Guide to Passive House

Passive House is a construction concept that can be applied to all buildings, whether residential or commercial. The voluntary standards are performance-based, with a limited prescriptive option for certain scopes. States in the NEEP region such as New York and Massachusetts incorporate Passive House standards as alternative compliance pathways and/or requirements in their stretch energy codes, and other states are considering this approach as one strategy for achieving their carbon reduction goals. The following resource introduces passive building concepts, explores Phius (formerly known as Passive House Institute U.S) options, and provides links to additional Phius resources to further educate states, jurisdictions, builders, homeowners, and energy efficiency advocates. It also addresses the availability of incentives for Phius compliance and the use of Passive House principles in affordable housing.

Passive Design Principles

The concept of Passive House construction isn't new, having originated in the United States and Canada during the 1970s and 80s. Later, the Passive House Institute (PHI) established the PassiveHaus standard in Europe in the 1990s. Passive design principles optimize costs and minimize energy usage by continually reducing heating and cooling demands. Passive conservation strategies are practiced globally. PHI and Phius are the two options for passive buildings in North America. Passive Homes are designed to significantly reduce energy loads in all climates. The heating and cooling energy of a passive home is up to 90 percent lower than buildings built to less stringent building energy standards. The insulation requirements of passive projects play a significant role in achieving substantial energy savings. Passive solar gains and internal gains (from sources such as occupants and appliances) meet some heating demands, reducing demand of the building's heating system. Passive building design principles are integral to the advanced level of energy efficiency in these buildings; they also significantly improve occupant comfort and indoor air quality (IAQ).

Passive design principles emphasize four central concepts:

1. **Thermal Control**
2. **Air Control**
3. **Moisture Control**
4. **Radiation Control**

Thermal Control

Passive House design utilizes high levels of insulation that maximize heat retention as outdoor temperatures drop and maintain cooler indoor temperatures as outdoor temperatures rise. Continuous insulation is central to minimizing heat loss. Continuous insulation refers to insulation that wraps a building's floor, roof, and walls with little to no gaps, and little to no thermal bridges. Continuous insulation separates the thermal temperatures of the internal and external environment. A thermal bridge occurs when part of the building envelope has a higher heat transfer rate than the areas around it. This means that a material, such as wood studs in a wall, is allowed to conduct heat from the interior to exterior of the building envelope, or vice versa. In this case, the studs are thermal bridges, because traditional construction places the insulation only between the studs. Since Passive House principles require continuous insulation, one way to fulfill this requirement is to add exterior insulation, which is continuous across the exterior faces of the wood studs.

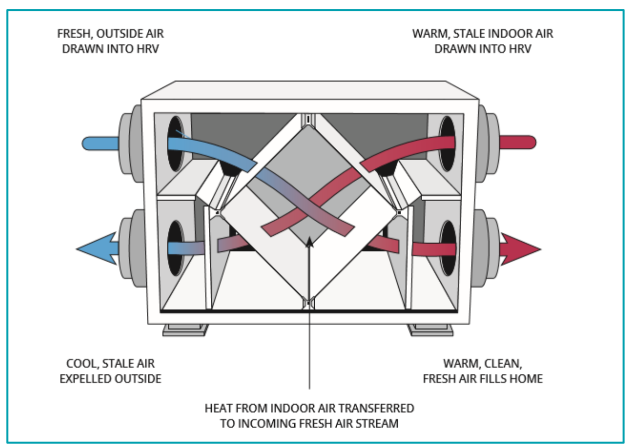
Thermal bridging is a prominent culprit of energy loss in poorly insulated homes and causes thermal energy transfers through gaps with low levels of resistance. Passive House requires airtight construction with a building envelope that will have zero gaps and perfect seals at every joint. This is significantly more stringent than recent national energy codes. Airtightness further prevents thermal loss caused by air leakage because airtight design prohibits all uncontrolled flows of air between internal and external environments that would otherwise occur because of gaps and cracks in the building envelope.

Alongside continuous insulation and airtightness, Passive House design performance standards require windows that provide better insulating properties than single pane windows, and many double pane windows. Window requirements are based on quantifiable performance standards that minimize heat loss. Project designers usually select triple pane windows to meet these standards. High-performance doors and windows control solar radiation to prevent internal overheating.

