phius 2021 Passive Building Standard

Standard-Setting Documentation

Version 1.1
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Table of Contents

1. phius 2021: Emissions Down, Scale Up

At phius, our mission is to make high-performance passive building mainstream. We are largely driven by concern about the environmental impact of inefficient buildings that waste energy. Climate science[1] [2] clearly shows that the burning of fossil fuels needs to stop, and the sooner the better. Passive building measures such as superinsulation, air-sealing, and heat-recovery ventilation have always been great for saving energy (especially on space heating). Even if CO_2 emissions stopped yesterday, climate chaos and weather extremes will continue to increase for a long time to come. A passive building offers good protection from the elements and is therefore good for both climate mitigation and climate adaptation. Passive building becomes "both a sword and a shield in the climate fight." To promote passive building, phius created a standard to guide builders in the successful design and construction of passive buildings.

In recent years, a movement has formed around the idea of getting buildings to be zero-emission by completely electrifying them, and then powering them from renewable sources. We believe that passive building is the right foundation for this strategy because it significantly reduces the heating/cooling load in the first place. For 2021, phius goes further with new provisions in support of electrification.

The design methodology we promote relies on energy modeling, and on energy design to aggressive performance targets, and we have been dedicated to the idea that this methodology is necessary to achieve high performance while leaving enough flexibility for designers to find their most cost-effective solutions. In the fall (2019) the phius Tech Committee considered whether the overhead and the skills needed for such modeling were a barrier to wider use of the standard and whether there was enough data and experience to provide a path without modeling. Although the count and the size of certified buildings has been growing, passive

[1] IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.

[2] Reidmiller D, Avery CW. 2018. CHAPTER 29 Reducing Risks Through Emissions Mitigation. In: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. Washington DC, USA: U.S. Global Change Research Program. [accessed February 28, 2021]. https://nca2018.globalchange.gov/chapter/29/

building still has a small share of the overall market. A more prescriptive process was considered to create a simpler way to design passive single-family residences. Phius 2021 adds a single-family prescriptive path that removes the requirement for an energy model. As a hybrid approach, this path has prescriptions for both the envelope and mechanical aspects of buildings while allowing some performance tradeoffs within those two realms.

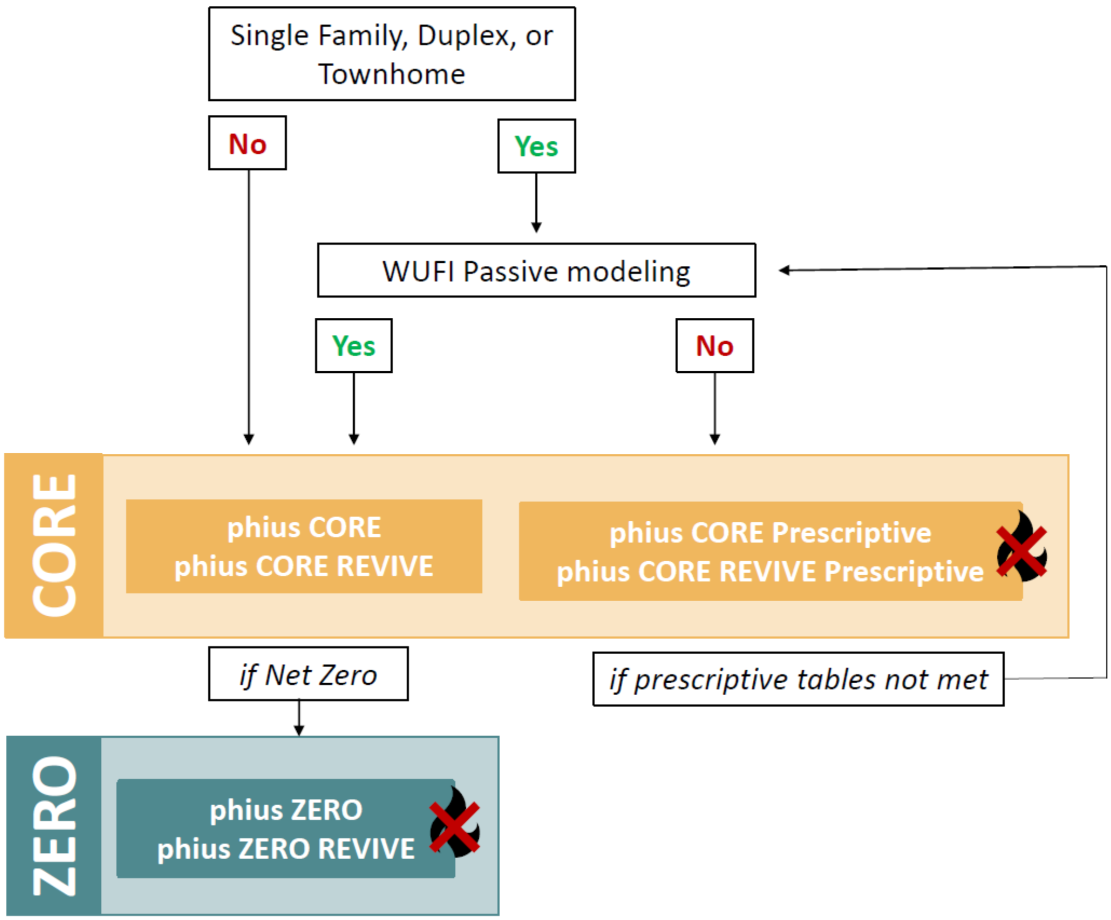

Figure 1. Certification Options. All are climate-specific. Fossil fuel combustion is only allowed for phius CORE and phius CORE REVIVE, and electrification readiness is required.

As shown in Figure 1, there are now six certification options under 2021:

- phius CORE, phius CORE REVIVE
- phius CORE Prescriptive, phius CORE REVIVE Prescriptive
- phius ZERO, phius ZERO REVIVE

The “middle tier” of net source energy from PHIUS+ 2018 goes away. Phius 2021 sets one target for on-site conservation and one that goes all of the way to net zero. This is intended to accelerate the glide path to zero – the net source energy target is zero as of 2021 instead of the original goal of 2030.

2. Timeline

November 9 - December 7, 2020: Public comment period
March 1, 2021: phius 2021 Full Release
January 1 - December 31, 2021: PHIUS+ 2018 and phius 2021 Submission Overlap
December 31 2021: PHIUS+ 2018 ends
January 1, 2022*: All new projects under phius 2021
**Must have a signed project contract submitted to PHIUS by above date to secure the version.*

The 2021 updates to the performance path options are discussed in **section 4** below, and the new prescriptive path in **section 5**, but let us first address quality assurance.

3. Quality assurance

3.1 New for phius 2021

- Alignment with the Energy Star Multifamily New Construction (MFNC) Program
  - The MFNC program is available for all residential new construction, except single-family detached homes and two-family dwellings.Visit this page to determine eligibility.
  - Notable Updates: Dwelling unit compartmentalization limit decreases from 0.30 $cfm50/ft^2$ to 0.23 $cfm50/ft^2$
- Alignment with EPA Indoor airPLUS v2
  - Notable Updates: Direct, intermittent kitchen exhaust is required in **only** single family, duplex, and townhomes. Guidance on designing makeup air systems is under development.
- New nonresidential Quality / Commissioning Protocol

3.1.1 Nonresidential QA Protocol

There is now a more formal and detailed quality assurance protocol and QA Workbook for nonresidential (and mixed-use) projects. It is based on the EPA Energy Star Multifamily New

Construction Program. The PHIUS Verifiers have the overall responsibility for field verification, data collection, performance testing and air balancing tolerances. The PHIUS Verifier has responsibility for the Heat + Cool worksheet. The Applicable items on the Energy Star MFNC Functional Testing Checklist shall be completed by responsible parties with qualifications as defined under "HVAC Functional Testing Agent Responsibilities".

The Verifier is also responsible for verifying all items on the EPA Indoor airPLUS checklist. For dwelling units in mixed use buildings: all items for the Energy Star MFNC and Indoor airPLUS programs shall be verified and dwelling units certified under each of those programs so long as EPA allows them to be certified based on building configuration.

For non-residential spaces and purely non-residential buildings, only the applicable items for EPA Energy Star MFNC and Indoor airPLUS shall apply and be verified by PHIUS Verifier "as if" they were being certified, but certification under the programs is not required.

4. phius CORE 2021 and phius ZERO 2021

4.1 What's the same

Phius remains a pass/fail passive building standard. For the CORE and ZERO options, it remains a "performance-based" energy standard that also includes prescriptive quality assurance requirements adopted from U.S. government programs – Energy Star, DOE Zero Energy Ready Home, and EPA Indoor airPLUS.

The standard has three pillars, or marquee-level requirements:

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

4.1.1 Software

For the performance requirements, compliance is determined by energy modeling. Only WUFI® Passive is accepted for phius CORE 2021 and phius ZERO 2021, Version 3.2.0.1 and later.

The difference between phius CORE and phius ZERO pertains only to the limit on overall source energy use – the heating/cooling criteria and quality assurance requirements are the same for both options. The two options represent two tiers of overall performance, and two slightly different perspectives on how to measure it. The idea of the phius CORE overall performance target is that it is a performance level that is challenging but usually achievable with conservation measures alone. The idea of phius ZERO is to go to net zero with some combination of conservation measures, on-site renewables, and off-site renewables.

For 2021 there are changes to both the heating/cooling criteria and the source energy limits. These are discussed separately in sections 4.1 and 4.2 below.

