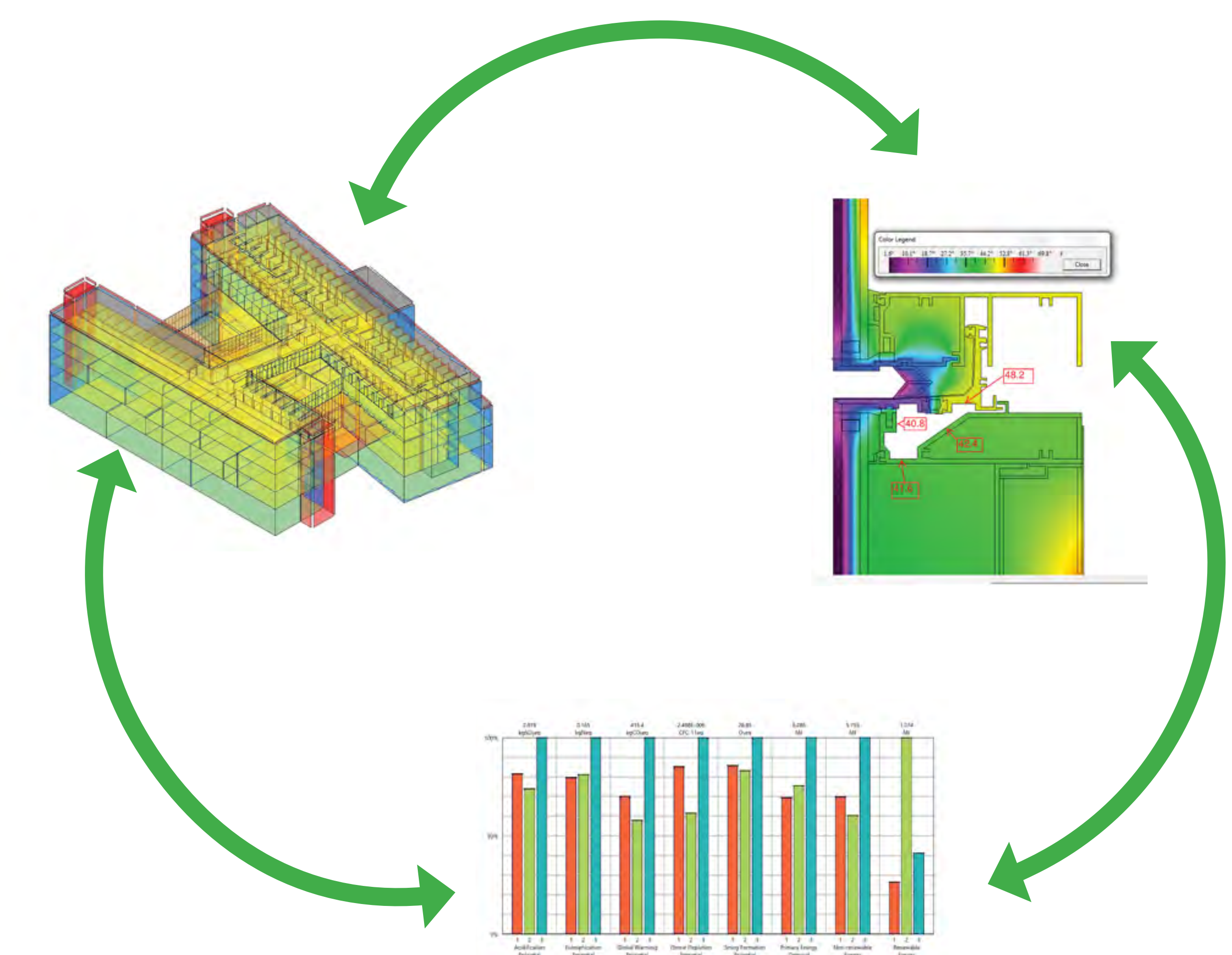
Thermal & Energy Analysis for Architects: Why, When, & How

Lori Ferriss, PE & Elaine Hoffman, CPHC

NESEA BuildingEnergy Boston | March 9, 2018



GOODY CLANCY
ARCHITECTURE / PLANNING / PRESERVATION

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
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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

I. Introduction

ANALYSIS TOOLS

II. Thermal Modeling - THERM

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.

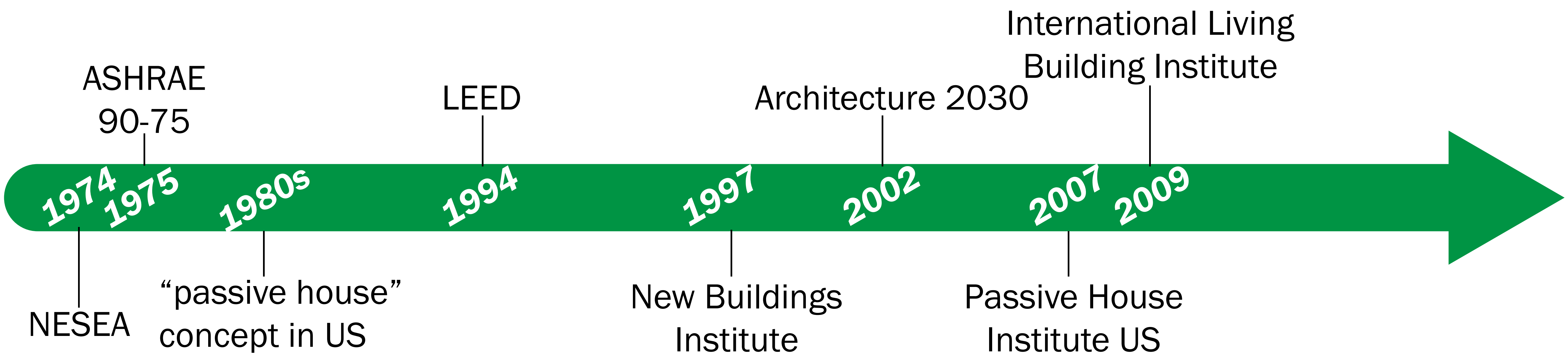
If you can't understand it, you can't control it.

If you can't control it, you can't improve it."

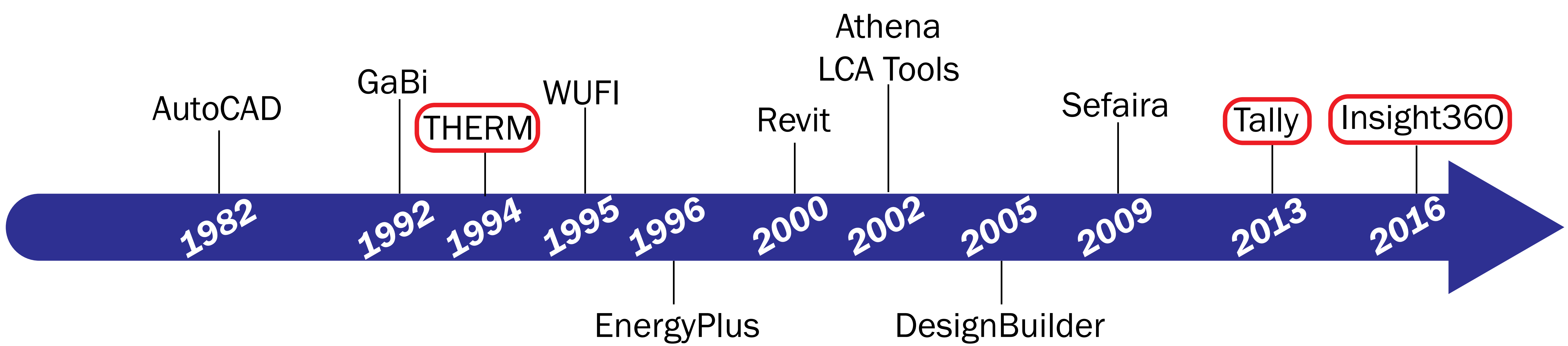
- H. JAMES HARRINGTON

HOW WE GOT HERE AND WHERE WE'RE GOING

Emergence of Organizations and Standards

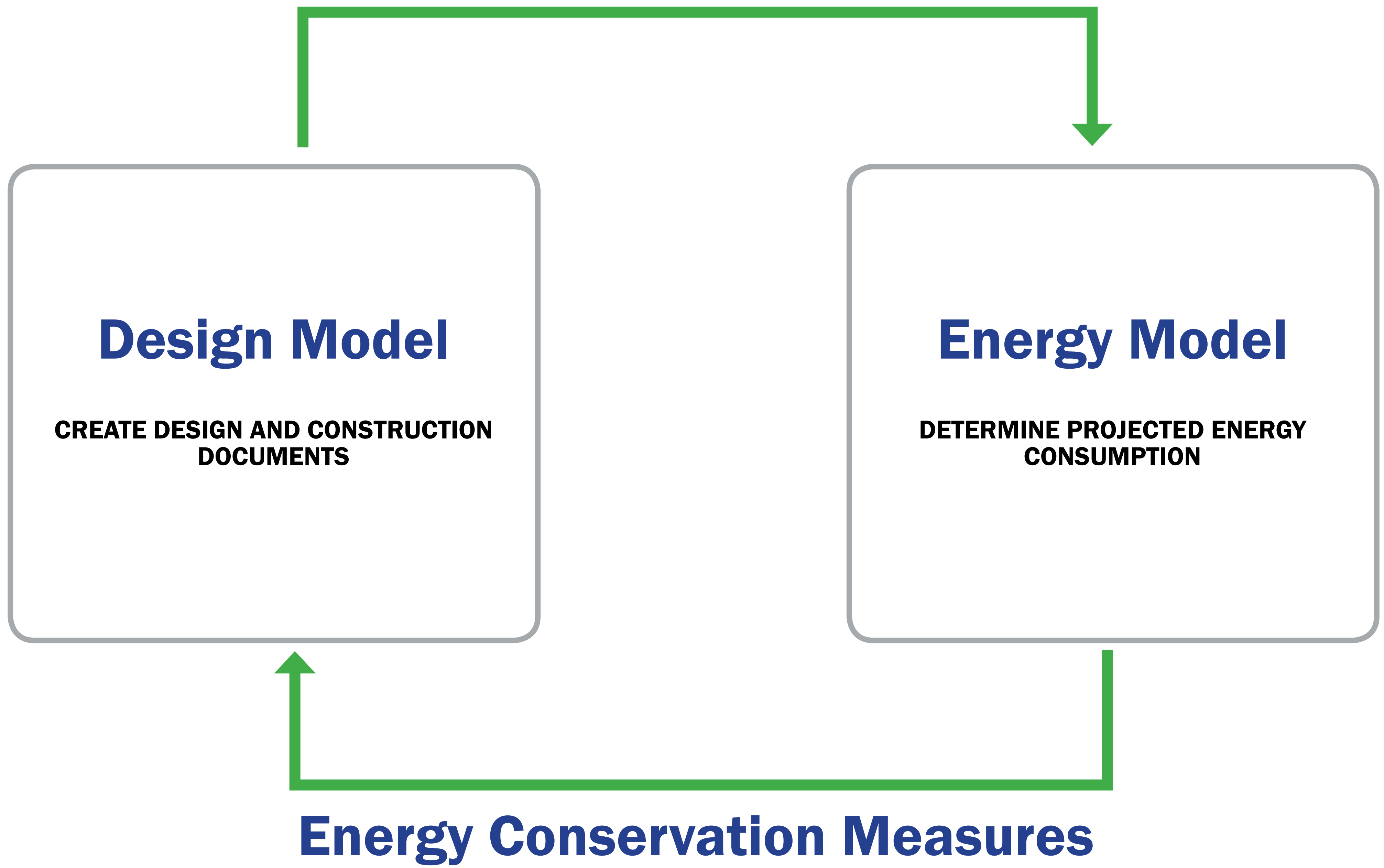


Development of Software Tools



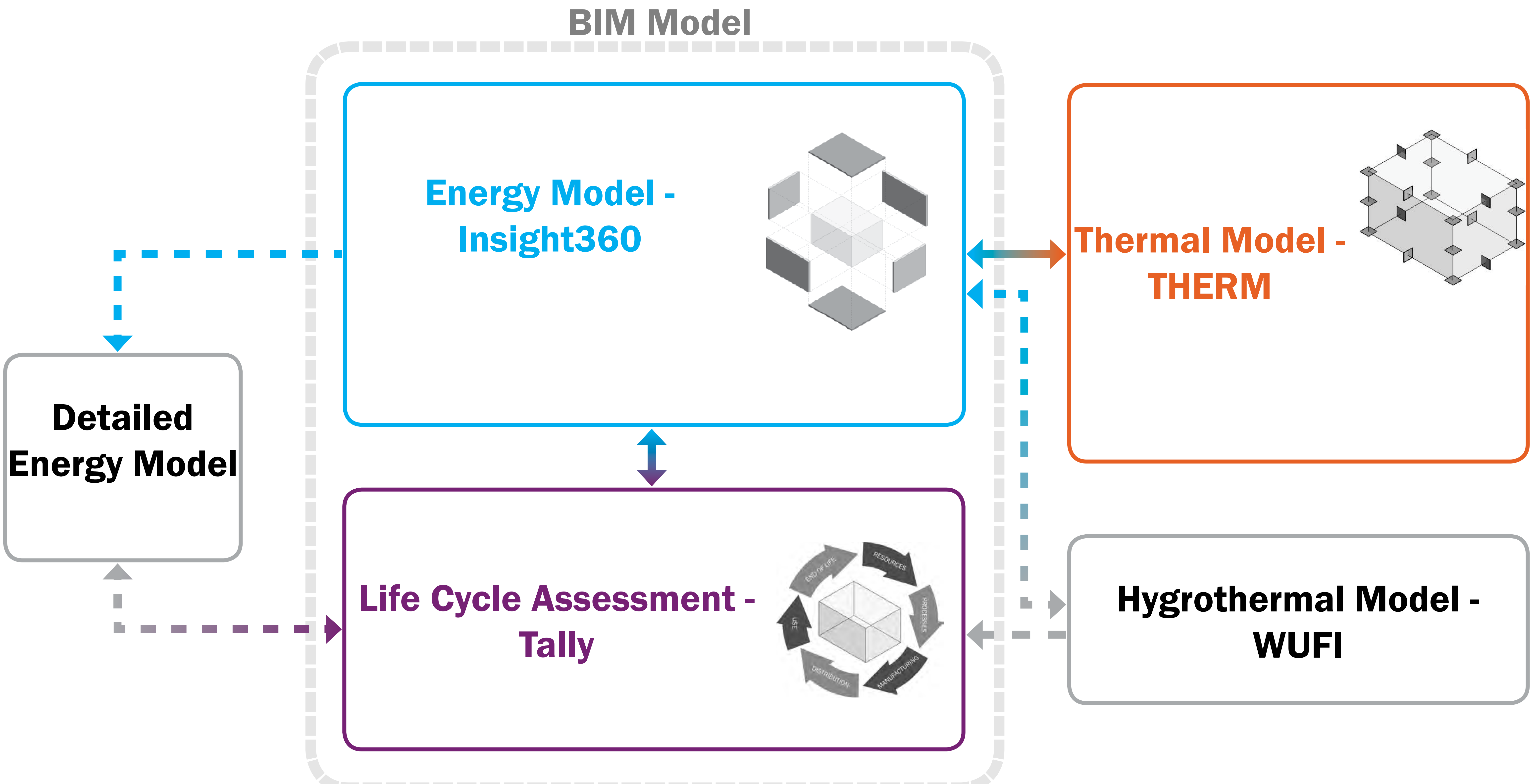
THE PROCESS OF SUSTAINABLE DESIGN - STATUS QUO

Analysis as a Decision Making Tool



THE PROCESS OF SUSTAINABLE DESIGN

Integrating Tools into the Design Process



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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

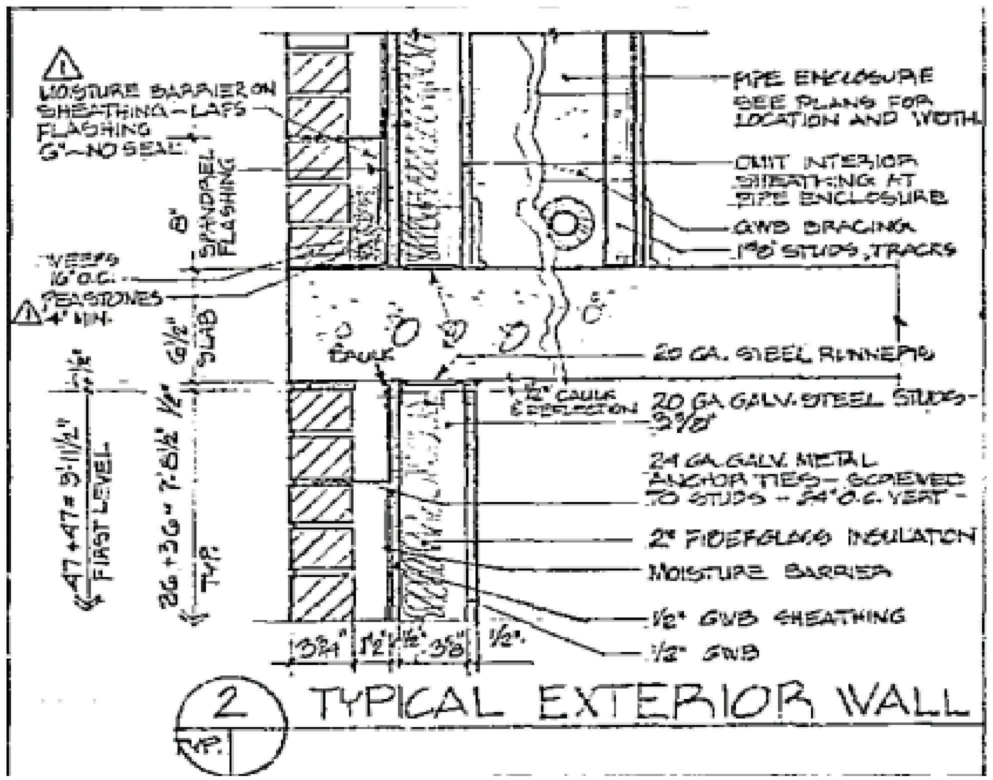
THERMAL MODELING

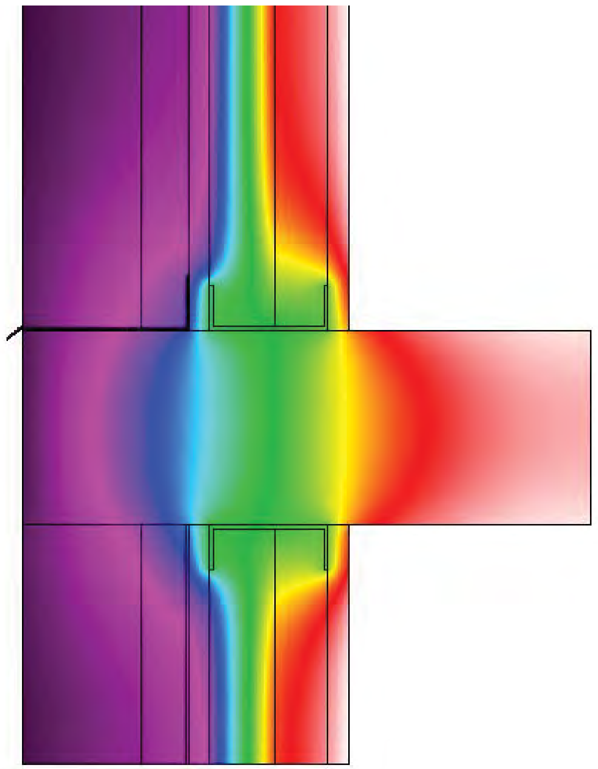
WHY - THERM by LBNL

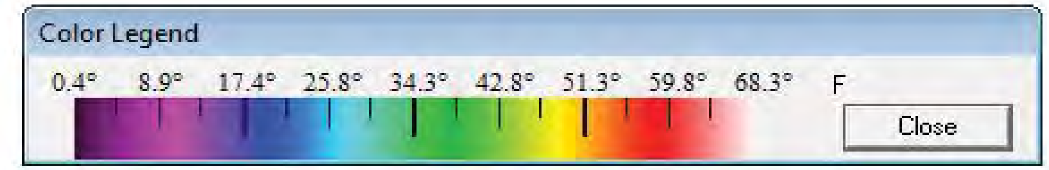
- Calculates 2-D heat transfer of elements or assemblies based on finite element analysis
- Renders resulting temperatures across the section
- Simple to use in-house, independent of energy modeling or full envelope design by a consultant
- Understand the implications of material selection on R-Value 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

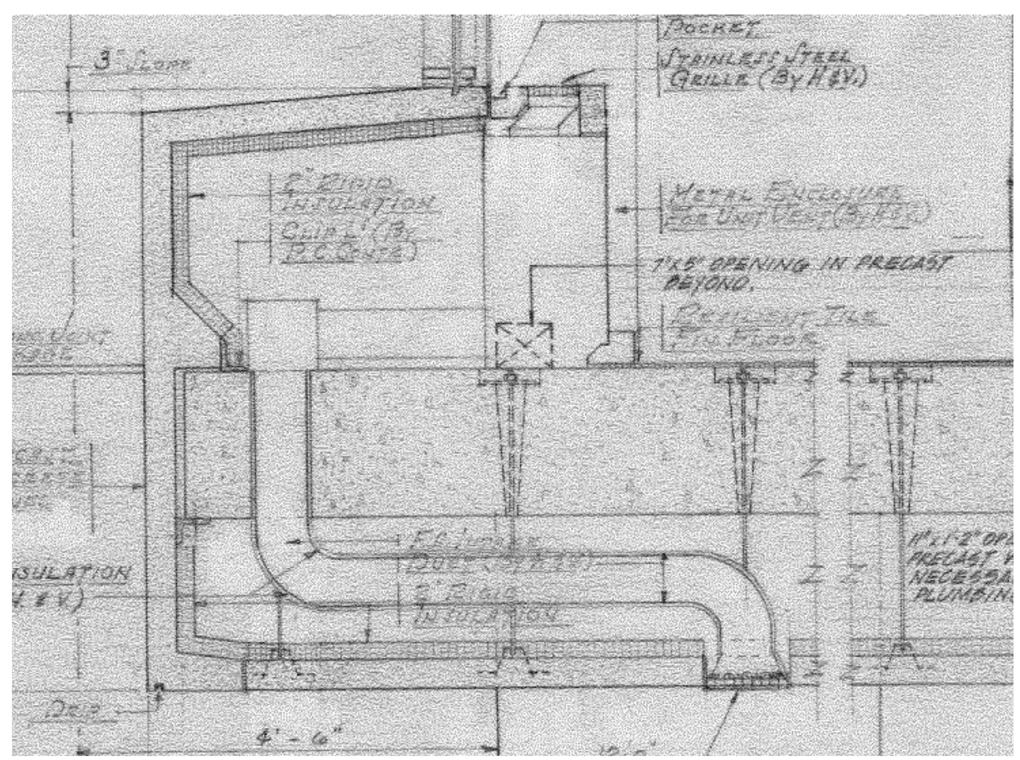
THERMAL MODELING

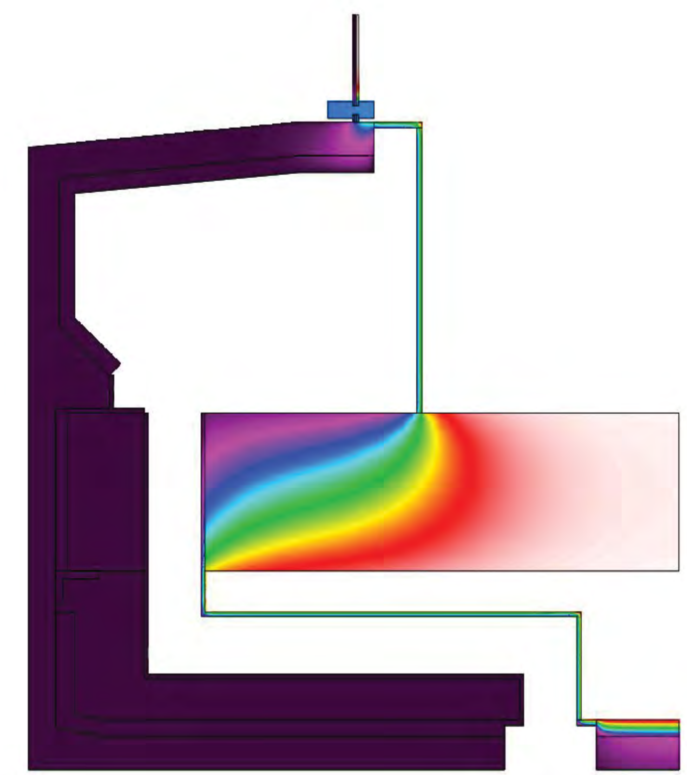
HOW - Evaluating Existing Conditions











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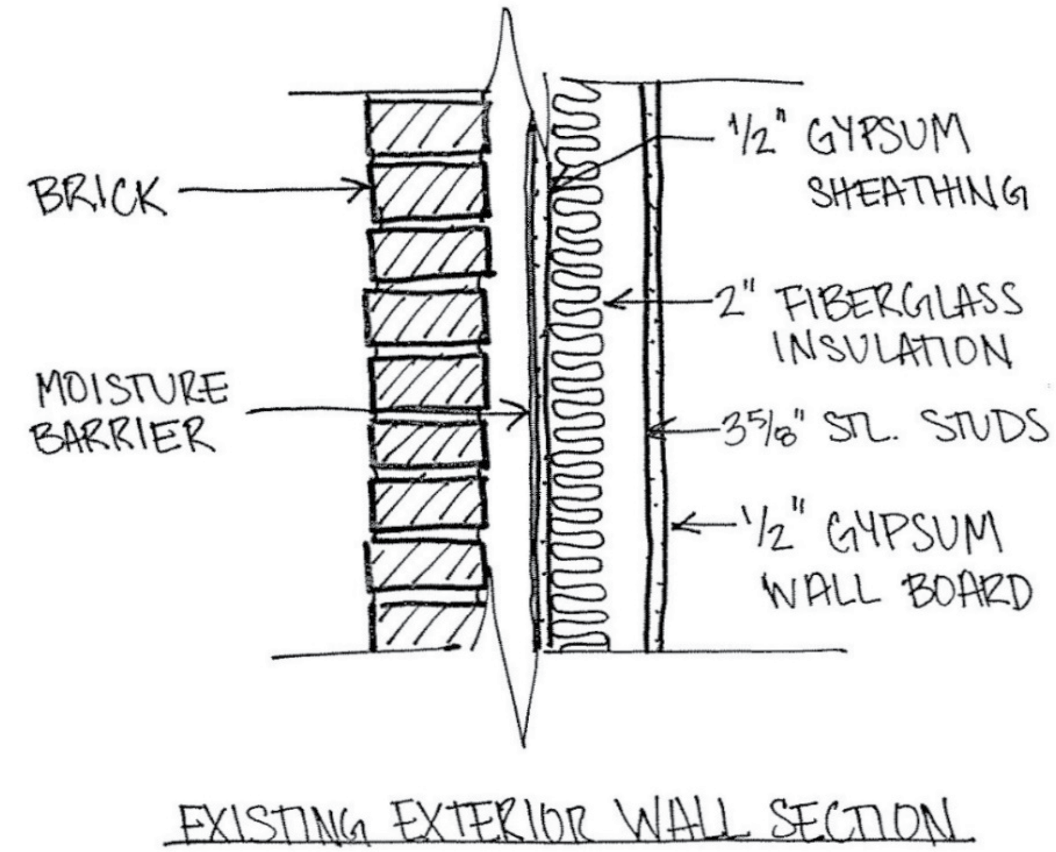
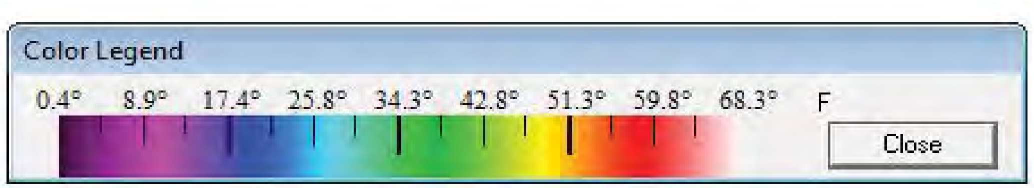
THERMAL MODELING

