

PHIUS+ 2018 Passive Building Standard  
Standard-Setting Documentation

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## PHIUS+ 2018: Getting to Zero

In 2014, under a grant from the [U.S. Department of Energy](#) (DOE), and in partnership with [Building Science Corporation](#), PHIUS developed PHIUS+ 2015—the first and only climate-specific passive building standard. The 2015 standard accounted not only for substantial differences between climate zones, but also for market and other variables, and retained rigorous conservation goals while making passive building more rational and cost effective. PHIUS+ 2015 helped dramatically accelerate adoption.

PHIUS recognized that technologies, market conditions, carbon reduction goals and even climates could change over time. Consequently, PHIUS committed to revising the standard to reflect such changes. PHIUS+ 2018 is the first updated revision, and it will be phased in through 2018 and will eventually replace PHIUS+ 2015. This update focuses on adding more nuance for different building types, and supporting an overall transition to renewable energy.

### Timeline:

September 21, 2018 – Full launch of PHIUS+ 2018  
October 1, 2018 – PHIUS+ 2018 pilot ends  
October 2018–March 2019 – Submit under 2015 or 2018  
March 31, 2019 – PHIUS+ 2015 ends  
April 1, 2019 – All new projects PHIUS+ 2018

\*Must have project contract in by above dates to secure version

### Software:

Only WUFI Passive accepted for PHIUS+ 2018

- Version 3.1.1.25 and later accepted

### Space Conditioning:

#### What's the same

PHIUS+ 2018 remains a pass/fail passive building standard, serving as an update to replace PHIUS+ 2015. It remains a “performance-based” energy standard that includes prescriptive quality assurance requirements adopted from U.S. government programs - Energy Star, Zero

Energy Ready Home, and EPA Indoor airPLUS.

The standard has three pillars, or marquee-level requirements

- Limits on heating/cooling loads (both peak and annual)
- Limit on overall source energy use
- Air-tightness and other prescriptive quality assurance requirements

PHIUS+ 2015 recognized that there are diminishing returns on investment in energy-conserving measures, and an optimum level in a life-cycle cost sense. Climate plays a large role in determining where that point is. For PHIUS+ 2015, researchers studied optimization in 110 cities, and developed interpolation formulas to set heating and cooling (space-conditioning) energy targets for 1000+ cities across the US and Canada. The same criteria applied to buildings of all sizes.

Under PHIUS+ 2018, the same level of granularity is used for the climate-dependence of the heating/cooling criteria – they vary by city/location and are continuous functions of climate parameters.

### New in PHIUS+ 2018

Because size and occupant density influence the optimal path to a low energy building, the new criteria implement continuous adjustments for a range of different building sizes and occupant densities.

The space conditioning criteria result from optimizing based on upgrade costs vs. savings in operational energy, and guide building energy planners accordingly. As with PHIUS+2015, the optimization studies include some forced upgrades, notably on air-sealing and windows, but window costs have come down considerably in the past few years, and designers still have flexibility to meet the resulting performance targets in different ways.

*For example:* A 2,000 sf single-family home does not have the same optimal space conditioning energy performance targets as a 200,000 sf tower, even if they have the same occupant density. That's because the two have different envelope-to-floor area ratios. Conservation improvements are generally applied to the envelope, but ventilation effects follow occupancy and floor area, and performance targets are set per square foot of floor area. This means that two side-by-side

10,000 sf buildings, in the same location, with different occupant densities will have slightly different space conditioning targets.

## Source Energy:

### What's the same

The *overall* energy limit under PHIUS+ 2018 is based on *source* energy, rather than *site* energy, as it is a better proxy for resource consumption and emissions associated with the site's energy use. The source energy limit is not set based on cost optimization, but rather on the 'fair share' of carbon emissions allowed for each sector. To limit global warming and avoid many harmful impacts on society, emissions must go to zero overall and the energy system must go to 100% renewable.

### New in PHIUS+ 2018

In PHIUS+ 2018, the source energy criterion is tightened, with a view toward zero. But, there are more options for meeting the target. We aim to answer the question:

*When has the building done all it can with both conservation and on-site renewables and must look to its energy suppliers for clean/renewable energy?*

There is no cap on total source energy use as long as the predicted 'annual net source energy' use meets the new (lower) target. This 'net' source energy use is the remaining source energy use, after what is offset by qualified renewable energy measures, on-site and off-site.

