4.430 Daylighting

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4.430 Where is the sun?

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Goals for This Week

- ❑ Where is the sun?
- ❑ Designing Static Shading Systems

MISC

- ❑ Meeting on group projects
- ❑ Reduce HDR image size via

  pfilt –x 800 –y 550 filne_name_large.pic > filename_small>.pic

Note: pfilt is a Radiance program. You can find further info on pfilt by googeling: “pfilt Radiance”

Daylight Factor Hand Calculation

Mean Daylight Factor according to Lynes

Move into the building, design the facade openings, room dimensions and depth of the daylit area.

Determine the required glazing area using the Lynes formula.

$$DF = \frac{A_{glazing} \tau_{vis} \theta}{A_{total} 2(1-R_{mean})}$$

$A_{glazing}$ = required glazing area
A_{total} = overall interior surface area (not floor area!)
R_{mean} = area-weighted mean surface reflectance
τ_{vis} = visual transmittance of glazing units
θ = sun angle

'Validation' of Daylight Factor Formula

$$DF = \frac{A_{glazing}\,\tau_{vis}\,\theta}{A_{total}\,2(1-R_{mean})}$$

Graph of mean daylighting factor according to Lynes formula v. Radiance removed due to copyright restrictions.
Source: Figure 5 in Reinhart, C. F., and V. R. M. LoVerso. "A Rules of Thumb Based Design Sequence for Diffuse Daylight." *Lighting Research and Technology* 42, no. 1 (2010): 7-32.

- Comparison to Radiance simulations for 2304 spaces.
- Quality control for simulations.

LEED 2.2 Glazing Factor Formula

$$\text{Glazing Factor} = \frac{A_{glazing}}{A_{floor}} \cdot \text{Window Geometry Factor} \cdot \frac{\tau_{vis\,actual}}{\tau_{vis\,reference}} \cdot \text{Window Height Factor}$$

Graph of mean daylighting factor according to LEED 2.2 v. Radiance removed due to copyright restrictions.
Source: Figure 11 in Reinhart, C. F., and V. R. M. LoVerso. "A Rules of Thumb Based Design Sequence for Diffuse Daylight." *Lighting Research and Technology* 42, no. 1 (2010): 7-32.

LEED 2.2 Glazing Factor Formula (enhanced)

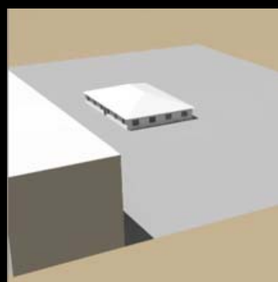
$$\text{Glazing Factor} = \frac{A_{glazing}}{A_{floor}} \cdot \text{Window Geometry Factor} \cdot \frac{\tau_{vis\,actual}}{\tau_{vis\,reference}} \cdot \text{Window Height Factor} \cdot \frac{\theta}{90°}$$

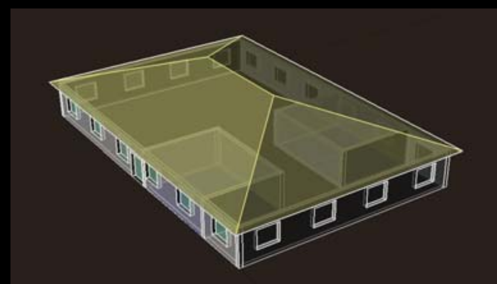
Graph of mean daylighting factor according to LEED 2.2 with obstruction correction factor v. Radiance removed due to copyright restrictions. Source: Figure 12 in Reinhart, C. F., and V. R. M. LoVerso. "A Rules of Thumb Based Design Sequence for Diffuse Daylight." *Lighting Research and Technology* 42, no. 1 (2010): 7-32.

