U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

HVAC Right-Sizing Part 1: Calculating Loads

Thursday, April 28

11:00 a.m. - 12:00 p.m. Eastern

Building America U.S. Department of Energy

Presented by: Mike Gestwick - National Renewable Energy Laboratory

Arlan Burdick, Anthony Grisolia – IBACOS, a Building America Research Team

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building America: Introduction

April 28, 2011

Mike Gestwick

michael.gestwick@nrel.gov

Building America
U.S. Department of Energy

- Reduce energy use in new and existing residential buildings
- Promote building science and systems engineering / integration approach
- "Do no harm": Ensure safety, health and durability are maintained or improved
- Accelerate adoption of high performance technologies

www.buildingamerica.gov

15 Industry Research Teams

CARB
CONSORTIUM FOR ADVANCED RESIDENTIAL BUILDINGS

Alliance for Residential Building Innovation (ARBI)

BA-PIRC

IBACOS®
| Home Quality + Performance |

NAHB RESEARCH CENTER[SM]

NorthernSTAR Building America Partnership

BIRA
BUILDING INDUSTRY RESEARCH ALLIANCE
...a catalyst for change

Building America Retrofit Alliance (BARA)

bsc Building Science Corporation

Fraunhofer USA

ARIES Collaborative

Dow
Building Solutions
Habitat Cost Effective Energy Retrofit Program

Building Energy Efficient Homes for America (BeeHa)

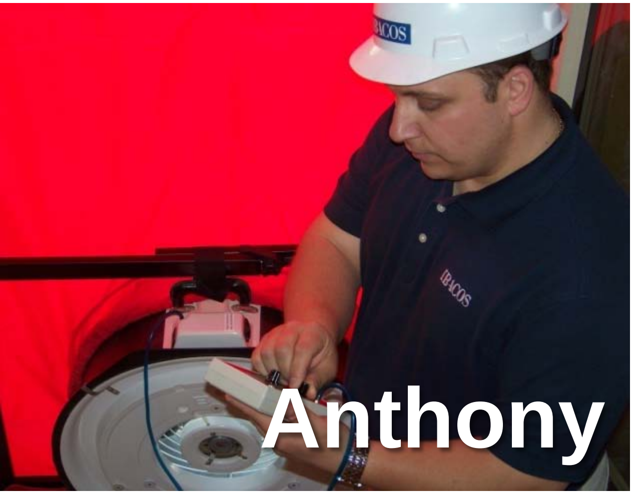
PARR
The Partnership for Advanced Residential Retrofit

N.E.L.C.
The National Energy Leadership Corps

About Our Speakers

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Building Performance Specialist
- Bachelors in Mechanical Engineering Technology
- LEED® Accredited Professional
- Formerly worked for a large-scale production homebuilding company



- IBACOS Services Manager
- Helps builders create construction standards
- Evaluates construction quality and comfort issues
- Performs quality assessments

About Today's Session

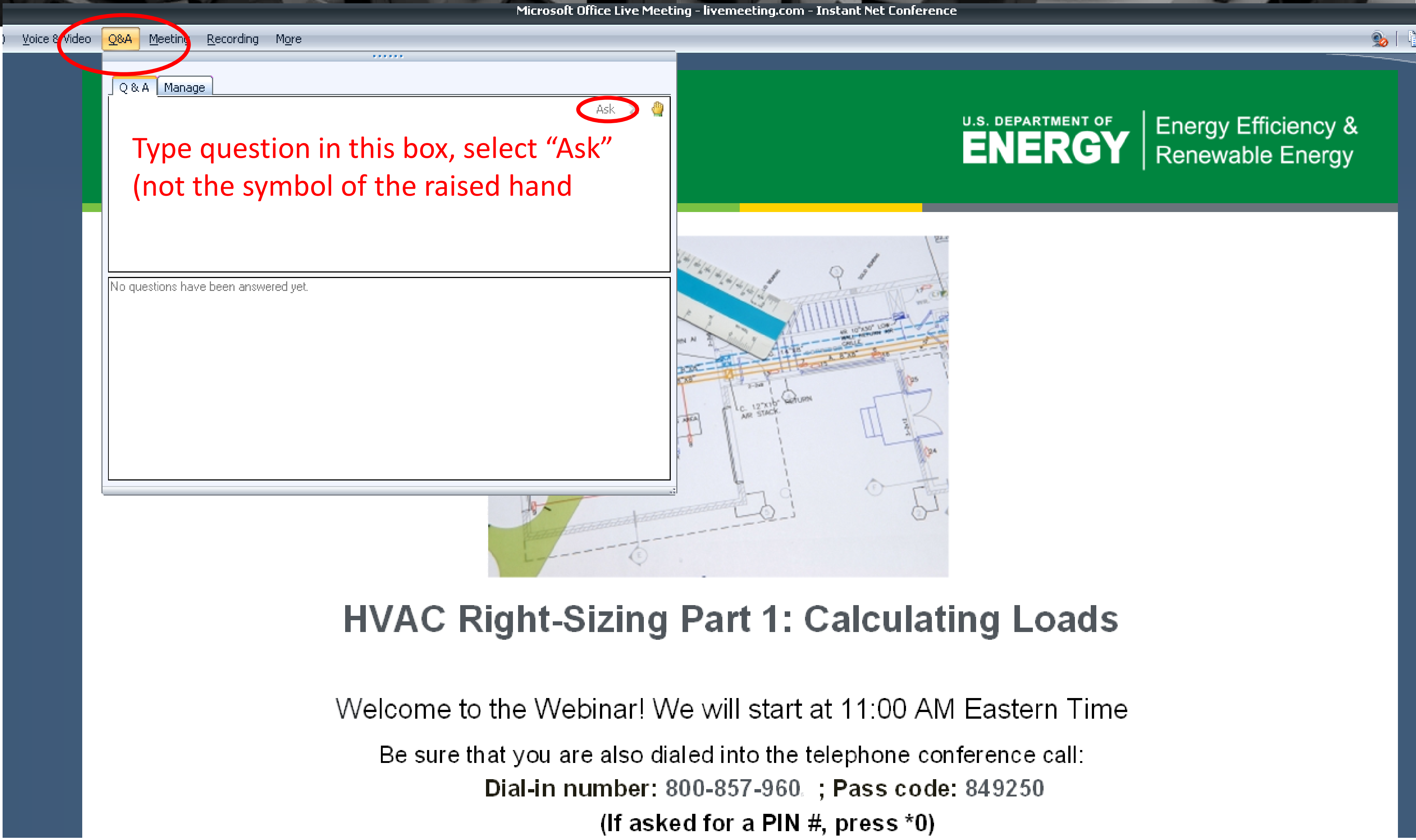
The BIG PICTURE – Why Care?

