Whole-Building Energy Modeling with OpenStudio

Commercial Building Energy Alliance Webinar

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Outline

- Energy Modeling Introduction
- OpenStudio Demo (Modeling for Retrofits)
- Typical Barriers to Using Simulation
- Conclusions and Questions
Energy Modeling Introduction
The Design Process
Energy efficiency is often not a primary consideration during the building design process, and evidence from modeling and energy simulation is often used only to get a LEED certification if it is used at all.

Source: A Handbook for Planning and Conducting Charrettes for High-Performance Projects, Second Edition, 2009, Figure 1.
Effective Use of Energy Modeling

Energy modeling needs to be about more than getting a checkbox on a certification.

Source: A Handbook for Planning and Conducting Charrettes for High-Performance Projects, Second Edition, 2009, Figure 1.
Why Use Energy Simulation?

• Inform energy decisions from the earliest phases
• Help the design team and owner focus on energy-use reduction
• Assess predicted performance with project goals
• Size renewable energy systems and determine contribution
• Evaluate design alternatives throughout programming, design, construction, operation—as well as retrofit
• Simulation is cheaper than constructing the wrong building!
What Can Energy Simulation Do for My Building?

• Compare different design or retrofit options
  o Load calculations
  o Energy performance
  o Peak demand
  o Cost-benefit calculations

• Simulate complex technologies
  o Naturally ventilated, passive buildings
  o Thermal energy storage
  o Daylighting
  o Overheating in unconditioned spaces
  o Advanced controls operation

• Heating, cooling equipment design
• Dynamic response
• Regulatory compliance
• Green building ratings
Why Use Energy Simulation for Retrofit Projects?

• Evaluate technology packages
  o Lighting Technology
    ▪ Window VLT
    ▪ Daylighting controls
  o Envelope Changes
    ▪ Windows
    ▪ Shading devices
    ▪ Skylights

• Analyze specific components
  o HVAC performance
  o Operational characteristics
  o On-site renewables
  o Internal load reductions
Simulation vs. Operating Energy

DOE’s analysis tools have been critical for supporting decision-making in the design and operation of buildings.

Focus on energy efficiency, then renewable energy.

Compared to simulations, real buildings typically:

- Use more energy
- Produce less power
- Have worse controls
- Have more varied schedules
- Have more occupant complaints

Garbage in, garbage out.
Thick Wall vs. Thin Wall

- Most energy modeling occurs on “Thin Wall” vs. “Thick Wall” models.

Credit: David Goldwasser / NREL
Energy Modeling Introduction
Skylight Analysis
Skylight Analysis:  
Daylighting for Large Retail Building

133,275 ft² energy model

Add skylights and lighting controls (103,750 ft² total)
- Skylights: modeled 1% to 5% skylight to floor area (SFA) ratio in 1% increments
- Skylight properties: U-Value = 0.82, SHGC = 0.49, VLT = 0.65
- Lighting control: one sensor per zone, 50 footcandle set point, continuous dimming to off

Investigate annual energy for models in 7 different climate zones
Skylight Analysis:
3% SFA Energy Model Rendering

Credit: Eric Bonnema / NREL
Skylight Analysis:
Determining SFA Ratio to Report

Curves flatten out after 3% SFA for climate zones simulated

Credit: Eric Bonnema / NREL
Skylight Analysis:
Energy Savings for Atlanta, Climate Zone 3A, Hot and Humid

Baseline Model
- Refrigeration: 19.2%
- Fans: 9.0%
- Equipment: 26.3%
- Lighting: 28.4%
- Refrigeration: 11.9%
- Heating: 5.1%
- Cooling: 10.8%
- Heating: 7.0%

3% SFA Daylit Model
- Refrigeration: 19.2%
- Fans: 8.4%
- Equipment: 26.3%
- Lighting: 28.4%
- Savings: 12.3%
- Heating: 7.0%
- Lighting: 16.0%

Credit: Eric Bonnema / NREL
Energy Modeling Introduction
Tools – EnergyPlus and OpenStudio
What is EnergyPlus?

- Fully integrated building, envelope, HVAC, water, and renewables simulation program
- One of the most robust whole-building energy simulation tools available in the world today
- Enables integrated energy performance analysis of low-energy technologies in commercial and residential buildings including on-site generation and renewable energy systems
- Interfaces available from private sector developers
- Free
- Windows 7/XP, Linux & Mac

http://www.energyplus.gov
What is OpenStudio?