HOW - Evaluating Retrofit Options

Existing Wall (shown in plan):
Calculated Baseline R-Value = **9.84 h·ft2·F/Btu**
Simulated R-Value = **8.6 h·ft2·F/Btu**



Retrofit Option A: Fill Stud Cavity w/ Closed Cell Spray Foam
Calculated R-Value = **20.4 h·ft2·F/Btu**
Simulated R-Value =**15 h·ft2·F/Btu**



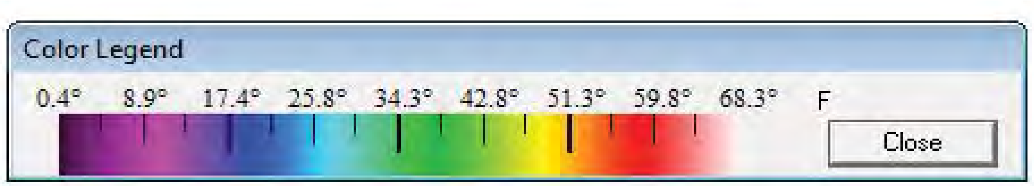
Retrofit Option B: Fill Stud Cavity w/ Closed Cell Spray Foam + 1" Continuous Interior
Calculated R-Value = **26.4 h·ft2·F/Btu**
Simulated R-Value = **25 h·ft2·F/Btu**

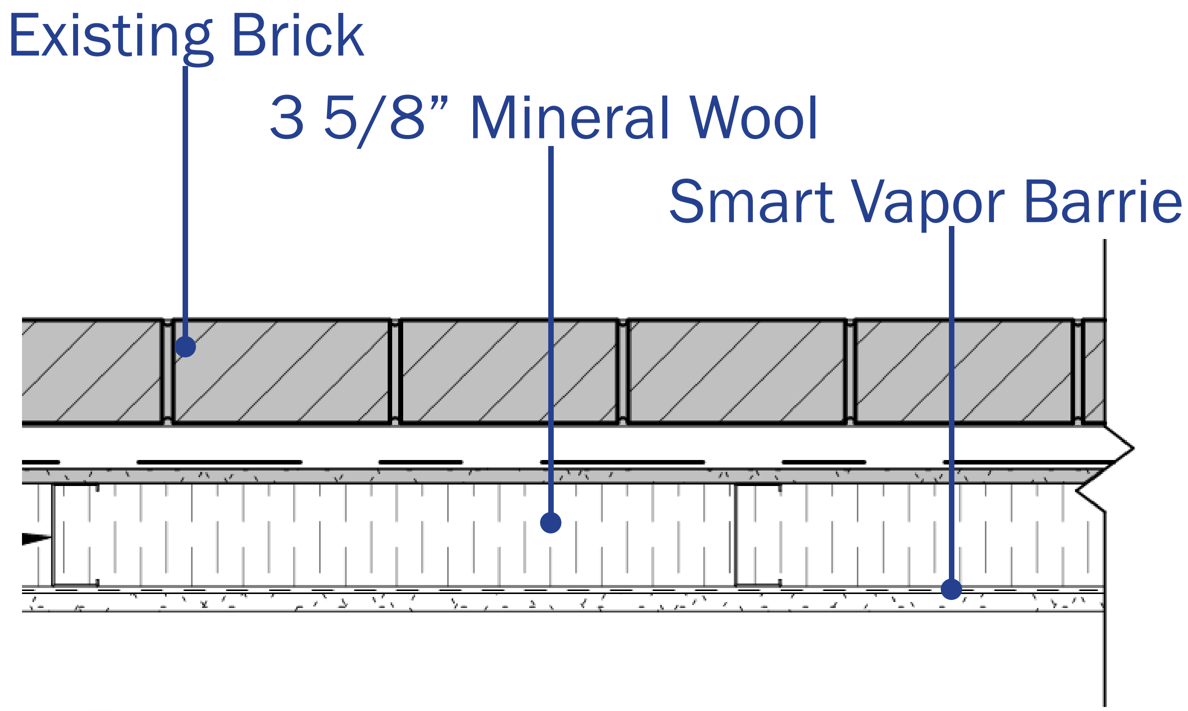
THERMAL MODELING

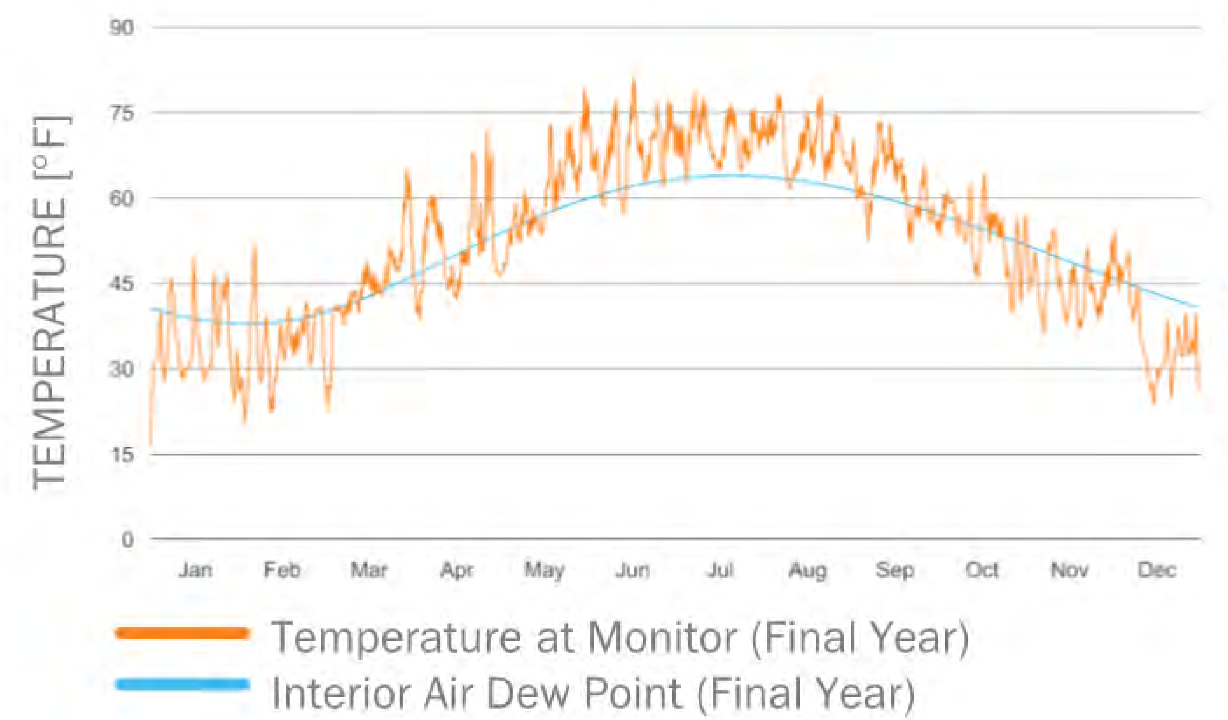
HOW - Evaluating Retrofit Options

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

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







WUFI Analysis

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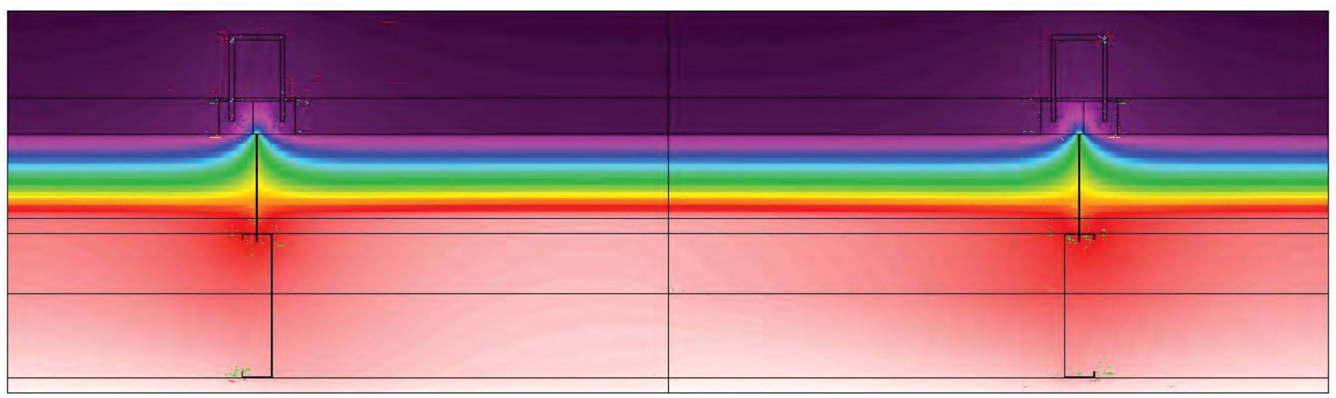
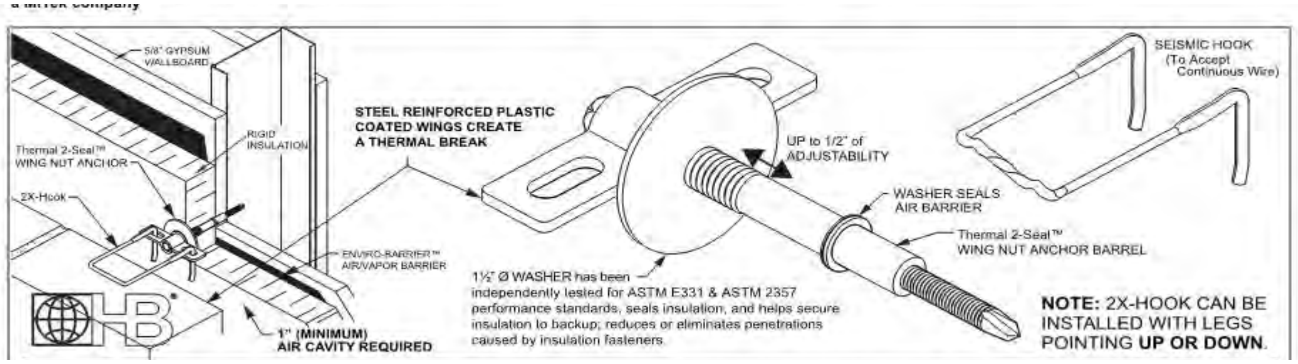
THERMAL MODELING

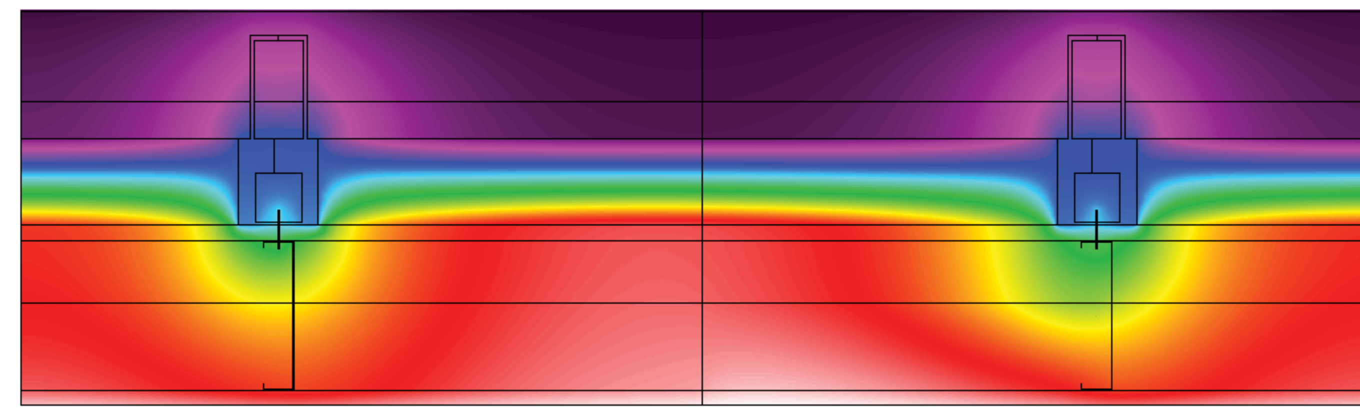
WHEN - Detailing and Material Selection

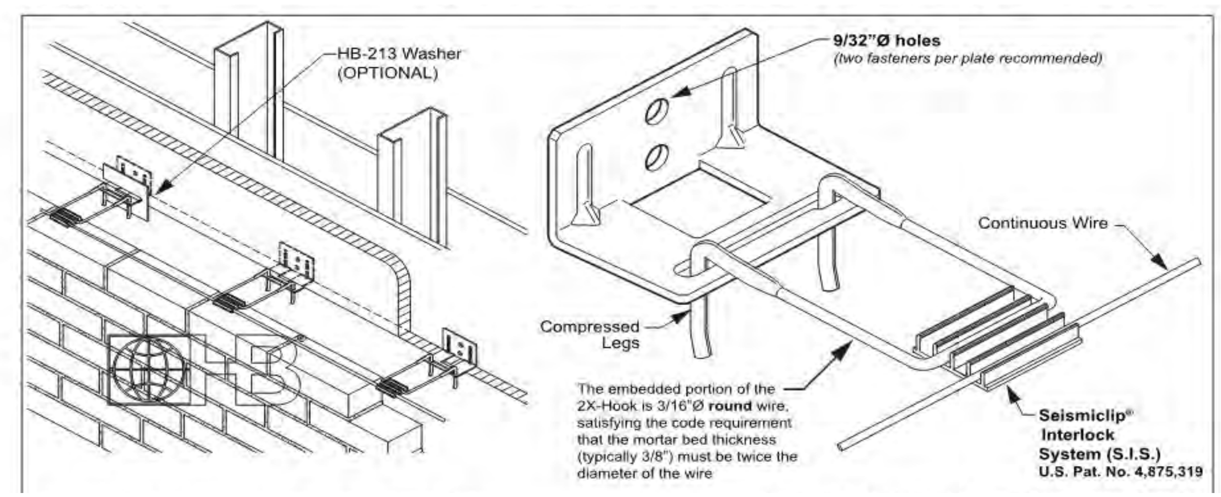
Thermally-Broken Brick Tie
R = 31.2 h·ft2·F/Btu





Standard Brick Tie
R = 8.6 h·ft2·F/Btu





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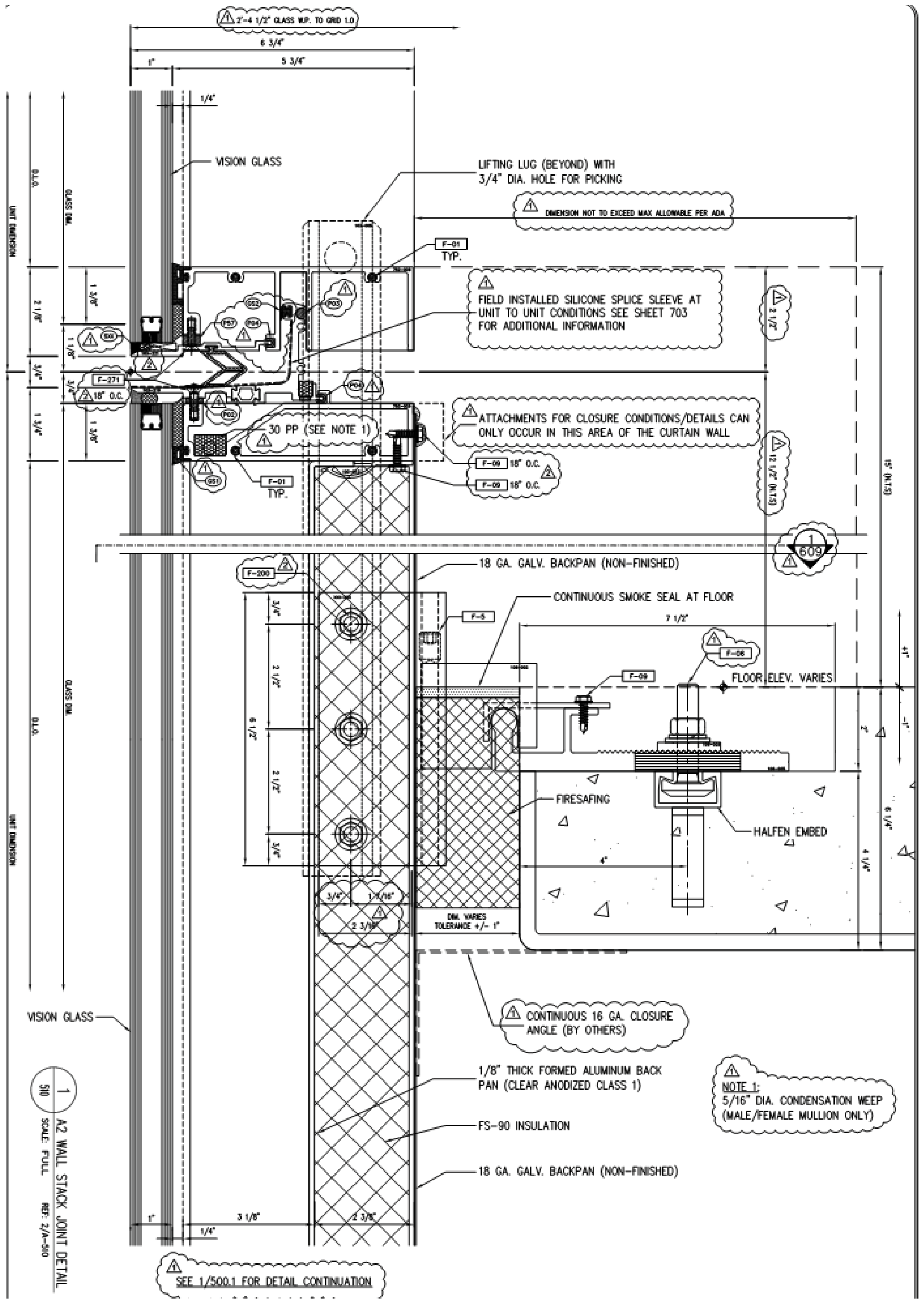
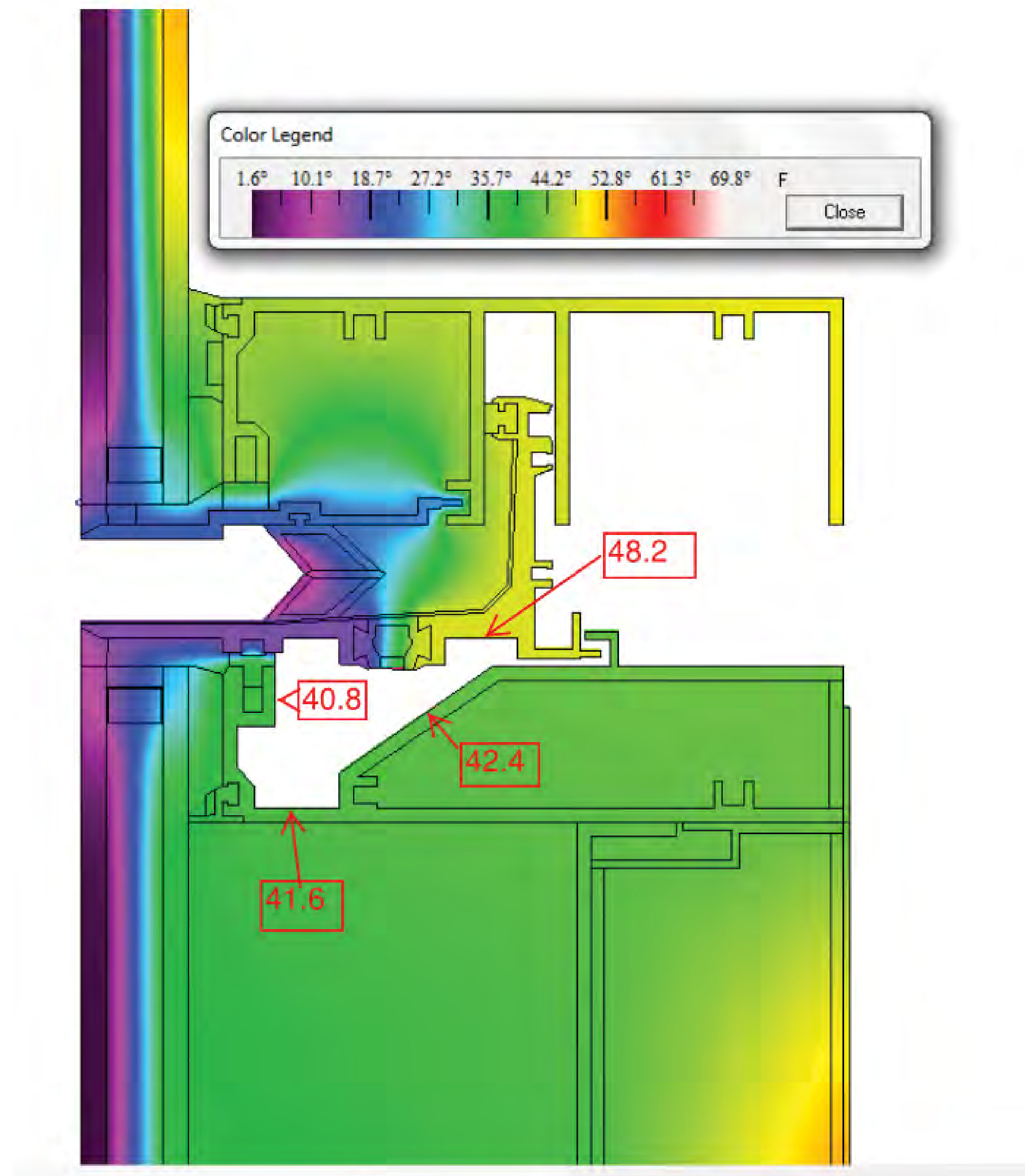
THERMAL MODELING

