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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Learning Objectives

Participants will :

1. Learn how to link the performance of individual building enclosure components in a holistic framework to achieve high-performance buildings.

2. Explore, through built case studies, how building envelope design determines overall energy conservation and sustainability capabilities

3. Learn innovative practices for avoiding heat loss as well as moisture and air infiltration in enclosure design for healthy new and existing buildings.

4. Understand the role of building enclosure commission-ing in the design, construction, and operation and maintenance of commercial facilities.

Thermal Performance and Energy Savings Potential of Attic Radiant Barrier Systems

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BUILDING ENCLOSURE SCIENCE & TECHNOLOGY

BEST4 CONFERENCE

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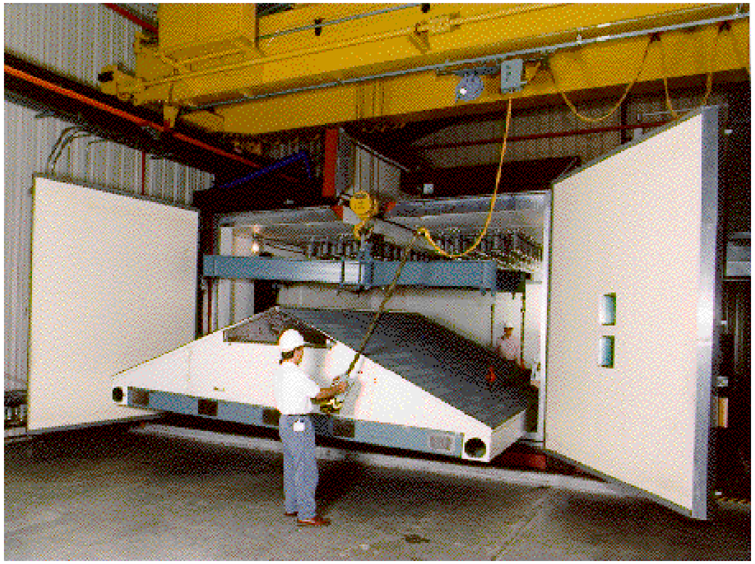
Overview

- Motivation
- Large Scale Climate Simulator (LSCS)
- Attic radiant barrier systems tested
- Test results
- EnergyPlus Simulation Results

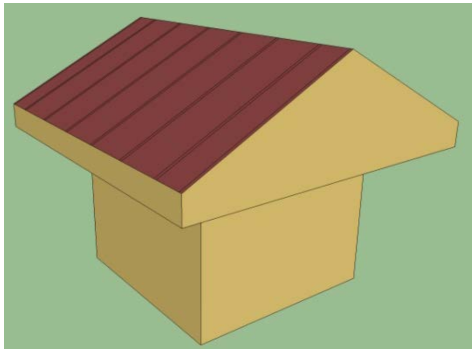


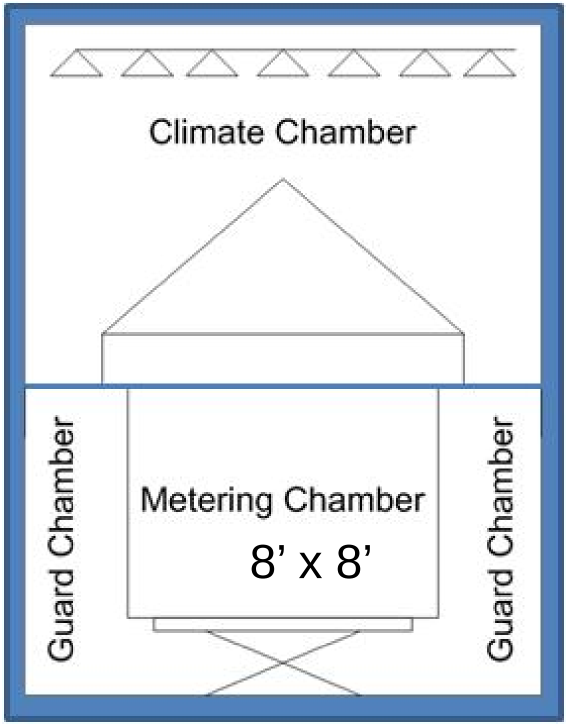
Motivation

- Radiation is the predominant mode of heat transfer in typical building attics, particularly during summer months
- Radiant barriers and low-emittance surface coatings in roof decks of residential building attics can significantly reduce air conditioning loads
- Various radiant barrier systems and low-emittance (low-e) surface coatings are being used
- Implementation of radiant barriers is becoming more prominent in building codes
- Minimal data are available that quantify the effectiveness of these technologies

LSCS – one of a kind apparatus

- DOE user facility
- Capable of testing whole roof and attic systems
- Can be operated as an environmental chamber or as a guarded hot box
- ASTM C1363 or C1373

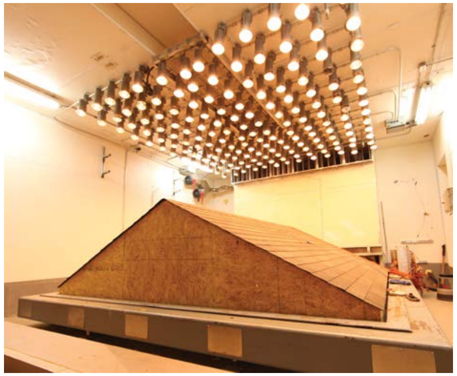




CC: –40°F to 150°F
MC, GC: 45°F to 150°F
Roof surface temperature can be Maintained at a higher temperature than CC air temperature

Test attic

- 12’ 8” (3.86 m) by 12’ 8 in” (3.86 m)
- 6:12 roof slope
- Nominal R_{US} 13 h·ft^2·°F/Btu (R_{SI} 2.29 m^2·K/W) fiberglass batt insulation on the attic floor
- Net free ventilation area of 1:150 (soffit-to-ridge)



Four attic configurations evaluated:

1. No radiant barrier (control)
2. Perforated low-e foil laminated oriented strand board (OSB) deck
3. Low-e foil stapled on rafters
4. Liquid applied low-emittance coating, (Interior Radiant Control Coating (IRCC) on roof deck and rafters.

Thermal emittance of the surfaces were measured either using ASTM C1371 or using transient method

Attic 1: Ordinary OSB roof deck (control)

Thermal emittance: OSB = 0.89, rafters = 0.87

Attic 2: Perforated low-e foil laminated OSB deck

Thermal emittance = 0.03

Attic 3: Low-e foil stapled on rafters

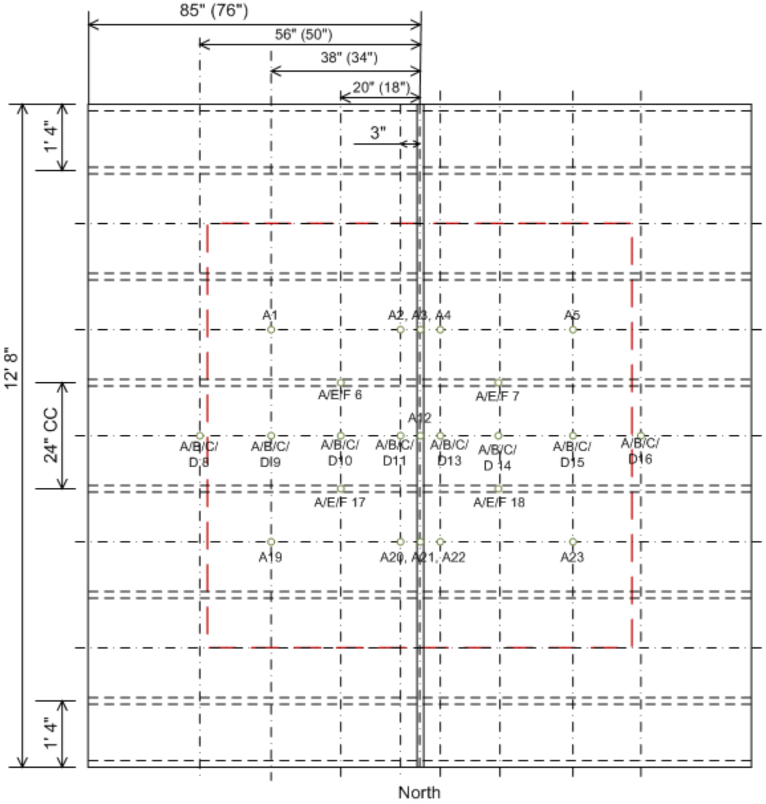
- Thermal emittance = 0.02 on both sides
- 3.5”-high air space between the foil and roof sheathing
- This is the preferred method of installing a retrofit radiant barrier by the US DOE, ENERGY STAR, California Title 24, ASTM International, RIMA International, and others.

