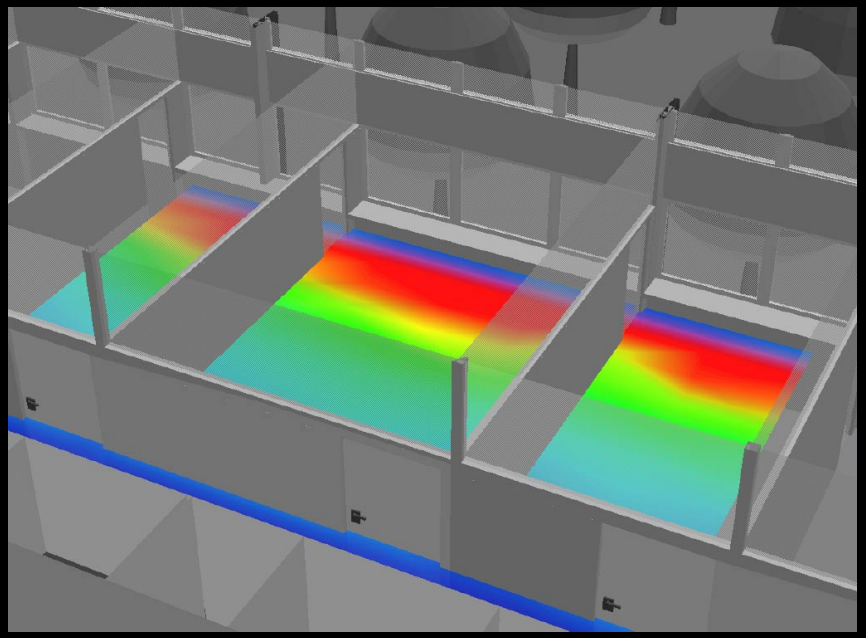
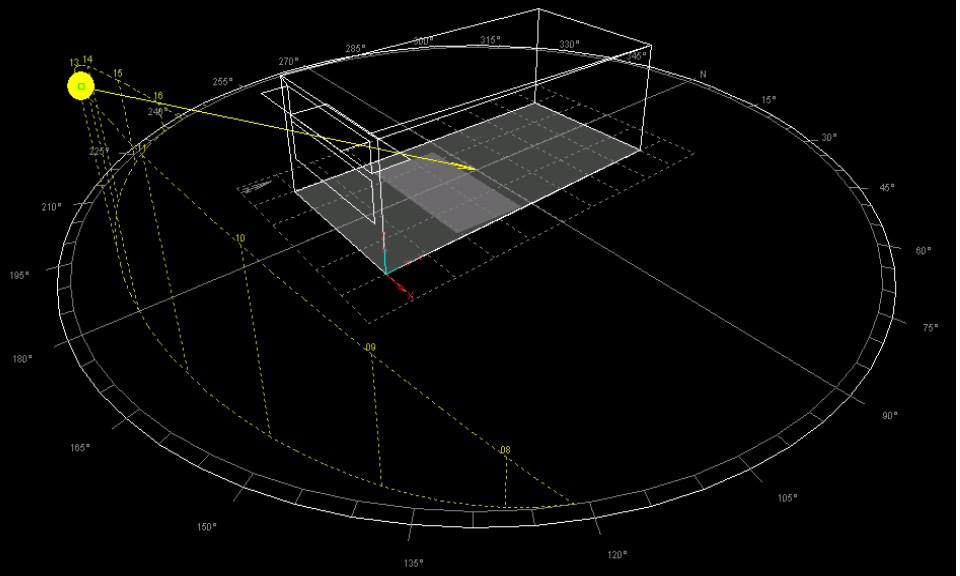
ARCH 447 Electrical Services - Lighting

Oct 5: Lighting Simulation I - Ecotect



Daylight Factor



Avoidance of Direct Sunlight

Christoph Reinhart, Ph.D.

Course Outline

1	Sep 7	Vision and Color, History
2	Sep 14	Daylighting
3	Sep 21	Electric Lighting
4	Sep 28	Fixture Design
5	Oct 5	**Lighting Simulation I - Ecotect**
6	Oct 12	Field Trip – Tour of Montreal Architectural Lighting Installations
7	Oct 19	Lighting Simulation II – Radiance
Event	Oct 24	James Carpenter (lecture series)
8	Oct 26	Midterm Project Critique and Introduction of Final Project Parameters
9	Nov 2	Lighting Simulation III – Daysim
10	Nov 9	Integrating Lighting in the Design Process (guest lecture)
11	Nov 16	Field Trip – Custom Fixture Manufacturing Workshop Tour
12	Nov 23	Advanced Daylighting Techniques
13	Nov 30	Final Project Critique

Misc

- Any problems with the Getting Started document/email communication?
- Which group considers buying an Ecotect student license?
- Attendance sheet.
- Proposals are due next week. (Browse examples for last year.)
- Reminder: There will be no lecture next week.

Mailing Lists

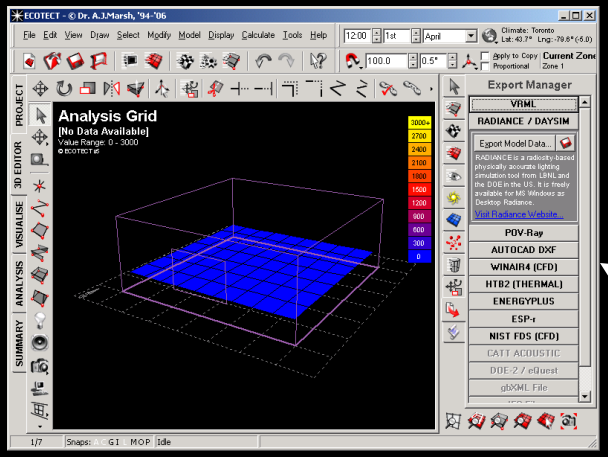
Mailing List : Radiance Online http://www.radiance-online.org/

Mailing List: Building Simulation http://www.gard.com/ml/bldg-sim.htm

(technical information and job postings)

