J∆S Engineering Suite

Module Guide: HVAC Load Calculations

Version 1.2 — April 2026
JS Engineering Solutions

Version: 1.1 **Methodology:** ASHRAE CLTD/CLF (Cooling Load Temperature Difference / Cooling Load Factor) **Reference Standards:** ASHRAE Fundamentals 2021 Ch. 18, ASHRAE 62.1-2022, ASHRAE 90.1-2022 **Engine File:** `engine.py` | **Data Models:** `models.py` | **Weather:** `weather.py`

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1. Overview

What Are Load Calculations?

HVAC load calculations determine how much heating and cooling capacity a building or individual space requires to maintain comfortable indoor conditions. They answer two fundamental questions:

- **Cooling:** How many BTU/hr must the air-conditioning system remove on the hottest design day to keep the space at the target temperature and humidity?
- **Heating:** How many BTU/hr must the heating system deliver on the coldest design day to maintain the target indoor temperature?

The results of a load calculation drive every downstream design decision: equipment sizing, duct sizing, piping sizing, electrical infrastructure, and energy code compliance.

Why Load Calculations Matter

1. Correct Equipment Sizing. An oversized system wastes energy, increases first cost, and causes short-cycling (frequent on/off) that degrades comfort and equipment life. An undersized system cannot maintain setpoint on design days.

2. Energy Code Compliance. ASHRAE 90.1-2022 and Title 24-2022 require documented load calculations to demonstrate that installed equipment capacity does not exceed 125% of the calculated load (with limited exceptions).

3. Ventilation Design. ASHRAE 62.1-2022 mandates minimum outdoor air quantities. Load calculations quantify the energy penalty of conditioning that outdoor air.

4. Cost Estimation. Mechanical construction costs scale roughly with tonnage. Accurate loads prevent over-budgeting or change-order surprises.

5. Comfort. Proper loads ensure that every zone can maintain its setpoint under peak conditions, including extreme occupancy in conference rooms or high solar gains on west-facing glazing.

ASHRAE CLTD/CLF Method Overview

The J∆S Engineering Suite implements the ASHRAE Cooling Load Temperature Difference / Cooling Load Factor (CLTD/CLF) method, as documented in ASHRAE Fundamentals Chapter 18. This method is the industry standard for commercial load calculations.

Key concepts:

- **CLTD (Cooling Load Temperature Difference):** Replaces the simple steady-state delta-T for opaque surfaces (walls, roofs). CLTD accounts for thermal mass delay -- the fact that heat conducted through a heavy wall at noon does not appear as a cooling load until 3-5 PM.
- **CLF (Cooling Load Factor):** A fractional multiplier (0 to 1) that reduces the instantaneous heat gain from lights, equipment, and people to the actual cooling load, again accounting for thermal mass absorption and re-radiation.
- **SCL (Solar Cooling Load):** Tabulated values for glazing solar heat gain by orientation and hour, replacing the simpler SHGF x SC method with time-lagged values.

The engine calculates loads for all 24 hours of a design day and identifies the true peak hour, which is typically between 2 PM and 5 PM for perimeter zones with west-facing glass.

Accuracy Target

The engine targets loads within 5% of actual measured performance, with a deliberate conservative bias (slight oversizing). A configurable safety factor defaults to 15% for cooling and 10% for heating.

2. Getting Started

Opening the Load Calculation Module

1. Launch the application: run `python launcher.py` from the project root.
2. Log in with your credentials (2FA if enabled).
3. From the Dashboard, locate **Load Calculations** in the sidebar under the "Calculations" category.
4. Click to open the module. The interface presents a tabbed layout:

Tab	Purpose
Project Setup	Location, weather data, design conditions, indoor setpoints
Rooms	Add/edit rooms with envelope, occupancy, and load parameters
Results	Room-by-room load summary table with detailed breakdowns
Reports	Generate PDF/TXT/Excel load calculation reports

Interface Layout

The module uses a split-panel layout:

- **Left panel:** Room tree navigator showing all rooms grouped by zone and air system.
- **Center panel:** Active tab content (inputs or results).
- **Right panel (optional):** Real-time load summary bar chart that updates as you change inputs.
- **Bottom status bar:** Current location, outdoor design temperatures, and total building load.

Setting Up a New Project

1. Select Location. On the Project Setup tab, choose your city and state. The engine automatically fetches ASHRAE design conditions from its built-in database of 500+ US locations. You will see the 0.4% cooling dry-bulb, coincident wet-bulb, and 99.6% heating dry-bulb populate immediately.

2. Confirm Indoor Conditions. Defaults are 75 deg F cooling / 70 deg F heating. Adjust if project requirements differ.

3. Add Rooms. Switch to the Rooms tab and click "Add Room." Select a space type from the comprehensive list (office, conference, server room, etc.) and the module will pre-populate ASHRAE default values for LPD, EPD, occupancy density, and ventilation rates.

4. Define Envelope. For each room, specify exterior wall orientations, wall lengths, ceiling heights, window-to-wall ratios, and construction types.