Exercise: DF Calculations

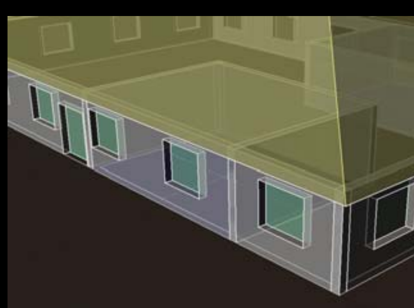
Calculate the daylight factor and the daylight feasibility test in the two offices in Simple Office Building

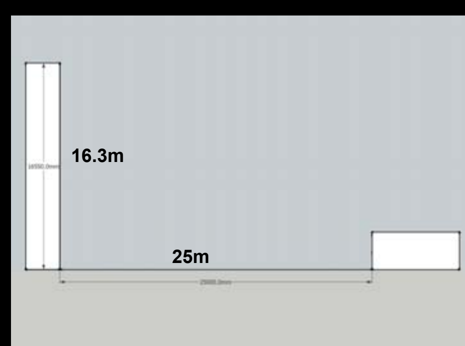
Simple Office Building





Simple Office Building





Room depth = 6m
Room width = 8m
Room height = 3.05m
Window size 1.52 x 1.83m^2
R_{mean} = 0.5
τ_{vis} = 0.72 (double glazing)

street width = 25m
height of neighboring building = 16.3m
height of centre of glazing = 1.8m

$$DF = \frac{A_{glazing}\,\tau_{vis}\,\theta}{A_{total}\,2(1-R_{mean})}$$

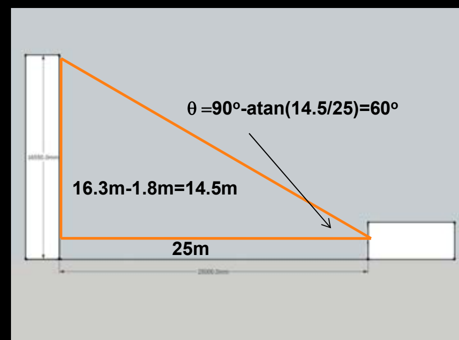
Simple Office Building

$$DF = \frac{A_{glazing}\,\tau_{vis}\,\theta}{A_{total}\,2(1-R_{mean})}$$

$A_{glazing}$ = 5.56m^2
A_{total} = 181.4m^2
R_{mean} = 0.5
t_{vis} = 0.72
θ = 60°

$$DF_{Lynes} = \frac{5.56m^2 x0.72x60^o}{181.4m^2 x2(1-0.5)} = 1.3\%$$

DF_{Lynes}= 1.3%



street width = 25m
height of neighboring building = 16.3m
height of centre of glazing = 1.8m

Simple Office Building

$$DF = \frac{A_{glazing}\,\tau_{vis}\,\theta}{A_{total}\,2(1-R_{mean})}$$

$A_{glazing}$ = 5.56m^2
A_{total} = 181.4m^2
R_{mean} = 0.5
t_{vis} = 0.72
θ = 90°

$$DF_{Lynes} = \frac{5.56m^2 x0.72x90^o}{181.4m^2 x2(1-0.5)} = 2.0\%$$

DF_{Lynes}= 2.0%

Simple Office Building

$$WWR > \frac{DF}{10 \times \tau_{vis}} \frac{90^o}{\theta}$$

For South Office:

DF(Target)= 2.0%

t_{vis} = 0.72

θ = 60°

$$WWR > \frac{2}{10x0.72}\frac{90}{60} = 0.42 = 42\%$$

For North Office:

DF(Target)= 2.0%

t_{vis} = 0.72

θ = 90°

$$WWR > \frac{2}{10x0.72}\frac{90}{90} = 0.27 = 27\%$$

Actual WWR for both

Actual WWR = 2x(1.52m x 1.83m)/ (3.05m x 8m) = 23%

Where is the sun?

