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Using Building Modeling Software to Enhance Building Envelope Design/Performance

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Learning Objectives

- How to use Building Envelope Modeling Software
- How to Improve Building Envelope Performance using Building Modeling Software

Note: Please refer to handouts for terminology, definitions, formulae etc.

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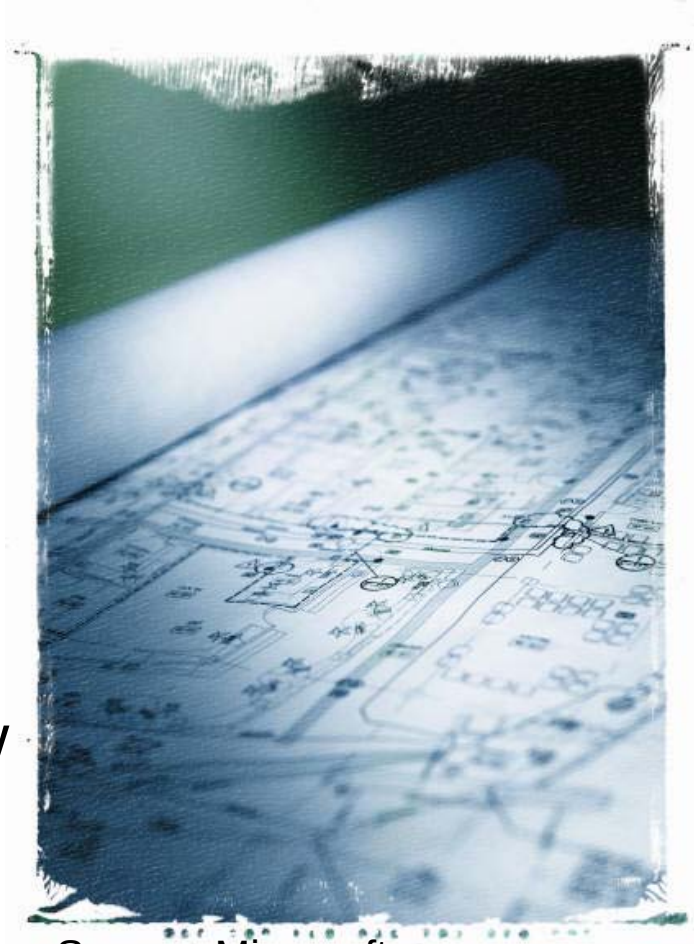
Building Modeling Software

- Not all software is created equal
  - Some simulation software is NOT intended for design
  - Design decisions stem from building simulation
  - Choose the right tool to optimize the design
  - Integrate design results with energy modeling tool

Note: Please refer to handouts for additional building modeling software details



Source: Microsoft

Partial Listing of Available Modeling Software

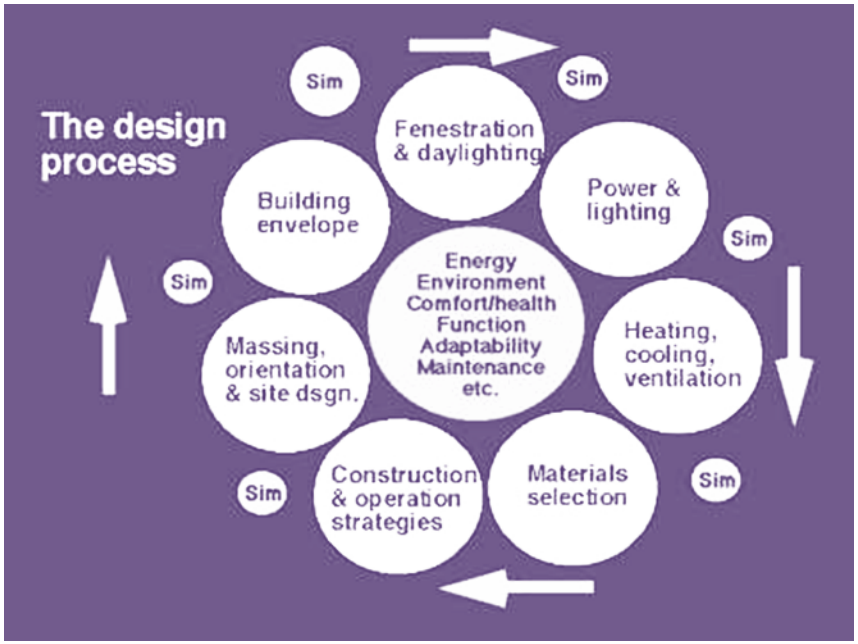
- DOE-2.1(Building Energy Modeling Program from LBNL; Recognized as the Industry Standard)
- ECOTECT (Environmental Design Tool with Solar, Thermal, Lighting, Acoustic, and Cost Analysis Functions; from CRBE, UK)
- ENERGY-10 (Conceptual Design Tool for Residential and Small Commercial Buildings; from NREL)
- EnergyPlus (Energy Modeling Program Based on BLAST and DOE-2; from DOE)
- eQUEST (Uses DOE-2.2 as Simulation Engine; from JJH&A)
- ESP-r (General Purpose Simulation Environment from University of Strathclyde, U.K)
- HAP (Integrated Design and Energy Simulation Tool; from Carrier)
- IES <VE> (General Purpose Simulation Environment; from IES, UK)
- TRACE 700 (Integrated Design and Energy Simulation Tool; from Trane)
- TRNSYS (Energy Simulation Program with Mod. Structure; from Univ. of Wisconsin)

Reference: Building Energy Software Tools Directory (www1.eere.energy.gov/buildings)

Integrated Whole Building Design

U.S. Government embraces green initiatives, resulting in a changed approach to building design

Source: www.wbdg.org



Source: www.iisbe.org

Note: Please refer to handouts for additional integrated building design information

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Cooling Load Calculating Principles

- Analyze Conductive, Convective and Radiant Load Components
  - External Loads
    - Walls, Roofs, Fenestration, Doors, Infiltration etc.
  - Internal Loads
    - People, Lights, Plug Loads etc.
  - System Loads
    - Ventilation, Fans, Coil By-Pass, Duct Leakage etc.

