

# Building Envelope Thermal Performance

Calculation Methods & Standards - ASHRAE 90.1-2022

Document: BEC-ASHRAE-2025-002 | Standard: ASHRAE 90.1-2022 | Date: November 2025 | Revision: 4.1

## 1. Wall U-Value Calculation Method

$$U\text{-value} = 1 / R_{\text{total}}$$

$$R_{\text{total}} = R_{\text{inside}} + \sum R_{\text{layers}} + R_{\text{outside}}$$

### Multi-Layer Wall Assembly Analysis:

Layer Description	Thickness (mm)	Conductivity (W/m·K)	R-Value (m <sup>2</sup> ·K/W)
Inside Air Film	-	-	0.130
Gypsum Plasterboard	12.5	0.25	0.050
Concrete Masonry Unit	200	1.70	0.118
XPS Insulation	100	0.034	2.941
Air Gap (ventilated)	25	-	0.180
Clay Brick	100	0.77	0.130
Outside Air Film	-	-	0.040

### Calculation Steps:

- Sum all R-values:  $0.130 + 0.050 + 0.118 + 2.941 + 0.180 + 0.130 + 0.040$
- $R_{\text{total}} = 3.589 \text{ m}^2\cdot\text{K/W}$
- $U\text{-value} = 1 \div 3.589 = 0.279 \text{ W/m}^2\cdot\text{K}$

Final U-Value: 0.279 W/m<sup>2</sup>·K

ASHRAE 90.1 Limit (Climate Zone 4): 0.35 W/m<sup>2</sup>·K

Status: COMPLIANT ✓

## 2. Thermal Bridging Correction

$$U_{\text{corrected}} = U_{\text{clear wall}} + \Delta U_{\text{thermal bridges}}$$

$$\Delta U_{\text{thermal bridges}} = \Sigma(\psi \times l) / A_{\text{wall}}$$

### Thermal Bridge Analysis:

#### Linear Thermal Bridges:

- Steel studs (16" o.c.):  $\psi = 0.15 \text{ W/m}\cdot\text{K}$ , Length = 120 m
- Window perimeter:  $\psi = 0.08 \text{ W/m}\cdot\text{K}$ , Length = 180 m
- Floor slab edge:  $\psi = 0.25 \text{ W/m}\cdot\text{K}$ , Length = 80 m
- Balcony connections:  $\psi = 0.45 \text{ W/m}\cdot\text{K}$ , Length = 24 m

#### Calculation:

$$\begin{aligned}\Delta U &= [(0.15 \times 120) + (0.08 \times 180) + (0.25 \times 80) + (0.45 \times 24)] \div 2400 \\ \Delta U &= [18 + 14.4 + 20 + 10.8] \div 2 \quad \Delta U = [18 + 14.4 + 20 + 10.8] \div 2400 \\ \Delta U &= 63.2 \div 2400 = 0.026 \text{ W/m}^2\cdot\text{K}\end{aligned}$$

**Corrected U-Value:  $0.279 + 0.026 = 0.305 \text{ W/m}^2\cdot\text{K}$**

**Still within ASHRAE 90.1 limit ✓**

### 3. Window Performance Calculations

#### Overall Window U-Value:

$$U_{\text{window}} = (A_{\text{glass}} \times U_{\text{glass}} + A_{\text{frame}} \times U_{\text{frame}} + L_{\text{edge}} \times \psi_{\text{edge}}) / A_{\text{total}}$$

#### Double-Glazed Window Analysis:

Component	Area/Length	U-Value/ $\psi$ -Value	Heat Loss (W/K)
Glass Area	1.8 m <sup>2</sup>	1.4 W/m <sup>2</sup> ·K	2.52
Frame Area	0.7 m <sup>2</sup>	2.8 W/m <sup>2</sup> ·K	1.96
Edge Seal	5.2 m	0.06 W/m·K	0.31

#### Overall Calculation:

$$\text{Total Heat Loss} = 2.52 + 1.96 + 0.31 = 4.79 \text{ W/K}$$

$$\text{Total Window Area} = 1.8 + 0.7 = 2.5 \text{ m}^2$$

$$U_{\text{window}} = 4.79 \div 2.5 = 1.92 \text{ W/m}^2 \cdot \text{K}$$

#### 4. Solar Heat Gain Coefficient (SHGC)

**SHGC = Solar Heat Gain / Incident Solar Radiation**

**Solar Heat Gain = Direct Transmission + Inward Flowing Fraction**

##### Low-E Glazing SHGC Calculation:

###### Glass Properties:

- Solar Transmittance ( $\tau$ ): 0.42
- Solar Absorptance outer pane ( $\alpha_1$ ): 0.15
- Solar Absorptance inner pane ( $\alpha_2$ ): 0.08
- Inward flowing fraction outer: 0.12
- Inward flowing fraction inner: 0.89

###### SHGC Calculation:

Direct transmission = 0.42

$$\text{Absorbed heat flow} = (0.15 \times 0.12) + (0.08 \times 0.89)$$

$$\text{Absorbed heat flow} = 0.018 + 0.071 = 0.089$$

$$\text{SHGC} = 0.42 + 0.089 = 0.509$$

**Calculated SHGC: 0.51**

**ASHRAE 90.1 Limit (South-facing, Zone 4): 0.40**

**Status: REQUIRES EXTERNAL SHADING**

## 5. Climate Zone Requirements

### Zone 1 (Hot)

Wall U-Value: 0.89  
Window U-Value: 1.22  
SHGC: 0.25

### Zone 2 (Hot)

Wall U-Value: 0.89  
Window U-Value: 0.65  
SHGC: 0.25

### Zone 3 (Warm)

Wall U-Value: 0.89  
Window U-Value: 0.57  
SHGC: 0.25

### Zone 4 (Mixed)

Wall U-Value: 0.35  
Window U-Value: 0.48  
SHGC: 0.40

### Zone 5 (Cool)

Wall U-Value: 0.35  
Window U-Value: 0.48  
SHGC: NR

### Zone 6 (Cold)

Wall U-Value: 0.35  
Window U-Value: 0.48  
SHGC: NR

**Note:** All U-values in W/m<sup>2</sup>·K. SHGC values are dimensionless. NR = No Requirement. Values shown are for non-residential buildings per ASHRAE 90.1-2022.

## 6. Air Leakage Calculations

$$\text{Air Leakage Rate} = Q / A_{\text{envelope}}$$

$$Q = C \times \Delta P^n$$

Where: C = flow coefficient,  $\Delta P$  = pressure difference, n = flow exponent

### Blower Door Test Results:

#### Test Conditions:

- Test Pressure: 75 Pa
- Measured Airflow: 8,500 CFM
- Building Envelope Area: 25,000 ft<sup>2</sup>
- Flow Exponent (n): 0.65

#### Calculation:

$$\text{Air Leakage Rate} = 8,500 \text{ CFM} \div 25,000 \text{ ft}^2$$

$$\text{Air Leakage Rate} = 0.34 \text{ CFM/ft}^2$$

$$\text{ASHRAE 90.1 Limit} = 0.40 \text{ CFM/ft}^2$$

**Measured: 0.34 CFM/ft<sup>2</sup> @ 75 Pa**

**Required: ≤ 0.40 CFM/ft<sup>2</sup> @ 75 Pa**

**Status: COMPLIANT ✓**