ARCHITECTURE
STUDENT
CONTEST

VISUAL COMFORT
DAYLIGHT

SAINT-GOBAIN

SUMMARY

ARCHITECTURE STUDENT CONTEST

SAINT-GOBAIN

INTRODUCTION

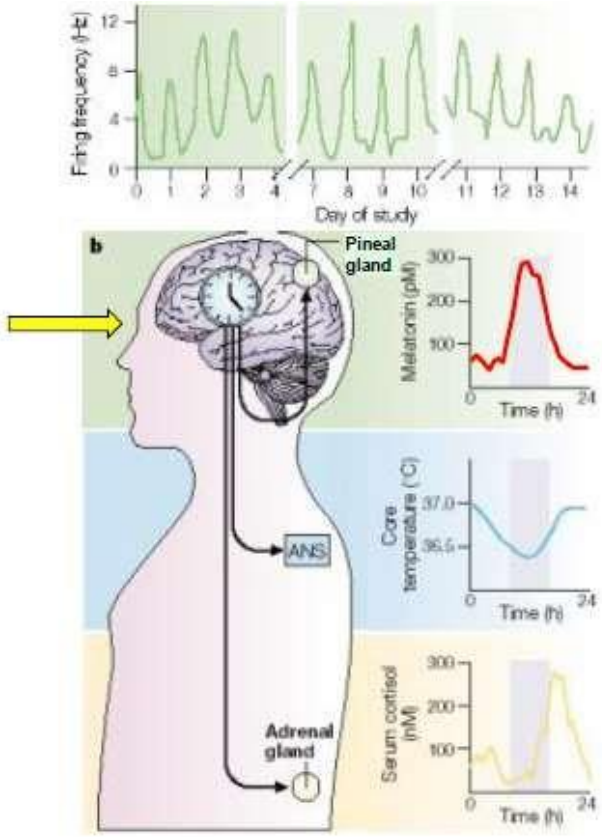
WE LIKE NATURAL DAYLIGHT…

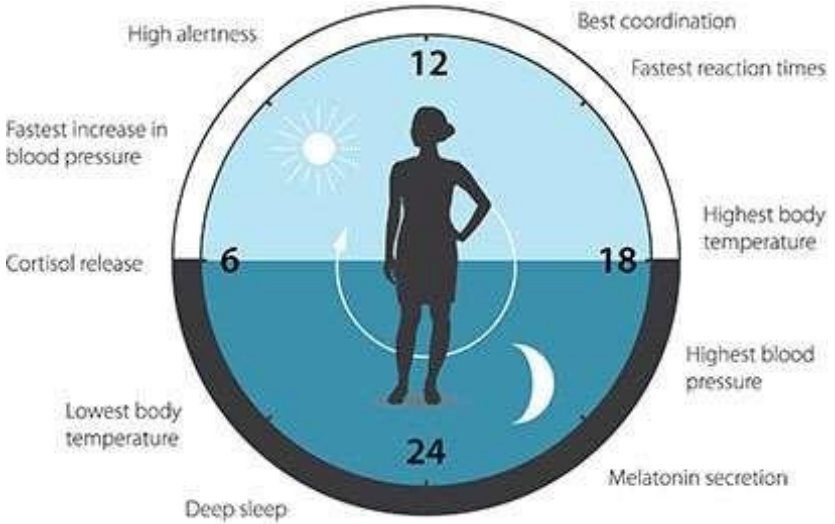
… BUT WE SPEND MORE OF OUR TIME INDOORS

AN INTERNAL (CIRCADIAN) CLOCK TO SET UP EVERY DAY

Endogen rythm near to 24 h

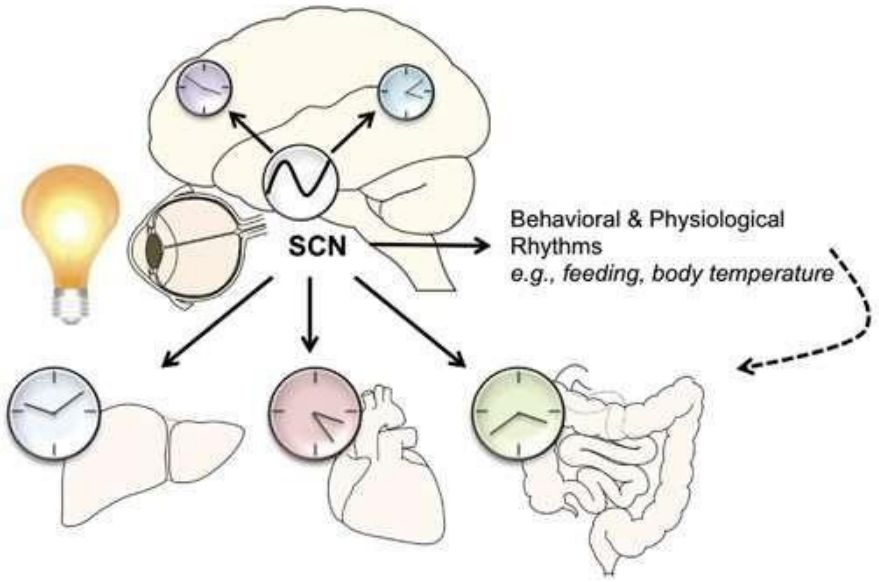
Synchronisation by Light

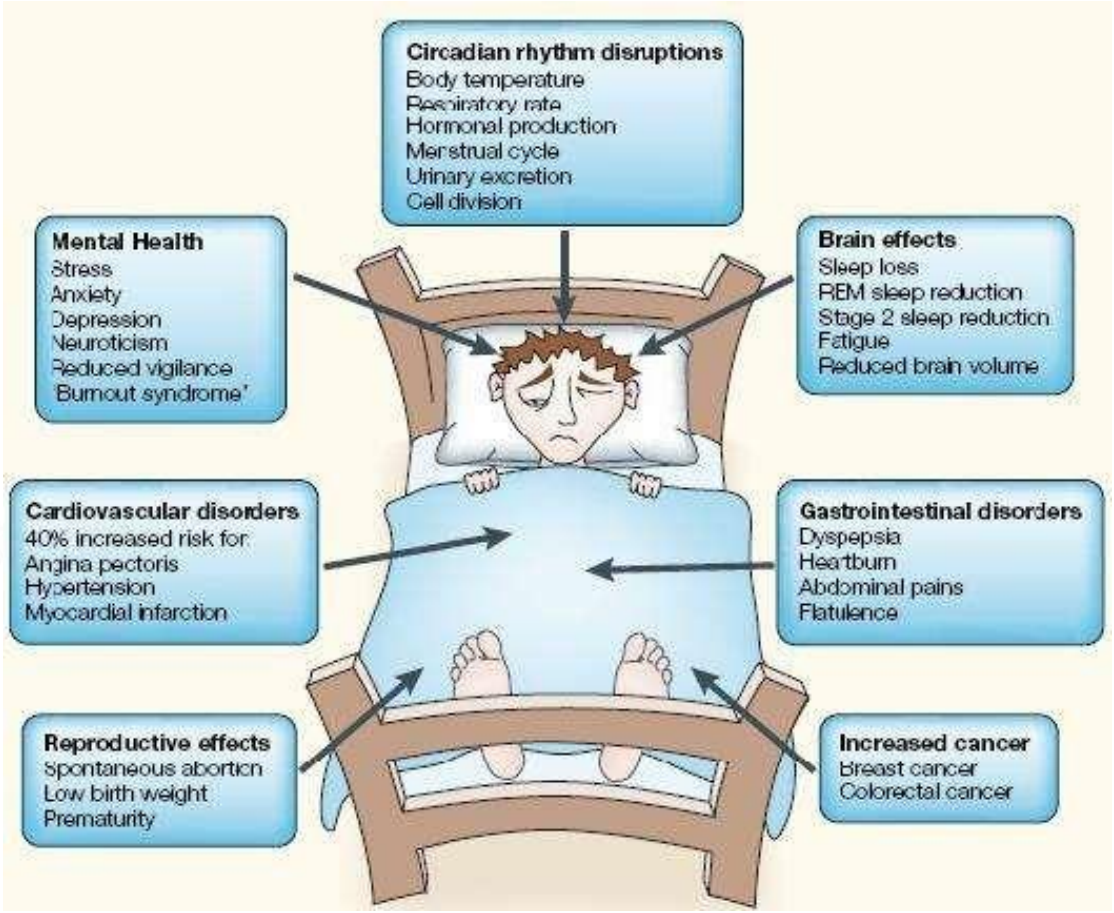




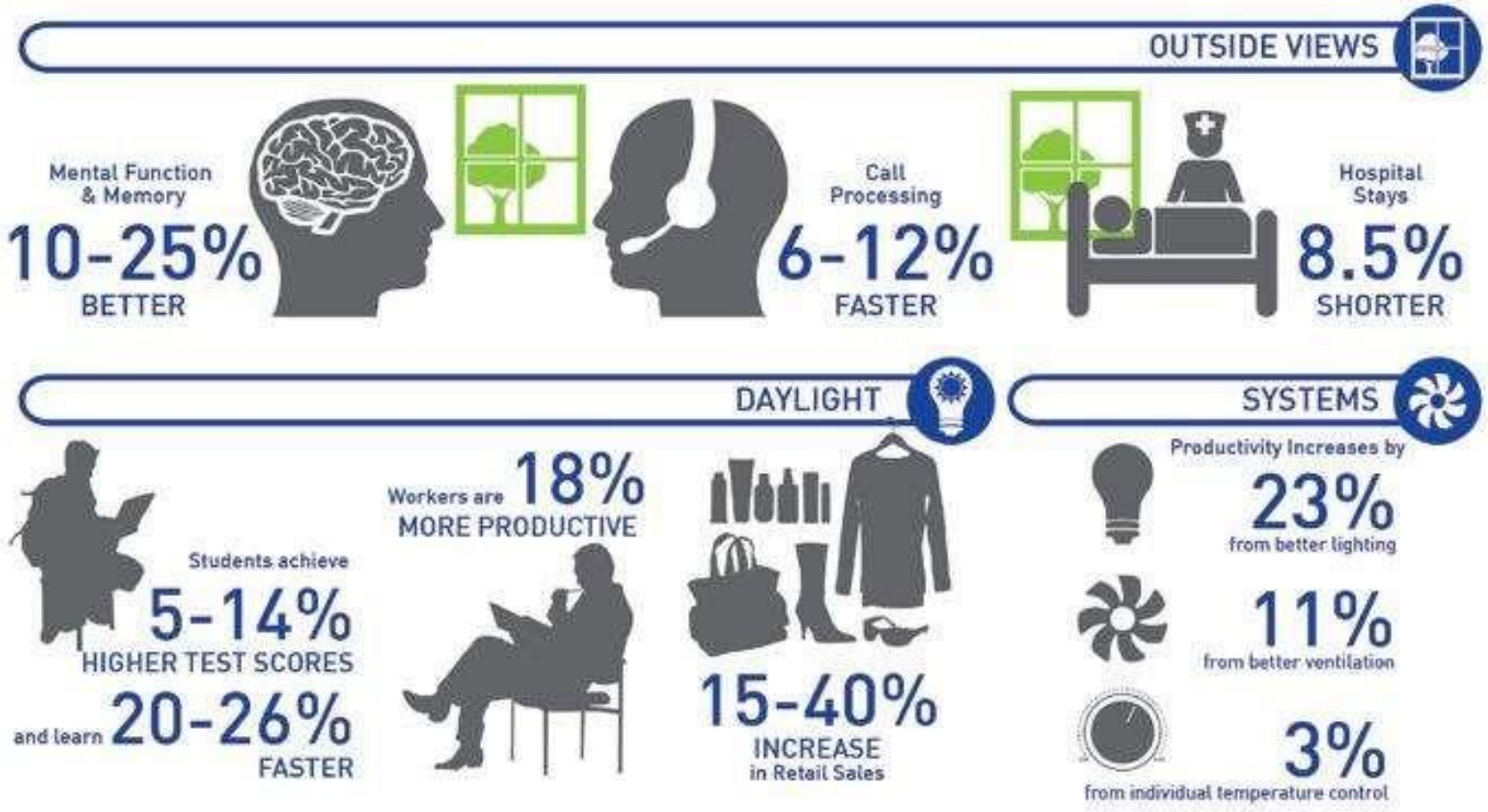
The circadian clock anticipates and adapts our physiology to the different phases of the day. Our biological clock helps to regulate sleep patterns, feeding behavior, hormone release, blood pressure, and body temperature.