Cooling Load Calculating Principles

- Radiant Heat Gain
  - Absorbed by building mass
  - Transient behavior
  - Dependent on composite heat storage capacity of building materials
    - Governs conversion of radiant gain to zone load

Cooling Load Calculation Principles

- Thermal Process
  - Convection from element surface to room air
  - Thermal radiation to other elements
    - *Triggering more convection to room air*
  - Heat storage within materials and further radiative exchange
  - Eventually all heat flow becomes a load

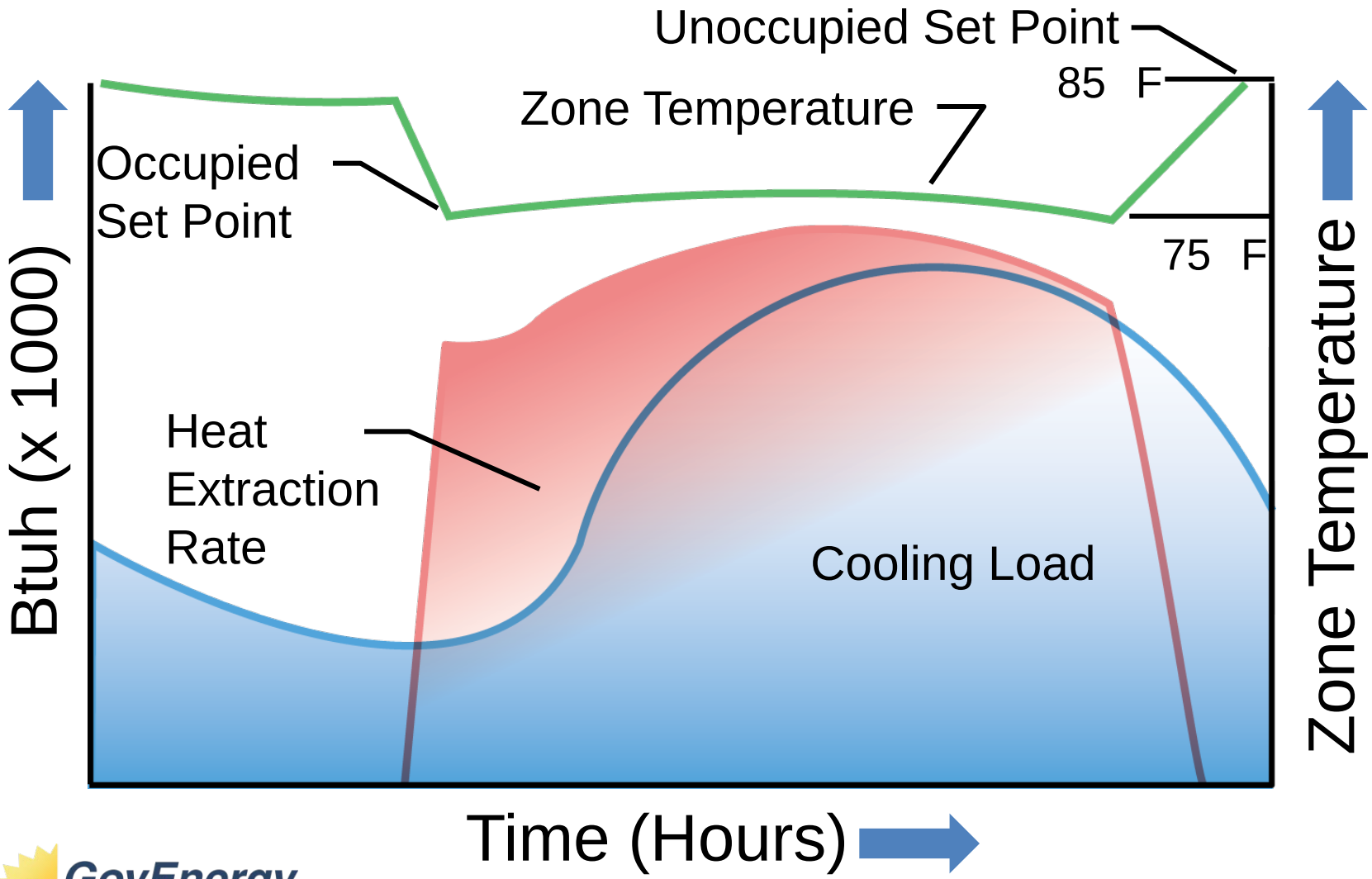
Note: Please refer to the handouts for details of Transfer Function Equations

Thermal Lag

- Analyzing Thermal Lag
  - Mandatory requirement for calculating cooling load
  - Space loads typically lower than instantaneous heat gain
  - Significantly impact space peak load.
  - Accounting for the time delay effect is the major challenge in cooling load calculations.

Note: Please refer to handouts for details of Transfer Function Equations

Thermal Lag (Results)



