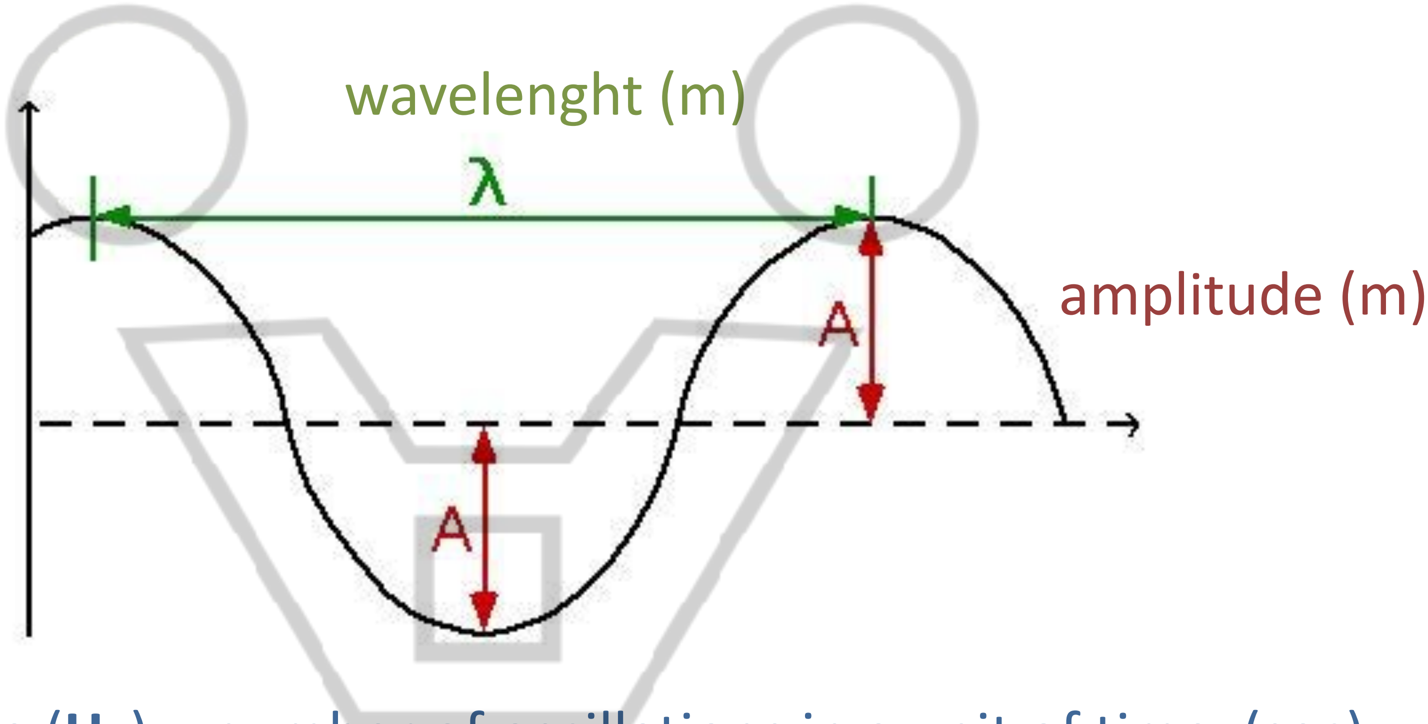
UNIVERSITÀ DEGLI STUDI FIRENZE
Scuola di Architettura

MULTIMEDIA | ARCHITECTURE | INTERACTION

DAYLIGHT.
A CONFLICTUAL RELATIONSHIP BETWEEN THERMAL AND VISUAL COMFORT

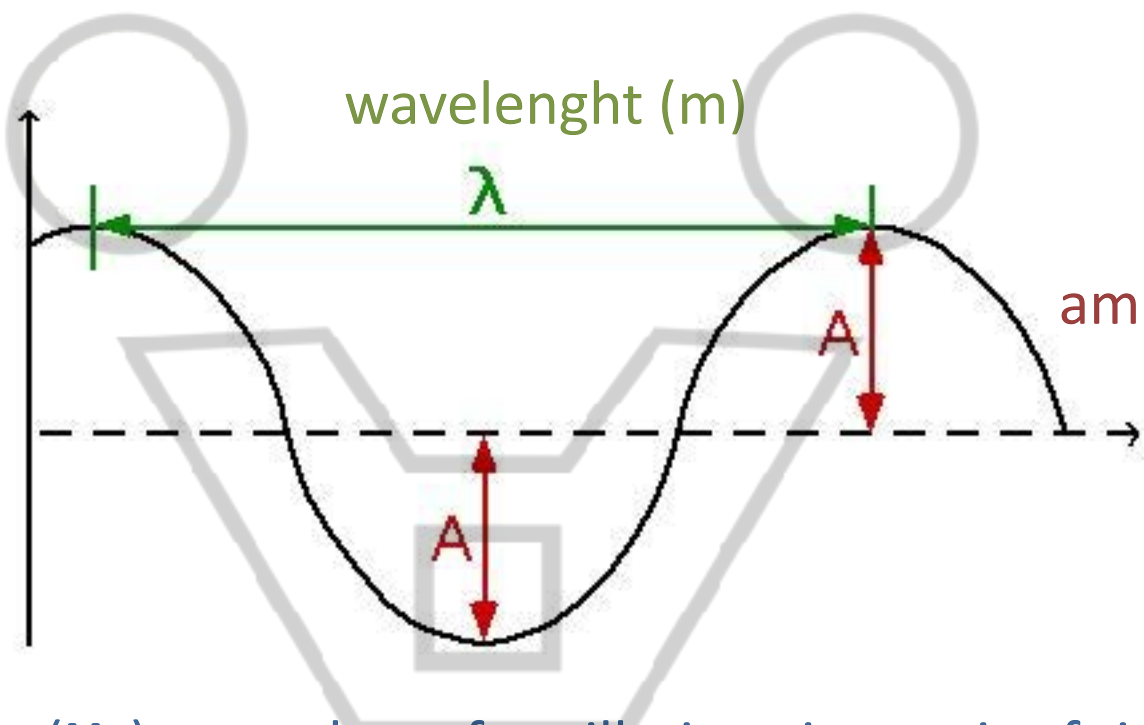
prof. arch. Giuseppe Ridolfi PhD

WAVES THAT CARRY ENERGY: DIFFERENT TYPES OF RADIATIONS



frequence (**Hz**) = number of oscillations in a unit of time (sec)

WAVES THAT CARRY ENERGY: DIFFERENT TYPES OF RADIATIONS

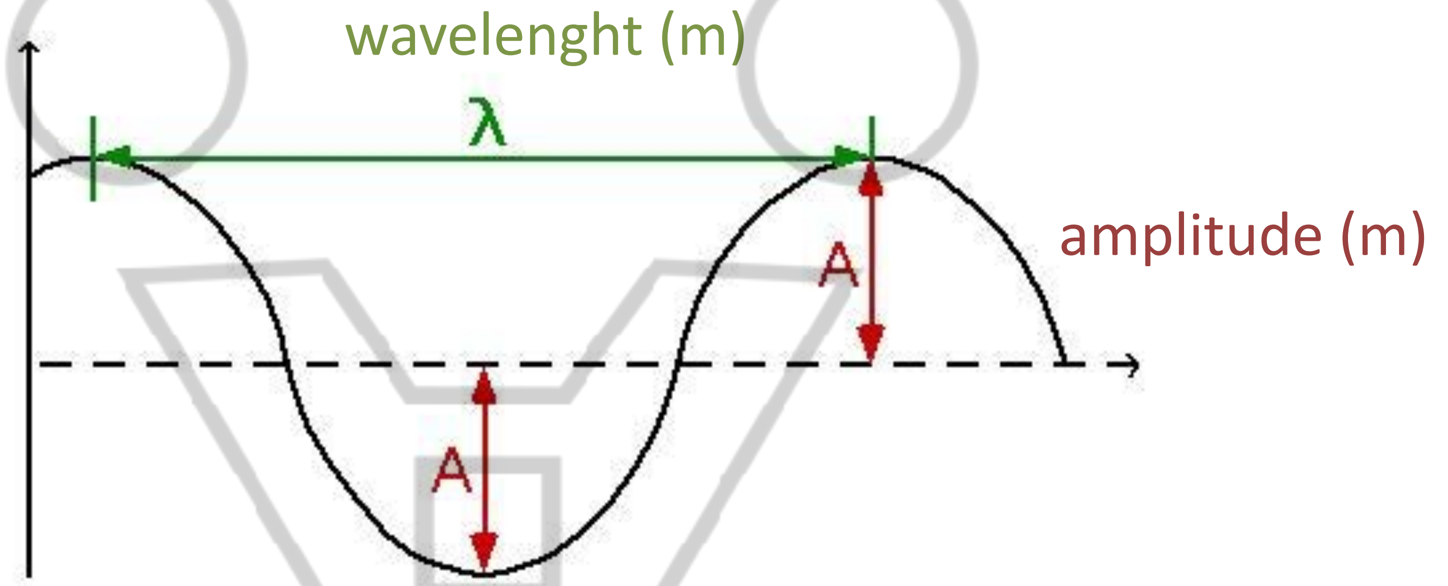


frequence (**Hz**) = number of oscillations in a unit of time (sec)

Each wave brings different quantity of energy!

shorter is its length, <u>higher is its frequency, and its energy</u>

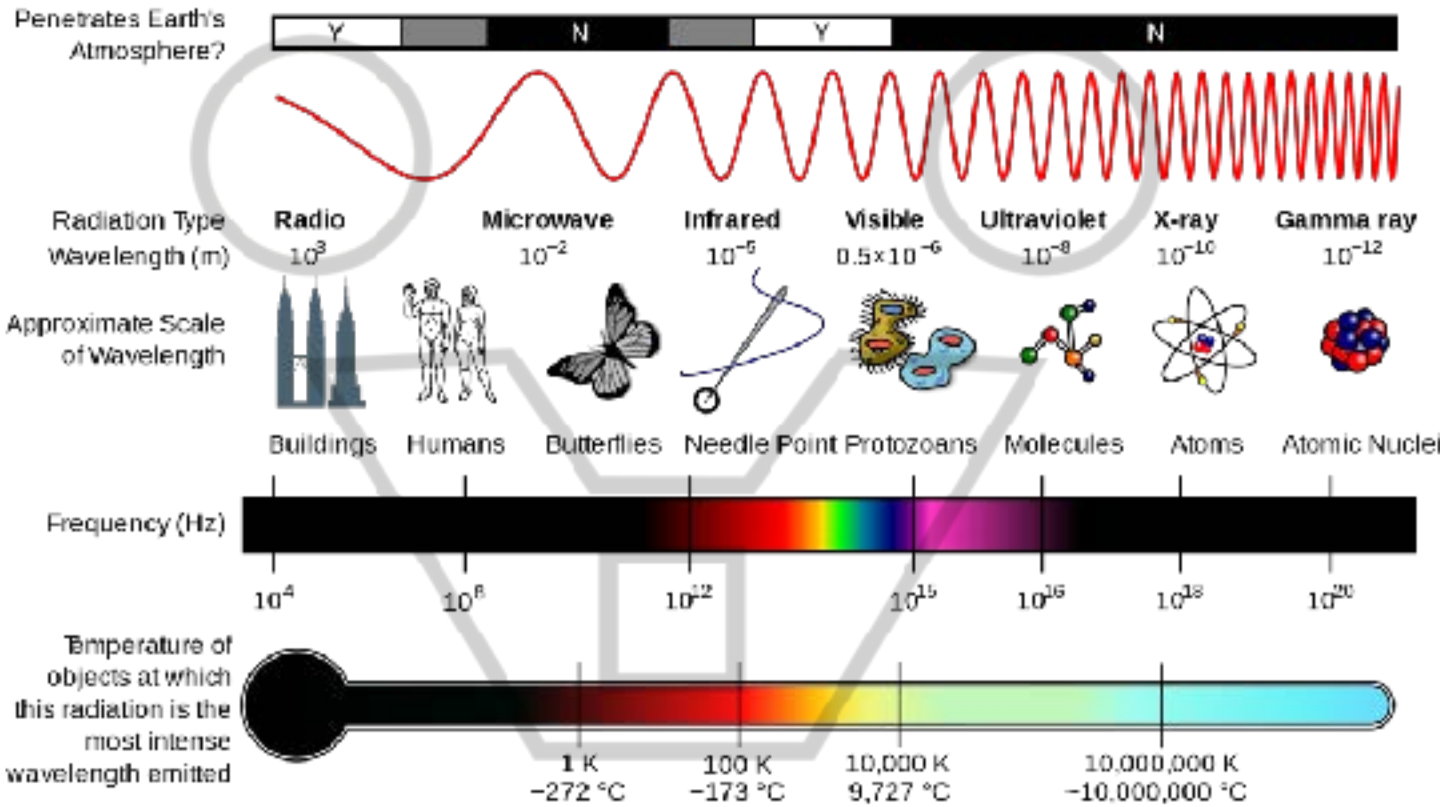
WAVES THAT CARRY ENERGY: DIFFERENT TYPES OF RADIATIONS



frequence (**Hz**) = number of oscillations in a unit of time (sec)

RADIATION (light, heat, sound)
expresses the transfer of kinetic energy of the particles (photons) hittting the matter

WAVES THAT CARRY ENERGY: DIFFERENT TYPES OF RADIATIONS



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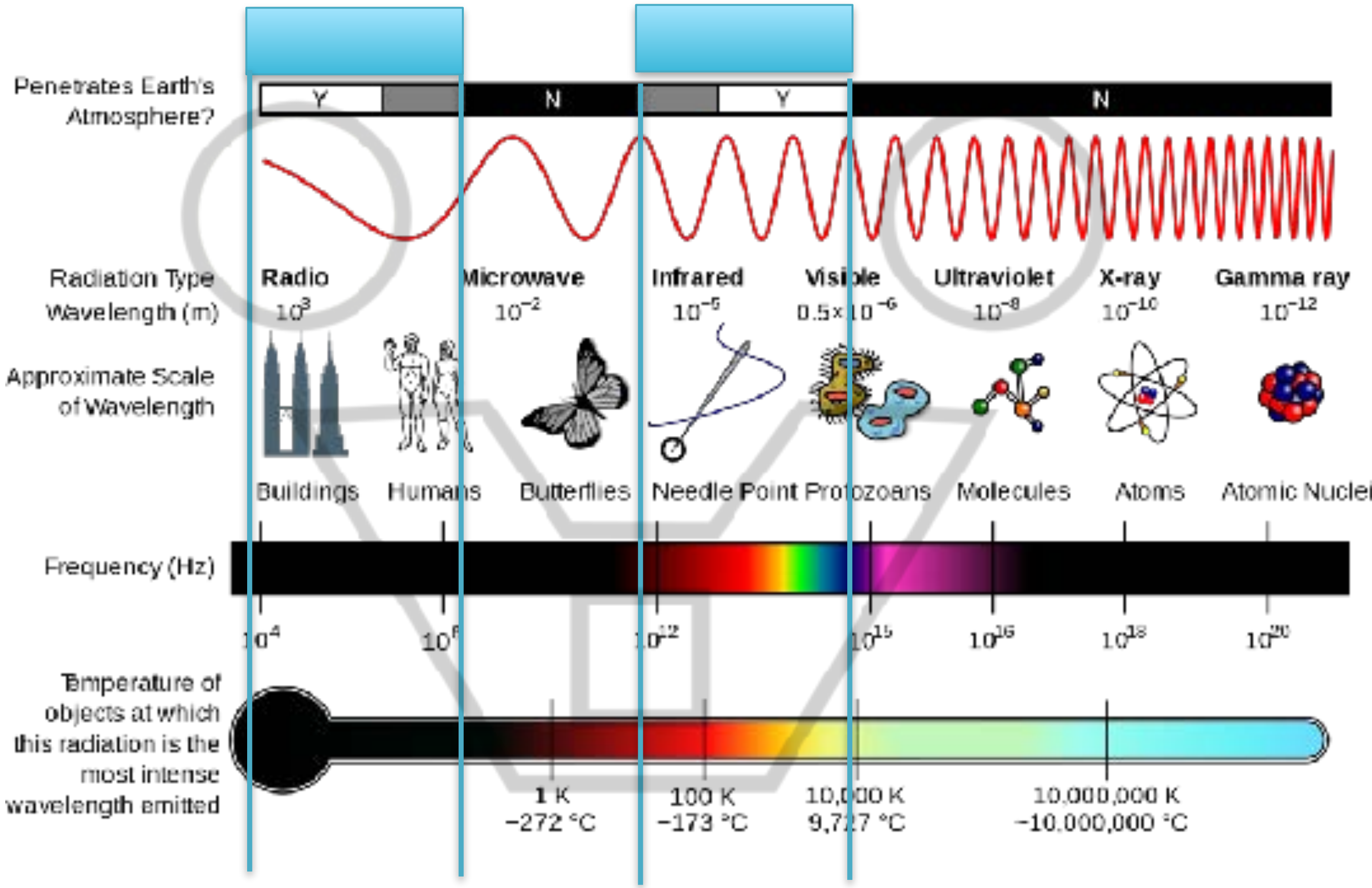
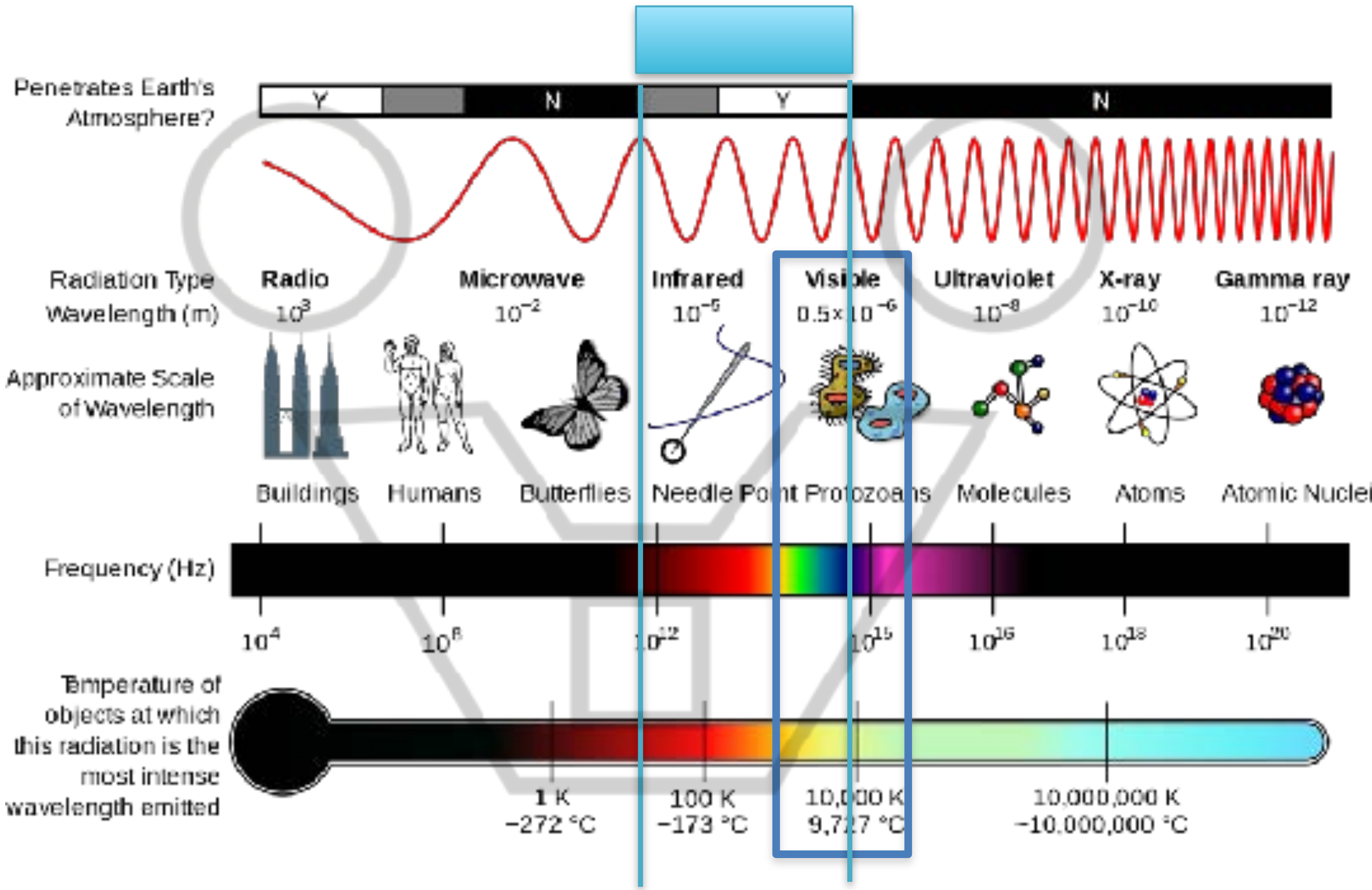
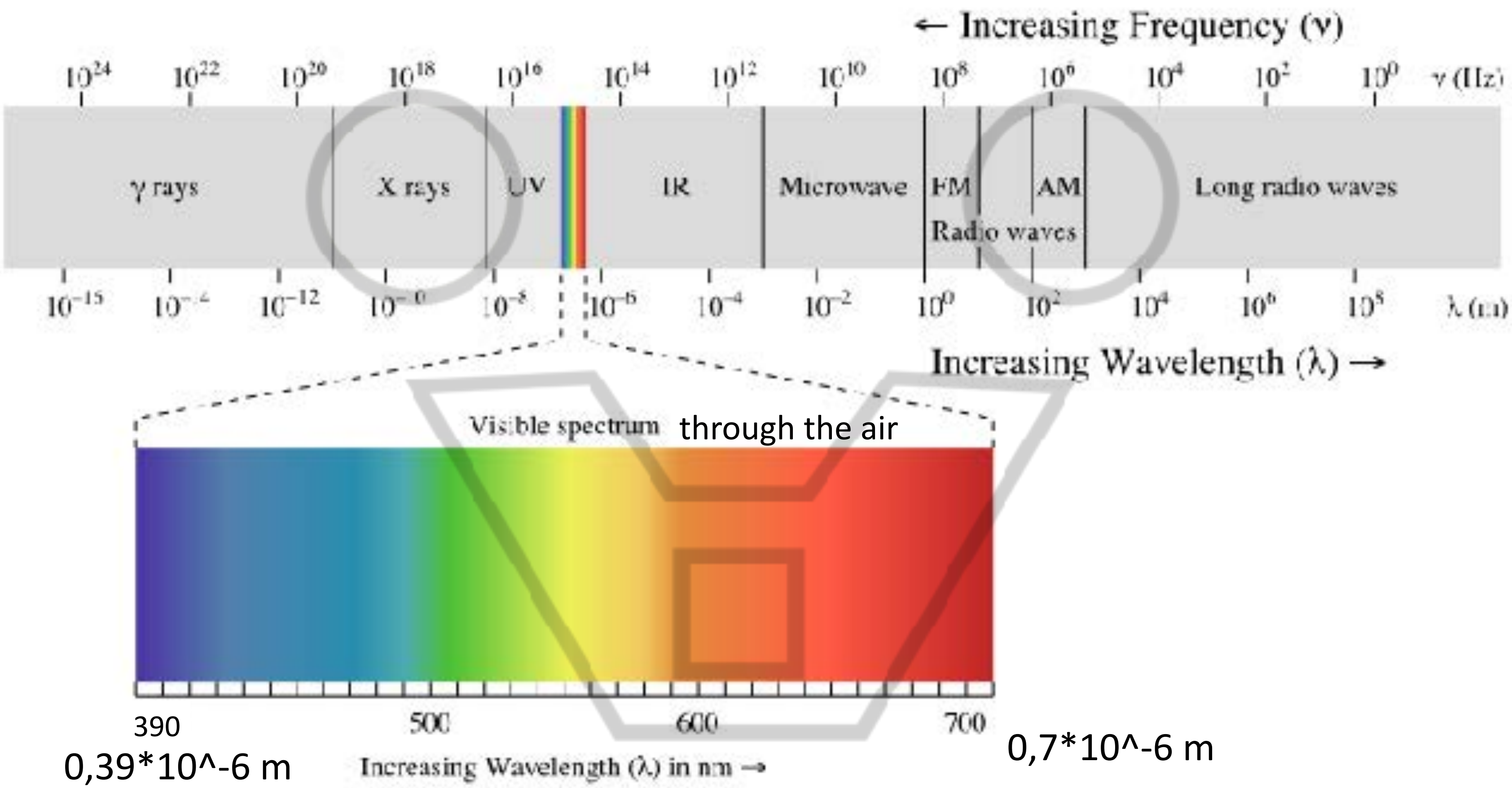