OpenStudio is:

• An EnergyPlus/Radiance framework for national labs, code/standard officials, and third parties to easily extend the base capability of EnergyPlus for diverse purposes
• Free
• Open source
• Cross-platform
What does OpenStudio include?

• A plug-in to Google SketchUp
  o SketchUp has more than 2,000,000* users per week worldwide
  o ~55% of these users are architects
  o Mature product with a well-defined interface for extension

• Other front ends
  o Results visualization
  o Simple HVAC SystemOutliner
  o ModelEditor
  o RunManager

• Back-end functionality
  o Scripting interfaces
  o Workflow management
  o Pre- and post-processing capabilities
  o Component libraries (e.g. MELs)
  o Interoperability with other engines for analysis

* Usage statistics released by Google in 2011.
OpenStudio Demo
(Modeling for Retrofits)
OpenStudio Demo
Geometry Input Methods

Credit: David Goldwasser / NREL
OpenStudio Demo
Geometry From Photos of Existing Buildings (Calibration)

Credit: David Goldwasser / NREL
OpenStudio Demo
Geometry From Photos of Existing Buildings (Modeling)

Credit: David Goldwasser / NREL
OpenStudio Demo
Vintage and Climate-Zone-Specific Constructions

Credit: David Goldwasser / NREL
OpenStudio Demo
Vintage and Space-Type-Specific Internal Loads

Credit: David Goldwasser / NREL
OpenStudio Demo
Running the EnergyPlus Simulation Through OpenStudio RunManager

Credit: David Goldwasser / NREL
OpenStudio Demo
ABUPS's Comparison for Upgraded Kitchen Equipment

Baseline End Use Breakdown
- Heating: 42.9%
- Cooling: 10.8%
- Interior Lighting: 8.7%
- Interior Equipment: 39.5%

Proposed End Use Breakdown
- Heating: 13%
- Cooling: 29.6%
- Interior Lighting: 8.7%
- Interior Equipment: 42.4%
- Savings over Baseline: 12.95%

Total EUI Savings (Kbtu/ft²): 72.9

Credit: David Goldwasser / NREL
OpenStudio Demo

Time-Series Simulation Data in OpenStudio ResultsViewer (Line Plot)
OpenStudio Demo
Time-Series Simulation Data in OpenStudio ResultsViewer (Flood Plot)

Kitchen - Sensible Cooling

Dining - Sensible Cooling

Credit: David Goldwasser / NREL
Retrofit Guide PDF and Videos

Use OpenStudio to Create Your Own Energy Model

1. Introduction to OpenStudio Energy Modeling and EnergyPlus Thermal Zones
2. Onsite Building Documentation
3. Setting Up a New File
4. Creating Building Geometry
5. Defining Building Envelope Materials and Constructions
6. Adding Internal Loads and Schedules to Your Model
7. Adding Site Context
8. Running Your EnergyPlus Simulation
9. Viewing and Understanding Simulation Results
10. Creating Variations of Your Baseline Model to Evaluate Retrofit Options

Results
Identify Retrofits That Will Save Energy for Your Building

Go Back to Steps 5 or 6 and Run Simulation With Different Retrofit Options

http://openstudio.nrel.gov/energy-modeling-retrofit-projects

Credit: Marjorie Schott/ NREL
Typical Barriers to Using Simulation
Typical Barriers to Using Simulation

Some real, some perceived

- Complexity
- Time investment
- Experience required
- Lack of data
- Belief of inaccurate results

How to overcome?

- Training courses
- Conference proceedings (IBPSA)
- Energy modeling conferences
- User listservs (i.e. bldg-sim)
- Software documentation
- Design Guides
  - ASHRAE/AIA/DOE/IES/USGBC Advanced Energy Design Guide series
- Example files as starting point / wizards
  - Included with some software
  - DOE’s commercial reference buildings

Credit: Nicholas Long / NREL
Inputs Needed for Whole-Building Simulation

- Weather Data
- Ground Temperatures
- Building Geometry
- Window Areas
- Constructions
- Ground Coupling
- Building Program / Thermal Zoning
- Plug Loads (Electric / Gas)
- Miscellaneous Electrical Loads
- People Activity
- Lighting Type
- Infiltration
- Daylighting Configuration
- Schedules

