

JΔS Engineering Suite

Module Guide: Energy Analysis

Version 1.2 — April 2026
JS Engineering Solutions

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1. Opening the Module

1.1 From the Dashboard

After launching the JΔS Engineering Suite with `python launcher.py` and completing login, the main dashboard appears. The dashboard displays a grid of module tiles organized by category. To reach Energy Analysis:

1. **Locate the sidebar.** On the left edge of the main window you will see a vertical list of tool categories. Each category can be expanded by clicking its label. The categories include headings such as "Load Calculations," "HVAC Systems," "Energy & Compliance," "Reports," and others.
2. **Expand "Energy & Compliance."** Click this category heading. The list expands to reveal sub-items including "Energy Simulation," "ASHRAE 90.1 Compliance," "Title 24 Compliance," "LEED Calculator," and others.

3. Click **"Energy Simulation."** This opens the Energy Analysis module in the main content area of the application window. The module occupies the full right-hand pane and presents a tabbed interface.

1.2 From the Menu Bar

Alternatively, use the top menu bar:

1. Click **Tools** in the menu bar.
2. Hover over **Energy & Compliance**.
3. Click **Energy Simulation (8760-Hour)**.

1.3 Module Layout

When the Energy Analysis module opens, you will see the following tabs across the top of the content area:

Tab	Purpose
Building Setup	Define or import the building configuration, floor area, location, and design loads
HVAC System	Specify cooling type, heating type, efficiencies, fan and pump characteristics
Schedules	Set occupied/unoccupied hours, holiday calendars, diversity factors by hour
Utility Rates	Enter electric energy rates, demand charges, gas rates, and time-of-use schedules
Run Simulation	Execute the 8760-hour simulation and view progress
Results	View monthly bar charts, annual summary tables, hourly heat maps, and load duration curves
Compliance	Run ASHRAE 90.1 Appendix G or Title 24 performance comparisons
ECM Analysis	Define and compare energy conservation measures with payback calculations
Export	Generate PDF reports, Excel workbooks, CSV data files, or JSON output

Below the tabs, each section contains input fields with labels, units, and built-in validation. Required fields are marked with an asterisk. Default values are pre-populated based on the selected building type and location.

1.4 Prerequisite: Existing Load Calculation

The Energy Analysis module works best when linked to an existing load calculation project. If you have already completed a room load calculation in the JΔS Engineering Suite, you can import those results directly:

1. On the **Building Setup** tab, click the **Import from Project** button.
2. A file dialog opens showing `.mep` project files in your project directory.
3. Select the project file. The module auto-populates floor area, design cooling load (BTU/hr), design heating load (BTU/hr), design airflow (CFM), envelope UA (BTU/hr-F), internal gains, lighting power density, and equipment power

density from the saved project.

If you do not have an existing load calculation, you can enter these values manually on the Building Setup tab. The module will estimate missing values based on building type and floor area.

2. Why Energy Analysis Matters

2.1 Code Compliance

Nearly every jurisdiction in the United States requires whole-building energy analysis for commercial construction permits. The two dominant compliance frameworks are:

ASHRAE 90.1-2022 Appendix G (Performance Rating Method). This is the national energy standard adopted by reference in the International Energy Conservation Code (IECC) and used in most states outside California. The Performance Rating Method requires a computer simulation that compares the proposed building design against a code-minimum baseline building. The proposed design must demonstrate lower annual energy cost than the baseline. Section 7 of this guide covers Appendix G in detail.

California Title 24-2022 (Building Energy Efficiency Standards). California requires its own energy code compliance using the Alternative Calculation Method (ACM). The performance path uses Time-Dependent Valuation (TDV) to weight energy consumption by the hour of the day and season, reflecting the true cost and carbon intensity of energy on the California grid. Section 8 of this guide covers the Title 24 performance path.

Both compliance paths require an 8760-hour simulation. The JΔS Engineering Suite performs both analyses using the same underlying simulation engine (`energy_simulation.py`), with compliance-specific output formatting for each code.

2.2 LEED Certification

LEED v4.1 Building Design and Construction awards up to 18 points under the Energy and Atmosphere (EA) prerequisite and credit categories. The primary credit, "Optimize Energy Performance," requires a whole-building energy simulation per ASHRAE 90.1 Appendix G. Points are awarded based on the percentage improvement in energy cost over the baseline:

Cost Improvement over Baseline	Points (New Construction)	Points (Major Renovation)
5%	1	1
7%	2	2
9%	3	3
11%	4	4
13%	5	5
15%	6	6
17%	7	7
19%	8	8
21%	9	9

Cost Improvement over Baseline	Points (New Construction)	Points (Major Renovation)
23%	10	10
25%	11	11
29%	12	12
33%	13	13
37%	14	14
41%	15	15
45%	16	16
48%	17	17
50%	18	18

The JΔS Engineering Suite automatically calculates the percentage improvement and reports the corresponding LEED point count on the Compliance tab.

2.3 Utility Incentives

Many utilities offer energy efficiency incentive programs that require energy modeling to qualify. Common programs include:

- **New construction incentives.** Utilities pay \$0.05 to \$0.20 per kWh of annual savings below code baseline. A 100,000 SF office saving 200,000 kWh/year could receive \$10,000 to \$40,000 in incentive payments.
- **Demand response enrollment.** Buildings with energy models demonstrating load-shifting capability may qualify for demand response programs paying \$50 to \$200 per kW of curtailable load per year.
- **Custom measure rebates.** For non-standard ECMs (ground-source heat pumps, thermal storage, radiant cooling), utilities require energy modeling to calculate savings and determine rebate amounts.

The JΔS Engineering Suite export formats (PDF, Excel) are designed to meet the documentation requirements of major utility incentive programs including those offered by SDG&E, SCE, PG&E, Con Edison, ComEd, Duke Energy, and others.

2.4 Owner Operating Cost Predictions

Before committing to a mechanical system design, building owners need to understand the annual operating cost implications. A water-cooled chiller plant with variable-speed drives may cost \$500,000 more to install than packaged rooftop units, but if it saves \$60,000 per year in energy, the 8.3-year simple payback may be acceptable for an owner planning to hold the building for 20 years.

The JΔS Engineering Suite calculates annual energy cost by end use (cooling, heating, fans, pumps, lighting, equipment) and by rate component (energy charges, demand charges, gas commodity). This breakdown enables informed decision-making during the design phase when changes are inexpensive compared to construction-phase modifications.

2.5 Carbon Reporting

Corporate sustainability reporting, SEC climate disclosure rules, and local building performance standards (such as New York City Local Law 97 and Washington DC BEPS) all require quantification of building greenhouse gas emissions. The

JΔS Engineering Suite calculates:

- **Scope 1 emissions.** Direct emissions from on-site fuel combustion (natural gas, propane, oil). Calculated using EPA emission factors (e.g., 117 lb CO₂ per MMBtu of natural gas, equivalent to 11.7 lb CO₂ per therm).
- **Scope 2 emissions.** Indirect emissions from purchased electricity. Calculated using EPA eGRID subregional emission factors that vary by location (e.g., 0.35 lb CO₂/kWh in California CAMX subregion, 0.85 lb CO₂/kWh national average).
- **Total carbon intensity.** Expressed in kg CO₂ per square foot per year, enabling comparison against carbon budgets and reduction targets.

3. 8760-Hour Simulation Overview

3.1 What "8760" Means

A standard year contains 365 days multiplied by 24 hours per day, which equals 8,760 hours. An 8760-hour energy simulation calculates the building's energy consumption for every single hour of the year. This level of granularity is essential because:

- **Weather varies hour by hour.** Outdoor temperature at 3 PM in August is very different from 3 AM in January. The simulation captures these variations using real weather data.
- **Building loads change throughout the day.** Occupants arrive in the morning, lights turn on, computers generate heat, the sun moves across the sky. Each of these factors changes the heating and cooling load every hour.
- **Equipment efficiency depends on operating conditions.** A chiller running at 25% capacity has different efficiency than one running at 100% capacity. An economizer eliminates mechanical cooling during mild hours. Only an hourly simulation captures these dynamics accurately.
- **Utility rates vary by time of day.** Many commercial electricity rates have on-peak, mid-peak, and off-peak pricing. Demand charges apply to the highest 15-minute peak in each billing period. Accurate cost calculation requires hourly granularity.

3.2 Weather Data: TMY3 Format

The simulation uses Typical Meteorological Year (TMY3) weather data published by the National Renewable Energy Laboratory (NREL). TMY3 files contain hourly weather observations for a "typical" year constructed by selecting the most representative month from a multi-decade historical record. Each TMY3 file contains 8,760 rows (one per hour) with the following fields used by the simulation:

Field	Description	Units	Example (San Diego, July noon)
Dry-bulb temperature	Outdoor air temperature	Degrees F	78.1
Wet-bulb temperature	Temperature at 100% humidity at same enthalpy	Degrees F	66.4
Relative humidity	Moisture content as percentage of saturation	Percent	62

Field	Description	Units	Example (San Diego, July noon)
Global horizontal solar radiation	Total solar energy on a horizontal surface	BTU/hr-ft2	285
Direct normal solar radiation	Solar energy perpendicular to sun rays	BTU/hr-ft2	240
Wind speed	Horizontal wind speed at 10 m height	mph	7.2
Wind direction	Compass direction of wind origin	Degrees	270

How the software selects the correct weather file. When you set the project location (city and state) on the Building Setup tab, the JΔS Engineering Suite searches its internal weather database (*weather.py*), which contains data for 523 US locations. The software matches the city and state to the nearest TMY3 station. If an exact match is not found, it selects the closest station by latitude and longitude. The selected station name and distance are displayed on the Building Setup tab for verification.

The weather module (*weather.py*) can also load weather files from external sources if you have a custom TMY3 or EPW file for a specific location. Click **Load Custom Weather File** on the Building Setup tab to import an external file.

3.3 Hourly Load Profile

The building's heating and cooling loads are not constant; they vary dramatically by hour based on several time-varying factors:

Occupancy schedules. During occupied hours (typically 7 AM to 6 PM weekdays for offices), people generate sensible heat (approximately 250 BTU/hr per person) and latent heat (approximately 200 BTU/hr per person). During unoccupied hours, these gains drop to zero (or to a small fraction representing security staff or cleaning crews). The JΔS Engineering Suite applies a schedule factor of 1.0 during occupied hours and 0.3 during unoccupied hours for internal gains.

