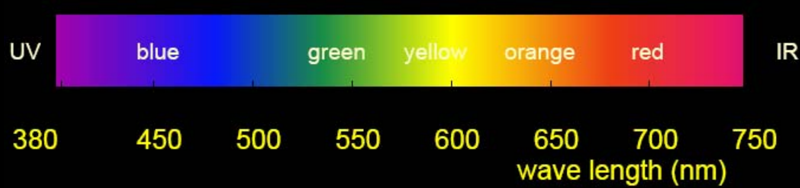
# What is daylight?

Daylight is the part of the electromagnetic spectrum that lies between 380 and 780 nm.

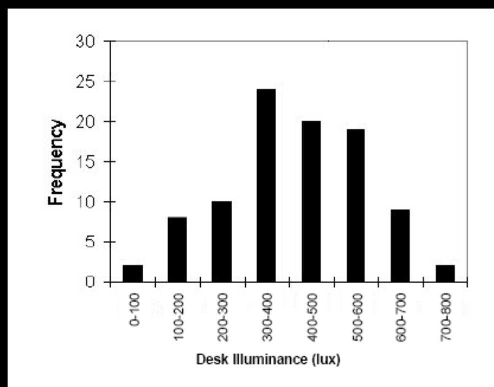



# Some Illuminance Values

| | |
|---|---|
| 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.

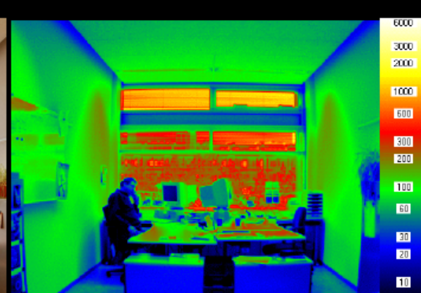
# Preferred Illuminance Levels




Energy saving potential through personal controls.

# Luminance Distribution

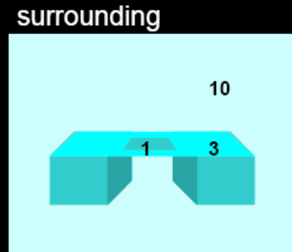
*Photo*




*Falecolor MappingPhoto*

False color representation to display a larger range.

## Preferred Luminances in the field of view (1:3:10 rule)



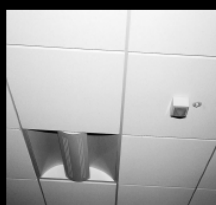

- Very difficult to maintina with daylight. Might not be necessary.
- Upper lumiance level of 2500 to 3000 $cdm^{-2}$.

## Generic Definition of Daylighting

*Daylighting is the act of lighting a building's interior with natural daylight.*

## Objectives for Daylighting

- Enhanced esthetics
- Visual comfort, occupant well-being, organizational productivity
- Lighting energy savings
- Overall energy savings



## Enhanced Esthetics

- Primary architectural consideration
- Daily and seasonal variations of daylight
- View to the Outside

⇒ Open up the building through windows, skylights, and clerestories

⇒ Use narrow Floor Plans to maximize the daylit area

⇒ Orient the building towards the sun

*dynamic interaction of light and building form*

## Measuring Daylight – Quality vs. Quantity

- General concensus is that daylight is « good »
  - Good for health and psychological wellbeing
  - Good for energy conservation
  - Good for aesthetics

- But how much, what kind, where?
  - Metrics and the quality vs quantity debate
  - Often a good design idea distilled to its numeric essentials, is stripped bare of much of its aesthetic value.
  - The best of intentions are not enough
  - The intangibles of physical environment design are complex and multilayered factors that embrace the
    - Psychological
    - Cultural
    - Stylistic - temporal

## Daylight Controls

- Physical
  - Louvers
  - Blinds
  - Architectural Shading Devices
  - Orientation
  - Material Reflectances
  - Trees (!)

- Electronic
  - Automated blinds
  - Heliostats

## Daylight Factors

-Definition: Percentage of exterior daylight available inside the building… It is a function of window size and placement, sky obstructions, glazing transmission, and interior reflectances. (Brown and DeKay, 2001)

-Numerically, the « desired » daylight factor is a required illuminance fraction of the available daylight.

