J∆S Engineering Suite

Module Guide: Energy Code Compliance

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JS Engineering Solutions

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Applicable Modules: `compliance.py`, `t24_compliance.py`, `t24_acm.py`, `t24_nrcc_forms.py`, `t24_lmcc_forms.py`, `ufc_compliance.py`

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1. Opening the Module

Step-by-Step Navigation from the Dashboard

1. Launch the application. Run `python launcher.py` from the project root directory, or double-click the `Design_Suite.exe` executable if you are using the compiled release. The login dialog appears first.

2. Log in. Enter your username and password. If two-factor authentication (2FA) is enabled on your account, you will be prompted to enter a six-digit TOTP code from your authenticator app. Click **Sign In**.

3. Arrive at the Dashboard. After successful authentication, the main dashboard loads. It displays a grid of tiles representing all available module categories. The dashboard uses a dark theme with KPI summary cards across the top.

4. Locate the Compliance category. In the left-hand sidebar, scroll down to the **Compliance & Codes** category. This category groups all code compliance tools together. If the sidebar is collapsed, click the hamburger menu icon at the top-left to expand it.

5. Click "Code Compliance." Under the Compliance & Codes category you will see these entries:

• **Code Compliance** (ASHRAE 90.1-2022 and IECC 2021)

• **Title 24 Compliance** (California Title 24-2022)

• **UFC Compliance** (DOD/Military projects)

• **Title 24 ACM** (Alternative Calculation Method — performance path)

• **NRCC Forms** (Nonresidential Certificate of Compliance generator)

• **LMCC Forms** (Low-Rise Residential Certificate of Compliance generator)

6. The Code Compliance window opens. A new tab or window appears with the compliance checking interface. The interface has the following layout:

• **Top toolbar:** Code edition selector (ASHRAE 90.1-2022, ASHRAE 90.1-2019, IECC 2021), Climate Zone selector, and a "Run Compliance Check" button.

• **Left panel:** Building data input fields — envelope assemblies, HVAC equipment, lighting, and controls.

• **Center panel:** Compliance results table showing requirement, code limit, design value, pass/fail status, and margin.

• **Right panel:** Summary dashboard with pass/fail counts and a compliance score percentage.

• **Bottom toolbar:** Export buttons for TXT, PDF, and Excel reports.

7. Select your code and climate zone. From the top toolbar, choose the applicable energy code edition and climate zone for your project. The module automatically loads the correct prescriptive requirements from its internal database.

8. Enter or import building data. You can manually enter building envelope, HVAC, lighting, and controls data in the left panel, or you can import data from an existing project file (.mep format) by clicking **File > Import from Project**.

9. Run the compliance check. Click the **Run Compliance Check** button. The module compares every entered value against the applicable code requirements and populates the results table in the center panel.

10. Review results and export. Examine each row for pass/fail status. Export the report as needed for plan review submission.

2. Why Code Compliance Matters

Legal Requirements

Energy codes are not voluntary guidelines. They are **legally enforceable minimum standards** adopted by state and local jurisdictions as part of their building codes. In the United States:

• **ASHRAE 90.1** is adopted by reference in the International Energy Conservation Code (IECC), which in turn is adopted by most states and municipalities outside of California. When a jurisdiction adopts the IECC (or adopts ASHRAE 90.1 directly), compliance becomes a legal prerequisite for obtaining a building permit.

• **California Title 24, Part 6** is mandatory for every building project in California — new construction, additions, and alterations — with very limited exceptions (unconditioned storage buildings under certain square footage thresholds, temporary buildings, and certain historic structures). The California Energy Commission (CEC) enforces these standards, and local building departments verify compliance during plan review and field inspection.

• **IECC 2021** serves as the model code for commercial buildings in states that have not adopted ASHRAE 90.1 directly. Some jurisdictions adopt the IECC commercial provisions, which reference ASHRAE 90.1 tables and requirements.

Failure to demonstrate code compliance results in **rejected plan-check submittals**. The building department will not issue a building permit until the design team provides acceptable compliance documentation. This causes project delays, redesign costs, and contractual disputes.

Permit Approval Process

The typical permit approval sequence for energy code compliance is:

1. Design phase: The engineer calculates loads, selects equipment, and verifies that all components meet or exceed code minimums.

2. Documentation phase: The engineer prepares compliance documentation — either prescriptive checklists (like COMcheck reports) or performance-path energy models (like CBECC-Com or Appendix G models).

3. Plan review submission: Compliance documentation is submitted to the authority having jurisdiction (AHJ) along with construction drawings and specifications.

4. Plan check review: A plan reviewer (often a third-party energy consultant or a building department staff member) reviews the compliance documentation against the code. They compare submitted U-factors, efficiencies, lighting power densities, and control sequences against the code tables.

5. Corrections or approval: If any item does not comply, the plan reviewer issues a correction notice. The design team must revise and resubmit. If everything complies, the plans are approved and a permit is issued.

6. Construction inspection: During construction, inspectors verify that installed materials and equipment match the approved compliance documentation. In California, HERS (Home Energy Rating System) raters perform field verification of certain mechanical features such as duct leakage, refrigerant charge, and fan watt draw.

7. Certificate of occupancy: Final compliance verification is required before a certificate of occupancy is issued.

Professional Liability

Registered Professional Engineers (PEs) who stamp mechanical plans are **personally liable** for code compliance of the HVAC systems they design. Errors in compliance calculations can result in:

- **Professional discipline** by the state licensing board, including fines, license suspension, or revocation.
- **Malpractice claims** if non-compliant systems cause increased energy costs, comfort complaints, or construction delays.
- **Errors and omissions (E&O) insurance claims** against the engineering firm.
- **Contractor claims** for redesign costs if non-compliance is discovered during construction.

Insurance Implications

Many building owners and institutional clients require compliance documentation as a condition of property insurance and financing. Lenders for commercial real estate may require evidence that the building meets current energy codes as part of due diligence. Green building certifications (LEED, ENERGY STAR, etc.) require code compliance as a baseline prerequisite.

Beyond Minimum Compliance

While energy codes set the legal floor, designing to or beyond code provides significant benefits:

- **Reduced operating costs:** Every point of improved efficiency translates to lower utility bills over the building's lifespan.
- **Improved occupant comfort:** Code-compliant envelopes and HVAC systems deliver better thermal comfort, fewer drafts, and more consistent temperatures.
- **Reduced carbon emissions:** Energy-efficient buildings consume less electricity and natural gas, directly reducing greenhouse gas emissions.
- **Higher asset value:** Energy-efficient buildings command higher rents, higher sale prices, and lower vacancy rates.
- **Future-proofing:** Energy codes become more stringent with each update cycle (typically every 3 years). Designing above current minimums reduces the risk of obsolescence.

3. ASHRAE 90.1-2022 Comprehensive Coverage

3.1 Scope and Applicability

ASHRAE Standard 90.1-2022, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, applies to:

Buildings that ARE covered:

- All commercial buildings (offices, retail, restaurants, hotels, hospitals, schools, warehouses, etc.)

- High-rise residential buildings (4 or more stories above grade)
- Mixed-use buildings (the commercial portions)
- Additions to existing buildings (the addition must comply)
- Alterations to existing buildings (altered components must comply)

Buildings that are EXEMPT:

- Single-family houses and multifamily buildings of 3 stories or fewer above grade (these are covered by ASHRAE 90.2 or the residential provisions of the IECC)
- Manufactured homes (covered by HUD standards)
- Buildings that do not use either electricity or fossil fuel (extremely rare)
- Equipment and portions of building systems that use energy primarily for manufacturing processes (the industrial process portion only, not the building shell or comfort HVAC)

Partial exemptions:

- Semi-heated spaces (maintained between 50 and 60 deg F) have relaxed envelope requirements
- Unconditioned spaces (not heated or cooled) are exempt from most provisions but still require envelope insulation if they enclose conditioned spaces
- Historic buildings may be exempt from certain provisions if compliance would threaten the building's historic character, subject to approval by the AHJ

Jurisdictional adoption: ASHRAE 90.1-2022 is not self-enforcing. It becomes law only when adopted by a state, county, or city. As of 2026, the majority of US states have adopted either ASHRAE 90.1-2019 or 90.1-2022 (directly or via the IECC). Some jurisdictions adopt amendments that modify specific requirements. The J∆S Engineering Suite defaults to the 2022 edition but also supports the 2019 edition for jurisdictions that have not yet updated.

3.2 Three Compliance Paths

ASHRAE 90.1-2022 offers three distinct compliance paths. The engineer must choose one path for each building or portion of a building. The paths cannot be mixed within a single compliance demonstration (except that mandatory provisions from Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 always apply regardless of path).

Path 1: Prescriptive (Sections 5 through 10)

The prescriptive path requires **every individual component** to meet or exceed the minimum requirements in the prescriptive tables:

- **Section 5 (Envelope):** Each opaque assembly (wall, roof, floor) must have a U-factor at or below the value in Tables 5.5-0 through 5.5-8 for the applicable climate zone and construction type. Each fenestration (window, curtain wall, skylight) must have a U-factor and SHGC at or below the tabulated limits. Window-to-wall ratio (WWR) is limited to 40%.
- **Section 6 (HVAC):** Each piece of HVAC equipment must meet the minimum efficiency in Tables 6.8.1-1 through 6.8.1-10. Economizers, energy recovery, controls, and fan power must comply with the requirements in Sections 6.4 and 6.5.
- **Section 7 (Service Water Heating):** Water heaters must meet minimum efficiency ratings. Pipe insulation must comply with Table 7.4.3.

- **Section 8 (Power):** Voltage drop limits, automatic receptacle controls, transformer efficiency.
- **Section 9 (Lighting):** Lighting power density (LPD) must not exceed the limits in Table 9.5.1 (Building Area Method) or Table 9.6.1 (Space-by-Space Method). Lighting controls must include occupancy sensors, daylight responsive controls, and automatic shutoff per Section 9.4.
- **Section 10 (Other Equipment):** Escalators, elevators, and other permanently wired equipment.

Advantages of prescriptive: Simple to document, straightforward for plan review, no energy modeling required.

Disadvantages of prescriptive: No trade-offs allowed. If any single component fails, the entire building fails prescriptive compliance and must either fix the failing component or switch to a different path. WWR is capped at 40%.

Path 2: Performance Rating Method (Appendix G / PRM)

The Performance Rating Method (commonly called "Appendix G") compares the annual energy cost of the **proposed building** against a computer-generated **baseline building**. The baseline building is defined by Appendix G tables and represents a code-minimum building with the same geometry, use, and occupancy as the proposed design but with standard HVAC systems, prescriptive envelope values, and standard lighting.

Compliance is achieved when:

```
Proposed Building Annual Energy Cost <= Baseline Building Annual Energy Cost
```

Both the proposed and baseline buildings must be modeled using an approved energy simulation program (EnergyPlus, eQUEST, Trane TRACE, IES VE, etc.) with identical weather data, schedules, and operating assumptions. The J∆S Engineering Suite uses its built-in 8760-hour simulation engine (`energy_simulation.py`) for this purpose.

Advantages of Appendix G: Allows trade-offs between all building systems. A building with high WWR or poor SHGC can still comply if it has superior HVAC efficiency, lighting, or other features. No WWR limit.

Disadvantages of Appendix G: Requires a full energy model, which is time-consuming and expensive. The model must be reviewed by the AHJ or a third-party reviewer. Modeling assumptions must be carefully documented and justified.

Path 3: Energy Cost Budget Method (Section 11 / ECB)

The Energy Cost Budget (ECB) method is similar to Appendix G but uses a slightly different baseline building definition. It is defined in Section 11 of the standard.

Key differences from Appendix G:

- The ECB baseline building uses the prescriptive requirements from Sections 5 through 10 directly as the baseline, rather than the Appendix G baseline tables.
- The ECB method is sometimes used for code compliance, while Appendix G is also used for beyond-code programs (LEED, ENERGY STAR).
- Some AHJs prefer the ECB method because the baseline is more directly traceable to the prescriptive code language.

Compliance is achieved when:

```
Proposed Building Energy Cost <= Energy Cost Budget (from baseline building)
```

The J∆S Engineering Suite supports all three paths and automatically generates the appropriate baseline building when a performance or ECB analysis is selected.

3.3 Envelope Requirements by Climate Zone

The following tables present the prescriptive envelope requirements from ASHRAE 90.1-2022, Tables 5.5-0 through 5.5-8. These are the maximum allowable U-factors (in Btu/h-ft2-F) for opaque assemblies and fenestration, and maximum allowable SHGC for fenestration and skylights. The J∆S Engineering Suite stores these values in the `ASHRAE_ENVELOPE_REQUIREMENTS` dictionary within `compliance.py`.

