PHIUS+ 2018
PASSIVE BUILDING STANDARD
CERTIFICATION GUIDEBOOK

Version 2.1 | June 2019






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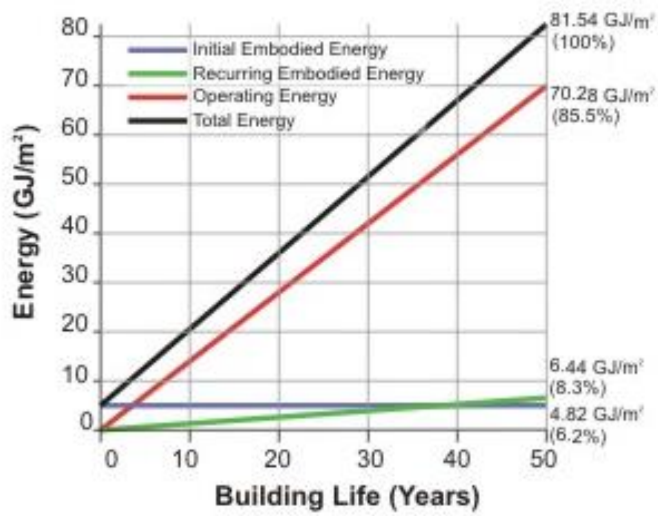
1. About PHIUS+ 2018

1.1 Introduction

Thank you for your interest in the PHIUS+ 2018 Passive Building Standard.

PHIUS+ is a "high-performance building standard" – it challenges the building industry to construct buildings that can maintain a comfortable indoor environment with very low *operating* energy. Since the operating energy of a building over its lifetime far exceeds the embodied energy to construct the building, the PHIUS+ standard just focuses on reducing operating energy and does not specifically address the environmental impacts of the building materials and construction process. However PHIUS+ is still compatible with other green building certification programs and broader sustainability concepts. An illustrative example of embodied versus operating energy is shown below in Figure 1.1.



Components of Energy Use During 50-Year Life Cycle of Typical Office Building with Underground Parking, Averaged Over Wood, Steel and Concrete Structures in Vancouver and Toronto [Cole and Kernan, 1996].

Figure 1.1. Example comparing operating energy and embodied energy of a building. [i]

PHIUS+ is a pass-fail standard for building energy performance, with additional requirements for quality assurance inspections, and for low-moisture-risk design.

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. It recognized that there are diminishing returns on investment in energy-conserving measures, and an optimum level in a life-cycle cost sense, and that 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. PHIUS+ 2015 helped dramatically accelerate adoption. Download the full report at www.nrel.gov/docs/fy15osti/64278.pdf. [ii]

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 replace PHIUS+ 2015. This update focuses on adding more nuance for different building types and supporting an overall transition to renewable energy.

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, and now are also adjusted for building size and occupant density.

The particular focus of PHIUS+ is on **reducing heating and cooling energy using passive measures**. In addition to an overall limit on energy use for all purposes, it features limits on heating and cooling energy, in both the annual-total and peak-power sense. The targets for these heating and cooling "loads" are climate-specific and have been set based on consideration of the best that can be achieved "cost-competitively".

There are also two add-on badges available for buildings that reach even higher levels of performance beyond the PHIUS+ Standard – Supply Air Heating and Cooling Sufficient and PHIUS+ Source zero.

The energy performance is assessed based on calculation, a.k.a. mathematical modeling, using standardized climate conditions and occupant behavior. As such, it is a certification of a building design; there is not a certification path based on measured performance.

Additionally, PHIUS+ emphasizes quality assurance. It demands more than calculating out to the energy standards in the model and passing a blower door test. PHIUS+ requires additional reasonable assurances that projects are going to perform as designed, have healthy indoor environments, and be durable. To that end, PHIUS+ requires both pre-certification review as well as third-party on-site quality assurance checks. Pre-certification is performed by PHIUS staff, and final certification involves also the participation of PHIUS-certified independent Raters or Verifiers who carry out on-site quality inspections (see Section 3.6).

Certification proceeds through two stages:

- **Pre-certification** verifies that the *energy model* matches the plans and specifications, and
- **Final certification** verifies that the *finished building* matches the plans and specifications.

1.2 Why Certify?

Certification represents a third-party verification that the building is designed to meet the high performance standards for energy use, is constructed with quality assurance, and that critical systems are commissioned into proper operation. Third-party verification is also typically required by the incentive programs of utilities and governments. Certification also shares knowledge – it builds the public online database of projects. Also, as more situations come up, more solutions and guidance are developed. Certification staff can pass that knowledge on to other project teams directly and via ongoing updates to this Guidebook.

PHIUS Certification staff also provides guidance and support for project submitters, especially when working on their first PHIUS+ project.

1.3 About this Guide

The list of certification requirements and protocol in this Guidebook may seem lengthy. But all of it is intended to help – to help your project team design and execute high-performance, high-quality buildings and avoid as many pitfalls as possible.*

This Guidebook contains the following kinds of information, roughly in the order for which they are relevant in the building delivery process.

- General hints and tips for success.
- Design-phase requirements, both performance and prescriptive.
- Construction-phase requirements.
- The certification process, pricing, and roles of the parties involved.
- Energy modeling protocol.

1.4 The Project Team

Delivering a high-performance building requires very good cooperation between the design professionals and the building professionals. "Design-build" or "integrated-project-delivery" organization is more common in passive building and often mentioned as a success factor.

It is very preferable and highly recommended that a Certified Passive House Consultant (CPHC®), PHIUS Certified Builder, and PHIUS+ Rater/Verifier are all involved. However, the only professional that is required to have PHIUS training and certification is the PHIUS+ Rater/Verifier.

The CPHC® works with the project team throughout the design process to ensure the project will meet all certification requirements. This includes completing the WUFI® Passive energy modeling.

The Rater/Verifier is responsible for site visits, testing, and verification during construction. They are an integral part of the project team and should be hired early in the process. PHIUS asks that you hire a Rater/Verifier when you submit a contract at the start of the Certification process.

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*Simplicity is a popular idea in the abstract, but in practice a simple rule often meets objections that it is lacking some desired nuance in certain cases; as a result, certification protocol tends to become more elaborate over time.

1.5 Types of Projects

As in RESNET, "residential" includes single-family detached, single-family attached, and multifamily buildings, excepting hotels and motels.

1.5.1 Single-family Residential Projects

Herein, "single-family" refers to single-family detached. What may elsewhere be called "single-family attached" housing is here considered to be "multifamily." Single-family projects should follow the PHIUS+ Single Family Quality Assurance Workbook.

1.5.2 Multifamily Residential Projects

Multifamily projects are defined as anything residential other than "single family". They should follow the PHIUS+ Multifamily Quality Assurance Protocol for quality assurance, prescriptive design requirements, and commissioning. All performance-based certification criteria remain the same as for single-family.

Modeling protocol for multifamily projects differs slightly from single-family because of the addition of common space lighting loads, elevators, shared spaces, etc., as noted in Section 6.6.

1.5.3 Campus/Community Certification

For campus/community certification, where there are multiple residential buildings being certified that share a common building or space, a source energy limit applies for the campus/community as a whole. For example laundry rooms and kitchens may be in a common shared space.

Space Conditioning: Each individual enclosure must be modeled separately, allocating the correct internal loads to each enclosure for accuracy of the internal heat calculation (ex: if all of the laundry is done in one building, the gains from this laundry should only be counted in that enclosure). The space conditioning targets (heating demand, heating load, cooling demand, cooling load) must be met for each enclosure in the separate energy models, and the airtightness requirements also apply for each enclosure individually.

Net Source Energy Allowance: If the campus/community is strongly/mainly residential in character the source energy allowance is proportional to the design occupancy. For non-residential day schools, commuter campuses and the like, the source energy allowance is per square foot of interior conditioned floor area (iCFA). See Section 3.3 Net Source Energy Criterion for specific target values.

1.5.4 Commercial/Non-Residential Projects

The criteria for non-residential projects are the same as for residential projects, apart from the Source Energy requirement. The Source Energy limit for commercial buildings is proportional to floor area, rather than occupancy. There may be additional differences that require additional documentation for PHIUS+.

Compared to residential projects, the energy models for non-residential projects need more detailed information on lighting systems, usage patterns, plug loads, and custom internal heat gains. For commercial buildings with process loads, PHIUS will determine the Source Energy allowance on a case-by-case basis. See Section 3.3.4 for process load definition.

Non-Residential QA/QC Commissioning is required.

Non-residential certification protocol will be updated as more information becomes available on these types of projects. Download the most updated Non-Residential QA/QC Commissioning Protocol here.

1.5.4.1 Dorms & Hotels/Motels

The IBC/IECC codes draw the line between residential and commercial based on number of stories and whether the occupancy is primarily "transient", which means < 30 days. Transient occupancy is considered commercial.

Dorms:
Transient occupancy (< 30 days) = Commercial
Long term occupancy (> 30 days) = Residential
On-site prescriptive requirements: PHIUS+ MF Protocol

Hotel/Motel: Commercial
On-site prescriptive requirements: PHIUS+ Commercial Protocol

1.5.5 Mixed-Use Projects

Submitting a Mixed-Use Project for PHIUS+ Certification

Overview

New-construction mixed-use projects come in two basic variants – in the first case, the usage types are known at design time. In the second case, part of the building is designed for and finished for known usage types, and part of it is designed for some form of "shell lease", wherein a tenant leases the unfinished shell of a building and agrees to complete construction by installing ceilings, plumbing, HVAC systems, electrical wiring, or even insulation. The degree of finish offered varies and is sometimes denoted by terms such as "cold dark box," "warm white box," which are not completely standardized. This document addresses certification and energy modeling protocol for both these cases, wherein the building is new construction and consists mostly of spaces "F" designed to be finished for known uses, and a smaller part "UF" intended for some form of non-residential shell lease.

PHIUS+ Mixed-Use Approach

It is encouraged to certify the whole building, but this is not required. Certification may be sought for part of the building only, even if all usage types are known at design time, as long as most of the building by floor area (50% or more) is within the scope of the planned certification.

Residential and non-residential parts of the building may be certified separately or together as a whole building. Due to software limitations, separate energy models are required if part of the building is residential and other parts non-residential, even if it is being certified as a whole building. Multifamily common spaces that primarily serve the residents can be included in a residential energy model.

Parts "F" and part "UF" of the project must be separately metered and have separate mechanical systems. The predicted energy use can then be compared to actual usage.

Also, separate systems allow for flexibility in accommodating the differing schedules and capacities for the different usage types within the project. However, if all the usage types are known, the mechanical engineer may find it possible / advantageous to design a system with a shared thermal storage for low-temperature space conditioning.

It should be kept in mind that for any spaces that change tenants, (post-construction), modeled energy use may vary from predicted energy use.

If, between pre-certification and final certification, prospective tenants can be found for the parts UF who are able and willing to meet the constraints of whole-building certification in their build-out plans, the tenant fit-out may be certified under its planned function rather than as unfinished space.

The source energy allowance for residential spaces is calculated on a per person basis, and for nonresidential spaces on a per square foot basis (Section 3.3).

Office and retail spaces do not qualify for an additional source energy allowance for process loads, but restaurants and groceries do. Contact PHIUS about process load allowances for other usage types.

General recommended practices include:

- Thermally isolating residential spaces from a nonresidential portion to some extent (for soundproofing and other considerations).
- Air sealing to separate the two parts to prevent odor transference.

PHIUS Protocol for modeling Unfinished spaces (UF):

- Building Type: Non-residential
- Occupancy Type: Undefined/unfinished
- Internal gains: 1 BTU/hr.ft^2
- Continuous ventilation rate of 0.3 ACH (air changes per hour)
- Ventilation heat recovery efficiency matching the average for the rest of the building

The foregoing points pertain to calculating the heating and cooling loads and demands – it is necessary to assume a scenario to apply the certification criteria. For the source energy criterion that is not necessary – there is no additional source energy allowance for unfinished spaces and therefore no assumption about their energy use.

In general, there are 4 unique paths, listed below.

A) Whole Building Certification– One combined certification for Residential and Non-Residential

Separate energy models must be constructed for residential and nonresidential parts.

An overall source energy limit for the building applies, consisting of a per person portion for residential space, per-square-foot portion for nonresidential space, and additional custom process load allowance for some usage types. For details please refer to the equation below, which uses Net Source Energy targets for PHIUS+ 2018. For additional tiers, visit Section 3.3.

$$\left(Res_{use} * Res_{Occ} * 3.412 \frac{kBTU}{kWh}\right) + \left(Non - res_{use,fin} * iCFA_{non-res,fin}\right) \leq$$

$$(3840 \frac{kWh}{yr} * Res_{Occ} * 3.412 \frac{kBTU}{kWh}) + \left(34.8 \frac{kBTU}{ft2.yr} * iCFA_{non-res,fin}\right) + PLA$$

Res_{use} = Primary Energy use in residential portion in kWh/person.yr

Res_{Occ} = Occupancy of residential portion

$Non - res_{use,fin}$ = Primary Energy use in kBTU/ft^2.yr of non-residential finished space

$iCFA_{non-res,fin}$ = Non-residential iCFA of finished space only

PLA = Process Load Allowance (case by case basis)

Space conditioning energy targets apply to the building as a whole and the floor area includes both parts. For details please refer to the equation below.

$$(X_{res} * iCFA_{res}) + (X_{non-res} * iCFA_{non-res})$$
$$\leq (X_{res,limit} * iCFA_{res}) + (X_{non-res,limit} * iCFA_{non-res})$$

X_{res} = Specific Heating demand or Cooling Demand (kBTU/ft^2.yr), Heating Load or Cooling Load (BTU/ft^2.hr) modeled for the residential portion

$X_{non-res}$ = Specific Heating demand or Cooling Demand (kBTU/ft^2.yr), Heating Load or Cooling Load (BTU/ft^2.hr) modeled for the non-residential portion

$X_{res,limit}$ = Certification limit for the residential portion in kBTU/ft^2.yr or BTU/ft^2.hr

$X_{non-res,limit}$ = Certification limit for the residential portion in kBTU/ft^2.yr or BTU/ft^2.hr

$iCFA_{res}$ = Residential iCFA
$iCFA_{non-res}$ = Non-residential iCFA

Note: When calculating space conditioning targets for individual portions of a whole building, shared/adiabatic envelope area should not be included in the Envelope/iCFA ratio for any portion.

B) Whole Building Certification – Separate Residential and Non-Residential Certifications

Residential and nonresidential parts of the building are both modeled separately and certified separately, that is, they meet the certification criteria individually.

This separated approach is recommended for projects where the nonresidential spaces include a part UF. This way, the energy design for a main residential portion of the project can be settled earlier.

C) Partial Building Certification – One combined certification for Residential and Non-Residential

Same as A) above, except that only part of the building (50% or more by floor area) is certified.

D) Partial Building Certification - Separate Residential and Non-Residential Certifications

Same as B) above, except that only part of the building (50% or more by floor area) is certified.

		Whole Building		Partial Building	
		One combined certification for Residential and Non-Residential	Separate Residential and Non-Residential Certifications	One combined certification for Residential and Non-Residential	Separate Residential and Non-Residential Certifications
Modeling/ Certification	Separate energy models for residential and non-residential	x	x	x	x
	All building floor area included in certification	x	x		
	At least 50% of building floor area must be modeled and certified.			x	x
	Unknown non-residential spaces may not be certified alone.		x		x
	Model unfinished space with internal heat gains of 1 BTU/hr.ft2, a ventilation rate of 0.3 ACH, and ventilation heat recovery efficiency at the average for the rest of the building	x	x	x	x
Source Energy Allowance	Determined for building by applying a mix of residential and non-residential allowance to certified spaces	x		x	
	Determined by space type (residential/non-residential)		x		x
Space Conditioning Targets	Apply to whole/certified portion of building	x		x	
	Apply to partial builidng and must be met in each energy model		x		x

1.5.6 Retrofit Projects

The criteria for retrofit projects are the same as for new construction, except that a case-by-case energy allowance may be made for a foundation perimeter thermal bridge or other such hard-to-fix structural thermal bridges - provided that the design is also “damage-free,” that is, low risk from a moisture point of view.

As with new construction projects, there is a moisture criterion that basically requires less than 80% RH on interior surfaces. Any critical areas that need surface temperature calculation will be noted in pre-certification. The calculation will be performed in accordance with ISO 13788.

Airtightness requirements are the same as for new construction (see Section 3.2).

Some ZERH requirements are not applicable to retrofit projects.

1.5.7 Buildings with Seasonal Use

Certification of seasonal-use buildings is discouraged, for two reasons.

1. First, if a building can be used year-round, it may tend to gravitate to year-round use over time - the intentions of the current or initial users notwithstanding.
2. Second, it is not fully supported by the current energy modeling software and requires significant workarounds.

Certification staff may allow it if there are other factors indicating that the seasonal use pattern will persist during the life of the building, e.g., "remote location on a seasonal road" and if the season of use encompasses at least half the year.

2. General Notes/Guidance

2.1 General Challenges Associated with Energy Efficient Buildings

Please be aware of these general issues with "super-insulated," "low-load" buildings:

- Better insulation leads to colder exterior surfaces and less heat available to evaporate water in the assemblies.[3] See also Section 3.4.3.
- The "sensible heat ratio problem", that is, HVAC dehumidification capacity at part load conditions. Sensible cooling demands and loads are reduced, while dehumidification demands and loads still exist. [4] [5]

2.2 "Yellow Flag" Items

Please contact us early for more information if the project entails any of these items:

- Retrofit projects with foundation thermal bridges.
- Non-residential projects with "process loads" or unusual heating/cooling set point temperatures.
- Site altitude very different from the nearest climate dataset location. See Section 6.1.2 for more details.
- Thermal bridge calculations: contact certification@passivehouse.us for assistance, or refer to PHIUS' THERM Training Package.
- No PHIUS+ Rater/Verifier within 100 miles of the project location.

Please study the referenced information soon, if the project entails any of these items:

- Spray foam, flash-and-fill assemblies: see Section 3.4.3.1 and Appendix B.
- Floors with air-permeable insulation: see Section 3.4.3.2.
- Thermal mass, or anything more than "light construction": see Section 6.4.5.
- Heat pumps of any kind: Download the Heat Pump COP Protocol Kit.

2.3 Tips to Design a Low-Cost Passive Building

- Keep thermal envelope simple (add "architectural interest" outside of it).
- Keep window area down (10-15% of wall area for single-family houses).
- For small buildings, design a compact shape. For large buildings, bump-ins for daylighting may be more important.
- Limit "open to below" areas in the floor.
- Not too "tiny" and detached – design attached housing with small units instead.
- Use good details that don't require excessive labor to air-seal (avoid "conceptual retrofitting".)

2.4 Tips on Assemblies

Air Barrier

- Mid-wall is the best place for the air barrier, exterior or interior placement is more vulnerable.

Two Wall Types

- Keep in mind the "perfect wall" concept - structure to the inside, insulation to the outside. Diffusion open or exterior rigid foam, both versions can work moisture-wise and super-insulated. [6] [7]

Slab

- Moisture barrier and air barrier are typically placed between foam layer and slab.
- Polyisocyanurate insulation is typically not to be used below grade. [8] Thoroughly follow the application guidance of the manufacturer's warranty and any ICC Evaluation Service report that pertains.

Things to Avoid

Exterior Load Bearing Double-Stud Wall: This wall type is discouraged in climate zones 3 and higher. These will generally incur additional certification cost for hygrothermal analysis (WUFI), need a spray foam global warming potential (GWP) impact calculation, or both. They tend to be too vapor-closed on the outside for those climates and also put the air barrier on the exterior where it will be less durable than a mid-wall air barrier.

In heating dominated climates, double stud walls should be of the interior load-bearing type, either Larsen truss (standoff truss) or the kind described in [9], [10].

When insulation with a high global warming potential is used (some closed cell sprayfoam or XPS), PHIUS may ask the project team to complete a global warming potential calculation to assess the overall impact of the insulation.

"Vapor-sandwiched" or "double vapor barrier" assemblies: These should generally be avoided and can make a project uncertifiable. There are some subtleties, e.g., it may be acceptable in compact roof assemblies. See these articles for a more detailed discussion [BSI-073] [BSI-092]. That discussion starts with "For the record, it makes no sense to have a vapor barrier on both sides of an assembly. If the assembly gets wet or starts out wet we are pretty much doomed…except if we are perfect and we start out dry."

- Building Science Corporation BSI-073: Macbeth Does Vapor Barriers
- Building Science Corporation BSI-092: Doubling Down-How Come Double Vapor Barriers Work?

2.5 Tips on Assembly R-Values

Sample R-Value Guidelines**		R-value ranges		
Zone	**Example Cities**	**Wall**	**Ceiling**	**Slab**
1	Miami, FL or Honolulu, HI	19 - 27	44 - 60	2ft R-8 vertical perim.
2	Jacksonville, FL or Phoenix, AZ	19 - 27	30 - 70	Uninsulated
3	Charleston, SC or Sacramento, CA	15 - 31	30 - 60	Uninsulated, or 2-4ft R-8 vertical perim.
Marine 3	San Francisco, CA	19 - 23	30 - 38	4ft R8-20 vertical perim.
4	Baltimore, MD or Amarillo, TX	31 - 51	49 - 80	2-4ft R8-20 vertical perim.
Marine 4	Salem, OR or Seattle, WA	31 - 43	60 - 70	4ft R-20 vertical perim., or whole-slab R-20
5	Providence, RI or Flagstaff, AZ	31 - 43	60 - 70	4ft R-20 vertical perim., or whole-slab R-20
6	Burlington, VT or Billings, MT	39 - 51	70 - 90	whole-slab R20-28
7	Duluth, MN or Edmonton, AB	49 - 65	80 - 90	whole-slab R28-40
8	Fairbanks, AK	89	120	whole-slab R-40

** actual values will vary by project

See Energy Star Residential New Construction Program Requirements for guidance on prescriptive values based on county This may be used a starting point for design.

3. Building Certification Requirements

3.1 Overview/Space Conditioning

All of the requirements in Section 3.1.1 and 3.1.2 need to be met to achieve PHIUS+ Certification. The specific heating and cooling energy targets for the project will be determined by the envelope area, floor area, occupant density, and location of the project. Refer to the PHIUS+ 2018 Final Criteria Calculator to determine criteria for the project.

3.1.1 Main Performance Criteria for Certification

- Annual Heating Demand[2] ≤ A (kBTU/ft^2.yr)
- Annual Cooling Demand[2,3] ≤ B (kBTU/ft^2.yr)
- Peak Heating Load[2] ≤ C (BTU/ft^2.hr)
- Peak Cooling Load[2,3] ≤ D (BTU/ft^2.hr)
- Airtightness[4] ≤0.060 cfm/ft^2 envelope @50Pa
- Net Source Energy Demand[5,6,7] ≤ 3840 kWh/yr/person

3.1.2 Summary of Other Requirements

- Moisture design criteria for assemblies and details (see Section 3.4 and Appendix B)
- Quality-related prescriptive design elements (see Section 3.5)
- Field quality assurance inspections (see Section 3.6)
- Contractor declaration (see Section 3.9)
- Window Comfort Assessment (Section 3.11)

3.1.3 Optional Additional Certification Badges

- Supply Air Heating and Cooling Sufficient

2 The space conditioning criteria are all per square foot of interior Conditioned Floor Area (iCFA). See Appendix H for details on the development of PHIUS+ 2018.

3 Annual Cooling Demand is total cooling, latent plus sensible. Peak Cooling Load target is sensible only.
Cooling criteria apply regardless of whether or not a cooling system is planned.
See Appendix C for method to evaluate when a cooling system is recommended. It is recommended in most climates especially for residential projects.
Certification staff may require that occupant-installed cooling, e.g. window A/C, is included in the energy model, even if it is not designed into the building as-delivered, so that the impact on source energy use is accounted for.

4 See detailed explanation in Section 3.2 below.

5 See Section 3.3 for further detail on alternate Net Source Energy targets for three "tiers".

6 For residential buildings, occupancy is determined by the # of bedrooms + 1, per unit.

7 For non-residential buildings, the Net Source Energy limit is proportional to the floor area instead of occupancy. There is also a provision for "process load allowances" in some cases. See Section 3.3 for details.

3.1.4 Window Recommendations

It is generally recommended to follow the zone-by-zone guidelines on the PHIUS Certified Data for Window Performance Program page. As noted in Section 3.4 and 3.11 below, there is a "hard requirement" on window performance to avoid condensation risk, and to meet window comfort requirements.

3.2 Airtightness Criterion

<u>Normative:</u>

A whole-building test for air tightness must be performed. See Section 3.8 for further details. If testing at 75 Pa, report the flow coefficient and exponent from the blower door tests.

The certification requirement is as follows:

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

q50 <= 0.080 CFM_{50}/ft^2 <u>or</u> q75<= 0.110 CFM_{75}/ft^2 of gross envelope area

For all other buildings:

q50 <= 0.060 CFM_{50}/ft^2 <u>or</u> q75<= 0.080 CFM_{75}/ft^2 of gross envelope area

**Non-combustible in this sense is construction that is not subject to mold and rot. This would mean no wood-based framing members or sheet goods, and no wood-based or paper-based insulation.*

Gross envelope area is measured at the exterior of the thermal boundary, the same as for the energy model, and includes surfaces in contact with the ground.

Exception, for non-threatening air leakage: If the airtightness criterion is missed, and the extra leakage can be proven to be due to a non-assembly-threatening leakage element, certification staff may allow that element to be taped off for the purpose of passing the airtightness criterion. The un-taped test result must be used for the energy model. Further details are subject to staff interpretation as detailed below.

Informative:

Exception

Non-threatening leakage elements that may be taped upon PHIUS approval:

- Fire rated entry doors - leakage through operable components
- Entry doors with panic hardware requirements - leakage through operable components
- Entry door thresholds with universal accessibility requirements - leakage at threshold/sweep
- Elevator doors - leakage through operable components into shaft
- Dampers - leakage at seal
- Trash chutes and compactor systems, code required dampened openings like elevator shaft vents, gas meter room vents, coiling doors
- Direct vent gas fireplace – leakage through firebox
- Window mounted space conditioning unit – leakage through unit itself or through gasket inset in window glazing or window frame (some frames present durability risk and certifier has discretion to decline request for taping)

Non-threatening leakage elements already accounted for in the cfm/ft^2 gross envelope limit. May not be taped:

- Standard casement/TT/awning windows - leakage through operable components
- Standard lift and slide doors - leakage through operable components
- Standard Balcony/French doors – leakage through operable components
- Duct/vent leakage if fully exposed and in conditioned space

Threatening leakage sources. May not be taped.

- Window or door installation - leakage at rough opening
- Duct/vent/wiring - leakage at penetration of exterior wall
- Duct or vent - leakage inside assembly
- Exterior wall mounted space conditioning unit installation– leakage through rough opening

For comparison to 0.6 ACH_{50}, the "crossover" is at roughly 10,000 square feet of envelope area, that is, the air-tightness target for projects larger than this will be slightly tighter than the 0.6 ACH_{50} metric and projects smaller than this will be slightly looser than the 0.6 ACH_{50} metric.

The higher limit for tall buildings should be considered temporary – more research is needed and the criterion might be tightened in the future.

Background

The PHIUS Technical Committee goal was a clear standardized building enclosure metric for all buildings, large and small. ACH_{50} is not an equitable metric since the volume of a building does not scale at the same rate as surface area. PHIUS views the primary purpose of the airtightness threshold as the reduction the risk of building assembly damage due to air-leakage driven moisture in super insulated assemblies with minimized mechanical systems, and energy efficiency as the secondary purpose.

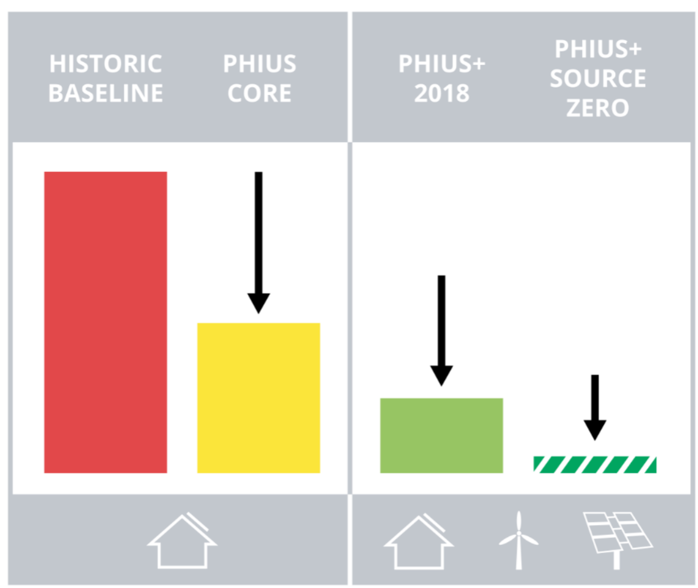
Establishing a maximum durability leakage rate recognizes that in many smaller buildings, while the conversion of a 0.060 cfm/ft^2 leakage limit to ACH_{50} results in a threshold higher than 0.6 ACH_{50}, the driver behind a project team's leakage target for these structures will be achievement of energy performance thresholds, rather than durability. That is, the heating/cooling criteria may effectively require air-sealing tighter than the certification limit for the blower door test noted above, and in that case the assumed air-tightness in the energy model becomes the new certification limit for the blower door test.

Testing at 75 Pa aligns with commercial code (IBC, IECC) and U.S. Army Corps of Engineers (as well as U.S. General Services Administration Facilities Standards, ASTM E779, ASHRAE 90.1, and the National Building Code of Canada.)

Related Documents

1. Acceptable Air Tightness of Walls in Passive Houses – Salonvaara and Karagiozis 2015
2. PHIUS Technical Committee Airtightness Comparison

3.3 Net Source Energy Criterion



In addition to heating/cooling performance requirements (Section 3.1), the overall performance, including all other energy end-uses, must be addressed in the design. The metric used for this criterion is net source energy use. The overall energy limit is based on source energy because that is a good measure of the impact of the building's operation has on society. That impact consists mostly of CO_2 emissions but the source energy metric differs from carbon-scoring in that it includes the impact of nuclear power as well.

There are three certification "tiers" available. These differ with respect to stringency and in how renewable energy is regarded as offsetting source energy use.

3.3.1 PHIUS+ Core

The PHIUS+ Core path emphasizes on-site conservation and efficiency and allows for meeting the Net Source Energy target on-site.

3.3.1.1 Residential Buildings: Low-Rise and High-Rise

Buildings considered residential include single-family detached housing, single-family attached housing, multifamily buildings, excepting hotels and motels.

The net source energy (SE) limit for all residential buildings is 5500 kWh/yr/person.

For purposes of the SE limit, the number of persons, the design occupancy, is taken to be the number of bedrooms+1, on a per unit or unit-by-unit basis (e.g., four 2-bedroom units have a design occupancy of 12, not 9.)

3.3.1.2 Non-Residential Buildings

The annual source energy limit for non-residential buildings is 11.1 kWh per square foot of interior conditioned floor area (iCFA), equivalent to 38 kBTU/ft^2.yr or 120 kWh/m^2.yr. See Section 4.4.1.4 for the iCFA calculation rules.

For commercial buildings with process loads, PHIUS will determine the source energy allowance on a case-by-case basis. See Section 3.3.1.

3.3.1.3 Renewables Credits

Source Energy demand is calculated as the annual usage *net of* renewable energy that is produced and used directly on-site**.** Renewable energy production that is exported from the site is not credited.

Solar thermal:

- An active solar thermal system is regarded as reducing the source energy demand associated with water heating and, if so configured, space heating as well. The system is not regarded as reducing the space heat demand itself, but rather the source energy use needed to provide the heating.

Solar PV and other renewable electricity:

- An estimate of coincident production-and-use of energy from renewable energy systems (such as PV) may be included in the calculation similarly to the way solar thermal systems are treated, that is, the limit applies to source energy consumption net of that generation.
- NREL's PVWatts calculator may be used to calculate annual PV array output.
- The amount of source energy that may be offset by a renewable electricity source depends on the utilization factor. This can be calculated by determining the coincident production-and-use fraction of the generation. If only using PV without battery storage, PHIUS' pre-defined utilization curves may be used to determine the utilization factor, and are built into WUFI Passive.
- If using more than one renewable electricity generation technology on-site, electrical battery storage, or for off-grid buildings, see Appendix A.

3.3.2 PHIUS+ 2018

In PHIUS+ 2018, the source energy criterion has a view toward zero. 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. But, there are many options for meeting the target. This criterion aims to answer questions like:

> *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?*

The answer is there is no cap on total source energy use as long as the predicted 'annual net source energy' use meets the 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. Any combination of conservation measures and qualifying renewables can be used to meet the net source energy criterion. This target 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.

This varies from PHIUS+ Core, where off-site renewable energy is not accounted for, and only a fraction of on-site renewable energy can be counted to offset source energy use (exports do 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. More details can be found in Section 3.3.2.3.

3.3.2.1 Residential Buildings: Low-Rise and High-Rise

Buildings considered residential include single-family detached housing, single-family attached housing, multifamily buildings, excepting hotels and motels.

The net source energy (SE) limit for all residential buildings is 3840 kWh/yr/person.

For purposes of the SE limit, the number of persons, the design occupancy, is taken to be the number of bedrooms+1, on a per unit or unit-by-unit basis (e.g., four 2-bedroom units have a design occupancy of 12, not 9.)

3.3.2.2 Non-Residential Buildings

The annual source energy limit for non-residential buildings is 10.2 kWh per square foot of interior conditioned floor area (iCFA), equivalent to 34.8 kBTU/ft^2.yr or 110 kWh/m^2.yr. See Section 4.4.1.4 for the iCFA calculation rules.

For commercial buildings with process loads, PHIUS will determine the source energy allowance on a case-by-case basis. See Section

3.3.2.3 Renewables Credits

Source Energy demand is calculated as the annual usage *net of* all on-site renewable energy production, and *net of* off-site renewable energy procured (subject to the offset weighting factors listed below).

Solar thermal:

- An active solar thermal system is regarded as reducing the source energy demand associated with water heating and, if so configured, space heating as well. The system is not regarded as reducing the space heat demand itself, but rather the source energy use needed to provide the heating.

Solar PV and other renewable electricity:

- 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 (as in PHIUS+ Core).
- On-site renewable electricity generation counts toward source net zero with the same source energy multiplier for electricity, i.e. 2.8. In other words, with the source energy factor for grid electricity at 2.8, every kWh electric generated on site is considered to neutralize 2.8 kWh at the source.
- NREL's PVWatts calculator may be used to calculate annual PV array output. [16]
- The following arrangements for procuring off-site renewable energy are also regarded as offsetting the source energy use:
  - 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.

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
Renewable Energy Certificates (RECs)	0.2

- 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.

3.3.3 PHIUS+ Source Zero

PHIUS+ Source Zero pushes past the target set for PHIUS+ 2018. To meet PHIUS+ Source Zero, the building must generate or procure as much renewable energy as it uses, on an annual, source-energy basis.

For an all- electric building, the same on-site PV array (or PPA, etc) that gives site zero also gives source zero. It is different if the building uses other fuels - for example if the building made heavy use of biomass for heating, the overall source/site ratio of its usage might be only 1.5, while the source/site ratio of the PV is 2.8. Therefore on that building the PV array size for source zero would be smaller than the array size for site zero, because of the additional source-reduction strategy.

To determine if a project meets this certification, determine if the total estimated annual renewable energy production will offset the annual source energy.

There are no process load allowances for non-residential buildings under PHIUS+ Source Zero, i.e. the net source energy use must equal zero with process loads included in the model.

3.3.3.1 Renewables Credits

See Section 3.3.2.3 Renewables Credits.

3.3.4 Non-Residential Building Process Loads

For non-residential/commercial buildings with process loads, PHIUS will determine the source energy allowance on a case-by-case basis. The process load allowance is added to the base net source energy use allowance specified in 3.3.1.2 and 3.3.2.2, that is, it applies to PHIUS+ Core and PHIUS+ 2018 tiers, but does not apply to PHIUS+ Source Zero.