WHEN - Evaluating Shop Drawings and Material Substitutions





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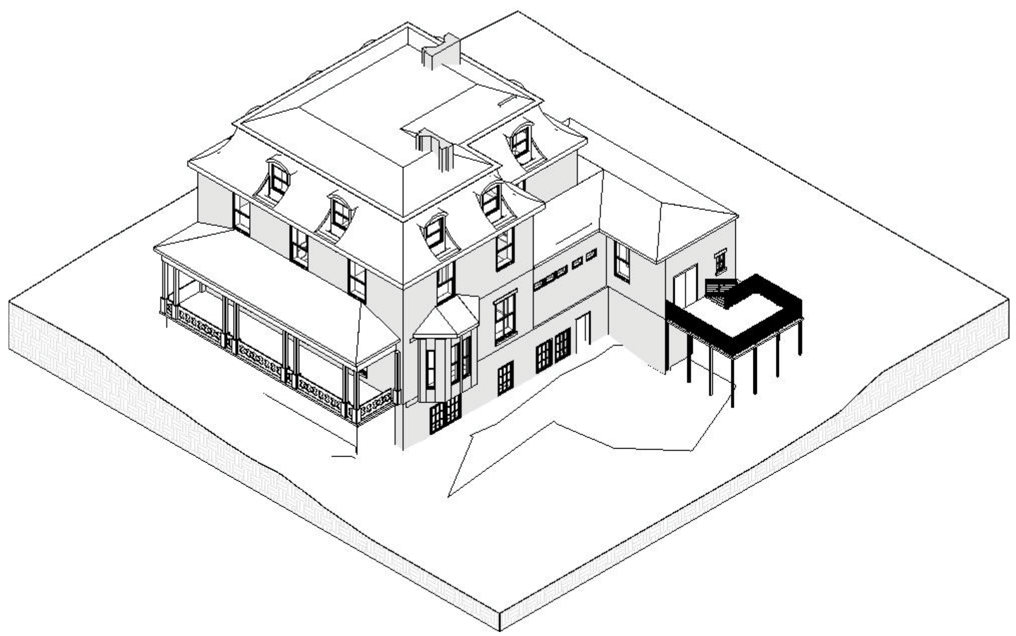
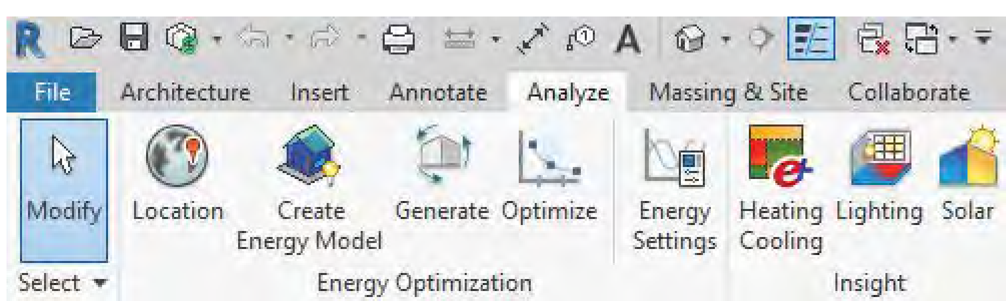
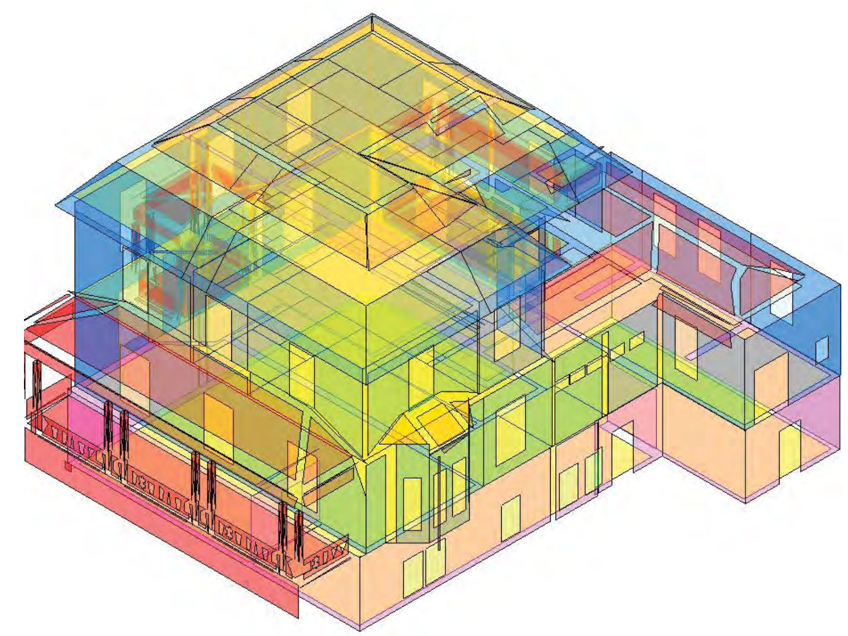
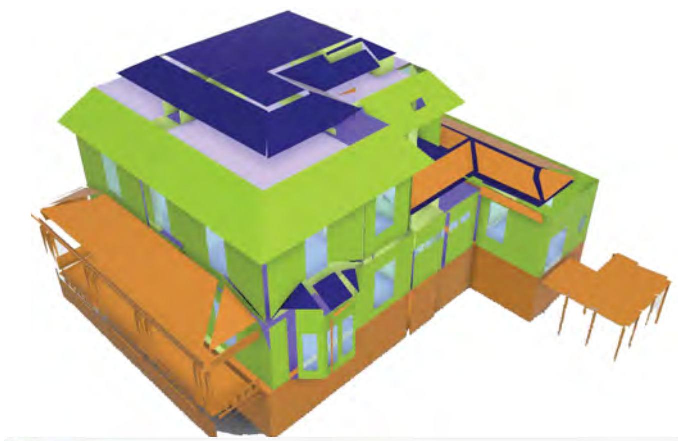
ENERGY MODELING - INSIGHT360

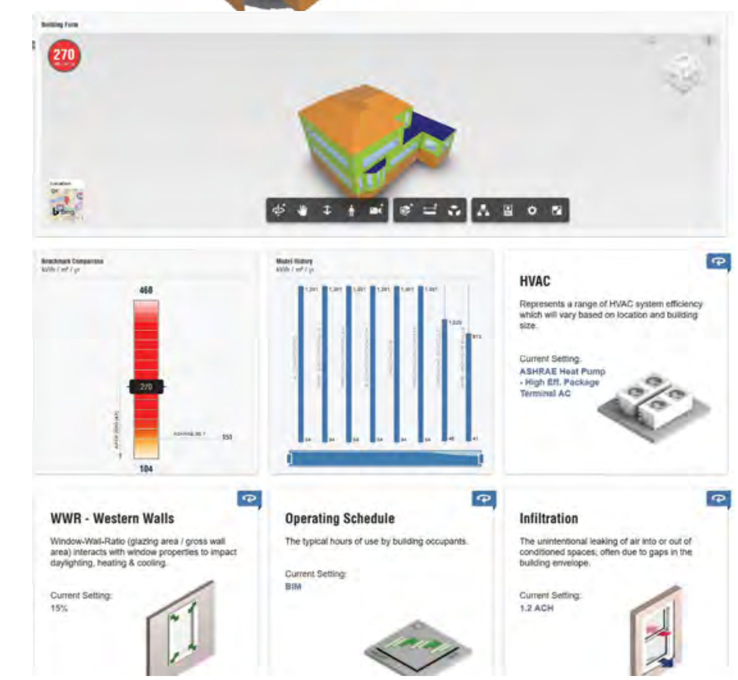
HOW - Generating an Energy Model in Revit











BUILDING INFORMATION → ANALYTICAL MODEL → INSIGHT ANALYSIS

ENERGY MODELING - INSIGHT360

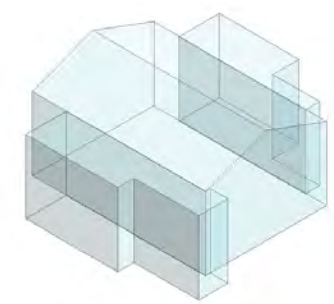
"Scalable Precision" in Generating the Model

BIM Energy Settings → **CHOOSE Geometry Mode** → **CHOOSE Material Thermal Properties Mode**

Energy Settings

Parameter	Value
Energy Analytical Model	
Mode	Use Conceptual Masses
Ground Plane	LEVEL 1
Project Phase	Project Completion
Analytical Space Resolution	1' 6"
Analytical Surface Resolution	1' 0"
Perimeter Zone Depth	12' 0"
Perimeter Zone Division	☑
Advanced	
Other Options	Edit...
Identity Data	
Workset	Project Info

Conceptual Masses

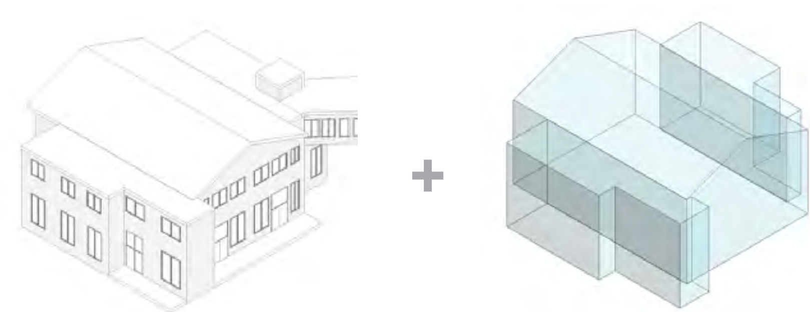


OR

Building Elements

OR

Both



Conceptual Types

Mass Exterior Wall	Lightweight Construction – Typical Mild Climate Insulation
Mass Interior Wall	Lightweight Construction – No Insulation
Mass Exterior Wall - Underground	High Mass Construction – Typical Mild Climate Insulation
Mass Roof	Typical Insulation - Cool Roof
Mass Floor	Lightweight Construction – No Insulation
Mass Slab	High Mass Construction – No Insulation
Mass Glazing	Double Pane Clear – No Coating
Mass Skylight	Double Pane Clear – No Coating
Mass Shade	Basic Shade
Mass Opening	Air

OR

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·ft^2·°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	☐	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	☐	Large double-glazed windows (reflective coating) - industry (U=0.5628 BTU/(h·ft^2·°F), SHGC=0.13)

OR

Detailed Elements

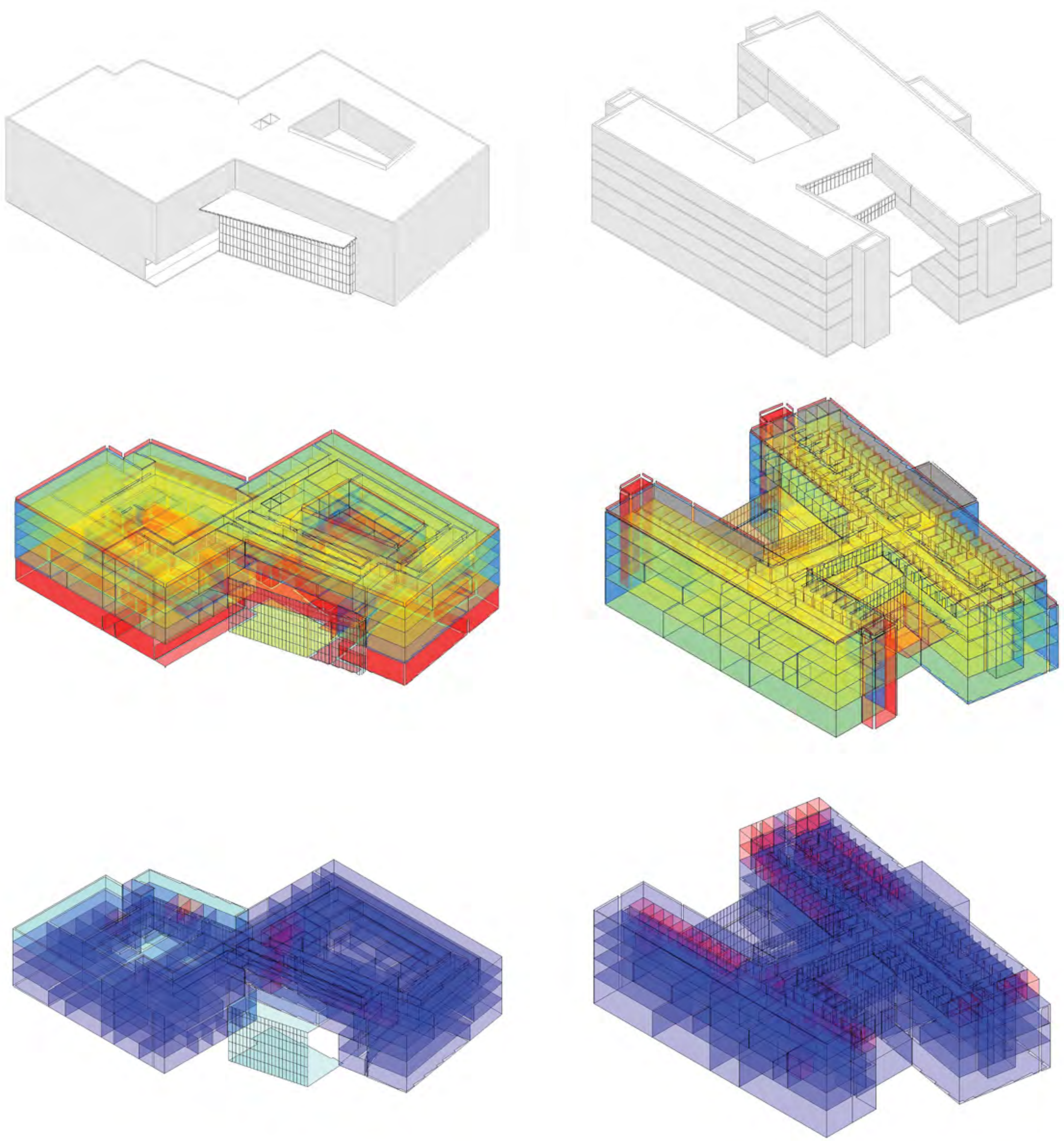
Edit Assembly

Family:	Basic Wall
Type:	Exterior Wall
Total thickness:	1' 1 7/8"
Resistance (R):	12.9942 (h·ft^2·°F)/BTU
Thermal Mass:	3.6839 BTU/°F

Sample Height: 20' 0"

ENERGY MODELING - INSIGHT360

New Construction Example



Defined in Revit

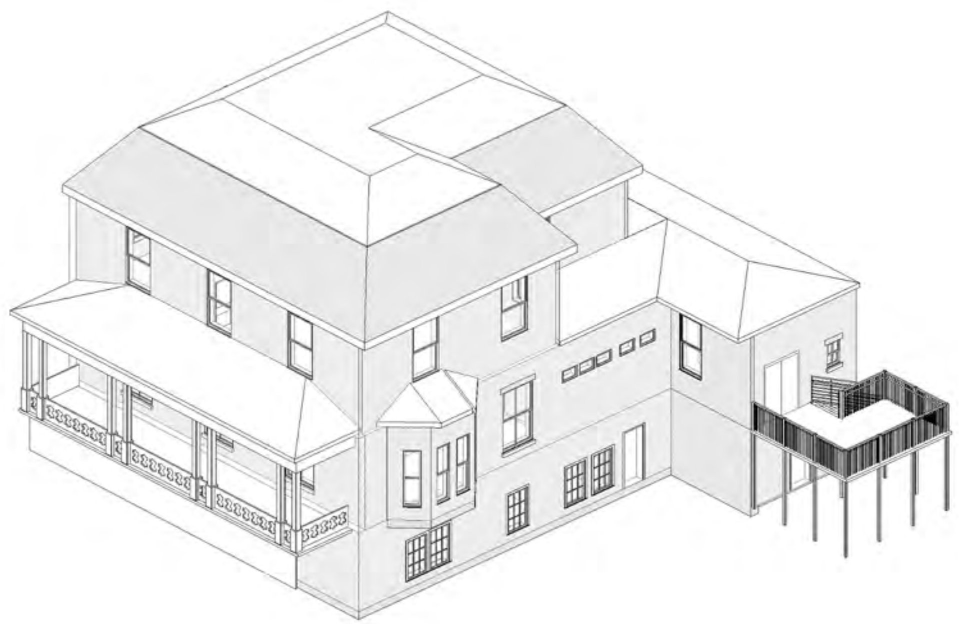
Project Location
Building Use
Building Mass/Building Elements

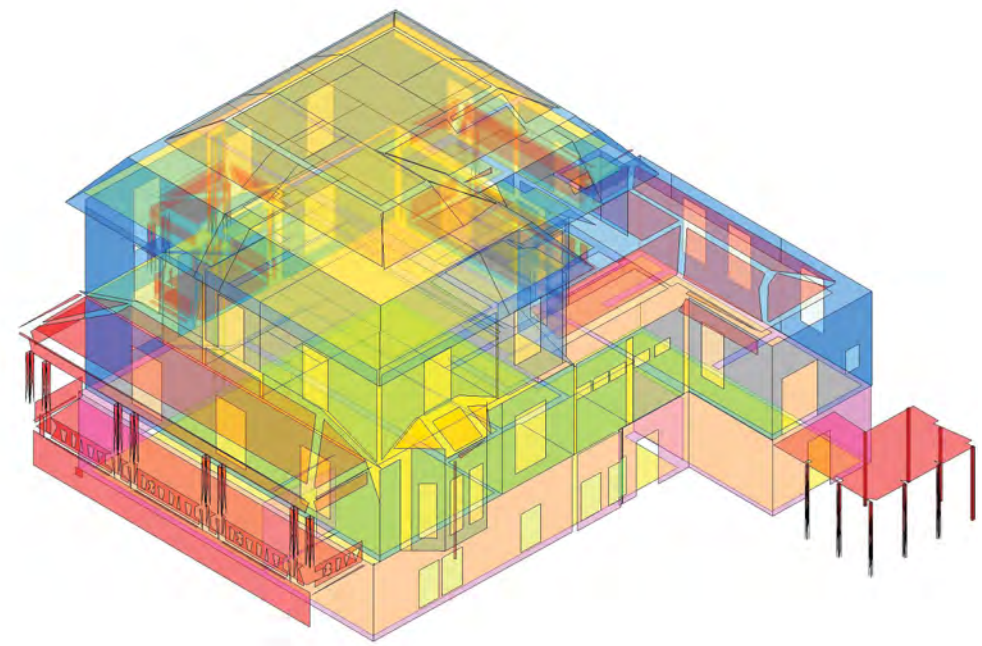
Iteratively Tested through Insight

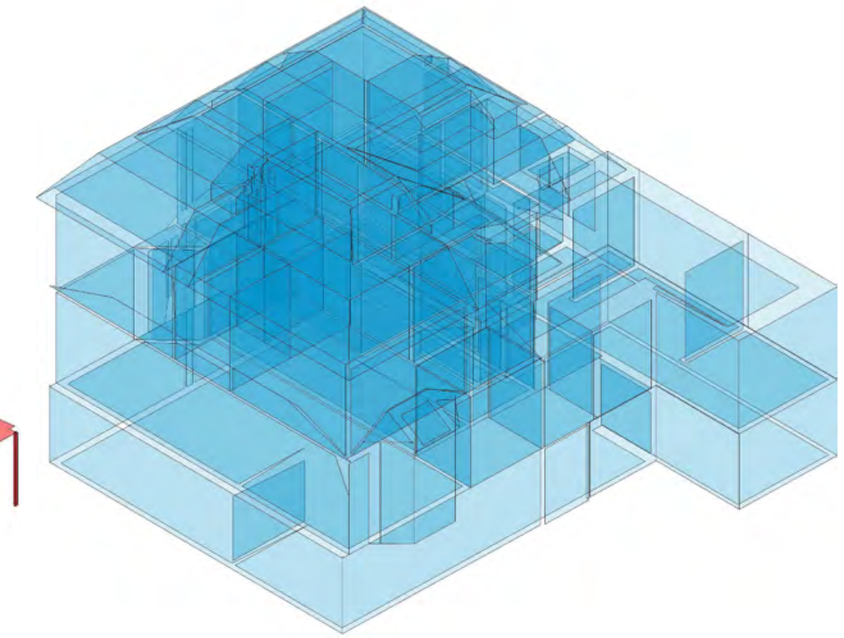
Building Orientation
Window-Wall-Ratio - by elevation
Window Shades – by elevation
Window Type – by elevation
Wall Construction
Roof Construction
Infiltration
Lighting/Plug Load Efficiency
Daylighting and Occupancy Controls
HVAC Types (limited options)
Operating Schedule
PV Potential

ENERGY MODELING - INSIGHT360

Existing Building Example







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Iteratively Tested through Insight

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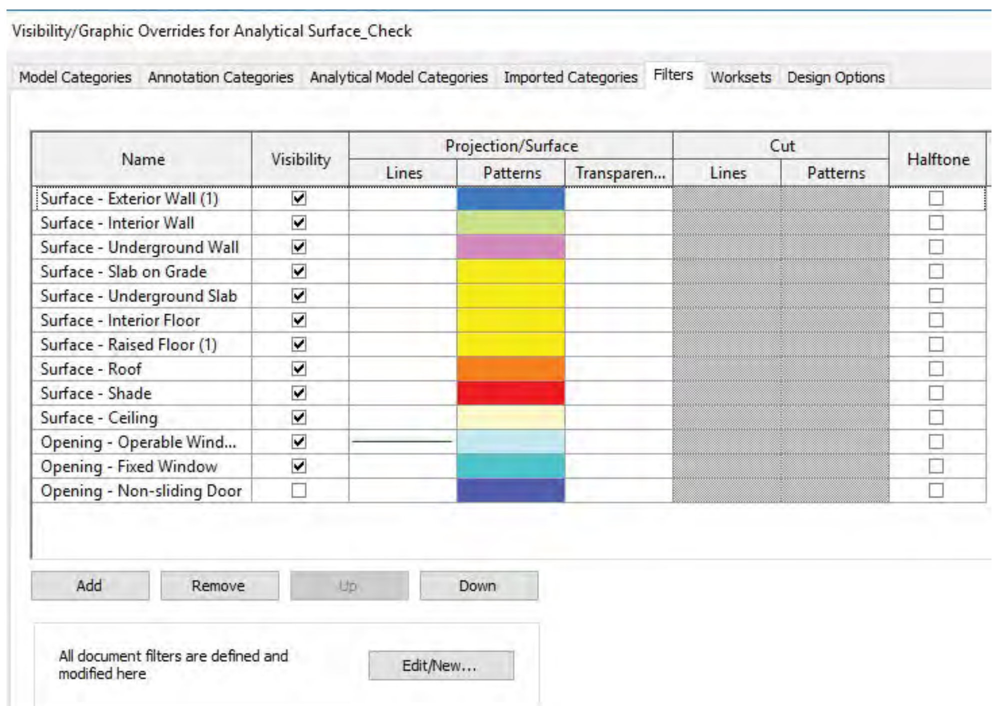
ENERGY MODELING - INSIGHT360

How to tell if your analytical surfaces are working


Visibility/Graphic Overrides for Analytical Surface_Check

Model Categories | Annotation Categories | Analytical Model Categories | Imported Categories | Filters | Worksets | Design Options

Name	Visibility	Projection/Surface			Cut		Halftone
		Lines	Patterns	Transparen...	Lines	Patterns	
Surface - Exterior Wall (1)	☑						☐
Surface - Interior Wall	☑						☐
Surface - Underground Wall	☑						☐
Surface - Slab on Grade	☑						☐
Surface - Underground Slab	☑						☐
Surface - Interior Floor	☑						☐
Surface - Raised Floor (1)	☑						☐
Surface - Roof	☑						☐
Surface - Shade	☑						☐
Surface - Ceiling	☑						☐
Opening - Operable Wind...	☑						☐
Opening - Fixed Window	☑						☐
Opening - Non-sliding Door	☐						☐