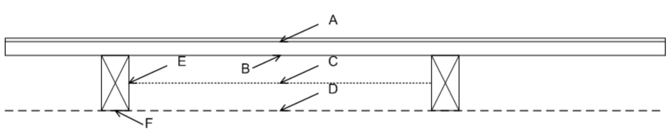
Attic 4: Liquid applied low-e coating on roof deck and rafters

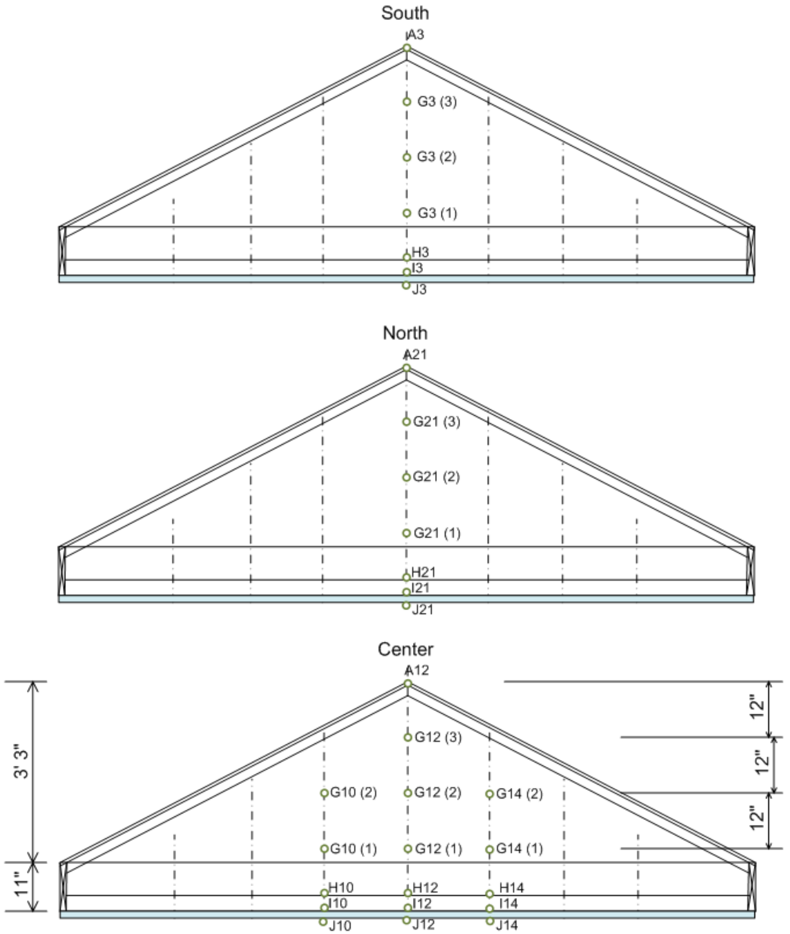
Thermal emittance = 0.23

Instrumentation

A = Above deck B = Underside of deck
C = Air cavity between rafters D = RB foil stapled between rafters
E = Side of the Rafter F = Under the Rafter (towards attic)
G = Attic air H = Attic floor (above insulation)
I = Attic floor (under insulation) J = Ceiling (on guard side)
NO/NI/SO/SI = North in, north out, south in, south out (Gable)







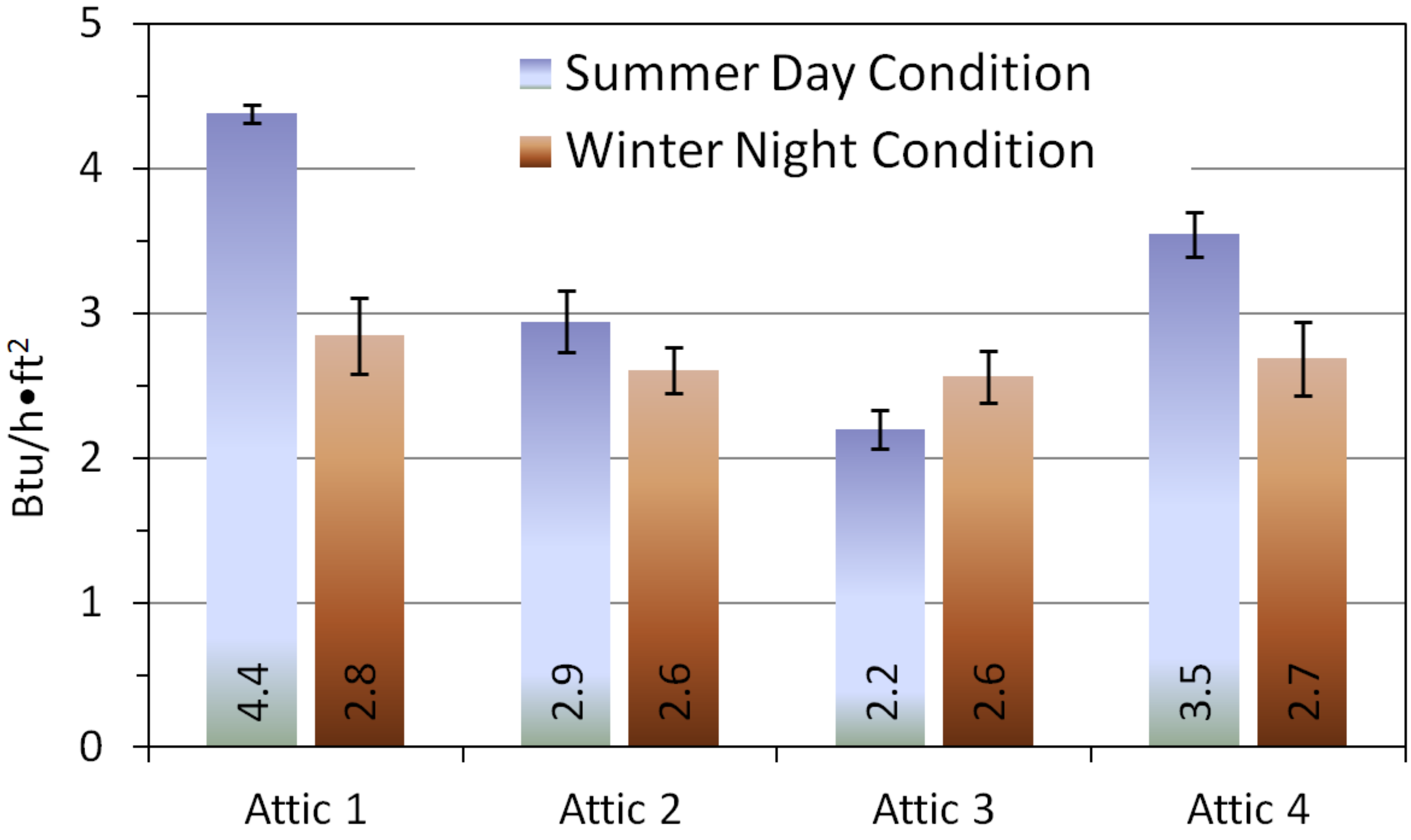
Test conditions

- Summer daytime and winter nighttime conditions for a cooling dominant climate zone (based on AtticSim simulation result using TMY3 weather file for Austin)
- For the summer daytime condition: CC air temperature 100°F (37.8°C) and roof exterior surface temperature 140°F (60.0°C)
- For the winter night condition: CC air temperature 32°F (0°C)
- MC and GC temperature: 70°F (21.1°C) in both cases

