Daylighting buildings
Course plan

1. Short historic overview
2. Benefits of using daylight
3. Risks with daylight

4. Design strategies for daylight harvesting

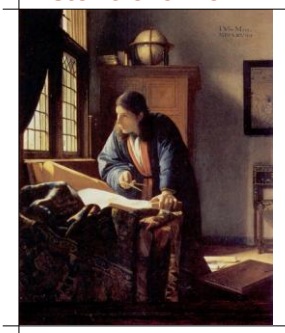
5. DAYSIM and its daylight metrics

Daylighting buildings
Definition

Daylighting is the practice of placing windows or other openings and reflective surfaces so that during the day natural light provides effective internal lighting.

[source: www.wikipedia.org]

Daylighting buildings
Historic overview

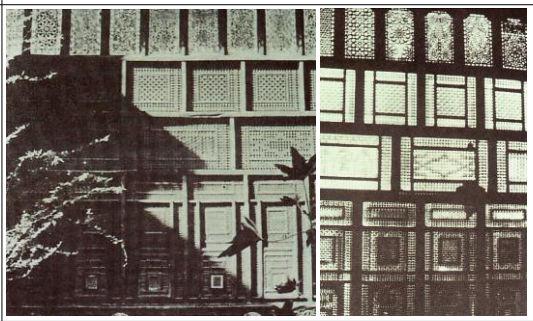


The history of architecture is the history of the struggle for light. (Le Corbusier)

[source: The geographer by Jan Vermeer, in Millet, 1996, Light revealing architecture]

Daylighting buildings
Historic overview

[source: Exterior and interior view of the mashrabiya at the As-Suhaymi house in Cairo, Egypt, in Baker & Steemers, 2002, Daylight Design of Buildings]



Daylighting buildings
Historic overview

[source: Column at the Baths of Caracalla in Rome, in Millet, 1996, Light revealing architecture]

[source: The Parthenon, Athens, in Baker & Steemers, 2002, Daylight Design of Buildings]

Daylighting buildings
Historic overview

[source: Pantheon, Rome, artist Giovanni Battista Piranesi]

Daylighting buildings
Historic overview

[source: King's College Chapel, Cambridge, Baker & Steemers, 2002, Daylight Design of Buildings]

Daylighting buildings
Historic overview

[source: The breakfast room, John Soane's Museum, London, in Baker & Steemers, 2001, Daylight Design of Buildings]

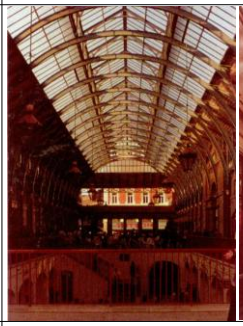
[source: Palladio, Palazzo Chiericati, Vicenza, 1550-1557, et Villa Foscari, 'La Malcontenta', 1558 ca, sur le Brenta, photo Georges Teyssot]

Daylighting buildings
Historic overview

[source: St Peter's Church, architect Bernini, Rome, and The Trasparente, Toledo, Spain, in Baker & Steemers, 2002, Daylight Design of Buildings]

Daylighting buildings
Historic overview

[source: Covent Garden, London, in Millet, 1996, Light revealing architecture]



Daylighting buildings
Historic overview

[source: Bibliothèque Nationale, Paris, Henri Labrouste, in Baker & Steemers, 2002, Daylight Design of Buildings]

Daylighting buildings
Historic overview

[source: Rookery building by John Root & D Burnham, 1885-88, Chicago, in Millet, 1996, Light revealing architecture]

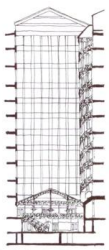
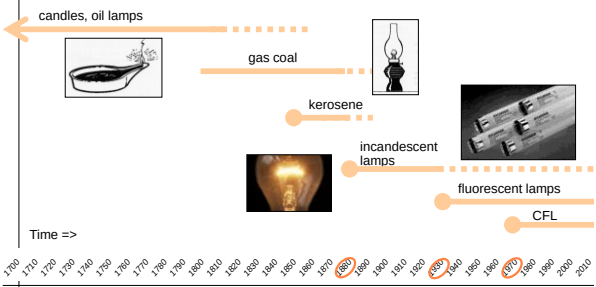


FIGURE 2–29A *Section of the ten-story light well of the Rookery in Chicago, Illinois.*

FIGURE 2–29B *View of the light court in the Rookery.*

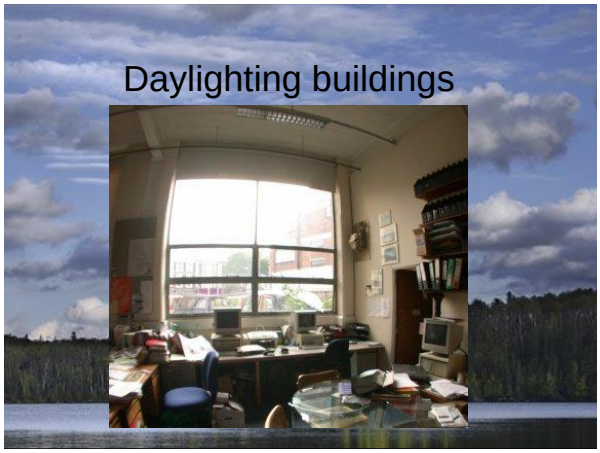
Daylighting buildings
Historic overview

[source: Lechner, 2001, Heating, Cooling, Lighting]



Daylighting buildings
Historic overview

[source: Shallow plan for Trinity Library, Cambridge and Deep plan office at Canary Wharf, London, in in Baker & Steemers, 2002, Daylight Design of Buildings]



Daylighting buildings
Benefits of daylight

[source: Boyce, Hunter & Howlett, 2003, The benefits of daylight through windows]

1. Performance of the visual system
2. Stimulation of circadian cycle (night day)
3. Synthesis of vitamin D (skin)
4. Reduction of stress
5. Variation = positive biological response

6. Luminous efficacy (lm/W) = energy efficiency
7. Increased rental value
8. Positive effect on sales
9. Increased productivity

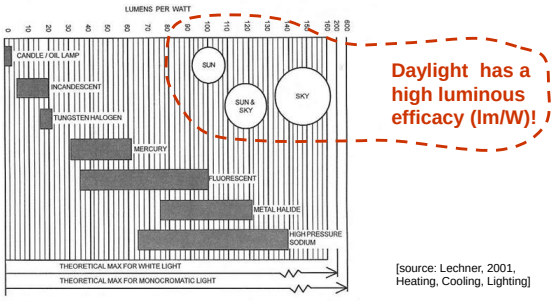
Why daylight...?

[source: Jens Christoffersen, SBI, Denmark, 2009]

- ✓ **People prefer daylight as light source**
- ✓ **Daylight is 'free' and efficient**
- ✓ **Daylight is available during working hours**
- ✓ **Large energy savings potential**
- ✓ **Health and well-being**

Quality parameters: View, light, air and variation

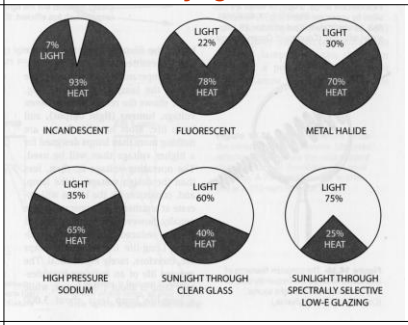
Daylighting buildings
Benefits of daylight



Daylight has a high luminous efficacy (lm/W)!

[source: Lechner, 2001, Heating, Cooling, Lighting]

Daylighting buildings
Benefits of daylight



Daylight has a high luminous efficacy (lm/W)!