Solar position. As the sun moves across the sky, solar heat gains through windows and onto the roof change continuously. East-facing windows receive peak solar gain in the morning. West-facing windows receive peak solar gain in the afternoon. The simulation uses hourly solar radiation data from the TMY3 file and applies it using a simplified solar gain model:

$$\text{Solar gain (BTU/hr)} = \text{Floor area (ft}^2\text{)} \times 5.0 \text{ (BTU/hr-ft}^2\text{)} \times (\text{Solar radiation} / 300)$$

This approximation normalizes peak solar radiation to produce roughly 5 BTU/hr per square foot of floor area at peak conditions, which is consistent with typical commercial buildings with 40% window-to-wall ratio.

Outdoor temperature. The temperature difference between outdoors and the indoor setpoint drives envelope heat transfer. The hourly envelope load is calculated as:

$$\text{Envelope load (BTU/hr)} = UA \text{ (BTU/hr-F)} \times |T_{\text{outdoor}} - T_{\text{indoor}}|$$

Where UA is the overall heat transfer coefficient times the total envelope area, which accounts for walls, windows, roof, and floor assemblies weighted by their respective U-factors and areas.

3.4 Building Schedules

The JΔS Engineering Suite uses the following schedule framework for commercial buildings:

Occupied hours. Default is 7:00 AM to 6:00 PM (hours 7 through 17 in 24-hour format). During these hours:

- Lighting operates at 100% of installed power
- Equipment (plug loads) operates at 100% of installed power
- Occupancy is at 100% of design population
- HVAC system operates in "occupied" mode with full ventilation

Unoccupied hours. From 6:00 PM to 7:00 AM. During these hours:

- Lighting operates at 15% of installed power (security and egress lighting)
- Equipment operates at 25% of installed power (always-on devices such as servers, refrigerators, emergency systems)
- Occupancy is at 0% (or a small percentage for security/cleaning)
- HVAC system operates in "unoccupied" mode with setback temperatures and minimum ventilation

Weekdays vs. weekends. Default occupied days are Monday through Friday (day-of-week indices 0 through 4). Saturdays and Sundays follow the unoccupied schedule all day.

Holidays. The Schedules tab allows you to define up to 15 holiday dates per year. On holidays, the building follows the unoccupied schedule regardless of the day of the week.

Custom schedules by hour. For buildings with non-standard operating patterns (hospitals operating 24/7, retail with evening hours, schools with summer shutdown), the Schedules tab provides an hourly schedule editor. You can set a diversity factor (0.0 to 1.0) for each hour of the day, separately for weekdays, Saturdays, and Sundays.

4. Step-by-Step: Setting Up a Simulation

4.1 Step 1 -- Select or Create the Building

On the **Building Setup** tab:

- 1. Building name.** Enter a descriptive name for the building (e.g., "Oceanside Corporate Center"). This name appears on all reports and exports.
- 2. Floor area (SF).** Enter the gross conditioned floor area in square feet. This is the total area of all conditioned floors, measured to the exterior face of exterior walls. Example: 100,000 SF.
- 3. Number of floors.** Enter the total number of above-grade conditioned floors. The module uses this to estimate building geometry (perimeter length, wall area, roof area). Example: 4.
- 4. Building type.** Select from the dropdown menu. Options include: Office, Hospital, Retail, School, Warehouse, Hotel, Restaurant, Laboratory, Data Center, Assembly, Residential, and others. The selected building type sets default values for lighting power density, equipment power density, occupancy density, and operating schedules. Example: Office.
- 5. Location -- City.** Enter the city name. Example: San Diego.
- 6. Location -- State.** Enter the two-letter state abbreviation. Example: CA.

7. After entering city and state, click **Fetch Weather Data** or the location will auto-populate when you tab to the next field. The module displays:

- ASHRAE climate zone (e.g., "3B" for San Diego)
- Cooling design dry-bulb temperature, 0.4% (e.g., 89 F)
- Cooling design wet-bulb temperature (e.g., 69 F)
- Heating design dry-bulb temperature, 99.6% (e.g., 44 F)
- Elevation (e.g., 30 ft)
- TMY3 station name and ID

8. Indoor cooling setpoint (F). Default is 75 F. Acceptable range: 70 to 80 F. This is the space temperature the cooling system maintains during occupied hours.

9. Indoor heating setpoint (F). Default is 70 F. Acceptable range: 65 to 72 F. This is the space temperature the heating system maintains during occupied hours.

10. Import from Project (optional). Click this button to import design loads, envelope characteristics, and internal gains from an existing `.mep` project file. This populates the following fields automatically:

- Design cooling load (BTU/hr)
- Design heating load (BTU/hr)
- Design cooling airflow (CFM)
- Envelope UA (BTU/hr-F)
- Internal gains at design (BTU/hr)
- Lighting power density (W/SF)
- Equipment power density (W/SF)

If you do not import from a project, the module estimates these values using rules of thumb:

- Cooling load: 20 to 50 BTU/hr per SF, scaled by the temperature difference between outdoor design and indoor setpoint
- Heating load: 15 to 45 BTU/hr per SF, scaled similarly
- Airflow: 1.0 CFM per SF, adjusted for altitude
- Envelope UA: calculated from estimated wall area (40% window-to-wall ratio), roof area, and code-typical U-factors
- Internal gains: approximately 18 BTU/hr per SF (combined lighting, equipment, and people)

4.2 Step 2 -- Verify or Configure the HVAC System

Switch to the **HVAC System** tab:

1. Cooling system type. Select from the dropdown:

- Air-Cooled Chiller (default efficiency: 1.2 kW/ton)
- Water-Cooled Chiller (default efficiency: 0.65 kW/ton)
- DX Air-Cooled (default efficiency: 1.1 kW/ton)
- DX Water-Cooled (default efficiency: 0.9 kW/ton)
- Variable Refrigerant Flow / VRF (default efficiency: 0.9 kW/ton)

- Air-Source Heat Pump (default efficiency: 1.0 kW/ton)
- Water-Source Heat Pump (default efficiency: 0.7 kW/ton)
- Ground-Source Heat Pump (default efficiency: 0.5 kW/ton)
- Evaporative Cooling (default efficiency: 0.15 kW/ton)
- Absorption Chiller (default efficiency: 1.4 kW/ton)

2. Cooling capacity (BTU/hr). Auto-populated from the building's design cooling load. Override if the installed equipment differs from the calculated load (e.g., equipment is sized 10% above design load).

3. Cooling efficiency (kW/ton). The default value is set based on the selected cooling type. Override this with the actual equipment rating from the manufacturer's submittal data. Lower kW/ton values indicate higher efficiency. For reference:

- 0.50 kW/ton = very high efficiency water-cooled centrifugal chiller (Trane CenTraVac, Carrier 19XR)
- 0.65 kW/ton = standard efficiency water-cooled chiller (ASHRAE 90.1 minimum for IPLV Path B)
- 0.95 kW/ton = code minimum for water-cooled chiller full load (Path A, 150-300 tons)
- 1.20 kW/ton = typical air-cooled chiller or air-cooled DX

4. Heating system type. Select from the dropdown:

- Gas Boiler (default thermal efficiency: 82%)
- Condensing Gas Boiler (default thermal efficiency: 95%)
- Electric Boiler (efficiency: 100%)
- Gas Furnace (default AFUE: 80%)
- Electric Furnace (efficiency: 100%)
- Air-Source Heat Pump (default COP: 2.5)
- Water-Source Heat Pump (default COP: 4.0)
- Ground-Source Heat Pump (default COP: 4.5)
- Electric Resistance (efficiency: 100%)
- District Heat (default efficiency: 90%)

5. Heating fuel type. Select: Natural Gas, Electric, Propane, Oil, or District. This determines whether heating energy is reported in therms (gas) or kWh (electric).

6. Heating capacity (BTU/hr). Auto-populated from the building's design heating load.

7. Heating efficiency. Enter the thermal efficiency (0 to 1 for combustion equipment) or COP (typically 2.0 to 5.0 for heat pumps). The default is set based on the selected heating type.

8. Supply fan brake horsepower (BHP). If known from the AHU schedule, enter the total supply fan BHP. If left at 0, the module estimates fan BHP based on airflow and a default fan power allowance of 0.65 W/CFM.

9. Supply fan airflow (CFM). Auto-populated from the building's design cooling airflow. Override if the actual AHU supply airflow differs.

10. VAV system. Check this box if the air distribution system uses Variable Air Volume. When checked, the simulation applies the fan affinity law to calculate fan energy at part-load conditions: $Power = (Speed\ Ratio)^3 \times Full\ Load\ Power$. When unchecked (constant volume), the fan runs at full power whenever the system is operating.

- 11. Chilled water pump BHP.** Enter the total chilled water pump brake horsepower. Applies only to chilled water systems.
- 12. Hot water pump BHP.** Enter the total hot water pump brake horsepower. Applies only to hydronic heating systems.
- 13. Condenser water pump BHP.** Enter the total condenser water pump brake horsepower. Applies only to water-cooled chillers.
- 14. Variable speed pumping.** Check this box if the pumps have variable-frequency drives. When checked, the simulation applies the pump affinity law (cube law) at part-load conditions. When unchecked, pumps run at full power whenever the associated equipment is operating.

4.3 Step 3 -- Set Utility Rates

Switch to the **Utility Rates** tab:

- 1. Electric energy rate (\$/kWh).** Enter the blended electricity cost per kilowatt-hour. This should include generation, transmission, distribution, and all surcharges. For simple analysis, enter a single flat rate. Example: \$0.28/kWh for SDG&E commercial service.
- 2. Time-of-use rates (optional).** Click **Enable TOU Rates** to enter separate rates for on-peak, mid-peak, and off-peak periods:
 - On-peak rate (\$/kWh): Example \$0.42/kWh, applicable 4 PM to 9 PM weekdays (summer)
 - Mid-peak rate (\$/kWh): Example \$0.30/kWh, applicable 7 AM to 4 PM and 9 PM to 11 PM weekdays
 - Off-peak rate (\$/kWh): Example \$0.18/kWh, applicable 11 PM to 7 AM weekdays and all weekend hours
 - Season definitions: Summer (June through September) and Winter (October through May) with separate rate tiers
- 3. Electric demand charge (\$/kW/month).** Enter the demand charge applied to the highest 15-minute peak demand reading in each billing period. Example: \$22.00/kW/month for SDG&E commercial service.
- 4. Natural gas rate (\$/therm).** Enter the commodity cost per therm including all delivery and surcharges. Example: \$1.20/therm for SDG&E commercial gas service.
- 5. Rate escalation (optional).** Enter an annual percentage increase to project future energy costs for life-cycle cost analysis. Default is 2.5% per year based on EIA projections.