Measured Temperatures

Measurement Location	Attic Configuration	Summer Day Condition	Winter Night Condition
Climate Chamber Air Temperature, °F (°C)	Attic 1	99.8 (37.7)	32.0 (0.0)
	Attic 2	100.1 (37.8)	31.9 (-0.1)
	Attic 3	99.5 (37.5)	32.1 (0.1)
	Attic 4	99.9 (37.7)	32.1 (0.0)
Roof Exterior Surface Temperature, °F (°C)	Attic 1	140.5 (60.3)	32.2 (0.1)
	Attic 2	140.6 (60.3)	32.0 (0.0)
	Attic 3	139.6 (59.8)	32.2 (0.1)
	Attic 4	139.5 (59.7)	32.0 (0.0)
Attic Air Temperature, °F (°C)	Attic 1	120.2 (49.0)	33.9 (1.1)
	Attic 2	111.1 (44.0)	35.0 (1.7)
	Attic 3	105.6 (40.9)	38.5 (3.6)
	Attic 4	114.1 (45.6)	34.6 (1.4)
Attic Floor Temperature, °F (°C)	Attic 1	121.3 (49.6)	37.1 (2.8)
	Attic 2	105.7 (40.9)	39.2 (4.0)
	Attic 3	98.1 (36.7)	41.9 (5.5)
	Attic 4	110.7 (43.7)	38.3 (3.5)
Gypsum Board Surface Temperature Towards the Metering Chamber, °F (°C)	Attic 1	74.6 (23.7)	68.1 (20.0)
	Attic 2	73.2 (22.9)	68.2 (20.1)
	Attic 3	72.6 (22.6)	68.4 (20.2)
	Attic 4	73.7 (23.2)	68.2 (20.1)
Metering Chamber Air Temperature, °F (°C)	Attic 1	70.0 (21.1)	69.9 (21.1)
	Attic 2	70.0 (21.1)	70.0 (21.1)
	Attic 3	70.1 (21.1)	70.0 (21.1)
	Attic 4	70.0 (21.1)	70.0 (21.1)
Gable Exterior Surface Temperature, °F (°C)	Attic 1	105.0 (40.5)	32.8 (0.4)
	Attic 2	102.1 (38.9)	32.6 (0.3)
	Attic 3	100.8 (38.2)	33.9 (1.0)
	Attic 4	102.6 (39.2)	32.8 (0.4)

Summary LSCS test results



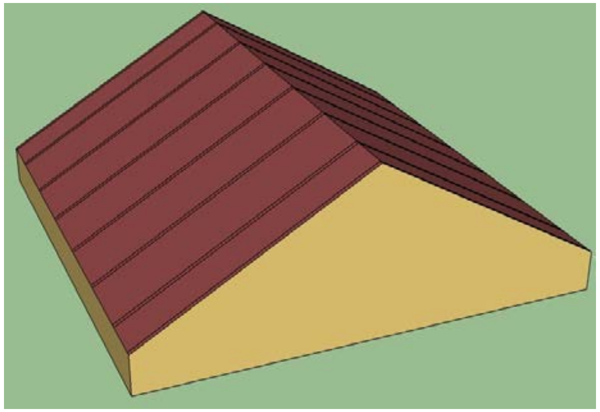
Cooling Load Reduction	33%	50%	19%
Heating Load Reduction	8%	10%	6%

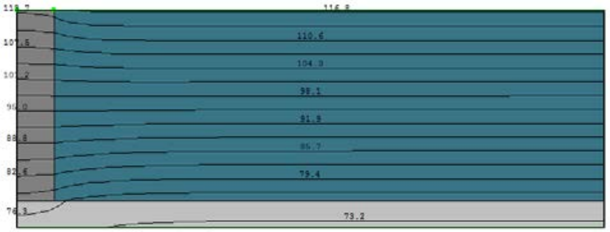
Limitations

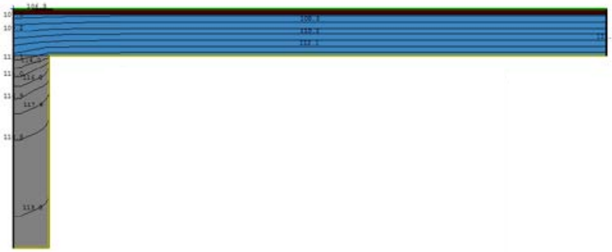
- The exterior roof surface temperature was held fixed for a given climate condition. For a actual building exposed to natural conditions, the exterior roof surface temperatures would not be the same for all attics.
- The test attic had R_{US} 13 insulation on the floor. For attics with higher insulation R-values the potential savings due to the application of radiant barrier systems will be lower than the results shown in this study.
- The heat flow through the attic floor decreases during milder weather conditions; annual savings will be lower.
- This particular experiment did not have A/C ducts in the attic, homes with ducts in attic could see greater savings

Benchmark EnergyPlus against LSCS test data

- EnergyPlus model was based on geometry and construction details of the test attic
- Finite-element method was used to model two-dimensional heat-transfer to account for thermal bridges
- SurfaceProperty:OtherSideCoefficients were used to fix exterior surface temperatures per test data
- Custom weather files representing conditions at Climate Chamber were used for simulations







Benchmark EnergyPlus against LSCS test data

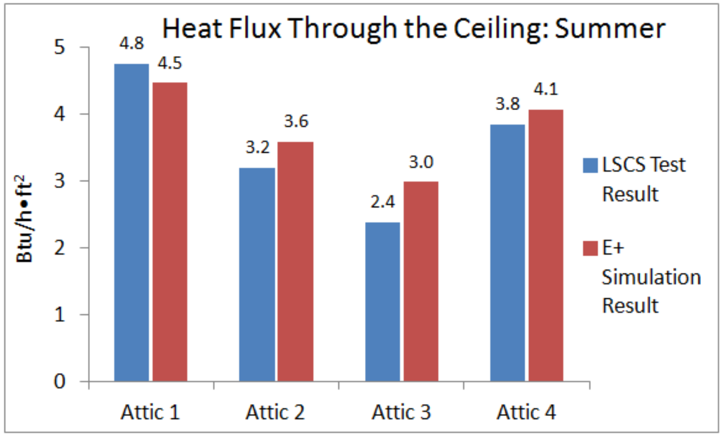
Test Attic	Attic Air Temperature, °F			Attic Floor Temperature, °F			Heat Flux Through Ceiling, Btu/h•ft²		
	Measured	EnergyPlus Predicted	Difference	Measured	EnergyPlus Predicted	Difference	Measured	EnergyPlus Predicted	Difference
Attic 1	120.2	123.2	-3.0	121.3	121.3	0.0	4.8	4.5	0.3
Attic 2	111.1	118.1	-7.0	105.7	110.8	-5.1	3.2	3.6	-0.4
Attic 3	105.6	110.6	-5.0	98.1	103.8	-5.7	2.4	3.0	-0.6
Attic 4	114.1	120.1	-6.0	110.7	116.2	-5.5	3.8	4.1	-0.2