The Analemma

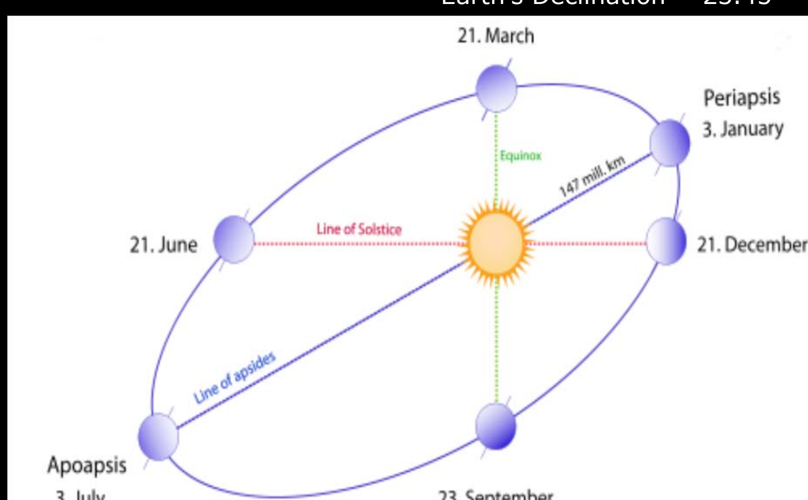
Photograph of analemma removed due to copyright restrictions.

Source: *http://www.uwm.edu/~kahl/Images/Weather/Other/analemma.html*

Declination, Solar Time Adjustment (elliptic movement, site longitude, Daylight Savings Time); Solar time vs. local time.

Earth Orbit around the Sun

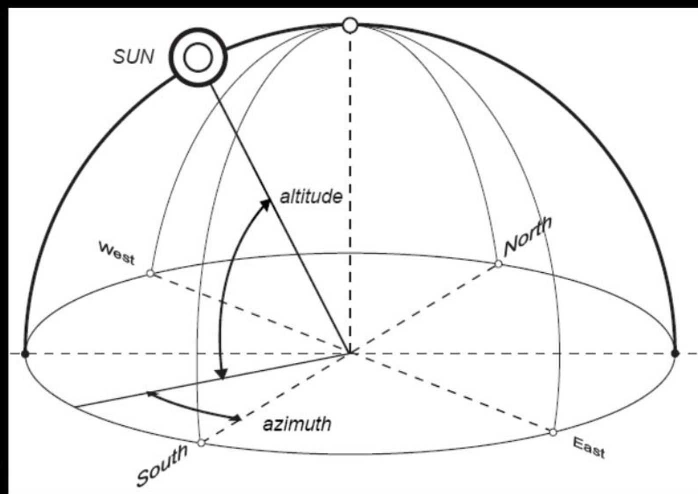
Earth's Declination 23.45°



Elliptical path; declination 23.45°

Source: NASA

Local Coordinate System



What time is it?

- ❑ In our daily life we commonly refer to our location's standard local time.
- ❑ Standard times are synchronized with the times of all other locations within the same time zone.
- ❑ Greenwich Mean Time (GMT) is the local time at Greenwich, England.
- ❑ In Boston we are five time zones west of Greenwich (GMT 5).
- ❑Time zones divide the earth into 24 strips that are each about 15° wide even though time zones also follow political and geographic boundaries.

Why a standard time?

- ❑ The introduction of a standard time facilitates long distance travel and communication.

- ❑ A disadvantage of using standard time is that our experience of time is not directly linked to the position of the sun any more.

- ❑Before the introduction of standard time in the US in 1883, different versions of solar time were used instead.

- ❑ In true solar time it is noon exactly when the sun is located to the South (azimuth angle equals zero).

- ❑ Solar time Boston is about 11 minutes ahead of solar time New York since both cities have different longitudes.

Equation of Time

- ❑A second difference between standard time and solar time is caused by the elliptical movements between sun and earth. As a result of these movements, the time between two solar noons can be about 15 minutes shorter or longer than 24 hours depending on the time of year. This time difference is called the 'equation of time'.