3 Key Factors for Calculating Loads

1. **Design Considerations** ***(15-18 min.)***
2. **The Thermal Enclosure** ***(10 min.)***
3. **Internal Loads** ***(5 min.)***

What Happens When You "Fudge" the Numbers?

Q&A: How to Participate



Webinar Poll

Webinar

The BIG Picture

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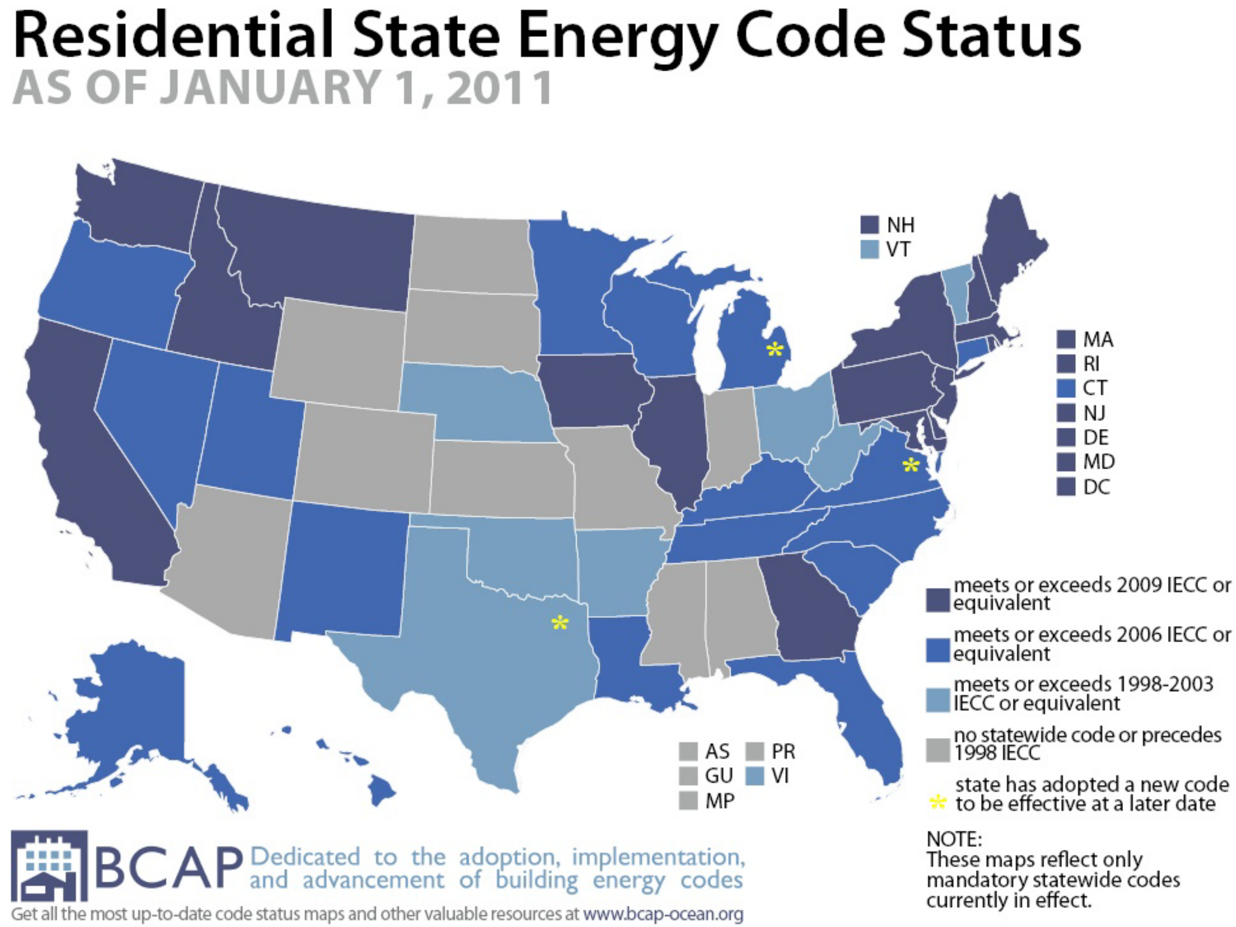
What is HVAC supposed to do?

- Keep the occupants of a home more comfortable by
  - Adjusting internal temperatures
  - Mixing air in rooms
  - Maintaining humidity levels
- Operate unnoticed
- Be energy efficient