Add | Remove | Up | Down

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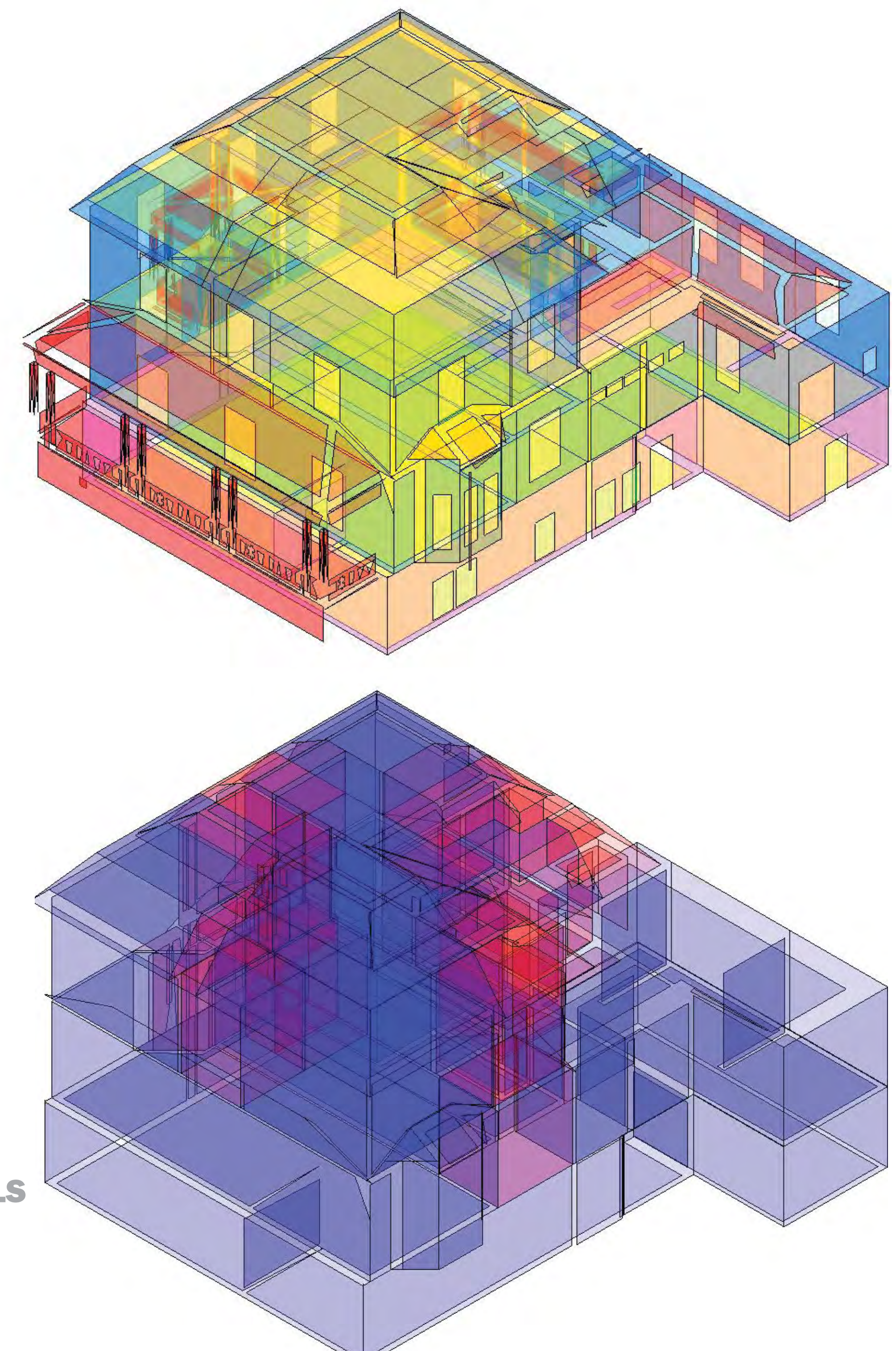
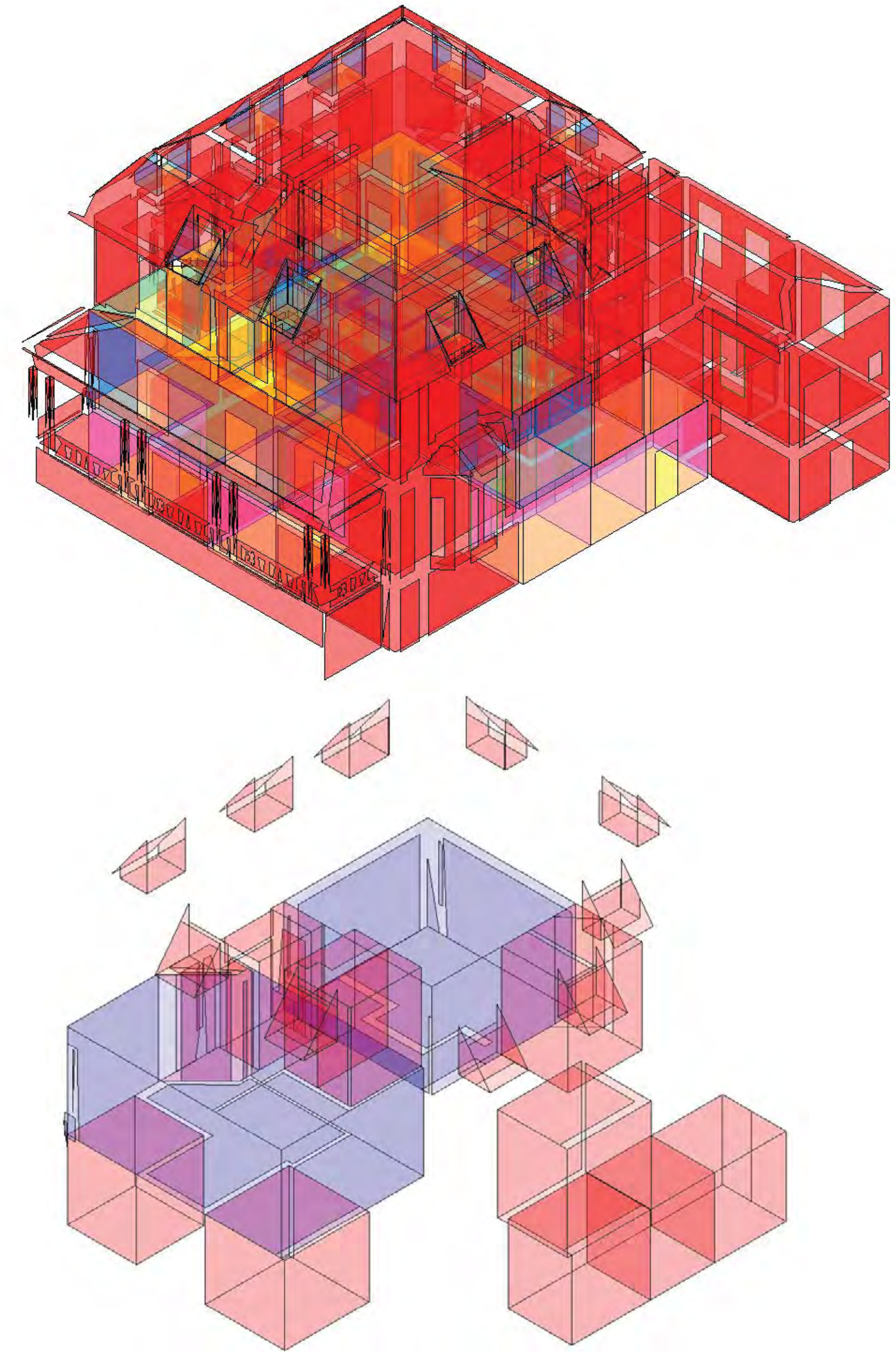
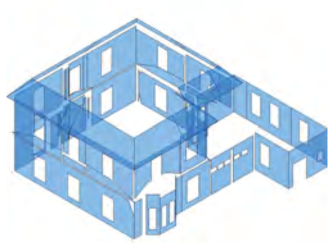
WORKING

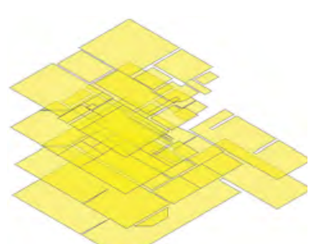


ERROR





EXTERIOR WALLS ONLY



FLOORS ONLY

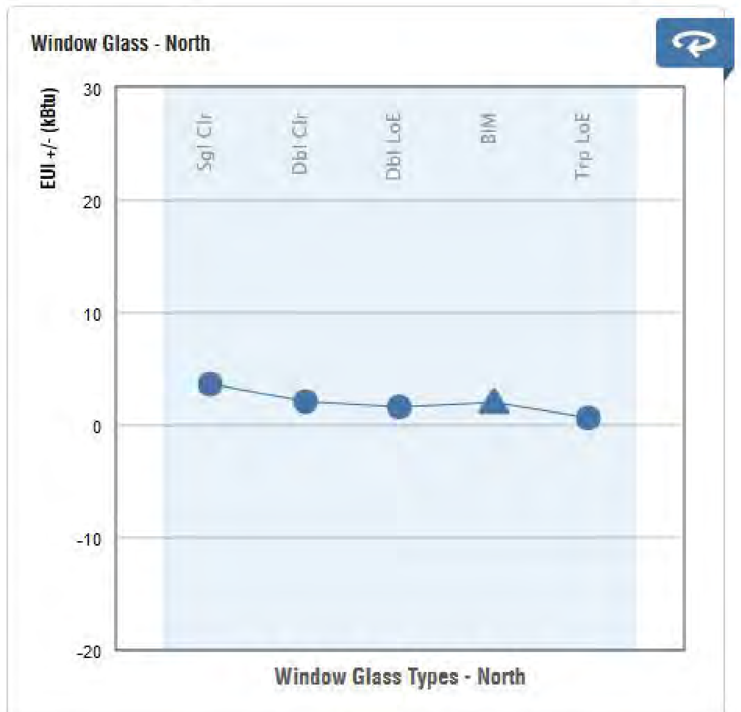
INTERIOR WALLS ONLY

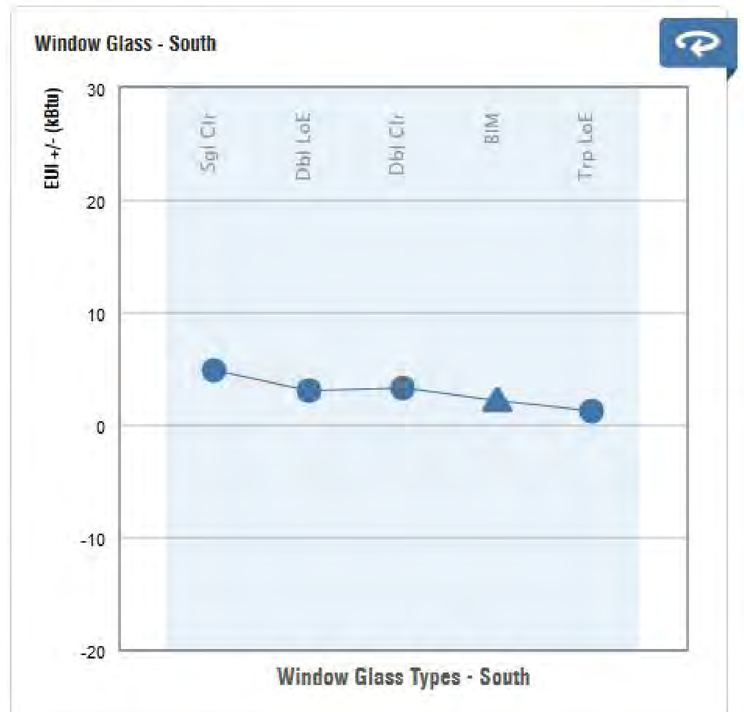
ENERGY MODELING - INSIGHT360

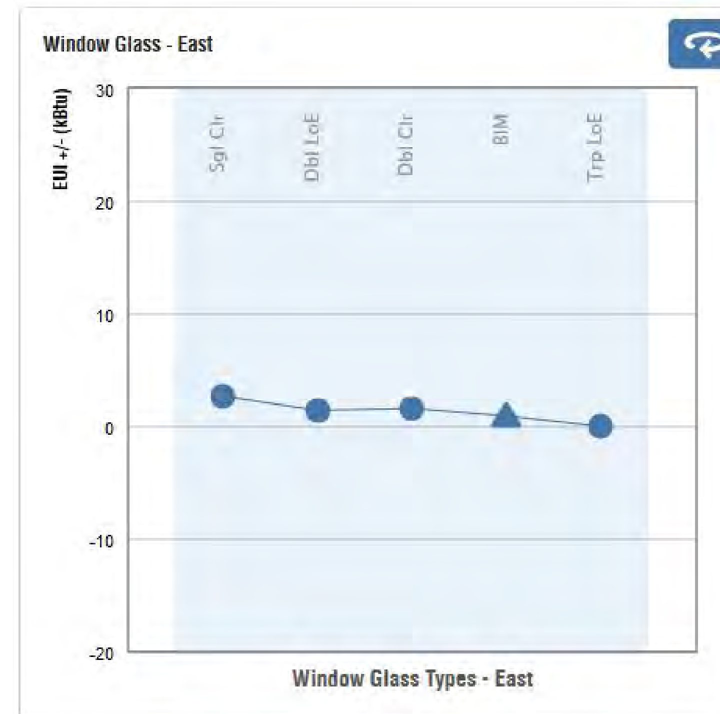
How to use Insight to drive decisions about your exterior glazing

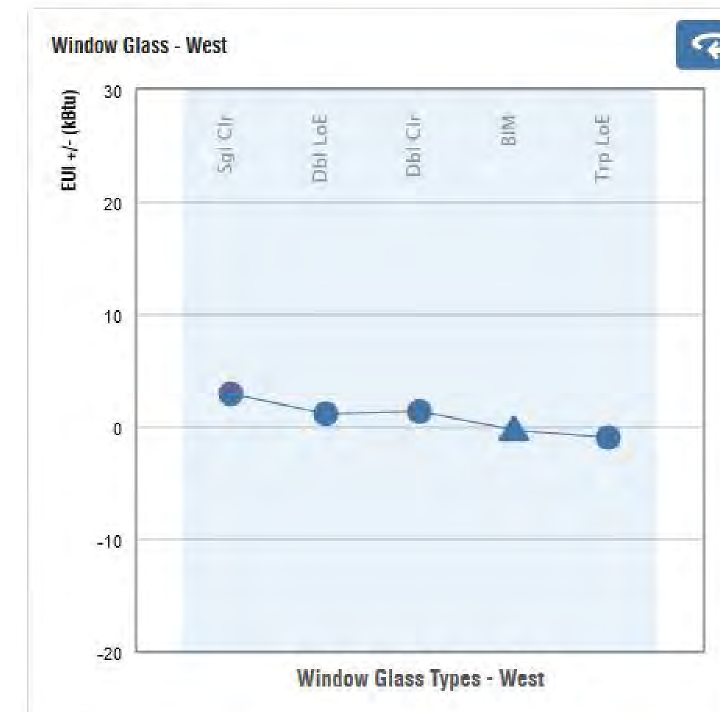
ENERGY MODELING - INSIGHT360

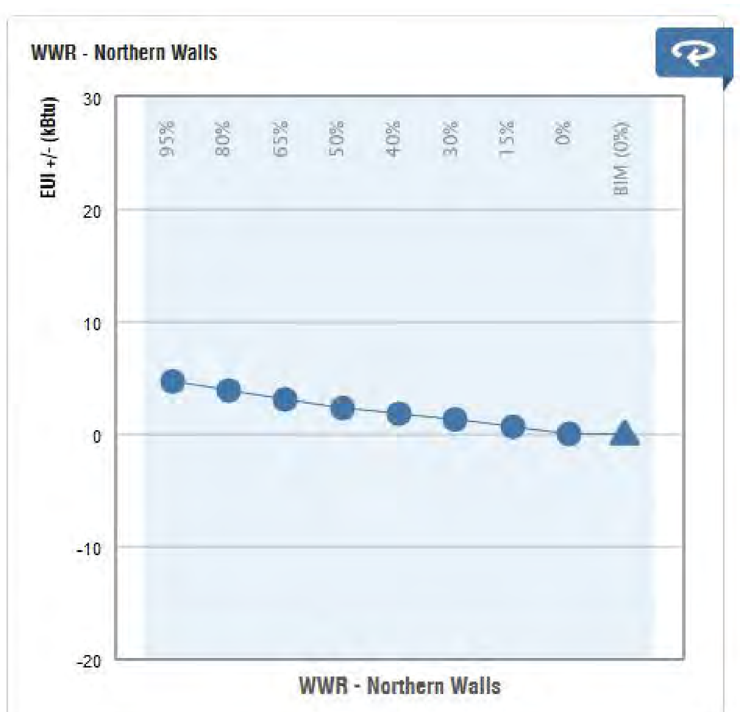
Study each variable to determine significance to energy use intensity (EUI)

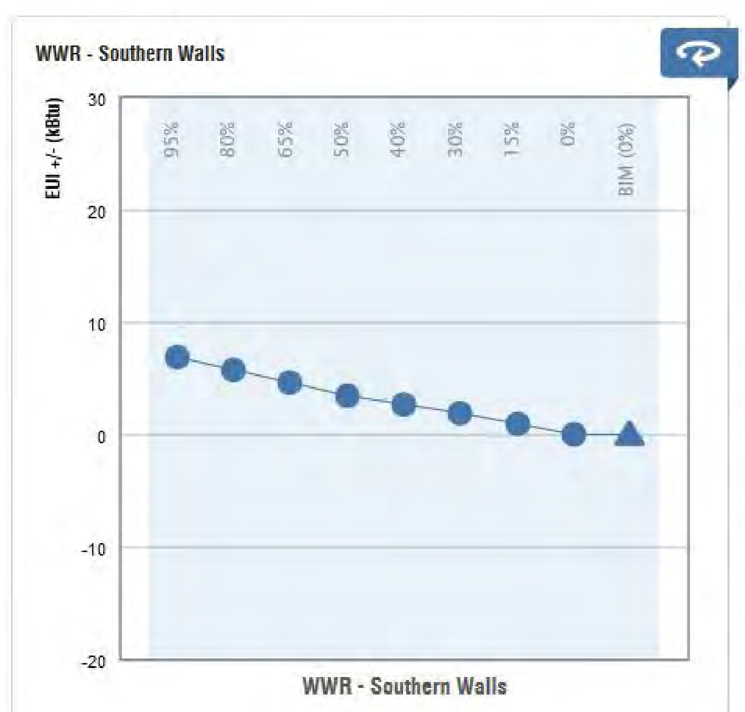


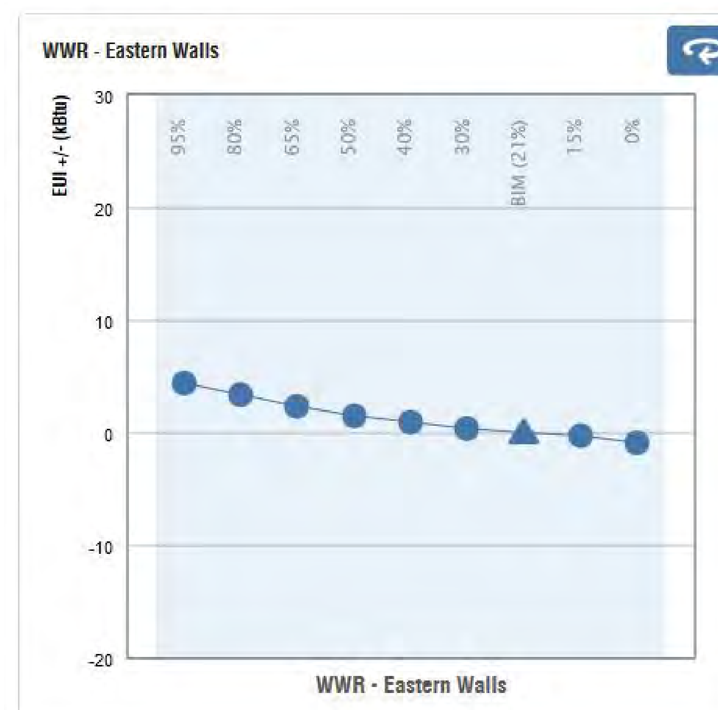


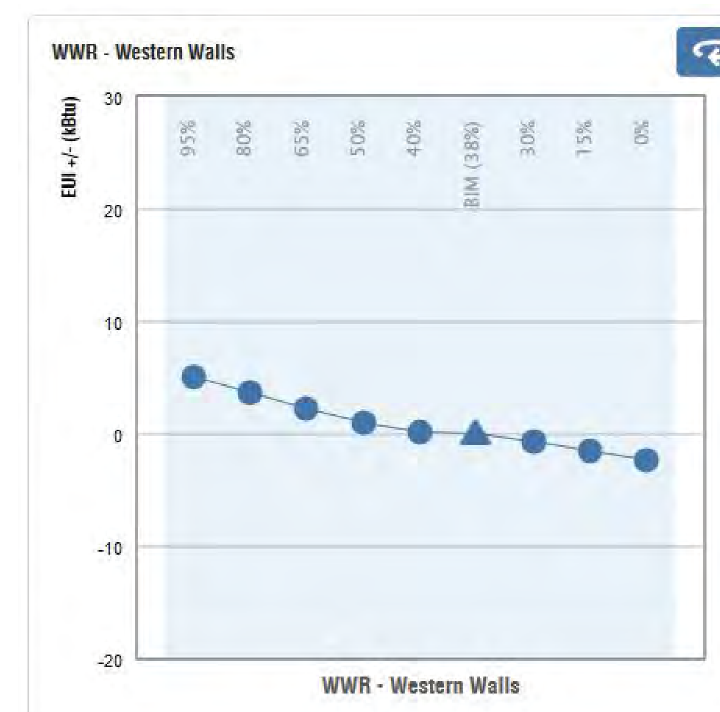






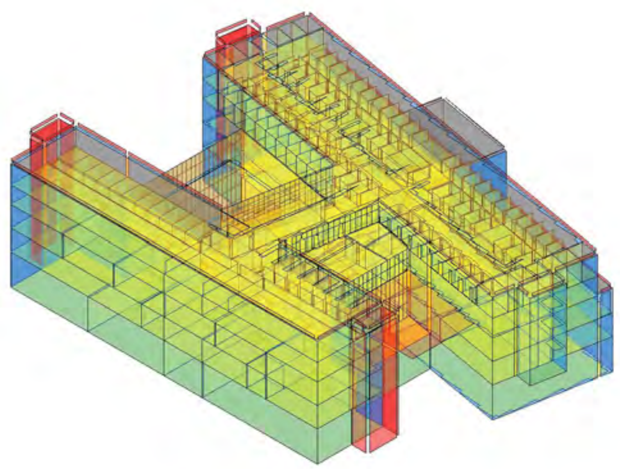


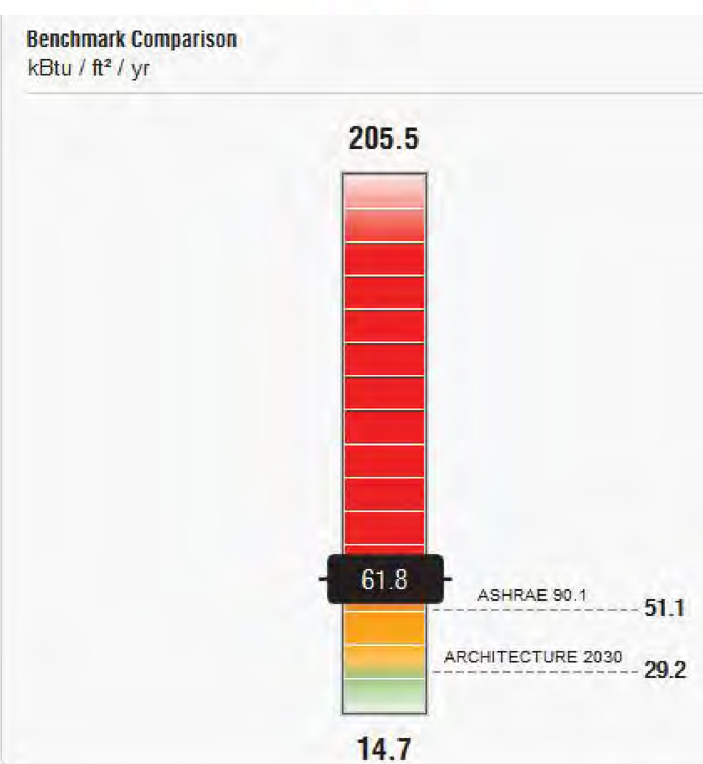


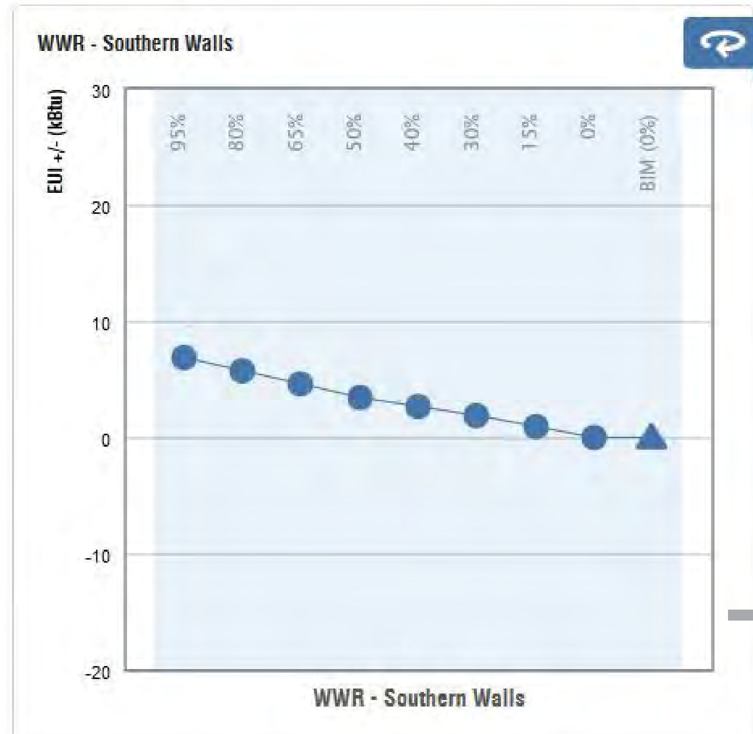


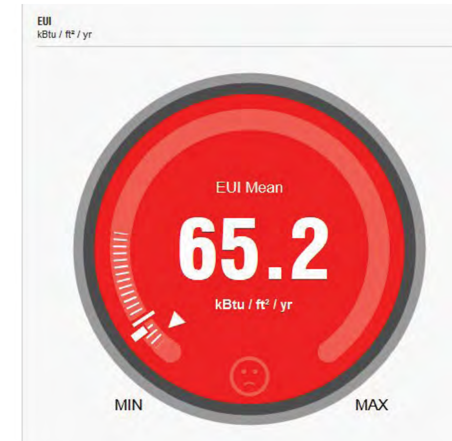
ENERGY MODELING - INSIGHT360

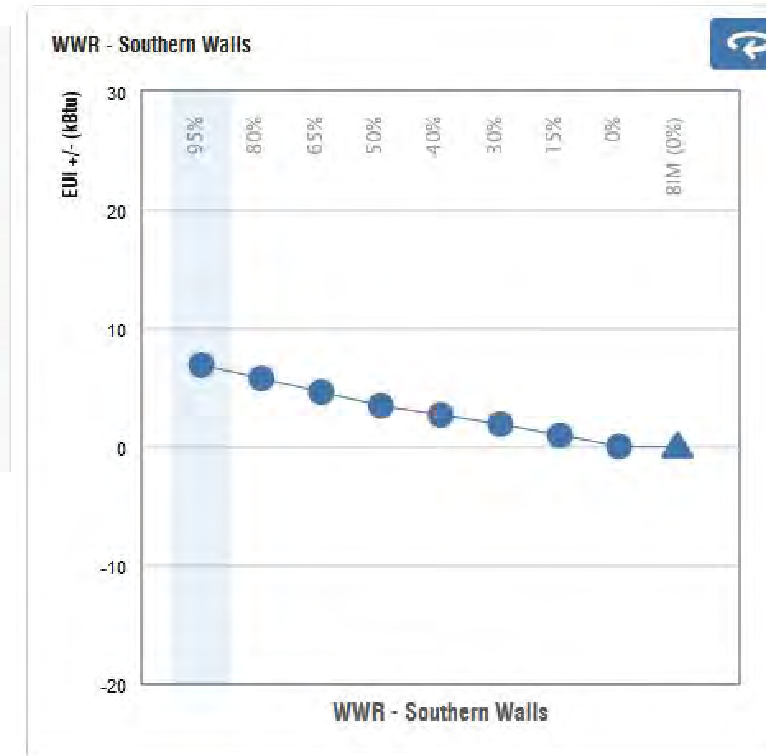
Understanding relative impact of each variable