CONSEQUENCES OF BAD SYNCHRONISATION





LIGHT BENEFITS KNOWN FOR YEARS



Source: the business case for green building Report, WGBC, 2013

POTENTIAL DAYLIGHT VALORIZATION IN NON RESIDENTIAL SEGMENT

Workplace productivity

- Daylight Impact on mood
- Impact on stress reduction
- Impact on job satisfaction

Health

- Hospitals
- Schools
- Offices

Savings / sales increase

- Reduce peak electricity lighting demands
- Lower CO_2 emissions
- Increase of sales in daylit shops

DAYLIGHT IS A CRITICAL WELL-BEING AND HEALTH FACTOR

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DAYLIGHT CONTRIBUTES TO ELEVATING THE MOOD AND HAS DIRECT IMPACT ON HEALTH AND PRODUCTIVITY OF BUILDING OCCUPANTS

SCHOOLS

DAYLIGHT HELPS STUDENTS FOCUSING AND LEARNING.

STUDIES SHOW STUDENTS ACHIEVE **5 14% TEST SCORES** AND **20 26% FASTER LEARNING**.

OFFICES

IN OFFICIES, WORKERS ARE **23% MORE PRODUCTIVE**. STUDIES OBSERVE **REDUCED STRESS, INCREASED CREATIVITY, LOWER ABSENTEEISM AND TURNOVER**; RESEARCH SHOWS THAT IN AVEREAGE WORKERS WITH WINDOWS BENEFITS OF **46 MINUTES MORE SLEEP PER NIGHT**.

HOSPITALS

IN HOSPITALS, DAYLIGHT IS A HEALING FACTOR AND SOURCE OF WELL-BEING; STUDIES SHOWS **REDUCED STRAIN AND FATIGUE FOR STAFF AND IMPROVED PHYSIOLOGICAL AND PSYCHOLOGICAL WELL-BEING FOR PATIENTS**;

PATIENT ROOM WITH IMPROVED DAYLIGHT **REDUCED AVERAGE LENGTH OF STAY BY 16% TO 41%**. PATIENT IN UNITS WITH SUNLIGHT PERCEIVED LESS PAIN AND THE **PAIN MEDICATION IS RECUDED BY 22%.**

SALES SHOP INCREASE WITH DAYLIGHT! REPORTED IN MANY STUDIES

AFTER THE NUMBER OF HOURS OPEN PER WEEK, THE PRESENCE OF SKYLIGHTS WAS THE BEST PREDICTOR OF THE SALES PER STORE OF ALL THE VARIABLES THAT WE CONSIDERED. THUS, IF A **TYPICAL NON-SKYLIT STORE WERE AVERAGING SALES OF $2/SF, THEN ITS SALES MIGHT BE EXPECTED TO INCREASE TO BETWEEN $2.61 AND $2.98 WITH THE ADDITION OF A SKYLIGHTING SYSTEM.**

WHEN COMPARING ABOUT 11 STORES IN ONE DISTRCIT, THE **DAYLIT STORES SOLD 28% MORE PRODUCT THAN THE OTHER STORES.**

Pacific Gas and Electric Company/Mahone1999 Skylighting and Retail Sales An Investigation into the Relationship Between Daylighting and Human Performance
http://www.h-m-g.com/downloads/Daylighting/retailc.pdf

POTENTIAL DAYLIGHT VALORIZATION IN RESIDENTIAL SEGMENT

Healthy house

- Well being/comfort during winter and summer
- Recovery
- Circadian house

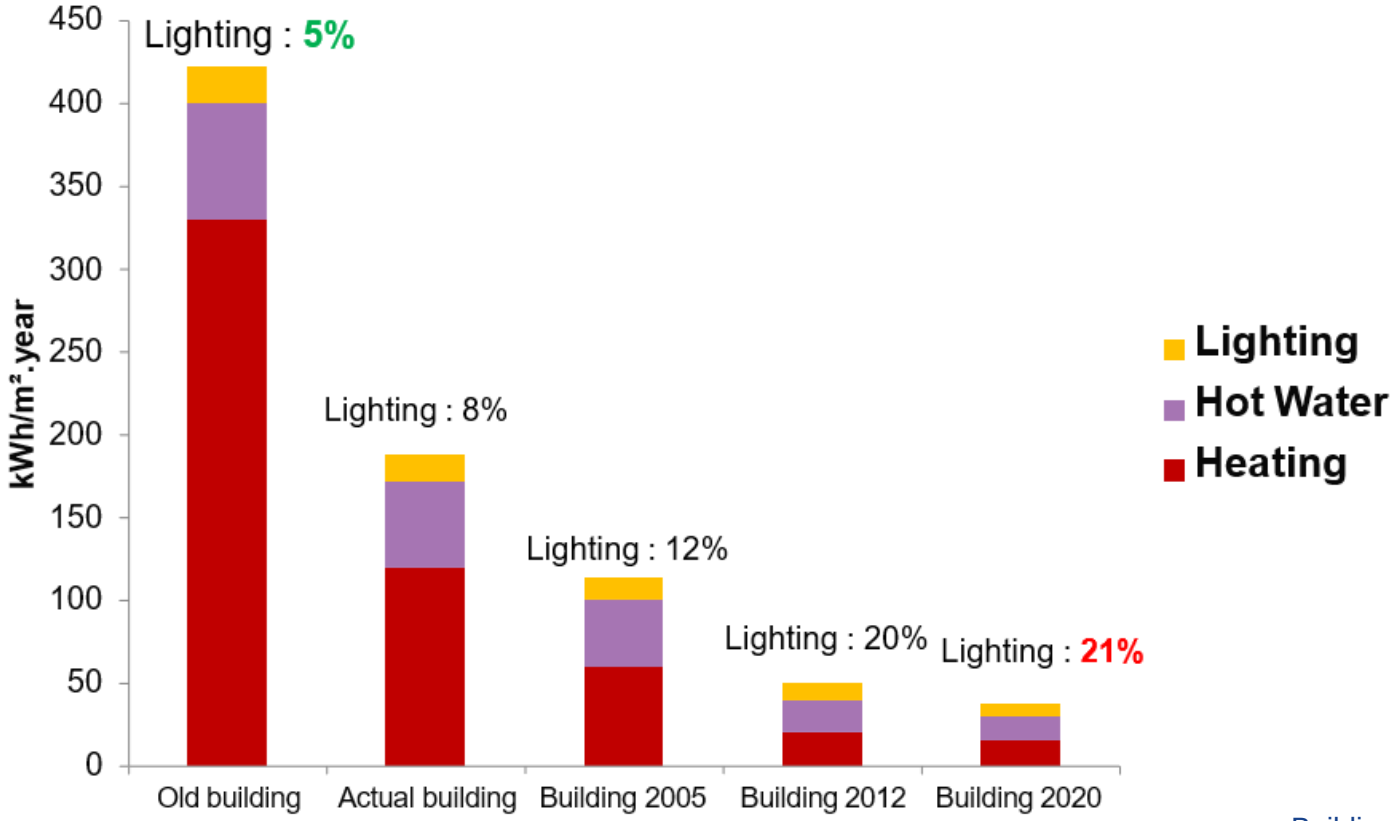
Energy balance and CO_2 reduction

- Light as free energy
- E < 0 with advanced coatings
- Lower CO2 emissions

Home office productivity // Covid

- Daylight Impact on mood
- Impact on stress reduction
- Impact on job satisfaction

ENERGY SAVINGS ALSO PUSH FOR DAYLIGHT…



Building 2020

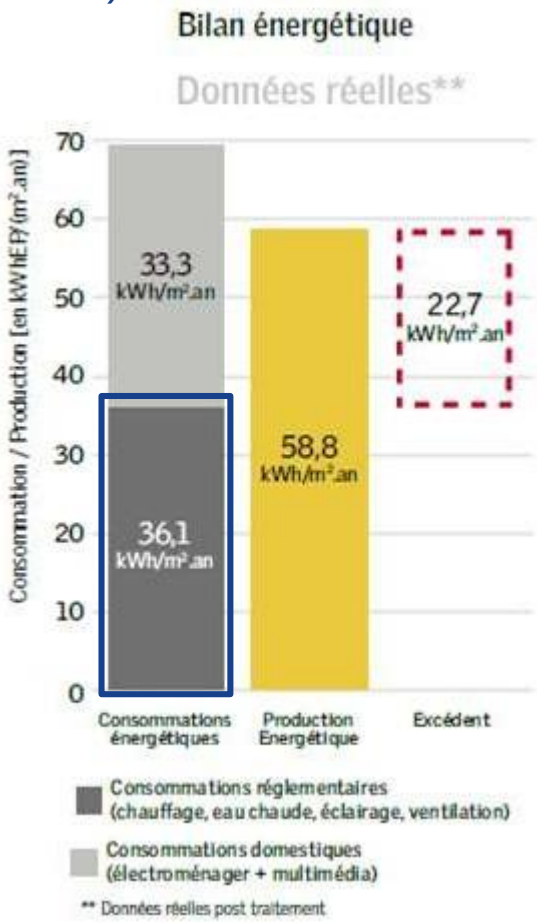
Source: CSTB data (France)

… but energy savings also with low consumption LED lighting

DAYLIGHT COMBINE WITH ENERGY EFFICIENCY

VELUX EXPERIENCE « MAISON AIR & LUMIÈRE » (2013) – WINDOWS 33% OF THE LIVING SPACE

➔ Energy-efficient home consistent with well-being thanks to increased daylight (Glazings 33% of the living space vs standard 17%)



Primary energy consumption
(heating, hot water, lightening, ventilation)
of 36,1 kWh/m².y

far below the maximum recommended level for zero emission building
for single family houses
(oceanic climate)
of 60 kWh/m².y

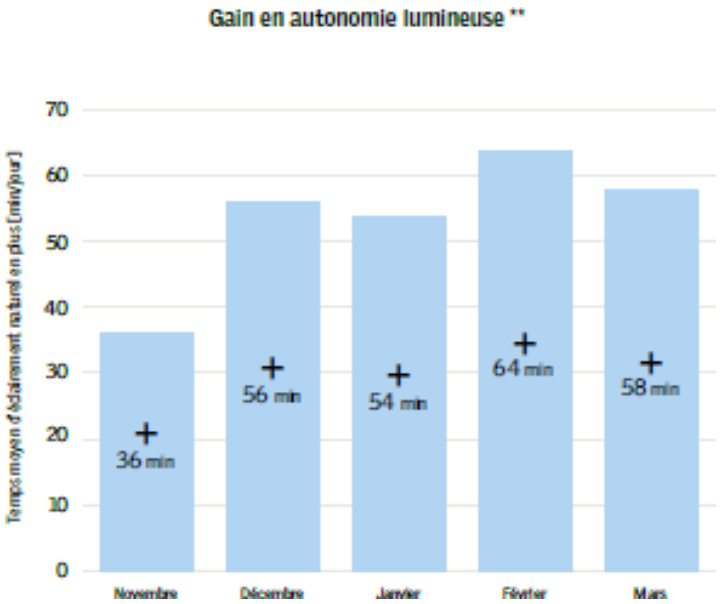
Le ressenti de la famille

La famille n'a ressenti aucune contrainte à voir ses consommations suivies en permanence et assure ne pas avoir sacrifié son confort de vie aux données chiffrées. *« Je ne me suis pas restreinte sur l'eau chaude par exemple ou sur le chauffage. Pour moi, j'étais bien dans la maison en moyenne à 21°C. Mon fils Rayan par contre souhaitait avoir 18°C dans sa chambre »* dit Samantha.

