



Introduction to Energy Modeling



What you will Learn in this Lesson

- Types of models
- When to model in design
- Basics of energy modeling
- Reducing energy drivers
- Workflow
 - Scope, methodology, software, model creation, quality checks...

What is a model?

- A model is:
 - Representation of a thing or process
 - Often simple processes that interact to create a complex process
 - A tool to follow the scientific process
 - Form a theory, have an idea of the outcome, run the experiment, and analyze the results
 - Models are then corrected by experiments to more accurately predict outcomes

Types of Models

- Daylighting models
 - Model the light from the sun
 - Measure footcandles
 - Any location
 - Any time of the year
 - Used to estimate savings of natural light over interior lighting
 - Devise daylighting control strategies

Types of Models

- Computational Fluid Dynamics (CFD)
 - Models air flow patterns as a function of:
 - Supply type
 - Supply air volume and speed
 - Internal heat gains
 - Envelope interactions
 - Used to evaluate
 - Space temperature
 - Airflow patterns
 - Occupant comfort indices (drafts)
 - Percentage of people dissatisfied (PPD)
 - Ventilation distribution – local mean age (LMA)
 - Most common in UFAD and/or data center designs
 - Optimize supply and return locations

Types of Models

- Energy/energy cost models
 - Input your building and system
 - Calculate energy/energy cost for hours (8760hrs), days(365 days), months(12 months), years, etc.
 - Evaluate the entire system
 - Analysis of the walls, windows, solar gains, internal gains, etc.
 - HVAC equipment
 - External factors such as utility rates, holidays, etc.
 - May include daylighting, CFD, or other analysis
- **This is what we are interested in!**

Purpose of Energy Modeling

- Determine approximate building loads
- Compare alternative designs
- Prove code compliance
 - LEED
- Tax deductions
- Utility rebates (energy conservation)
- To make a well-informed guess at the EUI for a particular design

Who contributes to the Model?

- Architect
 - Provides details on the building
- Engineer
 - Generally responsible for the energy model and gathering information
- Sales representative
 - Provide engineer with equipment information and design alternatives
- Standards

When to Energy Model

- Start at conceptual design
 - Simple modeling/limited information
 - Compare building configurations, orientations
 - Theoretical minimum
- Schematic design
 - Theoretical minimum
 - Determine energy drivers
 - Optimize energy saving tactics
 - Site orientation, glazing, etc.
 - Basic HVAC options
 - Show the impact of design decisions

When to Energy Model

- Design development
 - Typically first extensive energy model
 - Parametric studies determine priorities
 - Life cycle cost analysis
 - Specific manufacturer product selection
- Construction documents
 - Few model changes
 - Documenting process/inputs for LEED or code compliance
- Post-Occupancy
 - Cross reference energy model to actual performance of the system → Calibrate models

When NOT to Energy Model

- x Energy modeling does not calculate the actual performance of a building. It only calculates a well informed guess.**
- x It does not:**
 - x Estimate actual performance**
 - x Weather, operation, and building use change!**
 - x Settle disputes over equipment performance**
 - x Manufacturing discrepancies**
 - x Explain why a building is not meeting targets**
 - x Building construction variances**
 - x Make the case for downsizing equipment**

How to Energy Model

- Hand calculations
 - CLTD- cooling load temperature difference
 - Heat balance
 - TETD- total equivalent temperature difference
- Rules of thumb
- Use computer program(s)

Rule of Thumb Example

Determine the ft²/ton. Which of the following scenarios give you a result you might not expect.

Cooling Design Load:

1. Office, 25k ft², Miami, design load = 67 tons
2. Fast food restaurant, 5k ft², Chicago, design load = 29 tons
3. Small hotel, 10k ft², Seattle, design load = 35 tons

Rule of Thumb Answer

Determine the ft²/ton. Which of the following scenarios give you a result you might not expect.

Cooling Design Load:

1. Office, 25k ft², Miami, design load = 67 tons
 - $25,000 / 67 = 375 \text{ ft}^2/\text{ton}$ *Okay, Miami is warm and offices have average load*
2. Fast food restaurant, 5k ft², Chicago, design load = 29 tons
 - $5,000 / 29 = 175 \text{ ft}^2/\text{ton}$ *Okay, fast food restaurants are energy intensive regardless of climate*
3. Small hotel, 10k ft², Seattle, design load = 35 tons
 - $10,000 / 35 = 285 \text{ ft}^2/\text{ton}$ *SF per ton seems too low; hotels have relatively low loads, especially in a temperate climate like Seattle*

Rule of Thumb Example

Determine the EUI of the buildings below. Which of the following values don't give you what you might expect.

EUI's:

1. K-12 school, 40k ft², NYC, annual energy = 3,200 Btu*10⁶
2. Data center, 6k ft², Chicago, annual energy = 900 Btu*10⁶
3. LEED office, 100k ft², LA, annual energy = 7,500 Btu*10⁶

Rule of Thumb Answer

Determine the EUI of the buildings below. Which of the following values don't give you what you might expect.