Roof Assembly U-Factors by Climate Zone

Climate Zone	Insulation Above Deck	Metal Building Roof	Attic and Other
0A (Extremely Hot - Humid)	0.063	0.065	0.034
0B (Extremely Hot - Dry)	0.063	0.065	0.034
1A (Very Hot - Humid)	0.063	0.065	0.034
1B (Very Hot - Dry)	0.063	0.065	0.034
2A (Hot - Humid)	0.048	0.055	0.027
2B (Hot - Dry)	0.048	0.055	0.027
3A (Warm - Humid)	0.048	0.055	0.027
3B (Warm - Dry)	0.048	0.055	0.027
3C (Warm - Marine)	0.048	0.055	0.027
4A (Mixed - Humid)	0.039	0.047	0.024
4B (Mixed - Dry)	0.039	0.047	0.024
4C (Mixed - Marine)	0.039	0.047	0.024
5A (Cool - Humid)	0.032	0.037	0.021
5B (Cool - Dry)	0.032	0.037	0.021
5C (Cool - Marine)	0.032	0.037	0.021
6A (Cold - Humid)	0.028	0.031	0.017
6B (Cold - Dry)	0.028	0.031	0.017
7 (Very Cold)	0.028	0.029	0.017
8 (Subarctic)	0.028	0.029	0.017

How to read this table: For a building in Climate Zone 5A (Chicago) with insulation entirely above the roof deck, the maximum allowable roof assembly U-factor is 0.032 Btu/h-ft2-F. This corresponds to approximately R-31 continuous insulation (accounting for thermal bridging through metal fasteners).

Wall Assembly U-Factors by Climate Zone

Climate Zone	Mass Wall	Metal Building Wall	Steel Framed Wall	Wood Framed Wall
0A	0.580	0.094	0.124	0.089
0B	0.580	0.094	0.124	0.089

Climate Zone	Mass Wall	Metal Building Wall	Steel Framed Wall	Wood Framed Wall
1A	0.580	0.094	0.124	0.089
1B	0.580	0.094	0.124	0.089
2A	0.450	0.079	0.084	0.089
2B	0.450	0.079	0.084	0.089
3A	0.197	0.069	0.084	0.089
3B	0.197	0.069	0.084	0.089
3C	0.197	0.069	0.084	0.089
4A	0.151	0.057	0.064	0.064
4B	0.151	0.057	0.064	0.064
4C	0.151	0.057	0.064	0.064
5A	0.123	0.057	0.055	0.051
5B	0.123	0.057	0.055	0.051
5C	0.123	0.057	0.055	0.051
6A	0.104	0.052	0.049	0.045
6B	0.104	0.052	0.049	0.045
7	0.090	0.047	0.042	0.042
8	0.080	0.039	0.037	0.037

Mass wall definition: A wall with a heat capacity exceeding 7 Btu/ft2-F or a weight exceeding 25 lb/ft2. Typical examples include CMU (concrete masonry unit) walls, poured-in-place concrete, and brick walls. Mass walls benefit from thermal mass effects and therefore have more relaxed U-factor requirements in mild climates (Zones 0-3) but converge toward the same requirements as framed walls in cold climates (Zones 6-8).

Steel framed wall note: Steel studs create significant thermal bridges due to steel's high conductivity. A steel-framed wall with R-19 cavity insulation alone has an effective assembly U-factor of approximately 0.12 — far worse than the same R-19 in a wood-framed wall (approximately 0.07). Continuous insulation (ci) outboard of the steel studs is essential in Climate Zones 4 and higher. The J∆S Engineering Suite's envelope calculator accounts for steel stud thermal bridging using the parallel path or isothermal planes method per ASHRAE 90.1 Appendix A.

Fenestration (Vertical Glazing) U-Factor and SHGC by Climate Zone

Climate Zone	Max U-Factor	Max SHGC	Max Skylight U	Max Skylight SHGC
0A	0.50	0.25	0.75	0.25
0B	0.50	0.25	0.75	0.25
1A	0.50	0.25	0.75	0.25
1B	0.50	0.25	0.75	0.25
2A	0.45	0.25	0.65	0.25

Climate Zone	Max U-Factor	Max SHGC	Max Skylight U	Max Skylight SHGC
2B	0.45	0.25	0.65	0.25
3A	0.42	0.25	0.55	0.25
3B	0.42	0.25	0.55	0.25
3C	0.42	0.36	0.55	0.36
4A	0.38	0.38	0.50	0.40
4B	0.38	0.38	0.50	0.40
4C	0.38	0.39	0.50	0.40
5A	0.36	0.40	0.50	0.40
5B	0.36	0.40	0.50	0.40
5C	0.36	0.40	0.50	0.40
6A	0.34	0.40	0.50	0.40
6B	0.34	0.40	0.50	0.40
7	0.32	0.45	0.50	0.40
8	0.30	0.45	0.50	0.40

Key observations:

- **SHGC is most restrictive in hot climates** (Zones 0-3): 0.25 maximum. This is because solar heat gain is the dominant cooling load driver in these zones. In cold climates (Zones 7-8), the SHGC limit relaxes to 0.45 because passive solar gain is beneficial for heating.
- **U-factor is most restrictive in cold climates** (Zones 7-8): 0.30 maximum. Triple-pane glazing is typically required. In hot climates, U = 0.50 allows double-pane with low-e coatings.
- **Climate Zone 3C (San Francisco)** has a notably relaxed SHGC of 0.36 compared to 3A and 3B at 0.25. This reflects the marine climate's low cooling loads and frequent fog.
- **Window-to-wall ratio (WWR)** is limited to **40%** under the prescriptive path (Section 5.5.4.2). Projects exceeding 40% WWR must use the performance path (Appendix G) or the envelope trade-off method (Section 5.6 ECB).
- **Skylight-to-roof ratio (SRR)** is limited to **3%** under the prescriptive path (Section 5.5.4.2.3).

Calculating assembly U-factor from R-value:

The assembly U-factor is NOT simply 1/R for the cavity insulation. It must account for framing members, air films, sheathing, and thermal bridging:

```
U_assembly = 1 / (R_outside_film + R_sheathing + R_effective_cavity + R_ci + R_gypsum +
R_inside_film)

Example: Steel-framed wall with R-19 cavity + R-7.5 ci
R_outside_film = 0.17
R_sheathing = 1.00 (1/2" OSB)
R_eff_cavity = 8.55 (R-19 derated for steel stud bridging, ~45% effectiveness)
R_ci = 7.50 (1.5" polyiso continuous insulation)
R_gypsum = 0.45 (5/8" gypsum board)
R_inside_film = 0.68
```

```
R_total = 0.17 + 1.00 + 8.55 + 7.50 + 0.45 + 0.68 = 18.35
U_assembly = 1 / 18.35 = 0.055 Btu/h-ft2-F
```

This value of U = 0.055 would pass in Climate Zones 5A/5B (limit 0.055) but would fail in Climate Zone 6A (limit 0.049). Adding R-10 ci instead of R-7.5 ci brings U down to approximately 0.048, which passes Zone 6A.

3.4 HVAC Efficiency Minimums

ASHRAE 90.1-2022 Section 6 and Tables 6.8.1-1 through 6.8.1-10 establish minimum equipment efficiency requirements. The J∆S Engineering Suite stores these in the `ASHRAE_HVAC_EFFICIENCY` dictionary within `compliance.py`.

Unitary Air Conditioners and Condensing Units (Table 6.8.1-1)

Equipment Type	Capacity Range	Min EER	Min SEER/IEER
Packaged Air Conditioner	< 65 kBtu/h	11.2	14.0 (SEER)
Packaged Air Conditioner	65 - 135 kBtu/h	11.0	13.0 (IEER)
Packaged Air Conditioner	135 - 240 kBtu/h	10.6	12.5 (IEER)
Packaged Air Conditioner	240 - 760 kBtu/h	9.8	11.6 (IEER)
Packaged Air Conditioner	> 760 kBtu/h	9.5	11.2 (IEER)

EER vs SEER vs IEER:

- **EER (Energy Efficiency Ratio):** Cooling output (Btu/h) divided by power input (W) at a single rating condition (95 deg F outdoor, 80 deg F entering air, 67 deg F wet bulb). Used for equipment >= 65 kBtu/h.
- **SEER (Seasonal Energy Efficiency Ratio):** Weighted average efficiency over an entire cooling season. Used for equipment < 65 kBtu/h (residential-sized). Higher SEER indicates better part-load performance.
- **IEER (Integrated Energy Efficiency Ratio):** Weighted average of EER at four operating points (100%, 75%, 50%, 25% load at corresponding outdoor temperatures). Used for commercial equipment >= 65 kBtu/h. IEER replaced the older IPLV metric for unitary equipment.

Air-Cooled Chillers (Table 6.8.1-3)

Equipment Type	Capacity	Min Full-Load COP	Min IPLV (COP)
Air-Cooled Chiller	< 150 tons	2.80	3.70
Air-Cooled Chiller	>= 150 tons	2.80	3.95

Water-Cooled Chillers (Table 6.8.1-3)

Equipment Type	Capacity	Min Full-Load COP	Min IPLV (COP)
Centrifugal Chiller	< 150 tons	5.00	5.60
Centrifugal Chiller	150 - 299 tons	5.50	6.00
Centrifugal Chiller	300 - 399 tons	6.10	6.50

Equipment Type	Capacity	Min Full-Load COP	Min IPLV (COP)
Centrifugal Chiller	>= 400 tons	6.17	6.60
Screw/Scroll Chiller	< 150 tons	4.70	5.40
Screw/Scroll Chiller	>= 150 tons	5.20	5.90

COP (Coefficient of Performance): Cooling output (kW-thermal) divided by power input (kW-electrical). A COP of 5.0 means the chiller produces 5 kW of cooling for every 1 kW of electricity consumed.

IPLV (Integrated Part Load Value): Weighted average COP at four part-load conditions:

```
IPLV = 0.01A + 0.42B + 0.45C + 0.12D
where:
A = COP at 100% load (leaving chilled water = 44 deg F)
B = COP at 75% load
C = COP at 50% load
D = COP at 25% load
```

Converting between kW/ton and COP:

```
COP = 12.0 / kW_per_ton (since 1 ton = 12,000 Btu/h = 3.517 kW)
-- OR --
COP = 3.412 / kW_per_ton (when using the Btu-to-kW factor directly)

Example: A chiller rated at 0.65 kW/ton
COP = 12 / 0.65 = 18.46 -- WRONG (this is IPLV in kBtu/kWh, not COP)

Correct conversion:
COP = 3.517 / 0.65 = 5.41 -- This is the correct COP
-- OR equivalently --
kW/ton = 12 / (COP x 3.412) ... so COP = 12 / (kW/ton x 3.412)
```

The J∆S Engineering Suite performs these conversions automatically and flags any equipment that falls below the applicable minimum.

Boilers (Table 6.8.1-6)

Equipment Type	Capacity Range	Min Thermal Efficiency (Et)
Gas-Fired Hot Water Boiler	< 300 MBH	82%
Gas-Fired Hot Water Boiler	300 - 2,500 MBH	84%
Gas-Fired Hot Water Boiler	> 2,500 MBH	85%
Gas-Fired Steam Boiler	< 300 MBH	80%
Gas-Fired Steam Boiler	300 - 2,500 MBH	82%
Gas-Fired Steam Boiler	> 2,500 MBH	83%
Gas-Fired Condensing Boiler	All sizes	92%

Thermal efficiency (Et): The ratio of heat output to heat input, measured at steady-state operating conditions per ANSI Z21.13 or UL 795. Condensing boilers achieve higher efficiency by recovering latent heat from flue gas condensation. The 92% minimum for condensing boilers reflects the fact that these units are specifically marketed as high-efficiency products.

AFUE vs Et: Residential boilers are rated by AFUE (Annual Fuel Utilization Efficiency), which accounts for cycling losses. Commercial boilers >= 300 MBH are rated by Et (thermal efficiency), which is measured at steady state. The two metrics are not directly comparable.

Furnaces (Table 6.8.1-5)

Equipment Type	Min AFUE
Gas-Fired Furnace (non-condensing)	80%
Gas-Fired Furnace (condensing)	92%

Heat Pumps (Table 6.8.1-2)

Equipment Type	Capacity	Min COP (Heating)	Min EER (Cooling)	Min HSPF
Air-Source Heat Pump	< 65 kBtu/h	3.3	11.2	8.8
Air-Source Heat Pump	65 - 135 kBtu/h	3.2	10.6	N/A
Air-Source Heat Pump	>= 135 kBtu/h	3.1	10.0	N/A
Water-Source Heat Pump	All sizes	4.2	12.0	N/A
Ground-Source Heat Pump	All sizes	3.6	16.4	N/A

HSPF (Heating Seasonal Performance Factor): Seasonal heating efficiency metric for residential-sized heat pumps (< 65 kBtu/h). Expressed in Btu/Wh, with higher values indicating better performance. HSPF of 8.8 is equivalent to approximately COP 2.58.