4.2 Performance Paths: Space Conditioning

4.2.1 What's the same

4.2.1.1 Energy Modeling Protocol

There are no changes from PHIUS+ 2018 in the energy modeling protocol outside of an adjustment to the source energy factor for electricity and renewable energy offset factors as shown below.

4.2.1.2 Target-setting process for Heating and Cooling Limits

For PHIUS+ 2018, the basic process for setting the heating and cooling criteria was:

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

The BEopt study cases from 2018 were also used for 2021, but there were additional optimization cases run on a Tiny house design, and some corrections were made to the Crossover models of the 2018 cases. Therefore, the curve-fitting was also redone.

4.2.2 New in phius 2021

4.2.2.1 Tiny House Study:

While the PHIUS+ 2018 study buildings covered a wide range of envelope to floor area ratios, some of the smaller projects submitted for certification ran into difficulty with very tight space conditioning criteria. For phius 2021, a 'tiny house' case was created and run to extend the envelope to floor area ratio of studied buildings from the previous ratio of 3.07 up to 9.20. Forty cases were run (using BEopt 2.8) comprising two different occupancy levels (one or two people), each in twenty climate locations. Fixed parameters of the 'tiny house' are noted below. It was inspired by the "Bodega" design from Tumbleweed Tiny House Company.

- iCFA: 146 to 229 square feet, depending on the wall package chosen by BEOpt. (Base iCFA was 192 ft2.)
- 18 ft (long) x 14 ft (wide)
- 16' tall with 12:12 gable roof
- 14% Window-to-wall ratio
- Oriented facade-south
- Foundation: Assumed pier-and-beam – floor was considered in contact with outer air.

Figure 2. Design inspiration for the Tiny house study cases.

Unlike for some of the 2018 study buildings, the window sizes and locations remained static. Otherwise the variables and constraints for the optimization were set as for the 2018 study, including IECC code minimums. In the crossover models, the exterior dimensions were kept fixed but the floor area was adjusted depending on the wall thickness.

4.2.2.2 Revised curve-fits for space conditioning targets

In the fitting of regression formulas for the heating/cooling performance to functions of the climate factors, the Tiny houses did not fall into the same pattern as the 2018 study buildings. Therefore, a separate set of formulas was fitted to the Tiny house results. The phius 2021 criteria calculator interpolates between the two sets of criteria formulas based on the building floor area. For buildings with over 1000 ft², it just uses the updated 2018 criteria, and limits the envelope-to-floor area adjustment to the range studied in 2018 (0.71 to 3.07). For buildings between 200 and 1000 ft², it interpolates linearly, and below 200 ft² it uses the Tiny house formulas.

The following changes were made in refitting the regression formulas for the three hundred 2018 study cases:

- The WUFI Passive Crossover models were recalculated using the new shading algorithm.
- Window areas in the Crossover models were corrected (lower) for some of the cases.
- Unit density was tested as a predictor along with the occupant density. For the Annual Heating and Cooling Demands, unit density was found to be a better predictor than occupant density. The peak loads were sensitive to both, but not strongly.
- The formula for the Peak Heating Load limit now uses the heating design-day temperature of the clear-cold day (THD-1), as one of its predictor variables, instead of the average of the two design-day temperatures. For most projects the clear-cold day condition calculates a higher heating load than the cloudy, warmer day (THD-2). Therefore, using THD-1 in the curve-fitting slightly improved the fit and raised the peak heating load limit in the warm climates.

The *best-fit* climate-sensitive regression formulas for the heating and cooling criteria are shown in Appendix A, for both the Tiny homes and the Non-Tiny. As was done for the 2018 mid-cycle update, the Criteria calculator actually uses *inclusive-fit* formulas for all the criteria except the annual heat demand. The inclusive fit adds an additional allowance of 120% of the RMS error.

On average, for the study buildings and for 52 recent projects, these changes resulted in about an 11% loosening of the annual heating demand target and about a 14% tightening of the annual cooling and peak cooling targets, with little average change in the heating load target, compared to 2018.

4.2.2.3 Certification Criteria

Use the **phius 2021 Performance Criteria Calculator** **v2** to determine project specific space conditioning criteria.

- **General Inputs** apply to all building types.
  - Envelope Area: Building exterior envelope area, including partitions to adjacent

non-certified spaces or buildings.
        - The envelope area can be calculated manually or found in the WUFI Passive model under the results report or visualized components branch.
    - Interior Conditioned Floor Area (iCFA): The total iCFA of the building. iCFA is defined as 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.
- **Residential Mode** should be used for certification of all residential type buildings: single-family detached, single-family attached and multifamily buildings, excepting hotels and motels.
    - Dwelling Units: The total number of dwelling units in the building.
    - Total Bedrooms: The total number of bedrooms in the building.
        - Studio apartments are counted as '0' bedrooms.
        - Input all bedrooms, not number of bedrooms per dwelling unit.
- **Non-Residential Mode** should be used for certification of all non-residential building types.
    - Design Occupancy: Maximum occupancy of the building.
    - **Custom Optimization:** For unique non-residential buildings with very high internal loads, ventilation loads, or highly variable occupancy, custom optimization may be needed to determine the appropriate targets. This will be done on a case-by-case basis. An additional certification fee will apply.

Mixed-Use building types currently require two separate calculations to represent different use types.

4.3 Performance paths: Source Energy & Overall Impact

4.3.1 What's the same

The *overall* energy limit under phius 2021 is based on *source* energy, rather than *site* energy, as it is a better proxy for resource consumption and emissions associated with the site's energy use. The source energy limit is not set based on cost optimization. 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.

Source energy factors for electricity will continue to be calculated on a national scale. The perspective here is like that of the "benchmarking" perspective in Energy Star Portfolio Manager, that buildings should be compared on how efficient they are without being either credited or penalized for the efficiency of their local energy providers.

For phius CORE, as in PHIUS+ 2015 and 2018, solar thermal can offset part of the source energy for water heating, and PV can get partial credit for an estimated fraction of the generation that is used at the same time it is produced. On-site battery storage can increase this PV utilization fraction (requires side calculations).

4.3.2 New in phius 2021

4.3.2.1 Adjustment of the residential source energy allowance for occupant density and unit density for phius CORE

A particular residential use case was noted that had great difficulty meeting the 2018 limit on source energy per person. This happened with designs that had many single-occupant apartments together. Under 2018 these designs required large PV arrays to offset their predicted energy use. Because such designs are common for affordable/supportive housing, we decided to look for a way to revise the requirement so that it could more likely be met with conservation measures alone. The 2018 study building results were reanalyzed for overall source energy use, and a good correlation was found in terms of the floor area per person and unit density (see Figure 3.) The Tiny house cases for 2021 fell into the same pattern and these were incorporated as well.

$$
\begin{aligned}
&-3816.86953 \\
&+ 15.66697695 \cdot iCFA/p \\
&+ 3748420.7252 \cdot UnitDens \\
&+ \left(iCFA/p - 478.09075196 \right) \cdot \left(\left(UnitDens - 0.0013443515 \right) \cdot 8337.2140192 \right)
\end{aligned}
$$

Figure 3. Best-fit regression formula for source energy per person (kWh/p.yr), at a current grid electricity factor of 2.8, using all 300 cases from the 2018 study and the 40 Tiny-house cases. Rsq=0.91. Unit density (*UnitDens)* is the inverse of the iCFA per unit (including corridors).

To make the fit "inclusive", the RMS error of 921.4 kWh/p.yr is added to the allowance. The result is then multiplied by 1.8/2.8 to rescale for equivalent stringency at the future grid factor.

The iCFA *per unit* adjustment is range-limited between 146 and 2058 ft². The iCFA *per person* adjustment is range-limited between 225 and 750 ft². The low end of the studied range was 86 ft²/person in the tiny homes, but this leads to very low allowances for highly-occupied units. Adjusting the source energy allowance per person based on the floor area per person would appear to undermine the concept we espoused of an equal share per person, but range-limiting the iCFA/person on the high side restores a limit against increasing the allowance merely by increasing the floor area. (For nonresidential buildings the source energy allowance goes by floor area in any case.)

Testing of the formula described above on 49 recent projects, with any PV offset removed, indicated that they would pass by 14% on average.

4.3.2.2 Grid Factors for Electricity

In past versions of the phius certification program, the source-site ratio for grid electricity was defined by the Energy Star Portfolio Manager and was determined based on past generation and consumption data from the EIA (Energy Information Administration).

Moving forward, phius will use a source energy factor for grid electricity that reflects a future outlook. The intent is to more appropriately reflect future conditions and to better weigh the impact of using electricity versus natural gas on-site. For projects in the US, phius 2021 uses a source energy factor based on a projected 2050 electricity generation mix. This future source energy factor was calculated from NREL's MidCase scenario in 2050, as reported in their 2020 Standard Scenario Report. This report details the future grid generation resource mix based on policies that were in place as of June 30, 2020. A full calculation methodology report can be found here. 2050 is the furthest year out that the data is projected to, and is roughly a midpoint on the anticipated life of a building built today.

The source energy multiplier for grid electricity is adjusted **from PHIUS+ 2018 to phius 2021** as outlined below:

- **USA:** from 2.8 to 1.8
- **Canada:** remains at 1.96

4.3.2.3 Fossil Fuel Use

phius CORE: Fossil fuel combustion equipment is allowed.
phius ZERO: No on-site fossil fuel combustion equipment shall be installed.

4.3.2.4 Electrification Readiness

phius CORE: Required for all residential projects.

Appendix E of this document outlines the proposed text for the phius 2021 Guidebook, Section 3.5.