Eg:

Target lux =400 (desk) lux

Total available daylight (Montreal) = 6500lux

Daylight factor (DF) = 400\6500  = 6.1%

## Daylight Factors

-From this it can be extrapolated that:

-Daylight factor is an average that is highly variable based on geographical location, micro climate and does not predict daily variations in daylight contribution.

-Additionally:

« Since the sun is in a particular position only a short period each day, direct-beam light from the sun is most often ignored in architectural approaches to daylight design »

(Brown and DeKay, 2001)

-This presents problems, since direct daylight is most often the cause of problems (eg: glare) and also wonder in architecture

## Daylight Factors

-Paradox?

« Illumination from the sun's direct rays is extremely powerful compared to that reflected from the sky dome; however, not including the sun, the clear sky is less bright than the overcast sky. The disttribution of light from a clear sky, with the exception of the sun and the area immediately around it, is opposite that of the overcast sky – three times brighter at the horizon than at the zenith. Therefore, building openings that face the top of the sky dome, do not face reflective surfaces, and do not admit direct light may receive less light on clear days than on overcast days »

(Brown and DeKay, 2001)

Direct vs. Reflected light

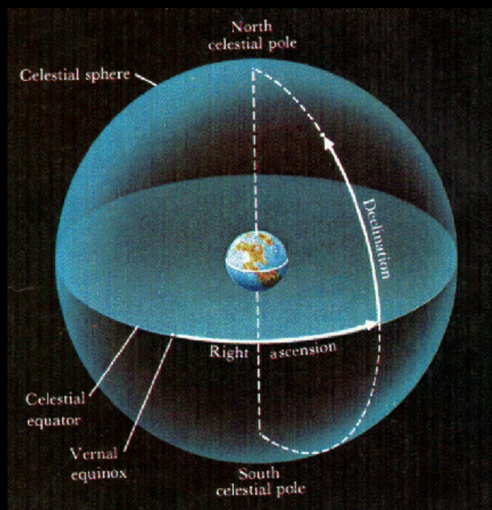
- quality
- quantity

## Daylight Factors

-Obstruction mask (hemispherical projection)


## Daylight Factors

-Skydome

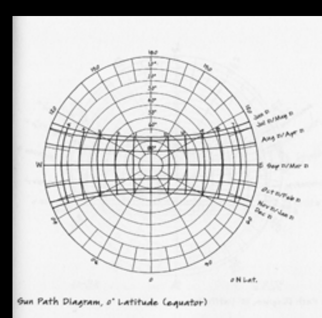



## Daylight Factors

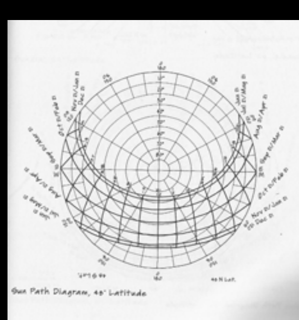
-Sun path diagram – tracks the position of the sun by date and location

-Can be overlayed to allow anticipated position of sun relative to building openings.

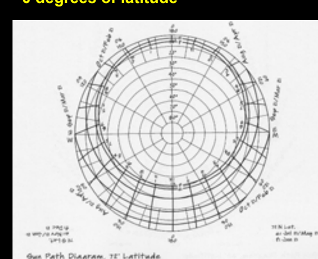
-Sun path by Latitude:




0 degrees of latitude



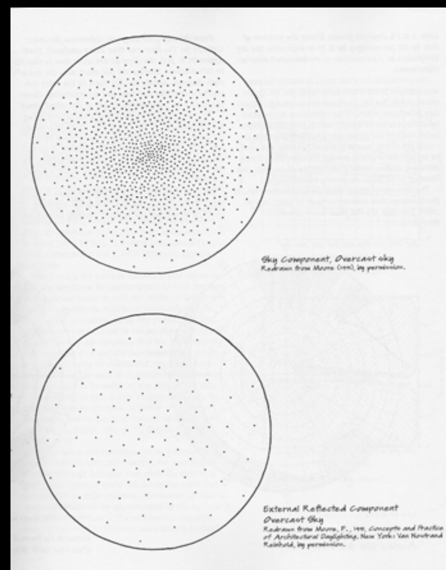

48 degrees of latitude




72 degrees of latitude

## Daylight Factors

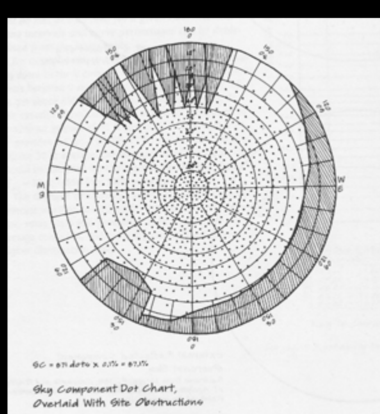
-Daylight obstruction charts
– Overcast vs. Clear sky




## Daylight Factors

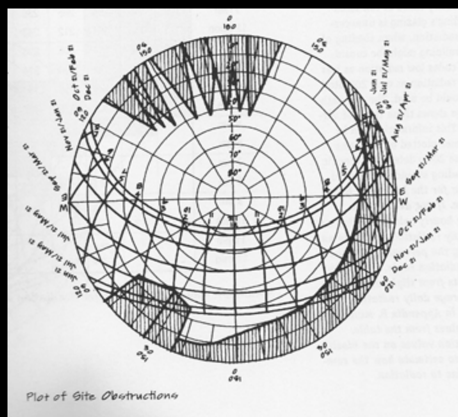
-Overlaying an obstruction diagram with a sky component (SC) chart allows an estimate of the contributed direct light

-Superimposing the two diagrams, counting the dots in the unobstructed areas, and dividing by 10 gives an aproximate daylight factor



## Daylight Factors

-Composite diagram




# "2 minute" Daylight Feasibility Study

(1) Determine Window to Wall Ratio (typical value 35%)

____________ / _________________ = _________

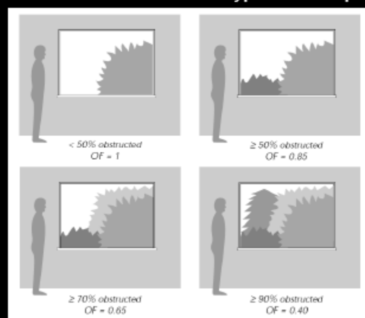
net glazing area / gross exterior wall area = WWR

(2) Make a preliminary Glazing Selection (typical value 70%)

| Generic Glazing type (1/4" panes) | Typical VT | Generic Glazing type (1/4" panes) | Typical VT |
|---|---|---|---|
| Single pane clear | 0.89 | Double pane tint - bronze | 0.47 |
| Single pane tint - green or blue-green | 0.70 | Double pane tint - gray | 0.39 |
| Single pane tint - blue | 0.57 | Double pane light reflective | 0.30 |
| Single pane tint - bronze | 0.53 | Double pane medium reflective | 0.20 |
| Single pane tint - gray | 0.42 | Double pane high reflective | 0.10 |
| Single pane tint - extra dark | 0.14 | Double pane low-E clear | 0.70 |
| Single pane light reflective | 0.35 | Double pane low-E tint - green or blue-green | 0.63 |
| Single pane medium reflective | 0.25 | Double pane low-E tint - blue | 0.49 |
| Single pane high reflective | 0.12 | Double pane low-E tint - bronze | 0.45 |
| Double pane clear * | 0.80 | Double pane low-E tint - gray | 0.37 |
| Double pane tint - green or blue-green | 0.65 | Suspended low-E film products | 0.27-0.60 |
| Double pane tint - blue | 0.51 | | |

# “2 minute” Daylight Feasibility Study

(3) Estimate Obstruction Factor from a typical workspace

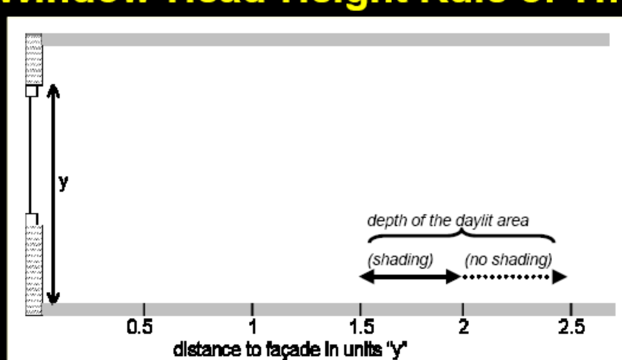



(4) Calculate Feasibility Factor (should be > 0.25)