- HVAC Systems
  - Fans
  - Coils
  - Boilers
  - Chillers
  - ERV
  - PTHP/VAV/etc.
- Ventilation Requirements
- Exhaust Requirements
- HVAC Performance Data
- Control Sequences
- Temperature Set Points
- SWH / DHW
- Water Use
- Utility Rates

... and more
Typical Barriers to Using Simulation
A Solution to the Data Problem
The Building Component Library
http://bcl.nrel.gov/
• Taxonomy of components (tags)
  o Includes Windows, Walls, MELs, HVAC Systems, Fans, Utility Rates, Weather Files
  o Site manages synonyms, related terms, and the hierarchy

• Description of components (attributes)
  o Each component type has an “infinite” number of attributes
  o Defines the characteristics of the components
    o Length, width, location, HDD, U-Factor, SHGC, Volumetric Flow Rate, etc.
  o Costs

• Other metadata
  o Provenance (who submitted it, when, etc.)
  o Files (list of files associated with the component)
  o Videos, images (if applicable)
### The Building Component Library

#### Building Component Library - Facets

**Filter by**

**Attributes**
- Facade
- U-Factor
  - 4 to 5
- Standard
- Vt
- Standard Type
- Climate Standard Year
  - 4 to 7
- Construction Type
- Construction
- Minimum Glazing Fraction
- Maximum Glazing Fraction
- Climate Zone

**Component Types**
- Construction Assembly (19)
- Fenestration (19)
- Window (14)

---

**19 results**

<table>
<thead>
<tr>
<th>Show</th>
<th>Sort By</th>
<th>Relevance</th>
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</thead>
</table>

**ASHRAE Std 90.1-2007 Residential 4B Window Metal Framing (entrance door)**
- Source: nong - 04/09/11
- Component Types: Construction Assembly, Window, Fenestration, Construction Assembly
- User rating: Not yet rated
- Downloads: 0
- Fidelity rating: 3

**ASHRAE Std 90.1-2007 Residential 8A Window Metal Framing (entrance door)**
- Source: nong - 04/09/11
- Component Types: Construction Assembly, Window, Fenestration, Construction Assembly
- User rating: Not yet rated
- Downloads: 0
- Fidelity rating: 3

**ASHRAE Std 90.1-2007 Residential 7A Window Metal Framing (entrance door)**
- Source: nong - 04/09/11
- Component Types: Construction Assembly, Window, Fenestration, Construction Assembly
- User rating: Not yet rated
- Downloads: 0
- Fidelity rating: 3

**ASHRAE Std 90.1-2007 Residential 6D Window Metal Framing (entrance door)**
- Source: nong - 04/09/11
- Component Types: Construction Assembly, Window, Fenestration, Construction Assembly
- User rating: Not yet rated
- Downloads: 0
- Fidelity rating: 3

**ASHRAE Std 90.1-2007 Residential 6B Window Metal Framing (entrance door)**
- Source: nong - 04/09/11
- Component Types: Construction Assembly, Window, Fenestration, Construction Assembly
- User rating: Not yet rated
- Downloads: 0
- Fidelity rating: 3

---

Credit: David Goldwasser / NREL
### ASHRAE 90.1-2001 Residential B-8 Window fixed

**Attributes**

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<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
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<tr>
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<td>Construction</td>
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<td>Vlt</td>
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<td>Facade</td>
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<tr>
<td>Maximum glazing fraction</td>
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**Source**

**Files**

- **Version**: 5.0.0
- **File Name**: ASHRAE 90.1-2001_Residential_B-8_Window_fixed.idf
- **File Type**: .idf

**Cost Data**

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**Provenance**

- **Byline**: September 30th, 2010

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*Credit: David Goldwasser / NREL*
The Building Component Library

Viewing Components

**ASHRAE 90.1-2001 Residential B-8 Window fixed**

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Credit: David Goldwasser / NREL
Conclusions

Energy modeling is useful for evaluating designs in both new and retrofit projects.

OpenStudio can support energy modeling as an integrated part of the design process, from pre-design through post occupancy.

The Building Component Library makes it easier to find reliable and appropriate energy modeling input data.
Q & A

Thank You

http://openstudio.nrel.gov
openstudio@nrel.gov