DAYLIGHT COMBINE WITH ENERGY EFFICIENCY

VELUX EXPERIENCE « MAISON AIR & LUMIÈRE » (2013) – WINDOWS 33% OF THE LIVING SPACE

➔ Daylight is key for well-being and lower electricity consumption for lightning



**Glazings 33% of the living space vs 17% (Cardonnel Ingénierie)*

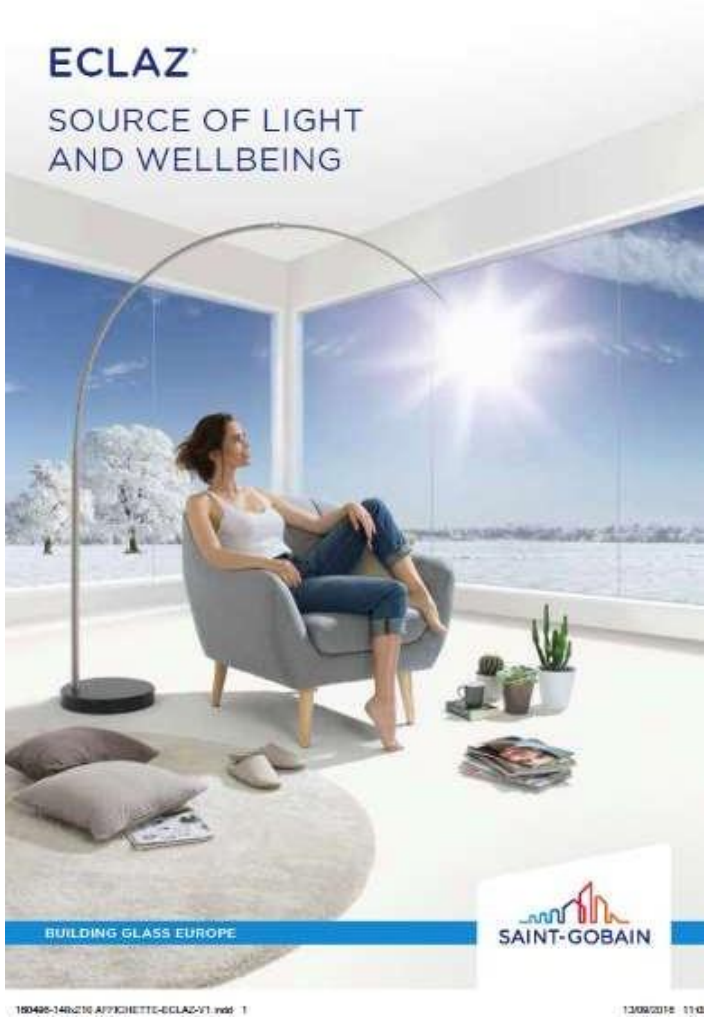
***Calcul du gain de temps d'éclairement naturel dans la maison Air et Lumière (à partir de l'algorithme RT2012 – seuil minimum de confort visuel fixé à 300 Lux) par rapport à la même maison avec 1/6ème de surface de baies.*

The optimization of natural light in the house had a direct impact on electricity consumption for lighting:
1.7 KWh/m².year vs 3.5 KWh/m².year forecast by the regulatory calculation.

Natural light covered 43% of home lighting needs versus 22% in the same virtual home with less glass *.

In winter, calculations show that the house has benefited from more than 50 minutes of additional natural light per day **.

DAYLIGHT: MAJOR ARGUMENT IN MARKETING



K•LINE

Les Herbiers, mars 2021

K•LINE fête le retour de la lumière avec son nouveau spot TV « Let the sunshine in »

https://www.youtube.com/watch?v=AKobJ8Gx82Y&t=4s

HOW TO BRING NATURAL LIGHT INSIGHT OUR BUILDING?





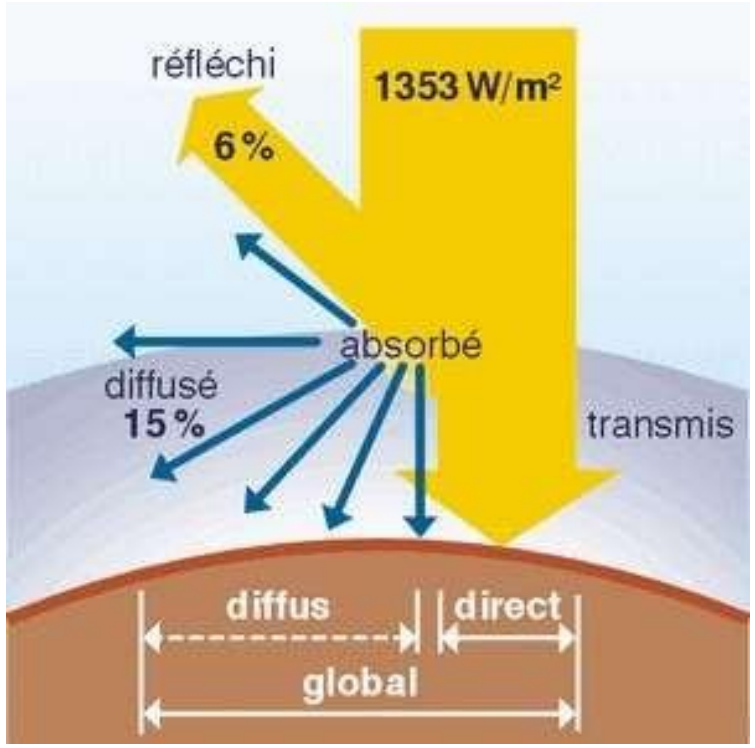


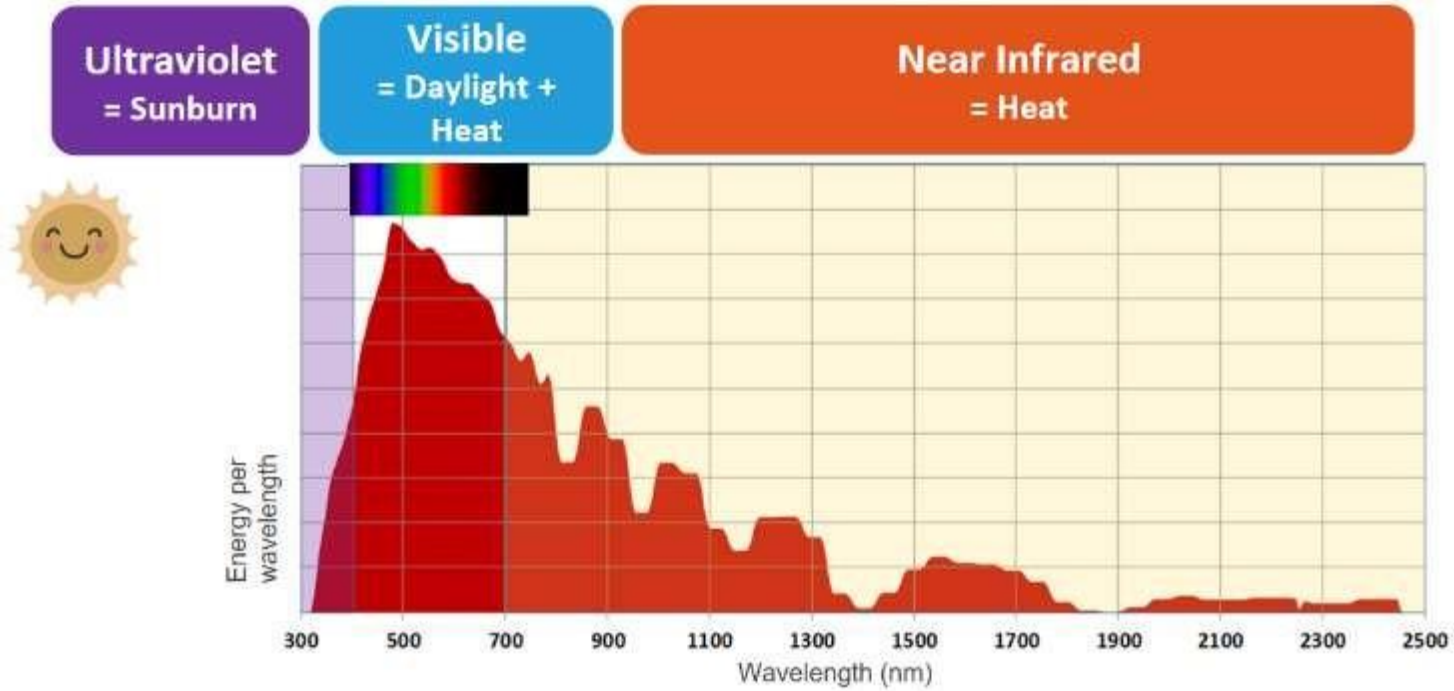

… WITH A GOOD COMFORT?

Uncontrolled light can easily become uncomfortable!!!

BASIC PRINCIPLES OF DAYLIGHTING

SOLAR SPECTRUM CONTAINS DAYLIGHT AND HEAT



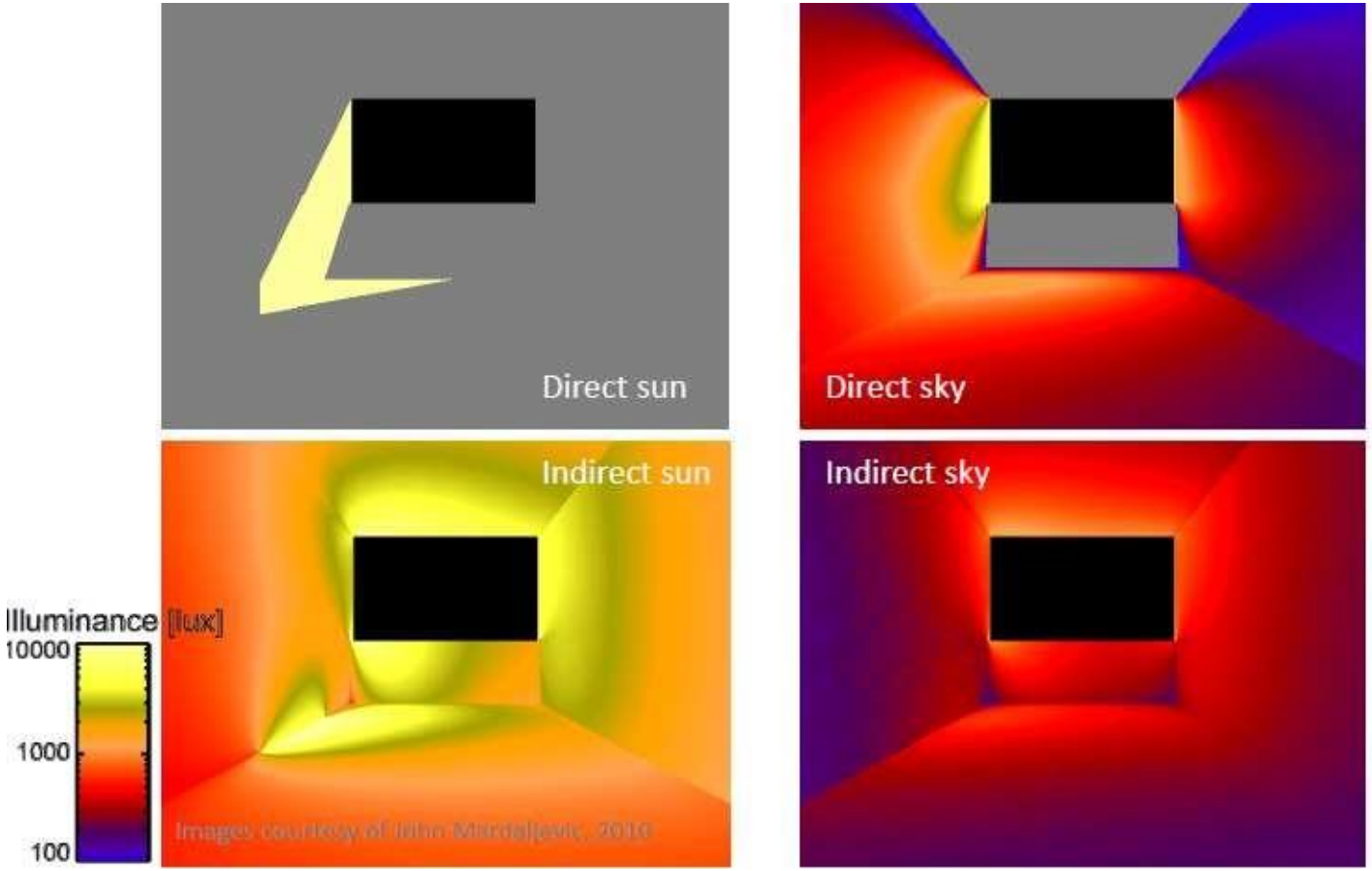


Visible light range situated at sun's maximum output wavelength (400 – 700 nm)

