Certified Passive House Designer Course

Summary of Formulas

January 2026

Certification Criteria https://passiv.de/downloads/03_building_criteria_ip_en.pdf

New Build Passive House Certification Criteria

Space Heating Demand: ≤ 4.75 kBtu/(ft² yr)
or **Heat Load:** ≤ 3.17 Btu/hr ft²

Space Cooling Demand: ≤ 4.75 kBtu/(ft² yr) + additional allowance for dehumidification where needed (PHPP determined)

Excess temperature frequency (>77°F): ≤ 10% of the year (for projects without active cooling)
Building airtightness: ≤ 0.6 $^{1}/_{h}$ (or h^{-1})

Primary energy demand (renewable):
Classic (19.02 kBtu/(ft² yr)), Plus (14.26), Premium (9.51)
Renewable energy generation:
Classic (0 kBtu/(ft^2_{ground} yr)), Plus (19.02), Premium (38.04)
Up to 4.75 kBtu/(ft² ·yr) can be 'traded' between PER demand and renewable energy generation
Primary energy demand (non-renewable): ≤ 38 kBtu/(ft² ·yr) – to be phased-out at some point in the future

EnerPHit Certification Criteria

Space Heating Demand method: ≤ 7.92 kBtu/(ft² yr) Note: this value is a Cool-temperate climate, typically used in the exam. As this value is climate specific, if another climate is called out, refer to the Certification Criteria, page 15.

Component method: detailed table of required minimum R-values for opaque elements, U-values for windows and doors and heat recovery efficiency for ERVs (see certification criteria).

Space Cooling Demand: Same as for new-build Passive House

Building airtightness: ≤ 1.0 $^{1}/_{h}$ (or h^{-1})

Primary energy demand (renewable):
Classic (19.02 kBtu/(ft² yr)), Plus (14.26), Premium (9.51) + allowance for additional heating / cooling demand compared to new-build Passive House

Renewable energy generation:
Classic (0 kBtu/(ft^2_{ground} yr)), Plus (19.0), Premium (38.04)

Up to 4.75 kBtu/(ft² ·yr) can be 'traded' between PER demand and renewable energy generation

Transmission Heat Losses through Planar Elements
(roof, walls, windows and floors)

Space Heating Demand of Transmission Losses: (kBtu/yr)

$Q_T = A \times (1/R) \times f_t \times G_t$

- A = Area of the thermal envelope: ft^2
- 1/R-Value = U-Value: Btu/(hr ft^2 ˚F)
- f_{t} = Temperature correction factor (rarely needed in the exam – only relevant for elements in contact with the ground): unitless
- Yearly heating degree hours: (k ˚F hr)/yr

Heat Load of Transmission Losses: (Btu/hr)

$P_T = A \times (1/R) \times f_t \times \Delta T_{1,2}$

- A = Area of the thermal envelope: ft^2
- 1/R-Value = U-Value: Btu/(hr ft^2 ˚F)
- f_{t} = Temperature correction factor (rarely needed in the exam): unitless
- $\Delta T_{1,2}$ = Temperature difference between inside (always 68˚F) and outside in Weather Condition 1 (cold and sunny) and 2 (mild and cloudy): ˚F

R-Value Calculation: (hr ft² ˚F / Btu)

$R = R_{si} + (d_1 \times r_1) + (d_2 \times r_2) + (d_3 \times r_3) + (d_n \times r_n) + R_{se}$

- R_{si} = interior surface film resistance: Roof = 0.57 hr ·ft^2 ·F/Btu, Walls = 0.74, Floors = 0.97
- d_1, d_2, d_3, d_n = thickness of each layer: inches
- r_1, r_2, r_3, r_n = resistivity (R per inch) of materials in each layer: (hr ft^2 ˚F)/ Btu in
- R_{se} = exterior surface film resistance: Roof = 0.23 hr ft^2 ˚F/Btu, Walls = 0.23, Ground = 0.0

