SHADING CALCULATIONS FOR PASSIVE HOUSES ACCURACY MATTERS ! THE NEW PHIUS+ 2018 SHADING METHODOLOGY

PASSIVE HOUSE ALLIANCE UNITED STATES

PHIUS

Passive House Institute US

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13th NAPHC Boston - Sept. 22, 2018

Outline:

TRANSPARENT COMPONENTS - SOLAR PROTECTION

POTENTIAL SHADING ELEMENTS

- Reveals, mullions
- Landscape Obstructions (volumes, planes)
- Roof overhangs, cantilevers, moldings, canopies
- Sunscreen devices
- ‘Other’ shading reduction factor

REVEALS

Depth: of window reveal (in)
Distance: from edge of glazing to reveal (in)

Image credit: 1156 Karpiak.

Image credit: 1236 Madrona

Previous methodology:

Reveal numeric entries were not visualized into the WUFI Passive model.

New methodology addresses:

- Reveal shading to the left and right sides of the window from the window in-set in the wall.
- Windows that have dissimilar reveal depths/distances (Bump-out reveal shading. Such as 'L' shaped buildings.
- Depth of reveals on mulled windows (reveals about the same on both sides but the edge-to-reveal distance is different left and right).

LANDSCAPE OBSTRUCTION

Height of obstruction: from window sill to the top of the shading object

Distance of obstruction: from glass pane to highest point shading object

Previous methodology:

Height and distance of obstructions were estimated by the angle of obstruction.

It helped simplify the approach because of possible many objects in the distance at varying distances away.

New methodology addresses:

Site shading inputs can now be added into the geometry. It allows having a more accurate calculation from:

- Volumes (neighboring houses).
- Planes (fences, tree lines).
- Obstructions for windows in tall floors.

WINDOW OVERHANG

Depth
Vertical distance

Image credit: 1058 Orchards St.

Previous methodology:

- Overhang calculated “directly above the window”
- Couldn’t model a continuous overhang on a façade.
- Other limitations – couldn’t accurately assess overhangs from slanted roofs

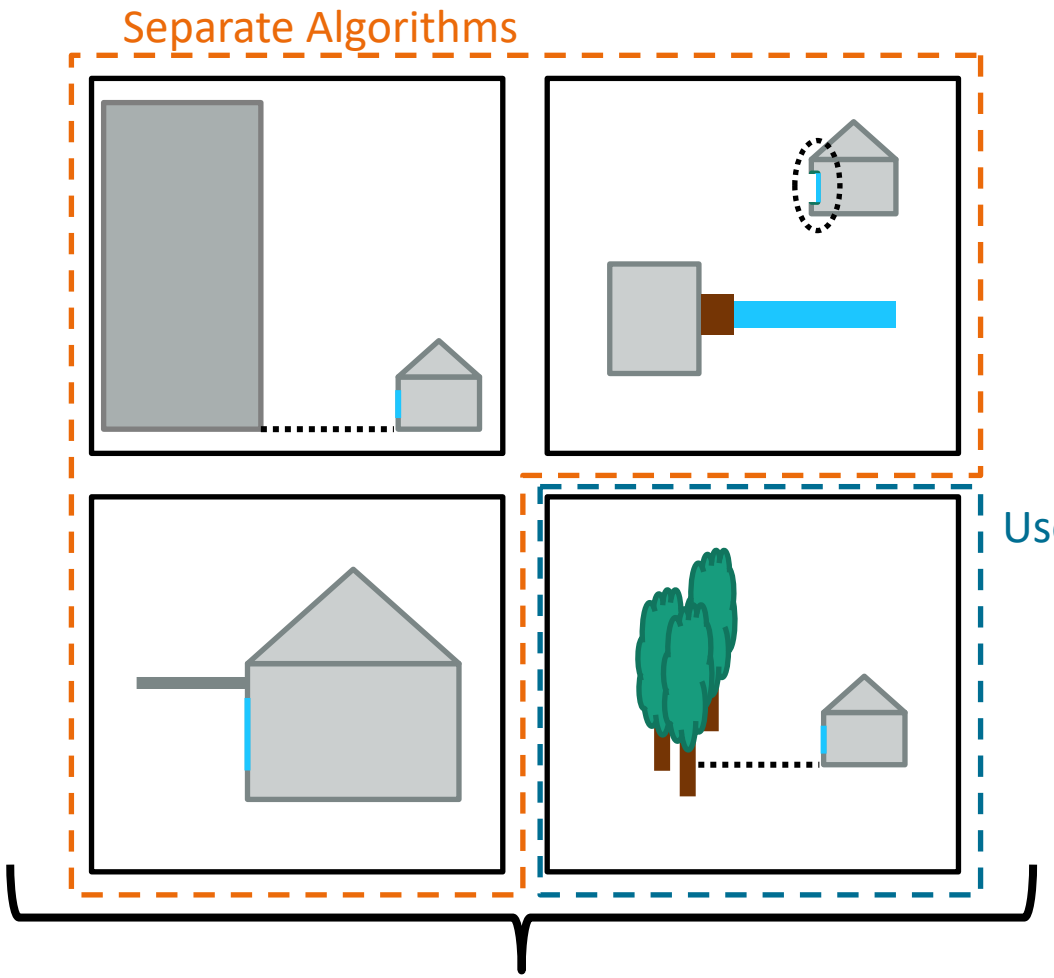
In the new methodology:

Shading elements can be added into the building geometry.

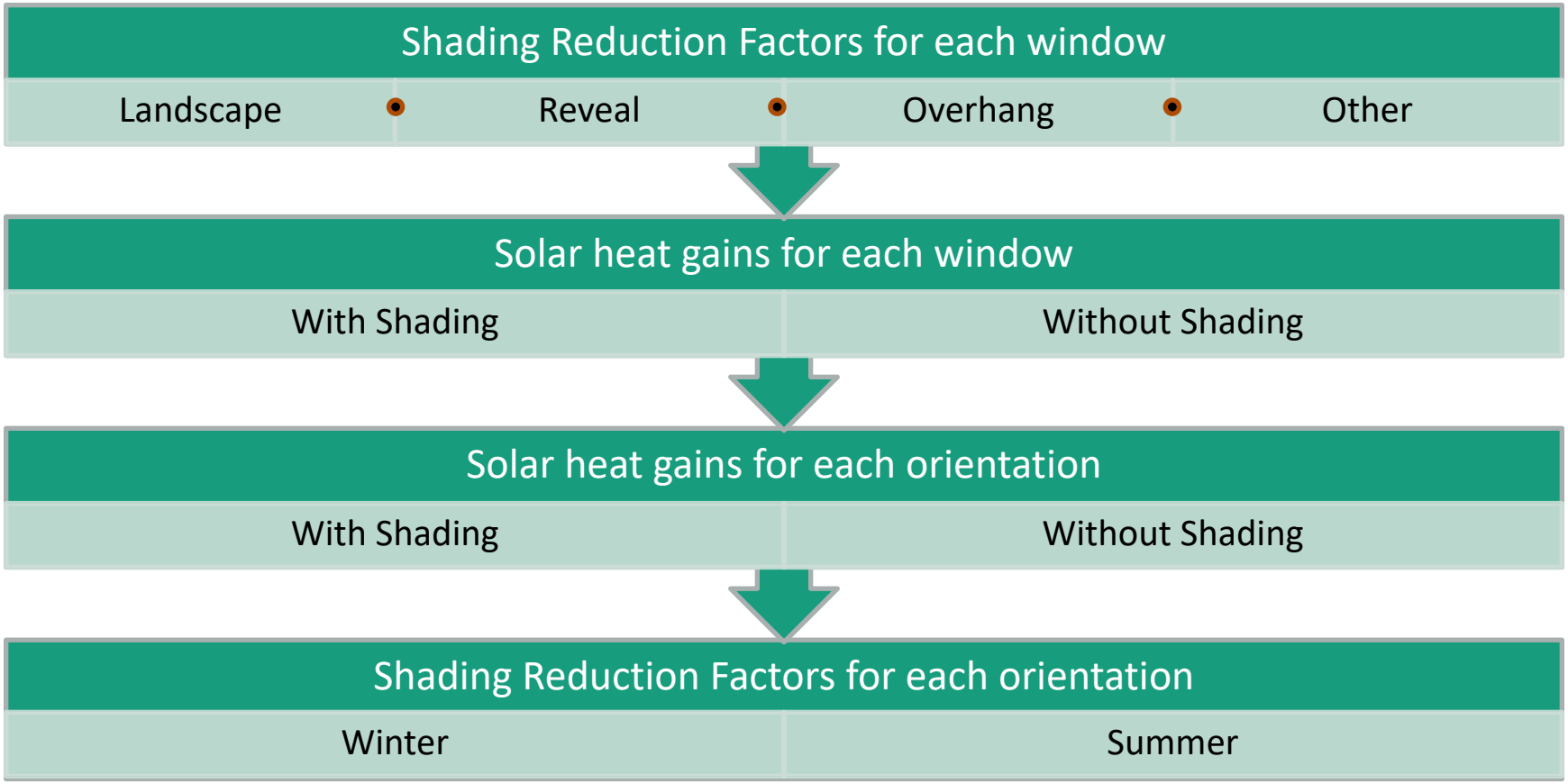
More accurate calculation from:

- Continuous overhangs
- Roof eaves
- Cantilevers
- Moldings on facades

Previous Methodology



Previous Methodology

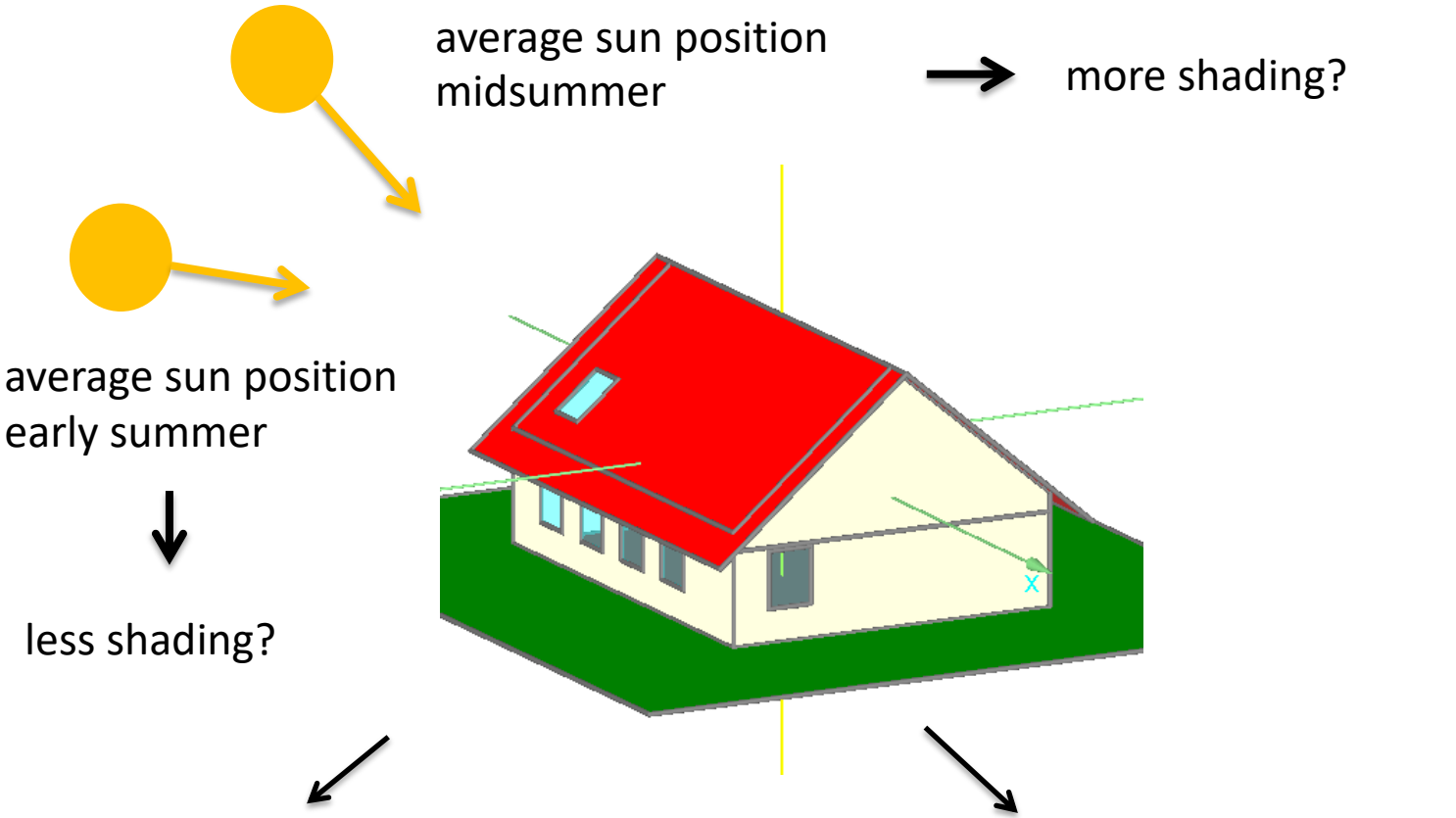


Previous Methodology

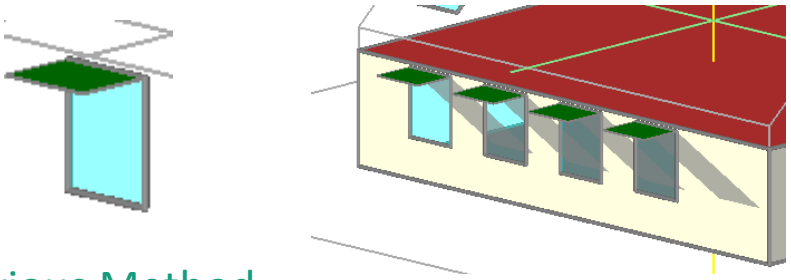
Shading Reduction Factors for each orientation	
Winter	Summer
Used for calculation of solar heat gains in: ▪ Heating demand ▪ Heating load	Used for calculation of solar heat gains in: ▪ Cooling demand ▪ Cooling load ▪ Overheating frequency

→ Shading reduction factors are of high importance for calculation of solar heat gains and passive house design