Fan Power Limitation (Section 6.5.3.1)

ASHRAE 90.1-2022 limits the total fan system power based on system type and supply airflow:

System Type	Base Allowance	Units
VAV systems	1.2	bhp per 1,000 CFM
CAV systems	0.8	bhp per 1,000 CFM

Pressure drop credits (Table 6.5.3.1-2) allow the fan power budget to be increased for specific system features:

Feature	Pressure Drop Credit (in. w.g.)
MERV 9-12 filters	0.35
MERV 13-15 filters	0.50
MERV 16 and higher / HEPA filters	0.90
Exhaust air energy recovery device	Actual device pressure drop
Sound attenuation section	0.15 per section
Dehumidification coil (series)	Coil pressure drop

Feature	Pressure Drop Credit (in. w.g.)
Evaporative humidifier/cooler	Actual device pressure drop

Fan power calculation example (20,000 CFM VAV system with MERV 13 filters):

```
Base allowance: 20,000 / 1,000 x 1.2 = 24.0 bhp
MERV 13 credit: 20,000 x 0.50 / 4,131 = +2.4 bhp
Sound attenuation: 20,000 x 0.15 / 4,131 = +0.7 bhp
Total = 27.1 bhp

Our design: supply fan = 22.0 bhp, return fan = 5.0 bhp, total = 27.0 bhp
27.0 bhp < 27.1 bhp --> PASS
```

The factor 4,131 converts in. w.g. pressure drop at a given CFM to bhp:

```
bhp = (CFM x delta_P_inwg) / (6,356 x fan_efficiency)
Assuming 65% total fan efficiency: bhp = CFM x delta_P / 4,131
```

3.5 Economizer Requirements

When Economizers Are Required (Section 6.5.1)

Air-side economizers are required for individual cooling systems with a mechanical cooling capacity of **54,000 Btu/h (4.5 tons) or greater**. This applies to all ASHRAE climate zones except for very limited exemptions:

Climate Zone	Economizer Required?	Notes
0A (Extremely Hot - Humid)	YES with restrictions	High humidity limits economizer hours
0B (Extremely Hot - Dry)	YES	Dry bulb economizer effective
1A (Very Hot - Humid)	YES with restrictions	Limited free-cooling hours
1B (Very Hot - Dry)	YES	Dry bulb economizer effective
2A (Hot - Humid)	YES	
2B (Hot - Dry)	YES	
3A (Warm - Humid)	YES	
3B (Warm - Dry)	YES	Excellent economizer climate
3C (Warm - Marine)	YES	Best economizer climate in US
4A (Mixed - Humid)	YES	
4B (Mixed - Dry)	YES	
4C (Mixed - Marine)	YES	Excellent economizer climate
5A (Cool - Humid)	YES	
5B (Cool - Dry)	YES	
5C (Cool - Marine)	YES	
6A (Cold - Humid)	YES	
6B (Cold - Dry)	YES	

Climate Zone	Economizer Required?	Notes
7 (Very Cold)	YES	
8 (Subarctic)	YES	

Exceptions to the economizer requirement (Section 6.5.1 exceptions):

1. Systems with cooling capacity < 54,000 Btu/h

2. Systems with energy recovery that meet the requirements of Section 6.5.6.1 where outdoor air exceeds 70% of total supply

3. Systems where the engineer can demonstrate that economizer use would increase overall HVAC energy consumption (rare; must be justified with energy modeling)

4. Systems serving spaces with process requirements that preclude introducing outdoor air (clean rooms with specific contamination limits, operating rooms with strict humidity control)

5. Systems with condenser heat recovery providing at least 60% of the design reheat requirements

High-Limit Shutoff Settings (Table 6.5.1.1)

The economizer high-limit shutoff determines when the economizer disengages (returns to minimum outdoor air). Different control strategies are appropriate for different climate zones:

Control Type	CZ 0B-3B (Hot/Warm-Dry)	CZ 3C-4C (Marine)	CZ 0A-3A (Hot/Warm-Humid)	CZ 4A-8 (Mixed/Cool/Cold)
Fixed dry-bulb	75 deg F	75 deg F	65 deg F	70 deg F
Differential dry-bulb	Return air temp	Return air temp	N/A (not recommended)	Return air temp
Fixed enthalpy	28 Btu/lb	28 Btu/lb	28 Btu/lb	28 Btu/lb
Differential enthalpy	Return air enthalpy	Return air enthalpy	Return air enthalpy	Return air enthalpy
Dew point and dry-bulb	55 deg F DP, 75 deg F DB	55 deg F DP, 75 deg F DB	55 deg F DP, 65 deg F DB	55 deg F DP, 70 deg F DB

Recommended strategy by climate:

- **Dry climates (B suffix):** Fixed or differential dry-bulb is simple and effective. Enthalpy-based controls add complexity without significant benefit because humidity is already low.
- **Humid climates (A suffix):** Differential enthalpy or dew point + dry-bulb is recommended to prevent introducing high-humidity air that increases latent cooling load.
- **Marine climates (C suffix):** Fixed dry-bulb works well due to mild, stable conditions.

The J∆S Engineering Suite automatically selects the recommended high-limit strategy based on the selected climate zone and allows the user to override it.

3.6 Energy Recovery Requirements

When Energy Recovery Is Required (Section 6.5.6.1)

Exhaust air energy recovery is required when the system meets BOTH of these conditions:

1. **The design supply airflow exceeds 5,000 CFM**, AND
2. **The outdoor air fraction exceeds 30%** of the design supply airflow at design conditions

Additional triggers that mandate energy recovery regardless of the 30% threshold:

- Systems serving spaces with **exhaust airflow exceeding 70% of supply airflow** (such as laboratory fume hood exhaust systems)
- Systems in Climate Zones **3B, 3C, 4B, 4C, 5B, 5C** where the OA exceeds **5,000 CFM** and OA fraction exceeds **70%**
- Systems in Climate Zones **0A through 3A, 4A through 8** where the OA exceeds **5,000 CFM** and OA fraction exceeds **30%**

Minimum Energy Recovery Effectiveness

Condition	Min Sensible Effectiveness	Min Total (Enthalpy) Effectiveness
Heating (cold OA entering, warm exhaust leaving)	50%	N/A (sensible only acceptable)
Cooling, dry climates	50%	N/A
Cooling, humid climates (A-suffix zones)	N/A	50% (enthalpy wheel recommended)

Types of energy recovery devices:

Device Type	Sensible Effectiveness	Latent Recovery	Cross-Contamination	Best Application
Enthalpy wheel (total energy wheel)	70-80%	YES (55-75%)	Possible (1-3%)	Humid climates; labs with high OA
Sensible heat wheel	70-80%	NO	Minimal	Dry climates; applications where moisture transfer is undesirable
Plate heat exchanger (fixed plate)	50-75%	NO (sensible only)	NONE	Healthcare, clean rooms where cross-contamination is prohibited
Heat pipe	50-65%	NO	NONE	Corrosive exhaust environments
Runaround coil	40-60%	NO	NONE	When supply and exhaust ducts are not adjacent

Example assessment for a 20,000 CFM office AHU:

```
Supply airflow: 20,000 CFM
Outdoor airflow: 5,600 CFM
Outdoor air fraction: 5,600 / 20,000 = 28%

Is ERV required?
Supply > 5,000 CFM? YES
OA fraction > 30%? NO (28% < 30%)
Result: ERV is NOT REQUIRED by code

But note: If occupancy increases push OA to 6,000 CFM:
OA fraction = 6,000 / 20,000 = 30%
Result: ERV WOULD BE REQUIRED
```

Design advisory: Even when not code-required, installing an ERV can be cost-effective. The J∆S Engineering Suite's energy simulation module (`energy_simulation.py`) can model the annual energy savings and simple payback period for a voluntary ERV installation. Typical payback periods for ERVs in commercial buildings range from 3 to 7 years depending on climate, operating hours, and utility rates.

3.7 Controls Requirements

ASHRAE 90.1-2022 Sections 6.4 (Mandatory) and 6.5 (Prescriptive) require a comprehensive set of automatic controls for HVAC systems. These control sequences are verified during plan review and must be documented in the building automation system (BAS) sequence of operations.

Thermostat Deadband (Section 6.4.3.1.2)

All thermostats must have a **minimum deadband of 5 deg F** between heating and cooling setpoints. This prevents simultaneous heating and cooling (also called thermostat "fighting") and reduces energy waste.

```
Example:
Cooling setpoint: 75 deg F
Heating setpoint: 70 deg F
Deadband = 75 - 70 = 5 deg F --> COMPLIANT

Cooling setpoint: 74 deg F
Heating setpoint: 72 deg F
Deadband = 74 - 72 = 2 deg F --> NON-COMPLIANT (less than 5 deg F)
```

Setback Requirements (Section 6.4.3.3.2)

During unoccupied periods, the HVAC system must automatically setback to:

- **Heating setback:** No higher than 55 deg F (typical unoccupied heating setpoint)
- **Cooling setup:** No lower than 90 deg F (typical unoccupied cooling setpoint) or system off

The setback/setup capability must be automatic, programmable, and capable of being overridden for a maximum of 2 hours per occurrence.

Optimum Start (Section 6.4.3.3.3)

Systems serving occupied spaces with a design heating or cooling capacity exceeding **54,000 Btu/h** must have optimum start controls. Optimum start algorithms automatically adjust the HVAC start time based on:

- Current indoor temperature at the start of the warm-up or cool-down period
- Outdoor temperature
- Building thermal mass and heat transfer characteristics
- Historical data (adaptive algorithms that learn from past performance)

The goal is to bring the building to occupied setpoint exactly at the scheduled occupancy time, rather than starting at a fixed time that may be too early (wasting energy) or too late (causing comfort complaints).

Demand-Controlled Ventilation (Section 6.5.3.8)

DCV using CO2 sensors is required for all spaces that meet ALL of the following criteria:

- Designed for an occupant density exceeding **25 people per 1,000 ft2**

- Served by a system with an air economizer or an automatic modulating outdoor air damper
- Not a space where special contaminant or pressurization requirements preclude DCV

Spaces that commonly trigger DCV requirements:

Space Type	Typical Occupant Density (per 1,000 ft2)	DCV Required?
Conference room (large)	50-65	YES
Auditorium / assembly	60-150	YES
Classroom (K-12)	25-35	YES
Lecture hall	50-65	YES
Restaurant dining	70-100	YES
Bar / cocktail lounge	100	YES
Gymnasium (exercise area)	7-10	No
Open-plan office	5-7	No
Private office	3-5	No
Lobby / reception	10-15	No
Corridor	0-2	No
Retail sales floor	8-15	No

CO2 sensor requirements for DCV:

- Mount sensors 3 to 6 ft above floor level
- Locate away from supply diffusers, doors, and windows
- CO2 setpoint: Typically 800-1,000 ppm above outdoor ambient (approximately 1,200-1,400 ppm total)
- Sensor accuracy: +/- 75 ppm
- Calibration: Self-calibrating sensors recommended; manual calibration every 5 years minimum
- Signal output: 4-20 mA or 0-10 VDC to BAS

Supply Air Temperature Reset (Section 6.5.3.7)

Multi-zone HVAC systems must implement supply air temperature (SAT) reset. The supply air temperature must be automatically adjusted based on building loads to reduce reheat energy and fan energy. Common strategies:

1. Warmest zone reset: SAT increases when no zone requires full cooling. If the zone with the largest cooling demand is satisfied at a higher SAT, the entire system resets up, reducing reheat in other zones.

2. Outdoor air reset: SAT varies linearly with outdoor air temperature. As outdoor temperature drops, SAT resets upward (warmer supply air reduces reheat). Typical reset schedule:

```
OAT = 65 deg F --> SAT = 55 deg F (full cooling)
OAT = 55 deg F --> SAT = 60 deg F
OAT = 45 deg F --> SAT = 65 deg F (maximum reset)
```

3. Trim and respond (ASHRAE Guideline 36): The BAS incrementally adjusts SAT based on zone requests. If cooling requests decrease, SAT trims up by a small increment (e.g., 0.2 deg F). If any zone sends a cooling request above a threshold, SAT responds down by a larger increment (e.g., 0.5 deg F). This method is self-optimizing and adapts to changing conditions.

Static Pressure Reset (Section 6.5.3.4)

VAV systems must reset duct static pressure setpoint based on zone demand. Requirements:

- The duct static pressure sensor must be located **at least two-thirds of the way** downstream from the AHU toward the most remote terminal unit.
- The setpoint must reset downward when zone dampers are not fully open.
- Typical reset range: 0.5 in. w.g. (minimum) to design static (maximum).
- Trim and respond logic per Guideline 36 is the recommended approach.

Simultaneous Heating and Cooling Limits (Section 6.5.2)

Systems that provide both heating and cooling to the same zone must limit simultaneous heating and cooling. Specific requirements:

- Zone-level reheat must be limited to the minimum necessary to meet the zone heating load.
- VAV terminal units must reduce airflow to minimum before energizing reheat.
- Deadband between heating and cooling must be at least 5 deg F.
- Dual-duct systems must have controls to prevent mixing hot and cold air simultaneously.