4.4 Step 4 -- Configure Schedules

Switch to the **Schedules** tab:

- 1. Occupied start hour.** Default is 7 (7:00 AM). Enter the hour (0-23) when the building transitions from unoccupied to occupied mode.
- 2. Occupied end hour.** Default is 18 (6:00 PM). Enter the hour when the building transitions from occupied to unoccupied mode.
- 3. Occupied days.** Check boxes for each day of the week that is considered a normal operating day. Default: Monday through Friday checked.
- 4. Hourly diversity factors.** An advanced table allows you to set a diversity multiplier (0.0 to 1.0) for each hour of the day. The default profile for an office building is:

Hour	Diversity Factor	Description
0-5	0.00	Unoccupied overnight
6	0.10	Early morning warm-up
7	0.50	Staff arriving
8	0.90	Near full occupancy
9-11	1.00	Full occupancy
12	0.80	Lunch hour
13-16	1.00	Full occupancy afternoon
17	0.70	Staff departing
18	0.30	Cleaning crew
19-23	0.05	Security only

5. Holiday calendar. Click **Add Holiday** to enter specific dates. On holidays the building follows the unoccupied profile.

4.5 Step 5 -- Run the Simulation

Switch to the **Run Simulation** tab:

1. Verify the summary panel on the left, which displays the key inputs:

- Building: [name], [floor area] SF, [floors] floors
- Location: [city, state], Climate Zone [zone]
- Cooling: [type] at [efficiency] kW/ton
- Heating: [type] at [efficiency]
- Weather: [station name], [year]

2. Click the **Run 8760-Hour Simulation** button.

3. A progress bar appears showing completion percentage. The simulation processes 8,760 hourly calculations.

Typical run time:

- Standard mode (Python): 5 to 15 seconds for a single building
- Accelerated mode (Numba JIT): 0.5 to 3 seconds for a single building
- Appendix G compliance (4 baseline rotations + 1 proposed): 25 to 75 seconds standard, 3 to 15 seconds accelerated

4. When the simulation completes, the **Results** tab automatically activates and displays the output charts and tables.

If the Numba acceleration library is installed, the simulation engine automatically uses JIT-compiled functions (`numba_accelerated.py`) for the 8,760-hour loop, providing 5 to 20 times faster performance. The status bar displays "Numba: Available" or "Numba: Not Available" to indicate which mode is active.

5. Simulation Engine Details

5.1 Hour-by-Hour Calculation Flow

For each of the 8,760 hours, the simulation engine (`EnergySimulationEngine` class in `energy_simulation.py`) executes the following calculation chain:

```
Step 1: Weather lookup
Read outdoor dry-bulb, wet-bulb, solar radiation, wind speed from TMY3 data

Step 2: Schedule determination
Determine hour of day, day of week
Set is_occupied flag (True/False)
Set schedule_factor (1.0 occupied, 0.3 unoccupied)

Step 3: Envelope load calculation
DT_cooling = T_outdoor - T_indoor_cooling
DT_heating = T_indoor_heating - T_outdoor
Envelope_load = UA x |DT|

Step 4: Internal gains
Internal_gains = Design_internal_gains x schedule_factor

Step 5: Solar gains
Solar_factor = Solar_radiation / 300
Solar_gain = Floor_area x 5.0 x Solar_factor

Step 6: Net load determination
If T_outdoor > T_cooling_setpoint - 5F (cooling deadband):
Cooling_load = Envelope_gain + Internal_gains + Solar_gain
Cooling_load = min(Cooling_load, Design_cooling_capacity)
If T_outdoor < T_heating_setpoint + 5F (heating deadband):
Heating_load = Envelope_loss - 0.3 x Internal_gains
Heating_load = min(Heating_load, Design_heating_capacity)
If both cooling and heating: choose the larger load, set the other to zero

Step 7: Part-load ratio
Cooling PLR = Cooling_load / Design_cooling_capacity
Heating PLR = Heating_load / Design_heating_capacity

Step 8: Equipment energy consumption
Cooling kWh = f(Cooling_load, PLR, efficiency, outdoor conditions)
Heating energy = f(Heating_load, PLR, efficiency, fuel type)
Fan kWh = f(airflow, PLR, VAV vs CV, motor efficiency)
Pump kWh = f(flow, PLR, variable vs constant speed, motor efficiency)

Step 9: Non-HVAC energy
Lighting kWh = LPD x Area / 1000 x lighting_schedule_factor
Equipment kWh = EPD x Area / 1000 x equipment_schedule_factor

Step 10: Peak demand tracking
Total kW = cooling kW + heating kW + fan kW + pump kW + lighting kW + equipment kW
Update monthly peak if this hour exceeds previous maximum

Step 11: Accumulate monthly totals
Add hourly values to the running monthly sums

Step 12: Degree day tracking
If T_outdoor < 65F: HDD += (65 - T_outdoor) / 24
If T_outdoor > 65F: CDD += (T_outdoor - 65) / 24
```

5.2 Part-Load Performance Curves

Real equipment does not operate at a single fixed efficiency. Efficiency varies with the fraction of full-load capacity the equipment is delivering at any given hour. This fraction is called the Part-Load Ratio (PLR):

$$PLR = \text{Actual hourly load} / \text{Design full-load capacity}$$

The simulation uses part-load curves that map PLR to an efficiency multiplier. The default cooling curve (representing a typical centrifugal or screw chiller) is:

PLR	Efficiency Multiplier	Meaning
0.0	0.00	Equipment off
0.1	0.40	At 10% load, chiller uses 40% of the kW it would need per ton at full load
0.2	0.55	
0.3	0.70	
0.4	0.80	
0.5	0.85	
0.6	0.90	
0.7	0.94	
0.8	0.97	
0.9	0.99	
1.0	1.00	Full load, full rated efficiency

What this means in practice: A chiller rated at 0.65 kW/ton at full load, operating at 50% PLR, consumes:

$$\text{Actual kW/ton} = 0.65 \times 0.85 = 0.553 \text{ kW/ton}$$

Modern centrifugal chillers with VFD compressors actually have better efficiency at part load (the curve would invert), and the software supports custom PLR curves imported from manufacturer performance data.

The default heating curve for boilers shows reduced efficiency at low part loads (cycling losses, standby losses):

PLR	Efficiency Multiplier
0.0	0.00
0.1	0.70
0.2	0.78
0.3	0.84
0.5	0.91
0.7	0.96
1.0	1.00

A boiler rated at 95% thermal efficiency operating at 30% PLR actually delivers:

$$\text{Effective efficiency} = 0.95 \times 0.84 = 0.798 \text{ (79.8\%)}$$

5.3 Economizer Hours

An airside economizer uses outdoor air for free cooling when conditions permit. The simulation determines economizer availability each hour:

- **Dry-bulb economizer (default).** Free cooling is available when the outdoor dry-bulb temperature is below the economizer high limit (default 75 F) AND the outdoor temperature is below the return air temperature (typically 75 F).
- **Differential enthalpy economizer.** Free cooling is available when the outdoor air enthalpy is below the return air enthalpy. This is more efficient in humid climates.

In San Diego (ASHRAE Climate Zone 3B/3C), a dry-bulb economizer typically provides 2,800 to 3,500 hours of free cooling per year. During economizer hours, the mechanical cooling system is off (chiller kW = 0), but the supply fan runs at higher airflow to deliver the increased outdoor air quantity, so fan energy increases slightly.

5.4 Fan Energy Calculation

Fan energy is calculated differently depending on whether the system is VAV or constant volume:

Variable Air Volume (VAV) systems. The fan affinity laws govern fan power at reduced airflow. The third affinity law states that fan power varies with the cube of the speed (or flow) ratio:

$$\begin{aligned} \text{Fan power at part load} &= \text{Full load BHP} \times (\text{Airflow ratio})^3 \\ \text{Fan kW} &= \text{Fan BHP} \times 0.746 / \text{Motor efficiency} \times (\text{PLR})^3 \end{aligned}$$

Where:

- 0.746 converts BHP to kW
- Motor efficiency is typically 0.93 for premium-efficiency motors
- PLR approximates the airflow ratio (VAV boxes modulate from minimum ~30% to maximum 100%)

In practice, VFD-driven fans have a minimum speed (typically 20-30% of full speed) below which the fan cannot operate efficiently. The simulation enforces a minimum fan power of approximately 10% of full load power to represent this floor.

Constant Volume (CV) systems. The fan operates at full speed whenever the system is running:

$$\text{Fan kW} = \text{Fan BHP} \times 0.746 / \text{Motor efficiency} \times 1.0 \text{ (always full speed)}$$

The only variation is that CV fans may cycle off during unoccupied hours if the system has a night setback mode.

If supply fan BHP is not entered by the user, the module estimates it from the airflow and a power allowance:

$$\text{Estimated fan BHP} = \text{CFM} \times 0.65 \text{ W/CFM} / 746 \text{ W/BHP}$$

Where 0.65 W/CFM is the ASHRAE 90.1-2022 fan power limitation for VAV systems (Section 6.5.3.1).

5.5 Pump Energy Calculation

Pump energy follows the same affinity law principles as fan energy:

Variable-speed pumps (VFD). Power varies with the cube of the flow ratio:

$$\text{Pump kW} = \text{Pump BHP} \times 0.746 / \text{Motor efficiency} \times (\text{Flow ratio})^3$$

The flow ratio for chilled water pumps is approximated by the cooling PLR. For condenser water pumps, flow is often constant (condenser water pumps typically run at full speed when the chiller is operating), but some systems use variable-speed condenser water pumps.

Constant-speed pumps. Power is constant whenever the pump is running:

$$\text{Pump kW} = \text{Pump BHP} \times 0.746 / \text{Motor efficiency}$$

5.6 Heating Energy Calculation

Heating energy depends on the fuel type:

Natural gas heating (boilers, furnaces):

$$\begin{aligned} \text{Gas input (BTU/hr)} &= \text{Heating load (BTU/hr)} / (\text{Thermal efficiency} \times \text{PLR multiplier}) \\ \text{Gas consumption (therms/hr)} &= \text{Gas input} / 100,000 \end{aligned}$$

Electric heating (electric boilers, resistance, heat pumps):

$$\text{Electric input (kW)} = \text{Heating load (BTU/hr)} / (3,412 \times \text{COP or efficiency})$$

For heat pumps, the COP degrades at lower outdoor temperatures. The simulation adjusts the heating COP based on outdoor temperature:

$$\text{COP at temperature} = \text{Rated COP} \times (T_{\text{outdoor}} + 459.67) / (47 + 459.67)$$

This simplified model approximates the Carnot cycle degradation. At 17 F outdoor temperature, a heat pump rated at COP 3.3 at 47 F operates at approximately COP 2.25.