Simulation Tools used in this Course

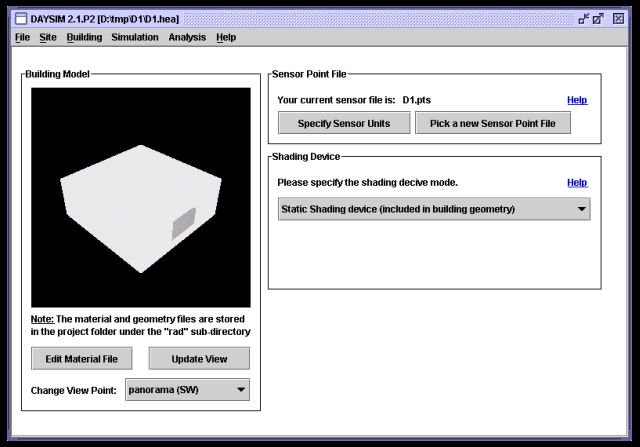
Ecotect



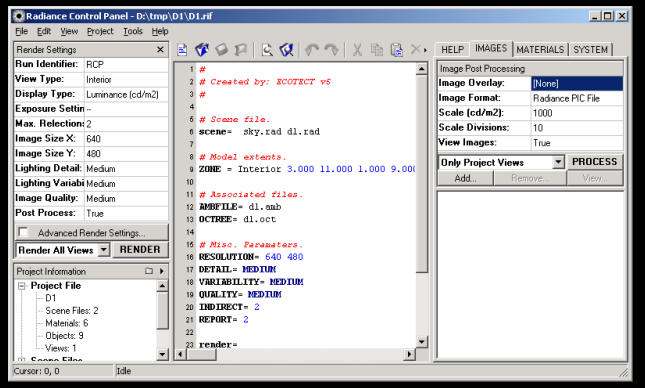
Dynamic Metrics

Physical based Renderings

Daysim

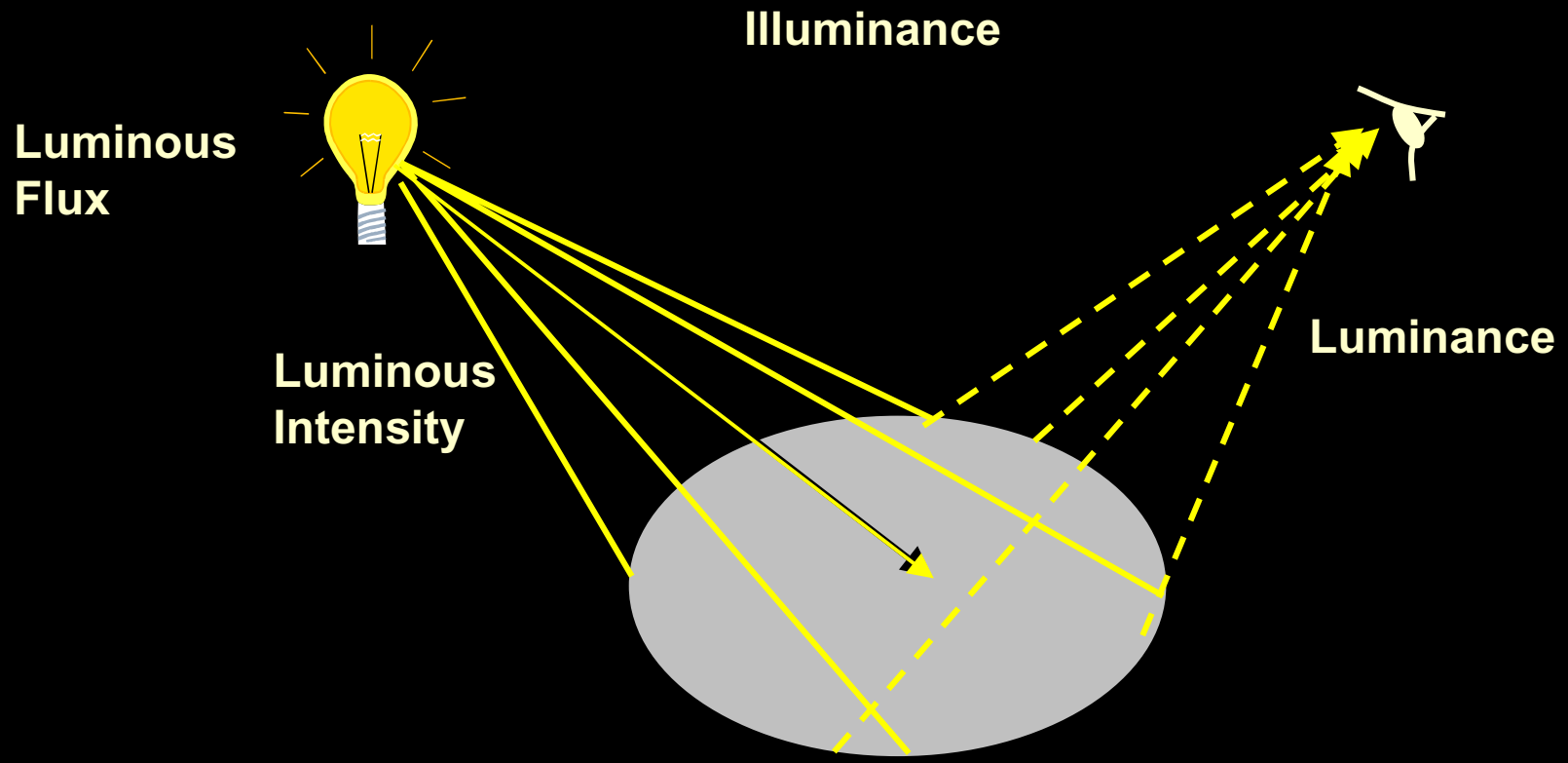


Radiance Control Panel



Review - Photometric Quantities

Characterize how a space is perceived.



Review - Some Illuminance Values

sunny summer day	70000 - 100000 lux
cloudy summer day	20000 lux
cloudy winter day	3000 lux
requirement for reading	100 lux
moonlight	1 lux
requirement for office work	300 - 800 lux

Recommended values can be found in IESNA Lighting Handbook.

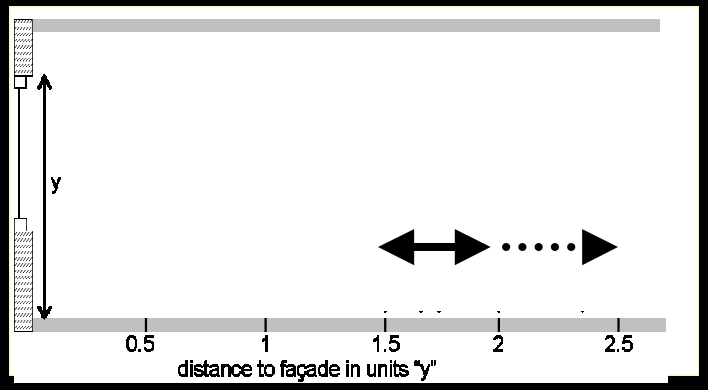
If you have Daysim installed you find recommended values on your PC under: file:///C:/DAYSIM/html/keywords/minimumilluminancelevel.html

Review – Rules of Thumb

(1) Daylight feasibility

$$\frac{}{WWR} \times \frac{}{V_T} \times \frac{}{OF} = \frac{}{\text{Feasibility Factor}} \qquad >0.25$$

(2) Window head height & Uniformity Room Depth



$$L = \frac{2}{1 - R_B} / \left(\frac{1}{W} + \frac{1}{H} \right)$$

(3) Glazing Area (based on Daylight Factor)

$$A_g = \frac{2 \cdot DF_a \cdot A_{TOT} (1 - R_a)}{V_T \cdot \theta}$$

$$A_w = A_g \cdot 1.25$$

Note: Rules of thumb only for sidelit spaces.

Objectives for Today's Lecture

- Introduce Selected Daylight Performance Metrics
- Daylight Factor Calculations in Ecotect
- Underlying Simulation Models
- Direct Shading Studies in Ecotect

Simulation Tips

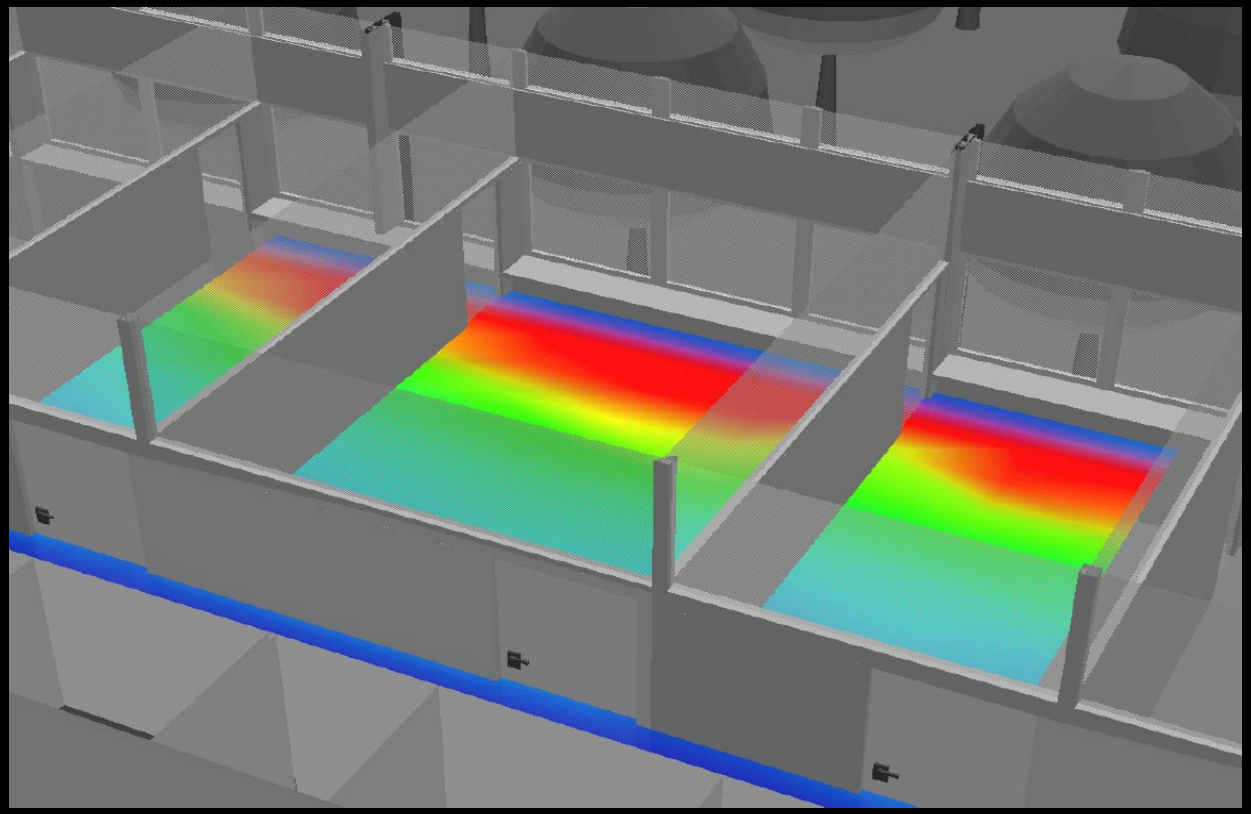
- Use daylight simulations to ‘create value’ for the design process.
- Have the end in mind before you start.
- Use a validated simulation tool.
- You have to understand the assumptions and limitations of the underlying simulation models and performance metrics.
- Build you model as simple as your intended use allows.
- If possible divide your model into pieces for a detailed analysis.

Daylight Performance Metrics

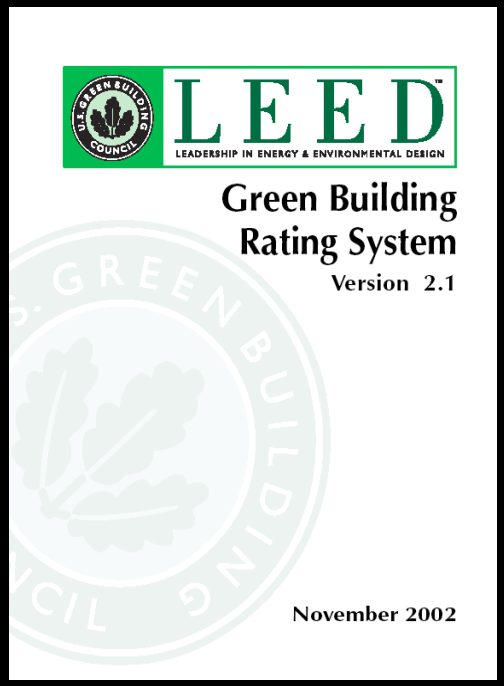
Daylight Factor Definition

$$DF = (E_{point}/E_{outside\ horizontal}) * 100\%$$

The DF is only defined under overcast skies!



Daylight Factor (now glazing factor) in LEED

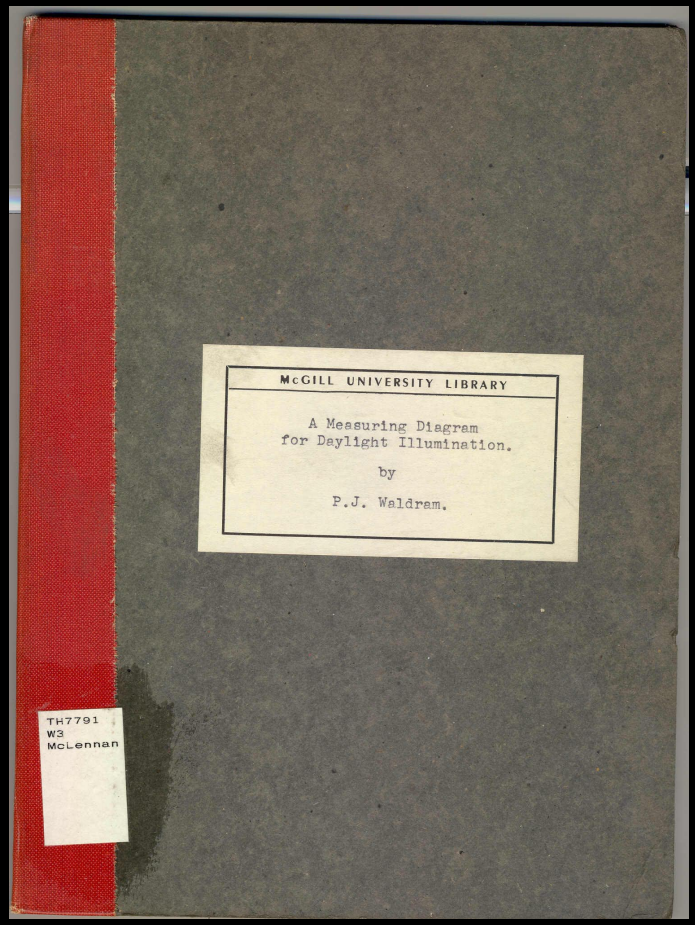


Credit 8.1 Daylight 75% of Spaces 1 Credit

- Archive a minimum Daylight factor of 2% in 75% of all space occupied for critical visual tasks. Spaces excluded from this requirement include copy rooms, storage areas, mechanical plant rooms, laundry and other low occupancy support areas.