Infrequently used Planar Heat Loss formulas

Monthly Heating Degree Hours: (k °F h / month)

$G_{t,month} = (T_i - T_e) \times (\text{days per month} \times 0.024\ kh/d)$

- T_i : temperature of the interior (always 68°F): °F
- T_e : 'design' temperature of the exterior for that month (climate dependent): °F
- days per month: how many days per month ;-)
- 0.024 kh/d: conversion factor, a constant

The worked example below is for January in New York where the exterior 'design' temperature is 30°F:

- $G_{t,Jan}$ = (68°F - 30°) × (31 days × 0.024 kh/d) = 28.272 k °F h / Jan

Thermal Bridging Formulas

Space Heating Demand of Linear Thermal Bridges (kBtu/yr)

$Q_{T\text{-}tb} = L \times \Psi \times f_t \times G_t$

- L = Length of thermal bridge: feet
- Ψ = Psi-value: Btu/(hr ft ˚F)
- f_t = Temperature correction factor (very rarely needed): unitless
- G_t = Yearly heating degree hours: (k ˚F hr)/yr

Space Heating Demand of Point Thermal Bridges (kBtu/yr)

$Q_{T\text{-}tb} = n \times \chi \times f_t \times G_t$

- n = Number of point thermal bridges: unitless
- χ = Chi-value: Btu/(hr ˚F)
- f_t = Temperature correction factor (very rarely needed): unitless
- G_t = Yearly heating degree hours: (k ˚F hr)/yr

Heat Load of Linear Thermal Bridges (Btu/hr)

$P_{T\text{-}tb} = L \times \Psi \times f_t \times \Delta_t$

- L = Length of thermal bridges: feet
- Ψ = Psi-value: Btu/(hr ft ˚F)
- f_t = Temperature correction factor (very rarely needed): unitless
- Δ_t = Temperature difference between inside (set at 68˚F) and the exterior worst case 'design' temperature determined by PHPP between scenarios 1 & 2 : ˚F

Heat Load of Point Thermal Bridges (Btu/hr)

$P_{T\text{-}tb} = n \times \chi \times f_t \times \Delta_t$

- n = Number of point thermal bridges: unitless
- χ = Chi-value: Btu/(hr ˚F)
- f_t = Temperature correction factor (very rarely needed): unitless
- Δ_t = Temperature difference between inside (set at 68˚F) and the exterior worst case 'design' temperature determined by PHPP between scenarios 1 & 2 : ˚F

Infrequently Used Thermal Bridging Formulas

- Thermal bridge "free" = $\Psi_{(\text{exterior dimensions})} < 0.006$ Btu/hr ft °F

- Point thermal bridges = $\Delta U_{TB} = \Sigma X / A < 0.0018$ Btu/(hr ft² °F)
  In English, this means the different in the U-value (due to thermal bridges) = the sum (Σ) of all the point thermal bridges (X) divided by the surface area (A) should be less than 0.0018 Btu/(hr ft² °F)

Airtightness Formulas

Space Heating Demand of Ventilation Infiltration Losses (kBtu/yr)

$Q_{V\text{-infill}} = V_{n50} \times e \times n_{50} \times C_{air} \times G_t$

- V_{n50} = airtightness test volume: ft^3
- e = fraction of air changes per hour at resting atmospheric pressure (value of 0.07 (=7%) commonly used): unitless
- n_{50} = airtightness test result @ 50 Pascal: $^1/_h$ or h^{-1}
- C_{air} = Heat carrying capacity of air: a constant: 0.018 Btu/ft^3 °F
- G_t = Yearly heating degree hours: (k ˚F hr)/yr

Heat Load of Ventilation Infiltration Losses (Btu/hr)

$P_{V\text{-infill}} = V_{n50} \times e \times n_{50} \times 2.5 \times C_{air} \times \Delta T_{1,2}$