WAVES THAT CARRY ENERGY: DIFFERENT TYPES OF RADIATIONS



VISIBLE SPECTRUM



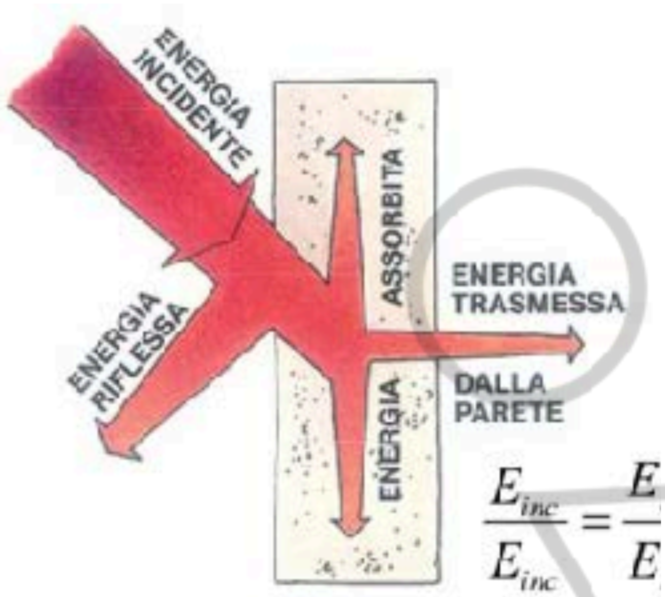
through the water

430 770

LIGHT AND THERMAL RADIATION

The Greenhouse Effect

How to deal with building glazing



Every material, above the 0°K **emits** energy in form of **radiation**

Every **irradiated** material **absorb** some kind of energy

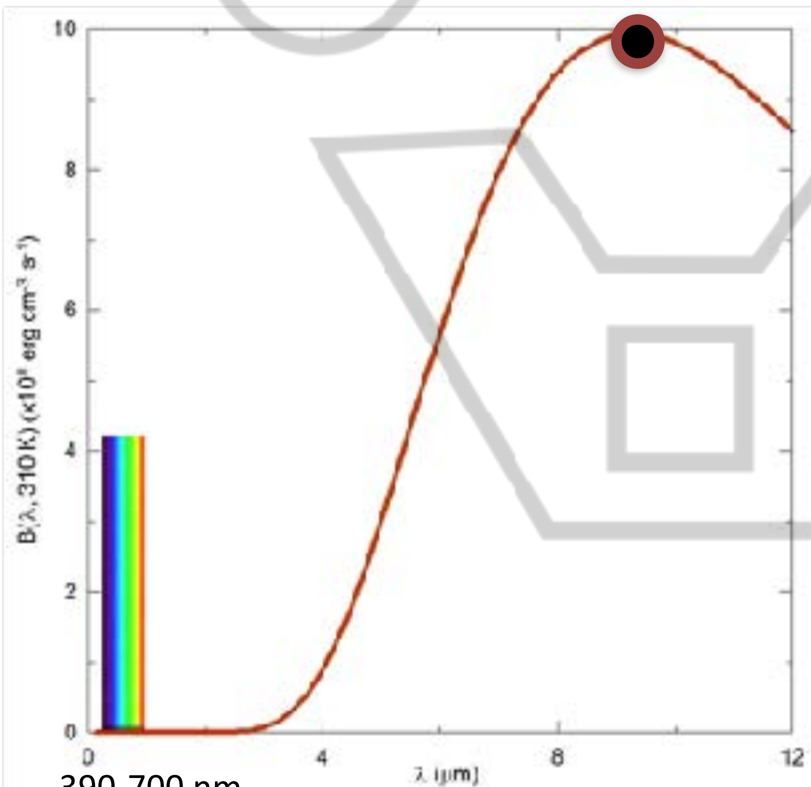
Every **irradiated** material **reflects** some amount of energy

Every material, above the 0°K **emits** energy in form of **radiation**

human body

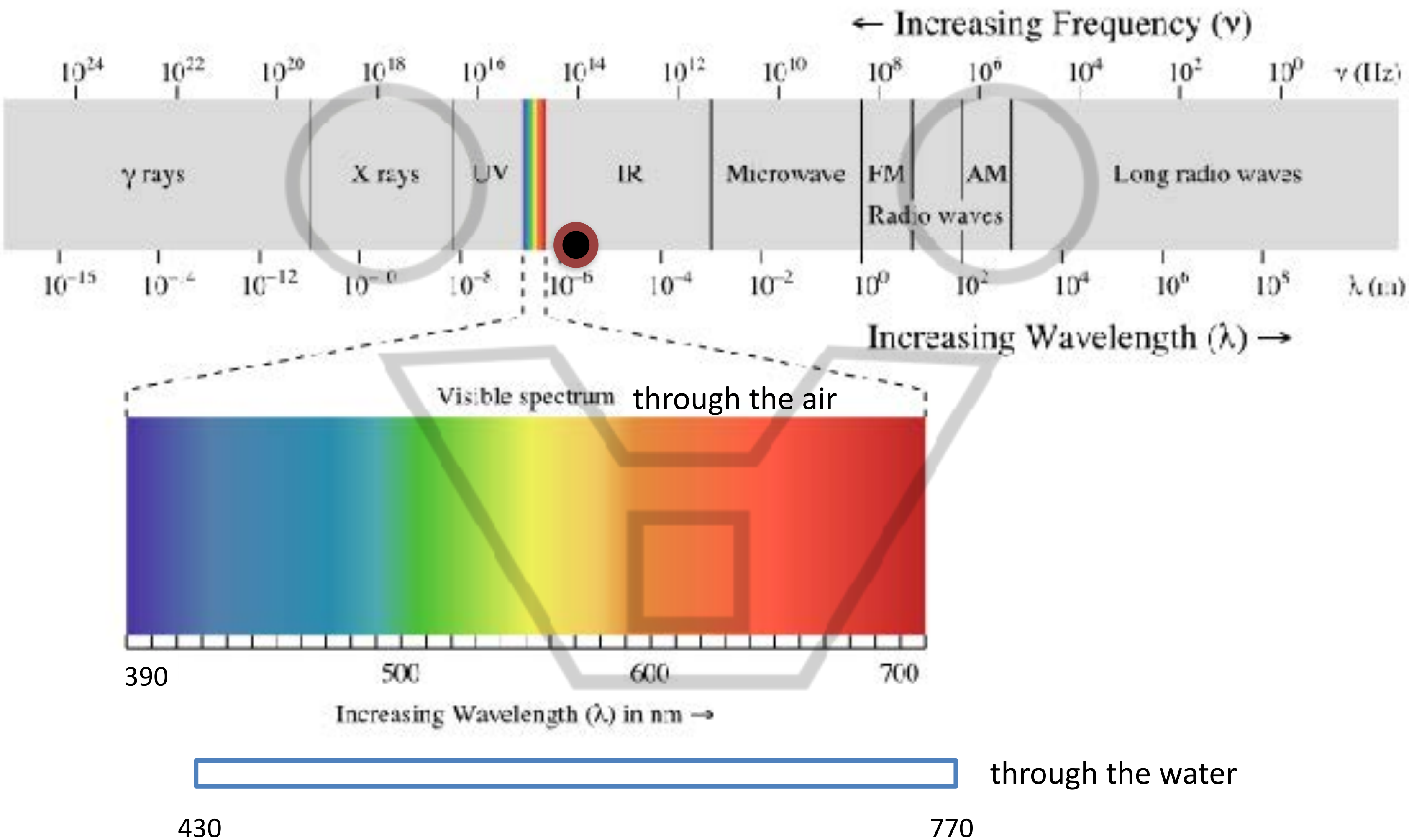
T = 37° C = 310 K

$\lambda_{max} \approx 9\,\mu$ micron (nm= 9000 =9*10^3)

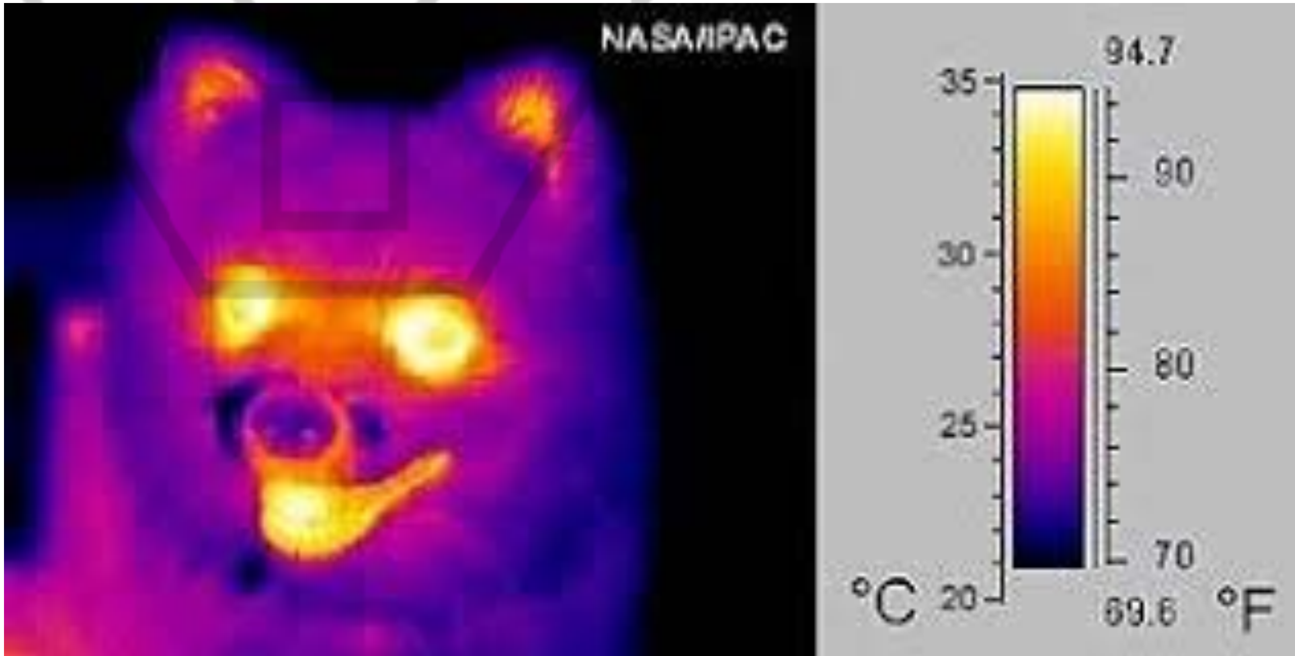


390-700 nm
0.39-0.7 micron
3,9-7*10^-7 metri

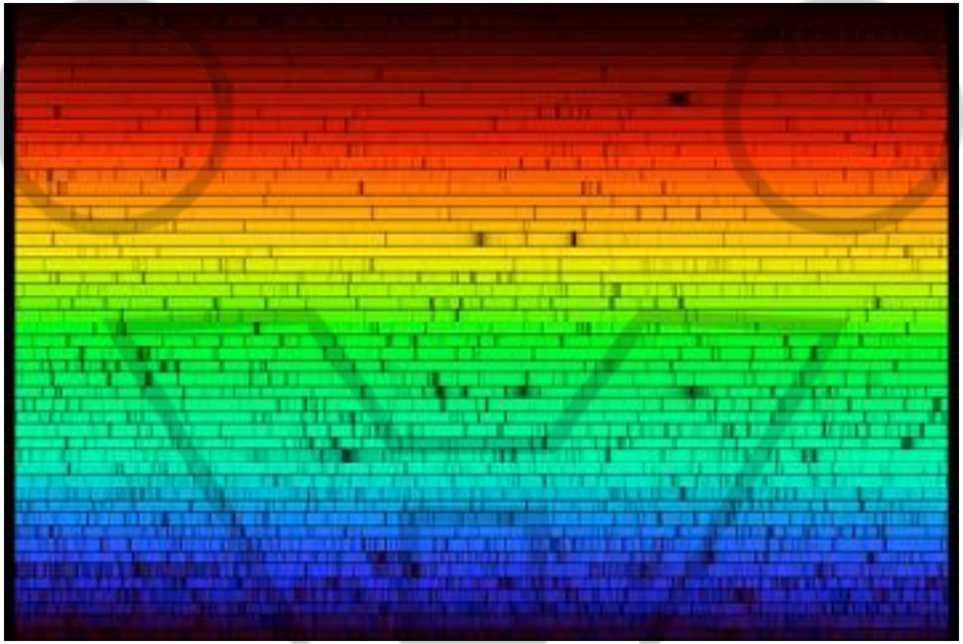
VISIBLE SPECTRUM



thermography to see in the dark and to read body temperature

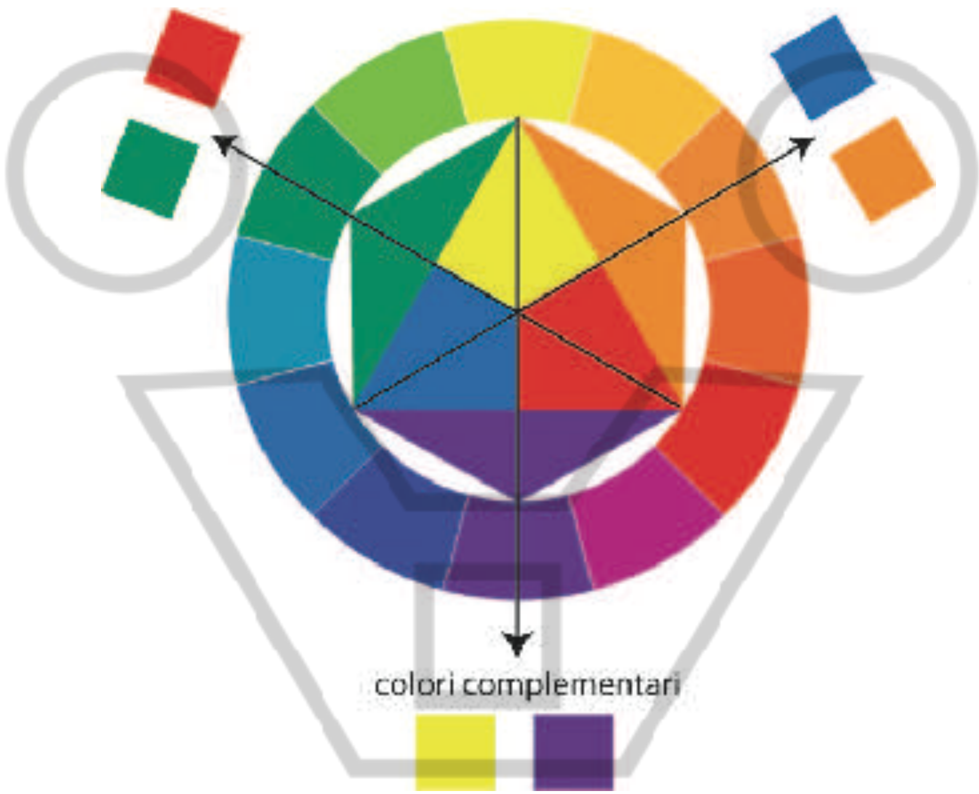


SPECTRUM ANALYSIS REVEALING MATERIAL COMPOSITION



every material has its specific absorption frequency

SPECTRUM ANALYSIS REVEALING MATERIAL COMPOSITION



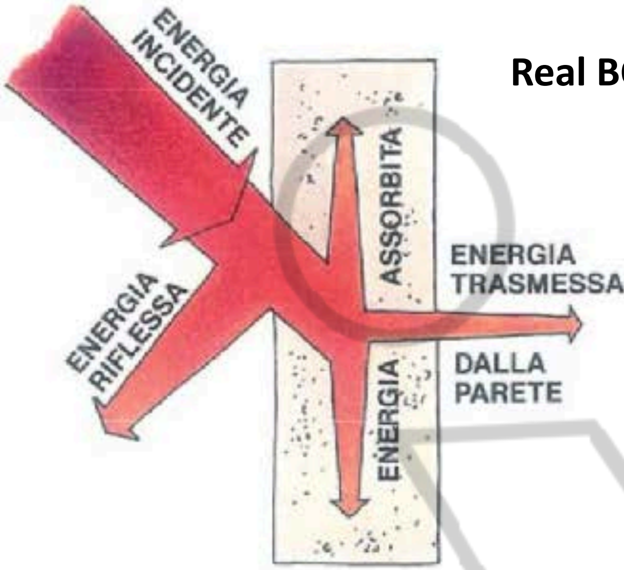
Every **irradiated** material **<u>absorb</u>** some kind of energy

Every **irradiated** material **<u>reflects</u>** some amount of energy

SPECTRUM ANALYSIS REVEALING MATERIAL COMPOSITION

every material change its emission frequency in relation to the temperature

The BLACKBODY

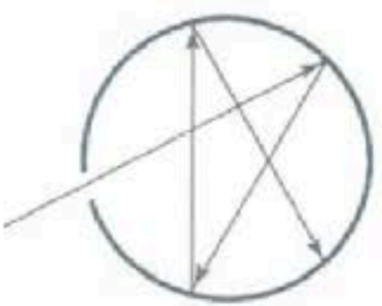


Real BODY

$$E_{inc} = E_{rifl} + E_{ass} + E_{trasm}$$

$$\frac{E_{inc}}{E_{inc}} = \frac{E_{rifl}}{E_{inc}} + \frac{E_{ass}}{E_{inc}} + \frac{E_{trasm}}{E_{inc}}$$

Theoretical BLACKBODY



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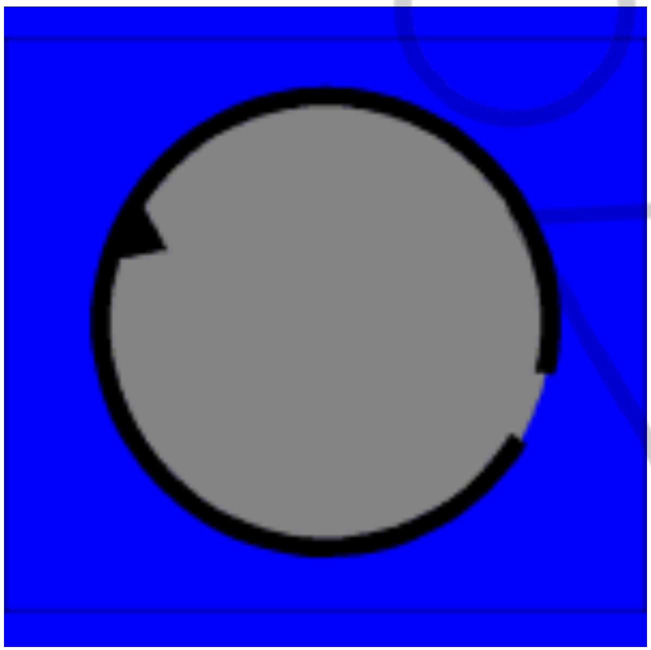
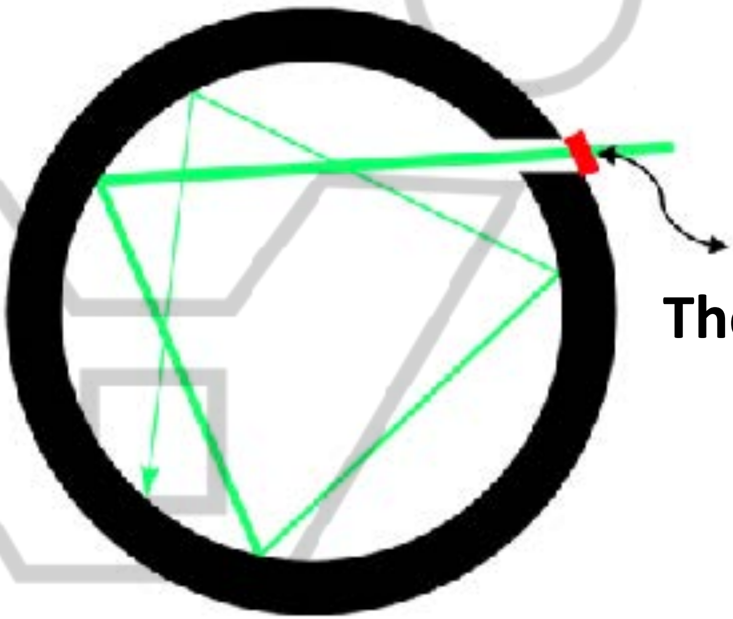
ENERGY, WAVELENGHTS AND TEMPERATURE OF A BLACK BODY