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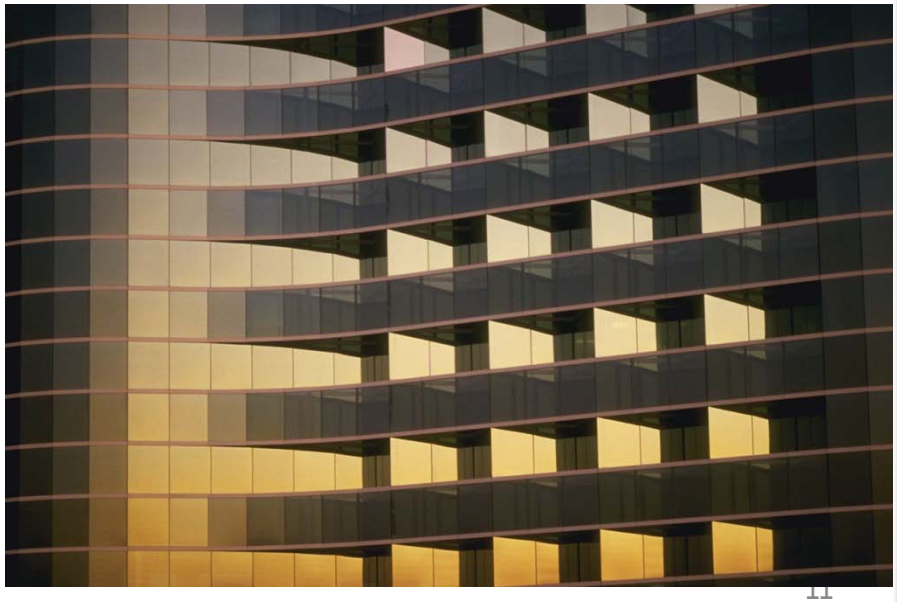
Building Envelope

- Establish Minimum Requirements
  - Defined by Local Building/Energy Codes
  - ASHRAE 90.1-2007 or 2010
  - Based on Project Location and Climate Zone



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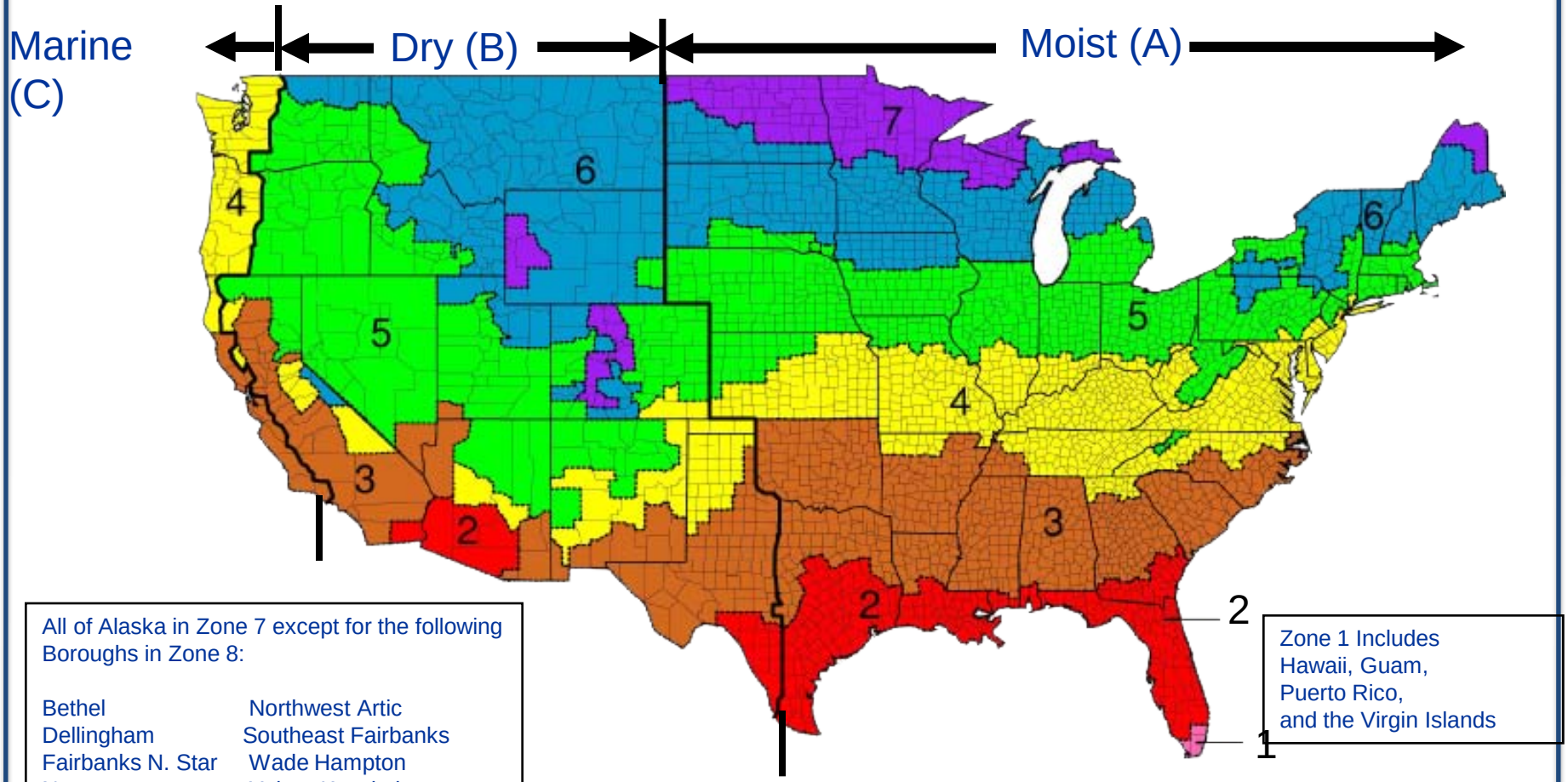
ASHRAE US Climate Zones*



All of Alaska in Zone 7 except for the following Boroughs in Zone 8:

Bethel	Northwest Artic
Dellingham	Southeast Fairbanks
Fairbanks N. Star	Wade Hampton
Nome	Yukon-Koyukuk
North Slope	

Zone 1 Includes Hawaii, Guam, Puerto Rico, and the Virgin Islands

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Source: ANSI/ASHRAE. *Standard 90.1-2007 Energy Standard for Buildings Except Low-Rise Residential Buildings.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia, 2007.