- V_{n50} = airtightness test volume: ft^3
- e = fraction of air changes per hour at resting atmospheric pressure (value of 0.07 (=7%) commonly used): unitless
- n_{50} = airtightness test result @ 50 Pascal: $^1/_h$ or h^{-1}
- 2.5 = safety factor used for heat load to ensure building can be heated in windy weather: unitless
- C_{air} = Heat carrying capacity of air: a constant: 0.018 Btu/ft^3 °F
- $\Delta T_{1,2}$ = Temperature difference between inside (always 68˚F) and outside in Weather Condition 1 (cold and sunny) and 2 (mild and cloudy): ˚F

n_{50} calculation ($^1/_h$ or h^{-1})

$n_{50} = (V_{50} \times 60\ min/hr) \div V_{n50}$

- V_{50} = air-flow rate through the fan at 50 Pascal: ft^3 / minute (CFM)
- 60 min/hr = conversion factor
- V_{n50} = airtightness test volume: ft^3

Infrequently Used Airtightness Formulas

q_{50} calculation (ft^3 / hr.ft^2)

$q_{50} = (V_{50} \times 60\ min/hr) \div EA_{n50}$

- V_{50} = air-flow rate through the fan at 50 Pascal: ft^3 / minute (CFM)
- 60 min/hr = conversion factor
- EA_{n50} = building envelope surface area: ft^2

W_{50} calculation (ft^3 / hr.ft^2)

$w_{50} = (V_{50} \times 60\ min/hr) \div TFA$

- V_{50} = air-flow rate through the fan at 50 Pascal: ft^3 / minute (CFM)
- 60 min/hr (conversion factor, a constant)
- TFA = treated floor area: ft^2

Equivalent Leakage Area (in^2)

$A_{50} = (V_{50} \div 7.6\ CFM / in^2)$

- V_{50} = air-flow rate through the fan at 50 Pascal: ft^3 / minute (CFM)
- 7.6 CFM / in^2 = conversion factor, a constant

Window Formulas

Window U-value (Btu/(hr ft² °F))

$$U_{w,\,installed} = \frac{(U_g \times A_{glass}) + (U_f \times A_{frame}) + (\Psi_{spacer} \times L_{spacer}) + (\Psi_{install} \times L_{install})}{A_{window}}$$

Heating Demand Window Energy Balance (kBtu/year)

$$Q_S - Q_T = (r \times SHGC \times A_w \times G) - (A_w \times U \times G_t)$$

- r = reduction factor (unitless) = shading × dirt × non-perpendicular incident radiation × glazing fraction (dirt = constant of 0.95 and non-perpendicular incident radiation = constant of 0.85): unitless
- SHGC = solar heat gain coefficient: unitless
- A_w = gross window area: ft^2
- G = global radiation: kBtu/(ft².yr) – will vary with location and orientation
- U = overall U-value: Btu/(hr ft² °F)
- G_t = Heating degree hours: (k °F hr)/yr

Infrequently Used Window Formulas

Interior Surface Temperature of Glazing or Frame (°F)

$$T_{si} = T_i - (U \times R_{si} \times \Delta T)$$

- T_{si}= surface temperature inside: °F
- T_i = inside air temperature: °F
- U = U-value of the component: Btu/(hr ft² °F)
- R_{si} =surface film resistance inside (for a window = 0.74 (hr·ft²·F)/Btu)
- Δ T = Temperature difference between interior & exterior ($T_i - T_e$), always assuming 68 °F interior: °F

Heat Load Window Energy Balance (Btu/hr)

$$P_s - P_T = (r \times SHGC \times A_w \times G_{1\ or\ 2}) - (A_w \times U \times \Delta T_{1\ or\ 2})$$

Factors are the same as for the heating demand formula, with exception of the following:

- $\Delta T_{1\ or\ 2}$ = temperature difference between interior (68°F) and exterior 'design' temperature in 2 weather conditions, cold and sunny and mild and cloudy: °F
- G_1 or G_2 = solar radiation in 2 weather conditions, cold and sunny and mild and cloudy: Btu/hr ft²

Ventilation Formulas

Volumetric Air Flow Rate ($V_{airflow}$)

To determine the ventilation rate for a Passive House, the following 3 calculations are needed (each pertaining to maximum flow setting (also referred to as 'boost setting')). The largest of the three rates is selected as the ventilation rate for the project.