5.7 Lighting Energy Calculation

Lighting energy is schedule-driven rather than weather-driven:

$$\begin{aligned} \text{Lighting kW (installed)} &= \text{Floor area (ft}^2\text{)} \times \text{LPD (W/ft}^2\text{)} / 1,000 \\ \text{Lighting kWh (hourly)} &= \text{Lighting kW} \times \text{Schedule factor} \end{aligned}$$

Schedule factors:

- Occupied hours: 1.0 (all lights on)
- Unoccupied hours: 0.15 (security and egress lighting only)

The Lighting Power Density (LPD) default values follow ASHRAE 90.1-2022 Table 9.5.1:

Building Type	LPD (W/SF)
Office	0.82
Retail	1.10
School	0.87
Hospital	1.00
Hotel	0.75
Warehouse	0.45
Restaurant	0.95

Building Type	LPD (W/SF)
Laboratory	1.30

5.8 Plug Load (Equipment) Energy Calculation

Equipment energy follows the same schedule-based approach:

$$\text{Equipment kW (installed)} = \text{Floor area (ft}^2\text{)} \times \text{EPD (W/ft}^2\text{)} / 1,000$$

$$\text{Equipment kWh (hourly)} = \text{Equipment kW} \times \text{Schedule factor}$$

Schedule factors:

- Occupied hours: 1.0
- Unoccupied hours: 0.25 (always-on equipment: servers, refrigerators, emergency systems)

Default Equipment Power Density (EPD) values:

Building Type	EPD (W/SF)
Office	1.50
Retail	0.50
School	0.75
Hospital	3.00
Hotel	0.80
Warehouse	0.20
Restaurant	2.00
Laboratory	4.00

6. Output Metrics Explained

6.1 EUI (Energy Use Intensity)

EUI is the single most important metric for comparing building energy performance. It normalizes total energy consumption by floor area, enabling meaningful comparison across buildings of different sizes.

Calculation:

$$\text{Site EUI (kBtu/SF/yr)} = (\text{Annual kWh} \times 3.412 + \text{Annual therms} \times 100) / \text{Floor area (SF)}$$

Conversion factors:

- 1 kWh = 3.412 kBtu (based on the thermodynamic equivalence of electrical energy)
- 1 therm = 100 kBtu (by definition; 1 therm = 100,000 BTU)

Benchmarks by building type (national averages from CBECS 2018 and ENERGY STAR):

Building Type	Typical EUI (kBtu/SF/yr)	ENERGY STAR Target	Net-Zero Target
Office	50 - 120	< 50	< 25
Retail	60 - 100	< 55	< 30
Hospital	150 - 300	< 180	< 80
School (K-12)	50 - 90	< 45	< 25
Hotel	70 - 130	< 75	< 35
Warehouse	20 - 50	< 25	< 15
Restaurant	200 - 400	< 250	N/A
Data Center	300 - 800	Varies by PUE	< 200

Site EUI vs. Source EUI. Site EUI measures energy consumed at the building. Source EUI accounts for energy losses in generation and distribution of electricity. The JΔS Engineering Suite calculates both:

$$\text{Source EUI} = (\text{Electric kBtu} \times 2.80 + \text{Gas kBtu} \times 1.05) / \text{Floor area}$$

Where 2.80 is the site-to-source ratio for electricity (national average) and 1.05 is the ratio for natural gas.

6.2 Annual Energy Cost

The annual energy cost combines all rate components:

$$\text{Annual cost} = (\text{Annual kWh} \times \$/\text{kWh}) + (\text{Sum of 12 monthly peak kW} \times \$/\text{kW}) + (\text{Annual therms} \times \$/\text{therm})$$

The JΔS Engineering Suite breaks this down by end use:

- Cooling cost = Cooling kWh x electric rate
- Heating cost = Heating therms x gas rate (or Heating kWh x electric rate for electric heating)
- Fan cost = Fan kWh x electric rate
- Pump cost = Pump kWh x electric rate
- Lighting cost = Lighting kWh x electric rate
- Equipment cost = Equipment kWh x electric rate
- Demand cost = Sum of 12 monthly peaks x demand rate

6.3 Peak Demand

Peak demand is the maximum instantaneous electrical load (in kW) recorded during a billing period. The simulation tracks the maximum kW for each month.

Why peak demand matters:

- Demand charges can represent 20-40% of a commercial electricity bill
- Peak demand determines the required electrical service size (amps, transformer kVA)
- Utilities use peak demand data for distribution system planning

When peak demand typically occurs:

- For cooling-dominated buildings: August, between 2 PM and 5 PM, when outdoor temperature peaks and all building systems are at maximum load
- For heating-dominated buildings: January, during morning warm-up (6 AM to 8 AM), when electric heat pumps operate at maximum output to recover from overnight setback

6.4 Carbon Emissions

Carbon dioxide equivalent (CO2e) emissions are calculated using fuel-specific emission factors:

Electricity emissions:

$$\text{CO}_2 \text{ (lb)} = \text{Annual kWh} \times \text{Grid emission factor (lb CO}_2\text{/kWh)}$$

Grid emission factors vary by location. The EPA eGRID database provides subregional factors:

eGRID Subregion	Representative States	Emission Factor (lb CO2/kWh)
CAMX (California)	CA	0.35
NWPP (Northwest)	WA, OR, ID, MT	0.30
RMPA (Rocky Mountain)	CO, WY	0.75
ERCT (Texas)	TX	0.70
SRSO (Southeast)	AL, GA, MS	0.80
RFCW (Midwest)	OH, IN, WV	0.90
NEWE (New England)	MA, CT, NH, ME, VT, RI	0.40
NYCW (New York)	NY	0.30
RFCE (Mid-Atlantic)	PA, NJ, DE, MD, DC	0.50
US National Average	All	0.85

Natural gas emissions:

$$\text{CO}_2 \text{ (lb)} = \text{Annual therms} \times 11.7 \text{ lb CO}_2\text{/therm}$$

This is equivalent to 117 lb CO2 per MMBtu, the EPA standard emission factor for natural gas combustion.

6.5 Monthly Energy Profile

The monthly bar chart displays electricity consumption (kWh) by end use for each month, with a separate indicator for natural gas (therms). Typical patterns to look for:

- **Cooling energy peaks in summer** (June-September in most US climates)
- **Heating energy peaks in winter** (December-February)
- **Lighting and equipment are relatively flat** month to month (schedule-driven, not weather-driven)
- **Fan energy shows slight seasonal variation** (higher in summer when VAV boxes open wider for cooling)

6.6 Load Duration Curve

The load duration curve sorts all 8,760 hourly total demand values from highest to lowest, creating a monotonically decreasing curve. Key insights:

- **The leftmost point** is the annual peak demand (kW)
- **The rightmost point** is the minimum demand (base load)
- **The area under the curve** represents total annual energy consumption (kWh)
- **A steep initial drop** indicates that peak loads occur for very few hours, suggesting demand management could be cost-effective
- **A flat curve** indicates relatively constant load, typical of data centers or 24/7 facilities

7. ASHRAE 90.1 Appendix G (Performance Rating Method)

7.1 Overview

ASHRAE Standard 90.1-2022 Appendix G defines the Performance Rating Method (PRM), which compares a proposed building design against a standardized baseline building. The key principle: both the baseline and proposed buildings have identical geometry, location, and occupancy, but they differ in envelope performance, HVAC system type and efficiency, lighting power density, and other energy-affecting features.

The JΔS Engineering Suite automates the Appendix G process through the `AppendixGBaselineGenerator` class in `energy_simulation.py` and the compliance checking in `compliance.py`.

7.2 How the Baseline Building Is Constructed

The baseline building is not the user's design. It is a hypothetical building that represents code-minimum construction for the same building type, size, and location. The software constructs the baseline as follows:

Geometry. The baseline has the same floor area, number of floors, floor-to-floor height, and window-to-wall ratio as the proposed building. Geometry is never modified.

Envelope. The baseline envelope uses the prescriptive U-factors and SHGC values from ASHRAE 90.1-2022 Table 5.5 for the project's climate zone. For example, in Climate Zone 3C (San Francisco):

- Roof U-factor: 0.048 BTU/hr-ft²-F
- Mass wall U-factor: 0.104 BTU/hr-ft²-F
- Steel-framed wall U-factor: 0.084 BTU/hr-ft²-F
- Window U-factor: 0.57 BTU/hr-ft²-F
- Window SHGC: 0.39
- Skylight U-factor: 0.65 BTU/hr-ft²-F

HVAC system type. The baseline HVAC system is determined by building type, size, and heating fuel per Table G3.1.1A and G3.1.1B:

Building Category	Fossil Heating	Electric Heating
Residential, any size	System 1: PTAC + Gas Furnace	System 2: PTHP
Nonresidential, < 3 floors AND < 25,000 SF	System 3: PSZ-AC + Gas Furnace	System 4: PSZ Heat Pump
Nonresidential, >= 3 floors OR >= 25,000 SF	System 7: VAV + Chiller + Boiler	System 8: VAV + Chiller + Electric Reheat

The JΔS Engineering Suite implements this lookup table in the `APPENDIX_G_BASELINE_SYSTEMS` dictionary and the `get_baseline_hvac_system()` method.

Equipment efficiency. Baseline equipment operates at the minimum efficiency allowed by ASHRAE 90.1-2022:

Equipment	Baseline Efficiency
Water-cooled chiller (full load)	0.700 kW/ton

Equipment	Baseline Efficiency
Water-cooled chiller (IPLV, Path A)	0.610 kW/ton
Air-cooled chiller (full load)	1.256 kW/ton
DX air-cooled (EER)	11.2
Gas boiler (thermal efficiency)	80% Et
Gas furnace (AFUE)	80%
Air-source heat pump (COP at 47F)	3.3

Lighting power density. The baseline uses the ASHRAE 90.1-2022 building area method LPD. The proposed design uses the actual installed LPD.

7.3 Four Baseline Orientations

ASHRAE 90.1 Appendix G Section G3.1.5.1 requires the baseline building to be simulated in four orientations: 0 degrees (as-designed), 90 degrees (rotated clockwise), 180 degrees, and 270 degrees. The four baseline results are averaged to produce the final baseline energy cost. This prevents designers from gaining an unfair advantage or disadvantage based on building orientation.

$$\text{Baseline energy cost} = (\text{Cost}_{0\text{deg}} + \text{Cost}_{90\text{deg}} + \text{Cost}_{180\text{deg}} + \text{Cost}_{270\text{deg}}) / 4$$

The proposed building is simulated in its actual orientation only.

7.4 Compliance Determination

$$\text{Percent improvement} = (\text{Baseline cost} - \text{Proposed cost}) / \text{Baseline cost} \times 100\%$$

The proposed design passes if the percent improvement is greater than or equal to 0% (the proposed building must not cost more to operate than the baseline). For LEED, the improvement must meet the thresholds listed in Section 2.2 of this guide.

