Thermal & Energy Analysis for Architects: Why, When, & How

Lori Ferriss, PE & Elaine Hoffman, CPHC NESEA BuildingEnergy Boston | March 9, 2018









SPEAKERS



Lori Ferriss, PE

Project Manager in Architecture and Preservation at Goody Clancy **ICOMOS** International Scientific Committee for Energy and Sustainability Co-Chair of Assocation for Preservation Technology Zero Net Carbon Collaborative B.S., M.Eng., Massachussetts Institute of Technology



Elaine Hoffman, CPHC

Architect/Co-chair of Goody Clancy 2030 Committee B.A. in Environmental Studies, Tufts University M.Arch, Columbia University



LEARNING OBJECTIVES

- Become familiar with the sustainability analysis tools available to designers and how to implement them
- Identify strategies to expand designers' use of analysis tools
- Understand how design tools can be used to ensure compliance with energy codes
- Understand the terminology and fundamental principles of life cycle assessment



OVERVIEW

- Introduction Ι.
- **ANALYSIS TOOLS Thermal Modeling - THERM** Π.
 - III. Energy Modeling Insight360
 - IV. Life Cycle Assessment Tally
- V. **Integrating the Process**
- **VI.** Discussion



SUSTAINABLE ANALYSIS TOOLS Value of Analytical Thinking

"If you can't measure it, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it." - H. JAMES HARRINGTON



HOW WE GOT HERE AND WHERE WE'RE GOING

Emergence of Organizations and Standards



Development of Software Tools







THE PROCESS OF SUSTAINABLE DESIGN - STATUS QUO Analysis as a Decision Making Tool







THE PROCESS OF SUSTAINABLE DESIGN Integrating Tools into the Design Process





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- TOOLS **II. Thermal Modeling - THERM**
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THERMAL MODELING

WHY - Impacts of Thermal Bridging on Building Performance

- Thermal bridging can reduce effectiveness of insulation by ~40% (Morrison) Hershfield, 2011)
- R-Values can vary from laboratory tested values by as much as 3-5x when installed in an assembly (Straube)
- Two primary impacts of thermal bridging:

1. Affect total heat loss through the envelope

2. Create local cold spots resulting in condensation, material degradation, and/or occupant discomfort



THERMAL MODELING WHY - THERM by LBNL

- Calculates 2-D heat transfer of elements or assemblies based on finite element analysis
- Renders resulting temperatures across the section
- Simple to use in-house, independent of energy modeling or full envelope design by a consultant
- Understand the implications of material selection on R-Value early in design
- Understand how R-Value is impacted by how we detail assemblies and transitions
- Results feed into energy modeling for more accurate results
- Model assemblies to comply with building code requirements
- Graphic output can be used to communicate with clients and others \bullet



THERMAL MODELING HOW - Evaluating Existing Conditions













Simulated R-Value = 8.6 h-ft2-F/Btu

<u>Retrofit Option A</u>: Fill Stud Cavity w/ Closed **Cell Spray Foam** Calculated R-Value = **20.4 h-ft2-F/Btu**

68.3°

Simulated R-Value =15 h-ft2-F/Btu

Color Legend

0.4° 8.9° 17.4° 25.8° 34.3° 42.8° 51.3° 59.8°

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Close

THERMAL MODELING HOW - Evaluating Retrofit Options

Existing Wall (shown in plan): Calculated Baseline R-Value = **9.84 h-ft2-F/Btu**

<u>Retrofit Option B:</u> Fill Stud Cavity w/ Interior Calculated R-Value = **26.4 h-ft2-F/Btu** Simulated R-Value = 25 h-ft2-F/Btu



EXISTING EXTERIOR WALL SECTION.

Closed Cell Spray Foam + 1" Continuous



THERMAL MODELING HOW - Evaluating Retrofit Options

Existing Wall (shown in plan): Simulated R-Value = 8.6 h-ft2-F/Btu







Proposed Wall: Simulated R-Value = 14 h-ft2-F/Btu



0.4°	8.9°	17.4°	25.8°	34.3°	42.8°	51.3°	59.8°	68.3°	F	
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Interior Air Dew Point (Final Year)

WUFI Analysis



THERMAL MODELING WHEN - Detailing and Material Selection

Thermally-Broken Brick Tie R = 31.2 h ft 2 F/Btu











Standard Brick Tie R = 8.6 h ft 2 F/Btu



THERMAL MODELING WHEN - Evaluating Shop Drawings and Material Substitutions







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ENERGY MODELING - INSIGHT360 HOW - Generating an Energy Model in Revit