- **Supply:** 18 CFM per person
- **Extract:** Kitchens @ 35 CFM, Bathrooms @ 24 CFM + WCs @ 12 CFM
- **Minimum ventilation air change rate:** (0.39 ACH × TFA x ceiling height of 8.2 feet) ÷ 60 min/hr. (in the presentation notes, 'V_V' is defined as the 'ventilation volume' which is the TFA x 8.2 feet)

Heating Demand ERV Ventilation Losses (kBtu/yr):

n_{erv}

$$Q_{V\text{-}ERV} = V_v \times n_{V,system} \times (1-\eta_{ERV}) \times C_{air} \times G_t$$

- V_v = Ventilation volume (TFA X 8.2 ft): ft^3
- $n_{V,system}$ = number of ventilation air changes per hour at normal setting: $^1/_h$ or h^{-1}
- $(1-\eta_{ERV})$ = 1 minus the heat recover efficiency of the ERV, minimum of 0.75: unitless
- C_{air} = heat carrying capacity of air (a constant, 0.018 Btu/($ft^3 \cdot °F$))
- G_t = Heating degree hours: (k °F hr)/yr

Alternative method for Heating Demand ERV Ventilation Losses (kBtu/yr):

$$Q_{V\text{-}ERV} = V_{airflow} \times 60\ min/hr \times (1-\eta_{ERV}) \times C_{air} \times G_t$$

- $V_{airflow}$ = Ventilation flow rate: ft^3 / minute (CFM), multiply number of occupants by 18 ft^3/min or CFM to get the $V_{flow\ rate}$
- 60 min/hr (conversion factor, a constant)
- $(1-\eta_{ERV})$ = 1 minus the heat recover efficiency of the ERV, minimum of 0.75: unitless
- C_{air} = heat carrying capacity of air (a constant, 0.018 Btu/($ft^3 \cdot °F$))
- G_t = Heating degree hours: (k °F hr)/yr

Infrequently Used Ventilation Formulas

Electrical efficiency of ERV fans (W/CFM)

= Power of the fans & controls (in Watts) ÷ volumetric flow rate (ft^3/min, or CFM)

Ventilation Duct diameter (inches)

$$24 \times \sqrt{(V_{airflow} \div (Airspeed \times \pi))}$$

- V_{flow} = air flow rate in ft^3 / minute or CFM at normal speed
- Airspeed = velocity of air in duct (target 400 ft/min but may be 300 to 600 ft/min)
- π (pi) = 3.14159

Ventilation air change rate ($^1/_h$ or h^{-1})

= (Ventilation airflow (ft^3/min, or CFM) × 60 min/hr) ÷ Room volume (ft^3)

$$\text{ERV efficiency} = \frac{(T_{ETA} - T_{EHA}) + \left\{\frac{P_{elec} \times 3.413}{V_{airflow} \times C_{air} \times 60}\right\}}{(T_{ETA} - T_{ODA})}$$

- T_{ETA} = temperature of extract air (°F)
- T_{EHA} = temperature of exhaust air (°F)
- T_{ODA} = temperature of outdoor (°F)
- P_{elec} = electric power of the fans + controls in Watts
- 3.413 = unit conversion factor
- V = ventilation flow rate in ft^3/min or CFM
- C_{air} = heat carrying capacity of air (a constant, 0.018 Btu/($ft^3 \cdot °F$))
- 60 = minutes per hour (unit conversion factor)

Heating and Hot Water Formulas

Max Heat Load Deliverable by Supply Air (Btu/hr)

$P_{air\ heating} = C_{air} \times V_{airflow} \times (T_{SUPPLY\text{-}MAX} - T_{SUPPLY\text{-}MIN}) \times 60\ min/hr$