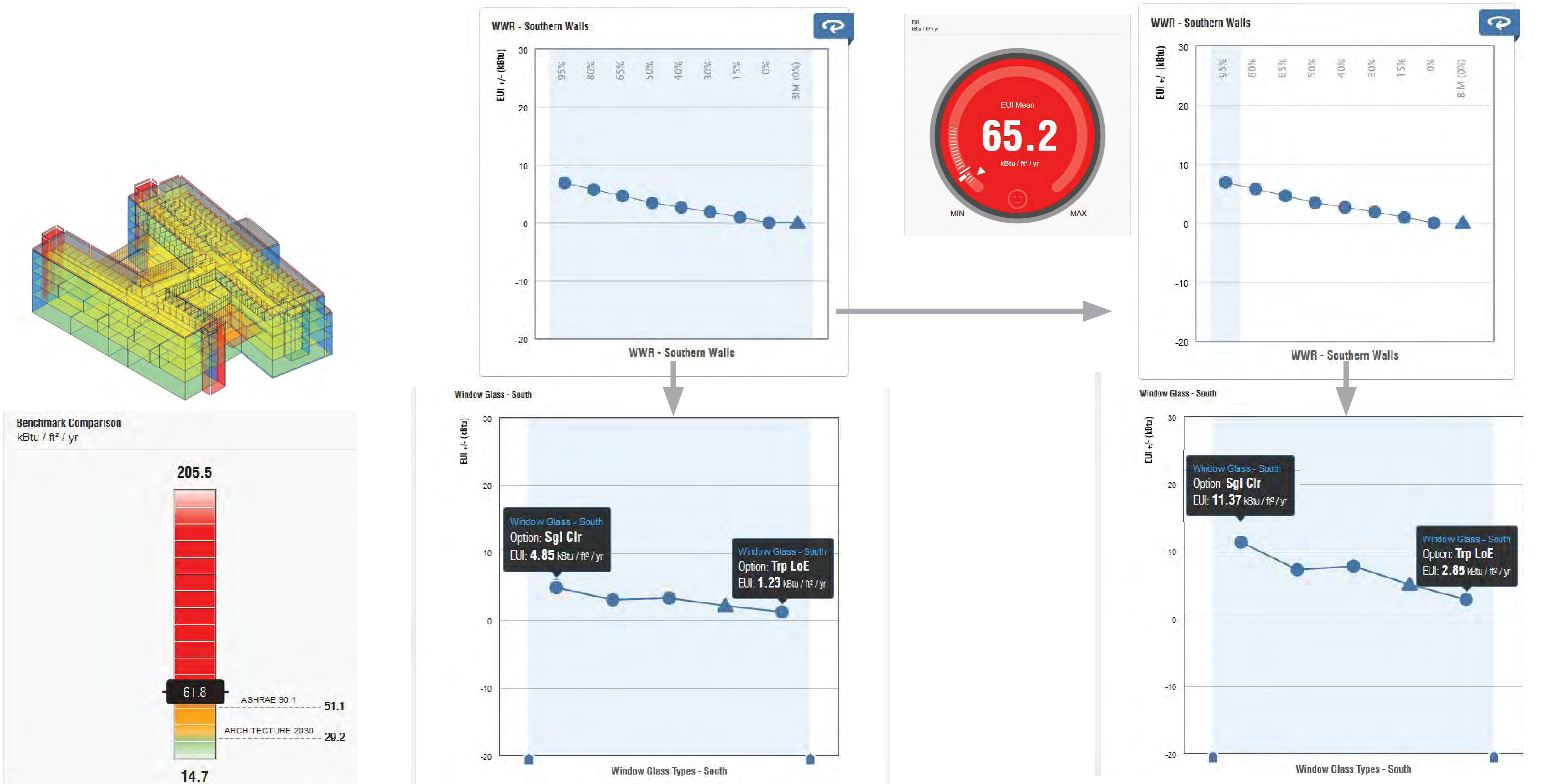






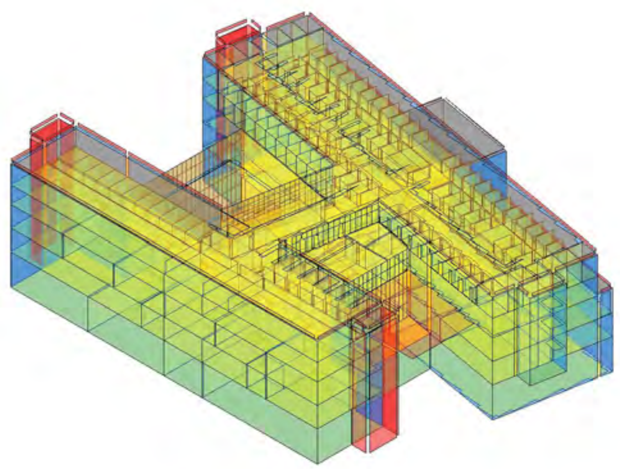
ENERGY MODELING - INSIGHT360

Understanding relative impact of each variable

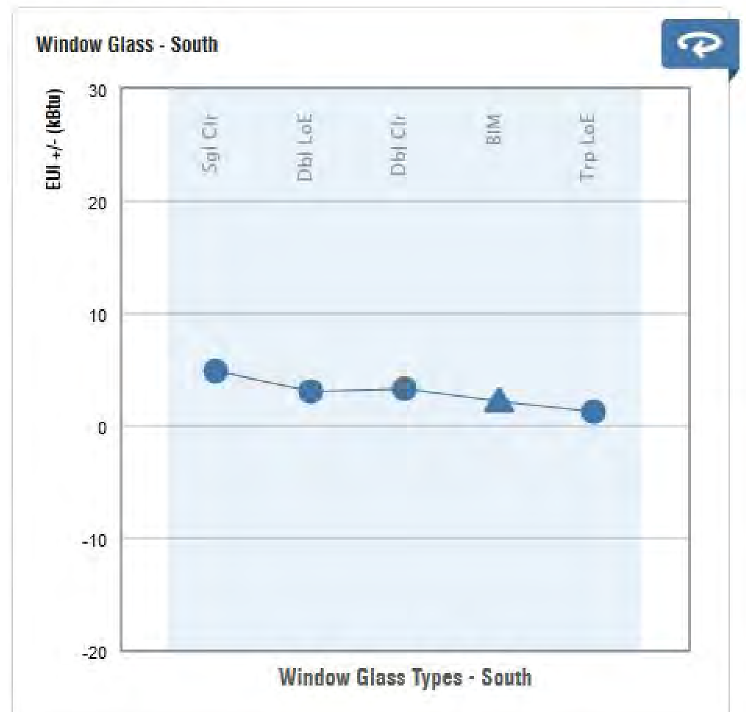


ENERGY MODELING - INSIGHT360

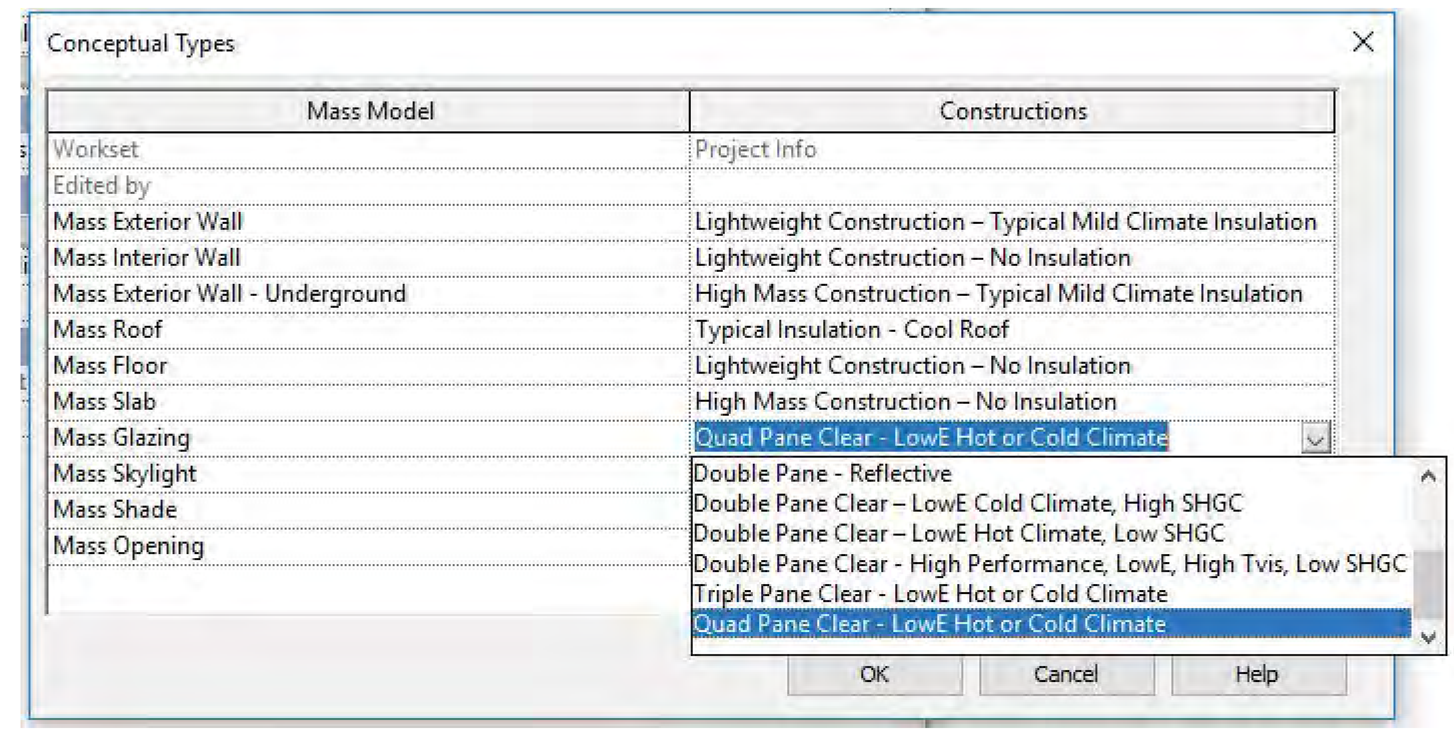
Window Types: defined within tiers of precision



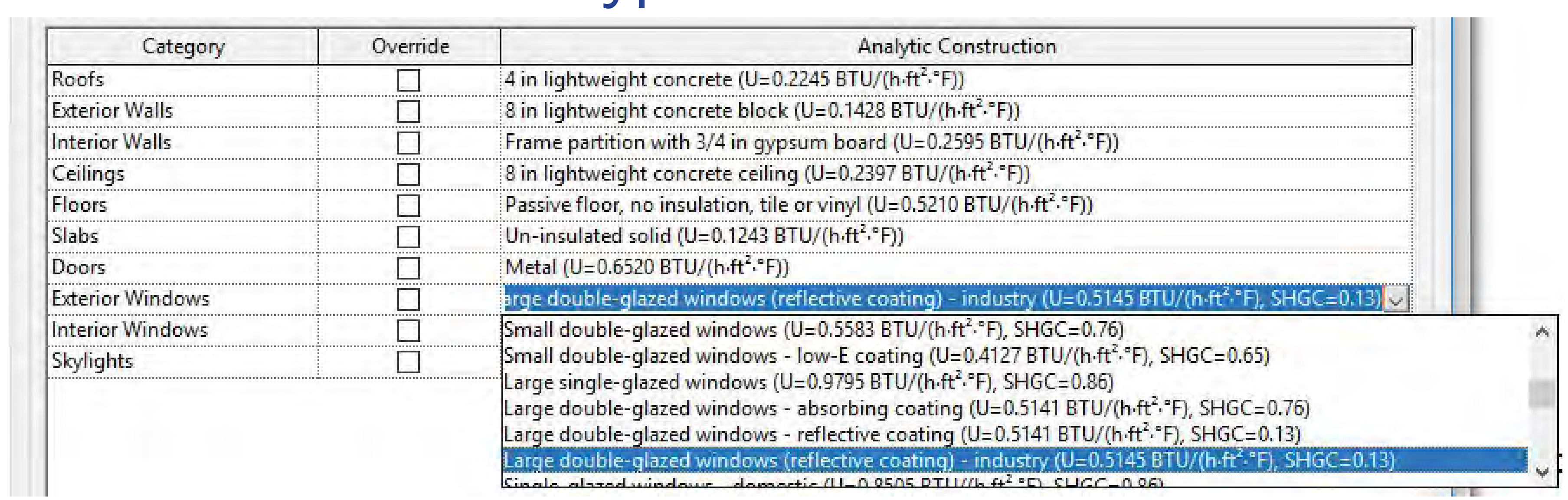
Tier 1: Slider



Tier 2: Conceptual Options



Tier 3: Schematic Types



ENERGY MODELING - INSIGHT360

Insight360 vs. traditional energy model

Insight360

Inputs: flexible to allow for scalable precision to evolve throughout your process

Process: Meant to be run iteratively from within your BIM model

Output: EUI range

Limitations: Cannot parametrically test building form, limited HVAC presets

BOTH

Essential tools for evaluating performance of design

Can be run from recorded weather data or regional averages, uses DOE-2 engine

Typical Energy Model

Inputs: specific numerical value across many fields

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

Output: Generate a specific estimate rather than a range

Advantages: More nuaned HVAC evaluation

CONTENTS

I. Introduction

ANALYSIS TOOLS

II. Thermal Modeling - THERM

III. Energy Modeling - Insight360

IV. Life Cycle Assessment - Tally

V. Integrating the Process

VI. Discussion

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 life-time.

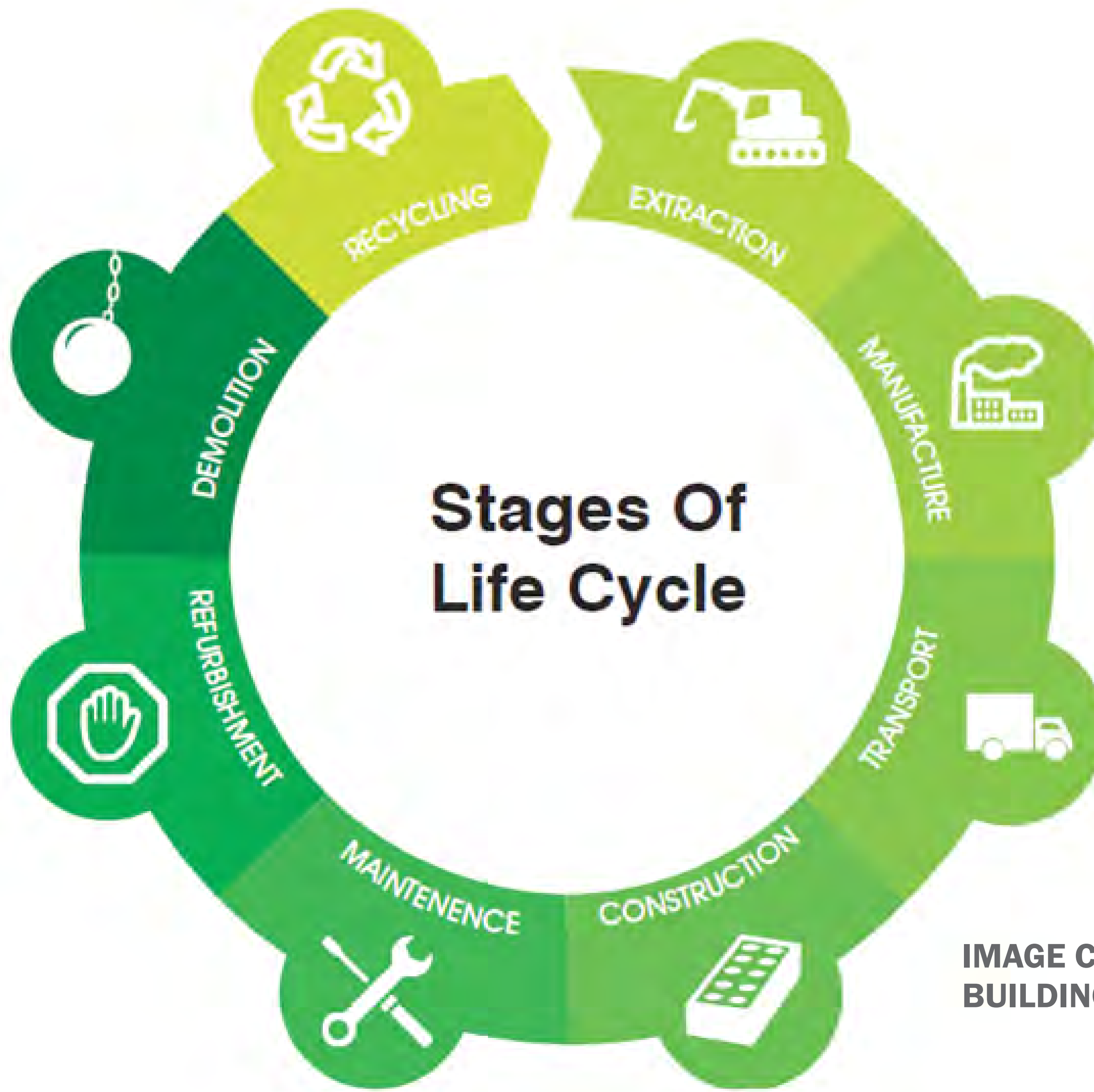
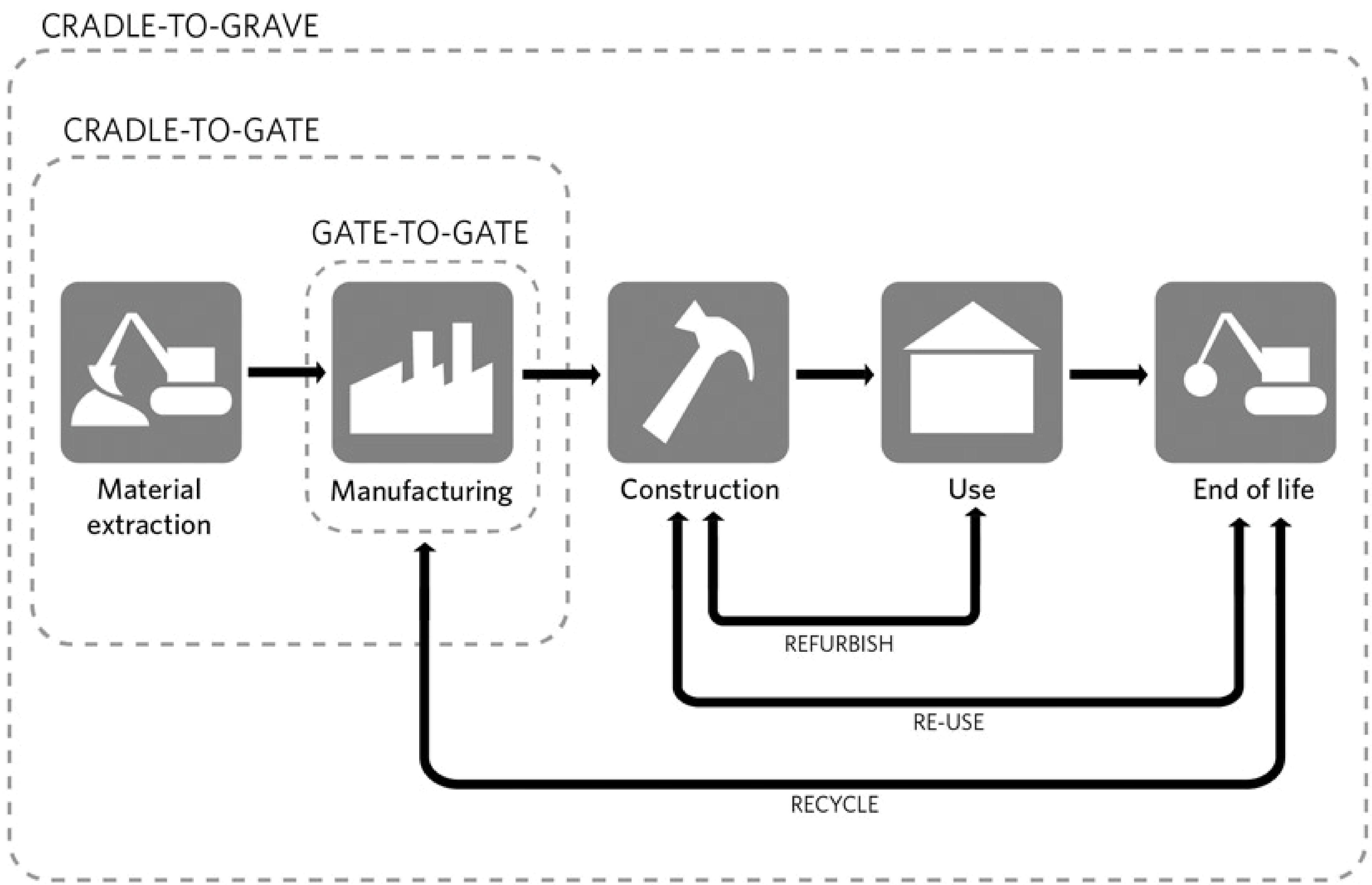


IMAGE CREDIT: IRISH GREEN BUILDING COUNCIL

LIFE CYCLE ASSESSMENT (LCA)

WHY - Cradle to Grave Impacts



Adapted from K. Simonen, Life Cycle Assessment

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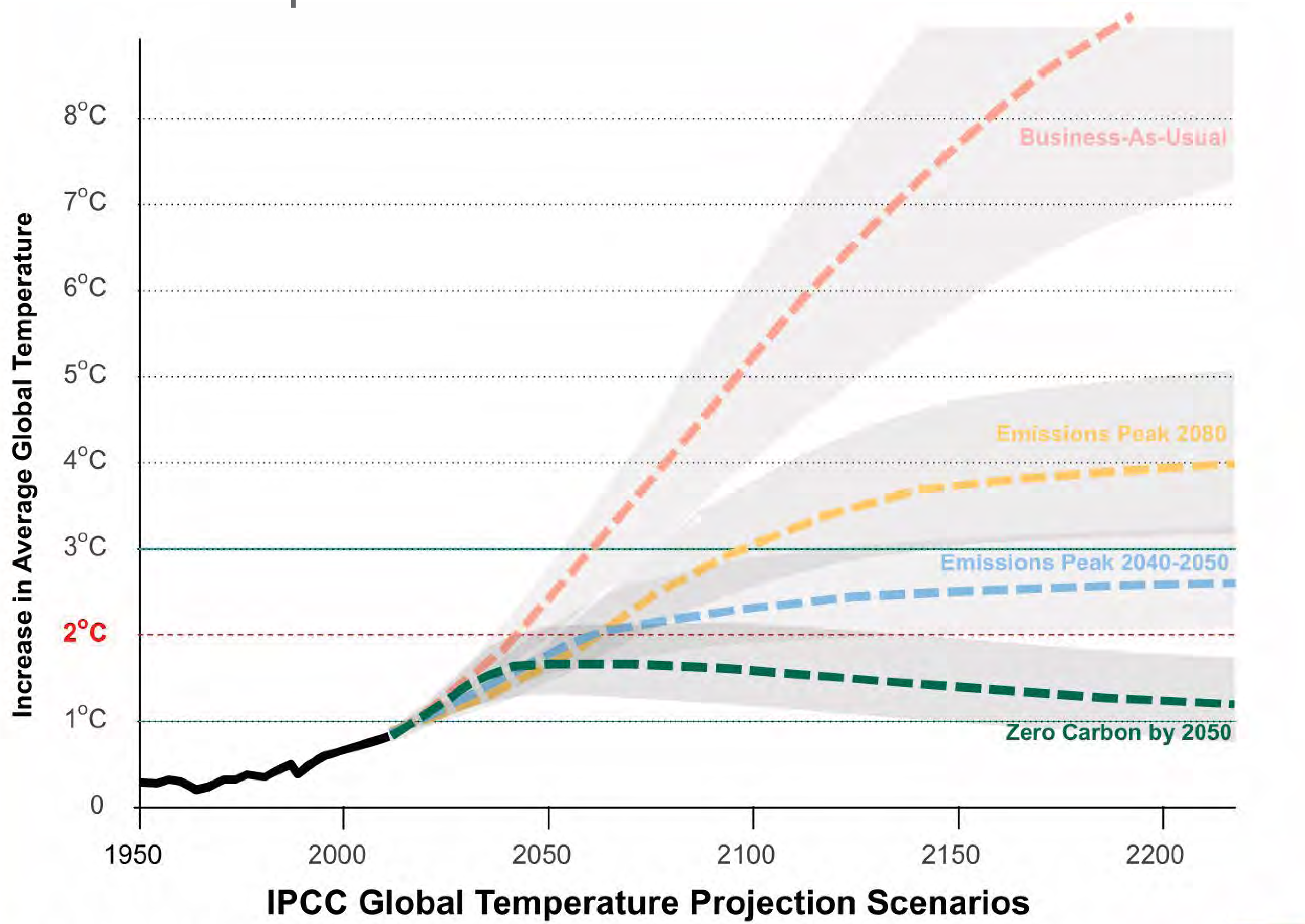
LIFE CYCLE ASSESSMENT (LCA)

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



Source: IPCC 2013, Representative Concentration Pathways (RCP); Stockholm Environment Institute (SEI), 2013; Climate Analytics and ECOFYS 2014.
Note: Emissions peaks are for fossil fuel CO2–only emissions.

