1: Energy performance of buildings – Energy requirements for lighting, from the 2017 published revision and further, includes dynamic aspects, like the shadings, local climate, orientation, and variance of daylight, incorporating their influence in Lighting Energy Numeric Indicator (LENI), requirement that reunites both daylight and electric light (Aghemo et al., 2016). EN 17037: Daylight in Buildings, also European, uses Target Illuminance (E_T) and Minimum Target Illuminance (E_{Tmin}) (Paule and Flourentzou, 2019, Solvang et al., 2020). EN 17037 also includes requirements to assess outside views, exposure to sunlight, and DGP (Paule and Flourentzou, 2019, Solvang et al., 2020, Mardaljevic, 2021). Requirements from the standards analysed are summarized in the Table 5 below.

Table 5 – Daylight requirements found in international standards

<table>
<tr><th rowspan="2">STANDARD</th><th colspan="2">REQUIREMENTS</th></tr>
<tr><th>METRIC</th><th>PARAMETER</th></tr>
<tr><td rowspan="2">LM 83:2023</td><td>$sDA_{300/50\%}$
$sDA_{150/50\%}$</td><td>300 lux in 50% of daylit hours in 75% of task area (preferrable) and 55% of task area (acceptable)
150 lux in spaces with less critical visual tasks</td></tr>
<tr><td>$ASE_{1000/250h}$</td><td>threshold of 1000 lux in 250h/year</td></tr>
<tr><td rowspan="4">EN 15193-1:2017</td><td>DF</td><td>Values vary according to different locations, classified as: DF ≥ 6%: strong; 6% > DF ≥ 4%: medium; 4% > DF ≥ 2%: low; and DF < 2%: none</td></tr>
<tr><td>$F_{D,S}$</td><td>Daylight Supply Factor, depends on location, façade, openings; standard values in Annex F</td></tr>
<tr><td>F_D</td><td>Daylight Dependency Factor, depends on location, façade, openings; standard values in Annex F</td></tr>
<tr><td>LENI</td><td>$F_{D,S}$ + F_D + electric light; values vary according to each case</td></tr>
<tr><td rowspan="5">EN 17037:2018</td><td>E_T</td><td>min = 300 lux / 50% area; med = 500 lux / 50% area; max = 750 lux / 50% area</td></tr>
<tr><td>E_{Tmin}</td><td>min = 100 lux / 95% area; med = 300 lux / 95% area; max = 500 lux / 95% area</td></tr>
<tr><td>View out</td><td>Min.: angle ≥ 14°, dist. ≥ 6,0m + 1 layer (landscape); Med.: angle ≥ 28°, dist. ≥ 20,0m + 2 layers (landsc. + other); Max.: angle ≥ 54°, dist. ≥ 50,0m, all 3 layers.</td></tr>
<tr><td>Exposure to sunlight</td><td>Min.: 1.5h; med.:3 h; max.: 4h (on a selected date between February 1st and March 21st)</td></tr>
<tr><td>Glare</td><td>DGP ≤ 0.35 (not noticed); 0.35 < DGP ≤ 0.40 (noticed without discomfort); 0.40 < DGP ≤ 0.45 (noticed with discomfort); DGP ≥ 0.45 (intolerable)</td></tr>
</table>

LM 83 consolidated both sDA and ASE (Sepúlveda et al., 2020). EN 15193-1, instead, used predominantly DF as reference, even though $F_{D,S}$ and F_D already try to embody daylight dynamic features — building location, latitude and orientation — as contributions to a wide evaluation about through LENI. In EN 17037, Target Illuminance (E_T) relates temporal and spatial distribution of light, representing the same concept presented in spatial Daylight Autonomy (sDA). Exposure to sunlight accounts the amount of sunlight exposure, in hours, per day, instead of a cumulative yearly amount mentioned in Annual Sunlight Exposure; nonetheless, the concept is the same.

3.4.3 Building and Urban Codes, Regulations and Guidelines

Only three articles discussing daylight requirements in building and urban codes, regulations and guidelines were found in this SLR. The studies conducted by Bournas (2021), Alenius and Lundgren (2020) analyse how daylight requirements showed up in Swedish building regulations. The first author observed that the use of requirements — DF and glass-to-floor ratio (GFR) — did not enhance daylight performance in buildings, but only comply with prescript values (Bournas, 2021). This indicates the ineffectiveness of those requirements, since visual conditions do not improve substantially with the compliance (Bournas, 2021).