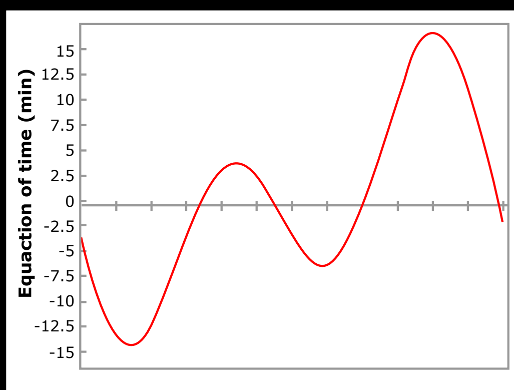
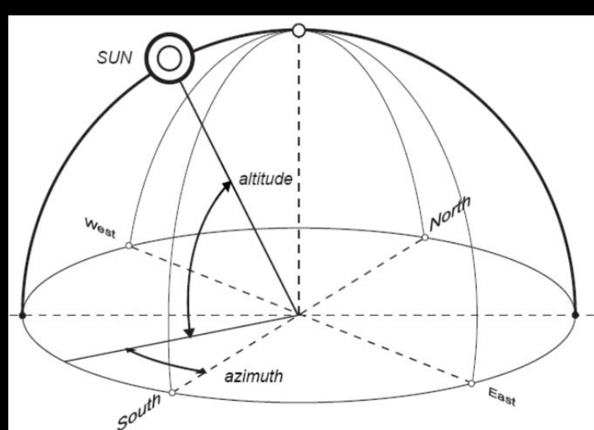


Image by MIT OpenCourseWare.

From Duffie & Beckman *Solar Engineering of Thermal Processes*

Solar Time = Standard Time
+ 4x(Longitude$_{standard}$ – Longitude$_{observer}$)
+ equation of time

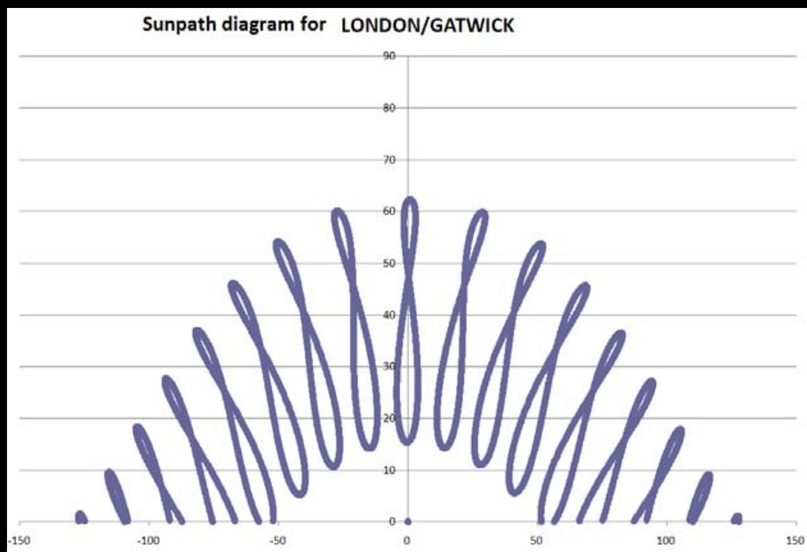
Sun Position



$$Azimuth = \tan^{-1}\left(\frac{\cos(Dec)\sin\left(\frac{ST}{24}\right)}{-\cos(latitude)\sin(Dec) - \sin(latitude)\cos(Dec)\cos\left(\frac{ST}{24}\right)}\right)$$

$$Altitude = \sin^{-1}\left(\sin(latitude)\sin(Dec) - \cos(latitude)\cos(Dec)\cos\left(\frac{ST}{24}\right)\right)$$