5. Calculate. Click "Calculate All" to run the engine. Results appear on the Results tab.

3. Input Parameters

3.1 Location and Weather Data

The weather module (`weather.py`) contains ASHRAE Fundamentals design conditions for 500+ US locations across all 50 states, DC, and US territories. Each location record includes:

Parameter	Description	Example (San Diego, CA)
Cooling DB 0.4%	Dry-bulb temperature exceeded only 0.4% of annual hours (~35 hrs/yr)	89 deg F
Cooling DB 1%	Dry-bulb exceeded 1% of annual hours (~88 hrs/yr)	85 deg F

Parameter	Description	Example (San Diego, CA)
Cooling DB 2%	Dry-bulb exceeded 2% of annual hours (~175 hrs/yr)	81 deg F
Coincident WB	Wet-bulb temperature occurring simultaneously with the cooling DB	68 deg F
Heating DB 99.6%	Dry-bulb temperature that is exceeded 99.6% of annual hours (i.e., colder than this only 0.4%)	44 deg F
Heating DB 99%	Slightly milder heating design temperature	47 deg F
Mean Daily Range (DR)	Difference between daily max and min dry-bulb, averaged over the cooling design month	12 deg F
ASHRAE Climate Zone	Classification (1A through 8) that drives code compliance paths	3B
Elevation	Station elevation in feet above sea level	30 ft
Latitude	Used for CLTD latitude-month correction and solar angle calculations	32.7 deg N

Selecting a design percentile: The 0.4% value is the most conservative (highest summer temperature, lowest winter temperature) and is the default. Use 1% or 2% for value-engineering scenarios where a small number of hours above setpoint is acceptable.

Altitude correction: At higher elevations, air density decreases. The engine automatically adjusts the sensible heat factor (1.08 at sea level) and latent heat factor (4840 at sea level) using the standard atmosphere pressure ratio:

```
pressure_ratio = (1 - 0.0000068753 * elevation_ft) ^ 5.2559
sensible_heat_factor = 1.08 * pressure_ratio
latent_heat_factor = 4840 * pressure_ratio
```

For Denver at 5,280 ft, the sensible factor drops to approximately 0.90, meaning 17% more CFM is needed to deliver the same cooling capacity.

3.2 Building Envelope

Wall Construction Types

The engine includes pre-defined wall assemblies with their overall U-values:

Wall Type	U-Value (BTU/hr-ft2-F)	R-Value (hr-ft2-F/BTU)	Mass Category
Steel Frame R-13	0.124	8.1	Light
Steel Frame R-19	0.089	11.2	Light
Wood Frame R-13	0.089	11.2	Light
Wood Frame R-19	0.060	16.7	Light
CMU Insulated	0.080	12.5	Heavy
CMU Uninsulated	0.350	2.9	Heavy

Wall Type	U-Value (BTU/hr-ft2-F)	R-Value (hr-ft2-F/BTU)	Mass Category
Curtain Wall	0.450	2.2	Light
Interior Partition	0.500	2.0	Light

Roof Construction Types

Roof Type	U-Value	R-Value	Mass
Metal Deck R-19	0.065	15.4	Light
Metal Deck R-30	0.039	25.6	Light
Wood Deck R-30	0.035	28.6	Light
Concrete Deck R-19	0.058	17.2	Heavy
Attic R-38	0.030	33.3	Light

Glazing Types

Glazing Type	U-Value	SHGC	Visible Transmittance
Single Clear	1.04	0.86	0.90
Double Clear	0.49	0.70	0.79
Double Low-E	0.35	0.40	0.70
Double Low-E Argon	0.29	0.38	0.68
Triple Low-E	0.20	0.35	0.60

U-value is the overall heat transfer coefficient in BTU/hr-ft2-F. Lower is better for energy performance.

SHGC (Solar Heat Gain Coefficient) is the fraction of incident solar radiation admitted through the glazing assembly (0 to 1). A SHGC of 0.40 means 40% of incident solar energy passes through the glass. Lower SHGC reduces cooling loads but also reduces beneficial passive solar heating in winter and natural daylight.

Window-to-Wall Ratio (WWR) is the fraction of gross exterior wall area that is glazing. A 40% WWR on a wall that is 190 SF gross means 76 SF of glass and 114 SF of net opaque wall. ASHRAE 90.1-2022 prescriptive limits are typically 30-40% depending on climate zone.

Door Types

Door Type	U-Value (BTU/hr-ft2-F)
Wood Solid Core	0.40
Metal Insulated	0.25
Metal Uninsulated	1.20
Glass Single Pane	1.10
Glass Double Pane	0.55

Door Type	U-Value (BTU/hr-ft2-F)
Storefront Glass	0.65
Overhead Insulated	0.30
Overhead Uninsulated	1.50

3.3 Internal Loads

Internal loads originate from sources inside the conditioned space that add heat regardless of outdoor conditions.

Lighting Power Density (LPD)

LPD is specified in watts per square foot (W/SF) and comes from ASHRAE 90.1-2022 Table 9.6.1 (Space-by-Space method). Common values:

Space Type	LPD (W/SF)
Open Office	0.98
Enclosed Office	1.11
Conference Room	1.23
Classroom	1.24
Retail Sales	1.44
Corridor	0.66
Restroom	0.98
Server Room	1.71

The conversion from watts to BTU/hr uses the constant: **1 watt = 3.412 BTU/hr.**

Equipment Power Density (EPD)

EPD covers computers, monitors, printers, copiers, and any other plug loads. It is also expressed in W/SF:

Space Type	EPD (W/SF)
Open Office	1.0
Conference Room	0.5
Computer Lab	15.0
Server Room	25.0+
Copy/Print Room	2.0
Retail Sales	0.5
Kitchen (Heavy)	50.0

For server rooms and data centers, equipment loads dominate all other load components and may range from 25 W/SF to 200 W/SF.

Occupancy

Occupancy density is expressed as square feet per person (SF/person). A lower number means more people per square foot:

Space Type	SF/Person	Sensible Heat/Person (BTU/hr)	Latent Heat/Person (BTU/hr)
Open Office	200	250	200
Conference Room	20	250	200
Classroom	20	250	200
Retail Sales	30	250	200
Auditorium	10	250	200
Restaurant (Dining)	15	250	200

The sensible heat per person (250 BTU/hr) represents metabolic heat for sedentary office work. For higher activity levels (gymnasium, manufacturing), this value increases to 400-800 BTU/hr. The latent heat per person (200 BTU/hr) represents moisture released through respiration and perspiration.