The `ComplianceComparisonResult` dataclass calculates and stores all improvement percentages: site energy, source energy, annual cost, and per-end-use breakdowns.

7.5 Running Appendix G in the Software

1. Navigate to the **Compliance** tab in the Energy Analysis module.
2. Select **ASHRAE 90.1-2022 Appendix G** from the compliance method dropdown.
3. The software displays the proposed building configuration summary.
4. Click **Generate Baseline and Run Comparison**.
5. The software:
 - a. Creates the baseline building configuration using `AppendixGBaselineGenerator`
 - b. Runs the proposed building simulation (1 run)
 - c. Runs four baseline simulations (0, 90, 180, 270 degrees)
 - d. Averages the four baseline results
 - e. Calculates improvement percentages
6. Results appear in a comparison table showing baseline vs. proposed values for each end use, total energy cost, and percent improvement.

8. Title 24 Performance Path (TDV Method)

8.1 What Is Time-Dependent Valuation?

California Title 24-2022 uses Time-Dependent Valuation (TDV) to weight energy consumption by when it occurs. Energy consumed during peak grid hours (summer late afternoons) is assigned a higher TDV multiplier than energy consumed during off-peak hours (spring nights). This approach reflects the true cost to society of energy at different times, including:

- Higher generation costs during peak hours (peaker plants are expensive)
- Higher grid carbon intensity during peak hours (gas peakers have high emission rates)
- Higher infrastructure costs driven by peak demand
- Higher reliability risk during peak hours

The TDV methodology is defined in CEC Joint Appendix JA3. The JΔS Engineering Suite implements TDV calculations in `t24_acm.py`.

8.2 TDV Multipliers by Climate Zone

The software stores annual average TDV multipliers for each of California's 16 climate zones. Representative values from the `TDV_ANNUAL_AVERAGES` dictionary in `t24_acm.py`:

Climate Zone	City	Electric TDV (kBtu/kWh)	Gas TDV (kBtu/therm)
CZ1	Arcata	7.84	105.0
CZ2	Santa Rosa	8.74	105.0
CZ3	Oakland	8.40	105.0
CZ4	San Jose	9.52	105.0
CZ5	Santa Maria	8.74	105.0
CZ6	Los Angeles	10.08	105.0
CZ7	San Diego	9.86	105.0
CZ8	Fullerton	12.10	105.0
CZ9	Pasadena	13.22	105.0
CZ10	Riverside	15.12	105.0
CZ11	Red Bluff	13.66	105.0
CZ12	Sacramento	14.00	105.0
CZ13	Fresno	16.24	105.0
CZ14	Palmdale	14.56	105.0
CZ15	Palm Springs	17.36	105.0

Climate Zone	City	Electric TDV (kBtu/kWh)	Gas TDV (kBtu/therm)
CZ16	Mount Shasta	8.06	105.0

The peak-period TDV multiplier is approximately 4.5 times the off-peak multiplier, reflecting California's "duck curve" pattern where net demand ramps sharply from 4 PM to 8 PM as solar generation drops and air conditioning loads remain high.

8.3 TDV Energy Budget: Standard vs. Proposed

The Title 24 performance method compares two buildings:

- **Standard Design (baseline).** A hypothetical building with the same geometry as the proposed design but with prescriptive-minimum envelope, lighting, and HVAC per Title 24-2022. The standard HVAC system type is selected per ACM Reference Manual Table 2 based on building type, size, and climate zone. The `StandardHVACSystem` enum in `t24_acm.py` defines 11 system types (System 1 through System 11).
- **Proposed Design.** The actual building as designed.

Both buildings are simulated for 8,760 hours. The hourly energy consumption is multiplied by the hourly TDV multiplier and summed to produce TDV energy (in kBTU-TDV):

```
TDV Energy = SUM over 8760 hours of (kWh_hour x TDV_electric_hour + therms_hour x TDV_gas_hour)
```

8.4 Compliance Margin

```
Compliance margin = (Standard TDV - Proposed TDV) / Standard TDV x 100%
```

The proposed design passes Title 24 if the compliance margin is $\geq 0\%$ (i.e., proposed TDV is less than or equal to standard TDV).

A positive compliance margin indicates the proposed design is better than code minimum. Larger margins provide a buffer against construction variances and post-occupancy load growth.

8.5 NRCC-PRF-01 Form Generation

The JAS Engineering Suite can generate the NRCC-PRF-01 compliance form required for California building permit applications. This form reports:

- Building identification and location
- Standard design TDV energy by end use
- Proposed design TDV energy by end use
- Compliance margin
- Mandatory measure checklist
- Software name, version, and registration number

To generate the form, click **Export NRCC-PRF-01** on the Compliance tab after running the Title 24 comparison.

9. Energy Conservation Measures (ECMs)

9.1 What Is an ECM?

An Energy Conservation Measure is any modification to the building design that reduces energy consumption relative to the baseline. ECMs are evaluated by running the 8760-hour simulation twice: once with the baseline configuration and once with the modified parameter. The difference in annual energy consumption and cost is the ECM savings.

9.2 How to Run an ECM Analysis

1. Navigate to the **ECM Analysis** tab.
2. The baseline simulation results must already exist (run the simulation first on the Run Simulation tab).
3. Click **Add ECM**.
4. Select the ECM type from the dropdown:
 - High-efficiency chiller
 - LED lighting upgrade
 - Enhanced economizer
 - VFD on pumps
 - Demand-controlled ventilation
 - Energy recovery ventilator (ERV)
 - Improved glazing (lower SHGC or U-factor)
 - Additional roof insulation
 - Custom (manually adjust any parameter)
5. Enter the modified parameter value (e.g., for LED lighting, enter the proposed LPD such as 0.55 W/SF).
6. Click **Run ECM Simulation**. The software re-runs the 8760-hour simulation with the single modified parameter.
7. Results appear in a comparison table showing baseline vs. ECM values.

9.3 Common ECMs and Typical Savings

ECM 1: High-Efficiency Chiller

Replace the code-minimum chiller with a premium-efficiency unit:

- Baseline: 0.95 kW/ton (ASHRAE 90.1 minimum for water-cooled, 150-300 ton, Path A full load)
- Proposed: 0.60-0.80 kW/ton (Carrier 19XR, Trane CenTraVac, York YK)
- Energy reduction: 15-37% of cooling energy
- Typical simple payback: 3 to 6 years
- Works best in: cooling-dominated climates with high chiller run hours

ECM 2: LED Lighting with Advanced Controls

Reduce lighting power density below code maximum:

- Baseline: 0.82 W/SF (ASHRAE 90.1-2022 office)
- Proposed: 0.45-0.60 W/SF (LED fixtures with occupancy sensors, daylight harvesting, task-ambient design)
- Energy reduction: 25-45% of lighting energy PLUS an HVAC interaction credit (reduced lighting waste heat reduces cooling load)
- HVAC interaction: In cooling-dominated climates, every 1 W/SF reduction in LPD saves approximately 3,412 BTU/hr-ft² in cooling, which at 0.65 kW/ton translates to 0.19 kW/ft² additional cooling savings
- Typical simple payback: 1 to 3 years
- Works best in: all climates, especially where lighting is a large fraction of total energy

ECM 3: Energy Recovery Ventilator (ERV)

Install a total energy recovery wheel on the outdoor air intake:

- Effectiveness: 60-80% sensible, 50-70% latent (total energy)
- Energy reduction: 15-30% of ventilation heating and cooling energy
- Typical simple payback: 3 to 7 years
- Works best in: extreme climates (hot-humid, very cold) with high ventilation rates (hospitals, labs, schools)
- Not cost-effective in: mild marine climates (San Francisco, San Diego) where the outdoor air temperature is frequently within the comfort range

ECM 4: Enhanced Economizer

Upgrade from dry-bulb economizer to differential enthalpy economizer with optimized controls:

- Energy reduction: 500-1,000 additional free cooling hours per year
- Annual chiller savings: 5-15% of cooling energy
- Typical simple payback: 0.5 to 2 years (controls upgrade only)
- Works best in: marine climates (CZ3C, CZ4C) with many mild-temperature hours

ECM 5: Variable-Frequency Drives on Pumps

Add VFDs to chilled water and hot water pumps:

- Energy reduction: 30-50% of pump energy
- Typical simple payback: 2 to 4 years
- Note: ASHRAE 90.1-2022 Section 6.5.4.2 already requires VFDs on pumps exceeding 5 HP, so this ECM only applies if the baseline uses constant-speed pumps (non-code systems)

ECM 6: Demand-Controlled Ventilation (DCV)

Install CO₂ sensors in variable-occupancy spaces to modulate outdoor airflow:

- Energy reduction: 10-25% of ventilation-related energy in affected zones
- Typical simple payback: 2 to 5 years
- Works best in: buildings with large conference rooms, auditoriums, cafeterias, or other spaces with highly variable occupancy

ECM 7: Improved Glazing

Replace standard glazing with high-performance low-e glass:

- Baseline SHGC: 0.25-0.40 (varies by climate zone)
- Proposed SHGC: 0.18-0.22 (spectrally selective low-e)
- Proposed U-factor: 0.22-0.30 (triple-pane or high-performance double-pane)
- Energy reduction: 5-15% of envelope cooling load, 5-10% of envelope heating load
- Typical simple payback: 5 to 12 years (glazing is expensive)
- Works best in: buildings with high window-to-wall ratio in hot or very cold climates

9.4 Simple Payback Calculation

$$\text{Simple payback (years)} = \text{Incremental first cost (\$)} / \text{Annual energy savings (\$/year)}$$

Where:

- Incremental first cost is the additional cost of the ECM above the baseline equipment cost
- Annual energy savings is calculated from the simulation results

9.5 Life Cycle Cost Analysis

For a more complete economic evaluation, the JAS Engineering Suite calculates Net Present Value (NPV) over a user-specified analysis period (default 25 years):

$$\text{NPV} = -\text{Incremental cost} + \text{SUM over N years of } [\text{Annual savings} \times (1 + \text{escalation})^n / (1 + \text{discount})^n]$$

Where:

- Escalation rate = annual energy cost increase (default 2.5%)
- Discount rate = cost of capital or required rate of return (default 5%)
- N = analysis period in years

9.6 ECM Summary Table Format

After running one or more ECMs, the ECM Analysis tab displays a summary table:

ECM	Annual kWh Saved	Annual Therms Saved	Annual \$ Saved	Installed Cost	Simple Payback (yr)	25-yr NPV
LED lighting	114,580	--	\$32,082	\$47,500	1.5	\$380,000
High-eff chiller	31,700	--	\$8,876	\$37,500	4.2	\$72,000
ERV	22,400	1,200	\$7,712	\$45,000	5.8	\$48,000
Combined	168,680	1,200	\$48,670	\$130,000	2.7	\$500,000

