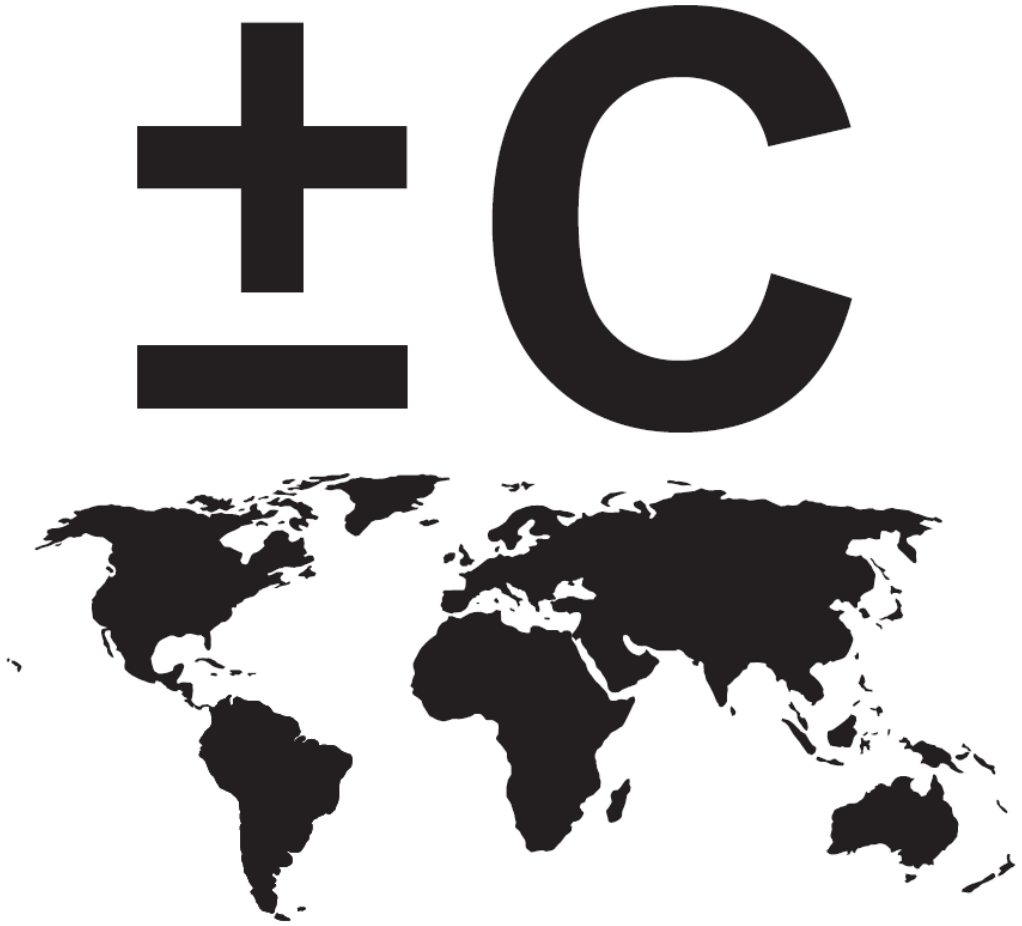


# PHIUS+ SOURCE ZERO

# Agenda

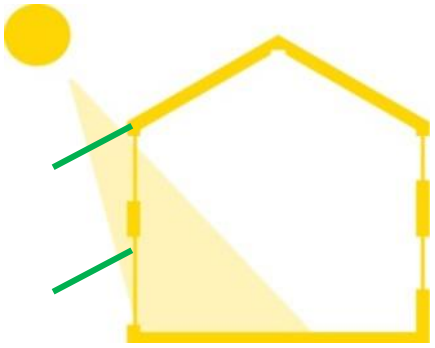
- Passive Building Principles
- Passive Building Standards Development
- PHIUS+ Source Zero Certification Requirements
- WUFI Passive modeling tool

# PASSIVE BUILDING PRINCIPLES

**Thermal Control**

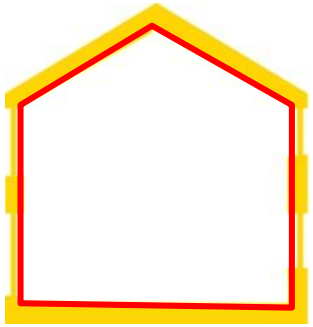
CONTINUOUS INSULATION

**Radiation Control**

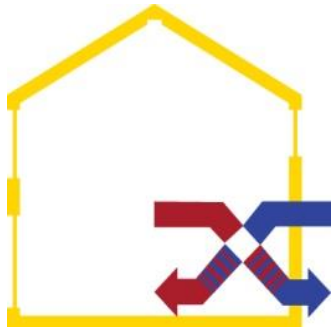


OPTIMIZED WINDOWS & SOLAR GAINS

**Air Control**



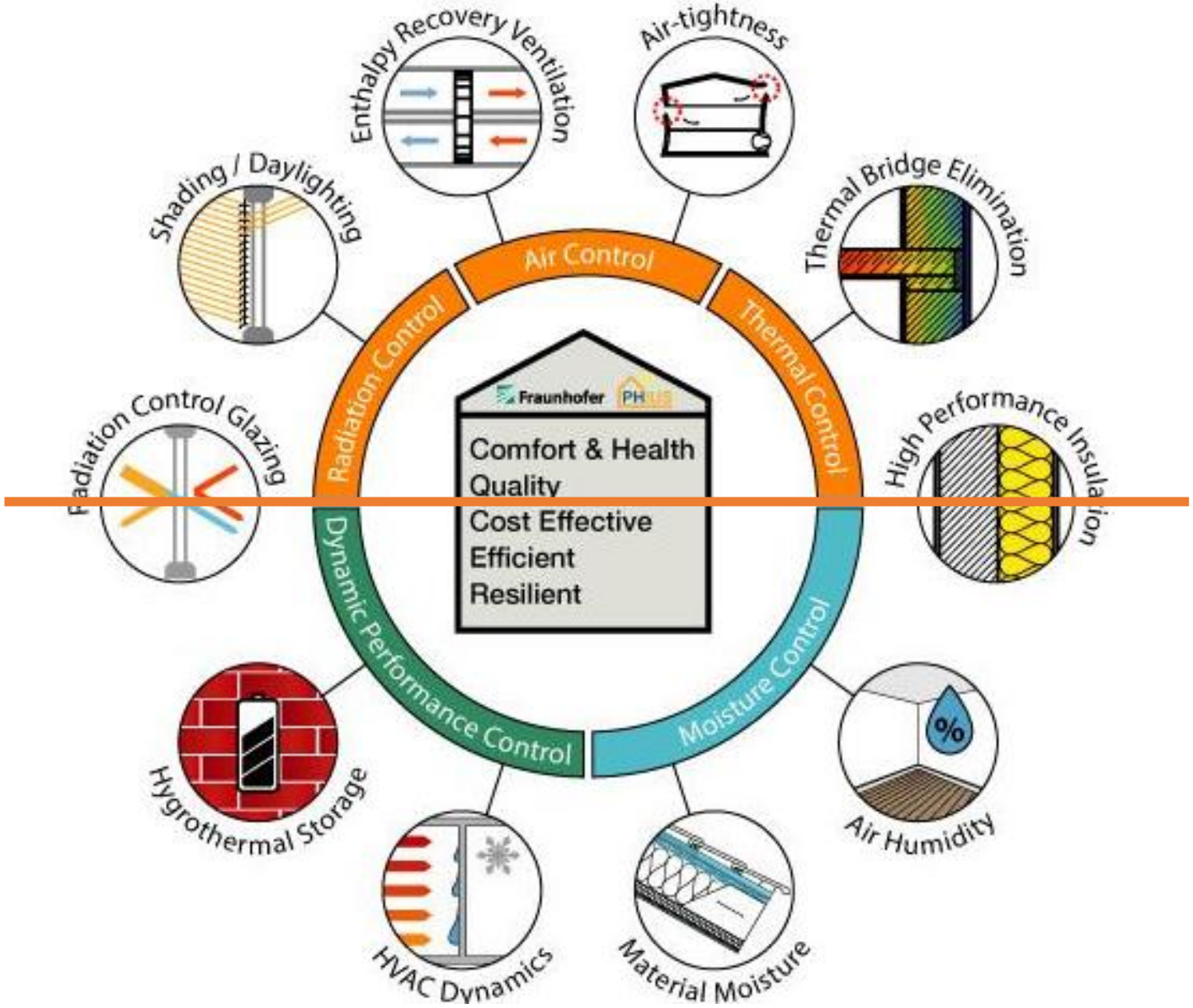
AIR-TIGHT CONSTRUCTION



BALANCED VENTILATION WITH HEAT RECOVERY

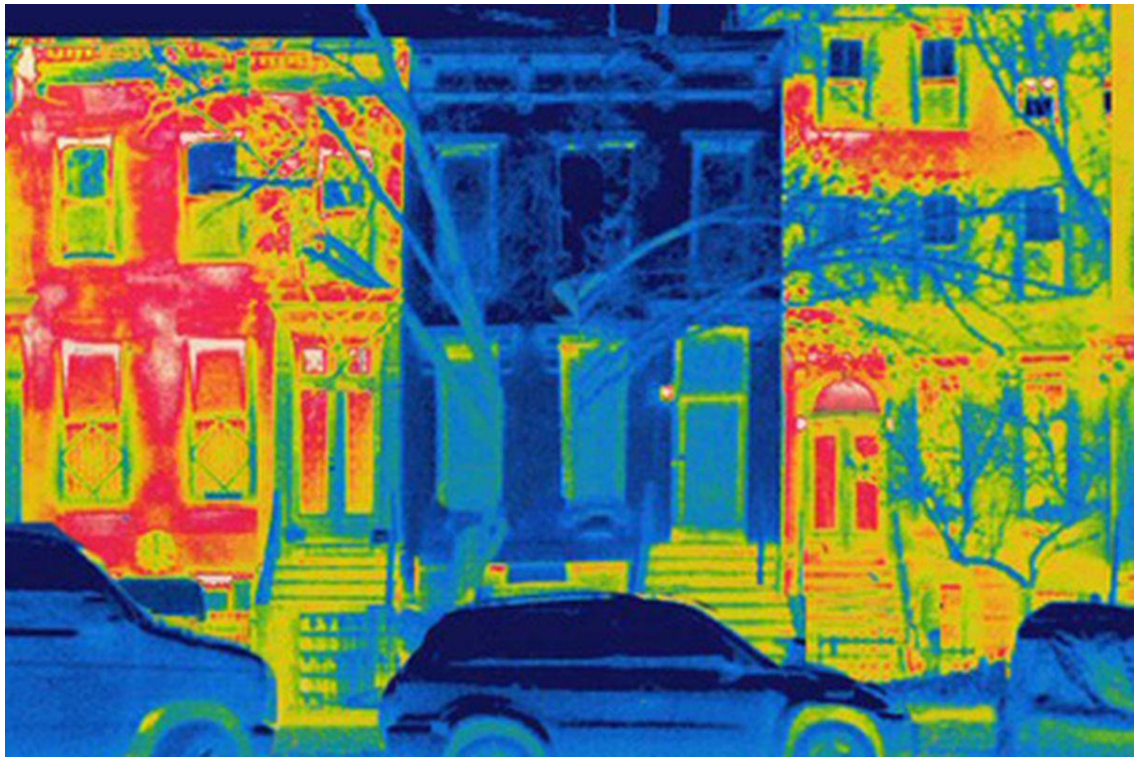
MINIMIZED MECHANICAL SYSTEMS

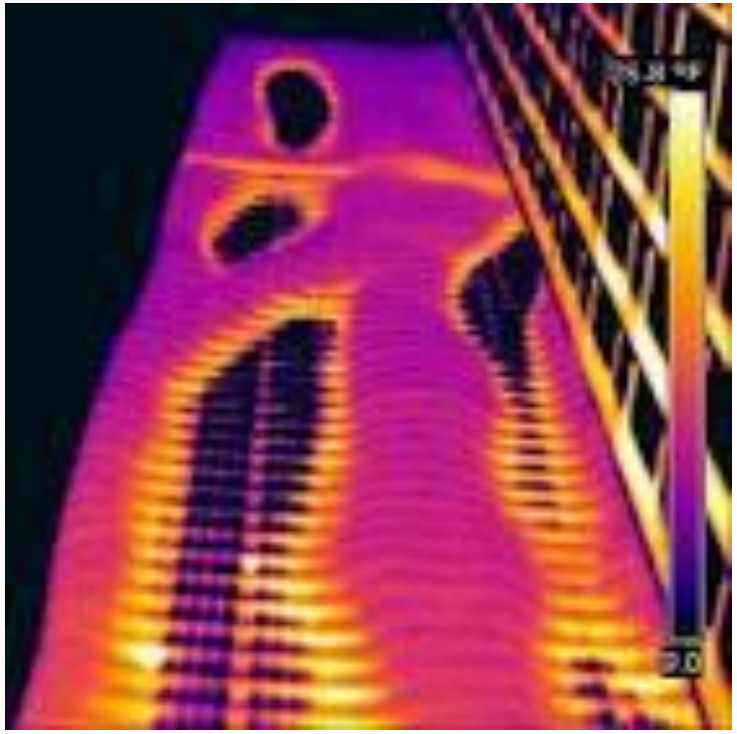
# PASSIVE BUILDING PRINCIPLES

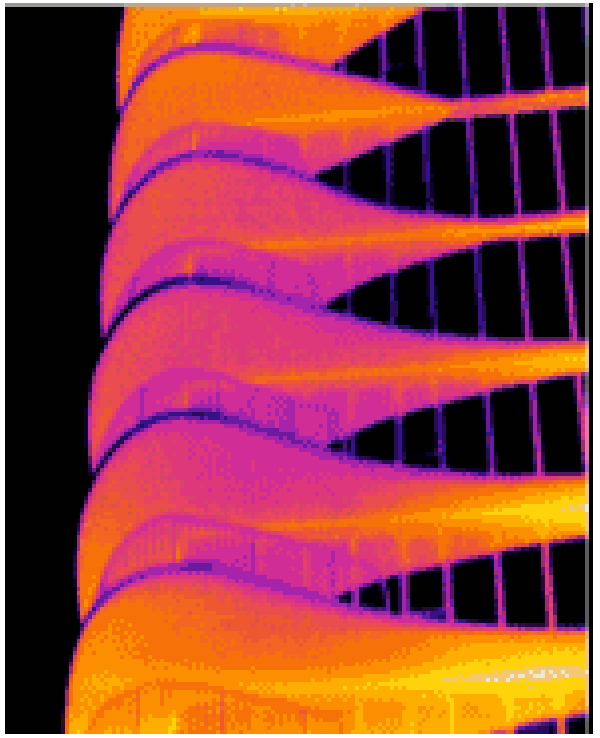


# CONTINUOUS INSULATION

MINIMIZE THERMAL BRIDGING

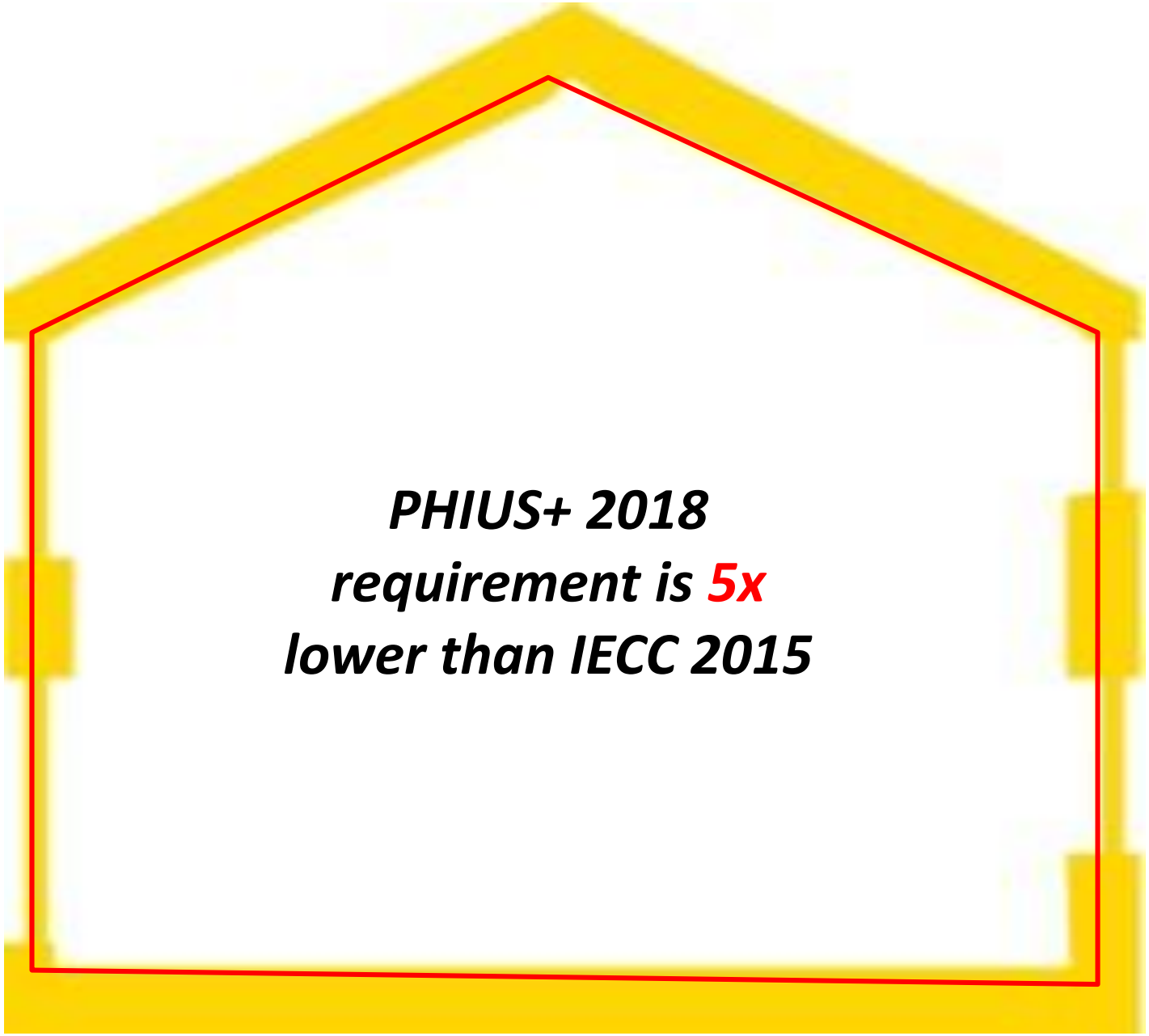


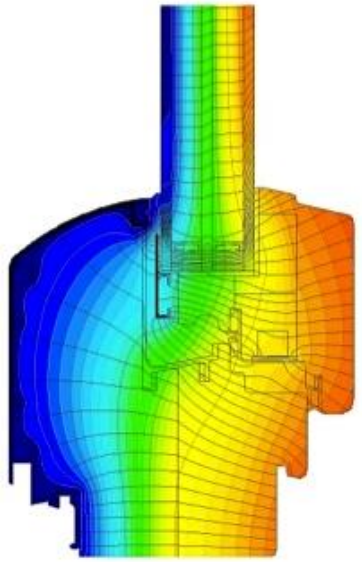


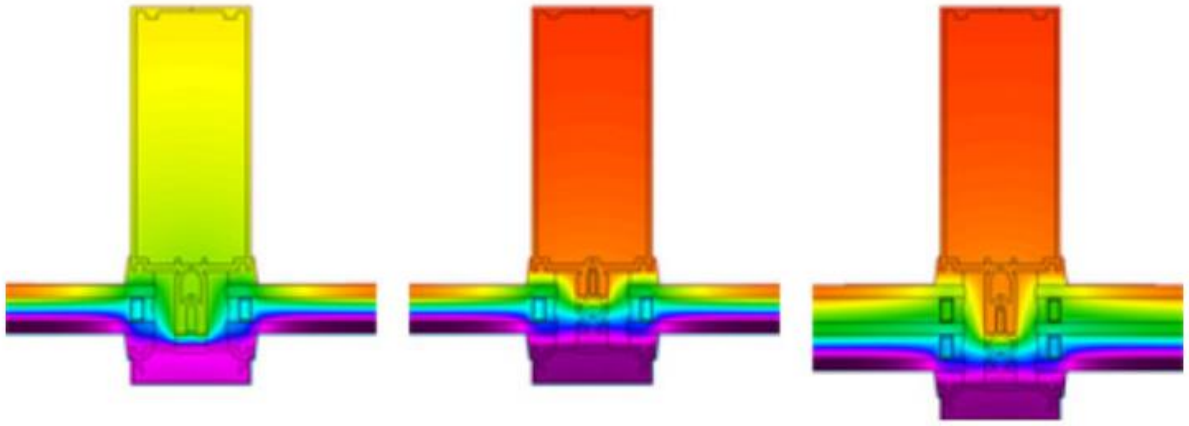


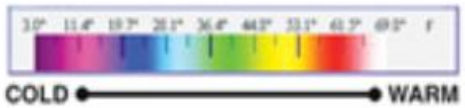
# MINIMIZE THERMAL BRIDGING

# AIR TIGHT CONSTRUCTION





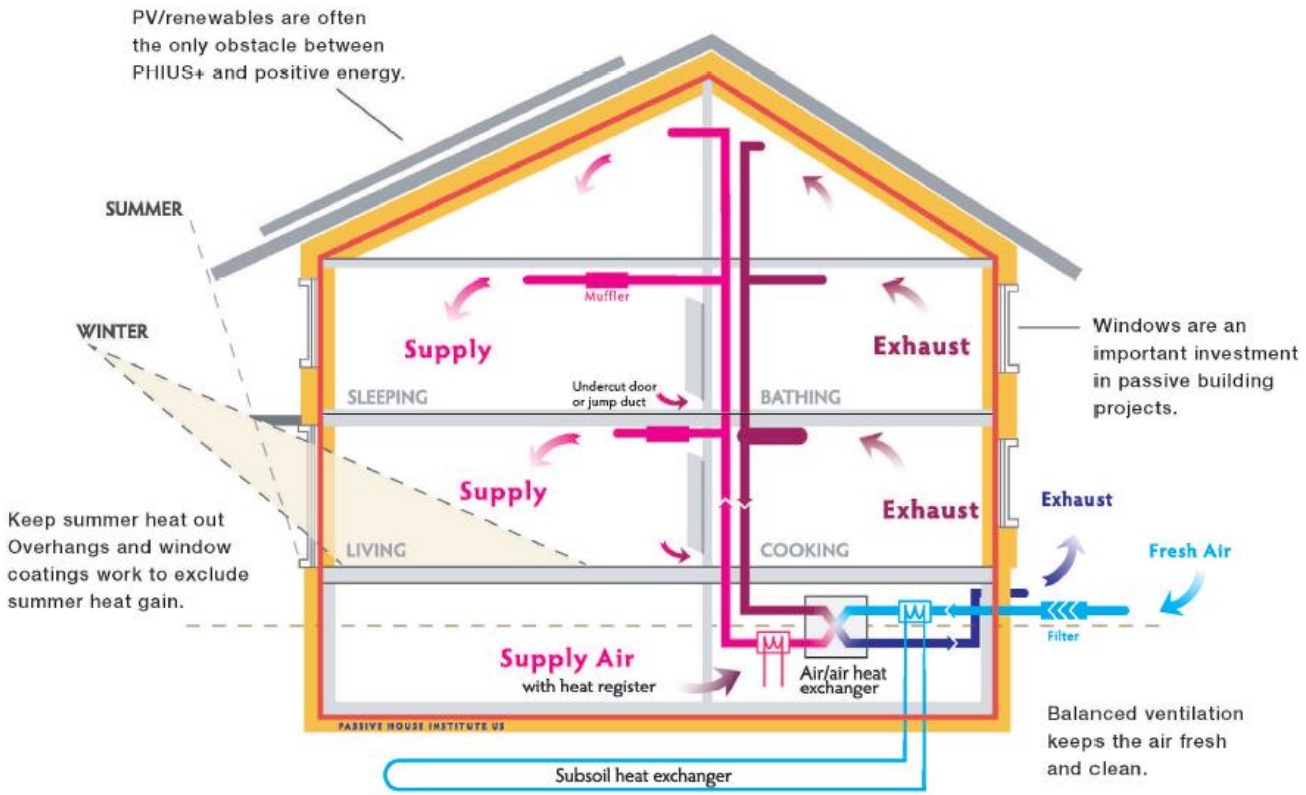


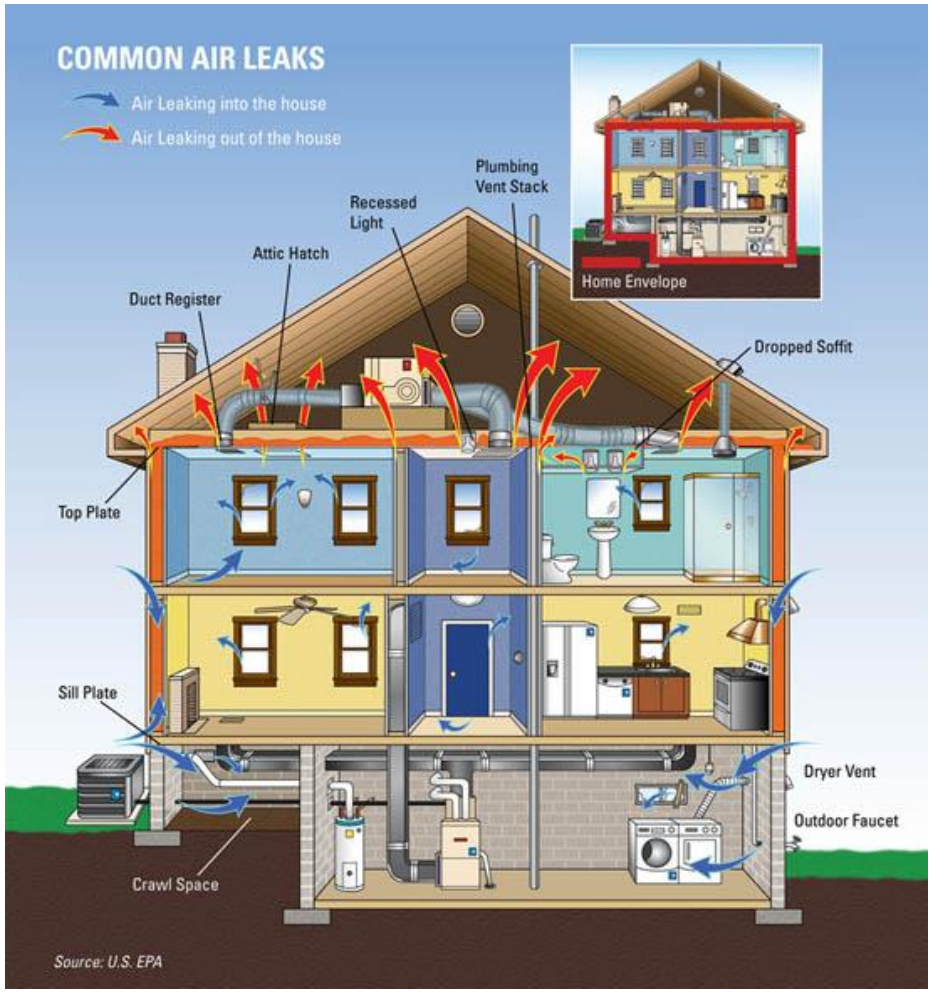




**OPTIMIZED**
WINDOWS
& SOLAR
GAINS

# BALANCED VENTILATION WITH HEAT RECOVERY

# *Controlled* Ventilation vs *Random* Ventilation



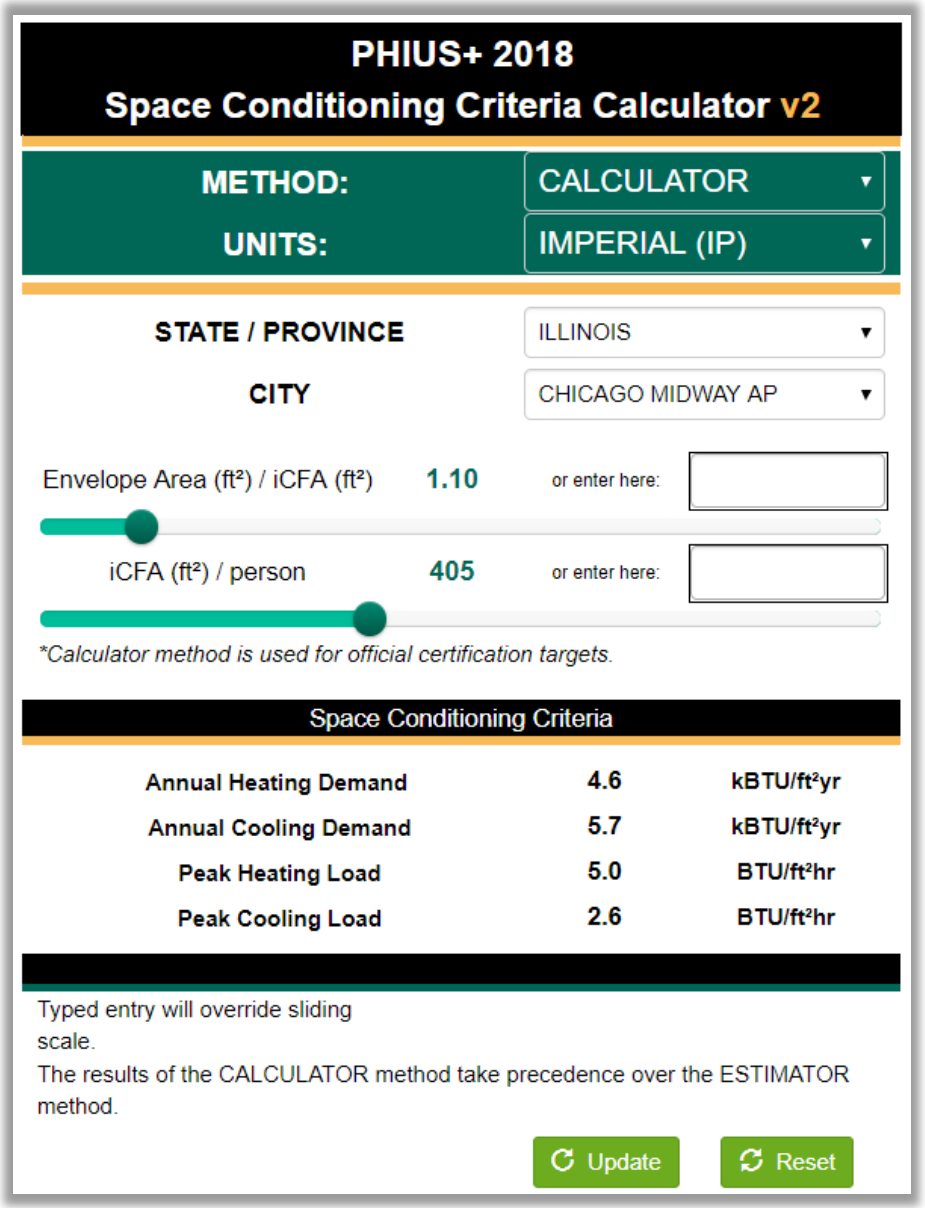



# MINIMIZED, EFFICIENT MECHANICAL SYSTEMS

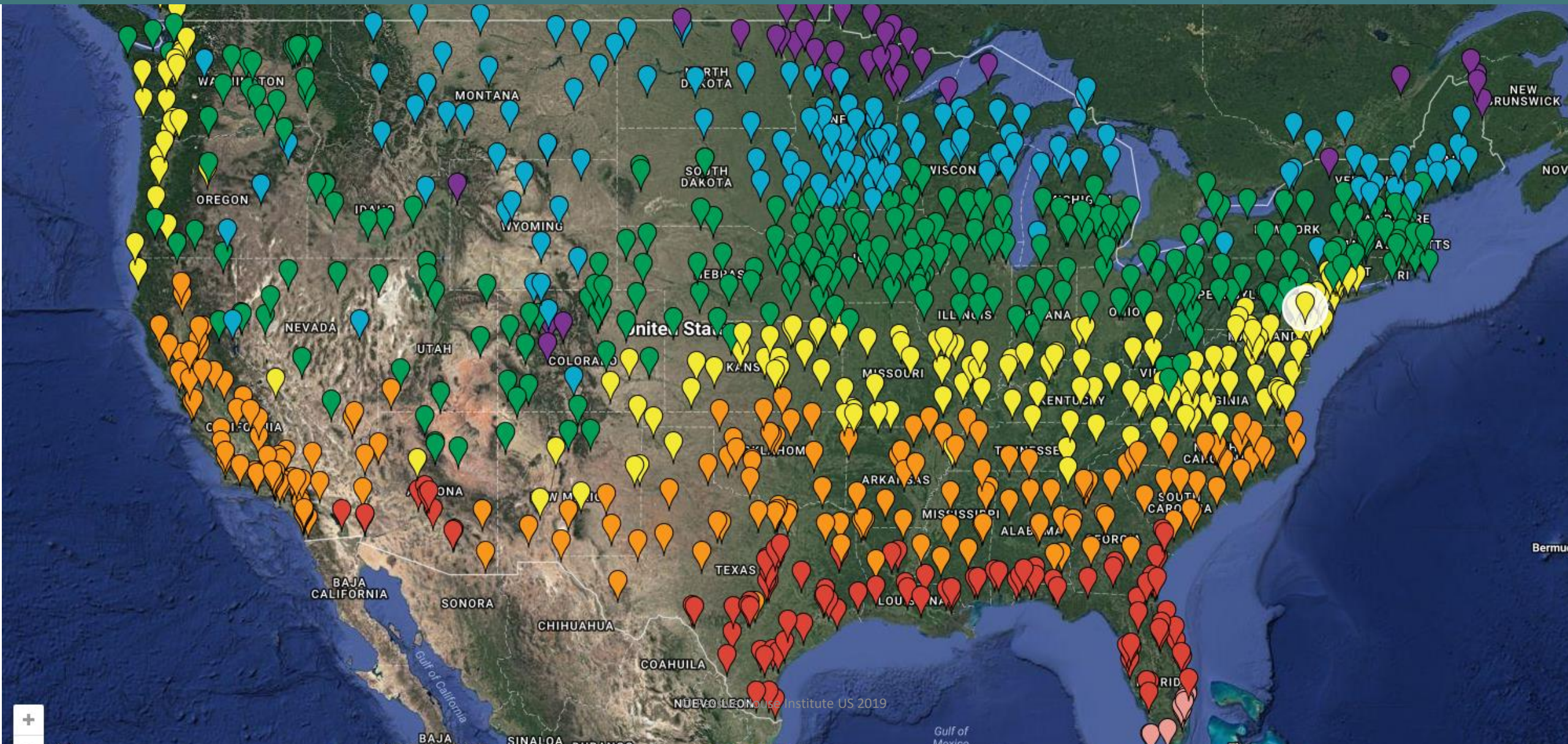
# How to quantify or set targets for investments in these passive measures?

# PHIUS+2018

A *performance* based ***passive building standard*** with *prescriptive* requirements.



# TARGETS for 1000+ CLIMATES & sliding scale for occupant density and building size

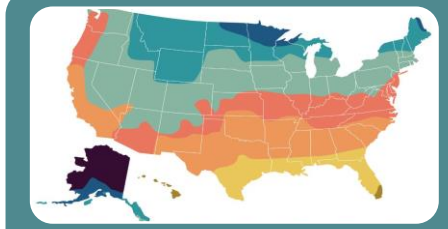


# PHIUS+ SOURCE ZERO

Built upon PHIUS+, it is a *conservation-first* design methodology for Net-Zero buildings with quality assurance throughout design and construction.

# MAIN CERTIFICATION REQUIREMENTS

REQUREIEMTNS FOR ALL PHIUS+ CERTIFICATIONS



## SPACE CONDITIONING TARGETS

- Based on cost optimization analysis
- Vary based on climate, occupant density, and envelope/floor area ratio

## AIR-TIGHTNESS

- 0.060 CFM50/ft$^2$ envelope area
- Required limit set based on building durability.  Pass/Fail.

PHIUS+ RATER

PHIUS+ VERIFIER

## ON-SITE QUALITY ASSURANCE TESTING/INSPECTION

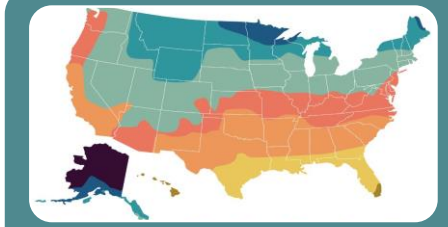
- Ensure quality for elements not reflected in energy modeling
- Required for all projects

VARIES

## NET SOURCE ENERGY TARGET

- Used instead of site energy as a better proxy for carbon emissions
- Target and renewable energy offsets vary based on program version

REQUREIEMTNS FOR ALL PHIUS+ CERTIFICATIONS



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PHIUS+ RATER  PHIUS+ VERIFIER

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- Required for all projects

VARIES

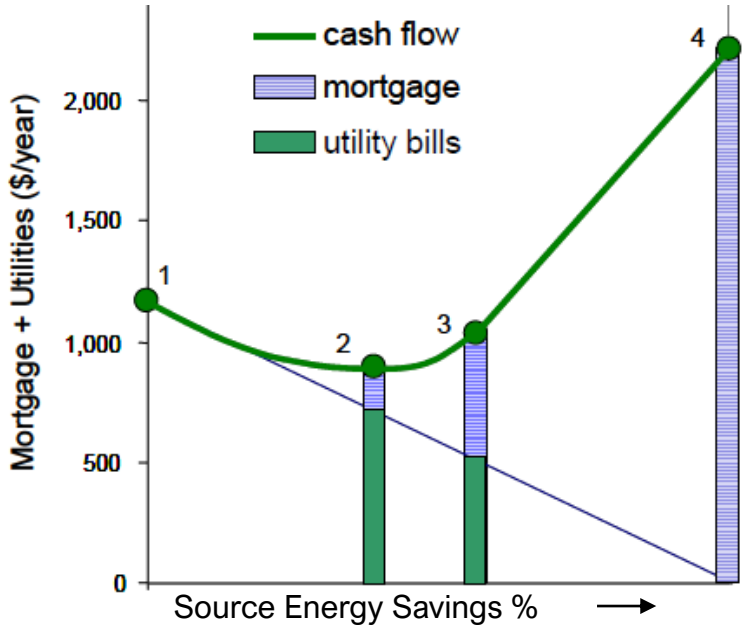
## NET SOURCE ENERGY TARGET

- Used instead of site energy as a better proxy for carbon emissions
- Target and renewable energy offsets vary based on program version

# How low can (and *should*) you go with passive measures, i.e. when to stop?

# TARGET SETTING METHODOLOGY

## Setting Cost Competitive Space Conditioning Criteria

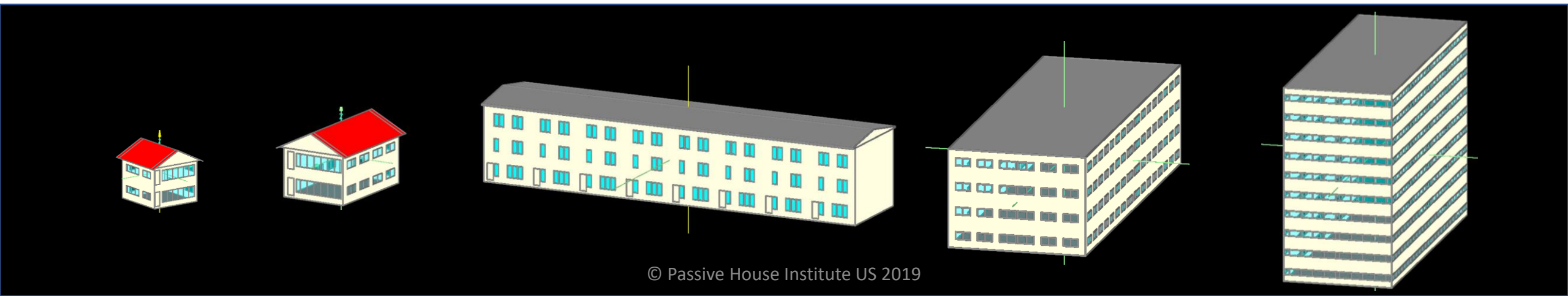



NREL BEopt optimizes upgrade package, set target at optimum point

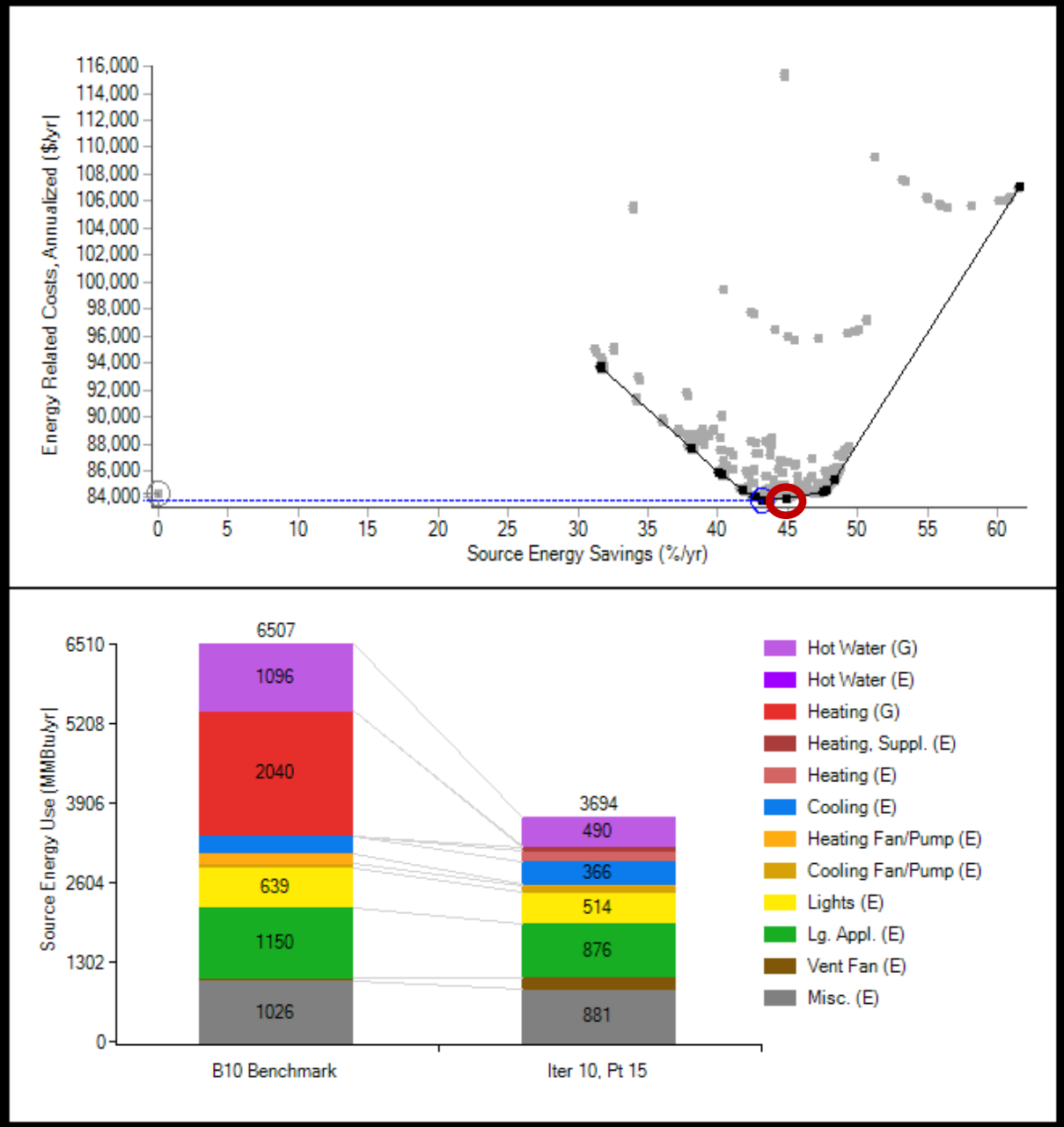
Factors:
Climate
Building Size
Occupant Density

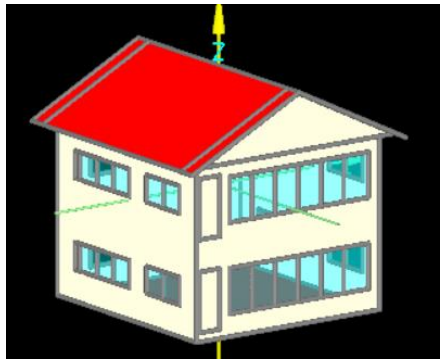
Ignore PV for space conditioning targets!!

Forced Constraints:
Air-sealing (meet PHIUS+ target)
Window performance (comfort & low loads)

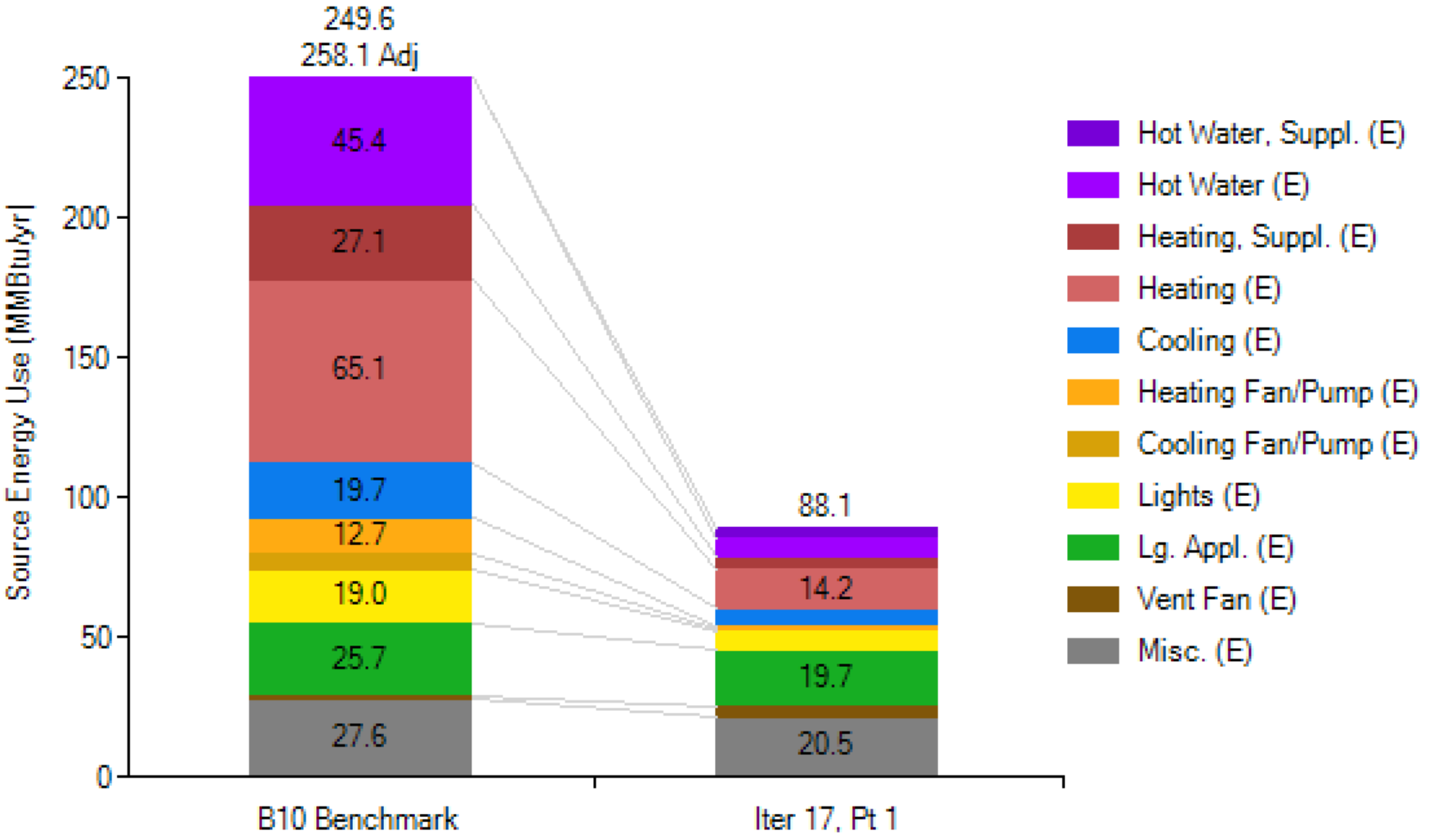


# *Cost optimal sweet-spot for investment in conservation*

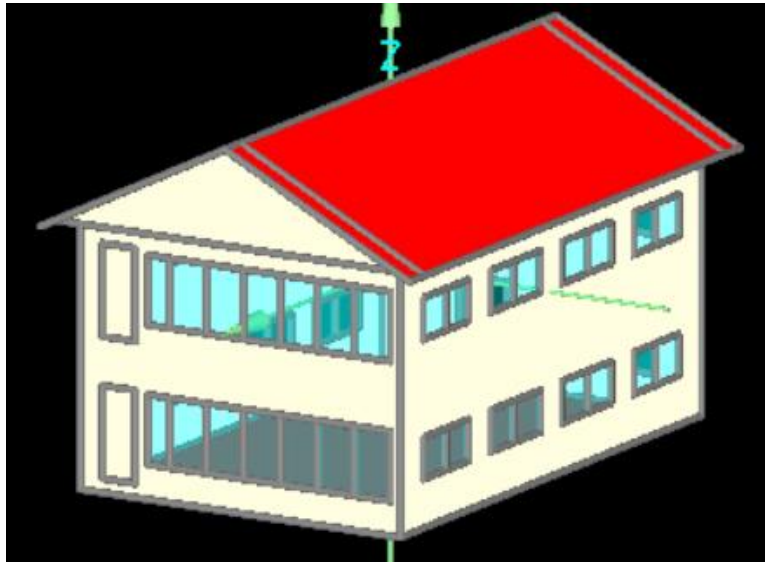


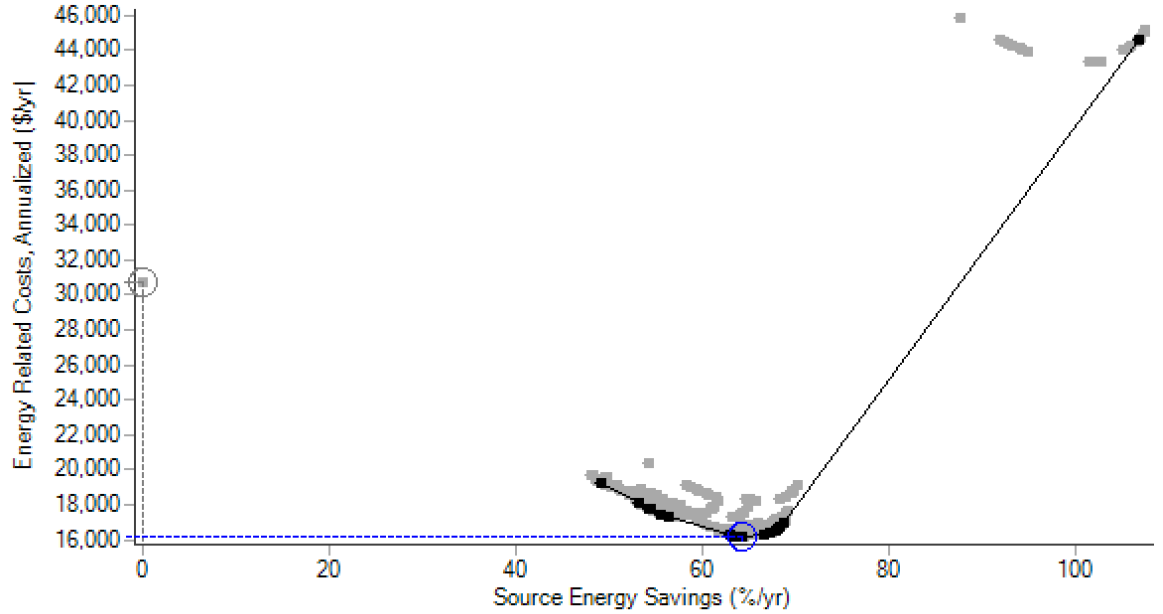


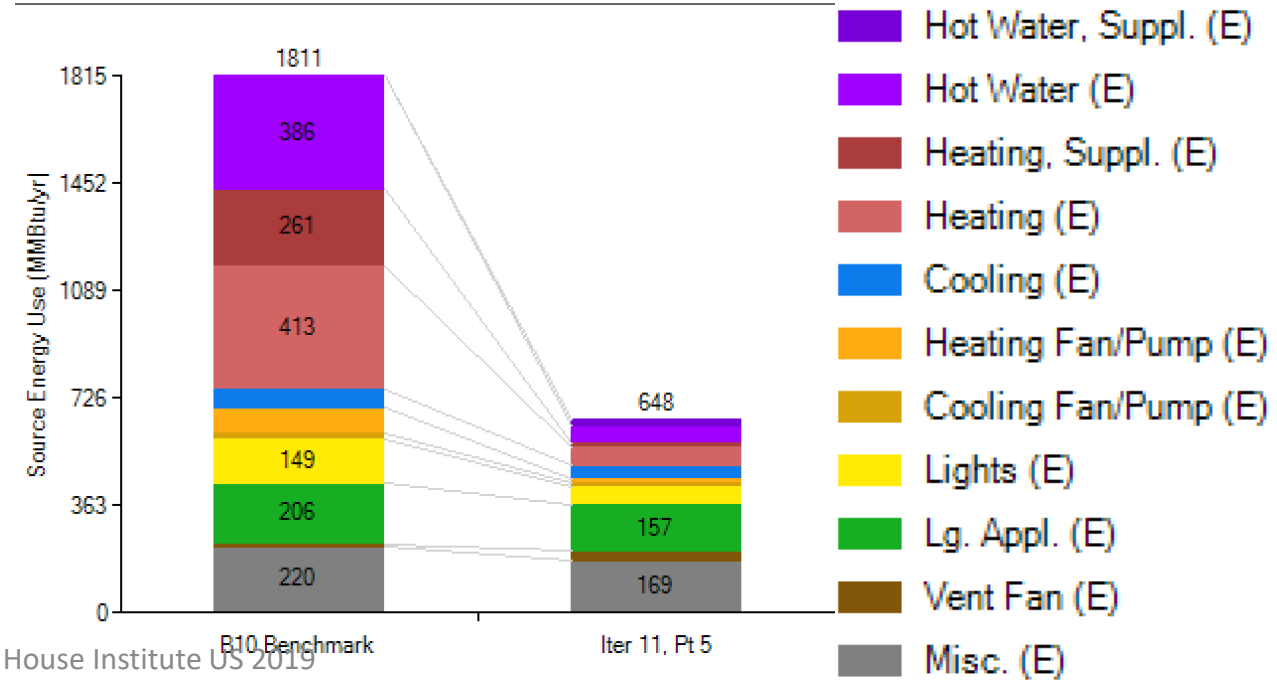
# Single Family Typical
# Medium Occupancy
# Clarinda, IA , $0.11/kWh



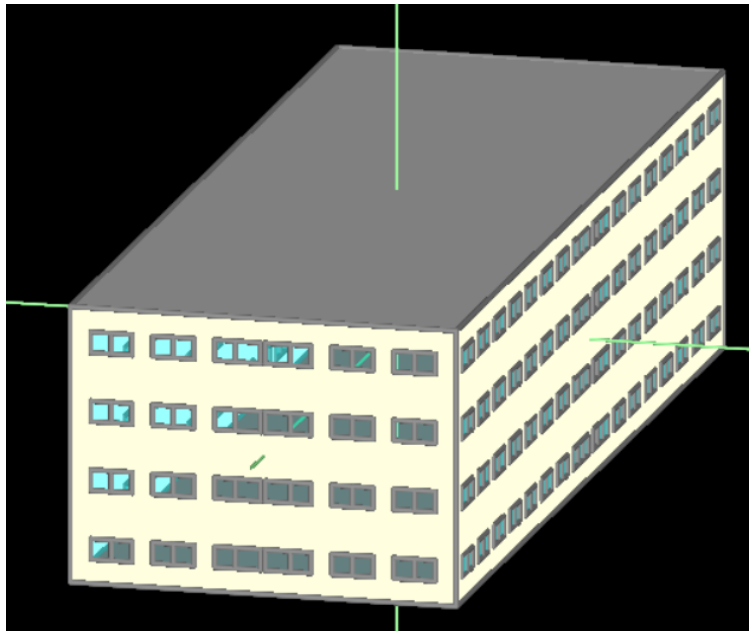
# Townhouse
# Medium-occupancy
# Chicago-Waukegan IL (5A)

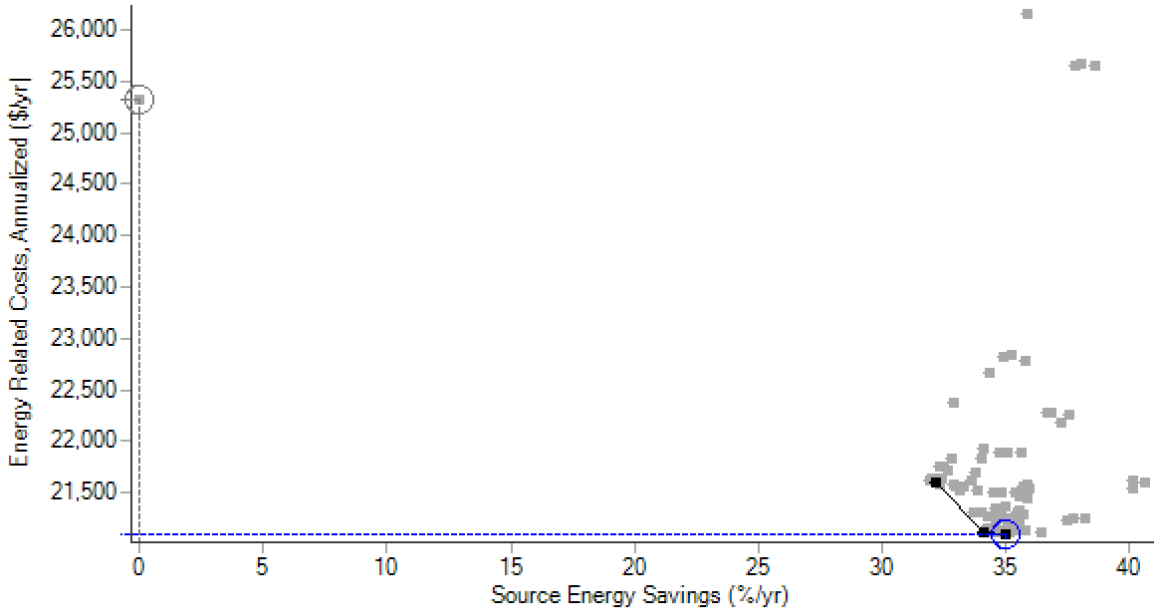


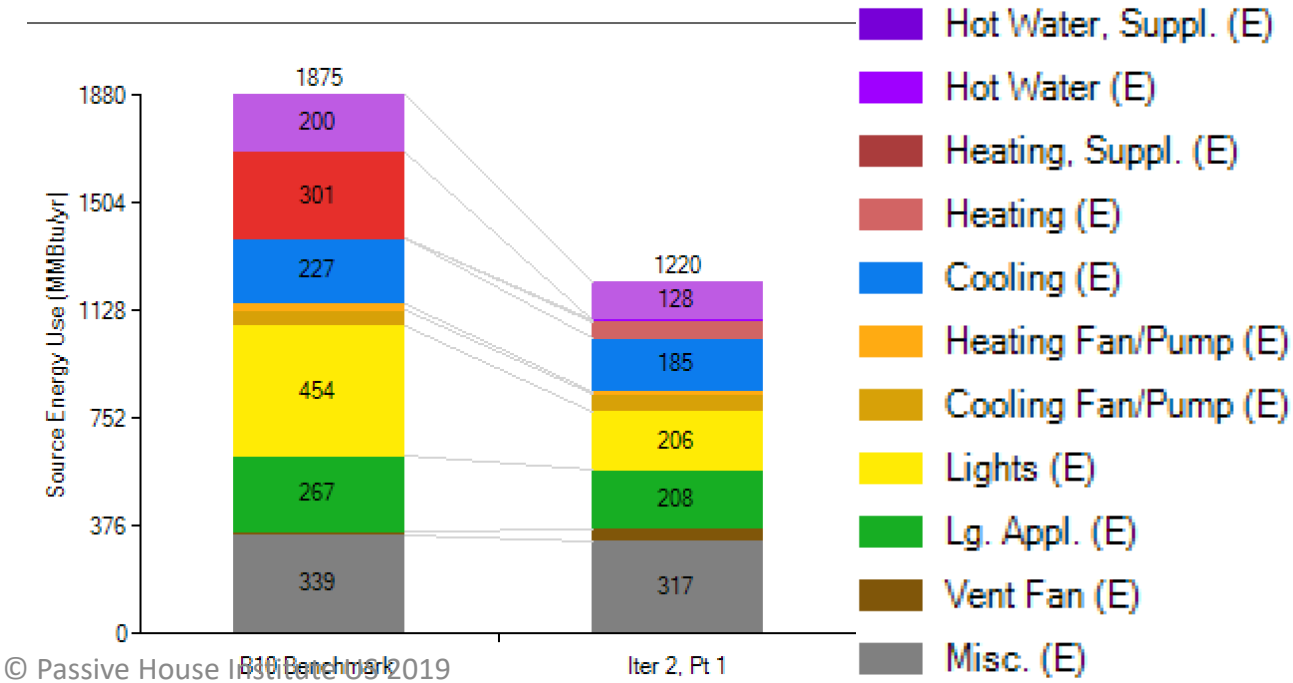


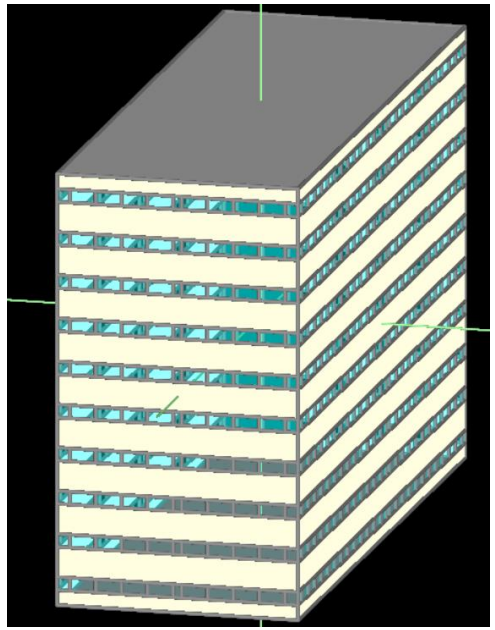
# Multifamily Mid-Rise
# Low Occupancy
# McAlester OK (Zone 3A)

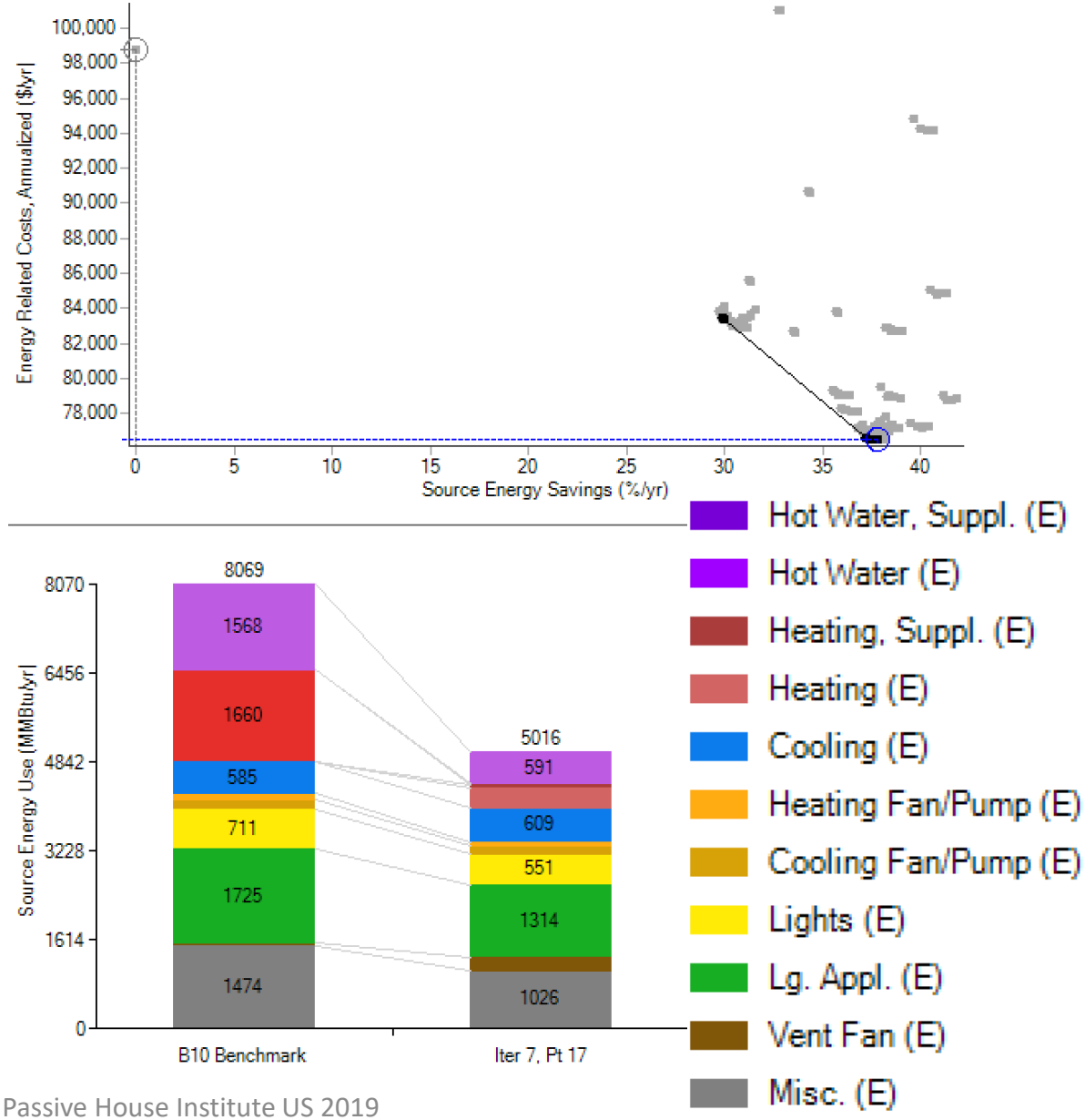




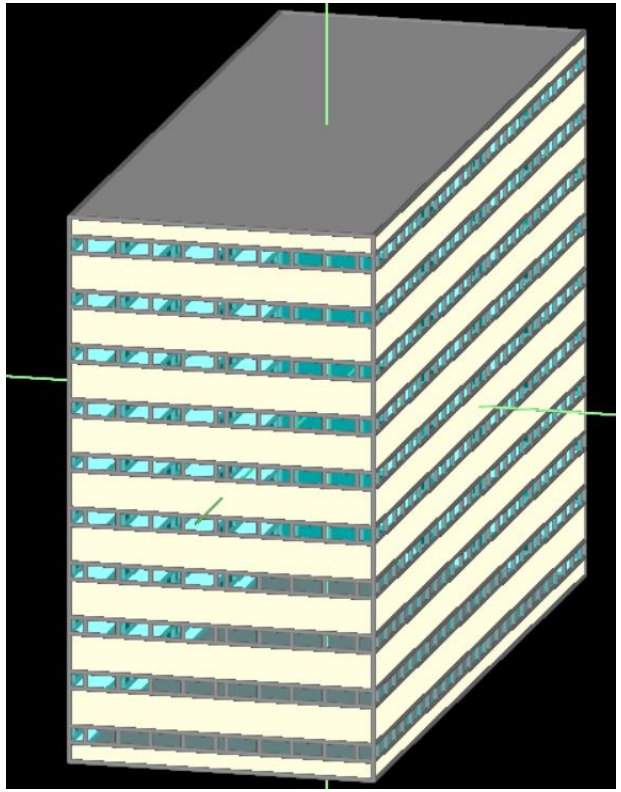



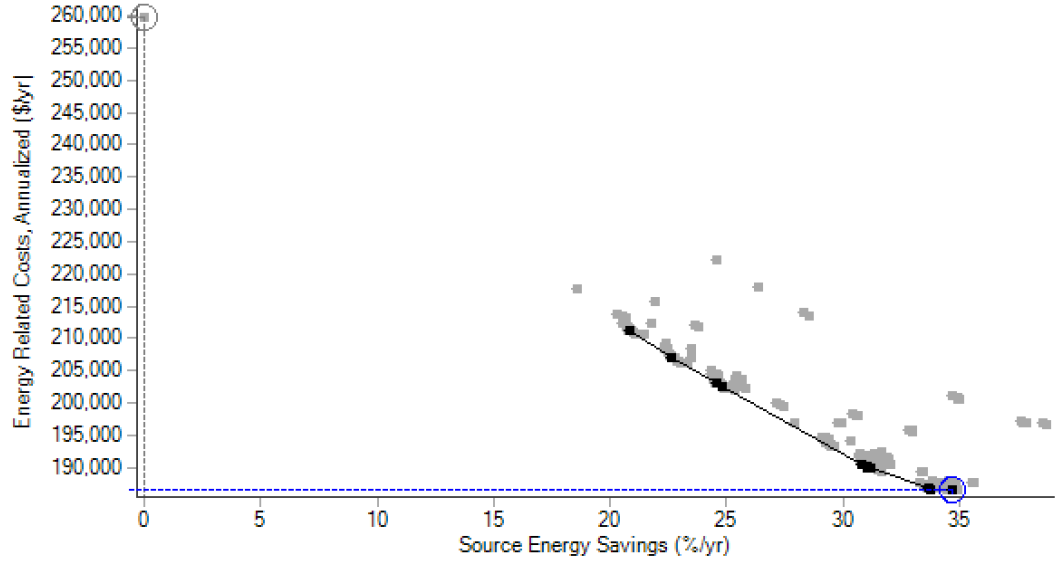
# MF High-rise
# High-occupancy
# Chariton, IA (5A)

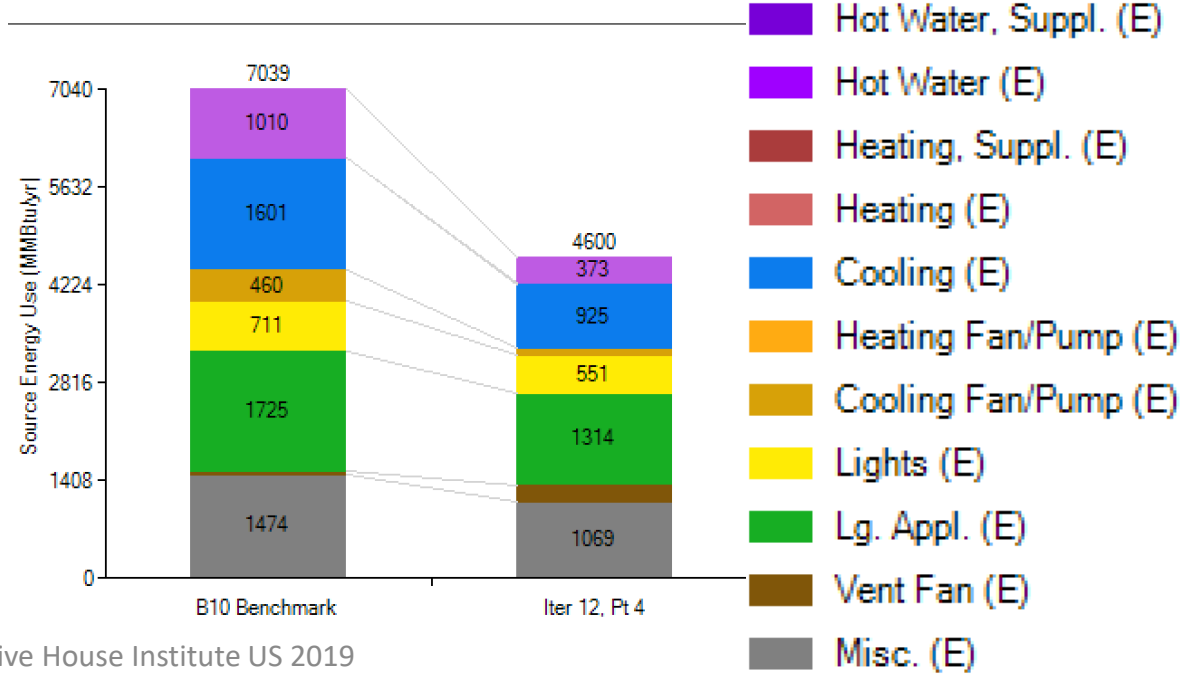


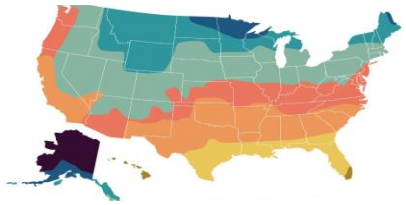


# MF High-rise
# High-occupancy
# Molokai, HI





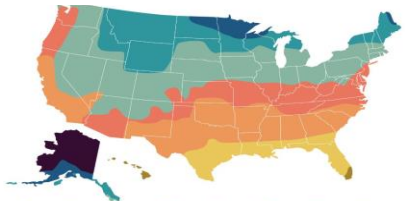





# SPACE CONDITIONING TARGETS

**Annual Demand [kBTU/yr.ft$^2$]:** Total annual heat (or cooling) energy that must be delivered to the space in order to maintain a desired setpoint.

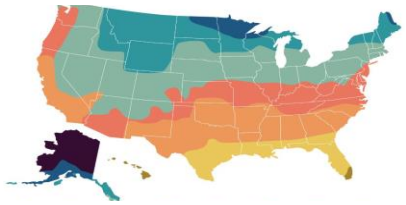
***Annual Heating Demand ≤ A (kBTU/ft$^2$.yr)***
***Annual Cooling Demand ≤ B (kBTU/ft$^2$.yr)***



# SPACE CONDITIONING TARGETS

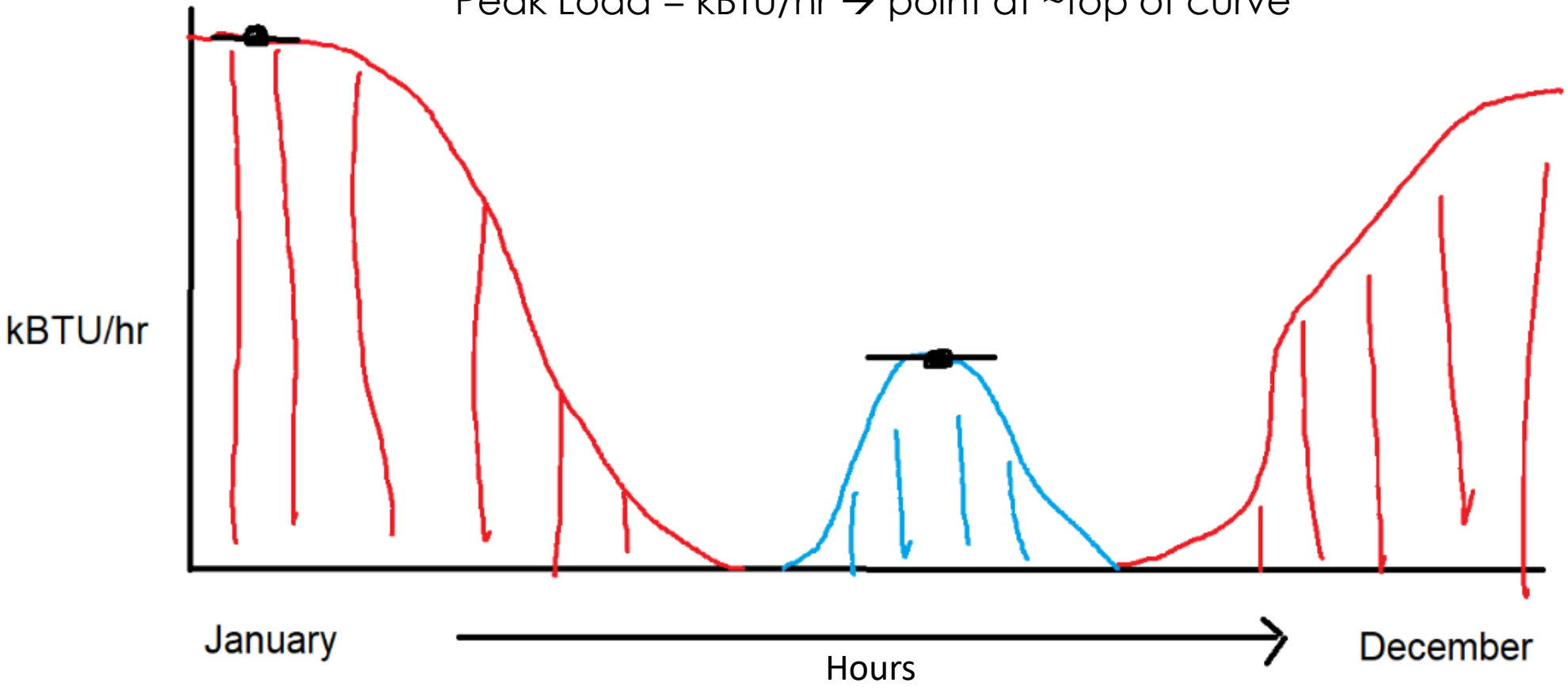
**Peak Load [BTU/hr.ft$^2$]:** Space conditioning requirement during the peak climate conditions (average over the worst 24 hours). Determines the size of the mechanical system.

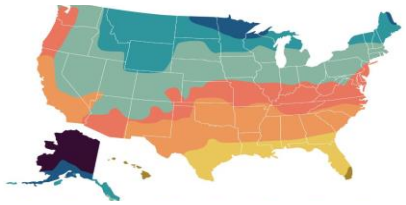
***Peak Heating Load ≤ C (BTU/ft$^2$.hr)***
***Peak Cooling Load ≤ D (BTU/ft$^2$.hr)***



# SPACE CONDITIONING TARGETS

Annual Demand = kBTU/yr → area under the curve
Peak Load = kBTU/hr → point at ~top of curve



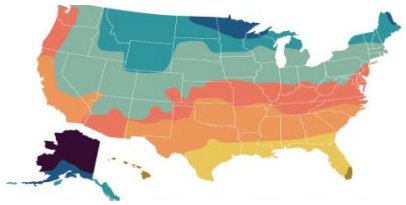


# SPACE CONDITIONING TARGETS

**MUST MEET ALL 4**! Different advantages for each:

- Low ***annual demand*** saves energy and operating cost
- Low ***peak loads*** ensure comfort, resilience, and reduce mechanical system size

***Annual Heating Demand ≤ A (kBTU/ft2.yr)*** ✓
***Annual Cooling Demand ≤ B (kBTU/ft2.yr)*** ✓
***Peak Heating Load ≤ C (BTU/ft2.hr)*** ✓
***Peak Cooling Load ≤ D (BTU/ft2.hr)*** ✓



# SPACE CONDITIONING TARGETS

**Met with passive building strategies.**
**Heating/cooling equipment efficiency does not influence result.**

Annual Demand is not the same as site energy.

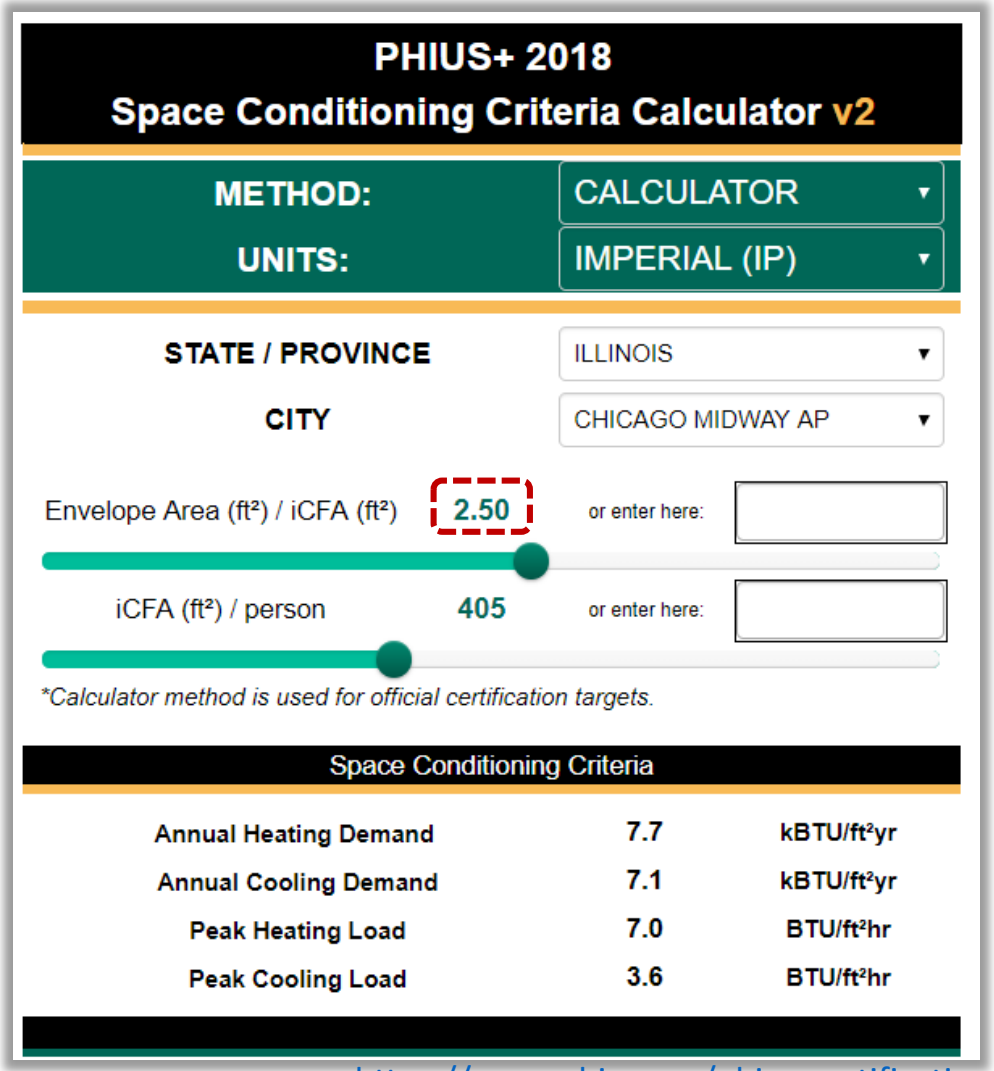
The heating/cooling *site* energy depends on the amount of heating/cooling that must be delivered to the space (annual demand) and the efficiency of the equipment delivering it.

The one piece of mechanical equipment that can influence the annual demand is the ERV or HRV, because it has a 'passive' recovery core, so the passive recovery efficiency matters.

# SPACE CONDITIONING TARGETS

## VARY BASED ON

## BUILDING SIZE AND OCCUPANT DENSITY



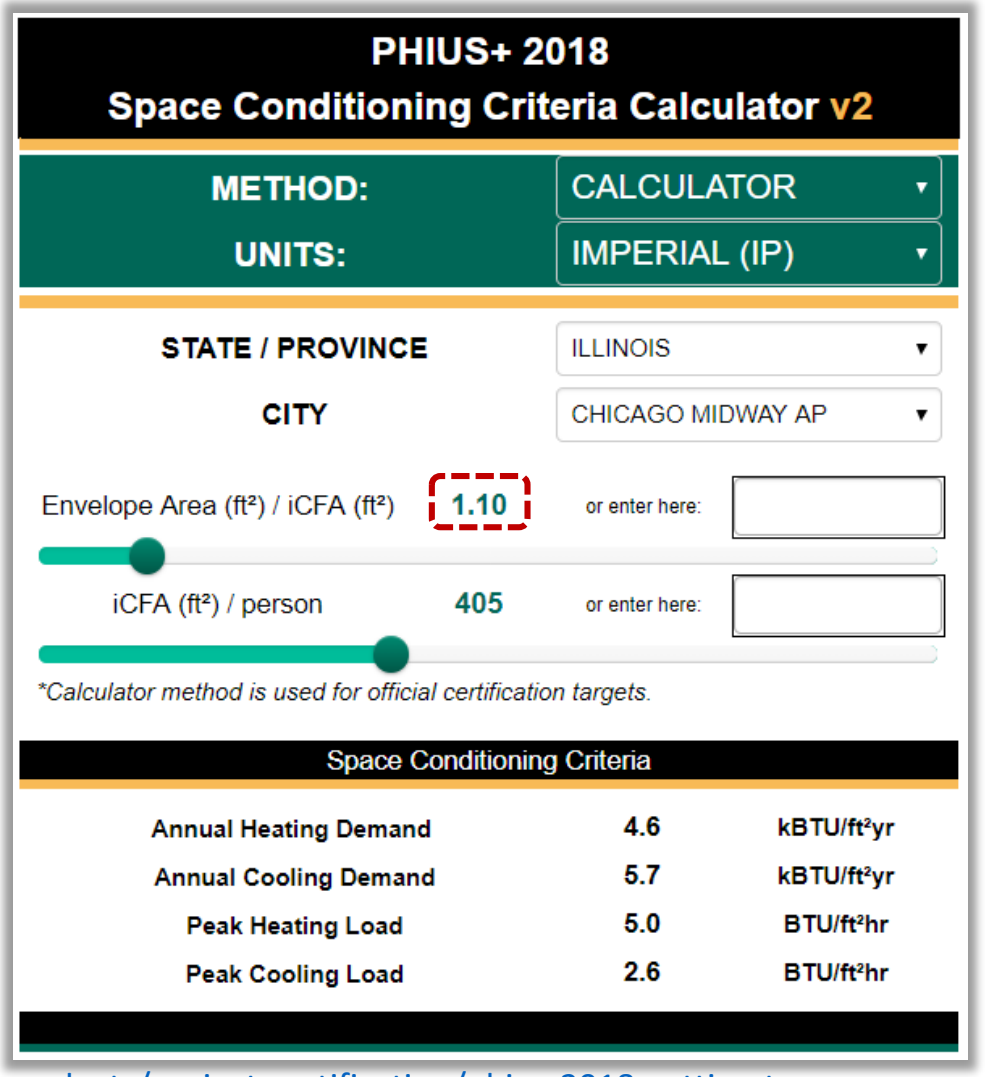
**PHIUS+ 2018**
**Space Conditioning Criteria Calculator v2**

| | |
|---|---|
| METHOD: | CALCULATOR |
| UNITS: | IMPERIAL (IP) |
| STATE / PROVINCE | ILLINOIS |
| CITY | CHICAGO MIDWAY AP |
| Envelope Area (ft²) / iCFA (ft²) | 2.50 |
| iCFA (ft²) / person | 405 |

*Calculator method is used for official certification targets.

**Space Conditioning Criteria**

| | | |
|---|---|---|
| Annual Heating Demand | 7.7 | kBTU/ft²yr |
| Annual Cooling Demand | 7.1 | kBTU/ft²yr |
| Peak Heating Load | 7.0 | BTU/ft²hr |
| Peak Cooling Load | 3.6 | BTU/ft²hr |



**PHIUS+ 2018**
**Space Conditioning Criteria Calculator v2**

| | |
|---|---|
| METHOD: | CALCULATOR |
| UNITS: | IMPERIAL (IP) |
| STATE / PROVINCE | ILLINOIS |
| CITY | CHICAGO MIDWAY AP |
| Envelope Area (ft²) / iCFA (ft²) | 1.10 |
| iCFA (ft²) / person | 405 |

*Calculator method is used for official certification targets.

**Space Conditioning Criteria**

| | | |
|---|---|---|
| Annual Heating Demand | 4.6 | kBTU/ft²yr |
| Annual Cooling Demand | 5.7 | kBTU/ft²yr |
| Peak Heating Load | 5.0 | BTU/ft²hr |
| Peak Cooling Load | 2.6 | BTU/ft²hr |

https://www.phius.org/phius-certification-for-buildings-products/project-certification/phius-2018-getting-to-zero

# SPACE CONDITIONING TARGETS

## VARY BASED ON

## BUILDING SIZE AND OCCUPANT DENSITY

**PHIUS+ 2018**
**Space Conditioning Criteria Calculator v2**

| | |
|---|---|
| **METHOD:** | CALCULATOR |
| **UNITS:** | IMPERIAL (IP) |
| **STATE / PROVINCE** | ILLINOIS |
| **CITY** | CHICAGO MIDWAY AP |

Envelope Area (ft²) / iCFA (ft²) **1.10** or enter here:

iCFA (ft²) / person **250** or enter here:

**Calculator method is used for official certification targets.*

**Space Conditioning Criteria**

| | | |
|---|---|---|
| **Annual Heating Demand** | **4.6** | **kBTU/ft²yr** |
| **Annual Cooling Demand** | **7.0** | **kBTU/ft²yr** |
| **Peak Heating Load** | **5.5** | **BTU/ft²hr** |
| **Peak Cooling Load** | **2.9** | **BTU/ft²hr** |

**PHIUS+ 2018**
**Space Conditioning Criteria Calculator v2**

| | |
|---|---|
| **METHOD:** | CALCULATOR |
| **UNITS:** | IMPERIAL (IP) |
| **STATE / PROVINCE** | ILLINOIS |
| **CITY** | CHICAGO MIDWAY AP |

Envelope Area (ft²) / iCFA (ft²) **1.10** or enter here:

iCFA (ft²) / person **500** or enter here:

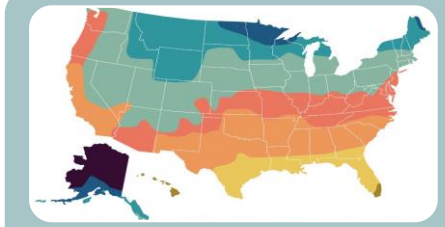
**Calculator method is used for official certification targets.*

**Space Conditioning Criteria**

| | | |
|---|---|---|
| **Annual Heating Demand** | **4.6** | **kBTU/ft²yr** |
| **Annual Cooling Demand** | **5.6** | **kBTU/ft²yr** |
| **Peak Heating Load** | **4.9** | **BTU/ft²hr** |
| **Peak Cooling Load** | **2.6** | **BTU/ft²hr** |

# What is an acceptable level of air-tightness, based on building durability?

REQUREIEMTNS FOR ALL PHIUS+ CERTIFICATIONS



## SPACE CONDITIONING TARGETS

- Based on cost optimization analysis
- Vary based on climate, occupant density, and envelope/floor area ratio

## AIR-TIGHTNESS

- 0.060 CFM50/ft$^2$ envelope area
- Required limit set based on building durability.  Pass/Fail.

## ON-SITE QUALITY ASSURANCE TESTING/INSPECTION

PHIUS+ RATER  PHIUS+ VERIFIER

- Ensure quality for elements not reflected in energy modeling
- Required for all projects

VARIES

## NET SOURCE ENERGY TARGET

- Used instead of site energy as a better proxy for carbon emissions
- Target and renewable energy offsets vary based on program version

# AIR-TIGHTNESS

**Passing test results (pressurization & depressurization) required for certification.**

*0.060* $CFM_{50}/ft^2$ envelope area*
*0.080 $CFM_{75}/ft^2$ envelope area*

**For buildings 5+ stories of non-combustible construction **0.080 $CFM_{50}/ft^2$**envelope or **0.110 $CFM_{75}/ft^2$**envelope.*

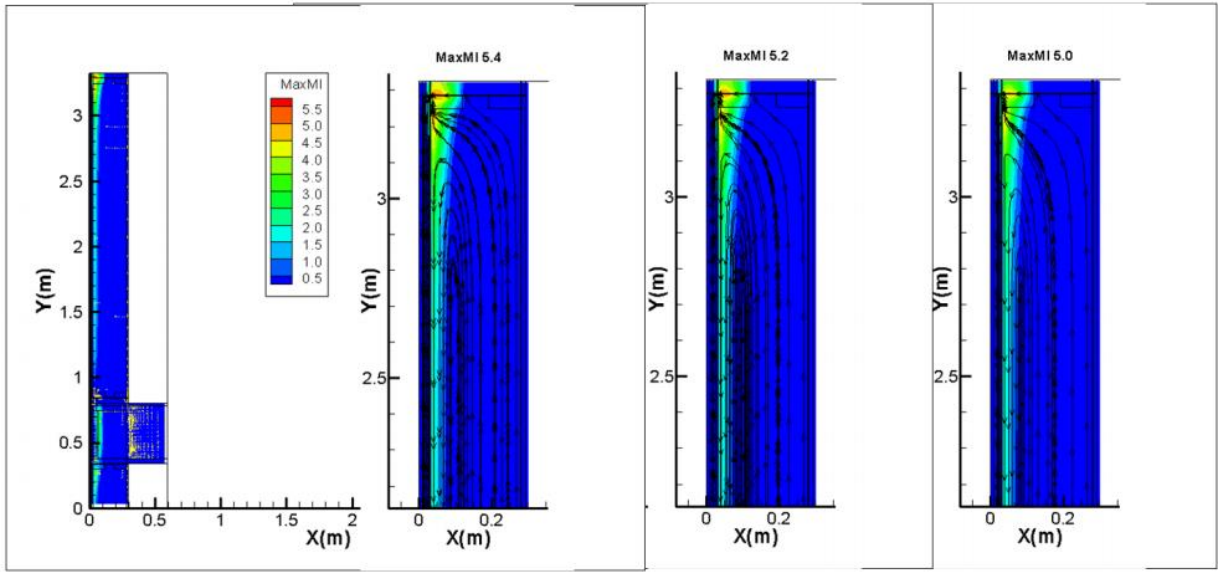
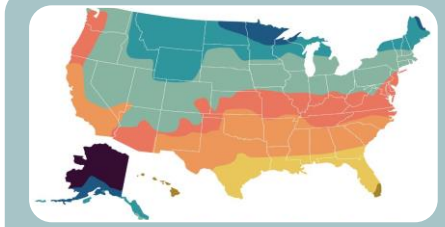



Figure 10. Predicted Mold Index at air tightness ratings 0.01, 0.02 and 0.04 cfm/sqft (left to right). Whole assembly for maximum mold index. Houston, TX.

# What are the other, quality-related items that are valuable, but don't show up in the energy model?

REQUREIEMTNS FOR ALL PHIUS+ CERTIFICATIONS



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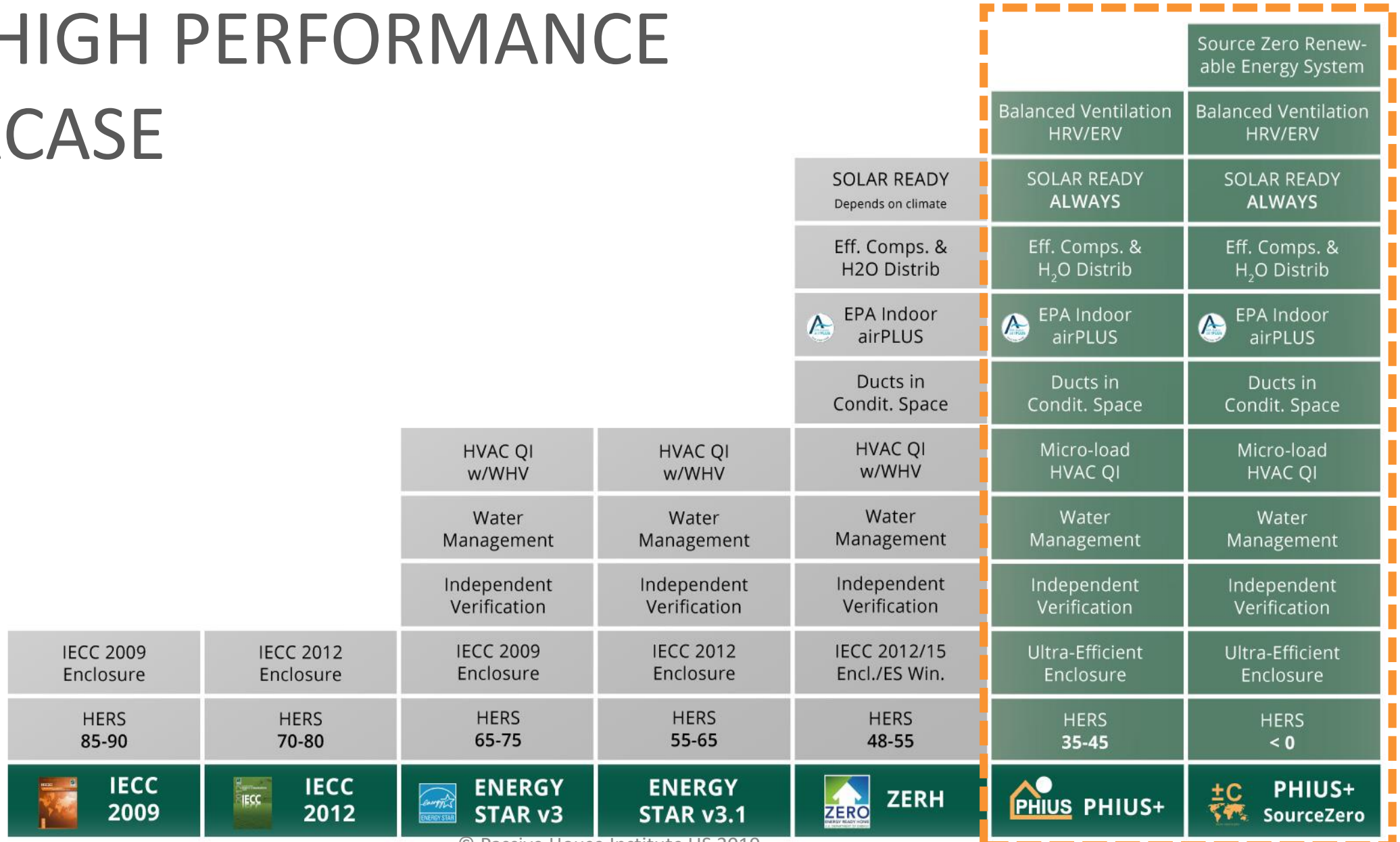
# ON-SITE QUALITY ASSURANCE TESTING/INSPECTION

- Built on US recognized systems (DOE, EPA IAP, RESNET)
- 3rd Party inspection process
- Multiple site visits
- Blower door testing
- Ventilation system balancing/commissioning
- Insulation inspection

***Critical for success. Provides assurance that the built product is what was planned.***

# DOE HIGH PERFORMANCE STAIRCASE



# OTHER REQUIREMENTS

Passive House Institute US

## PHIUS WINDOW COMFORT & CONDENSATION RISK ASSESSMENT

| | |
|---|---|
| Project Name | SAMPLE |
| Project # | SAMPLE |
| State | MASSACHUSETTS |
| City | BOSTON LOGAN INT ARPT |
| ASHRAE 99% Design Temperature [°F] | 13.4 |

http://ashrae-meteo.info/

*PHIUS+ Climate Data*

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ambient Temp (°F) | 26.6 | 31.1 | 38.8 | 47.5 | 58.8 | 66.0 | 74.1 | 71.1 | 64.6 | 54.0 | 43.3 | 36.0 |
| Dewpoint (°F) | 13.8 | 17.4 | 24.6 | 35.1 | 47.1 | 54.1 | 60.6 | 61.0 | 53.2 | 41.7 | 33.4 | 23.0 |

### 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]** | 0.4 |
| Safety Factor | 15% |

| | |
|---|---|
| Interior Surface Temperature of window frame/glass [°F] | **49.4** |
| 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 | **7.0** |
| Required Whole Window U-value [BTU/hr.ft$^2$.F] | **0.24** |

# OTHER REQUIREMENTS

## Moisture Control in Assemblies

Two options for compliance:

1. Follow prescriptive requirements
2. Pass by simulation in WUFI Pro

**Appendix B – Moisture Control Guidelines**

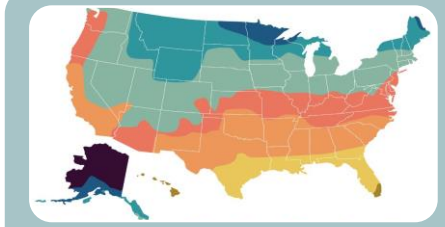
Excerpted from Straube (2012). [42]

### 3.4.1 Vapor Control Recommendations

Different types of assemblies have different vapor control requirements. Although the requirements can be developed through rational engineering analysis, a simplified summary of recommendations, many from the "I" codes, is presented below.

# When to stop with conservation and turn to renewables to offset Source Energy?

REQUREIEMTNS FOR ALL PHIUS+ CERTIFICATIONS



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# TERMINOLOGY

## *Site Energy & Source Energy*

**Site Energy [kWh/person.yr] OR [kBTU/yr.ft$^2$]:** Total energy consumed over the course of the year, including space conditioning, hot water, plug loads, lighting, appliances, systems, etc. (Excludes electrical vehicle charging energy, and ligthing energy specific to vehicle parking areas)

*No requirement for PHIUS+ Certification

**Source Energy [kWh/person.yr] OR [kBTU/yr.ft$^2$]:** Site energy as described above, multiplied by the source/primary energy factor for the specific fuel type used.

Ex: Electricity has a PE factor of 2.8 kWh/kWh (energy intensity at the source vs use on site)

# SOURCE ENERGY

## *PHIUS+ 2018 limit based on:*

"Fair share" of $CO_2$ emissions budget in order to avoid global warming by 2°C.

***Tapers to '0' by 2050 at the latest.***

# SOURCE ENERGY BUDGET

*Varies by building type*

## Residential:

Per person limit

PHIUS+ Core: 5500 kWh/person.yr

PHIUS+ 2018: 3840 kWh/person.yr

PHIUS+ Source Zero: 0 kWh/person.yr

## Commercial/Non-residential:

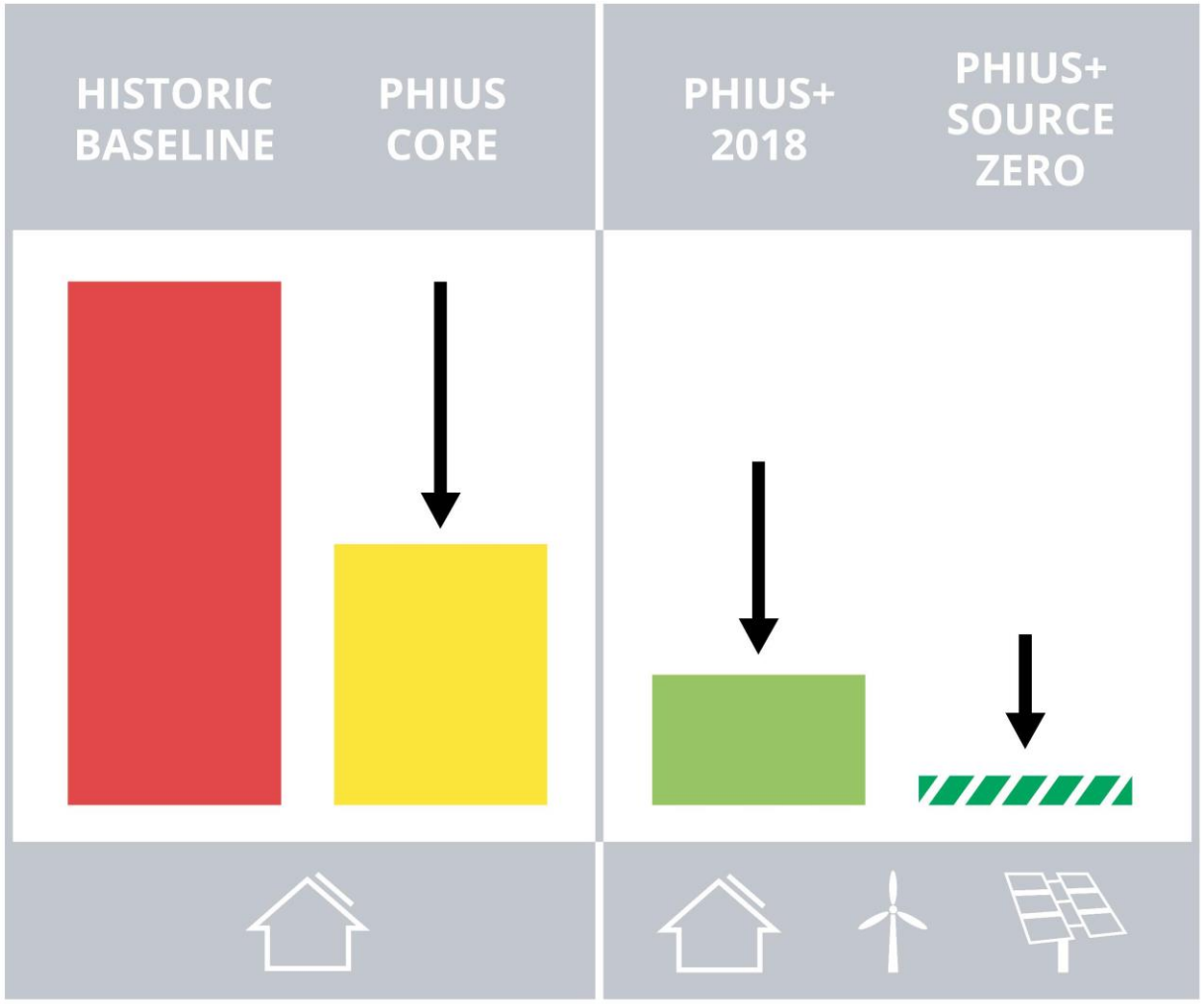
Per square foot limit **Additional allowance for process loads on case-by-case basis*