Process loads: If there is a service being provided to a customer or client in the building, this is considered a process load. Whether it's the customer or client using the energy (ex: arcade, training center), or if the energy is used on their behalf (ex: restaurant), both situations qualify as process loads.

- ASHRAE 90.1-2010 Process Energy Definition: Energy consumed in support of a manufacturing, industrial, or commercial process other than conditioning spaces and maintaining comfort and amenities for the occupants of a building.

3.3.5 Mixed-Use Buildings

The residential SE limit also applies if the building has common spaces and conditioned spaces that are not dwelling units, but that primarily serve the residents. Nonresident occupants of such common spaces (staff) are not included in the occupant count for determining the source energy allowance. (Nor do they determine lighting and miscellaneous energy use of the common spaces, as explained in Section 6.6.1.1).

If there are non-residential spaces designed to mainly serve non-resident customers/clientele, an additional PE allowance may be calculated based on the iCFA of those spaces. The nonresident occupants of such spaces, the staff and customers, are not included in the occupant count for determining the per-person portion of the source energy allowance.

Certification staff may require separate modeling of the residential and non-residential parts of a mixed-use building.

The mixed-use protocol (see Section 1.5.5) is written to avoid the calculation of the source energy in the unfinished/undefined spaces - there is no source energy allowance for the unfinished parts and no source energy impact associated with the internal gains, so the details of how the gain is generated are not pertinent.

3.3.6 Tip: Determining the Equivalent Source Energy Allowance in kBTU/ft2.yr

To determine the PHIUS+ source energy target per square foot: Calculate the design occupancy as the number of bedrooms plus one (unit-by-unit), multiply by the source energy allowance per person, convert (3.412 kBTU = 1 kWh), and divide by the iCFA.

Example: 4-bedroom house, 2000sf iCFA

Source Energy Limit (PHIUS+ 2018): 3840 kWh/person.yr

(5 persons * 3840 kWh/person/yr * 3.412 kBTU/kWh)/2000 ft^2 =

Source Energy Limit: 32.76 kBTU/ft^2.yr

3.3.7 Co-Generation

There are two ways to operate a combined-heat-and-power (CHP) unit – on electrical demand or on heating demand.

On the “E-priority” path, the CHP is run independently of the heating load, with the intent of producing electricity, and the heat production is a byproduct, which may or may not be usable.

On the “H-priority” path, the CHP is run to match the heating demand (hot water and/or space heat), and the electricity produced while the CHP operates is regarded as a byproduct, that is either used on site or sold to the grid.

The H-priority path in turn has two variants depending on whether the backup heat is supplied by electricity or fuel combustion. See Appendix A for more details. The calculation protocol is implemented in the PHIUS Co-Generation Source Energy Factor Calculator.

3.4 Moisture Design Criteria for Assemblies and Details

3.4.1 Minimum Interior Surface Temperature for Thermally-Bridged Construction Details

Sometimes, if a thermal bridge is significant enough, PHIUS may ask that an interior surface mold risk analysis be completed according to ISO 13788. The calculator can be downloaded from the Calculators and Protocols page on the PHIUS website.

One of the “hard requirements” for certification pertains to avoiding mold growth on interior surfaces caused by thermal bridges. Even if a thermal bridge is tolerable in terms its impact on the space conditioning loads and demands, it is not tolerable if it can lead to mold growth on the inside. The protocol follows ISO 13788, and one of our calculator tools follows its methods. Just as in calculating the *energy* impact of a thermal bridge, the detail is modeled in THERM. But instead of calculating the extra energy loss, the critical result is the point of lowest temperature on the inside surface, and the criterion is that at that point, the interior air, when chilled down to that temperature, should be at less than 80% relative humidity.

ISO 13788 addresses how to determine the appropriate boundary conditions – the outside temperature and the indoor relative humidity. This is based on consideration of the monthly average outside temperature and humidity for the climate. The outdoor humidity is added to an indoor source that depends on one of five building humidity classes from low to high.

For each month, a psychometric calculation is then done to determine a minimum inside surface temperature needed to keep the RH at the surface below 80%.

The critical month is the one in which that minimum surface temperature is farthest from the outside temperature and closest to the inside temperature, because that requires the detail to be the most “insulating.” This “surface temperature factor” (fRsi) of the building element is defined mathematically as:

$$\text{fRsi} = \frac{(Inside\ surface\ temp - Outside\ temp)}{(Inside\ temp - Outside\ temp)}$$

with a surface resistance at the inside surface of Rsi.

(Usually the critical month is also the coldest month - but not always. Depending on the climate it might be in October, for example.)

3.4.2 Window Condensation Resistance

ISO 13788 also addresses assessment of condensation on “low thermal inertia” elements such as windows and doors, using a similar procedure, but with some differences: instead of keeping the RH below 80%, the goal is to avoid outright condensation (RH=100%). This is because windows and doors have impermeable surfaces that aren’t as subject to mold, but vulnerable to rot and corrosion if outright wet. But it calls for a more sever outside design temperature - instead of a monthly average, the calculator uses for the ASHRAE 99% design temperature.

Currently, it is recommended to do a window condensation check when any of these risk factors are present:

- Window U-value significantly above the comfort requirement.
- Frame U-value significantly above the glass U-value.
- Presence of aluminum spacers.
- Low-e coating on the inside surface of the glass.

The current passing criterion is that:

1. 1-D calculations on the surface temperatures, OR

2. fRsi of the frame and the glass, OR
3. AAMA CRF rating

should meet the ISO 13788 minimums at the ASHRAE 99% design temperature for the climate, with some safety margin, or that a CSA I-value meets it without a safety margin.

Exception 1: Dog doors are not required to pass the condensation resistance test.

Exception 2: The whole door U-value may be used for the condensation risk assessment for exterior doors that are required to be ADA compliant, egress rated, fire rated, etc., instead of requiring that each of the individual elements pass (glazing and frame).

PHIUS has developed a Window Comfort & Condensation Risk Assessment Calculator to determine if a window is at risk of condensation.

Example: With an interior RH of 48% in the coldest month, the dew point of the interior air is 47.7 F, so the inside surface must be warmer than that.

The calculator does a one-dimensional calculation with the frame U-value, for example 0.28, to determine if this is the case. Instead of the lowest daily mean temperature, use (for convenience) the ASHRAE 99% design temperature. Suppose this is 13.8 F.

With an interior temperature of 68 F, and an inside film resistance of 0.74 h.ft^2.F/Btu, the inside surface temperature then is 68-(0.29*0.74)*(68-13.8) = 56.7 F, that is, 9 degrees above the dew point.

Of course, this does ignore the fact that the surface temperature could be lower right in the corner where the frame meets the glass, because of the conductivity of the spacer, but 9 F provides a comfortable margin. ISO 13788 does caution that one-dimensional calculations aren't generally good enough, but it is a place to start.

3.4.2.1 Other Condensation Resistance Ratings

We have been asked whether we can specify an NFRC Condensation Resistance rating (CR). The AAMA published a good summary paper (AAMA CRS-15) that explains the differences between NFRC's Condensation Resistance (CR), AAMA's Condensation Resistance Factor (CRF), and the Canadian temperature Index or I-value, per CSA A440.2. All of these are 0-100% higher-is-better ratings, but they are not directly comparable to each other. [19]

From that paper it is clear that the CRF and the I-value are similar to what ISO 13788 calls fRsi – ratios that indicate how far some critical inside surface temperature is towards the inside air temperature. Therefore, if that data is available for a window of interest, those ratings could be compared directly to the required fRsi from a 13788 calculation for "low thermal inertia elements" for an indication as to whether a window is good enough in the climate location of interest.

The AAMA white paper indicates that the I-value is generally more conservative/stringent than the CRF due to differences in the temperature sensor placements. Both of these are physical tests.

AAMA provides an online calculator that takes a given outdoor temperature, indoor temperature, and relative humidity, and computes the dew point and the required CRF, so it is making the same kind of calculation as called for in ISO 13788. (The disclaimer for it makes many valid points.) [20]

The NFRC Condensation Resistance rating is more complicated and harder to interpret, except as a relative ranking. It is basically the percentage of the window frame, glass, or edge-of-glass area (whichever is worst) that is below dew point under the standard test condition temperatures, averaged over interior RH levels of 30, 50, and 70%. It is based on modeling rather than a physical test.

3.4.3 Limiting Moisture Risk in Assemblies

3.4.3.1 Climate-Appropriate Wall and Roof Assemblies

It's important to avoid risks related to mold and moisture. Following the prescriptive guidelines in Appendix B will generally allow PHIUS to accept or "green light" an assembly in certification. Assemblies that do not comply are given a "yellow light". The next step is usually a request for revision of the assembly to follow the prescriptive guidelines. If revision is not possible or desired, next is a WUFI hygrothermal analysis. Sometimes a WUFI analysis will turn a yellow light green, but sometimes it will turn it red, in which case, we would require a letter from a qualified, licensed professional engineer, to the effect that the mold / moisture risk to the assembly is acceptably low.

- In general, we recommend against using wet spray cellulose.

3.4.3.2 Masonry Walls and Freeze-Thaw

Interior insulation retrofits of masonry walls in cold climates can cause durability problems. Please review the information in these articles: [21] [22] [23] Certification staff may require a "hold harmless" agreement.

3.4.3.3 Floor/Slab Components

Fluffy Floors

- Floors are subject to "bulk water events" from above, and have trouble drying out.
- Framed floors with fluffy insulation and rigid on the bottom are riskier than all-fluff or all-rigid.
- For fluffy floors without rigid on the bottom, over crawlspace or cantilevered over ambient conditions, hydrophobic insulation such as fiberglass or most preferably mineral wool, is preferable to cellulose (drain-down strategy instead of buffering.)
- Don't do: slab, with rigid on top, and then a framed floor with fluffy insulation on top of that. Such floors should be almost all rigid insulation with only a little fluffy insulation on top for sound deadening.

Framed Floors with Rigid and Fluffy Insulation

- Floors are preferably insulated with all rigid insulation, except for at most a thin layer of fluffy insulation near the inside for acoustic reasons.
- Not Certifiable: Mostly-fluffy floors directly on slabs, or with a thin layer of rigid on the bottom and slab or ground directly below. The risk of never drying out from a bulk water event is too high - repair would be very expensive, could entail removal of interior walls.
- Certifiable: Partly fluffy floors over crawlspace, over unheated basement, or cantilevered above ambient conditions with 50% or more insulation value from rigid on the bottom. The

floor structure is protected from humid conditions below, is accessible from below for repair in the event of water from above, and the cold side of the fluffy insulation stays warm enough to be out of trouble with mold under normal conditions.

- Conditionally Certifiable: Partly-fluffy floors over crawlspace or unheated basement with less than 50% insulation value from outboard rigid, are acceptable if WUFI Bio analysis, assuming outside climate without rain or sun (stress case for cold-season moisture accumulation), shows green light at the outboard side of the fluffy insulation in the years after the initial dry-out.

3.5 Quality-Related Prescriptive Design Requirements (QA/QC Checklist Items for CPHC/Designer)

Most of the items included in the PHIUS+ Single Family Quality Assurance Workbook are the responsibility of the builder, but there are some items that concern the designer as well. Those items are collected in this section for emphasis, along with some other prescribed items. Please refer to the Workbook linked to above for additional information and adhere to these guidelines. If there are any inconsistencies with what appears in the Workbook and this Guidebook, please bring these to our attention.

The requirements below are listed according to section headings and numbering in the quality assurance workbook – references to Sections below may be referring to external documents rather than the PHIUS+ Certification Guidebook.

3.5.1 Fireplaces

A passive house can have a woodstove, woodstove fireplace insert or sealed combustion gas fireplace vented to the outside, but the stove or fireplace box needs to be airtight. In an airtight house there is great danger of back drafting or for the fireplace/stove using the interior air for combustion. Therefore, the combustion intake air must be directly from the outdoors and independent of the interior air supply. Warning systems should be considered such as carbon monoxide detectors or depressurization sensors. If the building gets depressurized for some reason (one of the ventilator fans fails and the defect goes unnoticed) then, despite of all the precaution of airtight fire box and dedicated combustion air, back drafting could still occur and draw potentially life-threatening gases into the interior of the building.

Open and/or unvented fireplaces are prohibited in PHIUS+ projects. Per EPA Indoor airPLUS, this also applies to ethanol fireplaces.

Fireplace Disclaimer: The use of a fireplace/woodstove in a home can be dangerous due to the risk of carbon monoxide poisoning. The fireplace/woodstove specified for this home must be completely airtight to the room air. Combustion air must be provided by a dedicated pipe connecting to the outside. If smoke is seen to be leaking from the stove into the living area, immediately open all the windows, and discontinue using the stove. DO NOT LEAVE A FIRE BURNING UNATTENDED especially when going to sleep at night. Carbon monoxide detectors should be installed in locations so that they can be heard throughout the house. The Passive House Institute US|PHIUS or any of its employees are not responsible for any damage, injury or death caused.

3.5.2 Building Envelope

3.1a: Air Barrier Integrity: Air barrier is contiguous, including behind stairs, porch roofs, fireplaces, showers/tubs, attic knee walls, walls/ceilings adjacent to vented attics, and floors over unconditioned basements and vented crawlspaces. See ENERGY STAR Rater Field Checklist Section 2 for further details and criteria.

3.1b: Air Sealing: All penetrations (wire/pipe/HVAC/etc.) between conditioned and unconditioned space sealed, service chases capped at exterior, exterior/doors to garages weather-stripped, rough opening of doors/windows sealed, multifamily drywall shaft walls sealed at exterior, recessed lights ICAT and gasketed, etc. See ENERGY STAR Rater Field Checklist Section 4 for further details and criteria.

3.2: Insulation Quality Check: All insulated assemblies have achieved a RESNET Grade I cavity insulation level, or alternatively GII with continuous insulation. Per ES 1.3. Please see RESNET Standards Appendix A for information on insulation Grading.

3.3: Window Performance: Windows are ENERGY STAR certified, and/or triple-glazed with thermally broken frames/spacers, and meets project the design specs.

Per DOE ZERH footnote 13: Fenestration shall meet the applicable ENERGY STAR Windows Eligibility Criteria for U and SHGC, with the following exceptions:

a. An area-weighted average of fenestration products shall be permitted to satisfy the U-factor requirements;
b. An area-weighted average of fenestration products ≥ 50% glazed shall be permitted to satisfy the SHGC requirements;
c. 15 square feet of glazed fenestration per dwelling unit shall be exempt from the U-factor and SHGC requirements, and shall be excluded from area-weighted averages calculated using a) and b), above;
d. One side-hinged opaque door assembly up to 24 square feet in area shall be exempt from the U-factor requirements and shall be excluded from area-weighted averages calculated using a) and b), above;
e. Fenestration utilized as part of a passive solar design shall be exempt from the U-factor and SHGC requirements and shall be excluded from area-weighted averages calculated using a) and b), above. Exempt windows shall be facing within 45 degrees of true South and directly coupled to thermal storage mass that has a heat capacity > 20 btu / ft3x◦F and provided in a ratio of at least 3 sq. ft. per sq. ft. of South facing fenestration. Generally, thermal mass materials will be at least 2 in. thick.

3.4: Vented Attic Reduced Thermal Bridging: Vent baffles installed in bays with soffit vents to prevent wind-washing; Insulation over top plates and under attic walkways/platforms ≥ R-21in CZ 1-5; ≥ R-30in CZ 6-8

3.5: Slab Edge Insulation: For slabs on-grade in CZ 4-8, 100% of slab edge insulated to ≥ R-5 at the depth specified by the 2009 IECC

Per ENERGY STAR Rev 09 Rater Checklist footnotes 14 & 15:

a. Consistent with the 2009 IECC, slab edge insulation is only required for slab-on-grade floors with a floor surface less than 12 inches below grade. Slab insulation shall extend to the top of the slab to provide a complete thermal break. If the top edge of the insulation is installed between the exterior wall and the edge of the interior slab, it shall be permitted to be cut at a 45-degree angle away from the exterior wall. Alternatively, the thermal break is permitted to be created using ≥ R-3 rigid insulation on top of an existing slab (e.g., in a home undergoing a gut rehabilitation). In such cases, up to 10% of the slab surface is permitted to not be insulated (e.g., for sleepers, for sill plates). Insulation installed on top of slab shall be covered by a durable floor surface (e.g., hardwood, tile, carpet).
b. Where an insulated wall separates a garage, patio, porch, or other unconditioned space from the conditioned space of the house, slab insulation shall also be installed at this interface to provide a thermal break between the conditioned and unconditioned slab. Where specific details cannot meet this requirement, partners shall provide the detail to EPA to request an exemption prior to the home's certification. EPA will compile exempted details and work with industry to develop feasible details for use in future revisions to the program. A list of currently exempted details is available at: energystar.gov/slab edge.

3.6: Above-Grade Wall Reduced Thermal Bridging: AGWs achieve at least one of the strategies for Reduced Thermal Bridging listed in Section 3.4 of the ENERGY STAR Rater Field Checklist (Rev 09)

- Most PHIUS+ Projects will easily meet this requirement. Where any doubt or question exists about the strategy to meet this requirement, see the ENERGY STAR Rater Field Checklist (Rev 09) footnotes relating to section 3.4.

3.7: Other Thermal Bridging/mitigation strategy identification: Note any other meaningful thermal bridges observed on the project, as well as thermal bridging mitigation strategy identification. Special effort should be made to clearly document such bridging and mitigation strategies, or where such details are missed.

- PHIUS+ Rater shall discuss the presence of known thermal bridges with CPHC prior to inspection, as well as specific mitigation strategies.

Any significant bridging observed on a project not accounted for by the CPHC must be brought to the attention of PHIUS immediately.

3.5.3 Ventilation

3.5.3.1 Fresh Air Supply

- Fresh air (OA) supply to bedrooms is **required**:
  - Provision must be made to supply fresh air to all bedrooms in dwelling units.
  - Dedicated ventilation ductwork is best practice.
  - In the case of ventilation ductwork integrated with heating/cooling ducts, ERV should remain in balance under all fan speeds of the heating/cooling air handler, and said air handler fan must be designed to run continuously by default.

3.5.3.2 Ventilator Defrost

A pre-heater defrost (or ground loop pre-heater) is required for ERVs where the ASHRAE 99.6% design temperature is below the manufacturer's claimed minimum operating temperature, rather than relying on re-circulation defrost.

- If the unit can maintain the required fresh air ventilation rates with the unit in partial re-circulation mode, then this is acceptable. So basically, the unit needs to have enough boost to maintain the same typical fresh air ventilation rate as it would at higher temperatures.
- The ASHRAE 62.2-2010 Table 4.2 effectiveness factor calculation should be used to determine the required boosted intermittent rate, in the case that the cycle time is more than 3 hours.
  - See this article: https://homes.lbl.gov/ventilate-right/intermittent-ventilation-run-cycles

$$\text{Intermittent fan flow rate} = \frac{continuous\ fan\ flow\ rate}{(effectiveness\ factor\ \varepsilon)\ x\ \ (fractional\ on{-}time\ f)}$$

where:

continuous fan flow rate = **Required whole-building ventilation rate** for the house or apartment if the system was operated continuously

f = **Fractional on-time** for whole-building ventilation, or the percentage of time the whole-building ventilation equipment will operate in one duty cycle (the length of one complete on/off cycle).

ε = Ventilation Effectiveness for Intermittent Fans from Table 4.2 in ASHRAE Standard 62.2. **Note**: Table 4.2 is different in ASHRAE 62.2-2007 and ASHRAE 62.2-2010.

3.5.3.3 Balanced Ventilation Requirements

A whole-building mechanical ventilation system is required to be installed.

The system shall have at least one supply or exhaust fan with associated ducts and controls. Local exhaust fans can be part of a whole-house ventilation system.

In the Energy Star framework, the ventilation system type is characterized as either "Supply", "Exhaust", or "Balanced".

For PHIUS certification, regardless of type, the ventilation system must meet one of the following requirements for balance:

1. Total measured supply and exhaust airflows are within 10% of each other. (Use the higher number as the basis of the percentage difference.)
2. The total net pressurization or depressurization from the un-balanced ventilation system does not exceed 5 Pa. The net pressurization/depressurization that the ventilation system imbalance causes on the building is determined using the multi-point air-tightness test results graph.

<u>In the case of "Supply" or "Exhaust" systems:</u>

A ventilation system design with supply fans only or exhaust fans only will generally require dedicated openings in the envelope (with dampers) for make-up air in order to meet the balance requirements, because of the air-tightness requirement on the building overall. Such make-up air inlets or outlets must appear in the design documentation for pre-certification.

<u>In the case of "Balanced" systems with heat or energy recovery devices</u>:

If the exhaust or supply air flow exceeds the exhaust air flow by more than 10%, the associated additional infiltration or exfiltration must be accounted for. It will be assumed that this unconditioned airflow will be continuous at the same rate as the difference between the supply and exhaust air flows.

In WUFI Passive, this should be added under 'Ventilation Rooms>Exhaust Ventilation' as an 'other exhaust appliance' running for 525,600 minutes/year.

- It is recommended that the ventilation system is capable of at least 0.3 ACH (based on the net volume) at its maximum setting. It is not required.

1.3a: All ventilation air inlets located at least 10' ("stretched-string distance") from known contamination sources.

- Examples of contamination sources include: plumbing vents, bath/kitchen exhaust vents, combustion exhaust, vehicle exhaust. Exception: ventilation air inlets in the wall at least 3 ft. from clothes dryer exhaust or contamination sources exiting through the roof.
- Please note that ERV/HRV exhaust is not necessarily a "contaminant". Thus it is not subject to this provision. However, exhaust/intake separation shall meet manufacturer specifications.

1.3b: All ventilation air inlets located minimum 5' from ventilation exhaust outlet, recommended 10'.

1.4: Ventilation air inlets are at least 2' above grade and/or roof deck, and are not obstructed by snow, plantings, outdoor equipment, etc. at the time of inspection.

- Care should be taken by projects to position fresh air inlets additional appropriate distance above grade or roof deck where snow loads or plantings may be a greater concern

1.5: Ventilation air comes directly from outdoors, not from adjacent dwelling units, common spaces, garages, crawlspaces or attics.

1.6: Outside air passes through a minimum MERV 8 filter prior to distribution, is changed at final and home is ventilated prior to occupancy.

1.7: Outside air filter is located to facilitate regular service by the occupant and/or building superintendent

1.8: Air-sealed, class 1 vapor retarder shall be installed over all air-permeable insulation (such as fiberglass duct wrap) on ventilation ducts connected to outside

1.9: Bedrooms are pressure balanced to achieve a Rater-measured pressure difference of no more than 1Pa with respect to the main body of the house/apartment when all bedroom doors are closed and just the ventilation system is operating at 24/7 design speed

1.10: Fresh air supply to all bedrooms. Example, supply to living room only, in a one-bedroom apt, is not acceptable.

1.11: Rater-measured bathroom exhaust rates meets one of the following: >=20cfm continuous or 50 cfm intermittent

1.12: Direct exhaust bath fans ENERGY STAR rated; <= 1 sone

1.13: Rater-measured kitchen exhaust rates meets one of the following: >=25cfm continuous, 100cfm intermittent for range hoods, or 5ACH based on kitchen volume

1.14: If kitchen exhaust connected to ERV/HRV, register is min. 6' from cooktop and MERV 3 or washable mesh filter for trapping grease, and recirculation hood over range.

1.15: Clothes dryer is a condensing/heat pump dryer, or exhaust dryer with exhaust ducted to the outside.

HRV Filtering

A minimum of MERV 8 filtration is required for all ventilation systems, as well as ducted heating/cooling systems. MERV 12 or higher is recommended for filtration of the ventilation air.

3.5.4 Heating, Cooling & Domestic Hot Water

See Appendix C for ASHRAE-55 based evaluation of when a cooling system is recommended.

Heating/Cooling Distribution – Ducted systems only

> **2.4:** All return air passes through a min. MERV 8 filter which is located to facilitate regular service by the occupant and/or building superintendent
>
> **2.6:** Equipment selected to keep relative humidity < 60% in "Warm-Humid" climates OR install additional dehumidification. Exception: Climate Zones 4-8 3B, 3C and the portions of 3A and 2B above the white line as shown by IECC Figure 3012009
>
> **2.7:** Bedrooms are pressure balanced to achieve a Rater-measured pressure difference of no more than 3Pa with respect to the main body of the house when all bedroom doors are

closed, all heating/cooling air handlers are operating at full speed and ventilation system is operating at design speed

2.8: Ducts and air handlers located entirely within building thermal envelope

Combustion Safety and Condensation Management

4.1: Combustion heating/water heating systems located within the buildings' pressure boundary are sealed combustion, direct-vent appliances

4.2: Natural draft fireplaces are not installed

4.3: Installed fireplaces and woodstoves have a combustion air inlet connected to the firebox

4.4: No unvented combustion fireplaces installed in home

Domestic Hot Water Systems

6.4: Continuous, time, or temperature-based hot water recirculation systems not installed.

6.5: Hot water temperature-rise test.

For more information, see the EPA Watersense Guide for Efficient Hot Water Delivery Systems. [25] Download the associated design-aid calculator here.

WUFI Passive hot water distribution entries also support this calculation.

3.5.5 Lights, Appliances, & Renewables

Lighting

1.1: 80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 80% of sockets

Renewable Energy Systems

Note: PHIUS has moved to requiring homes to be solar PV-ready regardless of average daily solar radiation (kWh/m2/day). PHIUS+ projects are **not** exempt even if daily average solar radiation for the site is less than 5 kWh/m2/day. This rule is in effect as of April 2016.

4.3: If solar photovoltaic (PV) system not installed, document home's compliance with the DOE ZERH Home PV-ready checklist:

4.3B: Home has adequate roof area within +/-45° of true south based on table below

CFA	Min roof area within +/-45° of true south
<= 2000	110 sqft
<= 4000	220 sqft
<= 6000	330 sqft
>6000	440 sqft

4.4: If either of the above is false, the home is not required to meet the following requirements:

> **4.4A:** Provide code-compliant documentation of the maximum allowable dead load and live load ratings of the existing roof; recommended: allowable dead load rating can support an additional 6 lbs/sq. ft. for future solar system.
>
> **4.4C:** Install a 1″ metal conduit for the DC wire run from the designated array location to the designated inverter location (cap and label both ends)
>
> **4.4D:** Install a 1″ metal conduit from designated inverter location to electrical service panel (cap and label both ends)
>
> **4.4E:** Install and label a 4′ x 4′ plywood panel (or alternatively blocking) area for mounting an inverter and balance of system components.
>
> **4.4F:** Install a 70-amp dual pole circuit breaker in the electrical service panel for use by the PV system (label the service panel)

3.5.6 Water Management and Indoor Air Quality

Water/Moisture Managed Site/Foundation

1.1: Patio/porch slabs/walks/driveways sloped ≥ 0.25"/ft from home to edge of surface or 10 ft; back-fill tamped and graded ≥ 0.5"/ft from home for 10'. See footnote 2 of the ENERGY STAR Water Management System Builder Requirements Rev. 09

1.2: Layer of aggregate or sand (4 in.) with geotextile matting & capillary break beneath all slabs using either: ≥ 6 mil polyethylene sheeting, lapped 6-12 in., or ≥ 1 in. extruded polystyrene insulation with taped joints. Exceptions to the aggregate OR sand requirement: (Not applicable in EPA Radon Zone 1)

- Dry climates, as defined by 2009 IECC Figure 301.1. (Also exempt from capillary break requirement)
- Areas with free-draining soils – identified as Group 1 (Table R405.1, 2009 IRC) by a certified hydrologist, soil scientist, or engineer through a site visit.
- Slab-on-grade foundations

1.3: Basements/crawlspaces insulated, sealed, dampproofed and conditioned. Exceptions:

- Homes built in areas designated as flood zones (conditioned crawlspaces not recommended for use in flood zones).
- Raised pier foundations with no walls.
- Dry climates, as defined by 2009 IECC Figure 301.1.
- Marine climates, as defined by 2009 IECC Figure 301.1, if no air handler or return ducts are installed in the crawlspace

1.4: Class 1 vapor retarder not installed on interior side of air permeable insulation in exterior below-grade walls. See footnote 7 of ENERGY STAR Water Management requirements

1.5: Drain or sump pump installed in basements and crawlspaces; sump pump covers mechanically attached with full gasket seal or equivalent. See item 1.1 of IAP specs

1.6: Drain tile installed at basement/crawlspace walls, with the top of the drain tile pipe below the bottom of the concrete slab or crawlspace floor. See footnote 8 of ENERGY STAR Water Management requirements

Water Managed Walls/Roofs

2.1: Flashing at bottom of exterior walls with weep holes included for masonry veneer and weep screed for stucco cladding systems or equivalent system

2.2: Fully sealed continuous drainage plane behind exterior cladding that laps over flashing in Item 2.1 and fully sealed at all penetrations. Additional bond-break drainage plane layer provided behind all stucco and non-structural masonry cladding wall assemblies.

- See footnote 9 & 10 of ENERGY STAR Water Management requirements

2.3: Window and door openings fully flashed. Apply pan flashing over the rough sill framing, inclusive of the corners of the sill framing; side flashing that extends over pan flashing; and top flashing that extends over side flashing or equivalent details for structural masonry walls.

2.4: Step and kick-out flashing at all roof-wall intersections, extending ≥ 4" on wall surface above roof deck and integrated shingle-style with drainage plane above; boot / collar flashing at all roof penetrations." Intersecting wall siding shall terminate 1 in. above the roof or higher, per manf. recommendations. Continuous flashing shall be installed in place of step flashing for metal and rubber membrane roofs.

2.5: Non-slab on-grade homes shall have gutters/downspouts with discharge on sloping final grade ≥ 5 ft. from foundation. See footnotes and additional details from ENERGY STAR and IAP for other circumstances. See item 1.7 of IAP specs and footnotes 3, 13 & 14 from ENERGY STAR Water Management requirements

2.6: Self-adhering polymer-modified bituminous membrane at all valleys & roof deck penetrations AND in CZ 5+, over sheathing at eaves from the edge of the roof line to > 2 ft. up roof deck from the interior plane of the exterior wall. See footnote 3 & 15 of ENERGY STAR Water Management requirements

2.7: Piping in exterior walls insulated with pipe wrap.

Water Managed and Low-Emitting Building Materials

3.1: Hard-surface flooring in kitchens, baths, entry, laundry and utility rooms AND carpet not installed within 2.5 ft. of toilets, tubs, and showers.

3.2: Cement board or equivalent moisture-resistant backing material installed on all walls behind tub and shower enclosures composed of tile or panel assemblies with caulked joints. Paper-faced backerboard shall not be used. See footnote 16 of ENERGY STAR Water Management requirements.

3.3: In Warm-Humid climates, Class 1 vapor retarders not installed on the interior side of air permeable insulation in above-grade walls. Except at shower and tub walls. See footnote 7 of ENERGY STAR Water Management Requirements.

3.4: Materials w/ visible signs of water damage/mold not installed; framing members/insulation products w/ high moisture content not enclosed. See footnotes 17 &18 of ENERGY STAR Water Management Requirements

3.5: All composite wood products, interior paints/finishes, carpet/carpet adhesive/padding certified low-emission. See IAP construction specs for Section 6.

Radon, Pest & Combustion Pollutant Mitigation

4.1: Radon-resistant features installed in Radon Zone 1 homes in accordance with IAP Construction Specification 2.1.

> *Passive radon systems are highly recommended in Radon Zones 2 & 3.
>
> See EPA Consumers Guide to Radon Reduction for more details.

4.2: Corrosion-proof rodent/bird screens installed at all openings that cannot be fully sealed (Exception: dryer vents)

4.3: Emissions standards met for fuel-burning and space-heating appliances; CO alarms installed in each sleeping zone (e.g., common hallway) according to NFPA 720. Except at shower and tub walls. See footnote 7 of ENERGY STAR Water Management Requirements.

4.4: Multifamily buildings: Smoking restrictions implemented AND ETS transfer pathways minimized. See item 1.7 of IAP specs and footnotes 3, 13 & 14 from ENERGY STAR Water Management requirements.

4.5: Attached garages: Door closer installed on all connecting doors AND in homes with exhaust-only whole-house ventilation EITHER a 70cfm exhaust fan installed in garage OR a pressure test conducted to verify the effectiveness of the garage-to-house air barrier. See IAP spec for details.

3.6 Quality Assurance Requirements and Rater/Verifier Information

3.6.1 Residential

PHIUS+ uses the EPA ENERGY STAR New Homes (ESTAR), DOE Zero Energy Ready Home (ZERH), and EPA Indoor airPLUS (IAP) programs as prerequisites for all single-family projects, and other eligible residential projects.

The PHIUS+ Single Family Quality Assurance Workbook incorporates all of the checklist items into a single document. The single-family workbook shall be used for all PHIUS+ projects encompassing single family homes and small attached residential developments (duplexes, townhomes, etc).

All of the checklists, site visits, and tests are managed by the PHIUS+ Rater/Verifier. The PHIUS+ Rater also handles the actual submissions for EPA ENERGY STAR,DOE Zero Energy Ready Home, and EPA Indoor airPLUS certifications.

For multifamily projects, the PHIUS+ Multifamily Checklist should be used. See Section 1.5.2 for definition of multifamily. Multifamily projects that meet the eligibility criteria for the EPA ENERGY STAR New Homes (ESTAR) or EPA ENERGY STAR Multifamily New Construction Program (MFNC) and DOE Zero Energy Ready Homes (ZERH) programs shall be certified under those programs. Projects that do not meet eligibility criteria for certification under these programs shall be exempt from certification for both ESTAR and ZERH. However, the certification checklist criteria for these programs shall still be achieved in order to help ensure that multifamily projects seeking PHIUS+ Certification are not only energy efficient, but also a durable, comfortable and healthy buildings.

The EPA has released the EPA ENERGY STAR Multifamily New Construction Program (ES MFNC) which includes all multifamily buildings with more than 2 units, and less than 50% commercial space. Until January 1, 2021, PHIUS will support two paths for PHIUS+ Multifamily Quality Assurance, with requirements outlined in two separate workbooks:

- Version 2.2: Supports EPA ENERGY STAR for Homes
- Version 2.3: Supports EPA ENERGY STAR Multifamily New Construction (MFNC) Program

Projects with a permit date after January 1, 2021 will be required by EPA to follow v2.3, EPA ENERGY STAR Multifamily New Construction Program (ES MFNC).

Note: PHIUS tracks program version requirements by project contract date. PHIUS does not track project permit dates and is not responsible for a project team's selection of the QA program version above. Teams must select the appropriate program version based on expected permit date. Even if a PHIUS contract date is before January 1, 2021, if the permit date will be after that, version 2.3 must be followed.

For full program requirements, please see Appendix G: PHIUS+ Certification for Multifamily Performance Requirements (v2.2).

Download the PHIUS+ Multifamily Quality Assurance Workbooks.

3.6.1.1 Residential Exceptions

Generally, the only cases where an eligible residential PHIUS+ project may **not** earn ESTAR or DOE ZERH certifications* are:

1. Some retrofits, gut rehabilitations, partial renovations, or unforeseen circumstances that may arise
   *In such cases, a written submission should be sent to PHIUS for review during pre-certification.
2. Projects in California and Alaska
   *While earning the actual certification is not required, the project must meet all certification criteria.

3. Projects in Canada / International Projects

3.6.2 Non-Residential

Non-Residential commissioning protocol is currently under development. General concepts below – details are still being worked out.

The initial scope of requirements for commissioning of nonresidential buildings is focused on energy use impacts.

- 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.

The process will be comprehensive of USGBC's LEED requirements for basic level commissioning to support dual certification.

Provider requirements:

- Two projects experience, or
- Certification from CPMP, BCxP, ACG.

Commissioning procedures follow either:

- ASHRAE Standard 202 ‐ 2013
- NEBB Procedural Standards for Whole Building Systems Commissioning for New Construction

3.6.3 PHIUS+ Rater/Verifier Manual

Full document can be found in Appendix E, below.