4.3.2.5 Electric Vehicle Readiness

EV-Readiness will be required for all phius 2021 projects.
Appendix D of this document outlines the proposed text for the phius 2021 Guidebook, Section 3.5.

4.3.2.6 Certification Criteria

There are now two performance tiers: one to set a target for conservation, and the other to reach net zero source energy.

- phius CORE:
    - **Residential**: From 5500 kWh/person.yr in 2018 to a variable target based on unit and occupant density.
        - Use the [phius 2021 Performance Criteria Calculator] to determine project specific source energy criteria.
    - **Non-Residential:** Reduced from PHIUS+ 2018 target of 38.1 kBtu/ft^{2}yr down to a new target for phius CORE 2021:
        - **USA**: 24.5 kBtu/ft^{2}yr
        - **Canada**: 26.7 kBtu/ft^{2}yr
        - On a *site-energy* basis the stringency is the same – the level of efficiency/conservation required to meet this target remains in-line with PHIUS+ 2018, but the target was adjusted down to reflect the updated source energy factor for grid electricity.

- phius ZERO
    - **Residential & Non-Residential:** The target remains 0.

4.3.2.7 Protocol for Off-site Renewable Energy for phius ZERO

Appendix C of this document outlines the protocol for off-site renewable energy, which is aligned with the March 2020 Addendum J to ASHRAE 189.1-2017, from section 7.4.1.1 onwards, modified as indicated.

In summary, more guidance is provided for contracting off-site renewable energy, and on-site renewable energy production is now credited higher than off-site. For phius CORE, only on-site renewable energy is credited, see 4.3.1 above.

5. phius CORE Prescriptive 2021

5.1 Overview

A prescriptive certification path is now available for single-family detached residences, duplexes, and townhomes. As with the performance path, there are requirements for:

- Quality assurance, including air-tightness,
- Passive measures to limit heating and cooling peak loads and annual energy, and
- Overall energy use is limited by equipment efficiency measures. Renewable electric power generation systems are not required, nor credited as offsets. Electric vehicle readiness is also required.

The requirements are shown on the phius CORE Prescriptive Checklist. Notable scope limitations and design constraints include:

- No fossil fuel combustion equipment, natural draft fireplaces, indoor pools or jetted tubs.
- Limit on the ratio of floor area to bedrooms.
- Limits on window and skylight area, window orientation.
- Restrictions on wall assembly types.
- Limit on "noncompactness".
- Shading overhangs are required in hot climates.

Within the prescriptive path there are two arenas where performance tradeoffs can be made:

- Total thermal transmittance ΣUA of the building thermal envelope.
- Energy efficiency of builder-installed lighting, appliances, and water heating.

5.2 Climate/Building Specific Requirements

Several of the prescriptive requirements are calculated, depending on the climate location and/or the basic characteristics of the building (floor area, number of bedrooms, number of stories). The rules and rationale for each of these is described below.

5.2.1 Compactness

The compactness requirement is intended not to force an ideal or optimal level of compactness but rather to prevent particularly uncompact designs.

The enclosure surface area *AE* must not exceed that of a notional rectangular building with the proposed interior conditioned floor area *iCFA* and number of walkable levels *Ns*, calculated as follows:

$AE \leq AEmax = 2*(w*d+d*h+w*h)$

The height $h = Hs*Ns$

The depth $d = (iCFA/Ns)/(w\text{-}0.6\text{m})+0.6\text{m}$

The width $w = \text{sqrt}(awd*iCFA/Ns)+2$ feet (0.6m)

The width to depth aspect ratio awd=3.

The height per story Hs = 12 feet (3.7m)

5.2.2 Air Tightness

The limit is 0.04 cfm50/ft^2, which requires testing to verify compliance. The value must be achieved by the average of a pressurization and depressurization blower door test results, as with all phius projects. Additionally, a preliminary test is required for the prescriptive path.

This is tighter than the limit set for projects taking the performance route because:
1. Air-tightness was shown to be a cost-effective measure in the cost-optimization studies used to set the performance targets. Therefore, the study buildings used for the target-setting process often used better than required air-tightness. So, this tighter limit helps provide more consistent results with the performance path.
2. Project teams have also found over-performing on air-tightness to be a good strategy.

5.2.3 Solar protection

<u>Glazed fenestration solar heat gain coefficient:</u> Requirements vary by climate zone and align with DOE Zero Energy Ready Home.

<u>Fixed overhangs</u>: Required for south windows in hot climate zones, with a depth that depends on the latitude and window height.

5.2.4 Fenestration orientation (for detached houses only):

There are two rules pertaining to fenestration orientation, that is, the distribution of windows and glazed doors facing different directions.

- One rule aims to limit high peaks in cooling load in summer and shoulder seasons.

- The other rule aims to limit net heat loss from the windows in winter.

Roughly speaking, these rules do not conflict because the "summer" rule concerns mostly east-west balance and the "winter" rule concerns mostly north-south balance, but it is possible to violate both, in some climate zones.

5.2.4.1 For cooling

The fenestration orientation rule limiting cooling load peaks is based on the concept of adequate exposure diversity (AED) from ACCA Manual J. The idea is that the peak hour solar gain should not exceed the average over the daytime hours by more than a certain percentage. There are three compliance paths:

- The most straightforward path is that, per Manual J Appendix 3, a dwelling is considered to have AED if "the total area of the windows, glass doors, and skylight assemblies does not exceed 15% of the associated floor area."
- The most involved path is to actually calculate AED, which requires software qualified for Manual J, and meet its criterion that the peak is no more than 30% over the average.
- The middle path is to meet a simplified AED criterion developed for phius CORE Prescriptive that varies by climate zone. The required inputs for simplified AED are the glazed fenestration areas facing the cardinal directions (North, East, South, and West). All windows are to be assigned to the nearest cardinal direction. The checklist calculates a score and compares it to the zone's criterion.

The simplified AED score and criteria were derived from a computer experiment on a study building, using various fenestration orientation configurations in a representative city for each climate zone. The studied configurations comprised combinations of concentration and direction of concentration but with identical overall window area, e.g., 25% all around, 100% on one side, 50% on two sides, 33% on three sides. There are 15 such combinations x 19 zones, 0A to 8, for a total of 285 study cases. The study buildings were configured at the window SHGC limits and with south overhangs, as required for the climate zone by those other rules. Hourly simulations were done in EnergyPlus and the ratio of peak hour solar transmission to the day average (ST Pk/Av) was then averaged over 4 weeks around the summer solstice plus 4 weeks around the autumnal equinox.

The general patterns that emerged were: 1) a balance of east- and west-facing areas was good, 2) high concentration in one direction was bad, unless it was north, though all-south was not too bad.

Regression formulas were fitted, zone by zone, to the ST Pk/Av Jun+Sep data as functions of the orientation configuration variables (fraction facing each direction). The correlation coefficients of the fits fell between 0.85 and 0.95. The criteria thresholds were set relative to each zone, at the level of the mean over the 15 configurations. That was usually ST Pk/Av ~ 1.9, i.e., a peak hour about 90% over the day average. The score calculated in the checklist is the predicted ST Pk/Av from the regression function for the specified window configuration, rescaled to a percentage of the way towards the zone limit. This levelizes the passing criterion to ≤ 100% for all zones (lower is better).[3]

5.2.4.2 For heating

The fenestration orientation rule for winter is based on the idea that the windows should preferably be oriented to have a net gain over the worst case month (coldest/dimmest), or at least not too great a net loss. The same model buildings and representative cities were used as for the simplified AED cooling load study. The heat transmission loss from the windows was calculated with the windows at the U-value limit for the zone.

The results indicated that in zones 4C, 5C, and 8, net heat gain in the worst month was not possible with any window orientation, thus there is no orientation requirement for these zones. Also, in zones 0-3 the "winter" gain is either unavoidable, or again mostly unavailable due to the cooling season solar protection measures in place as required, thus there is no orientation requirement for zones 0-3.

For zones 4-7 except C, winter gain is desirable and fenestration orientation did make a big difference, so criteria were set: Regression functions of the orientation variables were fitted to the worst-month net heat gain data. The correlation coefficients of the fits were all over 0.98. The general pattern was that some North windows are tolerable if there are south-facing ones to compensate. The criteria thresholds were set relative to each zone, at the level of the median net gain over the 15 orientation configurations. The score calculated in the checklist is the difference between the predicted net gain from the regression function for the specified window orientation configuration, minus the zone target, then rescaled by the range of net gain over all the study cases. This makes for a levelized net gain score in the range of about ± 100, where zero is passing and higher is better.

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[3] An attempt was made to find a correlation between this simplified AED and Manual J AED, by calculating both on a subset of 30 of the 285 study cases, but this did not work - the correlation coefficient was only 0.4. This may be due to differences in the Manual J design-day data compared to the TMY type weather data used to develop the simplified AED, or other Manual J AED calculation details we are not aware of as of this writing

The "summer" and "winter" orientation rules were tested together in combination with the compactness rule on 33 certified projects and some randomly generated fenestration orientations and they appeared to give good guidance.[4]

5.2.5 Heat transmission

The maximum U-value for fenestration is derived from the idea of maintaining the inside surface temperature high enough to prevent cold air from pooling under the window and causing an uncomfortable draft at ankle level. This uses the same formula in the PHIUS window comfort calculator, evaluated at a window height of 9 feet and at the ASHRAE 99% outside design temperature.