Building Envelope

TABLE 5.5-4 Building Envelope Requirements For Climate Zone 4 (A, B, C)*

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.173	R-5.0 c.i.
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-0.097	R-10.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.053	R-19.0
Walls, Above-Grade						
Mass	U-0.104	R-9.5 c.i.	U-0.090	R-11.4 c.i.	U-0.580	NR
Metal Building	U-0.113	R-13.0	U-0.113	R-13.0	U-0.134	R-10.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.089	R-13.0	U-0.064	R-13.0 + R-3.8 c.i.	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-0.119	R-7.5 c.i.	C-1.140	NR
Floors						
Mass	U-0.087	R-8.3 c.i.	U-0.074	R-10.4 c.i.	U-0.137	R-4.2 c.i.
Steel-Joist	U-0.038	R-30.0	U-0.038	R-30.0	U-0.069	R-13.0
Wood-Framed and Other	U-0.033	R-30.0	U-0.033	R-30.0	U-0.066	R-13.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.540	R-10 for 24 in.	F-0.730	NR
Heated	F-0.860	R-15 for 24 in.	F-0.860	R-15 for 24in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Nonswinging	U-1.500		U-0.500		U-1.450	

**Source:* ANSI/ASHRAE. *Standard 90.1-2007 Energy Standard for Buildings Except Low-Rise Residential Buildings.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia, 2007.

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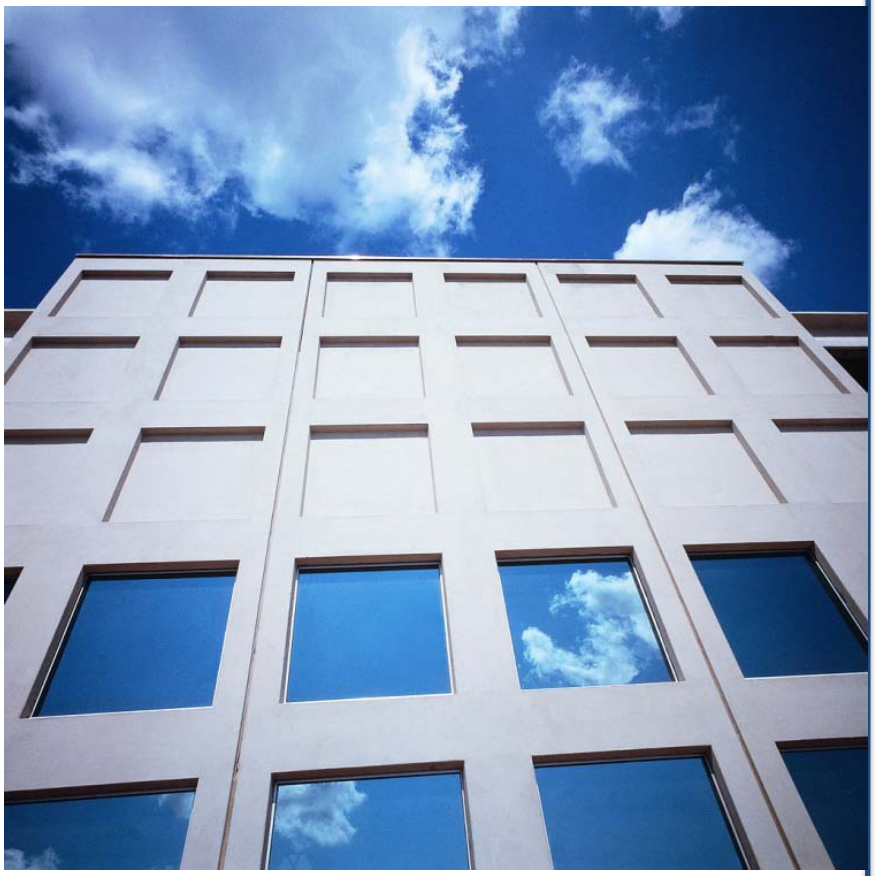
Building Envelope

Opaque Components and Fenestration

- "U" Values are common performance indicators
- "U" Values describe steady-state heat flow
- "U" Values assume zero mass
  - Envelope items have mass
  - Mass involves dynamic heat flow
  - Dynamic heat flow requires accurate component modeling
  - Heat gain calculation must consider the transient heat transfer through walls and roofs

Building Envelope

- Dynamic Heat Transfer Analysis requires surface:
  - Area
  - Orientation
  - Tilt
  - Layered Construction
    - Material Properties
      - Thickness
      - Density
      - Conductivity
      - Specific Heat