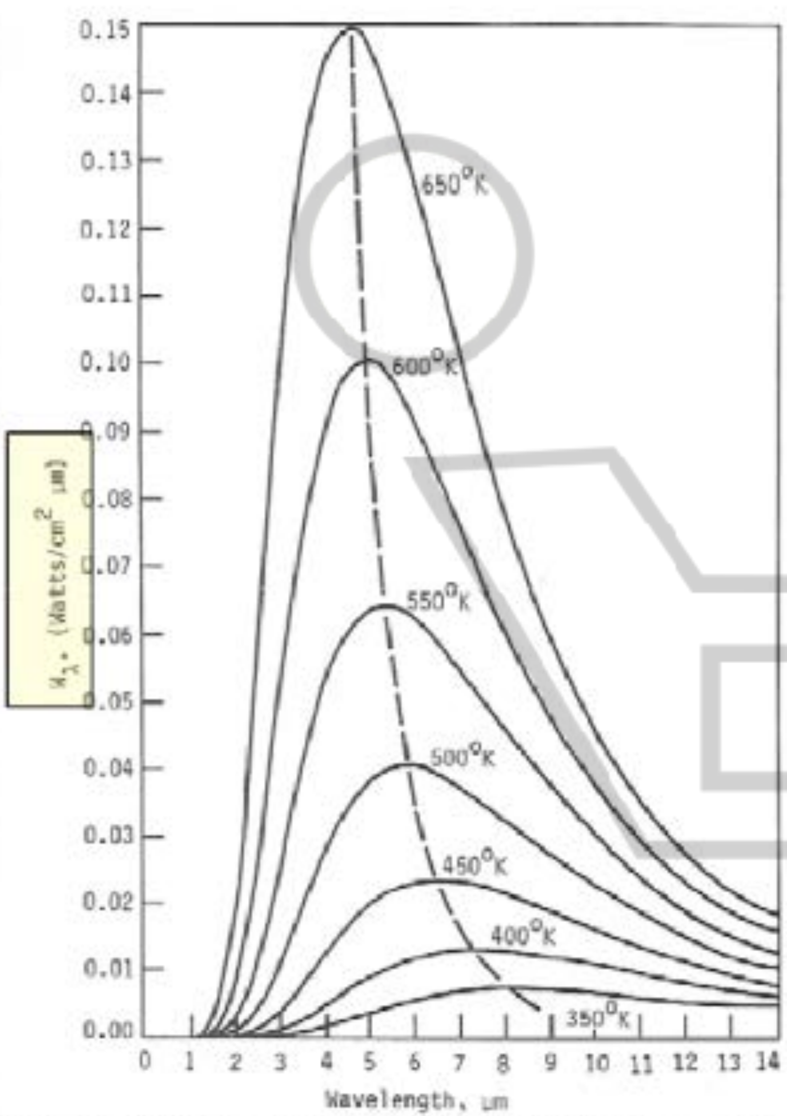




Black body is a perfect absorber and emitter without reflection

in real world each body has a balance between absorption and emission

ENERGY, WAVELENGHTS AND TEMPERATURE OF A BLACK BODY

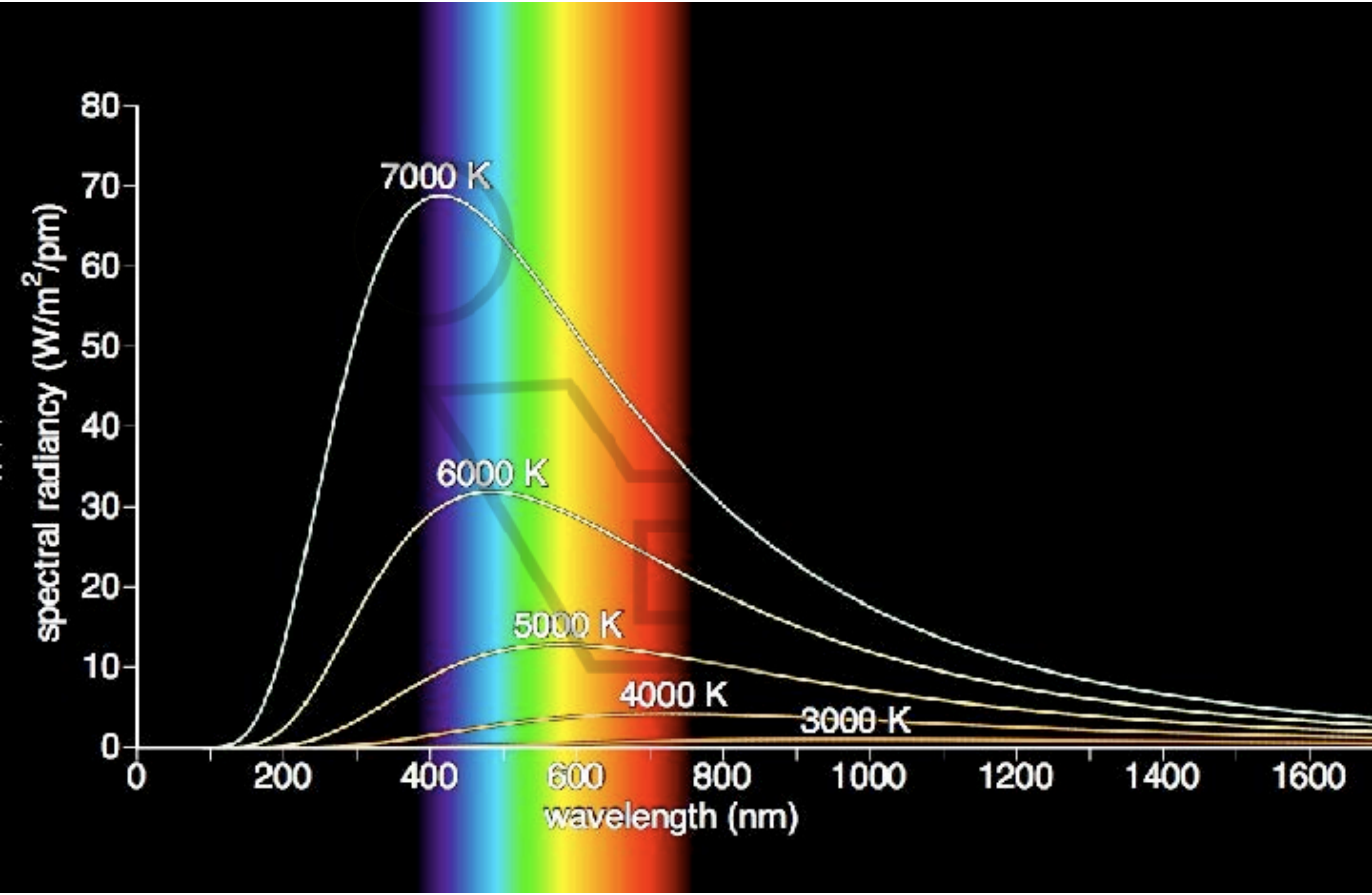


igure 11.8. Planck's law intensity I_λ at various temperatures. (From T. R. Harrison, Radiation Pyrometry and Its Underlying Principle of Heat Transfer." Copyright 1960, John Wiley & Sons, Inc., New York. Reprinted by permission.)

STEFAN_BOLTZMAN'S LAW

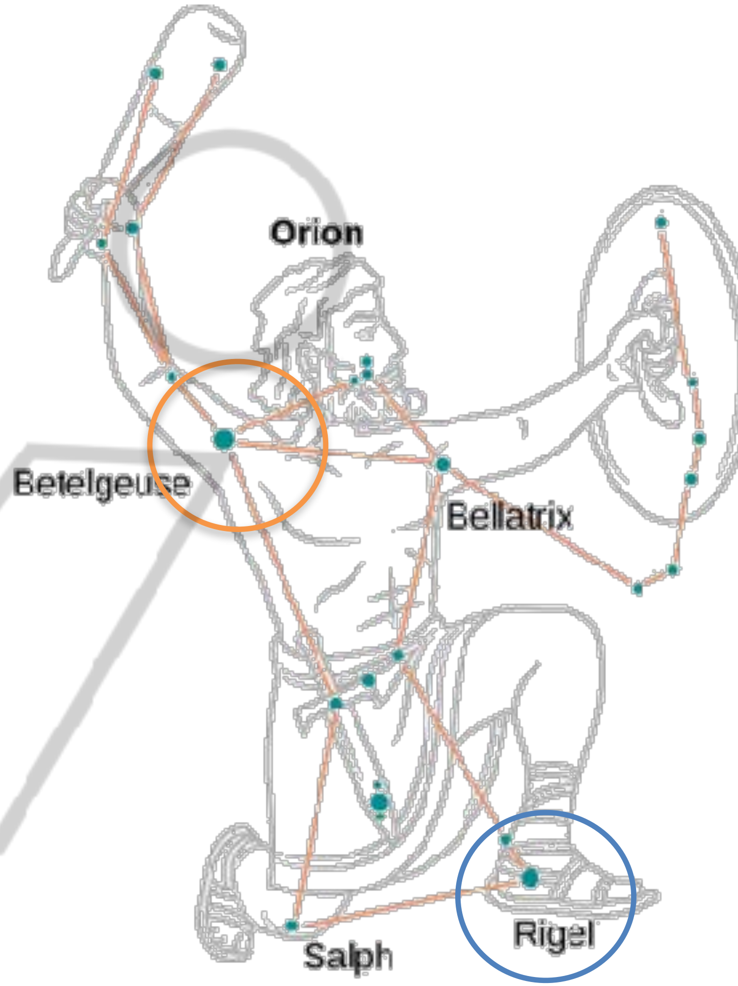
WIEN'S LAW (1893-)

PLANK'S LAW

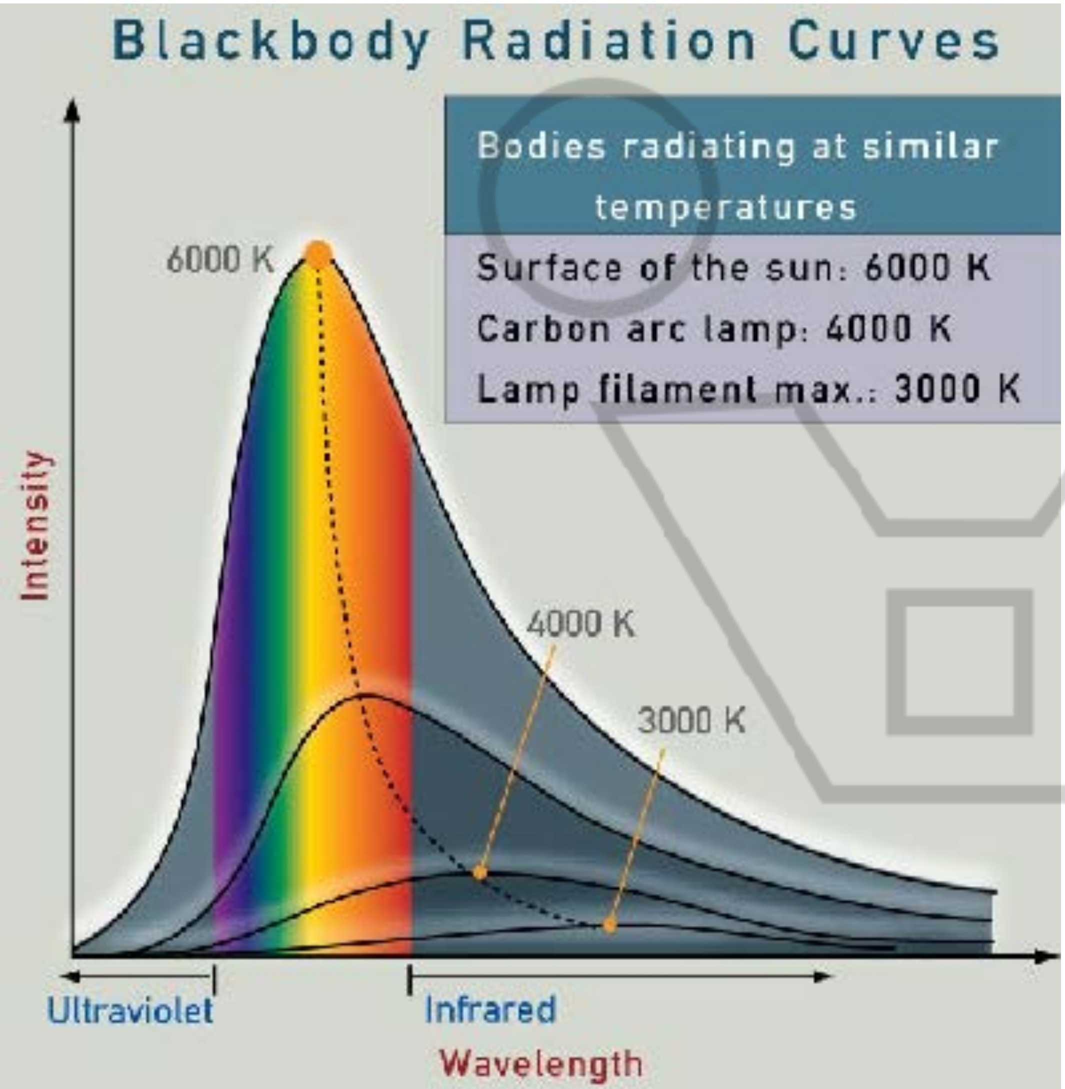


http://www.exo.net/~pauld/workshops/Stars/Stars.htm

ENERGY, WAVELENGHTS AND TEMPERATURE OF A BLACK BODY



QUALITY OF LIGHT: ENERGY, WAVELENGHTS AND TEMPERATURE

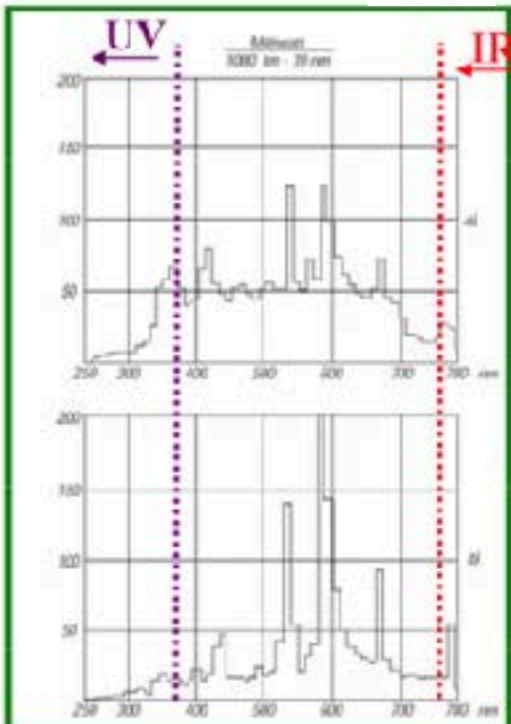


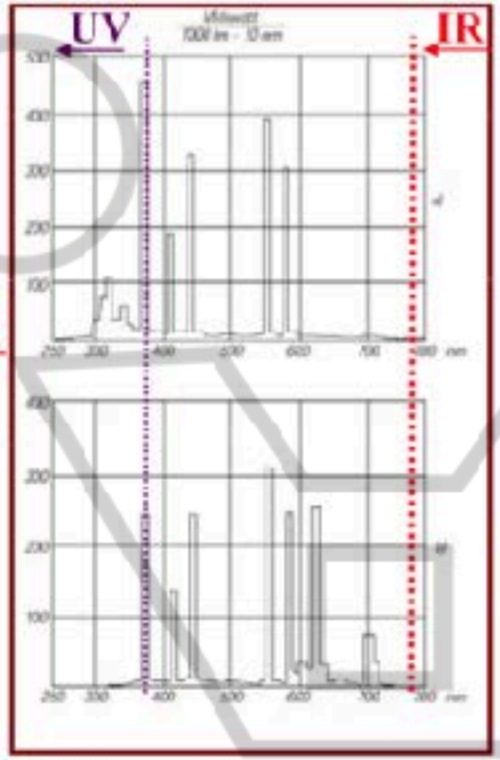
Color Temperatures of Common Light Sources

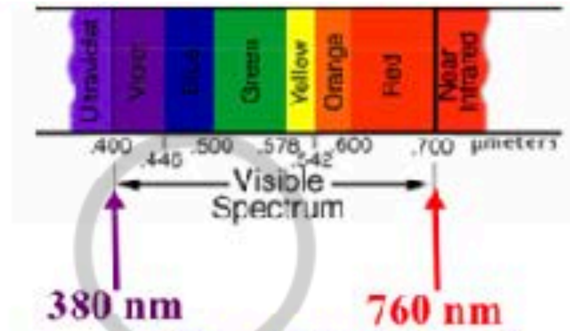
Daylight Sources	Color Temperature (K)
Skylight	12000 to 18000
Overcast Sky	7000
Noon Sun/Clear Summer Sky	5000 to 7000
Noon Sun/Clear Winter Sky	5500 to 6000
Photographic Daylight	5500
Noon Sunlight (Date Dependent)	4900 to 5800
Average Noon Sunlight (Northern Hemisphere)	5400
Sunlight at 30-Degree Altitude	4500
Sunlight at 20-Degree Altitude	4000
Sunlight at 10-Degree Altitude	3500
Sunrise and Sunset	3000
Artificial Sources	**Color Temperature (K)**
White LED	6500 to 9500
Electronic Flash	5500 to 6500
Xenon Burner	6000
White Flame Carbon Arc	5000
Warm White Fluorescent Tubes	4000
Aluminum-Filled Flash Bulbs (M2, 5, & 25)	3800
500-Watt 3400 K Photoflood	3400
12 Volt/100 Watt Tungsten-Halogen @ 9 Volts	3200
12 Volt/50 Watt Tungsten-Halogen @ 9 Volts	3200
100-Watt Household Lamp	2900
40-Watt Household Lamp	2650
Gaslight	2000 to 2200
Candlelight (British Standard)	2900