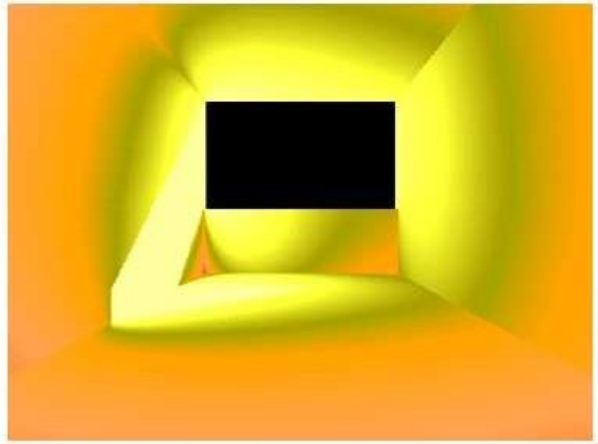
Almost half of the solar energy brings light

SOURCES OF DAYLIGHT IN BUILDINGS

4 components of Daylight



Total illuminance



SOURCES OF DAYLIGHT IN BUILDINGS

Illuminance (lux): measures the amount of light emanating from light source (lum) incident on a surface per m² (lux)

Luminance (cd/m²): measures the brightness of a surface when viewed from a particular direction

Luminance is the photometric quantity that the eye perceives, but it is much more complex to measure than illuminance

Luminous flux (lum): quantity of light emmited by a source in every directions per time (eq. Power)

Luminous intensity (cd): quantity of light emmited by a source in one given direction and solid angle

Source: « Le confort visuel et ses paramètres », M. Bodart

SOURCES OF DAYLIGHT IN BUILDINGS

Typical illuminance (E) and luminance (L) values under natural and articial light

	E (lx)
Sunlight	100000
Overcast sky	10000
Task lighting	1000
Circulation zone lighting	100
Street lighting	10
Moonlight	1

	L (cd/m²)
Sunlight	1000000000
Incandescent lamp (matt finish)	100000
Fluorescent lamp	10000
Sunlit Clouds	10000
Blue sky	5000
Luminous ceiling	500
Louvred luminaires	100
Preferred values in interior spaces	50–500
White paper at 500 lx	100
Monitor (negative)	10–50
White paper at 5 lx	1

FACTORS IMPACTING DAYLIGHT (DF or DA)

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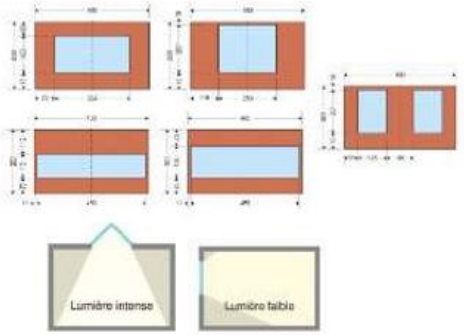
Climate conditions

Clear sky

Overcast sky

Sun position

Openings properties, properties & distribution



External environment

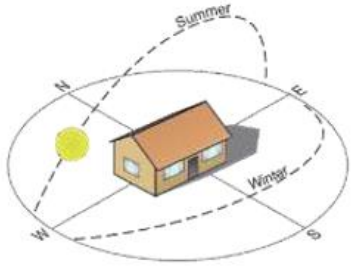
Neighboring buildings

Vegetation

Ground reflection

Louvers

Building orientation

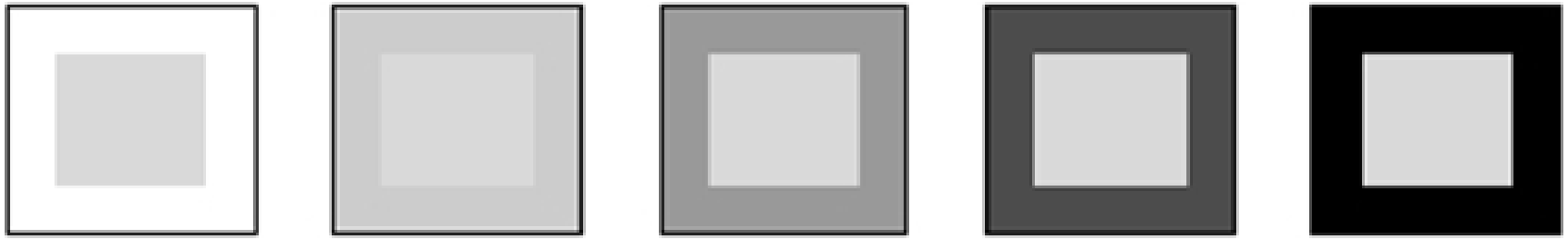


Interior layout (color, furniture)

Occupants behavior (eg on blinds)

High variability over time and space & sensitivity to many factors !!!

BUT THE VISUAL COMFORT IS ALSO IMPACTED BY OUR PERCEPTION…



… AND THE GLARE

Various causes

Veiling Reflections of bright sun or sky on computer screens

Direct view of sun

High luminance contrasts

Sun reflection from neighboring buildings

Very subjective, depends on occupant's view direction and its ability to move

HOW TO CHARACTERIZE DAYLIGHT PERFORMANCE?

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DAYLIGHT IN REGULATIONS AND STANDARDS

Regulation / standards / certifications are key drivers to promote daylighting in buildings

Daylighting more and more recognized as important factor, both for energy savings and comfort potential

Daylighting today considered mostly in green building labels

+ NEW European Standard on Daylight in buildings EN 17037

Performance criteria and evaluation methods exist but there is no consensus !

RECOMMENDED LIGHT LEVELS

Recommendations given in illuminance levels (lux), for a certain type of **building** (residential, office, etc.) and **task**

Associated with luminance ratios recommendations

Standard recommended illuminance values:

- *Offices:* ***500 lux***
- *Residential:* ***300 lux***

Recommended contrast against glare: ***1:3:10***
(visual task:immediate environment:extended environment)

No real consensus today on the « right » levels!

Recommendations initially developed for artificial lighting design

RECOMMENDED LIGHT LEVELS

Task lighting	1000
Circulation zone lighting	100

Illuminance (lux) = measure of the amount of light received on a surface
= measure used to determine daylight availability in the interior

Office Space

500 lux:

Normal work station space, open or closed offices / Training Rooms

300 lux:

Conference Rooms

200 lux:

Internal Corridors / Public Areas Entrance Lobbies, Atria / Elevator Lobbies, Public Corridors / Ped. Tunnels and Bridges / Stairwells

150-200 lux:

Auditoria

Specialty Areas

500 lux:

Kitchens / Outleased Space / Physical Fitness Space / Child Care Centers / Structured Parking, Entrances

150-200 lux:

Dining Areas

100 lux:

Structured Parking, Intersections

50 lux:

Structured Parking, General Space

Support Spaces

200 lux:

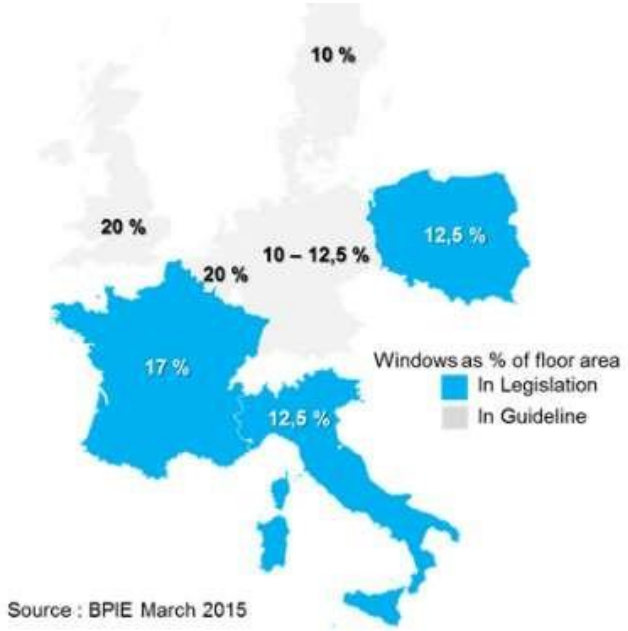
Toilets / Staff Locker Rooms / Storage Rooms, Janitors' Closets / Electrical Rooms, Generator Rooms / Mechanical Rooms / Communications Rooms / Maintenance Shops / Loading Docks / Trash Rooms

Source: « *Trends in recommended Illumiance Levels : An Internation Comparison"* Evan Mills and Nills Brog (1999)

WINDOW / FLOOR: BASIC PARAMETER IMPACTING DAYLIGHT AND VIEW

Ratio of window (glazing) area per floor area

- Minimum ratio as basic reference to daylight in some building codes
- Country dependant
- Impact on views and daylight provision



- Higher in non residential buildings (Facades)

→ generated heat compensated by special glazings with solar control

Residential = 10% to 20% (average ≈ 12%)
Facades = 45% to 60%

QUALITY OF DAYLIGHT: TWO MAIN METRICS

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Daylight factor

BREEAM HQE DGNB

- Ratio of the light level inside a structure to the light level outside the structure, in overcast sky conditions:
- DF = (Ei / Eo) x 100%
  - Ei = illuminance due to daylight at a point on the indoors working plane
  - Eo = simultaneous outdoor illuminance on a horizontal plane from an unobstructed hemisphere of overcast sky.

- Values recommended:

2-5% Easy to calculate

- Most widely used and accepted indicator

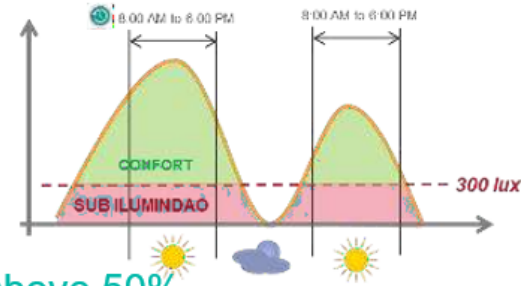
Daylight autonomy

LEED WELL BUILDING STANDARD

Percentage of the time of the year (during occupancy time*) when illuminance is above a given threshold**

* occupancy time usually 8.00am-6.00pm

** illuminance threshold usually 300 lux



Typical « good » values : above 50%

Easy to understand

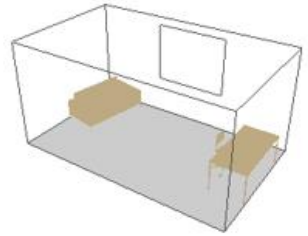
Climate and orientation dependant

Dynamic: // time and weather conditions over the year

LIMITS OF THE DAYLIGHT FACTORS

For Saint-Gobain, Daylight Factor is NOT the right parameter to evaluate Visual Comfort as it is independent from latitude and orientations and only depends on building geometry!