10. Worked Example A -- 100,000 SF San Diego Office

10.1 Building Description

- **Building name:** Torrey Pines Corporate Campus
- **Location:** San Diego, CA (ASHRAE Climate Zone 3B, Title 24 CZ7)
- **Floor area:** 100,000 SF gross conditioned
- **Floors:** 4 stories above grade
- **Occupancy:** Office, approximately 500 occupants (1 per 200 SF)
- **Operating hours:** Monday through Friday, 7 AM to 6 PM
- **Window-to-wall ratio:** 40%
- **Design cooling load:** 300 tons (3,600,000 BTU/hr) -- approximately 30 BTU/hr per SF
- **Design heating load:** 1,500,000 BTU/hr -- approximately 15 BTU/hr per SF

10.2 HVAC System

- **Cooling:** Two water-cooled centrifugal chillers, 200 tons each (one lead, one lag), 0.55 kW/ton at AHRI conditions (Trane CenTraVac)
- **Heating:** Two condensing gas boilers, 1,000 MBH each, 95% thermal efficiency
- **Air system:** Four VAV air handling units with VFD supply fans, total 100,000 CFM, 75 BHP total fan power
- **Chilled water pumps:** Two at 15 BHP each with VFDs, variable primary flow
- **Condenser water pumps:** Two at 20 BHP each, constant speed
- **Hot water pumps:** Two at 5 BHP each with VFDs
- **Cooling tower:** Two induced-draft crossflow towers, 15 BHP each

10.3 Utility Rates

- **Electricity:** \$0.24/kWh blended rate (SDG&E AL-TOU commercial)
- **Demand:** \$18.00/kW/month
- **Natural gas:** \$1.15/therm

10.4 Simulation Results -- Annual Summary

End Use	Annual kWh	Annual Therms	Annual kBTU	Annual Cost
Cooling (chillers)	298,000	--	1,016,776	\$71,520
Cooling towers	42,000	--	143,304	\$10,080
Heating (boilers)	--	52,000	5,200,000	\$59,800
Supply fans	410,000	--	1,398,920	\$98,400
CHW pumps	68,000	--	231,976	\$16,320
CW pumps	85,000	--	290,020	\$20,400
HW pumps	12,000	--	40,944	\$2,880

End Use	Annual kWh	Annual Therms	Annual kBTU	Annual Cost
Lighting	1,050,000	--	3,582,600	\$252,000
Equipment (plugs)	1,920,000	--	6,551,040	\$460,800
Total	3,885,000	52,000	18,455,580	\$992,200
Demand charges	--	--	--	\$170,640
Grand Total	3,885,000	52,000	18,455,580	\$1,162,840

10.5 EUI Calculation

Electric kBTU = 3,885,000 kWh x 3.412 = 13,255,620 kBTU
 Gas kBTU = 52,000 therms x 100 = 5,200,000 kBTU
 Total kBTU = 18,455,620 kBTU
 Site EUI = 18,455,620 / 100,000 = 184.6 kBTU/SF/yr
 HVAC-only EUI = (all HVAC end uses) / 100,000 = 83.2 kBTU/SF/yr

The HVAC-only EUI of 83.2 kBTU/SF/yr is reasonable for a water-cooled chiller office building in San Diego. The total EUI of 184.6 kBTU/SF/yr includes the high plug-load density (1.50 W/SF) that dominates in this mild climate.

10.6 Monthly Energy Profile

Month	Cooling kWh	Heating therms	Fans kWh	Pumps kWh	Lighting kWh	Equip kWh	Total kWh	Total therms
Jan	12,800	14,500	31,200	14,800	87,500	160,000	306,300	14,500
Feb	15,400	10,800	31,600	15,200	87,500	160,000	309,700	10,800
Mar	26,000	5,400	33,000	16,200	87,500	160,000	322,700	5,400
Apr	38,000	1,800	34,200	17,400	87,500	160,000	337,100	1,800
May	48,000	600	35,400	18,600	87,500	160,000	349,500	600
Jun	62,000	0	36,600	19,800	87,500	160,000	365,900	0
Jul	74,000	0	37,800	21,000	87,500	160,000	380,300	0
Aug	80,000	0	38,200	21,800	87,500	160,000	387,500	0
Sep	76,000	0	37,600	21,200	87,500	160,000	382,300	0
Oct	50,000	300	35,600	18,800	87,500	160,000	351,900	300
Nov	28,000	3,600	33,200	16,400	87,500	160,000	325,100	3,600
Dec	13,800	15,000	31,400	14,800	87,500	160,000	307,500	15,000
Annual	524,000	52,000	435,800	216,000	1,050,000	1,920,000	4,145,800	52,000

10.7 Peak Demand

- **Annual peak:** 790 kW in August (2:00 PM)

- **August breakdown:** Chillers 240 kW, Cooling towers 30 kW, Fans 55 kW, Pumps 45 kW, Lighting 82 kW, Equipment 150 kW, Other 188 kW
- **Annual demand cost:** 12 months x average peak ~790 kW x \$18/kW = \$170,640

10.8 Carbon Emissions

Electricity CO2 = 3,885,000 kWh x 0.35 lb/kWh = 1,359,750 lb = 616.6 metric tons
 Natural gas CO2 = 52,000 therms x 11.7 lb/therm = 608,400 lb = 276.0 metric tons
 Total CO2 = 1,968,150 lb = 892.6 metric tons/year
 Carbon intensity = 892.6 / 100,000 = 0.00893 metric tons/SF/yr = 8.9 kg CO2/SF/yr

11. Worked Example B -- ECM Comparison

Using the 100,000 SF San Diego office from Example A as the baseline, the following ECMs are evaluated:

11.1 ECM 1: LED Lighting Upgrade

- **Baseline LPD:** 0.82 W/SF
- **Proposed LPD:** 0.50 W/SF (LED with daylight harvesting and occupancy sensors)
- **Lighting energy reduction:** 1,050,000 kWh x (1 - 0.50/0.82) = 409,756 kWh
- **HVAC interaction credit:** 409,756 kWh x 3,412 / 12,000 x 0.55 kW/ton x 0.60 = 38,452 kWh cooling savings
- **Total annual savings:** (409,756 + 38,452) kWh x \$0.24 = \$107,570
- **Incremental cost:** \$180,000 (LED fixture upgrade + controls)
- **Simple payback:** 1.7 years

11.2 ECM 2: ERV on Outdoor Air

- **ERV total effectiveness:** 70%
- **Outdoor air cooling savings:** 22% of ventilation cooling load = 115,280 kWh
- **Outdoor air heating savings:** 35% of heating energy = 18,200 therms
- **Fan energy increase:** 5% (additional pressure drop from ERV) = +21,790 kWh
- **Net annual savings:** (115,280 - 21,790) kWh x \$0.24 + 18,200 therms x \$1.15 = \$22,438 + \$20,930 = \$43,368
- **Incremental cost:** \$220,000 (four ERV units, one per AHU)
- **Simple payback:** 5.1 years

11.3 ECM Summary Comparison

Measure	Annual kWh Saved	Annual Therms Saved	Annual \$ Saved	Cost	Payback
Baseline (no ECMs)	--	--	--	--	--

Measure	Annual kWh Saved	Annual Therms Saved	Annual \$ Saved	Cost	Payback
LED lighting	448,208	0	\$107,570	\$180,000	1.7 yr
ERV addition	93,490	18,200	\$43,368	\$220,000	5.1 yr
Both combined	541,698	18,200	\$150,938	\$400,000	2.7 yr

Implementing both ECMs reduces the annual energy cost from \$1,162,840 to \$1,011,902 -- a 13% reduction. The combined investment of \$400,000 pays for itself in 2.7 years and saves over \$3.7 million over 25 years (at 2.5% annual escalation, 5% discount rate).

12. Monthly Energy Breakdown (Reference Data)

This section presents a reference monthly energy breakdown for a **25,000 SF office building in San Diego, California** using a water-cooled chiller (0.95 kW/ton), condensing gas boiler (95% Et), VAV air handling with VFD supply fans, and variable-speed pumps.

12.1 Monthly Energy Table

Month	Cooling (kWh)	Heating (therms)	Fans (kWh)	Pumps (kWh)	Lighting (kWh)	Equip (kWh)	Total Elec (kWh)	Total Gas (therms)
January	5,200	4,800	12,100	3,200	25,000	37,500	83,000	4,800
February	6,100	3,600	12,200	3,400	25,000	37,500	84,200	3,600
March	9,500	1,800	12,500	4,100	25,000	37,500	88,600	1,800
April	14,000	600	12,800	4,800	25,000	37,500	94,100	600
May	18,500	200	13,200	5,600	25,000	37,500	99,800	200
June	24,000	0	13,500	6,400	25,000	37,500	106,400	0
July	28,500	0	14,000	7,200	25,000	37,500	112,200	0
August	30,200	0	14,100	7,800	25,000	37,500	114,600	0
September	29,000	0	13,900	7,500	25,000	37,500	112,900	0
October	19,500	100	13,300	5,800	25,000	37,500	101,100	100
November	10,200	1,200	12,500	4,200	25,000	37,500	89,400	1,200
December	5,800	4,500	12,100	3,100	25,000	37,500	83,500	4,500
Annual	200,500	16,800	156,200	63,100	300,000	450,000	1,169,800	16,800

12.2 Cooling Energy

Cooling energy tracks outdoor temperature. In San Diego, the coastal influence moderates summer temperatures (design dry-bulb 89 F, daily range 12 F), but the building requires cooling from May through October due to internal gains. The

economizer eliminates most mechanical cooling when outdoor air is below 60 F (November through March). Peak cooling month: **August at 30,200 kWh**. Minimum cooling month: **January at 5,200 kWh** (interior zones only).

12.3 Heating Energy

Heating is modest in San Diego's mild climate. The boiler fires primarily during morning warm-up in December through February when overnight lows reach the mid-40s. Peak month: **January at 4,800 therms**. Zero from June through September. Annual heating gas of 16,800 therms represents approximately 12% of total building energy in kBTU.

12.4 Fan and Pump Energy

Supply fan energy is relatively constant (12,100 to 14,100 kWh/month) because the VAV system maintains minimum airflow during unoccupied hours. Summer months are slightly higher as VAV boxes open wider. Pump energy follows cooling load: 3,100 kWh in December to 7,800 kWh in August. Both follow the cube law under VFD control.

12.5 Lighting and Equipment

These non-HVAC loads are schedule-driven and constant month to month: lighting at approximately 25,000 kWh/month (0.82 W/SF x 25,000 SF with occupancy scheduling) and equipment at 37,500 kWh/month (1.50 W/SF x 25,000 SF). Together they represent approximately 64% of total annual electricity, which is typical for well-insulated offices in mild climates.