3.4 Ventilation Rates (ASHRAE 62.1-2022)

ASHRAE 62.1 uses the Ventilation Rate Procedure (VRP) to determine minimum outdoor air. The breathing zone outdoor air (Vbz) has two components:

```
Vbz = Rp * Pz + Ra * Az
```

Where:

- **Rp** = outdoor air rate per person (CFM/person)
- **Pz** = number of occupants in the zone
- **Ra** = outdoor air rate per unit area (CFM/SF)
- **Az** = zone floor area (SF)

Space Type	Rp (CFM/person)	Ra (CFM/SF)
Office	5	0.06
Conference Room	5	0.06
Classroom	10	0.12
Retail Sales	7.5	0.12
Restaurant (Dining)	7.5	0.18
Gymnasium	20	0.18
Lobby	5	0.06

Ventilation Effectiveness (Ez):

- Ez = 1.0 for ceiling supply with ceiling or floor return (typical mixing ventilation)
- Ez = 0.8 for floor supply with high ceiling return (stratification reduces effectiveness)
- Ez = 1.2 for displacement ventilation (higher effectiveness)

The zone outdoor air (Voz) is:

```
Voz = Vbz / Ez
```

4. Cooling Load Methodology (ASHRAE CLTD/CLF)

This section details every component of the cooling load calculation as implemented in the engine.

4.1 Wall Conduction

Heat flows through opaque walls by conduction, but thermal mass delays the peak. CLTD values capture this delay.

```
q_wall = U_wall * A_wall * CLTD_corrected
```

The corrected CLTD adjusts the tabulated value (based on 78 deg F indoor, 85 deg F mean outdoor) for actual project conditions:

```
CLTD_corrected = CLTD_table + (78 - T_indoor) + (T_mean - 85) + LM
```

Where:

- **CLTD_table** = tabulated CLTD for the wall orientation and hour (from ASHRAE tables in the engine)
- **T_indoor** = indoor design dry-bulb (typically 75 deg F)
- **T_mean** = mean daily outdoor temperature = T_design_DB - daily_range/2
- **LM** = latitude-month correction (small, typically +1 to +3 for summer months)

Peak CLTD values by orientation (from engine data, deg F):

Orientation	Peak CLTD	Peak Hour
North	20	8 PM
Northeast	19	8 PM
East	19	8 AM
Southeast	20	8 AM
South	18	8 PM
Southwest	24	5 PM
West	27	5 PM
Northwest	25	5 PM

West and southwest walls consistently produce the highest peak CLTDs due to afternoon solar exposure combined with thermal lag.

4.2 Roof Conduction

Roofs receive solar radiation on a nearly horizontal surface all day and have the highest CLTD values of any opaque component.

```
q_roof = U_roof * A_roof * CLTD_corrected
```

The peak roof CLTD is approximately 48 deg F (for a flat, dark-colored roof without suspended ceiling). With CLTD correction:

```
CLTD_corrected = 48 + (78 - 75) + (83 - 85) + 2 = 48 + 3 - 2 + 2 = 51 deg F (San Diego: T_mean = 89
- 12/2 = 83)
```

4.3 Glazing Solar Load

Solar heat gain through windows is often the single largest cooling load component for perimeter zones.

```
q_solar = A_glass * SC * SCL * shade_factor
```

Where:

- **A_glass** = glazing area (SF)
- **SC** = Shading Coefficient = SHGC / 0.87 (converts from SHGC to the legacy SC used in SCL tables)
- **SCL** = Solar Cooling Load factor for the orientation and hour (BTU/hr-SF of glass, standard glass basis)
- **shade_factor** = reduction factor for shading devices (1.0 = no shading)

Peak SCL values by orientation (BTU/hr-SF):

Orientation	Peak SCL	Peak Hour
North	31	11 AM
East	192	9 AM
South	126	12 PM
West	192	4 PM
Southwest	166	3 PM
Horizontal (skylights)	204	12-1 PM

West-facing glass produces the highest peak solar loads, coinciding with afternoon occupancy. This is why west-facing glazing deserves careful attention in design.

4.4 Glazing Conduction

In addition to solar gain, windows conduct heat due to the indoor-outdoor temperature difference.

```
q_glass_cond = U_glass * A_glass * (T_outdoor - T_indoor + 3)
```

The extra 3 deg F accounts for the sol-air temperature effect on the glass surface, which is warmer than ambient air due to absorbed solar radiation.

4.5 Lighting Load

```
q_lights = A_room * LPD * 3.412 * CLF_lights
```

Where:

- **3.412** = conversion factor from watts to BTU/hr
- **CLF_lights** = Cooling Load Factor for lighting (accounts for thermal mass absorption)

The engine uses CLF_lights = 0.92 for typical occupied hours. During the first hour after lights turn on, CLF may be as low as 0.87; by the end of a 10-hour occupied period, it approaches 0.97.

4.6 Equipment Load

```
q_equip = A_room * EPD * 3.412 * CLF_equip
```

The engine uses CLF_equip = 0.95, slightly higher than lighting because equipment heat is more convective (less radiant delay).

4.7 People -- Sensible

```
q_people_sensible = N_occupants * q_sensible_per_person * CLF_people
```

Where:

- **q_sensible_per_person** = 250 BTU/hr for sedentary office work
- **CLF_people** = 0.85 (accounts for radiant component delay)

4.8 People -- Latent

```
q_people_latent = N_occupants * q_latent_per_person
```

Where:

- **q_latent_per_person** = 200 BTU/hr

Latent loads are immediate -- there is no thermal mass delay for moisture. CLF = 1.0 for latent loads.