QUALITY OF LIGHT: ENERGY, WAVELENGHTS AND TEMPERATURE

halogen incandescent lamps

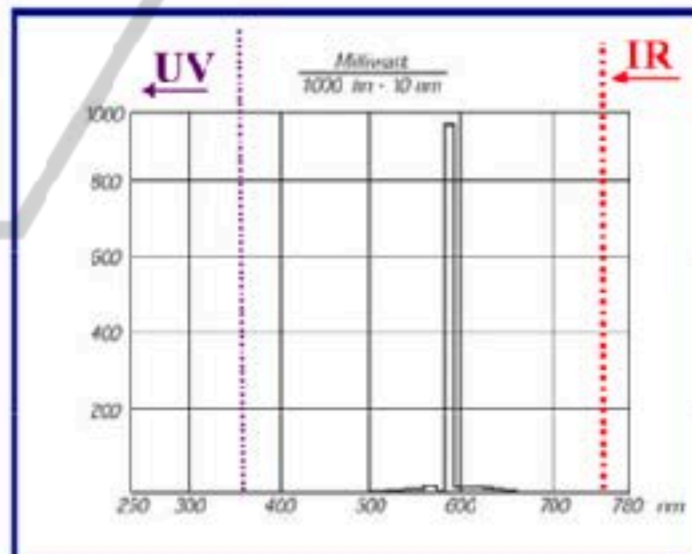


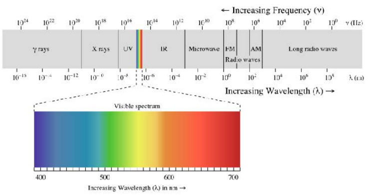




Low Pressure Sodium Vapor (LPSV) Lamps

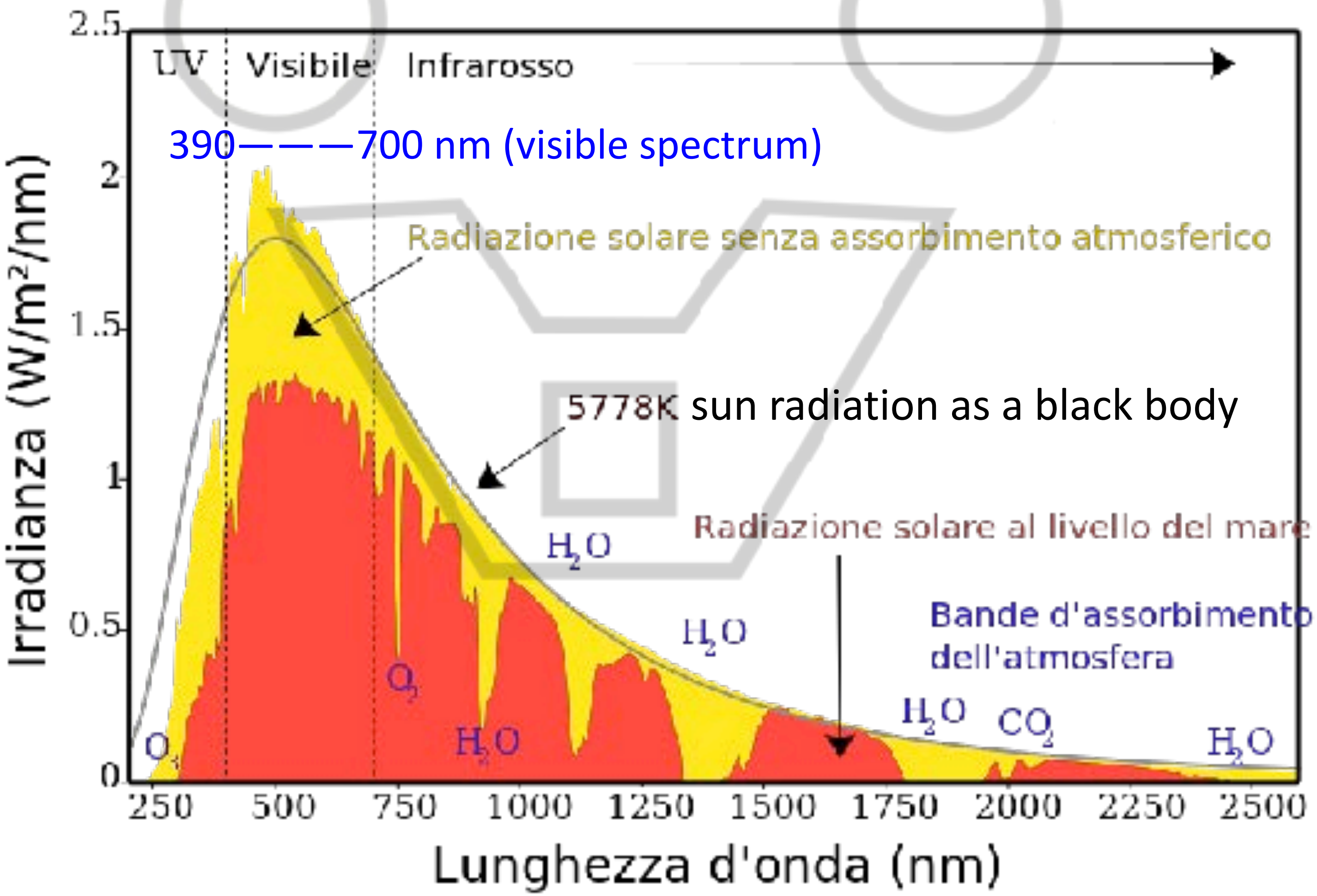
gas discharge tubes





ENERGY IN THE VISIBLE SPECTRUM

spectrum of solar radiation on earth



ENERGY IN THE VISIBLE SPECTRUM

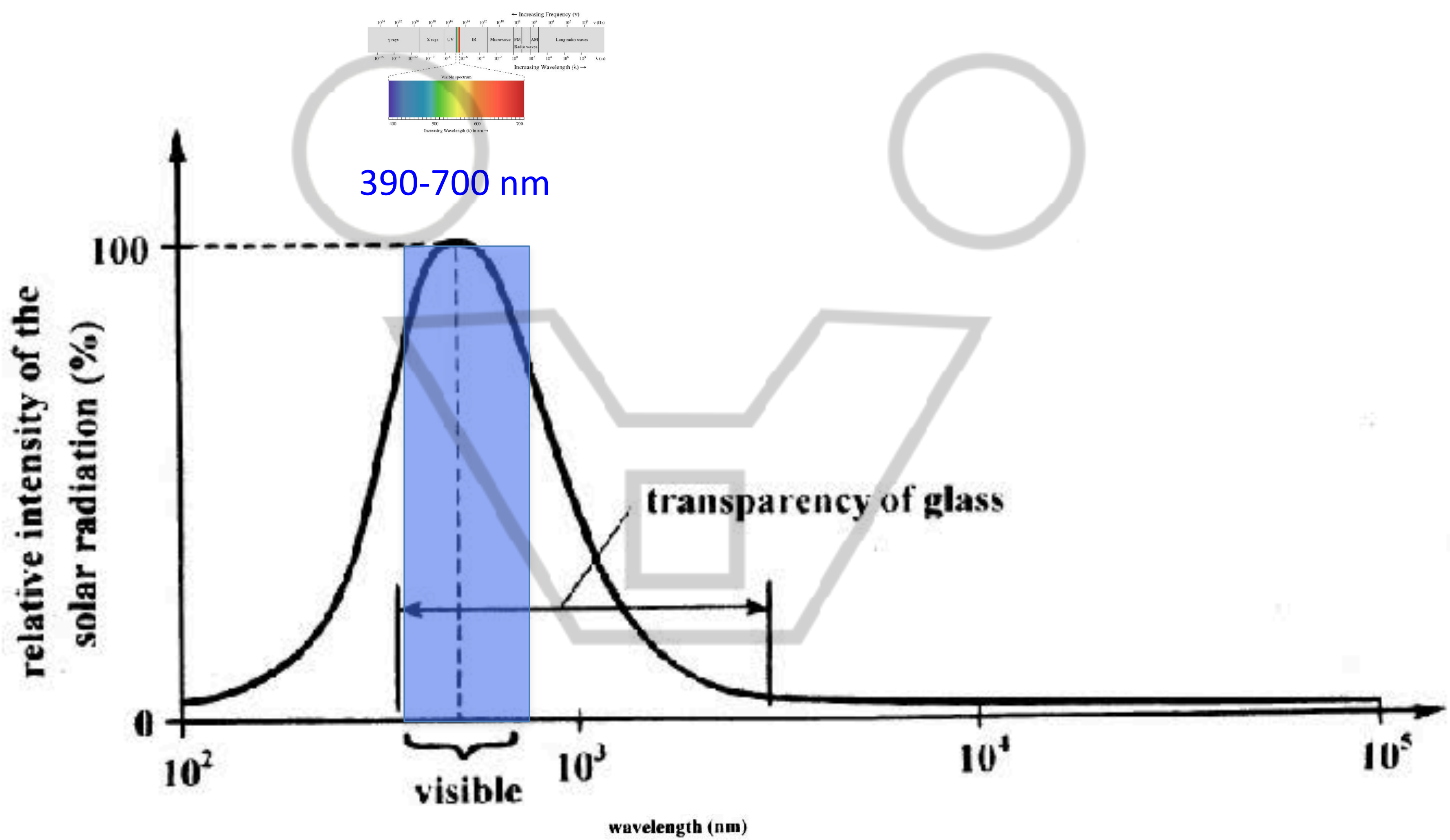


Fig. 7. Range di trasparenza del vetro rappresentato sullo spettro della radiazione solare.
Un confronto con la figura precedente mostra che il vetro non è trasparente nel range di emissione dei corpi a temperatura ambiente o di poco superiore.

ENERGY IN THE VISIBLE SPECTRUM & IN GLASS SPECTRUM

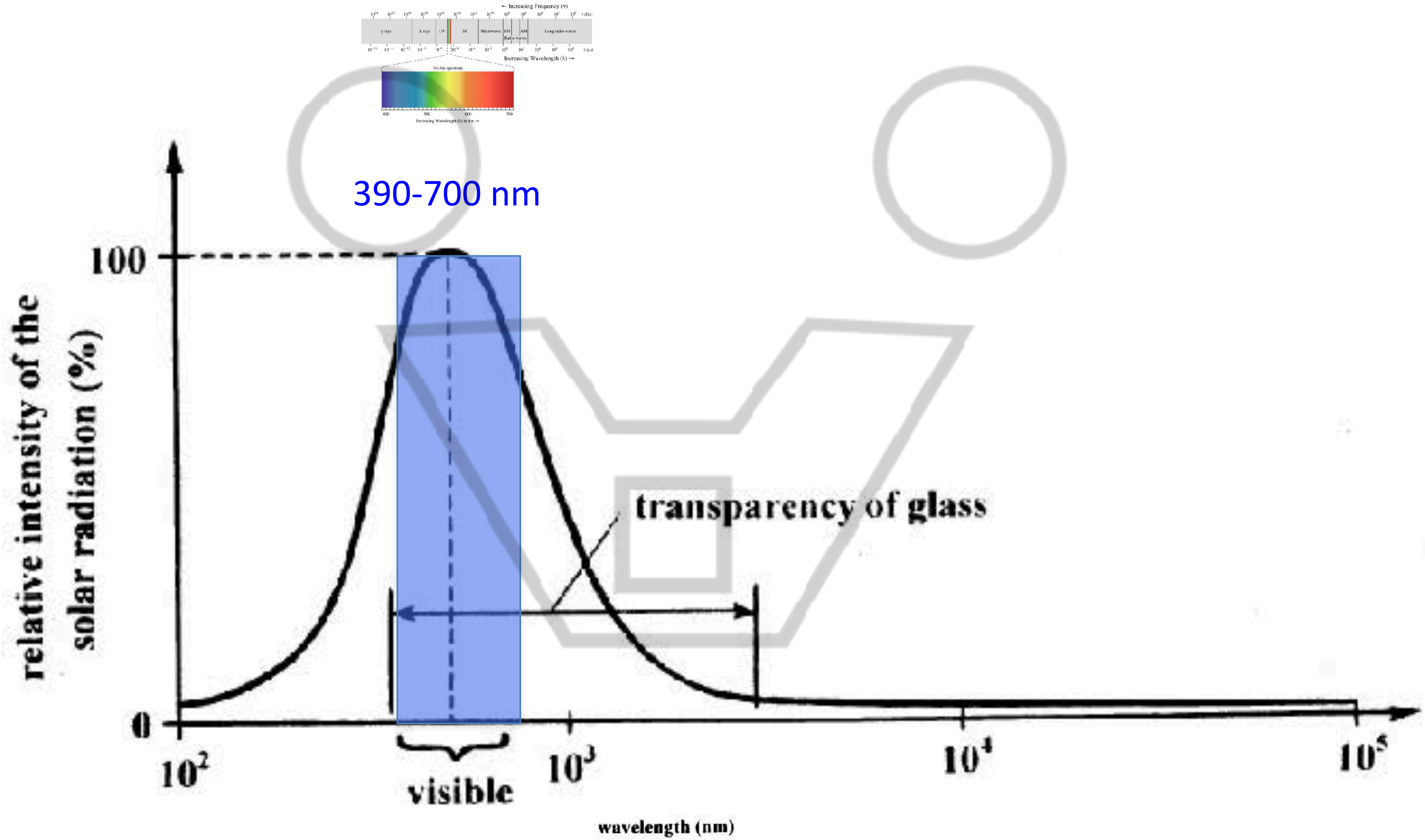


Fig. 7. Range di trasparenza del vetro rappresentato sullo spettro della radiazione solare.
Un confronto con la figura precedente mostra che il vetro non è trasparente nel range di emissione dei corpi a temperatura ambiente o di poco superiore.

TRASPARENCY OF GLASS & % OF RADIATION PASSING THROUGH GLASS

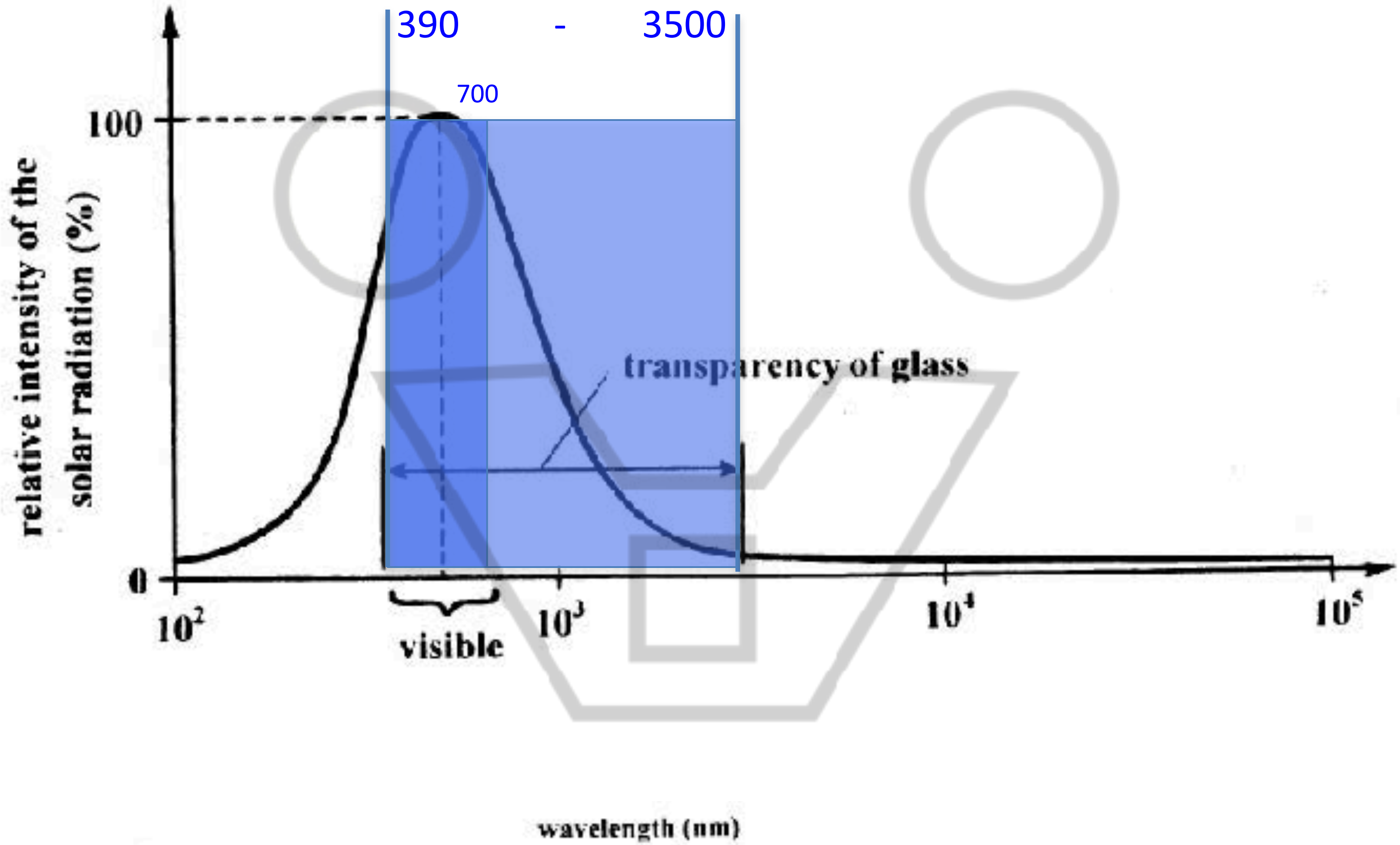
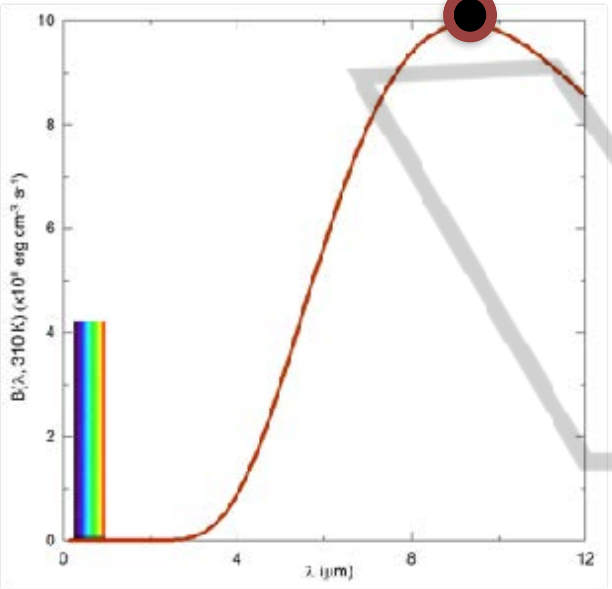


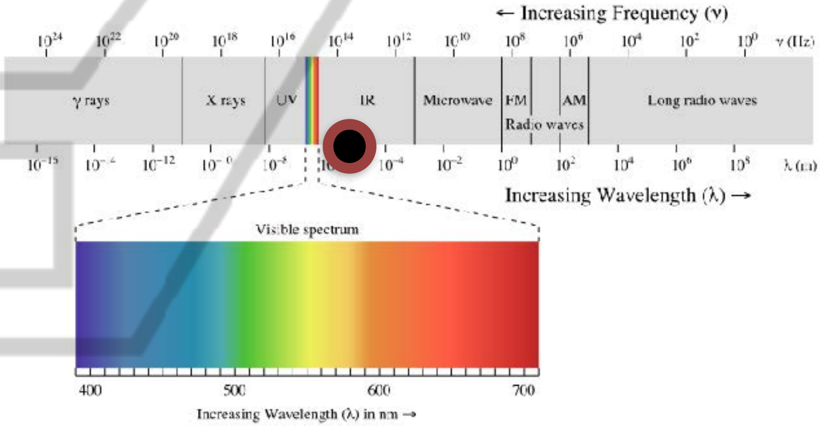
Fig. 6. Spettro della radiazione solare.

Sull'asse orizzontale è indicato il range di emissione relativo ad un corpo a 300 K. Lo spettro di emissione di questo corpo non è rappresentato e sarebbe interamente sotto la curva dello spettro solare.

human body

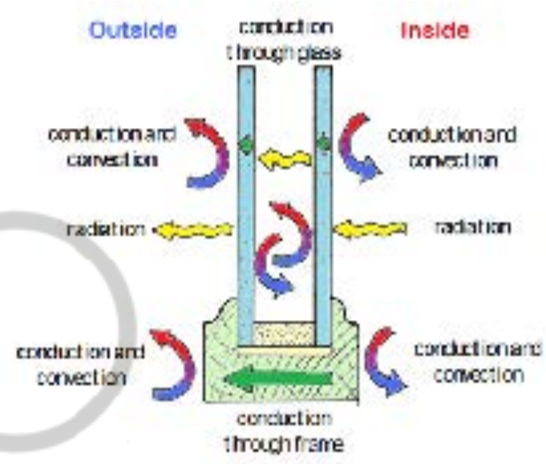
T = 37° C = 310 K $\lambda_{max} \approx 9\ \mu$