Big Picture: Market Demand

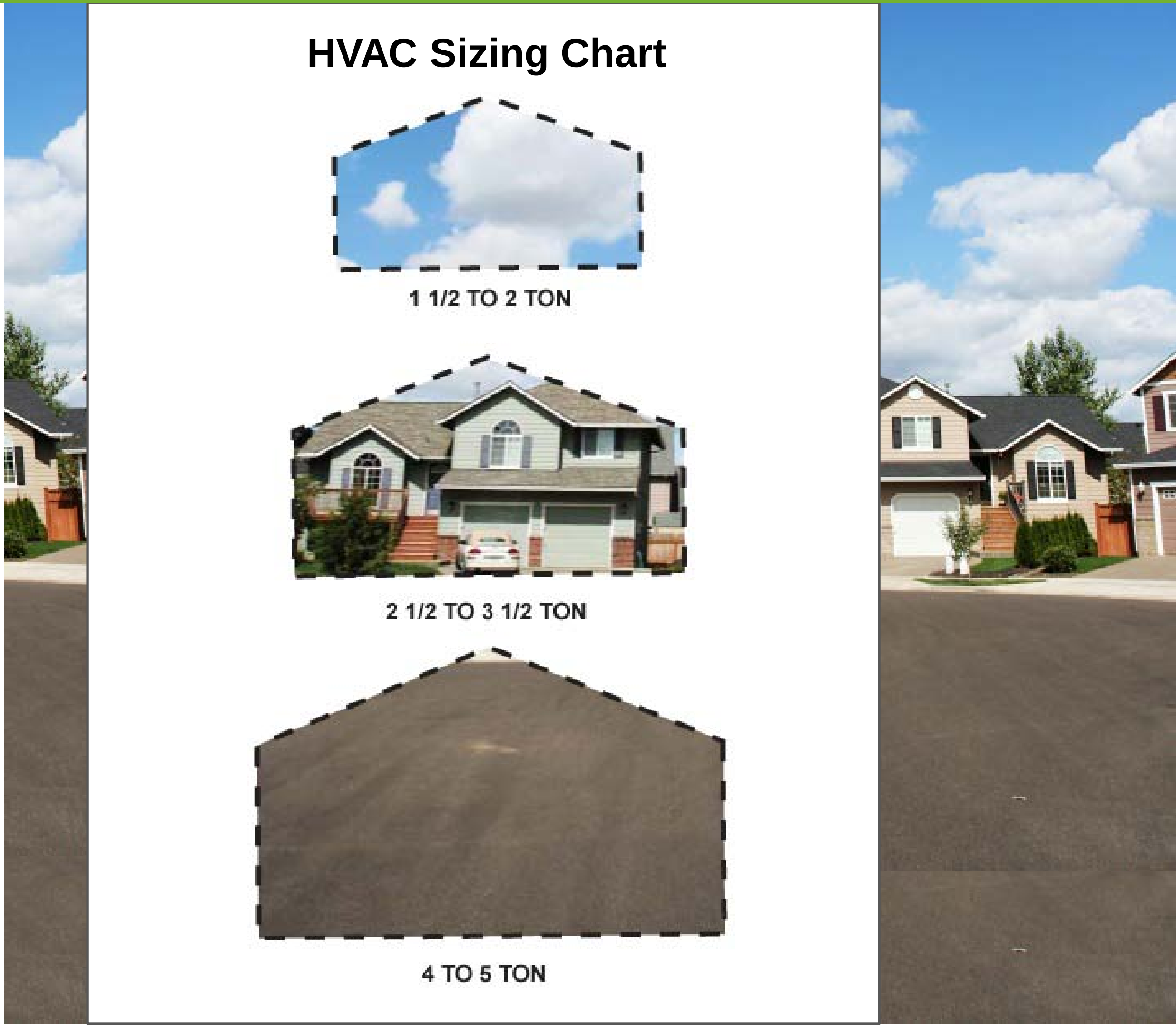
- New construction – 15% less energy each code cycle
- Existing homes – Homeowners updating with insulation, windows and more



Big Picture: Simplistic Design Approach

Instructions

1. Print this page.
2. Carefully cut out the holes.
3. Stand on curb across the street and hold page 1 foot from your face.
4. Find the hole that's the closest match.
5. Size HVAC accordingly



Big Picture: Just to be safe…

How many fingers do you put on the scale?

ACCA says NONE. Experience bears this out.

Big Picture: Why is right-sizing so important?

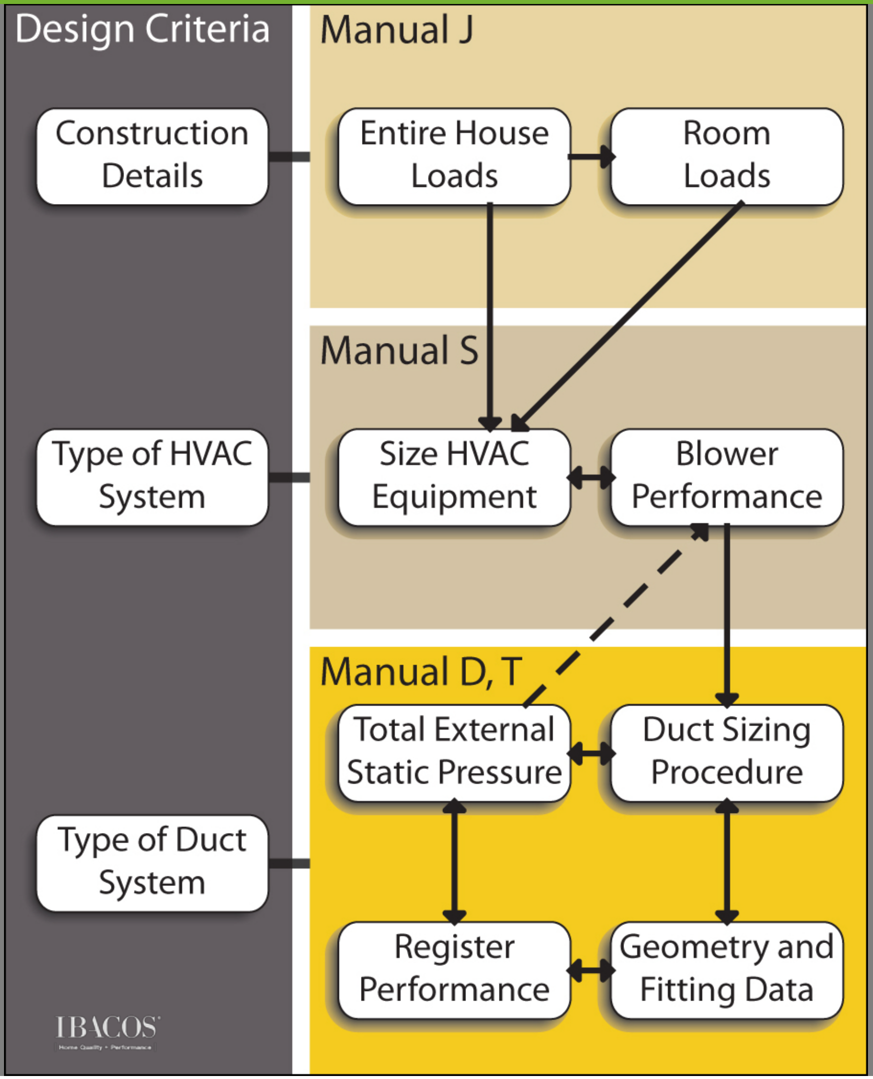
Enclosures are Improving Rules of Thumb Haven't

- Rooms have much lower loads
- More moisture is retained
- Less infiltration – or "natural ventilation"