4.9 Ventilation -- Sensible

```
q_vent_sensible = 1.08 * OA_CFM * (T_outdoor - T_indoor)
```

Where:

- **1.08** = sensible heat factor at sea level (60 min/hr x 0.075 lb/ft3 x 0.24 BTU/lb-F)
- **OA_CFM** = outdoor air flow rate from ASHRAE 62.1

At altitude, replace 1.08 with the altitude-corrected value.

4.10 Ventilation -- Latent

```
q_vent_latent = 4840 * OA_CFM * delta_W
```

Where:

- **4840** = latent heat factor at sea level (60 x 0.075 x 1076)

- **delta_W** = difference in humidity ratio between outdoor and indoor air (lb moisture / lb dry air)

For San Diego: outdoor W is approximately 0.0093 lb/lb at 89 DB / 68 WB. Indoor W at 75 deg F / 50% RH is approximately 0.0093 lb/lb. In this mild coastal climate, the latent ventilation load can be near zero. In Houston (2A), outdoor W can reach 0.0160, producing a substantial delta_W of 0.0067.

4.11 Infiltration

Infiltration is uncontrolled air leakage through the building envelope. The engine calculates infiltration CFM based on building tightness:

Tightness Class	ACH Range	Typical Building
Tight	0.10-0.20	New construction, tested envelope
Average	0.25-0.40	Typical commercial
Leaky	0.50-0.80	Older building
Very Leaky	0.80-1.20	Pre-1980 construction

```
infiltration_CFM = (room_volume * ACH) / 60

q_infil_sensible = 1.08 * infiltration_CFM * delta_T
q_infil_latent = 4840 * infiltration_CFM * delta_W
```

As a fallback (when tightness class is not specified), the engine uses 0.015 CFM/SF for rooms with exterior exposure and 0.005 CFM/SF for interior rooms.

4.12 System Loads

These are often overlooked but can add 3-8% to the total cooling load:

- **Fan heat:** Supply and return fan motors add heat to the air stream. Typical value: 0.35 BTU/hr per CFM of supply air.
- **Duct heat gain:** Ducts passing through unconditioned spaces pick up heat. 2% for ducts in conditioned space, 5% in unconditioned space, 8% in attic.
- **Duct leakage:** Conditioned air lost through duct joints. 2% for pressure-tested ducts (per ASHRAE 90.1), 4% for sealed but untested, 8% for older untested ductwork.

4.13 Safety Factor

After summing all components, the engine applies a safety factor:

```
Total Cooling = (Sum of all components) * Safety Factor (default 1.15 = 15%)
```

This ensures that equipment is never undersized relative to the calculation. Safety factors above 1.25 should be avoided, as they lead to oversizing.

4.14 Total Cooling Load

```
Total Cooling Load = Total Sensible + Total Latent
```

```
Total Sensible = Walls + Roof + Floor + Glass Cond + Glass Solar + Skylights + Doors
+ Lights + Equipment + People Sensible
+ Ventilation Sensible + Infiltration Sensible
+ Fan Heat + Duct Gain + Duct Leakage

Total Latent = People Latent + Ventilation Latent + Infiltration Latent
```

5. Heating Load Methodology

Heating loads are calculated using the steady-state method (no CLTD or thermal mass effects). Per ASHRAE practice, no credit is taken for solar gains, lighting, equipment, or occupancy at the heating design condition (early morning, coldest day).

5.1 Envelope Losses

For each exterior surface (walls, roof, glazing, doors):

```
q_heat = U * A * (T_indoor - T_outdoor_heating)
```

Where:

- **T_indoor** = indoor heating setpoint (typically 70 deg F)
- **T_outdoor_heating** = 99.6% heating design dry-bulb

5.2 Floor Losses

Floor losses depend on the floor condition:

Condition	Method
Slab on Grade	q = F * Perimeter. F-factor from ASHRAE 90.1 (BTU/hr-ft-F per linear foot of slab edge)
Over Unconditioned Space	q = U *A* (T_indoor - T_uncond). T_uncond is average of outdoor and ground temp
Over Conditioned Space	q = U *A* 3 (minimal assumed delta-T)
Below Grade	q = U *A* 0.8 * (T_indoor - T_ground). Ground temp ~55 deg F, stable
Cantilever	q = U *A* 0.9 * (T_indoor - T_outdoor)

5.3 Ventilation Heating Load

```
q_vent_heat = 1.08 * OA_CFM * (T_indoor - T_outdoor_heating)
```

If a heat recovery ventilator (HRV) or energy recovery ventilator (ERV) is present, the load is reduced:

```
q_vent_heat = 1.08 * OA_CFM * (T_indoor - T_outdoor_heating) * (1 - HRE)
```

Where HRE = heat recovery effectiveness (typically 0.70 for a good ERV).

5.4 Infiltration Heating Load

```
q_infil_heat = 1.08 * infiltration_CFM * (T_indoor - T_outdoor_heating)
```

5.5 No Credits at Heating Design

ASHRAE practice dictates that heating loads should NOT take credit for internal gains (lights, equipment, people, solar). The rationale is that the heating design condition represents early morning of the coldest day, when the building may be unoccupied, lights are off, and there is no solar gain.

5.6 Safety Factor

```
Total Heating = (Sum of all components) * Safety Factor (default 1.10 = 10%)
```

The heating safety factor is lower than cooling because heating equipment typically modulates more effectively and the consequences of slight undersizing are less severe (thermostat setback during unoccupied hours provides a buffer).