BUILDING INFORMATION —

ANALYTICAL MODEL

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INSIGHT ANALYSIS



ENERGY MODELING - INSIGHT360 "Scalable Precision" in Generating the Model

BIM Energy Settings

CHOOSE Geometry Mode

Conceptual Masses



OR **Building Elements**



OR Both



Mode **Conceptual Types**

Mass Exterior V	Vall
Mass Interior V	Vall
Mass Exterior V	Vall - Undergrour
Mass Roof	
Mass Floor	
Mass Slab	
Mass Glazing	
Mass Skylight	
Mass Shade	
Mass Opening	

OR Schematic Types

Category	Override	Analytic Construction
Roofs		4 in lightweight concrete (U=0.2245 BTU/(h·ft²·°F))
Exterior Walls		8 in lightweight concrete block (U=0.1428 BTU/(h·ft²·°F))
Interior Walls		Frame partition with 3/4 in gypsum board (U=0.2595 BTU/(h·ft².°F))
Ceilings		8 in lightweight concrete ceiling (U=0.2397 BTU/(h-ft ² .°F))
Floors		Passive floor, no insulation, tile or vinyl (U=0.5210 BTU/(h·ft².°F))
Slabs		Un-insulated solid (U=0.1243 BTU/(h·ft ² .°F))
Doors		Metal (U=0.6520 BTU/(h·ft ² ·°F))
Exterior Windows		Large double-glazed windows (reflective coating) - industry (U=0.5145 BTU/(h·ft ² ·°F), SHGC=0.13)
Interior Windows		Large single-glazed windows (U=0.6498 BTU/(h.ft ² .°F), SHGC=0.86)
Skylights	Π	Large double-glazed windows (reflective coating) - industry (U=0.5628 BTU/(h-ft ² .°F), SHGC=0.13

OR **Detailed Elements**

Edit Assembly

Family:	Basic
Type:	Exteri
Total thickness:	1'17
Resistance (R):	12.99
Thermal Mass:	3.683

Parameter	Value	<u>^</u>
Energy Analytical Model	*	
Mode	Use Conceptual Masses 🗸 🗸]
Ground Plane	LEVEL I	
Project Phase	Project Completion	
Analytical Space Resolution	1' 6"	
Analytical Surface Resolution	1' 0"	
Perimeter Zone Depth	12' 0"	
Perimeter Zone Division		
Advanced	*	1
Other Options	Edit	
Identity Data	*	
Workset	Project Info	U

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CHOOSE Material Thermal Properties

	Lightweight Construction – Typical Mild Climate Insulation
	Lightweight Construction – No Insulation
nd	High Mass Construction – Typical Mild Climate Insulation
	Typical Insulation - Cool Roof
	Lightweight Construction – No Insulation
	High Mass Construction – No Insulation
	Double Pane Clear – No Coating
	Double Pane Clear – No Coating
	Basic Shade
	Air

Wall ior Wall 20' 0' 42 (h•ft2•°F)/BTU 39 BTU/%



ENERGY MODELING - INSIGHT360 New Construction Example



Defined in Revit

Project Location Building Use Building Mass/Building Elements Iteratively Tested through Insight

Building Orientation Window-Wall-Ratio - by elevation Window Shades – by elevation Window Type – by elevation Wall Construction **Roof Construction** Infiltration Lighting/Plug Load Efficiency **Daylighting and Occupancy Controls** HVAC Types (limited options) **Operating Schedule PV** Potential



ENERGY MODELING - INSIGHT360 Existing Building Example



Defined in Revit

Project Location Building Use Building Orientation Window-Wall-Ratio - by elevation Window Shades – by elevation



Iteratively Tested through Insight Operating Schedule PV Potential

Wall Construction Roof Construction Infiltration Window Type – by elevation Lighting/Plug Load Efficiency **Daylighting and Occupancy Controls** HVAC Types (limited options)



ENERGY MODELING - INSIGHT360

How to tell if your analytical surfaces are working







ENERGY MODELING - INSIGHT360

How to use Insight to drive decisions about your exterior glazing



ENERGY MODELING - INSIGHT360

Study each variable to determine significance to energy use intensity (EUI)









ENERGY MODELING - INSIGHT360 Understanding relative impact of each variable



Benchmark Comparison kBtu / ft² / yr









ENERGY MODELING - INSIGHT360 Understanding relative impact of each variable





ENERGY MODELING - INSIGHT360 Window Types: defined within tiers of precision



Tier 1: Slider



Tier 2: Conceptual Options

Mass Model	
Workset	Proje
Edited by	
Mass Exterior Wall	Light
Mass Interior Wall	Light
Mass Exterior Wall - Underground	High
Mass Roof	Туріс
Mass Floor	Light
Mass Slab	High
Mass Glazing	Quad
Mass Skylight	Doub
Mass Shade	Doub
Mass Opening	Doub
	Doub Triple
	Quad