The manual contains:

1. Description of PHIUS+ Rater/PHIUS+ Verifier
2. Certification Requirements & Maintenance
3. Pre-Construction Requirements
4. Technical Inspection and Field Requirements
5. Post-Construction Requirements

3.7 Hiring a PHIUS+ Rater/Verifier

We recommend contacting a PHIUS+ Rater/Verifier as soon as certification becomes a goal for the project, and incorporate them into the project team early on. PHIUS asks that you hire a Rater/Verifier when you submit a project contract to PHIUS at the start of Certification.

- Before pre-certification is awarded to a project, PHIUS requires a letter of intent from the PHIUS+ Rater on the project, stating they have been hired to complete the on-site verification process.

PHIUS acknowledges that the addition of this component to our certification does raise fees. However, we also feel strongly that it helps create higher quality buildings.

PHIUS has not set a fee structure for the PHIUS+ Raters/Verifiers to charge for their services. For a single family home, expect 20 hours of work at the PHIUS+ Rater/Verifier's hourly rate (typically $75-$125 per hour depending on market). This does assume a relatively straightforward process. Significant problems could result in more time needed, but simple homes may expect less time for completion.

Be aware that travel can significantly affect the quote the project team receives from a PHIUS+ Rater/Verifier.

Find a PHIUS+ Rater

Find a PHIUS+ Verifier

3.7.1 Non-certified Inspectors

See Appendix E Section 2.3 below.

3.7.2 Typical Site Visits for the Rater/Verifier:

1. Sub-slab insulation check.
2. Preliminary blower door test.
3. Insulation quality check.
4. Final blower door, ventilation commissioning, final Quality Assurance Workbook.

Coordination of the site visits and design review by the PHIUS+ Rater/Verifier should occur between the Rater/Verifier and the project team. The number of site visits is up to the Rater/Verifier. If they are close by, we encourage them to see the slab insulation in person. However, they can choose just to collect photos. Preliminary blower door testing is, strictly speaking, optional, however, it is strongly encouraged.

3.8 Blower Door Instructions

Personnel:
The PHIUS+ Rater/Verifier will perform the blower door testing.

Building Preparation:
See Appendix F – ANSI/RESNET/ICC 380-2016: Procedure to Prepare the Building for Testing

Large building infiltration testing: Verifiers are encouraged to test the building as a whole, and if needed, to reach out to and attempt to contract a more experienced testing professional. PHIUS is open to alternative methods of testing, and is open to reviewing proposed work scopes from Verifiers.

The building should be prepared for the test in accordance with RESNET Mortgage Industry National Home Energy Rating Standards – Appendix A Section 9, Element: Air Leakage refer to ANSI Standard 380-2016.

- **PHIUS Variance**: Barometric/spring loaded dampers could be sealed for the direction of the test that they will be force-failed open by the test. Thus, fresh air intake dampers could be sealed during depressurization, while exhaust dampers could be sealed during pressurization. The idea here is that whatever small amount of damper gasket leakage will be captured in the opposite direct in which the damper is forced open so it is at least somewhat accounted for.

Test Method:
The blower door testing should be computer-controlled using automated testing software (such as "Tectite" from The Energy Conservatory or "Fantestic" from Retrotec).

The PHIUS+ Rater/Verifier will conduct multi-point testing in both pressurization and depressurization modes. The test method in the automated testing software should be set as "RESNET" or "ASTM E779". The final CFM50 for certification purposes is the average of the two results.

Note: It is important to route an additional pressure tap to the exterior for the reference pressure on channel B during the pressurization test. In some cases, when this is not done, the pressurization results are worse than the depressurization.

Documentation: The project team or PHIUS+ Rater/Verifier will submit PDF reports from the automated testing software documenting the test results.

3.9 Contractor Declaration

The intent of the Contractor Declaration is to have a written statement of proof that the as built building conforms to the provided documentation. This information will be verified through the site tests as performed by the PHIUS+ Rater/Verifier.

Here are some sample wordings:

I, _______________, as general contractor of the ________________ (project) located at ______________________ (address), confirm that the documents supplied to PHIUS on _____________ (date) are identical to the finished project.

Any discrepancies or changes are listed here: ________________________.

This declaration certifies that the ________________ (project) located at ______________________ (address), has been constructed according to the technical specifications in the ____________ energy model, which has been populated based on the drawings submitted on _______________ (date).

There are no deviances from the file or any of the supporting documentations that have previously been submitted to PHIUS.

These declarations should be placed on an official letterhead and signed by the construction supervisor or general contractor. These wordings can be adjusted, but these are good examples to start from.

3.10 Optional Additional Certification Badges

Additional recognition will be given to project designs that meet the regular requirements and also achieve any of the following performance goals:

3.10.1 Supply Air Heating and Cooling Sufficient

The design allows for adequate delivery of heating and cooling via ventilation supply air only per WUFI Passive static calculation, with average design ventilation rate no more 0.4 ACH. This is accomplished with low peak load design.
The 'Passive House Verification' Report in WUFI Passive can verify compliance with this add-on badge.

3.11 Window Comfort Requirements

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 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.

PHIUS Window Comfort & Condensation Risk Assessment

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

Maximum temperature difference ($\Delta \boldsymbol{T}$) =

$\mathbf{6.0}$ °F for double-height spaces;

$\mathbf{14.7}$°F $- (\mathbf{0.742}\ \boldsymbol{x}\ \boldsymbol{HHS(ft)})$ for window head-height-from-sill HHS of 10 feet or less,

or $\mathbf{13.3}$°F, whichever is less;

where the whole-window U is calculated as:

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

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

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

$$\boldsymbol{T_{air,inside}} = 68\text{°F}$$

$$\boldsymbol{T_d} = ASHRAE\ 99\%\ Design\ Temperature\ \text{°F (ASHRAE Fundamentals 2017)}$$

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.

3.12 Program Version Eligibility

The date that the PHIUS+ Certification Contract was executed determines the program versions required for that project. Generally, projects can voluntarily choose to comply with a newer version than required by contract date.

Please see the Program Version Dates page for the matrix of program version effective dates.

4. Process

4.0.1 Pre-Process Paperwork

- Review this Guidebook, which summarizes all requirements, covers energy modeling protocol, and includes vapor control recommendations and other technical details.
- Visit the Submitting a Project for Certification page on the PHIUS website to find a step-by-step outline of the certification process.
- Contract: Review and sign the PHIUS+ Certification Contract.
    - This contract must be requested using the form in Step 1 of the 'Submitting a Project' page linked above.
    - Email executed contract to certification@passivehouse.us.
- Payment: Make online payment via PayPal or request invoice for payment by check.

4.0.2 Create a Project

- Log on to the PHIUS+ Certified Projects Database.
- If necessary, PHIUS will create account or give access to submit projects.
    - For CPHCs, this should not be necessary.
- Create a project by adding at minimum a project name and location. Other information can be added at a later time.
- Once a project is created, PHIUS certifiers will be informed by the database. At this time, PHIUS will create a DropBox folder for the project, and invite the Submitter to the folder. The Submitter may invite other members of the project team.
- **When all documents have been prepared, uploaded to the DropBox, and the project is ready for review, the team must use the form on the Project Certification Review Queue page to add the project into the queue.**
- The project will be added into the PHIUS+ review queue as of the forms' submit date. This is a manual process, so please allow one business day before the project status is updated on the public queue.
    - Email notifications will be re-directed to use the submission form.
    - We recommend to keep a record of your submissions.
- The project review will not begin until the contract and payment are both received.

4.0.3 Quality Assurance and Quality Control (QA/QC)

- The QA/QC components of PHIUS+ Certification performed by PHIUS+ Raters/Verifiers are an essential part of the PHIUS+ process.
- That PHIUS+ component is covered under a separate contract between the project team and the Rater/Verifier.
- Before pre-certification is awarded to a project, PHIUS requires a letter of intent from the PHIUS+ Rater/Verifier on the project, stating they have been hired to complete the on-site verification process.

- PHIUS encourages project CPHCs to clearly communicate the following to the Rater/ Verifier as early as possible so that on-site verification can be performed as efficiently and effectively as possible:
    - Foundation condition and insulation strategy.
    - Primary whole-building air barrier/infiltration control strategy.
    - Intended insulation materials, installed thicknesses and R-values for all building enclosure assemblies.
    - HVAC and hot water system strategies, equipment and design drawings.
    - Intended labeled window performance values.
    - Known project thermal bridges and associated mitigation strategies/products.
    - Window install and sealing strategies.
    - Window shading strategies, including adjacent site shading, overhangs and/or external movable shading.
    - Intended tested whole-building infiltration values, including intended mid-construction infiltration testing values.
- For more information about the PHIUS+ Rater/Verifier process, see Section 3.6, 3.7, and 3.8.

4.0.4 Incentives

Updated local and national incentives can be found on PHIUS' Incentives webpage.

- With the addition of a QA/QC process, PHIUS+ projects are now able to gain more performance-based incentives.
- Since 2013, PHIUS has partnered with the DOE's Zero Energy Ready Home program as well as ENERGY STAR for Homes. These programs are pre-requisites for PHIUS+ Certification. Your PHIUS+ Rater/Verifier will complete documentation for all of these programs during their on-site visits, and the project will be awarded recognition from all three.
- Most projects will automatically receive a RESNET HERS Index score as part of certification. The RESNET HERS Index is the leading industry standard by which a home's energy efficiency is measured. Many local, state, and federal financial incentive programs require a HERS Index to demonstrate compliance.

4.0.5 PHIUS+ Certification (Final Stages)

- The PHIUS+ Rater/Verifier must upload all on-site documentation to the project DropBox.
- The CPHC should update the WUFI Passive energy model to match any known as-built changes as well as final test results. All changes should be tracked in the PHIUS+ Feedback form used during pre-certification.
- Once ready, submit the project for final review using the form on the Project Certification Review Queue page.

- PHIUS' QA Manager will review the submission and provide feedback requesting further documentation, or comments for clarification.
- If not adjusted by the CPHC, before final certification is awarded, PHIUS adjust the final WUFI Passive energy model to match the verified results for:
    - Air-tightness test results
    - Average continuous ventilation rate
    - Measured ventilation fan wattage
- Project team to upload final drawings, documents, pictures, etc. to the DropBox.
- Once all documentation is reviewed and approved, PHIUS issues a formal email notification and mail (3) copies of the PHIUS+ Certified Project Certificate to the CPHC.
- Purchase PHIUS+ Certified Project Plaque
    - One included per project, additional available for purchase for $75
    - If a project qualifies for PHIUS+ Source Zero, an additional plaque is available for purchase for $75.

4.1 General Tips During the Process

- When uploading new information, please also update the feedback form, so that we know what has changed. The feedback form is the primary communication channel. It covers all the bases, that is, it serves also as a checklist. It is a written record and keeps everything in one place to keep track of what was said by whom and when on each point.
- Communication by phone or email can be used from time to time, but these outside discussions should be captured in the feedback form.
- Likewise, when uploading new feedback, please give it a final run through to make sure that if you refer to new information, that those documents are in fact uploaded to the DropBox - and, that the noted adjustments to the energy model were implemented.
- Include dates in the file naming conventions, and name the files in a logical manner (i.e. v1, v2, etc.). Please also avoid uploading a file that was arbitrarily assigned a file name that is un-readable/non-descriptive of the file content. Rename files when necessary before uploading.
    - Ex: original file downloaded from online, file name 'k35fd8463yfh.pdf'. Rename to 'Dishwasher ES Rating.pdf'

From time to time we may ask for changes to the energy model even if it looks like the change will probably have a small impact, or in cases where there are two mistakes but net result is a wash. There are two reasons for this: one is educational—on the next project it may make more of a difference and we don't want people to repeat mistakes. The other is to improve the chances that the model will match actual energy use if the comparison is ever made.

4.1.1 Review Timeline

Generally, projects can expect the follow review timeframes:

Pre-Certification

- Round 1: 6-8 weeks
- Round 2: 4-6 weeks

- Round 3: 2-4 weeks

Final Certification

- First Full Review: 2-4 weeks
- Revision Review: 2-4 weeks

The overall certification process timeline is highly variable, and depends on the response time from both the reviewer and the submitter. It also depends on the completeness and accuracy of the first submission.

An expedited review path may be available for an additional fee (See Section 5). The expedited path provides each round of review in 5 business days, rather than the timeline listed above. Whether or not this option is available is up to the discretion of PHIUS and the volume of expedited reviews in the certification queue at the time of submission.

4.2 PHIUS+ Project Database Access

Go to the PHIUS+ Certified Projects Database

The **login link** is located at the top right of the page.

A current PHIUS CPHC can simply log into their CPHC database account. To create a new a project, click on the "New Project" button and following the instructions in Section 4.3.

4.2.1 Logging in

If you have any questions about logging into your account, contact certification@passivehouse.us.

If you are not currently a CPHC, please request login information to log into the system as a Project Submitter. This will be created once the certification fee is paid and the certification contract is signed. Once in the system, a Submitter can fill in project information to the PHIUS Projects Database.

4.3 Database/DropBox Instructions and Tips

Creating a New Project in the Database

To begin a new project, log into the system then:

Click the “New project” button near the top of the page. A comprehensive form of project detail fields will appear.

***Note**: Most of these fields will be completed later in the process, and many cannot be completed until the project proceeds. (Once the project is ultimately pre-certified or certified, many of these fields will be viewable to the public.)*

To create a new project in the PHIUS Project Database, you initially need only complete the following fields:

- Project Name (e.g. Dublin Project)
- Project Location

Click the “Add Project” button.

*If the information is available, we prefer that you also select the "building function" and then input the floor area and number of units.

After your project is created, PHIUS will create a DropBox folder for the project, and invite the Submitter to the folder. The Submitter may invite other members of the project team.

A few important notes:

- We strongly encourage you to click the "Add Project" button as soon as you have added the key pieces of project information listed above. That creates the record and puts the project in the system.
- **The database "times out" often, so if you are inputting the project details, be sure to save often or the information will be lost.**
- Uploading can take some time depending on the size of your file(s). **Do not click** "Add project" again or attempt to make any changes during the upload. Doing so can create duplicate projects, in which case you'll need to email certification@passivehouse.us so that we can delete duplicates.
- Upon successful upload, you will see a screen that indicates the project has been created.
- Important: To review or edit your project, click the "Edit" button at the end (right side) of the project listing. Do not use the "Back" button on your browser. In general, use the "Edit" button, or to return to the basic project listing, click "Projects" in the upper right of your screen.

As the project submitter you will be able to add to or modify the project until the project is marked as Certified by the PHIUS certifier.

Notes on Project Details Fields

- Projects that reach Pre-Certification status will be accessible by public search of the PHIUS+ Certification Database. Please note that not all information supplied for certification will be visible. In fact, only a subset of the Project Details fields will be listed, as well as photographs.
- The "Units" field in Project Details refers to the number of living quarters (not measurement units).
- Cost fields will only accept digits. Do not include commas or dollar signs.
- Once the project listing is public (pre-certified), it is highly recommended to fill out all details. This helps promote the project, and provides a resource to the passive building community.

4.4 Required Submission Documentation

Project Documentation:

For PHIUS to begin a Project Review, the following documents need to be added to the DropBox:

1. Energy Model

2. Drawings

For PHIUS to pre-certify a project, the following documents must be added to the DropBox and approved by the PHIUS+ Certification team:

1. Energy Model
2. Drawings
3. Specifications

All other documentation must be added to the folders before Final Certification can be awarded.

The following does not need to be completed for Pre-Certification (though any additional information available should be uploaded):

- Airtightness Reports
- Ventilation Commissioning
- Contractor Declaration
- Photos
- Applicable PHIUS+ Quality Assurance Workbook

4.4.0 Energy Model

For Accepted Modeling Software, see Section 6.1.1.

The energy model must be:

- Fully complete with all branches filled out.
    - The Pre-Certification review can begin without all final specifications developed for such items as appliance types or mechanical systems – but building envelope components should be specified for the first review.
- Congruent with the rest of the submitted documentation.

If more than one 'case' is used in the WUFI Passive Energy Model:

- Specify which case should be reviewed by adding 'REVIEW' in the case name OR
- Remove all cases that should not be used for certification review
- If unspecified, PHIUS will review Case 1.

4.4.1 Construction Drawings

The construction drawings should be submitted in .PDF format, show dimensions, and cover the following list of documents:

Design Drawings:

- Plans
- Sections
- Elevations

Detailed Drawings

- Show all unique junctions of the thermal envelope
    - Exterior and interior wall junctions to the basement floor or slab.

    - Exterior junctions to roof or ceiling.
    - Junctions between wall and intermediate floors.
    - Window installation conditions (including reveal dimensions).
    - Any exterior anchoring systems for balconies or awnings.
- Airtight details
    - Window installations
    - Building component connections
    - Penetrations
- All details must be fully annotated with dimensions and call-outs for specific materials.
    - e.g. call out insulation type rather than noting 'rigid' so the insulation type can be matched with the insulation specifications provided, and thermal resistance can be verified.
- Airtight details must be comprehensible and show a continuous uninterrupted barrier that forms from the different materials and components at all junctions.

Thermal Envelope

- Must be clearly identified. Best accomplished using section or elevation drawings with exterior dimensions
- Thermal bridges need to be called out and calculated when applicable.
    - The PHIUS reviewer will look for continuous and consistent insulation in all details, and flag any details that need to be calculated.
    - Submit both THERM files and psi-value calculation for any thermal bridge details calculated.

Mechanical Drawings

Mechanical drawings need to show:

- Ventilation
    - Duct layout and sizes
    - Supply and extract airflow rates at each diffuser and the diffuser location
    - Soundproofing, filters, pressure overflows
    - Outdoor penetrations for exhaust and supply ducts
    - Duct insulation thickness and type
    - Supply and exhaust duct length from the inside of the exterior wall to the ventilation unit
- Heating and Cooling
    - Location of elements - both point source and supply air
    - Size/capacity of elements
    - For incentives Manual J/D calculations or dynamic simulation may become necessary.
- DHW System
    - Type of tank(s) and system
    - Comprehensive length of the DHW pipe length calculation as described in the energy modeling protocol section of this Guidebook (see Section 6.10.1).
- Additional systems (solar thermal, defroster, ground loop, earth tube, etc.)

4.4.1.1 Ventilation Calculations

- Gross Building Volume
  - Total enclosed volume of the building.
  - Uses exterior dimensions, to the edge of the thermal boundary to calculate.
- Net Volume
  - The real interior building volume
  - Total volume within the building envelope - drywall to drywall, floor to ceiling
  - Same as ventilation volume.

4.4.1.2 Site Plan

Needs to show:

- The building's orientation.
- Changes in topography (if applicable).
- The location and height of neighboring buildings or structures.
- The location and height of trees or ground levels that cast lateral shadows.

The site plan and site shading photos together must show the complete shading situation. If necessary, other drawings should be included.

4.4.1.3 Site Shading

PHIUS requires a shading study on the project site. We will need sky-dome or sky-panorama images for each façade, with overlaid measurement grids. Solar Pathfinder images are preferred. However, other methods such as Solmetric are acceptable. No special programs need to be purchased to analyze the Solar Pathfinder images. A free analyzer is included in the PHIUS Shading Protocol Package, downloadable from the Calculators and Protocols page.

4.4.1.4 Interior Conditioned Floor Area (iCFA)

Briefly, iCFA is the interior-dimension (drywall-to-drywall) projected floor area of the conditioned spaces with at least seven feet ceiling height. It includes stairs, cabinets, interior walls, mechanical spaces, storage, but excludes open-to-below.

More specifically:

- Include the floor area of interior spaces at least 7′ in height, measured from the interior finished surfaces that comprise the thermal boundary of the building. Spaces that are open-to-below shall not be counted. (The general concept is "walkable").
- Other than open-to-below, the projected floor area of all spaces within this shall count toward the iCFA measurement, including walls, cabinets, mechanical spaces, storage, etc.
- Projected floor area of the stair treads counts toward iCFA on all floors, that is, once per floor. (By the 7′ height rule, some floor area under the stairs on the 1st floor would be excluded. This conflict is resolved by including it).

Naming Conventions

PHIUS has not dictated strict naming conventions. However, naming conventions should be included for all windows and areas. These should be clearly labeled and easily understood by a reviewer unfamiliar with the project. The best way to do this is to label the drawing and have the labels in the drawings match the labels used in the Energy Model. There should be enough overlap in the names such that each window and door can be positively identified. Often, following a logical rotation (such as clockwise) is helpful. A copy of the drawing set that is annotated specifically for PHIUS+ Certification is extremely helpful and preferred. All penetrations should be listed.

Formats and Sizes

PHIUS does not dictate drawing scales though they should be large enough to be comprehensive and readable. PDF is the preferred drawing file format. PHIUS respects the intellectual property right you have for your details and drawings. This concern should not inhibit the sending of drawings, specifications, or other documentation. Remember that comprehension of a project by an outside party (PHIUS) is the goal. The easier it is to understand a project the quicker and less costly the certification will be for all parties involved.

4.4.2 Technical Specifications

- Data sheets and performance specifications are necessary for all values input into the energy model.
- Generally, these should be provided by the product manufacturer. For some components and equipment, third party ratings are provided. More details on each component/system found under Section 6: Energy Modeling Protocols.
- This should include documentation from third party agents including shading calculations, appliance energy usage, earth tube efficiencies, and any other exteriorly derived values.
- It is best to have this information available and formatted ahead of the Pre-Certification process.

The following Sections: 4.4.3-7 must be submitted for final certification along with any updates to Sections 4.4.1 and 4.4.2.

See Appendix E: PHIUS+ Rater/Verifier Manual for full details.

4.4.3 Pressure Test Verification

- Must be performed by an approved PHIUS+ Rater/Verifier.
- Must be a multipoint test of both pressurization and depressurization.
- The final result is the average of pressurization and depressurization.
- See Section 3.8 for test protocol details.

4.4.4 Ventilation Commissioning

Will be completed by an approved PHIUS+ Rater/Verifier and should include the following information:

- Description and location of the project.
- Name and address of the Rater/Verifier.
- Time and date of commissioning.
- Manufacturer and model number of ventilation unit.
- Adjusted volumetric flows per diffuser - both supply and exhaust.
- Flow comparison between supply and exhaust airstreams as measured between the unit and the exterior, or the interior before any branch ducts (imbalance <10%).

- Power draw of the ventilation unit at nominal speed.

4.4.5 Declaration of the Construction Supervisor

- See Section 3.9 for an example.

4.4.6 Photographs

- 1 main photo, 6 additional for public project database.
- At least 3 photos of the final project.
- Exterior photos of each façade and surrounding site.
- Representative photos of the various insulated assemblies, window and door installs.
- Representative infrared photos, inside and outside.
- Documentation for the construction is also acceptable.

4.4.7 Additional Documentation

- Examples could be shading studies, extra calculations, system sizing, ground loop calculations, etc.
- See Section 6.1.5.

4.4.8 QA/QC Reports

- Supplied by the PHIUS+ Rater/Verifier, see Appendix E, Section 4.3 for more details.
- Available to both the project submitter and PHIUS.
- Submitter is able to update energy model and documentation based on reports.

4.5 PHIUS+ Feedback Document

The PHIUS+ Feedback Document is one of the main channels of communication between PHIUS and the project submitter. The document is used to track the pre-certification progress and includes feedback on the energy model, the drawings submitted, and specifications submitted. **This document must be uploaded to your project's designated DropBox Folder for each round of review.** When the submitter makes changes to the PHIUS+ Feedback Document, the updated energy model should also be uploaded.

Any external communication via email, phone call, etc. must be copied into this feedback form so the project reviewer is aware.

5. PHIUS+ Certification Fee Schedule

PHIUS quotes a single fee for the full certification process, rather than a separate fee for pre-certification and final certification. Certification fees are based upon the project's calculated square feet of iCFA (interior conditioned floor area).

If a project consists of residential and significant non-residential spaces, two energy models may be necessary and pricing may be based on each model individually.

PHIUS' quoted fees do not include the cost of the QA/QC visits and final on-site testing, which are determined by the PHIUS+ Rater/Verifier of choice, see Section 3.7.

	0-2500 ft²	2501-4500 ft²	4501+ ft²	Hourly Rate
PHIUS Professional (CPHC, Builder), & PHAUS Members	$1275	$1480	Custom	$127.50/hr.
Project Owner	$1500	$2000	Custom	$150/hr.

For projects larger than 4501 square feet, a custom quote is required. To request a quote, please email certification@passivehouse.us and provide the estimated iCFA (see Section 4.4.1.4).

An expedited review may be available for an additional 50% up-front cost on the base fee (i.e. a 3500 sf home which had a base fee of $2000 is now $3000). See details in Section 4.1.1 Review Timeline.

Discounts:

CPHCs that are also PHAUS Professional Members receive a 15% discount, up to $600.

Non-Profit Organizations such as Habitat for Humanity are eligible for a 25% discount, up to $1000.

Duplicate/repeating projects may receive a discount for each duplicate submitted after the first.

Estimated fees for larger buildings:

iCFA	10,000 ft²	20,000 ft²	50,000 ft²	100,000 ft²	200,000 ft²	500,000 ft²
Base Fee	$4000	$6750	$11,875	$16,250	$21,875	$33,125

PHIUS+ Certification Plaque	FREE (1 included, each additional $75)
Source Zero Plaque	$75

6. Energy Modeling Protocols

6.1 Getting Started

6.1.1 Accepted Modeling Software

For PHIUS+ 2018:

WUFI Passive: 3_2_0_1 or later*

WUFI Passive Free: 3_2_0_1 or later

**3_1_1_25 accepted for PHIUS+ 2018 pilot projects, or on a case-by-case basis.*

6.1.1.1 General Recommended WUFI Passive Settings

Options	**General**	**Dimensions, visualized geometry**	**Outer, extern partitions not included.**
Options	Usability	Tool tips	Check all boxes to ensure the proper hover-over hints are visible.
Options	Usability	Data Recovery	Turn this on to auto-save projects.
Options	Usability	Comments	Use this to save note within each screen of your project file. Helpful for colleague, reviewer, personal note, etc.
Options	Usability	Show edit icons in tables	Select to view cells with built-in calculators. Will appear with [...].
Options	Usability	Show project/case in footnote	Select to include case name in footer of printed results reports.
Options	Passive	Default Certificate Criteria	Set to PHIUS+ 2018

6.1.1.2 WUFI Passive Online Tutorials

Free online tutorials can be found here: http://www.phius.org/phius-certification-for-buildings-products/wufi-passive-tutorials

6.1.1.3 Project File Versions

Older project files can always be opened in newer version of the software, but newer files generally cannot be opened in older versions.

Sometimes*, a project file can be opened in a previous version of WUFI Passive. To do this, save the file type as 'XML' in the newer version WUFI Passive, then, open the XML file in the older version.

i.e. A project file created in WUFI Passive 3_2_0_1 cannot be opened in 3_1_1_0.

A project file created in WUFI Passive 3_1_1_0 can be opened in 3_2_0_1.

**It is not guaranteed that files created in "intermediate" or test versions of WUFI Passive can be opened in future release versions.*

6.1.1.4 Dynamic modeling in WUFIplus

Though not required for certification, consider also doing dynamic modeling (WUFI Plus) when:

- Cooling and/or moisture loads are high.
- Heating is discontinuous (during the heating period).
- Occupancy and indoor conditions vary considerably.
- Comfort and overheating should be assessed.

If dynamic modeling seems called for, PHIUS suggests running a 3-zone dynamic model as a comfort analysis using WUFI Plus (WUFI Passive dynamic side), or another dynamic energy model. The 3 zones would be coldest room, warmest room, rest-of-building. There are two possible approaches – one is to set the heating and cooling system capacities very high, and look for the per-square-foot differences in the heating and cooling loads among the zones. The other is to limit the system capacities and look for failure to maintain the desired interior temperature set-points.

6.1.2 Climate Data

- Must be approved by PHIUS for each project.
- It is important to choose the correct dataset, especially given that a project's space-conditioning performance targets vary by location.
- PHIUS has generated 1000+ climate datasets for locations around the United States; they are available as individual XML database import files for each state, as well as a single XML file for the entire United States. These datasets are available free to PHAUS members and can be downloaded from the PHAUS Member Resources page.
- A custom data set is required for a project location when the closest existing data set is more than 50 linear miles and >400′ different in elevation from the project location.
    - Project locations even within the parameters above might benefit from custom climate data.
    - Please refer to the PHIUS blog posts "Climate Data – When to Request a Custom Dataset" and "Climate Data and PHIUS+ 2015" for more information.
    - The cost of a custom climate data set is $75 and may be purchased here: http://www.phius.org/software-resources/wufi-passive-and-other-modeling-tools/climate-data-sets
- If project is within 50 linear miles and within 400 feet difference in elevation of an existing climate data set, you must use the PHIUS+ space conditioning targets associated with the existing data set. However, you can order custom climate data if you'd like to.

6.1.3 Energy Model Defaults

The accepted software versions agree on default input values for several input parameters. Unless otherwise noted below, these values should be used in the energy model for certification. These values (and the way they are calculated) may be updated in the future to coincide with research and best practices.

6.1.4 Energy Model Inputs Requiring Additional Documentation

- Ground Thermal Resistivity > 0.1 hr.ft^2.F/BTU.in.
- Window frame-to-wall psi value < 0.015 BTU/hr.ft.F
  Subsoil heat exchanger efficiency > 60%.
- Air change rate for window ventilation; see Section 6.7.3.
- Solar fraction for hot water – expert/specialist calculation recommended if greater than 65% estimated to be covered by solar in WUFI Passive model.

6.1.5 External Calculators & Protocol Documents

Many external calculation methods and protocol documents are developed as new modeling situations arise. Eventually, these calculation methods and protocol are built in or implemented into the WUFI Passive energy modeling tool. External calculators may be used in the interim.

- Always download the latest version of the protocol documents on the Calculators & Protocols page.

6.1.6 WUFI Passive Cases

WUFI Passive allows for quick creation of multiple 'cases' within a single project file. Cases are generally created by duplicating a previous case. This can be used to compare alternate designs and provides direct result comparison. Cases can contain varying geometry, and a new geometry file can be imported into a duplicate case.

For Mixed-Use projects, it is helpful to import the whole building as two zones (residential and non-residential). Then, one case can cover the residential portion as the 'active' or 'simulated zone', and the second case can cover the non-residential portion as the 'simulated zone'. This keeps the entire building in one WUFI Passive model.

6.2 Localization/Climate

Selecting a Climate Data Set

See Section 6.1.2.

Download and Save a PHIUS+ Climate File or PHIUS+ Climate XML Database

See Section 6.1.2.

6.2.1 Localization

To Upload a PHIUS+ Climate File into WUFI Passive

Select "User Defined" from the dropdown list, click the "Browse" button, and search for the saved climate file. Change the file type in the bottom right hand corner to "Excel (.xls)" if need be. Or, complete a one-time download of the climate database XML file to your WUFI Passive database. This can be done by selecting "Database", then selecting the drop down menu to "Import from XML File". These files are also available on the PHAUS Member Resources page. After this import, you will be able to browse your WUFI Passive database to select a climate dataset for your new project.

*Please note climate data import is not available in the free version of WUFI Passive; in this version the climate data must be input manually. See guidance below, Section 6.2.1.1.

About the Design Temperatures in the Climate Data

A super-insulated structure responds more slowly to outside conditions, so the peak loads are moderated. The static mode calculation does also assume a slightly wider comfort range on the inside, 68-77 F instead of for example the Building America default 71-76 F, and similarly, the reason for this is that the inside surface temperatures should be more stable, so the air temperature can vary a bit more and still be comfortable, because the radiant temperature of the surfaces varies less.

We recommend against taking the passive mode design temperatures and using them in an ACCA manual J calculation, but rather run each method on its own terms and compare the bottom line Btu/h results.

Altitude Building: The altitude of the project site must be input. Site altitude may be verified using Google Earth.

PHIUS recommends locating the project site on Google Earth, placing a 'marker' on the site at ground level, and providing a screenshot verifying site altitude. This should be uploaded in the Site Plan/Shading folder.

Time Zone: This entry is required for the dynamic shading calculation. Use standard time, not daylight.

- Eastern Standard Time: UTC -5
- Central Standard Time: UTC -6
- Mountain Standard Time: UTC -7
- Pacific Standard Time: UTC -8
- Alaskan Standard Time: UTC -9

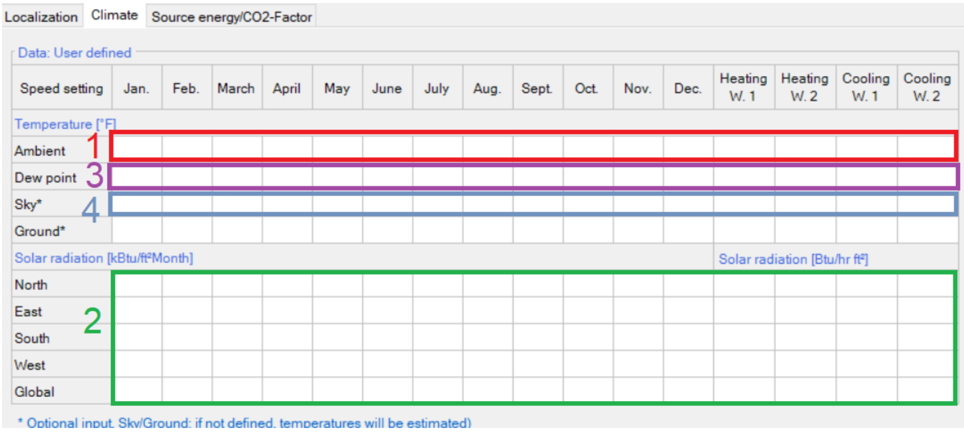
Ground Thermal Conductivity: In heating dominated climates, this value may not be lower than 0.833 (BTU/hr.ft.F), and should usually be left at the default of 1.1558 (BTU/hr.ft².F).

For thermal resistance, this is equivalent to no more than 0.1 R/in (hr.ft².F/BTU.in).

6.2.1.1 Entering climate data into WUFI Passive Free

US CUSTOMARY:

Month	1	2	3	4	5	6	7	8	9	10	11	12	Heating Load		Cooling Load
Days	31	28	31	30	31	30	31	31	30	31	30	31	Weather 1	Weather 2	Radiation
CHICAGO OHARE INTL AP IL	Latitude:	42.0	Longitude ° East:	-87.9	Altitude (ft):	659.4	0	Daily temperature variation summer (F)		18.7	Radiation Data:	kBTU/(ft².month)	Radiation: BTU/hr.ft²		BTU/hr.ft²
Ambient Temp (°F) 1	23.7	27.5	38.8	50.0	59.5	70.0	75.4	71.2	64.6	51.8	40.5	25.3	7.5	21.2	80.8
North	8.2	10.1	12.0	12.7	18.1	20.0	19.7	15.5	11.1	8.6	6.3	7.0	11.4	11.4	28.2
East 2	17.4	21.9	27.9	31.1	40.3	40.6	39.9	35.5	31.4	24.1	15.2	15.8	35.8	15.5	64.7
South	30.7	31.4	32.3	26.6	28.2	24.7	27.6	28.5	31.4	33.0	24.4	27.9	67.2	23.8	43.1
West	11.7	14.6	17.8	20.6	27.3	27.6	28.5	24.4	19.0	14.3	8.6	9.8	19.7	13.6	42.8
Global	17.1	21.9	33.0	41.2	57.7	59.0	59.9	49.8	39.0	27.9	16.8	14.3	27.6	20.3	95.1
Dewpoint 3	15.1	17.2	29.3	39.2	45.0	55.4	65.7	61.9	55.2	41.0	32.7	18.3			
Sky temperature 4	-16.2	-5.3	7.9	17.8	29.3	37.6	52.0	47.8	38.1	21.4	14.4	-11.4			



6.2.2 Space Conditioning Target Data

Use the PHIUS+ 2018 Target Calculator. Two calculation methods are possible:

- CALCULATOR method should be used for certification and is based on Envelope-to-Floor Area ratio.
- ESTIMATOR method approximates Envelope-to-Floor Area ratio based on floor area alone. This should only be used to get quick estimated targets if building envelope area is unknown.