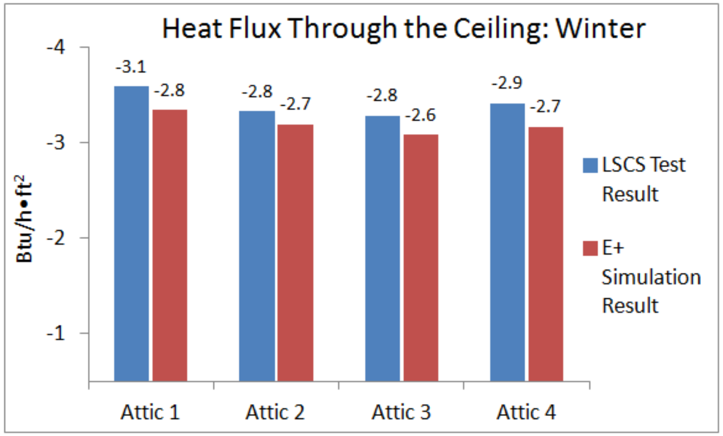
Summer

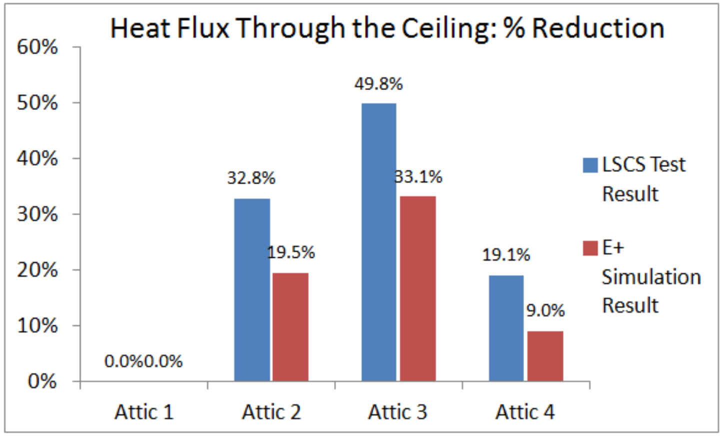
Test Attic	Attic Air Temperature, °F			Attic Floor Temperature, °F			Heat Flux Through Ceiling, Btu/h•ft²		
	Measured	EnergyPlus Predicted	Difference	Measured	EnergyPlus Predicted	Difference	Measured	EnergyPlus Predicted	Difference
Attic 1	33.9	35.1	-1.2	37.1	38.4	-1.3	-3.1	-2.8	-0.2
Attic 2	35.0	35.3	-0.3	39.2	40.0	-0.8	-2.8	-2.7	-0.1
Attic 3	38.5	36.4	2.1	41.9	41.4	0.5	-2.8	-2.6	-0.2
Attic 4	34.6	35.5	-0.9	38.3	40.3	-2.0	-2.9	-2.7	-0.2

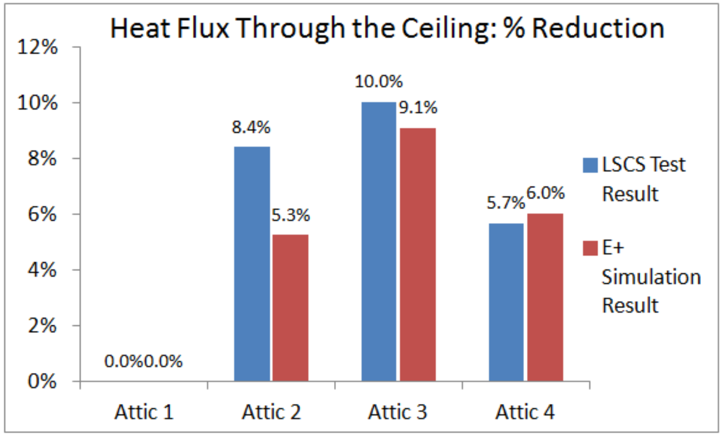
Winter

Benchmark EnergyPlus against LSCS test data







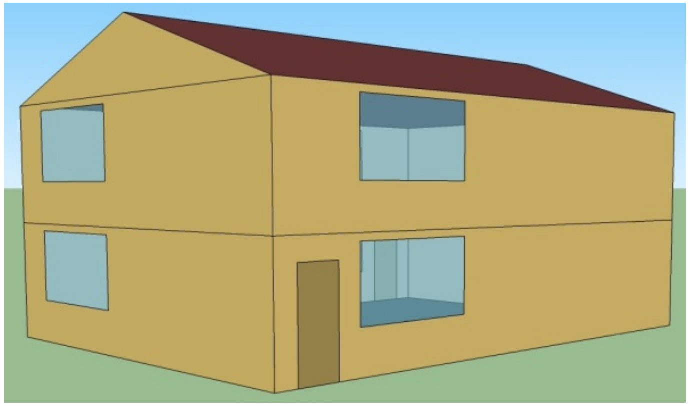


Energy Savings estimate using EnergyPlus simulation of DOE Residential Prototype Building Models

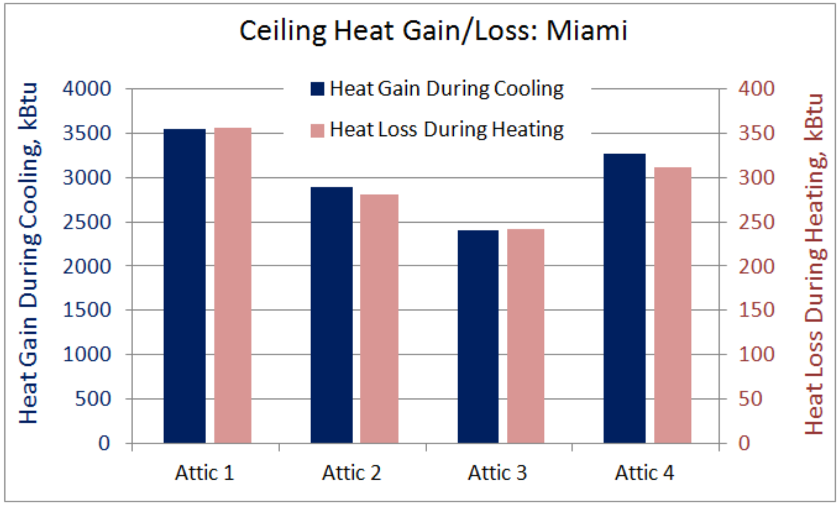
- Two cases:

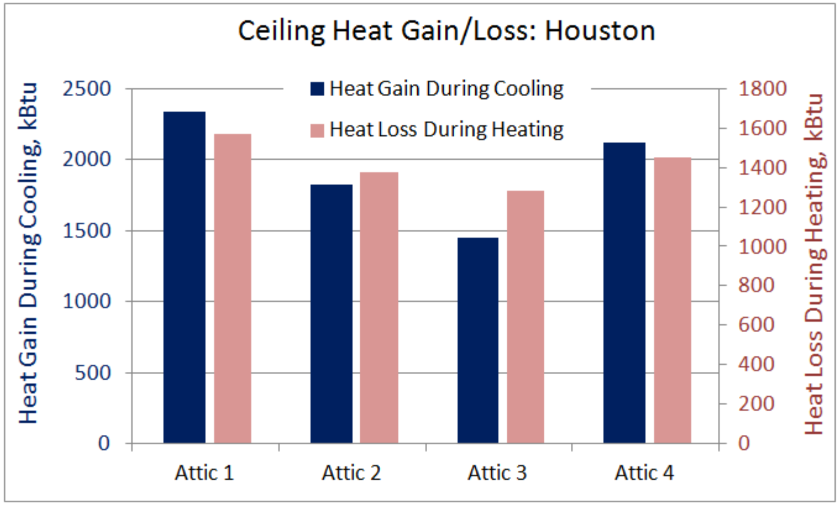
  1) IECC 2012 compliant residential building
  2) only 3.5" fiberglass batt on attic floor