Big Picture: Best Practice for Right-Sizing HVAC

Iterative Process

1. Load calculations
2. Equipment selection and sizing
3. Duct and register sizing



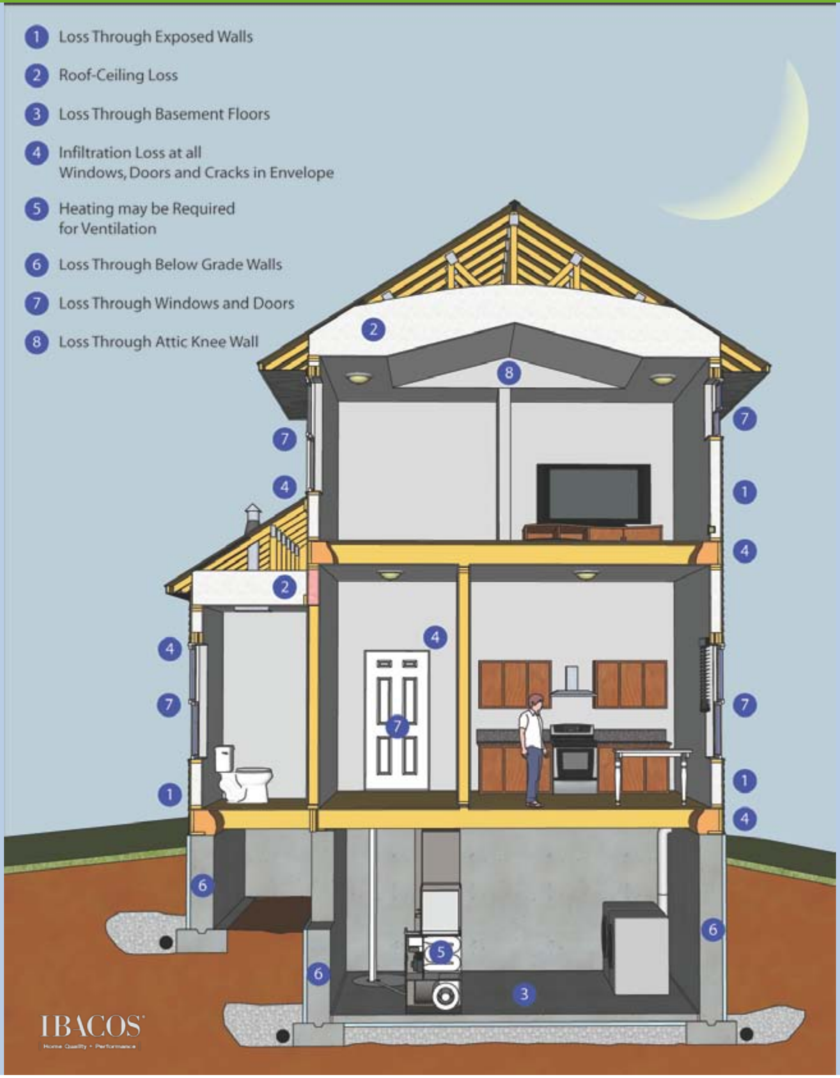
What Is the Load?

- The measure of energy the HVAC system needs to add or remove from a space to provide the desired level of comfort
  - Btu/h
- Not the *size* of the HVAC system
  - First piece of information needed
  - 12,000 Btu/h = 1 Ton Cooling
- *Can be* highly variable

Big Picture: Heating Loads

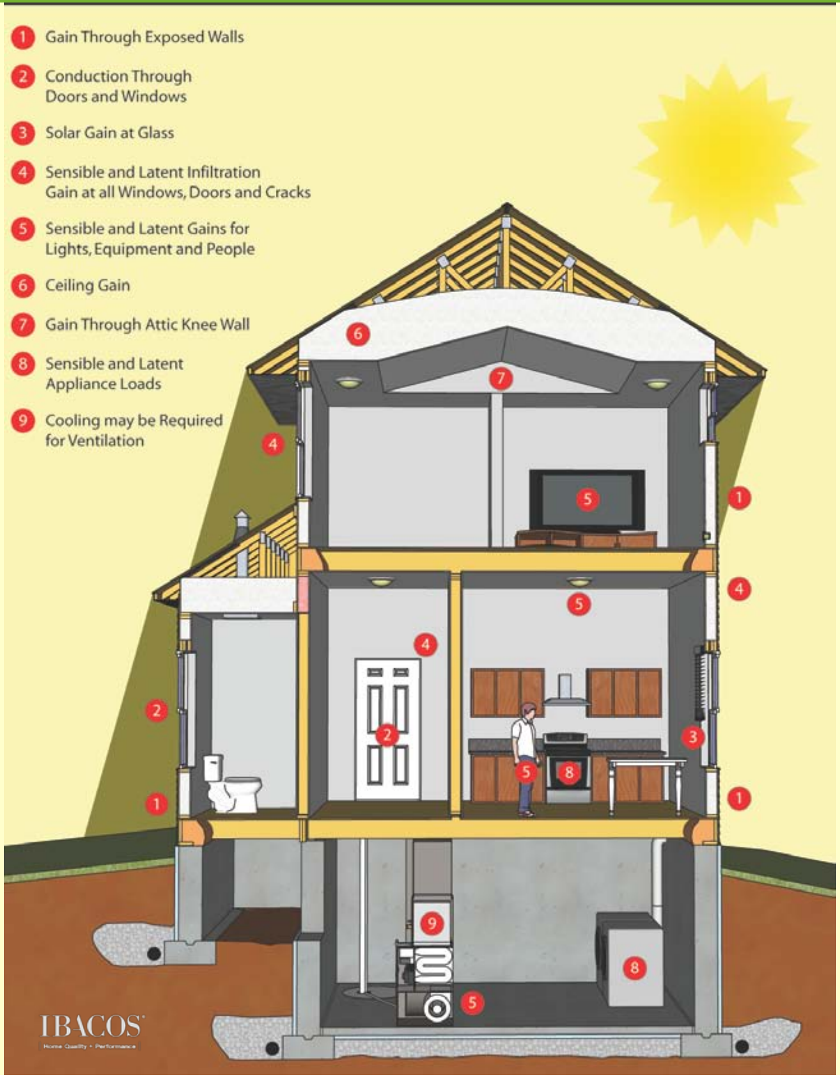
- Losses to the outside environment

- No credit is taken for solar gains or internal loads because the peak heat loss occurs at night during periods of occupant inactivity