Automatic Shutoff (Section 6.4.3.3.1)

All HVAC systems must automatically shut off during unoccupied periods. Acceptable methods:

- Time-of-day scheduling with a 7-day programmable controller
- Occupancy sensors (for zones < 5,000 ft2)
- Interlock with the security or lighting system
- Manual override must be limited to a maximum of 2 hours per occurrence

3.8 Lighting Power Density

ASHRAE 90.1-2022 Section 9 limits the installed lighting power density (LPD). Two methods are available:

Building Area Method (Table 9.5.1)

The Building Area Method assigns a single LPD limit to the entire building based on building type:

Building Type	LPD Limit (W/ft2)
Automotive Facility	0.75
Convention Center	0.64
Courthouse	0.85
Dining: Bar/Lounge	0.80
Dining: Cafeteria	0.52

Building Type	LPD Limit (W/ft2)
Dining: Fast Food	0.84
Dining: Family Restaurant	0.60
Dormitory	0.53
Exercise Center	0.52
Fire Station	0.56
Gymnasium	0.76
Healthcare Clinic	0.81
Hospital	0.96
Hotel/Motel	0.56
Library	0.83
Manufacturing Facility	0.82
Motion Picture Theater	0.44
Multifamily	0.45
Museum	0.55
Office	0.64
Parking Garage	0.15
Penitentiary	0.69
Performing Arts Theater	0.84
Police Station	0.66
Post Office	0.65
Religious Building	0.67
Retail	0.84
School/University	0.72
Sports Arena	0.52
Town Hall	0.69
Transportation	0.50
Warehouse	0.45
Workshop	0.91

Space-by-Space Method (Table 9.6.1)

The Space-by-Space Method assigns individual LPD limits to each space based on its function. This method is more favorable for buildings with a mix of space types, particularly those with low-LPD spaces (corridors, storage) that offset high-LPD spaces (operating rooms, laboratories).

Space Type	LPD Limit (W/ft2)
Office - Enclosed	0.74
Office - Open Plan	0.61
Conference/Meeting Room	0.87
Reception	0.53
Copy/Print Room	0.31
Classroom/Lecture	0.71
Laboratory - Classroom	0.85
Laboratory - Research	1.11
Hospital - Patient Room	0.62
Hospital - Nurses Station	0.71
Hospital - Exam/Treatment	1.66
Hospital - Operating Room	1.89
Hospital - Recovery	0.98
Sales Area (Retail)	1.05
Mall Concourse	0.75
Dining - Bar/Lounge	0.86
Dining - Cafeteria	0.40
Dining - Fine Dining	0.89
Dining - Fast Food	0.90
Dining - Family Restaurant	0.60
Kitchen - Food Prep	0.99
Warehouse - Fine Storage	0.43
Warehouse - Bulk Storage	0.33
Warehouse - Medium/Bulky	0.58
Manufacturing - Low Bay	0.86
Manufacturing - High Bay	0.86
Corridor	0.41
Lobby - Hotel	0.51
Lobby - Office/General	0.84
Stairway	0.49
Restroom	0.63
Locker Room	0.52

Space Type	LPD Limit (W/ft2)
Electrical/Mechanical Room	0.42
Library - Reading Area	0.61
Library - Stacks	0.85
Gymnasium/Fitness Center	0.52
Auditorium	0.63
Convention Center	0.64
Religious Worship	0.78
Courtroom	1.20
Bank/Financial	0.61
Museum - General	0.55
Museum - Restoration	1.02
Parking Garage	0.15
Data Center	0.82

Lighting Controls (Section 9.4)

Mandatory lighting controls include:

- **Occupancy sensors** in enclosed spaces <= 250 ft2, classrooms, conference rooms, break rooms, copy rooms, restrooms, and storage rooms
- **Daylight responsive controls** in daylight zones adjacent to vertical fenestration (primary sidelit zone = 1x head height from window, secondary sidelit zone = 2x head height) and under skylights (daylight zone = 0.7x ceiling height beyond the skylight edge)
- **Automatic shutoff** using time scheduling, occupancy sensors, or signal from another control system within 30 minutes of all occupants leaving
- **Manual ON capability** (not auto-ON) for most spaces to prevent unnecessary lighting

4. California Title 24-2022 Comprehensive Coverage

4.1 When Title 24 Applies

California Title 24, Part 6 — the Building Energy Efficiency Standards — applies to **every building project in California** including:

- New construction of nonresidential buildings
- New construction of residential buildings (high-rise and low-rise)
- Additions to existing buildings (the addition must comply; existing portions are not required to be upgraded unless altered)

- Alterations to existing buildings (altered components must comply; unaltered components may remain as-is)
- Change of occupancy when the new occupancy has different energy requirements

Very limited exemptions:

- Unconditioned storage buildings with no mechanical heating or cooling and no conditioned spaces adjacent
- Temporary buildings with a planned life of less than 180 days
- Buildings with less than 50% of the floor area enclosed (open structures)
- Agricultural buildings with no conditioned spaces
- Buildings listed on national, state, or local historic registers where compliance would require alterations that threaten the building's historic character (must receive approval from the CEC)

Enforcement: Title 24 compliance is enforced by local building departments during plan review and construction inspection. The California Energy Commission (CEC) provides the standards and approved compliance software. The design team (architect and engineer) is responsible for demonstrating compliance using approved methods.

Relationship to ASHRAE 90.1: Title 24 is independent of ASHRAE 90.1. California does not adopt the IECC or ASHRAE 90.1 by reference. However, many Title 24 requirements parallel or exceed ASHRAE 90.1 requirements. For California projects, Title 24 takes precedence. Projects outside California follow ASHRAE 90.1 (or the IECC, which references 90.1). For projects with both California and non-California scopes (e.g., a nationwide corporate standard), engineers must verify compliance with both codes separately.

4.2 Climate Zones 1 through 16

California uses its own climate zone system (CZ 1 through CZ 16), which differs from ASHRAE climate zones. The CEC climate zones are based on weather data, geography, and heating/cooling patterns specific to California.

CZ	Representative City	General Description	Corresponding ASHRAE Zone
1	Arcata	North Coast — cool, foggy, mild year-round	4C
2	Santa Rosa	North Coast Valleys — mild, some inland heat	3C
3	Oakland	Coastal — mild, Mediterranean climate	3C
4	San Jose / Sunnyvale	South Coast Inland — warm summers, mild winters	3C/3B
5	Santa Maria	South Coast — mild, coastal influence	3C
6	Los Angeles (Torrance)	South Coast — warm, dry, marine layer	3B
7	San Diego	South Coast — mild year-round, low humidity	3B
8	Fullerton	South Inland — hot summers, mild winters	3B
9	Pasadena / Burbank	South Inland — hot summers, warm winters	3B

CZ	Representative City	General Description	Corresponding ASHRAE Zone
10	Riverside	South Inland — very hot summers, mild winters	3B
11	Red Bluff	Central Valley — very hot summers, cool winters	3B/4B
12	Sacramento	Central Valley — hot summers, cool wet winters	3B
13	Fresno	Central Valley — very hot dry summers, tule fog winters	3B
14	Palmdale	High Desert — extreme heat, cold winters, high elevation	3B/4B
15	Palm Springs	Low Desert — extreme heat year-round, very dry	2B
16	Mount Shasta / Blue Canyon	Mountains — cold winters, moderate summers, high elevation	5B/6B

Key observations about California climate zones:

- **Coastal zones (1-7)** have mild temperatures year-round and benefit from marine influence. Cooling loads are moderate, and heating loads are low except in CZ 1 (Arcata area, which is cool and foggy).
- **Inland zones (8-13)** have significantly hotter summers due to lack of marine influence. Cooling is the dominant energy use.
- **Desert zones (14-15)** have extreme temperatures — very hot summers (110+ deg F) and cold winters (below freezing in CZ 14). These zones have the highest cooling loads in California.
- **Mountain zone (16)** has the coldest winters in California (heavy snowfall, below-zero temperatures) and requires the most envelope insulation.

4.3 Prescriptive vs Performance Path

Title 24-2022 offers two primary compliance paths:

Prescriptive Path (Section 140)

Under the prescriptive path, every individual building component must meet or exceed the requirements in Section 140 tables (primarily Table 140.3-B for envelope). No trade-offs are allowed. If any single component fails, the building cannot comply prescriptively and must either fix the failing component or switch to the performance path.

Advantages: Simple, no energy modeling required, straightforward documentation (fill in the NRCC forms with component values and compare against table limits).

Disadvantages: No flexibility for trade-offs. Projects with high WWR, unusual glazing requirements, or innovative systems that are not credited prescriptively must use the performance path.

Performance Path (Section 141)

The performance path compares the annual TDV (Time Dependent Valuation) energy consumption of the **proposed building** against a computer-generated **standard design building**. The standard design uses prescriptive values from

Table 140.3-B and standard HVAC system types per the ACM (Alternative Calculation Method) Reference Manual.

Compliance is achieved when:

```
Proposed Building TDV Energy <= Standard Design Building TDV Energy
```

TDV energy is unique to California. It weights energy consumption by time-of-use, assigning higher TDV values during peak demand periods (hot summer afternoons when the grid is stressed) and lower values during off-peak periods (mild spring mornings). This encourages designs that reduce peak demand, not just total energy. TDV also assigns different values to electricity, natural gas, and propane based on their source energy and time-dependent grid impacts.

The J∆S Engineering Suite implements the full Title 24 performance path via `t24_acm.py`, which generates the standard design building automatically and runs 8760-hour simulations using hourly TDV multipliers.

4.4 Mandatory Measures

Mandatory measures (Title 24 Sections 110 through 120) apply to ALL buildings regardless of compliance path. They cannot be traded off or waived. Even if a building demonstrates compliance through the performance path, it must still meet every mandatory measure.

Pipe Insulation (Section 120.3)

All HVAC piping carrying heating or cooling fluids must be insulated per Table 120.3-A:

Pipe Size (NPS)	Heating > 200 deg F	Heating 141-200 deg F	Heating 105-140 deg F	Cooling (all temps)
< 1"	1.5"	1.0"	0.5"	0.5"
1" - 1.5"	2.0"	1.5"	1.0"	0.75"
2" - 4"	2.5"	1.5"	1.0"	1.0"
5" - 8"	3.0"	1.5"	1.5"	1.0"
> 8"	3.5"	1.5"	1.5"	1.5"

Additional mandatory pipe insulation requirements:

- Chilled water piping insulation must include a **vapor retarder** on the outer surface to prevent condensation
- Refrigerant suction lines must be insulated to a minimum of R-4 per inch
- All piping insulation exposed to weather must have a protective jacket (aluminum, PVC, or stainless steel)
- Piping insulation must be continuous through all supports, hangers, and penetrations (thermal bridges at supports must be mitigated)

Duct Insulation and Sealing (Section 120.4)

All duct systems must meet Seal Class A requirements:

- All transverse joints sealed (with mastic or approved sealant, NOT duct tape)
- All longitudinal seams sealed
- All duct wall penetrations sealed
- Maximum allowable duct leakage: **4 CFM per 100 ft2 of duct surface area** at 1 in. w.g. test pressure

Duct insulation requirements:

- Supply ducts outside the building thermal envelope: R-8 minimum
- Return ducts outside the building thermal envelope: R-4.2 minimum
- Supply ducts within the building thermal envelope: R-4.2 minimum (if supply air temp differs from space temp by > 25 deg F)
- Ducts in unconditioned spaces: Full insulation required

Duct leakage testing is required for:

- All duct systems with supply ducts located outside the building thermal envelope
- Testing must be performed by a HERS rater per the Residential Appendix RA3.1 procedures (adapted for nonresidential)
- Test results must be documented on HERS verification forms

Economizer (Section 140.4(e))

Economizers are mandatory for cooling systems in most California climate zones with cooling capacity >= 54,000 Btu/h. Requirements are generally aligned with ASHRAE 90.1 but with California-specific high-limit shutoff values.

Demand-Controlled Ventilation (Section 120.1(d))

DCV is required for spaces with design occupant density > 25 people per 1,000 ft2 and served by systems with mechanical cooling capacity > 54,000 Btu/h. This parallels ASHRAE 90.1 Section 6.5.3.8 but with some California-specific thresholds.

Fault Detection and Diagnostics (Section 120.2(i))

Title 24-2022 requires FDD (Fault Detection and Diagnostics) for:

- Air-cooled unitary HVAC systems with mechanical cooling capacity >= 54,000 Btu/h
- Air handling units with total fan motor HP >= 5 HP

FDD systems must be capable of detecting and reporting:

- Air temperature sensor faults/failures
- Economizer damper not opening when conditions warrant
- Economizer damper not fully closing when conditions warrant
- Excess outdoor air intake
- Insufficient outdoor air intake
- Mechanical cooling operating when economizer should be providing free cooling

This FDD requirement is unique to California and is more stringent than ASHRAE 90.1, which does not mandate FDD for standard commercial systems.