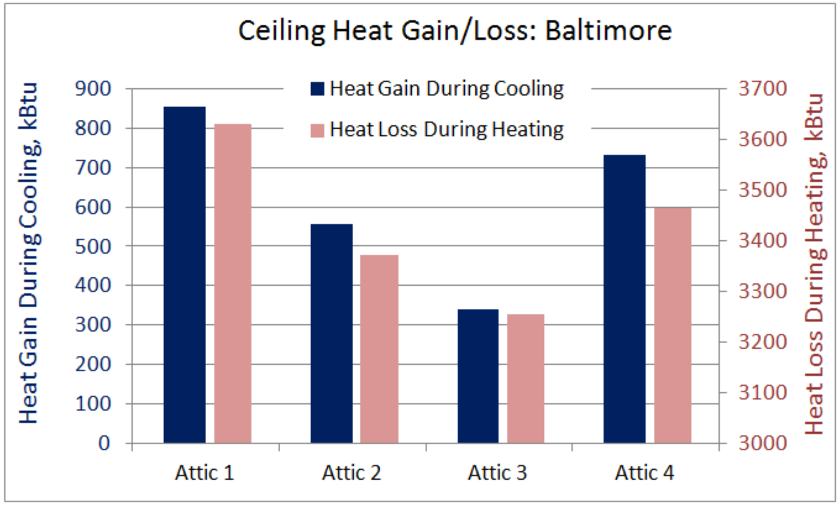
- Total building area 1200 sq. ft.
- Slab on grade
- Rated cooling COP 3.97
- 4 cities evaluated: Miami, Houston. Baltimore, and Chicago