The R-value requirements for the main assemblies (wall, roof, floor) are set using climate-dependent regression formulas fitted to the characteristics of the small houses, typical sized houses, and townhomes that were optimized in the 2018 standard-setting study, along with the tiny-home cases studied for 2021. The formulas are continuous functions of climate location parameters such as heating-degree days and design heating temperatures. The marginal electricity price (taken on a state average basis) also has an influence, with more insulation being justifiable at higher prices. See Appendix B for details.

5.2.6 Moisture Risk Limitation

5.2.6.1 Opaque Enclosure

Section 5.1 of the checklist includes built-in calculators for both effective R-value and vapor control requirements for various opaque assemblies (roofs, walls, floors).

5.2.6.2 Fenestration

A window condensation resistance requirement is calculated for the climate location, according to the ISO 13788 protocol for "low thermal inertia elements", using its simple method for indoor humidity at high occupancy. A number of different product-rating tests can be accepted as meeting the requirement, with differing safety factors.

5.2.7 Mechanical ventilation heat recovery effectiveness

A minimum sensible recovery efficiency in heating mode is calculated as the efficiency needed to deliver supply air at 60°F or warmer, without post-heating, at the average outside

[4] The original idea was to have uniform criteria on the raw metrics, e.g. net gain > 0 for winter and ST Pk/Av Jun+Sep < 1.XX for summer, but the zone-to-zone differences were large enough that testing suggested zone-by-zone criteria would be a better idea. . As noted above, the final scoring methods shift all zones to a uniform "≤ 1" and "≥ 0"basis.

temperature of the coldest month in the climate location. (The device rating adjustment takes credit for passive heat gain from the fan motors, in heating mode.)

A minimum total recovery efficiency in cooling mode (latent+sensible) is set based on the climate zone, as shown in Table 1. The required levels were set from consideration of both the range of available performance and the statistics of dehumidification degree-days zone-by-zone over 1000 climate locations.

There is also a maximum length imposed on the ducts between the ventilation recovery device and the enclosure, which is tied to the size of the building as indicated by its floor area and number of stories – notionally half the short side of the building if it was a rectangle of aspect ratio 1.6.

Table 1. Dehumidification degree-day statistics for US climate locations zone-by-zone, and the assigned total recovery efficiency requirement for ventilation heat recovery, in cooling mode.

Dehumidification Degree Days (DDD)				Cooling Mode	Dehumidification Degree Days (DDD)				Cooling Mode
Climate Zone	**Max**	**Avg**	**Min**	**Total Recovery Efficiency (TRE)**	**Climate Zone**	**Max**	**Avg**	**Min**	**Total Recovery Efficiency (TRE)**
0A	3.34	1.95	1.23	60%	**4A**	0.54	0.29	0.03	50%
0B	2.93	2.93	2.93	60%	**4B**	0.09	0.01	NR	NR
1A	2.30	1.53	1.02	60%	**4C**	0.01	NR	NR	NR
1B	3.46	2.25	1.04	60%	**5A**	0.49	0.14	NR	NR
2A	1.63	0.98	0.40	60%	**5B / 5C**	NR	NR	NR	NR
2B	0.82	0.28	NR	60%	**6A**	0.22	0.05	NR	NR
3A	1.11	0.55	0.19	60%	**6B**	0.01	NR	NR	NR
3B	0.25	0.04	NR	NR	**7**	0.09	NR	NR	NR
3C	0.04	0.01	NR	NR	**8**	NR	NR	NR	NR

5.2.8 Mechanical Ventilation Fan Efficiency

A limit on ventilation fan power was set based on the DOE ZERH Reference Home. The limit is 0.83 [W/cfm] or (1.2 [cfm/W]) on mechanical fresh air ventilation systems.

5.2.9 Heating/cooling system efficiency

For air-source heat pumps, the required efficiency goes by climate zone. Energy Star Most Efficient 2020 applies for CZ 0-3, 4C, and 5C. Other zones 4-8 must meet NEEP cold climate air-source heat pump v3.0 criteria.

For ground-source heat pumps, the requirement is tied to Energy Star Most Efficient 2020 criteria – it varies by equipment type but not by climate.

	Air Source Heat Pump	Ground Source Heat Pump
Climate Zones 0-3C, 4C, 5C	HSPF ≥ 9.6 SEER ≥ 18	COP ≥ 3.1 EER ≥ 16.1
Climate Zones 4A-B, 5A-B, 6-8	COP @ 5°F ≥ 1.75 SEER ≥ 15	

5.2.10 Lighting efficacy

Lighting is regulated by setting a minimum fixture efficacy of 83 lumens/watt for all fixtures. The alternate option is that the average efficacy of installed fixtures, weighted based on wattage, is equal to or greater than 83 lumens/watt.

Lighting is part of the equipment performance tradeoff path, and in that case, lamp efficacy can be lower as long as the overall annual energy budget for equipment is not exceeded. The annual energy use for the proposed building is calculated based on rated wattage of all fixtures installed and predetermined daily run times per fixture based on the room in which it is installed. The reference building annual lighting energy is calculated using the total lumens installed in the proposed building, applying the minimum efficacy of 83 lumens/watt to that lighting design to determine reference wattage per fixture, and using the same daily run times per fixture as the proposed building.

5.2.11 Appliances

Limits on individual appliance efficiencies were set based on either the top quartile of ENERGY STAR or ENERGY STAR Most Efficient 2020 appliance ratings. Project designs can meet each of these requirements individually, or take the performance tradeoff path in which these ratings are used for the 'reference' efficiency.

5.2.12 Water Heating

Water heating energy is regulated with two main requirements: First is that the water heater must be installed in conditioned space, with a few exceptions based on annual average ambient temperature. Second is that the water heater must meet or exceed the specified reference efficiency based on the type of water heater – heat pump or solar with electric backup

5.2.13 Performance Tradeoff Calculation

In the performance tradeoff for builder-installed appliances, lighting, and water heating, the reference energy allowances for the regulated items are calculated as shown in Table 2. The rationale for including items on the list is that they are: a) rated by Energy Star and b) typically builder-installed as opposed to resident-installed. For each item there is a reference level of efficiency for the equipment, and an embedded assumption about how much it is used. Together these factors determine the contribution of each item to the pooled energy allowance for builder-installed equipment. For ceiling fans and pool pumps, an amenity level is deduced from Building America benchmarks for annual energy use with ENERGY STAR Most Efficient 2020 device efficiency.

Table 2. Annual source energy budget calculation for equipment performance tradeoff.

Item	Efficiency Unit	Reference Efficiency	Reference Site kWh/hr
Clothes washers	LER (kWh/yr)	135	#planned * LER
Clothes dryers, electric	CEF	3.93	“
Dishwashers	LER (kWh/yr)	239	“
Refrigerators	LER (kWh/yr)	315	“
Freezers	LER (kWh/yr)	450	“
Ceiling fans	cfm/W	220.1	#planned * 84.1 kWh/yr
Pool pumps	WEF (kgal/kWh)	9.3	#planned * 158.5 kWh/yr
Light fixtures	Lumens/Watt (lm/W)	83	# installed lumens / 83 lumens/watt * annual runtime per fixture
Electric vehicle chargers	Standby Power (W)	1.81	#planned * Standby power * 8760/1000
Smart home energy management system (thermostat)	Standby Power (W)	0.17	“
Water Heating	UEF or SEF	1.975	#occupants * amenity /1.975, where amenity = 6.6 gal/p.day at 90 F temperature rise * 1.25 operational waste factor, in kWh/p.yr

LER - label energy rating
SEF - solar energy factor
UEF - uniform energy factor
WEF - weighted energy factor

5.2.14 Electric Vehicle Ready

Electric vehicle readiness aligns with the performance path, Section 4.3.2.5 above. One EV-Ready space is required per dwelling unit. The only exception is when there is no parking required, there is no requirement.

Appendix A: Regression formulas for space conditioning performance criteria

The best-fit regression formulas for the space conditioning criteria are shown in the figures below, along with plots that give an indication of the sensitivities to the factors.

The factor nomenclature is as follows:

- CDD50 – Cooling Degree Days, base 50°F *
- DDD – Dehumidification degree days (lb/lb days)
- EnvFlr – Envelope to Floor Area ratio
- HDD65 – Heating Degree Days, base 65°F *
- IGA – Irradiance, Global, Annual (kWh/m2.yr)
- IGCL – Irradiance, Global, at the cooling design condition (Btu/h.ft^2)
- IGHL – Irradiance, Global, at the heating design condition (Btu/h.ft^2)
- Occ – Occupant density (persons per ft^{2}of floor area)
- THD-1 – Temperature at the colder of the two heating design conditions (°F)
- TCD - Temperature at the cooling design condition (°F)
- UnitDens – Unit density (1/ft^2) (inverse of the floor area per unit)
- $elec – Marginal electricity price ($/kWh)

* Data from ASHRAE Fundamentals 2017. Other climate parameters are from phius climate data.

$$
\begin{aligned}
&3.2606827206 \\
&+ 1.1634499236 \cdot \text{EnvFlr} \\
&+ 904.39163818 \cdot \text{UnitDens} \\
&+ 0.000604853 \cdot \text{HDD65 [F.days]} \\
&+ -0.001645777 \cdot \text{IGA [kWh/m2.yr]} \\
&+ -11.87299596 \cdot \text{\$elec [\$/kWh]} \\
&+ (\text{EnvFlr} - 1.766) \cdot (\text{EnvFlr} - 1.766) \cdot 0.8314860529 \\
&+ (\text{EnvFlr} - 1.766) \cdot (\text{HDD65 [F.days]} - 5860.0833333) \cdot 0.0002310823 \\
&+ (\text{HDD65 [F.days]} - 5860.0833333) \cdot (\text{HDD65 [F.days]} - 5860.0833333) \cdot -5.736435e\text{-}8 \\
&+ (\text{HDD65 [F.days]} - 5860.0833333) \cdot (\text{IGA [kWh/m2.yr]} - 1451.0633333) \cdot -3.260379e\text{-}7 \\
&+ (\text{EnvFlr} - 1.766) \cdot (\text{\$elec [\$/kWh]} - 0.2029193333) \cdot -3.851052937 \\
&+ (\text{HDD65 [F.days]} - 5860.0833333) \cdot (\text{\$elec [\$/kWh]} - 0.2029193333) \cdot -0.001897043
\end{aligned}
$$