Tier 3: Schematic Types

Category	Override	Analytic Construction
Roofs		4 in lightweight concrete (U=0.2245 BTU/(h·ft ² ·°F))
Exterior Walls		8 in lightweight concrete block (U=0.1428 BTU/(h·ft ² .°F))
Interior Walls		Frame partition with 3/4 in gypsum board (U=0.2595 BTU/(h-ft ² +°F))
Ceilings		8 in lightweight concrete ceiling (U=0.2397 BTU/(h·ft².°F))
Floors		Passive floor, no insulation, tile or vinyl (U=0.5210 BTU/(h·ft ² ·°F))
Slabs		Un-insulated solid (U=0.1243 BTU/(h·ft ² ·°F))
Doors		Metal (U=0.6520 BTU/(h·ft ² .°F))
Exterior Windows		arge double-glazed windows (reflective coating) - industry (U=0.5145 BTU/(h-ft ^{2,o} F), SHGC=0.
Interior Windows		Small double-glazed windows (U=0.5583 BTU/(h·ft ² ·°F), SHGC=0.76)
Skylights		Small double-glazed windows - Iow-E coating (U=0.4127 BTU/(h·ft ² ·°F), SHGC=0.65) Large single-glazed windows (U=0.9795 BTU/(h·ft ² ·°F), SHGC=0.86) Large double-glazed windows - absorbing coating (U=0.5141 BTU/(h·ft ² ·°F), SHGC=0.76) Large double-glazed windows - reflective coating (U=0.5141 BTU/(h·ft ² ·°F), SHGC=0.13)
		Large double-glazed windows (reflective coating) - industry (U=0.5145 BTU/(h-ft ² .°F), SHGC= Single algorithmindows - domestic (U=0.9505 BTU/(h-ft ² .°F), SHGC=0.96)

	×
Constructions	f i
ct Info	
weight Construction – Typical Mild Climate Insulation weight Construction – No Insulation	
Mass Construction – Typical Mild Climate Insulation al Insulation - Cool Roof	
weight Construction – No Insulation	
Mass Construction – No Insulation	
Pane Clear - LowE Hot or Cold Climate	
le Pane - Reflective le Pane Clear – LowE Cold Climate, High SHGC le Pane Clear – LowE Hot Climate, Low SHGC le Pane Clear - High Performance, LowE, High Tvis, Low Pane Clear - LowE Hot or Cold Climate	/ SHGC
Pane Clear - LowE Hot or Cold Climate	
OK Cancel Help	
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ENERGY MODELING - INSIGHT360 Insight360 vs. traditional energy model



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Typical Energy Model

Process: Limited ability to iterate; must export or create file from scratch,

Output: Generate a specific estimate



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ANALYSIS TOOLS IV. Life Cycle Assessment - Tally

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LIFE CYCLE ASSESSMENT (LCA)

Scientific method for measuring the potential cradle to grave or cradle to cradle environmental footprint of materials, products, and services over their entire lifetime.



IMAGE CREDIT: IRISH GREEN



LIFE CYCLE ASSESSMENT (LCA) WHY - Cradle to Grave Impacts



Adapted from K. Simonen, Life Cycle Assessment



LIFE CYCLE ASSESSMENT (LCA) WHY - Impact Categories

- Global Warming Potential
- Ozone Depletion Potential
- Acidification Potential
- Eutrophication Potential
- Formation of Tropospheric Ozone (Smog) Potential







LIFE CYCLE ASSESSMENT (LCA) WHY - Cradle to Grave Impacts





LIFE CYCLE ASSESSMENT (LCA) WHY - Impact Categories

WE HAVE 35 YEARS TO GET TO ZERO CARBON, SO WHY ARE WE STILL MEASURING IMPACTS **BASED ON A BUILDING'S FULL LIFESPAN?** -Architecture2030





LIFE CYCLE ASSESSMENT (LCA)





LIFE CYCLE ASSESSMENT (LCA) Implementation

Excel Spreadsheet

U.S. Life Cycle Inventory Database



Environmental Product Declaration





Analysis Software Tools








IMPLEMENTATION - LCA SOFTWARE HOW - Window Products







LIFE CYCLE ASSESSMENT (LCA) HOW - Window Products

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IMPLEMENTATION - LCA SOFTWARE HOW - Window Products

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LIFE CYCLE ASSESSMENT (LCA) HOW - Window Products