Historical Background: “Right of Light”

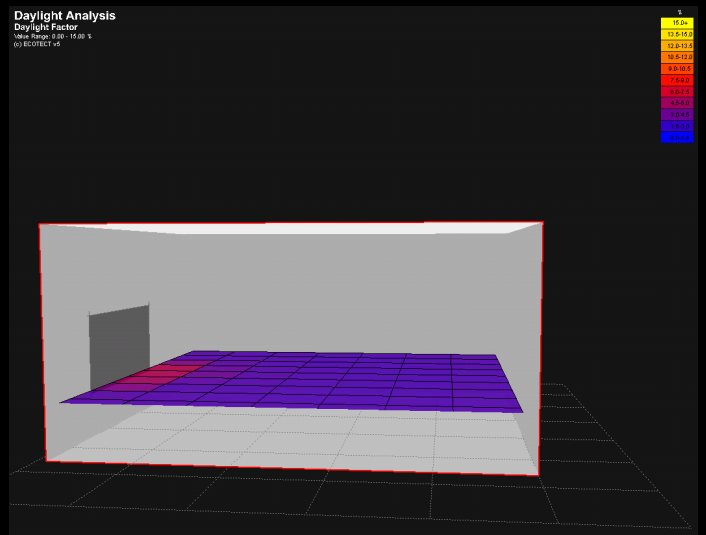
“Before WWII, legal rights of light constituted practically the only profitable field for daylight experts.”



Waldram 1945

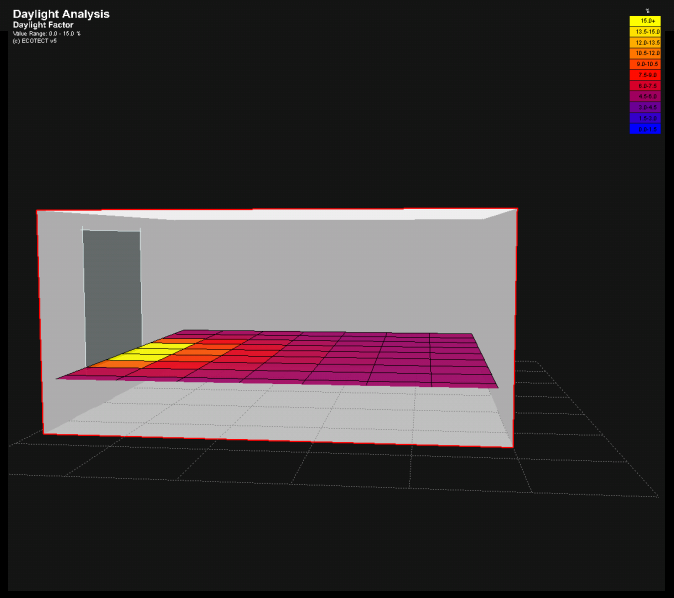
Daylight Factor – design implications I

reference

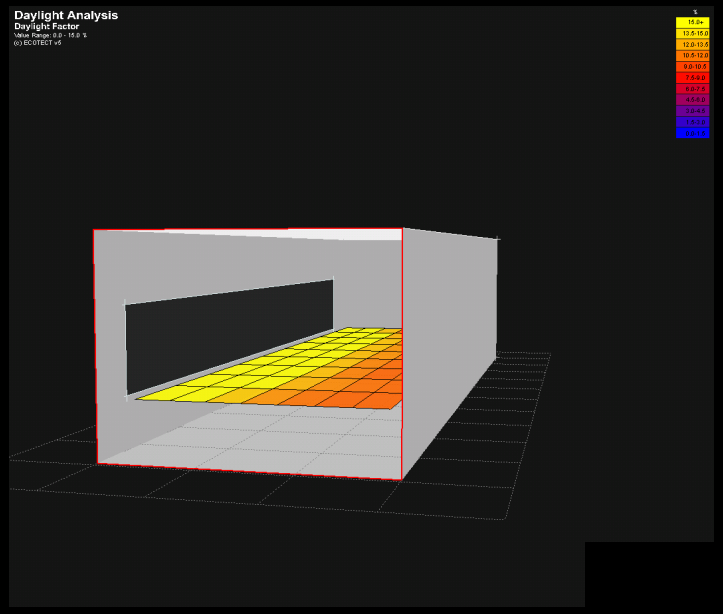


window head height

glazing type

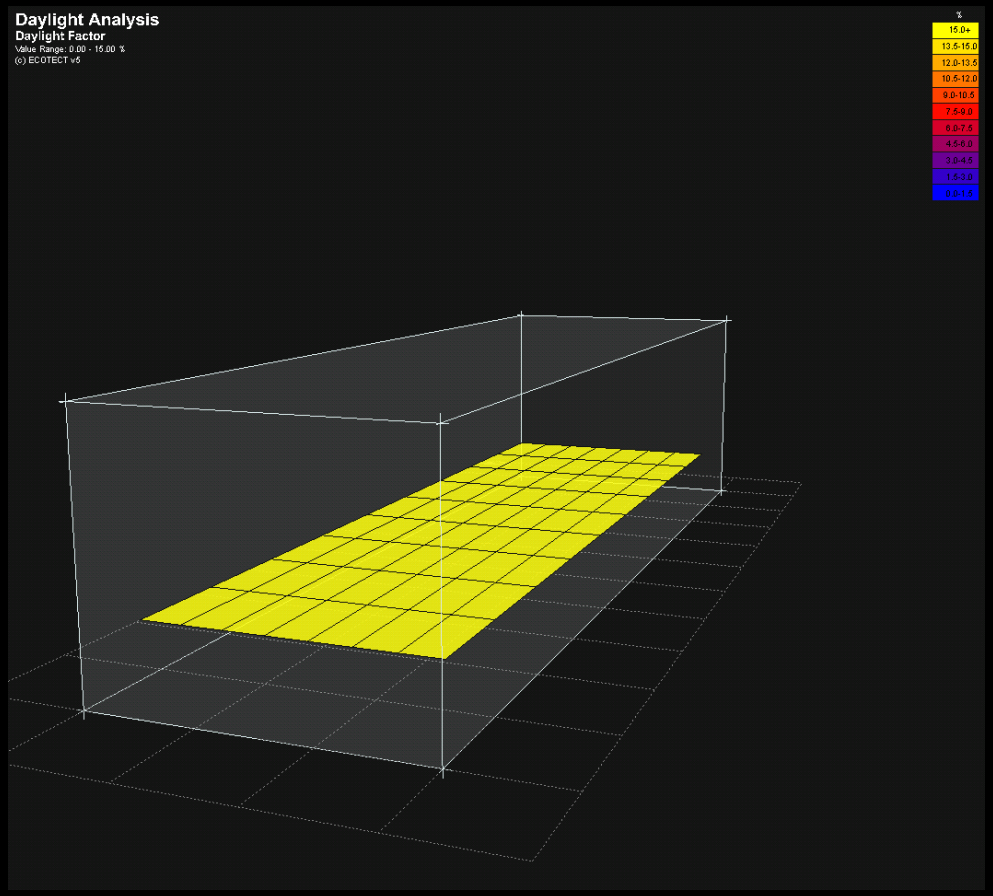


narrow floor plan



Daylight Factor – design implications II

The daylight factor optimized building is fully glazed.



Note, there are LEED certified buildings that are fully glazed!

Daylight Factor – design implications III

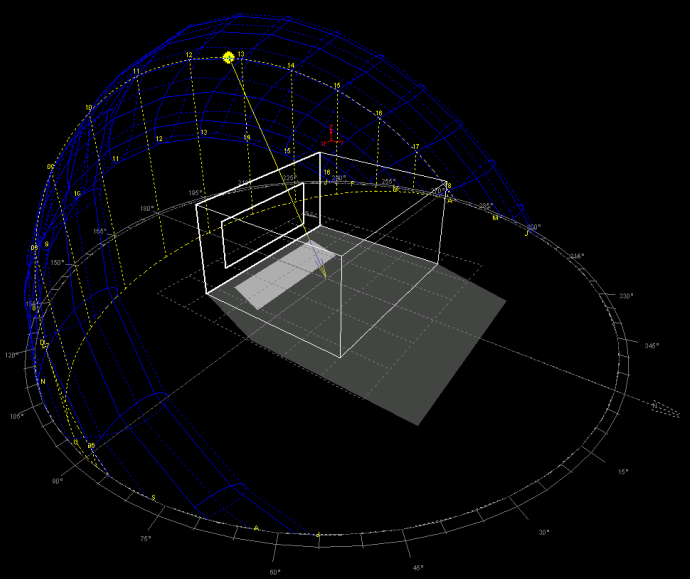
Common argument:

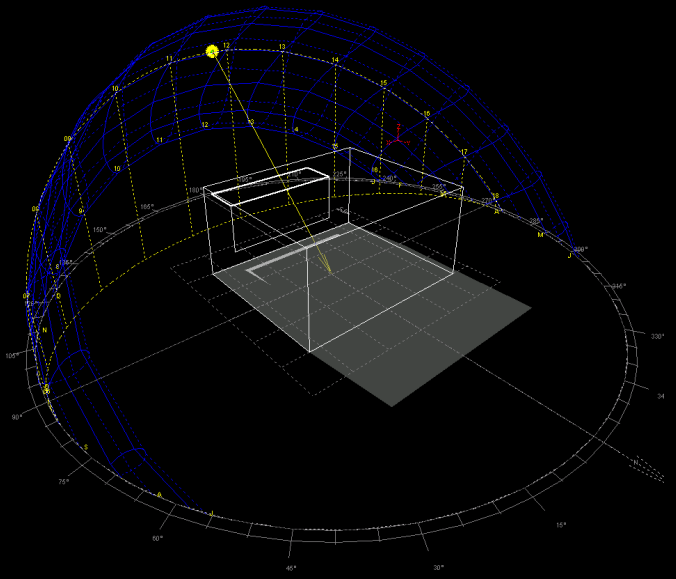
- overcast sky as a worst case scenario
- venetian blinds (even if closed) still admit sufficient DL

Daylight factor does not take glare or solar gain control into account. The consequence of too large glazings:
Venetian blinds are closed most of the time.