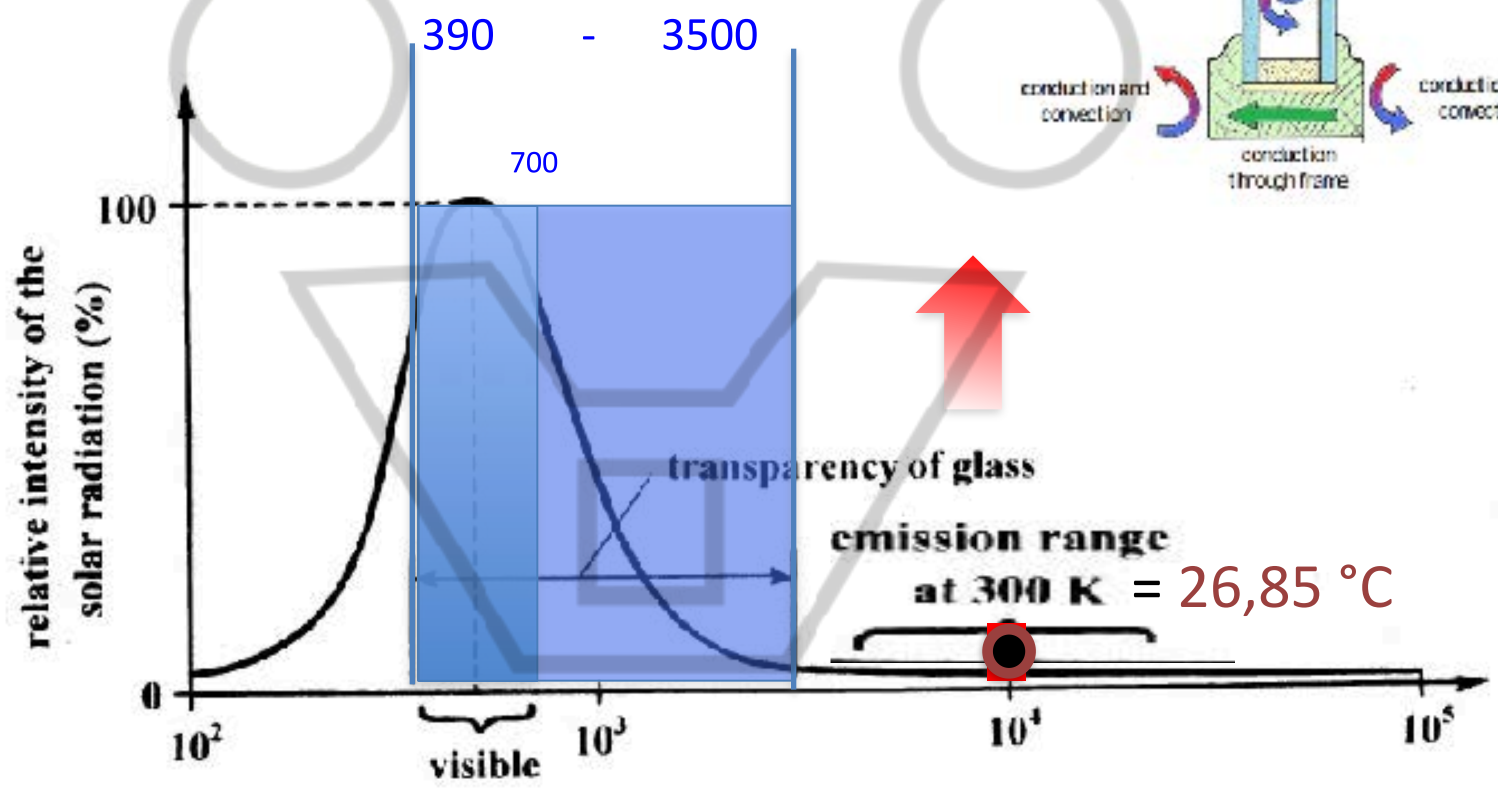




390-700 nm
0.39-0.7 micron
3,9-7*10^-7 metri

THE GREEN HOUSE EFFECT





GLAZING MATERIALS. Spectrally selective coating

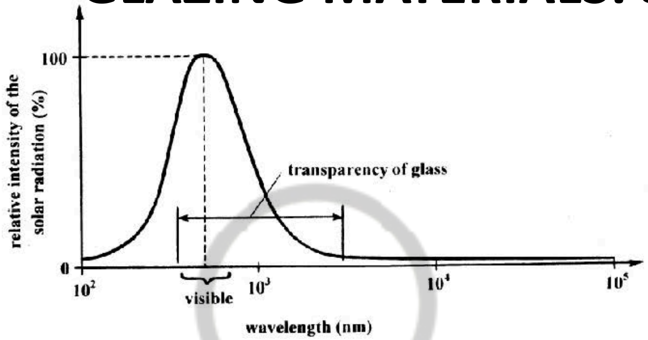
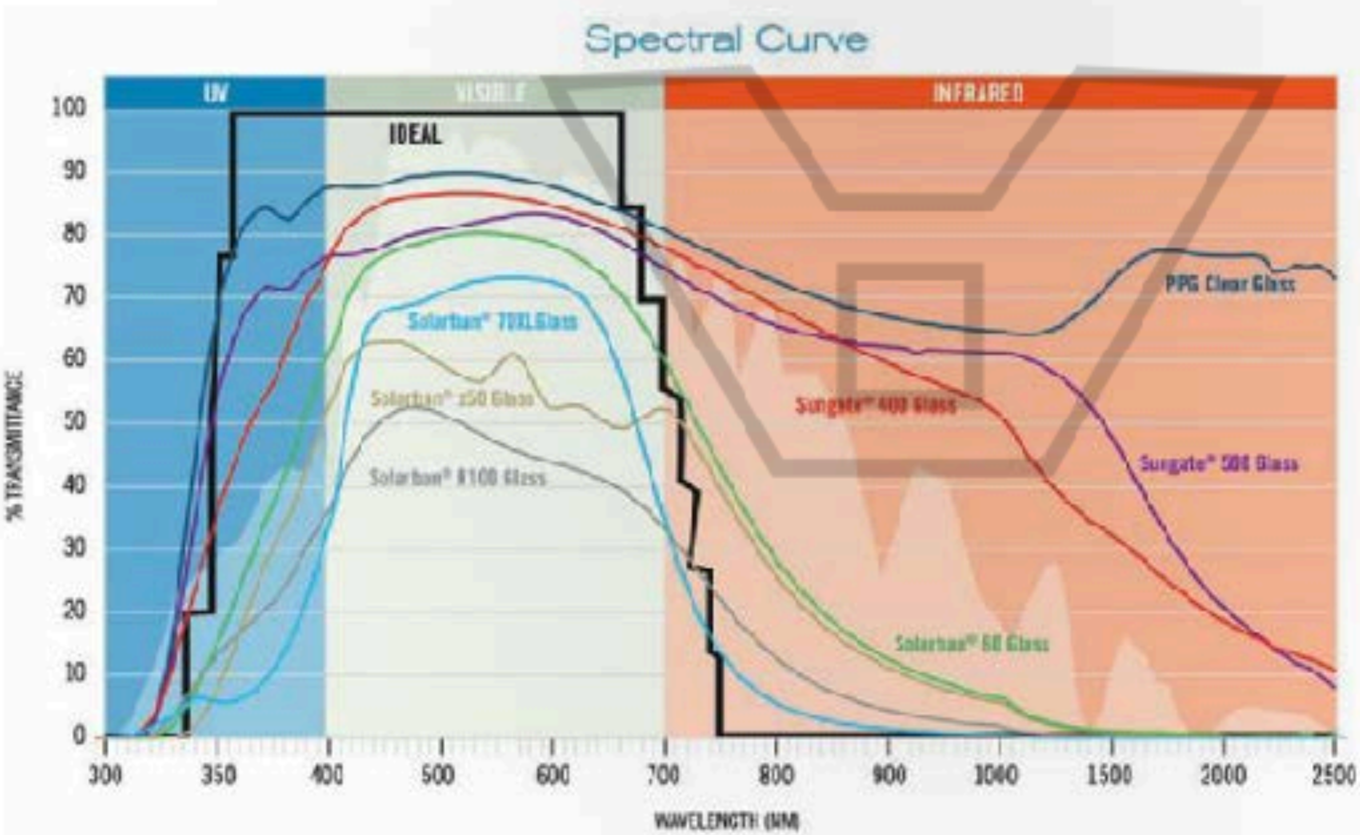


Fig. 7. Range di trasparenza del vetro rappresentato sullo spettro della radiazione solare. Un confronto con la figura precedente mostra che il vetro non è trasparente nel range di emissione dei corpi a temperatura ambiente o di poco superiore.



6.5

Spectrally selective coatings allow glazing products to reflect solar irradiation outside the visible spectrum without significantly reducing visible light transmittance. This allows low-SHGC products with high Tvis.

Source: Courtesy of PPG Industries.

GLAZING MATERIALS. Spectrally selective coating

(TVis) Visible Trasmittance for daylighting

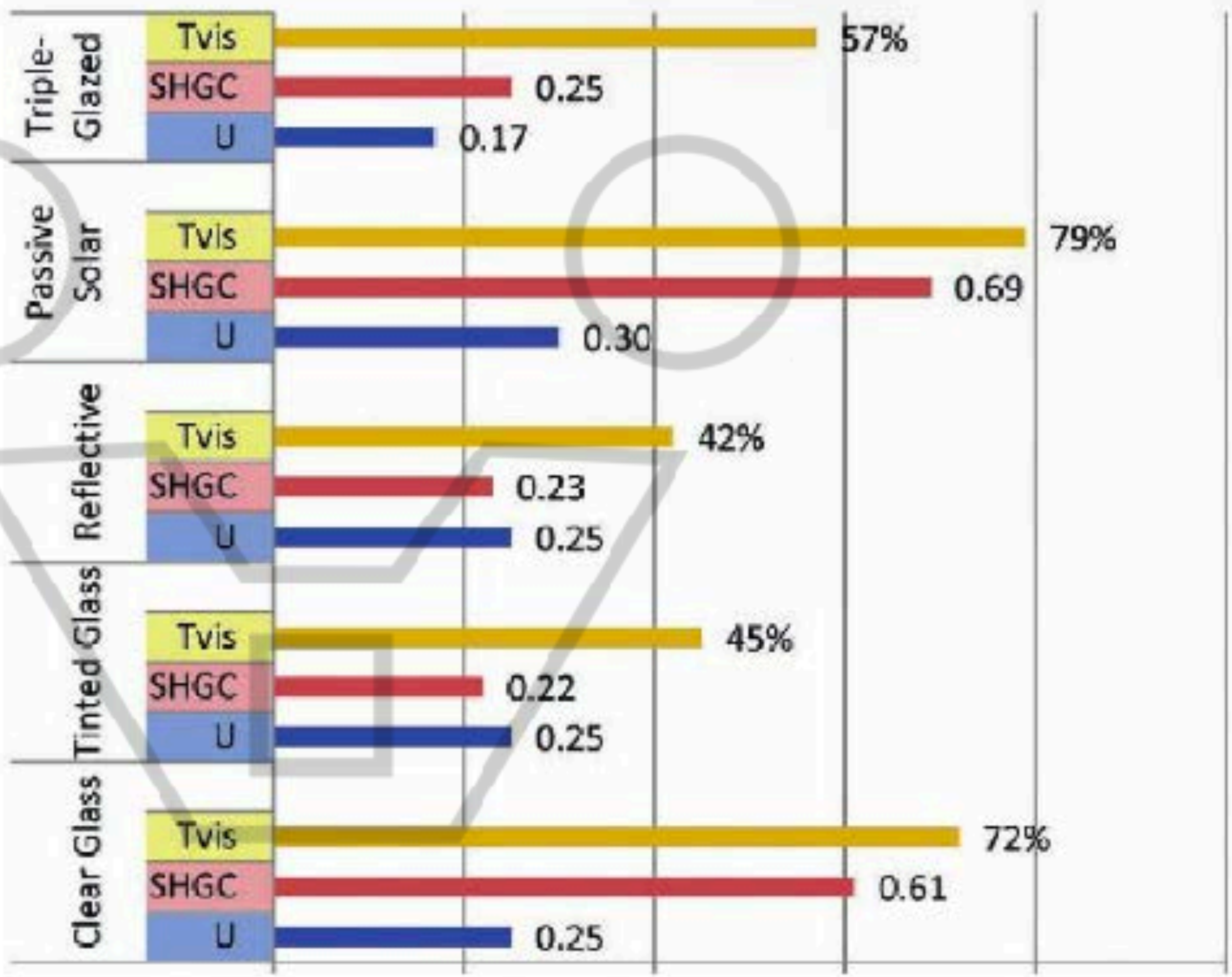
Visible transmittance is the amount of light in the visible portion of the spectrum that passes through a glazing material.

(SHGC) Solar Heat Gain Coefficient

is the fraction of the incident solar radiation transmitted through a windows plus the portion absorbed and subsequently released inward

U-value ability to transmit heat

it is expressed in units of W/m²·K. The lower the U-value, the better insulated the building element.



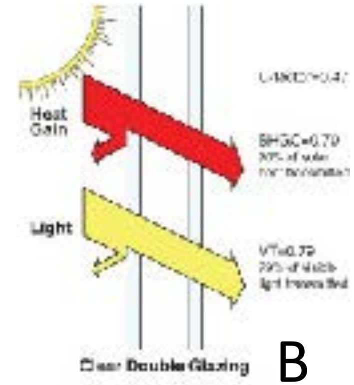
6.4

Glazing properties from some widely manufactured insulated glazing units (IGUs).

Source: Courtesy of Callison. Chart based on ©ASHRAE Handbook of Fundamentals (2005), 31.20.

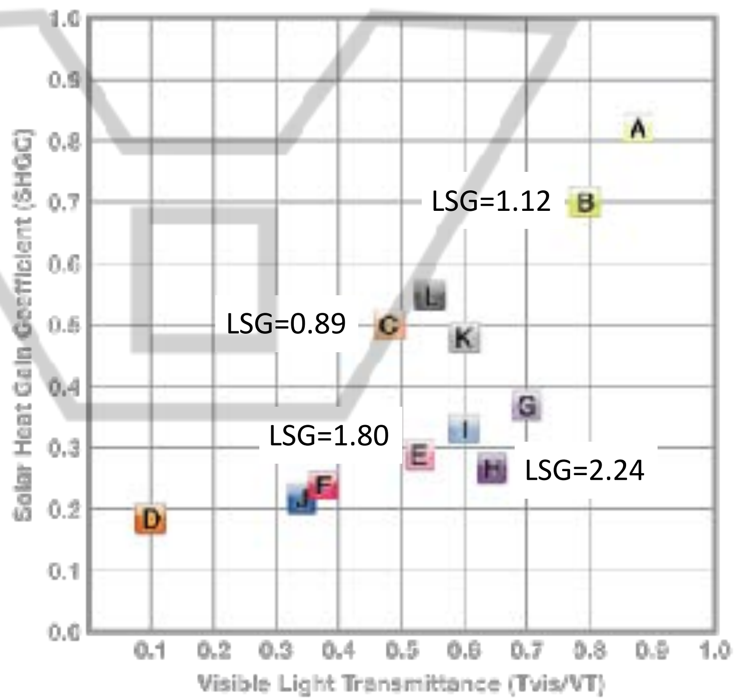
GLAZING MATERIALS. Spectrally selective coating

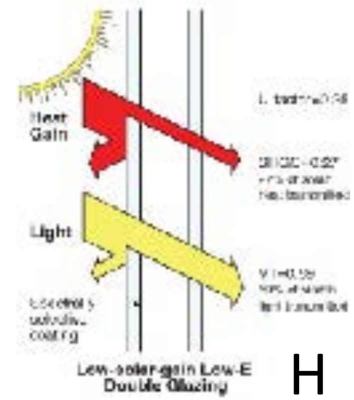
Light-to-Solar-Gain Ratio
In the past, windows that reduced solar gain (with tints and coatings) also reduced visible transmittance. However, new high-performance tinted glass and low-solar-gain low-E coatings have made it possible to reduce solar heat gain with little reduction in visible transmittance. Because the concept of separating solar gain control and light control is so important, measures have been developed to reflect this. The LSG ratio is defined as a ratio between visible transmittance (VT) and solar heat gain coefficient (SHGC).



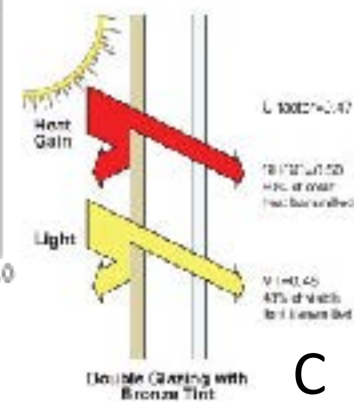
B

LSG ratio= VT/SHGC





H



C

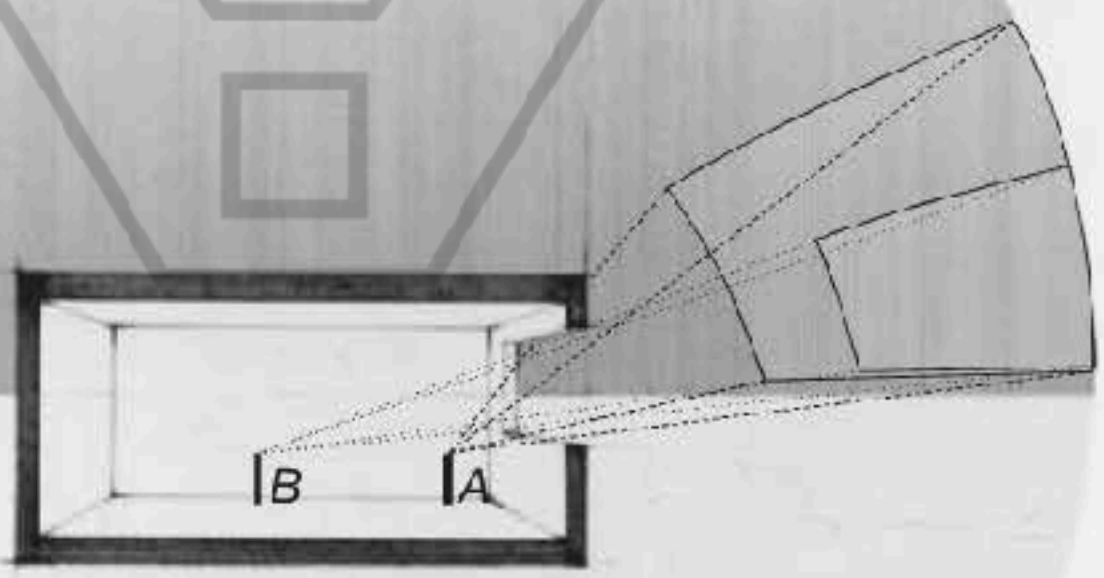
*The image illustrates the center-of-glass properties for the options used in the Facade Design Tool. A double-glazed unit with clear glass **(B)** has a visible transmittance (VT) of 0.79 and a solar heat gain coefficient (SHGC) of 0.70, so the LSG is VT/SHGC = 1.12. Bronze-tinted glass in a double-glazed unit **(C)** has a visible transmittance of 0.45 and a solar heat gain coefficient of 0.50, which results in an LSG ratio of 0.89. This illustrates that while the bronze tint lowers the SHGC, it lowers the VT even more compared to clear glass. The double-glazed unit with a high-performance tint **(E)** has a relatively high VT of 0.52 but a lower SHGC of 0.29, resulting in an LSG of 1.80—significantly better than the bronze tint. A clear double-glazed unit with a low-solar-gain low-E coating **(H)** reduces the SHGC significantly, to 0.27, but retains a relatively high VT of 0.64, producing an LSG ratio of 2.4—far superior to those for clear or tinted glass.*

GLAZING, GLARING AND GEOMETRY.
QUANTITATIVE & QUALITATIVE DAYLIGHT ANALISYS

Daylight Factor

Daylight factor is based on the amount of indoor light as a percentage of outdoor light levels. Using a CIE overcast sky, it reports the percentage of outdoor light that arrives at a given point. Point A has access to significantly more sky than point B, with a proportionally higher daylight factor.

Source: Illustration by Amal Kissoondyal.

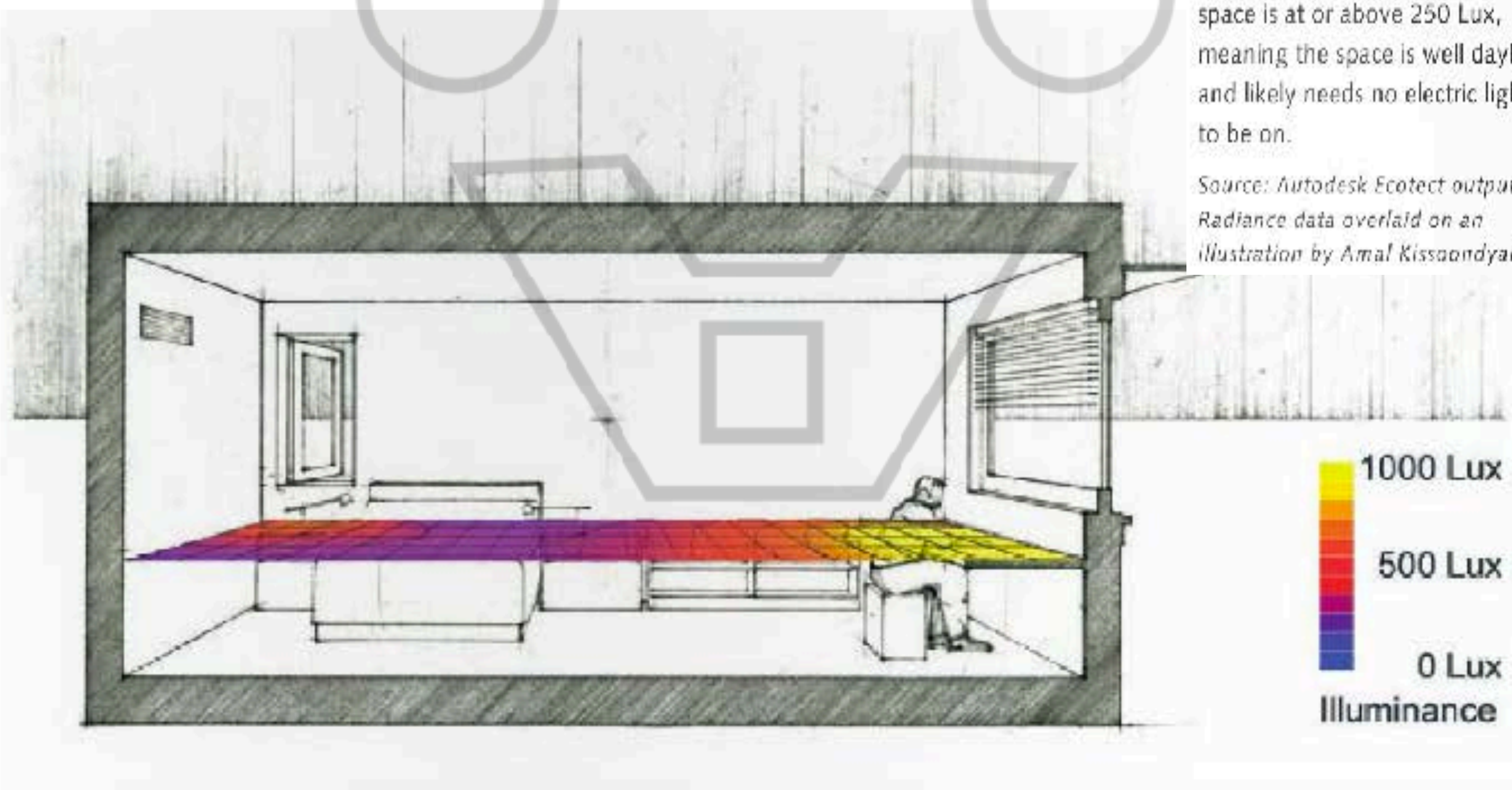


GLAZING, GLARING AND GEOMETRY.
HOW TO EVALUATE DAYLIGHT QUALITY

Illuminance Levels Analysis in False Color

False color illuminance levels for 2 p.m. on March 21 at a work plane height of 30" above floor level show that the majority of the space is at or above 250 Lux, meaning the space is well daylit and likely needs no electric lights to be on.

Source: Autodesk Ecotect output of Radiance data overlaid on an illustration by Amal Kissoondyal.