Sun Path Diagram



Generated with GSD Climate File Analyzer

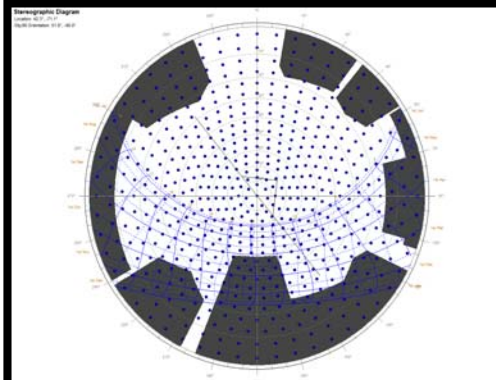
Sun Chart Examples in Ecotect

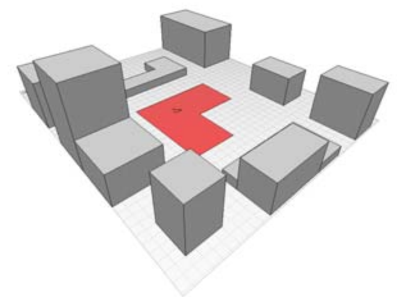
- *Stereographic vs. orthographic sun chart diagram*
- *Local time vs. solar time (Boston, New York City)*
- *Move from equator to pole*
- *Southern vs. Northern hemisphere*
- *Solar Altitude range at noon = 90^o – latitude $\pm 23.45^o$*
- *Example Cambridge (42.4^oN): $90^o - 42.4^o \pm 23.45^o$*

  24^o to 70^o

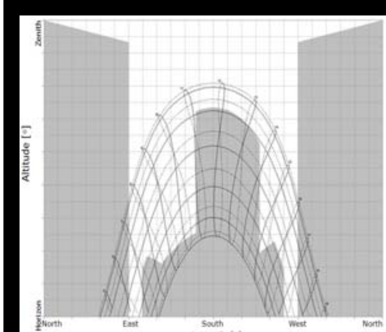
Shading Masks

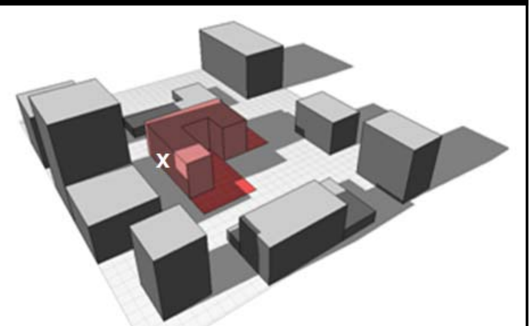
A shading mask combined a sun path diagram with neighboring objects such as buildings and landscape that lie between a reference point and the celestial hemisphere.





Sun Chart with Shading Mask





Autodesk Ecotect Shading Study

Urban Shading Studies

Street Orientation

- ❑ discussion of the Jeffersonian and Spanish grid: thermal comfort vs. glare

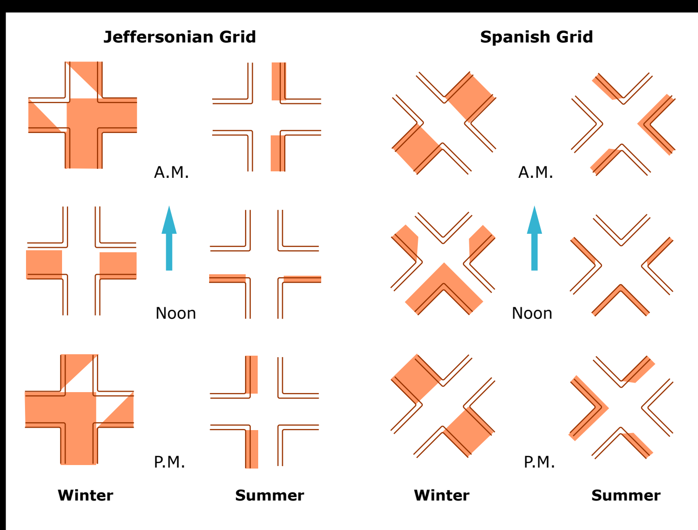


Image by MIT OpenCourseWare.

Solar Envelopes/Solar Fans

- A solar envelope defines the maximum buildable volume within a given site that does not shade adjacent sites during a certain time of the day and year, thereby assuring the availability of direct solar sunlight for those sites.

- The concept goes back to Ralph Knowles.(Ralph L. Knowles, 1978, *Energy and Form: An Ecological Approach to Urban Growth)*. The concept is also described in *Sun, Wind and Light* by Brown & deKay (Ch 29).

Ralph L. Knowles, 1978, Energy and Form: An Ecological Approach to Urban Growth

Geometric Construction of a Solar Envelope

- Assume a rectangular site in Miami (25° North) and require the to not shade adjacent site from 9AM to 3PM all year.

Step 1: Get solar azimuth and altitude on Dec/Jun 21 at 9AM/3PM in Miami.