Alenius and Lundgren (2020) claim that practitioners use DF as a theoretical knowledge during design phases, although avoiding calculations, therefore, simplifying the process. Moreover, the codes analysed do not address daylight specifically, and the lack of explicit requirements since the early urban control phases cause a delay in daylight evaluations that, at times, make ideal levels impossible to comply (Alenius and Lundgren, 2020).

Ishak et al. (2018) discuss some measures took by guidelines and building regulations against glare. According to the authors, Singapore, Hong Kong and Australia created measures in regulations against the high reflectance of building façades to avoid glare issues within the surrounding areas (Ishak et al., 2018), which are important recommendations, especially for places with great incidence of daylight, such as the countries mentioned.

4 Conclusions

Since the 2000s, daylight requirements have improved rapidly. The multiple discussions often result in various metrics and system proposals but there is still no consensus about which metric is the best or most representative. This gap defies designers to work with criteria with little or no overlaps, relying mostly on personal experience.

There is a fair coordination of daylight requirements between standards and rating systems, However, rating systems focus on higher performance compared to standards, which guide minimum performance. Rating systems are non-mandatory, but instead, have a great commercial value due to the sustainability argument. In some countries, standards are not mandatory, yet serve as reference for good projects. The search for daylight requirements in regulations, building and urban codes, and guidelines found few articles, which indicates that these documents are not a usual a research object, showing a gap between academic research — that reflects more on standards and rating systems — and the daily architectural practice — more influenced by building and urban codes, regulations and guidelines.

Among metrics, Daylight Factor (DF) keeps widely used, even with its limitations; so, static metrics require more attention, since overcast skies should not be used in climates where clear sky is most common: miscalculations would lead to overestimation of daylight levels, excessive heat load gains and glare. Dynamic metrics, instead, capture daylight according to variables that change according to local features, providing better guidance to architectural practice. Daylight Autonomy (DA) and Spatial Daylight Autonomy (sDA) are the most recurrent metrics in standards and rating systems, as well as Target Illuminance (E_T) and exposure to sunlight. sDA and E_T have similar concepts, as well as Annual Sunlight Exposure (ASE) and exposure to sunlight, which could suggest a possibility of harmonization in an international context. About glare assessment, Daylight Glare Probability (DGP) is the most used; and outside views are also a frequent requirement.

Finally, these considerations do not exempt further analysis of primary documents, that could provide more types of requirements. As this article is part of a wider research about daylight requirements, primary documents will be analysed further on, providing a deeper overview.

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ANNEX IV: ARTICLE PUBLISHED IN 37TH PLEA CONFERENCE

Daylight metrics and requirements:
a review of reference documents for architectural practice

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ABSTRACT: Daylight has always been part of the architectural practice, since architects always used it to define spaces and create complex structures. Daylighting is, nowadays, seen as key strategy for sustainability, energy efficiency and resilience in buildings. This article aims to investigate daylight requirements in reference documents for architectural practice, through the collection and qualitative analysis of documents. To the analysis, primary documents were collected through active searches and through the application of a survey to daylight specialists from different countries. Then, 130 reference documents were analysed, divided into standards, rating systems, building and urban codes, regulations and guidelines. Results show that static and dynamic metrics are common within standards and rating systems, while building and urban codes and regulations often use metrics based on building and urban geometry. Among standards and rating systems, Daylight Factor (DF) is still one of the most used metrics, even if dynamic metrics offer advanced analyses; building and urban codes and regulations are very specific from each location, with predominant use of geometric metrics; and guidelines can use both types of metrics.
KEYWORDS: Daylight requirements, Standards, Rating systems, Building and urban codes, Regulations, Guidelines.

1. INTRODUCTION

Daylight has always been essential to mankind's development: it allows visibility and influences health [1,2,3]. Due to that, it is a vital part of architectural practice: using daylight, architects define spaces and create high complexity structures, in order to provide comfortable and pleasant places [4,5]. Moreover, daylighting is one key strategy to increase energy efficiency and contributes to enhance buildings' resilience against failures of electricity [3,6].

Daylighting requires a wide comprehension of how it affects occupants and spaces, which is not always clear to architects [7,8,9]. In that context, daylight requirements, even though cannot ensure good design, may contribute to better guidance, avoiding poor design decisions and facilitating architectural practice [9,10,11].

The requirements concerning daylight in reference documents are composed by metrics — a combination of quantities and conditions — and parameters — values or boundaries that act as guidance to enable evaluations [10,11,12].