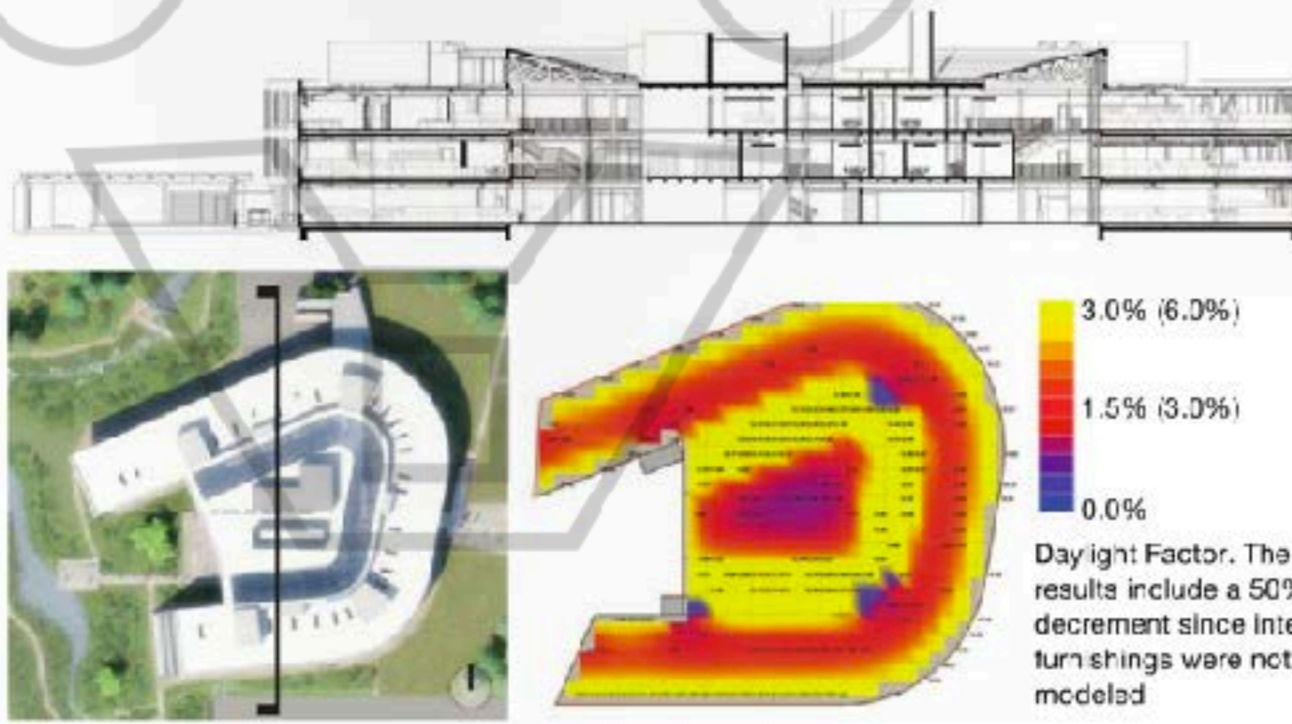


GLAZING, GLARING AND GEOMETRY.
HOW TO EVALUATE DAYLIGHT QUALITY

Daylight Factor Analysis in false color

Federal Center South, Building 1202, is a 60'-wide office plate in the form of a U-shape around a daylit atrium. The false color results of a daylight factor simulation on the ground floor show good daylight based on sectional properties, including: office plate width, skylight geometry and glazing properties.

Source: Courtesy of ZGF Architects LLP



Daylight Factor. The results include a 50% decrement since interior furnishings were not modeled

a **daylight factor** (DF)is the ratio of the light level inside a structure to the light level outside the structure.

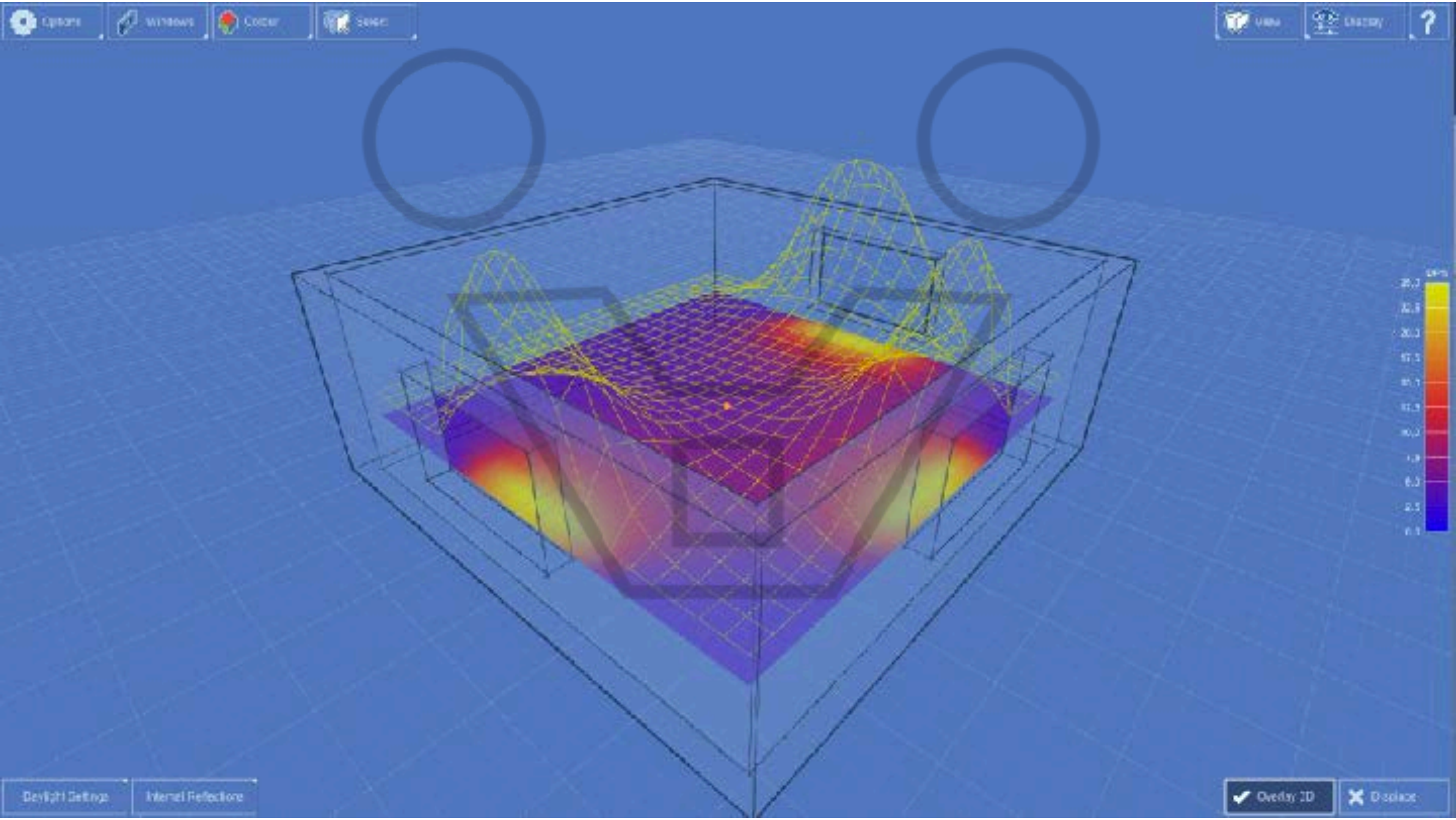
It is defined as:
DF = (Ei / Eo) x 100%

where,

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.

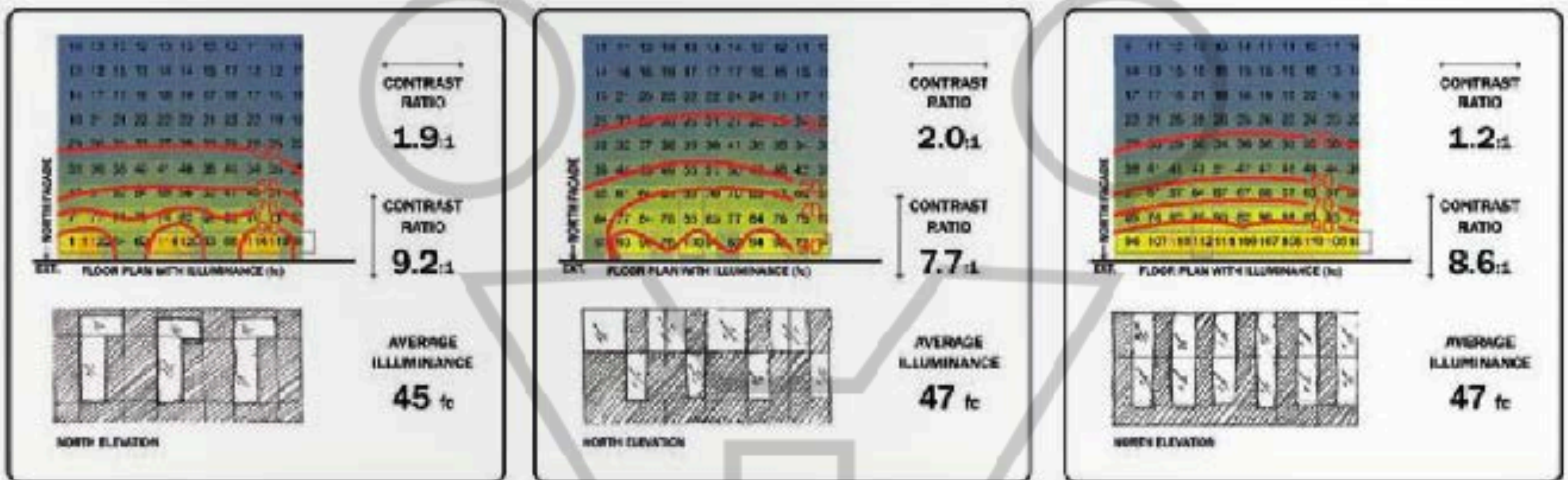
GLAZING, GLARING AND GEOMETRY.
HOW TO EVALUATE DAYLIGHT QUALITY Daylight Factor Analysis



http://andrewmarsh.com/apps/staging/daylight-box.html

GLAZING, GLARING AND GEOMETRY.
HOW TO EVALUATE DAYLIGHT QUALITY

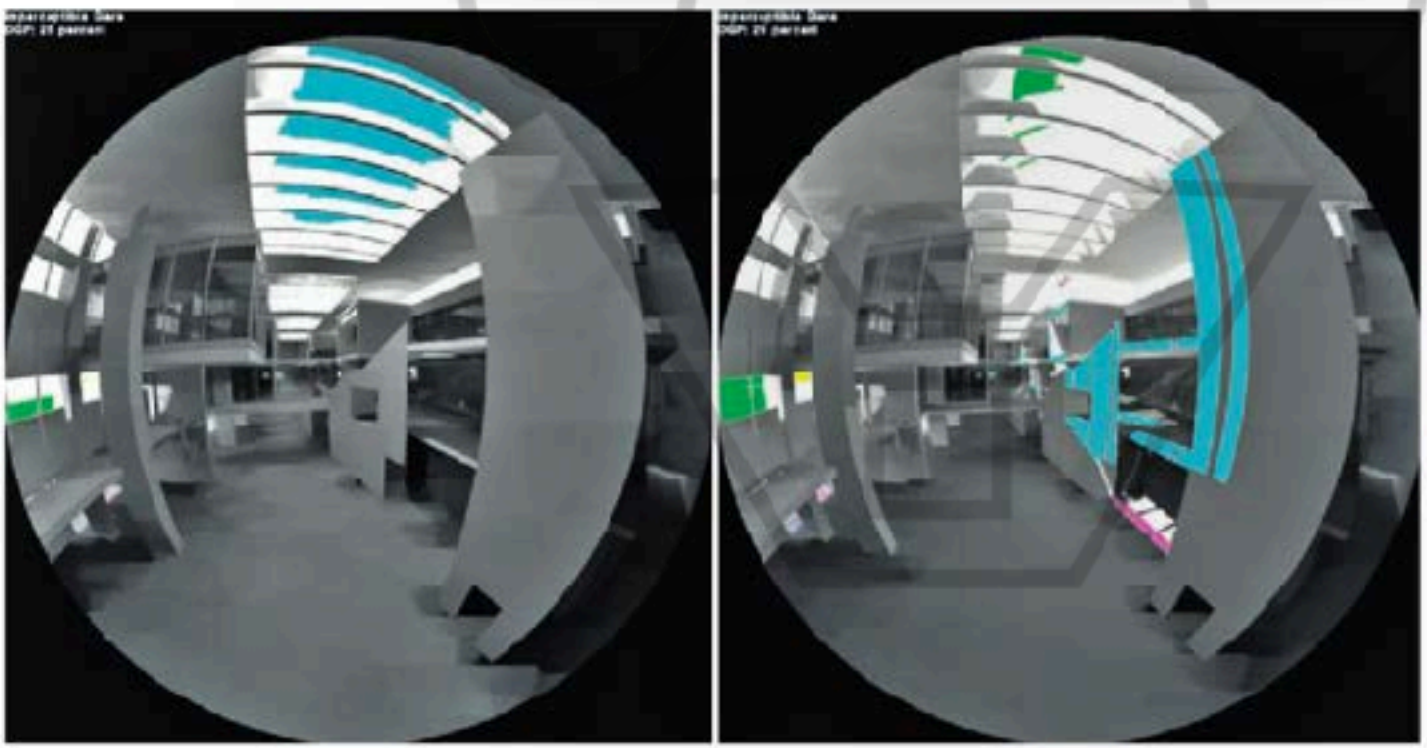
Illuminance Levels & Contrast Ratio



Plan-view studies showing illuminance levels for three window options on a north façade under overcast skies. The room's contrast ratios across width and depth are also shown, with lower contrast being preferable, but difficult to achieve, with side-lighting. Lighting designers typically include a room's contrast ratio in their studies to ensure even lighting throughout a space.

Source: Courtesy SERA Architects.

Glaring & Shading



8.12

Daylight glare probability studies of atrium skylight options using DIVA software shows .26 and .29, both considered imperceptible glare. Each area within a field of view that contributes to glare is assigned a random color to show its location.

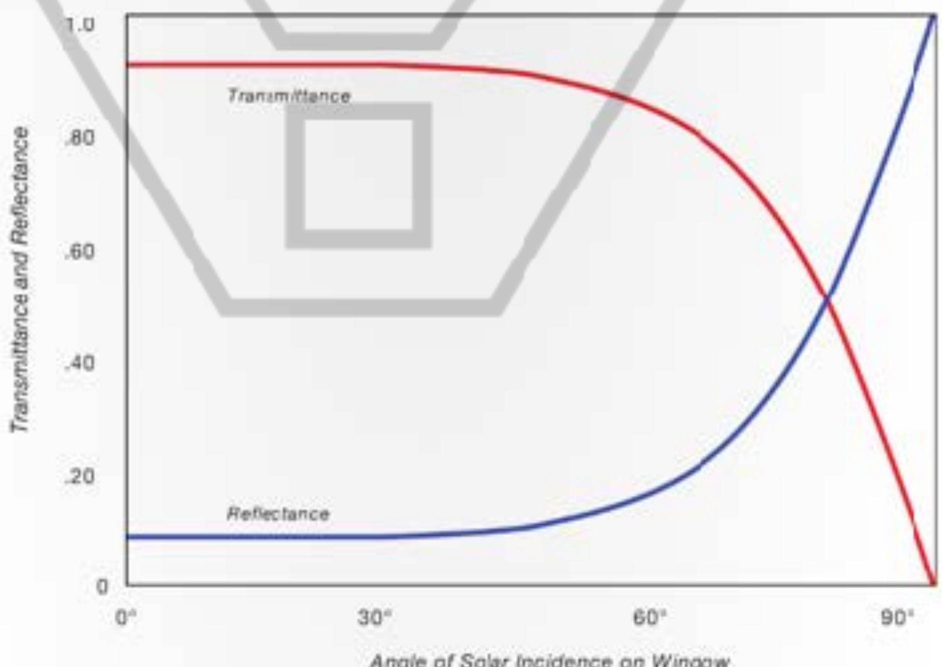
Source: Courtesy of SERA Architects.

SHADING AND DAYLIGHT DIFFUSION

Reflectance & Transmittance f(angle of incidence)

6.6

Translucent materials transmit some light and heat directly, and diffuse the rest of the transmitted light. In most cases, the diffused light is more concentrated around the directly transmitted light.



DAYLIGHT DIFFUSION

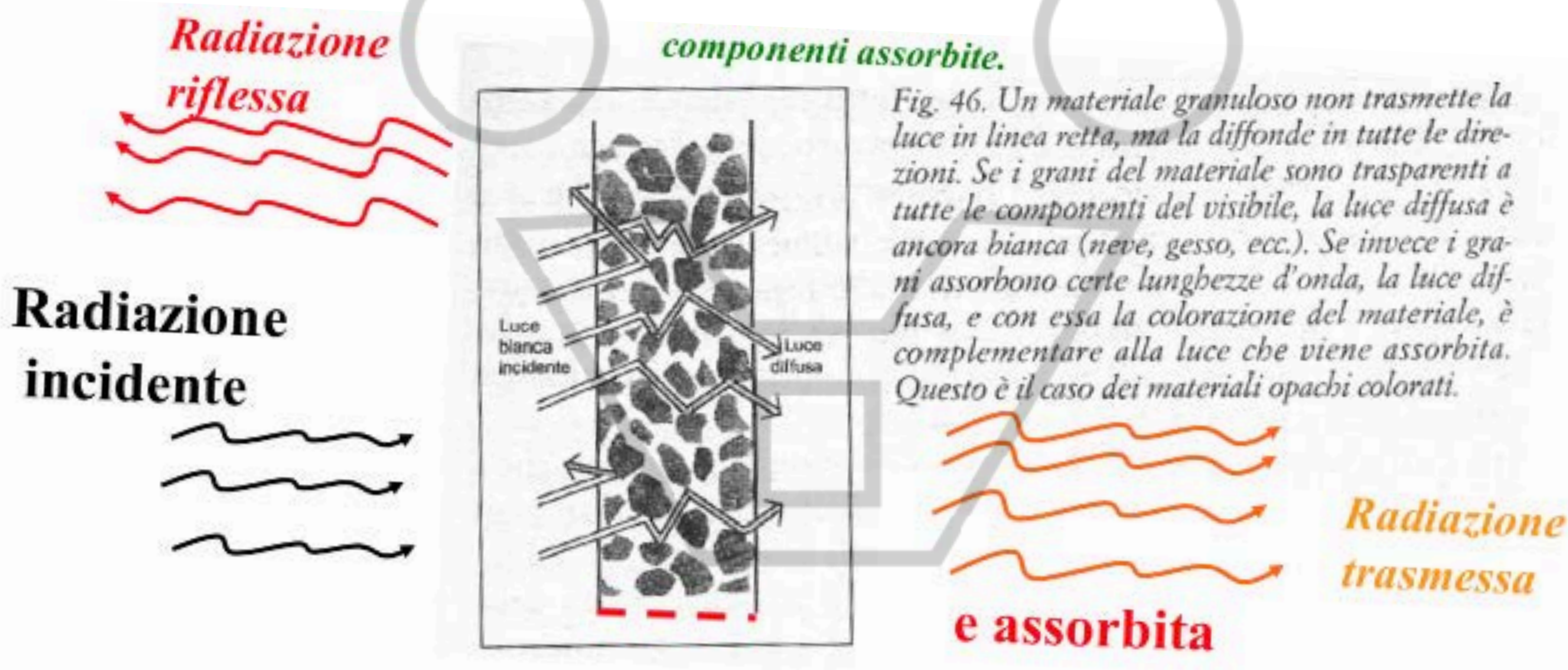
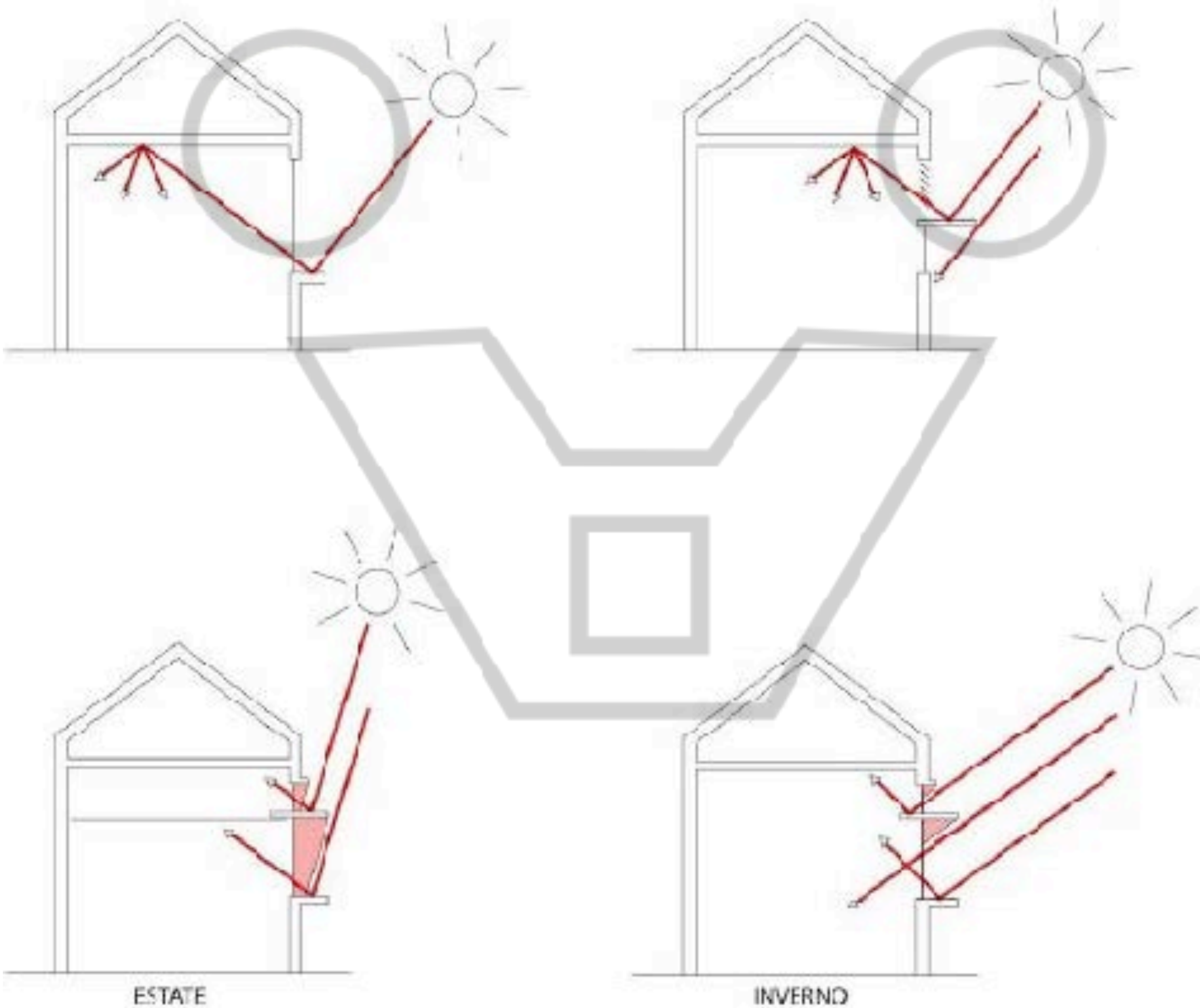


Fig. 46. Un materiale granuloso non trasmette la luce in linea retta, ma la diffonde in tutte le direzioni. Se i grani del materiale sono trasparenti a tutte le componenti del visibile, la luce diffusa è ancora bianca (neve, gesso, ecc.). Se invece i grani assorbono certe lunghezze d'onda, la luce diffusa, e con essa la colorazione del materiale, è complementare alla luce che viene assorbita. Questo è il caso dei materiali opachi colorati.