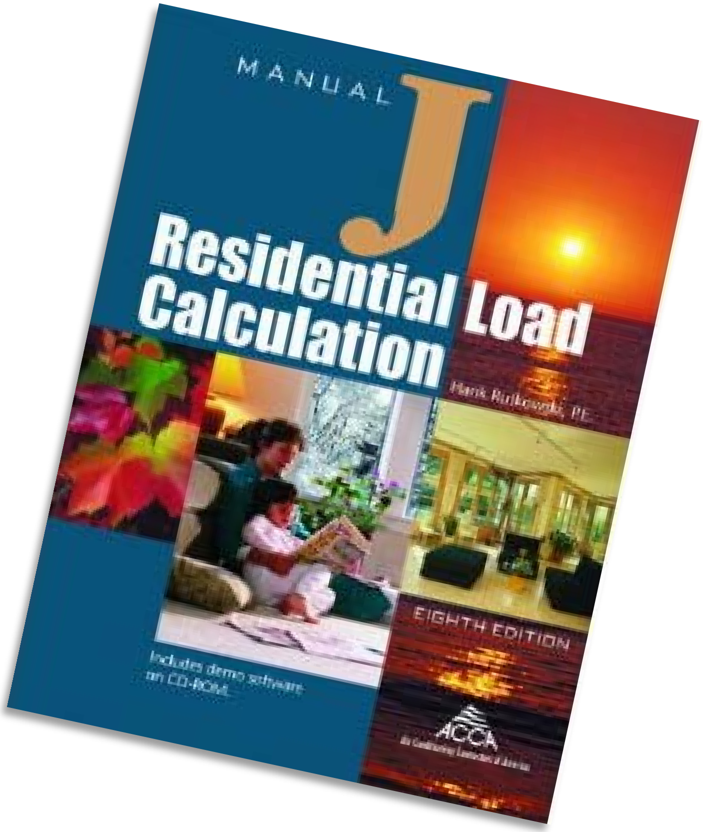
Big Picture: Cooling Loads

- Gains from the outside environment
- Solar Gains
- Internal Gains
- Sensible and Latent Components



Big Picture: How to Approach Manual J

- Designer should
  - Walk a house in production
  - Look at plans
  - Ask for all specifications
- Builder doesn't have the info? Get the homes tested!
  - Duct leakage
  - Air tightness



Big Picture: Importance of Getting It Right

HVAC Design Impacts

- 1^{st} construction costs
- Comfort
- Indoor air quality
- Building durability
- Energy efficiency
- Higher customer satisfaction/
  lower call backs

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Key Factor #1: Design Considerations

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Design Considerations

- Location of the House
- Size of the House
- Indoor Design Conditions

Design Considerations: Location of the House

- Latitude
- Elevation
- Outdoor temperature and relative humidity

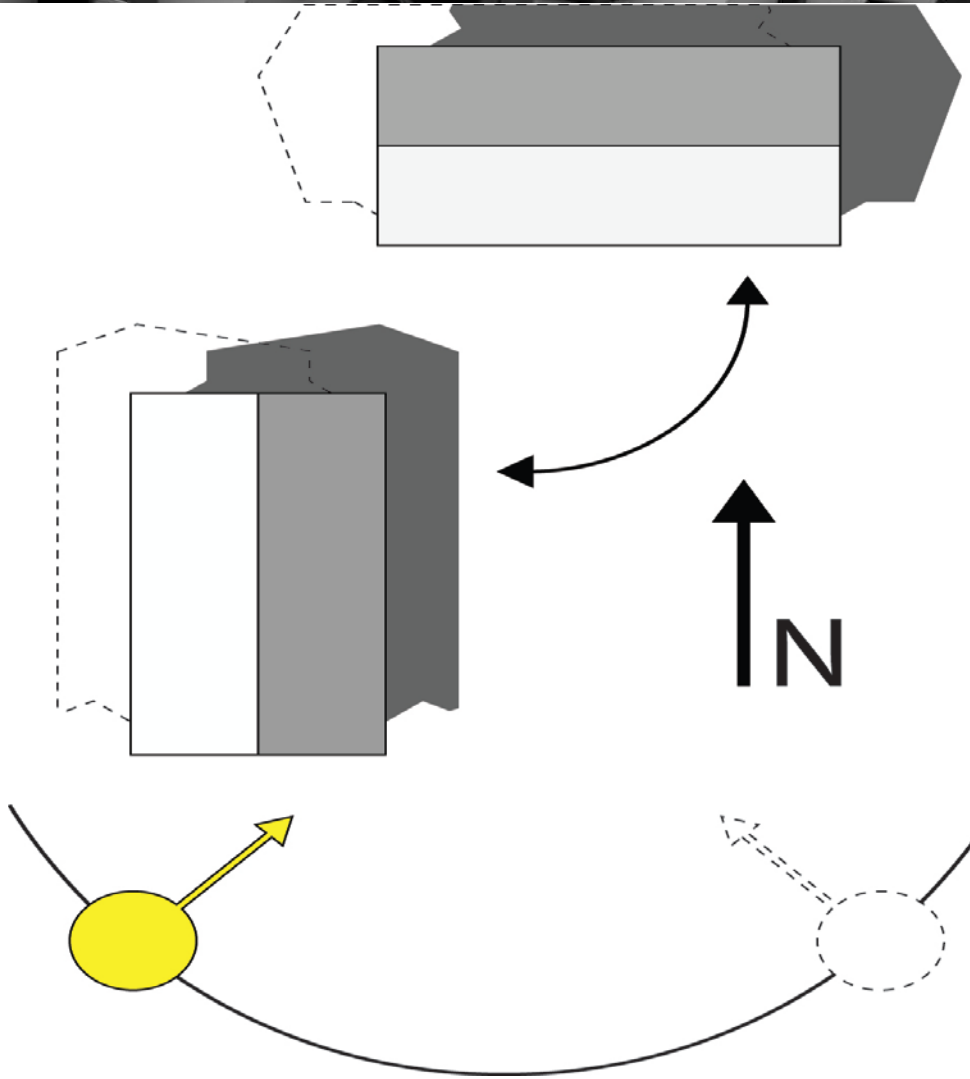
Outdoor Design Conditions for the United States