Air Control

The airtight design of Passive House buildings results in superior levels of indoor air quality that prevent air leakage. Airtight design eliminates most external air infiltration. An airtight barrier is especially beneficial for occupants sensitive to outdoor air pollution and odors.

Figure 1: Heat Recovery Ventilator Diagram, courtesy of CleanBC



A common misconception is that Passive House construction is unhealthy due to airtightness. In fact, Passive House requirements ensure high indoor air quality. Continuous mechanical ventilation exhausts stale air from the indoor environment (including kitchen and bathroom pollutants) and transfers captured thermal heat from outgoing air into incoming filtered air, or vice versa, depending on the season. In dry climates, buildings utilize a Heat Recovery Ventilation (HRV) system, as seen in Figure 1, whereas mixed humid environments will use an Energy Recovery Ventilation (ERV) system.

Moisture Control

Using above-code insulation measures, airtight construction, and high-performance windows and doors significantly minimizes the risks associated with increased levels of condensation and moisture penetration that can be a problem in other types of construction. Thermal bridge-free design improves building resiliency by actively preventing the development of internal and external damage (such as rot, mold and corrosion) due to excessive moisture.

Passive House requirements employ a superior level of vapor and moisture control. In cold climates, continuous insulation maintains warm temperatures indoors, and this warmth heats the indoor face of the building's exterior walls. The internal warmth maintained in the wall prevents condensation from accumulating and damaging the interior surface of the walls. Similarly, high performance windows prevent the formation of condensation within the interior glass surface by maintaining interior glass warmth in colder climates.

Radiation Control

Passive House design orients homes to optimize solar gains in cooler temperatures and benefit from shading design in warmer temperatures to maintain a comfortable environment. Passive House shading strategies prevent unwanted glare while still utilizing natural daylight, thereby reducing lighting loads. Double- or triple-pane high performance windows also control solar radiation by preventing indoor overheating in the summer as well as thermal loss in the winter.

Benefits of Passive House Design

States within the NEEP region such as Connecticut, Massachusetts, New York, and Rhode Island offer existing programs that provide financial incentives for Passive House projects. Federal and state tax incentives promoting renewable energy use and energy efficiency are detailed in the Green Tax Incentive Compendium. The Inflation Reduction Act (IRA) also provides clean energy and electrification rebates that can be calculated using the Rewiring America Calculator. Additionally, ENERGY STAR provides rebates for the use of qualifying appliances; the ENERGY STAR Rebate Finder provides consumers with local rebates and special offers.

Passive House certified homeowners can also expect lifelong benefits, such as:

- **Improved Comfort**: The thermal envelope is well insulated, and air sealed to maximize occupant comfort year-round. Additionally, Passive House design keeps the indoor environment free of outdoor noise and air pollution.
- **Improved Indoor Air Quality**: Passive House ventilation systems filter allergens like dust and pollen while simultaneously exhausting stale air, keeping the indoor air pollutant free. Passive House design also prevents the growth of contaminants such as mold.
- **Energy Conservation**: Certified passive homes are designed to minimize energy loads for heating and cooling, ventilation, lighting, appliances, water fixtures, and mechanical equipment, which contribute to additional energy conservation. They also offer an easy path to net-zero and net-positive buildings.
- **Durability:** Passive House design principles produce resilient buildings that are built to last.
- **Energy Savings:** With the combination of properly sized equipment and a well-insulated thermal envelope, buildings will have lower utility bills and smaller carbon footprints.

Phius Pathways to Zero

Phius provides climate- and building-specific standards to guide the design and construction of Passive House projects in North America. The two Phius certification paths, Phius CORE and Phius ZERO, can be applied to new construction, including: single family homes, multifamily buildings, offices, schools, and other projects. Phius CORE REVIVE and Phius ZERO REVIVE apply to existing buildings.

The Phius 2021 standards are founded on three central concepts:

- Limits to peak and annual heating and cooling loads;
- Limit on the overall source energy use;
- Air tightness and compliance with other quality assurance requirements.