As there is a large number of possible international reference documents, in this article, the documents evaluated were: standards, rating systems, building and urban codes, regulations and guidelines, considered crucial for buildings' and cities' projects. Those documents are developed by international and national authorities, professional organizations or institutions [11].

Standards are official publications with technical recommendations about the quality, safety and other features of a product [13]. In the case of buildings, standards provide guidance about daylight, acoustic, thermal comfort, performance, etc [2].

Rating systems are schemes that measure levels of compliance or performance of buildings, according to specific criteria [14]. Today, rating systems are seen as key drivers of sustainability in architecture, and have a significant commercial appeal [2].

Building and urban codes are elaborated by local authorities, focused on development and construction, defining rules about buildings and urban fabric. Building and urban codes propose design, regulation and planning, with the aim to achieve higher quality spaces [15]. Also, the existing urban fabric can and should be enhanced by the rules defined by codes, as they are expected to assure sustainable strategies, social and ecofriendly development, nature-based solutions, and so on. Usually, codes are legally binding and seen as "models" for jurisdictions [15,16].

Regulations are documents to ensure buildings are secure for people in or around them. Elaborated by the state or local government, regulations contain a series of approved requirements and rules for urban spaces and buildings, covering the technical aspects of construction. Historically, their application is necessary to building construction activities and to compose a city's governance [17,18].

Guidelines are a set of policies, rules and procedures promulgated and/or amended by the developer or the local control authority, that act as a guide for architectural activities [18]. Guidelines also help to preserve the long-term vision and property value of a community, by outlining requirements for builders, regarding styles and exterior features, as well as provide a set of good design practices [19].

This article investigates daylight requirements on reference documents for architectural practice. The work is part of the *Commission Internationale de l'Eclairage* (CIE) Technical Committee 3-61 (TC 3-61), which aims to assess the feasibility of global harmonization of daylight requirements.

2. METHOD

The steps fulfilled during the research were:

- Collection of primary documents: sent by members of TC 3-61 and other specialists, or collected from associations and stakeholders' websites, from Dec/2022 to Feb/2024;
- Application of survey: sent to daylight specialists from research institutes and associations, to gather information from different countries;
- Elaboration of summary tables: according to document, requirements, countries, metrics;
- Analysis of data and conclusions: quantitative and qualitative analysis of the findings.

This article comprehended the analysis of 130 primary reference documents obtained, including standards (45), rating systems (26), building and urban codes and regulations (49) and guidelines (10).

3. RESULTS AND DISCUSSION

The reference documents were received in their original versions or in summaries elaborated by specialists. The documents include not only requirements specifically related with daylight, but also those related to lighting in general, energy efficiency, architecture, and urbanism. This article, though, focused on requirements that influence daylighting in buildings and in urban fabric.

3.1 Daylight requirements and metrics

Daylight requirements are basically composed by parameters and metrics. Those must be accurate enough to evaluate the project's features [9]. A "parameter" is a limit, or a boundary, that acts as a factor that enables judgement or evaluation of something — e.g., a numerical value. As for "metric", it is a way to measure or evaluate something, with the use of figures or statistics [2,12].

Requirements influence directly on building and urban design strategies, since those are crucial references for practitioners [9]. Yet, for their use to be effective in architectural practice, requirements have to be objective, simple, testable, replicable, and able to give robust and reliable results [20].

Daylight metrics are classified between static, dynamic and geometric. Static metrics, the first created, were initially calculated by tables and two-dimensional drawings, based on point-in-time illuminances under a single sky condition [9,21,22, 23]. As main example of static metrics, there is Daylight Factor (DF) and its variations. Dynamic metrics, introduced by year-round climate-based daylight modelling (CBDM) embodying 8,760h/year of climatic data, allowed the acceleration of calculations and provision of realistic and accurate results [9,22]. Therefore, dynamic metrics are based on what time of the year daylight is able to provide the light levels required. As examples of dynamic metrics, there are Daylight Autonomy (DA), Spatial Daylight Autonomy (sDA), Useful Daylight Illuminance (UDI), Annual Sunlight Exposure (ASE), Sunlight Exposure and Daylight Glare Probability (DGP) [2,21,22].

The geometric metrics are those related to areas, distances, angles, as well as building shape and material properties, such as Window-to-Floor Ratio (WFR), Window-to-Wall Ratio (WWR), Outside views, setbacks, lightwells, obstruction and shadowing angles, Visible Light Transmittance (VLT) [20]. Metrics and their definitions are found in Table 1.