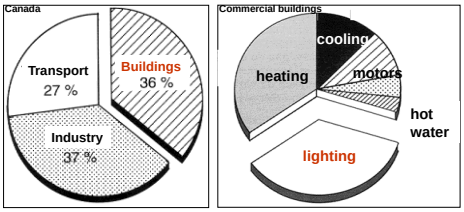
[source: Lechner, 2001, Heating, Cooling, Lighting]

Daylighting buildings
Benefits of daylight

[source: Energy use by sector and energy use of commercial buildings by final use in Canada in Boivin, 2007, La ventilation naturelle: outil d'évaluation du potentiel de la climatisation passive]

Energy savings with daylight utilization

Commercial buildings:
Artificial lighting = 30-40% energy use



Daylighting buildings
Benefits of daylight

[source: Public Works and Government Services, 2002, Daylight Guide for Canadian Commercial Buildings]

Energy savings with daylight utilization

Commercial buildings:
Artificial lighting = 30-40% energy use

Using daylight allows:

Reduction of installed power density (W/m^2)
up to 25% (Canada)

Reduction of electricity consumption for lighting
up to 50%

Daylighting buildings
Benefits of daylight

[source: Public Works and Government Services, 2002, Daylight Guide for Canadian Commercial Buildings]

Annual budget, typical office building

20 $/m^2	Energy
200 $/m^2	Building cost
2000 $/m^2	Salaries

An increase in productivity of employees of 1% can save $$$ corresponding to the annual energy budget

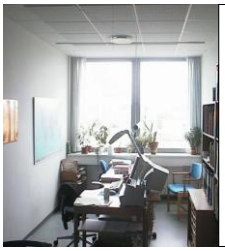
Daylighting buildings
Risks associated with daylight

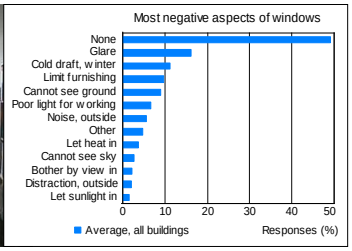
[source: Newsham, via Christoffersen, 2006, Light, health and well-being]

Disability glare
Loss of visual information

Discomfort glare
Caused by large contrasts
No loss of visual information
Long term effects (fatigue)

Daylighting buildings
Risks associated with daylight





[source: Christoffersen et al, 1999, Vinduer og dagslys – en feltunder-søgelse i kontor bygninger]

Daylighting buildings
Risks associated with daylight

Reflections in computer screen

Daylighting buildings
Risks associated with daylight

Glare and reflections in computer screens

"Bad screen glare, huh Jerry?"

Daylighting buildings
Risks associated with daylight

Overheating and direct glare

[source: Fontoynont, 1999, Daylight performance of buildings.]

Daylighting buildings

Daylighting buildings
Design strategies

Daylight Harvesting
Term used in sustainable architecture and the building controls and active daylighting industries for a control system that reduces the use of artificial lighting with electric lamps in building interiors when natural daylight is available, in order to reduce energy consumption.

- **Passive daylighting**
- **Active daylighting**

[source: Wikipedia.org]

Daylighting buildings
Design strategies

Passive daylighting
System of both collecting sunlight using static, non-moving, and non-tracking systems such as windows, sliding glass doors, most skylights, light tubes, and light louvers; and reflecting the collected daylight deeper inside with elements such as light shelves. Passive daylighting systems are different from active daylighting systems in that active systems track and/or follow the sun, and rely on mechanical mechanisms to do so.

[source: Wikipedia.org]

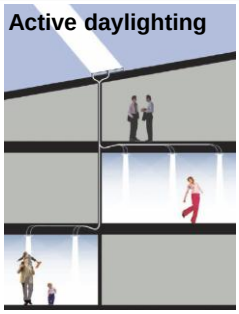
Daylighting buildings
Design strategies

Active daylighting
system of collecting sunlight using a mechanical device to increase the efficiency of light collection for a given lighting purpose. Active daylighting systems are different from passive daylighting systems in that passive systems are stationary and do not actively follow or track the sun.

[source: Wikipedia.org]

Daylighting buildings
Design strategies

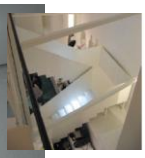
Active daylighting



[source: www.parans.com]

Daylighting buildings
Design strategies

Active daylighting

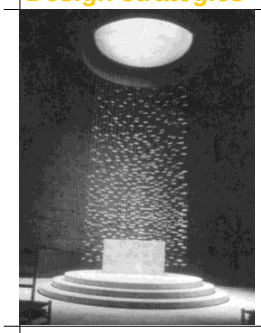


Daylighting buildings
Design strategies

Passive daylighting

1. **Site and orientation**
2. **Plan depth**
3. **Windows**
4. **Light distribution/reflection**
5. **Control**
6. ***Other things to know…***

Daylighting buildings
Design strategies



Good daylight design is not a restriction on architectural expression – on the contrary; it is more likely to act as an inspiration and foundation for good architecture.

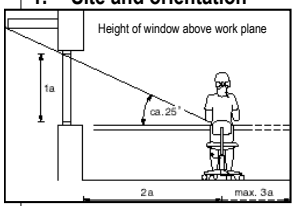
(Baker & Steemers, 2002, Daylight Design of Buildings)

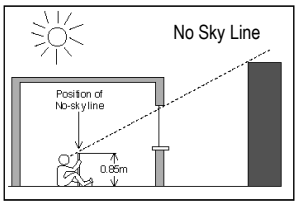
[source: MIT Chapel, by Eero Saarinen]

Daylighting buildings
Design strategies

[source: Jens Christoffersen, SBI, Denmark, 2009]

1. Site and orientation





The no-sky line is a divider between the part of the working plane from which a part of the sky can be seen directly and the part from which it can't. The scene appears brighter if the no-sky line penetrates larger part of the room. A room may be considered gloomy if more than 50% of the working plane area is beyond the no-sky line.

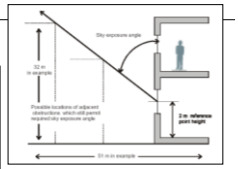
Daylighting buildings
Design strategies

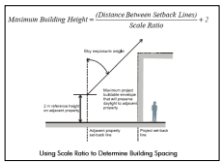
1. Site and orientation

Sky Exposure Angle and Scale Ratio for Major Canadian Cities

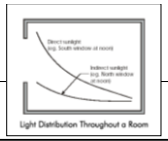
Latitude	Major Cities	Required Sky Exposure Angle	Scale Ratio
42 - 46°	Halifax, NS Toronto, ON Montreal, Q	59°	1.69
46 - 50°	Vancouver, BC Winnipeg, MN St. John's, NF Shawinigan, QC	62°	1.86

[source: Public Works and Government Services, 2002, Daylight Guide for Canadian Commercial Buildings, http://www.enermodal.com/Canadian/pdf/DaylightingGuideforCanadianBuildingsFinal6.pdf]





Daylighting buildings
Design strategies



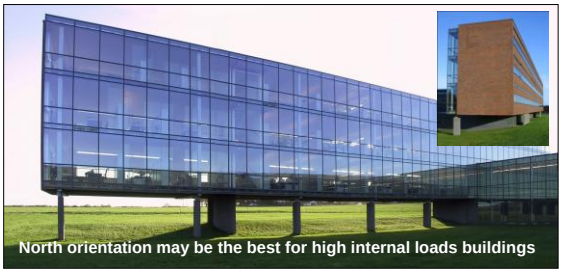
1. Site and orientation

Orientation	Potential for daylighting	Attributes [source: Public Works and Government Services, 2002, Daylight Guide for Canadian Commercial Buildings]
SOUTH	optimal	Solar control = easy Favourable daylighting
NORTH	excellent	No solar control necessary Most constant daylight
EAST WEST	avoid	Solar control = difficult Great variation in daylight

Daylighting buildings
Design strategies

[source: Bang og Olufsen, Denmark, photo by Steen Traberg-Borup]

1. Site and orientation

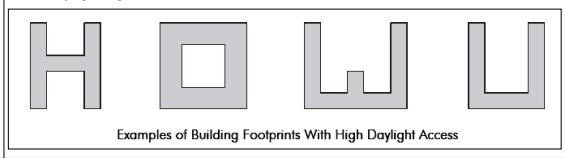


North orientation may be the best for high internal loads buildings

Daylighting buildings
Design strategies

2. Plan depth

Common building plans before XXth century, allowing natural ventilation and daylighting



[source: Public Works and Government Services, 2002, Daylight Guide for Canadian Commercial Buildings]

Daylight in buildings
Design strategies

[source: Public Works and Government Services, 2002, Daylight Guide for Canadian Commercial Buildings]