______ x ______ x ______ = ______________

WWR $\quad V_T \quad$ OF $\quad$ Feasibility Factor

# Window-Head-Height Rule of Thumb




*The depth of the daylit area in a sidelit space with a standard window combined with venetian blinds usually lies between 1 and 2 times the size of the window-head-height.*

*In the rare case that a space does not require the use of a shading device the ratio range increases up to 2.5.*

# Limiting-Room-Depth Rule of Thumb Uniformity Criterion

Limiting Room depth for a sidelit space:

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

L = depth of room from window to back wall [m]

W = width of room measured across the window wall [m]

$H_w$ = height of window head above floor [m]

$\rho_b$ = area-weighted average reflectance of surfaces [-]

(value for a typical office ~ 0.5)

Note: For rooms with windows on 2 opposite sides, the maximum depth that can be satisfactorily be daylit is twice the limiting room depth L, from window wall to window wall.

Example: Room height = Room Width = 3m

$$L = \frac{2}{1-0.5} / \left(\frac{1}{3m} + \frac{1}{3m}\right) = 6m$$

# Window-Sizing Rule of Thumb

Starting point for estimating required window size:

$$A_g = \frac{2 \cdot DF_a \cdot A_{TOT}(1-R_a)}{V_T \cdot \theta}$$ and $$A_w = A_g \cdot 1.25$$

Ag = net glazing area [m2]

Aw = window area [m2]

DFa = average Daylight Factor

- DFa = 1% low-light space
- DFa = 2% average-lit space
- DFa = 4% bright space

ATOT = total area of interior surfaces [m2]

Ra = area-weighted average reflectance [-] (Ra = 0.5 as default)

VT = Visible transmittance [-]

- VT = 0.7 for small windows
- VT = 0.5 for medium-sized windows
- VT = 0.3 for large windows

θ = vertical angle of sky [°] value between 0° and 90° (no obstruction à θ = 90°)

Note: "the equation assumes a rectangular room whose depth is no more than 2.5 times window head height and also assumes an overcast sky"

## More Rules of Thumb

- Preferred façade orientations for daylighting: South and North
- Desirable reflectances" to have a well daylit environment : ceiling > 80%, walls > 50-70%, floor > 20-40%, furniture > 25-45% (avoiding specular surface finishes)
- if daylighting with skylights, the openings must constitute at least 5% of the ceiling area

## Visual Comfort and Occupant Well-being

- View to the Outside
- Avoidance of glare and thermal discomfort
- Maintain occupants' privacy
- Full spectrum color rendering

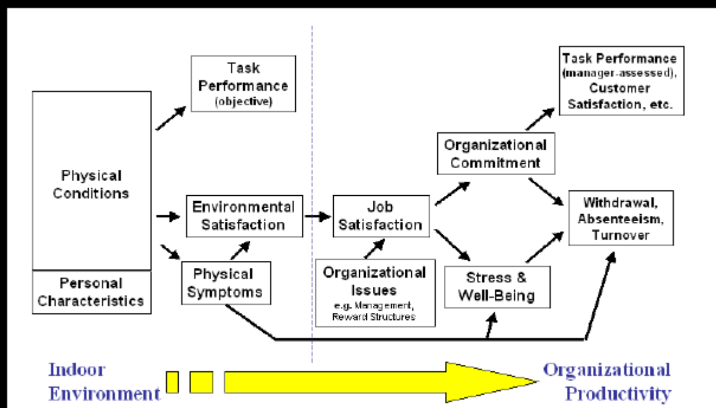
⇒ Maintain daylighting levels within acceptable limits

⇒ Develop a suitable shading device strategy (Shading from neighboring buildings, Venetian Blinds, Lightshelves)

⇒ Reduce window sizes to 'appropriate levels.