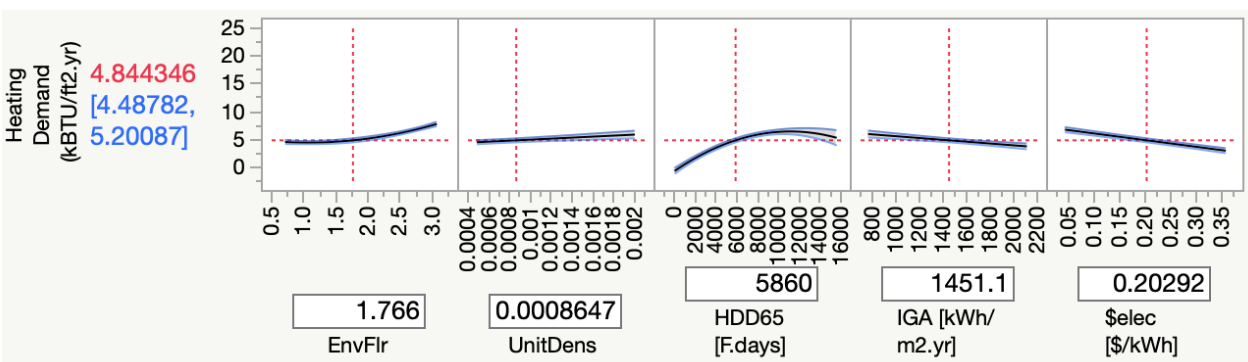

Figure A1. Non-Tiny buildings, Annual Heating Demand (kBtu/ft².yr). Rsq=0.85.

$$
\begin{aligned}
& -6.510791255 \\
& + -0.749993351 \cdot \text{EnvFlr} \\
& + 0.0004550801 \cdot \text{CDD50 [F.days]} \\
& + 0.004990109 \cdot \text{IGA [kWh/m2.yr]} \\
& + 7.9460878688 \cdot \text{DDD [lb/lb.days]} \\
& + (\text{EnvFlr} - 1.766) \cdot (\text{EnvFlr} - 1.766) \cdot 1.6367059356 \\
& + (\text{CDD50 [F.days]} - 4104.8333333) \cdot (\text{CDD50 [F.days]} - 4104.8333333) \cdot 8.6952014\text{e-}8 \\
& + (\text{EnvFlr} - 1.766) \cdot (\text{IGA [kWh/m2.yr]} - 1451.0633333) \cdot 0.001671947 \\
& + (\text{CDD50 [F.days]} - 4104.8333333) \cdot (\text{IGA [kWh/m2.yr]} - 1451.0633333) \cdot 0.0000013639 \\
& + (\text{UnitDens} - 0.0008646735) \cdot (\text{DDD [lb/lb.days]} - 0.3233057481) \cdot 5547.7542211 \\
& + (\text{DDD [lb/lb.days]} - 0.3233057481) \cdot (\text{\$elec [\$/kWh]} - 0.2029193333) \cdot -15.67511944 \\
& + 1624.6144639 \cdot \text{UnitDens}
\end{aligned}
$$

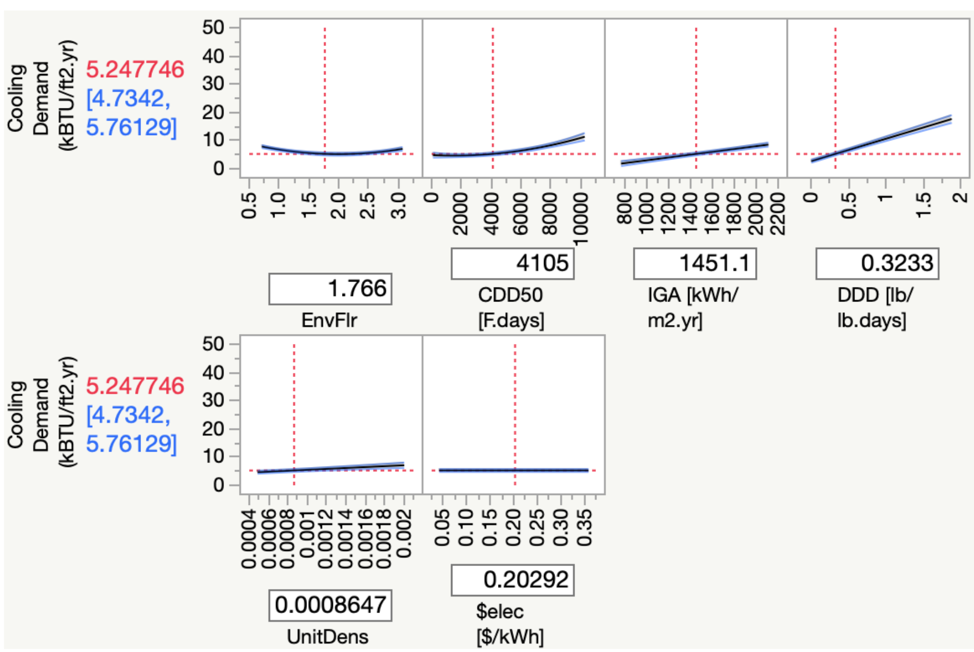

Figure A2. Non-Tiny buildings, Annual Cooling Demand (kBtu/ft².yr). Rsq=0.90. Inclusivity adjustment +2.38.

$$
\begin{aligned}
&4.6700403241\\
&+ 0.6774809481 \cdot \text{EnvFlr}\\
&+ 239.08369574 \cdot \text{Occ}\\
&+ 596.681543 \cdot \text{UnitDens}\\
&+ -0.000177742 \cdot \text{HDD65 [F.days]}\\
&+ -0.076727655 \cdot \text{THD-1 [F]}\\
&+ -0.03316804 \cdot \text{IGHL [Btu/h.ft2]}\\
&+ -4.140193817 \cdot \text{\$elec [\$/kWh]}\\
&+ \left(\text{EnvFlr} - 1.766\right) \cdot \left(\text{EnvFlr} - 1.766\right) \cdot 0.8449921713\\
&+ \left(\text{HDD65 [F.days]} - 5860.0833333\right) \cdot \left(\text{HDD65 [F.days]} - 5860.0833333\right) \cdot 2.8376386\text{e-}8\\
&+ \left(\text{EnvFlr} - 1.766\right) \cdot \left(\text{THD-1 [F]} - 14.7102\right) \cdot -0.013821021\\
&+ \left(\text{UnitDens} - 0.0008646735\right) \cdot \left(\text{THD-1 [F]} - 14.7102\right) \cdot -20.10551451\\
&+ \left(\text{HDD65 [F.days]} - 5860.0833333\right) \cdot \left(\text{THD-1 [F]} - 14.7102\right) \cdot 5.1870203\text{e-}6\\
&+ \left(\text{THD-1 [F]} - 14.7102\right) \cdot \left(\text{\$elec [\$/kWh]} - 0.2029193333\right) \cdot 0.1264922802
\end{aligned}
$$

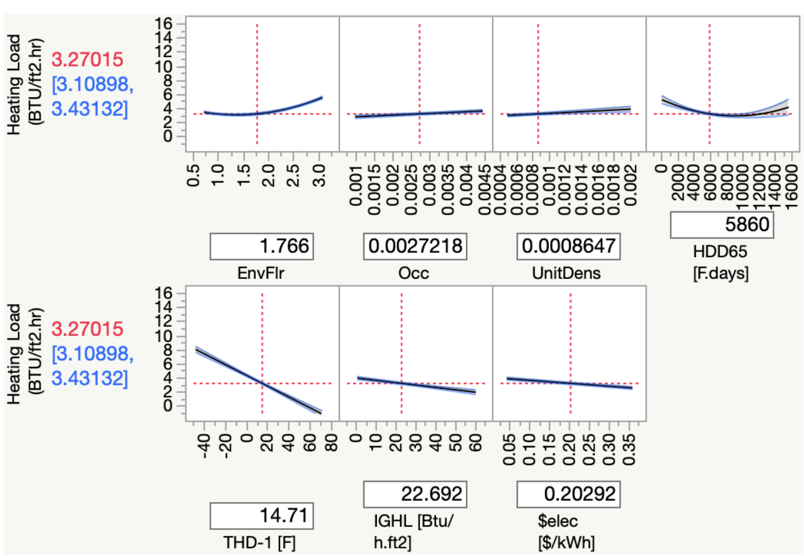

Figure A3. Non-Tiny buildings, Peak Heating Load (Btu/ft².hr). Rsq=0.92. Inclusivity adjustment +0.638.