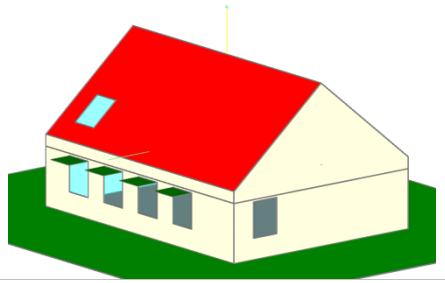
Orientation and Inclination

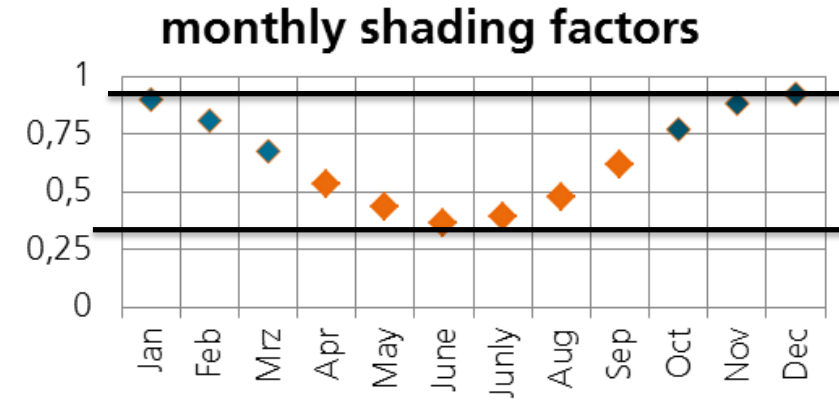


Shading Combination

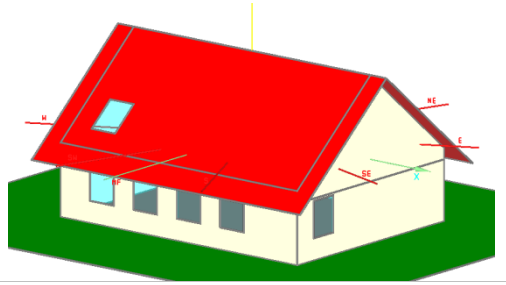


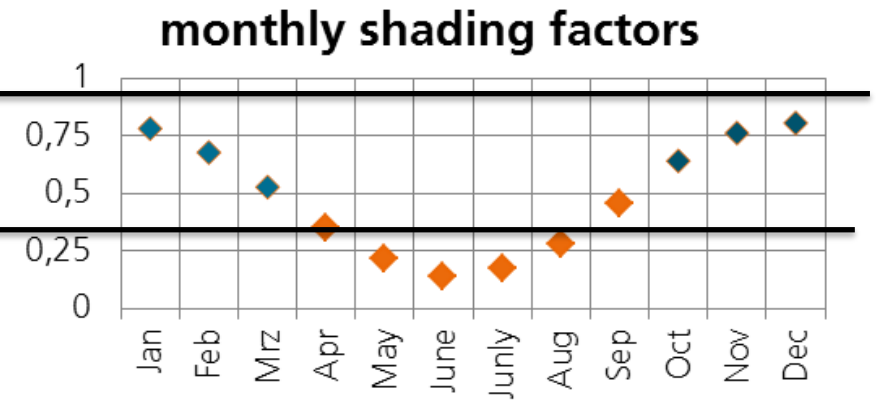
Previous Method





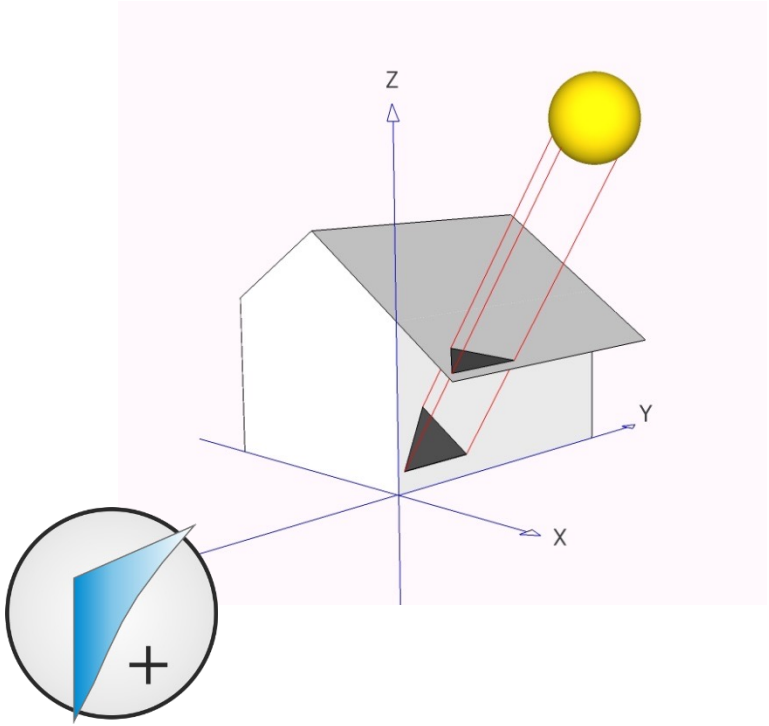
New Method

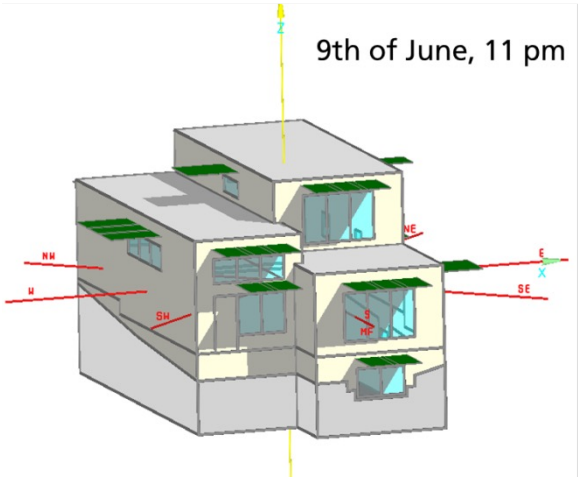


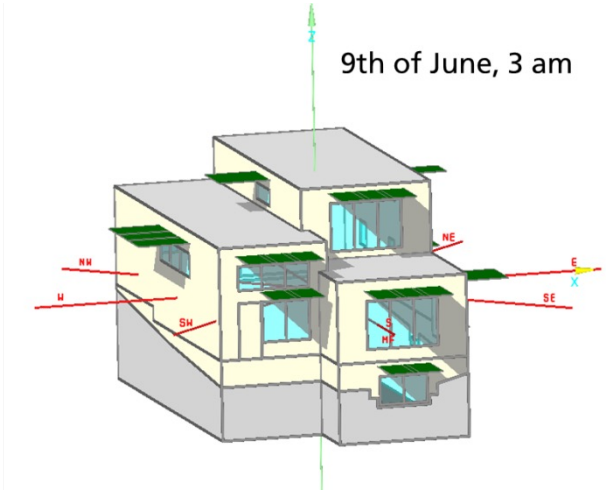


Fraunhofer IBP

Dynamic shading model in WUFI® Plus





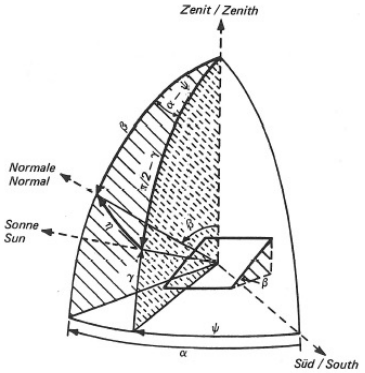


So how do we get to monthly shading factors?

- Sun position (solar altitude, solar azimuth)
  - Component surface incidence angle
- Shading data
  - Direct and diffuse shading
- Hourly radiation data for representative days
  - Direct and diffuse horizontal radiation
  - Solar radiation on an inclined surface towards the sun

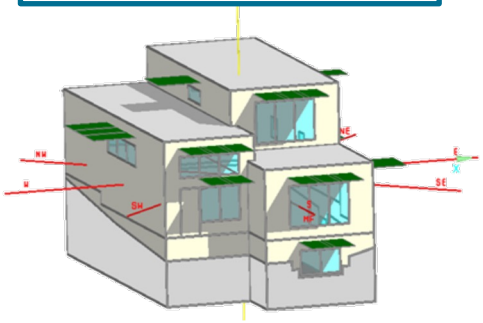
→ **Monthly shading factors**

Monthly dynamic shading calculation

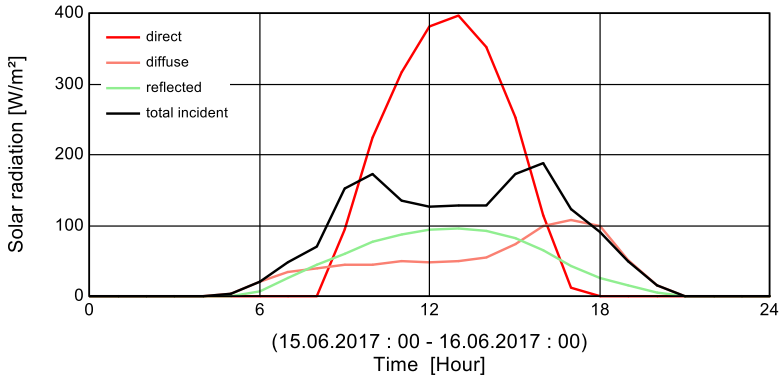


surface sun incidence angle

Shading data



Sun radiation data



Monthly shading factors

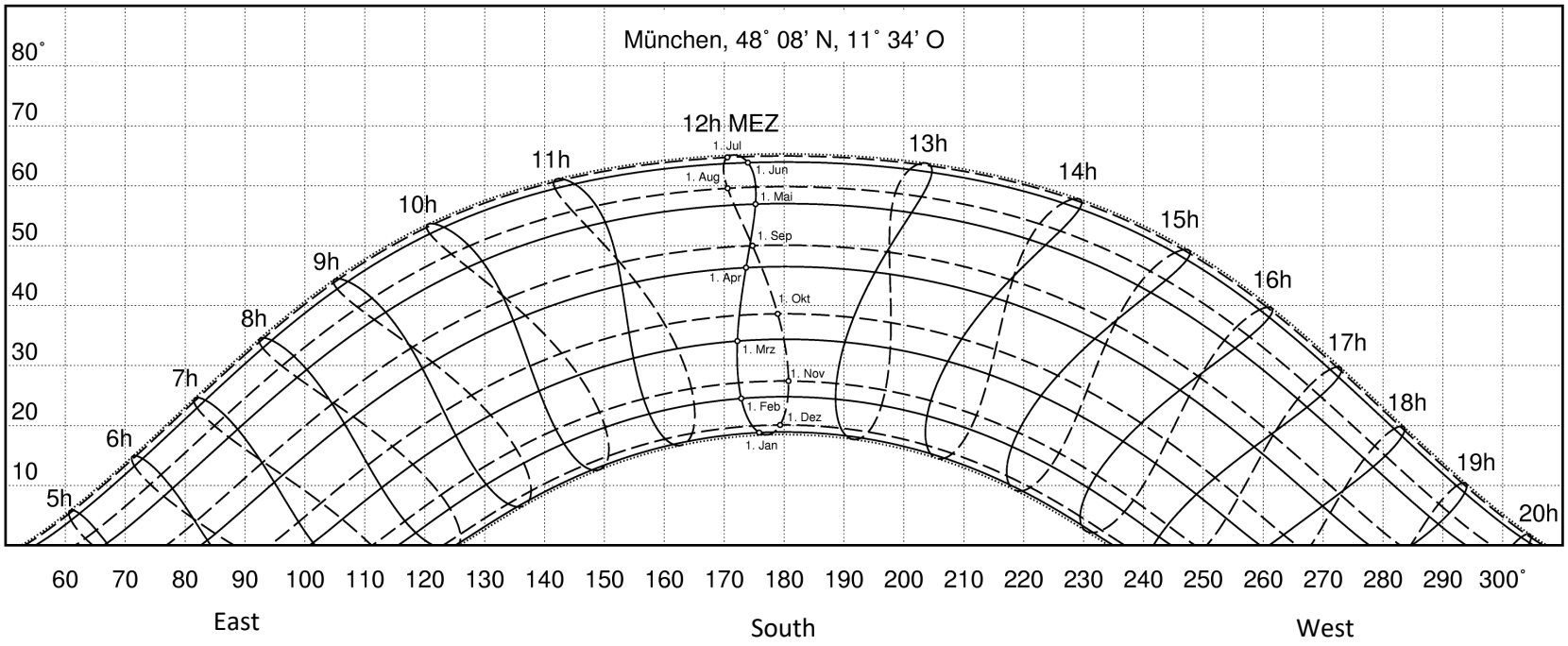
Jan.	Feb.	March	April	May	June	July	Aug.	Sept.,	Oct.	Nov.	Dec.
0,76	0,784	0,822	0,848	0,856	0,858	0,858	0,85	0,834	0,803	0,762	0,747

Fraunhofer IBP

Sun Incident Angle

Calculation of solar position

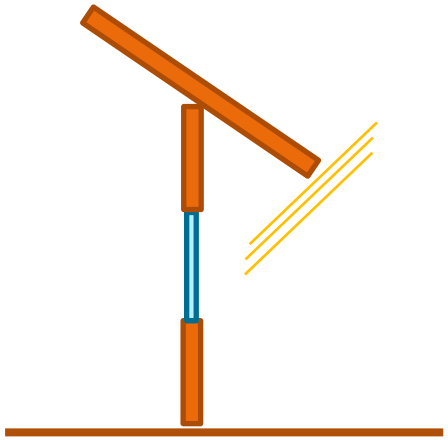
- Time depended solar position (solar altitude, solar azimuth)