Room with DF of 2% leads to different visual comfort depending on orientation



Daylighting results at Paris on March 21st at 12.00 intermediate sky:

Window North facing: DF = 2%

Window South facing: DF = 2%

DAYLIGHT AUTONOMY FOR SAME DAYLIGHT FACTOR 2%

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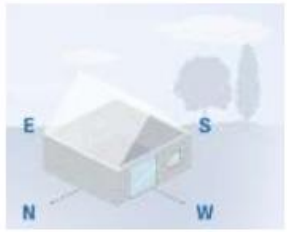
Daylight Autonomy calculated for an occupation time from 8.00am to 6.00pm a target illuminance of 300 lux in the room

Impact of latitude – Average on orientations

PARIS latitude – Impact of orientations

Window North facing
Average DA = 33%



Window East/West facing
Average DA =43%

Window South facing
Average DA = 55%

OTHER DESCRIPTORS FOR VISUAL COMFORT

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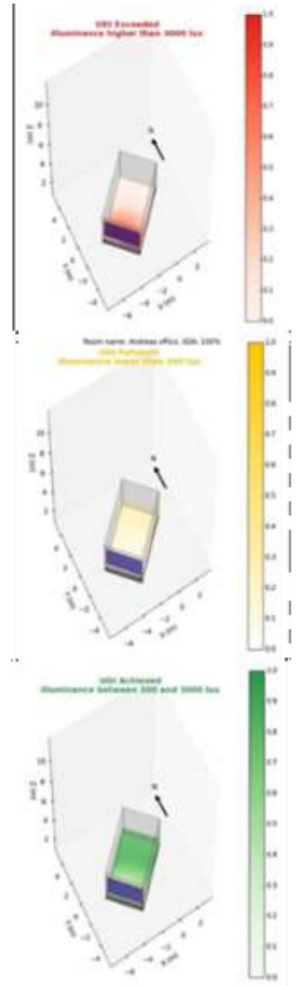
UDI (Useful Daylight Illuminance)

Mapping of annual occurrence of illuminance in a room on a horizontal plane:

- $UDI_{supplementary}$ <300 lux (Underlit Time)
- $UDI_{autonomous}$ between 300 and 3000 lux (Daylit Time)
- $UDI_{exceeded}$ > 3000 lux (Overlit Time)



Spatial Daylight Autonomy (sDA)

Spatial representation of Daylight Autonomy calculation for a whole room

- % of space for which illuminance is above an illuminance threshold (300 lux) more than a percentage of the year (50% during occupancy)
- Recommended value: sDA > 75%

EN17317: FIRST EUROPEAN GUIDELINES FOR DAYLIGHT IN BUILDINGS

3-level recommandations (minimum, medium, high) in terms of

- **Daylight Provision**
- **View Out**
- **Exposure to Sunlight**
- **Protection from Glare**

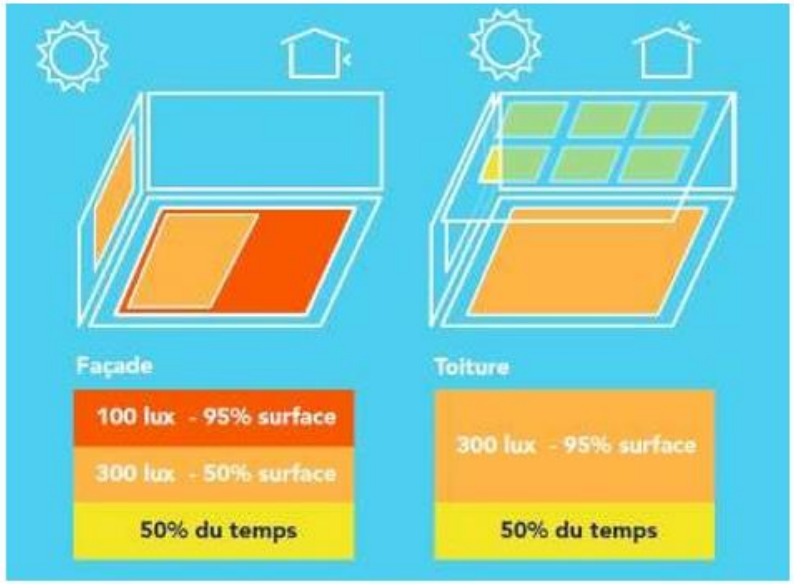
Very ambitious standard → simplifications under discussions

EN 17037: One small step for the world of standardization, one giant leap toward making our buildings more comfortable

https://www.sageglass.com/eu/visionary-insights/first-european-standard-daylight-buildings

EUROPEAN STANDARD EN 17037 (2019) → DAYLIGHT PROVISION

MIN 300 LUX @ 50% SURFACE AND 100 LUX @ 95% SURFACE, DURING 50% OF DAYLIGHT HOURS



Two calculation methods – location dependant:

- **Method 1 based on daylight factors** (objective DF > Target DF which is location dependant)
- **Method 2 based on daylight autonomy calculation**

For facades (vertical & inclined surface) :

Level	Target illuminance E_T (lux)	Fraction of space for target level	Minimum target illuminance E_{TM} (lux)	Fraction of space for minimum target level	Fraction of daylight hours
Minimum	300	50 %	100	95 %	50 %
Medium	500	50 %	300	95 %	50 %
High	750	50 %	500	95 %	50 %

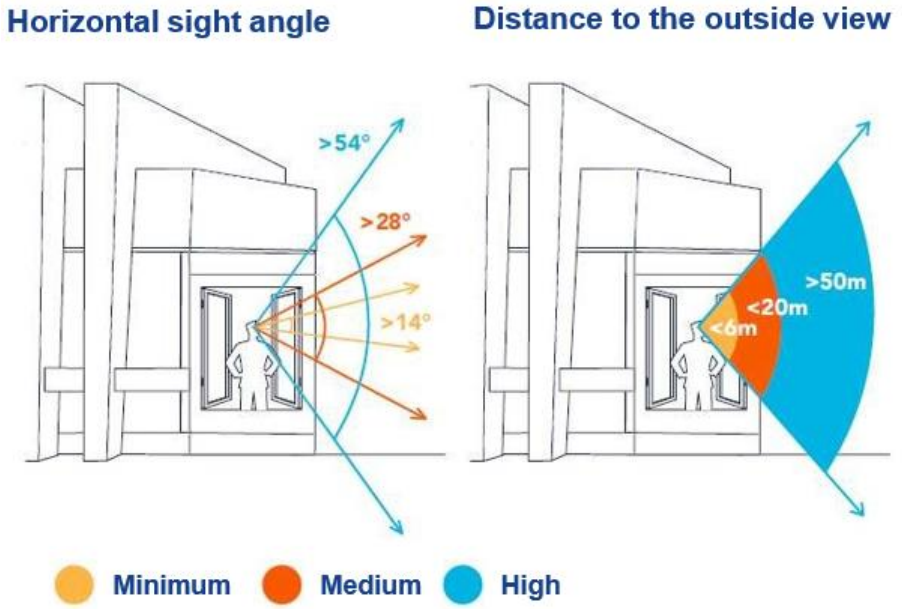
** Infography Kingspan https://www.kingspan.com/fr/fr-fr/produits/eclairage-naturel/actualites/2019/comprendre-la-norme-en-17037-la-nouvelle-norme-d*

EUROPEAN STANDARD EN 17037 (2019) → VIEW OUT

MIN 6 M VIEW WITH 14° HORIZONTAL SIGHT ANGLE

Type of layers

	Minimum	Medium	High
Sky		✓	✓
Landscape	✓	✓	✓
Ground		✓	✓



The quality of the view should be ensured with a clear and neutrally coloured glazing system

** Infography Kingspan https://www.kingspan.com/fr/fr-fr/produits/eclairage-naturel/actualites/2019/comprendre-la-norme-en-17037-la-nouvelle-norme-d*

EUROPEAN STANDARD EN 17037 (2019) → EXPOSURE TO SUNLIGHT

MINIMUM DIRECT SUN EXPOSURE OF 1.5 H IN AT LEAST ONE HABITABLE SPACE

Determination of the direct sun exposure from a reference point P position on the window opening, on a selected date between 1. February and 21. March

Level of recommendation	Sunlight exposure
Minimum	1.5 h
Medium	3.0 h
High	4.0 h

EUROPEAN STANDARD EN 17037 (2019) → PROTECTION FROM GLARE

DAYLIGHT GLARE PROBABILITY LOWER THAN 0.45 FOR 5% OF THE OCCUPATION TIME

Discomfort (« look away ») and disability glare (« can't see »)

Criterion	DGP
Imperceptible glare	DGP ≤ 0.35
Perceptible glare	0.35 < DGP ≤ 0.40
Disturbing glare	0.40 < DGP ≤ 0.45
Intolerable glare	DGP ≥ 0.45

Level of glare protection	$DGP_{e\ <5\%}$
Minimum	≤ 0.45
Medium	≤ 0.40
High	≤ 0.35

2 Methods:

- Evaluation of Annual Daylight Glare Probability DGP
  - the DGP should not exceed the level of glare protection for 5% of the total occupation time of a space
- Simplified Glare Evaluation SGE // solar protection devices assessment (opaque, see-through, low TL glazing)

Définition du Daylight Glare Probablilty (DGP)

Luminance de la source éblouissante

Angle solide de la source éblouissante

$$DGP = 5.87 \cdot 10^{-5} \cdot E_v + 9.18 \cdot 10^{-2} \cdot \log\left(1 + \sum_i \frac{L_{s,i}^2 \cdot \omega_{s,i}}{E_v^{1.87} \cdot P_i^2}\right) + 0.16$$

Eclairement vertical au niveau de l'oeil

Indice de position de Guth

$DGPs = 6{,}22.10^{-5} . Ev + 0{,}184$ (formule simplifiée)

DAYLIGHT CRITERIA IN SUSTAINABLE CONSTRUCTION BY SAINT-GOBAIN

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How can access to natural light be taken into account in building design?

- Maximized useful contribution of daylight
- Appropriate light levels and distribution on working planes for the occupier visual tasks
- Occupants able to tailor the lighting to their individual needs
- Electric light fittings of suitable quality

INDICATORS			DEFINITION	NEW BUILD		RENOVATION		REFERENCE STANDARD
				TARGET (MUST)	RECOMM. (NICE)	TARGET (MUST)	RECOMM. (NICE)	
Light quality	Artificial lighting (lux)			Required level for each room depending on use				
Light quality	DA		Daylight Autonomy (%)	>60%		Optimize existing openings through glazing specification	>60%	EN 12665
Light quality	UDI		Exceeded Useful Daylight Illuminance (%)	<10%			<10%	
Light quality	Offices only	sDA	Spatial daylight autonomy (% of floor surface)	65 – 75%	>75%		>75%	EN 12464-1
Light quality	Offices only	ASE	Annual Sunlight Exposure (% of floor surface)	7 –10%	<7%		<7%	
Views	Opening to floor ratio			>20%			>20%	
Views	Quality of the view (rating 0 –3)			2	3		3	Hester Hellinga method
Space quality	Space quality assessment (rating 0 – 3)			2	3		3	Saint Gobain questionnaire

** Definitions in annex*

DAYLIGHT CRITERIA IN SUSTAINABLE CONSTRUCTION BY SAINT-GOBAIN

ARCHITECTURE STUDENT CONTEST

Rooms/ segments specific requirements

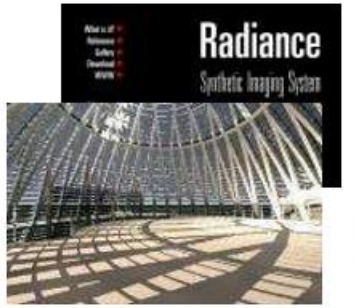
INDICATORS	LIGHT QUANTITY	LIGHT QUANTITY				VIEWS		SPACE QUALITY
	ARTIFICIAL LIGHTING (LUX)	DA	UDI	SDA	ASE	OPENING TO FLOOR RATIO[2]	QUALITY OF THE VIEW (RATING 0 – 3)	ASSESSMENT (RATING 0 – 3)
Res. children's bedroom		>60%	<10%			>20%		
Res. living room		>60%	<10%			>20%		
Open plan office	>300 (workplan) >200 (50cm around workplan) >100 (others)			65 – 75% (>75%)	7 – 10% (>7%)		2 (3)	2 (3)
Meeting room								
Individual office								
Classroom								
Patient room		>60%	<10%			>20% (>25%)		
Hotel room		>60%	<10%			>20%		

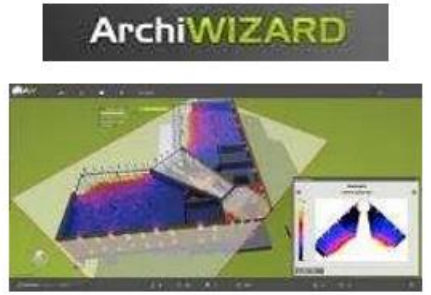
** Definitions in annex*

DAYLIGHT SIMULATION TO ASSESS DAYLIGHT PROVISION OR GLARE

ARCHITECTURE STUDENT CONTEST

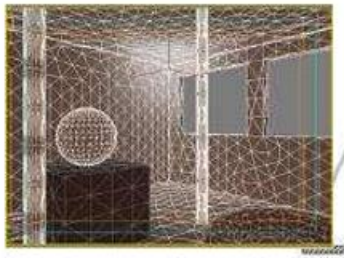
Various existing softwares...