$$
\begin{aligned}
&-7.289806442 \\
&+ 98.245977611 \cdot \text{Occ} \\
&+ 236.93351876 \cdot \text{UnitDens} \\
&+ 0.0967328928 \cdot \text{TCD [F]} \\
&+ 0.010777725 \cdot \text{IGCL [Btu/h.ft2]} \\
&+ (\text{CDD50 [F.days]} - 4104.8333333) \cdot (\text{CDD50 [F.days]} - 4104.8333333) \cdot 1.7699655e\text{-}8 \\
&+ (\text{CDD50 [F.days]} - 4104.8333333) \cdot (\text{TCD [F]} - 78.127) \cdot 6.5268802e\text{-}6 \\
&+ (\text{TCD [F]} - 78.127) \cdot (\text{EnvFlr} - 1.766) \cdot 0.0165401721 \\
&+ (\text{TCD [F]} - 78.127) \cdot (\text{Occ} - 0.0027218) \cdot 8.0465528305 \\
&+ (\text{CDD50 [F.days]} - 4104.8333333) \cdot (\text{EnvFlr} - 1.766) \cdot 0.0000322288 \\
&+ (\text{EnvFlr} - 1.766) \cdot (\text{EnvFlr} - 1.766) \cdot 0.6579032913
\end{aligned}
$$

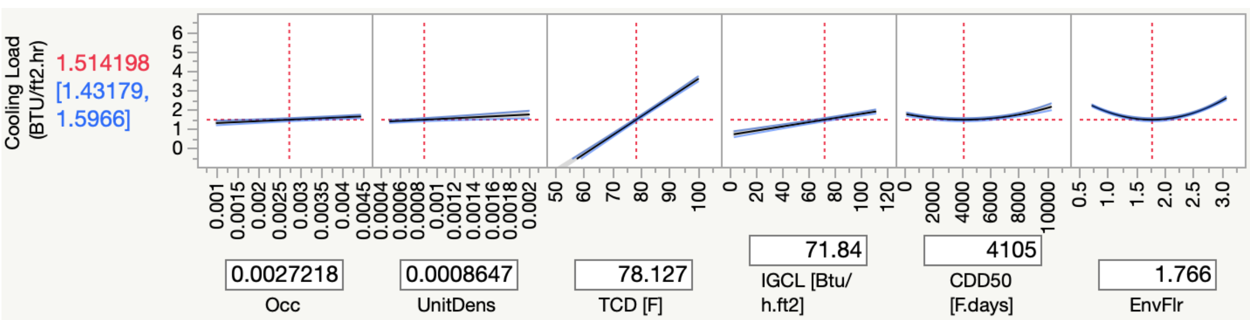

Figure A4. Non-Tiny buildings, Peak Cooling Load (Btu/ft²·h). Rsq=0.90. Inclusivity adjustment +0.405.

$$
\begin{aligned}
&4.8588228664 \\
&+ 0.0037156413 \cdot \text{HDD65 [F.days]} \\
&+ \left(\text{HDD65 [F.days]} - 4975.925\right) \cdot \left(\text{HDD65 [F.days]} - 4975.925\right) \cdot -2.045945\text{e-}7
\end{aligned}
$$

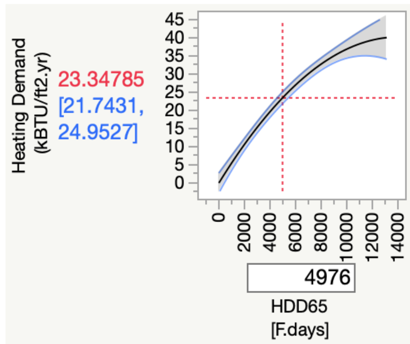

Figure A5. Tiny homes, Annual Heating Demand (kBtu/ft².yr). Rsq=0.92.

$$
\begin{aligned}
&-10.87202083 \\
&+ 0.0027845346 \cdot \text{CDD50 [F.days]} \\
&+ 0.0072197583 \cdot \text{IGA [kWh/m2.yr]} \\
&+ 11.226806376 \cdot \text{DDD [lb/lb.days]} \\
&+ \left(\text{CDD50 [F.days]} - 4281.125\right) \cdot \left(\text{IGA [kWh/m2.yr]} - 1493.525\right) \cdot 0.0000032584
\end{aligned}
$$

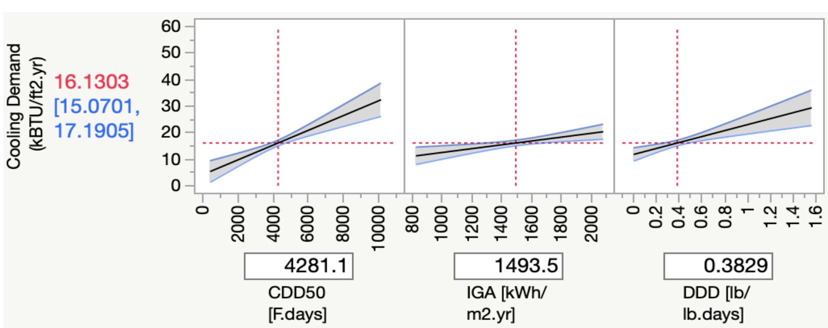

Figure A6. Tiny homes, Annual Cooling Demand (kBtu/ft².yr). Rsq=0.96. Inclusivity adjustment +3.74.

$$21.134086911 + -0.262119984 \cdot \text{THD-1 [F]} + -0.071037306 \cdot \text{IGHL [Btu/h.ft2]}$$

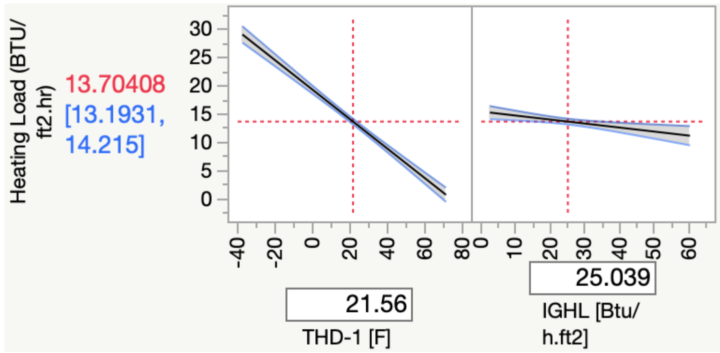

Figure A7. Tiny homes, Peak Heating Load (Btu/ft².h). Rsq=0.95. Inclusivity adjustment +1.59.

$$-17.06502686 + 0.2875015262 \cdot \text{TCD [F]}$$

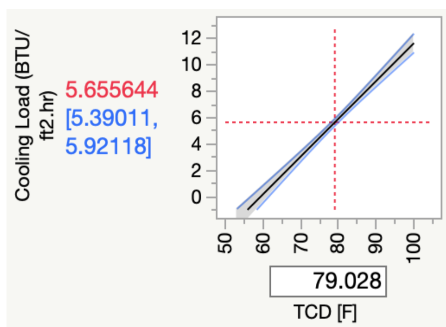

Figure A8. Tiny homes, Peak Cooling Load (Btu/ft².h). Rsq=0.90. Inclusivity adjustment +1.0.

Appendix B: Regression formulas for prescriptive opaque enclosure R-Values

The best-fit formulas for the R-values of the main assemblies of the optimized study buildings are shown in the Figures below. (The data set included the tiny home cases from 2021 and the updated small houses, typical houses, and townhomes from 2018.) The formulas for the required values were made conservative by adding the RMS error of the fit.

$$
\begin{aligned}
&19.138079236 \\
&+ 0.0021990688 \cdot \text{HDD65 [F.days]} \\
&+ -0.236302791 \cdot \text{THD [F]} \\
&+ 59.588089834 \cdot \text{\$elec [\$/kWh]} \\
&+ \left(\text{THD [F]} - 21.106045455\right) \cdot \left(\text{\$elec [\$/kWh]} - 0.2016890909\right) \cdot -1.619749528 \\
&+ \left(\text{\$elec [\$/kWh]} - 0.2016890909\right) \cdot \left(\text{\$elec [\$/kWh]} - 0.2016890909\right) \cdot -206.823859
\end{aligned}
$$

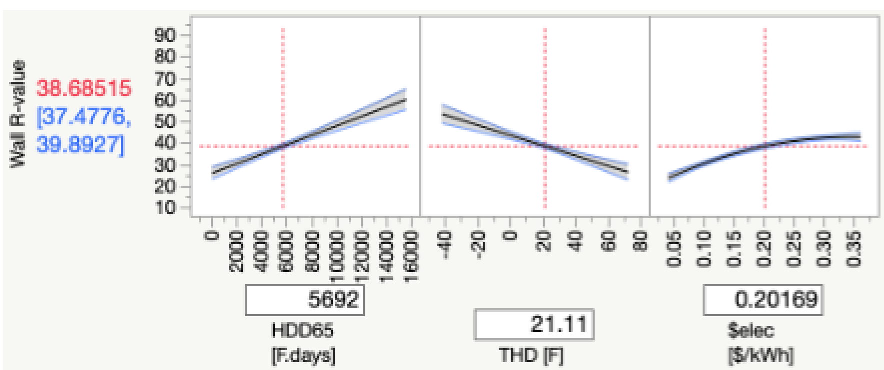

Figure B1. Wall R-value regression formula and factor sensitivities. Rsq=0.88. Conservative adjustment +5.6.