Table 1: Definitions of found daylight metrics.

Metrics	Definitions
Daylight Factor (DF)	ratio of illuminance on a horizontal surface to the unobstructed overcast sky, considering reflections [2,21]
Average Daylight Factor (DF_{avg})	ratio of illuminance on a horizontal surface to the unobstructed overcast sky, considering reflections, across a grid of points [2,21]
Daylight Autonomy (DA)	ratio of occupied hours in a year in which a minimum illuminance range is attended only by daylight [23,24]
Spatial DA (sDA)	area of work plane that meets an ideal illuminance ($sDA_{lx/\%}$) [21]
Useful Daylight Illuminance (UDI)	range of illuminances values across the work plane along one year [24]
Annual Sunlight Exposure (ASE)	amount of sunlight reached in a part of occupied hours per year [25,27]
Target Illuminance (E_T)	illuminance achieved across 50% of the reference plane for at least half of the daylit hours [28]
Minimum Target Illuminance (E_{Tmin})	minimum illuminance achieved across 95% of the reference plane for at least half of daylit hours [28]
Sunlight Exposure	sum of the time (h) in which spaces are exposed to sunlight [28]
Outside views	visual contact with the surroundings through openings façades [28]
Daylight Glare Probability (DGP)	probability of discomfort by glare, based on vertical luminance and illuminance of source [7,21]

Daylight Glare Index (DGI)	the ratio of total window area to total floor area [21]
Window-to-Floor Ratio (WFR)	the ratio of total window area to total floor area [29]
Window-to-Wall Ratio (WWR)	the portion of an exterior wall that consists of windows [30]
Obstruction angles	the angle from the centre of the window to the top of the surrounding elements [31]
Shadowing angles	the angle from the centre of the window to the most external point of the solar protection [31]
Setback distances	the minimum distance required between a structure and the front, side, or rear plot boundaries [32]
Visible Light Transmittance (VLT)	the portion of visible light that passes through a glazing system [33]
Lightwell	internal spaces open to the air that allow light and air indoors [34]

3.2 Documents collected

Table 2 shows the distribution of documents in different geographical and climatic conditions, with predominance of European countries. All other continents were also represented.

Table 2: Reference documents received and origin countries.

Document	Country	Quantity
STANDARDS	Europe	2
	Italy	5
	Denmark	1
	Norway	1
	UK	2
	Germany	2
	Netherlands	2
	Slovenia	1
	Greece	2
	Czech Republic	1
	Austria	1
	Turkey	1
	Poland	3
	France	6
	Sweden	1
	Brazil	3
	Chile	1
	Colombia	2
	USA	3
	Canada	1
	China	1
	Russia	2
	South Africa	1
GUIDELINES	UK	2
	Netherlands	1
	Estonia	1
	Turkey	1
	Singapore	1
	Japan	1
	Chile	2
	Colombia	1
RATING SYSTEMS	UK	1
	Netherlands	1
	Italy	1
	Sweden	1
	Germany	1
	France	3
	USA	3
	Canada	3
	Australia	1
	Colombia	1
	Brazil	5
	Chile	2
	Japan	1
	China	1
	South Africa	1
BUILDING AND URBAN CODES/ REGULATIONS	Italy	9
	Netherlands	1
	Norway	1
	Poland	1
	Austria	1
	Belgium	1
	Croatia	1
	Hungary	1
	Denmark	1
	France	4
	Germany	1
	Slovenia	1
	Sweden	2
	Spain	1
	Ireland	1
	Turkey	1
	USA	3
	Canada	1
	Brazil	9
	Chile	1
	Bolivia	2
	New Zealand	3
	Japan	1
	China	1

The documents are applied differently, according to each country. For example: building and urban codes are the common mandatory documents to comply, while rating systems and guidelines are optional. Standards are mandatory when laws give them this status, as happens in Brazil [26].

Different metrics appear on these documents, and the simple analysis of quantities is important to understand which are the most used worldwide. Table 3 summarizes the occurrence of daylight metrics in the 117 documents analysed.

Table 3: Occurrence of daylight metrics in documents.