Previously, off-site renewable energy was not accounted for, and only a fraction of on-site renewable energy was counted to offset source energy use (exports did not count). However, in tapering the source energy limit to zero, it is unproductive to put the entire burden on the building and its on-site production potential. Doing so may push past the point of diminishing returns in energy conservation, or prohibit projects with constrained sites from ever achieving this goal. At some point, the building has conserved and generated all it can, and the focus will shift to cleaning up the energy supply.

Therefore, off-site options such as Virtual Power Purchase Agreements, community renewables, directly owned off-site renewable, and renewable energy credits are valid measures of offsetting a project's source energy use under PHIUS+ 2018.

PHIUS+ 2018 is intended to guide designers toward a cost-effective investment in building envelope and other passive measures, while giving a wide range of options for the “must-do” job of contributing to an overall transition to renewable energy.

## Certification criteria – adjustments from PHIUS+ 2015

### Heating and cooling

- The criteria are adjusted for building size and occupant density. The adjustments are continuous within a limited range.
- The sensitivities to building size and occupant density are different for each of the four criteria, and also change depending on climate.
- See the summary table at the end of this document for examples.
- Use the [Space Conditioning Criteria Calculation Tool](#) to determine project criteria.
  - **CALCULATOR** Method should be used for certification and is based on Envelope-to-Floor-Area ratio
    - 'Envelope / iCFA' is the building's exterior envelope area divided by the interior conditioned floor area.
    - The building envelope area and floor area must be in the same units.
    - The envelope area can be calculated manually or found in your WUFI Passive model under the results report or visualized components branch.
    - 'Square feet per person' must be calculated using total occupancy divided by iCFA (interior conditioned floor area).<sup>1</sup>
  - **ESTIMATOR** Method can be used before exact ratios are known, and approximates Envelope-to-Floor Area based on floor area alone.
- As before, the same targets generally apply to both residential and non-residential buildings.
- For unique non-residential buildings with significant process loads, very high internal loads, or highly variable occupancy, custom optimization may be needed to determine

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<sup>1</sup> For nonresidential projects such as schools and offices, use total design occupancy to determine the peak load criteria, and annual average occupancy divided by 0.688 to determine the annual demand criteria.

the appropriate targets. This will be done on a case-by-case basis using BEopt. An additional certification fee will apply.

- For the first full year, until end of September 2019, staff may use discretion to grant an exception on one of the four main space conditioning criteria (Heating Demand/Load, Cooling Demand/Load).

## Source energy use

- The certification limit is reduced:
  - **Residential:** From 6200 kWh/person.yr 3840 kWh/person.yr for residential
  - **Non-Residential:** From 38.1 to 34.8 kBtu/ft<sup>2</sup> for non-residential.
  - This is intended to taper to zero in years to come, with downward revisions on a three-year cycle, the next coming in 2021. The zero year is not yet decided.
- The source energy multiplier for grid electricity is aligned with Energy Star Portfolio Manager:
  - **USA:** 2.8
  - **Canada:** 1.96
  - This factor is also intended to be rechecked every three years.
- There is a change to the source energy metric. It is now calculated as the usage *net of* annual on-site *and* off-site renewable production.
  - All of the predicted annual onsite-renewable electricity generation is now regarded as offsetting source energy use, not just the fraction used right away or stored and used on-site.
- Some arrangements for procuring off-site renewable energy are now also regarded as offsetting the source energy use, as follows:
  - Directly-owned off-site renewables.
  - Community renewable energy.
  - Virtual Power Purchase Agreements.
  - Green-E Certified Renewable Energy Certificates (RECs), discounted 80%, that is, each 1 kWh purchased offsets 0.2 kWh.
- The building owner must present an actual contract for procurement of renewable

energy sufficient to meet the source energy target (at time of certification) for 20 years.

- Projects that are off-grid for indoor water supply and for wastewater treatment have a process load allowance of 800 kWh/p.yr for residential projects, 14 kWh/kgal for non-residential. That allowance is cut in half that if a project is off-grid for water supply only or wastewater treatment only.