Avoidance of Direct Sunlight

optimized for static shading device louvers, lightshelves etc.

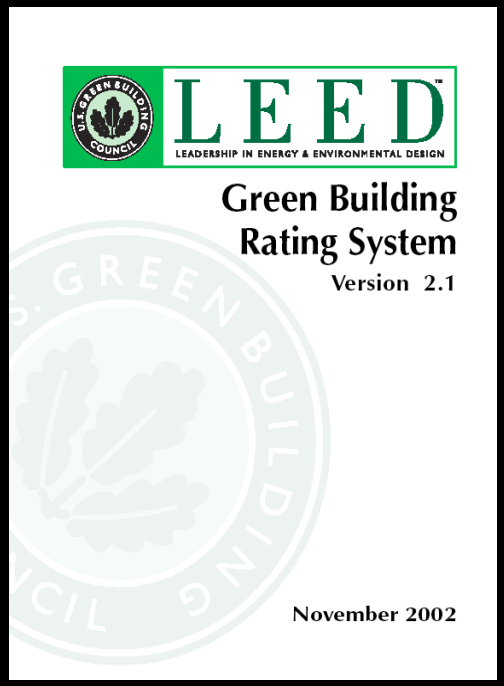




Avoidance during cooling period. For Montreal: May 1st to Oct 1st.

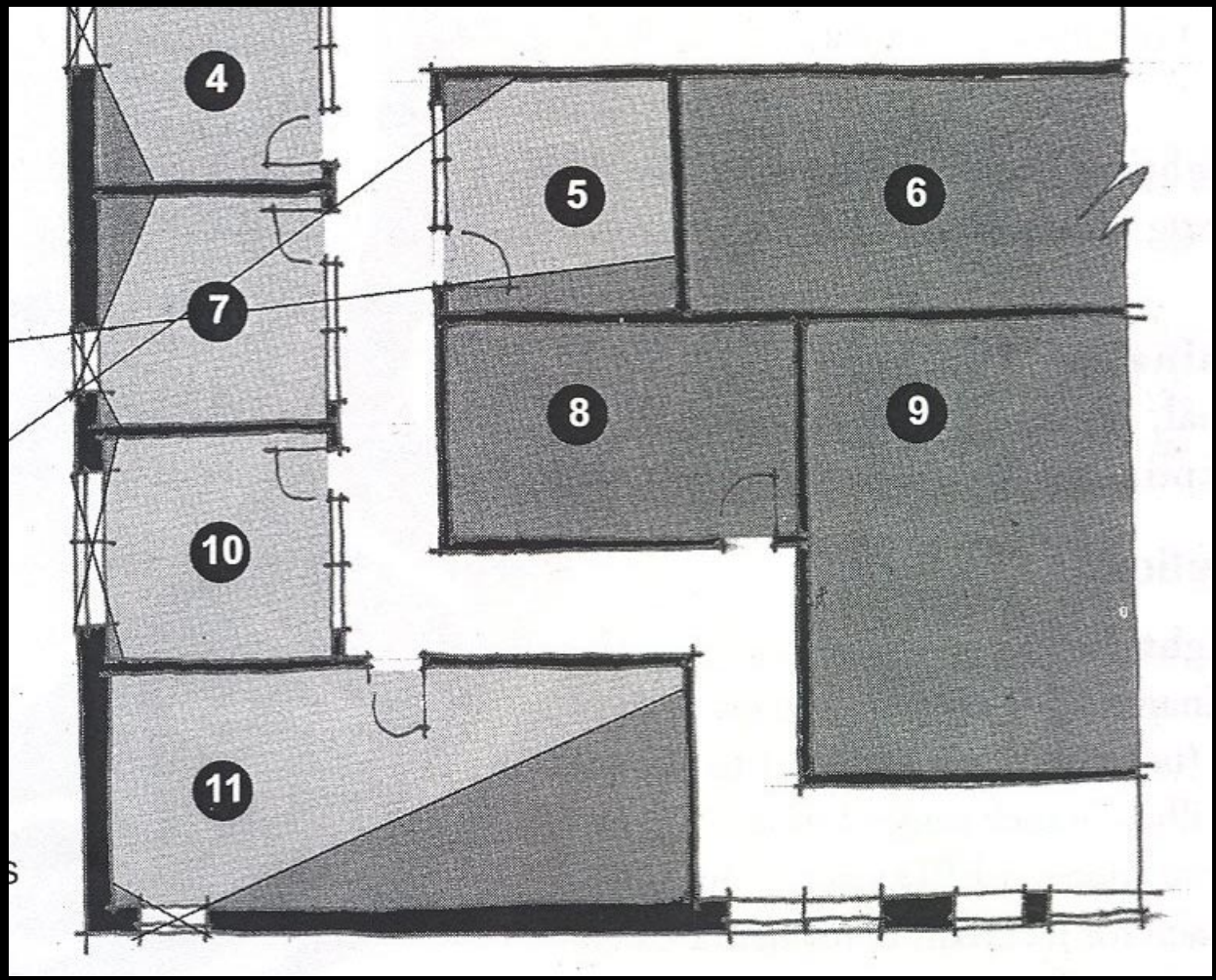
Resulting building design form is improved from an energy standpoint.

View to the Outside in LEED I



Credit 8.2 Views for 90% of Spaces Achieve direct line of sight to vision glazing for building occupants in 90% of all regularly occupied spaces. Examples for exceptions copy rooms, storage areas, mechanical, laundry and other low occupancy support areas.

View to the Outside in LEED II



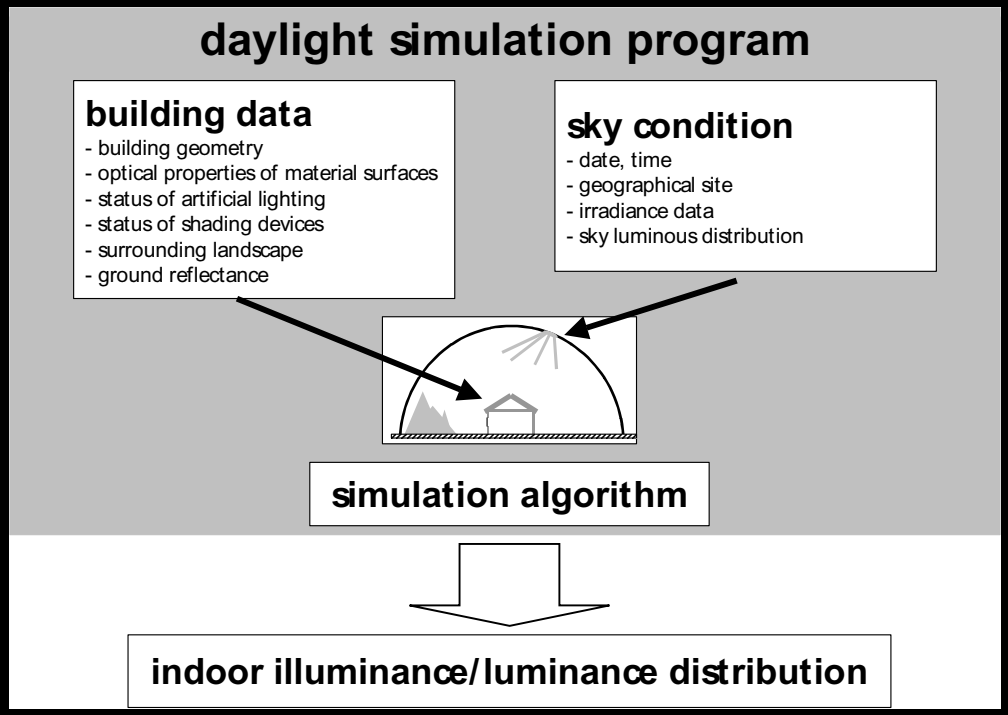
Source LEED 2.1 Ref. Manual

View to the Outside

- Size and content matter
- Information rich views with natural elements provide satisfaction and health benefits

Daylight Simulations in Ecotect

Elements needed for a DL Simulation



Performance Metrics

Building Model

Area of Interest (analysis grid)

Sky Model

Simulation Algorithm

Daylight Factor Calculation Methods

Average Daylight Factor (Spread Sheet Method)

Original Split Flux Method (Daylight Factor Protractors)

Split Flux Method in Ecotect

Raytracing/Radiosity (next lecture)