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)

INPUTS		ASSESSMENT		OUTPUTS
Material Attributes & Quantity	X	Material's GWP multiplier	=	Global Warming Potential in kg CO2e
	X	Material's ODP multiplier	=	Ozone Depletion Potential in kg CFC-11
	X	Material's AP multiplier	=	Acidification Potential in kg SO2
	X	Material's EP multiplier	=	Eutrophication Potential in kg nitrogen or kg phosphate
	X	Material's TOP multiplier	=	Tropospheric Ozone Potential in kg NOx or kg O3 eq
	X	Material's NRDP multiplier	=	Non-renewable Resource Depletion Potential in MJ
Project Location and Service Life				

LIFE CYCLE ASSESSMENT (LCA)

Implementation

Excel Spreadsheet

U.S. Life Cycle Inventory Database

circular ecology
Resource efficiency at its best

Environmental Product Declaration

EPD®

UL CERTIFIED
ENVIRONMENTAL PRODUCT DECLARATION
UL.COM/EPD

Analysis Software Tools

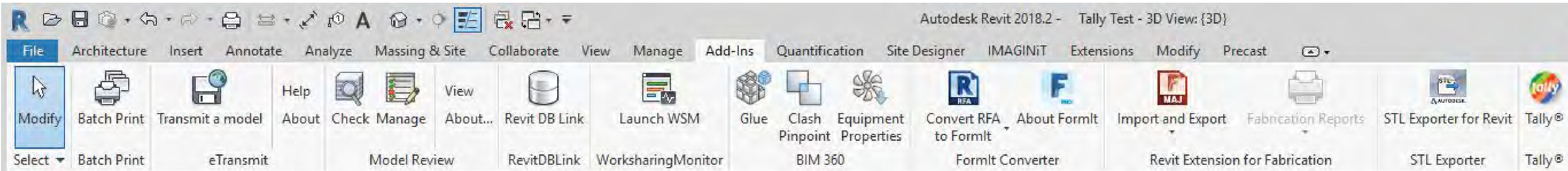
One Click LCA

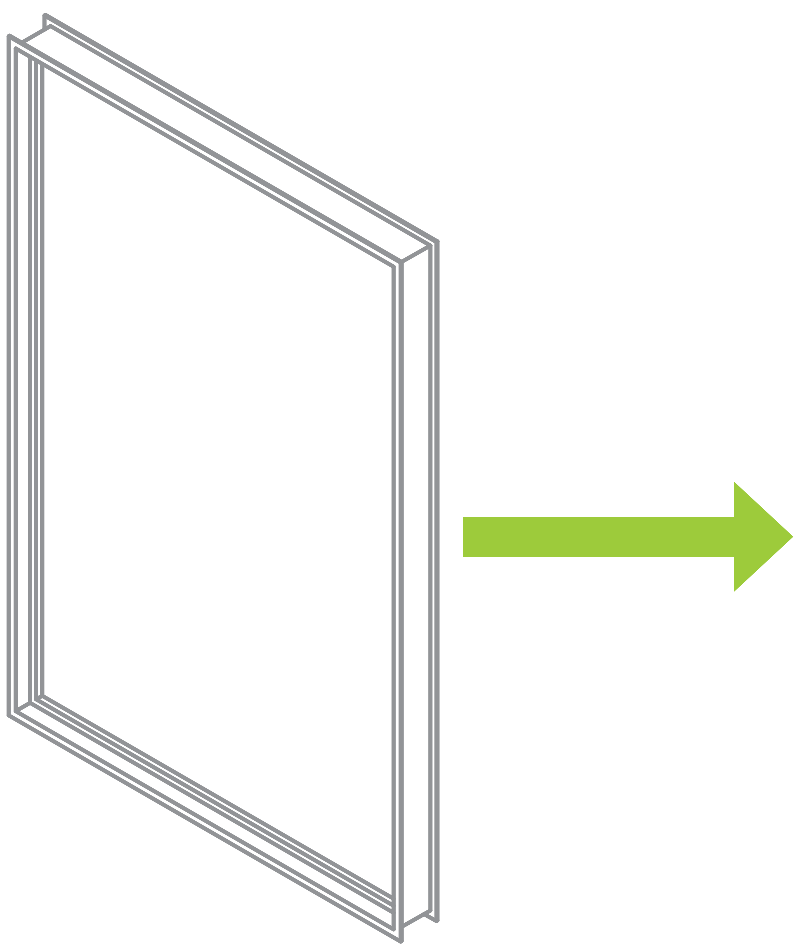
Athena Sustainable Materials Institute

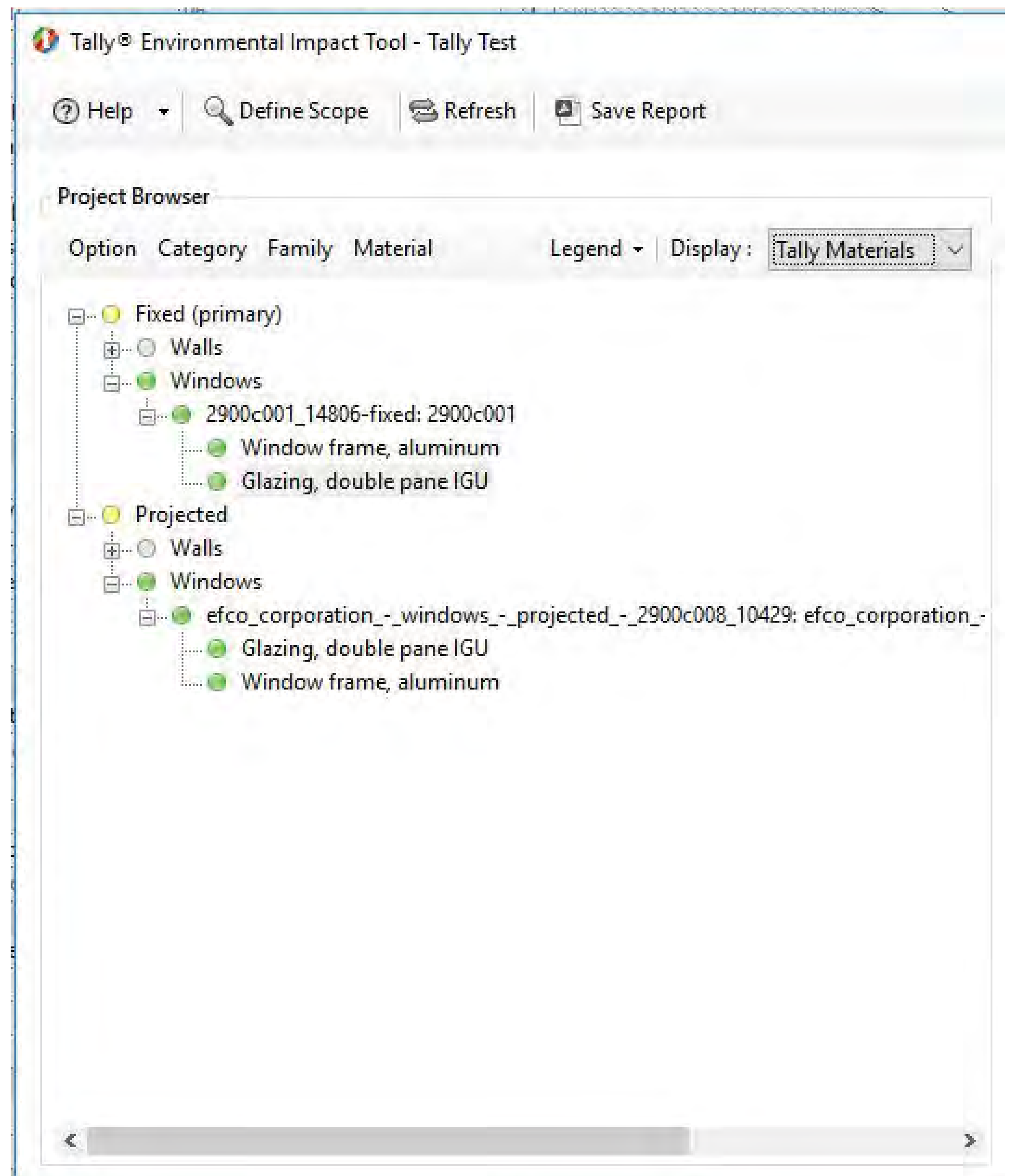
tally®

IMPLEMENTATION - LCA SOFTWARE

HOW - Window Products

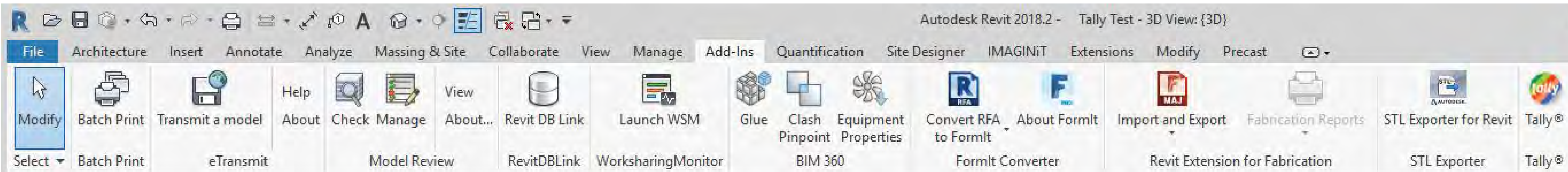


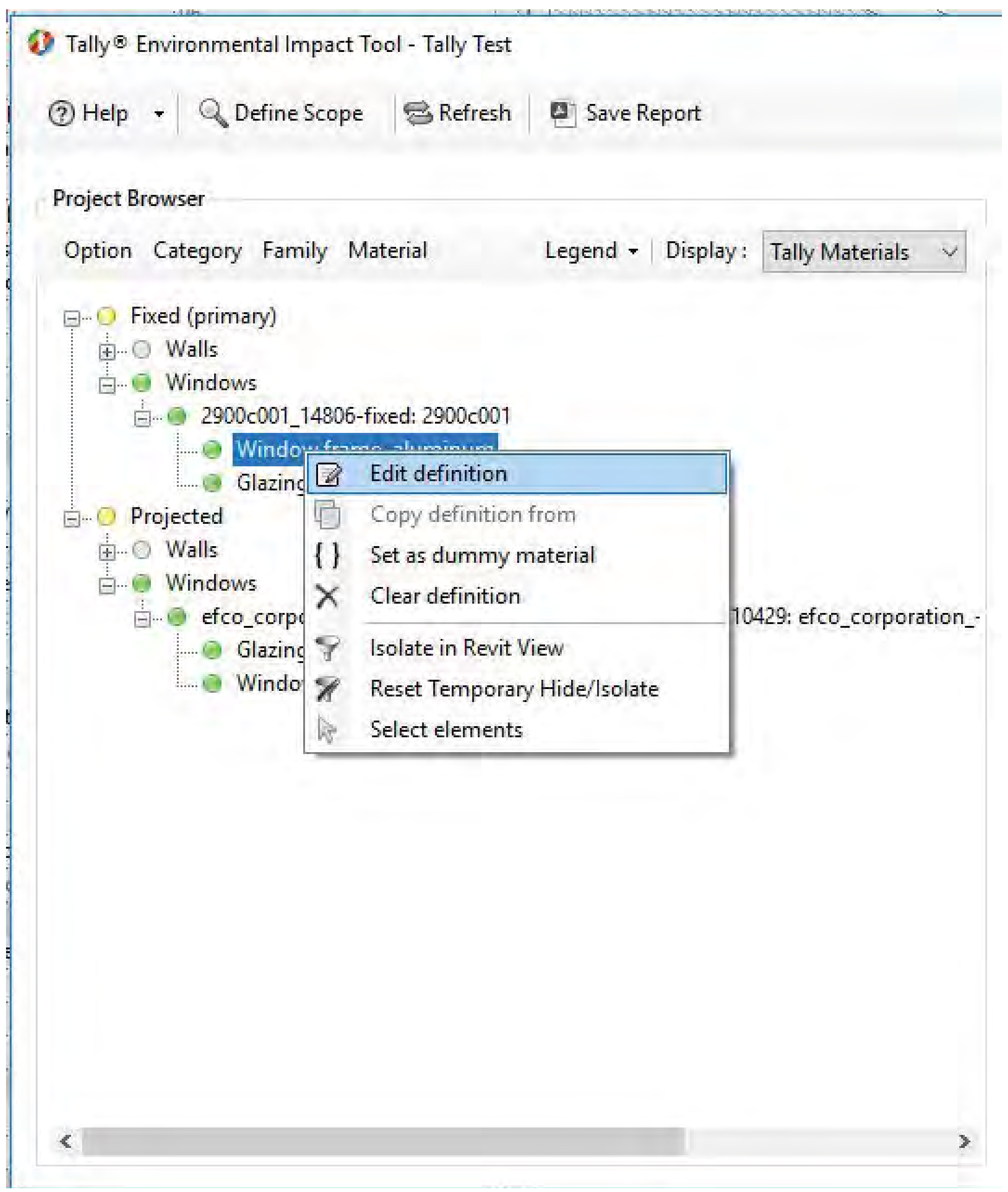


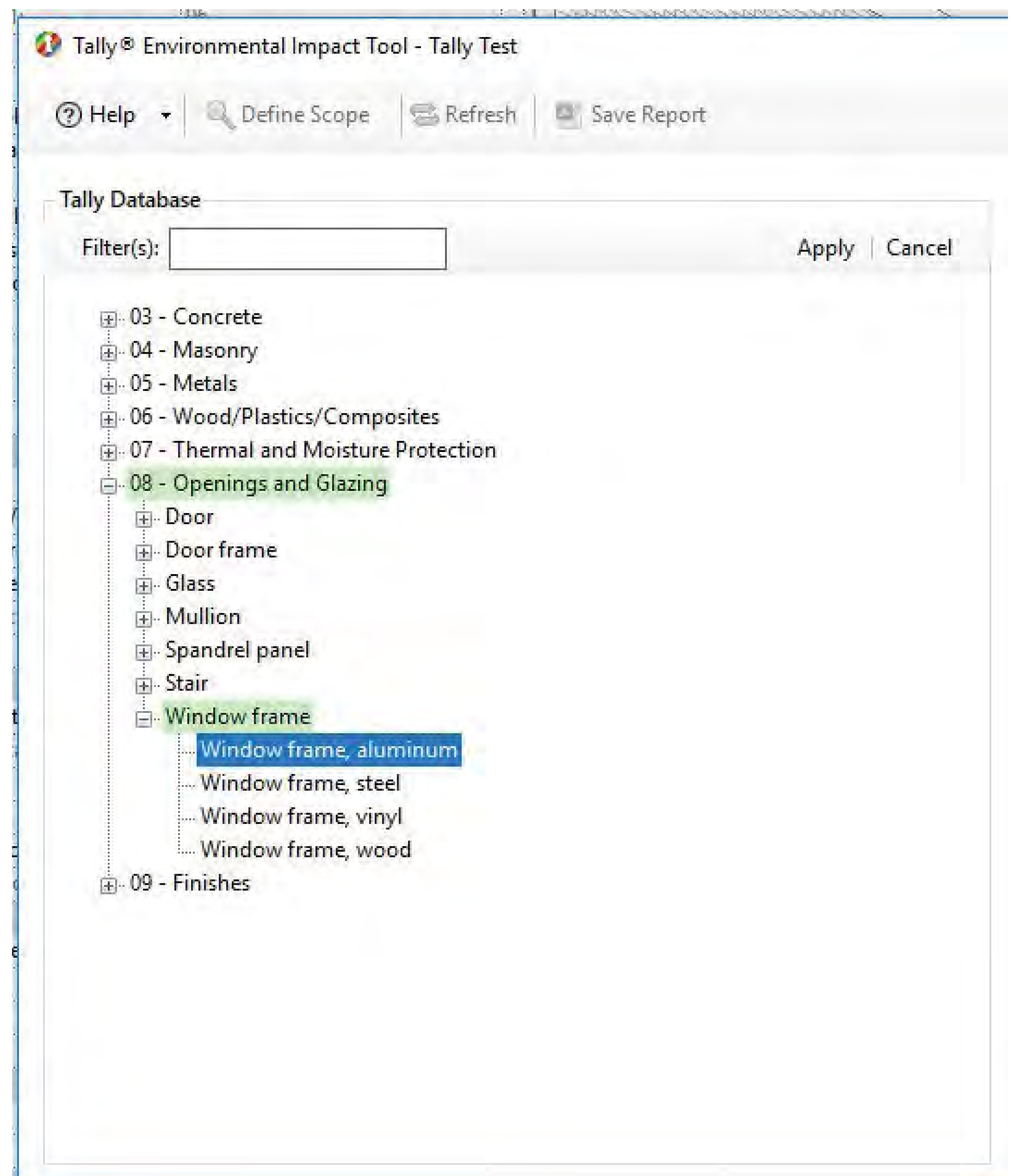


LIFE CYCLE ASSESSMENT (LCA)

HOW - Window Products







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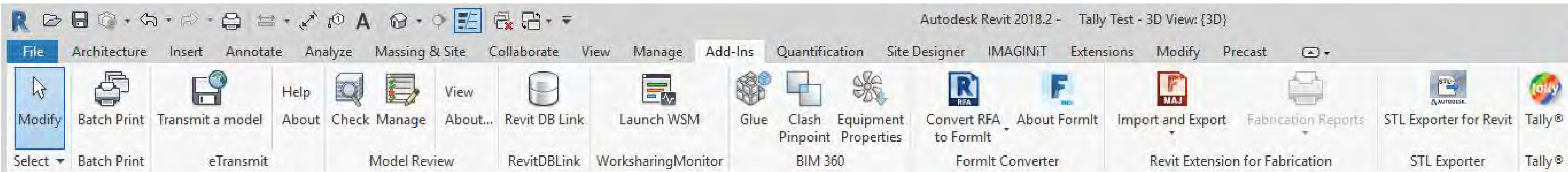
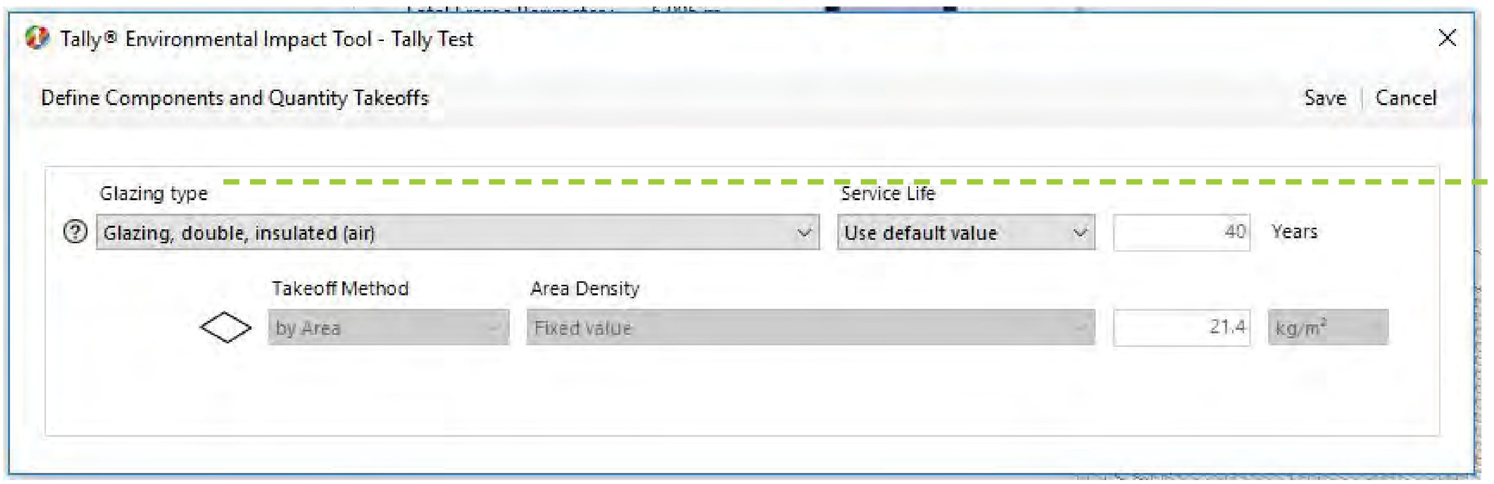
HOW - Window Products

