



Energy Modeling

Computer simulation of whole building energy use



Learning Objectives

Understand Value Proposition for Whole Building Energy Performance Simulations

Learn how software programs can be used to simulate a building's energy usage as a basis for optimizing energy efficiency.

Building Energy Modeling

What is Building Energy Modeling?

$$t_{a_j} = \frac{a + \sum_{i=1}^N A_i h_{ci} t_{si_{i,j}} + \rho c V_{infil_j} t_{o_j} + \rho c V_{vent_j} t_{v_j} + q_{c,int_j}}{-b + \sum_{i=1}^N A_i h_{ci} + \rho c V_{infil_j} + \rho c V_{vent_j}}$$

where

N = number of zone surfaces

A_i = area of i th surface, ft^2

h_{ci} = convection coefficient for i th surface, $\text{Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$

$t_{si_{i,j}}$ = surface temperature for i th surface at time step j , $^\circ\text{F}$

ρ = density, lb_m/ft^3

c = specific heat of air, $\text{Btu}/\text{lb}_m \cdot ^\circ\text{F}$

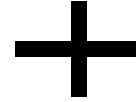
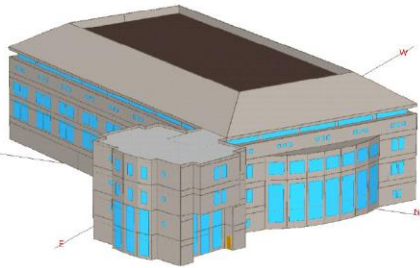
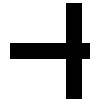
V = volumetric flow rate of air, ft^3/h

t_{o_j} = outdoor air temperature at time step j , $^\circ\text{F}$

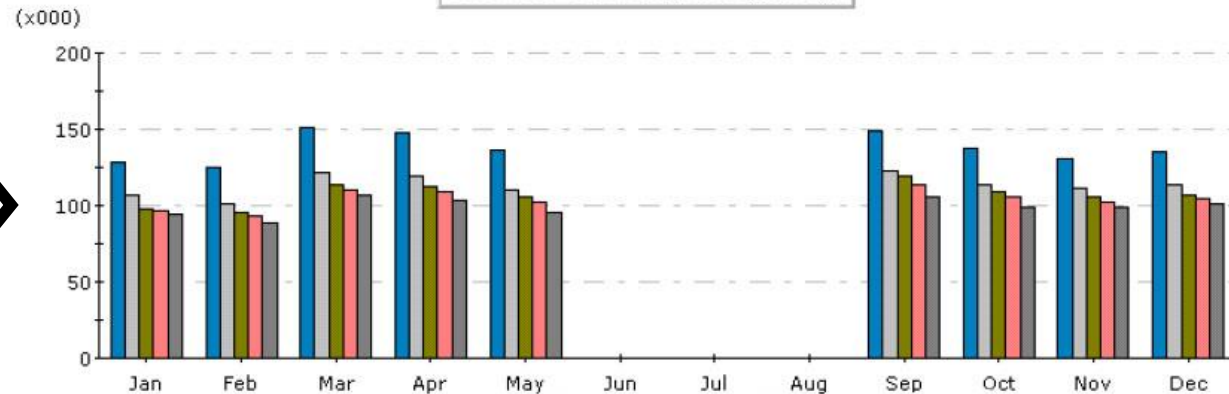
t_{v_j} = ventilation air temperature at time step j , $^\circ\text{F}$

q_{c,int_j} = sum of convective portions of all internal heat gains at time step j , Btu/h

Building Energy Modeling



Electric Consumption (kWh)



- 1. 2-Story High School - Baseline Run (03/09/00 @ 18:59)
- 2. 2-Story High School - Daylighting Controls (03/09/00 @ 19:00)
- 3. 2-Story High School - Air-Side Economizer (03/09/00 @ 19:01)
- 4. 2-Story High School - High Eff Chiller (03/09/00 @ 19:03)
- 5. 2-Story High School - 2-Spd Tower Fan & Reset (03/09/00 @ 19:04)



Building Energy Modeling

What is it?

- First - Heating and Cooling Peak Load Calculation (HCC) program (1967)
 - Calculated hourly peak
 - Gave annual heating-cooling loads (HVAC)
- U.S. DOE web site lists 391 software tools
- DOE-2 introduced in 1979
 - continually improved
 - the ‘gold standard’





Building Energy Modeling

How is it done?