Type	Metrics	Standards	Rating Systems	Guidelines	Building and Urban Codes / Regulations
Static	DF	30	13	4	8
	DF_{avg}	1	2	3	8

	DGI	2	1	0	0
	Outside Views	18	14	3	10
Dynamic	E_T	16	3	0	1
	E_{Tmin}	16	2	0	3
	DA	2	5	1	1
	sDA	6	6	0	2
	UDI	2	6	1	0
	ASE	4	4	0	0
	Sunlight Exposure	17	2	3	2
	DGP	17	4	2	0
Geometric	WWR	1	5	2	2
	WFR	5	4	3	28
	Window sizes / areas / head heights	2	1	0	6
	Setback distances	3	1	2	12
	Shadowing angles	1	2	2	3
	Obstruction angles	0	1	2	4
	Lightwells	0	0	0	1
	VLT	4	4	0	4

Static metrics, mostly DF and variations, are mentioned 69 times. Nonetheless, dynamic metrics now are more common: together, those metrics (DA, sDA, UDI, E_T, E_{Tmin}, DGP, ASE) are found in 104 of all documents. Sunlight exposure, found 24 times, is especially important to countries with cold winters, in order to ensure natural heating, as other benefits. In sunny climates, excessive sunlight exposure can provoke glare occurrence or elevated heat gains, if not properly regulated.

Outside views are also a recurrent requirement in all documents — mentioned in 45 of them — and are important for all buildings. In several documents, especially those based on EN 17037, there are objective parameters to classify views out (angles, view composition, distance of view, etc), while in other documents this analysis is still very subjective.

WFR is mentioned 40 times; followed by the setback distances, found in 18 of them; WWR was found in 10, while obstruction and shadowing angles appeared in 8 and 7 documents, respectively.

3.3 Standards

Standards, usually, are not mandatory, except when a law or government decree refers to it, or specifically gives the standard that status [26].

The metrics and requirements found were: DF, appearing in 30 documents; Outside views, 18 times; DGP and Sunlight Exposure, 17 times; E_T and E_{Tmin} appeared in 16 documents each; sDA, with 6 mentions; ASE and VLT, mentioned in 4 standards; setback distances were mentioned 3 times, while DA, UDI, DGI, window sizes were mentioned 2 times; other metrics, such as DF_{avg}, WWR and shadowing angles were mentioned in 1 standard each.

EN 17037:2018 is one of the most influent standards, since it became a reference for European countries — which have their versions of EN 17037 — and also for others outside Europe, like the Brazilian standards ABNT NBR 15215:2023 and ABNT NBR 15575:2023. Metrics used are DF, sDA, DGP, views.

EN proposed a climatic adaptation of DF, based on different median external diffuse illuminances and consequently different parameters (values) of target DF, e.g. from 0.2% in Cyprus (for 100 lux) to 5.4% (for 750 lux) in Reykjavik. Despite that, for sunny climates, this could lead to overheating and glare if windows are enlarged to achieve the target DF.

LM 83:2023 is another significant standard, published by the Illumination Engineering Society of North America (IESNA). LM 83 consolidated sDA and ASE in its first version from 2012. In 2023, the revision maintained the ASE method, but unfolded sDA in two parameters: the usual $sDA_{300/50\%}$ in 75% or 55% of used area, and $sDA_{150/50\%}$ in 50% of used area in spaces with less critical visual tasks. sDA and ASE became very common also in other documents.

$sDA_{300lx/50\%}$ and $ASE_{1000lx/250h}$ are the most found parameters for these metrics, meaning that those became the target values independently of the climatic conditions. This may seem a problem at first, but considering that sDA and ASE are dynamic metrics, it is possible to design spaces towards those results through computer simulations.

3.4 Rating systems

Rating systems are non-mandatory [27] but have an important economic appeal for stakeholders. LEED (USA) and BREEAM (UK) are the most popular rating systems worldwide, as they are applied in numerous countries. In most cases, those systems are adopted with the same metrics and parameters as the original American and British versions.

Other Rating Systems analysed were WELL (USA), Protocollo ITACA (Italy), Selo Azul Caixa and INI-C (Brazil), HQE (France), CASA Colombia, DGBN (Germany), Living Building Challenge (USA/Canada), CASBEE (Japan), BCA Green Mark (Singapore), Green Star (Australia), Green Star Rating (South Africa), CES and CVS (Chile) and GB/T 50378-2019 (China).

The requirements found were: DF, with 13 mentions; Outside views were mentioned 14 times; UDI and sDA, 6 times; DA and WWR, 5 times; ASE, WFR and VLT, 4 times; E_T is mentioned 3 times. With 2 mentions each, DF_{avg}, E_{Tmin}, shadowing angles and Sunlight Exposure. Setbacks, window areas, obstruction angles and DGI were mentioned once.