6. Worked Example -- Conference Room 800 SF

Room Description

- **Room:** Conference Room 101
- **Space Type:** Conference/Meeting
- **Floor Area:** 800 SF
- **Ceiling Height:** 9.5 ft
- **Location:** San Diego, CA (Climate Zone 3B)
- **Exterior Exposure:** One exterior wall facing West, 20 linear feet
- **Floor:** Over conditioned space (2nd floor)
- **Roof:** None (not top floor)

Design Conditions (San Diego, CA)

Parameter	Value
Cooling DB (0.4%)	89 deg F
Cooling WB	68 deg F
Heating DB (99.6%)	44 deg F
Mean Daily Range	12 deg F
Indoor Cooling	75 deg F
Indoor Heating	70 deg F
Climate Zone	3B

Step 1: Define Envelope

- Gross exterior wall: 20 ft x 9.5 ft = **190 SF**
- Window-to-wall ratio: 40% --> Glazing area = 190 x 0.40 = **76 SF**
- Net opaque wall: 190 - 76 = **114 SF**
- Wall type: Steel Frame R-19, U = 0.089 BTU/hr-ft2-F
- Glazing type: Double Low-E, U = 0.35, SHGC = 0.40
- Orientation: West

Step 2: Define Internal Loads (from ASHRAE defaults for Conference)

Parameter	Value	Source
LPD	1.23 W/SF	ASHRAE 90.1-2022
EPD	0.50 W/SF	Projector, laptop connections
Occupancy Density	20 SF/person	ASHRAE 62.1-2022
Number of Occupants	800 / 20 = 40 people	
Sensible/Person	250 BTU/hr	Seated, light work
Latent/Person	200 BTU/hr	

Step 3: Ventilation (ASHRAE 62.1-2022)

```
Vbz = Rp * Pz + Ra * Az
Vbz = 5 CFM/person * 40 people + 0.06 CFM/SF * 800 SF
Vbz = 200 + 48
Vbz = 248 CFM outdoor air
```

Step 4: Cooling Load Calculation

4a. Wall Conduction

Peak CLTD for west wall = 27 deg F (from engine table, at 5 PM)

```
CLTD_corrected = 27 + (78 - 75) + (83 - 85) + 2
= 27 + 3 + (-2) + 2
= 30 deg F

q_wall = 0.089 * 114 * 30 = 304 BTU/hr
```

4b. Glazing Solar

Peak SCL for west glass = 192 BTU/hr-SF (from engine table)

```
SC = SHGC / 0.87 = 0.40 / 0.87 = 0.46

q_solar = 76 * 0.46 * 192 = 6,713 BTU/hr
```

4c. Glazing Conduction

```
delta_T = (89 - 75) + 3 = 17 deg F

q_glass_cond = 0.35 * 76 * 17 = 452 BTU/hr
```

4d. Lighting

```
q_lights = 800 * 1.23 * 3.412 * 0.92 = 3,091 BTU/hr
```

4e. Equipment

```
q_equip = 800 * 0.50 * 3.412 * 0.95 = 1,297 BTU/hr
```

4f. People Sensible

```
q_people_sens = 40 * 250 * 0.85 = 8,500 BTU/hr
```

4g. People Latent

```
q_people_lat = 40 * 200 = 8,000 BTU/hr
```

4h. Ventilation Sensible

```
q_vent_sens = 1.08 * 248 * (89 - 75) = 1.08 * 248 * 14 = 3,749 BTU/hr
```

4i. Ventilation Latent

For San Diego (mild, dry climate), outdoor humidity ratio is approximately 0.0093 lb/lb, which is very close to the indoor value of 0.0093 lb/lb at 75 deg F / 50% RH.

```
delta_W = 0.0093 - 0.0093 = 0.0000 lb/lb (effectively zero for San Diego)

q_vent_lat = 4840 * 248 * 0.0000 = 0 BTU/hr (negligible in San Diego)
```

Note: In a humid climate like Houston, delta_W could be 0.0067, yielding q_vent_lat = 4840 *248* 0.0067 = 8,044 BTU/hr.

4j. Infiltration

Conference room with one exterior wall (interior rooms have minimal infiltration):

```
infil_CFM = 800 * 0.015 = 12 CFM

q_infil_sens = 1.08 * 12 * 14 = 181 BTU/hr
q_infil_lat = negligible (dry climate)
```

4k. Fan Heat (System Load)

Estimate supply CFM first:

```
Sensible subtotal = 264 + 6,713 + 452 + 3,091 + 1,297 + 8,500 + 3,749 + 181 = 24,247 BTU/hr

Supply CFM = 24,247 / (1.08 * 20) = 24,247 / 21.6 = 1,123 CFM

Fan heat = 1,123 * 0.35 = 393 BTU/hr
```

4l. Duct Heat Gain

Ducts in conditioned space = 2% of sensible subtotal:

```
q_duct = 24,247 * 0.02 = 485 BTU/hr
```

Summary -- Conference Room Cooling Load

Component	Sensible (BTU/hr)	Latent (BTU/hr)
Wall Conduction	264	--
Glazing Solar	6,713	--
Glazing Conduction	452	--
Lighting	3,091	--
Equipment	1,297	--
People	8,500	8,000
Ventilation	3,749	0
Infiltration	181	0
Fan Heat	393	--
Duct Gain	485	--
Subtotal	**25,125**	**8,000**
Safety Factor (x1.15)	**28,894**	**9,200**
Grand Total		**38,094 BTU/hr (3.2 tons)**

Supply Air Sizing

```
Supply CFM = 28,894 / (1.08 * 20) = 28,894 / 21.6 = 1,338 CFM
```

Check: minimum supply = ventilation = 248 CFM. 1,338 > 248, so cooling governs.

```
CFM/SF = 1,338 / 800 = 1.67 CFM/SF
BTU/hr/SF = 38,094 / 800 = 47.6 BTU/hr/SF
SF/ton = 800 / 3.2 = 250 SF/ton
```

This is a densely occupied conference room, so the SF/ton is lower (more cooling per SF) than a typical office.