Automatic Time Controls (Section 120.2(b))

All HVAC systems must have automatic time-switch or programmable controls:

- Seven-day programming with separate schedules for each day

- Manual override limited to 2 hours maximum per occurrence
- Holiday/vacancy programming capability
- Capability to reduce heating and cooling during unoccupied periods

4.5 Prescriptive Requirements

Envelope Requirements by California Climate Zone (Table 140.3-B)

Roof Assembly U-Factors:

CZ	Metal Building Roof	Attic and Other
1 (Arcata)	0.041	0.034
2 (Santa Rosa)	0.041	0.034
3 (Oakland)	0.041	0.034
4 (San Jose)	0.041	0.034
5 (Santa Maria)	0.041	0.034
6 (Los Angeles)	0.041	0.049
7 (San Diego)	0.041	0.049
8 (Fullerton)	0.041	0.049
9 (Pasadena)	0.041	0.034
10 (Riverside)	0.041	0.034
11 (Red Bluff)	0.041	0.034
12 (Sacramento)	0.041	0.034
13 (Fresno)	0.041	0.034
14 (Palmdale)	0.041	0.034
15 (Palm Springs)	0.041	0.034
16 (Mt. Shasta)	0.041	0.034

Note that CZ 6, 7, and 8 have a relaxed attic/other roof requirement (0.049 vs 0.034) due to the mild coastal/inland climate. Metal building roofs are universally 0.041 across all zones.

Wall Assembly U-Factors:

CZ	Metal Building	Steel Framed	Wood Framed
1 (Arcata)	0.113	0.060	0.095
2 (Santa Rosa)	0.061	0.055	0.059
3 (Oakland)	0.113	0.071	0.110
4 (San Jose)	0.061	0.055	0.059

CZ	Metal Building	Steel Framed	Wood Framed
5 (Santa Maria)	0.061	0.055	0.102
6 (Los Angeles)	0.113	0.060	0.110
7 (San Diego)	0.113	0.060	0.110
8 (Fullerton)	0.061	0.055	0.102
9 (Pasadena)	0.061	0.055	0.059
10 (Riverside)	0.061	0.055	0.059
11 (Red Bluff)	0.061	0.055	0.045
12 (Sacramento)	0.061	0.055	0.059
13 (Fresno)	0.061	0.055	0.059
14 (Palmdale)	0.061	0.055	0.059
15 (Palm Springs)	0.057	0.055	0.042
16 (Mt. Shasta)	0.061	0.055	0.059

Key observations:

- Coastal mild zones (3, 6, 7) have relaxed metal building and wood-framed wall requirements, reflecting lower heating loads.
- CZ 15 (Palm Springs) has the strictest wall requirements due to extreme summer heat.
- CZ 11 (Red Bluff) has strict wood-framed wall requirements (0.045) due to cold winters in the northern Central Valley.
- Steel-framed wall limits are consistently 0.055-0.071 across all zones, with the mild coastal CZ 3 being the most relaxed at 0.071.

Fenestration Requirements:

CZ	Fixed Window U	Operable Window U	Curtain Wall U	SHGC	Air Barrier Required
1	0.36	0.46	0.41	0.25	Yes
2	0.36	0.46	0.41	0.25	Yes
3	0.36	0.46	0.41	0.25	No
4	0.36	0.46	0.41	0.25	Yes
5	0.36	0.46	0.41	0.25	No
6	0.36	0.46	0.41	0.25	No
7	0.36	0.46	0.41	0.25	No
8	0.36	0.46	0.41	0.23	Yes
9	0.36	0.46	0.41	0.23	Yes
10	0.36	0.46	0.41	0.23	Yes

CZ	Fixed Window U	Operable Window U	Curtain Wall U	SHGC	Air Barrier Required
11	0.36	0.46	0.41	0.23	Yes
12	0.36	0.46	0.41	0.23	Yes
13	0.36	0.46	0.41	0.23	Yes
14	0.36	0.46	0.41	0.23	Yes
15	0.34	0.46	0.38	0.22	Yes
16	0.36	0.46	0.41	0.25	Yes

Important differences from ASHRAE 90.1:

- Title 24 distinguishes between **fixed**, **operable**, and **curtain wall** fenestration U-factors. ASHRAE 90.1 uses a single fenestration U-factor for all window types.
- CZ 15 (Palm Springs) has the most stringent SHGC requirement at 0.22 — reflecting extreme solar loads in the low desert.
- CZ 8-14 require SHGC <= 0.23, which is more restrictive than ASHRAE CZ 3B's 0.25 for the same geographic area.
- **Air barrier requirements** vary by zone. Coastal mild zones (3, 5, 6, 7) do not require air barriers under prescriptive. Inland and desert zones require air barriers.

HVAC Efficiency (Section 140.4)

Title 24 HVAC efficiency requirements generally align with ASHRAE 90.1 Tables 6.8.1-1 through 6.8.1-10 but may adopt more recent federal minimums sooner. As of the 2022 edition, the minimum efficiencies are equivalent or higher than ASHRAE 90.1-2022 for most equipment types.

Fan System Power (Section 140.4(c))

Fan System	Power Limit	Applicability
Supply fans > 25 HP total motor nameplate	0.8 W/CFM	All nonresidential
Supply fans <= 25 HP total motor nameplate	Exempt	Small systems
Return/exhaust fans	Included in system total	All fans counted

Comparison with ASHRAE 90.1:

```
ASHRAE 90.1: 1.2 bhp/1,000 CFM (VAV) = 1.2 x 0.7457 = 0.895 W/CFM
Title 24: 0.8 W/CFM

Title 24 is approximately 11% more stringent than ASHRAE 90.1.
```

A system that passes ASHRAE fan power limits may fail Title 24. The J∆S Engineering Suite checks both standards simultaneously for California projects and flags any differences.

Lighting Power Density (Section 140.6, Table 140.6-C)

Title 24 LPD limits by space type:

Space Type	LPD Limit (W/ft2)
Office - Enclosed (<= 250 SF)	0.85
Office - Enclosed (> 250 SF)	0.69
Office - Open Plan	0.61
Conference/Meeting	0.79
Reception/Waiting	0.58
Classroom - Lecture/Training	0.65
Classroom - Shop (Vocational)	0.80
Laboratory - Classroom	1.02
Laboratory - Research	1.17
Hospital - Patient Room	0.62
Hospital - Nurses Station	0.87
Hospital - Exam Room	1.02
Hospital - Operating Room	1.89
Hospital - Recovery	0.98
Hospital - Physical Therapy	0.80
Retail - Sales Area	0.93
Retail - Mall Concourse	0.82
Retail - Dressing Room	0.51
Dining - Bar/Lounge	0.86
Dining - Cafeteria	0.45
Dining - Fine Dining	0.89
Dining - Fast Food	0.65
Dining - Family Restaurant	0.60
Kitchen - Food Prep	0.76
Warehouse - Storage	0.38
Warehouse - Fine Material	0.65
Corridor	0.41
Lobby	0.84
Stairway	0.49
Restroom	0.70
Locker Room	0.52
Electrical/Mechanical Room	0.48

Space Type	LPD Limit (W/ft2)
Library - Reading Area	0.69
Library - Stacks	1.04
Gymnasium	0.65
Auditorium/Theater	0.63
Convention Center	0.87
Religious Assembly	0.78
Courtroom	1.20
Financial Transaction	0.71
Museum	0.62
Parking Garage	0.14

4.6 Performance Path and TDV Energy

Standard Design (Baseline) Building Definition

Under Title 24-2022 Section 141, the performance path compares the proposed design against a computer-generated standard design building. The standard design is automatically generated using:

- Same geometry, orientation, and floor area as the proposed design
- Prescriptive envelope values from Table 140.3-B for the applicable climate zone
- Standard HVAC system type based on building type and size per ACM Reference Manual Table 2
- Standard lighting power density per Table 140.6-C
- Standard service water heating per Section 140.5

The J∆S Engineering Suite generates the standard design via `t24_acm.generate_standard_design()` using the following standard HVAC system types:

System #	Type	Application
1	PTAC	Hotels, motels, dormitories
2	PTHP	Hotels in heating-dominated climates
3	PSZ-AC	Small nonresidential (< 25,000 ft2, 1-2 floors)
4	PSZ-HP	Small nonresidential in heating climates
5	PVAV-HW	Medium nonresidential (25,000-150,000 ft2)
6	PVAV-PFP	Medium nonresidential without gas service
7	VAV-HW	Large nonresidential (> 150,000 ft2)
8	VAV-ER	Large nonresidential without gas service
9	Heat Only (Gas)	Unconditioned heated spaces

System #	Type	Application
10	Heat Only (Electric)	Unconditioned heated spaces, no gas

TDV Energy Calculation

TDV (Time Dependent Valuation) energy is calculated hour by hour for an entire year (8,760 hours). For each hour:

```
TDV_energy_hour = (Electricity_kWh x TDV_elec_multiplier) + (Gas_therms x TDV_gas_multiplier)
```

The TDV multipliers vary by:

- **Climate zone** (CZ 1-16)
- **Hour of day** (1-24)
- **Day of year** (1-365)
- **Fuel type** (electricity vs natural gas)

Peak-period electricity has TDV multipliers that can be 5 to 10 times higher than off-peak multipliers, reflecting the true cost to the grid of generating and delivering electricity during peak demand.

Annual TDV energy:

```
TDV_annual = SUM over all 8,760 hours of TDV_energy_hour
```

Compliance check:

```
IF Proposed_TDV_annual <= Standard_Design_TDV_annual:
PASS (with energy margin = Standard - Proposed)
ELSE:
FAIL (energy overage = Proposed - Standard)
```

The **energy margin** (expressed as a percentage or absolute TDV kBtu) indicates how much better or worse the proposed building performs compared to the standard design. A positive margin means the building is better than code. A negative margin means it fails.

4.7 Forms Required

California projects must submit Nonresidential Certificates of Compliance (NRCC) forms. The J∆S Engineering Suite generates these via `t24_nrcc_forms.py`.

Envelope Forms

Form	Title	Required Content
NRCC-ENV-E	Envelope Component Certificate	Wall, roof, floor U-factors by assembly; fenestration U-factor and SHGC by product; area-weighted calculations; air barrier documentation

Information needed for ENV-1:

- Each opaque assembly: construction type, R-values, calculated assembly U-factor
- Each fenestration product: manufacturer, NFRC-rated U-factor, NFRC-rated SHGC, frame type, number of panes, low-e coating description

- Area of each assembly and fenestration type
- Area-weighted average U-factor and SHGC calculations
- Window-to-wall ratio calculation
- Skylight-to-roof ratio calculation

Mechanical Forms

Form	Title	Required Content
NRCC-MCH-01-E	Mechanical Systems Certificate	HVAC equipment types, capacities, efficiencies; fan power calculations; economizer details
NRCC-MCH-02-E	Mechanical Ventilation Certificate	Outdoor air rates per zone; DCV details; exhaust system description
NRCC-MCH-03-E	Mechanical Refrigeration Certificate	Refrigerant types, charge amounts, leak detection
NRCC-MCH-04-E	Mechanical Water Heating Certificate	SWH equipment, pipe insulation, solar thermal (if applicable)

Information needed for MECH-1:

- Every HVAC unit: manufacturer, model, capacity (MBH heating, tons cooling), rated efficiency (EER, SEER, IEER, COP, AFUE, Et)
- Fan schedules: CFM, motor HP, bhp, static pressure, W/CFM calculation
- Economizer details: control type, high-limit shutoff setting
- Controls: SAT reset strategy, SP reset strategy, DCV zones, FDD system
- Energy recovery: device type, effectiveness, airflow

Lighting Forms

Form	Title	Required Content
NRCC-LTI-E	Indoor Lighting Certificate	LPD by space (space-by-space method) or by building (area method); lighting controls (occupancy sensors, daylight responsive, auto shutoff)

Performance Path Forms

Form	Title	Required Content
NRCC-PRF-01-E	Performance Certificate of Compliance	Main compliance summary; TDV energy results for proposed and standard design; energy margin; all input assumptions
CF1R-PRF-01	Compliance Report	Detailed hourly TDV energy breakdown; compliance software version; weather file used

HERS Verification Forms

Form	Title	Verification Type
NRCC-MCH-22-H	Supply Fan Watt Draw	Field measurement of actual fan power
NRCC-MCH-24-H	Economizer FDD	Functional testing of economizer operation and fault detection
NRCC-MCH-25-H	DCV Verification	Functional testing of CO2 sensors and OA modulation
NRCC-MCH-27-H	Duct Leakage	Field pressure testing of duct system

5. How the Module Checks Compliance

The J∆S Engineering Suite compliance checking process follows a systematic workflow. Here is the step-by-step sequence that occurs when you click **Run Compliance Check**:

Step 1: Gather Building Data

The module collects all building data from the input panel or from an imported project file:

- Project location (city, state, climate zone)
- Building type and gross floor area
- Envelope assemblies: wall types with U-factors, roof types with U-factors, fenestration with U-factors and SHGC
- HVAC equipment: type, capacity, rated efficiency
- Fan systems: airflow, motor HP, brake horsepower
- Controls: economizer type, DCV zones, reset strategies
- Lighting: installed wattage by space, lighting power density

Step 2: Determine Applicable Requirements

Based on the selected code edition and climate zone, the module loads the appropriate prescriptive requirements:

- For ASHRAE 90.1: Looks up `ASHRAE_ENVELOPE_REQUIREMENTS[selected_climate_zone]` to get U-factor and SHGC limits for each construction type
- For Title 24: Looks up `TITLE24_ENVELOPE_REQUIREMENTS[selected_california_cz]` for envelope limits
- For HVAC: Looks up `ASHRAE_HVAC_EFFICIENCY` dictionary for the appropriate equipment category and capacity range
- For lighting: Looks up `ASHRAE_LPD_SPACE_TYPE` or `TITLE24_LPD_SPACE_TYPE` for the applicable LPD limits

Step 3: Compare Design Values to Code Limits

For each requirement, the module performs a simple comparison:

```
IF design_value <= code_limit: (for maximum limits like U-factor, SHGC, LPD)
result = PASS
```

```
margin = code_limit - design_value

IF design_value >= code_limit: (for minimum limits like COP, EER, AFUE)
result = PASS
margin = design_value - code_limit

OTHERWISE:
result = FAIL
overage = design_value - code_limit (or code_limit - design_value for minimums)
```

Step 4: Check Boolean Requirements

Certain requirements are pass/fail based on presence or absence:

- Economizer provided? (YES/NO)
- SAT reset provided? (YES/NO)
- SP reset provided? (YES/NO)
- DCV provided in required spaces? (YES/NO)
- Optimal start provided? (YES/NO)
- Automatic scheduling provided? (YES/NO)

Step 5: Generate the Compliance Report

The module populates the results table with one row per requirement:

Column	Description
#	Sequential number
Category	Envelope, HVAC, Lighting, Controls
Requirement	Description of the specific requirement
Code Reference	Section and table number in the applicable code
Code Limit	The prescriptive value from the code table
Design Value	The value from the project design
Status	PASS, FAIL, or N/A
Margin / Overage	How much better or worse than code

Step 6: Calculate Overall Compliance Score

The module calculates an overall compliance score:

```
Compliance Score = (Number of PASS items) / (Number of applicable items) x 100%
```

A score of 100% means full prescriptive compliance. Any score below 100% indicates at least one failure that must be addressed or resolved through a performance path approach.

6. Reading the Compliance Report

Report Structure

The compliance report generated by the J∆S Engineering Suite contains the following sections:

Header:

- Project name, location, and date
- Applicable code edition and climate zone
- Compliance path (prescriptive, performance, or ECB)
- Prepared by (engineer name and license number)

Executive Summary:

- Total checks performed
- Number of PASS results
- Number of FAIL results
- Number of N/A results
- Overall compliance score percentage
- Brief narrative summarizing results

Detailed Results Table:

Each row in the table represents one compliance check. Here is how to read each column:

Column	What It Means	How to Interpret
Requirement	The specific code requirement being checked	Describes what the code mandates
Code Limit	The threshold value from the code table	This is the pass/fail boundary
Design Value	Your project's actual value	This is what you are submitting
Status	PASS or FAIL	Green = compliant; Red = non-compliant
Margin	The difference between design value and code limit	Positive margin = room to spare; negative = overage
Code Reference	The specific section and table in the code	Use this to look up the requirement in the actual standard

Example rows:

```
| Wall U-factor (Steel Frame) | U <= 0.084 | U = 0.055 | PASS | Margin: 0.029 | 90.1 Table 5.5-5 |
| Glazing SHGC | SHGC <= 0.25 | SHGC = 0.38 | FAIL | Overage: 0.13 | 90.1 Table 5.5-5 |
| Chiller COP (Full Load) | COP >= 2.80 | COP = 3.69 | PASS | Margin: 0.89 | 90.1 Table 6.8.1-3 |
```

Interpreting Margins

- **Large positive margin** (e.g., chiller COP margin of 0.89): The equipment significantly exceeds code minimums. This provides a compliance buffer and may help offset failures in other areas if the performance path is used.

• **Small positive margin** (e.g., roof U-factor margin of 0.009): The design barely passes. Any construction change or value engineering that reduces insulation could cause a failure. Consider maintaining a minimum 10% margin for safety.

• **Zero margin**: The design is exactly at the code limit. This technically passes but leaves no room for field conditions or future code changes.

• **Negative margin (FAIL)**: The design does not meet the prescriptive requirement. The overage amount indicates how far the design is from compliance.

7. Fixing Failures

Common Failure: SHGC Too High

Symptom: Glazing SHGC of 0.35-0.45 fails in Climate Zones 0-3 (limit 0.25) or California CZ 8-15 (limit 0.22-0.23).

Root cause: Standard dual-pane low-e glass typically has SHGC of 0.25-0.38. Tinted glass or clear glass without solar control coatings will have even higher SHGC.

Solutions (in order of preference):

1. Upgrade glazing to triple silver low-e: Products like Solarban 72 or Guardian SunGuard SuperNeutral can achieve SHGC of 0.20-0.23 while maintaining visible light transmittance (VLT) of 55-65%. Cost premium: 15-25% over standard low-e.

2. Add ceramic frit pattern: A dot or line frit pattern at 30-50% coverage reduces effective SHGC by the frit percentage. A 40% frit on glass with SHGC 0.35 yields effective SHGC of approximately 0.21. Cost premium: 10-15%.

3. Install exterior shading devices: Horizontal overhangs (effective for south-facing) or vertical fins (effective for east/west-facing) reduce solar gain. ASHRAE 90.1 Table 5.5.4.4.1 provides projection factor (PF) credits that increase the allowable SHGC:

• PF >= 0.2: SHGC limit increases modestly

• PF >= 0.5: SHGC limit can increase from 0.25 to 0.33-0.36 depending on orientation

• PF = overhang depth / window height

4. Switch to performance path: If the building has superior HVAC efficiency, lighting, or other features that offset the SHGC penalty, the performance path may allow the higher SHGC while still demonstrating overall compliance.

Common Failure: Wall or Roof U-Factor Too High

Symptom: Assembly U-factor exceeds the prescriptive limit, typically in cold climates (Zones 5-8).

Solutions:

1. Add continuous insulation (ci): This is the most effective solution. Adding 1" of polyiso ci (R-6.5) to a steel-framed wall can reduce U-factor by 30-40%. Adding 2" (R-13) can reduce it by 50-60%.

2. Increase cavity insulation: Upgrade from R-13 to R-19 or R-21 batts. Note: In steel-framed walls, increasing cavity insulation alone has diminishing returns due to thermal bridging.

3. Switch to mass wall construction: CMU or concrete walls qualify as mass walls with relaxed U-factor requirements in mild climates. However, in cold climates (Zones 6-8), mass wall limits converge with framed wall limits.

Common Failure: No Economizer on Large System

Symptom: A cooling system >= 54,000 Btu/h does not have an air-side economizer.

Solution: Add an air-side economizer with appropriate high-limit shutoff control. For rooftop units, specify factory-integrated economizers. For AHUs, add a mixing box with outdoor air, return air, and relief dampers, along with the required sensors and controls.

Common Failure: LPD Over Limit

Symptom: Installed lighting power density exceeds the allowable LPD for the space type.

Solutions:

1. Switch to higher-efficacy light sources: Replace fluorescent fixtures with LED fixtures. Modern LED troffers provide 100-180 lumens per watt vs 80-100 lumens per watt for fluorescent.

2. Reduce fixture count: Use lighting design software (AGi32, DIALux) to optimize fixture layout and reduce quantity while maintaining required illuminance levels.

3. Use task lighting: Provide lower ambient lighting with supplemental task lighting at workstations. Task lights powered from furniture-mounted receptacles may not count toward the LPD calculation (check with AHJ).

4. Switch to Space-by-Space method: If using the Building Area Method, switching to the Space-by-Space Method may provide more favorable limits for buildings with a mix of high-LPD and low-LPD spaces.

Common Failure: Fan Power Budget Exceeded (Title 24)

Symptom: Total fan system power exceeds 0.8 W/CFM (Title 24) for systems with supply fans > 25 HP.

Solutions:

1. Select higher-efficiency fans: Upgrade from forward-curved to airfoil or backward-inclined fans. Upgrade to ECM (electronically commutated motor) drives.

2. Reduce system static pressure: Improve duct design to reduce friction losses. Use larger duct sizes, fewer fittings, and lower face velocity coils. Consider a low-pressure-drop air handling unit design.

3. Claim filtration credits: If the system has MERV 13+ filters, energy recovery devices, or sound attenuators, claim the appropriate pressure drop credits per ASHRAE Table 6.5.3.1-2 (note: Title 24 may have different credit allowances — verify with CEC documentation).

4. Use the performance path: The performance path allows trade-offs that may offset the fan power overage.

Common Failure: Missing DCV in Conference Rooms

Symptom: Conference rooms or other high-density spaces lack CO2-based demand-controlled ventilation.

Solution: Add CO2 sensors (wall-mounted, 3-6 ft above floor) in each affected zone. Connect sensor output to the BAS. Program the BAS to modulate the minimum outdoor air damper position based on CO2 readings, with a setpoint of approximately 1,000-1,200 ppm.

8. Worked Examples

8.1 San Diego CZ3B Office — ASHRAE 90.1

Project Parameters:

Parameter	Value
Building type	Office (nonresidential)
Location	San Diego, California
ASHRAE climate zone	3B (Warm-Dry)
Gross floor area	50,000 ft2
Number of stories	3
Gross wall area	24,000 ft2
Glazing area	9,600 ft2 (WWR = 40%)
Roof area	16,700 ft2
Occupancy	250 people (5 per 1,000 ft2)

Step 1: Open the Code Compliance module. From the sidebar, click Compliance & Codes > Code Compliance. Select ASHRAE 90.1-2022 and Climate Zone 3B from the top toolbar.

Step 2: Envelope Check

Wall assembly — Steel framed, 6" studs @ 16" o.c., R-19 fiberglass, R-2.5 XPS ci:

```
Assembly U-factor: 0.089 Btu/h-ft2-F
Code limit (CZ 3B): 0.084
Status: FAIL (overage = 0.005)
```

Wait — this fails. With only R-2.5 ci, the steel-framed wall in CZ 3B does not meet the 0.084 limit. We need to either add more continuous insulation or verify the assembly calculation. Let us upgrade to R-5 ci:

```
R_total = 0.17 + 1.00 + 8.55 + 5.00 + 0.45 + 0.68 = 15.85
U = 1 / 15.85 = 0.063
Code limit: 0.084
Status: PASS (margin = 0.021)
```

Roof assembly — Metal deck, insulation above deck, R-30 polyiso:

```
Assembly U-factor: 0.039 Btu/h-ft2-F
Code limit (CZ 3B): 0.048
Status: PASS (margin = 0.009)
```

Glazing — Low-e IGU, argon fill:

```
U-factor: 0.29 (NFRC rated)
Code limit: 0.42
```

```
Status: PASS (margin = 0.13)

SHGC: 0.38 (NFRC rated)
Code limit: 0.25
Status: FAIL (overage = 0.13)
```

WWR:

```
WWR = 9,600 / 24,000 = 40%
Limit: 40% (prescriptive)
Status: PASS (at limit)
```

Step 3: HVAC Efficiency Check

Chiller — Air-cooled screw, 120 tons:

```
Full-load COP: 3.69
Minimum COP: 2.80 (< 150 tons)
Status: PASS (margin = 0.89)

IPLV: 5.25 COP
Minimum IPLV: 3.70 (< 150 tons)
Status: PASS (margin = 1.55)
```

Boiler — Gas-fired condensing, 1,500 MBH:

```
Thermal efficiency: 95%
Minimum: 92% (condensing)
Status: PASS (margin = 3%)
```

Fan power — AHU-1, 20,000 CFM VAV:

```
Total fan bhp: 27.0 (22.0 supply + 5.0 return)
Allowable base: 20,000 / 1,000 x 1.2 = 24.0 bhp
MERV 13 credit: +2.4 bhp
Sound atten.: +0.7 bhp
Total allowed: 27.1 bhp
Status: PASS (margin = 0.1 bhp)
```

Step 4: Economizer and ERV Check

Economizer: All AHUs > 54,000 Btu/h have differential dry-bulb economizers. PASS.