## Quality assurance

- The air-tightness certification limit for most buildings is increased from 0.05 to 0.06 cfm50 per ft<sup>2</sup> of envelope. (The criterion for tall buildings of noncombustible construction remains the same.)
- The requirement that the ventilation system is capable of 0.3 ACH at max setting is removed, though still recommended.
- Projects outside of the US are exempt from the EPA Indoor airPLUS materials checklist requirements.
- Note also that the requirement in the 2 March 2018 addendum to the Certification Guidebook continues, “Fresh air must be ducted directly to all bedrooms in dwelling units.”
- The initial scope of requirements for commissioning of nonresidential buildings is focused on energy use impacts. Details are still being worked out.
  - Systems manual for building operators.
  - Infiltration testing.
  - Ventilation balancing and wattage measurement.
  - Ducted heating/cooling balancing.
  - Verification of envelope, air barrier, thermal bridge mitigation, and shading – that these are built to plans.
  - Verification of lighting, mechanical, and process load systems per plans/energy model.

## Energy modeling protocol

- Building energy models must be submitted in WUFI® Passive, using a version which supports the new solar shading algorithm.
- [Detailed updates can be found here.](#)
- The requirement that the ventilation system is modeled at a minimum of 0.3 ACH is removed. (Supply per person and exhaust-room minimums still apply, per [Certification Guidebook](#) section 6.7.)
- If a cooling system is planned, no natural ventilation cooling is to be included in the model.
- The following changes to the calculation protocol for hot water energy use are implemented in a new accessory calculator workbook:
  - Calculation support for meeting EPA Watersense delivery time requirement.
  - Revised pipe heat loss calculation scales more realistically to larger buildings.
  - Alignment with RESNET on low-flow fixture credit, drain water heat recovery, washer/dryer/dishwasher energy calculations, and monthly cold water inlet temperature variation.

## PHIUS+ 2018, target-setting process for heating and cooling

**As for PHIUS+ 2015, the basic process for setting the heating and cooling criteria was:**

1. Life-cycle cost optimization: Model study buildings in BEopt, giving its optimizer various energy-saving upgrades to weigh.
2. Crossover: Model the study buildings again in WUFI® Passive, with the chosen upgrade packages. This is necessary to tune the criteria to the calculation methods actually used in project certification.
3. Statistical smoothing: Note the resulting annual demands and peak loads for heating and cooling and do curve-fitting on that data to find interpolation formulas. Those formulas then determine the criteria for all cases.

**For 2018, there were five different study buildings:**

- A small 24x25 foot two-story house of about 1000 square feet floor area.
- A typical 26x40 foot two-story house of about 1800 sf.



- A townhome/rowhome design, 160x34 footprint, with about 15,000 sf.
- A 4-story apartment building, 152x56 footprint, around 33,000 sf.
- A 10-story apartment building, 152x56 footprint, around 82,300 sf.

In terms of size and window-to-wall ratio, the large apartments correspond to the US DOE Commercial Prototype buildings for Mid-rise and High-rise Apartment.

Each of these five geometries was set up for three different occupant densities, corresponding as closely as possible to 235, 370, and 875 square feet per person, making for a total of 15 “base buildings” in BEopt. In some cases the density was adjusted by changing the number of bedrooms per unit, and in some cases by changing the number of units per floor.

By default, BEopt runs its dynamic simulations according to Building America House Simulation Protocol. Some global overrides were applied to align with PHIUS modeling protocol, such as the heating and cooling setpoint temperatures, lighting, plug loads, hot water usage assumptions, and turning off natural ventilation. Some significant energy-saving upgrades were also imposed - ducts inside and stringent air-sealing. For the smaller three of five study building types, windows were upgraded with U-values low enough to keep their inside surface temperature within 4°C (7.2F) of the indoor air, at a winter extreme condition (12-hour mean minimum outdoor temperature.) For the mid-rise and high-rise, the windows were set with code minimum as a starting point, but the optimizer had the ability to upgrade to windows that maintained the 4°C temperature differential, and sometimes it did make that choice.

The optimization allowed for two air-tightness thresholds – meeting PHIUS+ 2018 targets, or an upgrade to half of that leakage. The opaque envelope started at IECC 2015 code minimums and had various increments of upgrades possible.

PV generation was essentially excluded from the calculation; that is, the optimization looked only at the diminishing-returns behavior of the conservation measures, both envelope and HVAC.