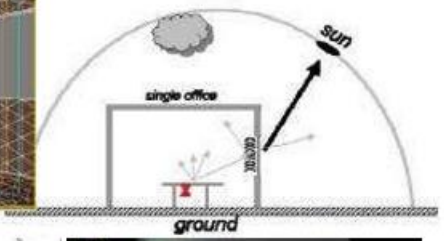


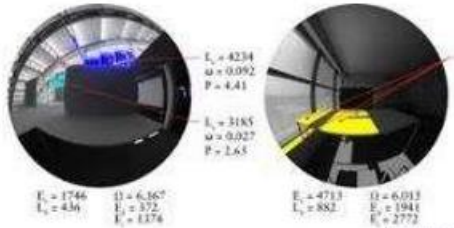


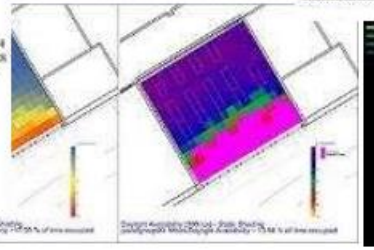
…With high differences in capabilities,

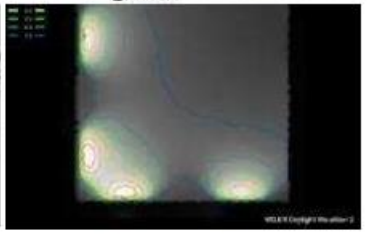
calculation method, accuracy, and audience



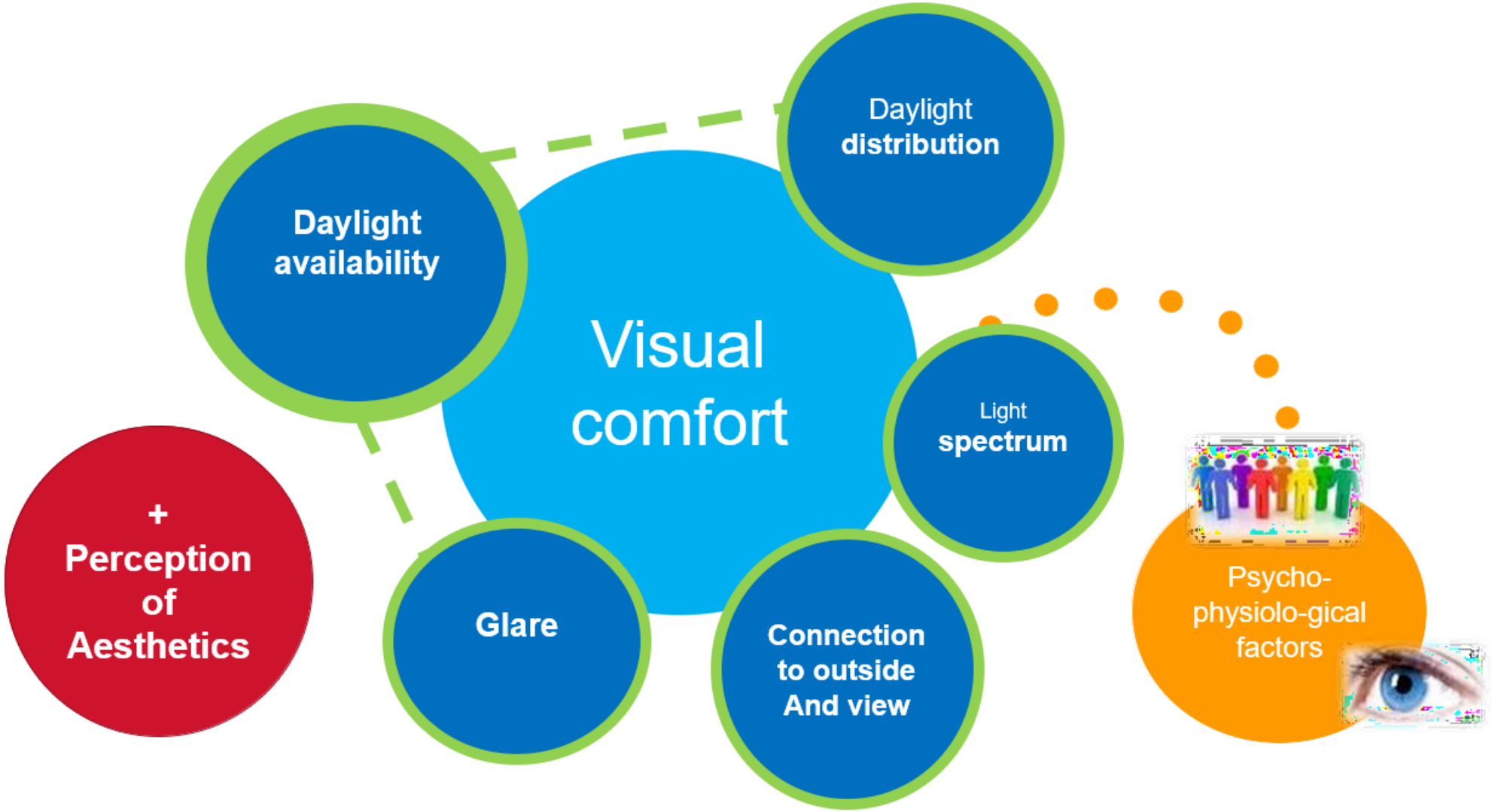








DAYLIGHT AND VISUAL COMFORT...



HOW TO DESIGN BUILDINGS WITH GOOD DAYLIGHTING?

ARCHITECTURE STUDENT CONTEST

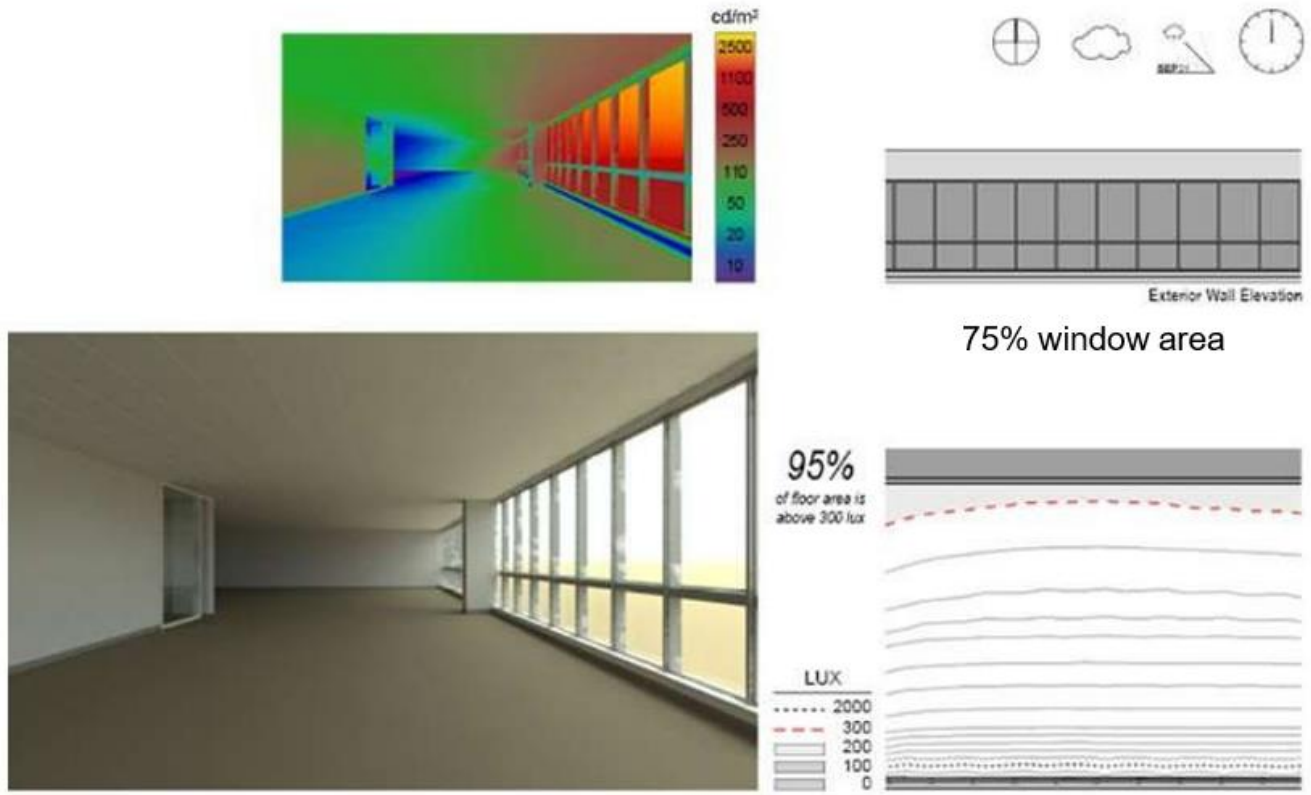
HOW TO DESIGN A WELL DAY-LIT SPACE?

Daylighting strategy **key factors**:

- Building orientation
- Openings (geometry, position, distribution, properties)
- Interior layout (transparent partitions, furniture)
- Room surfaces material (nature and color)
- Light distribution systems (lightshelves, light-pipes, light-redirecting shades etc.)

DAYLIGHTING DESIGN STRATEGIES

Impact of window area

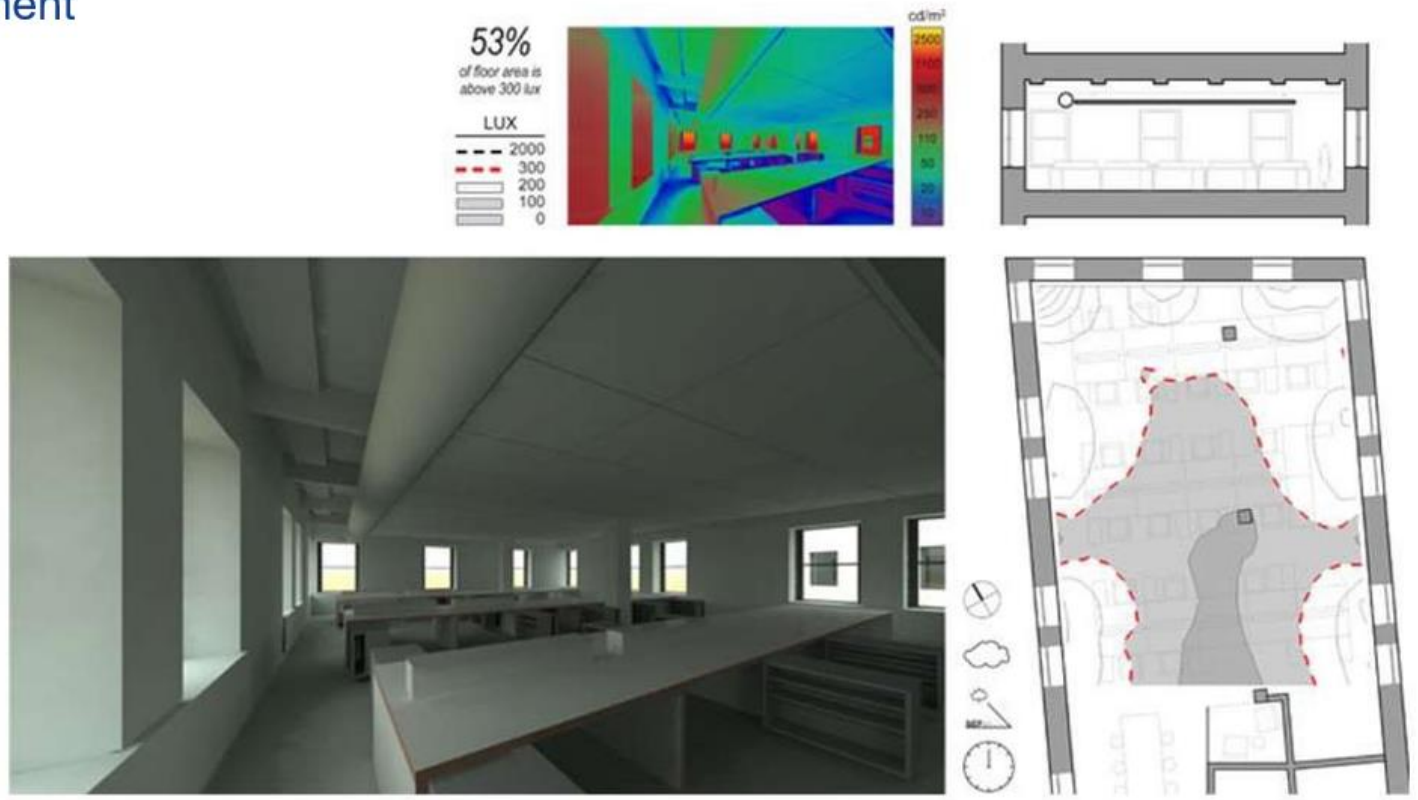


Source: the daylighting pattern guide (NBI)