Envelope/iCFA: Envelope area divided by interior conditioned floor area (iCFA)

Valid range is

Occupancy (ft2/person): Interior conditioned floor area (iCFA) divided by total occupancy in the building

For residential buildings, the calculations above are straight-forward.

For non-residential buildings, two different occupancy values should be used to determine space conditioning criteria. Therefore, the calculator should be filled out twice with varying occupancy.

Annual Heating/Cooling Demand: Calculate the average occupancy (OccAvg) for the building over all space types according to expected schedules. That average occupancy should then be divided by 0.688 to determine occupancy for the criteria calculator (Occ).

Occ = OccAvg / 0.688

Peak Heating/Cooling Load: Use the maximum occupancy.

6.2.3 Source Energy/CO2-Factor

Source Energy Factor for Grid Electricity

The source energy factor for the grid electricity mix in the U.S. is aligned with Energy Star Portfolio Manager. It is different from that of Europe. Use the national average value for certification, regardless of regional differences.

- **USA:** 2.8
- **Canada:** 1.96

This policy forestalls the tendency for "rebound effect" - of building designers taking advantage of locally "cleaner" grids to use more energy, and instead, in effect, shares that benefit with designers in "dirty grid" regions. This is consistent with the idea that with the current fossil-dominated primary fuel mix, energy impact translates into atmosphere impact.

6.3 PH Case

6.3.1 PH Case - General

The interior temperature thresholds for PHIUS+ Certification are 68F and 77F. Please contact PHIUS if the program of the project requires a different temperature set point.

Indoor Temperature defined on this tab is the 'heating setpoint', 68F should be used.

6.3.1.1 Occupancy and Internal Heat Gains

For residential projects, model occupancy as the # of bedrooms + 1. This is per unit if there are multiple units.

A bedroom is defined as per RESNET: [27]

> *A room or space 70 square feet or greater, with egress window and closet, used or intended to be used for sleeping. A "den." "library," "home office" with a closet, egress window, and 70 square feet or greater or other similar rooms shall count as a bedroom, but living rooms and foyers shall not.*

Internal heat gains are set "calculated", rather than using a default value by building type.

6.3.1.2 Non-permanent occupants in multifamily buildings: Visitors and Workers

Source Energy Allowance:
Workers: Non-Resident workers such as office workers, senior/medical service workers, etc. will add to the planned occupancy load of the building. Schedules and number of workers should be summed and equated to full time occupants. For example, 3 workers that work 8 hours/day each can equate to 1 full time occupant. The number of equivalent full-time workers can be added to the residential occupancy, and given the residential source energy allowance per person.
Visitors: If the building includes designated spaces that serve the residents as well as outside visitors, the commercial building source energy allowance per square foot should be applied to those spaces.

Internal Heat Gains + Energy Use:
Workers: By adding full time equivalent occupancy for workers into the total occupancy count, internal heat gains and other energy use is appropriately accounted for with no additional input.
Visitors: Depending on the nature of the typical visits (games, dinner, etc), the appropriate energy use of the visitors should be estimated and documented for pre-certification design review

6.3.1.3 Number of Units and Floors

Number of Units: This is used to calculate the reference quantity for refrigerator and freezer entries, as well as calculating the DHW tap openings per year.

Residential: The total number of residential units should be used. At minimum, a 'unit' includes a kitchen, bedroom/living space, and bathroom.

Non-Residential: Enter 1.

Number of floors: The number of floors should be entered. This is used to determine:

1. Air-tightness allowance adjustment, if applicable.
2. Number of floors to be used for the DHW distribution losses when using 'floor method'.

6.3.2 PH Case - Additional Data

Overheating temperature threshold: This entry is the cooling setpoint. For most cases, 77F should be used for certification.

Fresh Air Per Person: 18 cfm for residential, 9-12 cfm for school and daycare, 35 cfm for sports halls.

Hot water tap-openings per person per day: Defines how many times each DHW tap is opened per person, per day. Used to calculate DHW distribution losses ***only*** when using 'Simplified Individual pipes' method is for DHW individual pipes.

> Residential: This entry will not apply for PHIUS+ 2018 projects. DHW Distribution calculation method cannot be 'Simplified Individual pipes' for pre-certification.
>
> Non-Residential: A user defined value may be input here based on total occupants assumed on an average day in the building, the total number of tap openings, and

Infiltration/Airtightness: Per Section 3.2

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

$q50 <= 0.080\ CFM_{50}/ft^2$ or $q75 <= 0.100\ CFM_{75}/ft^2$ of gross envelope area

For all other buildings:

$q50 <= 0.060\ CFM_{50}/ft^2$ or $q75 <= 0.080\ CFM_{75}/ft^2$ of gross envelope area

Gross envelope is measured at the exterior of the thermal boundary, the same as for the energy model, and includes surfaces in contact with the ground.

Envelope airtightness at 50 Pa: PHIUS recommends entering the maximum limit for the building here. A lower value may be used to meet space conditioning targets, but the designer must acknowledge that the lower value must be met in the field in order for the project to pass at final certification.

Non-Combustible Materials: Check this box if the building is of non-combustible construction. If this box is checked, and the building is 5 stories or greater (input on PH Case>General), the 'target' air-tightness will be adjusted in the model and report.

Example project conversion from cfm50/ft^2 to ACH50:
Total envelope area 6958 ft^2

Net volume 19387 ft^3

$$6958 \text{ ft2} * (0.05 \text{ ft}^3/\text{min})/\text{ft}^2) * (60 \text{ min/hr.}) * (1/19387 \text{ ft}^3) = 1.08 \text{ ACH50}$$

Maximum Humidity Ratio (if dehumidification is planned)

The default value is 0.012 lbw/lba; it is not to be changed for PHIUS+ Certification. It is the upper limit for humidity levels according to the comfort standard ASHRAE 55-2004. This is essentially a humidity set-point. At 77 F and a 0.012 humidity ratio, it corresponds to approximately 60% relative humidity.

Domestic Hot Water Use Per Person

- Residential: 6.6 gal/person/day
  - Default should be used for certification. Higher values may be accepted.
- Non-residential: 3.2 gal/person/day
  - The default above will not fit for all non-residential projects. The entry may vary from the default if supporting documentation/calculation is provided and approved by PHIUS.

This input pertains to showers, hand-washing, and shaving. Laundry and dishwashing is separate from that, and calculated with the appliance entries. If there is no dishwasher, consider adding extra gallons to this daily value.

Remember, these are "hot gallons" (140 F). It calculates the energy to raise the water from the incoming water temperature (default 50 F) to 140 F, a 90 F rise. When mixed down to a temperature a person would actually want to shower under, it goes almost twice as far in terms of volume.

Cold Water Supply/Incoming Temperature

If this input is left blank in WUFI Passive, it will calculate using an average annual ground temperature.

A user defined entry may be used if supporting documentation is submitted to confirm the new groundwater temperature. The adjusted groundwater temperature generally should not exceed the average ambient air temperature for the project's climate.

6.3.3 PH Case - Foundation Interface

Up to 3 different foundation interface connections can be defined. These determine reduction factors to be applied to components with 'Ground' assigned on the Outer Side.

Floor Slab / Floor Ceiling Area

For heated basements, only include the interior floor area. For all other basement conditions, include the entire floor area calculated to the exterior of the thermal boundary.

Floor Slab Perimeter

For heated basements, only include the interior perimeter. For all other basement conditions, include the entire (exterior-adjacent portion of the) floor slab perimeter measured at the exterior of the thermal boundary.

6.4 Zone 1

6.4.1 Visualized Volume

This value is not used for the "Passive House Verification" calculation; it refers to the volume of the visualized 3D model. This will be equal to the gross volume in most cases (when the model is drawn to the exterior dimensions).

6.4.2 Gross Volume

This volume represents the volume of the building measured from the exterior boundary of the thermal envelope. Generally this is the same as the visualized volume. However, if objects are included in the 3D geometry that are not part of the thermal boundary, for shading, etc., the visualized volume may not represent the gross volume. In this case, the gross volume should be calculated.

6.4.3 Net Volume

To determine the net volume, calculate the home's interior volume (drywall to drywall floor to ceiling, wall to wall) minus volume taken up by interior walls and floor systems. A calculation must be submitted for certification.

6.4.4 Interior Conditioned Floor Area (iCFA)

The reference floor area. The space conditioning criteria (heating and cooling annual demands and peak loads) are per square foot of iCFA. See Section 4.4.1.4 for the definition of iCFA.

6.4.5 Specific Heat Capacity/Thermal Mass

With regard to thermal mass, it's not just the total mass that matters but the distribution, so that it can interact with the infrared radiation bouncing around the room. The way of figuring this is based on the number of heavy surfaces (0 to six) per room, in an average sense. For example, a two-story building with a first floor concrete slab would have 1/2 of a heavy surface per room on average.

Thermal mass is determined by the equation = $[60+n(\text{heavy})*24]*0.176$ (BTU/ft^2.F).

Guidelines for Accounting Heavy Surfaces

- Drywall = 0 heavy surfaces - (first ½" included in the baseline)
- 5/8" drywall = 0.34 heavy surfaces
- Double or high-density drywall = 0.5 heavy surfaces
- Two-inch-thick concrete or more, phase-change materials = 1 heavy surface
- Flagstone/tile = 0.5 heavy surfaces
    - **Example:**
      Concrete floor = 1 heavy surface
      Other 5 surfaces = 0.34 each = 1.7 heavy surfaces

Total n (heavy surfaces) = 2.7
Specific capacity = (60+2.7*24) *0.176 = 21.96 BTU/ft²F

6.5 Visualized Components

6.5.1 Wall Components

Framing

Framing must be included. For walls, vertical and horizontal framing must be included. Typical assemblies are built out in 3D.

Actual spacing of vertical framing should be used to define the 'width' of the typical assembly created, i.e. 16" o.c., and framing added in as horizontal subdivisions.

The 'height' of the assembly created should be defined by a typical floor to floor height. The top and bottom plates must be added into the assembly as vertical subdivisions.

Insulation Specifications

Some insulation is temperature-dependent; use the R-value at 75 F for the energy model. Some insulation is thickness-dependent; use the R-value at the appropriate thickness for the assembly.

In WUFI Passive, please note that default conductivity values are used from the existing database.

- Conductivity or thermal resistance values should be updated in the project file to match the insulation specification.
- This can be done under the Edit Assembly screen by clicking into the "Conductivity" input, for the specific assembly layer, selecting the [R/in] button, and inputting the accurate R per inch.

Surface / Radiation Balances / Solar Absorption/Emission

The radiation balances need to be input for every opaque surface above grade. This includes values for: emissivity, absorptivity, and shading. Rough values are acceptable.

6.5.2 Window Components

PHIUS has verified data for a number of windows and manufacturers; these are listed on the Find & Compare Windows page of the PHIUS website.

If the project is using windows included in the PHIUS Verified Data for Window Performance Program, PHIUS' data must be used.

Window Components in 3D visualization: In the energy model, each individual 'lite' or individual 'piece of glazing' should be its own clickable component. This ensures that the proper solar gain and frame to glazing ratio is accounted for.

Window Groups in 3D visualization: In WUFI Passive, windows could be grouped/ungrouped and through the 'Assign Data' option give them common properties.

- To add 'Basic Data' and 'Frame Data' and 'reveal' shading, they can be grouped by "Window Type".
- To add 'General Parameters' for site shading (fractions of solar exposure), you could group them by 'orientation' or by 'floor level'.
- WUFI Mean Monthly shading factors are calculated per window, regardless of grouping.

Window Sizes: The windows are entered into the building energy model in their actual size and configuration (every lite), with the performance of the framing members and the glass broken out separately (as opposed to using whole-window properties at a standard size.)

Window Performance Entries: Specification data is needed for:

- Center-of-glass U-value
- Solar Heat Gain Coefficient (SHGC)
- Frame width
- Frame U-value
- Linear heat loss coefficient at the edge of the glass ("psi-spacer")

PHIUS' window program calculates all these. But the project certification program is fairly flexible as to the source of that data, that is, it is not "hostage" to the window rating program. Usually, center-of-glass properties can be obtained from the glazing system manufacturer. For the frame, rating data per CEN standards or NFRC's CMAST can be used, or a conservative default based on frame material type can be used. The linear coefficient at the edge is the hardest to come by, but a conservative default can be used for that (0.023 BTU/hr.ft.F). Similarly, a default value can be used for the linear heat loss coefficient at the outer edge of the frame ("psi-install").

Psi-Installation / Frame-to-wall psi-value

The frame-to-wall psi-installation value is dependent on how the window is installed within the wall. Please do not use values from manufacturers' data sheets unless they have completed a project specific calculation for you.

- A default value of 0.030 BTU/hr.ft.F can be used for most installation details.
- Improved detailed can use the values below:
    - As low as 0.020 (Btu/hr.ft.F) for a mid-wall mounted window that is not over-insulated.
    - As low as 0.015 (Btu/hr.ft.F) for a mid-wall mounted window that is over-insulated.
- If a THERM calculation is provided, psi-installation values below these thresholds are acceptable.

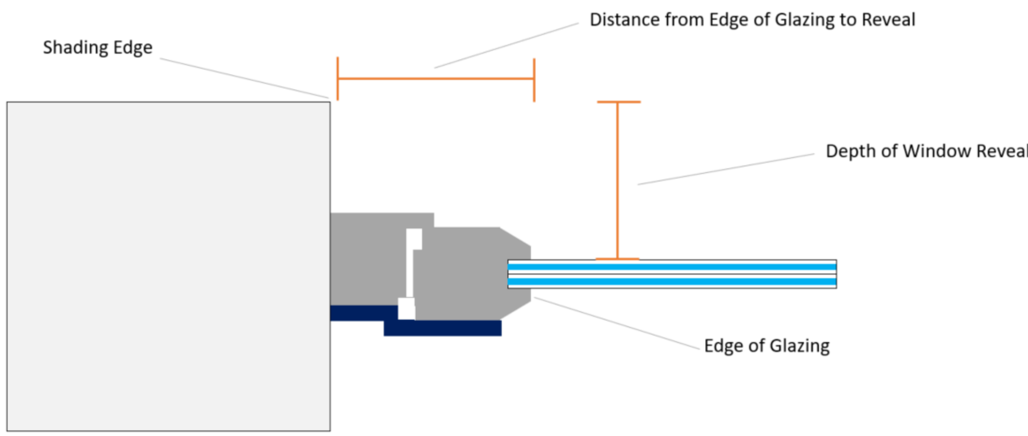
6.5.3 Solar Protection/Shading

6.5.3.1 Reveal Shading

Often windows are not installed flush with the exterior of the building façade which causes reveal shading to the left and right sides of the window from the window in-set in the wall.

- Depth of window reveal: Measured from the outside of the leading shading edge to the glazing.
- Distance from edge of glazing to reveal: Measured from the edge of glazing to the shading edge.

Reveal Shading (Plan view)



Reveal shading must be input for all windows.

- In WUFI Passive, this can be done quickly with the [Assign Data] function.
    - The 3D geometry will visualize the window in-set into the wall when entries are adjusted.
- All reveal entries are calculated as if on both sides of the window.
    - If the reveal depths are significantly different on the left and right, due to a vertical shading fin or similar, it is recommended that the irregular shading device is drawn into the 3D geometry rather than input numerically.
    - See 'Shading due to building geometry' below.

6.5.3.2 Shading Devices

Sunscreen/shading devices in WUFI Passive are assumed to be used only during the cooling season. If year-round blinds are used, please input as an "other shading fraction of solar exposure".

External blinds offer better thermal protection than internal blinds because the solar radiation is partially absorbed by the fabric before reaching the glazing and reflected outwards.

The effectiveness of window blinds needs to be de-rated if they are manually operated, to account for occupant behavior. If the shading reduction factor for a blind in the closed position is "z", and "Z effective" is in the input in WUFI Passive then:

For exterior blinds use:

Z effective = 0.3 + 0.7 * z

Example: If blinds allow 46% solar access (solar transmittance, Ts) when closed, use that for z, and z effective turns out to be 62%.

Z effective = 0.3 + (0.7*0.46) = 0.622

For interior blinds use:

Z effective = 1- (1-z) * (1-0.6)

Example: If blinds allow 46% solar access (solar transmittance, Ts) when closed, use that for z, and z effective turns out to be 78%.

Z effective = 1 – (1-0.46) * (1-0.6) = 0.784

Blind Ratings: Should be provided by manufacturers. Solar transmittance is used in the equations above. Solar radiation is always partially transmitted through, absorbed or reflected by the fabric.

Ts = Solar Transmittance – Proportion of solar energy transmitted through the fabric.
Low percentage means the fabric performs well at reducing solar energy.
Rs = Solar Reflectance – Proportion of solar radiation reflected by the fabric.
High percentage means the fabric performs well at reflecting solar energy.
As = Solar Absorptance – Proportion of solar radiation absorbed by the fabric.
Low percentage means the fabric absorbs little solar energy.
Ts + Rs + As = 100% of solar energy

OF = Openness Factor - Percentage of blind fabric/material that is open (between the threads)

Insulated Interior Blinds

Unless the blind is air sealed to the window opening and is airtight, much of the insulating value of the blind can be bypassed. Because of this, we are giving credit for essentially, the R-value of the two air films on either side of the blind and not the blind itself. We generally round this to R-2 in IP units. We also assume that user behavior impacts the use of the blinds and that somewhere around half the time, the blinds are not in the right spot, or are removed. Therefore, we currently allow an R-1 adjustment to be made directly to the glass R-value and the Frame R-value. One word of caution is that if they do work as intended/advertised, there is a significant risk of condensation on the window in cold climates, which over time could lead to problems and durability issues. This must be checked and managed.

6.5.3.3 Overhangs

Overhangs may be included in the 3D geometry or entered numerically into WUFI Passive.

If including in 3D geometry, angled or complex overhangs may be modeled.

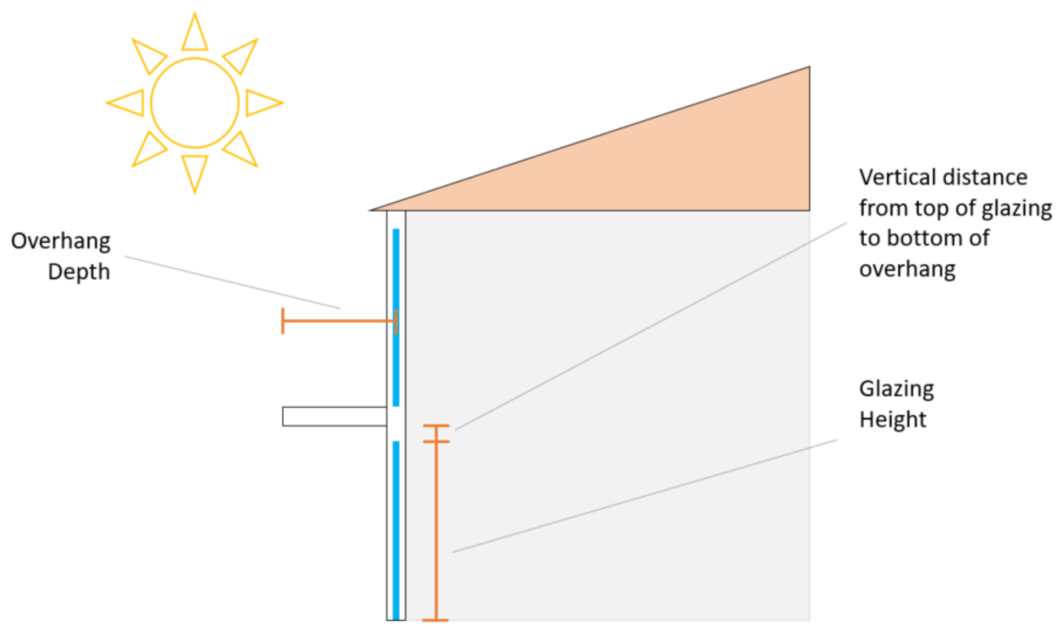
If entering numerically, an overhang parallel to the window head will be simulated. Three parameters must be defined:

- Depth of overhang: Measured horizontally out from the glazing to the shading edge.

- Vertical distance from top of glazing to bottom of overhang: Measured vertically from edge of glazing to shading edge.
- Side spacing: The default side spacing is '0', which would simulate an overhang that matches the width of the window it is assigned to.
    - If the overhang extends longer than the width of the window, 'side spacing' may be input to extend the overhang on each side of the window.
    - At this time, the extension must be uniform on each side of the window.

The numerically entered overhangs will appear in the 3D geometry.

- If an overhang is both included in the 3D visualization and entered numerically, that is OK, it will not double count the shading if the two overlap in the 3D geometry.



Please note in WUFI Passive, if no overhangs are assigned to a window, the reveal depth dimensions are automatically set as the overhang. If this inaccurately represents the shading condition, please assign an overhang to the specific window.

6.5.3.4 Mulled Windows and Divided Lites

Mulled Windows

If the connector for the frame mullion is similar in material to the frame, adding a bit of thickness to the frame may work. If the connector is substantially more conductive than the frame, a thermal bridge calculation may be necessary.

Divided Lites

There are some different ways to deal with true divided lites that bridge the gas cavity. The SHGC could be adjusted to account for the blocked light, and linear thermal bridges added to account for the extra conduction loss.

Simulated Divided Lites

If these are a kind of divided lites such that the gas cavity is not actually bridged, we will still reduce the SHGC, but no additional thermal bridging need be accounted for.

6.5.3.5 WUFI Mean Month Shading Factors

Shading due to building geometry

Shading from building geometry such as overhangs, bump-outs, complicated geometry, surrounding buildings etc. will be considered.

- Any elements that should be considered for shading can be included in the 3D geometry imported into WUFI Passive. This includes overhangs, surrounding buildings, etc.
  - These elements should be assigned as 'opaque' and 'Outer Air' should be assigned on both the Inner Side and Outer Side of the components.
- The 'Calculate WUFI shading' button should be used.
  - If an entry changes that affects the shading calculation, a warning will appear stating "Shading factors are not up-to-date…". When this appears, the shading calculation must be re-run.
- Monthly shading factors are calculated and shown on the 'WUFI Mean Month Shading Factors' tab.
  - Correction/reduction factor per month can be applied in the row above the results, or
  - Default correction factor input can be used to apply a uniform reduction factor for all months.
- Results are calculated per window, even when windows are grouped.
  - Note: Unique shading properties such as reveals, numerically entered overhangs, blinds, etc. will not be retained per window if grouping and ungrouping. When windows are grouped, they are given uniform numerical entries based on the first window selected when grouping.
- More information can be found in this presentation from NAPHC2018.

6.6 Internal Loads/Occupancy

6.6.1 Residential

Occupant Quantity

See Section 6.3.1.

Number of Bedrooms

Based on the total number of bedrooms in the building.

Humidity Sources
Internal sources due to respiration or evaporation. Default value of 0.0041 [lb/(ft²hr)].

Per ASHRAE standard 160, clause 4.3.2.1.1, if there is a jetted [whirlpool] tub installed in a room without an automatically controlled (e.g. humidistat) exhaust fan, it would be appropriate to add 1.3 liters/day or 0.12 lb/h to the moisture generation rate.

6.6.1.1 Calculation Methods

The energy use for most appliances is proportionate to the number of occupants. This holds true for dishwashers, clothes washers, dryers, and cooktops.

- Generally, do not adjust the quantity of these appliances.
- <u>Default:</u> If only 1 zone in the project, select "PH Case Occupants" as the "Reference Quantity".
- If multiple zones in the project, select "Zone Occupants" as the "Reference Quantity".

For refrigerators and freezers, consumption is not dependent on occupancy, it is proportional to the number of devices.

- <u>Default</u>: Select "PH Case Units" as the "Reference Quantity".
- The quantity may be adjusted as needed.

6.6.1.2 Devices/Appliances

Pre-defined devices are built into the software. Choose 'Set Standard Dataset' to insert one of each typical appliance.

Below is a list of typical devices. Median Energy Star (ES) values as of 2018 are listed for each device. This may be used for projects early in design, or in some cases for pre-certification until the appliance is selected.

Dishwasher

- 'Energy demand (norm) reference' = 'Year'
    - <u>Year</u>: Use Energy annual kWh rating.
        - Median value (ES, 2018): 260 kWh/yr
- Dishwasher Capacity: In place settings, from manufacturer or ES.
    - Standard (12), Compact (8), or User Defined.
- Calculated per ANSI/RESNET/ICC 301-2014

Kitchen fridge/freeze combo

- Select 'Energy demand (norm) reference' as 'Day' or 'Year'.
    - <u>Day</u>: Use annual kWh divided by 365 days.
    - <u>Year</u>: Use annual kWh rating.
- Median Values (ES, 2018):

Label	Volume	kWh/day	kWh/yr
Compact	<10 ft^3	0.69	253
Average	15-20 ft^3	1.23	449
Large	>25 ft^3	1.96	715

Kitchen freezer

- Select 'Energy demand (norm) reference' as 'Day' or 'Year'.
    - Day: Use annual kWh divided by 365 days.
        - Median Value (ES, 2018): 1.08 kWh/day
    - Year: Use annual kWh rating.
        - Median Value (ES, 2018): 394 kWh/yr

Laundry – washer

- 'Energy demand (norm) reference' = 'Year'.
    - Year: Use annual kWh rating
        - Median Value (ES, 2018): 116 kWh/yr
- Capacity of clothes washer: Tub volume, provided by Energy Star.
    - Default value of 2.87 ft^3.
- MEF (or IMEF) – (Integrated) Modified Energy Factor: From Energy Star. Considers the amount of dryer energy used to remove the remaining moisture content in washed items, in addition to the unit's energy use and water heating energy.
    - Median value (ES, 2018): 2.38
    - Higher the I/MEF, more efficient the clothes washer.
- Calculated per ANSI/RESNET/ICC 301-2014
  Whereas, Annual Gas Cost (AGC) = Labeled Energy Rating*0.0593 + 3.7066

Clothes Dryer

- Clothesline
    - May only be used if no future hookup/space for dryer.
- Drying Closet (cold), Drying Closet (cold) at exhaust
    - Input any auxiliary or fan energy.
- Condensation Dryer
    - Select 'Energy demand (norm) reference' as 'CEF – Combined Energy Factor'
        - CEF – From Energy Star
        - Median CEF Value (ES, 2018): 3.93
    - Calculated per ANSI/RESNET/ICC 301-2014
- Electric Exhaust Air Dryer
    - 'Energy demand (norm) reference' as 'CEF – Combined Energy Factor'
        - CEF – From Energy Star, if applicable.
        - Default CEF Value if no Energy Star Rating: 3.14
    - Select 'Field utilization factor' – Timer controls or Moisture sensing
    - Calculated per ANSI/RESNET/ICC 301-2014
- Gas Exhaust Air Dryer

- ‘Energy demand (norm) reference’ as ‘CEF – Combined Energy Factor’
  - CEF – Gas: From Energy Star, if applicable. Default 2.67 (lbs/kWh)
  - Gas Consumption: Match the electrical kWh/use of the washer and assign the rest to Gas consumption.
    - For example, if using the default 3.5 kWh/use for the dryer, and the washer is rated at 0.5 kWh/use, input for the gas consumption:
      - 3.5-0.5 = 3.0 kWh * 3412 Btu/kWh = 10236 Btu.
- Select ‘Field utilization factor’ – Timer controls or Moisture sensing
- Calculated per ANSI/RESNET/ICC 301-2014

Kitchen Cooking

- Cooking with gas: 0.25 kWh/use.
- Cooking with electricity/induction cooktop: 0.20 kWh/use.
- This input accounts for cooking energy from ovens, microwave, etc., not just the cooktop. It is assumed that 500 single serving size meals are cooked annually, per occupant.

6.6.1.3 Lighting and Miscellaneous Loads

The list of devices covering lighting and plug loads are listed below. The annual energy use is calculated internally per Section 6.6.1.1.

PHIUS+ Interior Lighting

- Should be used for all single family PHIUS+ projects.
- If only 1 zone in the project, select “PH Case Floor Area” as the “Reference Quantity”. If multiple zones in the project, select “Zone Floor Area” as the “Reference Quantity”.
- Input a fraction of high efficiency lighting.

PHIUS+ Exterior Lighting

- Should be used for all single family PHIUS+ projects.
- If only 1 zone in the project, select “PH Case Floor Area” as the “Reference Quantity”. If multiple zones in the project, select “Zone Floor Area” as the “Reference Quantity”.
- Input a fraction of high efficiency lighting.

PHIUS+ Garage Lighting

- Should be used for all single family PHIUS+ projects with a garage.
- No “Reference Quantity” required.
- Input a fraction of high efficiency lighting.

PHIUS+ MELS

- Includes all miscellaneous electric loads, including televisions and plug loads.

- Should be used for all single family PHIUS+ projects.
- Select "PH Case Floor Area" as the "Reference Quantity".
- If multiple zones in the project, only add the PHIUS+ MELS device to one zone.

User Defined – Misc electric loads (MELS)

- Enter value from external MELS calculation for multi-unit projects (see below)
- This will separate MEL energy use in your reports
- Do not enter commas - this will be interpreted as a decimal point!

User Defined – Lighting

- Enter value from external lighting calculation for multi-unit projects (see below)
- This will separate lighting energy use in your reports
- Enter interior and exterior lighting as separate line items
    - For exterior lighting, un-check the box for 'In conditioned space'.
- Do not enter commas - this will be interpreted as a decimal point!

User Defined

- Input any additional device not covered in the common device list
- Units are in kWh/yr.
- User Defined devices will be used for multi-unit projects, see details below in Section 6.6.1.
- Do not enter commas - this will be interpreted as a decimal point!

Multi-Unit Projects

- Energy use calculated for most appliances (dishwasher, washer, dryer, cooktop) are driven by occupancy. The "Reference quantity" that should be selected for these appliances is "PH case occupants" if the whole building is in one zone, or "Zone occupants" if the model has multiple zones.
- Fridge/freezer inputs are driven by the number of units input under the "PH Case" branch. The "Reference Quantity" in WUFI Passive for the fridge/freezer should be "PH Case Units".
- Calculating the lighting and plug loads should be done on a "per unit" basis using the PHIUS+ Multifamily Calculator.
- User Defined inputs are not applied to any internal patterns, and inputs are simply in kWh/yr. Therefore, when inputting lighting and plug loads as User Defined inputs, this should be for the whole building. (Or, if there are identical units, input per unit and adjust the quantity as needed).

Download the PHIUS+ Multifamily Calculator from the Calculators and Protocols page, which has all of the protocol below embedded.

The basic protocol for lighting and miscellaneous electric loads is that they are calculated at 80% of RESNET (2013) levels for the "Rated Home". [29] RESNET's formulas are intended to apply to living/dwelling units, whether detached or attached, and strictly speaking to buildings of three stories or less. RESNET does not yet have protocol for multifamily common spaces. For PHIUS certification, the scope of the RESNET formulas is expanded to include multifamily buildings four stories or more in height, but applies only to the dwelling units. Supplemental protocol for multifamily common spaces and certain outdoor loads follows Building America House Simulation Protocols (2014). [30] In the formulas, iCFA is used in place of RESNET's CFA and Building America's FFA. The RESNET lighting formulas have been expressed more compactly here but are algebraically equivalent to the published versions. There are additional options for calculating the energy use of pools and elevators.

Miscellaneous Electric Loads (MELs)

For whole-building certification:

$$MEL = MEL_{DWELL} + MEL_{COMM} + MEL_{YARD} \text{ (kWh/yr)}$$

MEL_{DWELL} accounts for the living units.
MEL_{COMM} accounts for the common spaces (if the design includes any).
MEL_{YARD} accounts for Large / Uncommon Electric and Gas loads (if the design includes any).

To facilitate verification, the MEL_{DWELL} calculation must be itemized. This may be done by unit type or floor-by-floor.

For itemization by unit type k:

$$MEL_{DWELL} = \sum_k units_k * (413 + 69 * Nbr_k + 0.91 * iCFA_k) * 0.8$$

k are the unit types.

$units_k$ is the number of units of type k in the building.

Nbr_k is the number of bedrooms in a unit of type k.

$iCFA_k$ is the interior conditioned floor area of a unit of type k. [31]

For purposes of this calculation, $iCFA_k$ may include or exclude the projected floor area of interior partition walls within or between units, whichever approach is simpler to document.

For itemization by floor n:

$$MEL_{DWELL} = \sum_n \left(units_n * 413 + 69 * Nbr_n + 0.91 * iCFA_{DWELL,n}\right) * 0.8$$

n are the floors.

$units_n$ is the number of units on floor *n*.

Nbr_n is the number of bedrooms on floor *n*.

$iCFA_{DWELL,n}$ is the interior conditioned floor area of all the dwelling units on floor *n*, including the partition walls within and between units, but not including the floor area of the common spaces.

For purposes of this calculation, $iCFA_{DWELL,n}$ may include or exclude the projected floor area of interior partition walls to common spaces, whichever approach is simpler to document.

For MEL_{COMM} add the following, or submit a more detailed accounting.

Multifamily Common Space MELs [32]

Room Type	Electricity (kWh/yr)
Office	3.2 x iCFA
Workout room	9.8 x iCFA
Corridor/Restroom/Mechanical	0
Elevator	1,900

Alternate for elevators: More detailed calculations may be made using the following resources.

https://www.thyssenkruppelevator.com/Tools/energy-calculator

http://www.schindler3300na.com/cgi-bin/calc/calc.pl

Although BAHSP has protocol for some "Multipurpose Room MELs", in a whole-building model any television, dishwasher, range, or microwave in a multipurpose room may be neglected – usage of these in the multipurpose room is assumed to displace usage in the units. However, any refrigerators or freezers in a multipurpose room should be added as additional appliances at their rated kWh/day.

For MEL_{YARD} use the table below or perform a more detailed calculation.

Large Uncommon Electric and Gas Loads [33]

Appliance	Electricity (kWh/yr)	Natural Gas (therms/yr)
Pool heater (gas)	-	3/0.014 × Fscale
Pool heater (electric)	10.1/0.0044 × Fscale	-
Pool pump	158.5/0.07 × Fscale	-

Hot tub/spa heater (gas)	-	0.87/0.011 × Fscale
Hot tub/spa heater (electric)	49/0.048 × Fscale	-
Hot tub/spa pump	59.5/0.059 × Fscale	-
Well pump	50.8/0.127 × Fscale	-
Gas fireplace	-	1.95/0.032 × Fscale
Gas grill	0.87/0.029 × Fscale	-
Gas lighting	0.22/0.012 × Fscale	-

Where the scaling factor, F_{scale} = (0.5 + 0.25 Nbr/3 + 0.25 iCFA/1920).

1 therm = 100 kBTU / [3.412 kBTU/kWh] = 29.3 kWh

IndoorPoolCalc, an online spreadsheet from the Washington State University Extension Energy Program, estimates the savings of several energy conservation measures for pools. Download the calculator and background information on the Calculators and Protocols page.

Lighting

The lighting formulas below refer to "qualifying" light fixtures or locations, which means high-efficacy lighting. For residential projects fluorescent hard-wired (i.e. pin-based) lamps with ballast, screw-in compact fluorescent bulb(s), LEDs,

$LIGHTS_{INT,DWELL}$ accounts for the living units. [34]or light fixtures controlled by a photocell and motion sensor, are all considered high-efficacy.

Interior Lighting

For whole-building certification:

$LIGHTS_{INT} = LIGHTS_{INT,DWELL} + LIGHTS_{INT,COMM}$ (kWh/yr)

$LIGHTS_{INT,COMM}$ accounts for the common spaces (if the design includes any).

As with MELs, the $LIGHTS_{INT,DWELL}$ calculation must be itemized. This may be done by unit type or floor-by-floor.

For itemization by unit type *k*:

$$LIGHTS_{INT,DWELL} = \sum_k units_k * (0.2 + 0.8 * (4 - 3 * qFFIL)/3.7) * (455 + 0.8 * iCFA_k) * 0.8$$

$qFFIL$ is the ratio of the qualifying interior light fixtures to all interior light fixtures in qualifying interior light fixture locations.