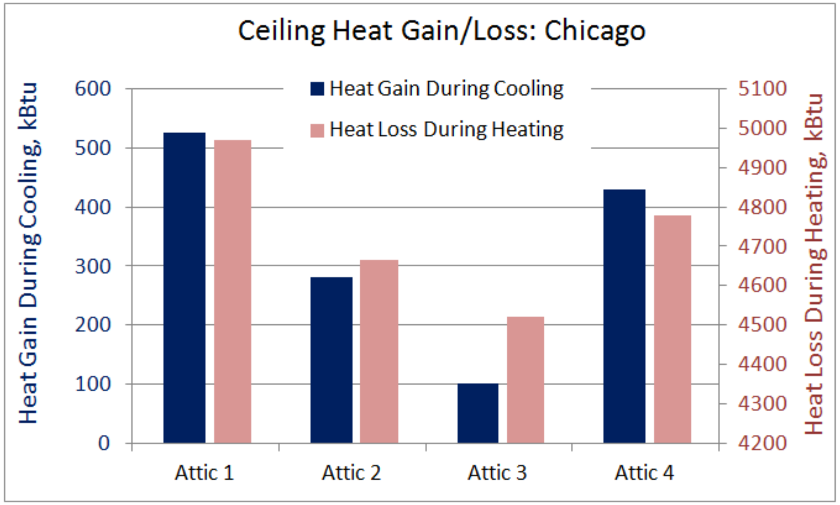


Cooling and heating load due to ceiling heat flow: IECC 2012 compliant building

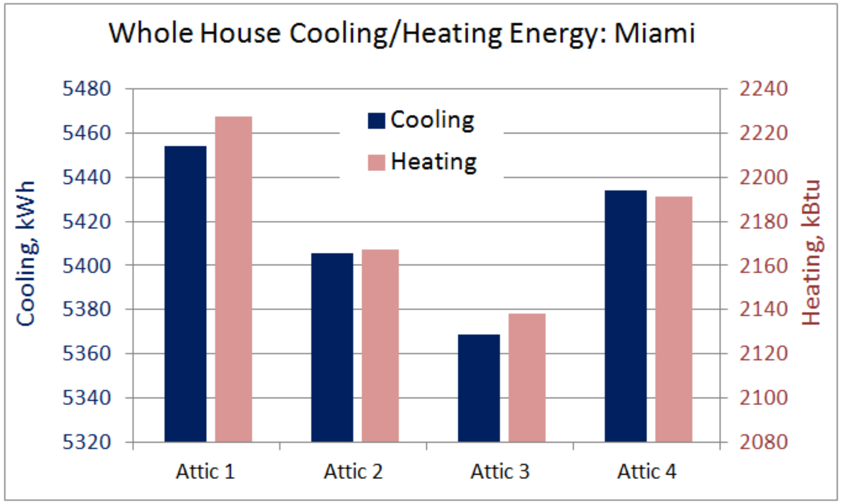


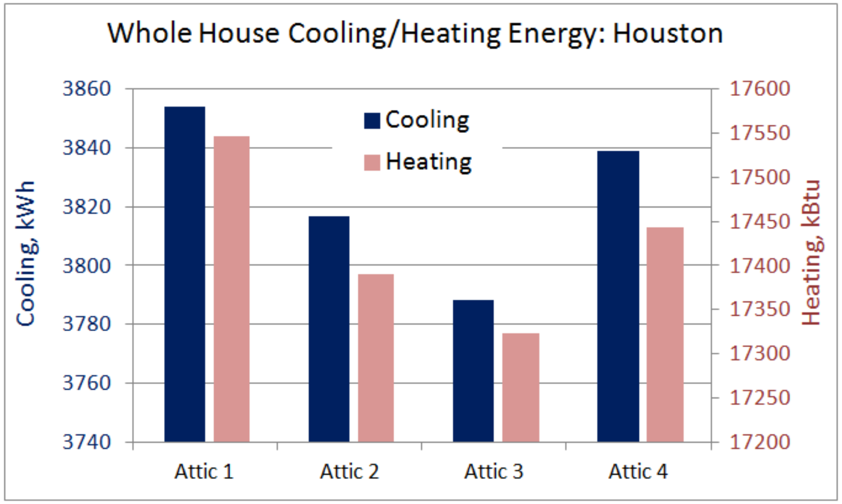


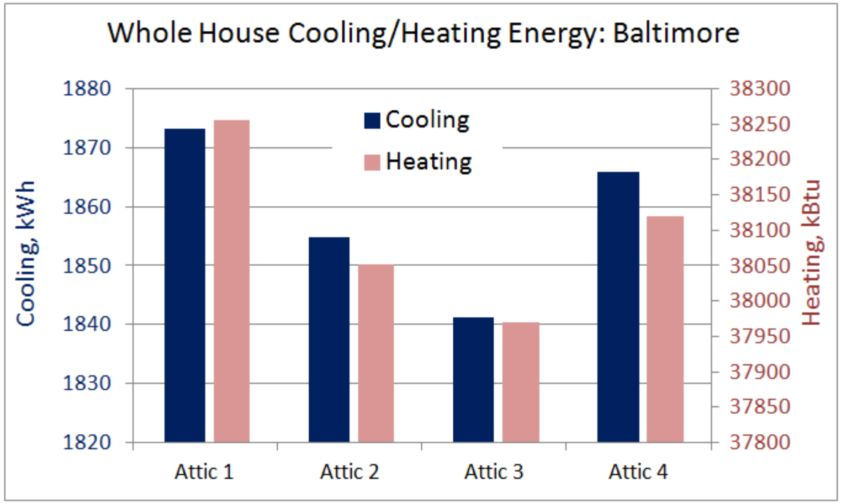


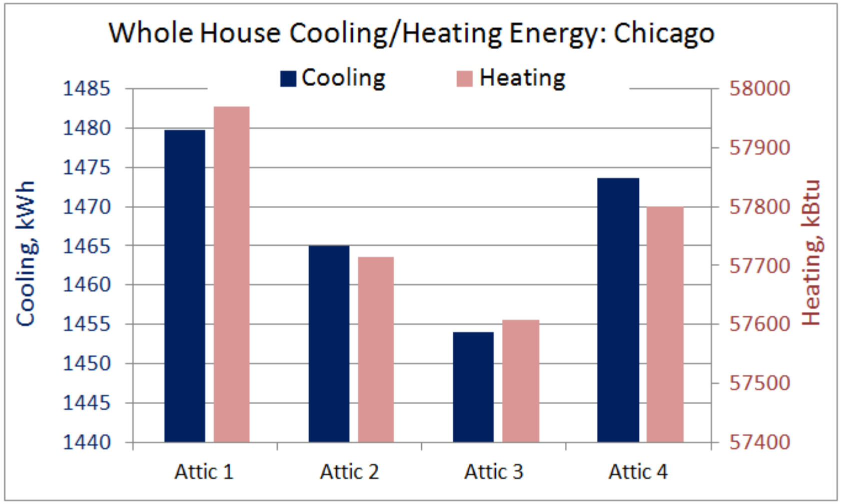


HVAC energy use: IECC 2012 compliant building



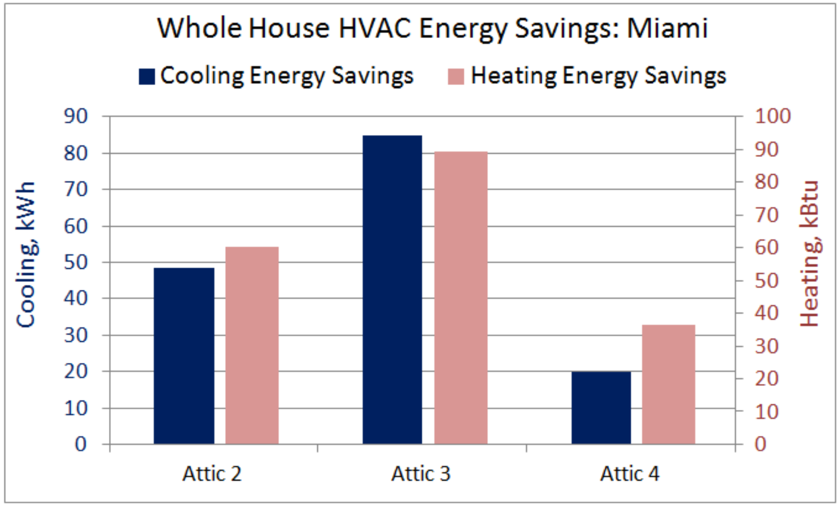


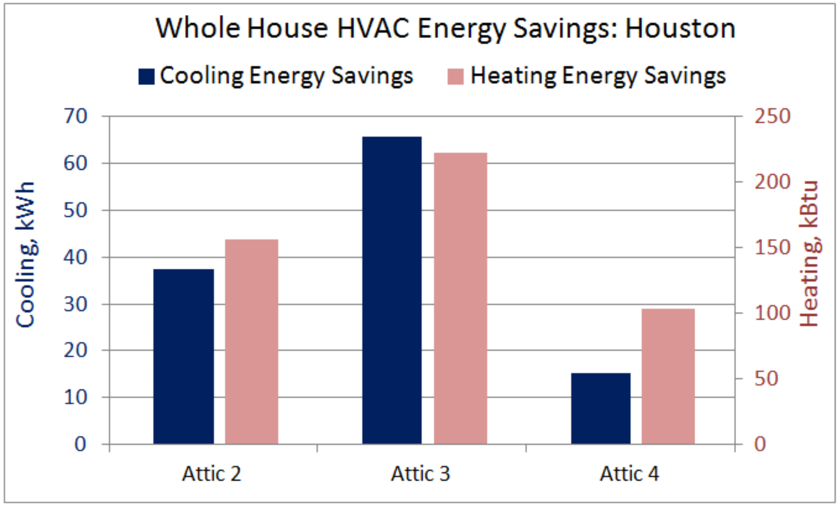


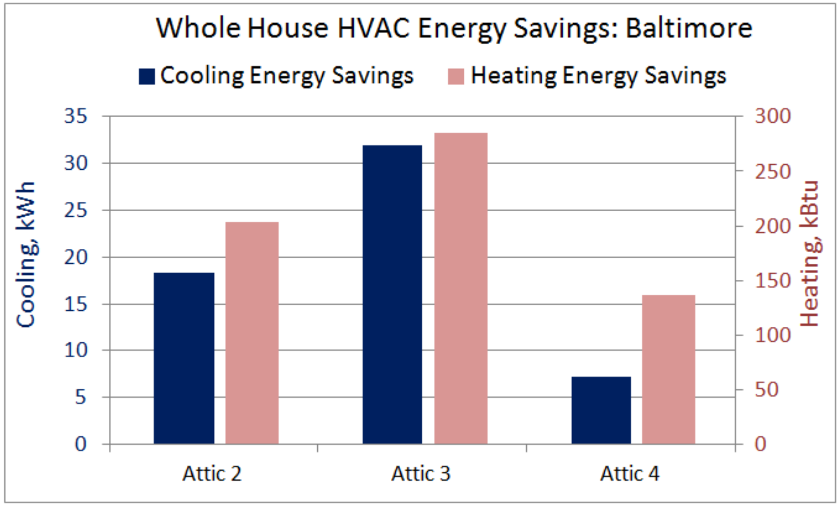


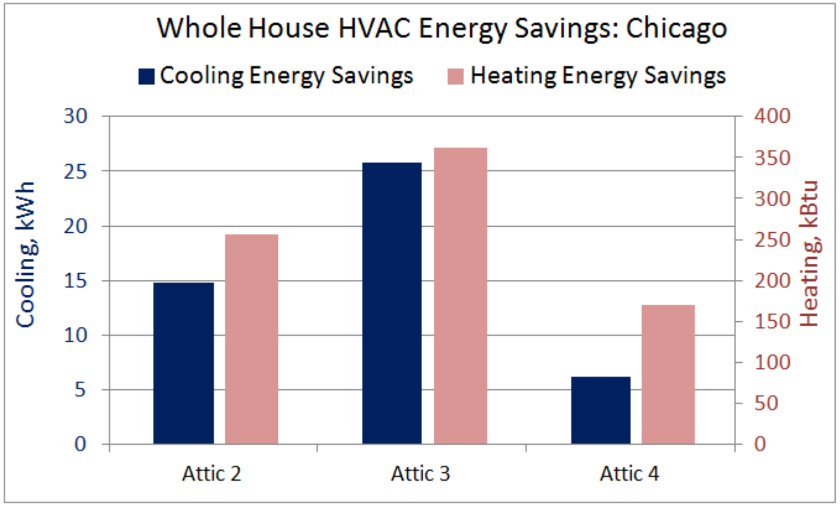
HVAC energy use: IECC 2012 compliant building