Average Daylight Factor Calculation

$$DF_{average} = \frac{\sum(W \cdot \tau \cdot \theta \cdot m)}{A(1 - R_2)}$$

W = The area of each window (m²),

τ = Transmittance of each glazing material

θ = Vertical angle of the sky as seen from the centre of each window

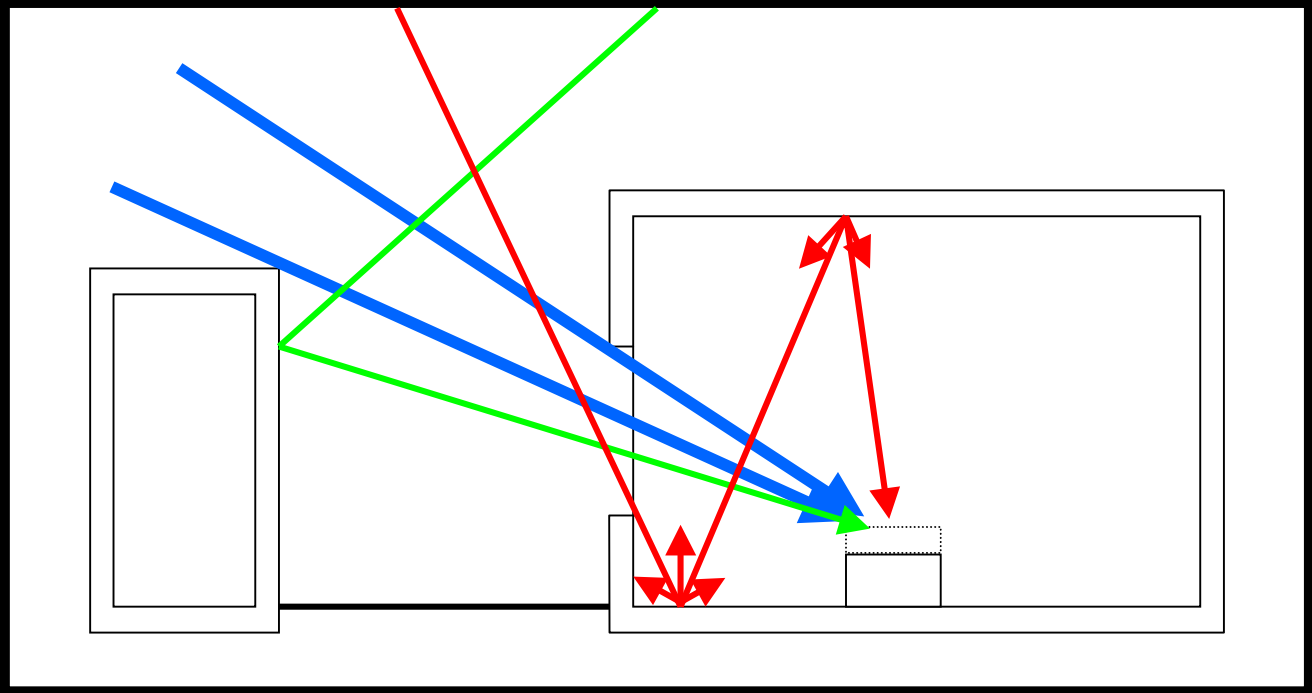
m = Maintenance factor based on angle of glazing and the cleanliness of its environment (0.5 – 0.9),

A = Total internal surface area of the space, including walls, floors, ceilings and windows (m²),

R_2 = Area weighted average reflectance of all surfaces making up *A*, (use 0.1 as reflectance for glass).

Split Flux Method

UK Building Research Establishment (BRE)



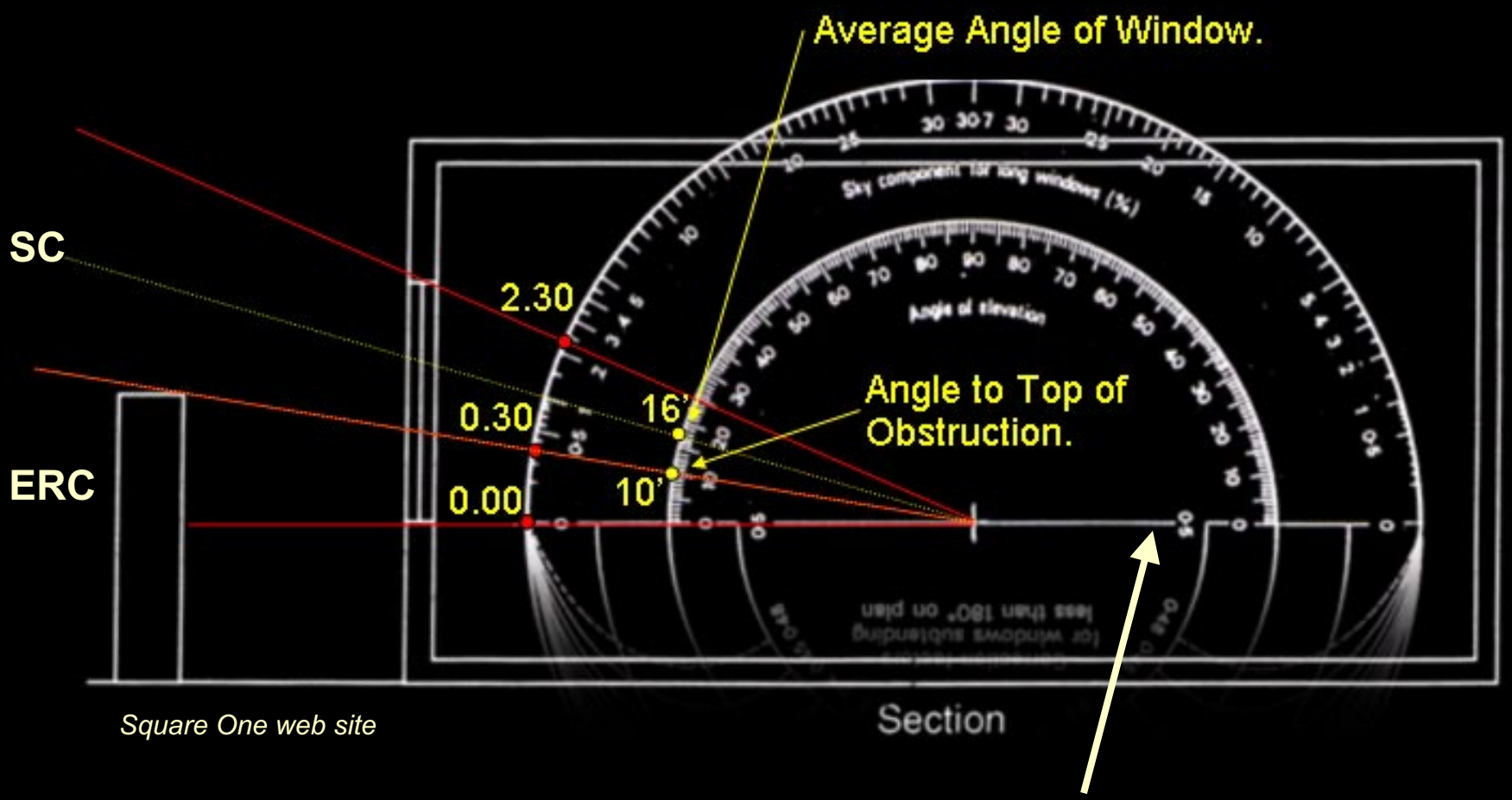
SC = direct component

ERC = externally reflected component

IRC = internally reflected component

DF= SC + ERC + IRC

Protractor Method I



Square One web site

Daylight Factor Protractors

Protractor Method II

Then the bottom side in plan view:

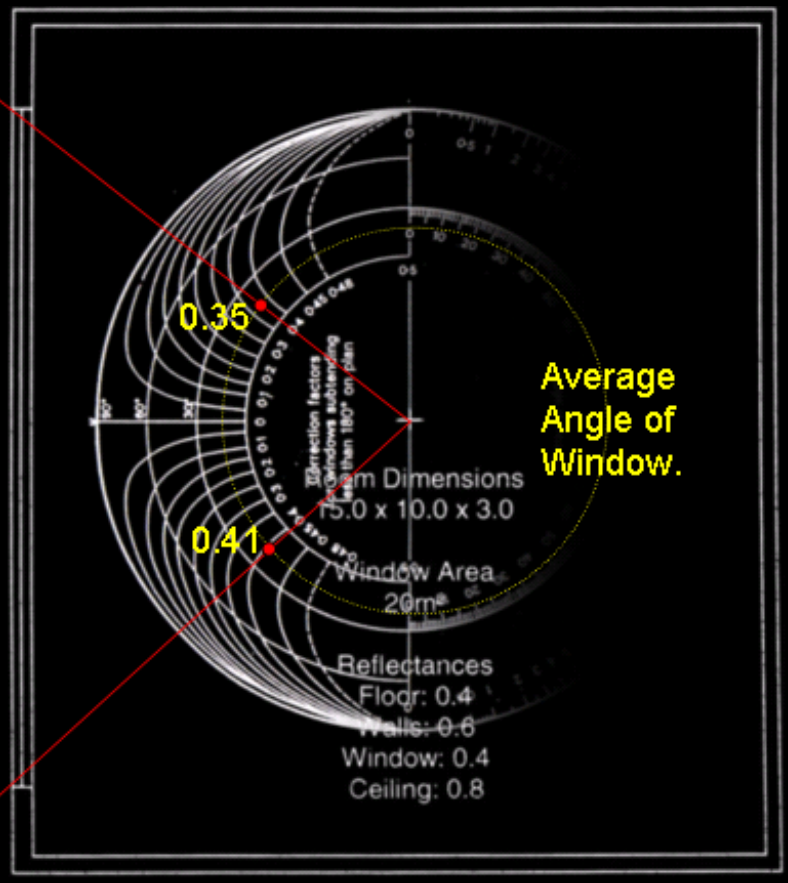
SC = 2.3 – 0.3
= 2.0

ERC = (0.3 – 0.0) x 0.2
= 0.06

Applying correction:

SC = 2.0 x 0.76
= 1.52

ERC = 0.06 x 0.76
= 0.0456



Square One web site Plan

Protractor Method III

Next find the Internally Reflected Component:

$$IRC = \frac{0.85\ W}{A\ (1 - p_1)} \times (Cp2 + 5p3)$$

Where:

W = Window area (m^2),
A = Total internal surface area, wall, floors ceilings and windows (m^2),
p_1 = Area weighted average reflectance of area A, (use 0.1 as reflectance for glass).
p_2 = Average reflectance of surfaces below working plane,
p_3 = Average reflectance of surfaces above working plane,
C = Coefficient of external obstruction.