Standards and Rating Systems improved along time in parallel with the evolution of metrics, from static to dynamic, using similar parameters. On one hand, Rating Systems focus on higher performance and, even though not being mandatory, the sustainability aspect is vital in those schemes. As a way to set higher performance goals, there are more categories — i.e., $sDA_{300lx/50\%}$ in 55%, 75% or 90% of occupied area; outside views for 50% or 100% of spaces, among others. On the other hand, Standards are a reference for professionals, to guide an acceptable performance and avoid design mistakes. Standards and Rating Systems also have in common that both are influential in many countries.

3.3 Building and urban codes/Regulations

As Building and Urban Codes and Regulations are similar, they were analysed together in this article. Codes, as well as Regulations, are the main reference for practitioners during architectural practice, since both are mandatory and legally binding — implying that inconsistencies with the requirements might even withhold constructions.

The found requirements were: WFR, in 28 documents; Setback distances, mentioned 12 times; Views out, mentioned 10 times; DF and DF_{avg}, 8 times each; window areas were mentioned in 6 documents; VLT and obstruction angles, 4 times; E_{Tmin} and shadowing angles, 3 documents; Sunlight exposure, WWR and sDA were found 2 times. Lightwells, DA and E_T are mentioned in 1 document.

Codes and Regulations are focused on a particular area of application and provide orientations for a wide quantity of schemes, projects and situations in that specific place [16,17]. Parameters commonly found for WFR, for example, vary according to the typologies of buildings and needs of the project. For housing, WFR falls into the range of 1/10 to 1/12 and from 1/7 to 1/8; for offices, from 1/8 to 1/10; for schools, kindergartens and classrooms, WFR values above 1/7, sometimes reaching 1/4 to 1/5, are recommended. Static and dynamic metrics do not appear often on these documents.

3.4 Guidelines

In the international context, guidelines are not common in many countries. This may justify why only few documents were found — a low representativity that hinders a wider evaluation. The requirements found were: DF, found 4 times in guidelines; DF_{avg}, found 3 times, as were Sunlight Exposure, Views out and WFR; DGP, WWR, setbacks, shadowing and obstruction angles were mentioned 2 times each. DA and UDI were found once each.

In countries that have Guidelines as manuals, those are elaborated by professional organizations. Guidelines are mostly not mandatory: instead, they can be a reference for practitioners, whether to facilitate the comprehension and application of other documents — e.g. Codes, Regulations — or to guide better design practices. Hence, guidelines' requirements are in between those two groups: those keen to aid professionals to apply mandatory documents regarding building and urban geometry; and those focused on better practices apply static and dynamic metrics.

4. CONCLUSION

This article explored daylight requirements in reference documents, demonstrating the many ways that daylight is treated. Three groups were verified: one composed by standards and rating systems, since those tend to have similar requirements; other by building and urban codes and regulations, also with similar metrics; lastly, the guidelines, that in most cases depend on the focus of the document.

The most well represented were the European countries. North and South America, Asia and Oceania were also represented. Only a few documents from Africa were received, possibly due to the lack of access or few published information.

DF remains a widely used metric, especially in European countries. Even the parameters being different, considering each local condition of median external diffuse illuminances as proposed by EN 17037, it is still limited and performs better for overcast skies. The parameters, in general, are the same for many countries, which could lead to issues with excessive heating, when used in sunny climates.

Dynamic metrics provide more reliable results. The key to dynamic metrics is to have target parameters to comply that truly consider local climates. With a goal set, the strategies used by designers may differ, but the results meet the recommendations. The most used dynamic metrics for daylight provision is Target Illuminance and variations, along with Spatial Daylight Autonomy (sDA). For glare assessment, Daylight Glare Probability (DGP) is the most used, while Sunlight Exposure expresses the access to sunlight indoors.

Metrics based on geometry, instead, influence directly the architectural and urban projects, since they shape the buildings and intermediate their relation to the surroundings. The most used are WFR and setback distances. Similar parameters are used for different locations, which indicates the limitation of this metrics, as used presently. Their main advantage is to be familiar to architects and urban planners, but new parameters should be further developed, to adapt to different climates and sky conditions, providing solutions to control the same variables — i.e., in sunny climates determine a reduced WFR, while colder climates might require more window areas. Connecting geometric to dynamic metrics could clarify how both types of metrics impact each other during the design process, as well as building and urban spaces.

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