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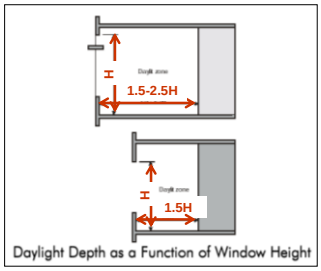
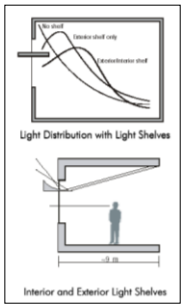
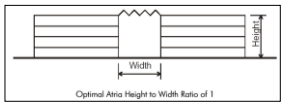


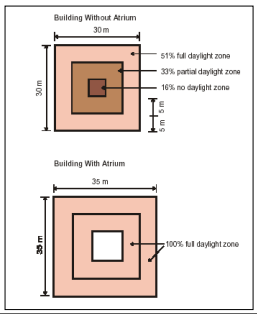


Daylight in buildings
Design strategies

[source: Public Works and Government Services, 2002, Daylight Guide for Canadian Commercial Buildings]

2. Plan depth





Daylighting buildings
Design strategies

2. Plan depth

ARUP - Sollihul

- Self reported increase in productivity of 17%
- Reduction of energy use by 33%
- Extra cost of £3 million

[source: Beaven, Warburton, Whitley (2004). Design for the workplace – fact or fiction – sustainability and profit. Closing the loop, Windsor Conference on Post-Occupancy Evaluation, Windsor, UK]

Daylighting buildings
Design strategies

2. Plan depth

[photo: *Claude Demers, GRAP, Université Laval, Québec Canada*]

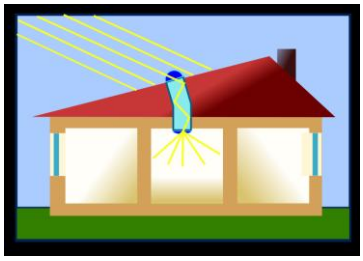
Daylighting buildings
Design strategies

2. Plan depth skylights

[photo: Jens Christoffersen, SBI, Denmark, 2009]

Daylighting buildings
Design strategies

2. Plan depth – solar tubes



[photo: Solar tubes, retrieved from Wikipedia, 2010, on daylighting]

Daylight in buildings
Design strategies

[source: CDP in Montreal]

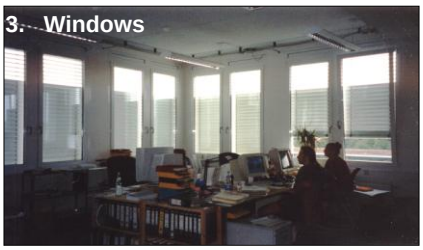
3. Windows

It is too simplistic to try to increase energy savings by increasing the size of windows. Daylight over-illumination may cause glare for occupants, causing them to deploy blinds or other window shading devices, and compromising the daylight harvesting system. Even partially-deployed venetian blinds can cut energy savings in half. [11]

[Galasiu, A.D.; Atif, M.R.; MacDonald, R.A. (2004). "Impact of window blinds on daylight-linked dimming and automatic on/off lighting controls". Solar Energy, 76(5). pp. 523–544. http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/nrcc46780/nrcc46780.pdf. Retrieved 03 September 2009.]

Daylight in buildings
Design strategies

3. Windows

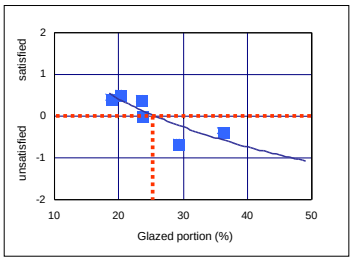


Daylight over-illumination may cause glare for occupants, causing them to deploy blinds or other window shading devices, and compromising the daylight harvesting system.

Daylight in buildings
Design strategies

3. Windows

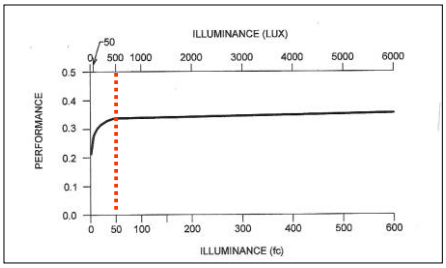
Relationship between the degree of satisfaction with indoor climate and glazed portion in offices



[source: Christoffersen et al, 1999, Vinduer og dagslys – en feltunder-sogelse i kontor bygninger]

Daylight in buildings
Design strategies

3. Windows

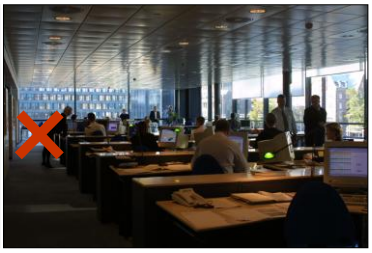


[source: Lechner, 2001, Heating, Cooling, Lighting]

Daylight in buildings
Design strategies

3. Windows

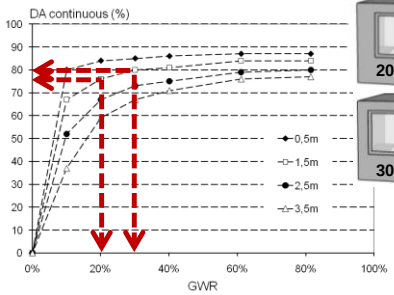
[source: Hewlett & Packard offices, Stockholm, arkitektur]

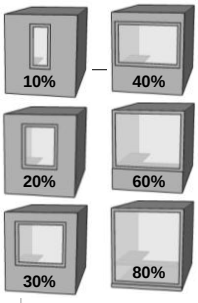


[source: Ny Credit, Copenhagen, photo Steen Traberg Borup]

Daylight in buildings
Design strategies

3. Windows – Stklm, South





[source: Dubois M-C (2010). Kontors projekt.]

Daylight in buildings
Design strategies

[source: Christoffersen, 2006, Light, health and well-being]

3. Windows

Comparable results of minimum and preferred window size as a percentage of window wall area:

- IES: 20-40 %
- CIBSE: 20-35 %
- Ne'eman et al: 25-32 %
- Ludlow: 50-80 % (scale models)
- Keighly: 60-75 % (scale models)
- Boyce (1981): 25-30 % (view), 55 - 60 % (daylight)
- **SBI (1999): 25-30 % (glazed area)**

Daylight in buildings
Design strategies

[source: Christoffersen et al, 1999, Vinduer og dagslys – en feltundersøgelse i kontor bygninger; Public Works and Government Services, 2002, Daylight Guide for Canadian Commercial Buildings]

3. Windows

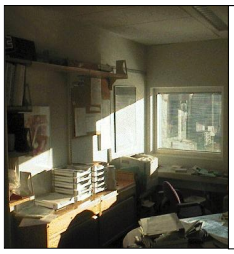
Glazed portion with respect to total building envelope in offices

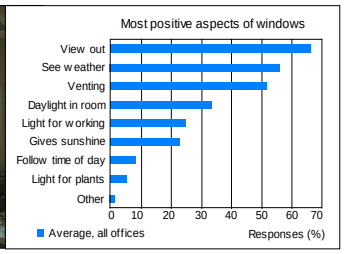
Never	< 20%
> 40%	= risk for overheating + glare
Optimal	**= 30%**

Daylight in buildings
Design strategies

[source: Christoffersen et al, 1999, Vinduer og dagslys – en feltunder-søgelse i kontor bygninger]

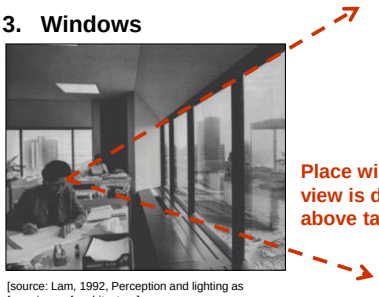
3. Windows





Daylight in buildings
Design strategies

3. Windows

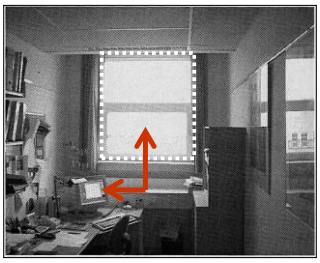


Place window where the view is desirable and above task area

[source: Lam, 1992, Perception and lighting as formgivers of architecture]

Daylight in buildings
Design strategies

3. Windows



Window is too high from sitting position!