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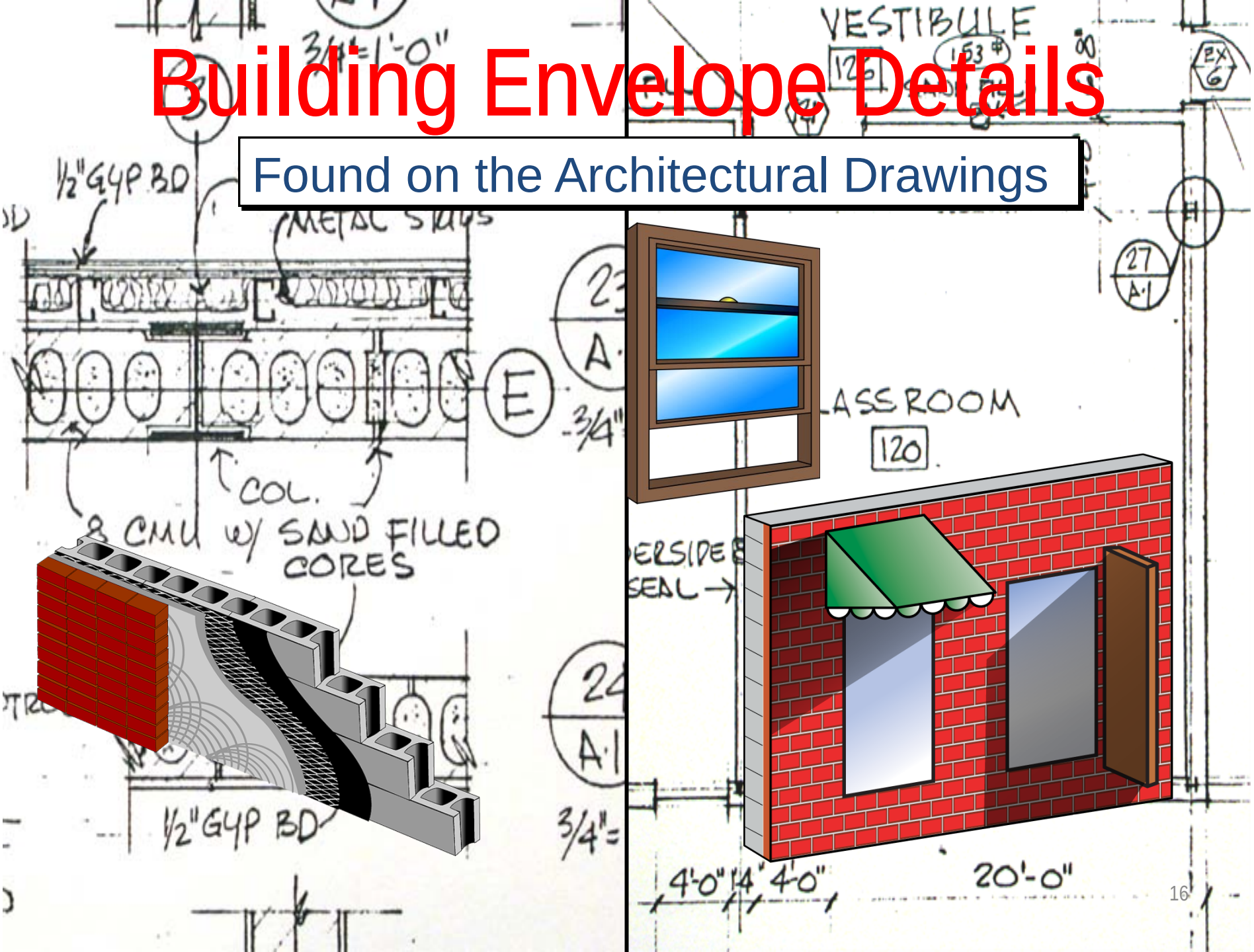
Building Envelope Details

Found on the Architectural Drawings



Sample Office Building

3 Story Office Building
Baltimore, MD Climate Zone 4A
16,875 ft² per Floor
50,625 ft² Total

Note: Please refer to handouts for additional details related to this example.

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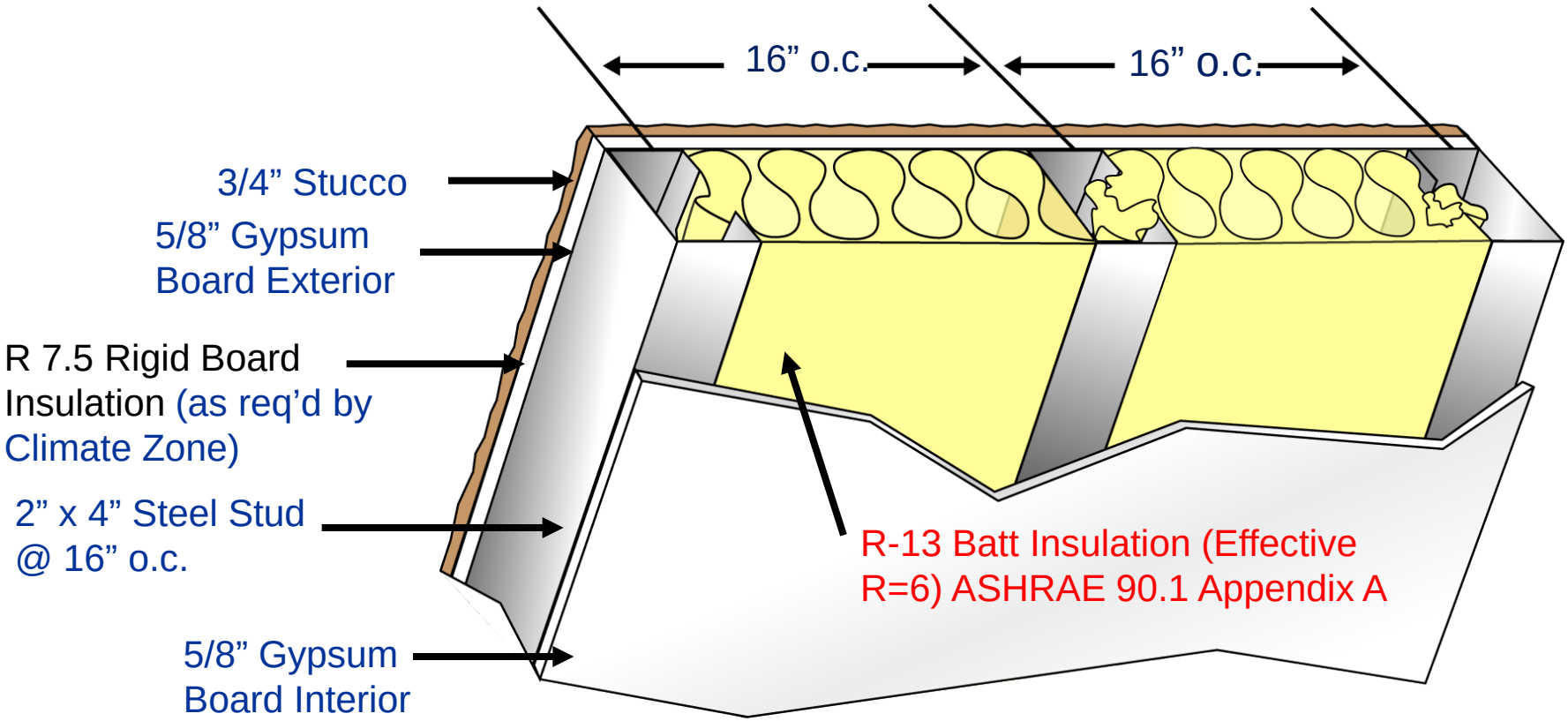
Wall Construction

Note: Location of rigid insulation impacts thermal performance.