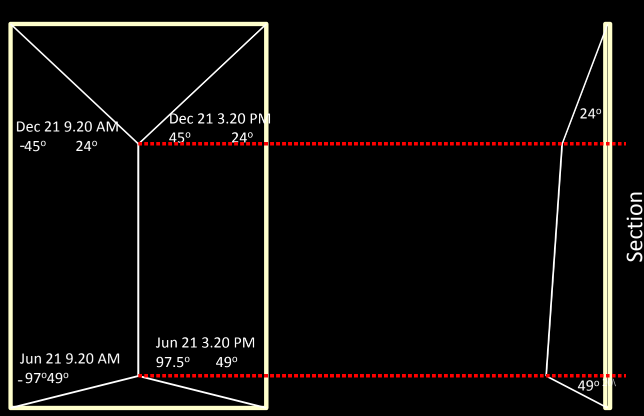
Geometric Construction of a Solar Envelope

Step 1: Get solar azimuth and altitude on Dec/Jun 21 at 9.00/15.00 solar time (corresponds to around 9.20 and 15.20 local time) in Miami:

	azi	alt	
Jun 21 9.20	- 97°	49°	(round so that both azimuth and altitudes are the same)
Jun 21 15.20	97°	49°	
Dec 21 9.20	- 45°	24°	
Dec 21 15.20	45°	24°	

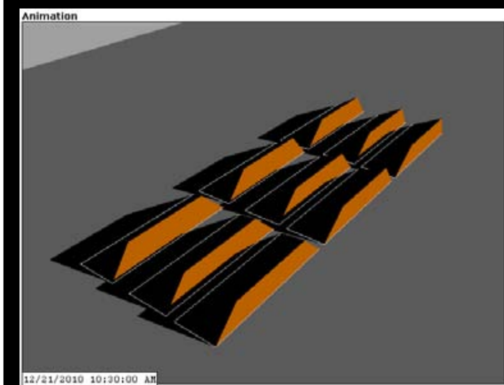
Geometric Construction of a Solar Envelope

Step 2: Draw the angles in plan and section on the four corners of the site:

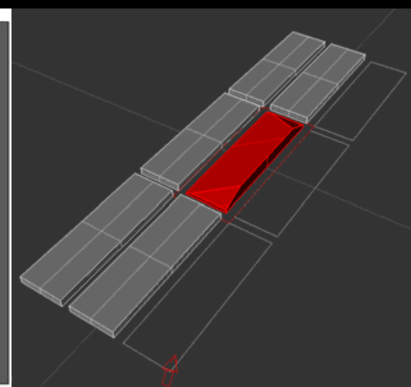


Plan

Solar Envelope Grasshopper Script



DIVA Grasshopper Script

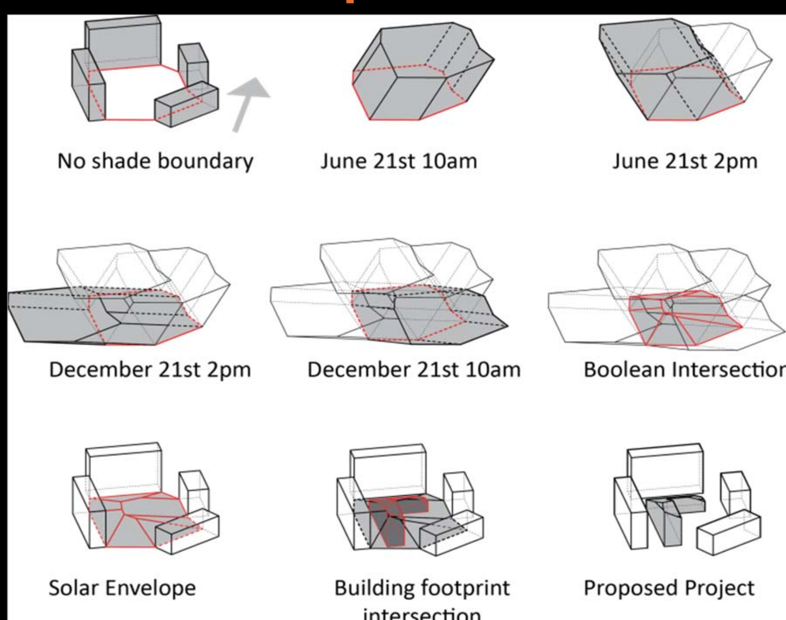


Solar Envelope with Urban Canyons

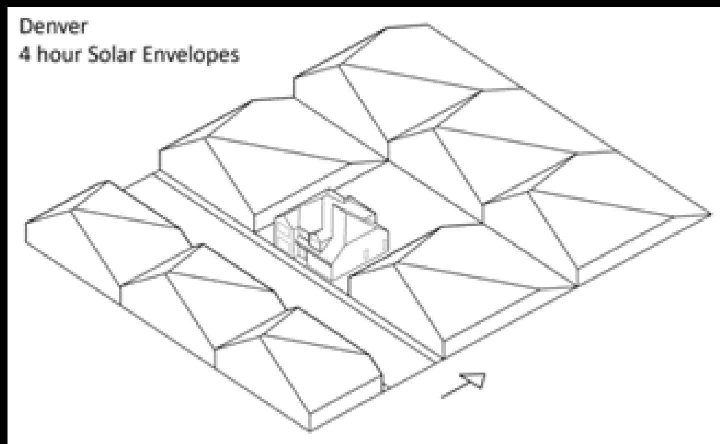
An urban and a local consideration/formgiver.

The script comes with DIVA for Rhino (www.diva-for rhino.com)

How does the script work?



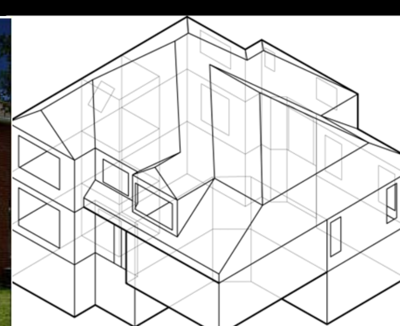
Solar Zoning and Energy in Detached Residential Dwellings



Niemasz, Sargent, Reinhart:
www.gsd.harvard.edu/research/gsdsquare/Publications/Solar_Envelope.SimAUD2011.pdf

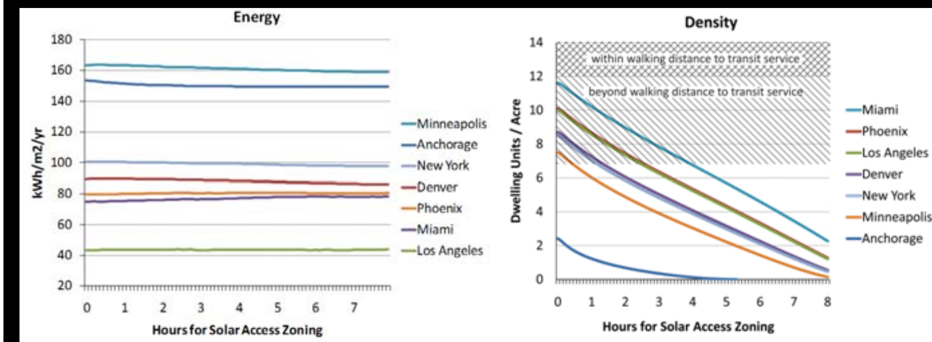
Solar Zoning and Energy in Detached Residential Dwellings

Canadian Center for Housing Technology (CCHT)



Grasshopper/E+ model of CCHT

Solar Zoning and Energy in Detached Residential Dwellings



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Niemasz, Sargent, Reinhart:
www.gsd.harvard.edu/research/gsdsquare/Publications/Solar_Envelope.SimAUD2011.pdf

Solar Fan

- ❑ Maintaining solar access to an outdoor site such as a park or sidewalk.
- ❑ The 'inverse' of the solar envelope.
- ❑ A good criteria can be the to maintain 6 hours of direct sunlight on the first frost of the season.
- ❑ Go through epw file to find the first frost date of the season.