For itemization by floor *n*:

$LIGHTS_{INT,DWELL} = \sum_n (0.2 + 0.8 * (4 - 3 * qFFIL)/3.7) * \left(units_n * 455 + 0.8 * iCFA_{DWELL,n}\right) * 0.8$

For $LIGHTS_{INT,COMM}$ use the table below for any of the listed Room Types that are included in the design, or submit a more detailed calculation.

Multifamily Common Space Lighting [35]

Room Type	Operating Hours (hrs/day)	LPD (W/ft^2)
Central Restroom	1.6	0.9
Common Laundry	24	0.7
Common Mail	12	2.8
Common Office	9	1
Elevator	24	1.25
Equipment Room	0	1.5
Indoor Corridor	24	0.5
Multi-Purpose	12	1.1
Workout Room	16	0.9

$LIGHTS_{INT,COMM} = (Operating\ hours * operating\ days\ * LPD * iCFA_{COMM})/1000$

Operating hours are per day.

Operating days are per year.

LPD is the lighting power density of the space in W/ft^2.

$iCFA_{COMM}$ is the interior conditioned floor area of each unique common space, not including interior partition walls.

Occupancy Sensors: A 10% reduction in LPD is allowed for common spaces where occupancy sensors are documented in project submission (as in ASHRAE 90.1 Appendix G).
Projects may also complete a custom calculation for reduction in LPD in corridors based on occupancy sensors, using PHIUS MF Interior Corridor Lighting Occupancy Sensor Calculator, downloadable on the Calculators and Protocols page.

Exterior Lighting

$LIGHTS_{EXT} = LIGHTS_{EXT,DWELL} + LIGHTS_{EXT,COMM} + LIGHTS_{GAR}$ (kWh/yr)

$LIGHTS_{EXT,DWELL}$ pertains to exterior lighting for the dwelling units (balcony/porch or general building lights). [36]

$LIGHTS_{EXT,COMM}$ pertains to exterior lighting for the common spaces (exterior courtyards, exterior corridors/stairs, outdoor walkways, etc.)

$LIGHTS_{GAR}$ pertains only if the project includes a garage.*

For itemization by unit type *k*:

$$LIGHTS_{EXT,DWELL} = \sum_k units_k * (1 - 0.75 * FFEL) * (100 + 0.05 * iCFA_k) * 0.8$$

FFEL is the fraction of exterior fixtures that are qualifying light fixtures.

For itemization by floor *n*:

$$LIGHTS_{EXT,DWELL} = \sum_n (1 - 0.75 * FFEL) * (units_n * 100 + 0.05 * iCFA_n) * 0.8$$

For $LIGHTS_{EXT,COMM}$ use the table below for any of the listed Room Types that are included in the design, or submit a more detailed calculation.

Exterior Lighting [37]

Room Type	Operating Hours (hrs/day)	(W/ft^2)
Open Parking*	12	0.15
Outdoor Stairs	12	0.3
Outdoor Walkways	12	0.3

$$LIGHTS_{EXT,COMM} = (Operating\ hours * operating\ days * LPD * iCFA_{COMM})/1000$$

$Operating\ hours$ are per day.

$Operating\ days$ are per year.

LPD is the lighting power density of the space in W/ft^2.

$iCFA_{COMM}$ is the interior conditioned floor area of each unique common space, not including interior partition walls.

Garage lighting may be calculated by the “80% RESNET” formula [38], BA default, or a more detailed calculation.

$LIGHTS_{GAR} = Units * 100*(1\text{-}0.75*FFGL) * 0.8$

Units is the total number of dwelling units in the building

FFGL is the fraction of garage fixtures that are Qualifying Light Fixtures.

Garage Lighting* [39]

Room Type	Operating Hours (hrs/day)	W/ft^2
Parking Garage*	24	0.2

*Note: PHIUS does not require projects to include lighting energy for an open parking lot / parking garage, block heaters, or vehicle charging in the energy model for certification. For now, these are considered to be part of the "transportation sector" as opposed to the "building sector".

6.6.2 Non-Residential

Utilization Pattern

The internal loads and occupancy calculation for non-residential projects begins with the definition of utilization patterns. These patterns are used for two purposes: lighting energy calculation and internal gains due to people and the equipment they use.

A utilization pattern consists of a set of several parameters:

- Beginning hour
- Ending hour
- Days/year
- Illumination level
- Height of utilization (0 or 2.62 ft)
- Relative absence
    - 1 = Occupants always absent
    - 0 = Occupants never absent
- Part use factor of building period for lighting
    - 1 = No reduction in lighting energy
    - 0 = Full reduction in lighting energy

A set of standard default patterns (per DIN V 18599-10:2007-02, Table 4) is shown in the table in Section 6.6.2.1 below. [40]

The illumination level, height of utilization, and part-use factor for lighting enter only into the lighting calculation.

The average occupancy (in ft^2/person) can be entered. It factors into the total occupancy associated with a utilization pattern if the mode of planning for occupancy is floor-area-based rather than direct entry. It influence the calculation of gains from people and the equipment they use if any equipment is assigned to that Utilization Pattern.

The other parameters enter into both the lighting and internal gains calculations.

Often, more utilization patterns will be needed for lighting purposes than for internal gains. For example in an office building with single-shift operation and everyone typically sitting at desks, a single pattern could suffice for internal gains due to people, but if there are space types that require a few different illumination levels, more patterns would be needed for lighting. That is, it may be necessary / appropriate to define utilization patterns that "overlap" in order to support the calculations for internal gains, lighting, and equipment electricity use.

In the table in Section 6.6.2.1, the patterns are grouped by required illumination level. The first step in the analysis is to identify the different space types that are present, from the floorplan. In the lighting calculation, the patterns can be applied room-by-room. Grouping of rooms may be appropriate if they share a pattern (or ones with similar required illumination) and have similar access to daylight.

6.6.2.1 Utilization Pattern

Standard Default Patterns (per DIN V 18599-10:2007-02, Table 4) for Internal Loads and Occupancy Calculations for Non-Residential Buildings

SPACE TYPE	BEGINNING OF USAGE (TIME)	END OF USAGE (TIME)	ANNUAL UTILIZATION DAYS (d/a)	MAINTAINED ILLUMINANACE (lux)	HEIGHT OF THE WORK PLANE (ft)	RELATIVE ABSENTEEISM	FACTOR FOR LIGHTING RELATIVE TO BUILDING OPERATION TIME
Garage buildings (for offices and private use)	7:00	18:00	250	75	0	0.95	1
Garage buildings (public use)	9:00	0:00	365	75	0	0.8	1
Traffic /circulation areas	7:00	18:00	250	100	0	0.8	1
Auxiliary spaces (without habitable rooms)	7:00	18:00	250	100	2.6	0.9	1
Storeroom, technical equipment room,archive	7:00	18:00	250	100	2.6	0.98	1
Library - magazine and stores	8:00	20:00	300	100	2.6	0.9	1
Booking hall	7:00	18:00	250	200	2.6	0	1
Hotel bedroom	21:00	8:00	365	200	2.6	0.25	0.3
Canteen	8:00	15:00	250	200	2.6	0	1
Restaurant	10:00	0:00	300	200	2.6	0	1
Toilets and sanitary facilities in non residential buildings	7:00	18:00	250	200	2.6	0.9	1
Spectators and audience area (theaters and event locations)	19:00	23:00	250	200	2.6	0	1
Exhibition rooms and museums with conservation requirements	10:00	18:00	250	200	2.6	0	1
Library-open stacks areas	8:00	20:00	300	200	2.6	0	1
Retail shop/Department store	8:00	20:00	300	300	2.6	0	1
Retail shop/department store (food department with refrigerated products)	8:00	20:00	300	300	2.6	0	1
Classroom (school and nursery school)	8:00	15:00	200	300	2.6	0.25	0.9
Hospital ward or dormitory	0:00	24:00	365	300	2.6	0	0.5
Kitchen - preparation room or storeroom	7:00	23:00	300	300	2.6	0.5	1
Other Habitable Room	7:00	18:00	250	300	2.6	0.5	1
Foyer (theaters and event locations)	19:00	23:00	250	300	2.6	0.5	1
Fair/Congress building	13:00	18:00	150	300	2.6	0.5	1
Sports hall (without public viewing area)	8:00	23:00	300	300	2.6	0.3	1
Personal office (single occupant)	7:00	18:00	250	500	2.6	0.3	0.7
Workgroup office (two to six workplaces)	7:00	18:00	250	500	2.6	0.3	0.7
Landscaped office (seven or more workplaces)	7:00	18:00	250	500	2.6	0	1
Meeting, conference and seminar room	7:00	18:00	250	500	2.6	0.5	1
Lecture room, auditorium	8:00	18:00	150	500	2.6	0.25	0.7
Kitchens in non-residential buildings	10:00	23:00	300	500	2.6	0	1
Server room, computer center	0:00	24:00	365	500	2.6	0.5	0.5
Workshop, assembly,manufacturing	7:00	16:00	250	500	2.6	0	1
Library - reading rooms	8:00	20:00	300	500	2.6	0	1
Stage (theaters and event locations)	13:00	23:00	250	1000	2.6	0	0.6

6.6.2.2 Occupancy

- **Occupant Quantity:** The top-level occupancy entry should reflect the average day occupancy. This value influences total DHW consumption, daily tap openings for DHW distribution losses, and the 'Supply air due to persons' ventilation requirement shown under Ventilation/Rooms>Utilization Pattern.
    - This entry does not influence the internal heat gains related to occupants.
- **Occupant Groups:** Occupant groups should be entered in the lines below.
    - Generally, each unique space type should have a new line entry.
    - Planned occupancy for the space should be entered.
        - Keep in mind that the relative absence on the 'Utilization Pattern' tab is relative to this occupancy.
    - Be careful not to double count occupants.
        - For example, if there is an office with 20 desks, that should be input with the 20 occupants. If there are also two conference rooms that serve the same occupants that occupy the desks, do not also add the conference room with 20 occupants, or that will double count the occupants. The conference room can be a separate line item for lighting, but not for occupancy.
    - Not all space types need designated occupants or entries on this tab.
        - Transient spaces such as, stairwells, restrooms, storage spaces, etc. may have occupants at certain times, but those occupants should be included in the space types where they will reside the majority of the time they occupy the space.

- **Heat loss due to evaporation (per person):** Default value of 51.2 BTU/hr
- **Number of flush toilets**: Enter the total number of toilets in the entire building.
- **Toilet Utilization Pattern**: The utilization pattern with the most 'Annual utilization days' should be selected.

6.6.2.3 Office Equipment

Planned equipment for the building should be input here.

- Pre-defined equipment types are built in.
- Power Rating [W] must be input for all equipment.

See Appendix D – ASHRAE Fundamentals Non-Residential Equipment Tables below for guidance on office equipment power ratings.

PC, Monitor:

- A utilization pattern must be assigned to each of these equipment types.
- The amount of time in operational mode vs power saving mode is built in.

Copier, Printer:

- A utilization pattern must be assigned to each of these equipment types.

- The number of hours in energy savings mode will be calculated automatically. Or, you may define this number. The number of hours input here is out of the total hours in the Utilization Pattern – not out of all 8760 hours in a year.

Telephone system:

- The quantity should be input, and the energy use is not dependent on the number of occupants.

User Defined:

- Enter the Power Rating [W] and the Utilization Hours per year.
- May be used for any miscellaneous items that do not fit the built-in options.
- External calculation for equipment energy use may be completed to determine kWh/yr. To input these external results:
  - Enter the resulting kWh/yr as the Power Rating [W]
  - Enter 1000 hrs/yr for the utilization
  - The result will be [W] x 1 khr/yr = kWh/yr.

6.6.2.4 Kitchen Equipment

Planned kitchen equipment for the building should be input here.

- Pre-defined equipment types are built in.

Cooktop:

- Utilization pattern must be defined to define the utilization days per year.
- Number of meals per utilization day refers to the total number of meals cooked in that zone, per day.
  - By default, the model will assume 0.25 kWh/meal for cooking energy.
- Quantity can also be input. Be sure not to double count the meals by adjusting the quantity. If quantity is adjusted, meals per individual cooktop should be input.

Dishwasher

- Utilization pattern must be defined to define the utilization days per year.
- Number of meals per utilization day refers to the total number of meals cooked (place settings washed) in that zone, per day.
  - By default, the model will assume 0.055 kWh/meal for dishwashing energy.

Refrigerator

- Norm demand [kWh/day] must be input.
- This data is available from Energy Star for residential fridges and some commercial fridges.

- To estimate energy use for walk-in fridges/freezers, an external calculator is available for download here.

User Defined

- May be used for any miscellaneous items that do not fit the built-in options.
- External calculation for equipment energy use may be completed to determine kWh/yr. To input these external results:
    - Enter the kWh/yr calculated into the 'kWh/day' field
    - Enter 1 day/yr
    - The result will be kWh/day x 1 day/yr = kWh/yr

6.6.2.5 Lighting

Space types should be split out into individual line items here.

If multiple Utilization Patterns are used to define the full usage hours for a single space, that space must be entered multiple times on this sheet and assigned to the appropriate Utilization Patterns to cover all hours of usage.

Fraction of conditioned floor area:

- This should generally add up to 1 for any given Utilization Pattern.

Daylighting: WUFI Passive will estimate daylighting potential by requiring the following inputs:

- **Derivation from North**: 0=North, 180=South
- **Glazing Visible Transmittance:** Select a pre-defined option, or enter User Defined if known. This value is generally provided by window manufacturers.
- **Room Depth**: Enter the room depth starting from a window on the wall defined in the Derivation from North.
    - For example, if you input 180, select a 'typical' window on the south wall and measure to the north wall enclosing that space.
- **Room Width:** Measure in the opposite direction of the Room Depth described above.
- **Room Height**: Floor to ceiling height.
- **Façade has windows**: Check this box if applicable. If not applicable, do not check the box and no daylighting potential will be assumed.
- **Lintel height**: Height of the typical window head from the floor.
- **Window width**: Sum of all the window widths on the wall specified above for 'Derivation from North'.

Installed Lighting Power: Value should be input in W/ft^2. PHIUS requires lighting plans and documentation to verify these values.

- Values entered here will override 'illuminance [lux]' entries from the Utilization Pattern.

Lighting full load hours: This entry will over-ride all entries utilized for the daylighting calculation built into the software.

- The daylighting calculation utilizes the Derivation from North, Glazing Visible Transmittance, Room Width/Depth/Height, Façade with windows checkbox, lintel height, and window width.

6.6.2.6 Process Loads

As mentioned in Section 3.3.4, process load allowances may be defined for commercial projects. Each unique process load should be input as an individual line item.

- Total energy in kWh/use may be input, or
- Power Rating [W] and Annual use hours [hr] may be used with the built in […] calculator

Include in Source Energy Total: This checkbox allows the modeler to include/remove this process load in the calculated source energy total for the purposes of verifying compliance with the base source energy target before process loads and allowances are included.

Increase Source Energy Allowance: This checkbox allows the modeler to adjust the source energy target by including the process load allowance in the model. This will auto-adjust the Source Energy target in the results to include this allowance

- Note: Process load allowances must be reviewed and approved by PHIUS.

6.7 Ventilation/Rooms

6.7.1 Utilization Pattern

The *maximum* design airflow is determined by the largest of 2 factors:

1. Supply air requirement (based on occupancy)
2. Exhaust air requirement (based on kitchens, baths, etc.)

The capacity of the ventilation system installed needs to exceed whichever rate is greatest (see Section 3.5).

*For pre-certification, it is recommended (but not required) that residential projects model with a ventilation rate of 0.3 ACH or higher.

The average air flow rate (cfm) and average air change rate (1/hr) is calculated as a reduction from the "design air flow rate". It is determined by the daily operation schedule and "fraction of design" airflow at the scheduled hours.

For non-residential projects, multiple utilization patterns may be set up to reflect varying levels of ventilation rates for different days (i.e. weekday vs weekend). Alternatively, one utilization pattern may be used and the 'daily operation schedule' can be revised to reflect the appropriate ratios of design airflow rates during occupied and unoccupied hours.

6.7.2 Rooms Ventilation

In WUFI Passive, it's best practice to enter both exhaust rooms and supply rooms, though only exhaust room entries are required if the model is setup with 'Balanced Ventilation' (under PH Case>Additional Data).

- Entering all rooms ensures the ventilation design is balanced.
- "Supply rooms" *must* be entered if there is to be more than one H/ERV device entered.
- When adding exhaust rooms, input 0 cfm supply. When adding supply rooms, input 0 cfm exhaust.

For multi-unit buildings with repeated exhaust rooms, the room may be input once and the quantity adjusted appropriately. For example, a 50-unit MF building with 50 kitchens may have a single line entry for the kitchen, quantity 50, if the exhaust flow rate is planned to be the same for all kitchens.

PHIUS recommends starting with the following exhaust rates as rules of thumb:

Kitchen: 35cfm

Bathroom: 24 cfm

Half Bath: 12 cfm

6.7.3 Summer Ventilation

Summer ventilation may be notionally either natural, via windows, or mechanical automatically controlled (e.g. whole house exhaust fan.)

Summer Bypass

<u>Summer/HRV Humidity Recovery</u>: Most heat recovery ventilation units (Both ERVs and HRVs) can bypass heat recovery in the summer condition, when outdoor temperatures are more favorable than indoor. Also referred to as 'economizer mode'. Typically, this is temperature-controlled bypass.

- <u>None</u>: If there is no heat/moisture recovery ventilation during the summer.
- <u>Temperature-controlled bypass:</u> If the bypass mode is activated based temperature.
- <u>Enthalpy-controlled bypass:</u> If the bypass mode is activated based on both temperature and humidity/moisture.
- <u>Always:</u> If there is no bypass mode and recovery mode is always active.

Additional Summer Mechanical Ventilation

Use these inputs when implementing a mechanical exhaust system in addition to the ERV. Ex: whole house fan. Use [Mechanical automatic controlled ventilation] if the system is tied to sensors for either temperature or humidity difference and define the control system in WUFI Passive.

- ACH via mechanical ventilation exhaust air
- Mechanical automatic controlled ventilation
- Specific Power Consumption

Summer Natural Ventilation (day)

ACH via natural ventilation (day)**:**

- If a cooling system is planned, no natural ventilation may be included in the model. An entry of '0' is required for PHIUS+ 2018 certification.
- If no cooling is planned, up to 0.3 ACH may be used.

Summer Mechanical Ventilation by the HRV/ERV

ACH via mechanical ventilation:

This value should match the year round average ACH from the ERV/HRV. In WUFI Passive, if you leave this cell empty, it will use your typical year round operation rate of the ERV.

If the climate allows for summer ventilation to be taken care of through windows and other passive features, and the HRV/ERV will be shut off, input 0 here.

**Note: Occupants must provide other means of ventilation if turning off continuous ventilation system.*

Additional Summer Ventilation (night)

ACH via natural ventilation (night)**:**

- If a cooling system is planned, no natural ventilation may be included in the model. An entry of '0' is required for PHIUS+ 2018 certification.
- If no cooling system is planned:
  - Be cautious and realistic with the amount of natural ventilation being counted on for cooling. There are two main concerns with the amount of cooling.
    1. Humidity - look for dew point temperature in the Climate Data. In many climates in the United States, there are high levels of humidity in the cooling situations.
    2. The built-in summer ventilation calculator can generate quite high air change rates, but during the night usually interior doors are closed so that cross ventilation is cut off.
  - For PHIUS+ Certification, either:
    1. Account for no higher than 0.3 ACH for nighttime ventilation; or
    2. Follow Building America House Simulation Protocol, which states: 33% of the

open-able windows are opened. This can happen 3 days a week (M, W, F), which would translate, to a fraction of opening duration of 43%, Or 10.3 hrs/day.

a. Use the additional calculator found under Summer Ventilation in WUFI Passive Model each window in one column. A second window group is allowed for stack effect and cross ventilation only for day, not night (unless there are no intervening doors.)

6.7.4 Exhaust Ventilation

Exhaust Air Appliances:

- In WUFI Passive, account for the exhaust appliances on the Ventilation/Rooms > Exhaust Appliances tab.
  - There are pre-defined devices for dryers and kitchen cooktops, which are tied to the annual usage patterns of the dryer and cooktop.
- Bathrooms with direct exhaust fans: There are two acceptable methods to account for this:
  - Assume 60 min/bathroom/day per BAHSP protocol
    - Exhaust volume flow rate [cfm]: Sum total bathroom exhaust fans in the building and enter that here
    - Run time per year [min]: Use (365 days/yr * 60 min/day) = 21,900 minutes/yr
  - Alternate: Assume 30 min/person/day
    - Exhaust volume flow rate [cfm]: Average exhaust flow rate of all bathroom exhaust fans in the building. Enter that exhaust rate for the *average* bathroom here.
    - Run time per year [min]: (30 min/occ/day * Occupants * 365 days/yr) = minutes/yr

Tips:

- Consider moving an exhaust dryer to the mudroom or outside the thermal envelope.
- Make-up air for a directly vented range hood is acceptable as long as the total meets the source energy requirements. If a make-up air system is planned then it can be tied directly to a vented dryer as well, i.e. it comes on when the dryer is running and venting.

Multiple Exhaust Dryer Protocol:

If a community building or similar is serving multiple buildings with a laundry room, multiple exhaust dryers with high usage patterns put a lot of load on the space conditioning system. If the makeup air is either fully ducted to the dryer case, or even near / behind it, then the makeup air may be regarded as not mixing with the room air and therefore does not increase the load/demand on the space heating/cooling system, because the room thermostat will not ever feel it. The extra energy must be accounted for, but it is considered to be moved from the space-conditioning category to the source energy category. That accounting may be done as follows:

- Duplicate the existing case, create a new 'test' case.
- Add the dryers to the Exhaust Appliances tab in WUFI Passive .
- Take the *difference* between the added heat demand and the added cooling demand. (On the theory that cold air makes the dryer work harder, warm air makes it work easier, than it does under its rated conditions.)
- Convert that to a source energy using the COP and SE factor of the dryer. Divide by 2.8 (source energy factor for electricity) and enter the result as an auxiliary electric load outside the thermal envelope.
- Furthermore, it is recommended to install an electric heater in the makeup air duct (near the point of entry) capable of raising the air temperature to at least 49 F (dew point of 68 F air at 50% RH.)
- If the dryer is not electric resistance, the SE factor in the above energy calculation should be adjusted with a seasonal weighting based on the percentage of the year that the makeup air heater would be expected to operate. This would prevent the makeup air from causing a frost or condensation problem.

Notice that, if the space heating system is efficient or has a low source energy factor, a heated makeup air duct may actually use more energy overall in a site or source energy sense. Therefore this is not necessarily the best strategy in all cases. It is offered as an option that may help some smaller buildings meet the certification criteria for space conditioning.

6.8 Thermal Bridges

To learn how to use THERM software developed by Lawrence Berkeley National Laboratory (LBNL) to calculate thermal bridges, an introductory training package may be purchased from the THERM Introduction page on the PHIUS website.

PHIUS has created a Psi-Value Calculator Template for consultants to use to document and calculate a project's thermal bridges.

Negative Thermal Bridges: If accounting for any negative thermal bridges, all thermal bridges in the project must be calculated, no matter how small. In general, we recommend against taking negative thermal bridges in the design phase, and only using these as a "last line of defense".

Temperature Zone Assignments in WUFI Passive

WUFI Passive Attachment	Temperature conditions in psi-value calculation		
	Interior (68F)	Exterior (14F)	Ground (41F)
Ambient	x	x	
Perimeter	x	x	x
Basement Floor	x		x

- Ambient**:** Use this selection for thermal bridges occurring above grade. Only two temperatures will be used in the THERM/psi value calculation -- ambient and interior.
- Perimeter: Use this selection for thermal bridges occurring at grade. In this case, there will be

three temperature zones used in the THERM calculation -- ambient, ground, and interior.

- Ground Floor: Use this selection for thermal bridges below grade. Only two temperatures will be used in the THERM calculation -- ground and interior.

6.9 Attached Zones & Remaining Elements

6.9.1 Attached Zones

Reduction Factors for Tempered Spaces

In passive house verification mode, the lowest reduction factor currently allowed for PHIUS+ Certification is >0.95. One example of this is a garage. Garages may be warmer in the winter and afford a reduction to the assemblies that come into contact with it. However, it also could be warmer in the summer. The exact reduction factor can't be calculated in passive house verification mode and a conservative approach is being taken.

If there is an infill project built directly adjacent to existing buildings, the walls neighboring the existing building can be assumed adiabatic if the space is occupied and residential or if the space is non-residential and always conditioned. The neighboring walls should be set to 'Space with same inner conditions'. (This will result in a slightly higher heating load than setting up the neighboring building as an 'Attached Zone w/a temperature reduction factor of 0').

6.9.2 Remaining Elements

Any components with 'Outer Air' or 'Ground' assigned to both the 'Inner side' and 'Outer side' will appear as remaining elements. This may include shading elements that are outside of the thermal boundary, a roof over a vented attic, etc.

The remaining elements only influence the calculation via the dynamic shading calculation. No heat transfer is considered through these components.

6.10 Systems

In WUFI Passive, systems consist of a set of devices. Often times, only one 'System' is needed per building. There are cases where multiple systems must be used, such as to add system capacity, or due to a limitation in the WUFI Passive software. More details below.

Devices must be added to cover Space Heating, Space Cooling (if applicable), Mechanical Ventilation and Domestic Hot Water (DHW).

System Coverage: If there is more than one 'device' serves the same purpose, both devices should be added, and the appropriate coverage must be assigned for each. Coverage can be determined based on the capacity of each piece of equipment used (i.e. if multiple different heat pumps are used with different performance ratings), or priority (i.e. heat pump for heating with backup electric resistance heaters). Coverage is assigned below the device list.

6.10.1 DHW Distribution

Domestic Hot Water (DHW)

Make sure the reviewer can verify the hot water distribution technology from the mechanical drawings. Document the actual pipe lengths used for the applicable entries described below.

Design Flow Temperature: This is used to calculate the circulation pipe losses. PHIUS will accept between 120-140°F. It's recommended, and common, to insulate plumbing. This is mostly to improve efficiency and slow the heat transfer from the pipe to the interior environment. Although this is recommended, it is not required.

6.10.1.1 Circulation Pipes

- **Length of Circulation Pipes:** A true circulation loop has hot water running through it for a certain period each day. Referred to below as 'Continuous or time-based recirculation'. The full length of these pipes should be entered here.
  - Recirculation systems are found most often in large or commercial buildings.
  - For this entry, determine the length of the circulation loop.
    The default calculation for the recirc pumping energy auto-sizes a pump based on the gross enclosed volume of the building, and conservatively assumes 24 hour a day operation. This can be overridden.
- **On-Demand Recirculation:** When recirculation is triggered by a demand-based system, rather than continuous/time-based, do NOT enter this as circulation pipes.
  - Use the 'Individual pipes' entry, select 'Hot water piping calculator'. See below.
    - The cautious view is that an on-demand system saves water, but it does not save much water heating energy, because the pipes cool off between uses like the individual branch pipes.
- **Daily running hours of the circulation:** 24 hours for continuous, or lower for time-based.
  - PHIUS strongly discourages, but shall not prevent, the use of continuous or time-based hot water circulation systems.

6.10.1.2 Individual Pipes – Calculation Methods

1. **Simplified Individual Pipes**

This method should be used for all non-residential projects.

- **Length of individual pipes:**
  - To determine this, determine the distance from the HW tank/tankless heater to each individual hot water tap. Sum these distances to find the total length of individual pipes.
  - For hot water pipes to the clothes washer and dishwasher, exclude the length of these pipes, or more conservatively, apply a reduction factor of 0.06 to the length.
  - If the project is using a continuous or time-based circulation loop, determine the distance from the recirc loop to each individual hot water tap. Sum these

distances to find the total length of individual pipes. (Note that a supporting drawing / diagram is part of the required documentation.)

- **Exterior Pipe Diameter:** Typically add ⅛" inch to the nominal pipe dimension to determine the exterior dimension. Projects using a variety of HW pipe thicknesses may use a weighted average for this value.

2. **Simplified hot water piping calculator**
   - May be used early in design. Not accepted for pre-certification.
   - **Pipe material**: Select the pipe material used. More information can be found in Appendix I.
   - **Pipe diameter**: Nominal pipe diameter in inches.
   - **Number of bathrooms**: Sum of all bathrooms in building covered by the DHW device in this 'System'.
     - If multiple 'Systems' with DHW devices are defined in WUFI Passive, do not double count bathrooms.
3. **Hot water piping calculator (unit/floor method)**
   - This calculation method is required for all residential PHIUS+ 2018 projects.
   - This calculator estimates hot water distribution losses, as well as 'time to hot' used to aid in the design of a DHW distribution network that will meet the EPA WaterSense Hot Water Delivery requirements.
   - The length of Demand-based recirculation pipes SHOULD be entered here. The length of time-based or continuous hot water recirculation pipes SHOULD NOT be entered in this section, but rather above under Circulation Pipes.
     - *Hint:* When considering how to enter the DHW distribution network, consider the source of the 'hot' water, as well as the full path from the source of the hot water to each individual tap.
   - For the purposes of this calculation, hot water lines to dishwashers and clothes washers can be ignored.
   - Sample DHW Distribution takeoff and WUFI Passive entry screen inputs can be found on the Calculators and Protocols page.

6.10.1.3 Individual Pipes – Steps for 'Hot Water Piping Calculator'

Step 1: Choose method based on layout and distribution method.

Unit Type Method**:** Use for any DHW system where hot water source* reaches the individual dwelling unit.

- Use for decentralized DHW systems i.e. 1 water heater in each unit OR central DHW systems with continuous or time-based hot water recirculation.

Floor Type Method**:** For semi/centralized DHW systems where hot water source* is not located at the unit.

- Use for or semi/centralized systems with demand-based recirculation or no recirculation.

*Hot water source: Hot water heater or continuous/time-based hot water recirculation loop

Unit Count		Location of Water Heater(s)			Recirculation Type			Unit Type Method	Floor Type Method
Single	Multiple	At unit	Semi de-centralized	Central	None	On-Demand	Continuous or Time-Based		
x	x	x			x	x		**X**	
	x		x	x			x	**X**	
	x		x	x	x	x			**X**

----- Follow path below for method selected. -----

UNIT TYPE METHOD:

Step 2: Summarize DHW trunks → create list of each unique unit type. A unit type is designated as 'unique' if it has a unique DHW layout.

- Name: Name trunk based on Unit Type (i.e. A, B, C, etc). If a single unit building, would recommend naming trunks based off 'zones/spaces' that the trunk serves.
- Length: The trunk always starts at the hot water heater or recirculation loop and runs to a distribution branch.
- Quantity: Number of times this unique unit occurs.

Step 3: Summarize DHW twigs → create a list of hot water fixtures in each unique unit type. The twig is the small diameter piping that serves an individual fixture.

- Name: Name based on DHW tap in the unique units listed above, with a 'T' at the front or end.
- Length: A twig only serves one fixture. To determine twig length, work from the fixture back to a central pipe that serves more than one fixture (branch).
  - Enter the entire twig length from the adjoining branch for each fixture no matter how many turns/twists.

Step 4: Summarize DHW branches → create list of branches connecting trunk to twig. Each twig will have its own branch, running from the trunk to the twig.

- Name: Name based on DHW tap in the unique units listed above (same as twig but without 'T')
- Length: Total length between twigs and trunks above.
- If a twig connects directly to a trunk, enter a branch with a length of '0' and connect the twig to that branch.
- Sometimes a branch off the trunk may only serve one fixture. In that case, it could all be considered a twig, or could be split into a branch and a twig. If the pipe dimension and

material are the same, either method will yield the same results.

Step 5: Enter information from spreadsheet above into WUFI Passive.

- A segment must be entered first with the trunk, then connecting branch, then connecting twig.
- To 'connect' a branch to a trunk, you must first click on the trunk, then add that branch.
- To 'connect' a twig to a branch, you must first click on the branch, then add that twig.
- Be careful to ensure you are always connecting the appropriate segments.

Step 6: Use the 'Watersense met?' column built into the twig entries to estimate whether all fixtures will pass the EPA WaterSense Hot Water Delivery requirement.

- This is an on-site test that applies to most residential projects.
- This tool is used to aid in design of a DHW distribution network that will pass on-site testing, but does not guarantee it.
- If a twig is not passing in the model, it is recommended to revise the tap location or circulation strategy for that tap.

Step 7: Double check entries:

- All trunks must have branch entries
- All branches must have twigs connected.
- Quantities must appropriately represent the building distribution network.

<u>FLOOR TYPE METHOD:</u>

Step 2: Summarize DHW trunks → create list of *unique* floors, and then list each unit number on those unique floors. A floor is designated as unique if the count or configuration of dwelling units varies from another floor.

- <u>Name:</u> Name trunk based on unit number (i.e. 401, 402, 403). If vertical risers, select an 'average' floor for unit numbers (about half-way up, see more below).
- <u>Length</u>: Trunk always starts at semi/central water heater and ends at the dwelling unit.
  - <u>On-demand recirculation loops</u>:
    - Enter only the Supply side of the loop, omit Return portion (downstream of last fixture and recirc pump temperature sensor.)
    - Check the box for 'demand-recirculation'. This will reset the 'up-stream volume' for any branch connected to that trunk, i.e. it will assume the branch will always be served with hot water and the trunk length should not be considered when estimating the 'time to hot' for the EPA WasterSense Hot Water Delivery test.
      - The on-demand recirculation pipes must still be entered to accurately account for DHW pipe distribution losses, even though it resets the volume in the trunk for the 'time to hot' calculation.
  - <u>Vertical Risers:</u>

- Determining the average vertical distance from the water heater to each unit.
- If all residential building:

  Calculating average vertical run: (# Floors * Floor-to-floor height)/2

  # **Floors:** Includes the floor the water heater is located on, even if there are no residences on that floor.

  - Ex 1: If there are 8 identical residential floors, the water heater is in a mechanical penthouse on the 9th floor, and floor-to-floor heights are 12', then use (9*12)/2 = 54 ft.

- If mixed-use building:

  Calculating average vertical run: ((Distance from water heater to residential floor + (# Floors * Floor-to-floor height))/2

  # **Floors:** Do not include floor water heater is located on.

  - Ex 2: Mixed use (floors 1-2), 8 residential floors (floors 3-11), all floors 12' in height and water heater in basement, then use ((36' + (8*12))/2 = 66 ft.

- Quantity: This is number of times this unique floor occurs.

Step 3: Summarize DHW twigs → create a list of hot water fixtures in each unique unit type. The twig is the small diameter piping that serves an individual fixture.

- Name: Name based on DHW tap in the unique units listed above, with a 'T' at the end.
- Length: A twig only serves one fixture. To determine twig length, work from the fixture back to a central pipe that serves more than one fixture (branch).
  - Enter the entire twig length from the adjoining branch for each fixture no matter how many turns/twists.

Step 4: Summarize DHW branches → create list of branches connecting trunk to twig. Each twig will have its own branch, running from the trunk to the twig.

- Name: Name based on DHW tap in the unique units listed above (same as twig but without 'T')
- Length: Total length between twig and trunk above.
- If a twig connects directly to a trunk, enter a branch with a length of '0' and connect the twig to that branch.
- Sometimes a branch off the trunk may only serve one fixture. In that case, it could all be considered a twig, or could be split into a branch and a twig. If the pipe dimension and material are the same, either method will yield the same results.

Step 5: Enter information from spreadsheet above into WUFI Passive.

- A segment must be entered first with the trunk, then connecting branch, then connecting twig.
- To 'connect' a branch to a trunk, you must first click on the trunk, then add that branch.

- To ‘connect’ a twig to a branch, you must first click on the branch, then add that twig.
- Be careful to ensure you are always connecting the appropriate segments.
- Note that pipe material, diameter, and length must be added for each new segment.

Step 6: Use the ‘Watersense met?’ column built into the twig entries to estimate whether all fixtures will pass the EPA WaterSense Hot Water Delivery requirement.

- This is an on-site test that applies to most residential projects.
- This tool is used to aid in design of a DHW distribution network that will pass on-site testing, but does not guarantee it.
- If a twig is not passing in the model, it is recommended to revise the tap location or circulation strategy for that tap.