EUI's:

1. K-12 school, 40k ft², NYC, annual energy = 3,200 Btu*10⁶
 - $3,200,000 / 40,000 = 80 \text{ kBtu/ft}^2$ *Okay, schools have average to high load (ventilation), NYC moderate climate*
2. Data center, 6k ft², Chicago, annual energy = 900 Btu*10⁶
 - $900,000 / 6,000 = 150 \text{ kBtu/ft}^2$ *Okay, data center have high energy use, regardless of climate*
3. LEED office, 100k ft², LA, annual energy = 7,500 Btu*10⁶
 - $7,500,000 / 100,000 = 75 \text{ kBtu/ft}^2$ *EUI seems high for a LEED (green building), should be lower than typical office building*

Rule of Thumb Example

Determine the heating load. Which of the following values don't give you what you might expect.

Heating Load:

1. Resort hotel, 100k ft², Hawaii, htg load = 2,800 kBtu/hr
2. K-12 school, 20k ft², Albany, htg load = 1,000 kBtu/hr

Architectural Modeling Programs

- Architectural design tools
 - Used to evaluate only architectural design considerations:
 - Daylighting
 - Fenestrations (type and size)
 - Building orientation
 - Available programs include:
 - Energy-10 (purchase from Sustainable Buildings Industry Council)
 - Building Design Advisor (LBNL)
 - Energy Scheming (Oikos)

Energy Modeling Programs

- EnergyPlus (E+)
 - Department of Energy (DOE) supported
 - Lawrence Berkley National Laboratories (LBNL) created
 - Transparent (no 'black box')
 - EAll based on E+
 - .idf file extension
 - Object-oriented

Energy Modeling Programs

EnergyPlus pros

- Full sub hourly analysis
- Iterative analysis
- Free
- Wide variety of HVAC
- Thermal/daylighting analysis
- Airflow modeling
- Highly customizable
- Open source
- Good support
- DOE supported

EnergyPlus cons

- Complicated!
- No real GUI
- Unpredictable results (at times)
- Long runtimes
- Mostly used for research
- Small number of experts

Energy Modeling Programs

- DOE-2 (2.2)
 - Previously Department of Energy (DOE) supported
 - Proprietary now (James J. Hirsch & Associates)
 - .BDL file extension
 - Various iterations
 - DOE 2.2 (basis of latest eQuest, a DOE engine front-end)
 - D2Comply (California energy code compliance)
 - DOE 2.1E (popular version)

Energy Modeling Programs

- eQuest
 - Quick Energy Simulation Tool (eQUEST)
 - .pd2 file extension
 - GUI for DOE-2.2
 - Wizards for different design phases

Energy Modeling Programs

eQuest pros

- Extremely popular
- Intuitive GUI
- Full sub hourly analysis
- Free
- Wide variety of HVAC
- Highly customizable
- Short runtimes
- Relatively easy to learn

eQuest cons

- Not iterative
- Minimally customizable
- Hard to master
- Predefined reports (not customizable)
- No SI units support

Energy Modeling Programs

- EnergyPro
 - Created by EnergySoft
 - Most well-known in relation to California Title 24
 - Automatically creates baseline
 - Automatically fills out required compliance worksheet
 - One of the few accepted programs

Energy Modeling Programs

EnergyPro pros

- Very popular in California
- GUI
- Full 8760 analysis
- Reports generated for
 - California Energy Code Title 24
 - ECB for 90.1-2007
 - LEED EA Credit 1

EnergyPro cons

- Fee-based
- 'Black box'
- Limited customizability
- Super simplified inputs
 - Easy to manipulate results

Energy Drivers

- Determine energy drivers
 - Heating or cooling dominated?
 - Internal gain or climate dominated?
 - Top contributors to heating/cooling energy use
- Owner/engineer should reduce lighting and plug loads if possible
- HVAC is:
 - 37% design day energy use
 - 26% annual energy use
 - Dominated by chiller energy

Energy Modeling Workflow

Energy Modeling Workflow

- Typical Workflow
 1. Establish the modeling scope
 2. Analysis methodologies
 3. Software/tool selection
 4. Gather relevant data
 5. Create energy model
 6. Ensure quality/integrity of the model
 7. Present results

Energy Modeling Workflow

1. Establish the modeling scope

- Understand what you want to accomplish
- Can't get what you're looking for if you don't know what you want
 - What do you want to get?
 - What do you need to get that answer?
- Example- LEED certification
 - Create a goal setting theoretical minimum energy model
 - Evaluate design *packages* in the energy model and use outputs from the energy model to inform a life cycle cost analysis
 - Climate analysis report

Energy Modeling Workflow

2. Analysis methodology

- Decide which method is most appropriate
 - Spreadsheet(s)
 - Design day
 - Bin analysis
 - Full energy model
 - Partial energy model
- Important factors
 - Deadline
 - Is the time effort (\$) worth the result?
 - Are you missing, meeting, or exceeding the scope?
 - Are you going to build further on the model?