Each of the 15 base buildings was optimized in 20 cities, for a total of 300 individual case studies. The idea was to explore the full range of climate factors. The various climate factors included were:

- (1) HDD65: Heating Degree Days, base 65F

Source: ASHRAE Fundamentals 2017

- (2) CDD50: Cooling Degree Days, base 50F  
Source: ASHRAE Fundamentals 2017
- (3) IGA [kWh/m<sup>2</sup>.yr]: Solar Irradiance, Global, Annual  
Source: Meteonorm
- (4) DDD [lb/lb.days]: Dehumidification Degree Days, base 0.10 lb/lb  
Source: Meteonorm
- (5) THD [F]: Peak Heating Design Temperature  
Source: Meteonorm
- (6) TCD [F]: Peak Heating Design Temperature  
Source: Meteonorm
- (7) DDHR [grains/lb]: Dehumidification Design Humidity Ratio 0.4%  
Source: ASHRAE Fundamentals 2017
- (8) IGHL [BTU/hr.ft<sup>2</sup>]: Peak Heating Solar Radiation  
Source: Meteonorm
- (9) IGCL [BTU/hr.ft<sup>2</sup>]: Peak Cooling Solar Radiation  
Source: Meteonorm
- (10) Pelec [\$/kWh]: Marginal cost of electricity

The marginal cost of electricity, in \$/kWh, was used as an independent factor in the experiment, so as to determine its impact on the resulting space conditioning targets. That is, its value was not tied to the city used, but rather test values were used to explore a full range of options.

To choose the upgrade package, the optimal, minimum life-cycle cost point was chosen for all cases, rather than manually choosing a point of diminishing returns on the cost curve as before in 2015.

In the crossover study, the 300 optimized buildings were re-modeled in WUFI® Passive, adding only a few effects from PHIUS protocol that BEopt neglects, such as window installation

thermal bridge coefficients, and corridor ventilation. It was challenging to match the ground contact modeling procedures between the two software, so workaround measures were taken to simulate uninsulated slabs with only perimeter insulation.

In the curve-fitting, each of the four criteria was fitted to a “response-surface” type of function in terms of envelope-to-floor-area-ratio (EnvFlr), occupant density (Occ) and three to five of the relevant climate factors. For example, Annual Heat Demand was fitted to a function of EnvFlr, Occ, HDD65, IGA, and Pelec. Such functions consist of a sum of several terms or “effects”: a constant, terms linearly proportional to each of the factors, terms proportional to the squares of the factors, (quadratics) and terms proportional to the two-way cross products of the factors (interactions). The constants of proportionality are adjusted by least-squares regression for the best fit. Effects that were not statistically significant were dropped from the fitted formula. The software used for this statistical analysis was JMP 13.

For the most part, the climate dependence in the resulting formulae for the heating/cooling targets behaves in an intuitive way – places with hotter design days are allowed more peak cooling load and so on. However, this is not always the case. Keep in mind that there has been an optimizer at work that is “trying” to compensate for climate variation; it chooses different upgrade packages for different conditions, so it may go against expectations based on “other things being equal” type of thinking. This is particularly so for the Annual Heat Demand, because that is typically where most of the energy savings comes from; therefore it interacts with the cost-optimization more strongly than the other heating/cooling metrics.

## Window Comfort

As mentioned above, the optimization used to set space conditioning targets allowed for code-minimum windows in the mid-rise and high-rise buildings. While the relaxed window performance may be most cost effective from an up-front cost and energy savings payback, it does not provide an adequate guardrail on ensuring comfort. Therefore, a new window comfort requirement will be enforced.

The window comfort criterion applies to all projects, regardless of size. The U-value required scales by window height – the taller the window, the lower the required U-value.

The whole-window U-value must be low enough such that the window surface inside is no more than a certain temperature difference ( $\Delta T$ ) lower than the inside air temperature when the outside air temp  $T_d$  is at the ASHRAE 99% design temperature.

Maximum temperature difference ( $\Delta T$ ) =

**6.0** °F for double-height spaces;

**14.7**°F – (**0.742** x *HHS(ft)*) for window head-height-from-sill HHS of 10 feet or less,

or **13.3**°F, whichever is less;

where the whole-window U is calculated as:

$$U = \Delta T / (R_{si}) T_{air,inside} - T_d$$

$$R_{si} = 0.74 \frac{hrft^2\text{°F}}{BTU}$$

$$T_{air,inside} = 68\text{°F}$$

$$T_d = \text{ASHRAE 99\% Design Temperature } \text{°F}$$

Exceptions:

- Windows in non 'regularly occupied' areas  
Example: a college dormitory with an entry lobby and no seating, or a hallway in a school with only transient occupants.
- ADA doors.

Window comfort calculator can be found here (coming soon): <http://www.phius.org/software-resources/wufi-passive-and-other-modeling-tools/calculators-and-protocols>