Location	Elevation	Latitude	Winter	Summer					
	Feet	Degrees North	Heating 1% Dry Bulb	Cooling 1% Dry Bulb	Coincident Wet Bulb	Design Grains 55% RH	Design Grains 50% RH	Design Grains 45% RH	Daily Range (DR)
Florida									
Apalachicola	20	29	35	90	78	57	64	70	M
Belle Glade	17	26	44	91	76	42	49	55	M
Cape Kennedy AP	10	28	42	90	78	57	64	70	L
Daytona Beach AP	31	29	37	90	77	51	58	64	L
Fort Lauderdale	10	26	50	90	78	57	64	70	L
Fort Myers AP	15	26	47	93	77	46	53	59	M
Fort Pierce	25	27	42	90	78	57	64	70	M
Gainsville AP	152	29	33	92	77	47	54	60	M
Homestead, AFB	7	25	52	90	76	57	64	70	L
Jacksonville AP	26	30	32	93	77	46	53	59	M
Jacksonville/Cecil Field NAS	80	30	34	95	76	35	43	49	M
Jacksonville, Mayport Naval	16	30	39	92	78	54	61	67	M
Key West AP	4	24	58	89	79	66	73	79	L
Lakeland CO	214	28	41	91	76	42	49	55	M
Melbourne	15	28	43	91	79	62	69	75	M
Miami AP	11	25	50	90	77	51	58	64	L
Miami Beach CO	8	25	48	89	77	52	59	65	L
Miami, New Tamiami AP	10	25	49	91	78	56	59	65	L
Milton, Whiting Field NAS	200	30	31	93	77	46	53	59	M
Ocala	90	29	34	93	77	46	53	59	M
Orlando AP	100	28	**42**	**93**	76	39	46	52	M
Panama City, Tyndall AFB	18	30	37	89	79	66	73	79	L
Pensacola CO	30	30	32	92	78	54	61	67	L

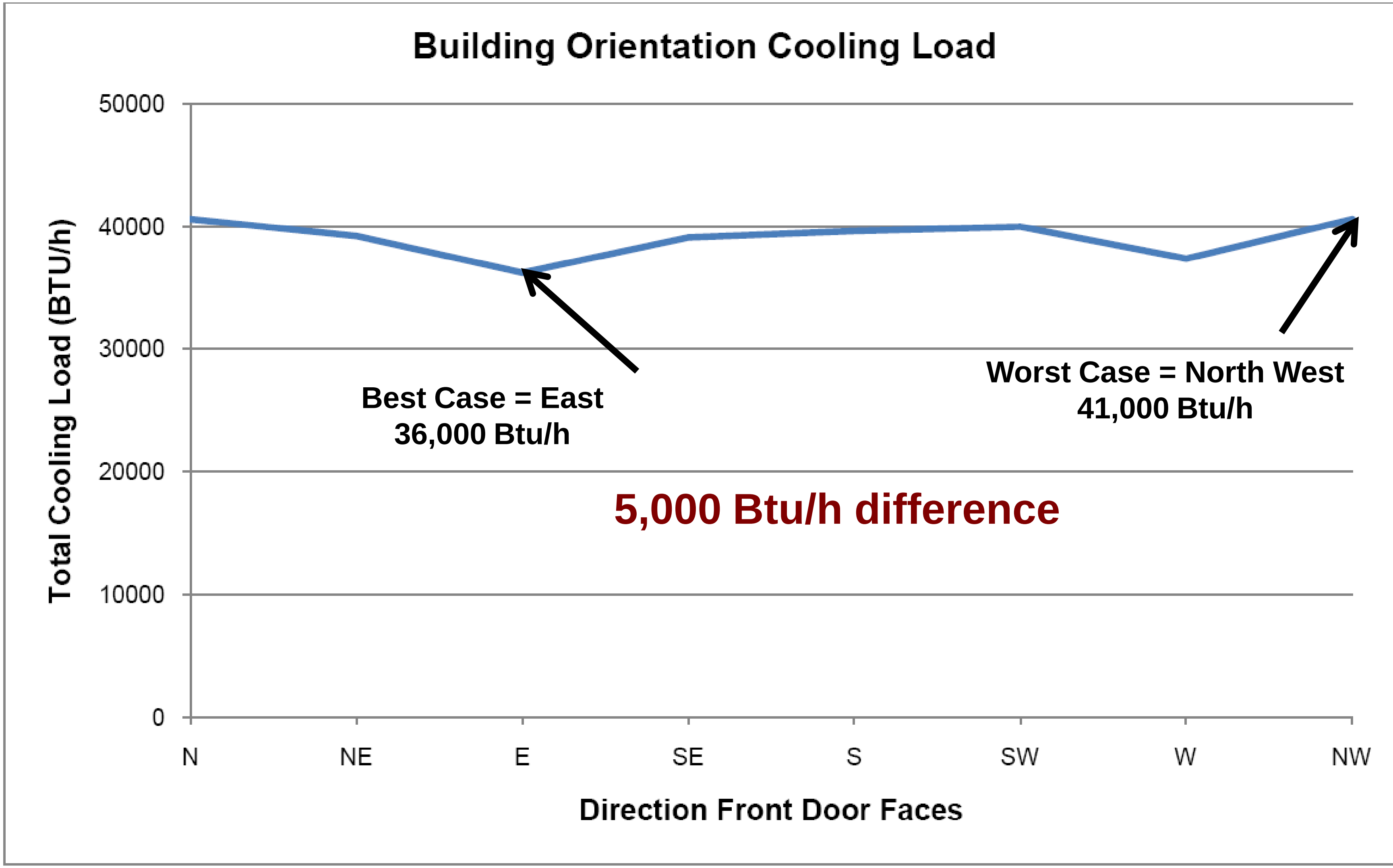
Source: ACCA Manual J Version 8, Table 1A

Orientation

The orientation of the house must be considered in the cooling load calculation due to changing solar heat gains at various times of the day.