Fraunhofer IBP

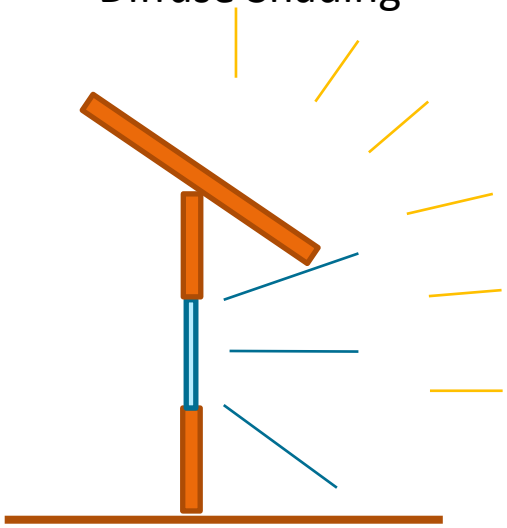
Direct and Diffuse Radiation Shading

Direct Shading



Dynamically dependent on solar position

Diffuse Shading

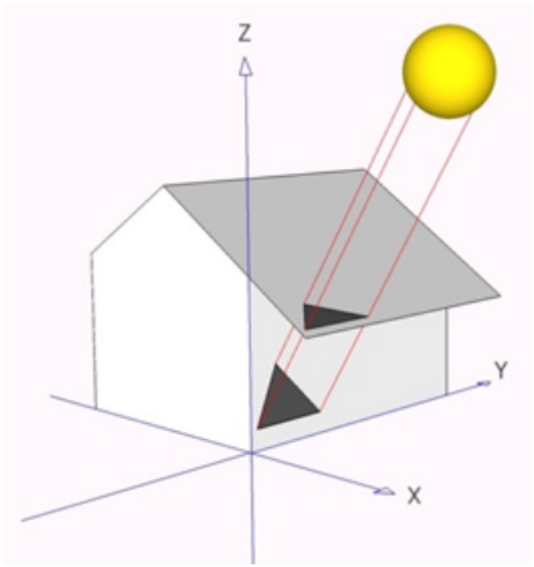


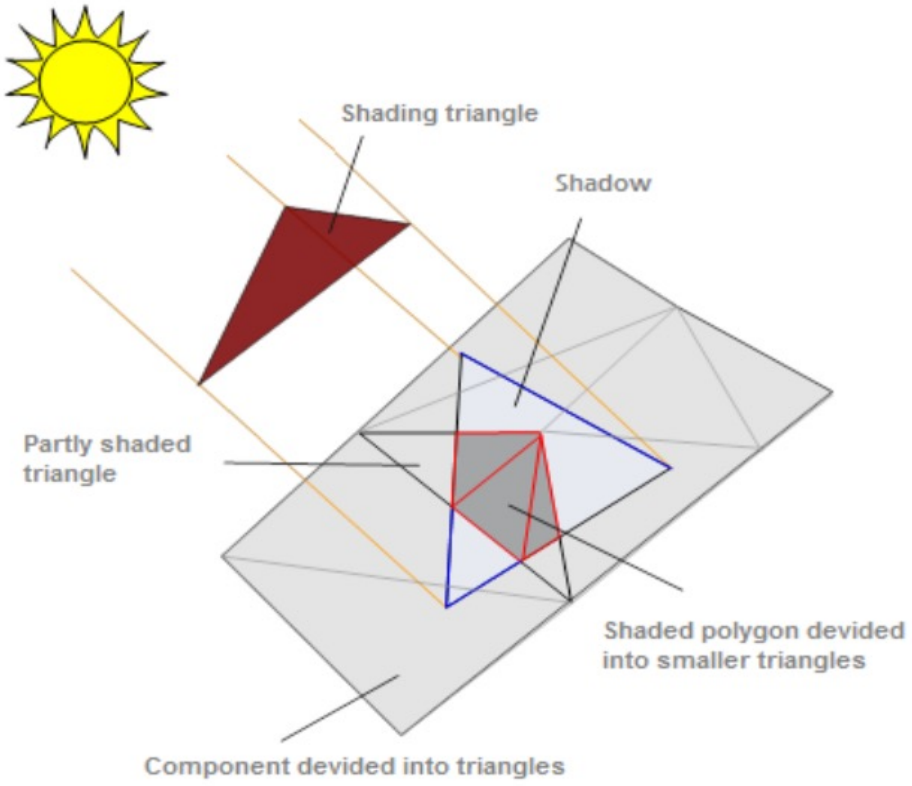
Static dependent on view factor window / surrounding

- Part of hemisphere
- Other shading components

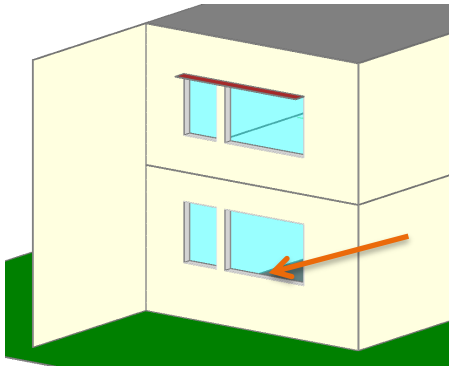
Dynamic Direct Shading

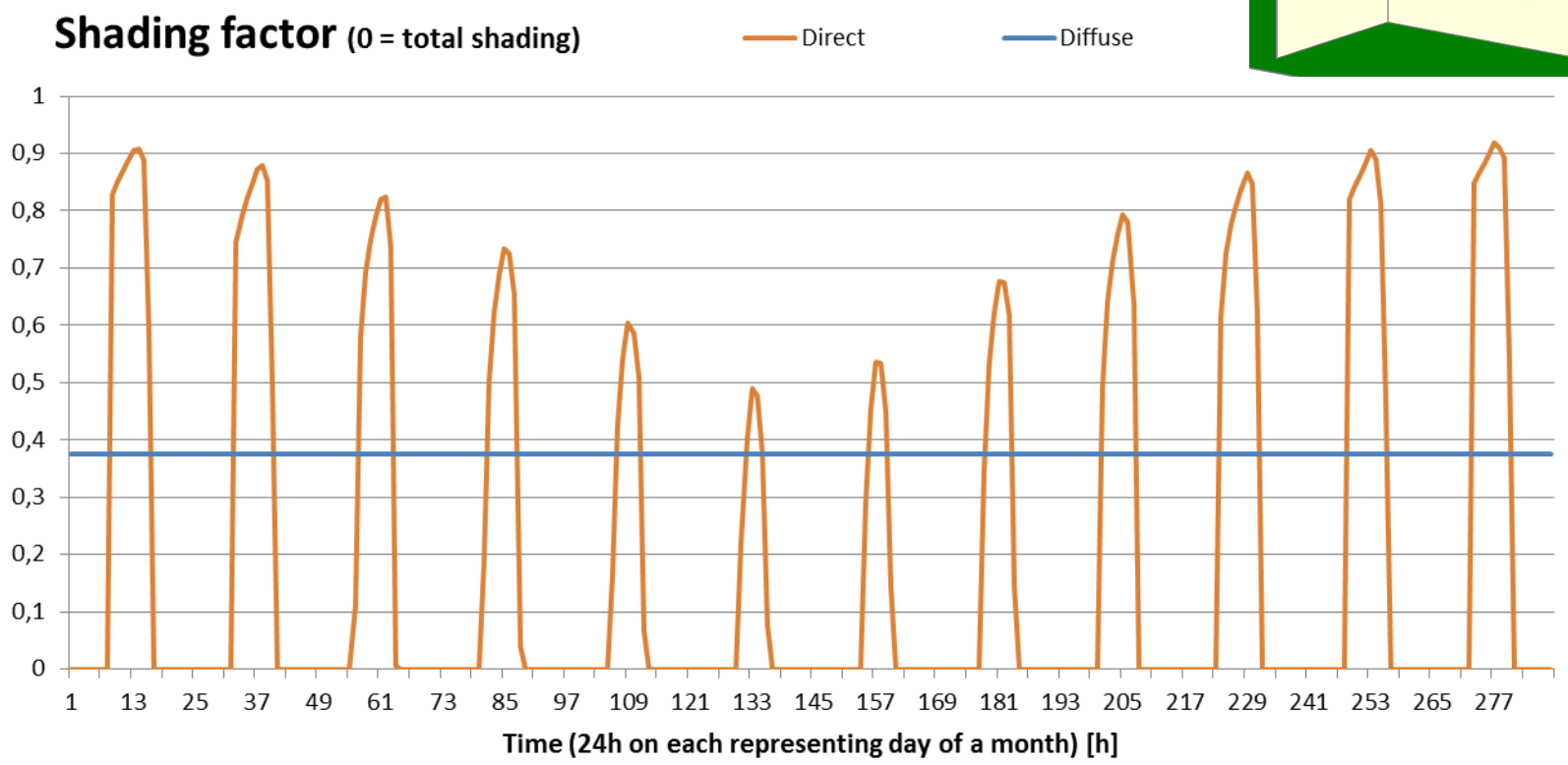
- Every shading component visualized in building geometry (as flat polygon)
- Shading is calculated with tri-angularization (shading overlap from triangle to triangle)





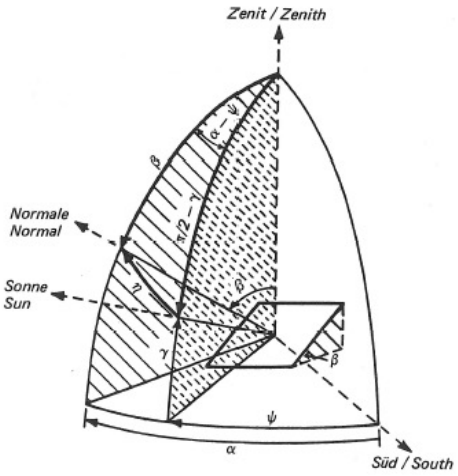
Direct and Diffuse Shading Factors per Month





Fraunhofer IBP

Clear Sky Radiation



Sun Position

Calculated according to Haurwitz (1945):

$$G = 1098\, cos(\gamma) * exp\left(\frac{-0.057}{\cos(\gamma)}\right)$$

G = Global Radiation

γ = Solar Altitude Angel

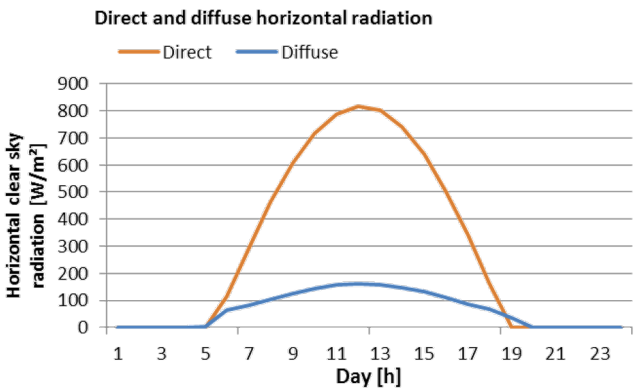
- Direct solar radiation on a horizontal surface