Step 5: Heating Load Calculation

```
delta_T = 70 - 44 = 26 deg F

q_wall_heat = 0.089 * 114 * 26 = 264 BTU/hr
q_glass_heat = 0.35 * 76 * 26 = 693 BTU/hr
q_vent_heat = 1.08 * 248 * 26 = 6,963 BTU/hr
q_infil_heat = 1.08 * 12 * 26 = 337 BTU/hr
--------
Subtotal 8,257 BTU/hr
Safety (x1.10) 9,083 BTU/hr
```

The heating load for San Diego is modest because the heating delta-T is only 26 deg F.

7. Worked Example -- Open Office 1,250 SF

Room Description

- **Room:** Open Office 201
- **Space Type:** Office - Open Plan
- **Floor Area:** 1,250 SF
- **Ceiling Height:** 9.5 ft
- **Location:** San Diego, CA
- **Exterior Exposure:** One south wall (30 LF) and one west wall (15 LF)
- **Floor:** Slab on grade (ground floor)
- **Roof:** Metal Deck R-30 (top floor, is_top_floor = True), 1,250 SF

Envelope

Surface	Gross Area (SF)	WWR	Net Wall (SF)	Glass (SF)	U-Value	SHGC
South Wall	30 x 9.5 = 285	40%	171	114	0.089 (wall), 0.35 (glass)	0.40
West Wall	15 x 9.5 = 142.5	40%	85.5	57	0.089 (wall), 0.35 (glass)	0.40
Roof	1,250	--	1,250	--	0.039	--

Internal Loads

Parameter	Value
LPD	0.98 W/SF
EPD	1.0 W/SF
Occupancy	1,250 / 200 = 6 people
Rp = 5, Ra = 0.06	Vbz = 5(6) + 0.06(1,250) = 30 + 75 = 105 CFM

Cooling Load Calculation

Component	Calculation	BTU/hr
South Wall	0.089 x 171 x (18 + 3 - 6 + 2) = 0.089 x 171 x 17	259
West Wall	0.089 x 85.5 x (27 + 3 - 6 + 2) = 0.089 x 85.5 x 26	198

Component	Calculation	BTU/hr
Roof	0.039 x 1,250 x (48 + 3 - 6 + 2) = 0.039 x 1,250 x 47	2,291
South Glass Solar	114 x (0.40/0.87) x 126	6,601
West Glass Solar	57 x (0.40/0.87) x 192	5,031
South Glass Cond	0.35 x 114 x 17	678
West Glass Cond	0.35 x 57 x 17	339
Floor (slab)	0.039 x 1,250 x 0 (ground temp < indoor)	0
Lighting	1,250 x 0.98 x 3.412 x 0.92	3,844
Equipment	1,250 x 1.0 x 3.412 x 0.95	4,052
People Sensible	6 x 250 x 0.85	1,275
People Latent	6 x 200	1,200
Vent Sensible	1.08 x 105 x 14	1,588
Vent Latent	~0 (San Diego)	0
Infiltration	1.08 x (1,250 x 0.015) x 14	284
Fan Heat	~1,220 CFM x 0.35	427
Duct Gain (attic, 5%)	26,867 x 0.05	1,343
Sensible Subtotal		**28,210**
Latent Subtotal		**1,200**
Safety (x1.15)		**33,822**
Grand Total		**33,822 BTU/hr (2.8 tons)**

```
SF/ton = 1,250 / 2.8 = 446 SF/ton
CFM/SF = (33,822 * 0.83 / 21.6) / 1,250 = 1.04 CFM/SF
```

This is within the expected 400-500 SF/ton range for offices. The roof load is significant because this is a top-floor room.

Heating Load

```
delta_T = 70 - 44 = 26 deg F

Walls: 0.089 x (171 + 85.5) x 26 = 593 BTU/hr
Glass: 0.35 x (114 + 57) x 26 = 1,556 BTU/hr
Roof: 0.039 x 1,250 x 26 = 1,268 BTU/hr
Floor: 0.039 x 1,250 x (70 - 58) = 585 BTU/hr (slab on grade, ground temp 58F)
Vent: 1.08 x 105 x 26 = 2,948 BTU/hr
Infil: 1.08 x 18.75 x 26 = 527 BTU/hr
------
Subtotal 7,477 BTU/hr
Safety (x1.10) 8,225 BTU/hr
```

8. Worked Example -- Server Room 200 SF

Room Description

Server rooms have a radically different load profile. Equipment power density dominates all other components, and the room often requires cooling year-round (even on the coldest winter day).

- **Room:** Server Room 301
- **Space Type:** Server Room
- **Floor Area:** 200 SF
- **Ceiling Height:** 10 ft
- **Location:** San Diego, CA
- **Exterior Exposure:** None (interior room)
- **Roof:** None (not top floor)
- **Equipment:** 40 W/SF (medium-density IT equipment)
- **Occupancy:** 1 person (occasional maintenance)

Internal Loads

Parameter	Value
LPD	1.71 W/SF
EPD	40.0 W/SF
Occupancy	1 person
Vbz = 5(1) + 0.06(200) = 17 CFM	

Cooling Load Calculation

Component	Calculation	BTU/hr
Walls	None (interior room)	0
Roof	None (not top floor)	0
Glass	None	0
Lighting	200 x 1.71 x 3.412 x 0.92	1,074
Equipment	200 x 40.0 x 3.412 x 0.95	25,931
People Sensible	1 x 250 x 0.85	213
People Latent	1 x 200	200
Vent Sensible	1.08 x 17 x 14	257
Vent Latent	~0	0

Component	Calculation	BTU/hr
Infiltration	0 (interior)	0
Fan Heat	~1,275 CFM x 0.35	446
Duct Gain (2%)	27,921 x 0.02	558
Sensible Subtotal		**28,479**
Latent Subtotal		**200**
Safety (x1.15)		**32,981**
Grand Total		**32,981 BTU/hr (2.7 tons)**

```
SF/ton = 200 / 2.7 = 74 SF/ton (!)
BTU/hr/SF = 32,981 / 200 = 165 BTU/hr/SF
```

Key observations for server rooms:

1. Equipment load is **93%** of the total sensible load. Envelope is zero.

2. At 74 SF/ton, this room needs roughly 6x the cooling per square foot of a typical office.

3. The server room requires cooling even in winter -- the 25,931 BTU/hr equipment load far exceeds any envelope heat loss.