13. Annual Energy Summary

13.1 Consumption Totals (25,000 SF Reference Building)

End Use	Annual Electricity (kWh)	Annual Gas (therms)	Energy (kBTU)
Cooling (chiller)	200,500	--	684,100
Heating (boiler)	--	16,800	1,680,000
Fans (AHU + exhaust)	156,200	--	532,900
Pumps (CHW + CW)	63,100	--	215,300
Lighting	300,000	--	1,023,600
Equipment (plugs)	450,000	--	1,535,400
Total	1,169,800	16,800	5,671,300

Conversion: 1 kWh = 3.412 kBTU; 1 therm = 100 kBTU.

13.2 Utility Rates and Annual Cost

Using SDG&E commercial rates:

Component	Rate	Annual Quantity	Annual Cost
Electricity (energy)	\$0.28/kWh	1,169,800 kWh	\$327,544
Electricity (demand)	\$22.00/kW/month	Avg ~220 kW peak	\$29,040
Natural gas	\$1.20/therm	16,800 therms	\$20,160
Total Annual Cost			\$376,744

13.3 Cost Breakdown by End Use

End Use	Annual Cost	Percent of Total
Cooling	\$56,140	14.9%
Heating	\$20,160	5.3%
Fans	\$43,736	11.6%
Pumps	\$17,668	4.7%
Lighting	\$84,000	22.3%
Equipment	\$126,000	33.4%
Demand	\$29,040	7.7%
Total	\$376,744	100%

Plug loads and lighting together account for over 55% of the annual cost. This is common in mild climates where HVAC loads are moderate.

13.4 EUI Breakdown

End Use	kBTU/SF/yr	Percent
Cooling	27.4	12.1%
Heating	67.2	29.6%
Fans	21.3	9.4%
Pumps	8.6	3.8%
Lighting	40.9	18.1%
Equipment	61.4	27.1%
Total	226.9	100%

14. Peak Demand Analysis

14.1 Monthly Peak Demand (25,000 SF Reference Building)

Month	Chiller (kW)	Fans (kW)	Pumps (kW)	Lighting (kW)	Plugs (kW)	Total Peak (kW)
January	35	22	8	20	38	123
February	42	22	9	20	38	131
March	60	23	10	20	38	151
April	85	24	12	20	38	179
May	110	25	14	20	38	207
June	135	26	16	20	38	235
July	155	27	18	20	38	258
August	165	27	19	20	38	269
September	158	27	18	20	38	261
October	115	25	14	20	38	212
November	65	23	10	20	38	156
December	38	22	8	20	38	126

14.2 Annual Peak

The annual peak of **269 kW occurs in August** (approximately 10.8 W/SF), driven by chiller operation near full capacity during the hottest afternoon hours.

14.3 Demand Reduction Strategies

- **Ice thermal storage.** Shift chiller to off-peak nighttime hours. Reduces on-peak demand by 100-150 kW. Payback: 5-8 years.
- **Battery storage.** A 100 kWh / 50 kW system can shave 40-50 kW from the 2-4 PM peak. Payback: 6-10 years (improving with battery cost reductions).
- **Pre-cooling.** Over-cool building mass during morning hours (6-10 AM), allow 2-3 F drift during afternoon peak. Reduces chiller demand 15-20% during critical hours.

15. Carbon Footprint

15.1 Emission Factors

Fuel	Emission Factor	Source
Electricity (CA, CAMX)	0.35 lb CO ₂ /kWh	EPA eGRID 2023
Electricity (US average)	0.85 lb CO ₂ /kWh	EPA eGRID 2023

Fuel	Emission Factor	Source
Natural gas	11.7 lb CO2/therm	EPA GHG Emission Factors Hub

15.2 Annual Emissions (25,000 SF Reference Building)

Electricity CO2 = 1,169,800 kWh x 0.35 lb/kWh = 409,430 lb CO2
 Natural gas CO2 = 16,800 therms x 11.7 lb/therm = 196,560 lb CO2
 Total CO2 = 605,990 lb = 274.9 metric tons CO2/year
 Carbon intensity = 274.9 / 25,000 = 11.0 kg CO2/SF/yr

15.3 Emissions by End Use

End Use	Annual CO2 (metric tons)	Percent
Cooling	31.8	11.6%
Heating	89.2 (gas)	32.5%
Fans	24.8	9.0%
Pumps	10.0	3.6%
Lighting	47.6	17.3%
Equipment	71.4	26.0%
Total	274.9	100%

15.4 Electrification Impact

Heating is the largest carbon source (32.5%) despite San Diego's mild climate, because natural gas has much higher carbon intensity per unit of useful heat than California grid electricity. Replacing the gas boiler with an air-source heat pump (COP 3.0) would reduce heating emissions by approximately 75%, from 89.2 to 22.3 metric tons per year, saving 66.9 metric tons CO2 annually.

15.5 Carbon Targets

The 2030 Architecture Challenge target for office buildings is approximately 5.0 kg CO2/SF/yr. At 11.0 kg CO2/SF/yr, this building would need approximately 55% carbon reduction through electrification, on-site solar, enhanced envelope, and grid decarbonization to meet that target.

16. Troubleshooting

16.1 "EUI Too High"

Symptom: The calculated site EUI is significantly higher than expected benchmarks for the building type and climate.

Common causes and solutions:

- 1. Plug load density too high.** Check the Equipment Power Density on the Building Setup tab. For offices, 1.50 W/SF is typical, but some older designs assumed 2.0-3.0 W/SF. Reduce to match actual expected loads.
- 2. Occupied hours too long.** If the building schedule shows 24/7 operation but the building actually closes at 6 PM, the simulation over-predicts lighting and equipment energy. Verify occupied hours on the Schedules tab.
- 3. Design load too high.** If the imported design cooling load is significantly larger than 30-40 BTU/hr per SF for an office, the chiller runs at higher output and consumes more energy. Check whether the load calculation included safety factors that should not be in the energy simulation.
- 4. Low equipment efficiency.** If the cooling efficiency is set to 1.2 kW/ton (air-cooled chiller) when the actual system is 0.65 kW/ton (water-cooled), cooling energy will be nearly double what it should be. Verify the HVAC System tab entries.
- 5. No economizer.** If the economizer is disabled (or the high limit is set too low), the chiller runs during many hours when free cooling should be available. In San Diego, this can add 15-25% to cooling energy.

16.2 "EUI Too Low"

Symptom: The calculated EUI is lower than any reasonable benchmark.

Common causes:

- 1. Missing end uses.** If lighting or equipment power density is set to 0, those loads are excluded. Verify all power densities are populated.
- 2. Floor area too large.** If the floor area is entered as 1,000,000 SF instead of 100,000 SF, the EUI (which divides by floor area) will be 10x lower than expected. Double-check the floor area entry.
- 3. Design loads not set.** If design cooling and heating loads are 0, the simulation has nothing to cool or heat, and HVAC energy will be near zero.

16.3 "Simulation Won't Run"

Symptom: Clicking "Run Simulation" produces an error or no output.

Solutions:

- 1. No weather data.** The simulation requires weather data for the selected location. If the city/state combination is not in the database (523 locations available), you will see a warning. Try a nearby major city or load a custom weather file.
- 2. Invalid inputs.** Check for negative values, zero floor area, or blank required fields. The module validates inputs before running and displays error messages for invalid entries.
- 3. Memory error on very large projects.** Each hour produces a `HourlySimulationResult` object. For 8,760 hours, this requires approximately 10-20 MB of memory. If running multiple buildings simultaneously, memory usage can grow. Close unused modules and try again.

16.4 "Baseline Doesn't Match Expected"

Symptom: The Appendix G baseline result seems too high or too low compared to expected values.

Solutions:

- 1. Wrong climate zone.** Verify the ASHRAE climate zone displayed on the Building Setup tab. San Diego is 3B (not 3C, which is San Francisco). The climate zone determines baseline envelope U-factors and HVAC system selection.
- 2. Wrong building category.** Appendix G selects different baseline systems for buildings under vs. over 25,000 SF, and under vs. over 3 stories. Verify floor area and number of floors.
- 3. Heating fuel type.** If the proposed building uses electric heating (heat pump) but the baseline generator defaults to fossil fuel, the baseline HVAC system selection changes. Set the heating fuel dropdown correctly on the Compliance tab.
- 4. Four-rotation averaging.** The baseline cost is the average of four orientations. If you compare it against a single-orientation proposed result from another tool, the numbers may differ. The JΔS Engineering Suite always averages four orientations per Appendix G requirements.

16.5 "Title 24 Margin Too Thin"

Symptom: The Title 24 compliance margin is barely positive (< 2%).

Solutions:

- 1. Check TDV multipliers.** In hot inland climate zones (CZ10, CZ13, CZ15), the TDV multiplier for electricity is very high (15-17 kBtu/kWh), which amplifies small differences in cooling energy. Ensure the cooling system efficiency is modeled accurately.
- 2. Increase envelope performance.** Reduce the proposed window U-factor or SHGC below the prescriptive minimum to gain margin.
- 3. Add ECMs.** Even small measures like enhanced economizer controls or occupancy-sensor-controlled lighting can add 2-5% compliance margin.

17. Reference Tables

17.1 EUI Benchmarks by Building Type

Building Type	Low (kBtu/SF/yr)	Median	High	ENERGY STAR Target
Office (general)	40	75	150	< 50
Office (large, > 100K SF)	50	85	130	< 55
Retail (standalone)	45	70	120	< 55
Retail (strip mall)	50	80	130	< 60
Hospital (acute care)	120	220	350	< 180
Outpatient clinic	60	100	160	< 80
School (K-12)	35	60	100	< 45
University	80	130	200	< 100
Hotel (full service)	65	95	150	< 75

Building Type	Low (kBtu/SF/yr)	Median	High	ENERGY STAR Target
Warehouse (non-refrig)	15	30	60	< 25
Warehouse (refrigerated)	40	75	120	< 60
Restaurant (sit-down)	180	300	450	< 250
Restaurant (fast food)	250	400	600	N/A
Laboratory	150	280	500	N/A
Data center	300	500	900	PUE < 1.4
Multifamily residential	30	55	90	< 45
Courthouse	80	120	180	< 100
Worship facility	25	45	80	< 35

Source: CBECS 2018, ENERGY STAR Portfolio Manager, DOE Building Performance Database.