Also, although the Envelope to Floor area ratio (EnvFlr) was used to improve the fit, it is locked at the average value of 3.14 for calculating the requirements. This is because its effect on the floor and roof R-values is confounded with the building type. The Tiny homes with their high EnvFlr had expensive roof and cheap floor insulation, thus the optimizer chose less roof and more floor insulation. For the walls, where the same construction was used for all the study buildings, there was not a statistically significant effect of EnvFlr.

$$
\begin{aligned}
&33.83918805 \\
&+ 2.6925620728 \bullet \text{EnvFlr} \\
&+ 0.002346005 \bullet \text{HDD65 [F.days]} \\
&+ -0.246594995 \bullet \text{THD [F]} \\
&+ 63.900654041 \bullet \text{\$elec [\$/kWh]} \\
&+ \left(\text{EnvFlr} - 3.14219615\right) \bullet \left(\text{EnvFlr} - 3.14219615\right) \bullet -1.6233214 \\
&+ \left(\text{THD [F]} - 21.106045455\right) \bullet \left(\text{\$elec [\$/kWh]} - 0.2016890909\right) \bullet -1.473627153
\end{aligned}
$$

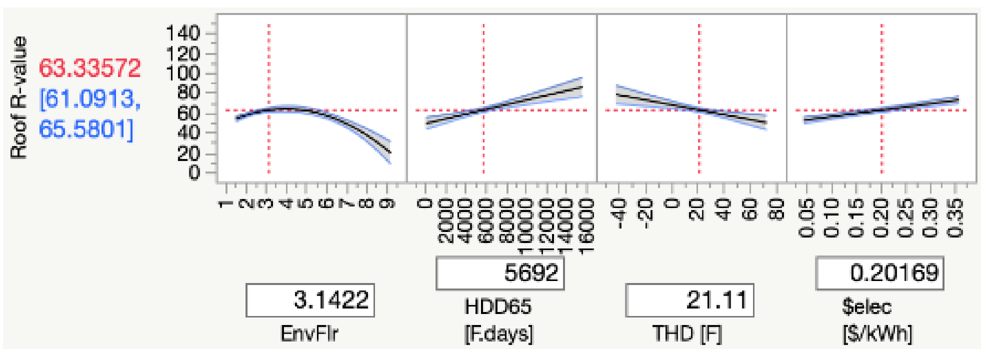

Figure B2. Roof R-value regression formula and factor sensitivities. Rsq=0.65. Conservative adjustment +11.5.

$$
\begin{aligned}
&-8.707891091 \\
&+ 6.073677415 \cdot \text{EnvFlr} \\
&+ 0.0014058337 \cdot \text{HDD65 [F.days]} \\
&+ -0.173638701 \cdot \text{THD [F]} \\
&+ 38.068227411 \cdot \text{\$elec [\$/kWh]} \\
&+ \left(\text{EnvFlr} - 3.14219615\right) \cdot \left(\text{IGA [kWh/m2.yr]} - 1455.5136364\right) \cdot 0.0033795416 \\
&+ \left(\text{IGA [kWh/m2.yr]} - 1455.5136364\right) \cdot \left(\text{TCD [F]} - 78.59\right) \cdot 0.000544254 \\
&+ \left(\text{THD [F]} - 21.106045455\right) \cdot \left(\text{\$elec [\$/kWh]} - 0.2016890909\right) \cdot -0.702958662
\end{aligned}
$$

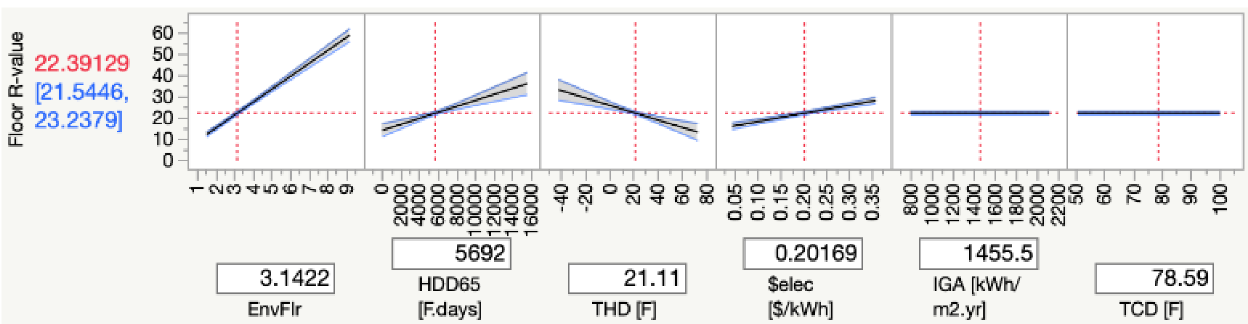

Figure B3. Floor R-value regression formula and factor sensitivities. Rsq=0.84. Conservative adjustment +6.3 used for ceilings of unconditioned basements or crawl spaces, and pier and beam floors.

Appendix C: ASHRAE 189.1-2017 Addendum J, phius markup

7.4.1.1 Renewable Energy Systems. For phius ZERO, the adjusted renewable energy provided to the project shall be equal to or greater than the modeled energy use. ~~gross conditioned and semiheated floor areas of the building project multiplied by the renewable energy requirement from Table 7.4.1.1. For allocations to multiple tenants within a building project, the requirements shall be assigned to each tenant based on the total of gross conditioned and semiheated floor area of each tenant space.~~

~~Building projects complying with the Alternate Renewables Approach shall comply with the applicable equipment efficiency requirements in Normative Appendix B, the water-heating efficiency requirements in Section 7.4.4.1, equipment efficiency requirements in Section 7.4.7.1, and the applicable ENERGY STAR® requirements in Section 7.4.7.3.2. For equipment listed in Section 7.4.7.3.2 that are also contained in Normative Appendix B, the installed equipment shall comply by meeting or exceeding both requirements.~~

Documentation shall be provided to ~~the AHJ~~ phius that substantiates procurement of renewable energy systems, of renewable energy contracts, or of a quantity of RECs required to meet the Exception to 7.4.1.1. RECs shall be tracked in accordance with Section 10.3.2.1.6.

Qualifying renewable energy systems are as follows:

a. On-site renewable energy system

b. Off-site renewable energy system

1. Self-generation (an off-site renewable energy system owned by the building project owner). The system shall comply with Section 7.4.1.3.
2. Community renewable energy facility—The system shall comply with Section 7.4.1.3.
3. Purchase contract—The system shall comply with Section 7.4.1.3.

~~Exceptions to 7.4.1.1: Building projects that demonstrate to the AHJ~~ ~~PHIUS~~ ~~that they cannot comply with Section 7.4.1.1 shall~~

4. Contract for renewable electricity products complying with the Green-e Energy National Standard for Renewable Electricity products of not less than ~~1.2 MWh/ft2 (12.6 MWh/m2) of gross floor area of conditioned spaces and semiheated spaces, or an amount equal to~~ 100% of the modeled annual energy use multiplied by 20 years~~, whichever is less~~. A combination of renewable electricity products and renewable energy systems shall be permitted to demonstrate compliance. RECs shall be tracked per Section 10.3.2.1.6.

7.4.1.2 Adjusted Renewable Energy. Each source of renewable energy delivered to or credited to the building project shall be multiplied by the factors in Table 7.4.1.2 when determining compliance with Section 7.4.1.1.

Table 7.4.1.2 Multipliers for Renewable Energy Procurement Methods

Location	Renewable Energy Source	Renewable Energy Factor
On-Site	On-Site Renewable Energy System	1.00
Off-Site	Directly Owned Off-Site Renewable Energy System	0.75
Off-Site	Community Renewable Energy System	0.75
Off-Site	Virtual PPA	0.75
Off-Site	Green-e RECs	0.20

7.4.1.3 Off-Site Renewable Energy Requirements. Off-site renewable energy delivered or credited to the building project to comply with Section 7.4.1.1 shall be subject to a legally binding contract to procure qualifying off-site renewable energy. Qualifying off-site renewable energy shall meet the following requirements:

a. Documentation of off-site renewable energy procurement shall be submitted to phius ~~the AHJ~~.
   1. Procurement plan is required for review and approval during phius' Design Certification phase.
   2. Contract as described below is required for review and approval during phius' Final Certification phase.

b. The purchase contract shall have a duration of not less than 15 years. The contract shall be structured to survive a partial or full transfer of ownership of the building property.

c. RECs associated with the purchase contract from an off-site renewable energy shall be assigned exclusively to the building owner for a period of not less than 15 years and tracked in accordance with Section 10.3.2.1.6.

d. The energy source shall produce electricity from solar, wind, or geothermal energy.

Exceptions to 7.4.1.3(d):
   1. Captured methane from feed-lots and landfills are permitted to be used to generate electricity for the purposes of this section.
   2. Hydropower from new generation capacity on a nonimpoundment or new generation capacity on an existing impoundment that meets one of the following conditions:
      a. The hydropower facility complies with the Low Impact Hydropower Certification Handbook and is certified by a nationally recognized accreditation organization.
      b. The hydropower facility complies with UL 2854 and is certified by an organization that has the standard in its ISO 17065 scope of accreditation.
      c. The hydropower facility consists of a turbine in a pipeline or a turbine in an irrigation canal. For facilities falling under Exception (2)(a) or (2)(b), only output generated

during the period of certification is eligible for RECs sale in accordance with the provisions of this section. Renewables from new impoundments of water are not eligible.

e. The generation source shall be located where the energy can be delivered to the building site by any of the following:
  1. By direct connection to the off-site renewable energy facility
  2. By the local utility or distribution entity
  3. By an interconnected electrical network where energy delivery capacity between the generator and the building site is available (Informative Note: Examples of interconnected electrical networks include regional power pools and regions served by Independent System Operators or Regional Transmission Organizations.)

f. Records on renewable power purchased by the building owner from the off-site renewable energy generator that specifically assign the RECs to the building owner shall be retained or retired by the building owner on behalf of the entity demonstrating financial or operational control over the building seeking compliance to this standard and made available for inspection by PHIUS ~~the AHJ~~ upon request. (Informative Note: Refer to Sections 10.3.2.1.6 and 10.3.2.1.7 for tracking and allocation requirements.)

g. Where multiple buildings in a building project are allocated energy procured by a contract subject to this section, the owner shall allocate for not less than 15 years the energy procured by the contract to the buildings in the building project. (Informative Note: Refer to Section 10.3.2.1.7 for allocation requirements.)