Source energy refers to the total amount of space-conditioned energy used by a building system. Phius sets source energy targets that limit the overall use of energy. The Phius ZERO certification is more stringent than Phius CORE and sets the net source energy target at zero. Both standards utilize passive construction design methods, specify heating and cooling criteria, and have quality assurance requirements. Phius ZERO is the Phius standard for net-zero energy design and goes beyond Phius CORE by requiring that the total annual energy consumption of the building is equivalent to the amount of renewable energy generated onsite.

Path	Performance		Prescriptive
New Const.	CORE	ZERO	CORE Prescriptive
Retrofit	CORE REVIVE	ZERO REVIVE	CORE REVIVE Prescriptive
Scope	All Building Types		Single-family Detached Residences Duplexes Townhomes
Combustion Limitations	N/A	No fossil-fueled combustion on-site.	
Design Limitations	N/A		• No indoor pools or jetted tubs. • Limit on the ratio of floor area to bedrooms. • Limits on fenestration area and orientation.

Phius 2021 standards for residential projects include quality assurance requirements built on existing programs such as ENERGY STAR, Department of Energy Zero-Energy Ready Home, and Environmental Protection Agency Indoor AirPLUS. In previous years, Phius standards were strictly performance-based, receiving a pass or fail evaluation, and compliance was solely achievable through energy modeling via WUFI Passive software. In 2021, Phius introduced Phius CORE Prescriptive, allowing some building types to comply with a set of pre-defined guidelines instead of conducting energy modeling to ensure compliance.

Key Phius Requirements

The Certification Guidebook outlines exact Phius 2021 requirements for all certification and building types. The limits can be calculated using the Phius 2021 Performance Criteria Calculator. Key categories of 2021 Phius project requirements include:

- **Source Energy Criteria**: Phius Core aims to reduce heating and cooling energy loads, and Phius Zero requires net zero source energy use. Phius focuses on conserving energy in all other energy end uses such as mechanical appliances, lighting, and other equipment.

- **Airtightness:** Whole building pressurization and depressurization tests are required to measure the pass/fail certification requirement.
- **Moisture Control**: Opaque building assemblies require close attention to avoid risks related to mold and excessive moisture.
- **High Efficiency Windows:** High performance fenestration such as double or triple paned glass windows prevent moisture and are tightly sealed to minimize draft. Window comfort criteria is measured using the whole window U-value (thermal transmittance).
- **Renewable Energy**: Phius CORE does not require renewable energy, however, projects must meet electrification readiness requirements in order to transition to all-electric appliances. Some on-site renewable energy offsets can be credited. Phius ZERO and Phius CORE Prescriptive do not allow the use of any fossil fuel combustion equipment.
- **Combustion:** Fossil fuel combustion criteria within Phius CORE requires all heating and water heating systems within the building pressure boundary to be sealed and direct-vented appliances. Fossil fuel combustion is not permissible in Phius ZERO or Phius Core Prescriptive.
- **Electrical Vehicle (EV) Ready:** EV-readiness is a mandatory requirement for all Phius projects, ensuring that buildings are well-prepared for the future installation of charging stations. The number of EV-ready and EV-capable spaces may vary based on the specific parking needs of the building, with EV-capable spaces already equipped with functional charging infrastructure.
- **Electrification Readiness:** Phius requires all projects to meet electrification requirements to allow an all-electric transition at a future date. All combustion equipment must meet the electrification readiness requirements.
- **Quality Assurance**: All Phius projects require on-site inspection and testing during the construction process. Phius Certified Raters conduct inspections for single family projects, and Phius Certified Verifiers conduct inspections for multifamily and non-residential projects. Certified Quality Assurance Providers review the work of the Raters to ensure accuracy and accountability in the rating

Limitations to Passive House Design

Embodied carbon, or the total carbon footprint of building materials as they are created, transported, installed, and disassembled, are not evaluated or regulated by Phius requirements. In the course of meeting the requirements of Passive House insulation, compliance with Passive House certification standards may significantly increase the overall embodied carbon footprint of a project compared to projects that meet less stringent requirements. For example, spray foam insulation used in some passive homes contains chemicals used in common blowing agents that have extremely high global warming potential. To minimize obstacles to decarbonization, future updates to Passive House Standards should also consider embodied carbon impacts.