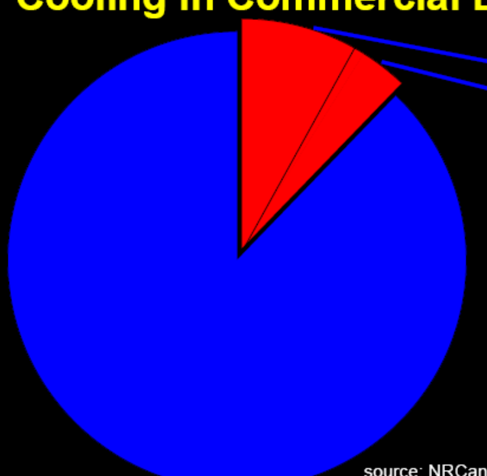
*workspace with high visual comfort*

## Organizational Productivity




*source: Newsham & Veitch*

## Energy Use for Electric Lighting and Cooling in Commercial Buildings

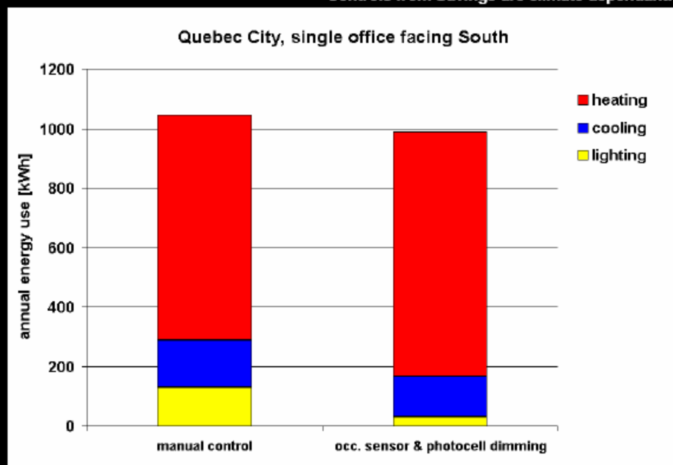



Can be significantly higher in office buildings.

source: NRCan for 2001

## Integration of Lighting and Energy

Controls from Savings are climate dependant!




## Lighting Energy Savings

- Replace electric lighting with with natural daylight

⇒ Consider the use of personal Controls (on/off switches, bi-level switching, dimming)

⇒ Consider the use of automated controls (occupancy sensors and photocell controlled dimming)

*occupancy & photocell controlled lighting*

*occupancy sensor*

## Rules of Thumb – Lighting Controls

*occupancy sensor*

*occupancy & photocell*

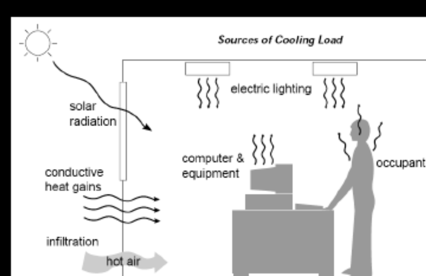
- ❑ occupancy sensors save 25% and 50% lighting energy
- ❑ photocell controlled dimming saves
  - 50-60% in perimeter zone
  - 25-40% in 'second row'
- ❑ commissioning photocells is easier for 'top-lighting' than 'side-lighting'

## Overall Energy Savings

- Choose the fenestration system (glazing and shading) to reduce overall building energy use for heating, lighting and cooling.

⇒ Select appropriate glazing type and shading.

⇒ Coordinate with the mechanical system to take advantage of internal load and solar gain reductions.




*Source: Tips for Daylighting*

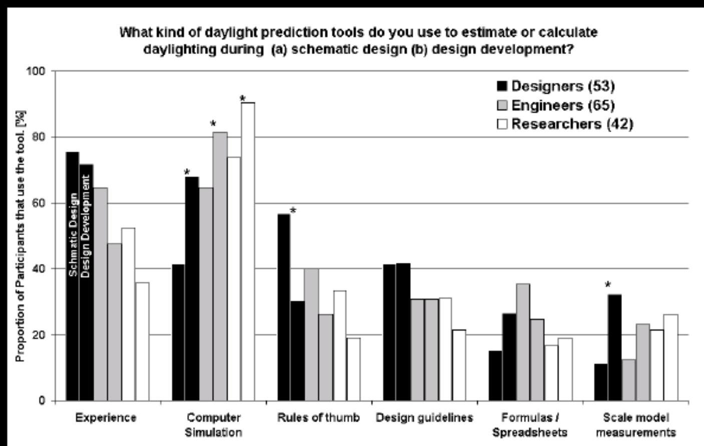
## Daylighting Design Stages

- Site Daylight Feasibility Study for Key Spaces
- Building Massing (room dimensions & program)
- Envelope Decisions (windows, skylights)
- Glazing Selection
- Shading Strategy
- Electric Lighting Coordination (fixtures, light sources, controls)