Step 7: Double check entries:

- All trunks must have branch entries
- All branches must have twigs connected.
- Quantities must appropriately represent the building distribution network.

Four example layouts are described below:

	Units	Location of Water Heater	Recirculation	Method
A	Single	At unit	On demand	Unit Type
B	Multiple Units	Semi de-centralized or Central	Continuous/Time-Based	Unit Type
C	Multiple Units	Semi de-centralized or Central	On demand	Floor Type
D	Multiple Units	Semi de-centralized or Central	None	Floor Type

A. Example Single Unit, On-demand recirculation (Unit Method):

Trunks	Branches	Twigs
Bathroom Floor 1	Bathroom Sink 1 (BS-1)	BS-1-T
	Shower 1 (S-1)	S-1-T
Bathroom Floor 2	Bathroom Sink 2 (BS-2)	BS-2-T
	Shower 2 (S-2)	S-2-T
Kitchen	Kitchen Sink (KS)	KS-T

<u>Trunk:</u> In this case, the trunk may serve rooms or ‘zones’. Check box for ‘Demand Recirculation’.

- Bathroom Floor 1
- Bathroom Floor 2
- Kitchen

<u>Branch:</u> Starting by clicking on ‘Bathroom Floor 1’ trunk and enter each tap name off of that trunk.

- Bathroom Sink 1 (BS-1)
- Shower 1 (S-1)

Etc. Repeat for all trunk zones listed above.

Twig: Starting by clicking on 'Bathroom Sink-1', enter the twig:

- BS -1– T

Etc. Repeat for all fixtures listed above.

B. **Multiple Units, Semi/Central WH, Continuous/Time-Based Recirculation (Unit Method):**

Quantity Unit Types	Trunks	Branches	Twigs
10	Unit A	Kitchen Sink (KS)	KS-T
		Bathroom Sink 1 (BS-1)	BS-1-T
		Bathroom Sink 2 (BS-2)	BS-2-T
		Shower (S)	S-T
12	Unit B	Kitchen Sink (KS)	KS-T
		Bathroom Sink 1 (BS-1)	BS-1-T
		Shower (S)	S-T
8	Unit C	Kitchen Sink (KS)	KS-T
		Bathroom Sink 1 (BS-1)	BS-1-T
		Bathroom Sink 2 (BS-2)	BS-2-T
		Bathroom Sink 3 (BS-3)	BS-3-T
		Shower (S)	S-T

Trunk:

- Unit A
- Unit B
- Unit C

Branch: Enter each unique fixture type as a branch for each trunk. Example for Unit A.

- Kitchen Sink (KS)
- Bathroom Sink - 1 (BS-1)
- Bathroom Sink - 2 (BS-2)
- Shower (S)

Twig: Click on 'Kitchen Sink (KS) branch', then add the KS twig (KS-T).

- Kitchen Sink (KS)
  - KS-T

Click on 'Bathroom Sink (BS-1) branch', then add the BS twig (BS-1-T).

- Bathroom Sink - 1 (BS-1)
  - BS-1-T

Etc. Repeat for all fixtures listed above.

C. **Multiple Units, Semi/Central WH, On-Demand Recirculation (Floor Method):**

Floor Type	Trunks	Branches	Twigs
1	Unit 401	Kitchen Sink (KS)	KS-T
		Bathroom Sink 1 (BS-1)	BS-1-T
		Bathroom Sink 2 (BS-2)	BS-2-T
		Shower (S)	S-T
	Unit 402	Kitchen Sink (KS)	KS-T
		Bathroom Sink - 1 (BS-1)	BS-1-T
		Shower (S)	S-T
	Unit 403	Kitchen Sink (KS)	KS-T
		Bathroom Sink 1 (BS-1)	BS-1-T
		Bathroom Sink 2 (BS-2)	BS-2-T
		Shower (S)	S-T

Trunk: Check box for 'Demand Recirculation' if applicable. Length includes vertical pipe length when applicable.

- Unit 401
- Unit 402
- Unit 403

Branch & Twig: Follow Example B.

D. **Multiple Units, Semi/Central WH, No Recirculation (Floor Method):**
Same as method 'C', but un-check 'Demand-Recirculation' for trunk.

6.10.2 Cooling

Cooling system properties are entered under System>Distribution>Cooling, rather than in individual cooling devices. If you are specifying varying cooling systems, add a new 'System', and a new device for cooling in that new system. It is not currently possible to enter varying cooling performance specifications when two cooling devices are included in the same 'System'.

- **Coverage:** WUFI Passive will estimate the available cooling coverage based on system entries. If the cooling demand is not covered, this will appear as a warning under the 'Data state/results' box. If the cooling demand is not coverage, capacity must be increased either by changing the numerical entries or adding an additional cooling system.
- **Cooling via ventilation air:**
    - Use this for cooling systems that cool incoming fresh air/outdoor air supply, in-line with the ventilation, and are not using additional airflow to satisfy the cooling needs.
    - Supply air cooling capacity: From manufacturer, based on available ventilation airflow and cooling coil.

- Supply air cooling COP: Use EER/3.412

- **Recirculation Cooling:**
  - Use for heat pump systems that cool indoor, recirculated air.

a. Recirculation air flow rate: Rated values provided by manufacturer, or estimate between 250-400 cfm/ton of cooling

b. Recirculation air cooling capacity: Rated value from manufacturer.

c. Recirculation Cooling COP: Use ((SEER + EER)/2) / 3.412.

   i. If only EER is provided, SEER = (1.12-√(1.2544-0.08*EER)) / 0.04

   ii. For commercial cooling units, the cooling COP may be estimated using the IEER rating. Use (IEER/3.412 = COP)

   iii. IEER = (0 .02 * A) + (0 .617 * B) + (0 .238 * C) + (0 .125 * D)

   Where as:
   A = EER at 100% net capacity at AHRI standard cond. (95 deg F)
   B = EER at 75% net capacity and reduced ambient (81 .5 deg F)
   C = EER at 50% net capacity and reduced ambient (68 deg F)
   D = EER at 25% net capacity and reduced ambient (65 deg F)

- **Dehumidification COP** use dehumidifier rating in Liter/kWh
  - 1 Liter/kWh = 0.625 COP
  - OR, use a COP of '2' for cooling systems that provide latent cooling as a product of sensible cooling.

- **Panel Cooling**
  - Only used for radiant cooling systems. External calculation needed to determine Panel Cooling COP.

6.10.3 Ventilation Distribution

Duct Length and Duct Separation

Supply and exhaust duct lengths should be measured from the inside of the exterior wall to the outside of the ventilation unit. Often, these lengths are different.

If there are multiple H/ERVs in the project covered by a single ERV device, do not increase the quantity of duct lengths input here. For example, if there are 50 identical ERVs in the project, the ERV device will have a quantity of 50. Determine the average supply/exhaust duct length for those 50 ERVs, and input only one entry for a supply duct, and one for exhaust. Then, check the box to assign those two average-length ducts to the appropriate ERV type. This will accurately assign those ducts to the 50 ERVs.

On the outside of the building the supply and exhaust diffusers should be located at least 10 feet apart to keep from short circuiting exhaust air back into the house.
Note: If the ventilation unit is running at a very low airflow, manufacturers may allow for less separation.

This will be reviewed on a case-by-case basis.

Taking the supply air from above the roof is generally not recommended, because of the possibility of excessive heat and hot-roof odor.

6.10.4 Auxiliary Energy

This should include any additional fans, pumps, air-handling units, space conditioning distribution systems, etc.

There is an option to 'Use Default values', which applies to many projects.

- When this box is un-checked, only the Ventilation fan energy and defrost energy are retained. Any pump entries for DHW recirculation, storage load pump, or heating system circulation pump are removed. (Note: The devices that remain are shown in the WUFI Passive reports under Auxiliary Energy).

DHW recirculation system: Add the DHW pump energy here, or use the default value.

On-demand recirculation system for DHW: Please input the pump energy here. There is a quick workaround to determine an average estimate for this value for your project:

1. Go to Distribution>DHW. Input a value of '1' under length of circulation pipes.
2. Then, go back to Distribution>Aux Electricity. Note the value that auto-populates for the 'Norm Demand [W]' of the DHW circulating pump.
3. Then, go back to Distribution>DHW, remove the '1' from the length of circulation pipes.
4. Go back to Auxiliary Energy, un-check the box for 'Use default values', and add a new pump with the 'Norm Demand' power rating noted from the DHW recirculating system in Step 2.

Air-Handling Units/Space Conditioning Distribution: Energy associated with space conditioning distribution networks/fans should be estimated and input here.

- If fresh air supply is connected to an air handling unit for distribution into bedrooms, the air handling unit fan energy must be input here and assumed to run 8760 hrs/yr. See Section 3.5.3.

Direct Exhaust Bathroom Fans & Makeup Air Fans: Energy associated with fans should be input here as an 'Other' device.

- Energy Demand (norm) [W]: Use fan energy data when available. If no fan energy data is available, use 0.3 W/cfm as a default.
  - Multiply total airflow (cfm) found on Ventilation/Rooms>Exhaust ventilation by 0.3 W/cfm for [W] entry.
- Run times are based on the assumed run times found under Ventilation/Rooms>Exhaust Ventilation
  - Convert minutes/yr to khr/yr: (minutes/yr)/60/1000 = khr/yr.

6.10.5 Heating Devices

Heat Pumps

If any heat pump technology is used for space heating, use the 'Heat Pump' device type. Within this device type, there are two options for modeling heat pumps used for space conditioning:

1. Heat Pump: Use when given a single COP (coefficient of performance) is provided for the heating system. Note that when a single value is given for air source heat pumps, often this is rated at an ambient temperature of 47F, and the entry should be de-rated if the climate often reaches temperatures below that.

   If only the HSPF given, COP may be estimated as HSPF/3.412. However, for colder climates, the COP is likely less than this and a HSPF de-rating calculator should be used. Download Heat Pump Protocol kit from PHIUS' Calculators and Protocols page.

   Ground source heat pumps should also use this heat pump type.

2. Heat Pump Rated Monthly COP: If COP data for two rated ambient temperatures can be found, use this device type. This takes the monthly heating demand and climate data into consideration to calculate a more accurate COP.

   - Generally, air source heat pumps are rated at 17°F and 47°F. By entering the rated performance at both temperatures, WUFI Passive can calculate an annual average heating COP based on the monthly heating demand and climate. This follows PHIUS' heat pump protocol.

Boiler

It is acceptable, and quicker, to enter this as a "User Defined" device in the system.

Find the Energy Factor (EF) or thermal efficiency of the model you are using.

- If using an EF, PHIUS recommends de-rating the EF by a factor of 0.92 (as in RESNET protocol), to account for the discrepancies between the heavy draws used in the DOE water heater testing protocol and the real world. This de-rated value can be thought of as a % efficiency for the boiler.

Performance Ratio of Heat Generator: Input the inverse of the efficiency (or Energy Factor)
Source Energy Factor: For natural gas, 1.1

If a specification sheet is available containing information to support the detailed entries for the Boiler device, feel free to use the Boiler option. The part-load efficiency curves in LBNL report 42175 may be used as defaults (See Figure 1 in the report for old boilers and Figure 6 for sealed combustion.) [41]

Wood Stove

A typical "off the shelf" wood stove is likely oversized for single family passive buildings. If using this system for a portion of heating, as a default, assign 25% heating coverage. For the efficiency, an estimate of 60% will suffice. The PE factor will be 0.2 for biomass. On the other hand, if using a system designed for a lower heat load or a more low-steady heating system, such as a masonry heater or pellet stove, it may be plausible to increase the % coverage.

6.10.6 Domestic Hot Water Devices

Heat Pump Water Heaters

- With Indoor Compressors:
    - In the Systems branch, add a 'Heat Pump' device in WUFI Passive.
    - Select 'Heat Pump water heater (HPWH) inside' as the device type. This will de-rate the efficiency of the HPWH heater to account for the heating systems working against each other in the heating season.
        - Enter the heating system COP or efficiency
        - Total System Performance Ratio: Enter $\frac{1}{Heating\ System\ COP}$ as a decimal.
        - HPWH EF: Enter the rated Energy Factor (EF) for the Heat Pump Water Heater
- With Outdoor Compressors:
    - Enter as a "User Defined" device.
    - Supplemental calculators that take the local climate into effect can be found on the Calculators and Protocols page.
    - The climate-adjusted Energy Factor (EF) of the specified model should be used
        - Total System Performance Ratio: Enter $\frac{1}{Adjusted\ Energy\ Factor}$ as a decimal.
- Details on calculation methodology can be found in the Heat Pump Protocol linked above.

Boiler or Gas Water Heater: See above.

- **Gas Tankless:** Enter the same as boiler; do not add water storage as a system.
- **Electric Tankless:** Choose electric heating; do not add water storage as a system.
- **Standard Electric with Tank:** Choose electric and add water storage as a system.
- **Solar Collector:** In cases where the energy model report shows a solar fraction above 65%, we require a predicted annual output from the solar inspector as to the kBTU/yr energy production; OR
    - A BEopt model run according to the PHIUS Solar DHW Fraction BEopt Protocol. This protocol can be downloaded here.

Ground Source Heat Pump

Enter as a 'Heat Pump' device and use the rated COP at the appropriate entering and exiting water temperatures.

6.10.7 Mechanical Ventilation Devices

Sensible Recovery Efficiency, Humidity Recovery Efficiency, Electric Efficiency:

- PHIUS projects should model ventilation efficiency according to the protocol described by the PHIUS Technical Committee, which can be found on the Calculators and Protocols page.

- Ventilation ratings from PHIUS Certified Ventilator program take priority over 3rd party ratings.
- Refer to the HVI Winter Ratings modified for PHIUS modeling for common ventilation units, also found on the Calculators and Protocols page.
- AHRI ratings for commercial units do not include electrical efficiency data. For pre-certification calculations, estimate electrical consumption from manufacturer's specifications.
- Latent/Humidity Recovery Efficiency**:** If this value is not specified for the ERV, 40% may be entered as a default. For an HRV, enter 0%. When a project falls under the summer test conditions (Climate zones 1A,2A,2B,3B), then request the HRV manufacturer provide their CSA 439 summer test point data. You can use this to break out ASE and LR. You'll see that most projects should use the HVI's winter test point data. Only the 2B and 3B zones will use different test data for the ASE and LR inputs.

- Default values may be used for performance of refrigerant-based heat recovery devices (such as CERV from Build Equinox). Or, PHIUS-approved calculation methodology may be used to determine performance entries.
  - Default accepted values:
    - Sensible Heat Recovery: 75%
    - Latent Heat Recovery: 40%
    - Electric Efficiency: 1 W/cfm

Assigning 'rooms ventilated by this unit': If multiple ERVs are used, the rooms assigned to each unit need to appropriately be assigned to their corresponding ERV. The list of rooms shown here is populated based on the entries on the Ventilation/Rooms branch. For the example beloiw, ERV Type X would check the boxes for all of the residential exhaust rooms. ERV Type Y would check the boxes for all common space exhaust rooms.

Quantity: When using multiple identical ERVs in one building, a single 'Mechanical ventilation' device in WUFI Passive can cover all of them. For example, if the project is a 50-unit MF building with 50 identical ERVs "Type X", this can be modeled as a single device, ERV Type X, and the quantity would be adjusted to 50.

- This applies when the identical ERVs are scheduled to run at roughly the same airflow rates, and therefore would have similar rated efficiencies (refer to HVI Winter Ratings document above for more information on rated efficiencies at different airflows).
- Because you have increased the quantity of ventilation units under the device, do not increase the quantity of ventilation ducts under Systems>Distribution (see Section 6.10.3).
- New mechanical ventilation devices only need to be added when a new unique ERV/HRV type is used in the project. For example, in a MF building, the residential units are being served by ERV Type X, and the common spaces are served by ERV Type Y.

Defrost: No matter the method of defrost, PHIUS requires that accounting for defrost energy and entering 23 F for the temperature in which defrost must be used.

- If using a ground loop pre-heater/sub-soil heat exchanger, defrost energy does not need to be accounted for in the energy model.

Subsoil Heat Exchanger: Use for earth air tubes and liquid-based ground loops for tempering supply air. Typical efficiency ranges from 40-60%. For entries above 60% efficiency, a corresponding calculation is required for certification.

6.10.8 Renewable Energy Systems

For any renewable energy, on-site or off-site, add a 'Photovoltaic / renewable energy' device.

- Use a descriptive name for the device
- Add a new device for each unique type of renewable energy.
- Location: Select on-site or off-site
    - On-site:
        - 'Onsite Utilization' drop-down: User Defined
        - Photovoltaic / renewable energy [kWh/yr] : Annual system output
            - NREL's PV Watts Calculator is an accepted method for estimating annual energy production from an on-site PV Array.
            - Please include PV Watts report in document submission.
        - Onsite Utilization: 1
    - Off-site:

Type	kWh/yr	Onsite Utilization
Directly owned off-site renewable	Varies	1
Community renewable energy	Varies	1
Virtual power purchase agreement	Varies	1
Renewable energy certificates (RECs)	Varies	0.2

For pre-certification, on-site renewable energy must be documented. For any off-site renewable energy, PHIUS will as that the project owner signs a letter of intent for contracting a sufficient quantity of renewable energy before final certification is awarded.

PHIUS+ Source Zero: To determine if a project complies with PHIUS+ Source Zero, only on-site renewable energy should be entered. If the resulting source energy is ≤0, the building meets this standard. See Section 3.10.2.

6.10.9 Drain Water Heat Recovery

The drain water heat recovery device is used to adjust the temperature of the incoming water supply by recovering warm drain water and pre-heating the incoming cold freshwater.

Note: DWHR device does not work in combination with the 'Simplified individual pipes' hot water distribution calculation method.

DW heat recovery unit indoor temp: Default 97F

DW Heat Recovery Unit Efficiency: As rated and labeled in accordance with CSA 55.1

Pipe Length: Measured length of hot water piping from the hot water heater to the farthest hot water fixture. Measured longitudinally from plans, assuming the hot water piping does not run diagonally. Plus 10 feet of piping for each floor level, plus 5 feet of piping for unconditioned basements (if any).

Supplies pre-heated water to: Select if the system supplies both hot and cold water, or just one of the two.

6.11 WUFI Passive Reports

Reports are automatically generated upon completion of a WUFI Passive model. If results are present, the reports are available. Reports can be printed to PDF or exported into Microsoft Word. If exported into MS Word, charts can easily be copied into Excel if needed.

Scope:

- Passive House Verification: Comprehensive summary of results and verification of compliance for all performance-based certification requirements, verification of compliance with PHIUS' add-on badges, breakdown of losses and gains for calculation of annual demands and peak loads, electricity c& DHW consumption, etc.
- REM-Rate Report: Summary report for PHIUS+ Rater/Verifier to view for coordination with REM/Rate model.
- Site Energy Report: Breakdown of site energy by end use.
- Source Energy Report: Breakdown of source energy by end use.
- Site Energy Monthly Report: Breakdown of monthly site energy by end use. Supports comparison of energy model results to monthly utility bills. New in PHIUS+ 2018 mode. Currently only available in residential mode.
- User Defined: Combines all reports into one, long report.

View Settings

- Normal: Used for viewing within WUFI Passive. Does not have headers or page numbers.
- Print/Export Layout: Includes a header, page numbers, and a footer which includes the case name on each page of the report.
    - Note: Select WUFI Passive Options> >Usability> 'Show project/case in footnote'

7. PHIUS Professional Credential Maintenance

7.1 Maintenance Fee

- A nominal maintenance fee will be billed on a yearly basis starting on January 15, 2018.
- One listing fee will be due per professional regardless of the number of certified credentials held by that professional.
  - Ex: a CPHC® who is also a Builder will be subject to a single maintenance fee.

The fee will help maintain and improve the listing database and assist in the development of the continuing education programs for all professionals.

7.2 Certified Passive House Consultant ®

7.2.1 CPHC Renewal Requirements

CPHC status expires every three years. CPHCs can maintain/extend their certification status through either one of the following methods:

1. Accumulate 36 PHIUS-approved Continuing Education Units before the expiration date.

Approved continuing education activities include the programs listed below. Programs earn 1 CEU per hour of instruction.

Programs presented by PHIUS and PHAUS:

- Attend the 2-Day Core Conference at the Annual North American Passive House Conference (~14 CEUs).
- Attend pre-conference workshops at the Annual North American Passive House Conference.
- Take PHIUS training programs such as PHIUS Certified Builder Training, PHIUS+ Rater Training, PHIUS+ Verifier Training, and WUFI Passive Workshops.
- Participate in the CPHC Online Refresher Course that comprises the Phase I Online portion of the CPHC training program (44.5 CEUs).
  - This program is especially valuable for any CPHCs that attended CPHC training prior to the introduction of the PHIUS+ 2015: The New Climate Specific Passive Building Standard.
- Participate in other PHIUS courses.
- Watch PHAUS Webinar presentations.
  - Webinars are available in the Members-Only Webinar Archive (PHAUS Professional level log-in required), or through the PHAUS Pay-Per-View Webinar page.

Programs presented by providers other than PHIUS and PHAUS:

- Participate in PHIUS-approved CEU programming.
- Upcoming CPHC CEU-eligible events are listed on the CPHC CEU Self-Report page.

7.2.1.2 Apply for PHIUS CPHC CEUs for your event

- Complete the form at the top of the CEU Program page
  - Apply at least three weeks before the event
  - If you are attending an event you would like to qualify for PHIUS CEUs but are not the organizer, please contact the organizer and ask them to fill out the request form.
  - Programs cannot be approved for CEUs after they have occurred
- Upon approval you will receive a self-report link and verification code, which must be provided to your attendees at the completion of your event.
  - If approved, the program will be listed on the Self-Report page.

2. Complete a PHIUS+ Certified Passive Building project

Acting as the CPHC on a PHIUS+ project will earn CEUs as outlined below.

- A CPHC that has completed the review process with PHIUS and whose project is Pre-Certified will earn 18 CEUs at the time of pre-certification for that project.
  - Projects Pre-Certified prior to January 15th, 2018 will not receive CEUs until they reach the status of Certified.
- A CPHC that completes a project with PHIUS that has been designated Certified will earn 18 CEUs at the time of certification for that project.
  - Any CPHC that completed a Certified project with PHIUS prior to January 15, 2018 earned 36 CEUs at the time of certification.
- If a project receives Pre-Certification & Certification on the same day, the CPHC will earn 36 CEUs on that day.
- Any PHIUS+ project can earn CEUs for up to two CPHCs working on the same project in tandem.
  - Each CPHC is entitled to the full CEUs associated with the project, granted that both CPHCs acknowledge the other's contribution.

7.2.2 Tracking CPHC Status

CPHCs will receive a quarterly email update that includes their current certification expiration date and total CEUs accumulated to date. It will also include all CEU-eligible events (and whether the CPHC participated and earned CEUs for them) dating back to the previous email update.

Any discrepancies or issues should be reported to PHIUS as soon as possible by emailing ceu@passivehouse.us.

7.2.3 CPHC Expiration

A CPHC who fails to meet one of the above requirements before their expiration date will be removed from the CPHC database and their credential will no longer be considered valid.

7.2.4 CPHC Status Re-Activation

A CPHC whose certification status has expired can reactivate their certification by re-taking and passing the in-class portion of the current CPHC exam. Exam dates fall at the end of each scheduled CPHC Training, and can be found in the CPHC Exam schedule. This exam can be re-taken remotely; travel to the class location is not required. The examinee has a 24-hour window to start the exam re-take, beginning at the in-class scheduled start time. The exam itself has a 3-hour time limit and must be completed in that 24-hour window.

7.3 PHIUS Certified Builder

7.3.1 PHIUS Certified Builder Renewal Requirements

PHIUS Certified Builder status expires every three years. PHIUS Certified Builders can maintain/extend their certification status through either one of the following methods:

1. Build a PHIUS+ Certified Passive Building Project: Successfully building a project within three years after the professional's certification date will maintain/extend the Builder's professional credential status by an additional three years.

2. Take and Pass the Current Builder Exam: Successfully completing the Builder exam will maintain/extend the Builder's professional credential status by three years.

7.3.2 PHIUS Certified Builder Expiration

A PHIUS Certified Builder who fails to meet one of the above requirements will be removed from the Builder database and their credential will no longer be considered valid.

7.3.3 PHIUS Certified Builder Re-Activation

A Builder whose certification status has expired can reactivate their certification by taking and passing the current Builder exam.

7.4 PHIUS+ Rater

7.4.1 PHIUS+ Rater Renewal Requirements

PHIUS+ Rater status expires every year on January 15th. To maintain/extend their standing another year, a Rater must:

1. Complete and return the Annual Rater Agreement to PHIUS at the beginning of each year (January 15th).
2. Maintain their status as a Certified HERS Rater in good standing with RESNET and a Quality Assurance Provider to be renewed. (Exception: CA and AK Raters must maintain status with their state-sponsored ratings systems and providers).
3. Complete **1** of **4** activities below:
   a) Fulfill the PHIUS+ Rater role on a PHIUS+ Certified Passive Building Project.
   b) Attend the 2-Day core conference of the PHIUS North American Passive House Conference.
   c) Attend the PHIUS CPHC training.

d) Attend and complete the PHIUS+ Rater/Verifier Webinar and online quiz offered in December. In combination with the annual Verifier agreement, this will extend the current expiration date to January 15th of the next year.

7.4.2 PHIUS+ Rater Expiration

A Rater who fails to meet one of the above requirements by January 15th of each year will be removed from the Rater database.

7.4.3 PHIUS+ Rater Re-Activation

A professional whose Rater status has expired can reactivate certification by taking and passing the current Rater exam.

7.5 PHIUS+ Verifier

7.5.1 PHIUS+ Verifier Renewal Requirements

PHIUS+ Verifier status expires every year on January 15th. To maintain/extend their standing another year, a Verifier must:

1. Complete and return the Annual Verifier Agreement to PHIUS at the beginning of each year (January 15th).
2. Complete **1** of **4** activities below:
   a) Verify a PHIUS+ Certified Passive Building project.
   b) Attend the 2-Day Core Conference at the annual PHIUS North American Passive House Conference.
   c) Attend the PHIUS CPHC training.
   d) Attend and complete the PHIUS+ Rater/Verifier Webinar and online quiz offered in December.

7.5.2 PHIUS+ Verifier Expiration

A Verifier who fails to meet one of the above requirements by January 15th of each year will be removed from the Verifier database and their credential will no longer be considered valid.

7.5.3 PHIUS+ Verifier Re-Activation

A Verifier whose certification status has expired can reactivate certification by taking and passing the current Verifier exam.

8. Monitoring

Post occupancy energy monitoring is highly recommended, however, PHIUS+ does not require it for certification. A main reason for this is because it is highly dependent on occupant behavior. PHIUS certifies projects based on values that assume how an occupants would behave, but most times occupant behavior cannot be controlled by the designer.

By gathering actual performance data – in the form of utility bills or from monitoring systems – PHIUS can improve modeling protocols and refine the practices used by all parties involved in the certified project, including component manufacturers. This may also provide insight into the intricacies of climate specific design and its financial implications for the passive building owner.

8.1 Monitoring Protocol

PHIUS has released draft monitoring protocol which defines background information on:

- The purpose of monitoring
- Research questions that guide selection of datapoints to monitor
- Various tiers of equipment to use based on project budget
- Roles and responsibilities of planning and executing a successful monitoring plan from design through construction to post occupancy.

The monitoring protocol will continue to develop as PHIUS gains more insight and experience on collecting data from certified projects.

8.2 Monitoring your project

Reach out to certification@passivehouse.us if:

1. You have a project in design-phase that is interested in participating in PHIUS' monitoring program.
2. You are willing to share monitored data for a PHIUS+ Certified project.
    - If 1+ years of utility bills are available, PHIUS will provide a free analysis of the predicted vs actual performance based on the WUFI Passive energy model.

Appendix A – Renewables Credits and Co-Generation in the Calculation of Source Energy

Renewables

The annual net source energy for a building is calculated by multiplying the site energy by the fuel-dependent source energy factor, and then subtracting credit for renewable energy production multiplied by the fuel-dependent source energy factor of the fuel type it is offsetting. Generally, the total annual source energy use of the building is calculated as

$$PE_A = \sum_{Fuel} \sum_{EndUse} SE_{A,Fuel,Enduse} F_{PE,Fuel} - TE_{DHW} F_{PE,DHW} - TE_{SH} F_{PE,SH} - RE_A C_{RE} F_{PE,elec}$$

where

$Fuel$ = gas, oil, coal, propane, biomass, electricity

RE_A = total annual site energy use (from the building energy model)

F_{PE} = primary energy factor

TE_{DHW} = usable onsite solar thermal energy for domestic hot water

TE_{SH} = usable onsite solar thermal energy for space heating

RE_A = total annual onsite renewable electricity generation

C_{RE} = offset factor of renewable electricity generation

F_{PE} = 2.8 for electricity, 0.2 for biomass, and 1.1 for fossil fuels.

The end uses specifically include space heating, cooling, humidification, dehumidification, ventilation fans, pumps, domestic hot water heating, major appliances, lighting, elevators, miscellaneous electric loads and miscellaneous gas loads. Electric vehicle charging is specifically excluded.

In the particular case where the only onsite renewable electricity generation is by PV and the system is grid-tied without battery storage, RE_A may be obtained from NREL's PVWatts calculator.

Co-Generation

With a combined-heat-and power (CHP) unit, the adjusted annual source energy for the building is given by:

$$PE = D_{ELEC} F_{ELEC} + D_{HEAT} F_{HEAT}$$

where

D_{ELEC} is the annual electricity demand of the building (excluding any supplemental heat provided by grid electricity.)

D_{HEAT} is the annual heating demand plus hot water demand (including storage and distribution losses) of the building.

F_{ELEC} is the adjusted PE factor for electricity.
F_{HEAT} is the adjusted PE factor for heating.

The adjusted PE factor for <u>electricity</u> F_{ELEC} is given by

$$F_{ELEC} = \frac{E_{CHP} F_{E,CHP}}{D^{*}_{ELEC}} + \frac{\left(D^{*}_{ELEC} - E_{CHP}\right) \times F_{E,GRID}}{D^{*}_{ELEC}}$$

The annual electrical energy production E_{CHP} by the CHP units / generators is given by

$$E_{CHP} = \begin{cases} \text{the intended amount}, & \text{for E-priority} \\ D_{HEAT} K_{COVG} \times \frac{\eta_{ELEC}}{\eta_{HEAT}}, & \text{for H-priority} \end{cases}$$

η_{ELEC} is the electrical generation efficiency of the CHP units (e.g. typically 25%.)
η_{HEAT} is the heat and hot water generation efficiency of the CHP units (e.g. typically 50%.)
$F_{E,GRID}$ is the source energy factor for grid electricity (currently 3.16).

$$D^{*}_{ELEC} = \begin{cases} D_{ELEC} + H_{GRID}, & \text{for H-priority with grid electric backup heat} \\ D_{ELEC}, & \text{otherwise} \end{cases}$$

H_{GRID} is the supplemental heat from grid electricity on the H-priority path with electric backup, given by

$$H_{GRID} = D_{HEAT} \times \left(1 - K_{COVG}\right)$$

K_{COVG} is the fraction of the heat demand intended to be covered by CHP for H-priority, e.g. 90%.

The source energy factor for electricity from CHP, $F_{E,CHP}$, is given by

$$F_{E,CHP} = \begin{cases} F_{FUEL} / \eta_{ELEC}, & \text{for E-priority} \\ 0, & \text{for H-priority} \end{cases}$$

in which

F_{FUEL} is the source energy factor of the fuel for the CHP units (e.g. currently 1.07 for gas.)

The adjusted PE factor for <u>heating</u> F_{HEAT} is given by

$$F_{HEAT} = \begin{cases} \dfrac{\left(H_{CHP} \cdot K_{UTIL}\right) F_{H,CHP}}{D_{HEAT}} + \dfrac{\left(D_{HEAT} - H_{CHP} \cdot K_{UTIL}\right) \cdot F_{FUEL}}{D_{HEAT}}, & \text{for E-priority} \\ K_{COVG} \cdot F_{H,CHP} + \left(1 - K_{COVG}\right) \cdot F_{FUEL}, & \text{for H-priority with fuel heat for backup} \\ F_{H,CHP}, & \text{for H-priority with grid electric heat for backup} \end{cases}$$

where the annual CHP heating byproduct H_{CHP} is given by

$$H_{CHP} = E_{CHP} \cdot \frac{\eta_{HEAT}}{\eta_{ELEC}}$$

K_{UTIL} is the usable fraction of CHP heat (if CHP heat is available when the building needs heat, $K_{UTIL} = 1$). This may require an additional side calculation, depending on how the CHP unit is intended to run.

The source energy factor for heat generation from CHP, $F_{H,CHP}$, is given by

$$F_{H,CHP} = \begin{cases} 0, & \text{for E-priority} \\ F_{FUEL} / \eta_{HEAT}, & \text{for H-priority} \end{cases}$$

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.

Above-Grade Wall Assemblies

Four categories of above-grade wall assemblies include most of the possible enclosures:

a) Framed assemblies with all or most of the insulation inside of the sheathing and between the framing members,

b) Framed assemblies with some insulation outboard of the framing and some insulation between the framing members,

c) Assemblies with all or most of the insulation outboard of the structure (framed or solid), and

d) Assemblies with insulation comprised only of air-impermeable and Class II vapor control insulation between, within, or outside of the structure.

a) Framed wall assemblies with all or most of the insulation value installed between the framing or structure (e.g. wood or steel stud) as vapor permeable (more than 10 perm) insulation (e.g., fiberglass, rockwool, cellulose, or open cell foam).

The goal of the vapor control design is to prevent vapor diffusing easily and condensing on either the cold sheathing in cold weather or the cold interior finish during warm weather.

- No vapor control layer is needed in climate zones 1,2,3,4a or 4b.

  `[v1.1 update: Smart membranes such as Membrain & Intello are not recommended in hot/humid and mixed/humid climates.]`

- A Class I or Class II vapor control layer is required on the interior side of framed walls in zones 4c, 5, 6, 7, and 8, with the exceptions of basement walls, below-grade portion of any wall, and wall construction that is not sensitive to moisture or freezing (e.g., concrete).

- Class I vapor control layers, including non-perforated vinyl wallpaper, reflective foil, glass, epoxy paint, white boards, melamine, etc. are not recommended and should be avoided on the interior of air-conditioned building occupancies in climates with humid summers in zones 1-6. The dividing line between dry (B) and moist (A) can be found in ASHRAE 90.1.

Enclosures clad with unvented water absorbent claddings (e.g., stucco, masonry, fiber cement, wood) are at especially high risk of summer condensation.

- A Class III vapor retarder can be used instead of a Class I or Class II when:
  - In zones 4c, or 5, vented cladding is used over sheathing with a perm rating of more than 1 (wet-cup), i.e., OSB, plywood, or exterior gypsum sheathing; or
  - In zone 6, vented cladding is used over high permeance (more than 10 perm) sheathings such as fiberboard and exterior gypsum.

Vented claddings include vinyl siding, metal panels, terra cotta, wood or fiber cement sidings on air gaps, and masonry veneers with clear airspaces and vent openings top and bottom. A clear gap of around ⅜" (10mm) will generally provide sufficient airflow to allow for ventilation, but at least 1" (25mm) should be specified for masonry walls.

b) Framed assemblies with some insulation value outside of the framing or structure.