Energy recovery:

```
AHU-1: 20,000 CFM supply, 5,600 CFM OA = 28% OA --> NOT REQUIRED (< 30%)
AHU-2: 8,500 CFM supply, 3,400 CFM OA = 40% OA --> NOT REQUIRED (< 5,000 CFM OA)
AHU-3: 6,000 CFM supply, 1,200 CFM OA = 20% OA --> NOT REQUIRED (< 30%)
```

Step 5: Controls Check

- SAT reset (warmest zone): PASS
- SP reset (trim and respond): PASS
- Optimal start (adaptive): PASS
- DCV in conference rooms: PASS
- Automatic scheduling: PASS
- 5 deg F deadband: PASS

Step 6: Results Summary

Total checks: 22. PASS: 20. FAIL: 2 (SHGC, wall U-factor before fix). N/A: 0.

After upgrading the wall ci to R-5, the wall passes. The SHGC failure (0.38 vs 0.25) requires either reselecting glazing (SHGC <= 0.25 product) or switching to the performance path. Given the superior chiller efficiency and low lighting power, the performance path is recommended.

8.2 Los Angeles CZ9 Retail — Title 24 Prescriptive

Project Parameters:

Parameter	Value
Building type	Retail store
Location	Pasadena, California
Title 24 climate zone	CZ 9
Gross floor area	15,000 ft2
Number of stories	1
Gross wall area	8,000 ft2
Glazing area	2,400 ft2 (WWR = 30%)
Roof area	15,000 ft2
HVAC	Two packaged rooftop units, 15 tons each

Step 1: Open Title 24 Compliance module. Select CZ 9.

Step 2: Envelope Check

Steel-framed wall:

```
Assembly U: 0.052
CZ 9 limit: 0.055
Status: PASS (margin = 0.003)
```

Attic roof:

```
Assembly U: 0.030
CZ 9 limit: 0.034
Status: PASS (margin = 0.004)
```

Fixed fenestration:

```
U-factor: 0.32
CZ 9 limit: 0.36
Status: PASS (margin = 0.04)

SHGC: 0.22
CZ 9 limit: 0.23
Status: PASS (margin = 0.01)
```

Air barrier: Required in CZ 9. Provided per specification. PASS.

Step 3: HVAC Check

Packaged RTUs (180 kBtu/h each, gas heat):

```
EER: 11.0
Minimum (135-240 kBtu/h): 10.6
Status: PASS (margin = 0.4)

IEER: 13.5
Minimum: 12.5
Status: PASS (margin = 1.0)
```

Economizer: Both RTUs > 54,000 Btu/h. Economizers provided with fixed dry-bulb high limit (75 deg F). PASS.

Fan power: Each RTU has < 25 HP total fan motor. EXEMPT from Title 24 fan power limits. PASS.

FDD: Both RTUs > 54,000 Btu/h. FDD system provided (factory-integrated diagnostics board). PASS.

Step 4: Lighting Check

```
Sales floor: 12,000 ft2 x 0.85 W/ft2 = 10,200 W installed
CZ 9 limit: 12,000 ft2 x 0.93 W/ft2 = 11,160 W allowed
Status: PASS (margin = 960 W)

Storage: 2,000 ft2 x 0.30 W/ft2 = 600 W installed
CZ 9 limit: 2,000 ft2 x 0.38 W/ft2 = 760 W allowed
Status: PASS

Office area: 1,000 ft2 x 0.55 W/ft2 = 550 W installed
CZ 9 limit: 1,000 ft2 x 0.69 W/ft2 = 690 W allowed
Status: PASS
```

Step 5: Mandatory Measures Check

- Pipe insulation per Table 120.3-A: PASS
- Duct sealing (Seal Class A): PASS
- Automatic time controls (7-day programmable thermostat): PASS
- DCV: Retail occupancy density = 15 per 1,000 ft2 < 25 threshold. NOT REQUIRED.

Result: Full prescriptive compliance. All items pass. No performance path needed.

8.3 Chicago CZ5A Hospital — Cold Climate Envelope

Project Parameters:

Parameter	Value
Building type	Hospital
Location	Chicago, Illinois
ASHRAE climate zone	5A (Cool-Humid)
Gross floor area	200,000 ft2
Number of stories	6
Gross wall area	80,000 ft2
Glazing area	24,000 ft2 (WWR = 30%)
Roof area	33,000 ft2

Envelope Requirements for CZ 5A:

```
Roof (Insulation above deck): U <= 0.032
Wall (Steel framed): U <= 0.055
Wall (Mass/CMU): U <= 0.123
Fenestration U-factor: U <= 0.36
Fenestration SHGC: SHGC <= 0.40
Skylight U-factor: U <= 0.50
Skylight SHGC: SHGC <= 0.40
```

Envelope Design and Compliance:

Roof — Metal deck with R-35 polyiso above deck (two layers staggered):

```
U = 0.029
Limit: 0.032
Status: PASS (margin = 0.003)
```

Exterior walls — Steel framed, R-19 cavity + R-10 ci polyiso:

```
U = 0.048
Limit: 0.055
Status: PASS (margin = 0.007)
```

Ground floor walls — CMU with R-13 ci (mass wall):

```
U = 0.079
Limit: 0.123
Status: PASS (margin = 0.044)
```

Glazing — Triple silver low-e IGU, argon fill:

```
U = 0.28
Limit: 0.36
Status: PASS (margin = 0.08)

SHGC = 0.35
Limit: 0.40
Status: PASS (margin = 0.05)
```

HVAC Efficiency — Hospital-Specific Considerations:

Water-cooled centrifugal chiller (400 tons):

```
Full-load COP: 6.30
Minimum: 6.17 (>= 400 tons)
Status: PASS (margin = 0.13)
```

Gas-fired condensing boilers (2x 3,000 MBH):

```
Thermal efficiency: 96%
Minimum: 92% (condensing) / 85% (> 2500 MBH non-condensing)
Status: PASS (margin = 4%)
```

Energy recovery — Operating room exhaust system:

```
100% OA supply to OR suite: 25,000 CFM
OA fraction: 100%
ERV required? YES (> 5,000 CFM and > 30% OA)
ERV type: Plate heat exchanger (no cross-contamination for healthcare)
Sensible effectiveness: 62%
Minimum: 50%
Status: PASS
```

Hospital LPD (Building Area Method):

```
Hospital building area LPD limit: 0.96 W/ft2
Total allowed: 200,000 x 0.96 = 192,000 W
Total installed: 180,000 W
Status: PASS (margin = 12,000 W)
```

Result: Full prescriptive compliance. Cold-climate hospitals require careful attention to roof and wall insulation but benefit from relaxed SHGC limits (0.40 in CZ 5A vs 0.25 in CZ 3B).

9. Documentation for Plan Review

What the Building Department Needs

When submitting for plan review, provide the following documentation organized in the order building departments typically expect:

For All Projects (ASHRAE 90.1)

Document	Content	Format
Compliance report (prescriptive)	Pass/fail checklist for all components	COMcheck report or J∆S Engineering Suite export
Equipment schedules	All HVAC equipment with rated efficiencies	Tabular, on mechanical drawings or in specifications
Envelope documentation	Assembly U-factors, NFRC glazing ratings	On architectural drawings or in compliance report
Controls narrative	Sequence of operations for all required controls	Written narrative, typically in Division 23 specifications
Lighting schedule	Fixture types, wattage, LPD calculations	On electrical drawings or in compliance report
Ventilation calculations	OA rates per ASHRAE 62.1, DCV zones identified	On mechanical drawings or in separate calculation
Fan power calculations	bhp budget with credits	In compliance report or separate calculation

For Performance Path Projects (Appendix G)

In addition to the above:

Document	Content
Energy model report	Proposed vs baseline annual energy, all assumptions documented
Input summary	Building geometry, schedules, HVAC system descriptions, weather file
Unmet load hours report	Demonstrate both proposed and baseline have < 300 unmet hours
Baseline system description	Appendix G system type, sizing, controls

For California Projects (Title 24)

Document	Content
NRCC-ENV-E	Envelope certificate of compliance
NRCC-MCH-01-E	Mechanical systems certificate
NRCC-MCH-02-E	Mechanical ventilation certificate
NRCC-LTI-E	Indoor lighting certificate
NRCC-PRF-01-E	Performance certificate (if performance path)
CF1R-PRF-01	Compliance report with TDV energy (if performance path)
HERS documentation	List of features requiring field verification
Manufacturer cut sheets	For all HVAC equipment, glazing products

Plan Review Tips

1. **Submit electronically** when the jurisdiction allows it. Many California jurisdictions now accept electronic NRCC forms.
2. **Include manufacturer data sheets** for all HVAC equipment showing AHRI-certified efficiency ratings.
3. **Provide a glazing schedule** with NFRC-rated U-factor and SHGC for every glazing type used on the project.
4. **Document all credits claimed** — overhangs (with PF calculations), cool roofs (with SRI values), daylighting controls (with sensor locations and control zones).
5. **For performance path** — include ALL input assumptions in the energy model report. Plan reviewers will reject models with undocumented assumptions.
6. **Cross-reference** compliance documents to drawing sheet numbers so the plan reviewer can verify equipment on the drawings matches the compliance submittal.
7. **Submit early.** Plan review for energy compliance can take 2-4 weeks. Budget this time into the project schedule.

10. UFC/DOD Compliance

Overview

The Unified Facilities Criteria (UFC) are Department of Defense construction standards that apply to all military installations and federal facilities worldwide. UFC compliance is **in addition to** ASHRAE 90.1 compliance — DOD projects must meet both the civilian energy code and UFC-specific requirements.

The J∆S Engineering Suite's UFC compliance module (`ufc_compliance.py`) checks the following UFC documents:

UFC Document	Title	Scope
UFC 1-200-01	DoD Building Code	General building requirements
UFC 1-200-02	High Performance & Sustainable Building	Energy reduction, water reduction
UFC 3-410-01	HVAC Systems	HVAC design requirements

UFC Document	Title	Scope
UFC 3-420-01	Plumbing Systems	Plumbing design requirements
UFC 3-530-01	Interior/Exterior Lighting	Lighting requirements
UFC 4-010-01	Minimum Antiterrorism Standards	ATFP requirements
UFC 4-010-06	Cybersecurity of Control Systems	BAS cybersecurity
UFC 4-024-01	CBR Protection	CBRN collective protection

Key UFC Requirements

Energy Reduction (UFC 1-200-02)

All new DOD construction must achieve a **30% energy reduction** below the ASHRAE 90.1 baseline. This is significantly more stringent than simply meeting ASHRAE 90.1 prescriptive requirements.

```
Target energy: ASHRAE 90.1 Baseline Energy x 0.70
(i.e., 30% less than baseline)
```

This effectively requires the performance path (Appendix G) for all DOD projects, since prescriptive compliance only achieves the baseline — not 30% below it.

Water Reduction

A **20% water reduction** below EPAct 1992 baseline fixture flow rates is required. This affects plumbing fixture selection and water-cooled HVAC systems.

Antiterrorism/Force Protection (UFC 4-010-01)

ATFP requirements have significant implications for HVAC design:

Outside air intake height: Minimum **12 ft above grade** or highest adjacent walking surface. This prevents ground-level CBR agent introduction into the HVAC system.

Intake screens: All outside air intakes must have screens to prevent insertion of objects.

Central HVAC shutdown: A central shutdown capability must be provided for all air handling units, operable from a security control center.

Damper closure time: Outside air dampers must close within **30 seconds** of receiving a shutdown signal.

Intake monitoring: CBR detection monitoring is required at outside air intakes for facilities at Medium or High Level of Protection.

Building pressurization: The HVAC system must be capable of pressurizing the building above ambient to resist CBR agent infiltration.

Standoff distances by Level of Protection:

Level of Protection	Parking Standoff	Roadway Standoff	Building Standoff
Very Low	10 ft	25 ft	33 ft

Level of Protection	Parking Standoff	Roadway Standoff	Building Standoff
Low	25 ft	25 ft	45 ft
Medium	33 ft	33 ft	82 ft
High	82 ft	82 ft	148 ft

Default Level of Protection by facility type:

Facility Type	Default LOP
Office/Administrative	Low
Barracks/Dormitory	Low
Command/Operations Center	High
Communications Facility	Medium
SCIF	High
Data Center	Medium
Hospital	Medium
Child Development Center	Medium
Emergency Operations Center	High
Fire Station	Low
Dining Facility	Low
Fitness/Gymnasium	Very Low
Warehouse/Storage	Very Low

System Redundancy for Critical Facilities

DOD critical facilities require HVAC system redundancy:

Criticality Level	Redundancy Requirement
Routine	N (no redundancy)
Important	N+1 (one backup unit)
Mission Critical	N+1 or 2N (full backup)
Mission Essential	2N or 2N+1 (full backup plus spare)

CBRN Protection (UFC 4-024-01)

Certain DOD facilities require collective protection (COLPRO) systems:

Protection Level	Description	HVAC Impact
None	No CBRN protection	Standard HVAC

Protection Level	Description	HVAC Impact
Basic	HEPA + carbon filtration	Add HEPA/carbon filter bank to AHUs
Enhanced	Positive pressure maintained	Dedicated pressurization system, airlock entries
Full COLPRO	Full collective protection	Dedicated filtered air supply, overpressure, airlocks, decontamination

DOD-Specific HVAC Requirements (UFC 3-410-01)

- **DOAS (Dedicated Outdoor Air Systems):** UFC 3-410-01 requires DOAS for most facility types. This separates ventilation from space conditioning and improves energy efficiency and indoor air quality.
- **Economizer restrictions:** Some service branches restrict or require specific economizer types based on climate zone and mission requirements.
- **Energy Compliance Analysis (ECA):** All DOD projects must submit an ECA demonstrating the 30% energy reduction below ASHRAE 90.1 baseline.