DAYLIGHTING DESIGN STRATEGIES

ARCHITECTURE STUDENT CONTEST

Impact of window placement

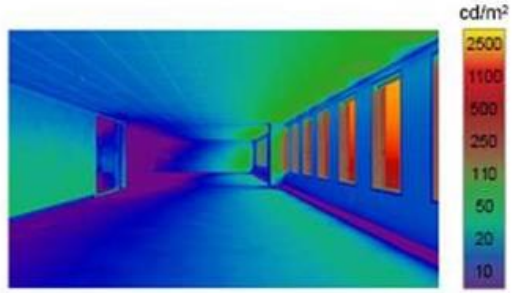


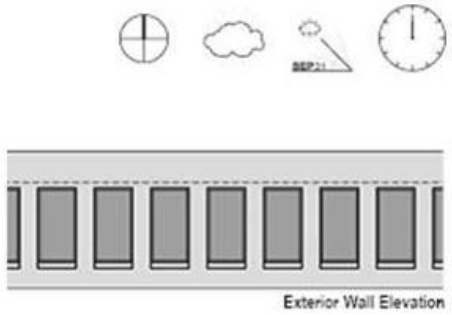
Source: the daylighting pattern guide (NBI)

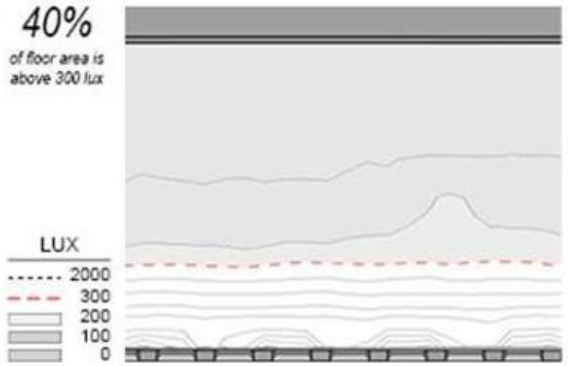
DAYLIGHTING DESIGN STRATEGIES

ARCHITECTURE STUDENT CONTEST

Impact of window placement



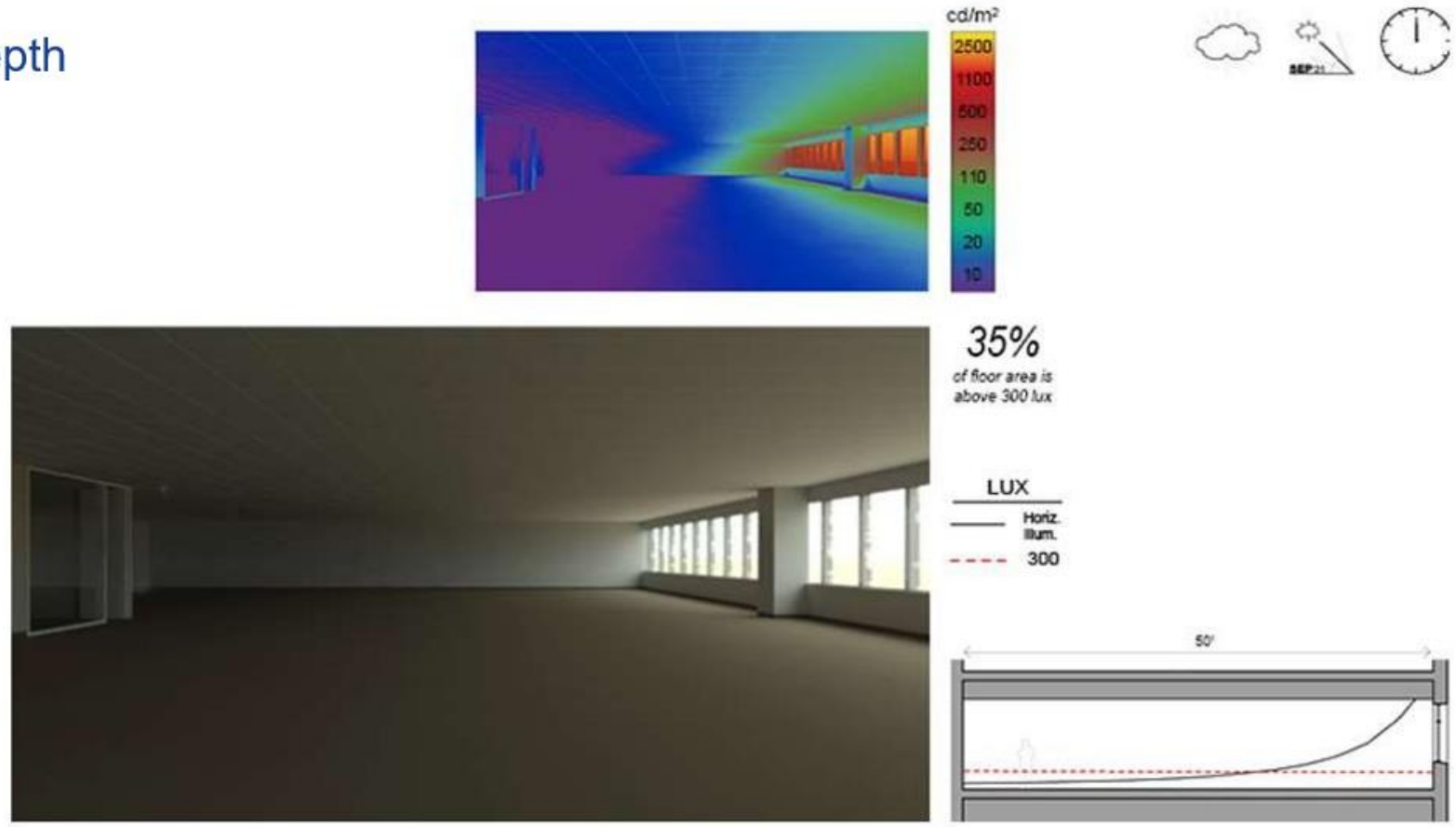




Source: the daylighting pattern guide (NBI)

DAYLIGHTING DESIGN STRATEGIES

Impact of room depth



Source: the daylighting pattern guide (NBI)

DAYLIGHTING DESIGN STRATEGIES

Source: the daylighting pattern guide (NBI)

SO THE VISUAL COMFORT IS ABOUT ARCHITECTURE DESIGN...