[source: Christoffersen et al, 1999, Vinduer og dagslys – en feltundersøgelse i kontor bygninger]

Daylight in buildings
Design strategies

3. Windows

Place window where the view is desirable

[source: CTBO, Laval University, Quebec City]

Daylight in buildings
Design strategies

3. Windows

Place window where the view is desirable

[source: E. Pihl & Søn AS, Lyngby, Denmark, KHR architects]

Daylight in buildings
Design strategies

3. Windows

Place window where the view is desirable

Daylight in buildings
Design strategies

3. Windows

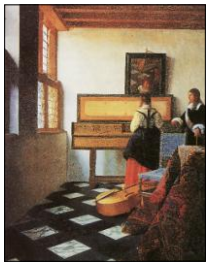
If the view is not important, place windows high up

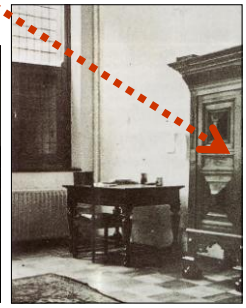
[source: CTBO, Laval University, Quebec City]

Daylight in buildings
Design strategies

[source: Dutch window and Music lesson by Vermeer, in Millet, 1996, Light revealing architecture]

3. Windows

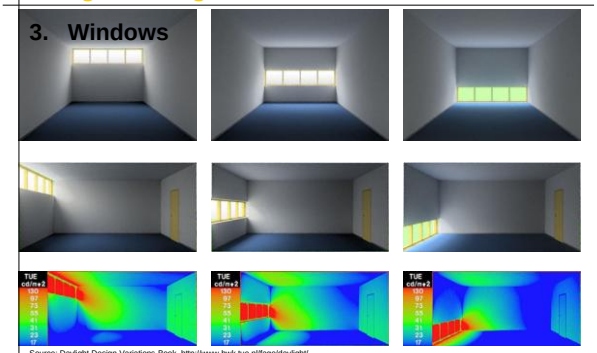




Daylight in buildings
Design strategies

If the view is not important, place windows high up

3. Windows



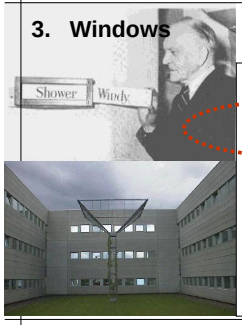
Source: Daylight Design Variations Book, http://www.bwk.tue.nl/fago/daylight/

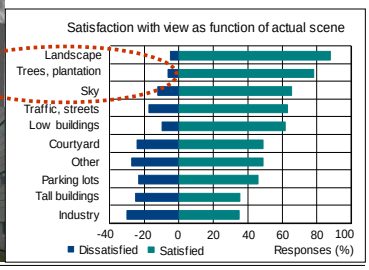
Daylight in buildings
Design strategies

[source: Christoffersen et al, 1999, Vinduer og dagslys – en feltundersøgelse i kontor bygninger]

3. Windows

A satisfying view should embrace both skyline and foreground

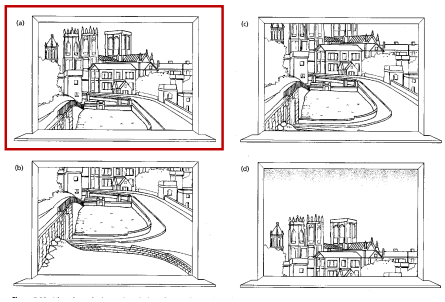




Daylight in buildings
Design strategies

A satisfying view should embrace both skyline and foreground

3.

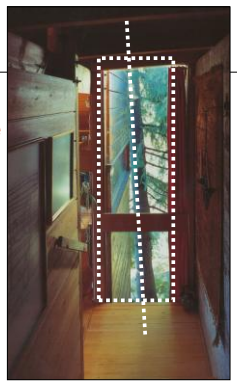


[Source: Jens Christoffersen]

Daylight in buildings
Design strategies

3. Windows

Shape windows according to the elements to be seen outside

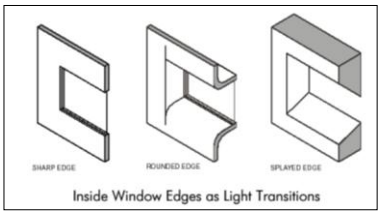


[source: Enebolig Lund, Oslo, Norway, architects Lund og Slaatto]

Daylight in buildings
Design strategies

[source: Public Works and Government Services, 2002, Daylight Guide for Canadian Commercial Buildings]

3. Windows **Use window reveals to allow soft light transitions**

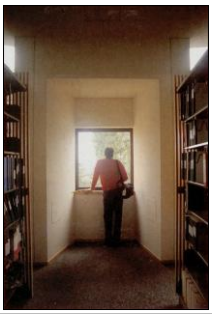


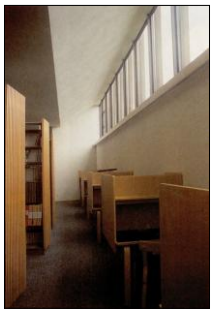
Daylight in buildings
Design strategies

[source: Mt. Angel Abbey Library by Alvar Aalto in Millet, 1996, Light revealing architecture]

3. Windows

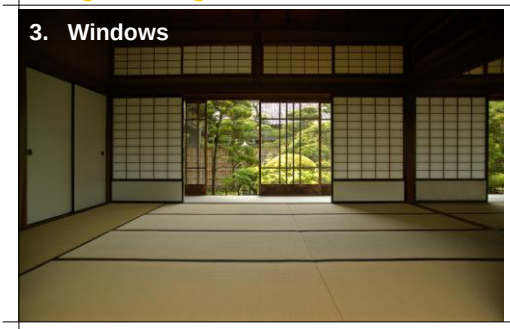
Soft light transitions





Daylight in buildings
Design strategies

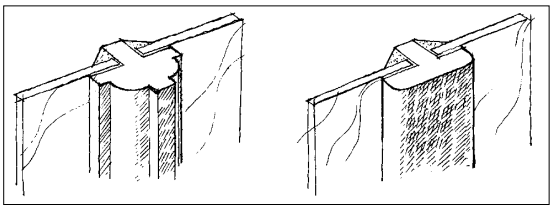
3. Windows



[source: Wikipedia.org, 2010]

Daylight in buildings
Design strategies

3. Windows **Use frame details that allow soft light transitions**



[source: Helena Bülow-Hübe]

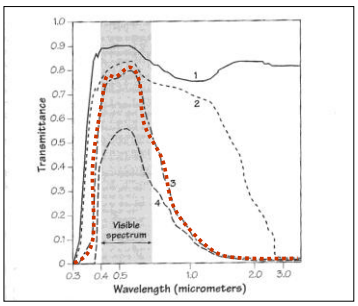
Daylight in buildings
Design strategies

[source: Carmody et al, 1996, Residential windows: a guide to new technologies and energy performance]

3. Windows

Choose appropriate glazing

Spectrally selective glazing reject heat, not light



Daylight in buildings
Design strategies

[source: Carmody et al, 1996, Residential windows: a guide to new technologies and energy performance]

3. Windows

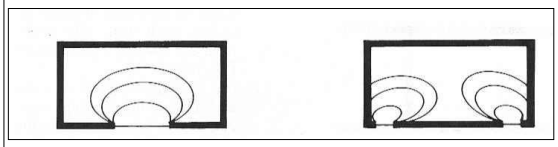
Choose appropriate glazing

	Glazing type	Tvis	SHGC	LSG
	Double glazing			
	Clear	0.82	0.75	1.20
Bad choice!	Bronze	0.62	0.60	1.03
	Reflective	0.20	0.16	1.25
Good choice!	**Spectrally selective**	**0.70**	**0.46**	**1.52**

Daylight in buildings
Design strategies

4. Light distribution/reflection

Admit light by more than one opening (better daylight distribution in space)