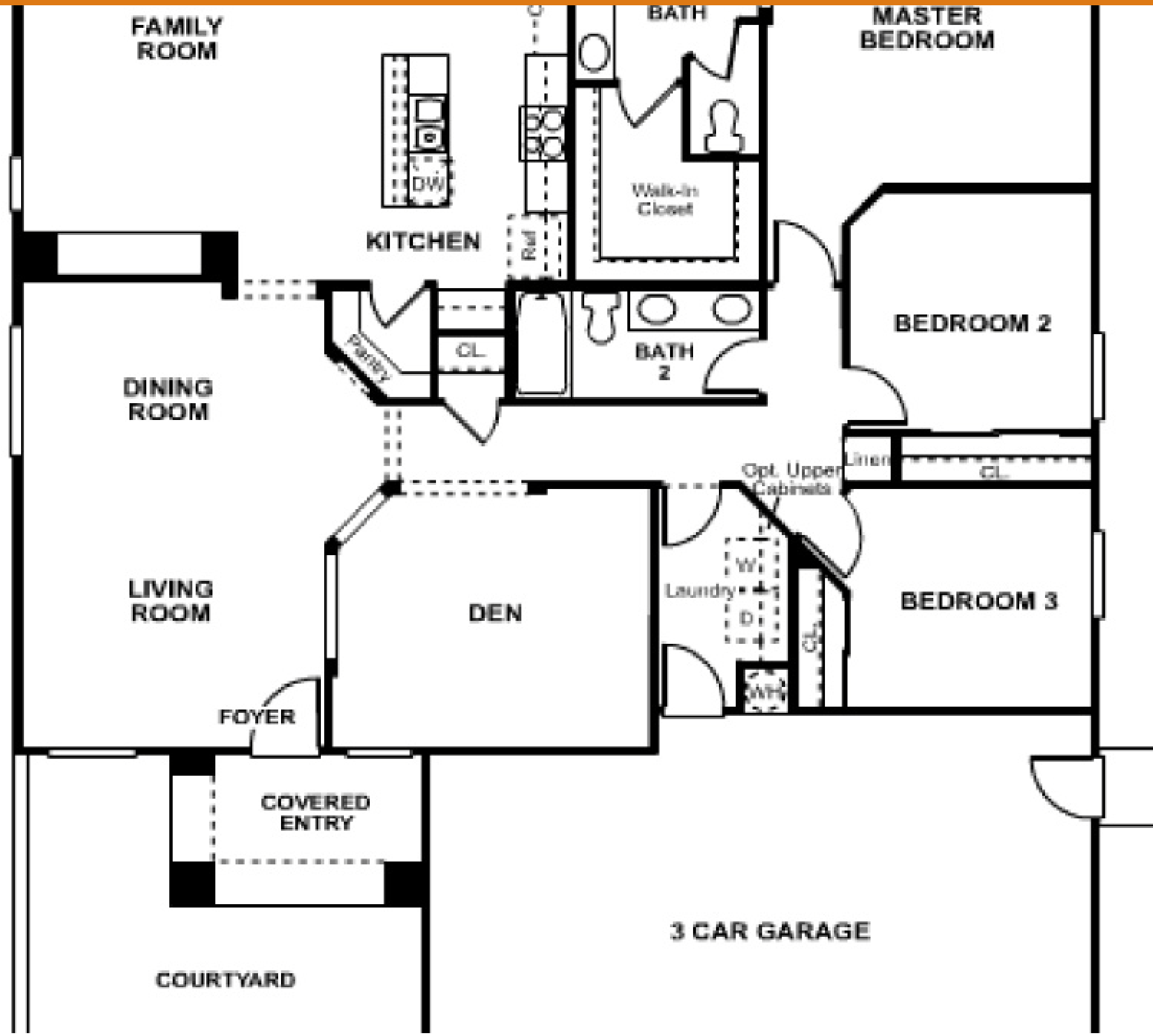


Design Considerations: Location of the House



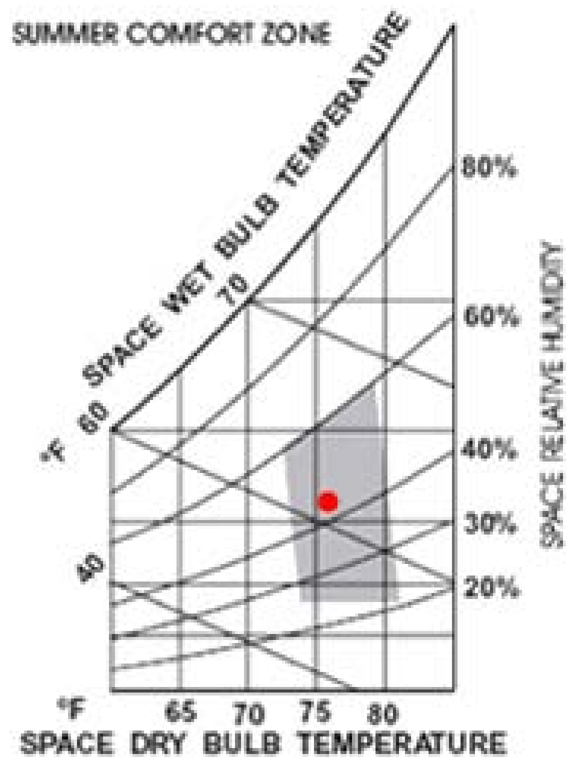
Design Considerations: Size of the House