-> Consult 'Tips for Daylighting'

# Daylight Simulations

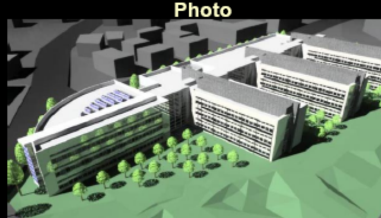
# Rule of Thumb – Simulation – Scale Model




# Computer Simulations & Scale Models I

**Case Study: Fraunhofer Institute for Solar Energy Systems**

**Photo**



**Computer Model**

**Scale Model**

## Computer Simulations & Scale Models II

Scale Model

- costs 10000 Euro
- accuracy under artificial skies within 20%
- provides opportunity to walk around
- used for presentational purposes

## Computer Simulations & Scale Models III

Computer Model

- costs ~10000 Euro (including analysis)
- accuracy within 20%
- influenced façade design
- walk around and within

## What are daylight simulations used for?

To compare different design options during design development.

To reduce risk through reduced planning uncertainty.

To demonstrate code compliance (absolute values).

## Who should 'do' daylight simulations?

# Architects!

**Better interfaces. Faster computers.**

**To interactively improve your design at the schematic design stage.**

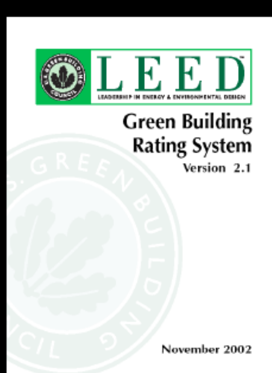
**To be able to engage in a dialogue with the HVAC engineer.**

**Competitive edge: high demand for simulationists**

**Opportunity to work on more interesting projects.**

**Caveat: You have to understand the underlying assumptions.**

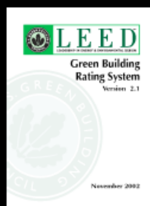
# Context - LEED Rating System




Categories for new commercial construction and major renovation projects

- Sustainable Sites (14)
- Water Efficiency (5)
- Energy & Atmosphere (17)
- Materials & Resources (14)
- Indoor Environmental Quality (15)
- Innovation & Design Process (5)

## Daylighting/Lighting in LEED




<u>Indoor Environmental Quality section:</u>
credits for:

- ❑ daylight factor
- ❑ view to the outside
- ❑ specification of shading devices (Green Globe only)

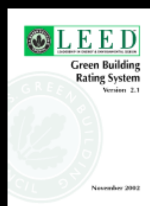
Compliance is verified via spreadsheet method.

## Daylighting/Lighting in LEED


<u>Energy and Atmosphere section:</u>
credits for automated lighting controls (occupancy sensors, continuous or two-step dimming).

Savings estimated via ASHRAE Power Adjustment Factors (occupancy sensors) or explicit daylight simulations (photocell dimming).

## Daylighting/Lighting in LEED



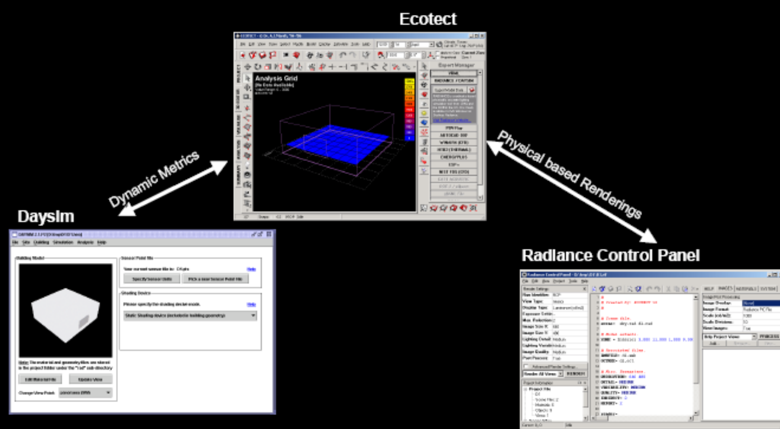

<u>Sustainable Sites:</u>
Light Pollution Credit "eliminate light trespass from the building and site, improve night sky access and reduce development impact on nocturnal environments".