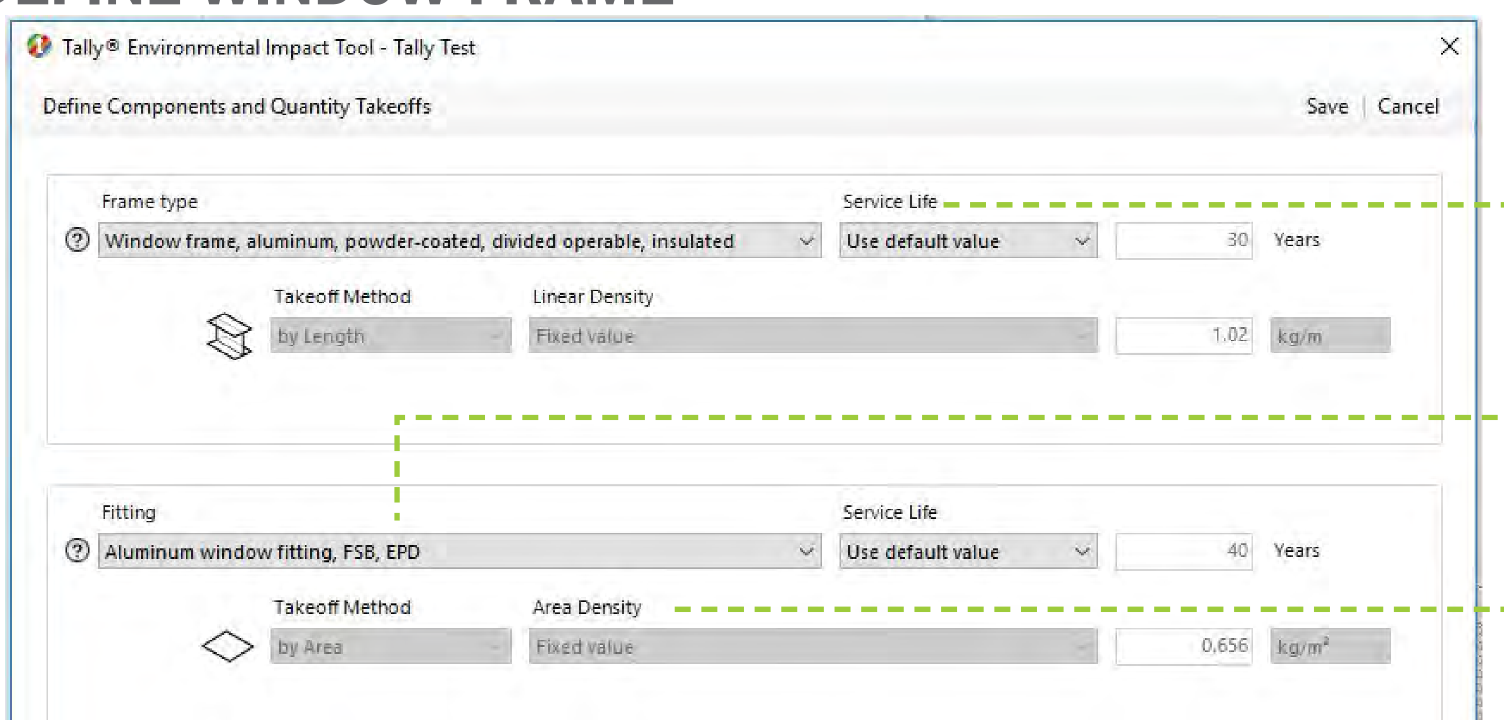


DEFINE GLAZING



CHOOSE FROM MATERIAL DROPDOWN

DEFINE WINDOW FRAME



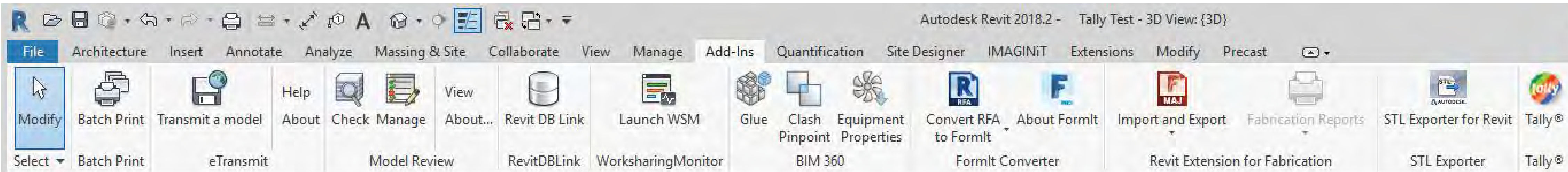
OPTION TO DEFINE SERVICE LIFE OF EACH ELEMENT

MATERIAL OPTIONS WITH EPDS ARE NOTED

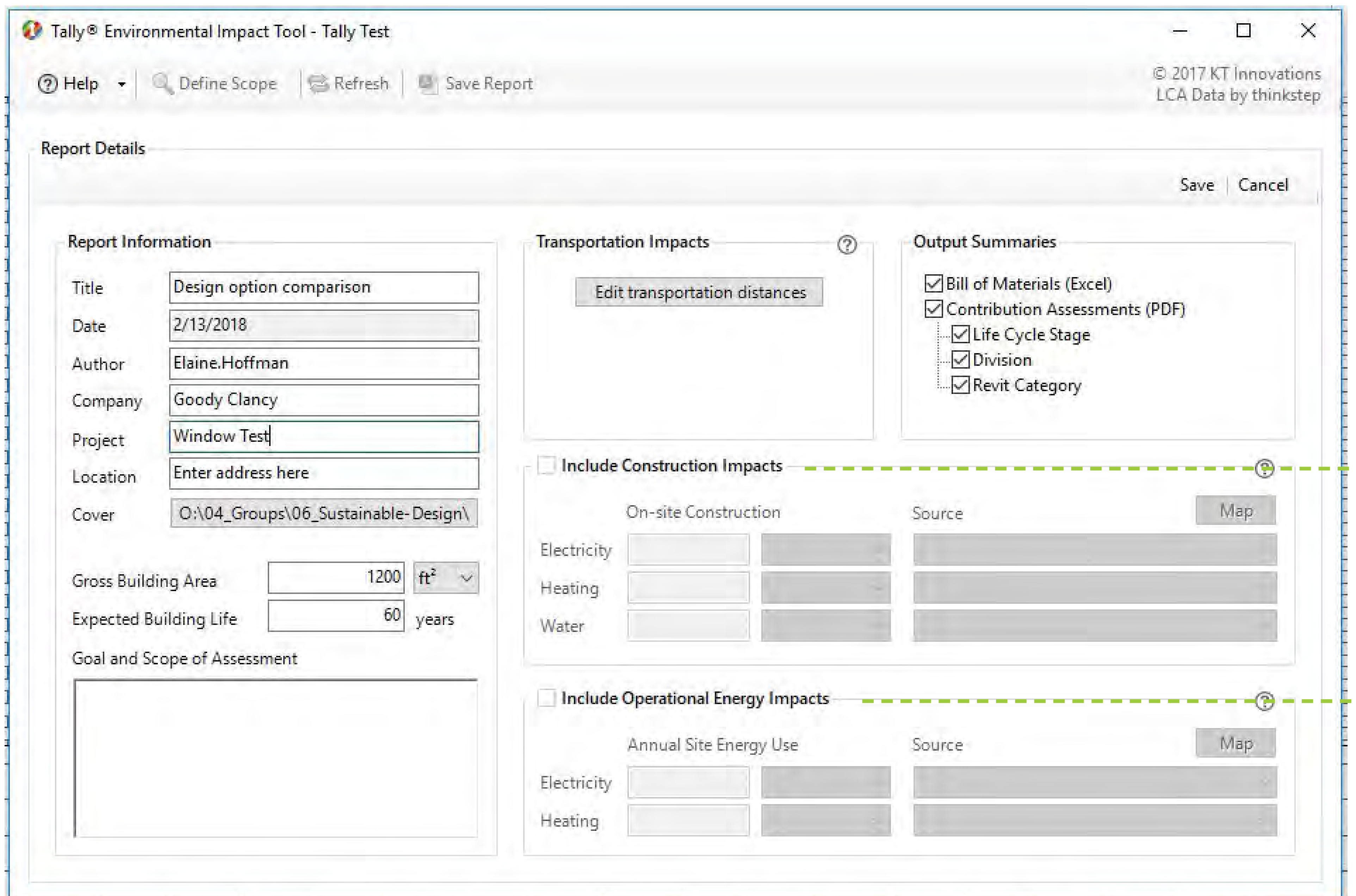
OPTION TO DEFINE MATERIAL TAKEOFF METHOD

LIFE CYCLE ASSESSMENT (LCA)

HOW - Window Products



FINALIZE PROJECT SETTINGS



OPTION TO INCLUDE CONSTRUCTION IMPACTS

OPTION TO INCLUDE OPERATIONAL ENERGY

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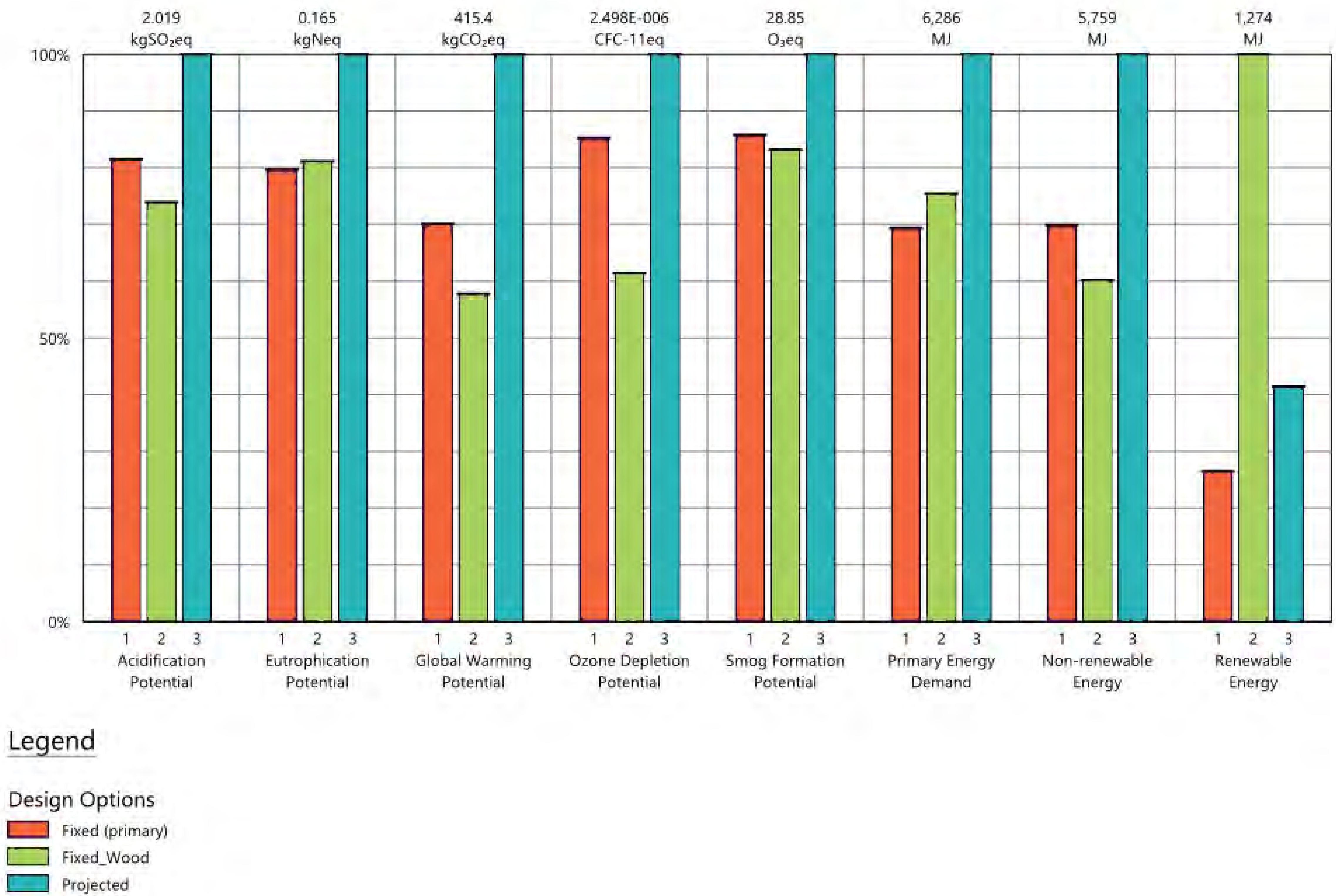
HOW - Window Products



IMPLEMENTATION - LCA SOFTWARE

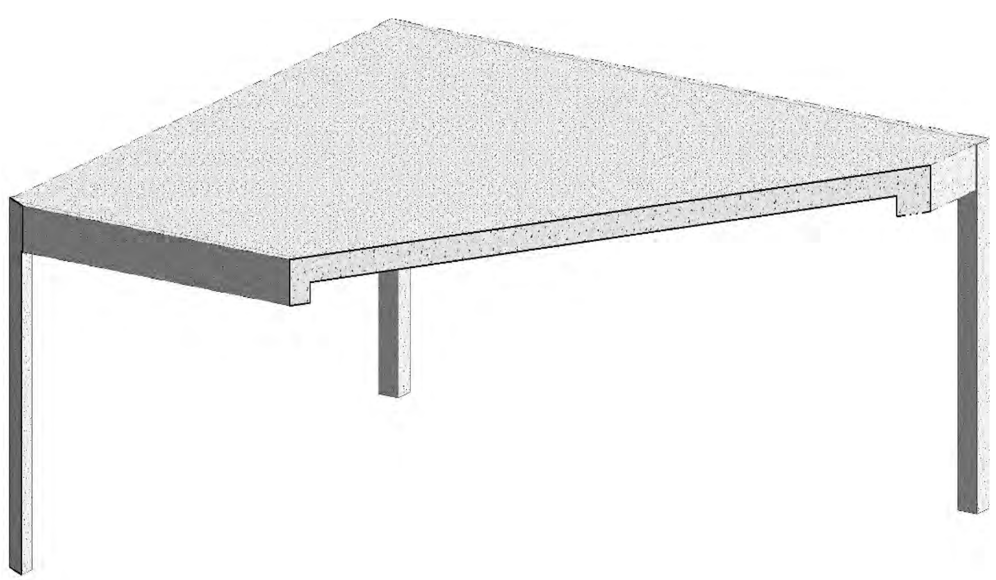
HOW - Structural System Selection

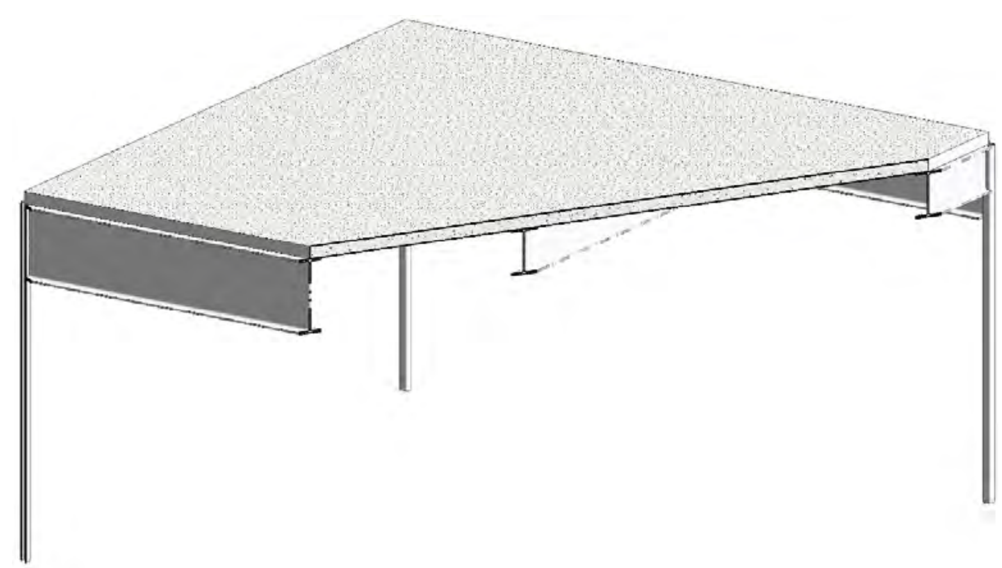
Compare an equivalent 30’ x 30’ structural bay constructed of:

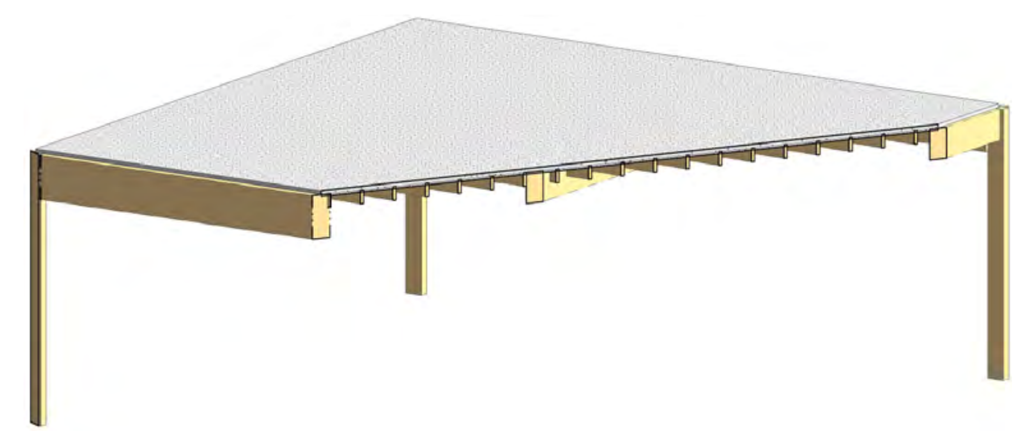
I. Concrete columns, beams, and slab

II. Steel columns, beams, and joists with concrete on metal deck

III. Glulam columns and beams with wood infill and a concrete topping slab







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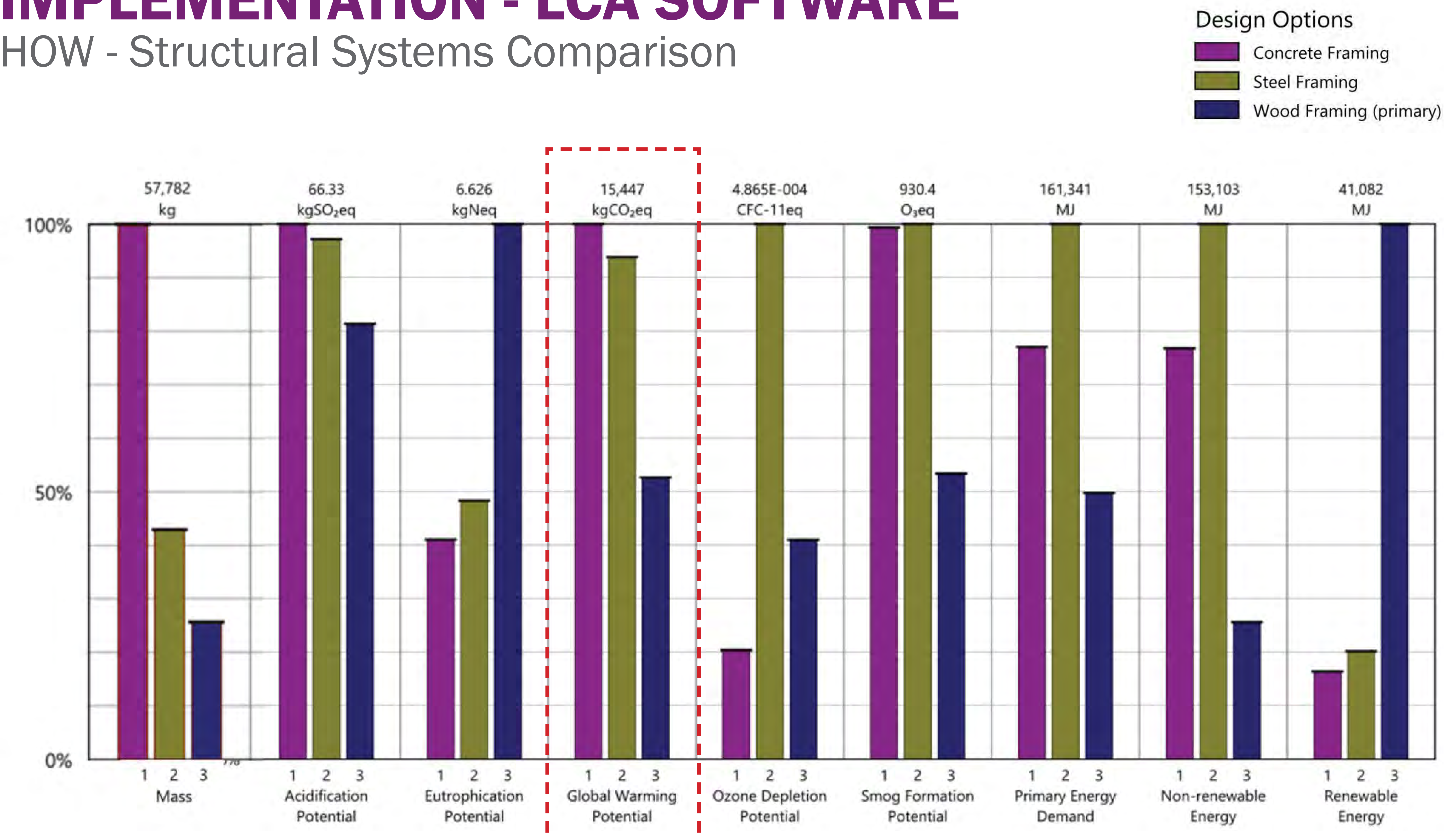
HOW - Structural Systems Comparison



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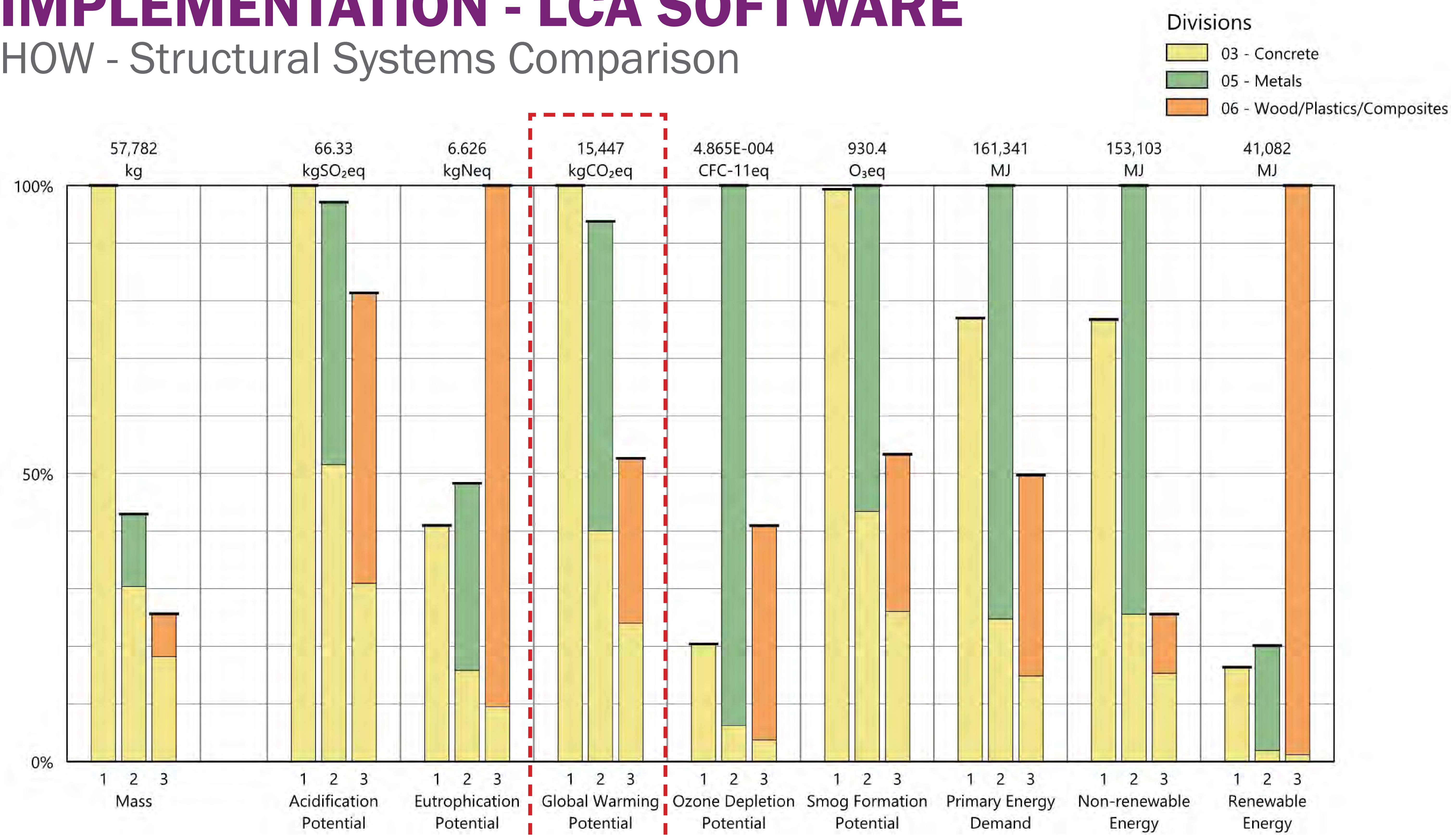

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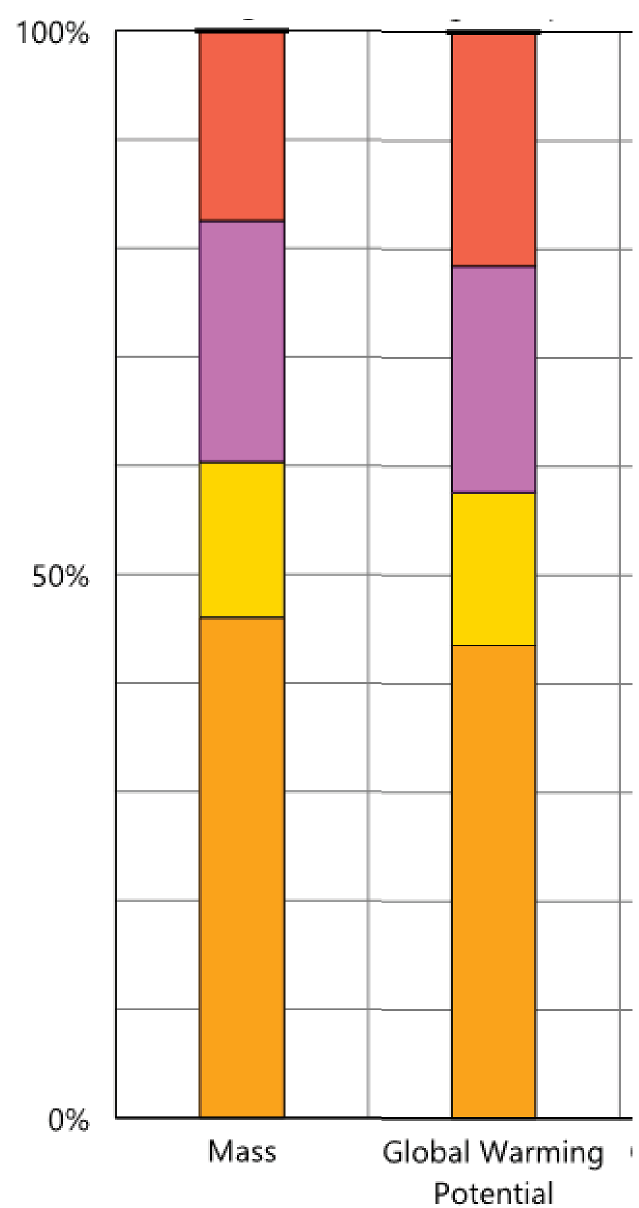
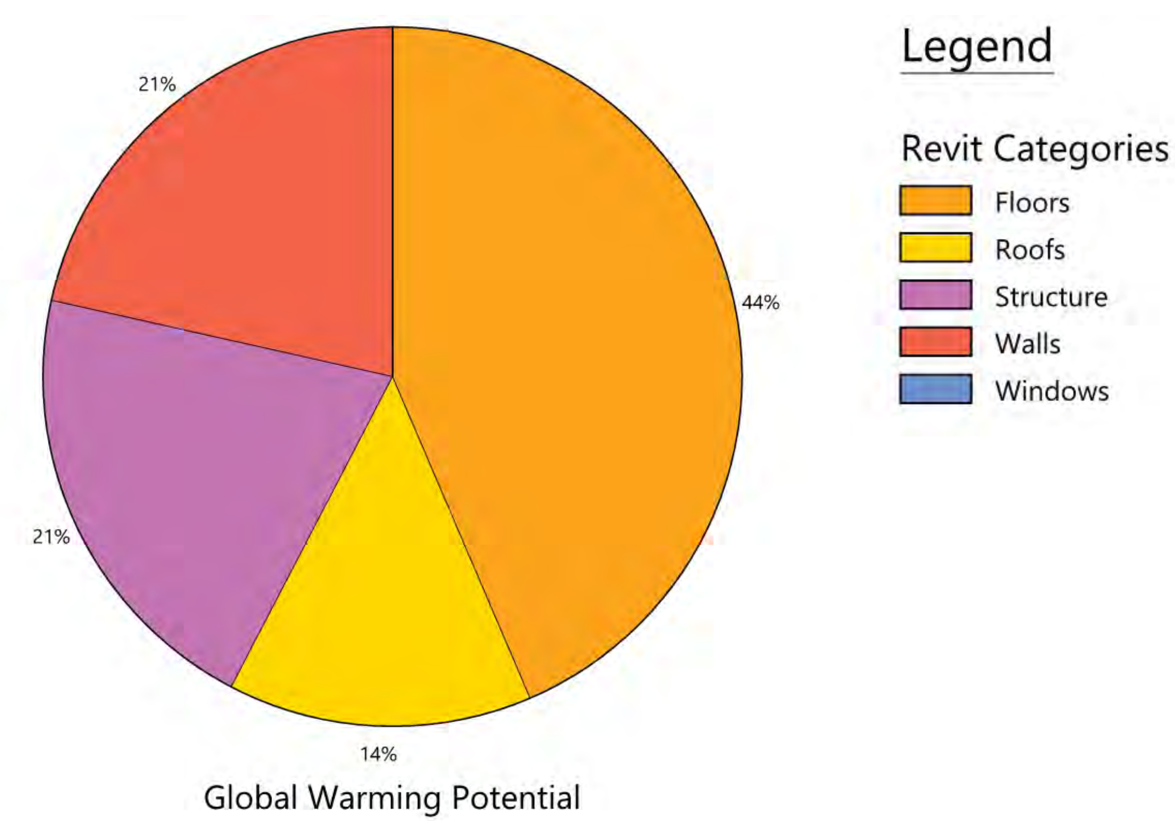
IMPLEMENTATION - LCA SOFTWARE
HOW - Existing Building Renovation Example