11. Troubleshooting

"Why Does My Building Fail Compliance?"

Common reasons and solutions:

Failure	Typical Cause	Solution
SHGC too high	Standard low-e glass in hot climate	Upgrade to triple silver low-e or add exterior shading
Wall U-factor too high	Insufficient continuous insulation	Add ci outboard of steel studs
Roof U-factor too high	Inadequate insulation thickness	Add more polyiso above deck
No economizer	Specified system lacks economizer	Add economizer to all systems >= 4.5 tons
Fan power exceeded	High-static-pressure duct system	Resize ducts, select higher-efficiency fans
LPD over limit	Too many fixtures or inefficient lamps	Switch to LED, reduce fixture count
Missing DCV	Conference rooms without CO2 sensors	Add CO2 sensors and BAS programming
Missing SAT reset	Sequence of operations incomplete	Add reset strategy to BAS sequence
Missing SP reset	VAV system without SP reset	Add trim-and-respond SP reset to BAS
ERV required but missing	High-OA system without energy recovery	Add ERV/HRV to the air handling system

"My Equipment Efficiency Doesn't Match the Manufacturer Data"

Possible causes:

1. Rating conditions differ. ASHRAE 90.1 references AHRI-certified ratings at specific conditions (95 deg F OAT for EER, for example). Manufacturer data may quote performance at non-standard conditions. Always use AHRI-certified values.

2. Units are mixed up. COP, EER, kW/ton, and IPLV are different metrics. Ensure you are comparing the correct metric. Use the J∆S Engineering Suite's built-in conversion tools.

3. Capacity range is wrong. A 65 kBtu/h unit falls into a different efficiency tier than a 64 kBtu/h unit. Verify the exact capacity and look up the correct tier.

"Can I Appeal a Failed Compliance Check?"

The energy code itself does not have a formal appeal process for individual requirements. However:

- You can request a **variance** from the AHJ (authority having jurisdiction) in cases of practical difficulty or hardship. Variances are granted on a case-by-case basis and typically require demonstrating equivalent energy performance through alternative means.
- You can switch to the **performance path**, which allows trade-offs between building systems. This is the most common resolution for prescriptive failures.
- In California, you can request an **interpretation** from the CEC if there is ambiguity in the code language.

"The Module Shows N/A for Some Checks"

N/A (Not Applicable) results occur when:

- The requirement does not apply to your building type (e.g., skylight requirements when there are no skylights)
- The requirement does not apply to your climate zone (e.g., certain ERV requirements only apply in specific zones)
- The equipment type is not present in your project (e.g., boiler requirements when the building has no boiler)

N/A results do not count against your compliance score.

12. Complete Reference Tables

ASHRAE Climate Zone Map — Representative Cities

Zone	Moisture	Representative Cities	HDD65 Range	CDD50 Range
0A	Humid	Singapore, Kuala Lumpur	0	> 6,000
0B	Dry	Riyadh, Abu Dhabi	0	> 6,000
1A	Humid	Miami, Honolulu, Key West	0-500	5,500-6,500
1B	Dry	New Delhi (parts)	0-500	5,000-6,000
2A	Humid	Houston, Tampa, New Orleans, Savannah	1,000-2,000	4,500-5,500
2B	Dry	Phoenix, Tucson	1,000-2,000	4,000-5,500

Zone	Moisture	Representative Cities	HDD65 Range	CDD50 Range
3A	Humid	Atlanta, Memphis, Dallas, Charlotte	2,000-3,000	3,500-4,500
3B	Dry	Los Angeles, Las Vegas, San Diego, Albuquerque	2,000-3,000	2,500-4,000
3C	Marine	San Francisco, Santa Barbara	2,000-3,000	1,500-2,500
4A	Humid	New York, Baltimore, Philadelphia, Washington DC	3,000-4,000	2,500-3,500
4B	Dry	Albuquerque (parts)	3,000-4,000	2,000-3,000
4C	Marine	Seattle, Portland, Vancouver (BC)	3,000-4,000	1,000-2,000
5A	Humid	Chicago, Boston, Detroit, Cleveland, Indianapolis	4,000-5,000	1,500-2,500
5B	Dry	Denver, Salt Lake City, Boise, Colorado Springs	4,000-5,000	1,500-2,500
5C	Marine	(Rare in US - some Pacific Northwest coastal)	4,000-5,000	1,000-1,500
6A	Humid	Minneapolis, Milwaukee, Burlington, Madison	5,000-7,000	1,000-2,000
6B	Dry	Helena, Billings, Casper	5,000-7,000	500-1,500
7	--	Duluth, Fairbanks, International Falls	7,000-9,000	200-800
8	--	Barrow (Utqiagvik), Nome	> 9,000	< 500

Complete ASHRAE 90.1-2022 Envelope Summary (All Zones)

This table consolidates all envelope U-factors and SHGC values from `compliance.py`:

Zone	Roof-IAD	Roof-MB	Roof-Attic	Wall-Mass	Wall-MB	Wall-SF	Wall-WF	Fen-U	Fen-SHGC	Sky-U	Sky-SHGC
0A	.063	.065	.034	.580	.094	.124	.089	.50	.25	.75	.25
0B	.063	.065	.034	.580	.094	.124	.089	.50	.25	.75	.25
1A	.063	.065	.034	.580	.094	.124	.089	.50	.25	.75	.25
1B	.063	.065	.034	.580	.094	.124	.089	.50	.25	.75	.25
2A	.048	.055	.027	.450	.079	.084	.089	.45	.25	.65	.25
2B	.048	.055	.027	.450	.079	.084	.089	.45	.25	.65	.25
3A	.048	.055	.027	.197	.069	.084	.089	.42	.25	.55	.25
3B	.048	.055	.027	.197	.069	.084	.089	.42	.25	.55	.25
3C	.048	.055	.027	.197	.069	.084	.089	.42	.36	.55	.36

Zone	Roof-IAD	Roof-MB	Roof-Attic	Wall-Mass	Wall-MB	Wall-SF	Wall-WF	Fen-U	Fen-SHGC	Sky-U	Sky-SHGC
4A	.039	.047	.024	.151	.057	.064	.064	.38	.38	.50	.40
4B	.039	.047	.024	.151	.057	.064	.064	.38	.38	.50	.40
4C	.039	.047	.024	.151	.057	.064	.064	.38	.39	.50	.40
5A	.032	.037	.021	.123	.057	.055	.051	.36	.40	.50	.40
5B	.032	.037	.021	.123	.057	.055	.051	.36	.40	.50	.40
5C	.032	.037	.021	.123	.057	.055	.051	.36	.40	.50	.40
6A	.028	.031	.017	.104	.052	.049	.045	.34	.40	.50	.40
6B	.028	.031	.017	.104	.052	.049	.045	.34	.40	.50	.40
7	.028	.029	.017	.090	.047	.042	.042	.32	.45	.50	.40
8	.028	.029	.017	.080	.039	.037	.037	.30	.45	.50	.40

Legend: IAD = Insulation Above Deck, MB = Metal Building, SF = Steel Framed, WF = Wood Framed, Fen = Fenestration, Sky = Skylight. All U-factors in Btu/h-ft2-F.

Complete Title 24 Climate Zone Descriptions

CZ	City	Latitude	Elevation	Summer Design DB	Winter Design DB	Annual HDD65	Annual CDD65	Primary Concern
1	Arcata	40.98N	217 ft	64 F	35 F	4,900	0	Heating
2	Santa Rosa	38.51N	125 ft	90 F	30 F	3,200	500	Heating/Cooling
3	Oakland	37.73N	6 ft	82 F	36 F	2,800	100	Mild
4	San Jose	37.36N	62 ft	92 F	32 F	2,500	700	Cooling
5	Santa Maria	34.90N	238 ft	80 F	32 F	3,000	100	Heating
6	Los Angeles	33.94N	97 ft	86 F	41 F	1,200	400	Cooling
7	San Diego	32.73N	13 ft	83 F	43 F	1,000	300	Mild/Cooling
8	Fullerton	33.88N	97 ft	98 F	35 F	1,400	1,200	Cooling
9	Pasadena	34.15N	864 ft	100 F	35 F	1,600	1,500	Cooling
10	Riverside	33.95N	840 ft	104 F	32 F	1,600	2,000	Cooling
11	Red Bluff	40.15N	342 ft	106 F	28 F	2,800	2,200	Heating/Cooling
12	Sacramento	38.51N	17 ft	102 F	30 F	2,600	1,600	Cooling
13	Fresno	36.77N	328 ft	106 F	28 F	2,500	2,400	Cooling
14	Palmdale	34.63N	2,543 ft	106 F	22 F	3,500	2,500	Heating/Cooling

CZ	City	Latitude	Elevation	Summer Design DB	Winter Design DB	Annual HDD65	Annual CDD65	Primary Concern
15	Palm Springs	33.83N	411 ft	115 F	32 F	1,200	4,800	Extreme Cooling
16	Blue Canyon	39.28N	5,280 ft	88 F	12 F	5,800	400	Heating

13. Abbreviations

Abbreviation	Definition
ACM	Alternative Calculation Method
AFUE	Annual Fuel Utilization Efficiency
AHJ	Authority Having Jurisdiction
AHU	Air Handling Unit
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ATFP	Antiterrorism/Force Protection
BAS	Building Automation System
bhp	Brake Horsepower
CAV	Constant Air Volume
CBECC	California Building Energy Code Compliance
CBR/CBRN	Chemical, Biological, Radiological (Nuclear)
CEC	California Energy Commission
CFM	Cubic Feet per Minute
ci	Continuous Insulation
CMU	Concrete Masonry Unit
CO2	Carbon Dioxide
COLPRO	Collective Protection
COP	Coefficient of Performance
CZ	Climate Zone
DB	Dry Bulb
DCV	Demand-Controlled Ventilation
DOAS	Dedicated Outdoor Air System
DOD	Department of Defense

Abbreviation	Definition
DP	Dew Point
ECA	Energy Compliance Analysis
ECB	Energy Cost Budget
ECM	Electronically Commutated Motor
EER	Energy Efficiency Ratio
ERV	Energy Recovery Ventilator
Et	Thermal Efficiency
FDD	Fault Detection and Diagnostics
HDD	Heating Degree Days
HEPA	High Efficiency Particulate Air
HERS	Home Energy Rating System
HP	Horsepower
HRV	Heat Recovery Ventilator
HSPF	Heating Seasonal Performance Factor
HVAC	Heating, Ventilation, and Air Conditioning
IECC	International Energy Conservation Code
IEER	Integrated Energy Efficiency Ratio
IGU	Insulated Glazing Unit
IPLV	Integrated Part Load Value
kW	Kilowatt
LOP	Level of Protection
LPD	Lighting Power Density
MBH	Thousand BTU per Hour
MERV	Minimum Efficiency Reporting Value
NFRC	National Fenestration Rating Council
NPS	Nominal Pipe Size
NRCC	Nonresidential Certificate of Compliance
OA	Outdoor Air
OAT	Outdoor Air Temperature
OSB	Oriented Strand Board
PE	Professional Engineer
PF	Projection Factor

Abbreviation	Definition
PRM	Performance Rating Method
PTAC	Packaged Terminal Air Conditioner
PTHP	Packaged Terminal Heat Pump
PSZ	Packaged Single Zone
PVAV	Packaged Variable Air Volume
RA	Return Air
RTU	Rooftop Unit
SAT	Supply Air Temperature
SCIF	Sensitive Compartmented Information Facility
SEER	Seasonal Energy Efficiency Ratio
SF	Square Feet
SHGC	Solar Heat Gain Coefficient
SP	Static Pressure
SRI	Solar Reflectance Index
SRR	Skylight-to-Roof Ratio
SWH	Service Water Heating
TDV	Time Dependent Valuation
UFC	Unified Facilities Criteria
VAV	Variable Air Volume
VLT	Visible Light Transmittance
W/CFM	Watts per Cubic Foot per Minute
WWR	Window-to-Wall Ratio
XPS	Extruded Polystyrene

This guide was prepared for use with J∆S Engineering Suite v1.2 by JS Engineering Solutions. Refer to ASHRAE Standard 90.1-2022, California Title 24-2022 Part 6, and the applicable UFC documents for authoritative code language. Software calculations should be verified by a licensed professional engineer before submittal to the authority having jurisdiction.