Rigid insulation located outboard of the exterior sheathing on stud walls reduces conductive heat transfer through the studs improving thermal performance

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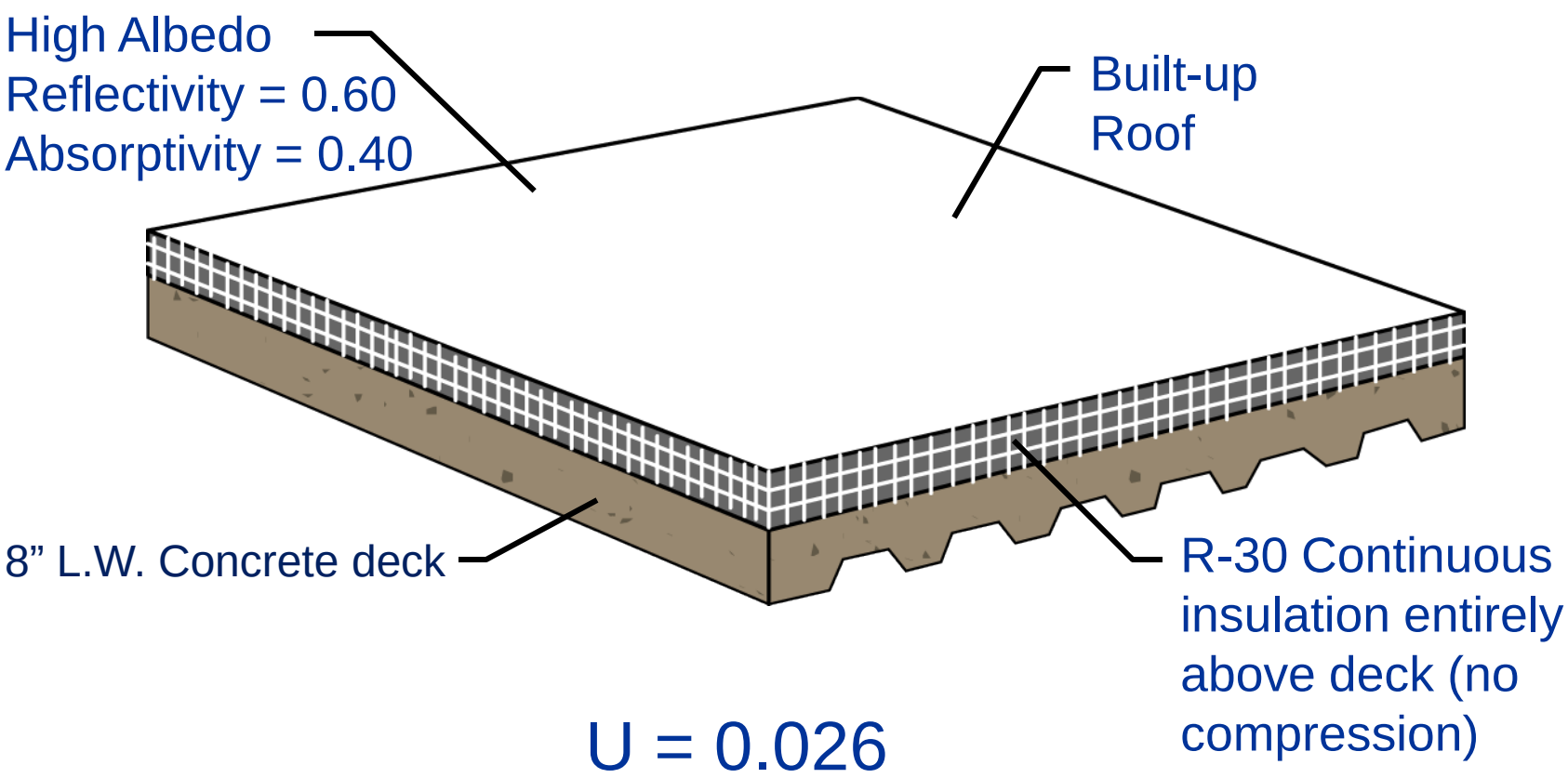
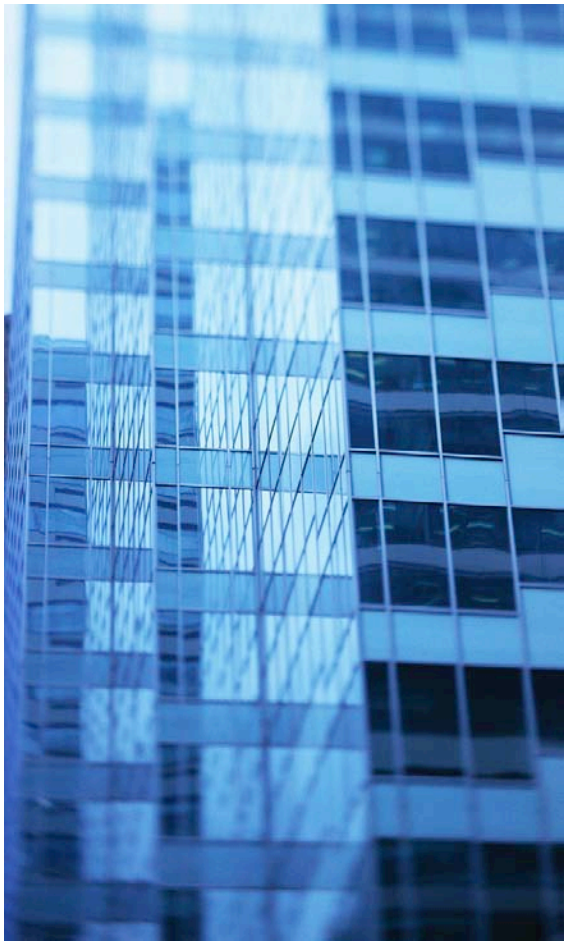
Roof Construction



