

Technical Documentation: Multi-Story House Builder & HVAC Calculator

1. Module Overview

This software module serves as a rapid-prototyping tool for residential building envelopes and HVAC load estimation. It combines an interactive 3D visualizer with a physics-based calculation engine to determine the heating and cooling requirements for a multi-story structure.

Key Capabilities

- **Geometric Modeling:** Dynamic generation of multi-story structures (Basement + 2 Floors) with gable roofs.
- **Material Specification:** User-selectable insulation types (R-Values), exterior claddings, and roof materials with defined reflectivity properties.
- **Environmental Simulation:** Real-time adjustment of solar angles (Latitude), wind vectors, and day/night radiative conditions.
- **HVAC Sizing:** Calculation of Heating Load (BTU/hr output and furnace input) and Cooling Load (AC tonnage) using standard heat-transfer principles.

2. Theoretical Basis & Equations

The core physics engine relies on Conductive Heat Transfer, Infiltration, and Solar Gain, modified by environmental coefficients.

A. Conductive Heat Transfer (Envelope Load)

Heat moves through solid barriers (walls, windows, roof) from the warmer side to the cooler side. The module calculates this for each surface using:

$$Q_{cond} = \frac{A}{R_{eff}} \times \Delta T$$

Where:

- Q_{cond} = Heat Loss/Gain (BTU/hr)
- A = Surface Area (ft²), net of windows/doors
- R_{eff} = Effective R-Value of the assembly
- ΔT = $|T_{inside} - T_{outside}|$

R-Value Note: A base structural R-value of **R-3** (studs + sheathing) is added to user-selected insulation. Example: Fiberglass R-13 + R-3 = **R-16 total**.

B. Infiltration (Air Leakage)

Buildings exchange indoor and outdoor air through cracks and seals. The sensible load is:

$$Q_{inf} = V \times 0.018 \times \Delta T \times ACPH$$

Where:

- V = House volume (ft³), including basement
- $ACPH$ = Air Changes Per Hour
- 0.018= Air density \times specific heat (constant)

C. Solar Heat Gain (Cooling Mode)

Radiant solar energy entering through glazing contributes to cooling load:

$$Q_{solar} = A_{glass} \times SHGC \times I_{solar} \times \sin(\text{Latitude})$$

Where:

- **SHGC** = Solar Heat Gain Coefficient (0.5 assumed)
- I_{solar} = Solar intensity (~200 BTU/ft²)
- Latitude affects angle of incidence; higher latitudes increase vertical window gain.

3. Environmental Factors & Algorithms

A. Wind Effects

Wind influences the thermal envelope in two ways:

1. **Infiltration Pressure:**
 - Base tightness: **0.5 ACPH**
 - Add **0.05 ACPH per 1 mph** of wind speed
2. **Convective Cooling (“Wind Washing”):**
 - Walls facing wind direction receive a **15% R-value penalty**
 - $R_{effective} = R \times 0.85$

B. The “Phantom” Basement (Ground Physics)

Basements behave differently due to earth thermal mass.

- **Temperature Delta:** Uses **ground temperature (50–55°F)** instead of air temperature.
- **Wind Immunity:** No wind-washing penalties.
- **Shadowing:** Basement walls rendered semi-transparent in visualization.

C. Sun & Latitude

- Sun position orbits based on latitude:
 - 0°= overhead (equator)
 - 90°= horizon (poles)

South-Facing Windows:

- **Heating Mode:** Provide a *solar bonus* (reduces load).
- **Cooling Mode:** Add significant *solar penalty*.

D. Roof Sol-Air Temperature

Roof surfaces heat above ambient due to solar absorption:

$$T_{surface} \approx T_{air} + ((1 - \text{Reflectivity}) \times 50)$$

Material Examples:

- Black asphalt (5% reflectivity): ~47°F added
- White metal roof (65% reflectivity): much cooler

4. Efficiency Factors (Sizing)

The module distinguishes between **building load** and **equipment rating**.

Heating (Furnaces)

Furnaces are sized by **input capacity**, but deliver heat based on **AFUE efficiency**:

$$\text{Required Input} = \frac{\text{Total Heat Loss}}{\text{AFUE}}$$

Typical AFUE values:

- **60%** – Older units
- **80%** – Standard
- **96%** – High-efficiency condensing furnace

Cooling (Air Conditioners)

AC units are rated in **tons**:

- **1 Ton = 12,000 BTU/hr**

Latent Load: High humidity increases cooling load by up to **1.3×**.

5. References & Industry Standards

This module uses simplified algorithms based on:

- **ACCA Manual J** – Standard for residential HVAC load calculations
- **ASHRAE Handbook – Fundamentals** – Solar factors, material thermal properties
- **DOE Guidelines** – Insulation R-values, window performance
- **NREL Research** – Sol-air temperature and roof reflectivity data