$$I = G - D$$

- Diffuse solar radiation

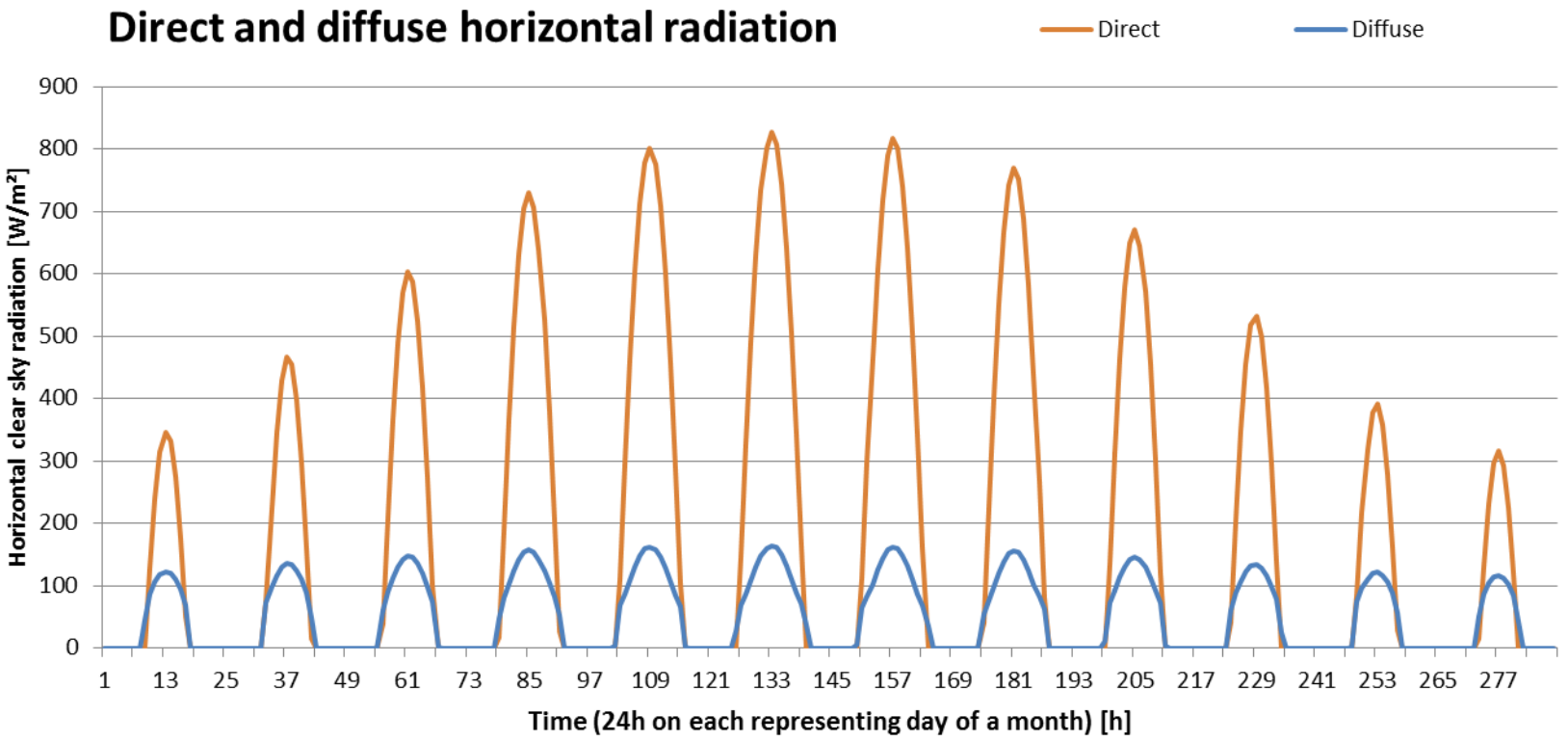
$$D = G * fd$$

G = Global Radiation
D = Diffuse Radiation
I = Direct Radiation on horizontal surface
fd = Turbidity factor



Fraunhofer IBP

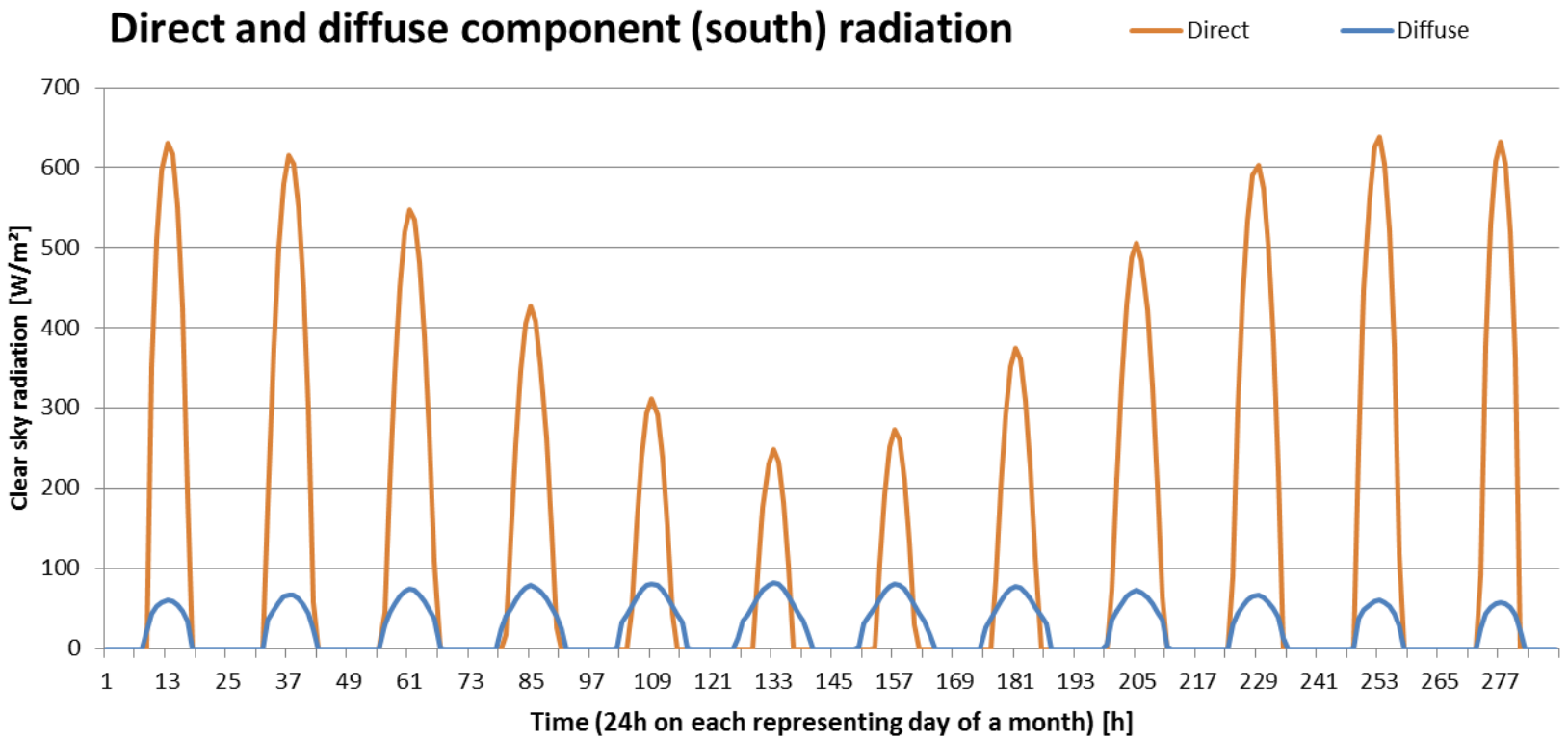
Clear Sky Radiation per Month Horizontal



Example case for Munich for the direct and diffuse horizontal clear sky radiation.

Fraunhofer IBP

Clear Sky Radiation per Month and Orientation



Example case for Munich for the direct and diffuse horizontal clear sky radiation.

Fraunhofer IBP

Monthly dynamic shading calculation

Monthly shading factors

- Input:
  - Direct radiation on component (12 Months, each 24 hours the representing day)
  - Diffuse radiation on component (12 Months, each24 hours the representing day)
  - Dynamic direct shading on each component (12 Months, each24 hours for representing day)
  - Diffuse constant shading on each component (constant whole year)
- Output:
  - Monthly shading factors for every transparent component
- Steps to be done:
  - Weight direct shading factors and diffuse shading factors

Calculation of Monthly Dynamic Shading Factors

- For each month for every single window dependent on orientation / inclination:
  - Hourly dynamic shading factor multiplied by the hourly direct radiation
  - Constant diffuse shading factor multiplied by the hourly diffuse radiation

→ Sum of radiation with shading

- Repeat without shading

→ Sum of radiation with shading

- Divide sum of radiation with shading by the sum of radiation without shading

→ Shading factor per month and component

$$F_{Month=} \frac{\left(\sum_{t=0}^{24} I(\beta,\alpha)_t \cdot F_{Dir_t} + \sum_{t=0}^{24} D(\beta,\alpha)_t \cdot F_{Diff_t}\right)}{\left(\sum_{t=0}^{24} I(\beta,\alpha)_t + \sum_{t=0}^{24} D(\beta,\alpha)_t\right)}$$

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.,	Oct.	Nov.	Dec.
0,76	0,784	0,822	0,848	0,856	0,858	0,858	0,85	0,834	0,803	0,762	0,747

Solar gain with monthly shading factors

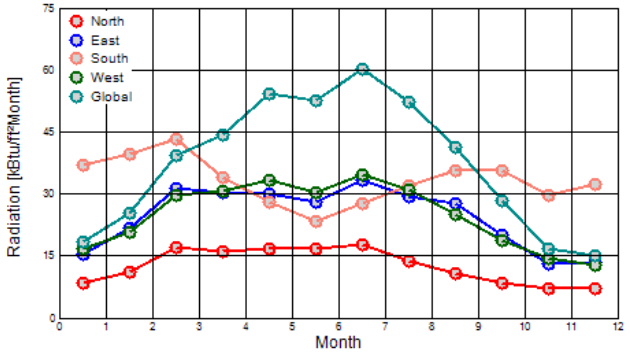
SolarGain = RadiationFromClimateFile *

MonthlyShadingFactor *

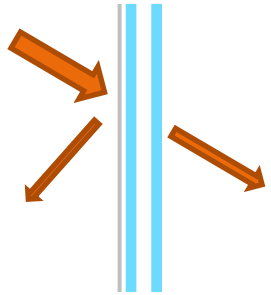
DirtWindowConstant *

NonPerpendicularRadiation *

SolarHeatGainCoefficient



Jan.	Feb.	March	April	May	June	July	Aug.	Sept.,	Oct.	Nov.	Dec.
0,76	0,784	0,822	0,848	0,856	0,858	0,858	0,85	0,834	0,803	0,762	0,747



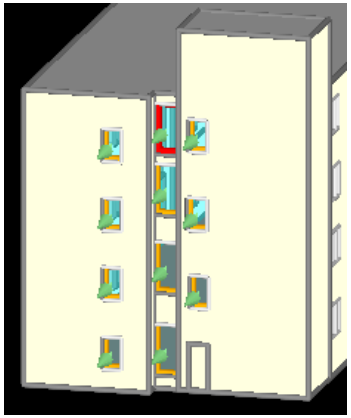
- DirtWindowConstant = 0.95
- NonPerpendicularRadiation = 0.85

Implementation of Shading Factors

The real shading factors unique for every window is used as follows:

- Demand Calculation: Monthly factors
- Heating Load Calc: January factor
- Cooling Load Calc: July factor
- Detailed Day Calc: July factor

The “old” shading calculation for the reveal, distant shading elements and for overhangs are not used with monthly shading!



Month mean shading factors

Speed setting	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.,	Oct.	Nov.	Dec.
South (A160,3°, 15 ft²)	0,627	0,559	0,473	0,352	0,262	0,235	0,242	0,301	0,417	0,529	0,6	0,641
South (A160°, 29,99 ft²)	0,517	0,496	0,459	0,38	0,317	0,287	0,299	0,345	0,424	0,484	0,508	0,518

Case studies
ASSESMENT

Seattle, WA	LAT	47.68	CZ	4C
Portland, OR		45.6		4C
Aberdeen, SD		45.45		6A
Rockford, IL		42.2		5A
Sharon, CT		41.9		5A
Chicago, IL		41.78		5A
Salt Lake City, UT		40.8		5B
Austin, TX		30.3		3A

PROTOCOL
SHADING ELEMENTS

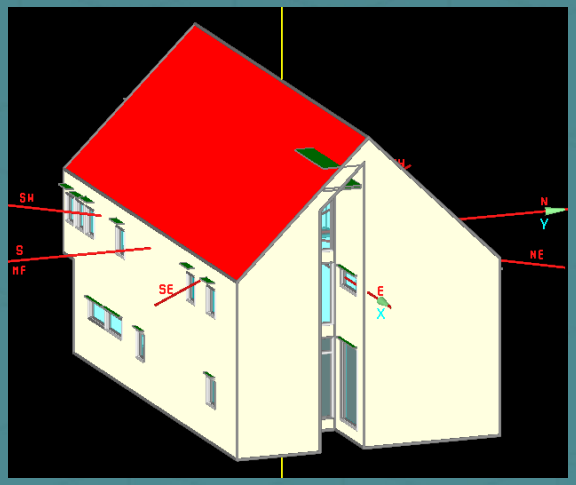
How to model shading elements ?
How far away an object matters ?

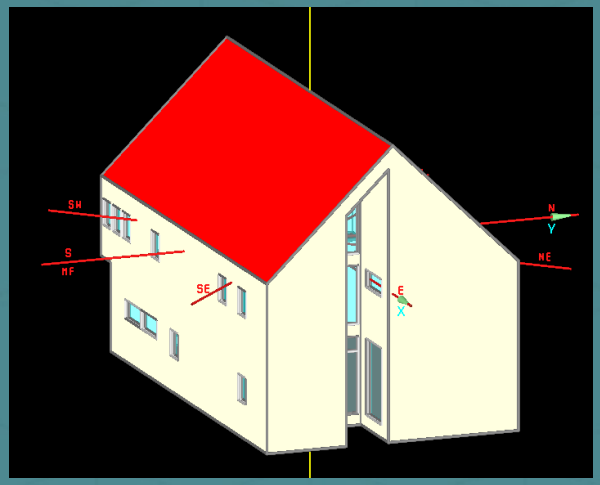
Shading **PROTOCOL**

	Previous methodology	With WUFI Shading
Reveals	Numeric entries (windows openings and (shading elements).	Numeric entries (window openings) OR building geometry
	Calculator for mulled windows and windows with dissimilar reveal depths/distances.	
Landscape obstruction	Numeric entries	From building geometry OR numeric entries
Shading fraction	Numeric entries	Numeric entries
Sunscreen devices	Numeric entries	Numeric entries
Window overhangs	Numeric entries	From building geometry OR numeric entries

Palatine House - Seattle, WA

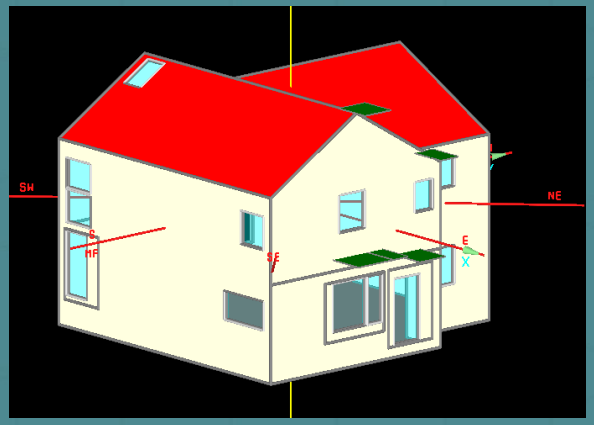
	HD	CD	HL	CL
Old	3.08	0.6	2.98	2.08
New	3.45	0.51	3.05	1.76

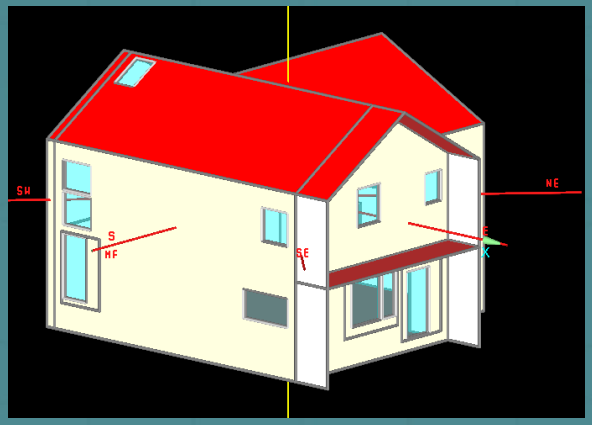




Phoenix House - Portland, OR

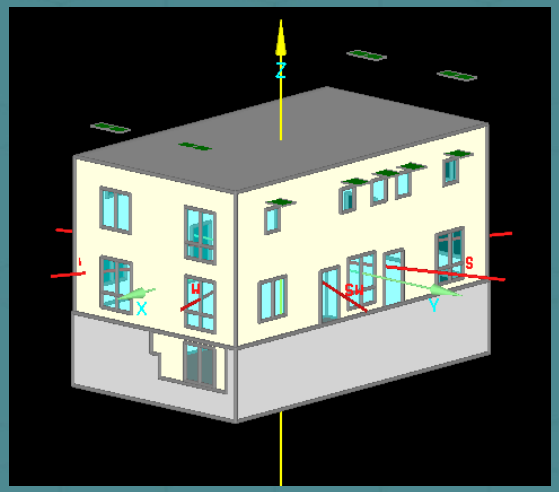
	HD	CD	HL	CL
Old	4.8	0.93	2.62	1.84
New	5.17	0.6	2.72	1.53

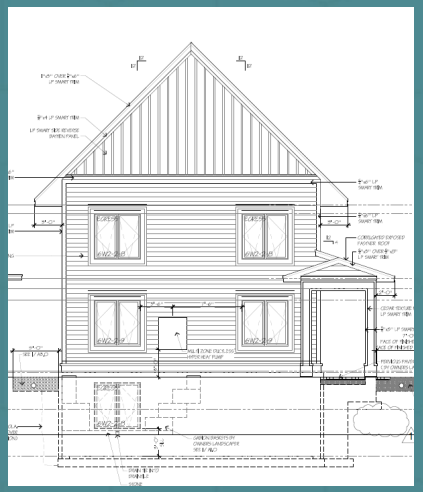


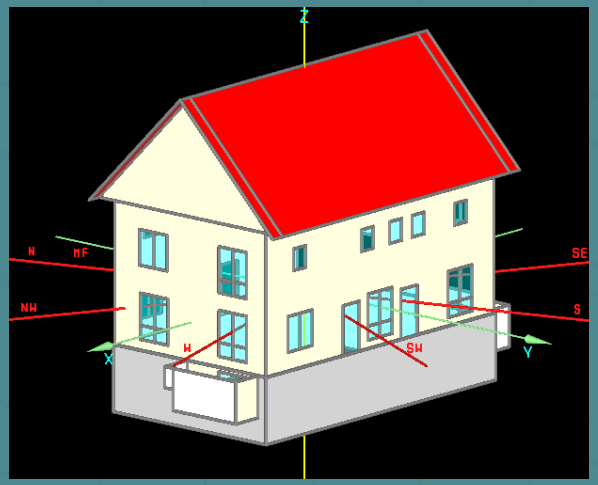


Wildwood Drive - Rockford, IL

	HD	CD	HL	CL
Old	7.73	3.22	5.45	2.43
New	6.75	4	5.12	2.76

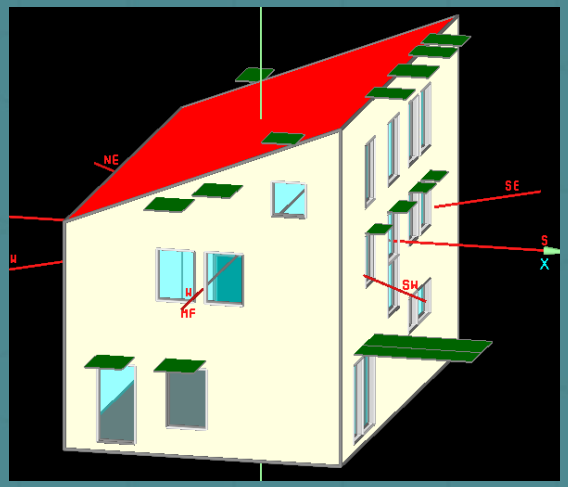


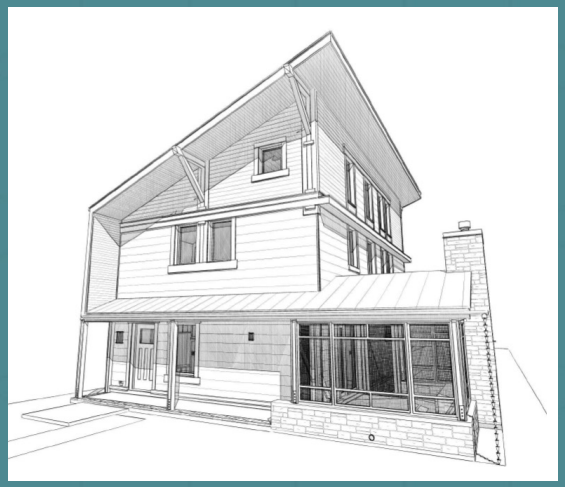


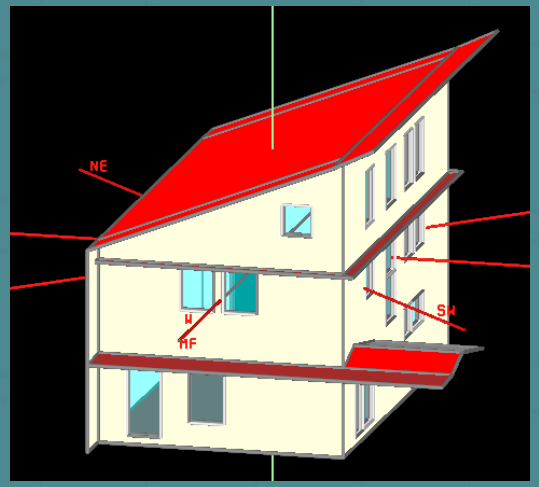


George House - Chicago, IL

	HD	CD	HL	CL
Old	4.7	3.78	5.72	3.36
New	4.86	3.15	5.68	3.02

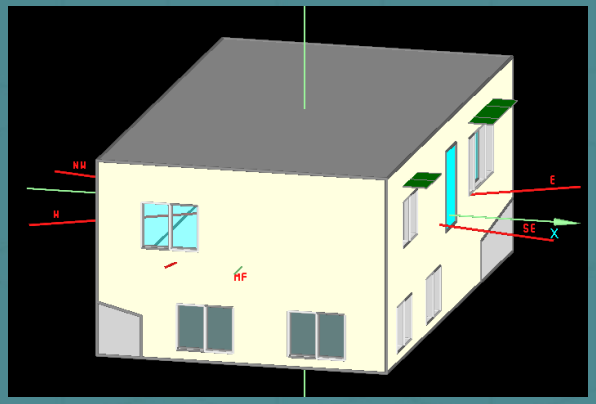


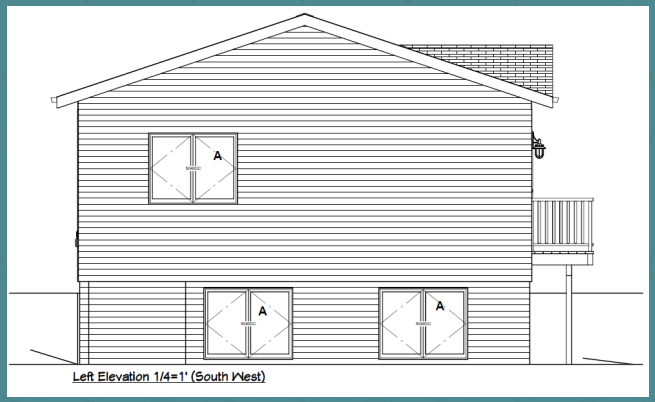


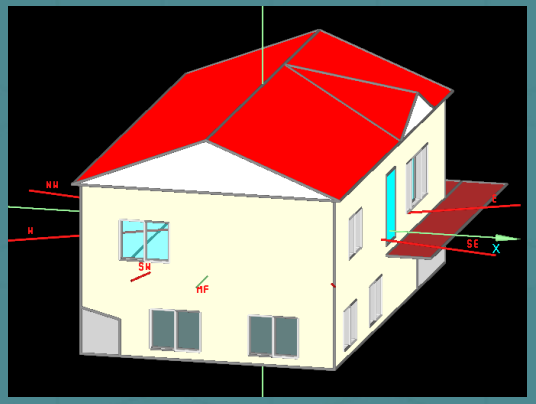


Governor's House - Aberdeen, SD

	HD	CD	HL	CL
Old	4.41	0.55	4.78	1.32
New	4.4	0.46	4.77	1.19

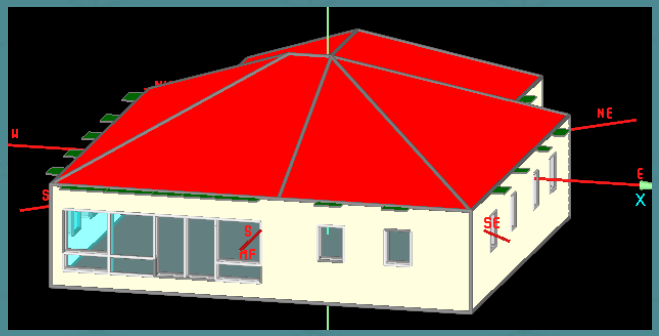


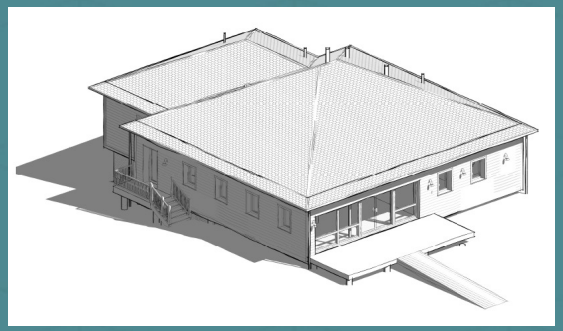


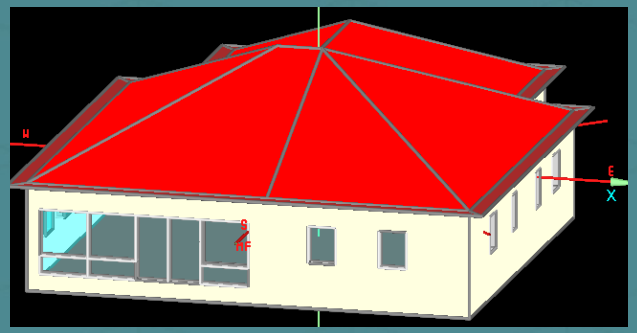


Silver Lake House - Sharon, CT

	HD	CD	HL	CL
Old	9.84	0.92	4	1.59
New	10.32	0.67	3.99	1.31

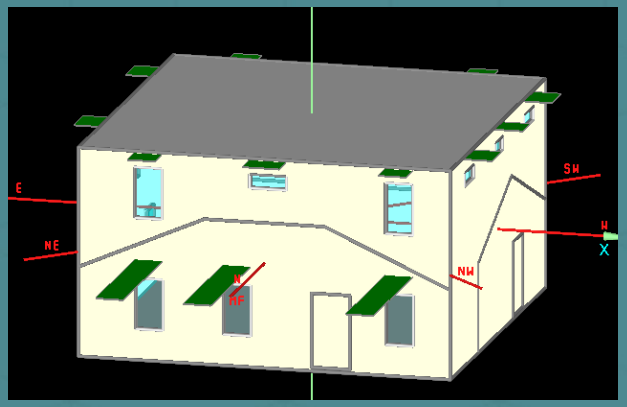


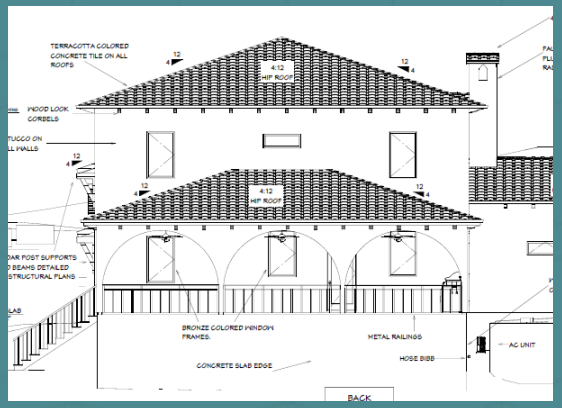


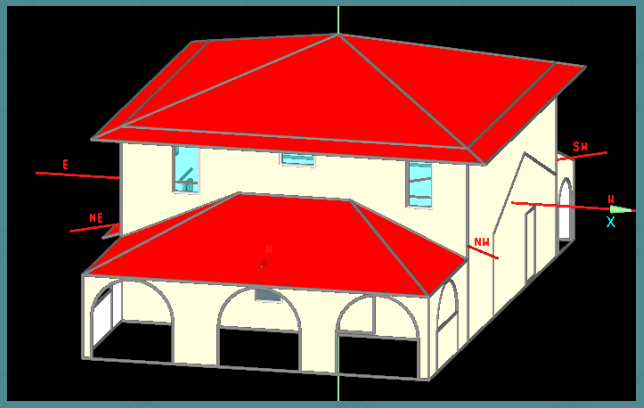


Casa La Vista - Austin, TX

	HD	CD	HL	CL
Old	2.02	10.92	4	2.59
New	1.26	9.19	3.05	2.14







Emery House - Salt Lake City, UT

	HD	CD	HL	CL
Old	3.95	2.76	3.84	2.75
New	4.06	3.02	3.52	2.89

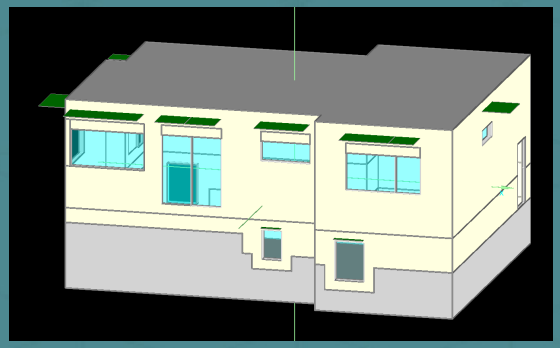
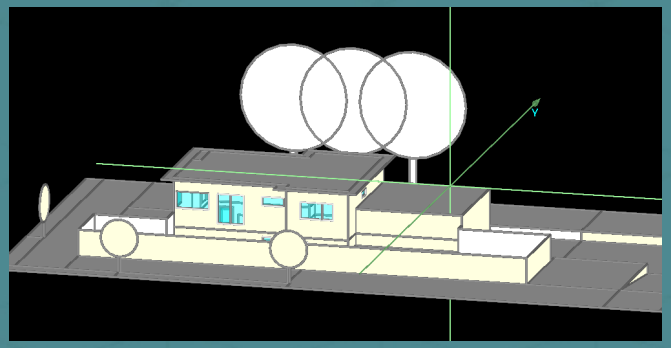
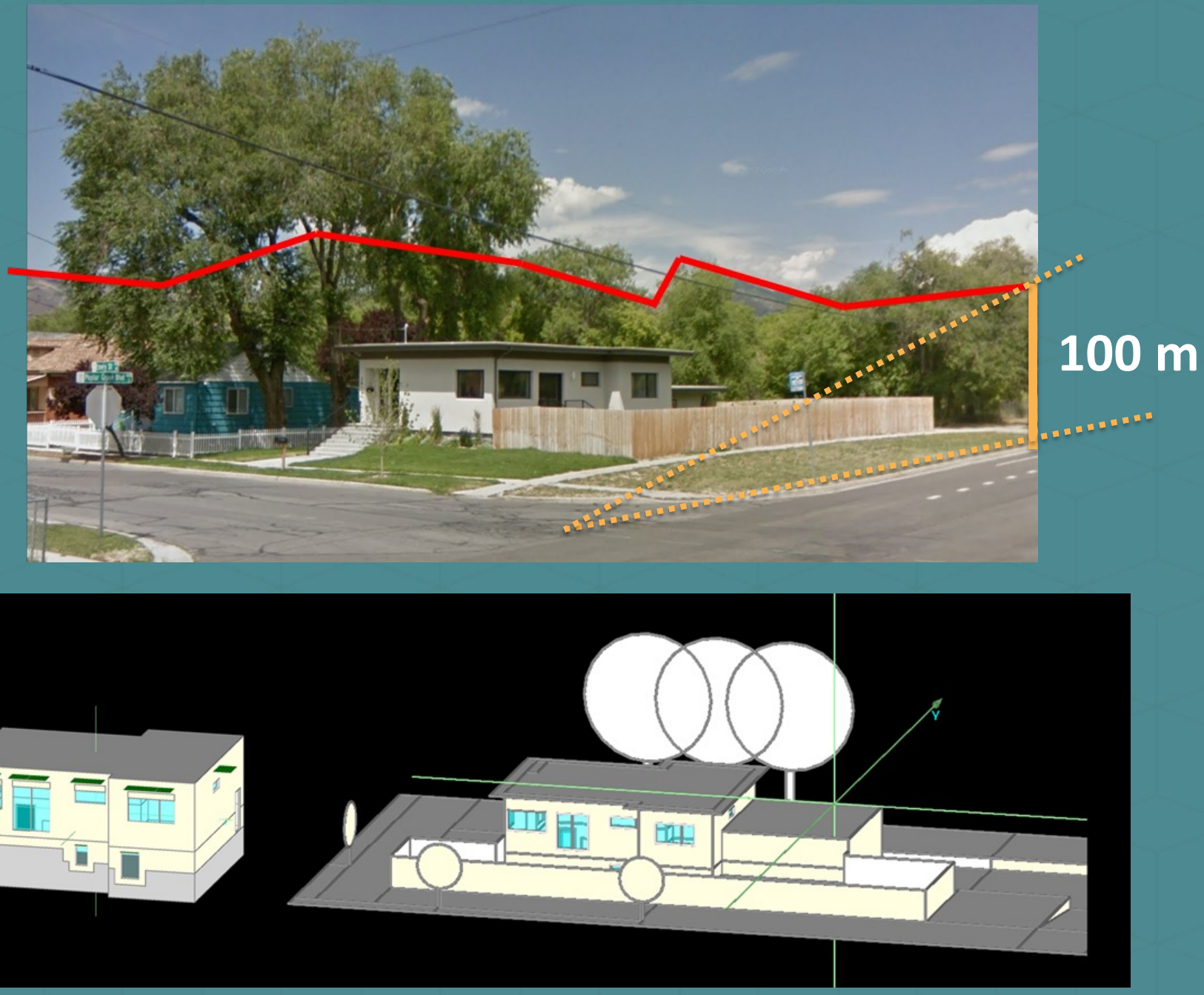


Image credit




100 m

Takeaway
RESULTS