SHADING AND DAYLIGHT DIFFUSION

Systems for daylight diffusion

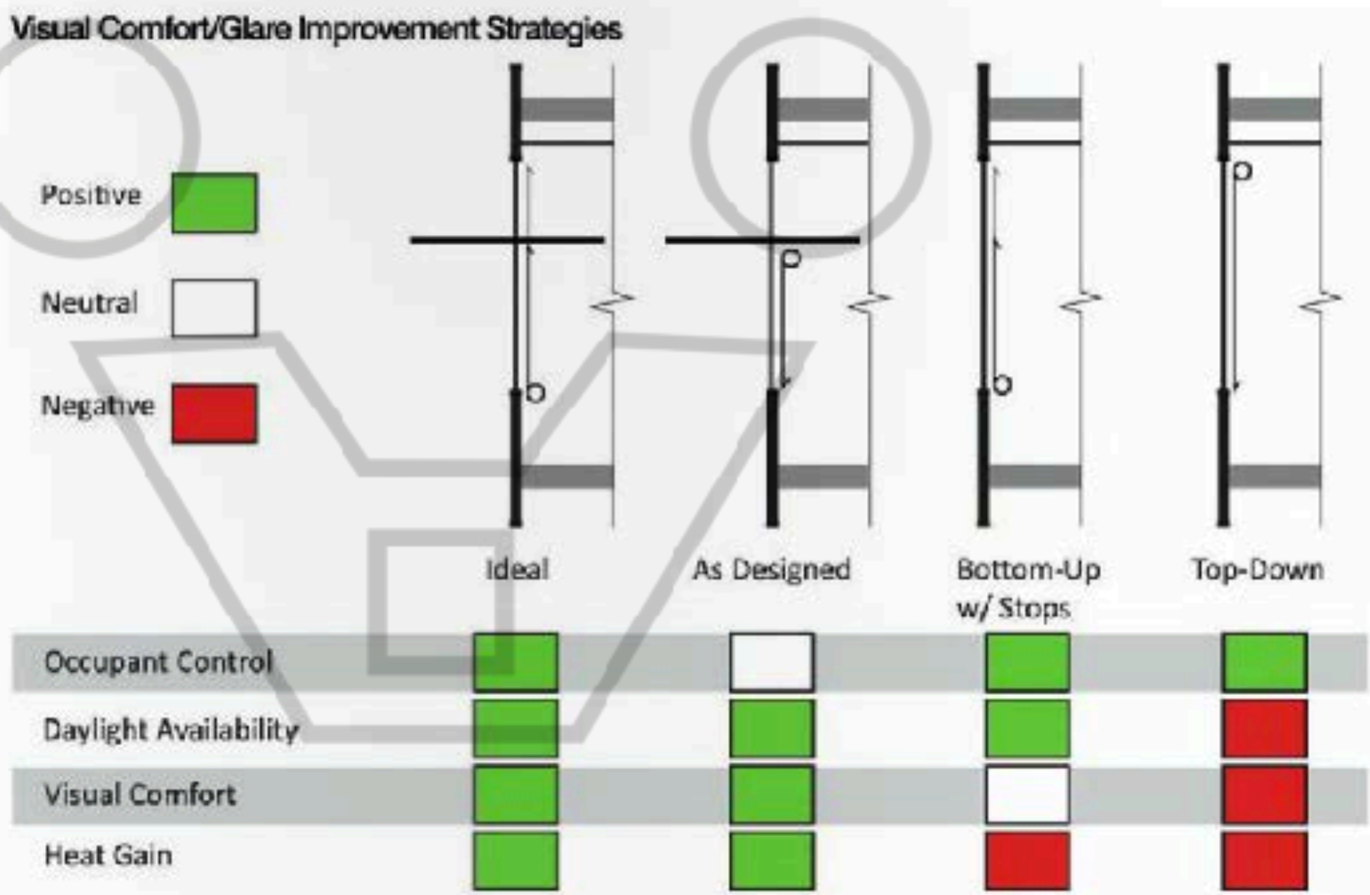


SHADING AND DAYLIGHT DIFFUSION

3.6

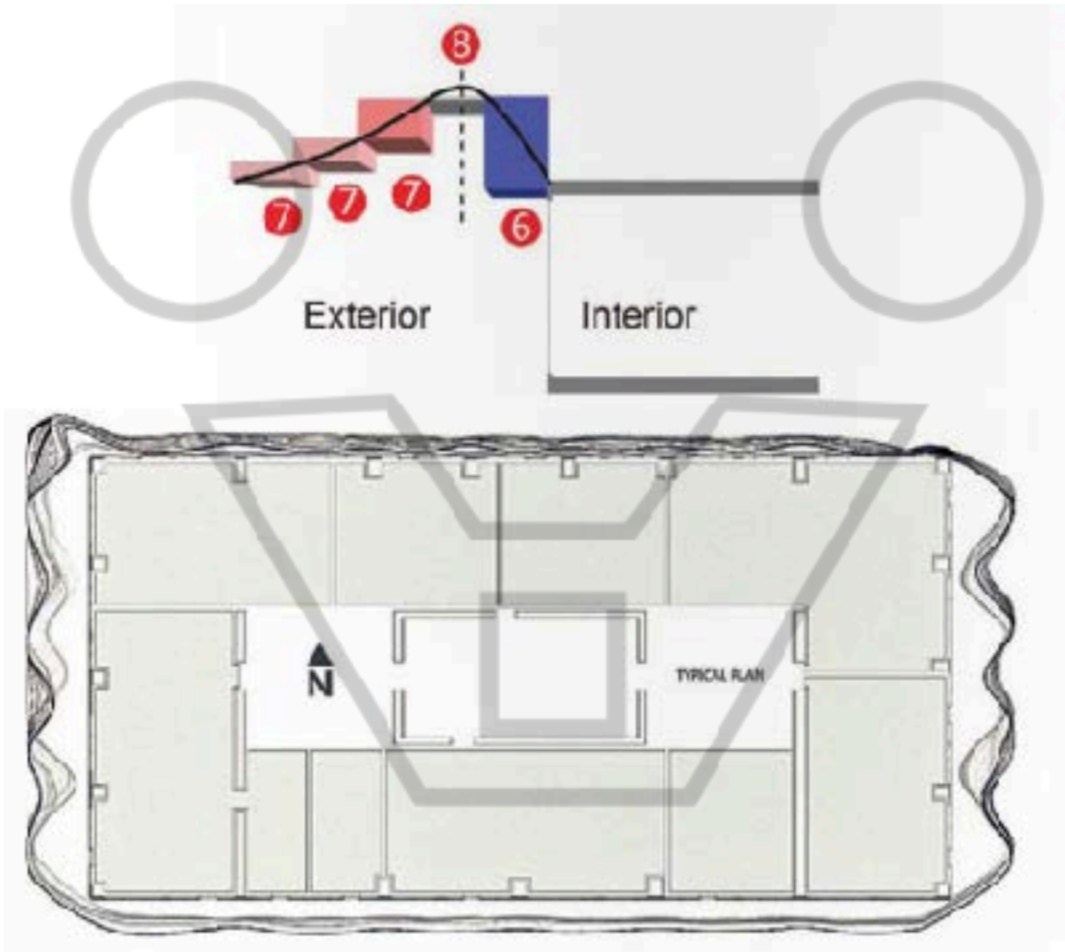
A study prepared for Iowa State University by ZGF Architects LLP rates four window options for user controllability, daylight availability, visual comfort, and heat gain. While simulations predict lighting energy savings due to the use of daylight, these savings are only realized when the system successfully blocks glare or allows users to block glare without blocking daylight.

Source: Courtesy of ZGF Architects LLP.



Glaring & Shading

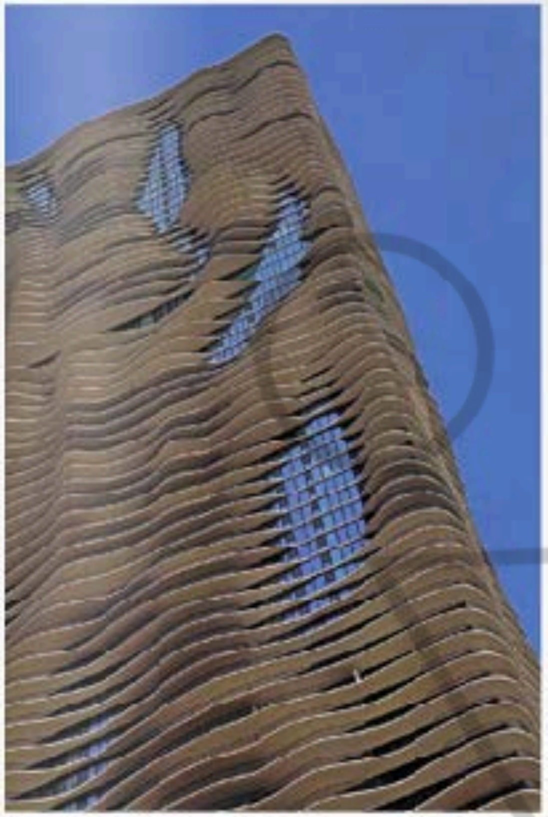
LIGHTING vs GLARING: Shaping windows and shading



The Shaderade approach, which advanced earlier work by Eran Kaftan and Dr. Andrew Marsh, involves mapping the annual energy consequences of each position where a shade could affect energy transmission through a window (1) in two or three dimensions (2).

The method begins by running a single simulation of a building shaded only by context, which yields hourly information about thermal loads and heat gains transmitted through the windows from

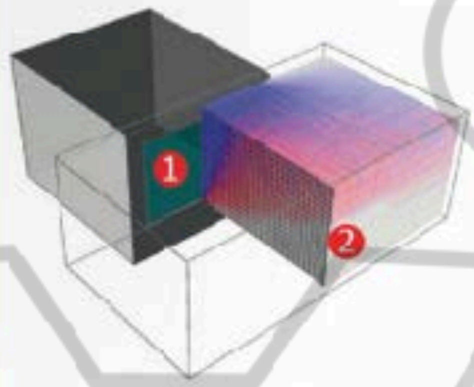
Glaring & Shading



7.30

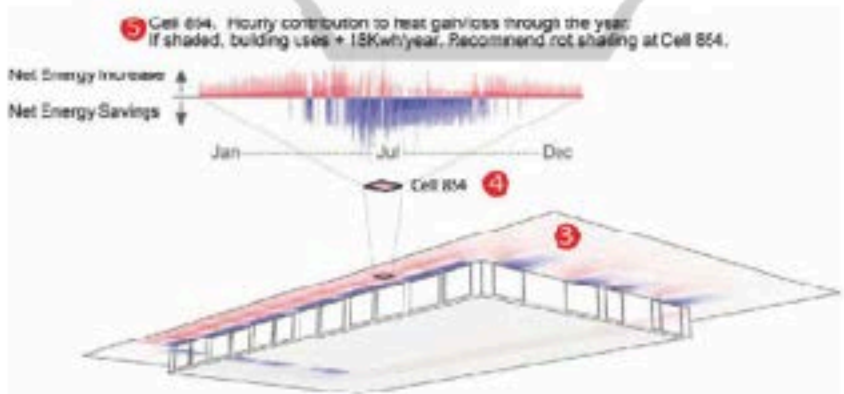
The Aqua Tower. The parametric aesthetic of the Aqua Tower was investigated using the Shaderade method of shading design.

Source: Photo by Jeff Nemasi.



7.31

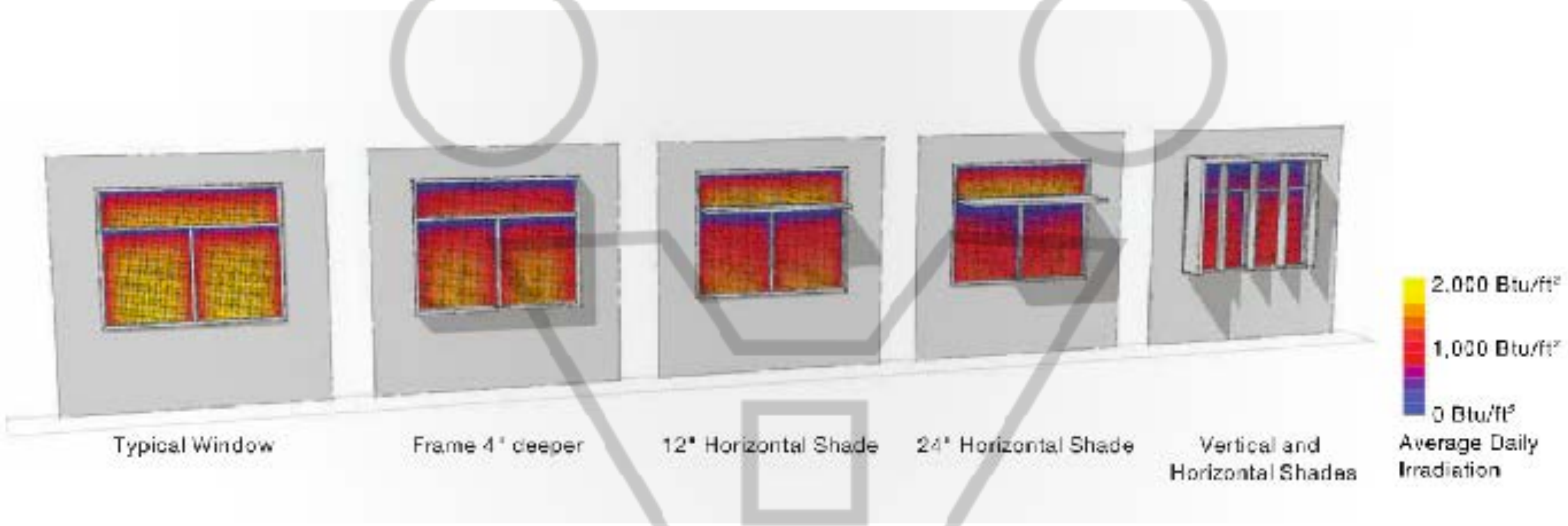
Shaderade Boston cube. Each colored cell shows net higher (red) or lower (blue) energy use if a shading device occupied its area.



7.32

Section through a typical window, showing ideal shading device depth at the inflection point of higher and lower energy use.

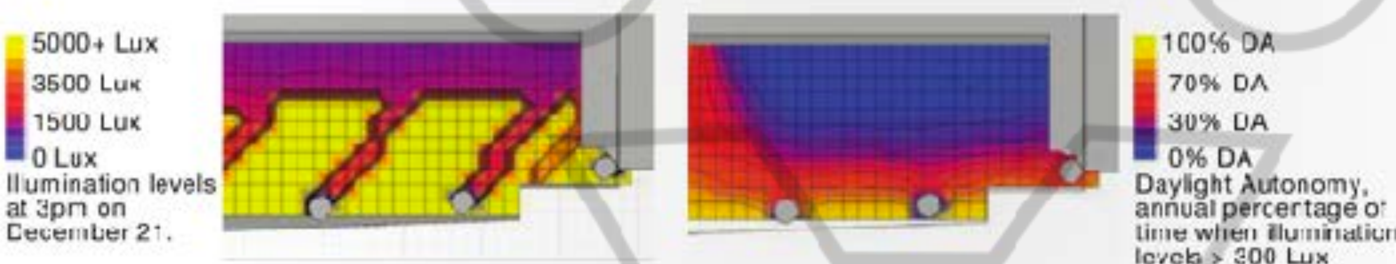
SIMULATION for DAYLIGHT ASSESSMENT



SIMULATION OF SHADING EFFECT

SIMULATION for DAYLIGHT ASSESSMENT

Point-in-time vs annual analysis
ILLUMINATION LEVEL



2.6

Plan view of an open office space, showing a façade with columns at the bottom. A point-in-time (PIT) analysis (left) provides information about daylight levels and potential for glare at 3:00 p.m. on the winter solstice, for example. An annual daylight autonomy analysis (right) shows areas that are successfully daylit for a certain percentage of the year. Both use false colors to illustrate lighting levels; they are Autodesk Ecotect outputs of Radiance and Daysim analyses, respectively.

on investment of 3 years. If the project team assumes that occupants will turn off the lights when they leave at night, occupancy sensors may only be projected to reduce lighting energy use by 20%, with a return on investment of 10 years. As a broader example, ASHRAE 90.1's baseline building energy use is unique to every design, leading to industry-wide misunderstanding regarding a building's modeled

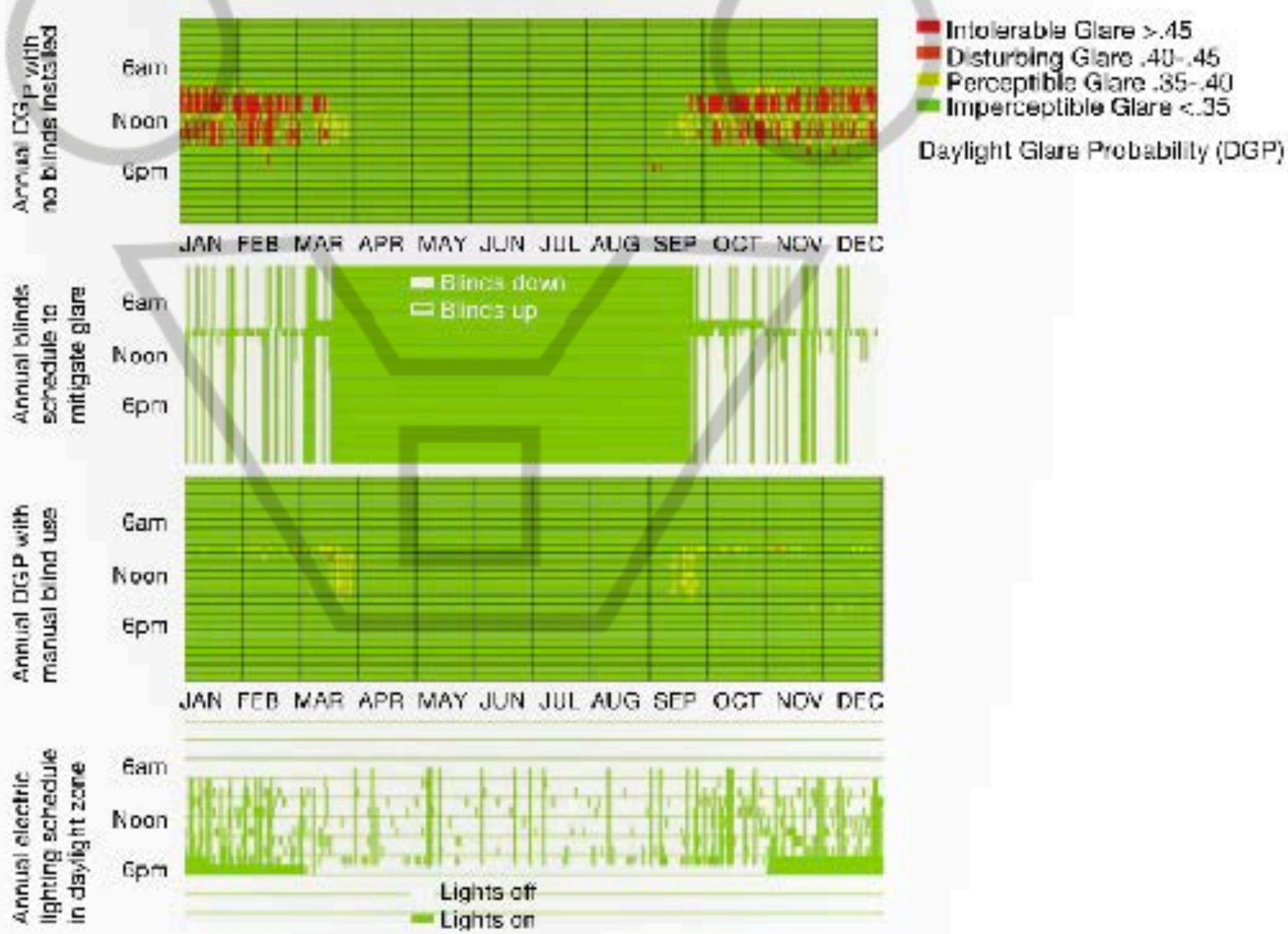
SIMULATION for DAYLIGHT ASSESSMENT

Point-in-time vs annual analysis
DGP - DAYLIGHT GLARE PROBABILITY

8.13

An east-facing viewpoint within a south-facing office space experiences glare primarily during times with low-angle sun in the Fall and Winter. Diva for Rhino software creates a blinds schedule to minimize glare, based on research of building occupants' tendency to lower them based on glare but raise them infrequently, per the Lightswitch model (Reinhart, 2002). The blind schedule helps create a lighting usage schedule that can estimate lighting energy use savings to compare design options.

Source: Courtesy of Jeff Niemasz.