ARCHITECTURE STUDENT CONTEST

Quantity of light

Quality of light

View to outside

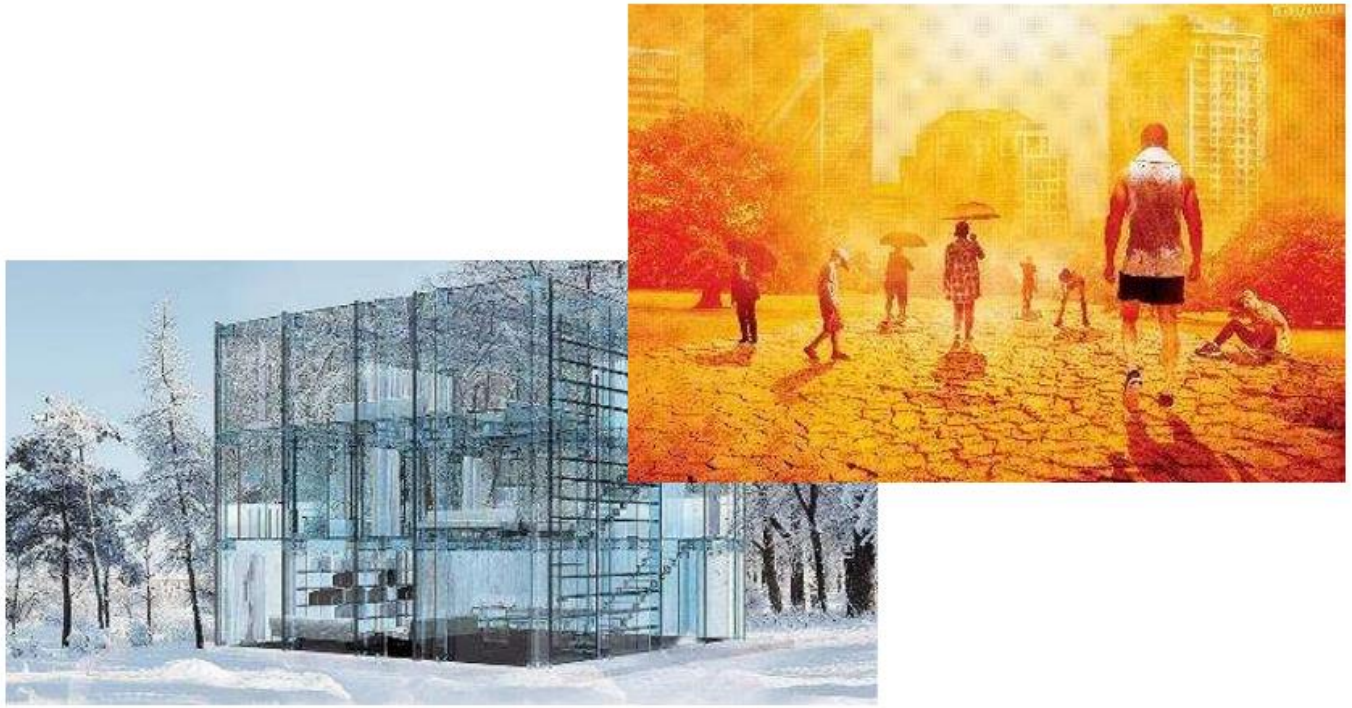
Aesthetics

…BUT ALSO, THE CHOICES OF BUILDING ENVELOPE COMPONENTS COUNT

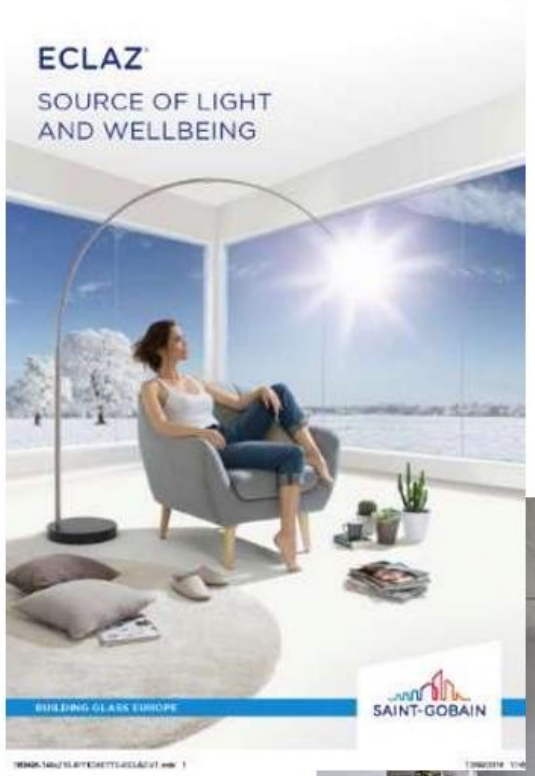
ARCHITECTURE STUDENT CONTEST

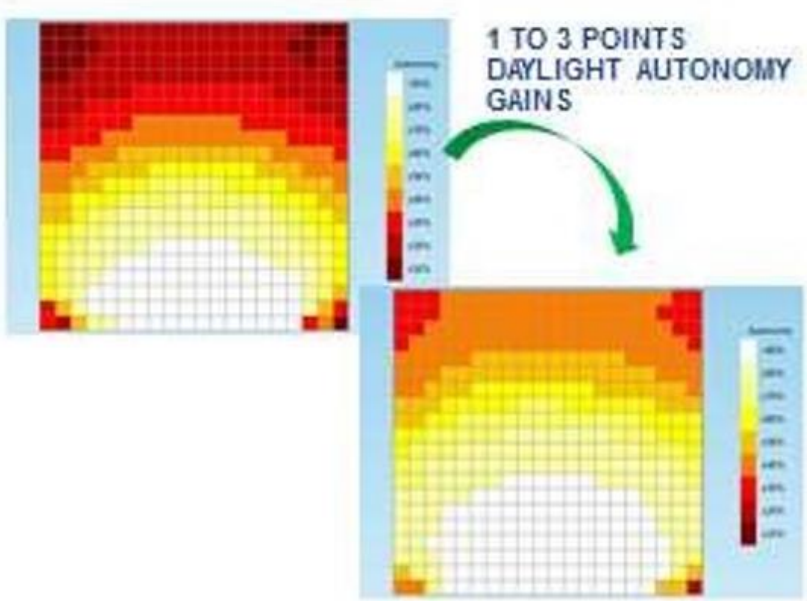
➔ CHOOSE THE RIGHT GLAZING PERFORMANCE FOR THE RIGHT APPLICATION

Renovation: Optimize existing openings through glazing specification



DAYLIGHT COMBINED WITH ENERGY EFFICIENCY IN WINTER





Energy savings

Heating cost savings thanks to free solar energy and optimum insulation

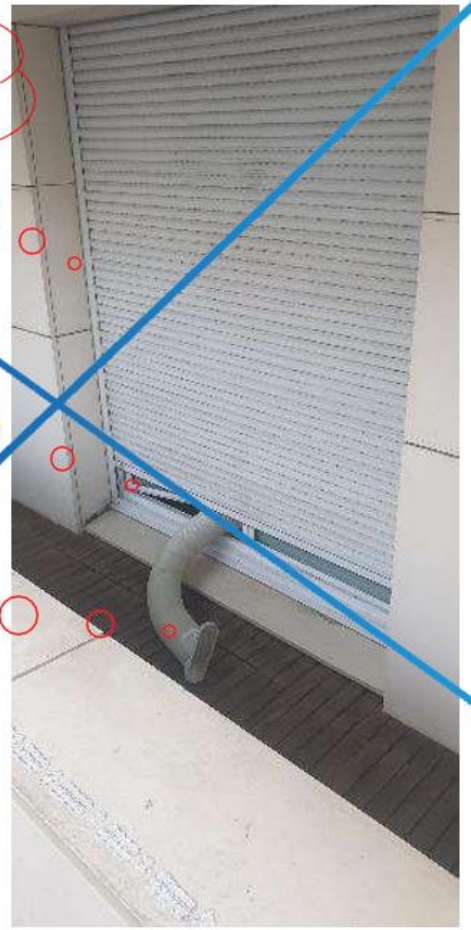
DAYLIGHT COMBINED WITH SUMMER COMFORT

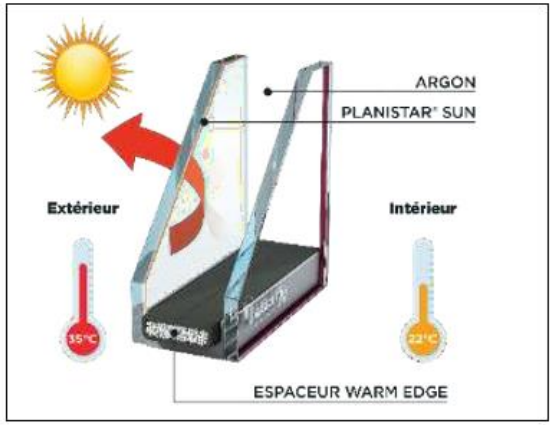
ARCHITECTURE STUDENT CONTEST

To Protect againt Sun Heat, **I'm living in the Dark**

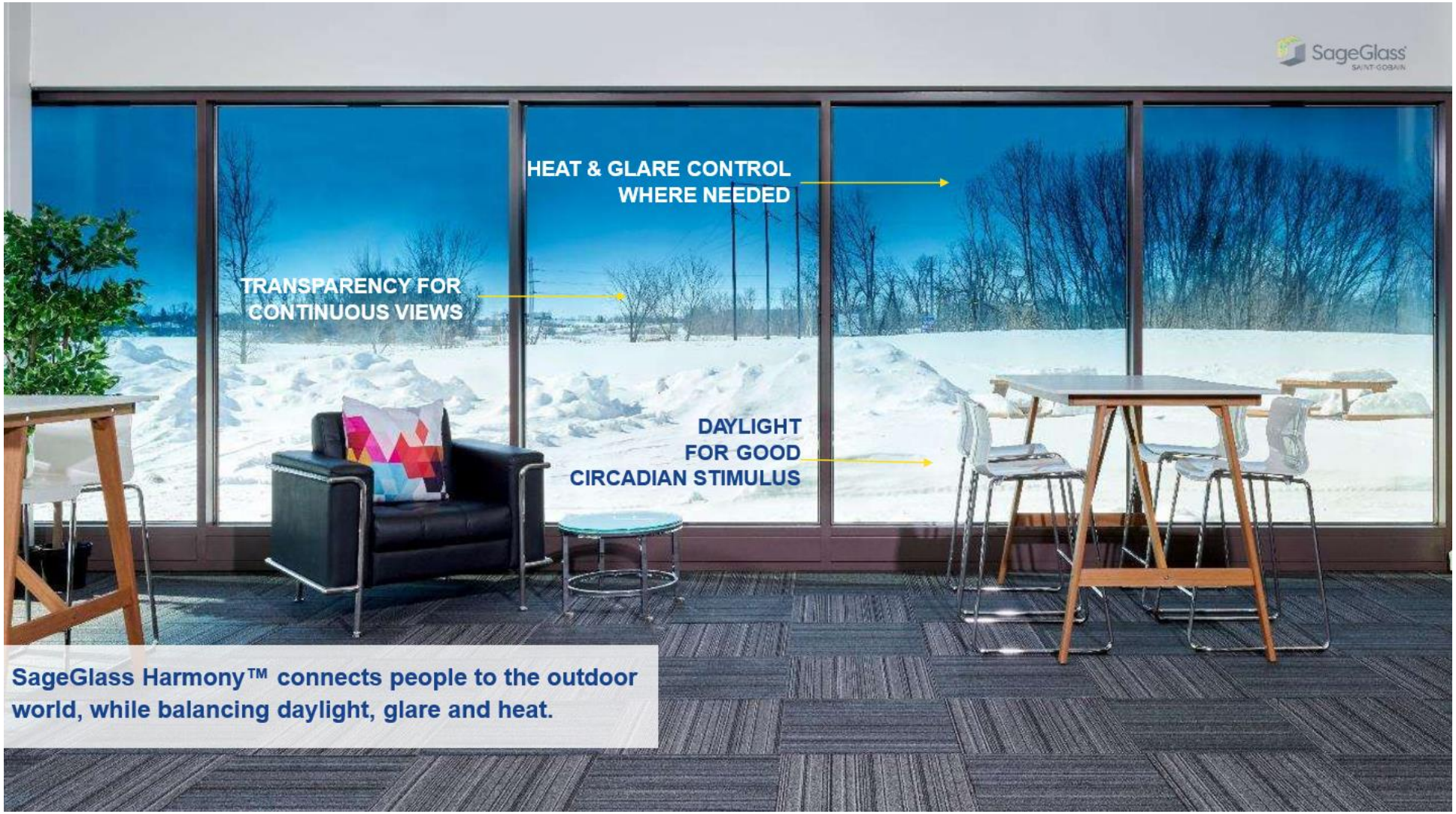
I Open the Window even if Heat come inside

Air Conditionning : **Noise + Energy consumption**





DYNAMIC GLASS FOR OCCUPANT WELLNESS



ANNEXES

SOME FIGURES

Typical values of walls reflection factors

Paint finish	
White	0.70–0.80
Pale yellow	0.60–0.70
Pale green, light red, pale blue, light grey	0.40–0.50
Beige, ochre, orange, mid-grey,	0.25–0.35
dark grey, dark red, dark blue, dark green	0.10–0.20

Metals	
Aluminium, highly specular	0.80–0.85
Aluminium, anodised, matt finish	0.75–0.85
Aluminium, matt finish	0.50–0.75
Silver, polished	0.90
Copper, polished	0.60–0.70
Chrome, polished	0.60–0.70
Steel, polished	0.50–0.60

Building materials	
Plaster, white	0.70–0.85
Gypsum	0.70–0.80
Enamel, white	0.60–0.70
Mortar, light	0.40–0.50
Concrete	0.30–0.50
Granite	0.10–0.30
Brick, red	0.10–0.20
Glass, clear	0.05–0.01

RECOMMENDED LIGHTING LEVELS

Table 1— Variation factor between highest and lowest recommendation in 19 countries (based on Table 2)

	19-country Low	19-country High	Variation Factor	CEN/TC-169 Proposed European Guideline
Offices				
General	50	1000	20,1	500
VDT Tasks	150	750	5,1	500
Desk	150	1000	7,1	500
Reading Task	75	1000	13,1	500
Drafting (det)	200	3000	15,1	750
Classrooms				
General	75	750	10,1	400
Chalkboards	250	1500	6,1	500
Retail Stores				
Ambient	50	1500	30,1	300
Tasks/Till Area	100	1500	15,1	500
Hospitals				
Common Area	50	300	6,1	200
Patient Room	30	300	10,1	100
Operating Room	300	2000	7,1	1000
Operating Table	100	1000	10,1	450
Manufacturing				
Fine Knitting	50	2000	40,1	750
Electronics	200	5000	25,1	1500

Source: « *Trends in recommended Illumiance Levels : An Internation Comparison"*
Evan Mills and Nils Borg (1999)

RECOMMENDED LIGHTING LEVELS

Preferred Luminance Ratios and Luminances

Investigation	Luminance (cd/m^2)	Task:wall luminance ratio	Ceiling:wall luminance ratio	Wall maximum :minimum
Tregenza et al. (1974)		2 to 1	1.6 to 1	
Ooyen et al. (1986/1987)		3.3 to 1		
VDT work (wall)	20-45			
Other tasks (wall)	30-60			
Miller (1994)	75			3 to 1
Miller et al. (1995)				
Direct/indirect systems			1:3 through 3:1	
Parabolic direct systems			1:5 and 1:3	
Loe et al. (1994)	5		1:1	161 to 1
Berrutto et al. (1994)				
Free choice	117-179			
Restricted power use	60-109			

Note. For Loe et al. (1994), the values are those of the configuration rated as most interesting, and the luminance value is the average wall luminance in the field of view. For Berrutto et al. the luminance values are mean values for walls on the right or the left of the desk in a room with VDTs.

Source: «*Determinants of Lighting Quality II: Research and Recommendations", Veitch et al, 1996*

PROOF OF DAYLIGHT IMPACT ON HEALTH

In healthcare building[1] : patients with access to natural daylight leave hospital sooner, are less exposed to risk of post-operative depression and need less pain relief

In schools[2] : students in building exposed to natural daylight achieve better scores, are calmer and more focused

In offices[3,4] : the absence of windows has been connected to higher stress level and increased absenteeism due to sick leave

1David Strong Consulting, *The distinctive benefits of glazing: the social and economic contributions of glazed areas to sustainability in the build environment*, 2012. http://tinyurl.com/kez68ny
2 Ibidem.
3Ihab M.K. Elzeyadi, Ph.D., LEED *Daylighting-Bias and Biophilia: Quantifying the Impact of Daylighting on Occupants Health*, School of Architecture & Allied Arts - University of Oregon, Eugene, USA http://tinyurl.com/ocfk7cw
4 American Academy of Sleep Medicine, "Study links workplace daylight exposure to sleep, activity and quality of life." ScienceDaily. http://tinyurl.com/ngqhj3z

DAYLIGHT CRITERIA IN SUSTAINABLE CONSTRUCTION BY SAINT-GOBAIN

ARCHITECTURE STUDENT CONTEST

Definitions and conditions

- Daylight Autonomy (DA) calculated from 8AM to 6PM over the whole year for a threshold of 300 lux.
- Exceeded Useful Daylight Illuminance (UDI-exceeded) to characterize glare. It is based on the same principle as Daylight Autonomy with illuminance over 3000 lux at a given place.
- Spatial daylight autonomy (sDA) characterizes the percentage of space in a room for which the percentage of daylight autonomy over a year is superior to (b)% for a fixed illuminance threshold called (a).
- Annual Sunlight Exposure (ASE) is the percentage of total floor surface exposed to more than a given threshold of direct light, (a), for a number of hours, (b), over a year.
- Opening to floor ratio is the ratio between the surface of exterior windows (in m^2) and the floor surface of the room (also in m^2).
- Depth of the view is defined as the longest uninterrupted line of view for an occupant through windows in the office. The line of view will be considered good if it is between 10 and 50m and excellent if superior to 50m.
- Qualitative evaluation of the view can be assessed by calculating a score based on the answer to a questionnaire (QVCA method – for small offices)