Protractor Method IV

DF = SC + ERC + IRC

= 1.52% + 0.0456% + 1.7586%

= 3.324 %

In Montreal:

Design sky = 7215 Lux

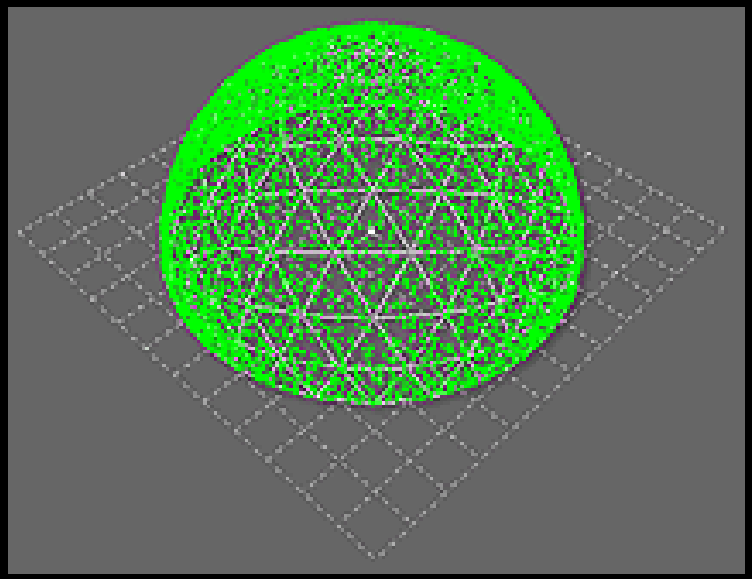
Light Level = 7215 Lux x 3.324%

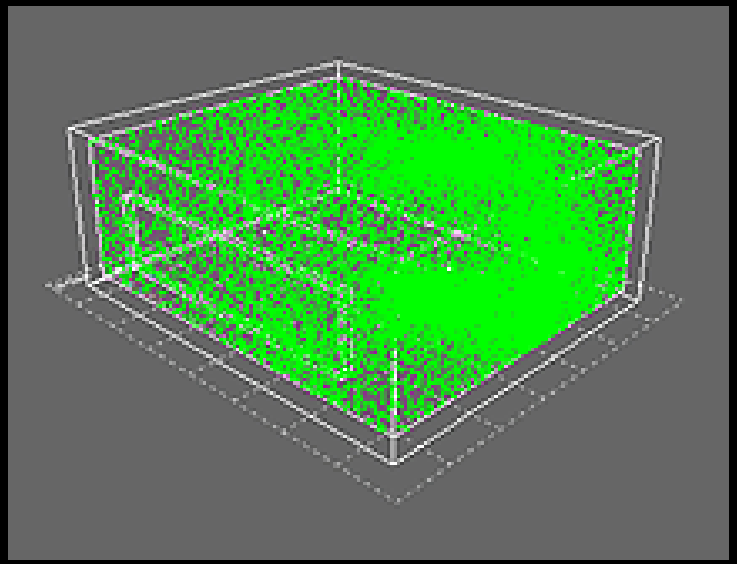
= 240 Lux

Split Flux Method in Ecotect

A geometric version of the Split Flux Method (BRE)

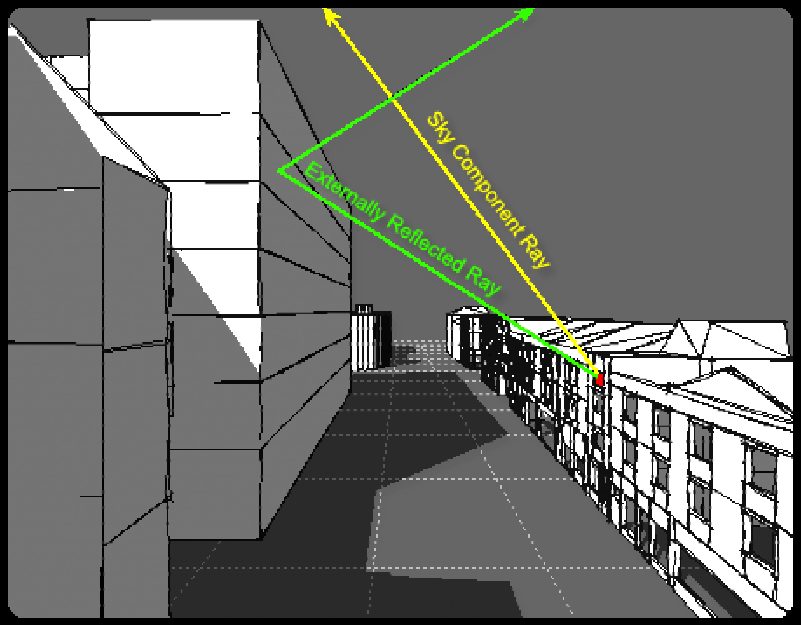
Raytracing: each ray represents an approximately equal solid angle of sky

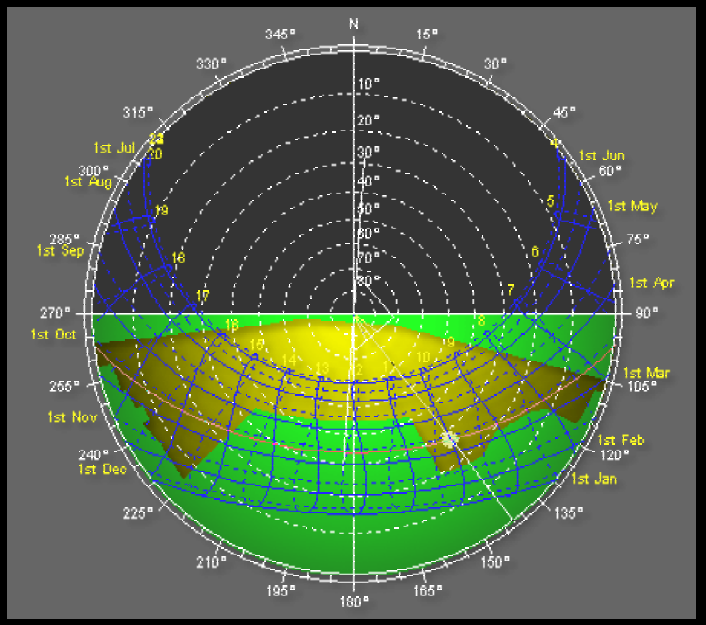




Square One web site

Split Flux Method in Ecotect



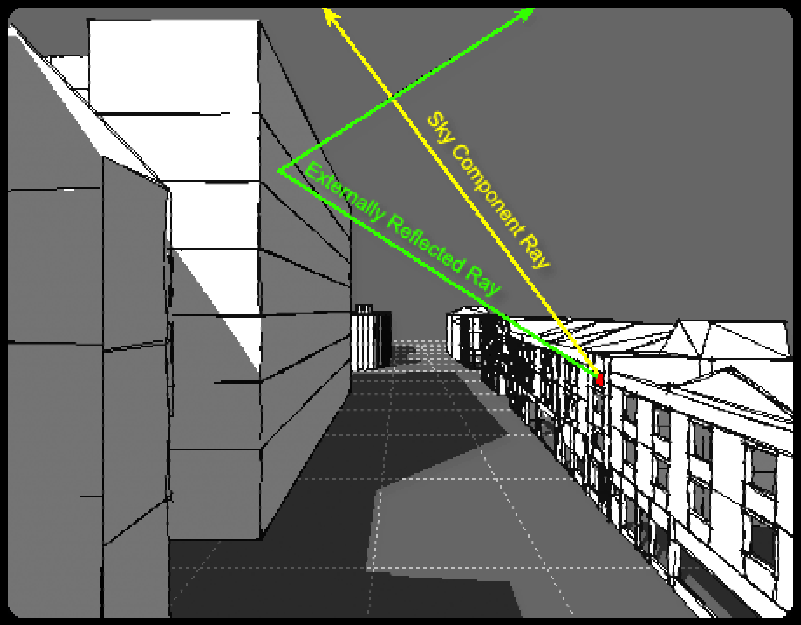


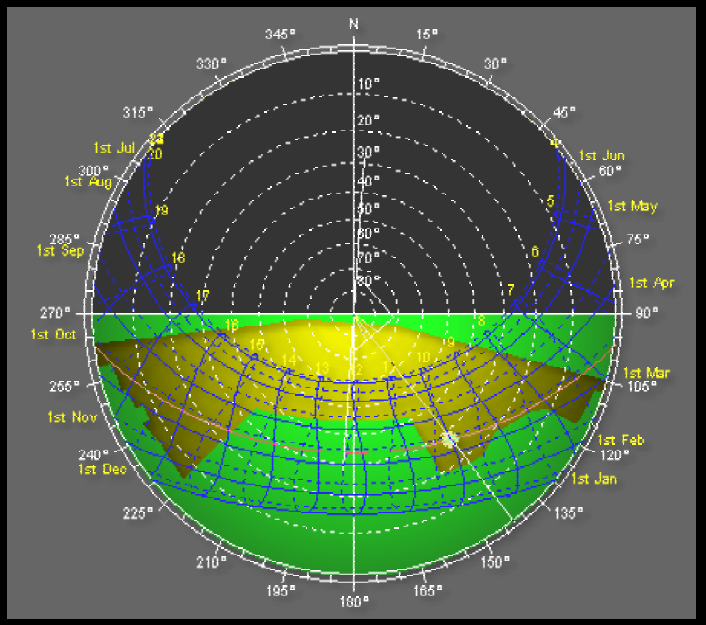
Square One web site

A Sky Component (SC) is modified by:

- relative sky illuminance of that particular sky patch
- relative angle of sky patch makes with a horizontal surface
- visible transmittance of each glazing material through which it travels