- C_{air} = heat carrying capacity of air (a constant, 0.018 Btu/(ft³·°F))
- V_{system} = volumetric air flow rate: ft³ / minute (CFM)
- $(T_{SUPPLY\text{-}MAX} - T_{SUPPLY\text{-}MIN})$ = temperature difference of supply air after (max. 125.6 °F) and before (min. 62 °F) a post-heater: °F
- 60 min/hr = unit conversion factor

Power of Ventilation Pre-Heating Coil (Btu/hr), also known as 'frost protection', to prevent the ERV core from freezing over

$P_{VPHC} = V_{airflow} \times 60\ min/hr \times C_{air} \times \Delta T$

- V_{cfm} = volumetric air flow rate: ft³ / minute (CFM)
- 60 min/hr = unit conversion factor
- C_{air} = heat capacity of air (a constant, 0.018 Btu/(ft³·°F))
- ΔT = temperature difference between exterior design temperature for that climate and the ERV set point frost protection temperature

Primary Energy Renewable (PER) Demand of Ventilation Pre-Heating Coil (VPHC) (kBtu/(ft² yr)

$PER_{VPHC} = (P_{VPHC} \times RT \times PER\ factor) \div TFA$

- P_{VPHC} = Power of the ventilation pre-heating coil
- RT = Running time: thousands of hours per year (divide total running hours per year by 1,000)
- PER factor = factor used for heating in the region under consideration: kBtu / kBtu – choose appropriate value from a table
- TFA = treated floor area: ft²

Hot Water Tank losses (Btu/hour)

$Tank\ losses = Area \times U\text{-}value \times \Delta T$

- Area = surface area of hot water tank: ft²
- U-value = U-value of the water tank walls. The U-value is the inverse of the R-value (U = 1/R). The R-value can be calculated as follows: 0.00 hr.ft².°F/Btu (internal heat transfer resistance) + (insulation thickness in inches x R-per inch of insulation (hr.ft².°F/Btu.in)) + 0.74 hr.ft².°F/Btu (external heat transfer resistance). Units for a U-value = Btu/hour.ft².°F
- ΔT = temperature difference between water storage temperature and plant room temperature: °F

Economic Formulas

Present Value calculation ($)

PV = present value of energy savings over the lifetime of the borrowing ($)

C = annual energy saving ($)

i = interest rate (written in decimal form, eg. 5% written as 0.05)

n = number of years over which present value is calculated

$$PV = C \times \frac{1 - (1+i)^{-n}}{i}$$

Annuity factor calculation (unitless)

AF = annuity factor used to multiply by the loan amount to determine the annual repayments (unitless)

i = interest rate (written in decimal form, eg. 5% written as 0.05)

n = number of years over which the borrowing is undertaken

$$AF = \frac{i}{1 - (1+i)^{-n}}$$

Real Interest Rate calculation (unitless)

i_{real} is the 'real' interest rate which takes into account inflation

$i_{nominal}$ = interest rate quoted by bank

r = inflation rate

Note: all rates written in decimal form, eg. 5% written as 0.05

$$i_{real} = \left\{ \frac{1 + i_{nominal}}{1 + r} \right\} - 1$$

Price of saved kWh/kBtu Calculation ($ / kWh or $ / kBtu)

AF = annuity factor (reciprocal of present value factor)

I_{add} = additional costs of investment for saving measures ($)

R = residual value of components ($)

Z = possible annual maintenance costs ($)

E_{SAVED}= annual site energy savings (kWh/year or kBtu/year)

$$P_{saved} = \frac{AF_{loan\ term} \times (I_{add} - R) + Z}{E_{saved}}$$

Residual Value Calculation ($)

AF_{50} = annuity factor calculated for the life of the component (in this example, 50 years),

PVF_{20} = present value factor calculated for the duration of the mortgage (in this example, 20 years)

I = additional costs of investment for saving measures ($)

$$R = (1 - AF_{50} \times PVF_{20}) \times I_{add}$$