17.2 Grid Emission Factors by eGRID Subregion

eGRID Subregion	Code	States (Primary)	lb CO2/kWh
AKGD (Alaska Grid)	AKGD	AK	0.95
AKMS (Alaska Misc)	AKMS	AK	0.45
AZNM (Southwest)	AZNM	AZ, NM	0.70
CAMX (California)	CAMX	CA	0.35
ERCT (Texas)	ERCT	TX	0.70
FRCC (Florida)	FRCC	FL	0.75
HIMS (Hawaii Misc)	HIMS	HI	1.10
HIOA (Hawaii Oahu)	HIOA	HI	1.30
MROE (Upper Midwest)	MROE	WI, MN (partial)	0.90
MROW (Central Midwest)	MROW	MN, IA, MO, ND, SD, NE, KS	0.85
NEWE (New England)	NEWE	CT, MA, ME, NH, RI, VT	0.40
NWPP (Northwest)	NWPP	WA, OR, ID, MT, NV, UT, WY	0.30
NYCW (New York City)	NYCW	NY (downstate)	0.30
NYLI (Long Island)	NYLI	NY (Long Island)	0.55
NYUP (Upstate NY)	NYUP	NY (upstate)	0.20
PRMS (Puerto Rico)	PRMS	PR	1.35
RFCE (Mid-Atlantic)	RFCE	PA, NJ, DE, MD, DC, VA	0.50
RFCM (Michigan)	RFCM	MI	0.80
RFCW (Ohio Valley)	RFCW	OH, IN, WV	0.90

eGRID Subregion	Code	States (Primary)	lb CO2/kWh
RMPA (Rocky Mountain)	RMPA	CO, WY (partial)	0.75
SPNO (South Central N)	SPNO	KS, OK, MO (partial)	0.75
SPSO (South Central S)	SPSO	AR, LA, OK (partial)	0.80
SRMV (Mississippi Valley)	SRMV	MS, LA, AR	0.60
SRMW (Central Southeast)	SRMW	MO (partial), IL, KY	0.85
SRSO (Southeast)	SRSO	AL, GA, MS (partial)	0.80
SRTV (Tennessee Valley)	SRTV	TN, VA (partial)	0.65
SRVC (Carolinas)	SRVC	NC, SC, VA (partial)	0.55
US National Average	--	All	0.85

Source: EPA eGRID 2023.

17.3 Utility Rate Structures (Representative)

Utility	Region	Energy (\$/kWh)	Demand (\$/kW)	Gas (\$/therm)
SDG&E (AL-TOU)	San Diego, CA	0.24 - 0.32	18 - 26	1.10 - 1.30
SCE (GS-2 TOU)	Southern CA	0.18 - 0.28	15 - 23	1.00 - 1.20
PG&E (B-19 TOU)	Northern CA	0.20 - 0.30	16 - 24	0.90 - 1.10
Con Edison (SC-9)	New York, NY	0.18 - 0.25	20 - 30	0.80 - 1.00
ComEd (General)	Chicago, IL	0.08 - 0.12	8 - 14	0.50 - 0.70
Duke Energy (OPT-V)	Charlotte, NC	0.08 - 0.11	10 - 15	0.60 - 0.80
PECO (GS-TOU)	Philadelphia, PA	0.10 - 0.14	12 - 18	0.55 - 0.75
Xcel Energy (SG)	Denver, CO	0.09 - 0.13	10 - 16	0.45 - 0.65
Georgia Power (PLL)	Atlanta, GA	0.07 - 0.10	9 - 14	0.70 - 0.90
APS (E-32 TOU)	Phoenix, AZ	0.08 - 0.14	10 - 18	0.80 - 1.00

Note: Rates shown are approximate 2026 ranges for commercial service. Actual rates vary by usage tier, season, and tariff structure.

17.4 Title 24 Climate Zone Quick Reference

CZ	Representative City	Cooling Design DB (F)	Heating Design DB (F)	Heating Dominated?
1	Arcata	67	32	Yes
2	Santa Rosa	95	28	Moderate
3	Oakland	85	35	Moderate

CZ	Representative City	Cooling Design DB (F)	Heating Design DB (F)	Heating Dominated?
4	San Jose	96	32	Moderate
5	Santa Maria	85	30	Moderate
6	Los Angeles	92	41	No (cooling)
7	San Diego	89	44	No (cooling)
8	Fullerton	101	33	No (cooling)
9	Pasadena	104	35	No (cooling)
10	Riverside	107	32	No (cooling)
11	Red Bluff	106	27	No (cooling)
12	Sacramento	104	30	No (cooling)
13	Fresno	106	28	No (cooling)
14	Palmdale	107	19	Mixed
15	Palm Springs	113	30	No (cooling)
16	Mount Shasta	94	10	Yes

17.5 ASHRAE Baseline HVAC System Types (Table G3.1.1)

System No.	Description	Building Application
1	PTAC + Gas Furnace	Residential, fossil heat
2	PTHP	Residential, electric heat
3	PSZ-AC + Gas Furnace	Small nonres (< 3 floors, < 25K SF), fossil
4	PSZ Heat Pump	Small nonres, electric heat
5	PVAV + HW Reheat	Mid-size nonres, fossil
6	PVAV + PFP Boxes	Mid-size nonres, electric
7	VAV + Chiller + Boiler	Large nonres (>= 3 floors or >= 25K SF), fossil
8	VAV + Chiller + Elec Reheat	Large nonres, electric
9	Gas Heating Only	Warehouses (heating only), fossil
10	Electric Heating Only	Warehouses (heating only), electric
11	SZ-VAV	Single-zone VAV (specialty)

18. Output Interpretation and Export

18.1 Monthly Bar Chart

The stacked bar chart shows monthly electricity by end use (cooling, fans, pumps, lighting, equipment) with a separate line for gas therms. When reviewing:

- **Seasonal patterns.** Cooling should peak in summer and drop in winter. Constant year-round cooling suggests excessive internal gains or a missing economizer.
- **HVAC vs. non-HVAC ratio.** In mild climates, non-HVAC loads (lighting + equipment) should dominate. If HVAC exceeds non-HVAC year-round, investigate envelope or system performance.
- **Zero-heating months.** Zero gas in summer is normal for most US locations. If heating gas appears in July, investigate simultaneous heating and cooling (a common VAV energy waste).

18.2 Annual Summary Table

Cross-check total kWh against the sum of monthly values. Verify EUI falls within the expected range for the building type. Confirm peak demand does not exceed the sum of all connected equipment ratings.

18.3 Load Duration Curve

The sorted hourly demand curve reveals peak-shaving opportunities. If the top 1% of hours (88 hours) shows demand significantly above the remaining 99%, thermal storage or battery systems may have favorable payback. The right side of the curve shows the building's base load (minimum 24/7 demand).

18.4 Hourly Heat Map

The 8760-hour heat map displays energy or demand as a color grid (months horizontal, hours 0-23 vertical). Hot colors (red) indicate high values. Look for:

- Clear occupied/unoccupied bands (7 AM - 6 PM high, overnight low)
- Weekend reduction in Saturday/Sunday columns
- Anomalies (e.g., high cooling at 3 AM in January = scheduling error)

18.5 Export Formats

Format	Description	Typical Use
PDF Report	Formatted document with summary tables, charts, narrative	Design submissions, compliance documentation, owner presentations
Excel Workbook	Separate worksheets: monthly summary, hourly data (8,760 rows), equipment, ECMS	Custom analysis, utility incentive applications
CSV Files	Raw hourly data (timestamp, temperature, loads, energy, demand)	Import into EnergyPlus, eQUEST, or third-party tools
JSON Dictionary	<code>AnnualEnergyResult.to_dict()</code> output	Programmatic access, API integration, web portal display

To export, navigate to the **Export** tab and click the desired format button. PDF reports use the report engine with professional formatting. Excel workbooks preserve formulas for further analysis. CSV and JSON files contain raw

simulation data.

19. Abbreviations

Abbreviation	Definition
ACH	Air Changes per Hour
ACM	Alternative Calculation Method (California Title 24)
AFUE	Annual Fuel Utilization Efficiency
AHU	Air Handling Unit
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BEPS	Building Energy Performance Standard
BHP	Brake Horsepower
BTU	British Thermal Unit
BTUH	BTU per Hour
CAMX	California/Mexico eGRID subregion
CB ECS	Commercial Buildings Energy Consumption Survey
CDD	Cooling Degree Days (base 65 F)
CEC	California Energy Commission
CFM	Cubic Feet per Minute
CHW	Chilled Water
CO ₂	Carbon Dioxide
CO ₂ e	Carbon Dioxide Equivalent
COP	Coefficient of Performance
CV	Constant Volume
CW	Condenser Water
DCV	Demand-Controlled Ventilation
DOE	U.S. Department of Energy
DX	Direct Expansion
ECM	Energy Conservation Measure
EER	Energy Efficiency Ratio
eGRID	Emissions & Generation Resource Integrated Database

Abbreviation	Definition
EIA	Energy Information Administration
EPA	U.S. Environmental Protection Agency
EPD	Equipment Power Density (W/SF)
EPW	EnergyPlus Weather (file format)
ERV	Energy Recovery Ventilator
Et	Thermal Efficiency
EUI	Energy Use Intensity (kBtu/SF/yr)
GPM	Gallons per Minute
HDD	Heating Degree Days (base 65 F)
HP	Horsepower
HSPF	Heating Seasonal Performance Factor
HVAC	Heating, Ventilation, and Air Conditioning
HW	Hot Water
IEER	Integrated Energy Efficiency Ratio
IECC	International Energy Conservation Code
IPLV	Integrated Part Load Value
JIT	Just-In-Time (compilation)
kBTU	Thousand BTU
kW	Kilowatt (electric demand)
kWh	Kilowatt-Hour (electric energy)
LEED	Leadership in Energy and Environmental Design
LPD	Lighting Power Density (W/SF)
MMBtu	Million BTU
NPV	Net Present Value
NRCC	Nonresidential Certificate of Compliance (California)
NREL	National Renewable Energy Laboratory
OA	Outdoor Air
PLR	Part-Load Ratio
PRM	Performance Rating Method (ASHRAE 90.1 Appendix G)
PSZ	Packaged Single Zone
PTAC	Packaged Terminal Air Conditioner
PTHP	Packaged Terminal Heat Pump

Abbreviation	Definition
PUE	Power Usage Effectiveness (data centers)
PVAV	Packaged Variable Air Volume
SDG&E	San Diego Gas & Electric
SF	Square Feet
SHGC	Solar Heat Gain Coefficient
SZ-VAV	Single Zone Variable Air Volume
TDV	Time Dependent Valuation
TMY	Typical Meteorological Year
TOU	Time of Use
UA	Overall Heat Transfer Coefficient x Area (BTU/hr-F)
VAV	Variable Air Volume
VFD	Variable Frequency Drive
VRF	Variable Refrigerant Flow

This guide was prepared for the JΔS Engineering Suite v1.2. For questions or feedback, contact JS Engineering Solutions.