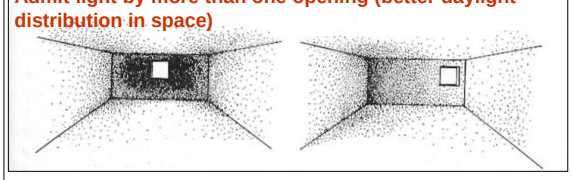
[source: Lechner, 2001,
Heating, Cooling, Lighting]

Daylight in buildings
Design strategies

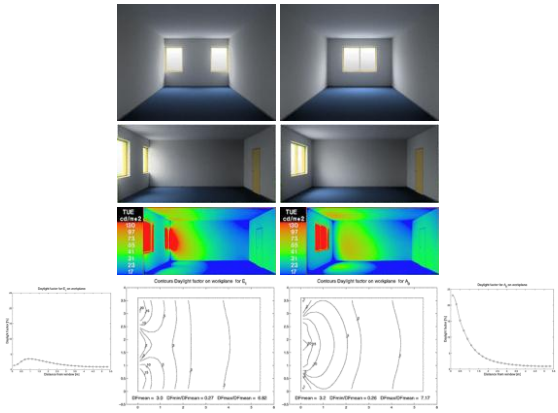
[source: Lechner, 2001,
Heating, Cooling, Lighting]

4. Light distribution/reflection

Admit light by more than one opening (better daylight distribution in space)



+ More daylight deep in space
+ Less contrast between sky and surrounding surfaces



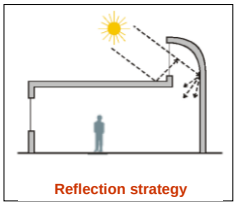
Source: Daylight Design Variations Book, http://www.bwk.tue.nl/fago/daylight/

Daylight in buildings
Design strategies

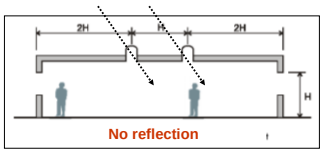
[source: Public Works and Government Services, 2002, Daylight Guide for Canadian Commercial Buildings]

4. Light distribution/reflection

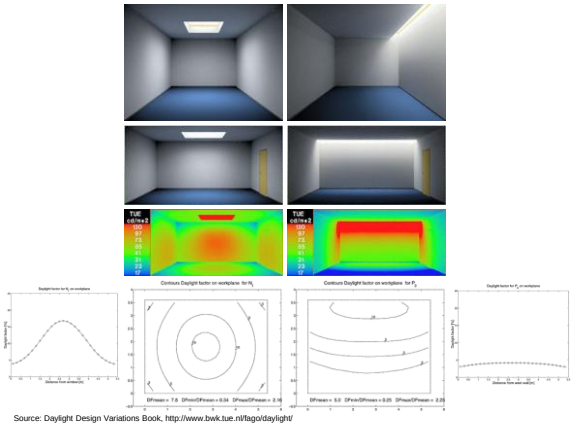
Reflect light with well located, light-coloured interior surfaces



Reflection strategy



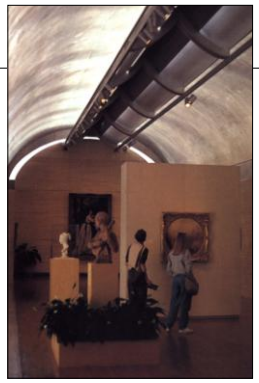
No reflection



Source: Daylight Design Variations Book, http://www.bwk.tue.nl/fago/daylight/

Daylight in buildings
Design strategies

4. Light distribution/ reflection

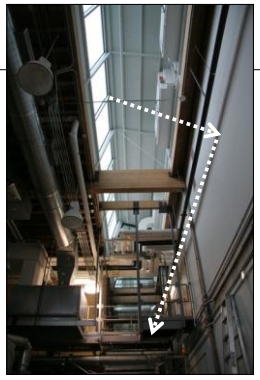


[source: Kimbell Art Museum, Louis Kahn]

Daylight in buildings
Design strategies

4. Light distribution/ reflection

Reflect light with well located, light-coloured interior surfaces

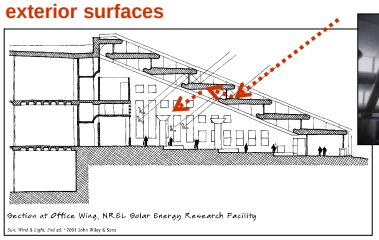


[source: CTBO, Claude Demers, consultant, Laval University, Quebec City]

Daylight in buildings
Design strategies

4. Light distribution/reflection

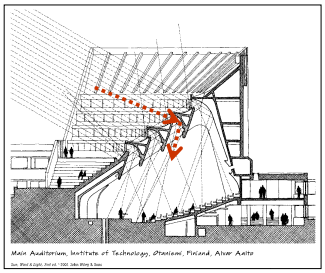
Reflect light with well located, light-coloured interior and exterior surfaces



[source: Section at Office Wing, NREL Solar Energy Research Facility, in Brown Dekay, 2001, Sun Wind Light]

Daylight in buildings
Design strategies

4. Light distribution/reflection



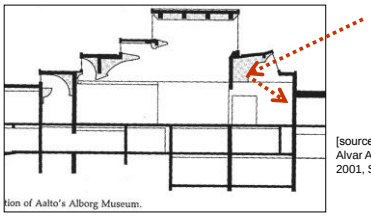
Reflect light with well located, light-coloured interior and exterior surfaces

[source: Main auditorium, Inst. of Technology, Finland, Alvar Aalto, in Brown Dekay, 2001, Sun Wind Light]

Daylight in buildings
Design strategies

4. Light distribution/reflection

Reflect light with well located, light-coloured interior and exterior surfaces



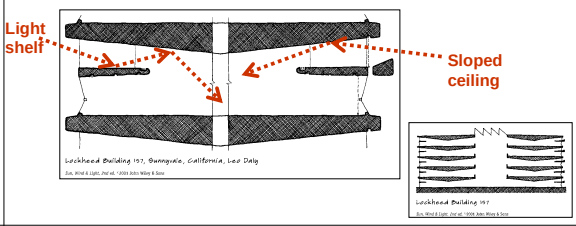
[source: Aalborg's Museum, Alvar Aalto, in Brown Dekay, 2001, Sun Wind Light]

Daylight in buildings
Design strategies

[source: Lockhead building, Sunnyvale, California, Leo Daly in Brown Dekay, 2001, Sun, Wind, Light]

4. Light distribution/reflection

Reflect light with well located, light-coloured interior and exterior surfaces



Daylight in buildings
Design strategies

4. Light distribution/ reflection

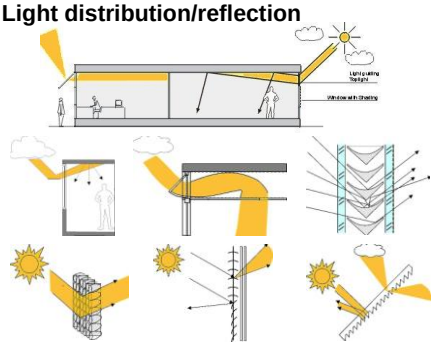
Study reflection strategy in plan and in section

[source: CTBO, Claude Demers, consultant, Laval University, Quebec City]

Daylight in buildings
Design strategies

[source: Jens Christoffersen, 2010]

4. Light distribution/reflection



Daylight in buildings
Design strategies

4. Light distribution/reflection

[source: CTBO, Claude Demers, consultant, Laval University, Quebec City]

Daylight in buildings
Design strategies

4. Light distribution/reflection

[source: Mt. Angel Abbey Library by Alvar Aalto, in Millet, 1996, Light revealing architecture]

Daylight in buildings
Design strategies

[source: Jens Christoffersen, 2010]

4. Light distribution/reflection

Choose interior finishes with light colour

Daylight in buildings
Design strategies

[source: Public Works and Government Services, 2002, Daylight Guide for Canadian Commercial Buildings, Brown & Dekay, 2001, Sun Wind Light]

4. Light distribution/reflection

Choose interior finishes with light colour

Surface Reflectance

Surface	Reflectance (%)
ceiling	80
wall	50-70
floor	20-40
furniture	25-45

Color	Reflectance (%)
white	80-90
pale yellow & rose	80
pale beige & lilac	70
pale blue & green	70-75
mustard yellow	35
medium brown	25
medium blue & green	20-30
black	10