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Title	Design option comparison		Edit transportation distances	Bill of Materials (Excel)		
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Author	Elaine.Hoffman					
Company	Goody Clancy					
Project	Window Test					
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			Electricity			
Gross Build	ling Area 1200	$ft^2 \sim$	Heating	5		
Expected B	uilding Life 60	years	Water			
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ICLUDE OPERATIONAL ENERGY

ICLUDE CONSTRUCTION IMPACTS

IMPLEMENTATION - LCA SOFTWARE HOW - Window Products



Legend

Design Options

Fixed (primary) Fixed_Wood

Projected



IMPLEMENTATION - LCA SOFTWARE HOW - Structural System Selection

Compare an equivalent 30' x 30' structural bay constructed of:

- I. Concrete columns, beams, and slab
- II. Steel columns, beams, and joists with concrete on metal deck
- III. Glulam columns and beams with wood infill and a concrete topping slab



k opping slab



IMPLEMENTATION - LCA SOFTWARE HOW - Structural Systems Comparison







IMPLEMENTATION - LCA SOFTWARE HOW - Structural Systems Comparison







- 115,000 sf existing building from the 1970s
- Brick cladding and concrete structural system
- Comprehensive renovation including new systems and partition walls







Legend

Floors

- 6 1/2" Concrete Slab 8" Concrete Slab East Connector Ramp: East Connector Ramp Wood Deck

Roofs

4" Concrete Slab 4" Concrete Slab 2 6 1/2" Concrete Slab Roof Type 2 - Membrane Roof on Wood Framing Roof Type 5 - Membrane Roof on Mtl. Deck 2 Roof Type 6 - Standing Seam Mtl. on Mtl. Deck_GWB int.

Structure

	Concrete-Rectangular-Column_07300: 10 x 16
-	Concrete-Rectangular-Column_07300: 10 x 31
	Concrete-Rectangular-Column_07300: 10 x 32
	Concrete-Rectangular-Column_07300: 10 x 48
	Concrete-Rectangular-Column_07300: 12 x 30
	Concrete-Round-Column: 16"
	HSS-Hollow Structural Section-Column: HSS4X4X1/2
1	HSS-Hollow Structural Section-Column: HSS5X5X1/2
	Pile Cap-1 Pile Angled Notched_07300: 70"x70"x11"
-	Pile Cap-1 Pile Angled_07300: 70"x70"x11"
	Pile Cap-1 Pile Unequal Width Notched_07300: 70"x91"x11
	Pile Cap-1 Pile Unequal Width_07300: 70"x91"x11"
	Pile Cap-1 Pile_07300: 6'6"x6'6"x1'3"
	Pile-Steel Pipe: 24" Diameter

Walls







Legend



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Global Warming Potential

— Net value (impacts + credits)

Maintenance and Replacement [B2-B4]





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Legend

Revit Categories

Ceilings

Curtain Panels

Curtain Wall Mullions

Floors

Roofs

Structure

Walls

Windows



Avoided Global Warming Potential = 3,764,469 kgC02eq

- = 800 passenger vehicles on the road for one year
- = burning **20** railcars of coal
- = operating **315** homes for a year
- = offset by growing **97,000** tree seedlings for 10 years



Avoided Global Warming Potential = 3,764,469 kgC02eq

- = 800 passenger vehicles on the road for one year
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Total embodied Global Warming Potential of renovation = 782,118 kgCO2eq





Avoided Global Warming Potential = 3,764,469 kgC02eq

- = 800 passenger vehicles on the road for one year
- = burning **20** railcars of coal
- = operating **315** homes for a year
- = offset by growing **97,000** tree seedlings for 10 years

Total embodied Global Warming Potential of renovation = 782,118 kgCO2eq

It takes = ~2 years of operation for the improved operational efficiency to payback the renovation impacts.



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ANALYTICAL WORKFLOW INTEGRATION





ANALYTICAL WORKFLOW Integrating tools into the envelope design process

BIM Model



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DETERMINE PSI VALUES AT ANY POTENTIAL THERMAL BRIDGES Slab details at Exterior wall & window Roof details at exterior wall **DETERMINE HYGROTHERMAL** PERFORMANCE OF ENVELOPE Whole building analysis



DISCUSSION

How can tools be integrated differently through the design and construction process?

What is the best workflow for collaborative design using analytic tools?

What tools do you wish were available?

Have you engaged in knowledge sharing or education about analytical tools?

What tools make the biggest impact on the performance of the final building?

What tools best communicate the urgency of high performance, low-carbon design to clients?

Should certain tools be used exclusively by certain members of the design team?

