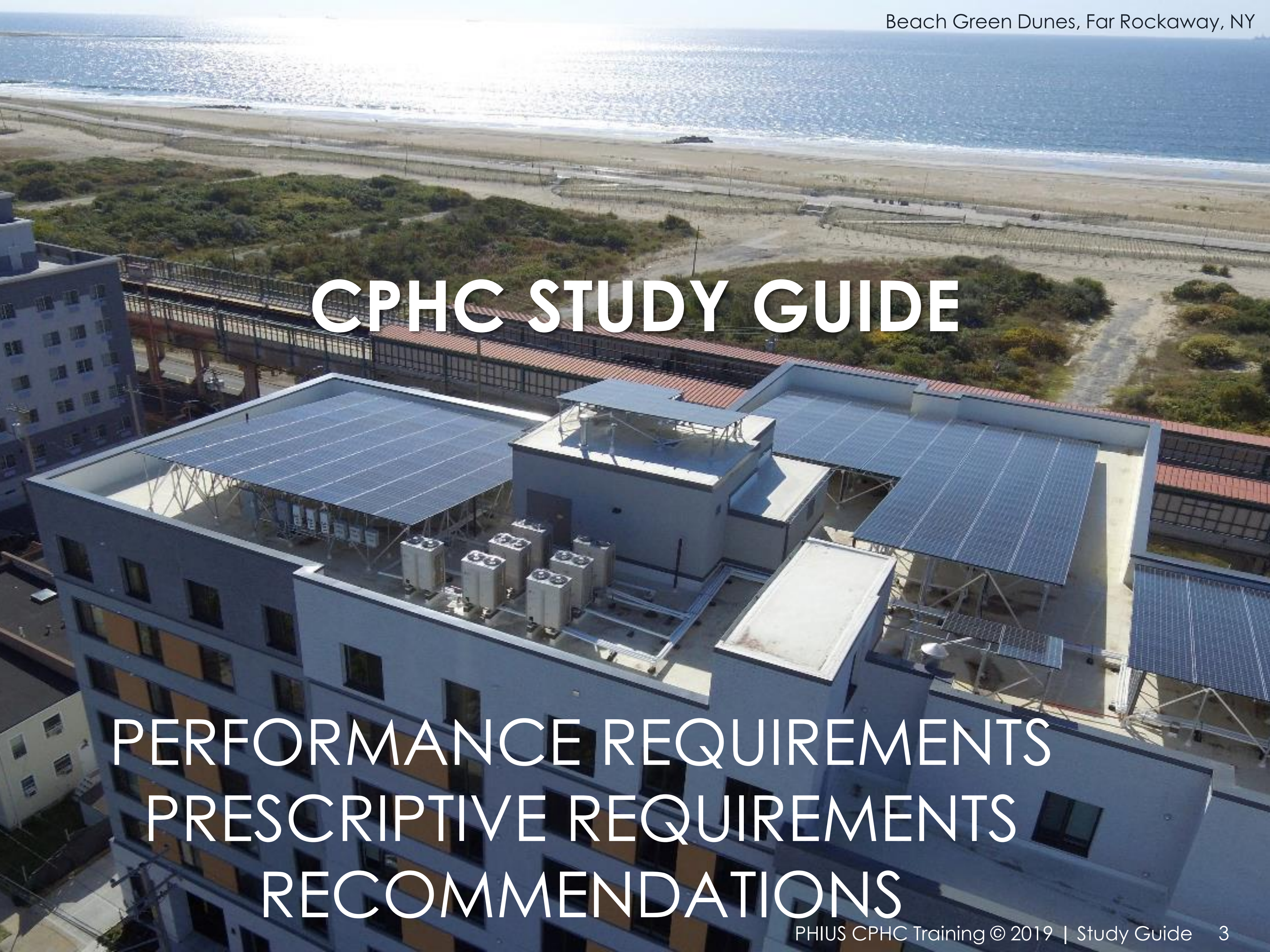
PHIUS

CERTIFIED PASSIVE HOUSE CONSULTANT

STUDY GUIDE

OUTLINE

- Passive Building Criteria (PHIUS+)
  - Click for PHIUS+ 2018 Space Conditioning Criteria Calculator
- Energy Balance
- Losses
  - Transmission Losses through Envelope
  - Ventilation Losses
- R-Values, U-Values and Surface Temperature
- Gains
  - Solar Gains
  - Internal Gains
- Unit Review



Beach Green Dunes, Far Rockaway, NY

CPHC STUDY GUIDE

PERFORMANCE REQUIREMENTS
PRESCRIPTIVE REQUIREMENTS
RECOMMENDATIONS

PHIUS+ 2018 **PASSIVE BUILDING** *PERFORMANCE REQUIREMENTS*

Source Energy, Residential	kWh/person/yr	≤ 3840 kWh/person/yr
	Occupancy	(# of Bedrooms + 1), per unit
Source Energy, Non-Residential	$kBTU/ft^2_{iCFA}/yr$	≤ 34.8
Airtightness	CFM_{50}/ft^2 of gross enclosure area	≤ 0.060
Airtightness, MF ≥ 5 stories, non-comb.		≤ 0.080
Annual Heating Demand	$kBTU/ft^2_{iCFA}/yr$	Climate Specific
Annual Cooling Demand		Climate Specific
	AND	
Peak Heating Load	$BTU/ft^2_{iCFA}/hr$	Climate Specific
Peak Cooling Load		Climate Specific

PHIUS+ 2018 **PASSIVE BUILDING** *PRESCRIPTIVE REQUIREMENTS*

PHIUS+ Ventilation Protocol	CFM	Balanced Ventilation, see Guidebook 3.5.3.3
Thermal Bridge Mold Risk	%RH	< 80% using ISO 13788/ASHRAE 160 calc
Window Condensation Risk	%RH	< 100% using ISO 13788/LTIE calc
Window Comfort Assessment	Max U-Value	Based on climate + window height, see calculator.
Assembly Moisture Risk	various	See Guidebook 3.4.3 & Appendix B
PHIUS+ QA/QC Protocol	various	Pre-Certification and On-Site Verification
Supporting 3rd Party Verifications	various	EPA Indoor AirPLUS, EPA Energy Star, DOE ZERH

PHIUS+ 2018 **PASSIVE BUILDING** *RECOMMENDATIONS*

Thermal Enclosure	$hr.ft^2.°F/BTU$	≈ R-25 - R-80; climate specific
Window SHGC	%	≈ 0.27 - 0.61; climate specific
Window Installed U-factor	$BTU/hr.ft^2.°F$	$U_{w\text{-}install}$ ≈ 0.41 - 0.08; climate specific
Ventilation Efficiency	% recovery	53% - 93%; climate specific
	Watt/cfm	0.27 - 2.23; climate specific
Thermal-Bridge Threshold	BTU/hr.ft.°F	$\Psi \leq 0.006$
Indoor Radiant Condition	ΔT°F	≤ 7.2 °F (Indoor setpoint vs. indoor surfaces)
Indoor Relative Humidity	%RH	40%-60% RH
Ventilation Air Velocity	ft/min	20- 30 ft/min (at supply diffusers)
Incoming Ventilation Air	°F	≥ 62.0 °F
Max Temp of Heating Coil	°F	125.6 °F
Daily DHW Use	gallons	6.6 gal/person.day @ 140F

THERMAL COMFORT HEATING SEASON

Feels: **comfortable + WARM!**

Temperate glass and wall surfaces and no drafts

PHIUS Conditions	
Envelope	**R 60**
Window	**R -9 Triple glazed (Climate specific)**
Outside Temp	**0° F**

PHIUS Comfort Guidelines	
Air Temp	**68 ° F**
RH	**40-60%**
Air Velocity	**<19.7 ft/min**
Radiant Condition	**Max Delta T < 7.2 ° F (4 °C)**

THERMAL COMFORT COOLING SEASON

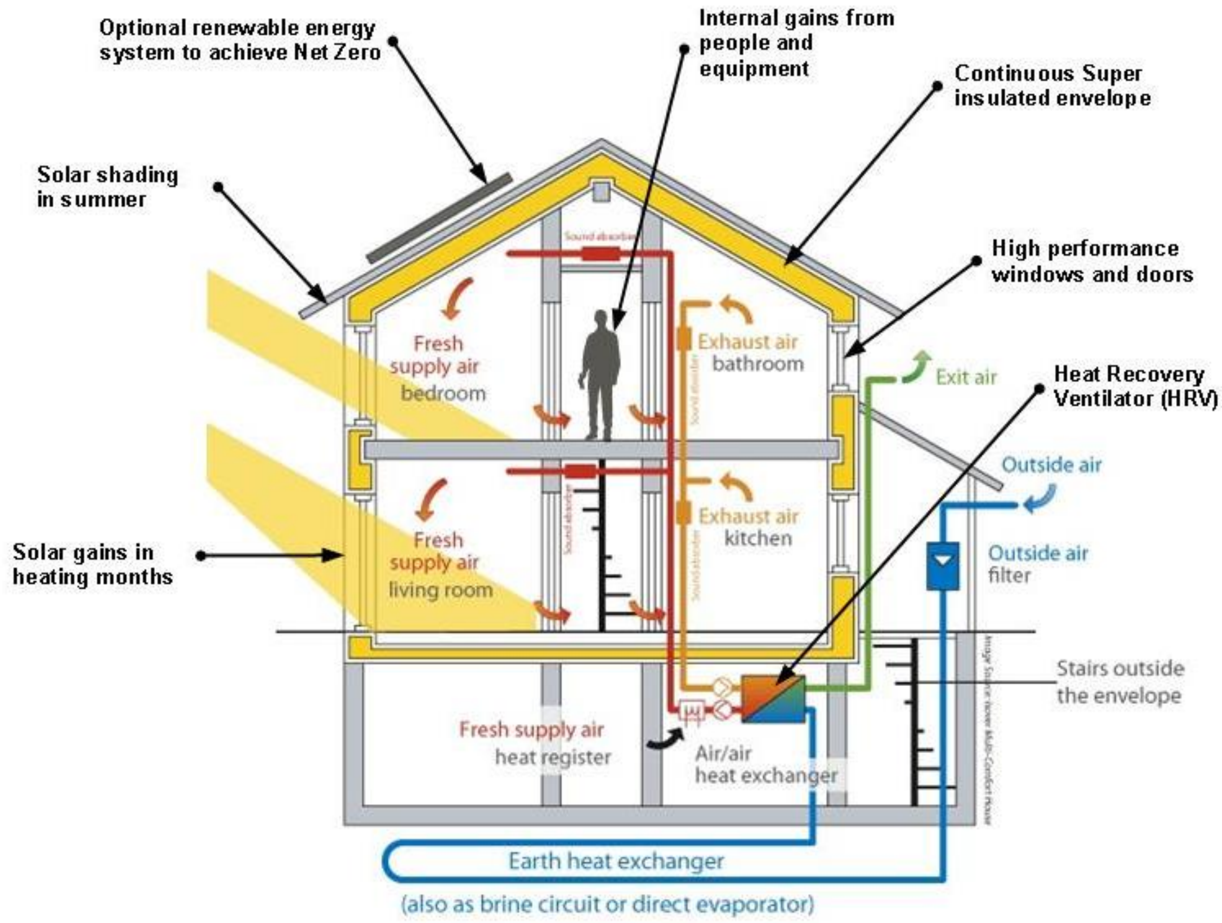
Feels: **comfortable** and cool

Temperate glass and wall surfaces and no drafts

PHIUS Example	
Envelope	**R 30**
Window	**R -5 Triple glazed (Climate specific)**
Outside Temp	**95° F**

PHIUS Comfort Guidelines	
Air Temp	**77 ° F**
RH	**40-60%**
Air Velocity	**(<19.7 ft/min)**
Radiant Condition	**Max Delta T < 7.2 ° F (4 °C)**

ENERGY BALANCE



Passive House Diagram

ENERGY BALANCE = 4 ENERGY 'BUCKETS'

2 LOSS BUCKETS:

- Transmission Loss
- Ventilation Loss

2 GAIN BUCKETS:

- Solar Gains
- Internal Gains

REMAINING ANNUAL HEATING DEMAND

HEATING

$$Q_H = Q_T + Q_V - n * (Q_S + Q_I)$$

Q_T	(kBTU/yr) transmission heat loss
Q_V	(kBTU/yr) ventilation heat loss
n	(%) utilization factor of gains
Q_S	(kBTU/yr) solar heat gains
Q_I	(kBTU/yr) internal heat gains

REMAINING ANNUAL COOLING DEMAND

COOLING

$$Q_C = Q_S + Q_I - n * (Q_T + Q_V)$$

Q_T	(kBTU/yr) transmission heat loss
Q_V	(kBTU/yr) ventilation heat loss
n	(%) utilization factor of losses
Q_S	(kBTU/yr) solar heat gains
Q_I	(kBTU/yr) internal heat gains

REMAINING PEAK HEATING LOAD

HEATING

$$P_H = P_T + P_V - (PS + P_I)$$

P_T	(BTU/hr) peak transmission heat loss
P_V	(BTU/hr) peak ventilation heat loss
P_S	(BTU/hr) peak solar heat gains
P_I	(BTU/hr) peak internal heat gains

REMAINING PEAK COOLING LOAD

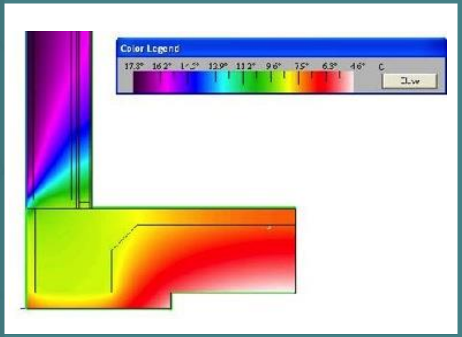
COOLING

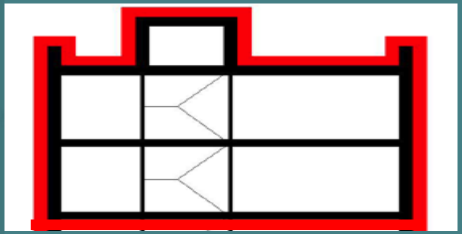
$$P_C = P_S + P_I - (P_T + P_V)$$

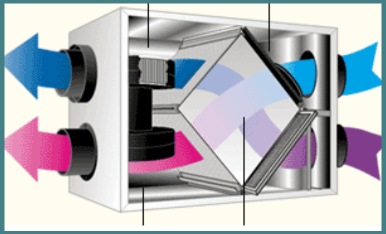
P_T	(BTU/hr) peak transmission heat loss
P_V	(BTU/hr) peak ventilation heat loss
P_S	(BTU/hr) peak solar heat gains
P_I	(BTU/hr) peak internal heat gains

TOTAL LOSSES:

ENCLOSURE LOSSES
+ VENTILATION LOSSES







ANNUAL TOTAL LOSSES

$$Q_L = Q_T + Q_V$$

Q_L	(kBTU/yr) Total heat loss
Q_T	(kBTU/yr) Transmission heat loss
Q_V	(kBTU/yr) Ventilation heat loss

Q_L / iCFA	(kBTU/ft$^2_{iCFA}$/yr) Total specific heat loss

PEAK TOTAL LOSSES

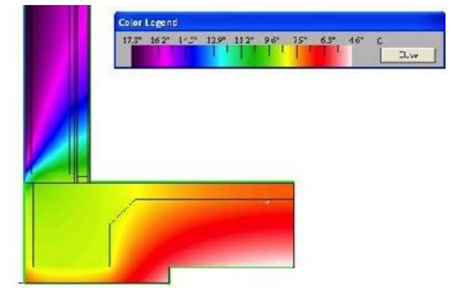
$$P_L = P_T + P_V$$

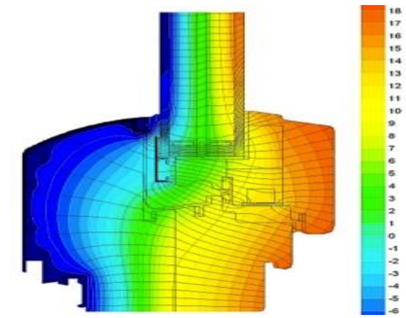
P_L	(BTU/hr) Total peak heat loss
P_T	(BTU/hr) Peak transmission heat loss
P_V	(BTU/hr) Peak ventilation heat loss

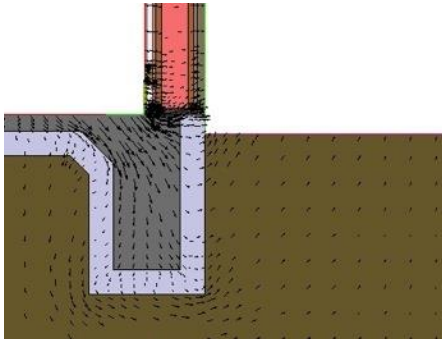
P_L / iCFA	(BTU/ft^2_{iCFA}/hr) Total specific peak heat loss

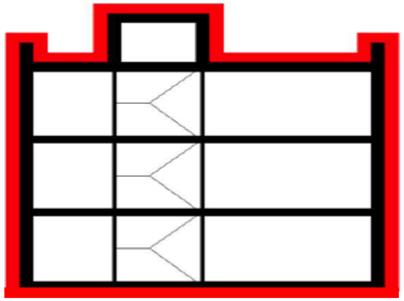
ENCLOSURE LOSSES:

THERMAL ENCLOSURE
THERMAL BRIDGES









ANNUAL TRANSMISSION LOSS

EXTERIOR WALL | ROOF | FLOOR | WINDOWS

$$Q_T = A * U * fT * G_T$$

Q_T	(kBTU/yr) transmission heat loss
A	(ft^2) assembly area to exterior dimensions
U	(BTU/hr.ft^2.°F) U-value, heat transfer coefficient
f_T	(≤1)temperature correction factor (used in cases like a ground condition or "X" where heat loss is mitigated)
G_T	(k F.hr/yr) heating degree hours : Conversion: HDD @68F * 24 hr/day/1000 = HDD *0.024 = G_T

CONVERT HEATING DEGREE DAYS
TO HEATING DEGREE HOURS G_T

CALCULATE G_T FOR A YEAR	
1	Determine annual heating degree days per climate file (°F.day/yr)
2	Multiply by 24 hours/day to obtain hours/yr (°F.hr/yr)
3	Divide by 1000 to obtain (k°F.hr/yr)

What are the heating degree hours G_T for a location with 6736 heating degree days?	
1	G_T = 6736 °F.days * 24hr.day/1000
2	G_T = 6736 °F.~~days~~ *24hr.~~day~~/1000
3	G_T = 6736 °F * 0.024khr
4	G_T = 161.66 k°F.hr

DETERMINE G_T

HEATING DEGREE HOURS

CALCULATE G_T FOR A GIVEN TIME PERIOD LESS THAN A YEAR	
1	Determine the number of days in the relevant period.
2	Multiply by 24 hours/day to obtain hours/period.
3	Determine ΔT between indoors and outdoors relevant to period (Monthly Avg Temp)
4	Multiply hours/period by ΔT.
5	Divide by 1000 to obtain k°F.hr/period

What is the G_T for the month of January for a location with a January monthly avg. temp of -2 F?

1	$G_{T\text{-January}}$ = days * 24hr/1000 * ΔT
2	$G_{T\text{-January}}$ = 31 ~~days~~ * .024 khr/~~day~~ * (68°F – (-2°F))
3	$G_{T\text{-January}}$ = 0.744 khr * 70 ° F
4	$G_{T\text{-January}}$ = 52.08 khr ° F

ANNUAL TRANSMISSION LOSS

EXTERIOR WALL | ROOF | FLOOR | WINDOWS

$$Q_T = A * U * fT * G_T$$

U_{wall} = 0.12 BTU/hr.ft². F | A_{wall} = 400 ft² | HDD = 6736 F.day/yr

Q_T	= 400ft² * (0.12 BTU/hr.ft² °F) * 1 *(6736 °F.day/yr) * 24 (hr/day) / 1000
	= 400~~ft²~~ * (0.12 BTU/~~hr.ft² °F~~) * 1 *(6736 ~~°F.day~~/yr) * 24 (~~hr~~/~~day~~) / 1000
	= (400 * 0.12 BTU) * 1* (6736 yr * 0.024k)
	= 48 kBTU * 1 * 161.66 yr
	= 7759.68 kBTU/yr
	Divide by ft² (or iCFA for whole) to get kBTU/ft²yr

PEAK TRANSMISSION LOSS

EXTERIOR WALL | ROOF | FLOOR | WINDOWS

$$P_T = A * U * fT * \Delta_T$$

P_T	(BTU/hr) peak transmission heat loss
A	(ft^2) assembly area to exterior dimensions
U	(BTU/hr.ft^2.°F) U-value, heat transfer coefficient
f_T	(≤1) temperature correction factor ALWAYS 1 for peak (except zone "x" and slab conditions)
Δ_T	Indoor minus outdoor temp (°F) for worst case of weather condition 1 (cold, clear) or 2 (moderate, cloudy)

PEAK TRANSMISSION LOSS

EXTERIOR WALL | ROOF | FLOOR | WINDOWS

$$P_T = A * U * fT * \Delta_T$$

U_{wall} = 0.12 BTU/hr.ft². F | A_{wall} = 400 ft² | Peak low = 15° F

P_T	= 400ft² * 0.12 BTU/hr.ft² °F * 1 * (68°F – 15°F)
	= 400~~ft²~~ * 0.12 BTU/hr~~.ft².°F~~* 1 * 53~~°F~~
	= 48 BTU/hr * 53
	= 2544 BTU/hr
	Divide by ft² (or iCFA for whole) to get BTU/ft^2_{iCFA}/hr

ANNUAL LINEAR LOSS

LINEAR THERMAL BRIDGES

$$Q_{T\Psi} = l * \Psi * fT * G_T$$

$Q_{T\Psi}$	(kBTU/yr) transmission heat loss
l	(ft) length of thermal bridge
Ψ	(BTU/hr.ft.°F) psi-value, linear heat transfer coefficient
f_T	(≤1)temperature correction factor (used in cases like a ground condition or "X" where heat loss is mitigated)
G_T	(k F.hr/yr) heating degree hours

PEAK LINEAR LOSS

LINEAR THERMAL BRIDGES

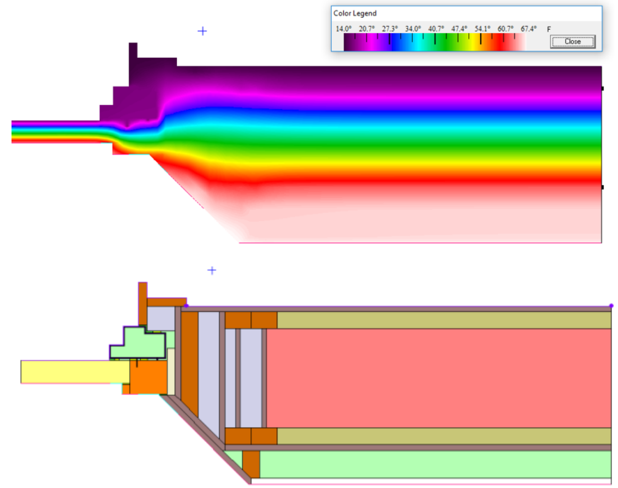
$$P_{T\Psi} = l * \Psi * fT * \Delta_T$$

$P_{T\Psi}$	(BTU/hr) transmission heat loss
l	(ft) length of thermal bridge
Ψ	(BTU/hr.ft.°F) psi-value, linear heat transfer coefficient
f_T	(≤1) temperature correction factor ALWAYS 1 for peak (except zone "x" and slab conditions)
Δ_T	(°F) worst case of weather condition 1 (cold, clear)or 2 (moderate, cloudy)

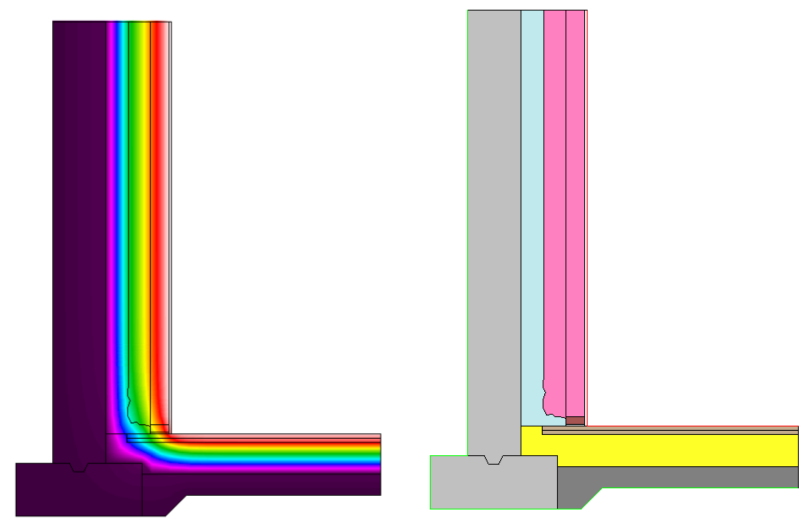
THERMAL BRIDGES:

MUST BE ACCOUNTED FOR

Thermal bridge free
≤ 0.006 BTU/hr.ft°F



Ψ – installation thermal bridge



Ψ = -0.05 BTU/hr.ft.°F **free** of thermal bridge

TOTAL ANNUAL TRANSMISSION LOSS

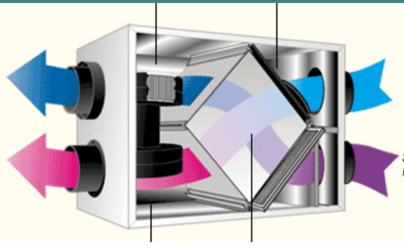
ENCLOSURE + LINEAR TB + POINT TB

$$H_T = \Sigma A j U_j + \Sigma \Psi_j l_j + \Sigma X_j$$

H_T	(kBTU/yr) transmission loss
$\Sigma A j U_j$	(kBTU/yr) sum enclosure transmission loss
$\Sigma \Psi_j l_j$	(kBTU/yr) sum linear transmission loss
ΣX_j	(kBTU/yr) sum point transmission loss

VENTILATION LOSSES:

AIR LEAKAGE
VENTILATION EQUIPMENT



ENCLOSURE AIR LEAKAGE LIMIT

$$\mathbf{CFM_{50}} = q_{50}\, limit * gross\ enclosure\ surface\ area\ ft^2$$

$\mathbf{CFM_{50}}$	(CFM_{50})Total permitted leakage for blower door test *CFM = ft^3/min
q_{50} ***limit***	0.060 CFM_{50}/ft^2 (or 0.080 CFM_{50}/ft^2 for MF 5 stories+)
Gross enclosure surface area	(ft^2) Total gross exterior surface area of building enclosure used for energy model

AIR LEAKAGE LIMIT CONVERSION

From ACH_{50} to CFM_{50}/ft^2

$$q_{50} = n_{50} * \frac{1}{60} * V/ft^2 \text{ gross enclosure}$$

q_{50}	(CFM_{50}/ft^2) leakage in reference to the gross enclosure area of the envelope
n_{50}	(ACH_{50} or 1/hr) Pressure test air changes at 50 pascal pressure difference *(1/60 = hour to minute conversion factor)
V	(ft^3) Net enclosed air volume for air pressure test

AIR LEAKAGE LIMIT CONVERSION

From CFM_{50}/ft^2 to ACH_{50}

$$n_{50} = q_{50} * \frac{60}{V} * ft^2 gross\ enclosure$$

n_{50}	(ACH_{50} or 1/hr) Pressure test air changes at 50 pascal pressure difference 1/60 = (hour to minute conversion factor)
q_{50}	(CFM_{50}/ft^2) leakage in reference to the gross enclosure area of the envelope *(60 = minute to hour conversion factor)
V	(ft^3) Net enclosed air volume for air pressure test

AIR LEAKAGE TEST PRESSURE CONVERSION/EQUIVALENT

From CFM_{50} to CFM_{75}

$$CFM_{75} = CFM_{50} * ((75/50)^h)$$

CFM_{50}	Measured air leakage in cubic feet per minute at 50 Pascals
50	Pressure used for test (Pa)
75	Test pressure converting to (Pa)
h	Flow exponent (from test result) If unknown, use 0.7

AIR LEAKAGE TEST PRESSURE CONVERSION/EQUIVALENT

From CFM_{Q1} to CFM_{Q2}

$$CFM_{Q2} = CFM_{Q1} * ((Q_2/Q_1)\text{^}h)$$

CFM_{Q1}	Measured air leakage in cubic feet per minute at Q1 pressure (Pascals)
Q_1	Pressure used for test (Pa)
Q_2	Test pressure converting to (Pa)
h	Flow exponent (from test result) If unknown, use 0.7

NATURAL INFILTRATION

AIR CHANGE RATE

$$n_{nat} = V * n_{50} * e/(1+f/e*(\text{excess extract air}/n_{50})^2)$$

n_{nat}	(ACH or 1/hr) natural infiltration air change rate *takes into account target ACH_{50} and wind protection coefficient
V	(ft^3) Net enclosed air volume for air pressure test
e, f	wind protection coefficients EN 13790
n_{50}	(ACH_{50} or 1/hr) Pressure test air changes at 50 pascal pressure difference

VENTILATION CONVERSIONS

VOLUME and AIR CHANGE (ventilation or leakage)

$$CFM = ACH/60_{min} * V$$

ACH	(1/hr) Air changes per hour
CFM	(ft^3/min) Cubic feet per minute
V	(ft^3) Net enclosed air volume

$$ACH = CFM * 60_{min}/V$$

ACH	(1/hr) Air changes per hour
CFM	(ft^3/min) Cubic feet per minute
V	(ft^3) Net enclosed air volume

ANNUAL VENTILATION LOSS

$$Q_V = n_v * V * c_p\rho * G_T$$

Q_V	(kBTU/yr) Ventilation heat loss
n_v	(ACH or 1/hr) energetically effective air exchange rate
V	(ft^3) Net encosed air volume
$c_p\rho$	Specific heat capacity of air: (0.018 BTU/ft^3 ° F or 33 Wh(m^3K) - aka c_{air}
G_T	(k°F.hr/yr) heating degree hours = Σ ($\Delta\vartheta$ * $h_{\Delta\vartheta}$) *To convert HDD to $G_{t,}$ multiply HDD by 0.024.

PEAK VENTILATION LOSS

$$P_V = n_V * V * c_p \rho * \Delta_T$$

P_V	(BTU/hr) Ventilation heat loss
n_v	(ACH or 1/hr) energetically effective air exchange rate
V	(ft^3) Net enclosed air volume
$c_p \rho$	Specific heat capacity of air: (0.018 BTU/ft^3 ° F or 33 Wh(m^3K)) - aka c_{air}
Δ_T	(°F, K or °C) Temperature difference (worst case or given temperature)

ENERGETICALLY EFFECTIVE

AIR EXCHANGE RATE

$$n_v = n_{v\ system} * (1 - \%HR) + n_{nat}$$

n_v	(ACH or 1/hr) energetically effective air exchange rate
$n_{v\ system}$	(ACH or 1/hr) average ventilation air change rate of building
$\%HR$	(%) Total system recovery efficiency *Ventilation ASE (apparent sensible effectiveness) and possible earth tube/geo thermal loop transmission combined
n_{nat}	(ACH or 1/hr) natural infiltration air change rate

VENTILATION FRESH AIR SUPPLY TEMPERATURE

BASED ON OUTDOOR DESIGN CONDITION

$$Supply\ Air\ Temp = \theta_e + [\%HR\ (\theta_i - \theta_e)]$$

θ_e	Outdoor Temperature, design condition (°F)
θ_i	Indoor Temperature, seasonal setpoint (°F)
%HR	(%) Total system recovery efficiency *Ventilation ASE (apparent sensible effectiveness) and possible earth tube/geo thermal loop transmission combined

PHIUS RECOMMENDED VENTILATION RATES

Village Center – Brewer, ME

Room	Airflow	Units
Kitchen	35	CFM
Bathroom	24	CFM
½ Bathroom	12	CFM
Laundry Room	12	CFM
Mech Room	12	CFM

CPHC STUDY GUIDE

U VALUE | R VALUE | SURFACE TEMP

R-VALUE (*Per ISO 6946)

OF HOMOGENEOUS SECTION

- R_{si} = 0.74 R
- Drywall = 0.91 R/in
- Cellulose = 3.75 R/in
- Plywood = 1.72 R/in
- Mineral Wool = 3.79 R/in
- R_{se} = 0.45 R

d = THICKNESS

R_{si} = INT SURFACE FILM

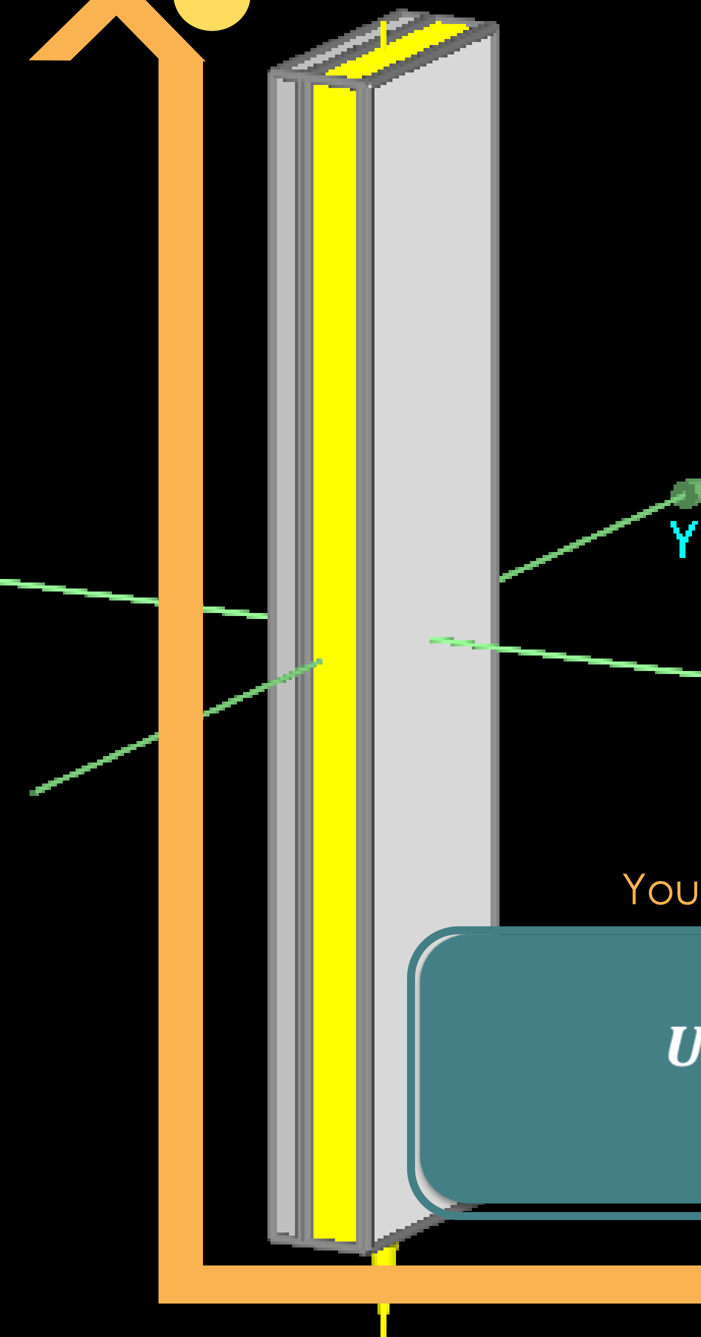
R_{se} = EXT SURFACE FILM

You are given R/in

$$R_T = R_{si} + (d_1 * R_1) + (d_2 * R_2) + (d_3 * R_3) + (d_4 * R_4) + R_{se}$$

You are given R per layer

$$R_T = R_{si} + R_1 + R_2 + R_3 + R_4 + R_{se}$$



(*Per ISO 6946) **U-VALUE**

OF HOMOGENEOUS SECTION

- R_{si} = 0.74 R
- Drywall = 0.91 R/in
- Cellulose = 3.75 R/in
- Plywood = 1.72 R/in
- Mineral Wool = 3.79 R/in
- R_{se} = 0.45 R

You are given R value

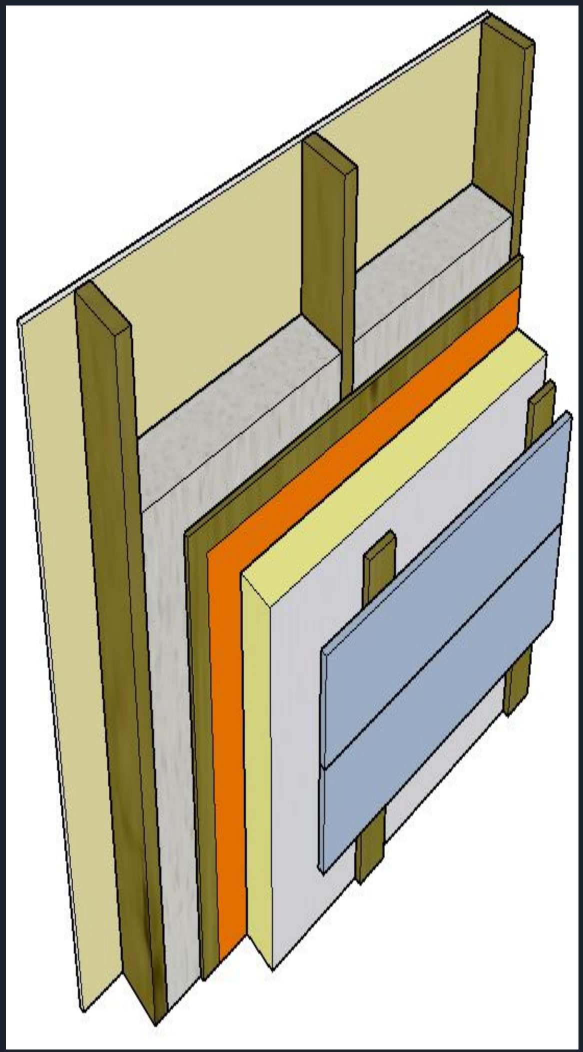
$$U = \frac{1}{R_T}$$

You are given thermal conductivity λ value

$$U = \frac{1}{R_{si} + \frac{d_1}{\lambda_1} + \frac{d_2}{\lambda_2} + \frac{d_3}{\lambda_3} + \frac{d_4}{\lambda_4} + Rs_e}$$

U/R-VALUE (*Per ISO 6946)

OF HETEROGENOUS SECTION

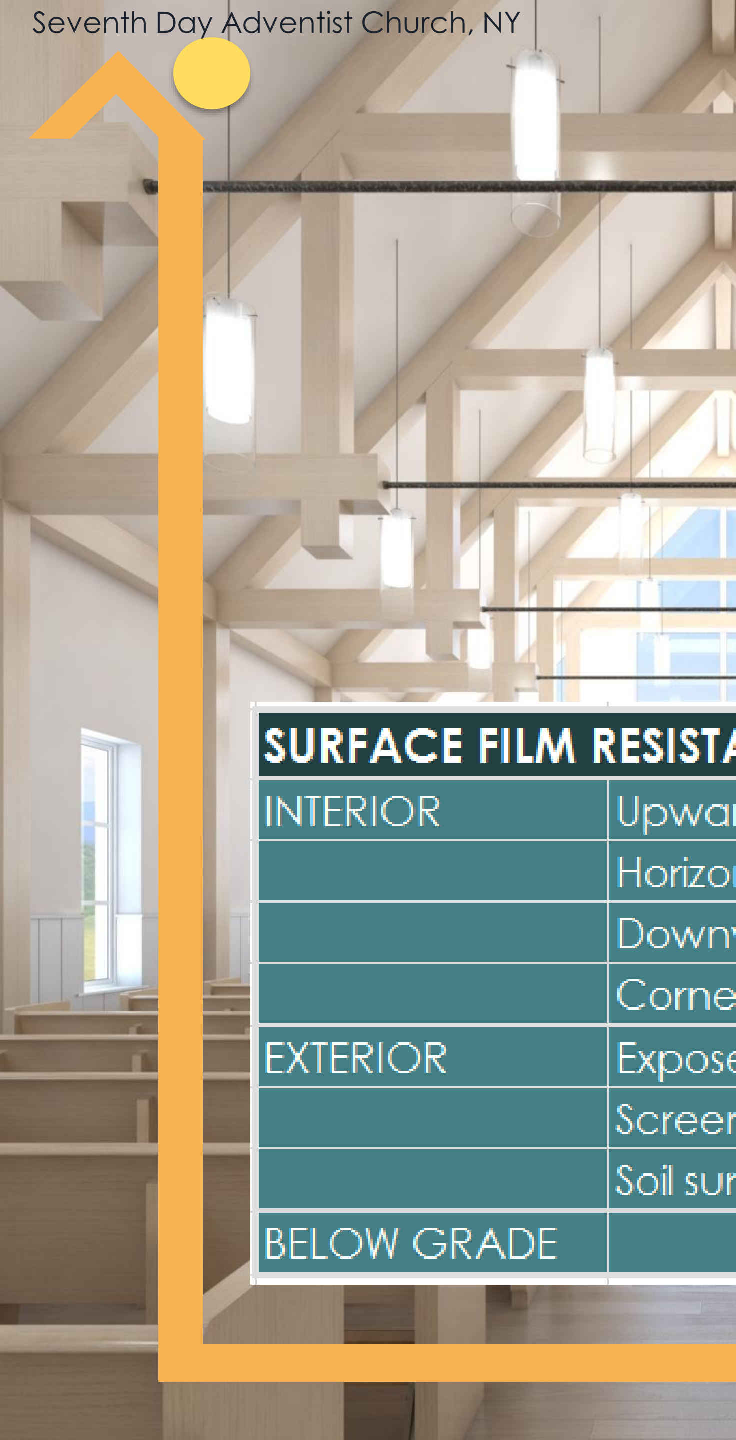


d_1 = THICKNESS

R_1 = R per inch

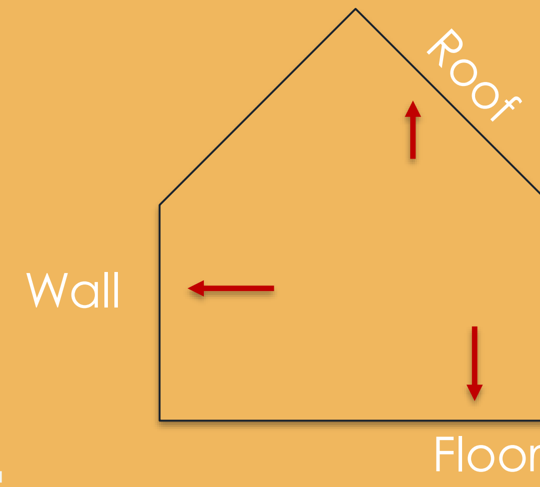
Calculated for insuation and framing of non-homogeneous layers

Total R of layer is normalized for area of each material in the shared layer



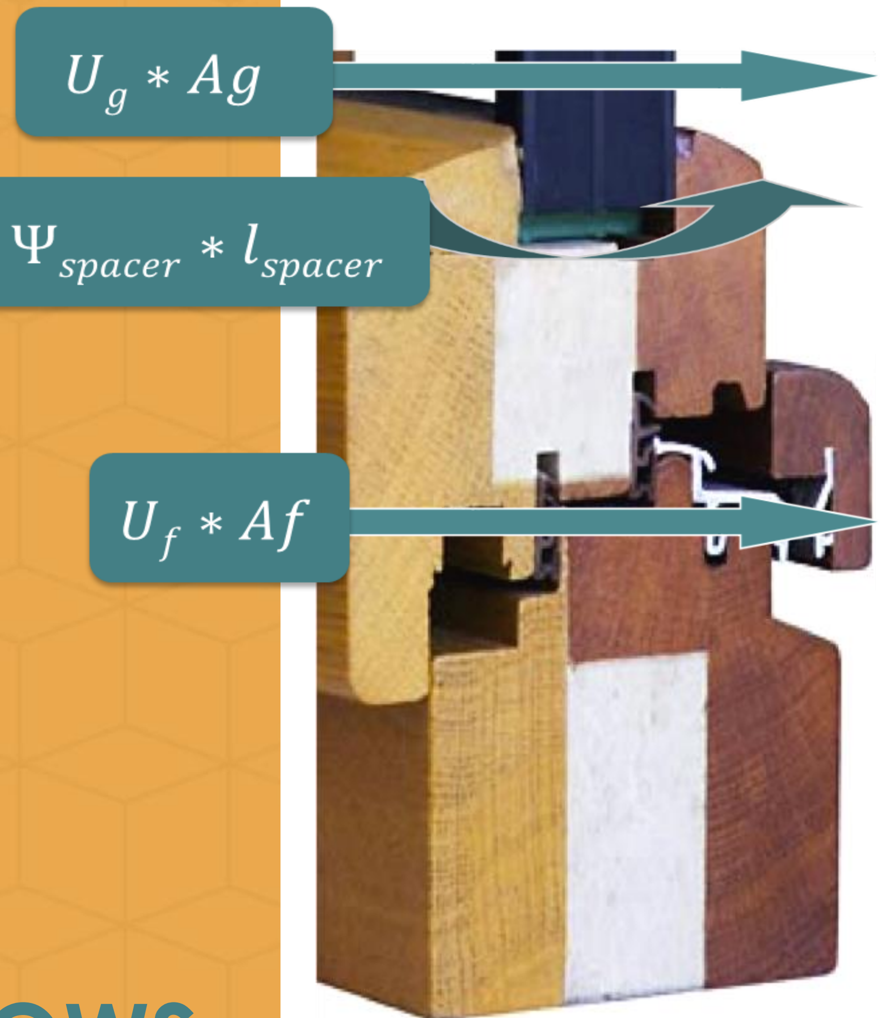
Seventh Day Adventist Church, NY

SURFACE FILM RESISTANCE VALUES



SURFACE FILM RESISTANCE VALUES		R-value	U-value
INTERIOR	Upward Heat Flow	0.57	1.754
	Horizontal Heat Flow	0.74	1.351
	Downward Heat Flow	0.97	1.031
	Corner (for THERM) 8" horz & vert.	1.14	0.877
EXTERIOR	Exposed	0.23	4.348
	Screened	0.45	2.222
	Soil surface (for THERM)	0.17	5.882
BELOW GRADE		0.00001	99999

U_f	BTU/hr.ft² °F
U_g	BTU/hr.ft² °F
Ψ_{spacer}	BTU/hr.ft °F
Glazing Dimensions	
Frame Dimensions	



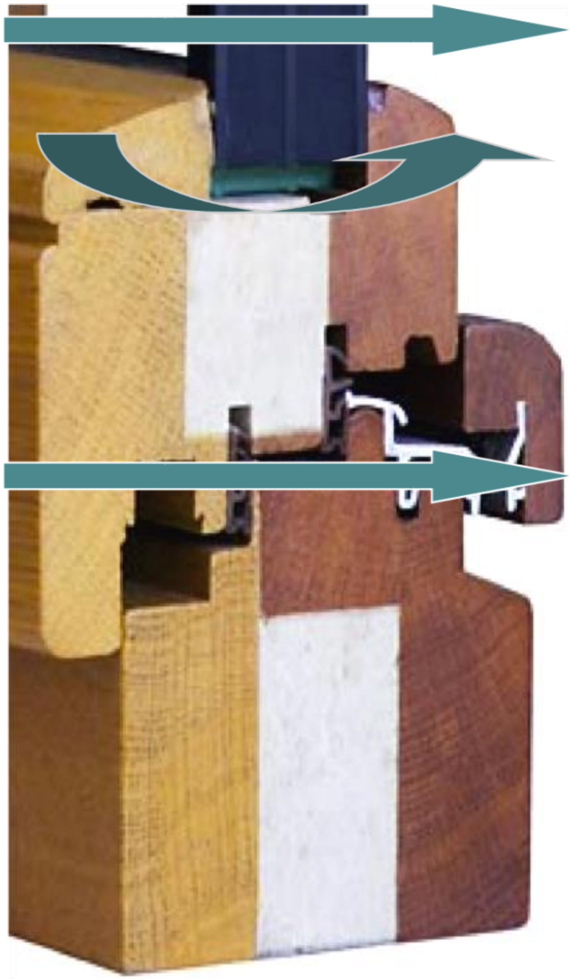
U VALUE OF WINDOWS:

REQUIRED CALCULATION FACTORS

U VALUE OF WINDOWS:

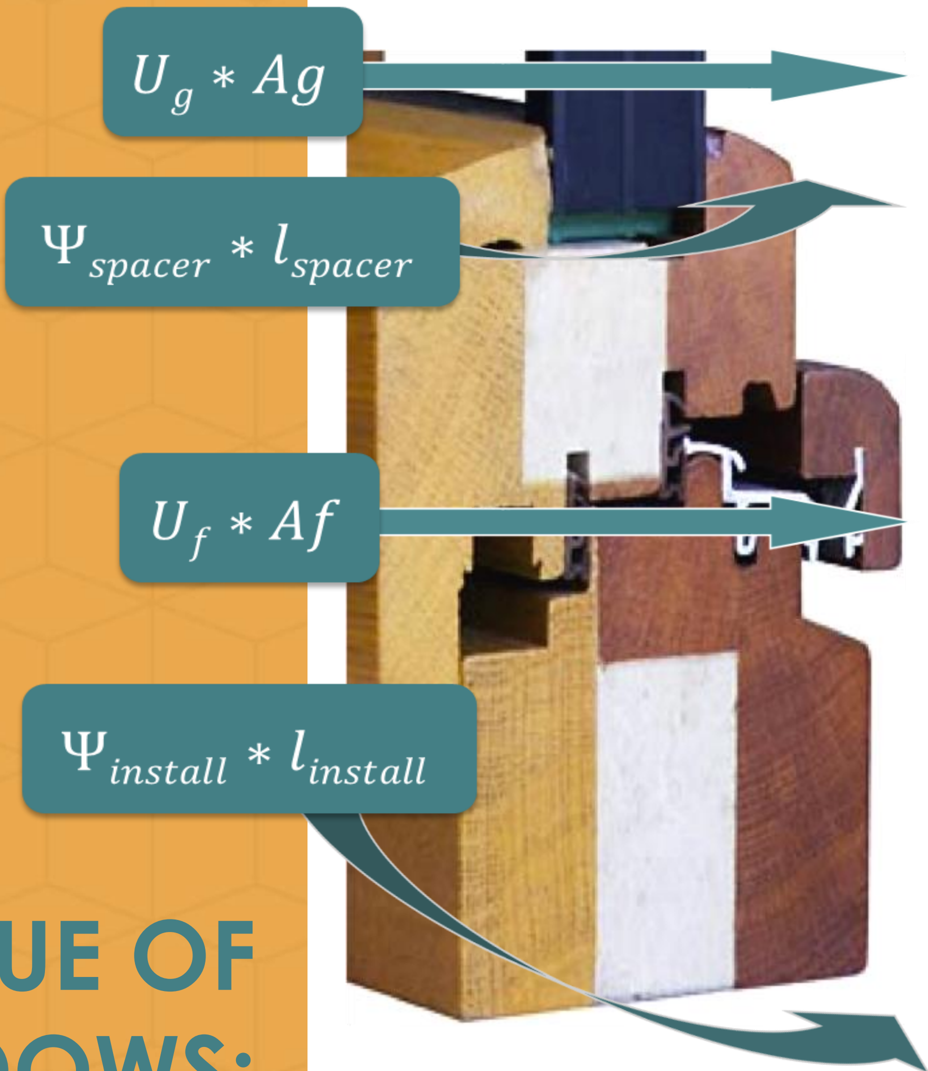
FORMULA

(*Per ISO 10077)



$$U_w = \frac{U_g * Ag + Uf * Af + \Psi_{spacer} * ls_{pacer}}{A_g + Af}$$

U_f	BTU/hr.ft² °F
U_g	BTU/hr.ft² °F
Ψ_{spacer}	BTU/hr.ft °F
$\Psi_{install}$	BTU/hr.ft °F
Glazing Dimensions	
Frame Dimensions	



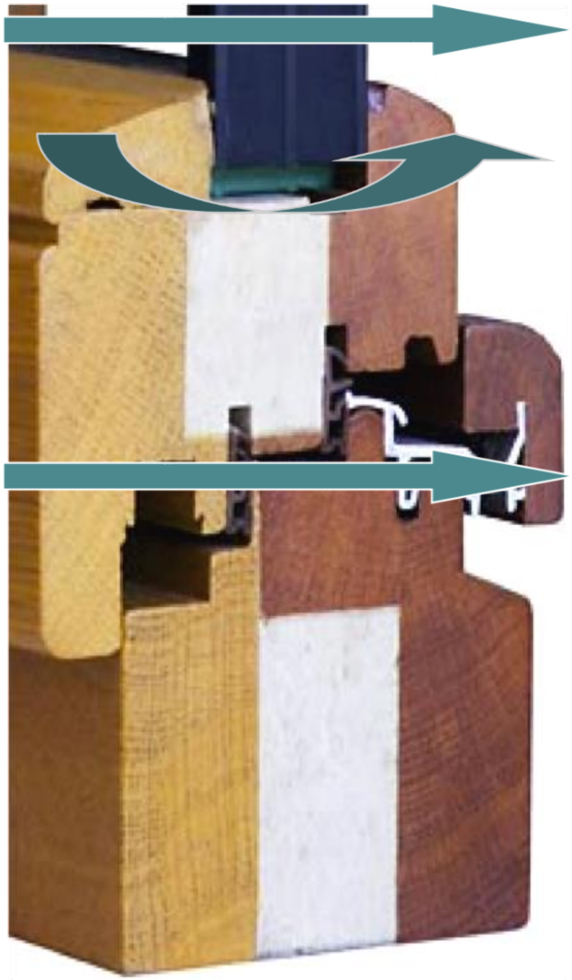
INSTALLED U VALUE OF WINDOWS:

REQUIRED CALCULATION FACTORS

INSTALLED U VALUE OF WINDOWS:

FORMULA

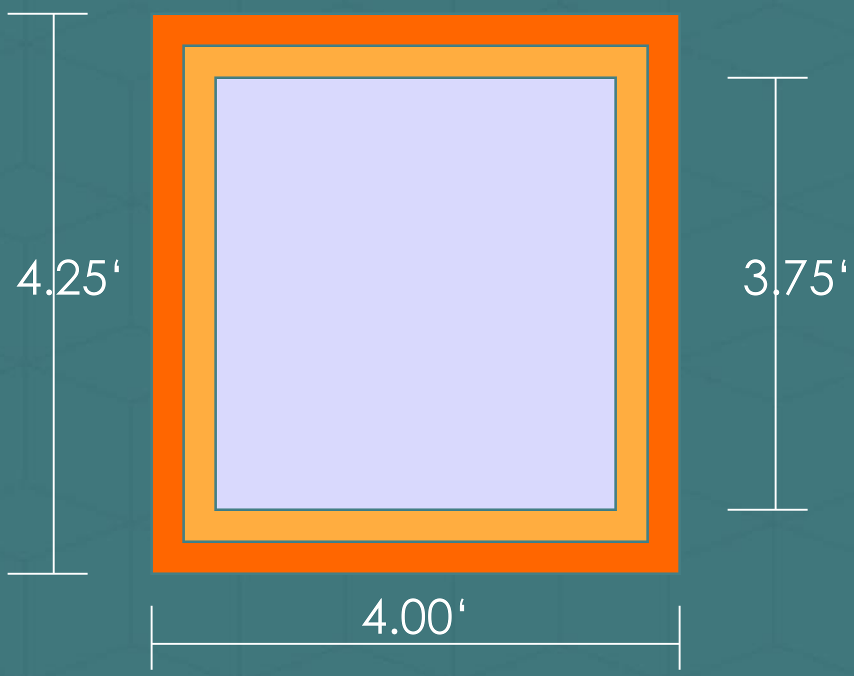
(*Per ISO 10077)



$$U_w = \frac{U_g * Ag + Uf * Af + \Psi_{spacer} * ls_{pacer} + \Psi_{install} * l_{install}}{A_g + Af}$$

INSTALLED U VALUE OF WINDOWS

$$U_w = \frac{U_g * Ag + Uf * Af + \Psi_{spacer} * l_{spacer} + \Psi_{install} * l_{install}}{A_g + Af}$$

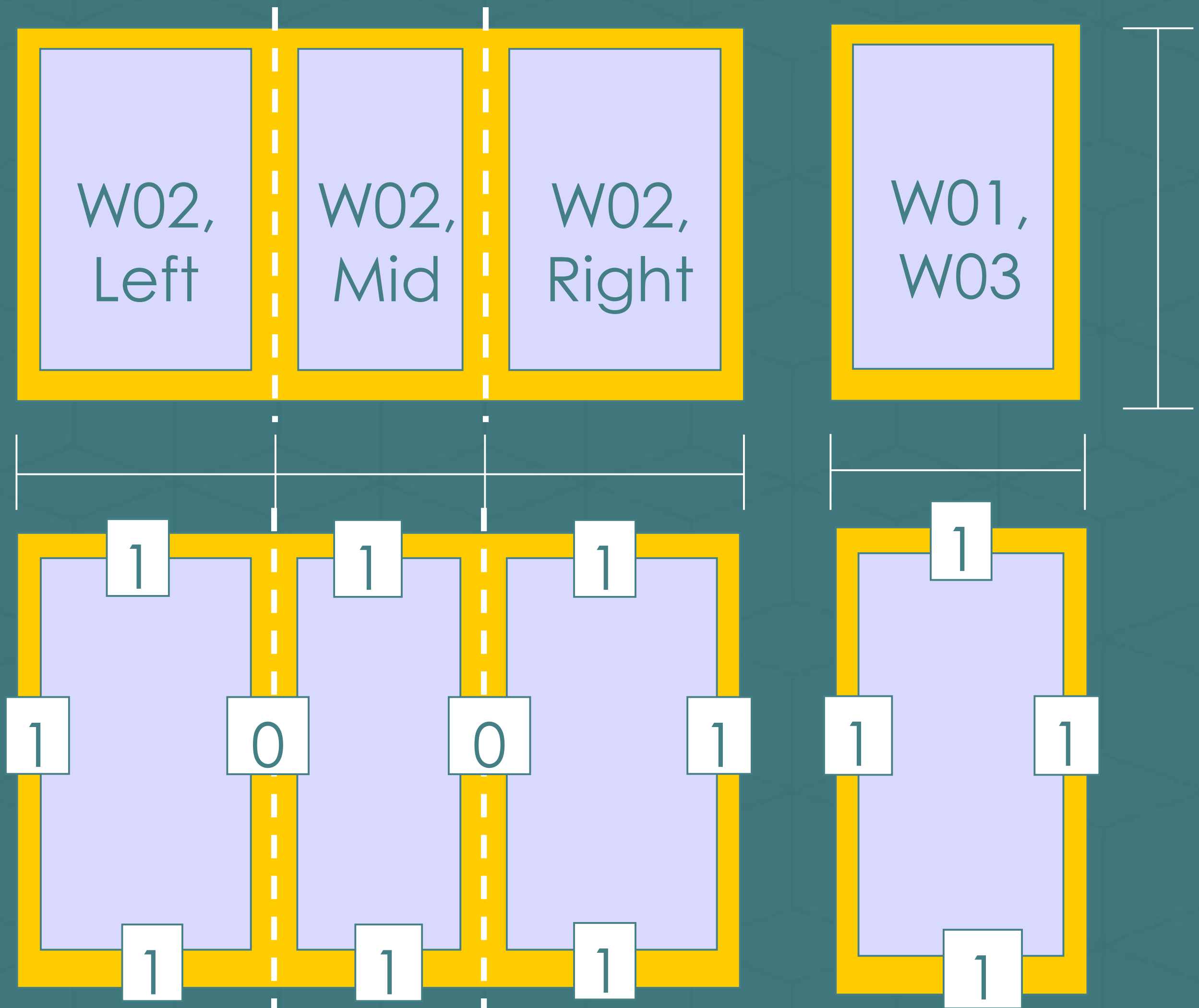


Example Window:

U_f	= 0.18 BTU/hr. ft². F
U_g	= 0.11 BTU/hr. ft². F
A_w	= 17 ft²
A_g	= 13.125 ft² (75+%)
A_f	= 3.875 ft² (25+%)
Ψ_{spacer}	= 0.02 BTU/hr. ft. F
$\Psi_{install}$	= 0.006 BTU/hr. ft. F
Frame width	= 3 in (all sides)
U_w	= 0.14 BTU/hr.ft². F
$U_{w\text{-}install}$	= 0.15 BTU/hr.ft². F

INSTALLED U VALUE OF WINDOWS

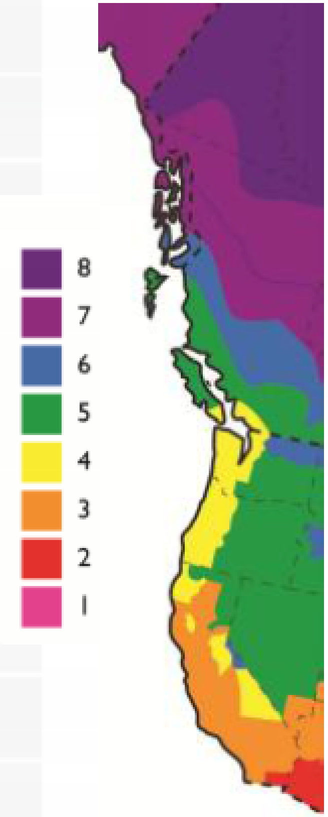
Precise dimensions and position are required



INSTALLATION condition determines the length of LOSS associated with the $\Psi_{install}$ value

PHIUS Climate Specific Window *Guidelines/Recommendations*

Based on Comfort Performance



ASHRAE/DOE North American Climate Zone	Overall Installed Window U-value - U_w Btu/hr·ft^2·°F	Center of Glass U-value - U_g Btu/hr·ft^2·°F	SHGC – South	SHGC – North, East, West
8	≤0.11	≤0.10	≥0.50	≤0.40
7	≤0.12	≤0.11	≥0.50	≤0.40
6	≤0.13	≤0.12	≥0.50	≤0.40
5	≤0.14	≤0.13	≥0.50	≤0.40
4	≤0.15	≤0.14	≥0.50	≤0.40
Marine North	≤0.16	≤0.15	≥0.50	≤0.40
Marine South	≤0.22	≤0.20	≤0.50	≤0.30
3 (west)	≤0.18	≤0.16	≤0.50	≤0.30
2 (west)	≤0.18	≤0.16	≤0.30	≤0.30
2 (east)	≤0.20	≤0.18	≤0.30	≤0.30

Reference: Table Values PHIUS, Climate Map DOE/ASHRAE/NECB Zones by RDH

PHIUS WINDOW COMFORT & CONDENSATION RISK ASSESSMENT

Click for online calculator

- ASHRAE 99% Design Temperature used for analysis
- Required U-value varies based on window height

PHIUS WINDOW COMFORT & CONDENSATION RISK ASSESSMENT

PHIUS

Project Name	Sample
Project #	Sample
State	ILLINOIS
City	CHICAGO OHARE INTL AP
ASHRAE 99% Design Temperature [°F]	4.4

http://ashrae-meteo.info/

PHIUS+ Climate Data

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ambient Temp (°F)	23.7	27.5	38.8	50.0	59.5	70.0	75.4	71.2	64.6	51.8	40.5	25.3
Dewpoint (°F)	15.1	17.2	29.3	39.2	45.0	55.4	65.7	61.9	55.2	41.0	32.7	18.3

CONDENSATION RISK

ISO 13788 Calculation for Low Thermal Inertia Elements

Is this a Heating Climate?	TRUE
Use simple method for indoor humidity?	TRUE
High occupancy?	TRUE
U-value of window frame/glass [BTU/hr.ft^2.F]	
Safety Factor	15%

Interior Surface Temperature of window frame/glass [°F]	68.0
Risk of condensation on interior surface acceptable?	YES
Critical fRsi	0.64
Critical Month	JAN
Critical CRF Rating	64

COMFORT REQUIREMENTS

Applies to all projects.

Windows >10' in height and above have the same required U-value.

Window Vertical Height (ft) - Use slider	7.4
Required Whole Window U-value [BTU/hr.ft^2.F]	0.20

INTERIOR SURFACE TEMP

FOR WALL OR GLASS

$$\theta_{si} = \theta_i - U * R_{si} * [\theta_i - \theta_e]$$

θ_{si}	(°F) Interior surface temperature
θ_i	(°F) Interior temperature
U	(BTU/hr.ft^2.°F) U-value of the wall assembly
R_{si}	(hr.ft^2.°F/BTU) Interior surface film resistance
θ_e	(°F) Exterior temperature

DETERMINE WINDOW U VALUE

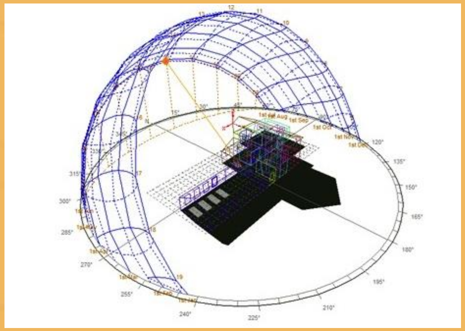
FOR MAX ΔT AT INTERIOR SURFACE

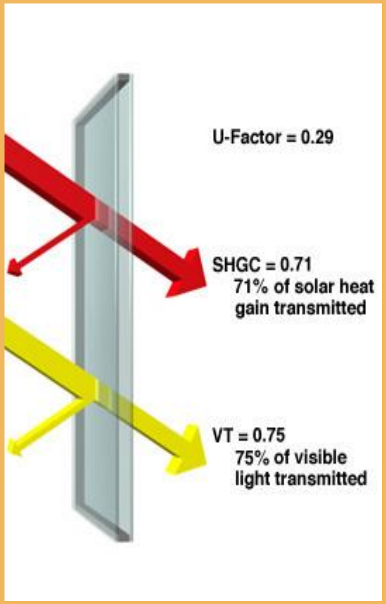
$$U \leq 7.2°\text{F} \div [R_{si} \times [\theta_i - \theta_e]]$$

U	(BTU/hr.ft^2.°F) U-value of the window
R_{si}	(hr.ft^2.°F/BTU) Interior surface film resistance
θ_i	(°F) Interior temperature
θ_e	(°F) Exterior temperature

TOTAL GAINS:

SOLAR GAINS
+ INTERNAL GAINS





Q_F TOTAL ANNUAL HEAT GAINS

GLAZING, PEOPLE, EQUIPMENT+ LIGHTING

$$Q_F = Q_S + Q_I$$

Q_F	(kBTU/yr) total heat gains
Q_S	(kBTU/yr) available solar heat gains
Q_I	(kBTU/yr) internal heat gains

P_G PEAK HEAT GAINS

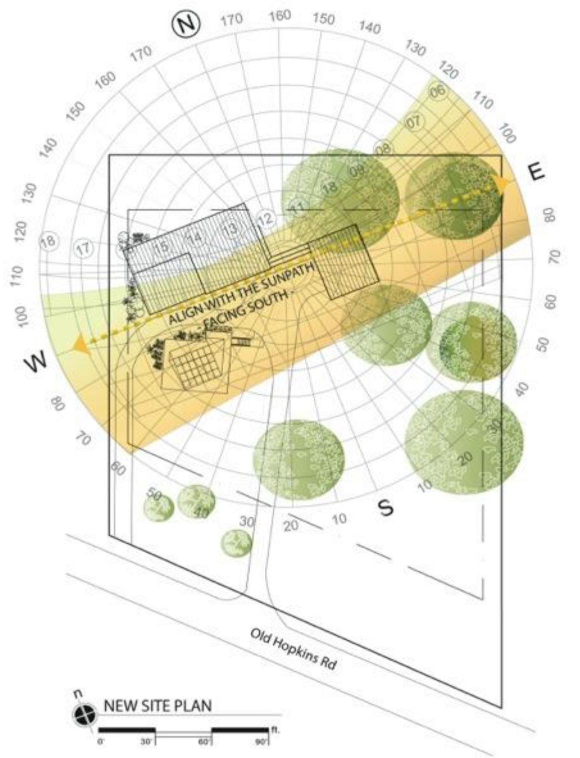
GLAZING, PEOPLE, EQUIPMENT+ LIGHTING

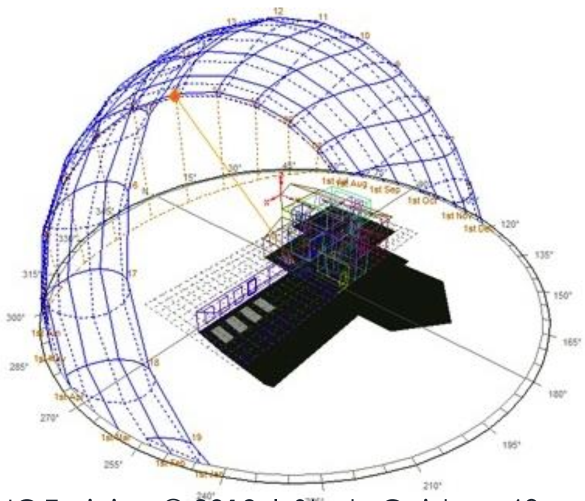
$$P_G = P_S + P_I$$

P_G	(BTU/hr) total peak heat gains
P_S	(BTU/hr) peak solar heat gains
P_I	(BTU/hr) peak internal heat gains

SOLAR GAINS:

WINDOWS
SKYLIGHTS
GLAZED DOORS





Q_S SOLAR GAINS ANNUAL

WINDOW, DOOR AND SKYLIGHT GLAZING

$$Q_S = r * g * A_W * G$$

Q_S	(kBTU/yr) total solar heat gains
r	(%) reduction factor for the frame portion, shading, dirt and non-perpendicular incidence of radiation 100% = no shading, 0% = full shading
g	(.) total energy transmittance via perpendicular radiation, aka glazing SHGC or g-value
A_W	(ft^2) window area (rough opening size)
G	($kBTU/ft^2.yr$) global radiation averaged over the heating season

P_S PEAK SOLAR GAINS

WINDOW, DOOR AND SKYLIGHT GLAZING

$$P_S = r * g * A_W * G_{worst}$$

P_S	(BTU/hr) total peak solar gains
r	(%) reduction factor for the frame portion, shading, dirt and non-perpendicular incidence of radiation 100% = no shading, 0% = full shading
g	(.) total energy transmittance via perpendicular radiation, aka glazing SHGC or g-value
A_W	(ft^2) window area
G	($BTU/hr.ft^2$) global radiation for worst case weather condition (cold+clear OR moderately cold+overcast)

r SOLAR REDUCTION FACTOR

WINDOW, DOOR AND SKYLIGHT GLAZING

$$r_T = r_{shade} * r_{dirt} * r_{npi} * r_{frame\,\%}$$

r_T	(%) total solar gain reduction factor (varies)
r_{shade}	(%) solar gain reduction due to shade (varies)
r_{dirt}	(%) solar gain reduction due to dirt on panes (5% blocked, then r = 95%)
r_{npi}	(%) solar gain reduction due to non-perpendicular incidence of radiation (15% blocked)
$r_{frame\,\%}$	(%) solar gain reduction due to frame % of overall window (varies)

100% = no shading, 0% = full shading

INTERNAL GAINS:

OCCUPANTS
EQUIPMENT
LIGHTING

Q_I INTERNAL HEAT GAINS ANNUAL

OCCUPANTS | EQUIPMENT | LIGHTING

$$Q_I = T_{heat} * q_i * iCFA$$

Q_I	(kBTU/yr) Internal heat gains
T_{heat}	days per heating season * 0.024 hrs
q_i	(BTU/hr.ft^2) calculated internal heat load (typically 0.8 – 1.5)
$iCFA$	(ft^2) interior conditioned floor area

P_I INTERNAL HEAT GAINS PEAK

OCCUPANTS | EQUIPMENT | LIGHTING

$$P_I = q_i * iCFA$$

P_I	(BTU/hr) peak internal heat gains
q_i	(BTU/hr.ft^2) 0.51 unoccupied building internal heat load (worst case)
$iCFA$	(ft^2) interior conditioned floor area


Glasswood Building | Hammer and Hand

UNIT REVIEW

Units	Description
kBTU/yr	Total Annual Demand
kBTU/ft^2_{iCFA}/yr	Specific Annual Demand
BTU/hr	Total Peak Load
BTU/ft^2_{iCFA}/hr	Specific Peak Load
CFM_{50}/ft^2 **ACH_{50}**	Airtightness or Infiltration (@ 50Pa)
hr.ft^2.°F/BTU	R-Value
hr.ft^2.°F/BTU.in	R per inch
BTU/hr.ft^2.°F	U-Value
ACH or CFM	Ventilation Rate
ACH	Air changes per hour
CFM	Cubic feet per minute

THANK YOU