Add these new sections to Section 10 as shown.

10.3.2.1.6 Renewable Energy Certificate Tracking. ~~For multitenant buildings where RECs are transferred to tenants, the plan for operation shall include procedures for tracking the quantity and vintage of RECs that are required to be retained and retired in compliance with Sections 7.3.2 and 7.4.1.1 of this standard. The plan shall include provisions to transfer the RECs to building tenants or to retire RECs on their behalf in proportion to the gross conditioned and semiheated floor area leased or rented.~~ The plan shall include provisions to use a REC tracking system that meets the requirements of Section V.B of the Green-e Framework for Renewable Energy Certification. The plan shall describe how the building owner will procure alternative qualifying renewable energy in the case that the renewable energy producer ceases operation.

10.3.2.1.7 Renewable Energy Allocation to Multiple Buildings. Where renewable energy is allocated to multiple buildings in compliance with Section 7.4.1.3 (g), the plan shall indicate how renewable energy produced from on-site or off-site systems that is not allocated before issuance of the certificate of occupancy will be allocated to new or existing buildings included in the building project. The plan shall indicate who will be responsible for retaining the documentation for allocations and where it will be stored so that it can be made available for inspection by phius ~~the AHJ~~ upon request.

Where multiple buildings in a building project share a common utility interconnection and are served by the same on-site renewable energy system, the building owner shall allocate for not less than 15 years the annual REC generation of the on-site renewable energy system to the buildings served by the system. The annual generation vintage date of delivered RECs shall be allocated to the same 12 month reporting year, up to six months prior, or up to three months after the calendar year in which the electricity is used in the building. The annual allocation of RECs shall be documented as part of the plan. The plan shall indicate who will be responsible for retaining the documentation and where it will be stored so that it can be made available for inspection by PHIUS ~~the AHJ~~ upon request.

Modify Section 11as shown.
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c/o Center for Resource Solutions
1012 Torney Ave., Second Floor
San Francisco, CA 94129, United States
1- 415-561-2100; www.green-e.org
Version 1.0, July 7, 2017 Green-e Framework for Renewable Energy Certification

Low Impact Hydropower Institute (LIHI)
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Version 2.03, December 20, 2018 Low Impact Hydropower Certification Handbook

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Appendix D: Electric Vehicle Requirements

New language for phius Certification Guidebook is proposed below. This aligns with the proposed language for IECC 2021, and the NBI Decarbonization Code.

3.5.8.1 Electric Vehicle Definitions

ELECTRIC VEHICLE (EV). An automotive-type vehicle for on-road use, such as passenger automobiles, buses, trucks, vans, neighborhood electric vehicles, electric motorcycles, and the like, primarily powered by an electric motor that draws current from a rechargeable storage battery, a fuel cell, a photovoltaic array, or another source of electric current. Plug-in hybrid electric vehicles are electric vehicles having a second source of motive power. Off-road, selfpropelled electric mobile equipment, such as industrial trucks, hoists, lifts, transports, golf carts, airline ground support equipment, tractors, boats and the like, are not considered electric vehicles.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE). The conductors, including the ungrounded, grounded,and equipment grounding conductors, and the *electric vehicle* connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premise's wiring and the *electric vehicle*.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) SPACE. A designated parking space with dedicated electric vehicle supply equipment capable of supplying not less than 6.2 kW to an electric vehicle located within 3 feet (914 mm) of the parking space.

EV-CAPABLE SPACE. A parking space that is provided with conduit that meets the following requirements:

1. The conduit shall be continuous between a junction box or receptacle located within 3 feet (914 mm) of the parking space and an electrical panel serving the area of the parking space with sufficient dedicated physical space for a dual-pole, 40-amp breaker

2. The conduit shall be sized and rated to accommodate a 40-amp, 208/240-volt branch circuit and have a minimum nominal trade size of 1 inch

3. The electrical junction box and the electrical panel directory entry for the dedicated space in the electrical panel shall have labels stating "For future *electric vehicle* charging"

EV-READY SPACE. A parking space that is provided with dedicated branch circuit that meets the following requirements:

1. Wiring capable of supporting a 40-amp, 208/240-volt circuit,

2. Terminates at a junction box or receptacle located within 3 feet (914 mm) of the parking space, and

3. The electrical panel directory shall designate the branch circuit as "For electric vehicle charging" and the junction box or receptacle shall be labeled "For electric vehicle charging".

ELECTRIC VEHICLE LOAD MANAGEMENT SYSTEM. A system designed to allocate charging capacity among multiple electric vehicle supply equipment.

3.5.8.2 Electric Vehicle (EV) charging infrastructure. Electric infrastructure for the current and future charging of electric vehicles shall be installed in accordance with this section. *EV ready spaces* are permitted to be counted toward meeting minimum parking requirements.

One- to two-family dwellings and townhouses. One- and two-family dwellings and townhouses with a dedicated attached or detached garage or on-site parking spaces and new detached garages shall be provided with one *EV-Ready space* per dwelling unit. The branch circuit for the *EV-Ready space* shall have a minimum capacity of 9.6 kVA.

Exception: EV-Ready Spaces are not required where no parking spaces are provided.

Multifamily dwellings (three or more units). EV Ready Spaces and EV Capable Spaces shall be provided in accordance with Table **EV**. Where the calculation of percent served results in a fractional parking space, it shall round up to the next whole number. The service panel or subpanel circuit directory shall identify the spaces reserved to support EV charging as "EV Capable" or "EV Ready". The raceway location shall be permanently and visibly marked as "EV Capable".

Total # of Parking Spaces	Minimum number of EV Ready Spaces	Minimum number of EV Capable Spaces
1	1	-
2-10	2	-
11-15	2	3
16-19	2	4
21-25	2	5
26+	2	20% of total

Table **EV:** Electric Vehicle Ready Space and EV Capable Space requirements

Non-Residential Buildings: TBD

3.5.8.3 Identification. Construction documents shall indicate the raceway termination point and proposed location of future EV spaces and EV chargers. Construction documents shall also provide information on amperage of future EVSE, raceway methods, wiring schematics and electrical load calculations to verify that the electrical panel service capacity and electrical system, including any on-site distribution transformers, have sufficient capacity to simultaneously charge all EVs at all required EV spaces at the full rated amperage of the EVSE.

Appendix E: Electrification Readiness Requirement

New language for phius Certification Guidebook is proposed below and is required for all residential projects. This aligns with the proposed language for IECC 2021, and the NBI Decarbonization Code.

Equipment serving multiple units. Combustion equipment that serves multiple dwelling units shall comply with section below:

Combustion water heating. Water heaters (with a capacity less than or equal to 300,000 Btu/h (88 kW)) shall be installed in accordance with the following:

1. A dedicated 240-volt branch circuit with a minimum capacity of 30 amps shall terminate within 3 feet (914 mm) from the water heater and be accessible to the water heater with no obstructions. Both ends of the branch circuit shall be labeled with the words "For Future Heat Pump Water Heater" and be electrically isolated.
2. A condensate drain that is no more than 2 inches (51 mm) higher than the base of the installed water heater and allows natural draining without pump assistance shall be installed within 3 feet (914 mm) of the water heater.
3. The water heater shall be installed in a space with minimum dimensions of 3 feet (914 mm) by 3 feet (914 mm) by 7 feet (2134 mm) high.
4. The water heater shall be installed in a space with a minimum volume of 700 cubic feet (20,000 L) or the equivalent of one 16-inch (406 mm) by 24-inch (610 mm) grill to a heated space and one 8-inch (203 mm) duct of no more than 10 feet (3048 mm) in length for cool exhaust air.

Combustion space heating. Where a building has combustion equipment for space heating, the building shall be provided with a designated exterior location(s) in accordance with the following:

1. Natural drainage for condensate from cooling equipment operation or a condensate drain located within 3 feet (914 mm), and
2. A dedicated branch circuit in compliance with IRC Section E3702.11 based on heat pump space heating equipment sized in accordance with R403.7 and terminating within 3 feet (914 mm) of the location with no obstructions. Both ends of the branch circuit shall be labeled "For Future Heat Pump Space Heater."

Exception: Where an electrical circuit in compliance with IRC Section E3702.11 exists for space cooling equipment.

Combustion clothes drying. A dedicated 240-volt branch circuit with a minimum capacity of 30 amps shall terminate within 6 feet (1829 mm) of natural gas clothes dryers and shall be accessible with no obstructions. Both ends of the branch circuit shall be labeled with the words “For Future Electric Clothes Drying” and be electrically isolated.

Combustion cooking. A dedicated 240-Volt, 40A branch circuit shall terminate within 6 feet (1829 mm) of natural gas ranges, cooktops and ovens and be accessible with no obstructions. Both ends of the branch circuit shall be labeled with the words “For Future Electric Range" and be electrically isolated.

Other combustion equipment. Combustion equipment and end-uses not covered by Sections above shall be provided with a branch circuit sized for an electric appliance, equipment or end use with an equivalent capacity that terminates within 6 feet (1829 mm) of the appliance or equipment.