The recommendation in the previous assembly category may be used, but it is usually desirable to design for more drying, especially in warmer climate zones (4 and 5 especially). The use of insulation on the exterior of the sheathing increases its temperature in cold weather, thereby relaxing the need to control cold-weather vapor diffusion. Exterior insulation made of foamed plastic has the benefit that it also tends to reduce inward vapor drives during warm weather. MFI insulation work different in that they allow more outward drying. [24]

A Class III vapor retarder can be used instead of a Class I or II in zones 4c, 5, 6, 7, or 8 where any of the criteria for the specific zone from the list below is met. These criteria may depend upon the climate zone and the ratio of the insulation value in the stud space to the insulation value installed outboard of the sheathing. [25]

A Class III vapor control layer may be used on the interior of framed walls in zone 4c and higher, if any of the following criteria are met:

- Zone 4c (e.g., Vancouver, Seattle, or Portland)
  - Sheathing-to-cavity R-value ratio of >0.20
  - Insulated sheathing with an R-value >2.5 on a 2x4 framed wall
  - Insulated sheathing with an R-value >3.75 on a 2x6 framed wall
- Zone 5 (e.g., Chicago, Windsor, Boston)
  - Sheathing-to-cavity R-value ratio of >0.35
  - Insulated sheathing with an R-value >= 5 (e.g., 1" XPS) on a 2x4 framed wall
  - Insulated sheathing with an R-value >= 7.5 (e.g., 1.5" XPS) on a 2x6 framed wall
- Zone 6 (e.g., Toronto, Ottawa, Helena, Montreal, Halifax, Minneapolis)
  - Sheathing-to-cavity R-value ratio of >0.50
  - Insulated sheathing with an R-value >= 7.5 (e.g., 1.5" XPS) on a 2x4 framed wall
  - Insulated sheathing with an R-value >= 11.25 (e.g. 2" PIC) on a 2x6 framed wall

- Zones 7 and 8 (e.g., Calgary, Edmonton, Whitehorse, Anchorage, Fairbanks)
    - Sheathing-to-cavity R-value ratio of >0.70
    - Insulated sheathing with an R-value >=10 (e.g., 2" XPS) on a 2x4 framed wall
    - Insulated sheathing with an R-value >=15 (e.g., 3" XPS) on a 2x6 framed wall

Insulated sheathing can be installed in the form of expanded polystyrene (EPS) or semi-rigid glass fiber and rockwool with approximately R-4 per inch, extruded polystyrene (XPS) with R-5 per inch, polyisocyanurate (PIC) with approximately R-6 per inch, or closed-cell spray foam (usually around R-6/inch).

Note: For walls, the sheathing-to-cavity R-value ratio is specified. This is different from the roof, which specifies a sheathing R-value as % of total assembly R-value.

c) Assemblies with all or most (more than 75% of the total) of the insulation value located outboard of the structure (framing or solid).

This is the simplest and most robust wall to design with respect to vapor control. Such walls should ideally have all moisture sensitive components and materials located on the inside of the insulation. In this location, a Class I or II layer on the inside of all or most of the insulation value is acceptable and recommended if all outboard components are moisture tolerant. [26] A Class III layer on the interface of a high permeance (more than 10 perms) insulation layer outboard of a moisture-sensitive structure should only be used if warm weather and inward vapor drive condensation are not an issue or are controlled by other means.

d) Assemblies comprised of only air-impermeable and Class II vapor control insulation between, within, or outside the structure.

The EPS and urethane foam cores of wood or metal SIPS, board foams, and medium density closed cell spray foam (between wood or steel studs), if installed as continuous layers, all provide their own vapor control layers and require no additional vapor-diffusion control in any climate. Wood studs and small cracks between steel or wood studs do not allow significant vapor to flow by diffusion. Their use does not change the recommendations.

Cracks between framing members and insulation boards are often significant for airflow control and must be addressed in all of the systems described in the previous paragraph.

Below-Grade Wall Assemblies

Below-grade spaces, such as basements, are of particular concern with respect to improperly located Class I vapor control layers. Because the moisture drive in below-grade walls is always from the exterior to the interior in zones 6 and lower, installing a low-permeance layer on the interior side of insulation wall will cause moisture related durability issues by trapping moisture in the enclosure. A Class I vapor control layer outside a concrete or masonry basement wall is recommended to control the flow of vapor from damp soil into the assembly. Installing a Class II vapor control layer on the inside of below-grade framed assemblies is recommended for zones 7 and higher.

In cold climates (zone 5 and higher), condensation may occur on the interior side of concrete/masonry structure of a below-grade wall assembly if insulated on the inside with an air and vapor permeable (Class II or more, e.g., fibrous insulation) layer. To control both inward and outward drives, it is recommended that a Class II or III insulation product (e.g. most foams) be used in contact with the interior face of the concrete/masonry, and any insulation installed between interior framing follow the rules of "Framed assemblies with some insulation value outside of the framing or structure."

Below-Grade Floor Assemblies

Locating all of the insulation below the structure (concrete slab, or framed) with a Class I vapor control layer between the structure and the insulation is the practical and economical manifestation of the perfect enclosure. Some insulations provide the same level of vapor control (foil-faced polyiso or EPS, plastic-faced XPS) but many products will require a special low-permeance layer (polyethylene sheet is commonly used, inexpensive, and effective).

If no impermeable floor finishes are likely to be used during the life of the structure, the vapor control class requirement can be relaxed to a Class II. See also BSI-003: Concrete Floor Problems and BSI-009: New Light in Crawlspaces online at buildingscience.com for more discussion of vapor control and flooring.

Roof Assemblies

Roofing behaves differently than walls from a vapor control point of view for a number of reasons: most roof membranes are located on the exterior and provide Class I vapor control. Roof membranes, shingles, metal roofing are all vapor impermeable. Only back-ventilated roofing such as concrete ties perform in a similar manner to walls.

Assuming a vapor impermeable roofing membrane, four categories of roof assemblies will include most practical roofing systems:

a) Unvented roof assemblies with all or most of the insulation outboard of the structure (framed or solid),

b) Vented, framed roof assemblies with all or most of the insulation inside of the sheathing and between the framing members,

c) Unvented, framed roof assemblies with either some insulation outboard of the framing and some insulation between the framing members, or some air-impermeable insulation outboard of air-impermeable insulation, and

d) Unvented roof assemblies with insulation comprised of air-impermeable and Class II vapor control between, within, or outside the structure.

a) Unvented roof assemblies with all or most (>75%) of the insulation outboard of the structure (framed or solid).

These types of roofs comprise most of the low-slope, rigid board insulated; commercial roof systems installed over metal and concrete decks. However, there is no technical difference between a low-slope roof built in this manner and a sloped roof. This type of roof has very little need for additional vapor control as all of the common board foam roofing insulations (PIC, EPS, XPS) provide sufficient vapor control for most climate zones

- No additional vapor control layer is needed if a Class II vapor control insulation layer is used (>2" of XPS, PIC, >3" of EPS).
- To control diffusion at joints in board foam, all board insulation should be installed in two layers or more, with joints offset vertically and horizontally. This is especially important in zones 5 and higher.

Such roofs should ideally have all moisture sensitive components and materials located to the inside of the insulation. In this location a Class I or II layer on the inside of all or most of the insulation value (e.g., 75%) is acceptable but will restrict desirable and effective inward drying. For zones 5 and lower, a vapor control layer of Class III or higher is recommended to allow for inward drying of incidental moisture due to solar heating to roof membranes (e.g., gypsum board on metal deck).

b) Vented, framed roof assemblies with all or most of the insulation value installed between the framing (e.g., wood/steel stud, metal buildings) as vapor permeable (more than 10 perm) insulation (e.g., fiberglass, rockwool, cellulose, or open cell foam).

If a compact roof is well-vented above the insulation (i.e., with soffit and ridge vents connected by an open air-space of 1.5"/38mm or more):

- No vapor control layer is required in zones 1 through 3
  [v1.1 update: Smart membranes such as Membrain & Intello are not recommended in hot/humid and mixed/humid climates.]
- Class III vapor control in zones 4 through 6
- Class II vapor control in zones 7 and higher

If a roof is sloped over a well-vented attic (i.e., with soffit and ridge vents connected by an open air volume of at least 12" (300mm) average height, and no less than 1.5"/38mm anywhere):

- No vapor control layer is required in zones 1 through 4
- Class III vapor control layer is recommended for zones 5 through 6

- Class II vapor control layer is recommended in zones 7 and higher

Unvented, framed assemblies with all the insulation value comprised of air permeable insulation (fiberglass, rockwool, cellulose) between the framing are not recommended due to the potential for air leakage condensation.

c) Unvented framed roof assemblies with some insulation provided by air impermeable insulation.

Roofs need not be vented if diffusion and air leakage related wetting can be strictly limited. To accomplish this, some air impermeable, some Class II insulation can be located outside of air and vapor permeable (more than 10 perm) insulation (e.g., fiberglass, rockwool, cellulose are both).

The ratio of the insulation value of the exterior air- and vapor-control insulation to the insulation value of the interior air- and vapor-permeable insulation increases as the climate becomes colder, and the interior more humid. For normal commercial and residential occupancies the following recommendations can be made (Note: painted drywall or more than about 150mm/6" of open cell foam are Class III retarder).

- For zones 1 through 3A, 3B
  - Outer air-impermeable insulation value >15% of total
  - No vapor control layer required
- For zones 3c/4c (e.g. Vancouver, Seattle, Portland, San Francisco)
  - Outer air-impermeable insulation value >25% of total
  - Class III vapor control
- Zone 4A, 4B, 5 (e.g. Windsor, Kansas City, Boston)
  - Outer air-impermeable insulation value >35% of total
  - Class III vapor control in zone 5
- Zone 6 (e.g. Toronto, Ottawa, Montreal, Halifax, St Johns, Minneapolis)
  - Outer, air-impermeable insulation value >50% of total
  - Class III vapor control
- Zones 7 and 8 (e.g. Edmonton, Calgary, Winnipeg, Whitehorse, Fairbanks)
  - Outer, air-impermeable insulation value >65% of total
  - Class III vapor control

Note: For roofs, a sheathing R-value as % of total assembly R-value is specified. This is different from walls which prescribe the sheathing-to-cavity R-value ratios.

Air-impermeable insulation can be in the form of expanded polystyrene (EPS) with approximately R-4 per inch, extruded polystyrene (XPS) with R-5 per inch, polyisocyanurate (PIC) with approximately R-6 per inch, 2 pcf (32 kg/m3) closed-cell spray foam (usually around R-6 per inch) or 0.5 pcf (8 kg/m3) open cell spray foam (usually around R-4 per inch). All of these products, other than open-cell spray foam and EPS, provide a Class II vapor control layer in thicknesses of 1.5" or more. EPS and 1 pcf density (16 kg/m3) which requires between 3" and 5" (depending on density) to reach Class II performance, and open cell foam requires a special vapor control coating.

d) Unvented roof assemblies with insulation comprised of only air-impermeable and Class II vapor control insulation between, within, or outside the structure.

The EPS and urethane foam cores of wood or metal SIPS, board foams, and medium density closed cell spray foam (between wood or steel studs), if installed as continuous layers, all provide their own vapor control layers and require no additional vapor diffusion control in any climate with normal residential and commercial interior humidity conditions. Wood studs and cracks between steel or wood studs do not allow significant vapor to flow by diffusion and hence do not change the recommendations.

Cracks between framing members and panels are significant for airflow control and must be addressed in all of the systems described above. A very effective airflow control layer is required on the inside of the insulation and/or framing for all unvented roof assemblies.

Appendix C – ASHRAE-55 Based Method for Evaluating when a Cooling System is Recommended

Some designers are quite set against the use of cooling systems, and indeed, with regard to the building code, the "cooling-is-a-luxury" perspective survived the introduction of air-conditioning – North American building codes do not require a cooling system in any climate, nor do the U.S. Energy Star requirements which are part of the PHIUS+ certification program.

The question of when to design in a cooling system could be decided with reference to ASHRAE 55. Clause 5.4 lays out the procedure for determining Acceptable Thermal Conditions in Occupant-Controlled Naturally Conditioned Spaces, based on the climate.

Basically, one looks at the daily mean outside temperatures in the hottest part of the year, calculates a running average, and then from a graph/formulas determines the acceptable range of indoor operative temperature, which cannot be any higher than 89 F regardless of climate. The formula for the upper limit is:

> **0.31 * Tpma-out + 60.5 F**
> where Tpma-out is the "prevailing mean outdoor temperature".

Tpma-out must be less than 92.3 F. (There is also a lower limit which is 12.6 F cooler.)

- Up to another 4.0 F can be added to the upper limit if increased air speed of 236 fpm can be provided (with fans).

The way to apply this would be to plug that upper-limit temperature into the building's WUFI Passive energy model as a cooling set-point, and see if there is any cooling load remaining. If there is, then a cooling system is advisable.

For the Tpma-out calculation the language of ASHRAE 55 prefers TMY3 or actual daily weather data, but monthlies are allowed if those are not available. Seven to thirty days of averaging is acceptable. For example in Dubuque, Iowa, picking in the middle at 18 days (432 hours) and running the average, Tpma-out tops out at 73.9 F which is a little warmer than the 70.2 maximum in the monthly file.

This makes the upper operative temperature limit (Top):

> Top = 0.31 * 70.2 + 60.5 = 82.2 F, by monthly data maximum
> Top = 0.31 * 73.9 + 60.5 = 83.4 F, by TMY3 18-day running average

Going by the monthly, then with the air speed adjustment the limits are

Top = 82.2 + 2.2 = 84.4 F, for air speed 118 fpm
Top = 82.2 + 3.2 = 85.4 F, for air speed 177 fpm
Top = 82.2 + 4.0 = 86.2 F, for air speed 236 fpm

It may be fair to credit the 118 fpm if there are any ceiling fans – probably it is not too difficult to get this much air speed. U.S. Energy Star ratings for ceiling fans report air flow in cubic feet per minute, which can be converted to fpm directly under the fan using the fact that the test duct is a cylinder eight inches larger in diameter than the fan. Air speed in the room could be then estimated from consideration of the room cross section compared to the fan.

Thus, a protocol could be written as follows:

<u>A cooling system may reasonably be foregone if:</u>
• Representative occupants have metabolic rates ranging from 1.0 to 1.3 met.
• Representative occupants are free to adapt their clothing to the indoor and/or outdoor conditions within a range at least as wide as 0.5 to 1.0 Clo.
• The prevailing mean outdoor temperature Tpma-out (monthly max) is greater than 50 F and less than 92.3 F.
• WUFI Passive model calculates no cooling load with a cooling set point of 0.31 * Tpma-out + 60.5 F (plus 2.2 F if there are ceiling fans).

The conditions on the representative occupants might always be assumed true for residential, but might not be for nonresidential. However, as noted above, residential occupancies are demographically more likely to be occupied by sensitive people than workplaces, so a cooling system is more strongly advisable for residential.

Appendix D - ASHRAE Fundamentals 2017 Non-Residential Equipment Tables

Table 8A: Recommended Heat Gain for Typical Desktop Computers

Table 8B: Recommended Heat Gain for Typical Laptops and Laptop Docking Stations

Table 8C: Recommended Heat Gain for Typical Tablet PC

Table 8D: Recommended Heat Gain for Typical Monitors

Table 9: Recommended Heat Gain for Typical Printers

Table 10: Recommended Heat Gain for Miscellaneous Equipment

Table 11: Recommended Load Factors for Various Types of Offices

Table 12: Diversity Factor for Different Equipment

Table 8A Recommended Heat Gain for Typical Desktop Computers

Description	Nameplate Power,[a] W	Peak Heat Gain,[b,d] W
Manufacturer 1		
3.0 GHz processor, 4 GB RAM, n=1	NA	83
3.3 GHz processor, 8 GB RAM, n=8	NA	50
3.5 GHz processor, 8 GB RAM, n=2	NA	42
3.6 GHz processor, 16 GB RAM, n=2	NA	66
3.3 GHz processor, 16 GB RAM, n=2	NA	52
4.0 GHz processor, 16 GB RAM, n=1	NA	83
3.3 GHz processor, 8 GB RAM, n=1	NA	84
3.7 GHz processor, 32 GB RAM, n=1	750	116
	NA	102
3.5 GHz processor, 16 GB RAM, n=3[c]	550	144
	NA	93
Manufacturer 2		
3.6 GHz processor, 32 GB RAM, n=8	NA	80
3.2 GHz processor, 16 GB RAM, n=1	NA	78
3.4 GHz processor, 32 GB RAM, n=1	NA	72
3.4 GHz processor, 24 GB RAM, n=1	NA	86
3.5 GHz processor, 4 GB RAM, n=1	NA	26
3.3 GHz processor, 8 GB RAM, n=1	NA	78
3.2 GHz processor, 8 GB RAM, n=1	NA	61
3.7 GHz processor, 4 GB RAM, n=1	NA	44
2.93 GHz processor, 16 GB RAM, n=1	NA	151
2.67 GHz processor, 8 GB RAM, n=1	NA	137
Average 15-min peak power consumption (range)	82 (26-151)	

Source: Bach and Sarfraz (2017)

n= number of tested equipment of same configuration.

[a]Nameplate for desktop computer is present on its power supply, which is mounted inside desktop, hence not assesible for most computers, where NA = not available.

[b]For equipment peak heat gain value, highest 15-min interval of recorded data is listed in tables.

[c]For tested equipment with same configuration, increasing power supply size does not increase average power consumption.

[d]Approximately 90% convective heat gain and 10% radiative heat gain.

Table 8B Recommended Heat Gain for Typical Laptops and Laptop Docking System

Equipment	Description	Nameplate Power, [a] W	Peak Heat Gain, [b,c] W
Laptop computer	Manufacturer 1,		
	2.6 GHz processor, 8 GB RAM, n=1	NA	46
	Manufacturer 2,		
	2.4 GHz processor, 4 GB RAM, n=1	NA	59
Average 15-min peak power consumption (range)		61 (26-151)	
Laptop with docking station	Manufacturer 1,		
	2.7 GHz processor,8 GB RAM, n=1	NA	38
	1.6 GHz processor, 8 GB RAM, n=2	NA	45
	2 GHz processor, 8 GB RAM, n=1	NA	50
	2.6 GHz processor, 4 GB RAM, n=1	NA	51
	2.4 GHz processor, 8 GB RAM, n=1	NA	40
	2.6 GHz processor, 8 GB RAM, n=1	NA	35
	2.7 GHz processor, 8 GB RAM, n=1	NA	59
	3.0 GHz processor, 8 GB RAM, n=3	NA	70
	2.9 GHz processor, 32 GB RAM, n=3	NA	58
	3.0 GHz processor, 32 GB RAM, n=1	NA	128
	3.7 GHz processor, 32 GB RAM, n=1	NA	63
	3.1 GHz processor, 32 GB RAM, n=1	NA	89
Average 15-min peak power consumption (range)		61 (26-151)	

Source: Bach and Sarfraz (2017)

n= number of tested equipment of same configuration.

[a]Voltage and amperage information for laptop computer and laptop docking station is available on power supply nameplates; however, nameplate does not provide information on power consumption, where NA = not available.

[b]For equipment peak heat gain value, highest 15-min interval of recorded data is listed in tables.

[c]Approximately 75% convective heat gain and 25% radiative heat gain.

Table 8C Recommended Heat Gain for Typical Tablet PC		
Description	**Nameplate Power, [a] W**	**Peak Heat Gain, [b] W**
1.7 GHz processor, 4 GB RAM, n=1	NA	42
2.2 GHz processor, 16 GB RAM, n=1	NA	40
2.3 GHz processor, 8 GB RAM, n=1	NA	30
2.5 GHz processor, 8 GB RAM, n=1	NA	31
Average 15-min peak power consumption (range)	36 (31-42)	

Source: Bach and Sarfraz (2017)

n= number of tested equipment of same configuration

[a]Voltage and amperage information for tablet PC is available on power supply nameplates; however, nameplate does not provide information on power consumption, where NA = not available.

[b]For equipment peak heat gain value, highest 15-min interval of recorded data is listed in tables.

Table 9 Recommended Heat Gain for Typical Printers				
Equipment	**Description**	**Max. Printing Speed, Pages per Minute**	**Nameplate Power, W**	**Peak Heat Gain,[a] W**
Multifunction printer (copy, print, scan)	Large, multiuser, office type	40	1010	540 (Idle 29 W)
		30	1300	303 (Idle 116 W)
		28	1500	433 (Idle 28 W)
Average 15-min peak power consumption			425 (303-540)	
	Multiuser, medium-office	35	900	732 (Idle 18 W)
	Desktop, small-office type	25	470	56 (Idle 3 W)
Monochrome printer	Desktop, medium-office type	55	1000	222
		45	680	61
Average 15-min peak power consumption			142 (61-222)	
Color printer	Desktop, medium-office type	40	620	120
Laser printer	Desktop, small-office type	14	310	89
		24	495	67
		26	1090	65
Average 15-min peak power consumption			74 (65-89)	
Plotter	Manufacturer 1		1600	571
	Manufacturer 2		270	173
Average 15-min peak power consumption			372 (173-571)	
Fax machine	Medium		1090	92
	Small		600	46
Average 15-min peak power consumption			69 (46-92)	

Source: Bach and Sarfraz (2017)

[a]Approximately 70% convective heat gain and 30% radiative heat gain.

Table 8D Recommended Heat Gain for Typical Monitors		
Description[a]	**Nameplate Power, W**	**Peak Heat Gain, [b,c] W**
Manufacturer 1		
1397 mm LED falt screen, n=1 (excluded from average because atypical size)	240	50
686 mm LED flat screen, n=2	40	26
546 mm LED flat screen, n=2	29	25
Manufacturer 2		
1270 mm 3D LED flat screen, n=1 (excluded from average because atypical size)	94	49
Manufacturer 3		
864 mm LCD curved screen, n=1 (excluded from average vecause atypical size and curved)	130	48
584 mmLED flat screen, n=3	50	17
584 mm LED flat screen, n=1	38	21
584 mm LED flat screen, n=1	38	14
Manufacturer 4		
610 mm LED flat screen, n=1	42	25
Manufacturer 5		
600 mm LED flat screen, n=1	26	17
546 mm LED flat screen, n=1	29	22
Manufacturer 6		
546 mm LED flat screen, n=1	28	24
Average 15-min peak power consumption (range)	21 (14-26)	

Source: Bach and Sarfraz (2017)

n= number of tested equipment of same configuration.

[a]Screens with atypical size and shape are excluded for calculating average 15-min peak power consumption.

[b]For equipment peak heat gain value, highest 15-min interval of recorded data is listed in tables.

[c]Approximately 60% convective heat gain and 40% radiative heat gain.

Table 12 Diversity Factor for Different Equipment		
Equipment	**Diversity Factor, %**	**Diversity Factor,[a] %**
Desktop PC	75	75
Laptop docking station	70	NA
Notebook computer	75[b]	75
Screen	70	60
Printer	45	NA

Source: Bach and Sarfraz (2017)

[a]2013 *ASHRAE Handbook-Fundamentals*

[b]Insufficient data from RP-1742; values based on previous data from 2013 *ASHRAE Handbook-Fundamentals* and judgement of Bach and Sarfraz (2017).

Table 10 Recommended Heat Gain for Miscellaneous Equipment

Equipment	Nameplate Power,[a] W	Peak Heat Gain,[b] W
Vending machine		
Drinks, 280 to 400 items	NA	940
Snakcs	NA	54
Food (e.g., for sandwiches)	NA	465
Thermal building machine, 2 single documents up to 340 pages	350	28.5
Projector, resolution 1024 x 768	340	308
Paper shredder, up to 28 sheets	1415	265
Electric stapler, up to 45 sheets	NA	1.5
Speakers	220	15
Temperature-controlled electronics soldering station	95	16
Cell phone station	NA	5
Battery charger		
40 V	NA	19
AA	NA	5.5
Microwave oven, 7 to 9 gal	1000 to 1550	713 to 822
Coffee maker		
Single cup	1400	385
Up to 12 cups	950	780
With grinder	1350	376
Coffee grinder, up to 12 cups	NA	73
Tea kettle, up to 6 cups	1200	1200
Dorm fridge, 3.1 ft^3	NA	57
Freezer, 18 ft^3	130	125
Fridge, 18 to 28 ft^3	NA	387 to 430
Ice maker and dispenser, 20 lb. bin capacity	NA	658
Top mounted bottled water cooler	NA	114 to 350
Cash register	25	9
Touch screen computer, 15 in. standard LCD and 2.2 GHz processor	NA	58
Self-checkout machine	NA	15

Source: Bach and Sarfraz (2017)

[a]For some equipment, nameplate power consumption is not availbale, where NA= not available.

[b]For equipment peak heat gain value, highest 15-min interval of recorded data is listed in tables.

Table 11 Recommended Load Factors for Various Types of Offices

Type of Use	Load Factor*, W/ft^2	Description
100% laptop, docking station		
light	0.34	167 ft^2/workstation, all laptop docking station use, 1 printer per 10
medium	0.46	125 ft^2/workstation, all laptop docking station use, 1 printer per 10
50% laptop, docking station		
light	0.44	167 ft^2/workstation, 50% laptop docking station use/50% desktop, 1 printer per 10
medium	0.59	125 ft^2/workstation, 50% laptop docking station use/50% desktop, 1 printer per 10
100% desktop		
light	0.54	167 ft^2/workstation, all desktop use, 1 printer per 10
medium	0.72	125 ft^2/workstation, all desktop use, 1 printer per 10
100% laptop, docking station		
2 screens	0.69	125 ft^2/workstation, all laptop docking station use, 2 screens, 1 printer per 10
100% desktop		
2 screens	0.84	125 ft^2/workstation, all desktop use, 2 screens, 1 printer per 10
3 screens	0.96	125 ft^2/workstation, all desktop use, 3 screens, 1 printer per 10
100% desktop		
heavy, 2 screens	1.02	85 ft^2/workstation, all desktop use, 2 screens, 1 printer per 8
heavy, 3 screens	1.16	85 ft^2/workstation, all desktop use, 3 screens, 1 printer per 8
100% laptop, docking station		
full on, 2 screens	1.14	85 ft^2/workstation, all laptop docking use, 2 screens, 1 printer per 8, no diversity
100% desktop		
full on, 2 screens	1.33	85 ft^2/workstation, all desktop use, 2 screens, 1 printer per 8, no diversity
full on, 3 screens	1.53	85 ft^2/workstation, all desktop use, 3 screens, 1 printer per 8, no diversity

Source: Bach and Sarfraz (2017)

*Medium-office type monochrome printer is used for load factor calculator with 15-min peak power consumption of 142 W.

Appendix E – PHIUS+ Rater/Verifier Manual: Version 1.0

E-1. Introduction

This manual outlines the process of becoming a PHIUS+ Rater or Verifier, eligibility to inspect and verify PHIUS+ projects, and the responsibilities of the Rater/Verifier in the certification of PHIUS+ projects.

E-1.1 PHIUS+ Rater

a. A PHIUS+ Rater is a certified professional who is eligible to perform the on-site inspections and performance testing requirements for verification of all aspects of PHIUS+ certification. This eligibility is specifically for single-family homes and multifamily (MF) projects 5 stories and lower.
b. See Section 2 for certification requirements and maintenance.

E-1.2 PHIUS+ Verifier

- A PHIUS+ Verifier is a certified professional who is eligible to perform the on-site inspections and performance testing requirements for verification of all aspects of PHIUS+ certification for multifamily projects over 5 stories or non-residential projects.
- PHIUS+ Verifiers may also perform verification of single-family and multifamily projects 5 stories and lower if they meet all certification requirements for PHIUS+ Raters, other than attending the PHIUS+ Rater course.
- See Section 2 for certification requirements and maintenance.

E-2. Certification Requirements and Maintenance

E-2.1 PHIUS+ Rater Certification Requirements

To be eligible to serve as a PHIUS+ Rater on a project, the following must be completed:

- For all candidates, attend in-person PHIUS+ Rater training, pass the PHIUS+ Rater exam, and sign the PHIUS+ Rater Agreement.
    1. Where a PHIUS+ Verifier also meets the eligibility requirements to be considered a PHIUS+ Rater, they shall be permitted to serve as a PHIUS+ Rater on qualifying projects without having separately taken the PHIUS+ Rater training.
- In all US states, except CA and AK:
    1. Be certified as a RESNET HERS Rater and be in good standing with a RESNET Quality Assurance (QA) Provider
    2. Be an EPA ENERGY STAR Certified Homes Rater/Verifier (having completed EPA Energy Star Version 3.0 Training), EPA Indoor airPLUS Certified Homes Rater/Verifier, and a DOE Zero Energy Ready Homes Rater/Verifier.
- In CA:

1. Be certified as a HERS Rater and be in good standing with either a RESNET QA Provider or a California Energy Commission approved-Provider
2. Be an EPA ENERGY STAR Certified Homes Rater/Verifier, EPA Indoor airPLUS Certified Homes Rater/Verifier, and a DOE Zero Energy Ready Homes Rater/Verifier.

- In AK:
    1. Be certified as a HERS Rater and be in good standing with either a RESNET QA Provider or a certified Energy Rater through the Alaska Housing Finance Corporation.
    2. Attest to knowledge and understanding of the EPA ENERGY STAR Certified Homes, EPA Indoor airPLUS Certified Homes, and a DOE Zero Energy Ready Homes programs.
- In Canada:
    1. Be a certified rater in good standing with either CRESNET or Natural Resources Canada.
    2. Attest to knowledge and understanding of the EPA ENERGY STAR Certified Homes, EPA Indoor airPLUS Certified Homes, and a DOE Zero Energy Ready Homes programs.
- Other international locations:
    1. Credentials will be verified on a case-by-case basis. Candidates should have a background in residential energy inspections and testing.
    2. Attest to knowledge and understanding of the EPA ENERGY STAR Certified Homes, EPA Indoor airPLUS Certified Homes, and a DOE Zero Energy Ready Homes programs.

E-2.2 PHIUS+ Verifier Requirements

To be eligible to serve as a PHIUS+ Verifier on a project, the following must be completed:

a. Attend in-person PHIUS+ Verifier training, pass the PHIUS+ Verifier exam, and sign the PHIUS+ Verifier Agreement.
    1. For projects where no PHIUS+ Verifier is within 200 miles of project, but a PHIUS+ Rater is within 200 miles of the project, the PHIUS+ Rater may serve as the PHIUS+ Verifier on the project so long as they hold the necessary experience listed below.

b. Have documented experience in the inspection and testing multifamily and/or non-residential buildings.

c. Attest to knowledge and understanding of the EPA ENERGY STAR Certified Homes, EPA Indoor airPLUS Certified Homes, and a DOE Zero Energy Ready Homes programs, or be approved Verifiers under the programs.

E-2.3 Non-certified Inspectors

a. Where no PHIUS+ certified professional is within 200 miles of a project, a project may elect to use a non-PHIUS+ certified professional to perform site inspections and testing.
    1. Alternatively, where a PHIUS+ Rater or Verifier has other verification staff who are otherwise qualified but are not yet PHIUS+ certified professionals, they may be permitted to perform verification so long as the PHIUS+ Rater/Verifier takes full responsibility for their verification work, completes a letter of attestation of training/mentorship on PHIUS-specific verification scopes of work, and the candidate otherwise meets all of the other eligibility criteria. At a minimum, the not yet PHIUS+ certified professionals should at least be certified as RESNET Rating Field Inspectors.

b. Non-certified inspectors shall meet the eligibility requirements for either PHIUS+ Rater or Verifier, other than having attended the training.

c. Non-certified inspectors shall contract with, and work directly under the supervision of an existing certified PHIUS+ Rater or Verifier.
    1. This relationship shall require at a minimum that the PHIUS+ certified professional conducts virtual training on the PHIUS+ Workbook and testing standards, and reviews all documentation issued by the PHIUS+ Verifier/Rater detailing their inspection and testing protocol.
    2. The PHIUS+ certified professional shall complete a letter of attestation to this training/mentorship.
        a. Letter of Attestation can be downloaded here.

d. For the inspector to be recognized as a Certified PHIUS+ Rater or Verifier and to work independently, they must either:
    1. Meet all eligibility criteria, including attending PHIUS+ Rater/Verifier training; OR
    2. Successfully complete a minimum of 3 PHIUS+ projects as a non-certified Inspector working under a PHIUS+ Rater/Verifier.

E-2.4 Certification Maintenance

a. PHIUS+ Raters and Verifiers shall maintain their certifications by completing the following:
    1. Complete and sign the PHIUS+ Rater or Verifier Agreement annually.
    2. Maintain their certification eligibility as described above.
    3. Pay the annual certification maintenance fee to PHIUS
    4. Complete one of the following:
        i. Attend annual PHIUS+ Rater/Verifier Webinar

ii. Complete PHIUS+ Rater or Verifier scope on a certified project within the calendar year.

E-3. Pre-Construction Requirements

E-3.1 Contracting with a project

- A project team attempting PHIUS+ certification for a project will contract with a PHIUS+ Rater or Verifier prior to construction, and perhaps even while the project is in design phase. Ideally, the project team will contract with a PHIUS+ Rater or Verifier as early in the design process as possible.
- Contracts can be entered into between the Rater/Verifier and any member of the project team. Preferably, but not a requirement, the contract will be with the project owner so that the Rater/Verifier can remain fully independent of the construction and design teams.
- PHIUS+ Rater/Verifiers cannot serve as the CPHC or builder on a project in which they are performing verification. However, another member of the Rater/Verifier's company may perform this scope with prior written approval from PHIUS certification staff.

E-3.2 Project Team Training

a. While it is ultimately the responsibility of the project team to ensure a project is fully compliant with PHIUS+ certification requirements, it is the Rater/Verifier's responsibility to ensure that all critical project team members understand the PHIUS+ Certification process, program requirements, and individual requirements from partner programs such as the EPA ENERGY STAR Certified Homes, EPA ENERGY STAR Multifamily New Construction Program, EPA Indoor airPLUS and DOE Zero Energy Ready Homes programs.

b. It is not the responsibility of the Rater/Verifier to train builders, building subcontractors, designers or any other project team member on specific scopes of work to construct PHIUS+ compliant projects, other than to make them aware of the requirements listed in the PHIUS+ Workbook or allied documents.

    1. The Rater/Verifier may choose to provide such guidance at their own discretion.

E-3.3 Design Review

a. It is encouraged that the PHIUS+ Rater/Verifier be present at design review meetings with the project team where possible.

b. While it is not the responsibility that the Rater/Verifier provide guidance or feedback on the design, it may be helpful where the Rater/Verifier has valuable experience to offer project team members.

1. Any guidance on design/implementation strategies shall be given at their own discretion.
2. It is encouraged that PHIUS+ Rater/Verifiers carry a minimum of $500,000 professional liability insurance if giving specific design or construction guidance.

E-4. Technical Inspection and Field Requirements

E-4.1 Mid-Construction Inspections

a. A minimum of two mid-construction inspections shall be required; one at foundation phase to verify foundation insulation systems, and another pre-drywall. Photo documentation is required.
    1. More frequent inspections and testing may be required or requested by project team depending on project scope, and if agreed upon by Rater/Verifier.

b. Foundation inspection - the following shall be observed at this phase:
    1. Slab (both edge and under) and foundation wall insulation materials and thicknesses and R-values
    2. Radon mitigation system piping (where applicable)
    3. Foundation drainage systems (where applicable)
    4. Presence of any known or unintended thermal bridges and associated mitigation strategies
    5. General site slope/grading

c. Pre-drywall inspection - the following shall be observed at this phase:
    1. Foundation and above grade wall cavity insulation and R-values (where applicable)
    2. Foundation and above grade wall continuous insulation and R-values
    3. Air sealing/air barrier details
    4. Presence of any known or unintended thermal bridges and associated mitigation strategies
    5. Window specification, NFRC data or equivalent data, rough opening sizes, location, overhangs, shading and install condition
    6. Mid-construction air tightness test (optional)

E-4.2 Final Inspection and Testing

Once final construction is substantially complete, the Rater/Verifier shall perform the following measures:

E-4.2.1 Verification

The following shall be verified at final:

a. Ceiling R-values and any other insulation not previously verified

b. Distance and R-value of ventilation ducts to exterior
c. Window overhang, external and adjacent shading attributes
d. Final site grading
e. Radon mitigation system final installation (where applicable)
f. Mechanical system make/models
g. Appliance make/models
h. Lighting efficiency percentages
i. Major process or other electrical loads (where applicable)
j. On-site renewable energy systems
k. Infrared Inspection of interior and exterior of building
l. Any other mandatory ENERGY STAR, Indoor airPLUS, Zero Energy Ready Homes or PHIUS requirements.