Split Flux Method in Ecotect



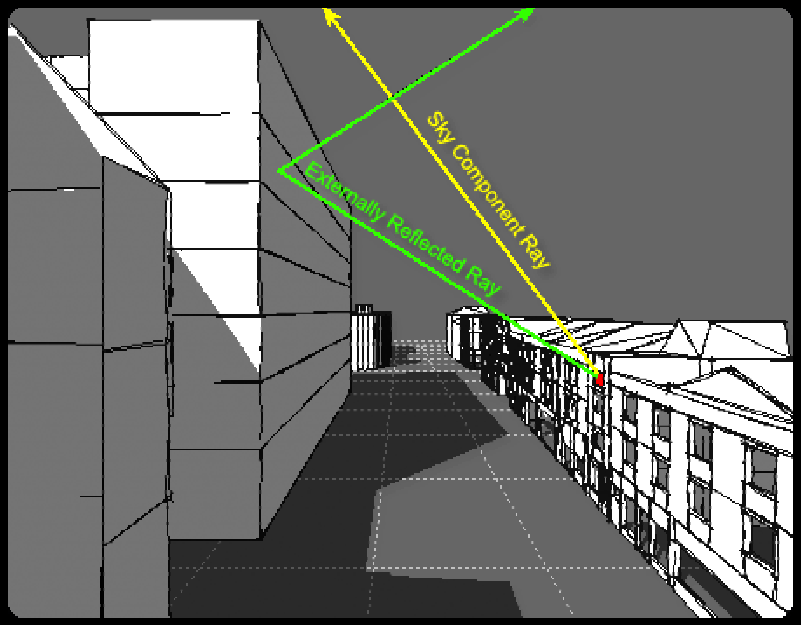


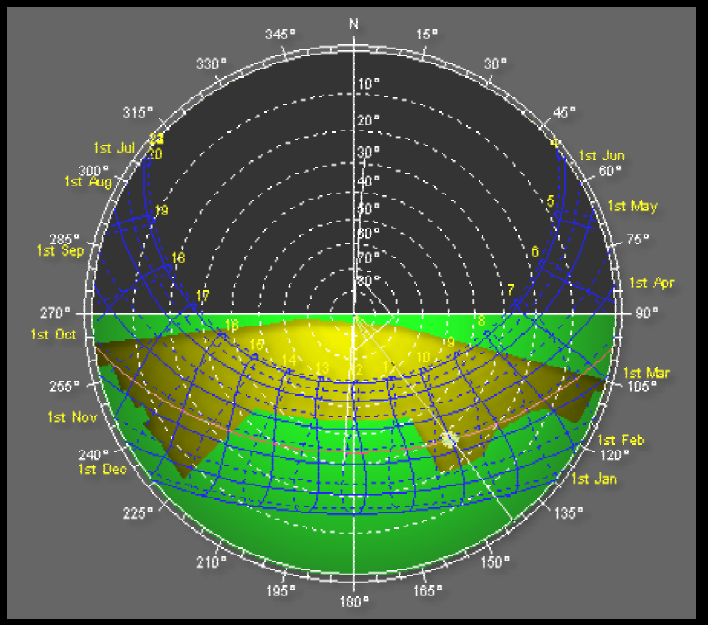
Square One web site

An Externally Reflected Component (ERC) is modified by:

- luminance of the sky it would have hit
- reflectance of the material assigned to the external object
- relative surface angle and glazing transmittances

Split Flux Method in Ecotect



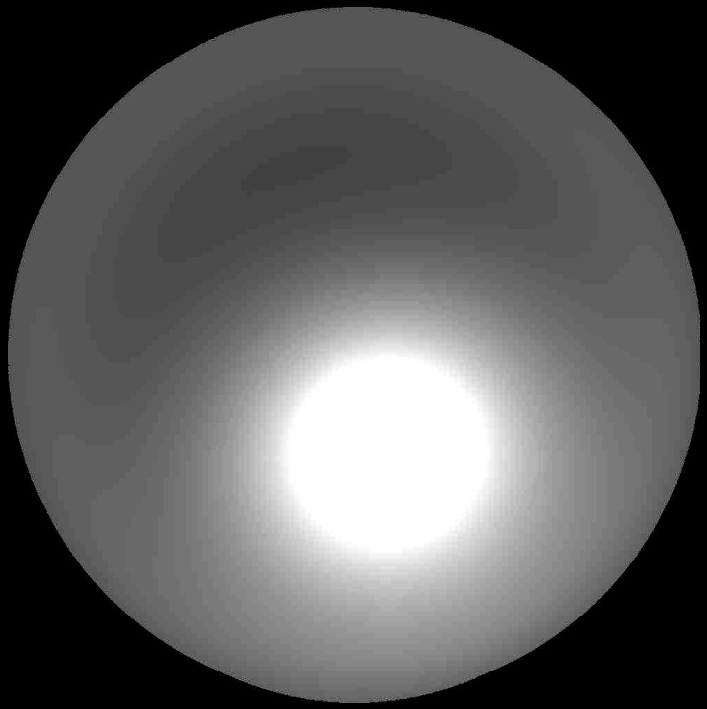


Square One web site

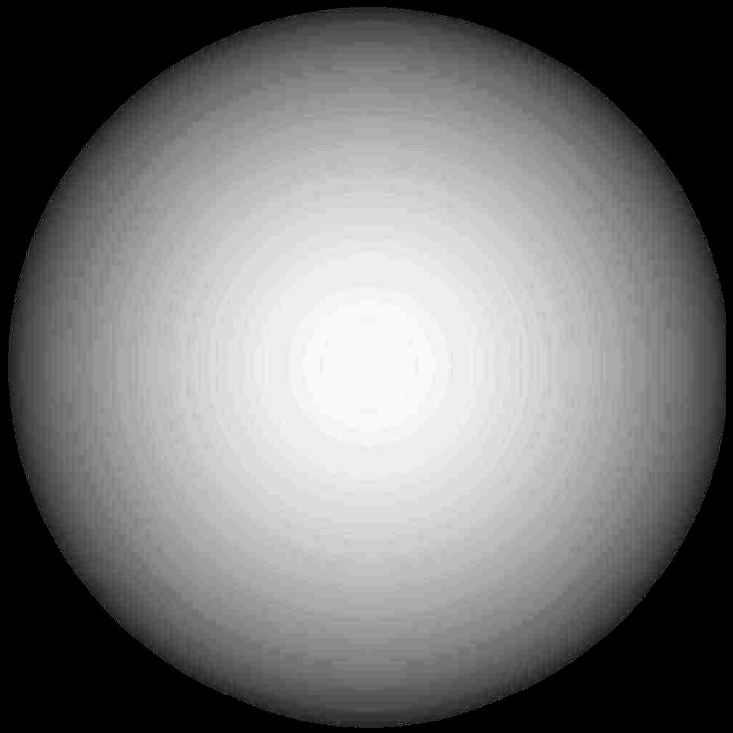
An Internally Reflected Component (IRC) is modified by:

- store internal surface reflectance of the object
- altitude angle of the ray is used to determine which parts of the IRC formula the ray contributes to.

Sky Models: CIE Sky Model



CIE clear sky

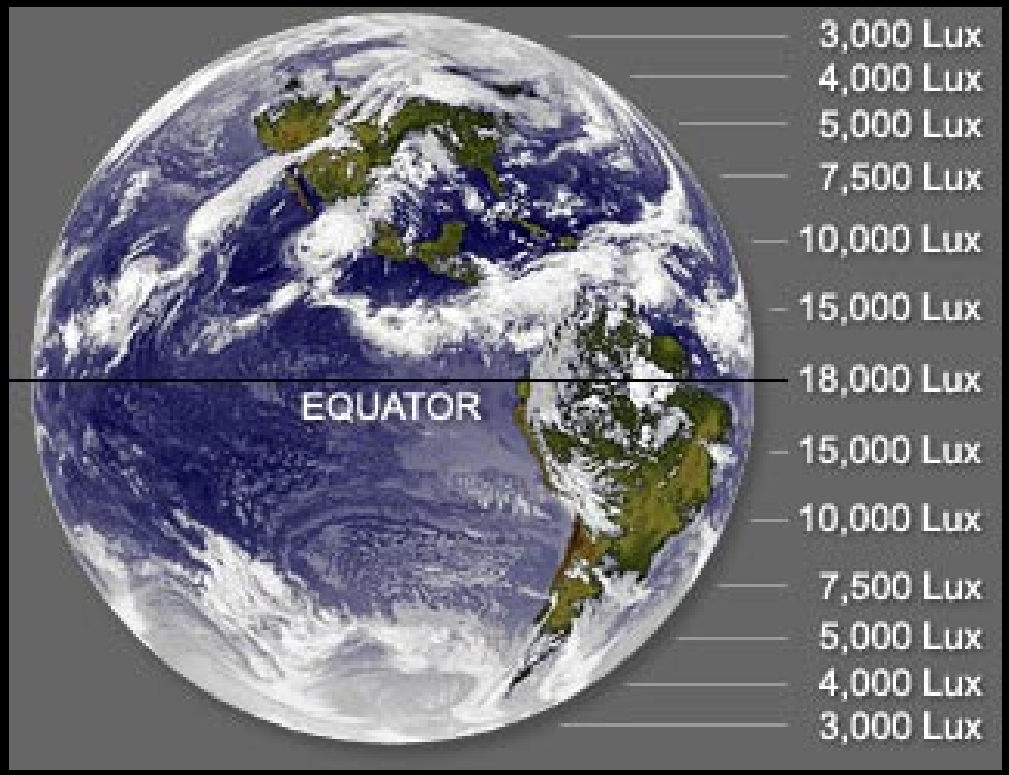


CIE overcast sky

Overcast sky: zenith to horizon 3-1

Design Sky Values

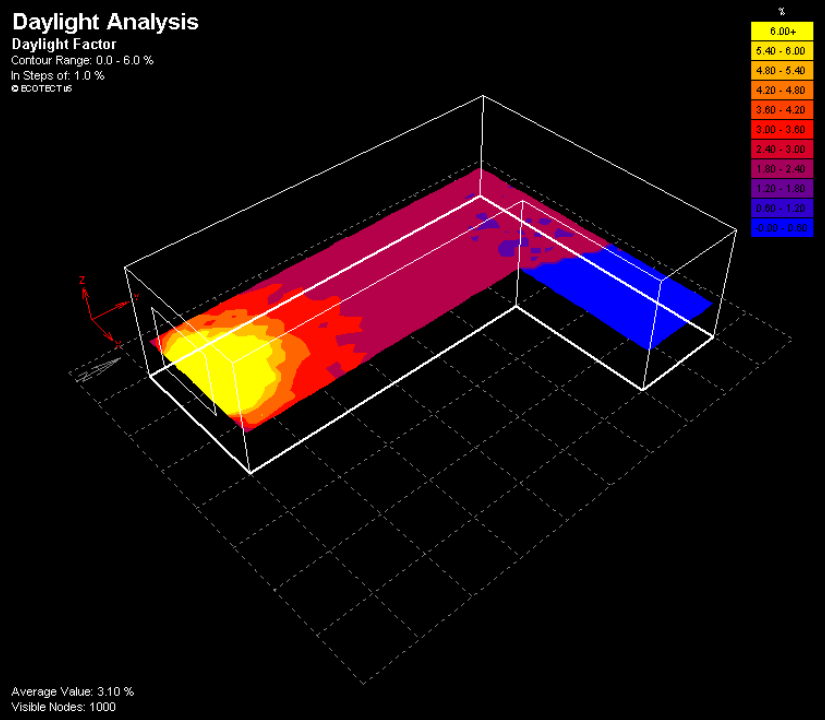
Design Sky values represent a horizontal illuminance level that is exceeded 85% of the time between the hours of 9am and 5pm throughout the working year. Thus they also represent a worst-case scenario that you can design to and be sure your building will meet the desired light levels at least 85% of the time.