4. Ventilation is minimal because occupancy is only 1 person.

5. A dedicated precision cooling unit (CRAC or in-row cooler) is typically used rather than the building's central air system.

Heating Load

For an interior server room with 40 W/SF equipment, the heating load is effectively zero. The room needs cooling year-round. The engine would calculate:

```
Envelope losses: 0 BTU/hr (no exterior surfaces)
Ventilation: 1.08 x 17 x 26 = 477 BTU/hr
Equipment credit: 25,931 BTU/hr (far exceeds any losses)

Net heating required: 0 BTU/hr
```

9. Output Interpretation

Room Detail Page

The Results tab displays a detailed breakdown for each room. The columns are:

Column	Units	Description
Room Name	--	User-defined room name
Area	SF	Floor area

Column	Units	Description
Cooling Total	BTU/hr	Peak total cooling load (sensible + latent, with safety factor)
Cooling Sensible	BTU/hr	Sensible cooling component only
Cooling Latent	BTU/hr	Latent (moisture) cooling component
Heating	BTU/hr	Peak heating load (with safety factor)
Supply CFM	CFM	Required supply air for cooling
OA CFM	CFM	Outdoor air per ASHRAE 62.1
Exhaust CFM	CFM	Required exhaust (if any)
BTU/SF	BTU/hr/SF	Cooling load intensity (cooling total / area)
SF/Ton	SF/ton	Area per ton of cooling (12,000 BTU/hr = 1 ton)
CFM/SF	CFM/SF	Supply air intensity
Peak Hour	0-23	Hour of day when peak cooling occurs

Load Breakdown Chart

Clicking on any room opens a stacked bar chart showing the relative magnitude of each load component. This visual helps identify which components dominate:

- **Perimeter office:** Solar and ventilation typically dominate.
- **Interior office:** Lighting and equipment dominate.
- **Conference room:** People loads dominate (high occupancy density).
- **Server room:** Equipment dominates almost exclusively.
- **Lobby/atrium:** Infiltration and solar can be the largest components due to frequent door openings and large glass areas.

Sensible Heat Ratio (SHR)

```
SHR = Total Sensible / (Total Sensible + Total Latent)
```

Typical SHR values:

Space Type	SHR
Dry climate office (San Diego)	0.90-0.95
Humid climate office (Houston)	0.75-0.85
Conference room	0.70-0.80
Server room	0.99
Restaurant	0.65-0.75
Natatorium	0.40-0.55

SHR affects coil selection. A room with SHR below 0.80 needs significant dehumidification capacity, which may require colder coil temperatures or a dedicated dehumidification system.

10. Validation and Benchmarks

Expected Load Ranges

Use these benchmarks to sanity-check your results. Values significantly outside these ranges may indicate input errors.

Building Type	Cooling (SF/ton)	Heating (BTU/hr/SF)	Supply (CFM/SF)
Office (standard)	300-500	10-25	0.8-1.2
Office (dense)	200-350	15-30	1.0-1.5
Conference Room	150-300	8-15	1.2-2.0
Retail	250-400	10-20	0.8-1.2
Restaurant	100-200	15-25	1.5-2.5
Classroom	200-350	10-25	1.0-1.5
Hospital Patient Room	250-400	15-30	1.0-1.5
Server Room	50-150	0 (net cooling)	2.0-5.0
Warehouse	800-2,000	5-15	0.2-0.5
Lobby/Atrium	200-400	15-35	1.0-2.0

Red Flags

Watch for these indicators of possible input errors:

1. **SF/ton below 100** (except server rooms/data centers): Likely an equipment load or occupancy input error.
2. **SF/ton above 800** (except warehouses): Missing loads or undersized envelope assumptions.
3. **Heating load exceeding cooling load** in a mild climate: Check that winter design temperature is correct.
4. **Latent load exceeding sensible load** (SHR < 0.50): Unusual except for pools, kitchens, or laundries.
5. **CFM/SF below 0.5** for occupied spaces: May indicate undersized ventilation.
6. **CFM/SF above 3.0** (except labs and clean rooms): Check equipment density inputs.
7. **Peak hour at 8 AM or midnight:** May indicate an orientation input error (e.g., east exposure labeled as west).
8. **Negative infiltration loads:** Not physically possible; check building tightness settings.
9. **Zero ventilation load:** Verify that occupancy is not set to zero in an occupied space.

Common Errors

Error	Symptom	Fix
Wrong climate zone	Loads do not match similar projects in the region	Verify city/state in Project Setup
Interior walls counted as exterior	Inflated envelope loads	Check surface_type and orientation assignments
Window area double-counted	Glass loads too high	Ensure WWR is applied to gross wall area, not added separately
Conference room at average occupancy	Loads too low	Use the design (maximum) occupancy, not average
Altitude factor ignored	Undersized CFM at high elevation	Verify elevation is set (auto from location)
Missing roof for top floor	Heating undersized	Set is_top_floor = True for rooms under the roof
Wrong U-value units	Orders of magnitude off	U must be in BTU/hr-ft2-F (not SI W/m2-K)