Daylight Reflectance of Colors

Sun, Wind & Light, 2nd ed. ©2001 John Wiley & Sons

Daylight in buildings
Design strategies

[source: Public Works and Government Services, 2002, Daylight Guide for Canadian Commercial Buildings, Brown & Dekay, 2001, Sun Wind Light]

4. Light distribution/reflection

Choose interior finishes with light colour

Daylight Factor, standard office room:
White walls/ceiling = 5.2% = 520 lux for 10 000 lux
Black walls/ceiling = 2.2% = 220 lux for 10 000 lux

$$Average\ Daylight\ Factor = \frac{V_T \cdot A_{Glazing} \cdot \theta}{A_s \cdot (1 - R^2)}$$

Daylight in buildings
Design strategies

[source: Public Works and Government Services, 2002, Daylight Guide for Canadian Commercial Buildings]

5. Controls

Artificial lighting system should be planned according to daylighting

Economy of 15-30%

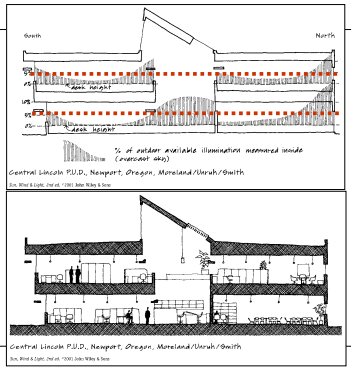
Types of controls

1. On-off (occupation: infra-red, ultra-sounds, programmed)
2. Staged (100%, 50%, etc)
3. Dimming (automatic or manual)

Daylight in buildings
Design strategies

5. Controls

Any space with a DF of 5% during some hours of the day should have artificial lighting controls



[source: Brown & Dekay, Sun Wind Light, 2001]

Daylight in buildings
Design strategies

[source: Lechner, 2001, Heating, Cooling, Lighting]

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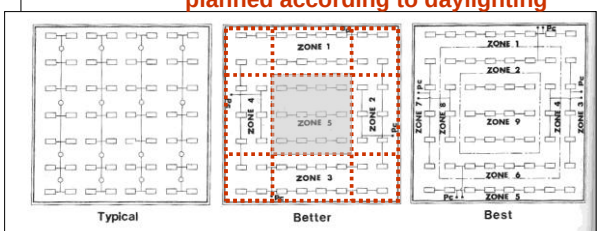
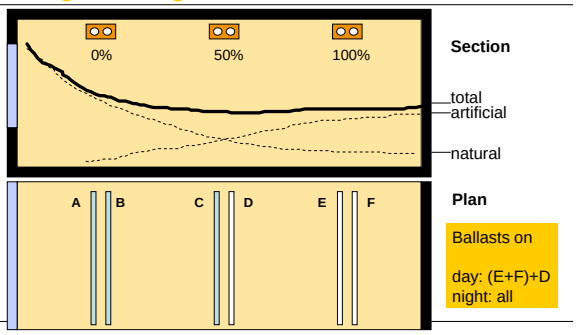


Figure 13.18b Lighting zones should consist of fixtures in rows parallel to the windows on each orientation. "Pc" stands for photocell light sensor. (From *Daylighting: Performance and Design*, by Gregg D. Ander. © Gregg D. Ander, AIA., Southern California Edison.)

Daylight in buildings
Design strategies

[source: Drawing by Claude Demers, GRAP]



Daylight in buildings
Design strategies

6. Other things to know

Use daylight for orientation (where do I go?)

[source: Museum of Anthropology, Vancouver, Arthur Erickson]

Daylight in buildings
Design strategies

[source: Mt. Angel Abbey Library, by Alvar Aalto in Millet, 1996, Light revealing architecture]

6. Other things to know

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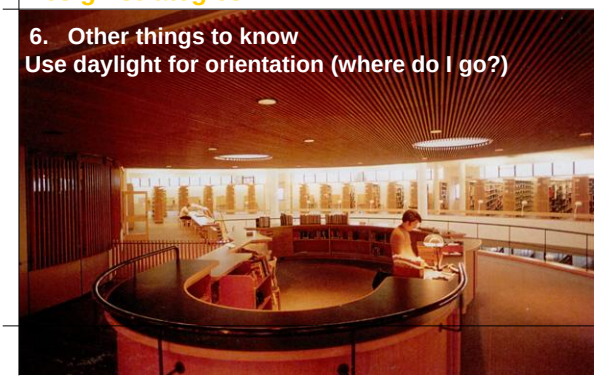


Daylight in buildings
Design strategies

6. Other things to know

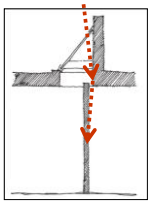
Use daylight for orientation (where do I go?)

[source: CTBO, Claude Demers, Laval University, Quebec City]

Daylight in buildings
Design strategies

6. Other things to know

Use daylight to highlight the building structure



[source: Männistö church, Finland, architect Juha Leiviskä]

Daylight in buildings
Design strategies

6. Other things to know

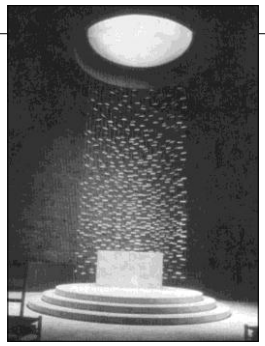
Use daylight to highlight the building structure

[source: Vuoksenniska church, Imatra, Finland, Alvar Aalto, from Millet, 1996, Light Revealing Architecture]

Daylight in buildings
Design strategies

6. Other things to know

Use daylight to bring attention to important activity

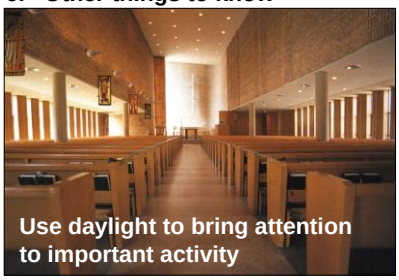


[source: MIT Chapel, Eero Saarinen]

Daylight in buildings
Design strategies

[source: Christ Church Lutheran, Minneapolis, architecte Eliel Saarinen, from Millet, 1996, Light Revealing Architecture]

6. Other things to know



Daylight in buildings
Design strategies

[source: Christ Church Lutheran, Minneapolis, architecte Eliel Saarinen, from Millet, 1996, Light Revealing Architecture]

6. Other things to know

Daylight in buildings
Design strategies

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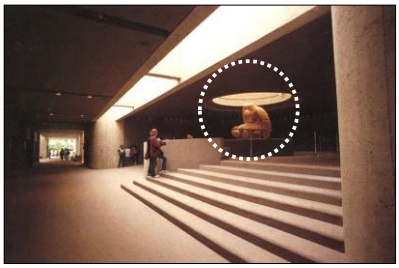


Use daylight to bring attention to beauty (relaxation, interest)

Daylight in buildings
Design strategies

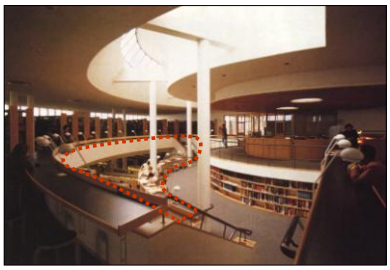
6. Other things to know

Use daylight to bring attention to beauty (relaxation, interest)

[source: Bonaventure Hotel, Montreal, architects Affleck Desbarats Dimakopoulos & Sise, in Lam,1992, Perception and lighting as formgivers of architecture.]