HVAC energy savings: IECC 2012 compliant building

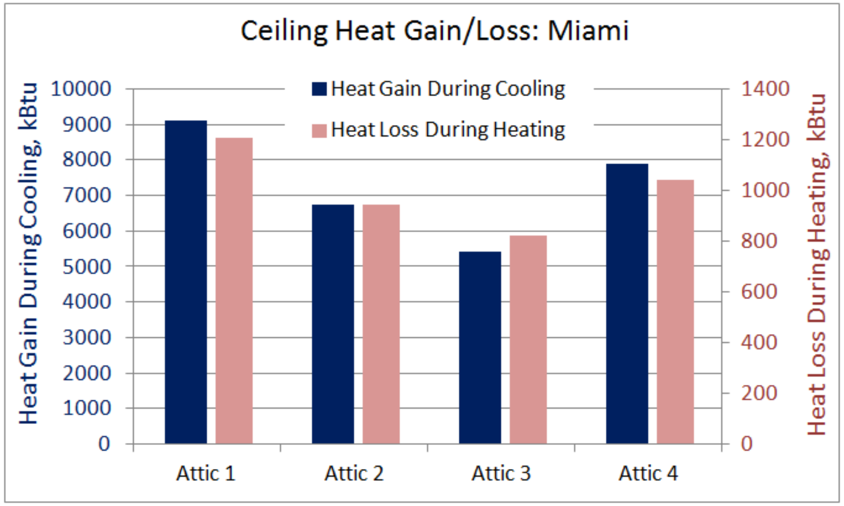


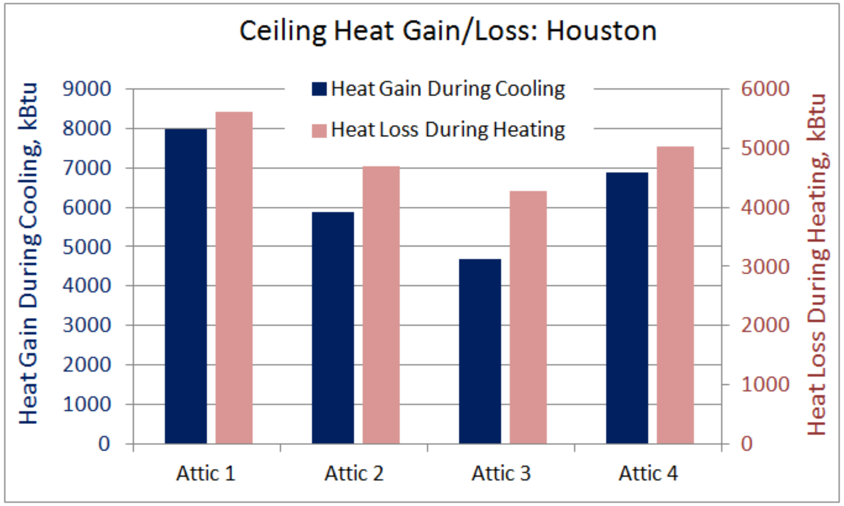


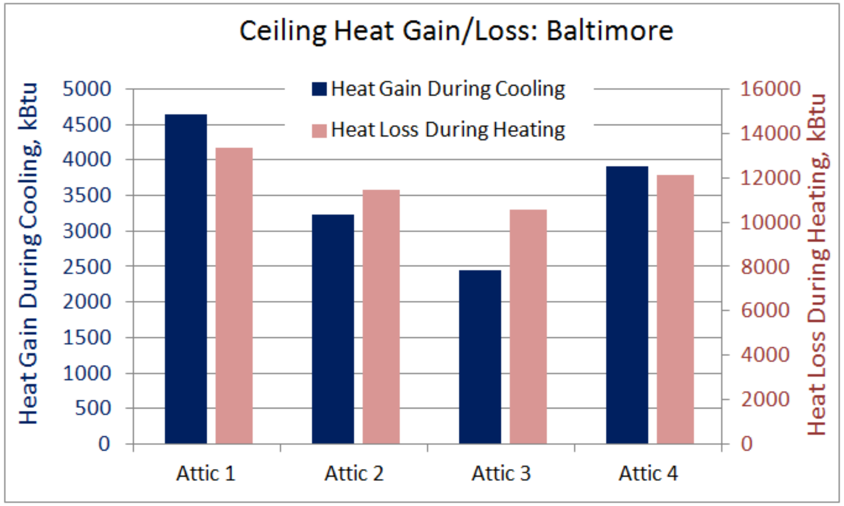


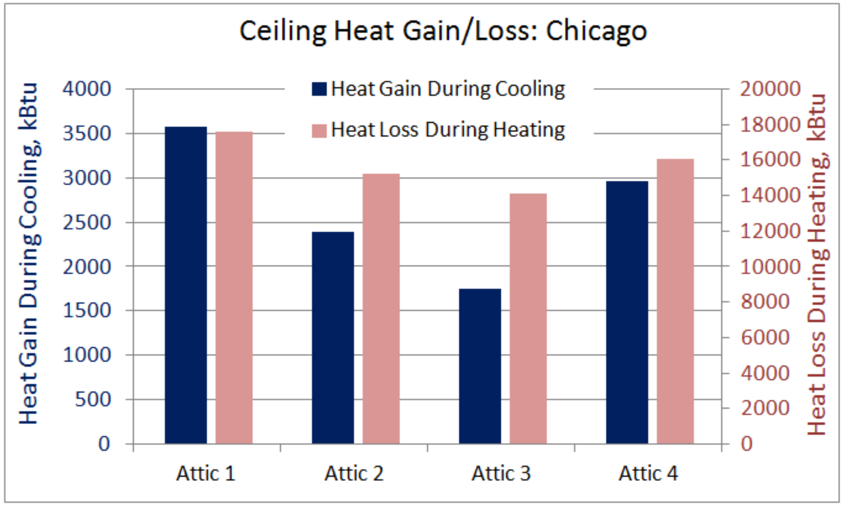


Cooling and heating load due to ceiling heat flow: 3.5” fiberglass on attic floor