U = 0.026

Fenestration

- A critical component of energy efficient buildings
  - Affects building thermal performance
  - Allows for daylighting
    - Reducing overhead lighting levels
    - Reduces lighting heat gain(cooling load)
    - Reduces lighting energy consumption
- Optimize fenestration through
  - Continuous analysis



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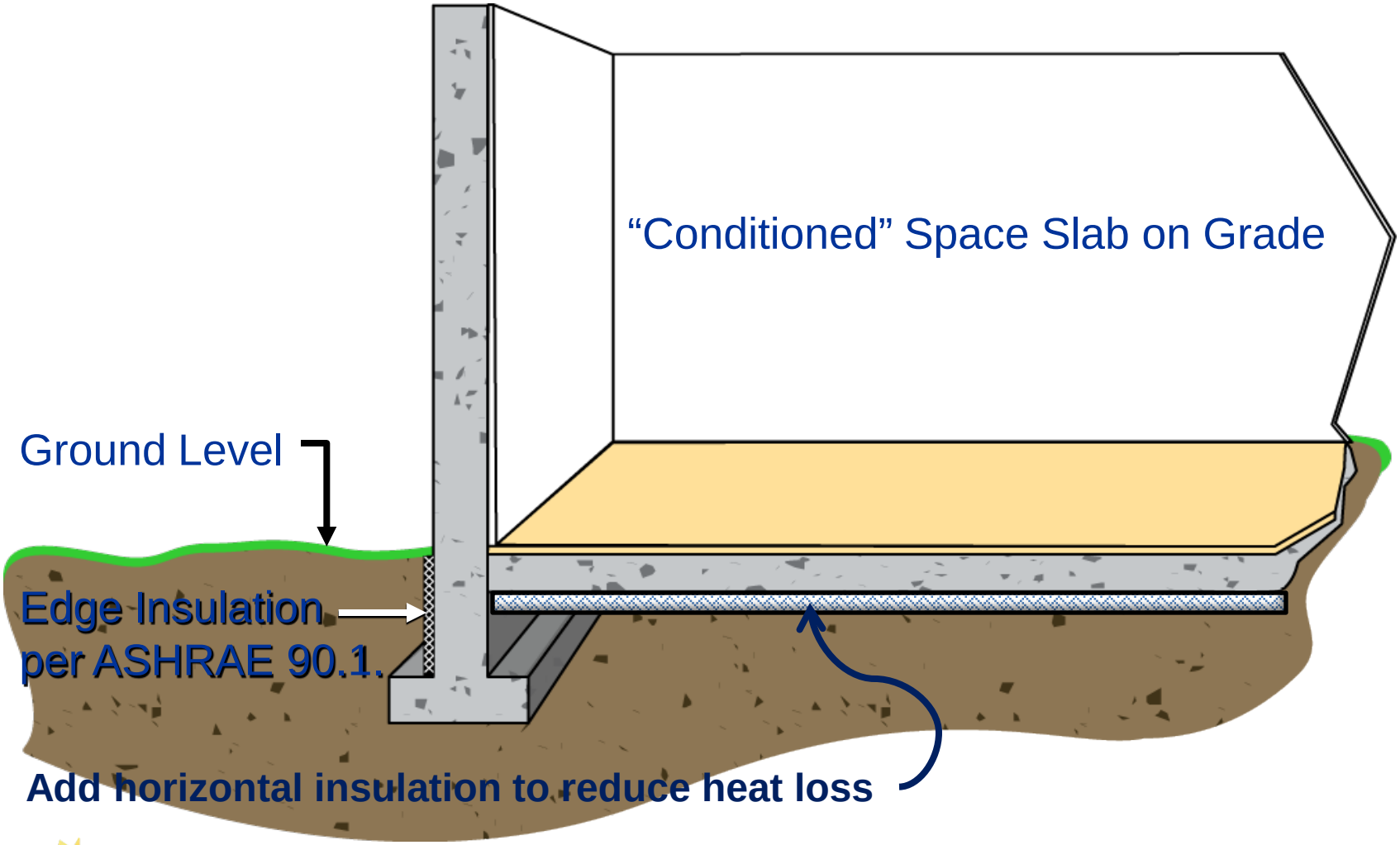
Floor Slab



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Building Envelope Considerations

- Beware of the "Thermos Bottle Effect"
  - In climate zones with hot summers and cold winters
    - Buildings with high internal heat gains or large core areas
      - Adding roof insulation reduces heating loads *but*,
      - Can increase off-design cooling loads and energy consumption
- Example: Chicago 14,000 ft^2 one story retail
  - Design roof U value = 0.104 BTU/hr/ft^2/°F
  - Added more roof insulation improved U value to 0.042

Design Case	Cooling kWh	Heating kWh	Total kWh
U = 0.104	71,571	9,260	365,663
U =0.042	75,720	693	361,214