- 'Baseline' reflecting a code compliant building
- Additional models then generated
 - HVAC options
 - Glazing
 - Exterior shading
 - Daylighting
- Document both costs and benefits of modified energy design

Building Energy Modeling

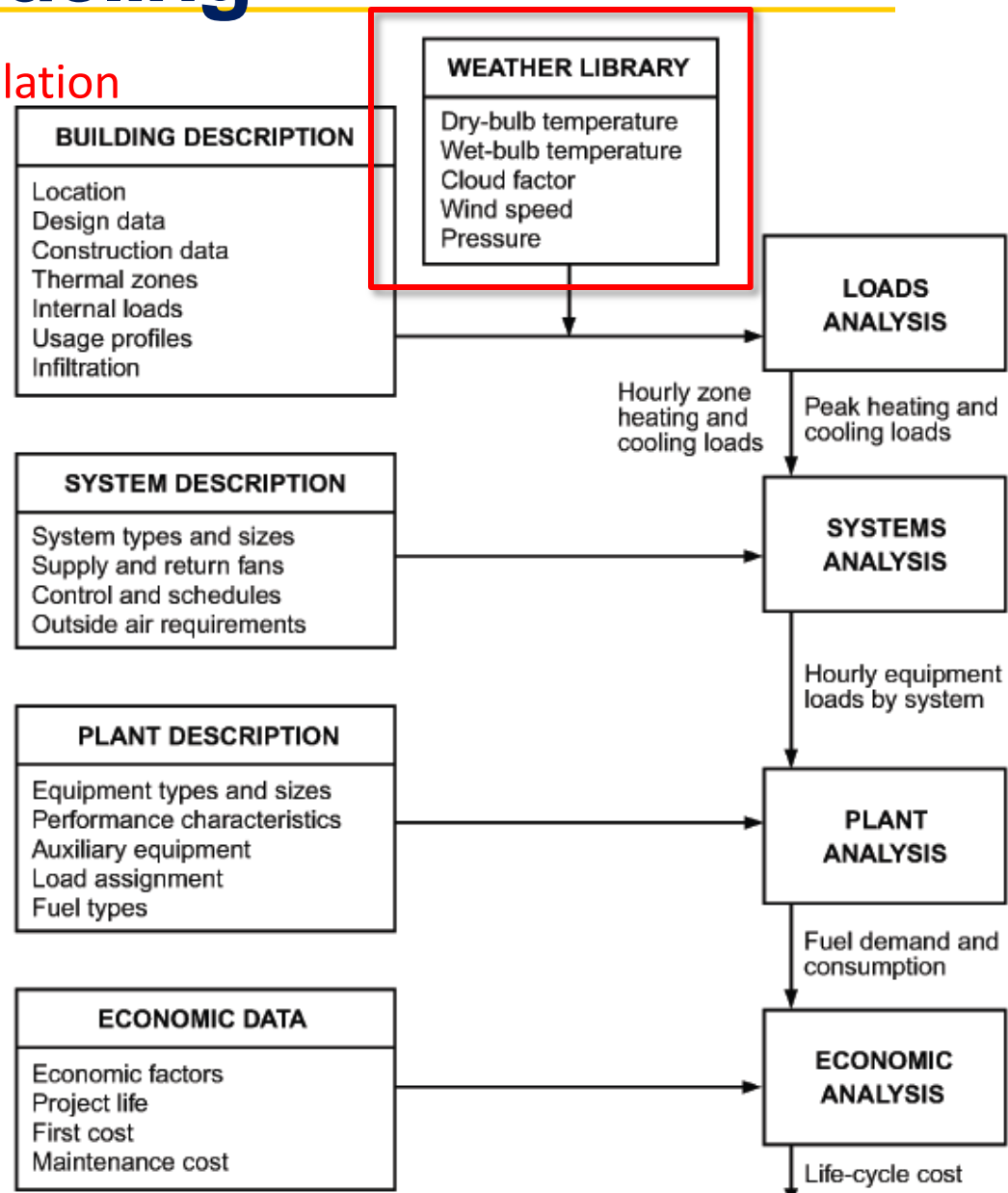
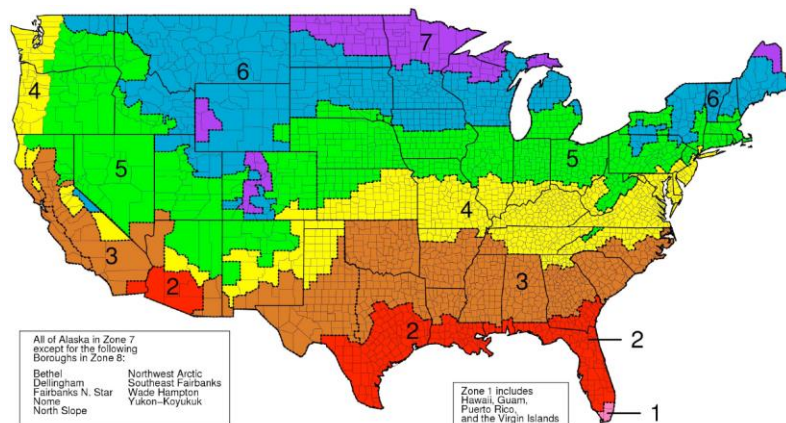
Typical Inputs:

- Building site data (weather data; orientation; adjacent structure shadows, etc.)
- Building envelope data (heat transfer surfaces e.g. walls, floors, roofs, windows, window shades & overhangs)
- Building operations and scheduling (occupancy, thermostat setpoints, daylighting photosensors, HVAC schedules)
- Internal loads (e.g. body heat, lights, equipment)
- HVAC equipment & performance
- Utility rates (electric/gas, peak/off-peak)
- Economic parameters (life-cycle costing, interest rates)

Building Energy Modeling

Fundamentals of Building Energy Simulation

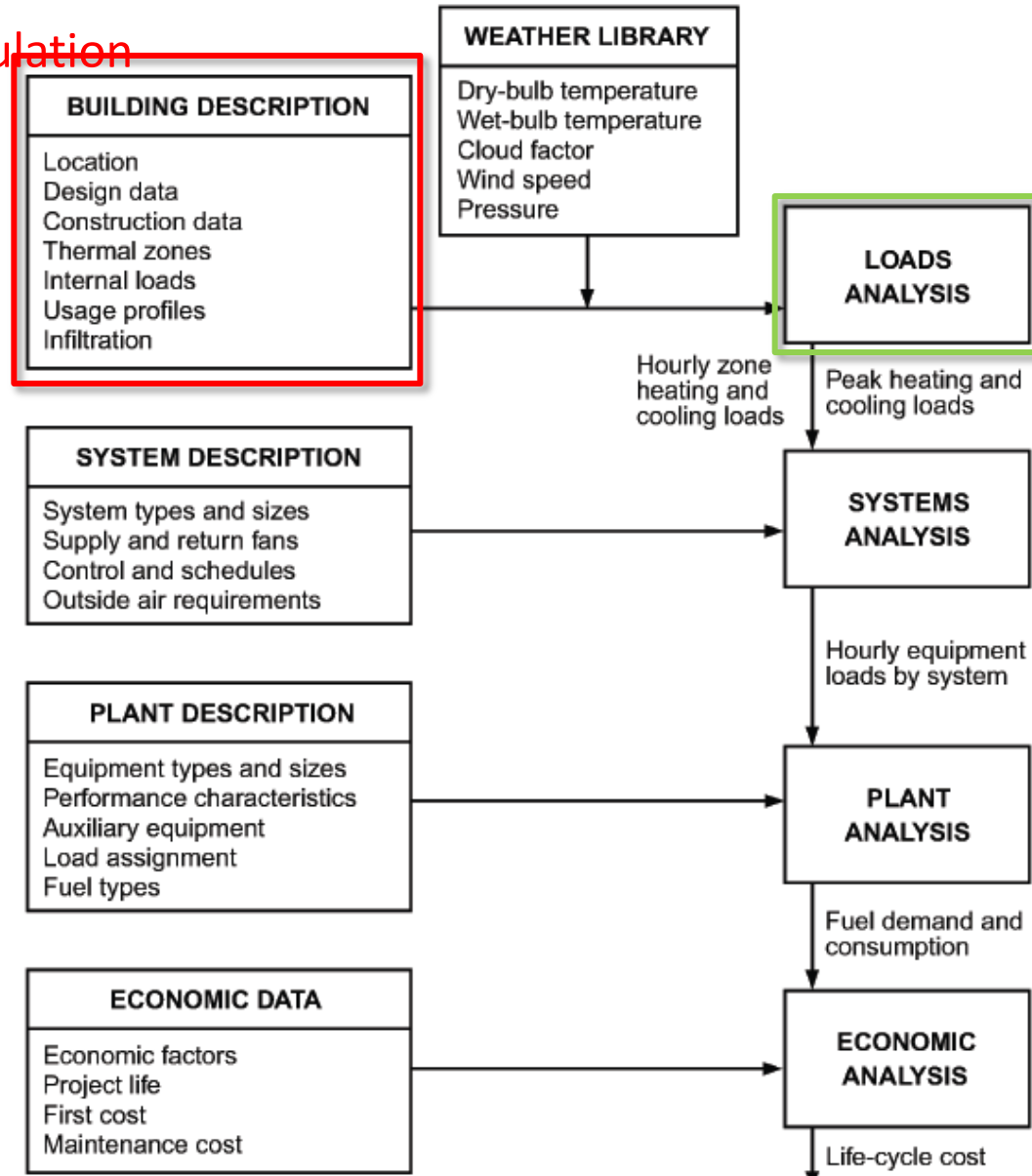
1 Weather Data



Building Energy Modeling

Fundamentals of Building Energy Simulation

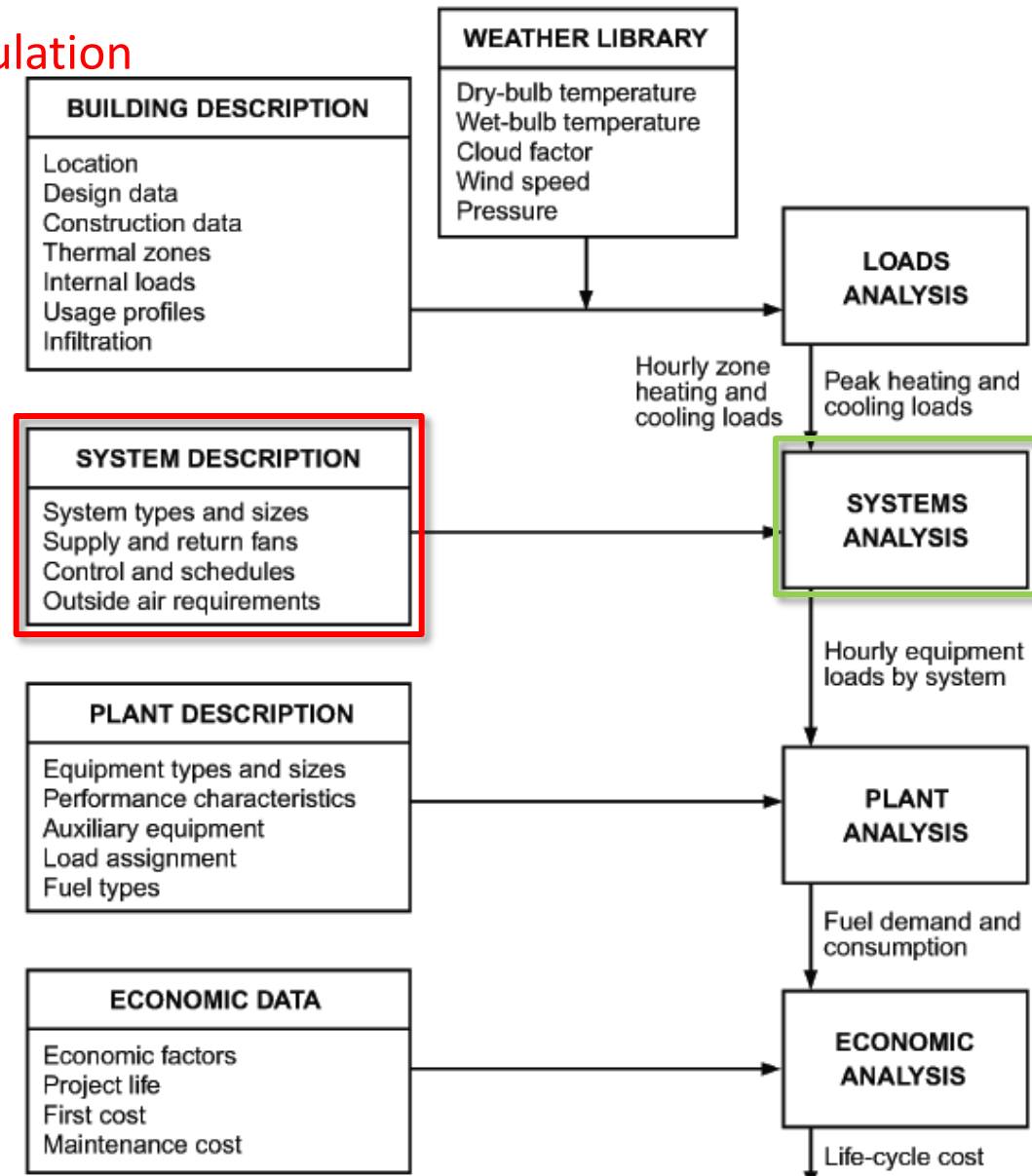
2 Building Data



Building Energy Modeling

Fundamentals of Building Energy Simulation

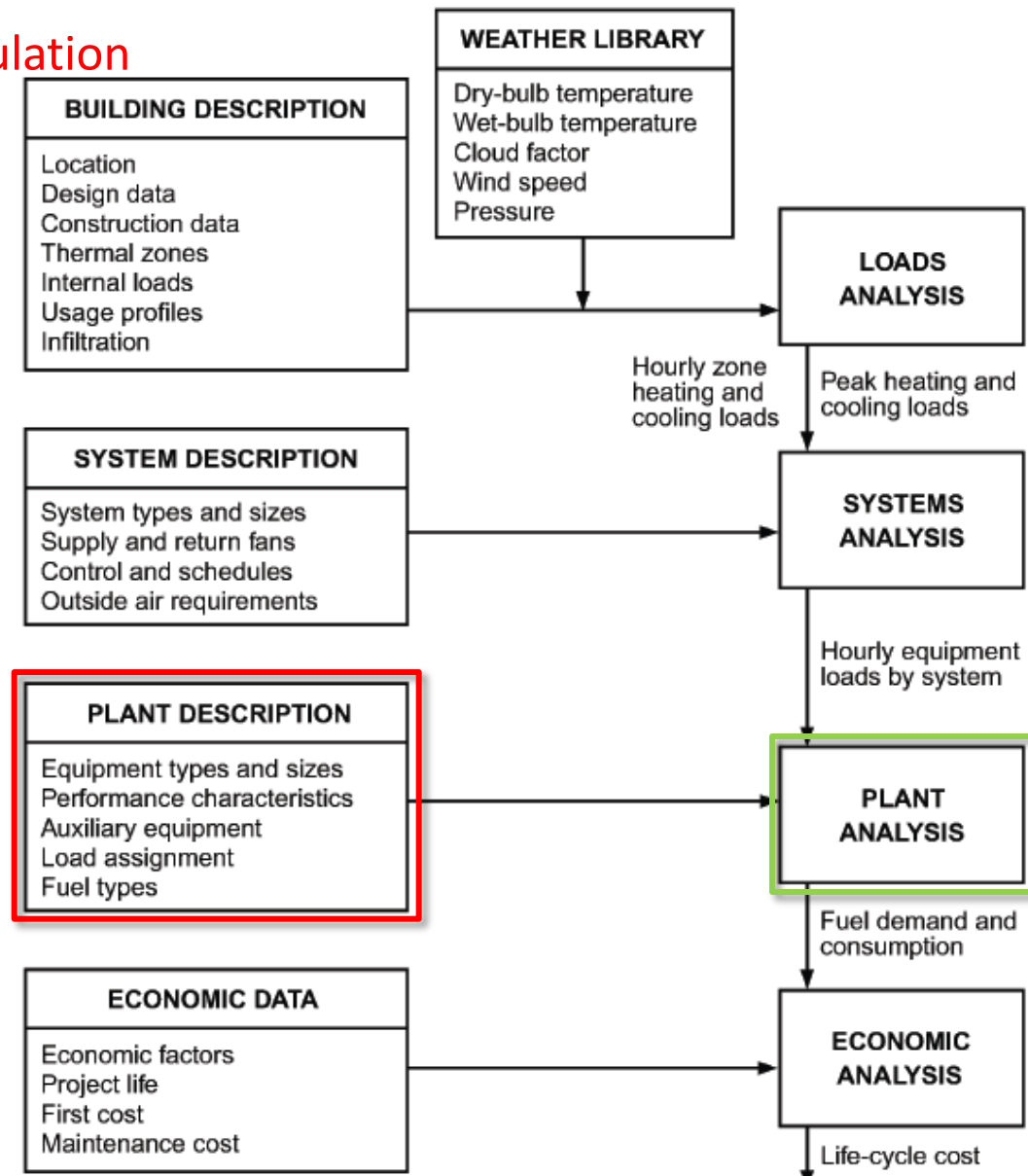