E-4.2.2 Testing

All testing required per the applicable PHIUS Workbook shall be used, including:

4.2.2.1 Whole-building airtightness

a. Conducted in both pressurization and depressurization modes
b. Using multipoint testing that meets either the provisions of:
    1. ANSI/RESNET/ICC 380-2016, or
    2. The Air Barrier Association of America Standard Method for Building Enclosure Airtightness Compliance Testing

4.2.2.2 Duct leakage testing (where applicable)

a. Only required for dwelling unit heating and cooling ducts >10′ total system length. It is encouraged that duct testing be conducted at rough-in stage before concealment.
b. Testing to be conducted in accordance with ANSI/RESNET/ICC 380-2016
c. While not required for ventilation system, common space systems, and non-residential systems, duct testing may still be a valuable diagnostic tool to ensure proper airflow

4.2.2.3 Ventilation system testing

a. Room-by-room balancing
    1. Testing can be performed using devices such as the Retrotec Flow Finder, Energy Conservatory Flowblaster, Energy Conservatory Exhaust Fan Flow Meter (for flows under 35 CFM), Testo 417 (for flows under 100 CFM) with flow straightener and capture hood, CFM-range appropriate non-powered flow hood, and duct tester device with custom capture hood attachment.
        i. Any other device or methodology must be preapproved by PHIUS
    2. Alternatively, a certified third-party air balancer or product commissioning agent can provide a detailed air balancing report in lieu of the Rater performing this

task. It is highly recommended that the Rater verify a portion of the measured airflows

i. For MF verification of 3rd party air-balancer work, see the most current version of the PHIUS+ MF Standard.

b. Total ventilation system airflow at unit (supply & exhaust)

1. Testing can be performed using in-duct measurement devices such as Kele FXP flow stations, manufacturer built in pressure taps, traversing tools such as hot wire anemometers or pitot tubes, or through using static pressure measurements compared to a manufacturer's fan curve table.
2. Alternatively, measurements of the outdoor air inlet and exhaust outlet of the ventilation system can be made on the exterior of a building using a pressure matching tool such as a duct tester or powered flow hood, so long as:
   i. Measurements can be made safely
   ii. The ducts connecting the system to outside are well sealed
   iii. Environmental conditions (wind) will not adulterate the test results.
   iv. Ventilation in/outlets are possible to test without building products or architectural features interfering.

c. Power consumption measurement recorded in watts for ventilation units in typical 24/7 mode using the following methods:

1. Using a power-factor adjusted wattage clamp meter, such as the Amprobe NAV-51, tested at the electrical panel or other accessible location
2. Using a plug-in watt meter such as the Kill-a-Watt, so long as the system has an electrical plug
3. Using measured total system airflow or external static pressure and a manufacturer's fan curve table
4. Alternatively, this may be tested by a third-party balancing firm, HVAC contractor or electrician.

4.2.2.4 Heating and cooling system airflow testing

a. Room-by-room balancing

1. See ventilation provisions above

b. Total system airflow

1. See ventilation provisions above

4.2.2.5 Bedroom pressure balancing

a. Ducted heating and cooling systems

1. Bedrooms shall be pressure balanced to +/- 3 Pa with respect to (WRT) the main body of the house with all other bedroom doors closed and the system running

b. Ventilation systems

1. Bedrooms shall be pressure balanced to +/- 1 Pa with respect to (WRT) the main body of the house with all other bedroom doors closed and the ventilation system running.

4.2.2.6 Hot water distribution system testing

a. With the hot water pipes not primed (i.e., do not turn on the hot water tap for a minimum of 2 hours ahead of time), measure the temperature of the hot water stream at the hot water fixture that contains the highest volumetric water content from water heater
    1. This is often, but not always, the longest hot water plumbing run from the water heater.
    2. It is recommended to use either an infrared camera or a digital meat thermometer to check the temperature rise of the water.

b. While measuring the temperature of the hot water stream, no more than 0.6 gallons shall be emitted before the hot water temperature increases by 10 deg. F.
    1. Hot water shall be captured using a bucket, pitcher or plastic bag with 0.6 gallons marked.

E-4.3 Documentation

a. All inspections and testing shall be documented using the most current version of the PHIUS+ Workbook that was available when the project was initially registered with PHIUS (based on contract date).

b. Additional documentation that shall be provided include:
    1. Multi-point automated testing software reports or digital files
    2. Ventilation and heating/cooling balancing reports (if not in Workbook)
    3. HERS energy modeling software files or Building Summary/Building File Report pdfs. Exceptions - not required for:
        i. CA, AK, or international projects
        ii. MF 6+ stories and non-residential projects
    4. Photos, including a minimum of:
        i. Foundation insulation
        ii. Above-grade insulated assemblies
        iii. Known thermal-bridges and/or mitigation strategies
        iv. Surrounding site and window shading systems
        v. Representative thermal images demonstrating no unexpected thermal bypasses
    5. Indoor airPLUS low-emitting products documentation
        i. While it is not necessarily the responsibility of the Rater/Verifier to verify compliance with the IAP low emitting products requirements, it is

necessary for the builder to provide documentation and attestation that all products are compliant.

ii. It is recommended that the Rater/Verifier work with the builder to develop a list of affected products, and to educate them on verifying compliance with these program requirements.

E-5. Post-Construction Requirements

a. All projects shall be documented as described above. This documentation shall be communicated to the project team so that any appropriate adjustments can be made to the PHIUS energy model.

b. For Single family homes and multi-family projects of 5 stories or less that include a formal HERS Rating, it is recommended that specific building characteristics be reviewed and coordinated with the Certified Passive House Consultant (CPHC);
   a. Over all iCFA
   b. Net Volume
   c. Building Envelope area
   d. Window areas & NFRC data

c. After communicating documentation to the project team and final updates made to the PHIUS energy model, either the Rater/verifier or a member of the project team shall notify PHIUS certification staff that the project is ready for final review.

d. Documentation shall be submitted to the shared Dropbox folder established by PHIUS for the project. PHIUS may request additional documentation where necessary.

e. PHIUS certification staff shall review final documentation of project and compare to the PHIUS energy model and intended project specifications.
   1. Where questions arise, or changes are necessary to be made for consistency, PHIUS certification staff shall communicate this information to the Rater/Verifier, and or the project team where applicable to make updates.
   2. The Rater/Verifier shall use this information to make any necessary adjustments and shall resubmit all project documentation to PHIUS certification staff for final approval.

E-6. Resources

Download the latest documents from this page:

1. PHIUS+ Multi Family Quality Assurance Workbook
2. PHIUS+ Single Family Quality Assurance Workbook
3. PHIUS+ Certification Guidebook
4. PHIUS+ Multifamily Quality Assurance Protocol
5. PHIUS+ Rater/Verifier Mentorship Letter of Attestation

Appendix F – ANSI/RESNET/ICC 380-2016: Procedure to Prepare the Building for Testing

3.2.1. Fenestration. Exterior doors and windows shall be closed and latched.

3.2.2. Attached garages. All exterior garage doors and windows shall be closed and latched unless the blower door is installed between the house and the garage, in which case the garage shall be opened to outside by opening at least one exterior garage door.

3.2.3. Crawlspaces. If a crawlspace is unvented, interior access doors and hatches between the house and the crawlspace shall be opened and exterior crawlspace access doors, vents, and hatches shall be closed. If a crawlspace is vented the interior access doors and hatches shall be closed and crawlspace vents shall be left in their as-found position and their position shall be recorded on the test report.

3.2.4. Attics. Attic access doors and hatches shall be closed unless the attic is air sealed and insulated at the roof deck, in which case the access doors and hatches shall be opened. The position of the attic access doors and hatches shall be recorded. Exterior access doors, dampers, or vents shall be left in their as-found position and their position shall be recorded on the test report.

3.2.5. Basements. All doors between basements and Conditioned Space Volume shall be opened unless the house floor above the basement is air sealed and insulated, in which case the door between the basement and Conditioned Space Volume shall be closed. The position of the basement doors shall be recorded. Where the door to the basement is required to be closed, the basement shall be excluded from Infiltration Volume and Conditioned Floor Area.

3.2.6. **Interior doors.** All doors between rooms inside the Conditioned Space Volume shall be opened.

3.2.7. Chimney dampers and combustion-air inlets on solid fuel appliances. Chimney dampers and combustion-air inlets on solid fuel appliances shall be closed. Precautions shall be taken to prevent ashes or soot from entering the house during testing.

3.2.8. Combustion appliance flue gas vents. Combustion appliance flue gas vents shall be left in their as-found position.

3.2.9. Fans. Any fan or appliance capable of inducing airflow across the building enclosure shall be turned off including, but not limited to, clothes dryers, attic fans, kitchen and bathroom exhaust fans, air handlers, ventilation fans used in a whole-house mechanical ventilation system1 , and crawlspace and attic ventilation fans. This requirement to turn fans off includes accessible fans in adjacent attached dwelling units.

3.2.10. **Dampers**

> **3.2.10.1**. Non-motorized dampers that connect the Conditioned Space Volume to the exterior or to Unconditioned Space Volumes shall be left in their as-found positions.

3.2.10.2. Motorized dampers that connect the conditioned space volume to the exterior or to unconditioned spaces shall be placed in their closed positions and shall not be further sealed.

3.2.11. Non-dampered openings for ventilation, combustion air and make-up air

3.2.11.1. Non-dampered ventilation openings of intermittently operating local exhaust ventilation systems that connect the Conditioned Space Volume to the exterior or to Unconditioned Space Volume shall be left open.

3.2.11.2. Non-dampered ventilation openings of intermittently operating whole-house ventilation systems, including HVAC fan-integrated outdoor air inlets, that connect the Conditioned Space Volume to the exterior or to Unconditioned Space Volume shall not be sealed.

3.2.11.3. Non-dampered ventilation openings of continuously operating local exhaust ventilation systems that connect the Conditioned Space Volume to the exterior or to Unconditioned Space Volume shall be sealed at the exterior of the enclosure where conditions allow.

3.2.11.4. Non-dampered ventilation openings of continuously operating whole-house ventilation systems that connect the Conditioned Space Volume to the exterior or to Unconditioned Space Volume shall be sealed at the exterior of the enclosure where conditions allow.

3.2.11.5. All other Non-dampered intentional openings between Conditioned Space Volume and the exterior or Unconditioned Space Volume shall be left open.

3.2.12. **Whole-building fan louvers/shutters**. Whole-building fan louvers and shutters shall be closed. In addition, if there is a seasonal cover present, it shall be installed.

3.2.13. Evaporative coolers. The opening to the exterior of evaporative coolers shall be placed in its off position. In addition, if there is a seasonal cover present, it shall be installed.

3.2.14. Operable window trickle-vents and through-the-wall vents. Operable window trickle-vents and through-the-wall vents shall be closed.

3.2.15. Supply registers and return grilles. Supply registers and return grilles shall be left in their as-found position and left uncovered.

3.2.16. **Plumbing drains with p-traps**. Plumbing drains with empty p-traps shall be sealed or filled with water.

3.2.17. Vented combustion appliances. Vented combustion appliances shall remain off or in “pilot only” mode for the duration of the test.

Appendix G: PHIUS+ Multifamily Certification Performance Requirements v2.2

G-1.0 Building Certification

All PHIUS+ Certified projects must meet the certification criteria of the current revision of the ESv3 and ZERH programs at the time that the project is permitted, as well as additional on-site verification criteria as contained in the *PHIUS+ Multifamily Quality Assurance Workbook* and associated checklists. Any building as part of a project that meets the eligibility criteria for ESv3 and ZERH shall additionally be fully certified under both programs, with the exception of projects in California, Alaska, and outside the USA.

The eligibility criteria for these programs include:

- Any multifamily building with 4 units or fewer; OR
- Multifamily buildings with 3 stories or fewer above-grade OR
- Multifamily buildings with 4 or 5 stories above-grade where dwelling units have their own heating, cooling, and hot water systems, separate from other units, and where dwelling units occupy 80% or more of the occupiable square footage of the building. When evaluating mixed–use buildings for eligibility, exclude commercial / retail space when assessing whether the 80% threshold has been met.
- Multifamily buildings with 4 or 5 stories above-grade that meet the above criteria, but that have central water heating system for domestic hot water are eligible for certification if solar energy provides at least 50% of the domestic hot water needs for the residential units.

Additional footnotes regarding eligibility for multifamily buildings is contained in the footnotes of the ENERGY STAR Version 3 National Program Guidelines.

Multifamily buildings that are not eligible for certification based on these criteria cannot be certified under ESv3 and ZERH, and therefore shall not be required to do so for PHIUS+ certification. However, the certification checklist criteria for these programs shall still be achieved and documented through the *PHIUS+ Multifamily Quality Assurance Workbook* and associated checklists. Specifically:

- Building envelope construction checklist items for air sealing, thermal bridging reduction, and water management strategies as specified by the ESv3 program shall be met for the entire project.
- HVAC design, installation, testing and commissioning checklist items shall be met for all dwelling units within the project, while HVAC systems for common spaces shall meet the design and commissioning requirements specified by this Standard.
- DOE ZERH requirements that affect dwelling units (the use of ENERGY STAR appliances, efficient lighting, hot water temperature rise testing) shall be implemented for all dwelling units. All other program criteria (heating/cooling ducts within conditioned space, high-

efficacy lighting, ENERGY STAR appliances, solar-ready construction, and EPA Indoor airPLUS certification criteria) shall be met for the entire project.

All certified buildings must meet the ENERGY STAR Multifamily High Rise requirements for lighting and pump motor efficiency shall be met for the entire project. PHIUS encourages, but does not require, that such ineligible projects also meet the criteria of and certify under the EPA ENERGY STAR Multifamily High Rise, LEED Multifamily, and/or National Green Building Standard Multifamily programs.

Program Versions: See PHIUS+ Certification Guidebook Section 3.6.1

G-1.1 Effective Date

The effective date of this v2.2 standard for certification of multifamily buildings shall be for any projects contracted with PHIUS on or after April 1, 2019. Any projects with a PHIUS contract date prior to this shall be encouraged but not required to follow this version's protocol and shall achieve certification based on the certification criteria agreed upon by the project and PHIUS upon original registration of project.

G-1.2 PHIUS+ Rater/Verifier

See Appendix E: PHIUS+ Rater/Verifier Manual

G-2.0 On-Site Verified Performance Criteria

G-2.1 Sampling

PHIUS accepts Sampling as a method for streamlining on-site verification by PHIUS+ Rater/ Verifier. If the project is being verified by a PHIUS+ Rater/ Verifier who is in good standing with a RESNET Sampling Provider, they shall have their plan for implementing Sampling approved by their Provider prior to Sampling being implemented. Where the Rater/Verifier is not a RESNET Rater working with a Sampling Provider, project Sampling plan must be submitted to PHIUS+ QA/QC Manager for approval prior to implementation of Sampling

Approved Sampling plan shall be no less stringent than the Sampling policies and procedures specified by the RESNET Chapter 6 Standards. Documentation of execution of Sampling plan shall be submitted to PHIUS+ QA/QC Manager as part of the final submission package of on-site project documentation.

The following dwelling unit-level on-site verification measures are likely candidates for implementation of Sampling controls:

- Compartmentalization testing.
- Duct system tightness testing.
- Ducted heating, cooling and ventilation air volume measurement and balancing.

    - If project has hired third-party air volume measurement and balancing professional other than the Rater/MF Verifier to conduct air volume measurement and balancing, Rater/MF Verifier shall be responsible for repeating the air volume measurement testing on 10% of dwelling units (maximum of 10, minimum of 3), whichever is greater. Any failures identified by the Rater/MF Verifier shall be corrected, and an additional unit shall be added to Rater/MF Verifier verified tally to ensure project failures are either isolated occurrences or are appropriately fixed.
    - If project has hired third-party professional as described above, Rater/MF Verifier shall not be responsible for repeating common space ducted HVAC system air volume measurements. However, testing professional shall submit documentation of this test to Rater/MF Verifier as described below.
- ZERH hot water distribution efficiency test.
- Bedroom pressure balancing for units with ducted HVAC systems
    - Per ESv3 standards, bedrooms shall be pressure balanced to +/- 3 Pa for dwelling units with ducted heating and cooling systems.
    - Per PHIUS+ standards, bedrooms shall also be pressure balanced to +/- 1 Pa for dwelling units with ducted ventilation systems.
- External static pressure testing of forced air heating and cooling systems.
- Spot ventilation air volume measurements to comply with ESv3 standards.
- Verification of insulated assemblies, mechanical systems, lighting and appliances.
- All other ESv3 and ZERH Rater-verifiable checklist requirements.

In addition to dwelling-unit-level measures, the Rater/MF Verifier may also implement a customized sampling plan for common space building envelope and mechanical system verification. A written plan of for sampling of these additional measures must be submitted to PHIUS+ QA/QC Manager for review prior to execution.

G-2.2 Whole-building air tightness Testing

Whole-building infiltration testing shall be performed by the PHIUS+ Rater/Verifier for each detached building in certification project. Testing shall be conducted using multi-point infiltration procedures as specified in Appendix F – ANSI/RESNET/ICC 380-2016, as well as additional guidance specific to multifamily building testing included in the [RESNET Guidelines for Multifamily Energy Ratings] document.

If a single blower door fan is utilized for testing, the Rater/MF Verifier shall use an automated multi-point testing software such as The Energy Conservatory *TECTITE* or Retrotec *Fantestic* software. If multiple fans are used, it is recommended that the test be performed using a multi-fan control testing software such as The Energy Conservatory *TECLOG* software. Alternative testing methodologies proposed by the Rater/MF Verifier must be presented in writing to the PHIUS+ QA/QC Manager and will be considered on a case-by-case basis.

Details on air-tightness criterion can be found in Section 3.2.

For attached multifamily housing developments without common access point to perform testing of all building common spaces and dwelling units, achieving uniform test pressure from a single testing location will likely be impossible. This will often be the case for attached townhouse developments, or apartment buildings without common enclosed hallways with doorways connecting the dwelling units to the common space. In such cases, multi-zone whole building testing shall be required, which will necessitate the use of multiple fans set up in multiple testing locations to achieve uniform testing pressure throughout all building zones, and either a multi-fan control testing software must be utilized, or sufficient fan operators must be employed to achieve accurate testing results.

If the nature of the development is such that the number of fans and/or fan operators needed to achieve uniform multi-zone testing conditions to assess whole-building infiltration result is beyond the ability of the project to reasonably coordinate (example: a 20-unit attached townhouse development, which would require 20 simultaneously running blower door tests to create a uniform result), the project shall use the following testing protocol:

2.2.1 Individual zone, "unguarded" testing

- Each unique building zone shall be tested individually, without adjusting the pressure of adjacent zones.
- The test results shall be adjusted using the coefficients provided in the *Guidance for modeling infiltration results for dwelling units in multifamily residential buildings* section of the RESNET Guidelines for Multifamily Energy Ratings document.
- All coefficient-adjusted test results for each individual zone shall be added together. The total sum of all project zone test results shall comply with the whole-building infiltration threshold.

2.2.2 Individual zone, "guarded" testing

- In general, "guarded" blower door testing of individual dwelling units is undesirable due to a lack of confidence in the isolation of individual dwelling unit infiltration to outdoor results. However, certain cases may require implementation of such a strategy to isolate the infiltration to outdoors of an individual dwelling unit.
- The strategy below shall only be allowed if an appropriate whole-building test is unable to be performed, and where dwelling units achieve the following prescriptive measures:
- All penetrations in dwelling unit enclosure shell shall be sealed, including pipes, wires, light fixtures, vent fans, duct/ventilation boots, light switches, electrical outlets, etc. so as to prevent leakage between the dwelling unit and other adjacent spaces.

- If electrical conduit is used to connect electrical fixtures or junction boxes, the conduit shall be sealed at each fixture or junction box to prevent air leakage within the conduit. Additionally, if each dwelling-unit contains an electrical service panel, the conduit leading from the service panel to outside of the dwelling unit shall be sealed.
- Dwelling unit bottom and top plates shall be sealed using appropriate sealing product, such as high-quality caulk, air sealing tape, foam gasket product, etc.
- Partition walls between dwelling units shall be capped at the top of the wall so as to prevent air leakage into the interstitial ceiling cavity space. In addition, solid blocking material shall be installed above partition walls for the entire perimeter of the dwelling unit so as to create a sealed ceiling cavity space directly above the dwelling unit. Any wires, pipes, ducts or other penetrations running through this blocking shall be sealed so as to prevent leakage into adjacent building chase spaces.
- For dwelling units with attic space above, ideally a fully sealed partition wall would extend from the attic floor to the roofline so as to isolate the attic space of each dwelling unit. Where this is not possible or practical, Rater/MF Verifier measured zonal pressure testing shall be conducted while performing individual unit blower door test to determine unit pressure connection to the attic space. The attic zonal pressure reading shall be 49 Pa or higher (more isolated) in comparison to the pressure within the dwelling unit while the dwelling unit is depressurized to -50 Pa.
- If the above criterion is met, the "guarded" testing strategy described below shall be accepted.
- Blower door is installed in individual dwelling unit to be tested. Blower door is also installed in each directly adjacent building zone surrounding the dwelling unit. (Example 1: A middle floor, interior apartment has 4 directly adjacent building zones – the unit above, the unit below, and the units on either side of the tested dwelling unit. Example 2: a townhouse end-unit has one directly adjacent building zone.)
- All fans are set to depressurize their respective zones to uniform test pressures. Multi-point testing shall be required and repeated for pressurization. The pressurization and depressurization results shall be averaged.
- This testing protocol shall be completed for all individual zones of the building. The averaged zone leakage rate for each individual zone shall be added together. The total sum of all project zone test results shall comply with the whole-building infiltration threshold.

2.2.3 Zone linking method

- An additional alternative may be employed whereby attached multifamily dwellings without common corridors to link them together may be linked through an approved "zone linking" method.

- Zone linking refers to connecting attached dwelling units together from a pressure perspective with some form of conduit connecting the zone of the building where the testing fan is installed and adjacent zones that will not have a testing fan installed.
- Examples of zone linking methods include using well sealed flex duct and taped transitions into windows of adjacent spaces, or using duct work of central ventilation systems. Using these methods, several zones can be linked together from a pressure perspective, allowing whole-building testing to be performed.

Any method of zone linking used will be required to documented with PHIUS prior to field execution. Once approved, the method may be used, but care must be taken during the test to ensure that all linked zones achieve the minimum testing pressure (i.e., a linked zone is depressurized to -50 Pa the same as the location of the testing fan). If consistent pressure cannot be maintained between zones (5 Pa) then either the conduit size must be increased in size, or additional fans may be required for testing to achieve consistent pressure.

G-2.3 Dwelling unit compartmentalization

Requirement: ≤0.30 CFM@50 Pa/sqft of dwelling unit shell

Individual dwelling unit compartmentalization testing shall be performed to test the air barrier integrity of each dwelling unit. Testing shall be performed as an "unguarded" test as described under the section *Procedures for Multifamily Dwelling unit/Building Air Tightness Testing*, Test 1 from the RESNET Guidelines for Multifamily Energy Ratings document, and shall not be adjusted by any multifamily infiltration correction coefficient.

Dwelling unit compartmentalization testing shall be performed in single-point depressurization mode following RESNET Chapter 8 protocol unless the testing condition at the time of the test qualifies as a *Reduced Level of Accuracy* testing condition per RESNET Chapter 8. Any adjustments for temperature, altitude or reduced accuracy as specified by Chapter 8 shall be applied to the measured CFM@50 Pa leakage rate.

This adjusted compartmentalization value shall be divided by the square footage of the dwelling unit enclosure shell area to demonstrate compliance with this requirement. For apartment-style dwelling units, "band joist" surface area accounted for as the perimeter of the ceiling cavity space of the dwelling unit shall be applied to the lower dwelling unit, and shall only be added if the entire perimeter of the ceiling cavity space is blocked and sealed (i.e., an open floor truss that is not blocked for the ceiling cavity spaces between building zones cannot have the "band joist" surface area included in this calculation.)

G-2.4 Heating and cooling air distribution system tightness testing

All heating, cooling and ventilation air distribution systems shall comply with the following:

- Located inside conditioned space (heating and cooling ducts only)

- Dwelling units
    - Comply with all HVAC design, installation and testing requirements of ESv3 Checklists
- Common spaces
    - Be designed, sized and installed according to all local and municipal code requirements by the project engineer or HVAC contractor,
    - Be constructed, installed and sealed per SMACNA Duct Construction Standards based on Class rating of duct system or the municipal mechanical code requirement where the project is permitted, whichever is more stringent.
    - Common space load calculations and duct designs submitted to the PHIUS+ Rater/MF Verifier for documentation.
    - Duct tightness testing performed by either the Rater/MF Verifier, HVAC contractor or third-party air balancing firm to demonstrate compliance with SMACNA HVAC Air Duct Leakage Test Manual thresholds or the municipal mechanical code requirement where the project is permitted, whichever is more stringent.
    - Tests completed by a party other than the Rater/MF Verifier shall be documented and sent to Rater/MF Verifier for documentation.

G-2.5 Heating, cooling and ventilation air distribution system measurement and balancing

HVAC air volume measurement and balancing shall be performed for all ducted heating, cooling and ventilation systems. All measurements shall be performed by the PHIUS+ Rater/MF Verifier unless a certified third-party air balancing contractor has been hired by the project team to perform air volume measurements and balancing. If no third-party air balancing contractor has been hired and Rater/MF Verifier is not experienced or qualified to perform system balancing, the project HVAC installing contractor shall be responsible for system air volume balancing, and the Rater/MF Verifier shall perform air volume measurements to confirm that air volume balancing has been performed and measurements are within design specifications.

Systems shall comply with the following:

- Air balancing reports produced listing the design airflows, tested airflows, locations of registers and grilles for all systems. Submitted to the PHIUS+ Rater/MF Verifier for review and documentation.
- Dwelling units
    - Comply with all air volume measurement and balancing requirements of ESv3 program and *PHIUS+ On-site Quality Control Workbook for Multifamily Projects*.
- Common spaces
    - Comply with all air volume measurement and balancing requirements of local and municipal codes.

- Exhaust ventilation systems that exert greater than -5 Pa of depressurization shall have make-up air systems with mechanical dampers that open while the exhaust system is operating installed that are sized to relieve depressurization effect.
- The Rater/MF Verifier shall document through zonal pressure testing that each zone containing an exhaust system does not depressurize the zone by more than -5 Pa.

G-2.6 Hydronic heating, cooling and hot water systems appropriately tested and balanced

Hydronic heating and cooling systems fall outside of the scope of ESv3 and ZERH standards. Nevertheless, their design, installation and performance are critical to building performance.

All hydronic heating and cooling systems shall be designed, sized and installed per local or municipal code requirements. Additionally, systems shall be balanced by installing contractor or third-party balancing professional. It is recommended that balancing be performed following either National Environmental Balancing Bureau (NEBB) *PROCEDURAL STANDARDS FOR TESTING ADJUSTING AND BALANCING OF ENVIRONMENTAL SYSTEMS - SEVENTH EDITION*, ACCA Manual B, or another professional industry-accepted testing and balancing standard. Documentation of balancing shall be provided to Rater/MF Verifier with design flows, tested flows, and locations of all terminal devices.

Rater/MF Verifier shall test hot water distribution effectiveness for each dwelling unit by measuring the temperature-rise of highest volume fixture per ZERH standards. PHIUS encourages, but does not require, project teams to install demand-based controls for central hot water distribution systems to meet this requirement. Additionally, PHIUS strongly discourages, but shall not prevent, the use of continuous or time-based hot water circulation systems.

G-2.7 Installed HVAC, pump, motor, and lighting verification and electrical measurement

The Rater/MF Verifier shall perform visual verification that all installed HVAC, pump, motor and lighting equipment meet the specifications of the building design. Where deviations occur, the Rater/MF Verifier shall report findings to the project energy modeler to revise the PHIUS+ energy model. Additionally, the Rater/MF Verifier shall perform electrical wattage measurement on installed ventilation systems, or alternatively shall shadow an electrical/mechanical contractor in their measurement of such systems.

G-2.8 Demonstration of compliance with all ESv3 and DOE checklist certification criteria

For projects where ESv3 and ZERH certification are required, as described in Footnote 4, the project team shall choose to comply with either the Performance or Prescriptive Path of each program. Choosing the Performance Path of these programs will require that the PHIUS+ Rater complete additional HERS-based energy modeling in addition to the PHIUS energy model. Choosing the Prescriptive Path will eliminate the need for modeling, but may only be chosen for projects where all dwelling units meet all Prescriptive Path eligibility criteria. Additionally, many utility and state energy efficiency programs offer incentives for HERS-based performance verification, and thus projects may benefit overall from using the Performance Path.

The appropriate version of the ESv3 and ZERH standards shall be based on the permit date of the project. ZERH also requires certification under the EPA Indoor airPLUS program as part of its certification criteria. PHIUS also encourages, but does not require, certification under the EPA WaterSense New Homes program. For more information on these programs, please see the following links:

ESv3: http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_v3_guidelines
ZERH: http://energy.gov/eere/buildings/zero-energy-ready-home
IAP: http://www.epa.gov/indoorairplus/index.html
WaterSense: http://www.epa.gov/watersense/new_homes/index.html

G-2.9 Verification of Renewable Energy System Installation, or Renewable Ready

All projects shall either have renewable energy systems installed or shall comply with the DOE Zero Energy Ready Home PV-Ready Checklist, regardless of how much average daily solar radiation the site receives. Sites with significant adjacent shading or insufficient roof area facing true south per the program checklist shall not be required to comply with this requirement.

G-3.0 Energy Model-Based Performance Requirements

See Section 3.

Appendix H - PHIUS+ 2018 Target-Setting Process for Heating and Cooling Limits

Building size and occupant density influence the optimal path to a low energy building. Therefore, the criteria implement continuous adjustments for a range of different building sizes and occupant densities (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 change depending on climate.

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 PHIUS+ 2018 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.

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 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.

Climate factors included:

(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/m2.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.ft2]: Peak Heating Solar Radiation
Source: Meteonorm
(9) IGCL [BTU/hr.ft2]: 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.

Crossover to WUFI Passive

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.

Curve-Fitting

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.

Appendix I – DHW Distribution Pipe Materials and Sizes

Ounces of water per foot of hot water tubing								
Nominal diameter [in]	Copper M	Copper L	Copper K	CPVC CTS SDR 11	CPVC SCH 40	PEX-AL-PEX	PE-AL-PE	PEX CTS SDR 9
	2	3	4	5	6	7	8	9
3/8	1.06	0.97	0.84	**#N/A**	1.17	0.63	0.63	0.64
1/2	1.69	1.55	1.45	1.25	1.89	1.31	1.31	1.18
5/8	**#N/A**	2.32	2.22	**#N/A**	**#N/A**	2.12	**#N/A**	1.72
3/4	3.43	3.22	2.90	2.67	3.38	3.39	3.39	2.35
1	5.81	5.49	5.17	4.43	5.53	5.56	5.56	3.91
1 1/4	8.70	8.36	8.09	6.61	9.66	8.49	8.49	5.81
1 1/2	12.18	11.83	11.45	9.22	13.20	13.88	13.88	8.09
2	21.08	20.58	20.04	15.79	21.88	21.48	21.48	13.86

Outside diameter [in]								
Nominal diameter [in]	Copper M	Copper L	Copper K	CPVC CTS SDR 11	CPVC SCH 40	PEX-AL-PEX	PE-AL-PE	PEX CTS SDR 9
	2	3	4	5	6	7	8	9
3/8	0.50	0.50	0.50	**#N/A**	0.68	0.47	0.47	0.50
1/2	0.63	0.63	0.63	0.63	0.84	0.63	0.63	0.63
5/8	**#N/A**	0.75	0.75	**#N/A**	**#N/A**	0.79	**#N/A**	0.75
3/4	0.88	0.88	0.88	0.88	1.05	0.98	0.98	0.88
1	1.13	1.13	1.13	1.13	1.32	1.26	1.26	1.13
1 1/4	1.38	1.38	1.38	1.38	1.66	1.58	1.58	1.38
1 1/2	1.63	1.63	1.63	1.63	1.90	1.97	1.97	1.63
2	2.13	2.13	2.13	2.13	2.38	2.48	2.48	2.13

Inside diameter [in]								
Nominal diameter [in]	Copper M	Copper L	Copper K	CPVC CTS SDR 11	CPVC SCH 40	PEX-AL-PEX	PE-AL-PE	PEX CTS SDR 9
	2	3	4	5	6	7	8	9
3/8	0.45	0.43	0.40	**#N/A**	0.49	0.35	0.35	0.36
1/2	0.57	0.55	0.53	0.51	0.62	0.50	0.50	0.49
5/8	**#N/A**	0.67	0.65	**#N/A**	**#N/A**	0.64	**#N/A**	0.58
3/4	0.81	0.79	0.75	0.72	0.82	0.81	0.81	0.68
1	1.06	1.03	1.00	0.92	1.05	1.03	1.03	0.88
1 1/4	1.29	1.27	1.25	1.13	1.38	1.28	1.28	1.07
1 1/2	1.53	1.51	1.48	1.33	1.61	1.63	1.63	1.26
2	2.01	1.99	1.96	1.74	2.07	2.03	2.03	1.65

Weight empty lb/ft								
Nominal diameter [in]	Copper M	Copper L	Copper K	CPVC CTS SDR 11	CPVC SCH 40	PEX-AL-PEX	PE-AL-PE	PEX CTS SDR 9
	2	3	4	5	6	7	8	9
3/8	0.14	0.20	0.27	**#N/A**	0.12	0.06	0.07	0.05
1/2	0.20	0.29	0.34	0.08	0.18	0.07	0.10	0.06
5/8	**#N/A**	0.36	0.42	**#N/A**	**#N/A**	0.10	**#N/A**	0.08
3/4	0.33	0.46	0.64	0.14	0.24	0.15	0.14	0.11
1	0.47	0.66	0.84	0.23	0.35	0.23	0.23	0.17
1 1/4	0.68	0.88	1.04	0.35	0.48	0.39	0.38	0.26
1 1/2	0.94	1.14	1.36	0.49	0.57	0.55	0.55	0.36
2	1.46	1.75	2.06	0.83	0.76	0.92	0.91	0.61

Empty pipe heat capacity Btu/ft.F								
Nominal diameter [in]	Copper M	Copper L	Copper K	CPVC CTS SDR 11	CPVC SCH 40	PEX-AL-PEX	PE-AL-PE	PEX CTS SDR 9
	2	3	4	5	6	7	8	9
3/8	0.01	0.02	0.02	**#N/A**	0.02	0.04	0.04	0.02
1/2	0.02	0.03	0.03	0.02	0.04	0.04	0.06	0.03
5/8	**#N/A**	0.03	0.04	**#N/A**	**#N/A**	0.06	**#N/A**	0.05
3/4	0.03	0.04	0.06	0.03	0.05	0.08	0.08	0.06
1	0.04	0.06	0.08	0.05	0.07	0.13	0.13	0.09
1 1/4	0.06	0.08	0.09	0.07	0.10	0.21	0.21	0.14
1 1/2	0.08	0.10	0.12	0.10	0.11	0.30	0.30	0.20
2	0.13	0.16	0.19	0.17	0.15	0.50	0.50	0.34

Pipe + water heat capacity Btu/ft.F								
Nominal diameter [in]	Copper M	Copper L	Copper K	CPVC CTS SDR 11	CPVC SCH 40	PEX-AL-PEX	PE-AL-PE	PEX CTS SDR 9
	2	3	4	5	6	7	8	9
3/8	0.08	0.08	0.08	**#N/A**	0.11	0.08	0.08	0.07
1/2	0.13	0.13	0.13	0.10	0.17	0.12	0.14	0.11
5/8	**#N/A**	0.18	0.18	**#N/A**	**#N/A**	0.19	**#N/A**	0.16
3/4	0.25	0.25	0.25	0.20	0.28	0.30	0.30	0.22
1	0.42	0.42	0.41	0.33	0.44	0.49	0.49	0.35
1 1/4	0.63	0.62	0.62	0.50	0.74	0.76	0.76	0.53
1 1/2	0.87	0.87	0.87	0.70	0.99	1.20	1.20	0.74
2	1.50	1.49	1.49	1.19	1.60	1.90	1.89	1.26

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