Daylight in buildings
Design strategies

6. Other things to know



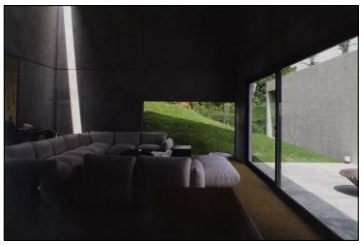
Use daylight to circumscribe personal territory

[source: Mt. Angel Abbey Library, Oregon, Alvar Aalto, from Millet, 1996, Light Revealing Architecture]

Daylight in buildings
Design strategies

6. Other things to know

A little sunlight spot is needed (psychologically)



[source: Koshino house, Tadao Ando]

Daylight in buildings
Design strategies

6. Other things to know

A little sunlight spot is needed (psychologically)

Be careful:
- of the amount
- in work environment

[source: Fontoynont, 1999, Daylight performance of buildings]

How to daylight buildings

'It's all about finding the right balance'

©*Lars Hansen & Politiken, 2003*

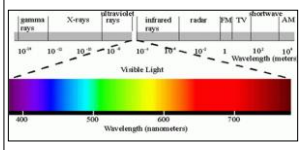
‘and not leave us in search of the good light...’

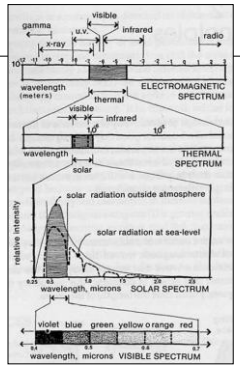
Daylighting buildings

Daylighting buildings
Daylight metrics

Light

Part of the electromagnetic spectrum for which our eye is sensitive.

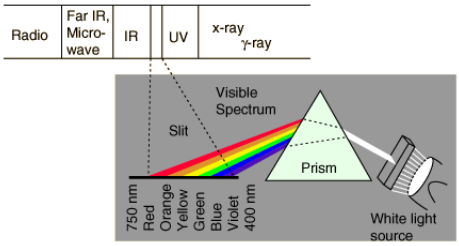




[source : Moore F, 1985]

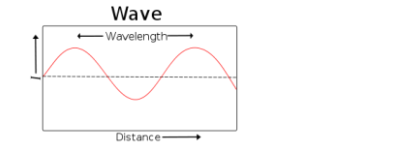
Daylighting buildings
Daylight metrics

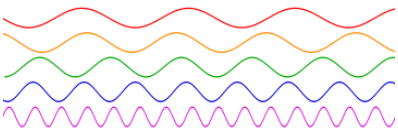
The color of light depends on the wavelength



[source : Hyperphysics]

Daylighting buildings
Daylight metrics



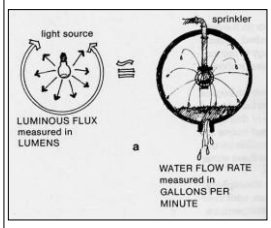


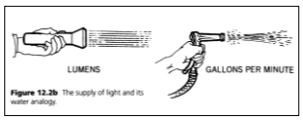
[source : Hyperphysics]

Daylighting buildings
Daylight metrics

Luminous flux

Rate of emission of luminous energy in time (lumen, lm).



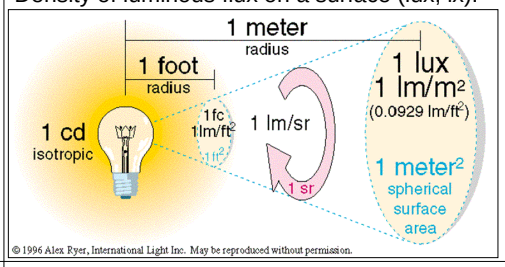


[source : Moore F, 1985, Fig. 2.3a, p. 18]

Daylighting buildings
Daylight metrics

Illuminance

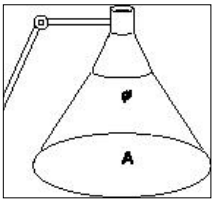
Density of luminous flux on a surface (lux, lx).



Daylighting buildings
Daylight metrics

Illuminance

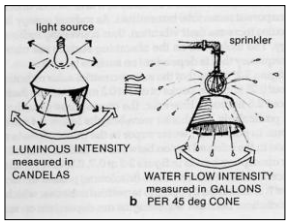
Density of luminous flux on a surface (lux, lx).

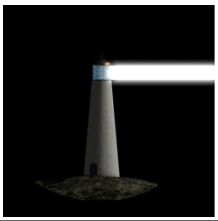


Daylighting buildings
Daylight metrics

Luminous intensity

Quantity of luminous flux **emitted in a given direction** (candela, cd). 1 cd = 1 lm/sr.



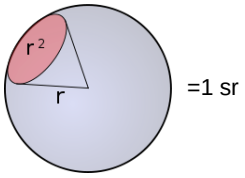


[source : Moore F, 1985]

Daylighting buildings
Daylight metrics

Steradian (sr)

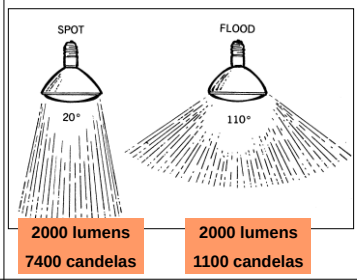
Solid angle subtended at the center of a sphere of radius *r* by a portion of the surface of the sphere whose area, A, equals r^2.



[source : Wikipedia]

Daylighting buildings
Daylight metrics

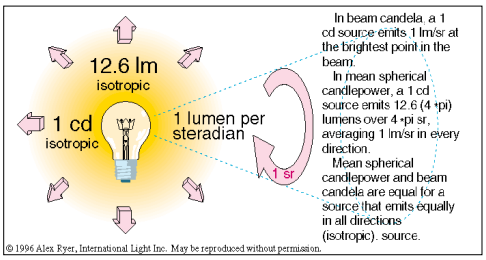
Luminous intensity



[source : Moore F, 1985]

Daylighting buildings
Daylight metrics

Luminous intensity

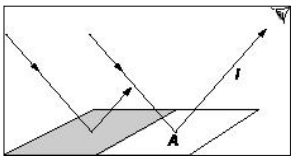


[source : Moore F, 1985, Fig. 2.2, p. 18]

Daylighting buildings
Daylight metrics

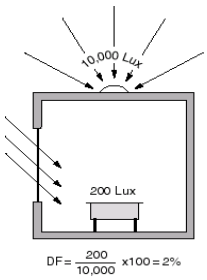
Luminance

Density of luminous intensity (cd/m^2).



[source : Moore F, 1985, Fig. 2.2, p. 18]

Daylighting buildings
Daylight metrics



- **Daylight factor (DF)**
  Ratio of inside illuminance to exterior illuminance, expressed in per cent.
- The higher the DF the more natural light is available in the room.
- The DF is often expressed for a fixed point on a desk.

[source : Jens Christoffersen, 2010]

Daylighting buildings
Daylight metrics

New daylight metrics:

1. Daylight autonomy, DA (%)
2. Daylight autonomy continuous, DAcon (%)
3. Daylight autonomy max, DAmax (%)
4. Useful Daylight Illuminance, UDI (%)

   -UDI < 100 lx

   -UDI 100-2000 lx

   -UDI > 2000 lx

Daylighting buildings
Daylight metrics

Daylight autonomy, DA (%)

Percentage of the occupied times of the year when the minimum illuminance requirement (e.g. 500 lx) at the sensor is met by daylight alone.

[Source: Reinhart CF, Walkenhost O. Dynamic RADIANCE-based Daylight simulations for a full-scale test office with outer venetian blinds. Energy and Buildings 2001; 33(7): 683-697]

Daylighting buildings
Daylight metrics

Daylight autonomy continuous, DAcon (%)

Partial credit is attributed to time steps when the daylight illuminance lies below the minimum illuminance level.

For example, in the case where 500 lx are required and 400 lx are provided by daylight at a given time step, a partial credit of 400lx/500lx=0.8 is given for that time step.

Daylighting buildings
Daylight metrics

Daylight autonomy maximum, DAmax (%)

DA_{max} compiles the percentage of times during a year when the illuminance at a sensor is at least ten times the recommended illuminance.

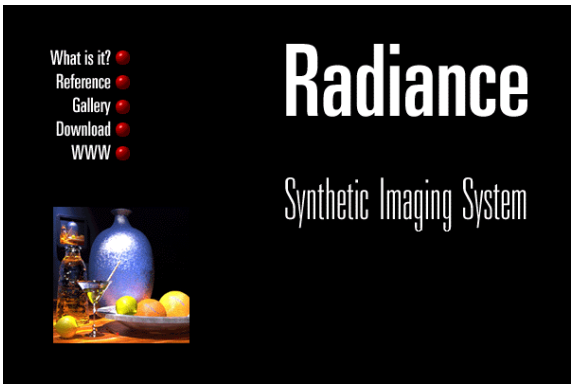
In such a situation, there is a high chance that this will correspond to a situation with direct sunlight patch at the sensor and hence glare.