11. Complete Abbreviations Reference

Abbreviation	Full Term	Units / Notes
ACH	Air Changes per Hour	1/hr
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers	Standards body
BTU	British Thermal Unit	Energy unit
BTU/hr	BTU per hour	Rate of heat flow (power)
CAV	Constant Air Volume	System type
CFM	Cubic Feet per Minute	Volumetric airflow
CLF	Cooling Load Factor	Dimensionless (0-1)
CLTD	Cooling Load Temperature Difference	deg F
CRAC	Computer Room Air Conditioner	Equipment type
DB	Dry-Bulb temperature	deg F
DOAS	Dedicated Outdoor Air System	System type
DR	(Mean) Daily Range	deg F
DX	Direct Expansion	Refrigerant-based cooling
EPD	Equipment Power Density	W/SF
ERV	Energy Recovery Ventilator	Equipment type
Ez	Ventilation Effectiveness	Dimensionless
GPM	Gallons Per Minute	Liquid flow rate
HRE	Heat Recovery Effectiveness	Dimensionless (0-1)

Abbreviation	Full Term	Units / Notes
HRV	Heat Recovery Ventilator	Equipment type
HVAC	Heating, Ventilation, and Air Conditioning	Industry acronym
LM	Latitude-Month correction	deg F
LPD	Lighting Power Density	W/SF
OA	Outdoor Air	Ventilation air from outside
PTAC	Packaged Terminal Air Conditioner	Equipment type
Ra	Outdoor air rate per unit area	CFM/SF
RH	Relative Humidity	% or decimal
Rp	Outdoor air rate per person	CFM/person
RTU	Rooftop Unit	Equipment type
SC	Shading Coefficient	Dimensionless (0-1), legacy
SCL	Solar Cooling Load	BTU/hr-SF
SF	Square Feet	Area
SHGC	Solar Heat Gain Coefficient	Dimensionless (0-1)
SHGF	Solar Heat Gain Factor	BTU/hr-SF
SHR	Sensible Heat Ratio	Dimensionless (0-1)
TMY3	Typical Meteorological Year (version 3)	Weather data format
EPW	EnergyPlus Weather	Weather data format
UA	U-value times Area product	BTU/hr-F
VAV	Variable Air Volume	System type
Vbz	Breathing Zone Outdoor Airflow	CFM
Voz	Zone Outdoor Airflow (= Vbz / Ez)	CFM
VRF	Variable Refrigerant Flow	System type
VT	Visible Transmittance	Dimensionless (0-1)
W	Humidity Ratio	lb moisture / lb dry air
WB	Wet-Bulb temperature	deg F
WSHP	Water Source Heat Pump	System type
WWR	Window-to-Wall Ratio	Dimensionless (0-1)

12. Formulas Quick Reference

Cooling Load Formulas

Component	Formula
Wall conduction	q = U x A x CLTD_corr
CLTD correction	CLTD_corr = CLTD_table + (78 - T_indoor) + (T_mean - 85) + LM
Roof conduction	q = U x A x CLTD_corr (CLTD_roof ~ 48 peak for flat dark roof)
Glass solar	q = A x SC x SCL x shade_factor
SC from SHGC	SC = SHGC / 0.87
Glass conduction	q = U x A x (T_outdoor - T_indoor + 3)
Lighting	q = Area x LPD x 3.412 x CLF_lights
Equipment	q = Area x EPD x 3.412 x CLF_equip
People sensible	q = N x 250 x CLF_people
People latent	q = N x 200
Ventilation sensible	q = 1.08 x OA_CFM x delta_T
Ventilation latent	q = 4840 x OA_CFM x delta_W
Infiltration sensible	q = 1.08 x infil_CFM x delta_T
Infiltration latent	q = 4840 x infil_CFM x delta_W
Fan heat	q = supply_CFM x 0.35
Duct heat gain	q = sensible_subtotal x duct_location_factor
Supply CFM	CFM = q_sensible / (1.08 x delta_T_supply)
Tons of cooling	Tons = q_total / 12,000

Heating Load Formulas

Component	Formula
Envelope (each surface)	q = U x A x (T_indoor - T_outdoor_heating)
Ventilation	q = 1.08 x OA_CFM x (T_indoor - T_outdoor_heating)
Ventilation w/ HRV	q = 1.08 x OA_CFM x (T_indoor - T_outdoor_heating) x (1 - HRE)
Infiltration	q = 1.08 x infil_CFM x (T_indoor - T_outdoor_heating)

Ventilation (ASHRAE 62.1)

Formula	Description
Vbz = Rp x Pz + Ra x Az	Breathing zone outdoor airflow
Voz = Vbz / Ez	Zone outdoor airflow

Formula	Description
Ez = 1.0 (ceiling supply)	Typical ventilation effectiveness
Ez = 1.2 (displacement)	Higher effectiveness

Psychrometric Relations

Formula	Description
W = 0.622 x Pw / (P_atm - Pw)	Humidity ratio from partial pressure
P_sat = 0.61078 x exp(17.27 x Tc / (Tc + 237.3))	Saturation pressure (kPa)
1.08 = 60 x 0.075 x 0.24	Sensible heat factor derivation (sea level)
4840 = 60 x 0.075 x 1076	Latent heat factor derivation (sea level)
factor_altitude = factor_sealevel x pressure_ratio	Altitude correction
pressure_ratio = (1 - 6.8753e-6 x elev_ft)^5.2559	Standard atmosphere

Unit Conversions

Conversion	Value
1 Watt	3.412 BTU/hr
1 Ton (cooling)	12,000 BTU/hr
1 HP	2,545 BTU/hr
1 kW	3,412 BTU/hr
deg F to deg C	(F - 32) x 5/9
1 psi	6.895 kPa
1 BTU/hr-ft2-F (U-value)	5.678 W/m2-K

This guide is part of the J∆S Engineering Suite documentation. For questions, contact JS Engineering Solutions.