Square One web site

Limitation in Ecotect. Climate files are not used by lighting simulation.

Limitations of the Ecotect Approach



BRE Daylight Factor method uses a relatively simple formula for the effect of internal reflections. To be fully compliant with this method, Ecotect cannot consider multiple reflections. Therefore, Ecotect underestimates indirect daylight solutions that rely on the reflection of light off multiple surfaces to illuminate a space. Limitations of the sky model (Ecotect does not use annual climate file data for daylighting).

Climate Data

Dry Bulb Temperature [°C]

Relative Humidity [%]

Direct Solar Radiation [W/m²]

Diffuse Horizontal Solar Radiation [W/m²]

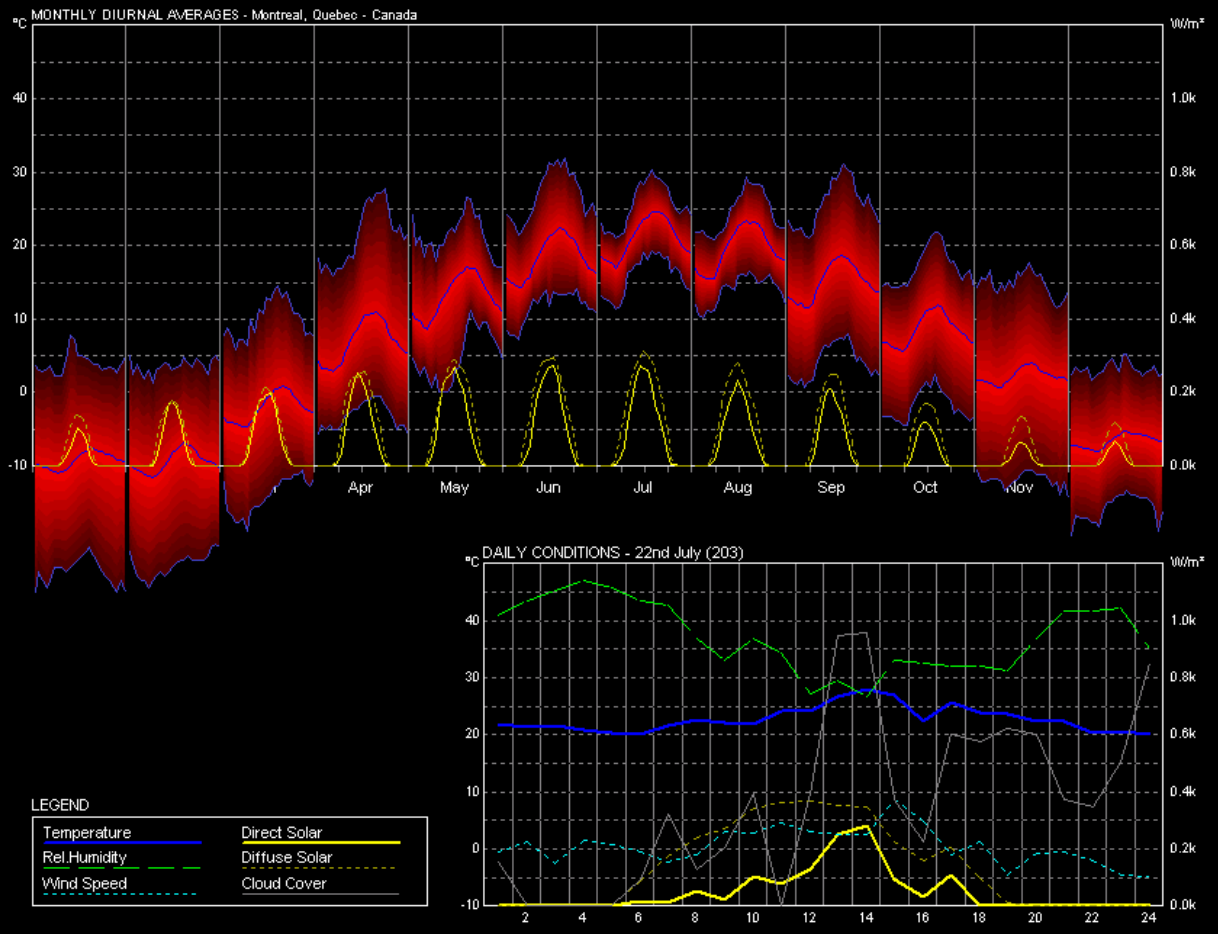
Cloud Cover [%]

Wind speed [km/h]

Wind direction [Degree]

Rainfall [mm]

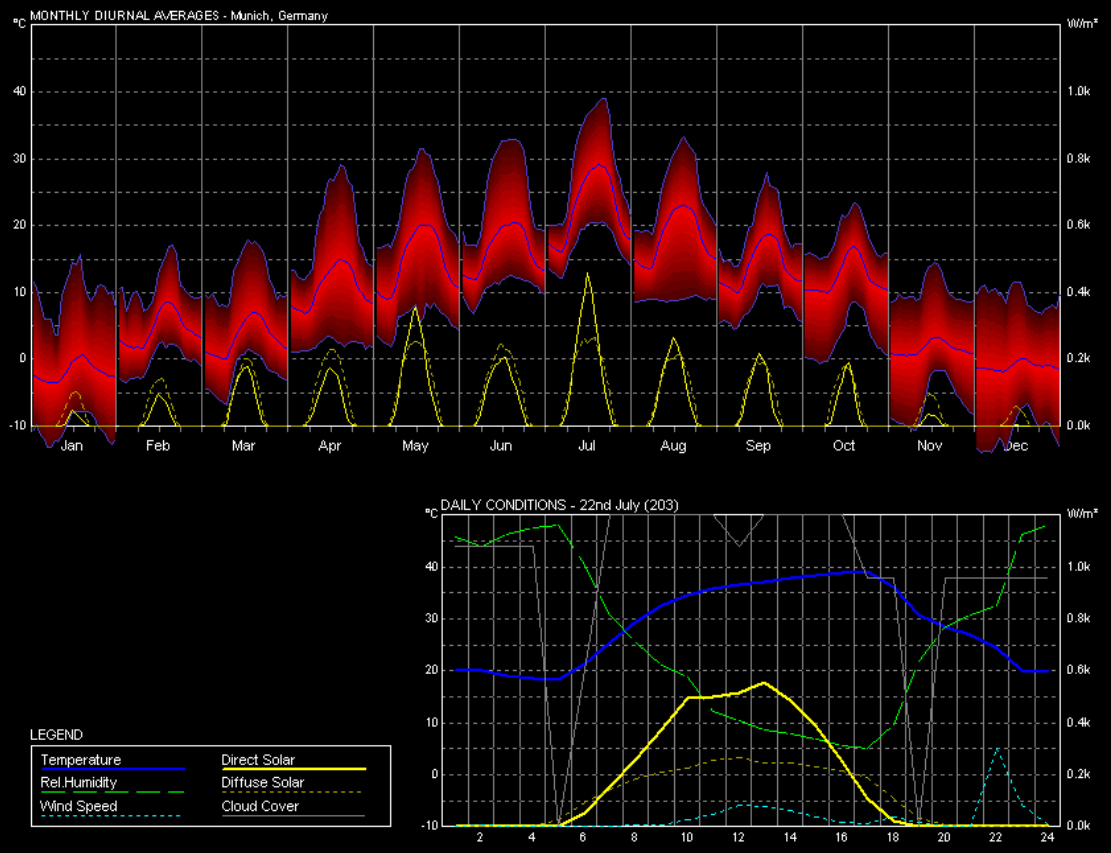
Climate Analysis - Montreal



small diurnal amplitude on hottest days of the year

=> Less potential for nighttime cooling

Climate Analysis - Munich



large diurnal amplitude on hottest days of the year

=> potential for nighttime cooling

Assignments for next two weeks

• By Thursday, Oct 12, 10.30AM: Submit your project proposals to Lia (File name: Group#_Proposal.pdf).

•By Tuesday, Oct 17, 5PM: Work through Getting Started Document – Ecotect. For a square, equator-facing window (dimensions1500mm x 1500mm) design an overhang similar to the one we designed in class. Send Lia a screenshot of your model and report the site name and coordinates, cut-off date, resulting the width of the overhang (File name: Group#_Assignment3.pdf). Use the following sites:

Group 1: Halifax	Group 2: London – UK
Group 3: Rome	Group 4: Los Angeles
Group 5: Sydney	Group 6: Edmonton
Group 7: Tokyo	Group 8: Singapore
Group 9: Vancouver	Group 10: North Pole
Group 11: Baghdad	Group 12: Cape Town

In case a site is not on the Ecotect database, download EPW weather files from: http://www.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm.