PHIUS+ Certification

AND IMPACTS ON BUILDING DESIGN

RYAN ABENDROTH, CPHC

PRINCIPAL OF PASSIVE ENERGY DESIGNS LLC

SENIOR LECTURER AT WASHINGTON UNIVERSITY IN ST LOUIS

Learning Objectives

I. Gain a greater understanding of the PHIUS+ 2018 Certification and modeling requirements

II. Understand the factors that influence building performance and the energy model

III. Understand the evolution of the standard from PHIUS, PHIUS+ 2015 and now PHIUS+2018 from a design and modeling perspective and what the systematic differences of the current standard are

IV. Look ahead to what may be coming with PHIUS+ 2021.

Outline

- PAST, PRESENT, FUTURE
- THEORY AND RESULTS
  - COMPACT SHAPE
  - SOURCE ENERGY
  - CASE STUDIES
  - AIR-TIGHTNESS
- THEORY AND RESULTS II
  - OCCUPANT DENSITY
  - BEDROOMS OR PEOPLE
  - CLIMATE OUTLIERS

Past, Present, Future

PHIUS CERTIFICATION THROUGH TIME

Past, Present, Future

Program Version Dates

Effective Date	2007	2013	2015	2015	2016	2017	2017	2018	2018	2019
	1-Jan	1-Jan	1-Mar	15-Sep	1-Jan	1-Mar	1-Sep	1-Mar	1-Oct	1-Apr
Space Conditioning Performance Req. Source Energy Req. Air-Tightness Req.	PHIUS Old Std.		PHIUS Old Std. // PHIUS+ 2015	PHIUS+ 2015				PHIUS+ 2015 / PHIUS+ 2018		PHIUS+ 2018
Single Family On-Site QA/QC	PHIUS Work-Sheet	PHIUS+ v3.0.2					v4.0		v4.1	
Multifamily On-Site QA/QC	Case-by-case				v2.0	v2.1			v2.2	

Image Source: phius.org

Past

PHIUS Old Standard

- Began by following the PHI Process and utilized the PHPP as the modeling tool
- Began deviating with the additional requirement of On-Site Quality Assurance (for single family)

PHIUS+2015

- Created the climate specific benchmarks for Annual Heating and Cooling Demands and Peak Heating and Cooling Loads
- Changed the Source/Primary Energy Criterion from a per sq ft. metric to a per person metric for residential building types

PHIUS+2018 V1

- Further adjusted the climate specific criteria by two additional factors (Envelope Area (ft^2) / iCFA (ft^2) and iCFA (ft^2) / person) to account for different building sizes and occupant densities.
- Updated the Source/Primary Energy Criterion by further reducing the target and by allowing Source Energy use to be offset by strategies such as on-site renewables and purchasing REC's (renewable energy credits).

Present

PHIUS+ 2018 V2

Certification Criteria Targets were updated:

- **Cooling Demand** = Original Target + 2.81 kBTU/ft2yr
- **Heating Load** = Original Target + 0.77 BTU/ft2hr
- **Cooling Load** = Original Target + 0.45 BTU/ft2hr

PHIUS+ 2018 V2 Core

The PHIUS Core Source energy targets are:

- Residential: 5500 kWh/person/yr
- Non-Residential: 38 kBTU/ft2.yr (120 kWh/ m2 yr)

*On-site renewable energy offset is calculated based on coincident production and use (utilization fraction)

*Source Energy limit is applied to the calculated net of the estimated utilization fraction of on-site PV or other renewable electricity generation

*Off-site renewable energy generation is not counted

Present

PHIUS+ Source Zero

- Add on certification
- Available for both PHIUS+ and PHIUS+ Core
- Currently, the main incentive for using PHIUS+ Core is to certify buildings that do not have access to, or enough site/roof space to, meet the Source Energy criteria by utilizing only on-site measures.

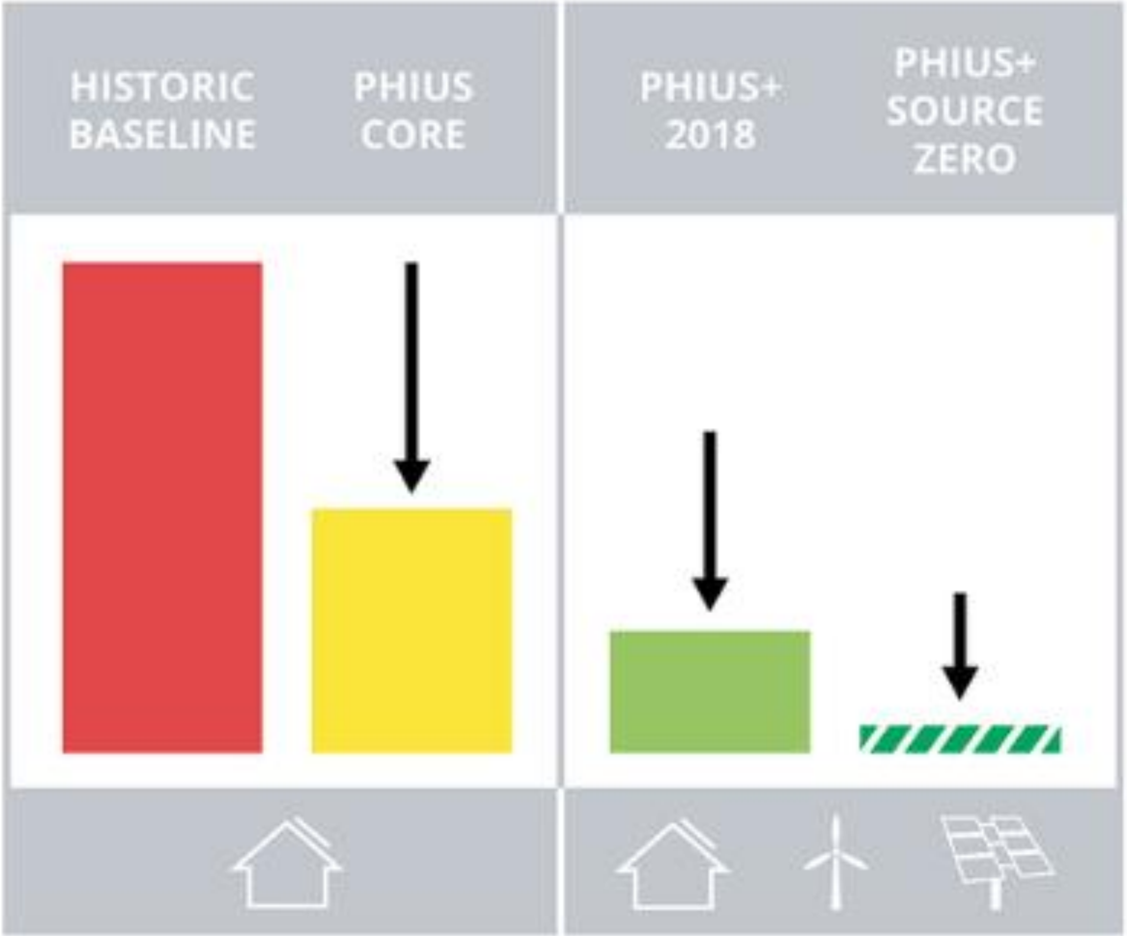


Image Source: phius.org

Present

Air-Tightness

PHIUS Original Standard

- 0.6 ACH50 of the Net Volume

PHIUS+ 2015

- The airtightness requirements have been adjusted to 0.05 CFM50 and 0.08 CFM75 per square foot of gross exterior envelope area

PHIUS+ 2018

For buildings of five stories and above that are also of noncombustible construction:

- q50 <= 0.080 CFM50/ft2 or q75<= 0.100 CFM75/ft2 of gross envelope area

For all other buildings:

- q50 <= 0.060 CFM50/ft2 or q75<= 0.080 CFM75/ft2 of gross envelope area

Future

Warning!
This is all conjecture!

PHIUS+ 2021

Reading the tea leaves, certification will continue on with two distinct tracks

PHIUS+ 2021

- Adjustment of Space Conditioning Criteria
- Adjustment of Source Energy Criteria and Factors
- Streamline modeling protocols and better support
- Strong focus on Decarbonization including embodied carbon, lifecycle analysis and grid interaction
- Adoption of local Zero Codes
- Scrutiny of Natural Gas, Refrigerants, Propellants
- Encourage resilience

PHIUS+ 2021 Core

- Adjustment of Space Conditioning Criteria
- Adjustment of Source Energy Criteria and Factors
- Streamline modeling protocols and better support
- Include strategies for mass adoption

Theory and Results

COMPACT SHAPE

SOURCE ENERGY

The PHIUS+ 2018 Calculator

PHIUS+ 2018 Final Calculator v2

PHIUS+ 2018
Space Conditioning Criteria Calculator v2

METHOD:	CALCULATOR
UNITS:	IMPERIAL (IP)
STATE / PROVINCE	NEW MEXICO
CITY	SANTA FE COUNTY MUNICIP

Envelope Area (ft²) / iCFA (ft²) 3.00 or enter here: 3.00

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

Calculator method is used for official certification targets.

Space Conditioning Criteria

Annual Heating Demand	7.0	kBTU/ft²yr
Annual Cooling Demand	16.7	kBTU/ft²yr
Peak Heating Load	6.3	BTU/ft²hr
Peak Cooling Load	4.9	BTU/ft²hr

Typed entry will override sliding scale.
The results of the CALCULATOR method take precedence over the ESTIMATOR method.

Update Reset

Compact Shape

The first slider on the PHIUS+ 2018 Calculator is for the envelope area to floor area ratio. This ratio can generally be read a s a measure of building compactness.

In the past, for a PHIUS+ project or any passive building project, there have been benefits for designing a building that has a compact shape or a low envelope to floor area ratio.

Now an equation for heat loss:

$$Q = uA\Delta T$$

u = assembly u-value

A = surface area

ΔT = temperature difference

* For comparisons on a single building in a given climate, the assumption can be made that the u-value of the assemblies is held constant and the temperature difference will be identical between cases and not affect the heat loss calculation. Therefore, the factor influencing building performance is limited to the envelope or surface area.

Compact Shape

Climate Data Location: Saint Louis, Spirit of Saint Louis Airport
iCFA: 4000 sq ft.
Occupants: 4
Envelope Area (EA): 10,000 sq ft.
EA/iCFA Ratio = 2.5
iCFA/Person = 1000

Base Design:

EA/iCFA Ratio of 2.5	Calculator V1	Calculator V2
Annual Heating Demand	6.3 $kBTU/ft^2yr$	6.3 $kBTU/ft^2yr$
Annual Cooling Demand	7.3 $kBTU/ft^2yr$	10.1 $kBTU/ft^2yr$
Peak Heating Load	4.3 BTU/ft^2hr	5.1 BTU/ft^2hr
Peak Cooling Load	3.6 BTU/ft^2hr	4.0 BTU/ft^2hr

Compact Shape

MODIFIED GEOMETRY: COMPACT

The EA/iCFA ratio was set to 2.126, which corresponds to a 50’ by 40’ footprint two story box. This EA/iCFA ratio is also very similar to a ratio that would correspond to a 54’ by 24’ three story, or 2 story plus basement, project.

MODIFIED GEOMETRY: NON COMPACT

The EA/iCFA ratio was set to 3.5, which corresponds to a single story “U” shaped building with a flat roof and slab where the long side is a 100’ in length and the short side is 60’ wide with a 50’ by 40’ void (typically a courtyard) located on the long side of the building.

Modified Design:

	EA/iCFA Ratio of 2.126 - V1 (V2)	EA/iCFA Ratio of 3.5 - V1 (V2)
Annual Heating Demand	5.2 (5.2) kBTU/ft^{2}yr	8.6 (8.6) kBTU/ft^{2}yr
Annual Cooling Demand	5.3 (8.2) kBTU/ft^{2}yr	12.1 (14.9) kBTU/ft^{2}yr
Peak Heating Load	3.5 (4.3) BTU/ft^{2}hr	6.0 (6.8) BTU/ft^{2}hr
Peak Cooling Load	2.8 (3.3) BTU/ft^{2}hr	5.3 (5.8) BTU/ft^{2}hr

Compact Shape

PHIUS+ 2018 was to make certification possible for situation and designs that were less ideal, not to mention varying building types.

However, it is also possible for those projects who do have workable sites to design non-optimal massing and still meet the PHIIUS+ criteria.

In fact, substantial benefits are given to projects with non-compact shapes and there is very little incentive to achieving a compact design.

While the criteria is more relaxed when the envelope area is increased, there is a corresponding increase in heat loss due to that increase in envelope area

Compact Shape

The exterior envelope difference between the EA/iCFA Ratio of 2.126 to the EA/iCFA Ratio of 3.5 as used in the previous example is ~5500 ft^2 (14000 -8504 ft^2).

The increase in total allowable Annual Heating Demand in terms of kBTU for the project is 13,600 kBTU/yr (34,400-20,800 kBTU/yr).

When the increase in heat loss is divided by the increase in EA, the result is that the additional heat loss is 2.47 kBTU/ft^2(exterior envelope area)/yr.

It is possible to calculate the heat loss per square foot if you assume an average exterior assembly u-value using $Q = uA\Delta T$. Where: G_T = 115.404 (calculated based on the Spirit of St. Louis climate) takes the place of ΔT, u-value = 0.025 (R40 average envelope), and the A = 1 square foot. This results in a total heat loss of 2.89 kBTU/ft^2(exterior envelope area)/yr. However, this does not include the reduction of heat loss due to assemblies being in contact with the ground.

PARTIAL CONCLUSION 1:

- The additional heat loss due to the increase in envelope area is roughly equivalent to the increase in allowable heating demand.

Compact Shape

Using the St. Louis climate to achieve an equivalent heat loss per square foot of 2.47 $kBTU/ft^2$(exterior envelope area)/yr, the r-value would need to be increased to R46.7 (u-value = 0.0214) as compared to the previously assumed R40.

The PHIUS Sample R-Value Guidelines for Climate Zone 4, where this project is located, are 31-51 for the walls, 49-80 for the roof and a R20 perimeter or whole slab. This seems to coincide with the values above.

Comparing the EA/iCFA Ratio of 2.126 to the EA/iCFA Ratio of 3.5 and looking at the Annual Heat Demand per square foot of exterior envelope area per year, they are almost identical.

Heat loss/ Envelope area:

34,400/14,000=2.457 $kBTU/ft^2$(exterior envelope area)/yr

20,800/8504=2.446 $kBTU/ft^2$(exterior envelope area)/yr

Almost Identical!

Compact Shape

Conclusion:

Adjusting the certification criteria by using the EA/iCFA Ratio has made the standard more equitable for various building types, but it has also disincentivized the design of compact building shapes.

Conclusion based on conjecture:

As PHIUS+ 2018 projects become less compact, the break they are given in the certification criteria does not quite keep up with the excess losses due to that envelope. However, it is close enough that small differences in the building will be able to make up that loss and allow virtually any shape or size of building to meet the PHIUS+ 2018 building standard, given a relatively standard occupancy.

Source Energy

The largest change in the PHIUS+ Certification program, from pre-PHIUS+ 2015, to PHIUS+ 2015, and now to PHIUS+ 2018 is the Source Energy criterion for residential projects.

Two Major Changes:

1. Source Energy Factor
2. Metric for measuring (per person or per ft^2)

Source (Primary) Energy is the amount of energy required to be produced at the source of power generation (typically a "power plant") to power the building.

Source Energy Factor

PHIUS Old

Used a national German source energy factor of 2.7 kWh/kWh

PHIUS+ 2015

The primary energy factor was increased to the US national average of 3.16 to be more realistic to conditions in the United States.

PHIUS+ 2018

By 2018, the US national average PE factor was 2.8 (Germany was down to 2.4 in 2015) which was reflected in the update for PHIUS+ 2018.

Source Energy Metric

PHIUS Old

Before PHIUS+, the source energy criteria had to be met in terms of kBTU/ft^{2}yr of treated floor area.

By using a per square foot metric, buildings with high occupant density and of compact space, both typically beneficial as energy efficient design strategies, were some of the most difficult types of buildings to get to pass in certification.

PHIUS+ 2015

For PHIUS+ 2015, the allowable source energy limit for a residential building was set at 6200 kWh/person/yr.

The allowable source energy limit should have been set at 4200 kWh/person/yr. However, this target was deemed too difficult for the majority of projects to meet and did not allow for a full accounting of on-site or off-site renewable energy.

PHIUS+ 2018

The target value for the criteria changed from 6200 kWh/person/yr to 3840 kWh/person/yr.

Source Energy

The major difference between PHIUS+ 2015 and PHIUS+ 2018 is that the source energy can now be offset by renewable energy using up to 5 different methods.

For residential buildings pursuing PHIUS+ 2018, it is virtually impossible to meet the source energy threshold without renewable energy. This is especially true in an all-electric building.

Due to higher primary energy factors for electricity when compared to gas, almost all single-family residential projects that use electricity are de facto required to utilize on site renewable energy generation in the form of a small PV system to comply with the PHIUS+2018 criteria. For buildings of 3 stories and under, enough PV can be provided on the roof to meet the PHIUS+ 2018 source energy requirement.

However, for larger buildings, especially those 4+ stories in height or that have limited lot and roof size, it is not possible to meet the criteria. Hence the introduction of the other ways to offset source energy such as buying renewable energy credits.

Example to come at end of Case Study.

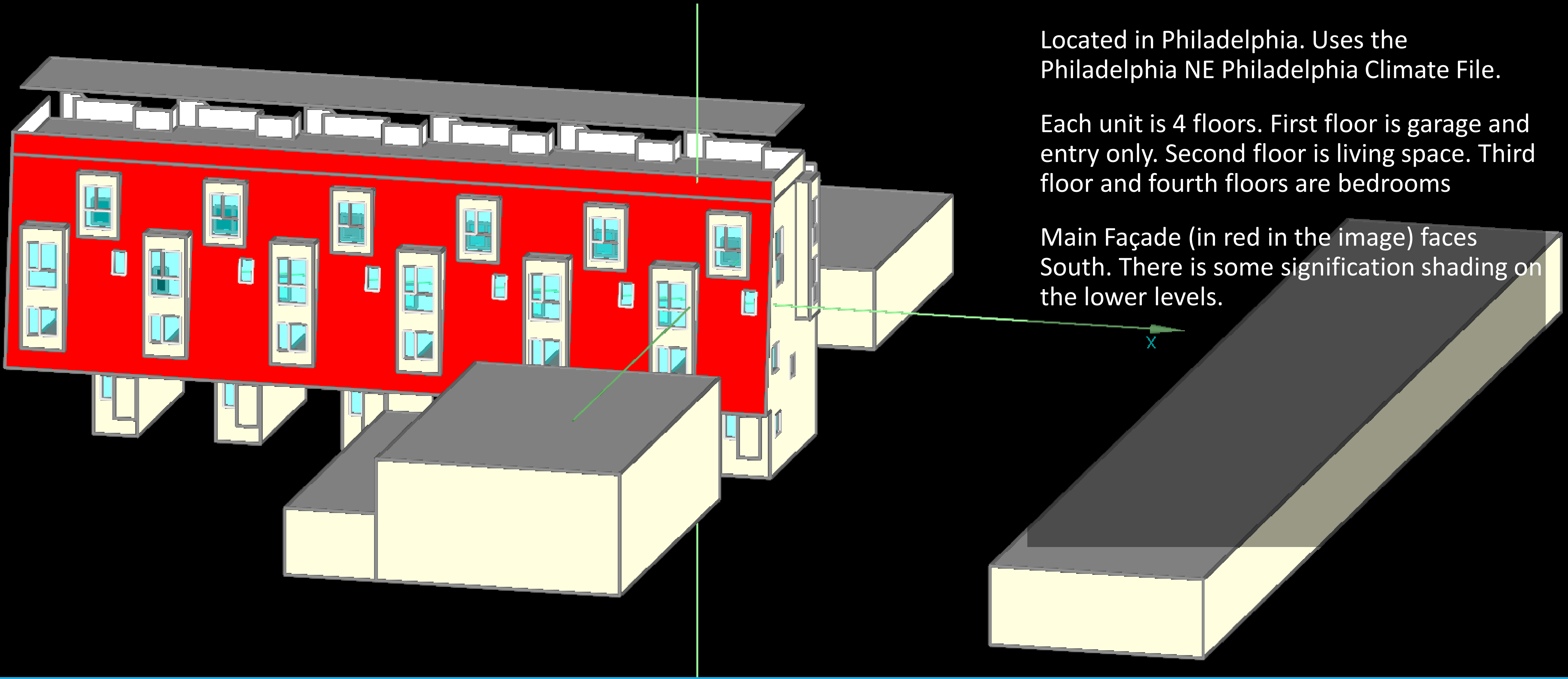
Case Study

6 UNIT TOWNHOME

PHILADELPHIA, PA

EXAMPLE PROJECT COURTESY OF ILKA CASSIDY AND HOLZRAUM SYSTEMS

6-Unit Townhome



Located in Philadelphia. Uses the Philadelphia NE Philadelphia Climate File.

Each unit is 4 floors. First floor is garage and entry only. Second floor is living space. Third floor and fourth floors are bedrooms

Main Façade (in red in the image) faces South. There is some signification shading on the lower levels.

PHIUS+ 2018 Certification Criteria Inputs

Unit Type	iCFA	Envelope Area (ft^2) / iCFA (ft^2)	iCFA (ft^2) / person
West End Unit	1,654.5	2.735	413.6
East End Unit	1,644.5	2.813	411.1
Middle Unit	1,689.3	1.869	422.3
Whole Building	10,940	2.18	455.8

PHIUS+ 2018 Certification Criteria Inputs

A few notes about multi-family buildings and the calculator:

1. Where units are adjacent to one another and share walls, the adiabatic conditions do not count toward the Envelope Area (ft^2) / iCFA (ft^2)

Middle Unit	Adiabatic Walls	Exterior Walls
	Envelope Area (ft^2) / iCFA (ft^2) If Adiabatic (partition) Walls are excluded (typical WUFI Calculation)	**Envelope Area (ft^2) / iCFA (ft^2) If Adiabatic (partition) Walls are Counted**
Value for V2 Calc.	1.869	3.181
	PHIUS+ 2018 V2 Calculator (Modeled) Results	PHIUS+ 2018 V2 Calculator (Modeled) Results
Heating Demand	4.5 (2.58)	8.60 (5.44)
Cooling Demand	6.3 (6.25)	13.2 (6.12)
Heating Load	4.6 (5.90)	7.60 (5.60)
Cooling Load	3.2 (4.67)	6.00 (3.08)

PHIUS+ 2018 Certification Criteria Inputs

A few notes about multi-family buildings and the calculator:

1. Where units are adjacent to one another and share walls, the adiabatic conditions do not count toward the Envelope Area (ft^2) / iCFA (ft^2)

Major takeaways from previous example:

a) The amount of envelope area a project has is a huge factor in what the certification criteria will be (remember earlier example)

b) In this extreme case (tall/slender) insulating the walls and assuming they are subject to exterior air temperatures is actually better in terms of meeting the certification requirements compared to adiabatic walls.

c) Adiabatic walls have no heat loss when calculating annual demands. However, they do have an impact on peak loads. This is why the project could not meet the heat load criteria under Adiabatic conditions, but did under exterior conditions when the walls were insulated.

PHIUS+ 2018 Certification - Results

Middle Unit Adiabatic Walls:

HEATING LOAD

	First climate		Second climate	
Transmission heat losses:	5,623.6	Btu/hr	3,676.8	Btu/hr
Ventilation heat losses:	4,005.4	Btu/hr	2,499.8	Btu/hr
Total heat loss:	9,629	Btu/hr	6,176.6	Btu/hr
Solar heat gain:	1,739.2	Btu/hr	405.8	Btu/hr
Internal heat gain:	856.8	Btu/hr	856.8	Btu/hr
Total heat gains heating:	2,596	Btu/hr	1,262.6	Btu/hr
Heating load:	7,033	Btu/hr	4,914	Btu/hr

Relevant heating load:	7,033	Btu/hr
Specific heating load:	4.2	Btu/hr ft²

COOLING LOAD

Solar heat gain:	1,337.6	Btu/hr
Internal heat gain:	2,213	Btu/hr
Total heat gains cooling:	3,550.6	Btu/hr
Transmission heat losses:	-733.4	Btu/hr
Ventilation heat losses:	-666.2	Btu/hr
Total heat loss:	-1,399.5	Btu/hr
Cooling load - sensible:	4,950.1	Btu/hr
Cooling load - latent:	0	Btu/hr
Relevant cooling load:	4,950.1	Btu/hr
Specific maximum cooling load:	2.9	Btu/hr ft²

PHIUS+ 2018 Certification - Results

Middle Unit Exterior Walls:

HEATING LOAD

	First climate		Second climate	
Transmission heat losses:	8,043.3	Btu/hr	5,094.3	Btu/hr
Ventilation heat losses:	4,005.4	Btu/hr	2,499.8	Btu/hr
Total heat loss:	12,048.8	Btu/hr	7,594.1	Btu/hr
Solar heat gain:	1,739.2	Btu/hr	405.8	Btu/hr
Internal heat gain:	856.8	Btu/hr	856.8	Btu/hr
Total heat gains heating:	2,596	Btu/hr	1,262.6	Btu/hr
Heating load:	9,452.8	Btu/hr	6,331.5	Btu/hr

Relevant heating load:	9,452.8	Btu/hr
Specific heating load:	5.6	Btu/hr ft²

COOLING LOAD

Solar heat gain:	1,628.8	Btu/hr
Internal heat gain:	2,213	Btu/hr
Total heat gains cooling:	3,841.7	Btu/hr
Transmission heat losses:	-701.2	Btu/hr
Ventilation heat losses:	-666.2	Btu/hr
Total heat loss:	-1,367.3	Btu/hr
Cooling load - sensible:	5,209	Btu/hr
Cooling load - latent:	0	Btu/hr
Relevant cooling load:	5,209	Btu/hr
Specific maximum cooling load:	3.1	Btu/hr ft²

PHIUS+ 2018 Certification - Results

Middle Unit Adiabatic Walls Not Included:

HEATING LOAD

	First climate		Second climate	
Transmission heat losses:	5,377.1	Btu/hr	3,430.4	Btu/hr
Ventilation heat losses:	2,801.8	Btu/hr	1,748.6	Btu/hr
Total heat loss:	8,179	Btu/hr	5,179	Btu/hr
Solar heat gain:	1,739.2	Btu/hr	405.8	Btu/hr
Internal heat gain:	856.8	Btu/hr	856.8	Btu/hr
Total heat gains heating:	2,596	Btu/hr	1,262.6	Btu/hr
Heating load:	5,583	Btu/hr	3,916.4	Btu/hr

Relevant heating load:	5,583	Btu/hr
Specific heating load:	3.3	Btu/hr ft²

COOLING LOAD

Solar heat gain:	1,337.6	Btu/hr
Internal heat gain:	2,213	Btu/hr
Total heat gains cooling:	3,550.6	Btu/hr
Transmission heat losses:	-486.9	Btu/hr
Ventilation heat losses:	-613.6	Btu/hr
Total heat loss:	-1,100.5	Btu/hr
Cooling load - sensible:	4,651.1	Btu/hr
Cooling load - latent:	0	Btu/hr
Relevant cooling load:	4,651.1	Btu/hr
Specific maximum cooling load:	2.8	Btu/hr ft²

PHIUS+ 2018 Certification - Results

Summary:

	Adiabatic	Exterior	None
	PHIUS+ 2018 V2 Calculator (Modeled) Results	PHIUS+ 2018 V2 Calculator (Modeled) Results	Modeled results if adiabatic walls were omitted from calculation completely
Heating Demand	4.5 (2.58) - PASS	8.60 (5.44) - PASS	2.13 - PASS
Cooling Demand	6.3 (6.25) - PASS	13.2 (6.12) - PASS	6.31 – FAIL
Heating Load	4.6 (5.90) - FAIL	7.60 (5.60) - PASS	3.30 - PASS
Cooling Load	3.2 (4.67) - FAIL	6.00 (3.08) - PASS	2.75 - PASS

PHIUS+ 2018 Certification - Results

Insulating Shared Walls Will Limit Heat Load Effects

	Adiabatic (R2.7)	Adiabatic Insulated to R28	Adiabatic Insulated to R48
	PHIUS+ 2018 V2 Calculator (Modeled) Results	PHIUS+ 2018 V2 Calculator (Modeled) Results	PHIUS+ 2018 V2 Calculator (Modeled) Results
Heating Demand	4.5 (2.58) - PASS	4.5 (2.58) - PASS	4.5 (2.58) - PASS
Cooling Demand	6.3 (6.25) - PASS	6.3 (6.25) - PASS	6.3 (6.25) - PASS
Heating Load	4.6 (5.90) - FAIL	4.6 (4.26) - PASS	4.6 (4.16) - PASS
Cooling Load	3.2 (4.67) - FAIL	3.2 (3.03) - PASS	3.2 (2.93) - PASS

Once the shared walls were insulated to ~R15, the project passed. This will be project dependent.

PHIUS+ 2018 Certification - Results

A few notes about multi-family buildings and the calculator:

2. Individual Units vs Whole Building

West End Unit						
	2015 Criteria	2015 Modeled		2018 Criteria	2018 V2 Criteria	2018 Modeled
Heating Demand	4.8	4.98		7.2	7.2	5.05
Cooling Demand	4.8	5.54		7.5	10.3	6.21
Heating Load	4.2	6.21		5.8	6.5	6.24
Cooling Load	4.6	4.09		4.5	4.9	3.89

PHIUS+ 2018 Certification Criteria Inputs

A few notes about multi-family buildings and the calculator:

2. Individual Units vs Whole Building

East End Unit						
	2015 Criteria	2015 Modeled		2018 Criteria	2018 V2 Criteria	2018 Modeled
Heating Demand	4.8	NA		7.4	7.4	5.13
Cooling Demand	4.8	NA		8	10.9	8.58
Heating Load	4.2	NA		6	6.8	6.52
Cooling Load	4.6	NA		4.7	5.1	4.97

PHIUS+ 2018 Certification Criteria Inputs

A few notes about multi-family buildings and the calculator:

2. Individual Units vs Whole Building

Middle Unit						
	2015 Criteria	2015 Modeled		2018 Criteria	2018 V2 Criteria	2018 Modeled
Heating Demand	4.8	2.59		4.5	4.5	2.58
Cooling Demand	4.8	5.12		3.3	6.3	6.25
Heating Load	4.2	5.91		3.9	4.6	5.9
Cooling Load	4.6	4.77		2.7	3.2	4.67

PHIUS+ 2018 Certification Criteria Inputs

A few notes about multi-family buildings and the calculator:

2. Individual Units vs Whole Building

Whole Building						
	2015 Criteria	2015 Modeled		2018 Criteria	2018 V2 Criteria	2018 Modeled
Heating Demand	4.8	NA		NA	5.3	4.27
Cooling Demand	4.8	NA		NA	6.9	4.76
Heating Load	4.2	NA		NA	5.1	4.54
Cooling Load	4.6	NA		NA	3.6	2.34

PHIUS+ 2018 Certification Criteria Inputs

A few notes about multi-family buildings and the calculator:

2. Individual Units vs Whole Building

   - PHIUS+ 2018 V2 allows the project to be certified. Under previous certification systems, the project would have had a much more difficult time completing certification.
   - Certifying this project individually would be very difficult without understanding some of the tricks and intricacies in the previous slides and requires either/both:
     1. Better than required Air-Tightness performance
     2. Insulating the walls between units for thermal performance.

Air-Tightness

Apparent in the treatment of the Middle Unit walls was how large of an impact Air-Tightness is in PHIUS+.

Whole Building						**Middle Unit**	
	0.06 (.96)	0.05 (.8)	0.04 (.64)	0.03 (.48)	0.02 (.32)	0.06 (1.29)	0.03 (.64)
Heating Demand	4.27	4.09	3.92	3.75	3.58	2.81	2.14
Cooling Demand	4.76	4.78	4.78	4.79	4.8	6.23	6.31
Heating Load	4.54	4.3	4.06	3.83	3.59	4.51	3.47
Cooling Load	2.34	2.33	2.32	2.31	2.3	2.95	2.9

CFM50/ft^2 (Equivalent ACH50)

An additional R-8.3 was required for all 11,625 ft^2 of exterior wall area to achieve the same Annual Heat Demand performance as the reduction in airtightness from 0.06 to 0.03 CFM50/ft^2

Source Energy

None of these projects was able to meet the Source Energy Criteria through conservation measure alone. However, a very limited PV system size of approximately 250 kwh/person will meet the PHIUS+2018 Criteria and a system sized at ~1500-1700 kWh/person will zero out the project.

	Whole Building	Middle Unit	West Unit
Heating Demand	4.27	2.58	5.05
Cooling Demand	4.76	6.25	6.21
Heating Load	4.54	5.9	6.24
Cooling Load	2.34	4.67	3.89
Source Energy	4343	4540	4779
PV System Sized to meet 3840	4310	1000	1342
PV System Sized to meet 0	37250	6485	6830
Installed PV/Person to 0	1552	1621	1707.5

Theory and Results II

OCCUPANT DENSITY

BEDROOMS OR PEOPLE

CLIMATE OUTLIERS

Occupant Density

Climate Data Location: Saint Louis, Spirit of Saint Louis Airport
iCFA: 4000 sq ft.
Occupants: 4
Envelope Area (EA): 10,000 sq ft.
EA/iCFA Ratio = 2.5
iCFA/Person = 1000

Base Design:

iCFA/Person = 1000	Calculator V2
Annual Heating Demand	6.3 kBTU/ft^{2}yr
Annual Cooling Demand	10.1 kBTU/ft^{2}yr
Peak Heating Load	5.1 BTU/ft^{2}hr
Peak Cooling Load	4.0 BTU/ft^{2}hr

Occupant Density

MODIFIED OCCUPANT DENSITY:

PHIUS+ 2018 V2 CERTIFICATION CRITERIA: PHILADELPHIA

EA/iCFA = 2.18	iCFA/Person = 250	iCFA/Person = 500	iCFA/Person = 750
Annual Heating Demand	5.3 $kBTU/ft^2yr$	5.2 $kBTU/ft^2yr$	5.3 $kBTU/ft^2yr$
Annual Cooling Demand	8.7 $kBTU/ft^2yr$	6.8 $kBTU/ft^2yr$	6.8 $kBTU/ft^2yr$
Peak Heating Load	5.6 BTU/ft^2hr	5.0 BTU/ft^2hr	4.8 BTU/ft^2hr
Peak Cooling Load	3.9 BTU/ft^2hr	3.6 BTU/ft^2hr	3.5 BTU/ft^2hr

EA/iCFA = 2.18	iCFA/Person = 1000	iCFA/Person = 1500	iCFA/Person = 2000
Annual Heating Demand	5.3 $kBTU/ft^2yr$	5.3 $kBTU/ft^2yr$	5.3 $kBTU/ft^2yr$
Annual Cooling Demand	6.8 $kBTU/ft^2yr$	6.8 $kBTU/ft^2yr$	6.8 $kBTU/ft^2yr$
Peak Heating Load	4.8 BTU/ft^2hr	4.8 BTU/ft^2hr	4.8 BTU/ft^2hr
Peak Cooling Load	3.4 BTU/ft^2hr	3.4 BTU/ft^2hr	3.4 BTU/ft^2hr

Occupant Density

MODIFIED OCCUPANT DENSITY:

PHIUS+ 2018 V2 CERTIFICATION CRITERIA: PHILADELPHIA

EA/iCFA = 3.0	iCFA/Person = 250	iCFA/Person = 500	iCFA/Person = 750
Annual Heating Demand	8.3 $kBTU/ft^2yr$	8.3 $kBTU/ft^2yr$	8.3 $kBTU/ft^2yr$
Annual Cooling Demand	14.2 $kBTU/ft^2yr$	12.4 $kBTU/ft^2yr$	12.3 $kBTU/ft^2yr$
Peak Heating Load	7.9 BTU/ft^2hr	7.3 BTU/ft^2hr	7.1 BTU/ft^2hr
Peak Cooling Load	6.0 BTU/ft^2hr	5.7 BTU/ft^2hr	5.6 BTU/ft^2hr

EA/iCFA = 3.0	iCFA/Person = 1000	iCFA/Person = 1500	iCFA/Person = 2000
Annual Heating Demand	8.3 $kBTU/ft^2yr$	8.3 $kBTU/ft^2yr$	8.3 $kBTU/ft^2yr$
Annual Cooling Demand	12.4 $kBTU/ft^2yr$	12.4 $kBTU/ft^2yr$	12.4 $kBTU/ft^2yr$
Peak Heating Load	7.0 BTU/ft^2hr	7.0 BTU/ft^2hr	7.0 BTU/ft^2hr
Peak Cooling Load	5.5 BTU/ft^2hr	5.5 BTU/ft^2hr	5.5 BTU/ft^2hr

Occupant Density

MODIFIED OCCUPANT DENSITY:

PHIUS+ 2018 V2 CERTIFICATION CRITERIA: PHILADELPHIA EXAMPLE

CRITERIA	iCFA/Person = 364.6	iCFA/Person = 455.8	iCFA/Person = 607.8
Annual Heating Demand	5.3 $kBTU/ft^2yr$	5.3 $kBTU/ft^2yr$	5.3 $kBTU/ft^2yr$
Annual Cooling Demand	7.2 $kBTU/ft^2yr$	6.9 $kBTU/ft^2yr$	5.8 $kBTU/ft^2yr$
Peak Heating Load	5.2 BTU/ft^2hr	5.1 BTU/ft^2hr	4.9 BTU/ft^2hr
Peak Cooling Load	3.7 BTU/ft^2hr	3.6 BTU/ft^2hr	3.5 BTU/ft^2hr

AS MODELED	iCFA/Person = 364.6	iCFA/Person = 455.8	iCFA/Person = 607.8
Annual Heating Demand	4.11 $kBTU/ft^2yr$	4.27 $kBTU/ft^2yr$	4.43 $kBTU/ft^2yr$
Annual Cooling Demand	5.00 $kBTU/ft^2yr$	4.76 $kBTU/ft^2yr$	4.53 $kBTU/ft^2yr$
Peak Heating Load	4.59 BTU/ft^2hr	4.54 BTU/ft^2hr	4.49 BTU/ft^2hr
Peak Cooling Load	2.42 BTU/ft^2hr	2.34 BTU/ft^2hr	2.26 BTU/ft^2hr

Occupant Density

MODIFIED OCCUPANT DENSITY:

PHIUS+ 2018 V2 CERTIFICATION CRITERIA: ST. LOUIS, MO

EA/iCFA = 2.5	iCFA/Person = 200	iCFA/Person = 250	iCFA/Person = 350
Annual Heating Demand	6.3 $kBTU/ft^2yr$	6.3 $kBTU/ft^2yr$	6.3 $kBTU/ft^2yr$
Annual Cooling Demand	12.8 $kBTU/ft^2yr$	12.4 $kBTU/ft^2yr$	10.9 $kBTU/ft^2yr$
Peak Heating Load	6.0 BTU/ft^2hr	5.9 BTU/ft^2hr	5.6 BTU/ft^2hr
Peak Cooling Load	4.6 BTU/ft^2hr	4.6 BTU/ft^2hr	4.3 BTU/ft^2hr

EA/iCFA = 2.5	iCFA/Person = 500	iCFA/Person = 750	iCFA/Person = 1000
Annual Heating Demand	6.3 $kBTU/ft^2yr$	6.3 $kBTU/ft^2yr$	6.3 $kBTU/ft^2yr$
Annual Cooling Demand	10.2 $kBTU/ft^2yr$	10.1 $kBTU/ft^2yr$	10.1 $kBTU/ft^2yr$
Peak Heating Load	5.3 BTU/ft^2hr	5.1 BTU/ft^2hr	5.1 BTU/ft^2hr
Peak Cooling Load	4.2 BTU/ft^2hr	4.1 BTU/ft^2hr	4.0 BTU/ft^2hr

Occupant Density

Conclusion:

PHIUS+ 2018 Certification is focused on giving relief to very dense buildings and does not benefit buildings with very low occupancies. Outside of a specified range 200-1000 ft^2/person, there is no change to the certification criteria.

The magnitude of the occupant density's influence on the criteria are typically small and are dwarfed by impact of the EA/iCFA ratio.

Bedrooms or People

Occupants (# of people) are based on number of Bedrooms+1, but not all entries are based on occupants. Miscellaneous electrical loads are based on bedrooms. However, the bedrooms and people always track together in that relationship.

For the calculator, it doesn't matter how you simulate iCFA/person (modify floor area or add bedrooms (people). In practice, it is fairly common to change a bedroom to an office or vice versa.

The real trick comes with occupancy.

- How many people live in a Studio apartment?
- Or a one bedroom?
- Or a 6 bedroom house?

The difference between certification assumptions and real world results in these cases can be dramatic. PHIUS has recently provided exceptions for setting occupancy based on data for specific project types.

The Santa Fe Climate

Example in climates with high solar insolation

	St. Louis (2.5 and 500)	Santa Fe (2.5 and 500)	Santa Fe (3.0 and 250)	Custom near Santa Fe (3.18 and 698.2)
Annual Heating Demand	6.3 $kBTU/ft^2yr$	5.3 $kBTU/ft^2yr$	7.0 $kBTU/ft^2yr$	6.5 $kBTU/ft^2yr$
Annual Cooling Demand	10.9 $kBTU/ft^2yr$	10.8 $kBTU/ft^2yr$	16 $kBTU/ft^2yr$	17.9 $kBTU/ft^2yr$
Peak Heating Load	5.6 BTU/ft^2hr	5.3 BTU/ft^2hr	6.3 BTU/ft^2hr	6.4 BTU/ft^2hr
Peak Cooling Load	4.3 BTU/ft^2hr	4.2 BTU/ft^2hr	4.9 BTU/ft^2hr	5.2 BTU/ft^2hr

Envelope Area (ft^2) / iCFA (ft^2) = 2.5

iCFA (ft^2) / person = 500

HDD/CDD – St. Louis: 4758/1561

HDD/CDD – Santa Fe: 6073/414

Summary

Things PHIUS+2018 gets right:

A lot.

Space conditioning targets have been set that in a way that will encourage adoption, lower the difficulty on small, compact projects, and force larger projects to look at their envelope in a more comprehensive way.

Focus on Source energy, which is the main goal. I don't really care whether my energy use goes to my TV or heating system. I am still paying for it at the utility and its environmental impact.

The emphasis on source energy over space conditioning allows project teams the necessary freedoms to succeed.

Summary

Limitations in regards to PHIUS+2018:

1. By using EA/iCFA ratios for standard setting, PHIUS+ 2018 is applicable to multiple building types and has reduced the "small home penalty", but introduced in its place is a standard that has little concern for the compactness of the building envelope.
2. Adiabatic walls between projects make meeting the heating and cooling loads difficult and require the building to have a higher level of air-tightness and insulated adiabatic walls. Huddling Up (sharing walls) is no longer advantageous, unless modeled as the whole.
3. Any certification program that attempts to be applicable, or even optimal, to such a wide variety of projects as the PHIUS+ 2018 standard will have an impossible task to satisfy all of those demands. By fixing issues and inherent biases, others appear.

Summary

Additional research is required to understand and further limit these issues in future versions of passive building standards. As strategic planning for PHIUS+ 2021 begins, it is important to fully understand the effects that past decisions have made on the PHIUS+ Standard and to determine if those choices have been effective in meeting the goals of the PHIUS+ Certification Program at large.

Questions?

Email: ryan@passiveenergydesigns.com