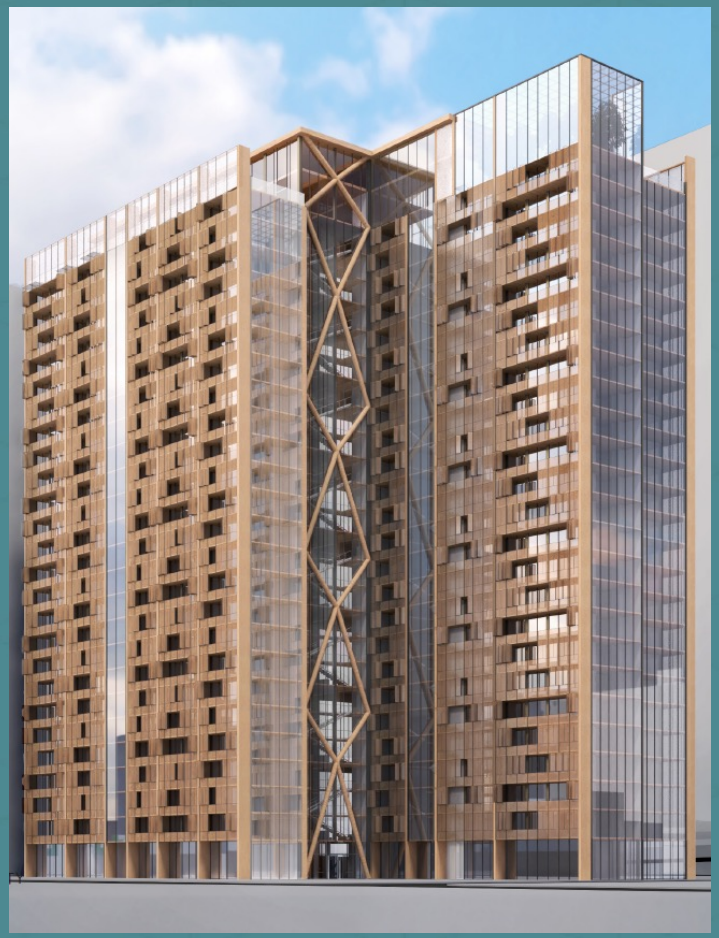
With the previous methodology shading was been over-estimated.

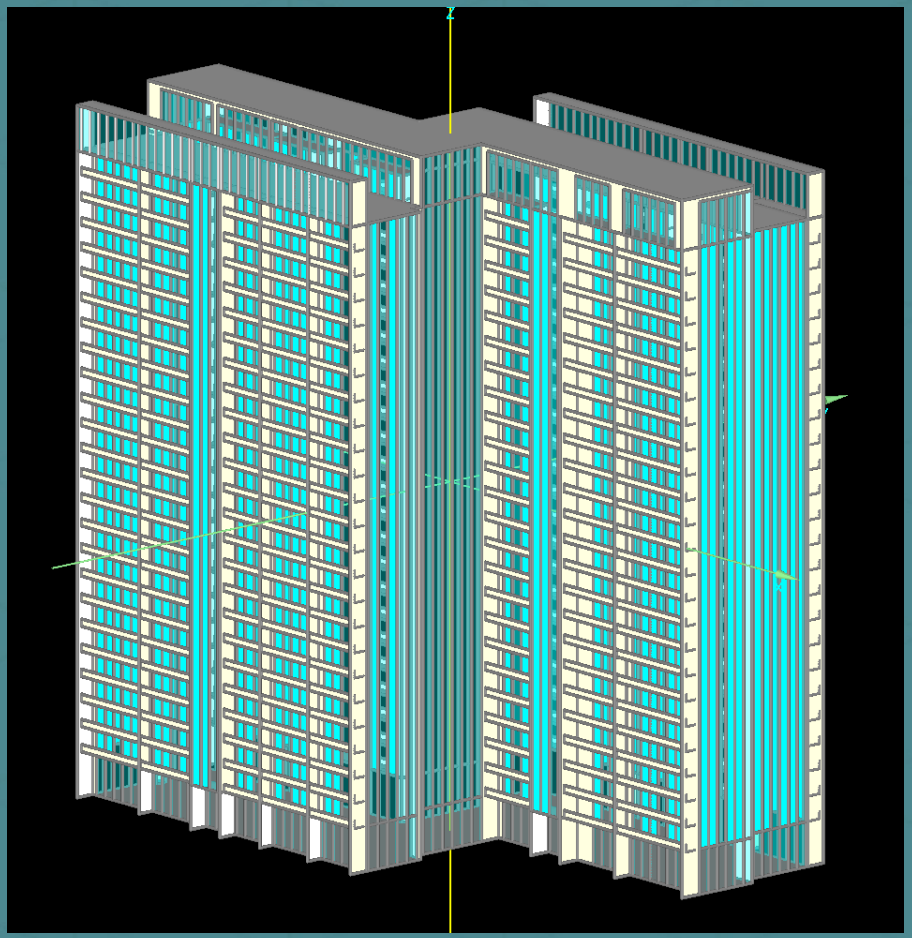
	Heating Demand	Cooling Demand	Heating Load	Cooling Load
Palatine House - Seattle, WA	12%	-15%	2%	-15%
Phoenix House - Portland, OR	8%	-35%	4%	-17%
Wildwood Drive - Rockford, IL	-13%	24%	-6%	14%
George House - Chicago, IL	3%	-17%	-1%	-10%
Governor's House - Aberdeen, SD	0%	-16%	0%	-10%
Silver Lake House - Sharon, CT	5%	-27%	0%	-18%
Casa La Vista - Austin, TX	-38%	-16%	-24%	-17%
Emery House - Salt Lake City, UT	3%	9%	-8%	5%

Results indicate that mostly cooling demand and cooling load went down

Calculation

Shading at Large Scale





Feasibility Study – Multifamily Conceptual Housing, Chicago

CONCLUSIONS

- The new methodology requires **less time** to model shading elements, and **improves accuracy**.
- It allows for modeling **more complex features** that could not be represented appropriately before
- The monthly shading factors provide **more accurate assessment** of real conditions
- Simple shading conditions will have similar results under each method, but more complex situations may modify results more significantly.

- We believe this should **streamline** the modeling required for PHIUS+ Certification

THANK YOU

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