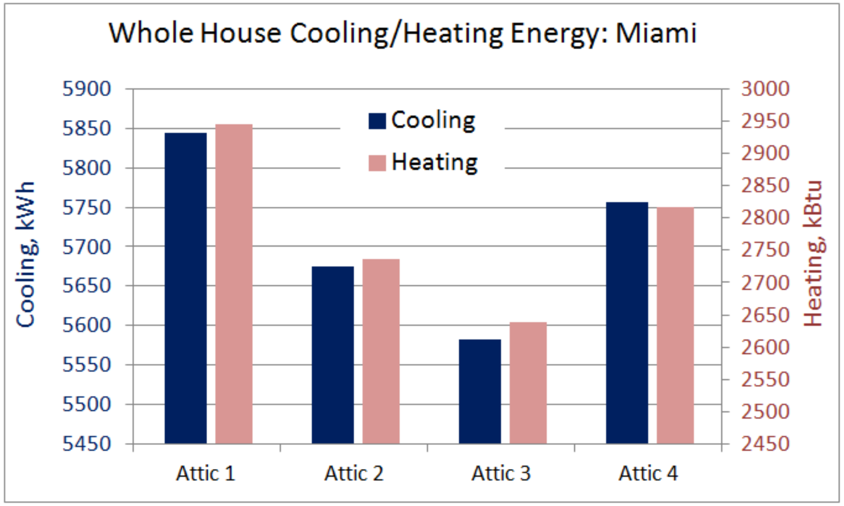


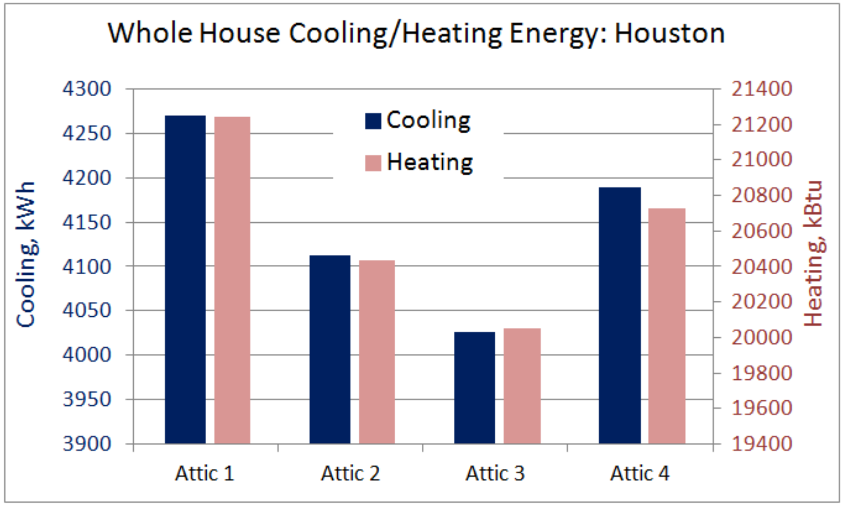


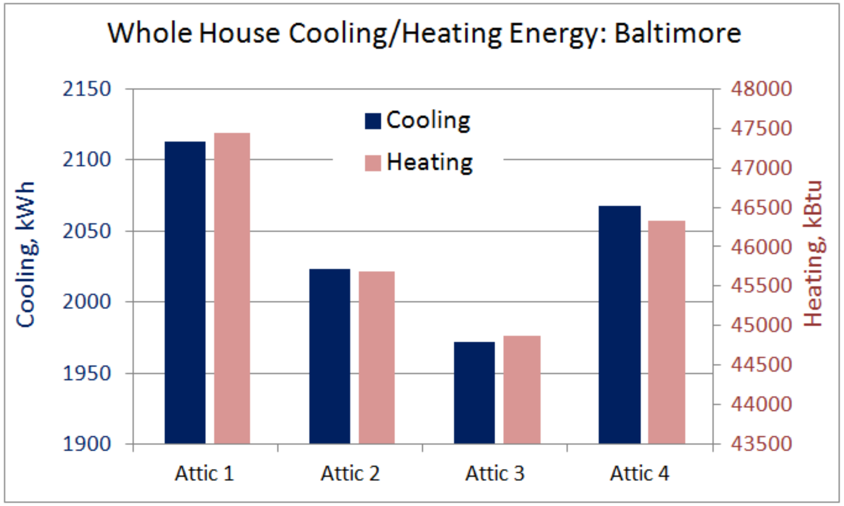


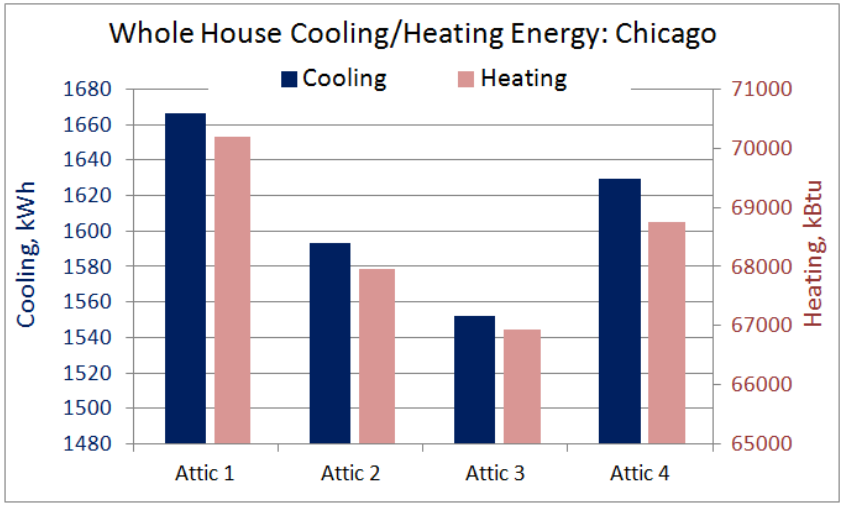


HVAC energy use: building with 3.5” fiberglass on attic floor





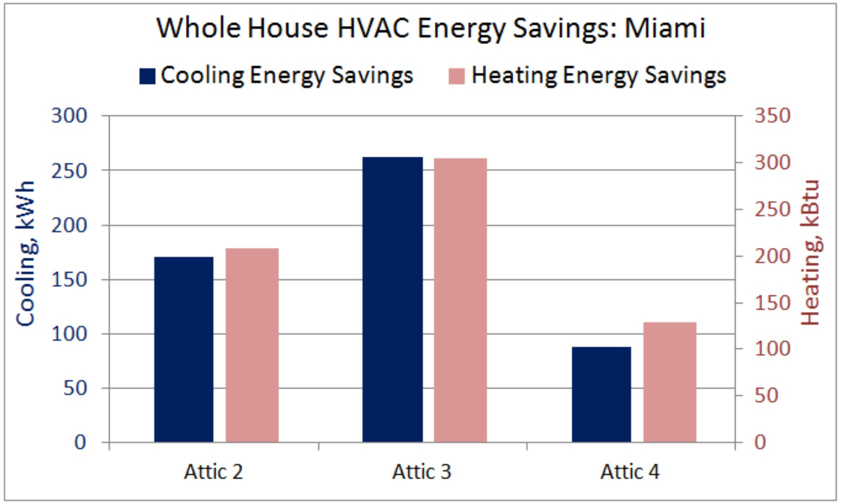


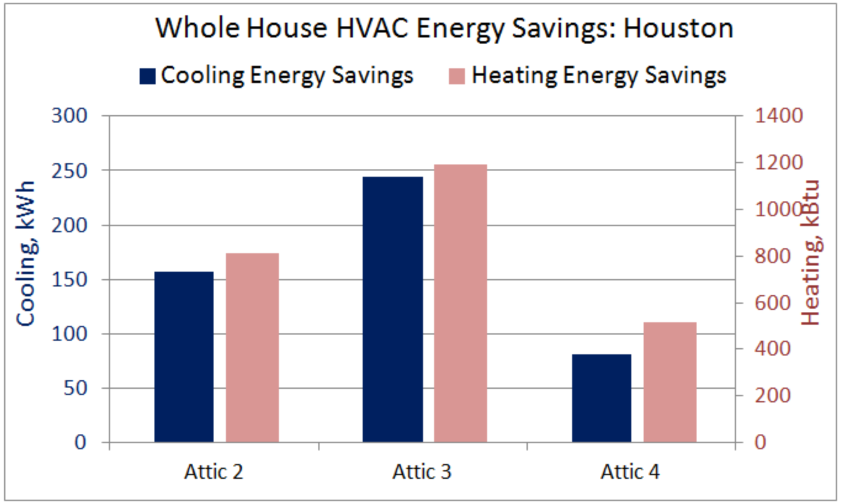


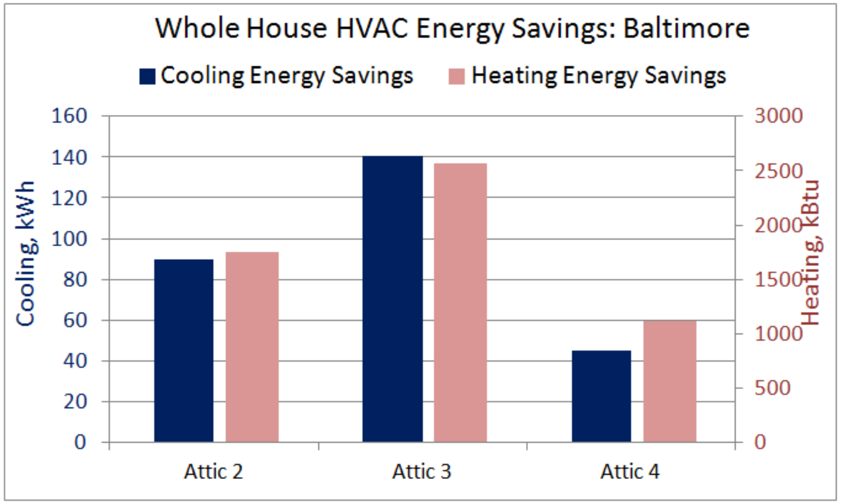
HVAC energy use: building with 3.5” fiberglass on attic floor

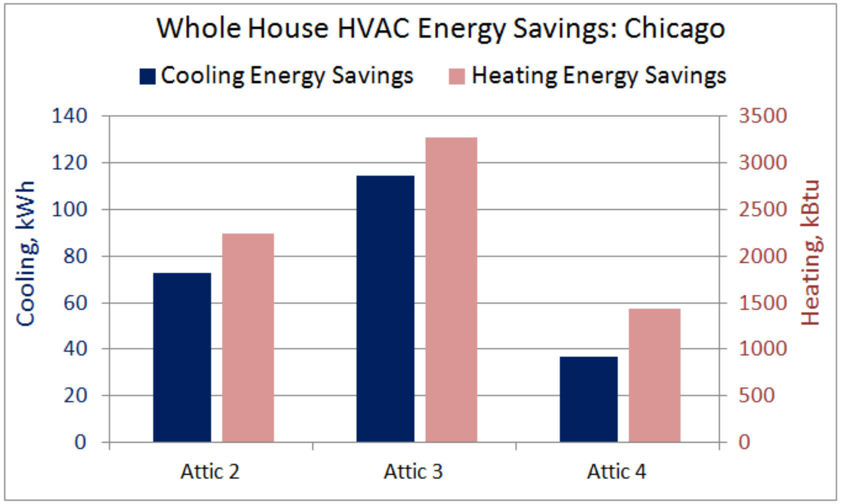
1.5 to 6.9% cooling energy savings and 2 to 10.4% heating energy savings

HVAC energy savings: building with 3.5” fiberglass on attic floor









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- The author would like to acknowledge the contributions of Jerald Atchley who supervised the operation of the LSCS; R&D Services, who constructed the attic modules; and industry supporters, who provided materials to build the attics

Thank You!

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