## Daylighting/Lighting in LEED

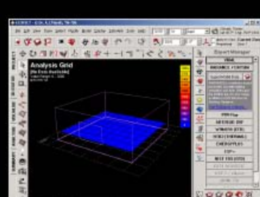
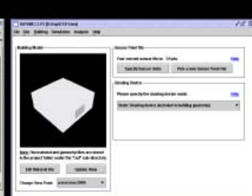
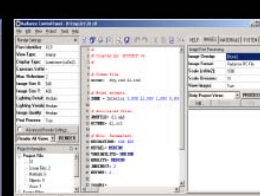

-Materials and Ressources

Credits for sourcing lighting fixtures locally

# Simulation Tools used in this Course




# Availability of Tools

**Ecotect**

The new version of Ecotect (5.50) will be shortly installed in the Computer Labs: 215C and 103. For

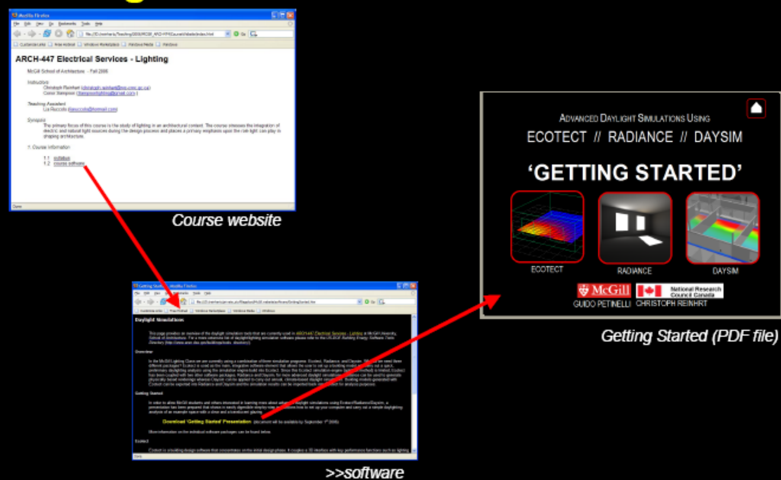
**Daysim**

Free download.

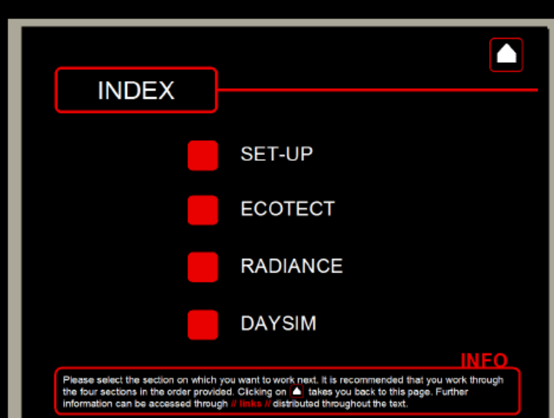
**Radiance**

Free download.

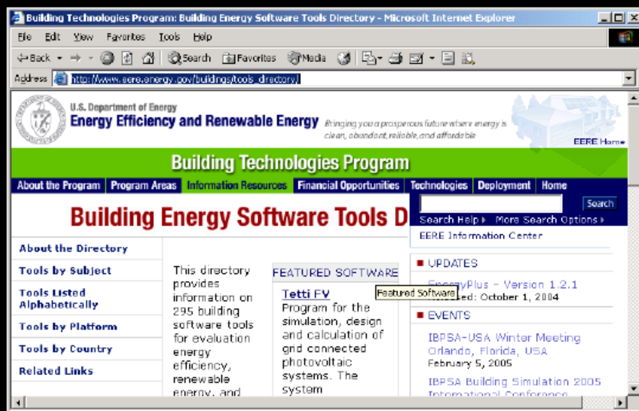
# Getting Started Document




# Getting Started Index



# Building Energy Software Tools Directory




www.eere.energy.gov/buildings/tools_directory/