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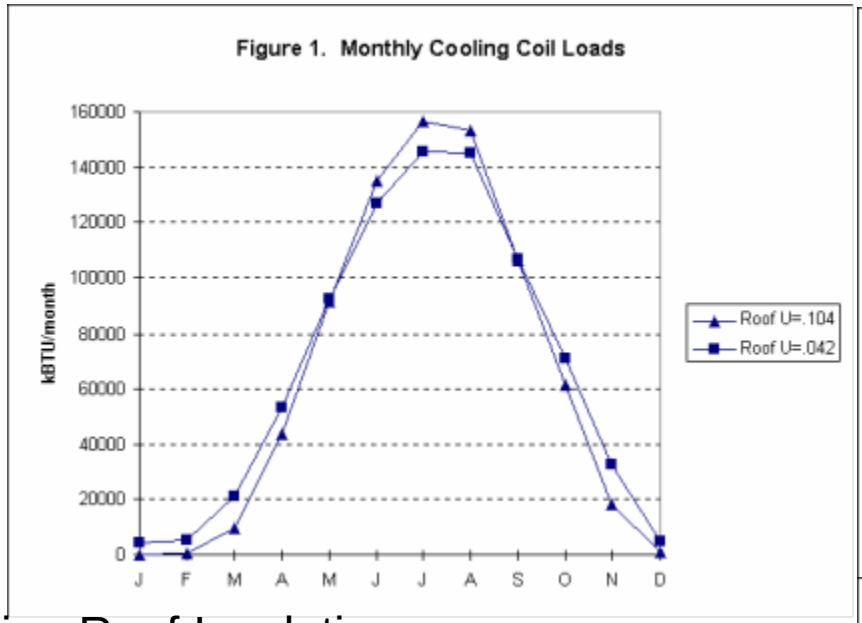
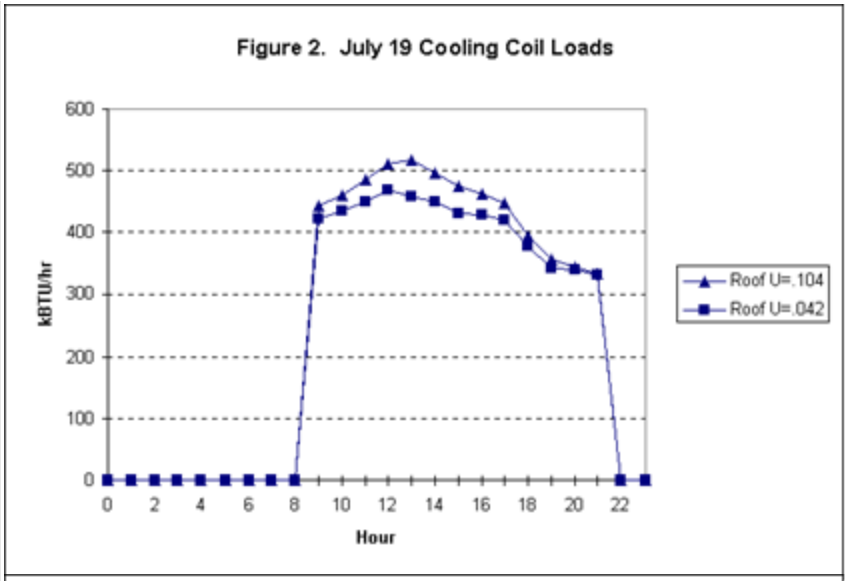
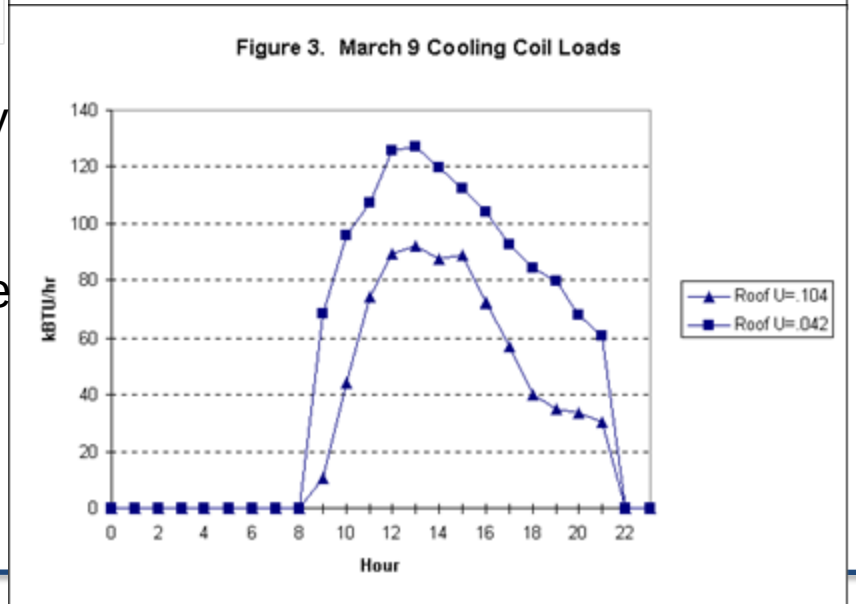
Building Envelope Considerations

- Heating Energy reduced by 93%
- Cooling Energy increased by 6%
  - Figure 1-Monthly total cooling coil loads
  - Figure 2-Hourly coil loads for July 19 (Temperature range from 69°F-82°F)
  - Figure 3-Hourly coil loads for March 19 (Temperature range from 35°F-50°F)

Building Envelope Considerations







Adding Roof Insulation

- Reduces heat flow through roof assembly
  - From hotter outside to cooler inside (reducing heat gain)
  - From warmer inside to colder outside (reducing heat loss) added internal heat gain requiring mech. cooling

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Review

- Choose the right tool
  - ✓ Appropriate, robust tool matched to project requirements
  - ✓ Tested in accordance with ASHRAE Std.140
  - ✓ Approved by rating authority
  - ✓ 8,760 hours per year analysis
  - ✓ Model proposed bldg. features
- Choose the right modeler
  - ➢ Proficient with:
    - ✓ HVAC engineering fundamentals
    - ✓ Building modeling software
    - ✓ Procedures required to achieve objectives

Review

- Integrate Whole Building Design
  - ✓Continuous communication
  - ✓Active collaboration among stakeholders
  - ✓Implement continuous simulation and design cycle
- Analyze Conductive, Convective and Radiant Load Components
  - ✓Analyze thermal lag
- Properly define building envelope
  - ✓Layered construction and material properties
  - ✓Allows for dynamic heat transfer analysis

Thank You

For more information related to Load Estimating and Building Energy Simulation please contact us anytime at:

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