3 *Systems Data*



Building Energy Modeling

Fundamentals of Building Energy Simulation

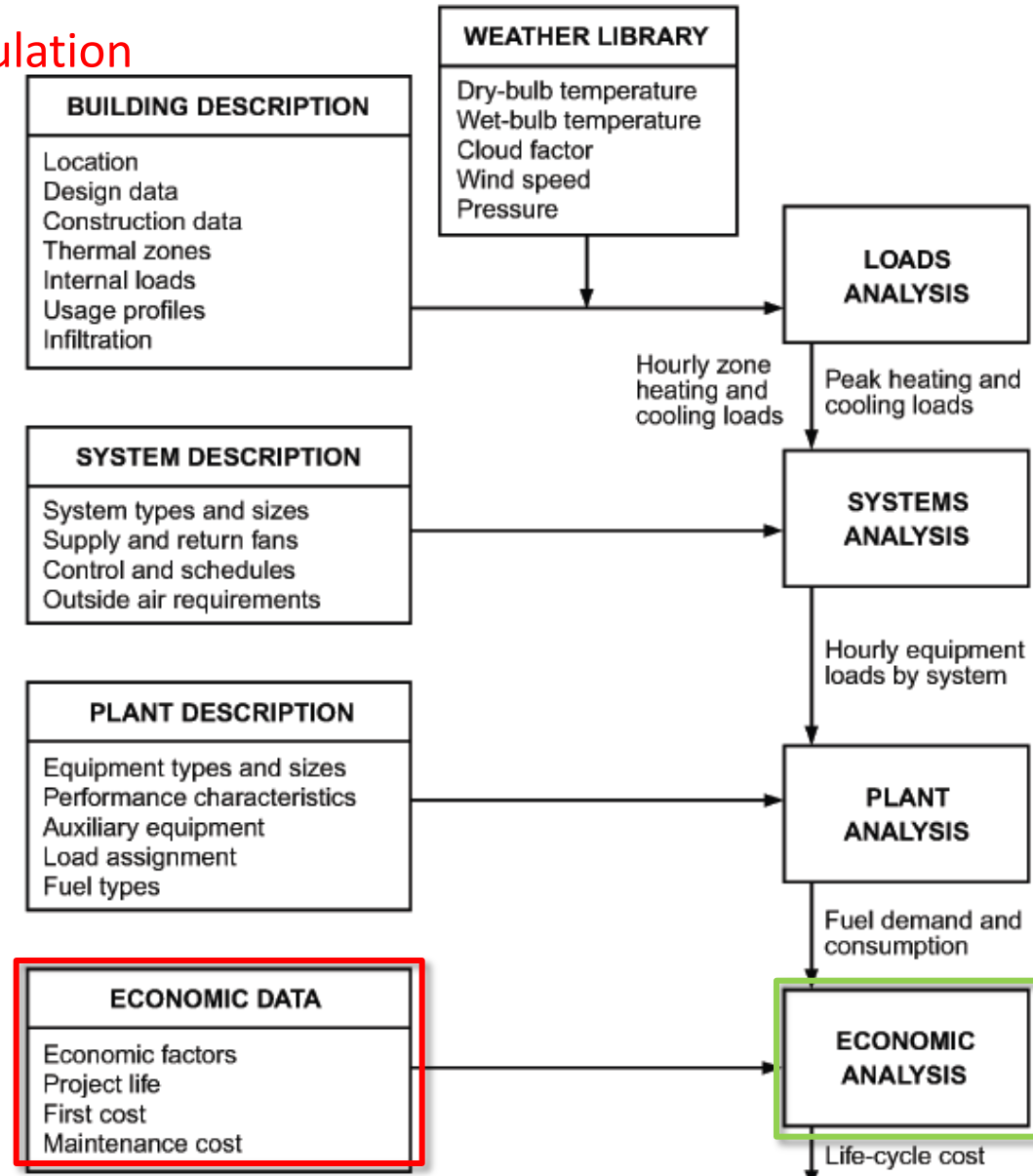
4 *Plant Data*



Building Energy Modeling

Fundamentals of Building Energy Simulation

5 *Economic Data*



Building Energy Modeling

Typical Outputs:

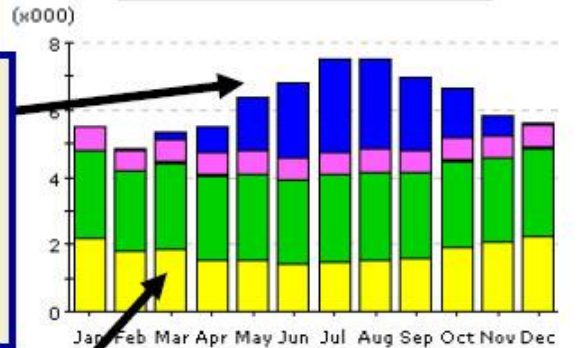
- Summary of annual projected utility costs and savings
- Performance graphs (e.g., monthly energy use for gas and electric, monthly facility peak kW, etc.) in comparison to the baseline
- Input parameter information (e.g., internal load specifications, building envelope characteristics, HVAC system definitions, etc.)
- Assumptions of building characteristics (e.g., schedules, HVAC set points, etc.)
- Notations of changes from previous models (e.g., changes made between baseline and modeling iterations)
- Interpretation of results
- Software input and output files (electronic)



Building Energy Modeling

With 5% Skylights

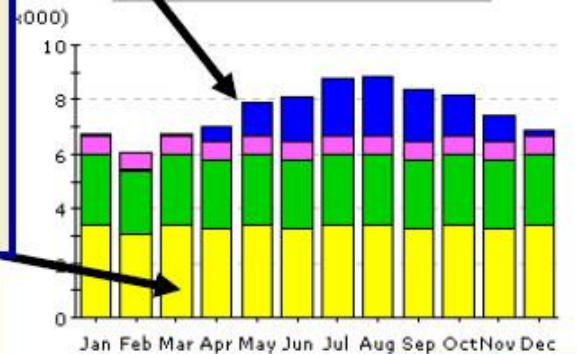
Electric Consumption (kWh)



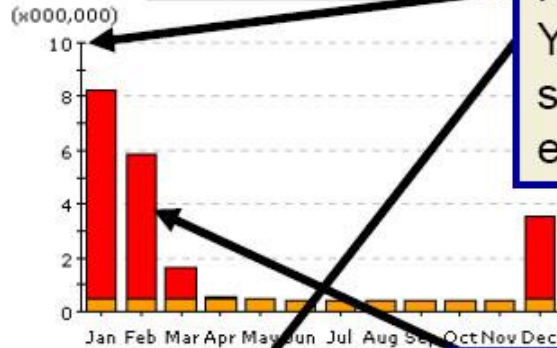
Cooling energy use increases with skylights

Electric Lighting energy use decreases with skylights

Electric Consumption (kWh)

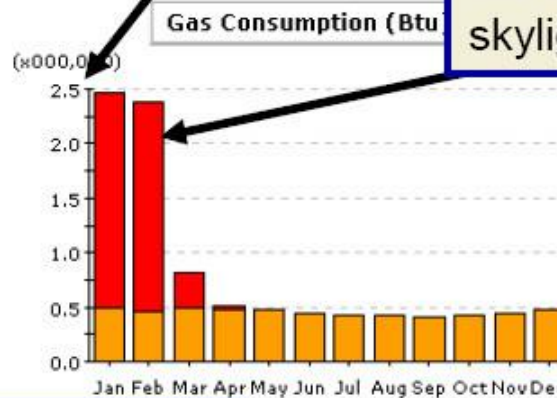


Gas Consumption (Btu)



Note that the Y-axis gets re-scaled for each run

Gas Consumption (Btu)



Space Heating energy use increases with skylights

Without Skylights



Building Energy Modeling

DesignBuilder software



Building Energy Modeling

LEED Forms

- EA Prerequisite 2: Minimum Energy Performance
- EA Credit 1: Optimize Energy Performance

LEED Worksheets

- EAp2 Section 1.4 Tables: Comparison of Baseline Design Versus Proposed Design



Building Energy Modeling

Energy Modeling Prologue

- Energy modeling is complex and difficult
- Energy modeling generates an estimate
- Energy modeling is more of an art than science
- Energy modeling success depends upon the modeler's judgment, i.e. garbage in, garbage out/
Hint: EPA's Target Finder can be your friend
- If you're not an HVAC design engineer, you'll be okay but you can get into deep water real fast (seek out expertise!)



Building Energy Modeling

Questions?



Building Energy Modeling

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