SIMULATION for DAYLIGHT ASSESSMENT

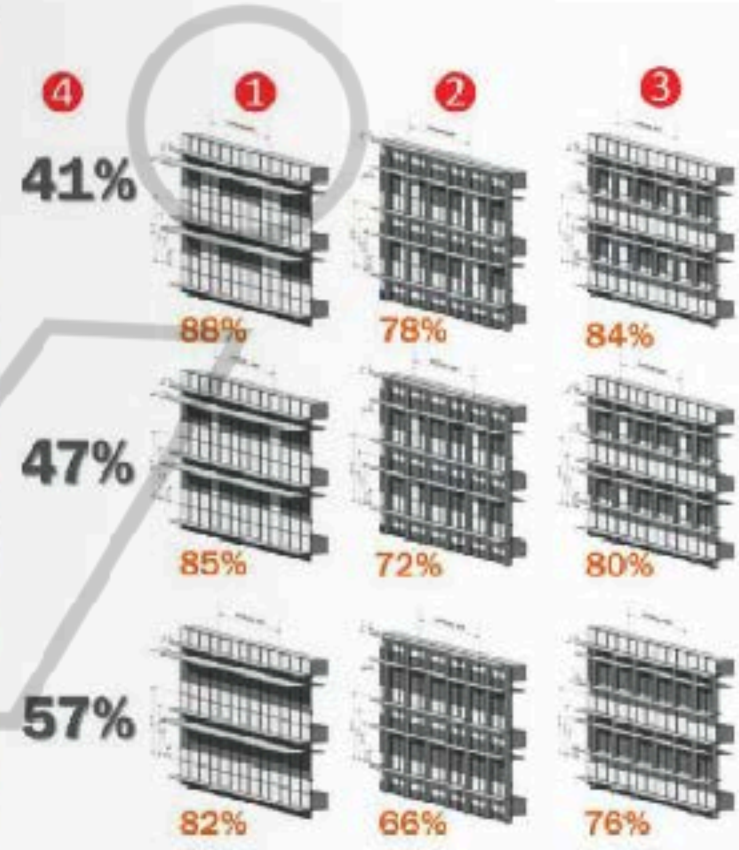
Physical scale model to evaluate daylight and glare

SIMULATION for DAYLIGHT ASSESSMENT

Physical scale model to evaluate daylight and glare

7.17

Façade shading studies testing options with (1) horizontal shade only, (2) vertical and horizontal fins with the horizontal element as a light shelf, and (3) vertical and horizontal fins with the horizontal as sill reflector. Each option was tested with 3 glazing percentage options (4). The orange number shows the percentage of the glazing that is shaded in each option.

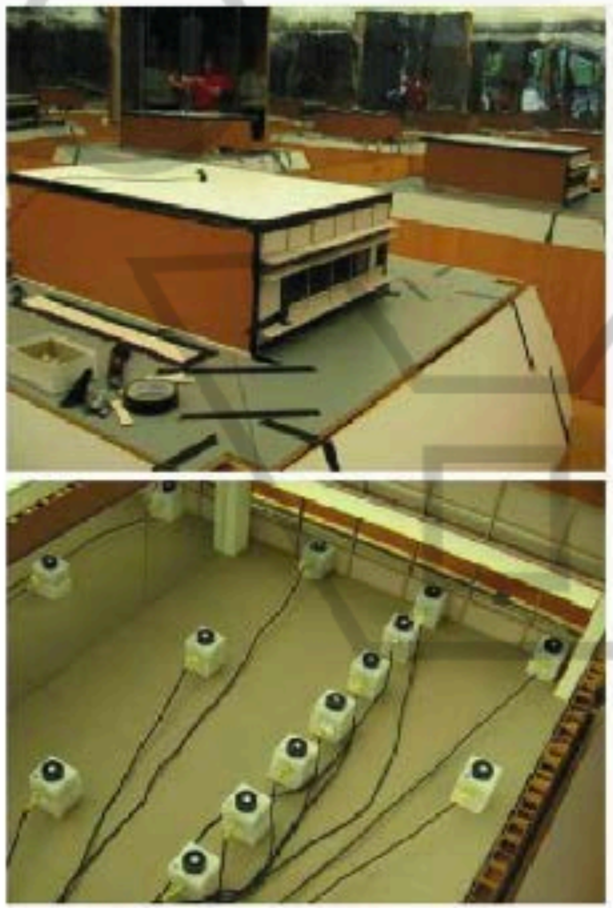


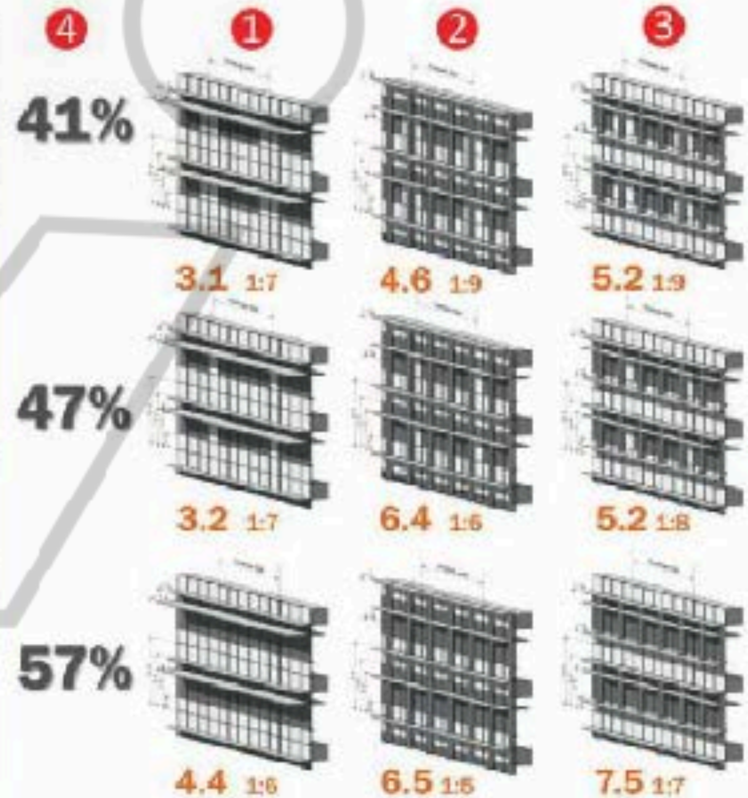
SIMULATION for DAYLIGHT ASSESSMENT

Physical scale model to evaluate daylight and glare

7.18

Daylighting studies testing the same 9 shading options as 7.17. The large orange number shows the average daylight factor in the 16' perimeter zone, and the small number shows the contrast ratio across this area.





SIMULATION for DAYLIGHT ASSESSMENT

Physical scale model to evaluate daylight and glare

8.14

A physical daylighting model showing use of light meters to calculate the daylight factor. An overcast sky is simulated by the light box, which has highly reflective ceiling and walls to create uniform light levels.

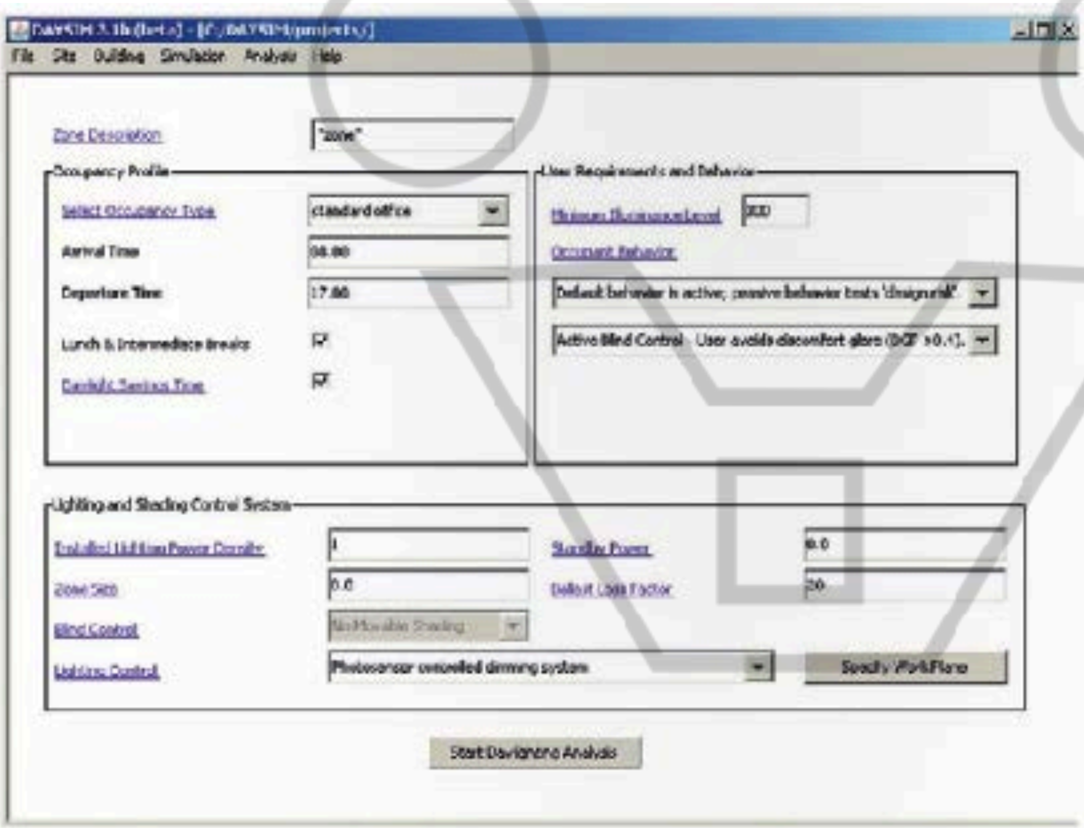
Source: Courtesy of SERA Architects.

And a physical daylighting model showing use of a heliodon at the Energy Studies in Buildings Laboratory in Portland, Oregon, to predict daylighting levels under sunny sky conditions. The large wheels rotate the model through specific solar angles in relation to a bright electric light.

Source: Courtesy of SERA Architects.

SIMULATION for DAYLIGHT ASSESSMENT

DIGITAL SIMULATION TO EVALUATE DAYLIGHT AUTONOMY vs DAYLIGHT AUTONOMY MAX



8.10

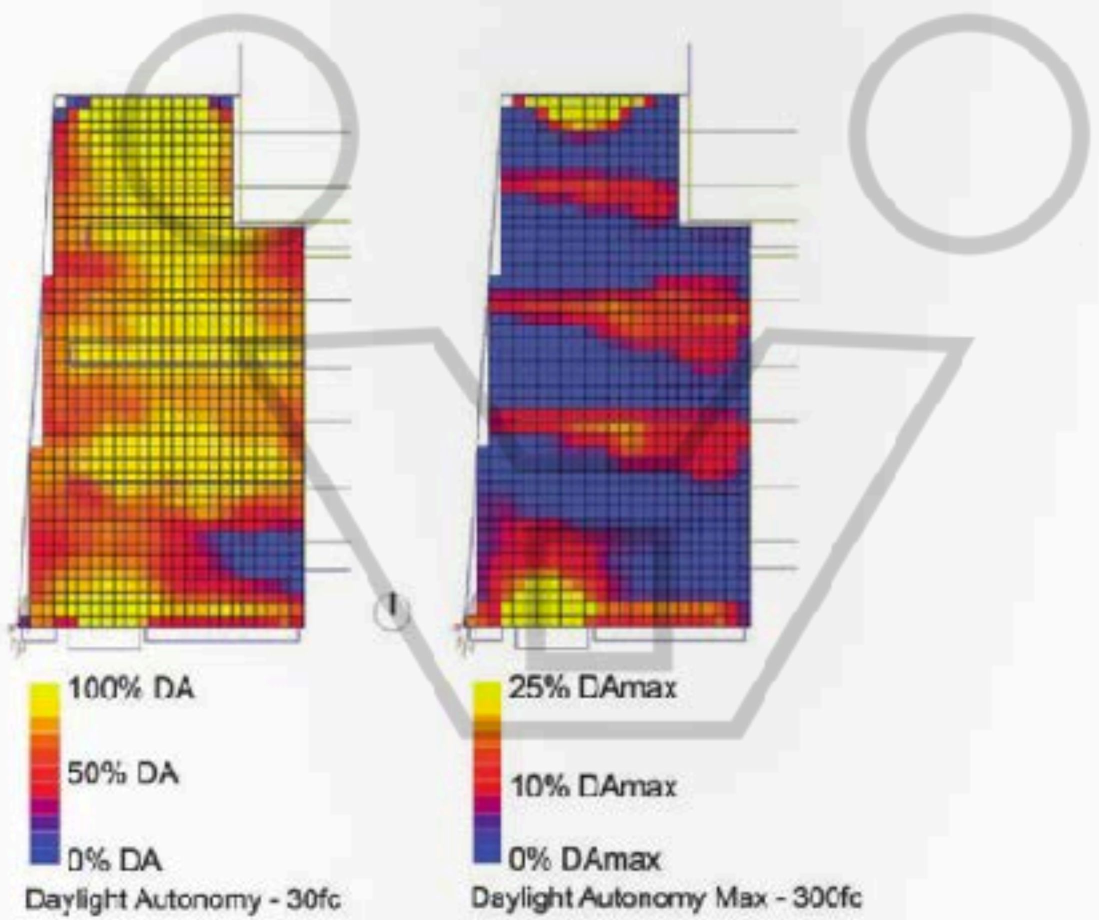
Daysim software, that estimates daylight autonomy, has a user-inputted minimum lighting threshold, generally the illuminance level recommended for electric lighting. The characteristics of the occupants, the hours of operation, and other information are necessary to accurately estimate when electric lights may be dimmed or off on an annual basis.

Gla

A given sensor that reports a DA of 75% means that electric lights would not be necessary at the sensor during 75% of the occupied hours each year. DA presents a best case scenario for lights to be dimmed or off, since glare may cause blinds to be deployed, reducing light levels at the sensor. DA software requires the input of various assumptions about the building or users' operations of blinds as

SIMULATION for DAYLIGHT ASSESSMENT

DIGITAL SIMULATION TO EVALUATE DAYLIGHT AUTONOMY vs DAYLIGHT AUTONOMY MAX

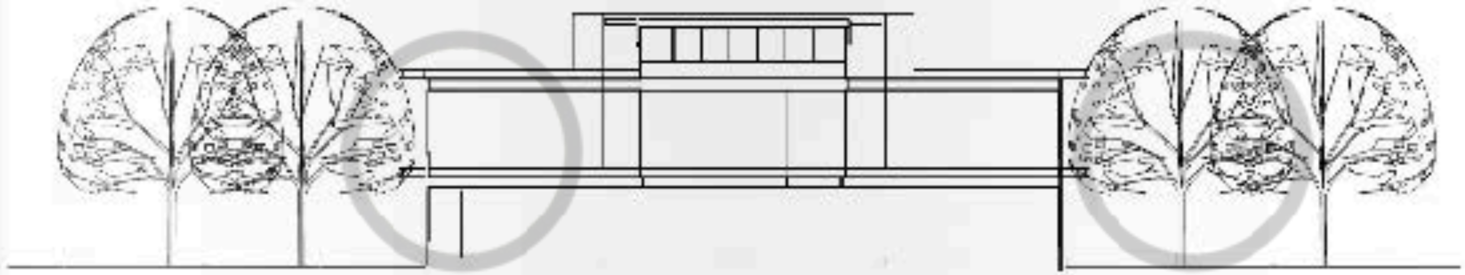


6.24

Plan view of reading room showing annual DA and DAmax. The skylight geometry is shown to provide enough daylight throughout most of the year with over-lighting in only a few places for only around 10% of occupied hours.

SIMULATION for DAYLIGHT ASSESSMENT

HOW TO MODEL TREES



8.53

Sectional line drawing looking south, showing trees at two potential distances from the façade.

Courtesy of Skidmore, Owings & Merrill, Chicago.

8.54

Creation of digital tree geometry.

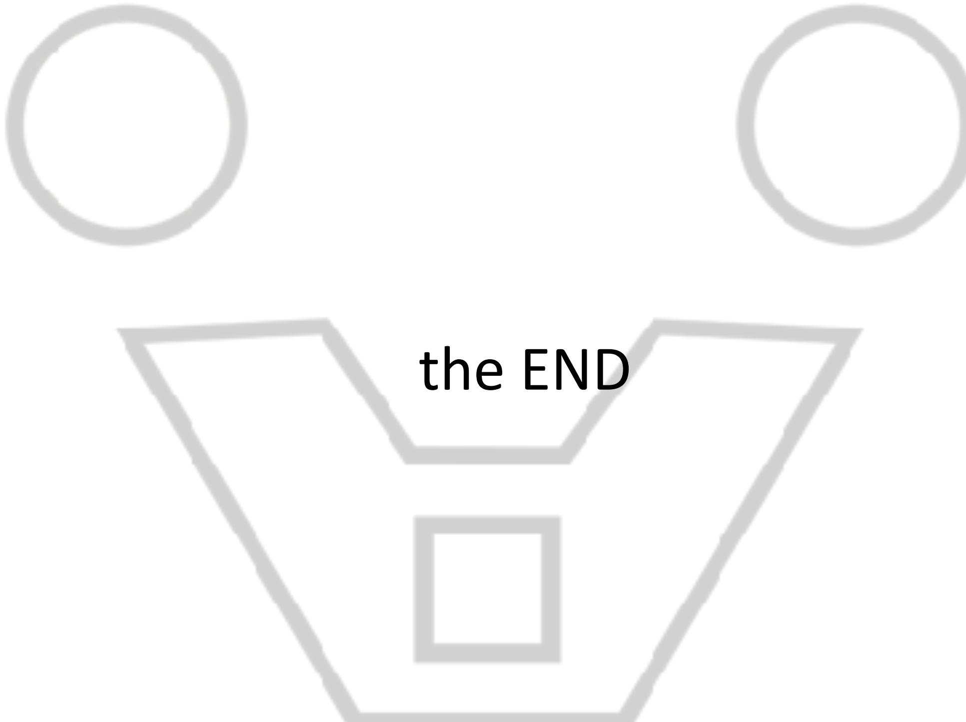
Courtesy of Skidmore, Owings & Merrill, Chicago.

Simulation

This simulation was performed by SOM's Design Performance Group, which specializes in early design simulations. The Revit-based model was imported and re-built in Rhino for this tree canopy study in the design development phase.

Research was conducted into modeling and defining the optics and seasonal behavior of a Thornless Honeylocust to create a simulated tree. A vector outline (1) of the species was projected onto two sides of a 3D volume. The canopy openness was approximated in the Rhino model (2) to allow direct, dappled light from various directions and a variation of light passing through and reflecting off leaves. This approach reduced meshed surfaces and simulation time.

Research and guidance from Christopher Meek at the University of Washington Integrated Design Lab (IDL) into the optical properties (3) of the leaves were used to create a Radiance material (4) for the leaves using Optics 6 Software. The tree leaves were scheduled to be present in the model between May 15th and October 15th to simulate deciduous vegetation.


the END

Aspects affecting daylight quality

- DAYLIGHT AVERAGE
- GLARING
- SHADING

The most relevant daylight effect on thermal condition
The green house phenomena.
LA CONDUZIONE DEL CALORE
Prima avevo fatto la radiazione

Radiazione raggi incidenti
Convenzione quando questo equilibrio si realizza attraverso l'aria
Conduzione materiali a contatto

si equilibrano talvolta molto
lentamente a causa di una specifica inerzia del materiale sia condurre che delle capacità d
accumulo
e tempi di assestamento con il sistema circostante.
La prima è una proprietà isolante ovvero di trasferire energia termica
La seconda capacità di …latenza….

4.4.4 Visible Light Transmittance (VLT)

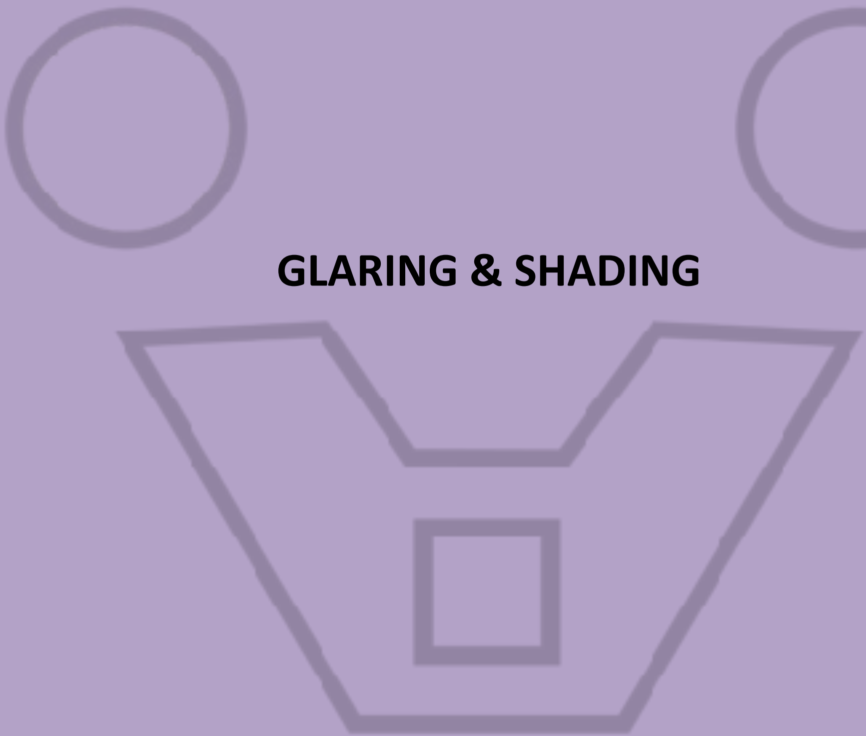
The percentage of visible light that passes through a window or glazing material is characterized by the parameter known as the Visible Light Transmittance (VLT). An opaque wall would have a zero VLT (0 %), whereas an unobstructed and empty facade opening would have a 100 % VLT. This property only measured the light in the visible portion of the spectrum (and not infrared light). A properly designed glazing unit with high VLT can reduce the electric lighting load and its associated cooling load.

Environmental parameters affecting daylight

GLAZING GEOMETRY & MATERIALS

- DAYLIGHT AVERAGE
- GLARING
- SHADING

Environmental parameters affecting daylight:



GLARING & SHADING

Textbook: https://issuu.com/jesic/docs/design_energy_simulation_for_archit

Other resources: :

http://andrewmarsh.com/software/sunpath-on-map-web/
http://andrewmarsh.com/software/app-shading/
http://andrewmarsh.com/software/app-daylight/
http://web.mit.edu/jaimelee/Public/ECOTECT_TUTORIAL_Fall09.pdf
http://bim.rootiers.it/node/143
http://comfort.cbe.berkeley.edu/EN
www.nrel.gov/docs/fy08osti/43156.pdf
http://www.tranebelgium.com/files/book-doc/13/en/13.ibowhx58.pdf

EMISSIVITY vs EMITTANCE