Energy Modeling Workflow

3. Tool selection

- Computer options
 - Internal spreadsheets (generally proprietary)
 - Energy analysis programs

Energy Modeling Workflow

4. Gather relevant data

- Pertinent data to achieve the scope of work
- Typical data to gather
 - Weather
 - Building information
 - Size (floor area, # of floors, orientation)
 - Windows (thermal properties, % glass, location)
 - Wall/roof (thermal properties, orientation)
 - HVAC system (type, layout, component information like efficiency)
 - Utility information

Energy Modeling Workflow

- Weather
 - Typical meteorological year (TMY)
 - Average year, typically over 30 years
 - Includes time-dependent solar data, precipitation, cloud cover
 - IWEC or WYEC
 - International weather for energy calculation
 - Weather year for energy calculation
 - Average weather derived from up to 18 years of data
 - Includes time-dependent solar data, precipitation, wind, cloud cover

Energy Modeling Workflow

- Weather
 - Bin data
 - Includes average number of hours in a particular temp bin

Weather Analysis

- Weather analysis
 - Psych charts
 - What is the weather like?
 - What systems?
 - Where is this?

Miami

Weather Analysis

- Weather analysis
 - Psych charts
 - What is the weather like?
 - What systems?
 - Where is this?

Phoenix

Weather Analysis

- Weather analysis
 - Psych charts
 - What is the weather like?
 - What systems?
 - Where is this?

Minneapolis

Energy Modeling Workflow

5. Create energy model

- The hard part starts...
- Computer energy models
 - Require a few to thousands of inputs
 - What are the important inputs???
 - Depends on what you want to get
- Generally...
 - Divide the building into thermal zones
 - Group zones with similar characteristics
 - Assign one terminal unit serving it
 - » Have properties of typical unit (one big fan coil with small fan coil properties)

Energy Modeling Workflow

- Define the boundaries of the zone
 - Interior partitions if there is heat transfer
 - Exterior surfaces
 - Walls, windows, roof, floor
 - Infiltration-difficult
 - Generally defined as tight, average, and loose (.14-.30 CFM/ft²)
 - Uncertainty in:
 - Operation (e.g. loading dock doors)
 - Construction (e.g. gaps in air barrier)

Energy Modeling Workflow

- Define design characteristics of the zone
 - People
 - Lights
 - Plug loads
 - Process loads
 - Domestic hot water
 - Ventilation
 - Thermostat
 - **Schedules**

Energy Modeling Workflow

- Schedules
 - Entire building never at design
 - People from cubicles walk the halls, conference room, restroom
 - Exception some unoccupied critical data centers
 - Most programs provide default type schedules
 - Use an 'average' schedule
 - Never get the lows or peaks

Energy Modeling Workflow

- Schedules
 - 100% design conditions year-round comparison
 - Almost double annual energy usage

Energy Modeling Workflow

- Define HVAC:
 - Input individual component characteristics
 - COP, IPLV, design capacity, pump head, fan pressure
 - Setup the system
 - Terminal equipment in appropriate zone
 - Secondary systems served by associated primary system
 - Set up the control logic
 - Economizer control (differential dry-bulb, fixed enthalpy, etc.)
 - Cooling tower set point (fixed temperature, floating to wet-bulb approach)

Energy Modeling Workflow

- Define controls:
 - Significantly affect the output
 - Supply air temperatures
 - Outdoor air control
 - Economizer
 - Ventilation calculation (outdoor air fraction)
 - Operating sequences
 - Chiller sequencing
 - Equipment availability

Energy Modeling Workflow

- Specify utility rates:
 - Most energy models use energy cost budget
 - Utility rates are essential
 - Get information specific to the building
 - Various rate structures
 - Time-of-use
 - Price depends on time of day
 - Tiered
 - Buy in bulk mentality
 - More later in the school

Energy Modeling Workflow

- Always document your work!
 - Assumptions
 - Source of assumption
 - Easy to interpret format
 - Version control

Energy Modeling Workflow

6. Ensure quality/integrity of the model

- Know what answer you expect
 - You may not get the answer you expect
 - Sanity check
 - Gives you a place to start QA
- Check against common rules of thumb

Energy Modeling Workflow

- Sensitivity analysis
 - Level of uncertainty in each user input
 - Test low and high end values keeping all other parameters the same
 - Reasons to conduct this analysis
 - Determine which inputs should be known vs. estimated
 - Energy drivers- most bang for the buck
 - Support decision making
 - More robust model

Energy Modeling Workflow

- Check the results:
 - Some programs give overwhelming # of outputs
 - Start in the space and work back
 - Are the space temperatures met?
 - First indicator, startup
 - For secondary loops (air), how is the loop performing?
 - Space EAT, AHU LAT, simultaneous heating cooling, OA fraction
 - For primary loops, is the loop performing as expected?
 - Temps maintained, operating when necessary
 - For auxiliary loops, is the loop performing as expected?
 - Condenser water loop, heat recovery loop

Energy Modeling Workflow

7. Present results

- A picture is worth 8,760 hours!

End of Lesson

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Questions?