Daylighting buildings
Daylight metrics

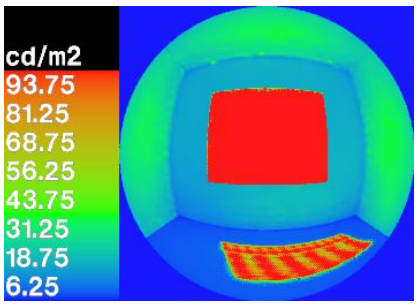
Useful Daylight Illuminance, UDI (%)

Annual occurrence of illuminances across the work plane that are within a range considered ‘useful’ by occupants:

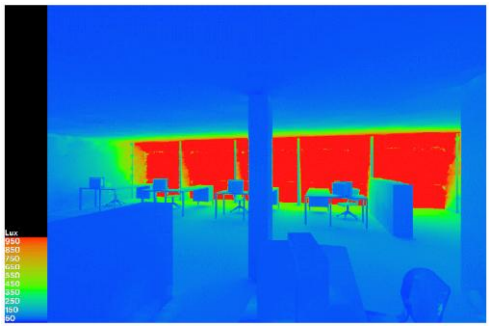
- UDI within the useful range (i.e. 100 lx to 2000 lx).
- UDI fall short of the useful range (i.e. less than 100 lx).
- UDI exceed the useful range (i.e. greater than 2000 lx).



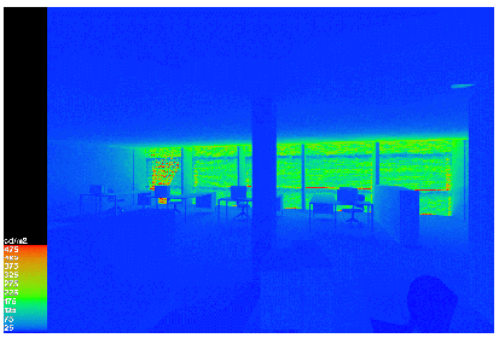
21 June, 12:00, Soltis screen



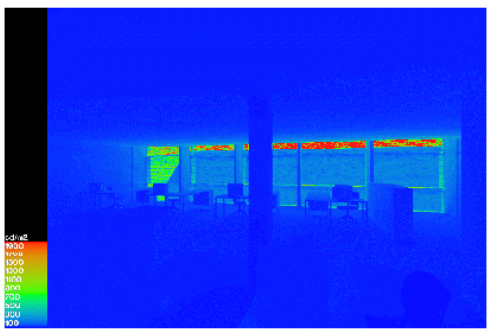
Buttericks: reflective venetian blinds 8º

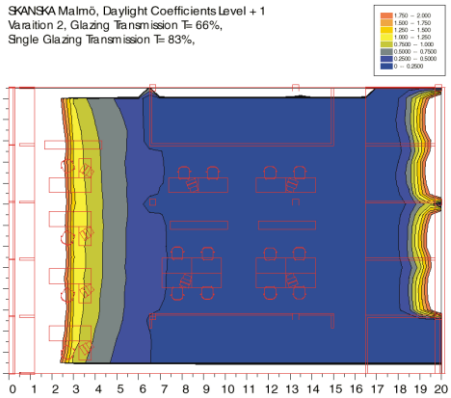


Buttericks: reflective venetian blinds 20º

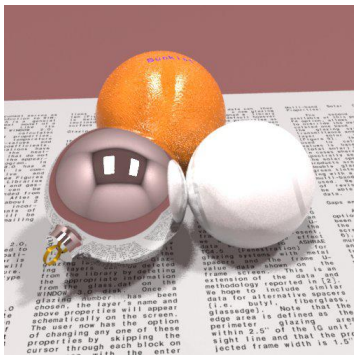


Buttericks: reflective venetian blinds 8º




SKANSKA Malmö, Daylight Coefficients Level + 1
Varaition 2, Glazing Transmission T= 66%,
Single Glazing Transmission T= 83%,
1.750 – 2.000
1.500 – 1.750
1.250 – 1.500
1.000 – 1.250
0.7500 – 1.000
0.5000 – 0.7500
0.2500 – 0.5000
0 – 0.2500
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

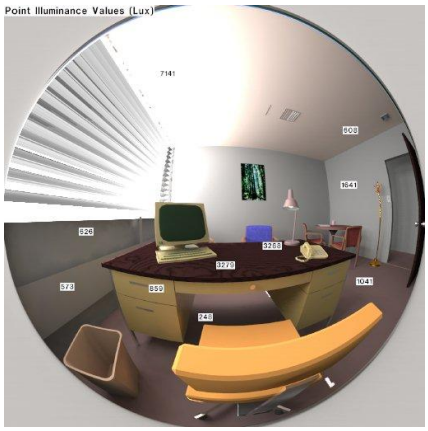
Radiance

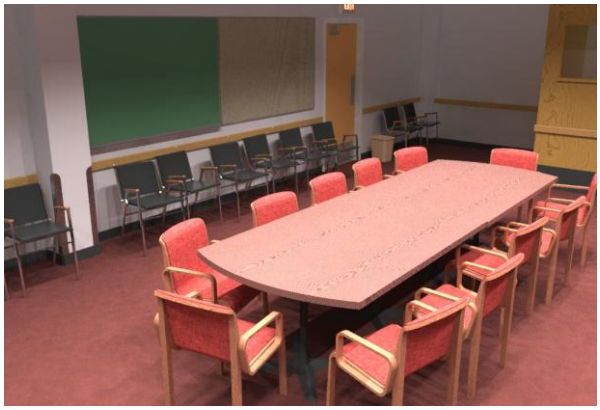



Sky
Sun
Monitor
Combined

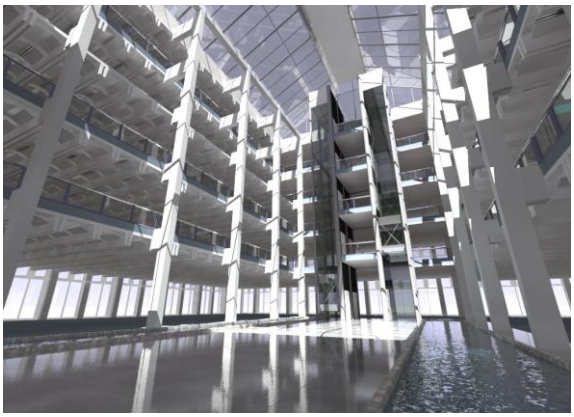

Combined

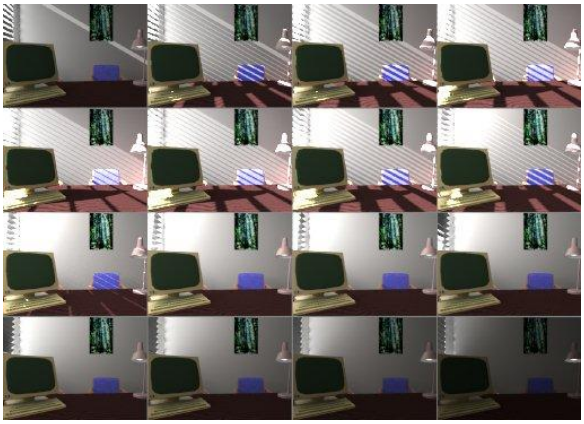

Monitor


Point Illuminance Values (Lux)
7141
908
1841
826
3268
3277
570
869
1041
248




Lux
140.625
121.875
103.125
84.375
65.625
46.875
28.125
9.375





Daylighting buildings
DAYSIM

- DAYSIM is a RADIANCE-based daylighting analysis tool
- Developed at the National Research Council of Canada and the Fraunhofer Institute for Solar Energy Systems in Germany.
- DAYSIM uses the daylight coefficient method to efficiently calculate illuminance distributions under all sky conditions in a year and the Perez sky model