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





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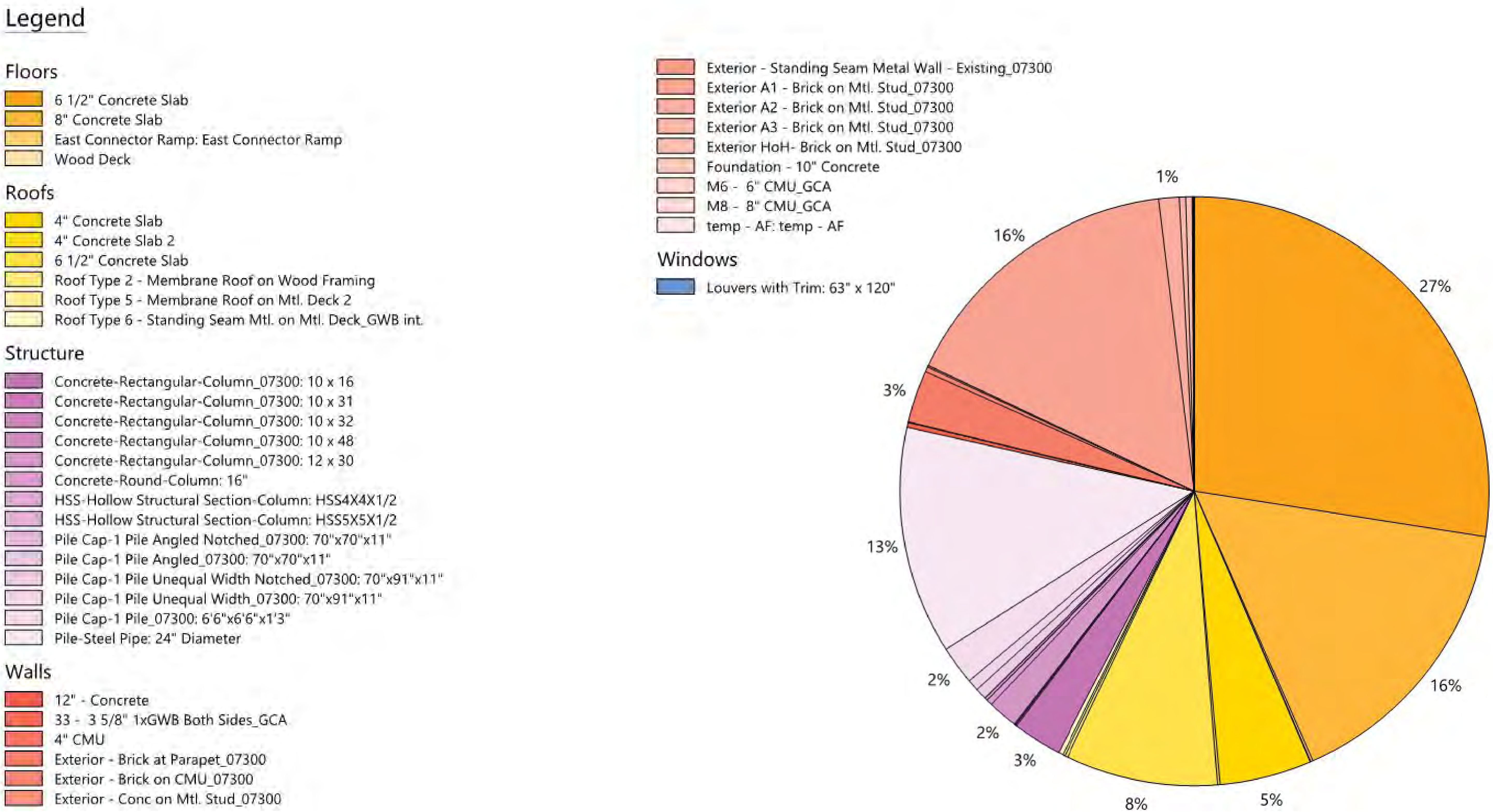
HOW - Existing Building Renovation Example



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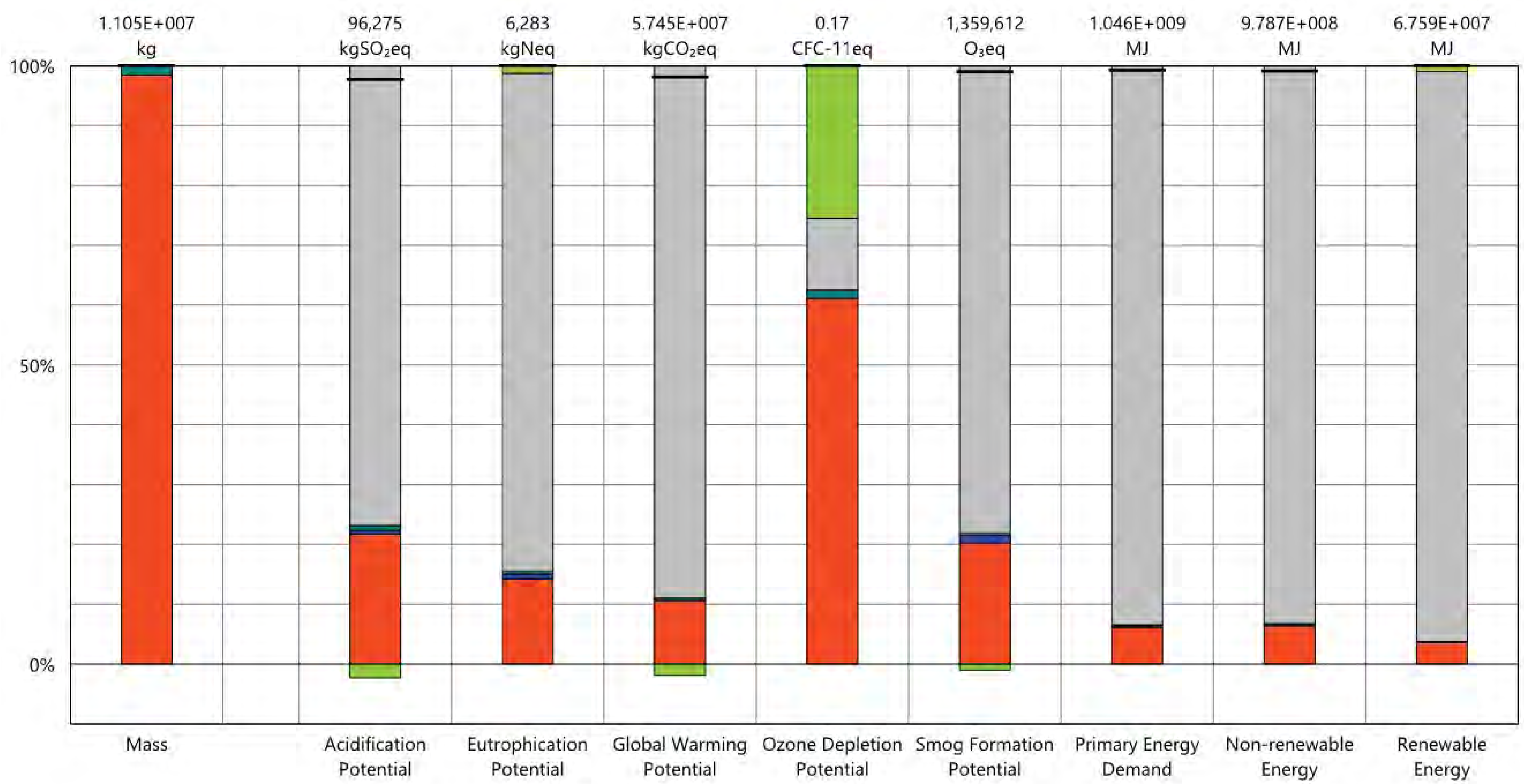

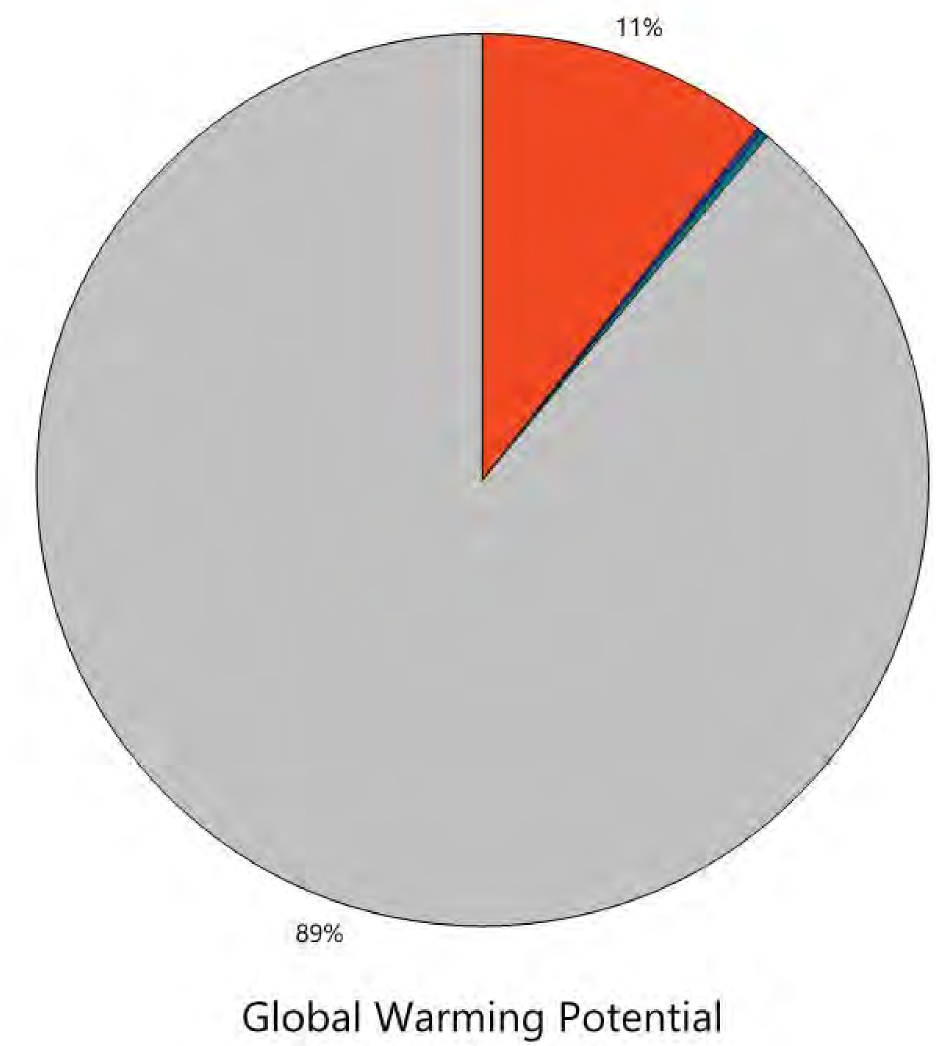

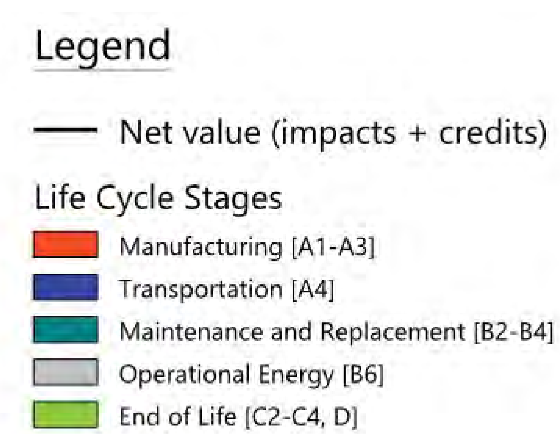

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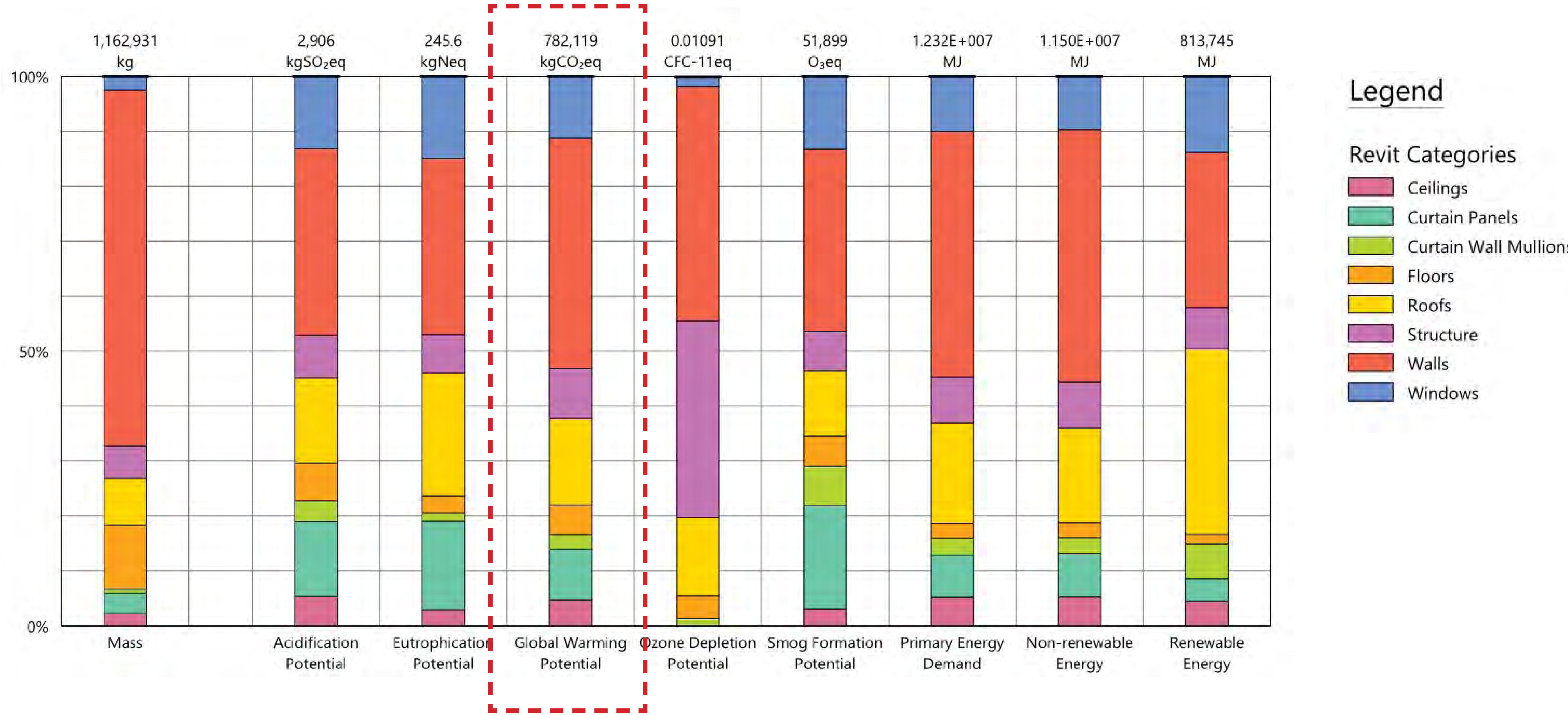
IMPLEMENTATION - LCA SOFTWARE

HOW - Existing Building Renovation Example



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IMPLEMENTATION - LCA SOFTWARE

HOW - Existing Building Renovation Example

Avoided Global Warming Potential = **3,764,469 kgCO2eq**

= 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

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IMPLEMENTATION - LCA SOFTWARE

HOW - Existing Building Renovation Example

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

IMPLEMENTATION - LCA SOFTWARE

HOW - Existing Building Renovation Example

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= 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.

OVERVIEW

I. Introduction

ANALYSIS TOOLS

II. Thermal Modeling - THERM

III. Energy Modeling - Insight360

IV. Life Cycle Assessment - Tally

V. **Integrating the Process**

VI. Discussion

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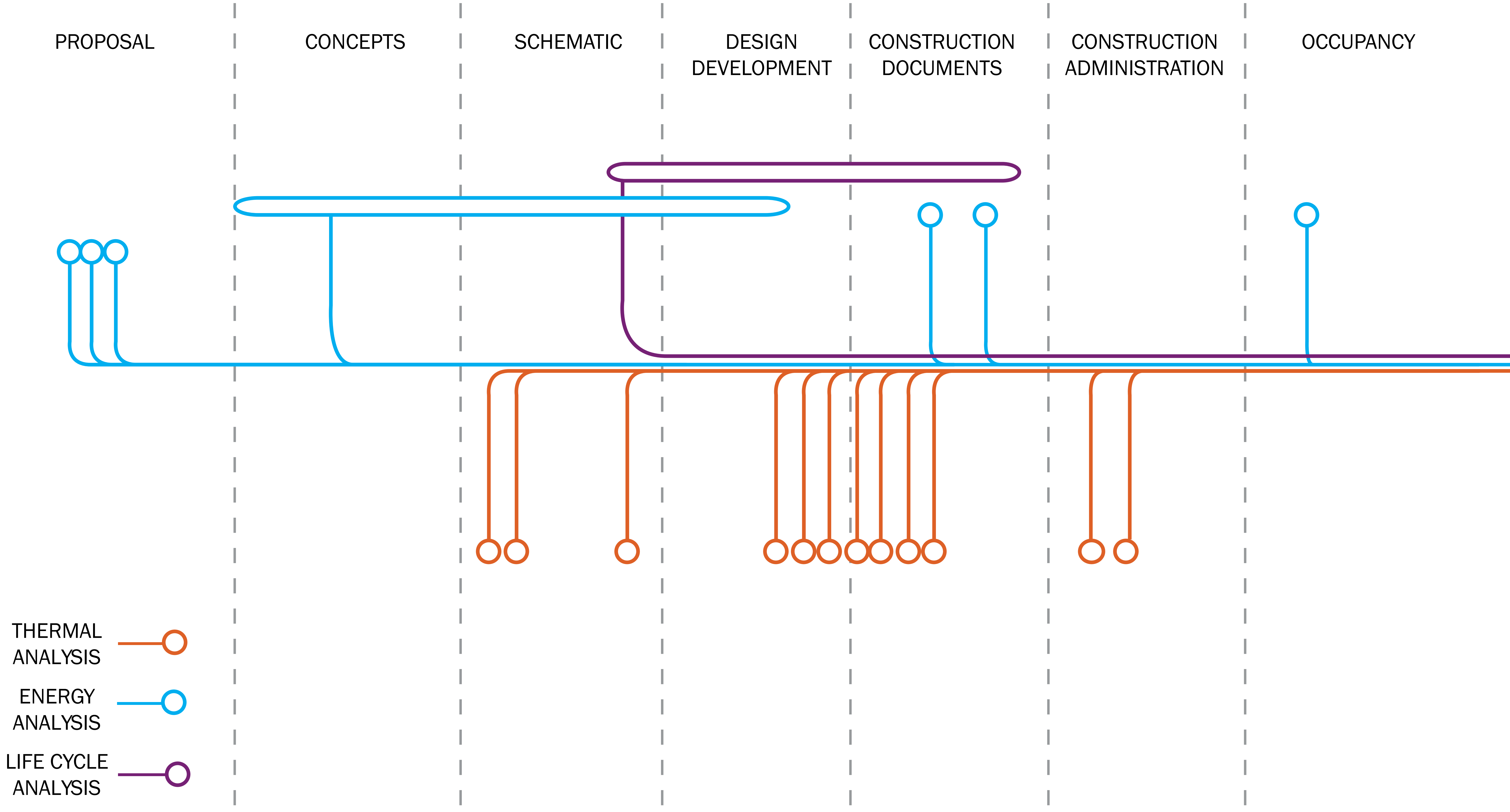
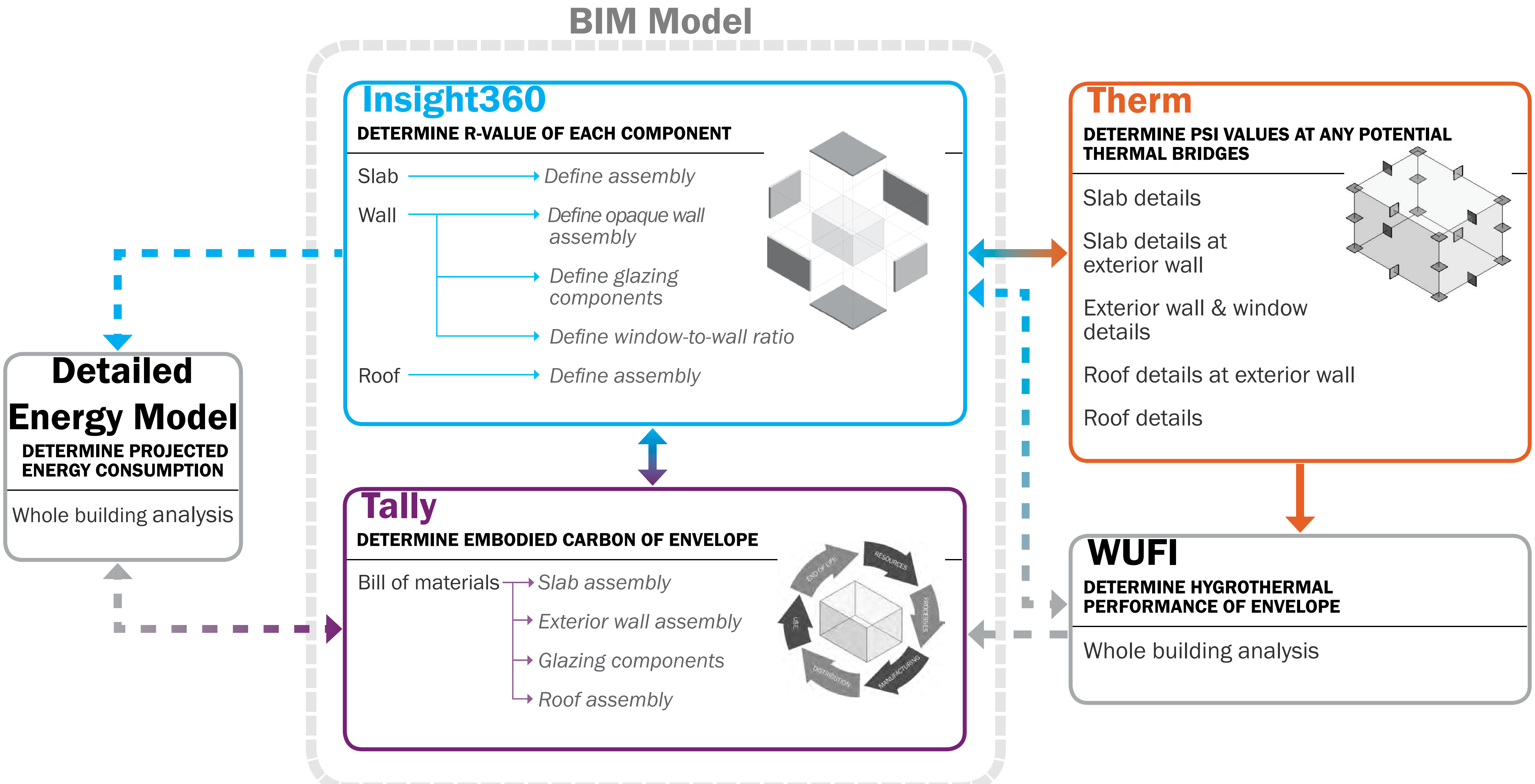
ANALYTICAL WORKFLOW INTEGRATION



ANALYTICAL WORKFLOW

Integrating tools into the envelope design process



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?