PHIUS+ Core: 38.0 kBTU/$ft^2$.yr

PHIUS+ 2018: 34.8 kBTU/$ft^2$.yr

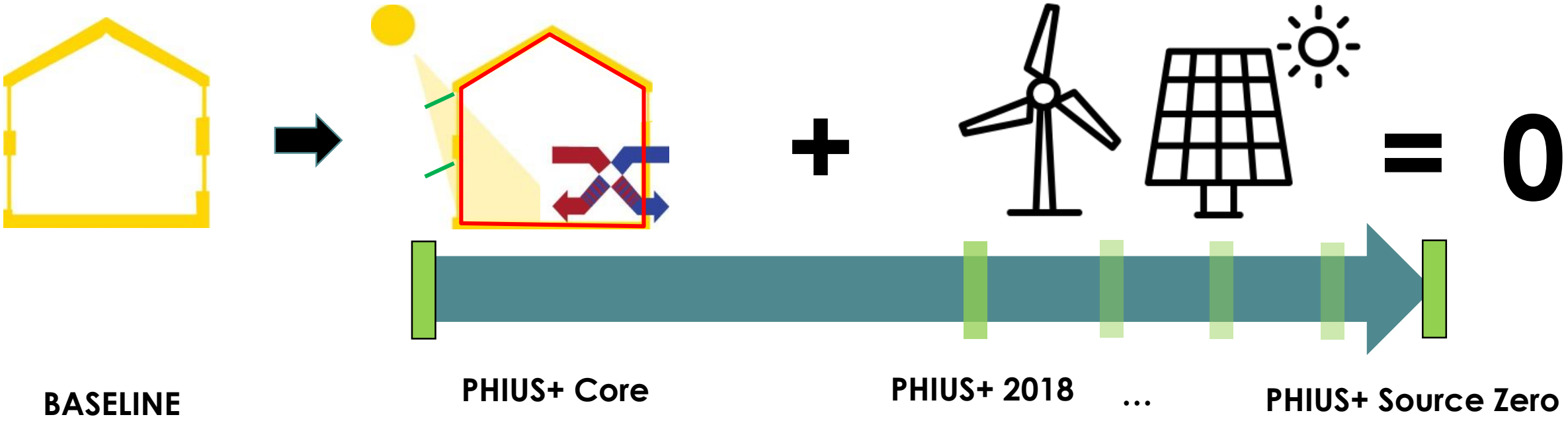
PHIUS+ Source Zero: 0 kBTU/$ft^2$.yr

# NET SOURCE ENERGY



# NET SOURCE ENERGY GOALS

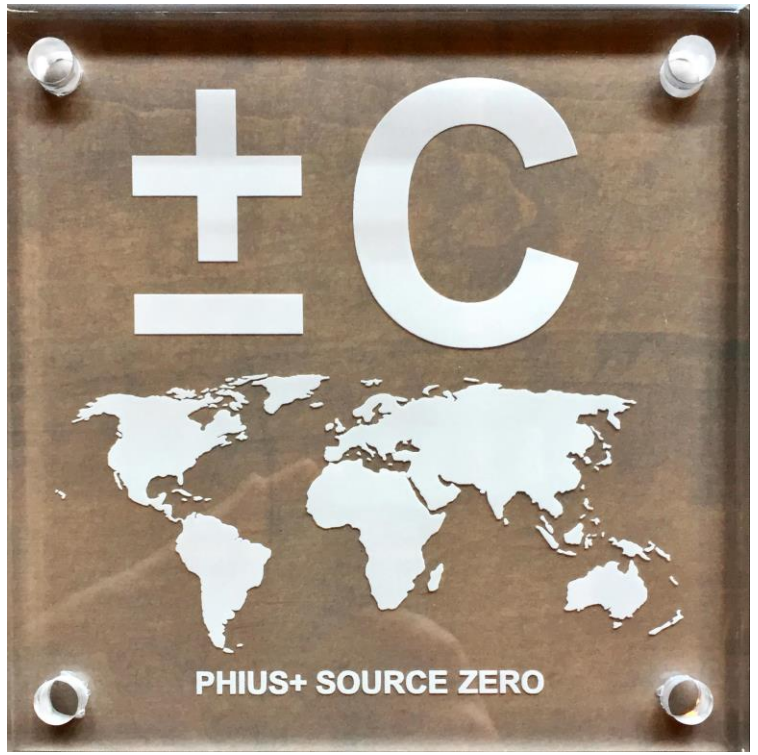
**PHIUS+ Core**: Targeting the sweet spot for on-site conservation
**PHIUS+ 2018**: Reduced target, on the "fair share" glide-path to zero by 2030.
**PHIUS+ Source Zero**: Targeting annual net zero operational energy



# PHIUS+ SOURCE ZERO

*Building must generate as much energy as it uses on an annual, source-energy basis.*

*Net Source Energy Target:* ***0!***




***For an all electric building → Site Zero = Source Zero***

# SOURCE ENERGY OFFSETS

For PHIUS+ 2018 and PHIUS+ Source Zero, all of the following renewables are recognized as offsets:

| *Type* | *Offset Factor ($C_{RE}$)** |
|---|---|
| *On-Site Photovoltaic Array* | 1 |
| *Directly Owned Off-Site Renewable* | 1 |
| *Community Renewable Energy* | 1 |
| *Virtual Power Purchase Agreements (PPA)* | 1 |
| *Green-E Certified Renewable Energy Certificates (RECs)* | 0.2 |

*1 kWh of renewable energy generated offsets **2.8** kWh/**1.96** (US/Canada) at the source when the offset factor is 1.

# SOURCE ENERGY OFFSETS

Additional provisos:

For PPAs, Community RE, and RECs, the building owner must present an actual contract to purchase sufficient RE to meet the (current-year) net source energy target for 20 years.

For onsite renewables or directly-owned off-site, RECs may not be sold off but must be retained/retired.

- Where the building owner does not have ownership of the RECs associated with the on-site RE system, owner must obtain and retire equivalent RECs.

# CERTIFICATION PROCESS

TWO PART CERTIFICATION

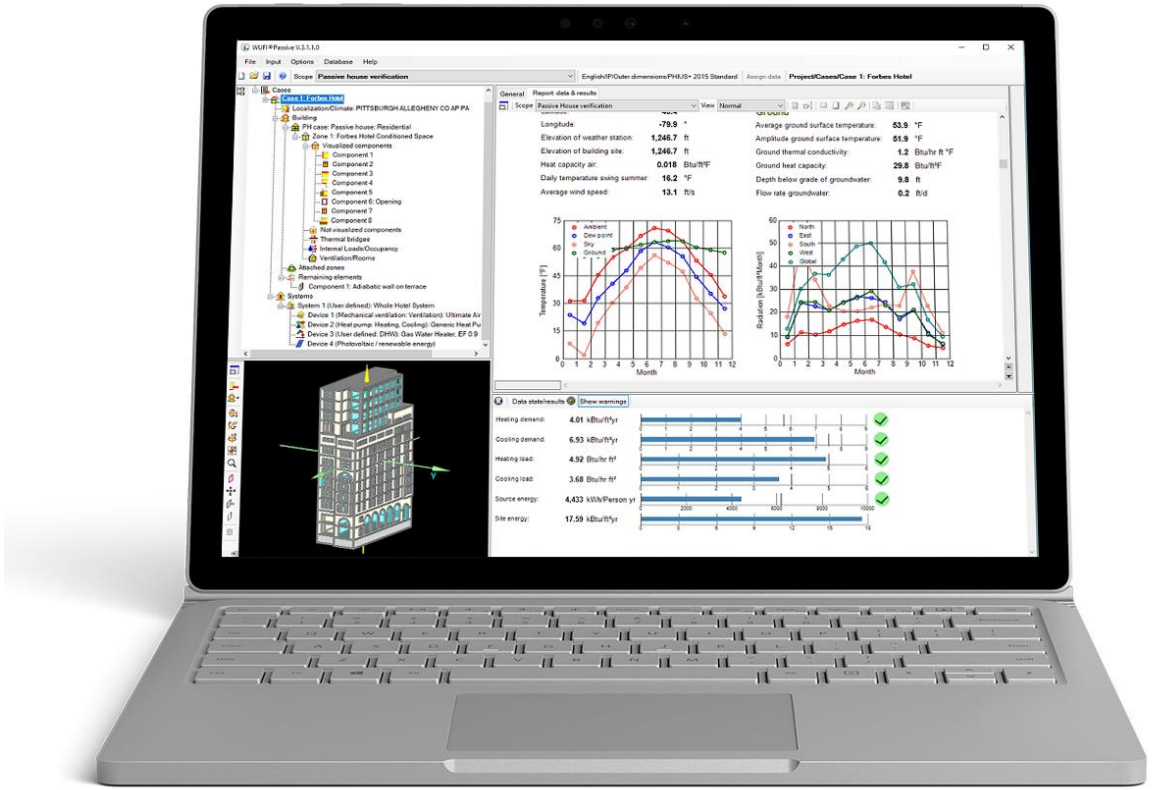
## PRE-CERTIFICATION: Design Stage Review

- CPHC Submits project
- Review completed by PHIUS
- Back-and-forth feedback process

## FINAL CERTIFICATION: On-Site Inspection

- Inspection completed by 3rd Party (PHIUS+ Rater/Verifier)
- Review of documents completed by PHIUS
- True-up final energy model to match “as-built”

# PERFORMANCE BASED ON MODELED USE



**WUFI® Passive modeling software**

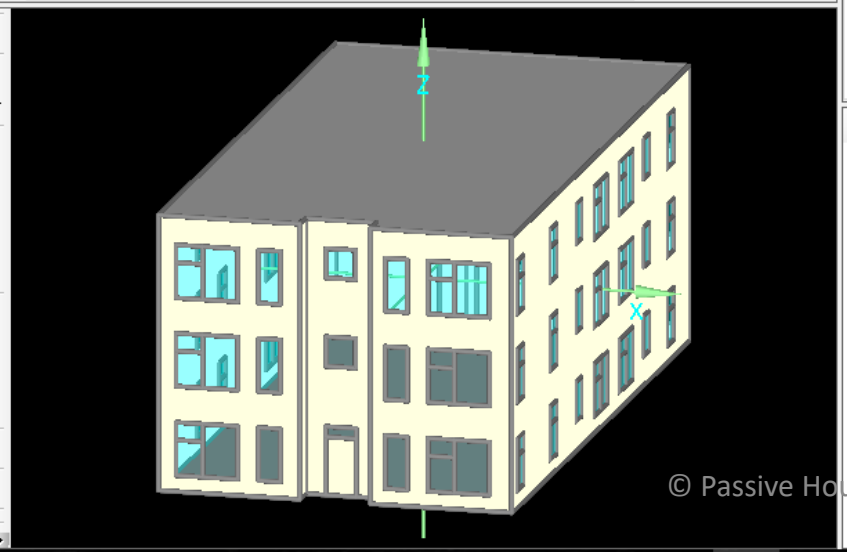
# VERIFY WITH WUFI PASSIVE

WUFI® Passive V.3.1.1.0 D:\Dropbox (PHIUS)\1468 - Tierra Linda\0. Energy Model\20170830.mwp

File Input Options Database Help

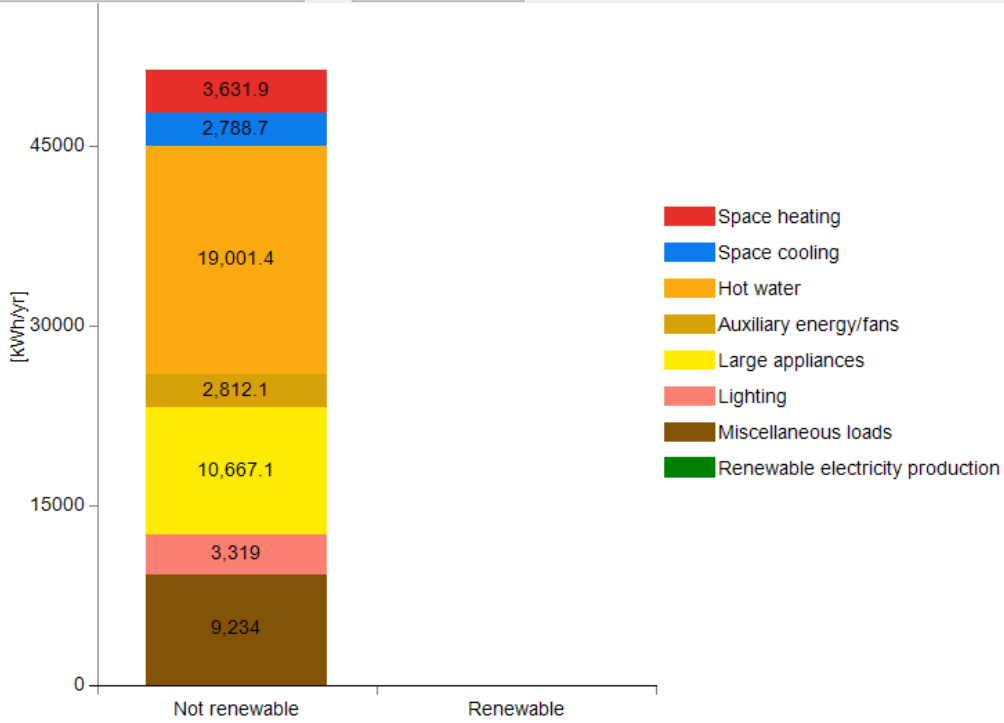
Scope **Passive house verification** | English/IP/Outer dimensions/PHIUS+ 2015 Standard | Assign data | **Project/Cases/Case 1: 6 Flat - PHIUS+ 2015**

- Project
  - Cases
    - **Case 1: 6 Flat - PHIUS+ 2015**
      - Localization/Climate: CHICAGO MIDWAY AP IL
      - Building
        - PH case: Passive house: Residential
          - Zone 1: Whole Building
            - Visualized components
              - Component 1
              - Component 2
              - Component 3
              - Component 4: (SOUTH, Floor 2, Fixed)
              - Component 5: (SOUTH, Floor 1, Fixed)
              - Component 6: (SOUTH, Floor 1, Casement)
              - Component 7: (SOUTH, Floor 3, Fixed)
              - Component 8: (SOUTH, Floor 3, Casement)
              - Component 9: (SOUTH, Floor 2, Casement)
              - Component 10: (NORTH, Floor 2, Casement)
              - Component 11: (NORTH, Floor 1, Fixed)
              - Component 12: (NORTH, Floor 1, Casement)
              - Component 13: (NORTH, Floor 3, Casement)
              - Component 14: (EAST, Floor 1, Casement)
              - Component 15: (EAST, Floor 2, Fixed)
              - Component 16: (EAST, Floor 3, Casement)
              - Component 17: (EAST, Floor 2, Casement)
              - Component 18: (EAST, Floor 3, Fixed)
              - Component 19: (EAST, Floor 1, Fixed
              - Component 20: (WEST, Floor 3, Casement)
              - Component 21: (WEST, Floor 1, Casement)
              - Component 22: (WEST, Floor 3, Fixed)




General | Report: data & results

Scope: Passive House Site Energy Report | View: Normal




Data state/results | Show warnings

| | | |
|---|---|---|
| Heating demand: | **4.32** | kBtu/ft²yr |
| Cooling demand: | **3.46** | kBtu/ft²yr |
| Heating load: | **4.8** | Btu/hr ft² |
| Cooling load: | **2.42** | Btu/hr ft² |
| Source energy: | **5,144** | kWh/Person yr |
| Site energy: | **20.43** | kBtu/ft²yr |

# WUFI Passive Calculation Methodology

## ENERGY BALANCE = 4 ENERGY 'BUCKETS'

**2 LOSS BUCKETS:**
- Transmission Loss
- Ventilation Loss

**2 GAIN BUCKETS:**
- Solar Gains
- Internal Gains

# WUFI Passive as a Design Tool

## Inputs:

- Climate
- Building Geometry
- Heating/Cooling Set-points
- Air-tightness
- Foundation Interface
- Thermal Mass
- Opaque Components
- Transparent Components
- Shading – Numerical or in 3-D Visualization
- Internal Loads
- Thermal Bridges
- Ventilation – Natural & Mechanical
- Balanced Ventilation Recovery Efficiency
- Ventilation Fan Power*
- Heating System Efficiency*
- Cooling System Efficiency*
- Hot Water Distribution*
- Hot Water System Efficiency*

**Do not influence Space Conditioning Demands or Peak Loads*

## Meeting PHIUS+ Source Zero Performance Targets:
## *Order of operations*

**Step 1:** Apply passive building strategies to design to meet space conditioning targets

**Step 2:** Apply other conservation measures such as equipment efficiency, improved appliances, etc. to meet the PHIUS+ Core Source Energy target

**Step 3:** Apply on or off-site renewable energy to meet PHIUS+ Source Zero.

# WUFI Passive Resources:

PHIUS+ Certification Guidebook:
https://www.phius.org/PHIUS+2018/PHIUS+%20Certification%20Guidebook%20v2.1.pdf

PHIUS Sample Project:
https://www.phius.org/software-resources/wufi-passive-and-other-modeling-tools/sample-project-single-family

WUFI Passive Tutorials:
https://www.phius.org/phius-certification-for-buildings-products/wufi-passive-tutorials

WUFI-wiki:
https://www.wufi-wiki.com/mediawiki/index.php/Hauptseite

# 93% Modeled vs Actual