It's easier to achieve Passive House standards cost-effectively with a larger project than a smaller one due to efficiencies of scale. The energy use value as measured in kilowatt-hours (kWh) per square meter per year is lower in larger projects than in smaller ones. While this is beneficial for larger commercial and non-residential building projects, both residential and commercial building sectors are significant sources of energy consumption. The application of Passive Standards to commercial and residential projects would significantly reduce end-use energy consumption in the region. State energy offices and other authorities having jurisdiction should aim to develop financial incentives for smaller passive building projects and can additionally take advantage of existing federal grants and energy efficiency rebate programs to support passive projects.

Stringent Passive House certification requirements require on-site consultation and review of certified Passive building professionals. Consequently, states and municipalities without Passive House design criteria included in their building energy codes may lack the necessary workforce required to design and certify passive projects. Phius' WUFI Passive energy modeling software is available to design professionals, builders, and homeowners for free. However, energy modeling is a sophisticated process that requires prerequisite knowledge and additional training. States and jurisdictions are encouraged to offer Passive House training to designers, code officials, and contractors.

Incorporating Passive House into Building Energy Codes

The adoption of Passive House standards is essential in achieving carbon reduction goals and advancing energy codes, in particular zero energy codes. The rigorous requirements and principles of Passive House provide a comprehensive framework for designing energy-efficient buildings that significantly reduce energy consumption and greenhouse gas emissions.

By integrating Passive House standards into building energy codes, jurisdictions can set a higher bar for energy performance and encourage the construction of zero energy buildings (for instance, when the Phius ZERO path is used). Massachusetts, for example, recognizes Passive House in their stretch code, multifamily residential code, and commercial code.

> Massachusetts has Passive House as an alternative compliance pathway in their stretch code in Section R405, with either Phius or PHI Certification. In their Opt-In Specialized Code, multifamily residential buildings over 12,000 sq ft must also achieve Phius CORE or PHI. Passive House is also an alternative compliance pathway in the commercial code for any building type as noted in Section C401.2.2. The Opt-In Specialized Code's Zero Energy Pathway can also be verified via Phius ZERO (Or HERS 0) in Section RC102 and CC103.

By implementing the rigorous requirements and design principles of Passive House, buildings can significantly reduce energy consumption, lower greenhouse gas emissions, and create more comfortable and healthier indoor environments. Incorporating Phius and/or PHI standards into building energy codes ensures that energy-efficient design practices are followed consistently, promoting sustainable development and contributing to a greener future.

Passive House Resources

- **Building Professionals**
  - Become a Phius Certified Professional
    - Phius provides a variety of training options for building and quality assurance professionals.
  - Phius Standards
    - Phius provides climate specific passive standards for single family homes, existing buildings and nonresidential buildings.

- Phius Certification Guidebook 2021 v3.1
  - The Phius Certification Guidebook contains information to assist building professional successfully construct certified passive buildings
- Phius CORE Prescriptive 2021 Checklist
  - The prescriptive program's requirements are listed in this exhaustive checklist. It also includes features such as R-value calculator, whole-building UA tradeoff calculator, moisture design requirements, condensation risk assessment, and more.
- Passive House Institute Requirements
  - Passive design requirements are discussed, as well as general Passive House Institute Requirements
- PHI Building Certification
  - The webpage links detailed resources including a building certification guide, energy standards, and more.

- **States**
  - Policy
    - Financing programs, incentives and other supportive programs for states and local jurisdictions are available on the Policy webpage
- **Homeowners**
  - Single Family Overview
    - Learn more about single family Passive House projects and see how to get started be reviewing this webpage
  - FAQ
    - See frequently asked questions and answers on the PHIUS FAQ webpage
  - Find a Professional
    - The professional locator assists homeowners and other interested parties identify relevant Phius professionals
  - (PHI)Passive House Certifiers
    - Certifiers that are internationally accredited by the Passive House Institute to certify Passive House buildings can be found here