- Square footage
- Volume
- Number of bedrooms

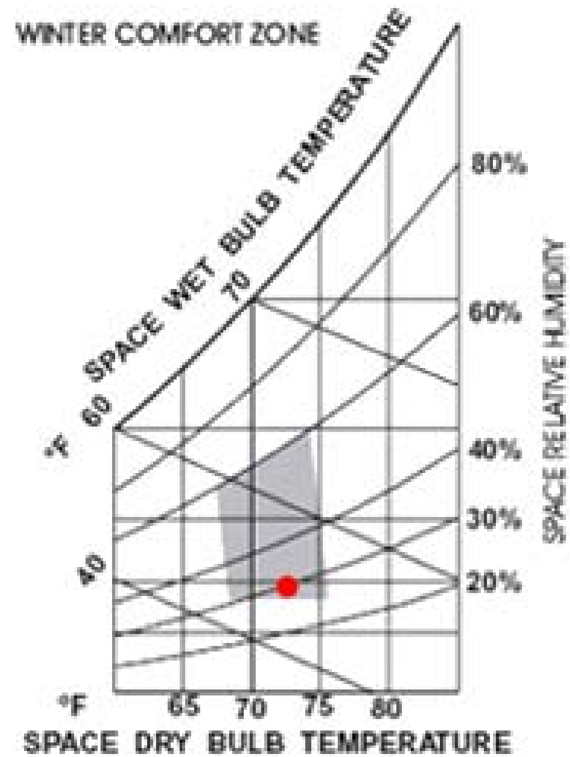


Design Considerations: Indoor Design Conditions

- Indoor temperature
- Relative humidity



Cooling Season =
75 F, 50% RH



Heating Season =
70 F, 30% RH

Source: MJ8 and ASHRAE Comfort Zone Chart

Fudge Factor #1

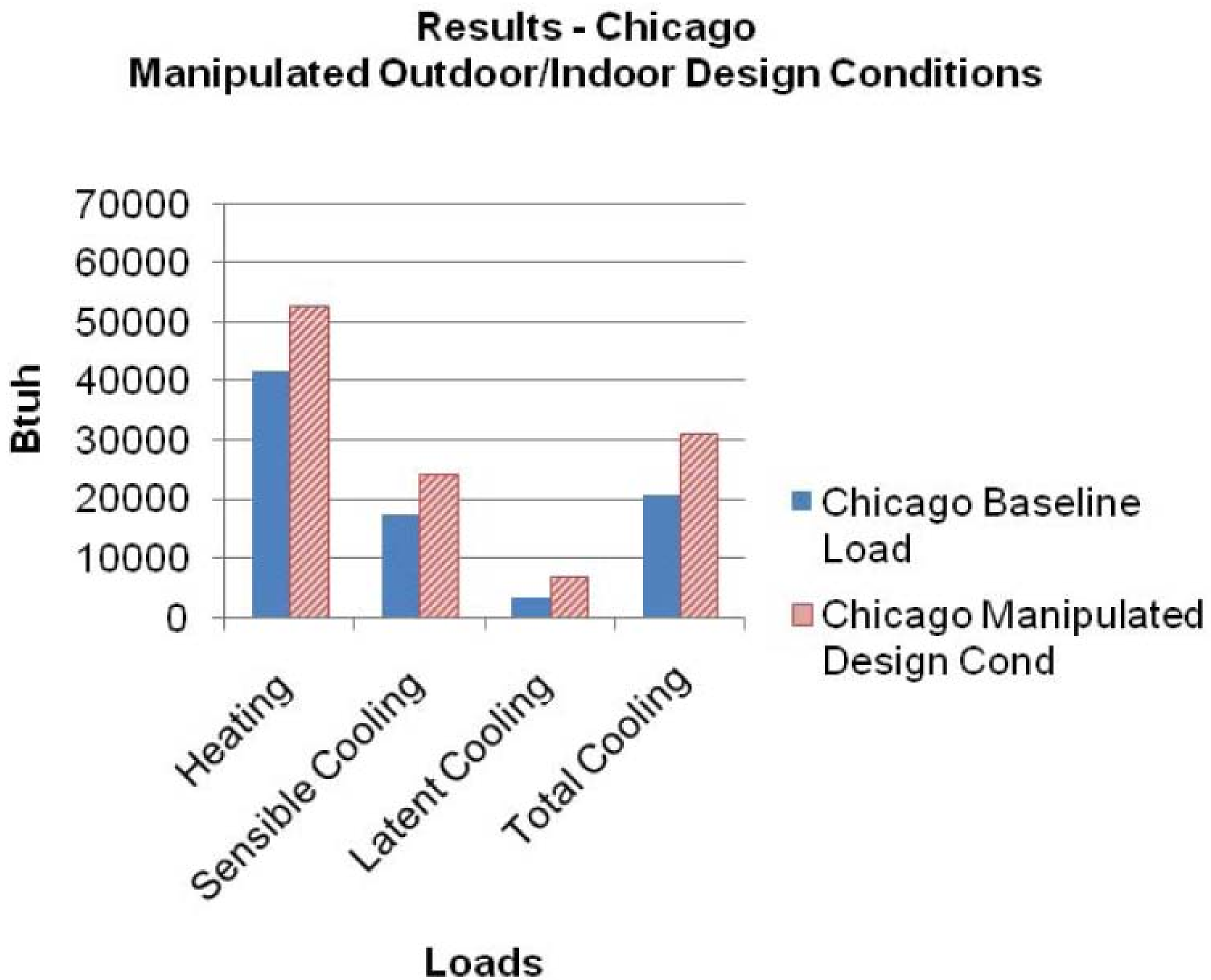
What happens when you fudge heating and cooling set points?

Chicago Outdoor/Indoor Design Conditions	
Baseline	**Manipulated**
Outdoor Design Conditions 89°F_{db} 73°F_{wb} Temp Cooling 2°F Temp Heating	*Outdoor Design Conditions* 97°F_{db} 78°F_{wb} Temp Cooling -11°F Temp Heating
Indoor Design Conditions 75°F Temp 50% RH Cooling 70°F Temp 30% RH Heating	*Indoor Design Conditions* 70°F Temp 30% RH Cooling 75°F Temp 50% RH Heating

Table 3 Chicago Manipulated Outdoor/Indoor Design Conditions

Fudge Factor #1

Fudging set points = 10,400 Btu/h additional cooling load, potentially over-sizing the cooling system by 1 ton



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Questions?

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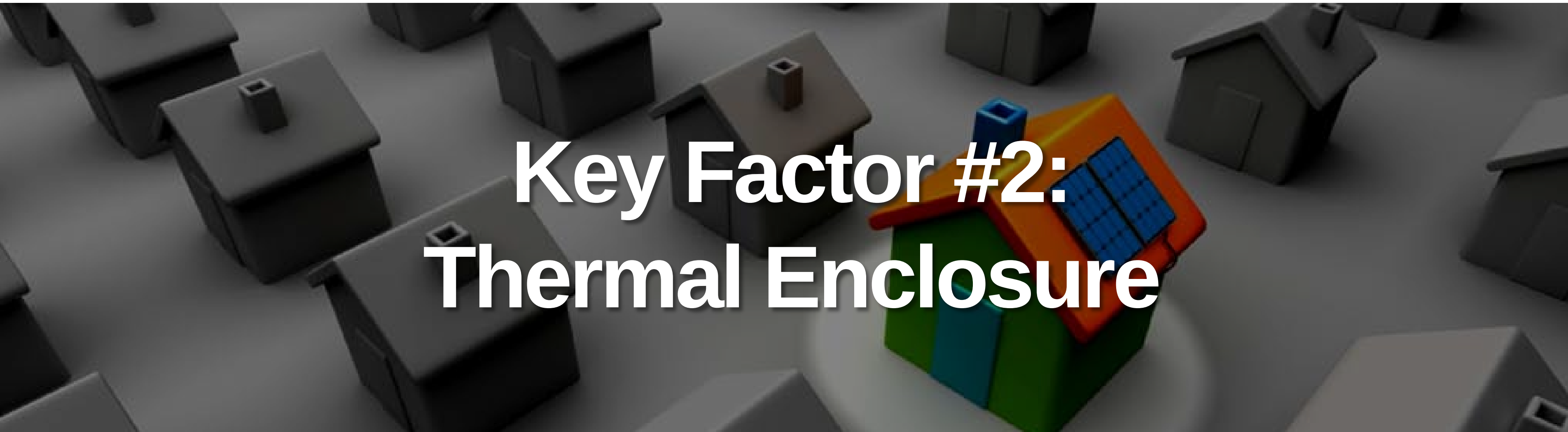

Key Factor #2: Thermal Enclosure

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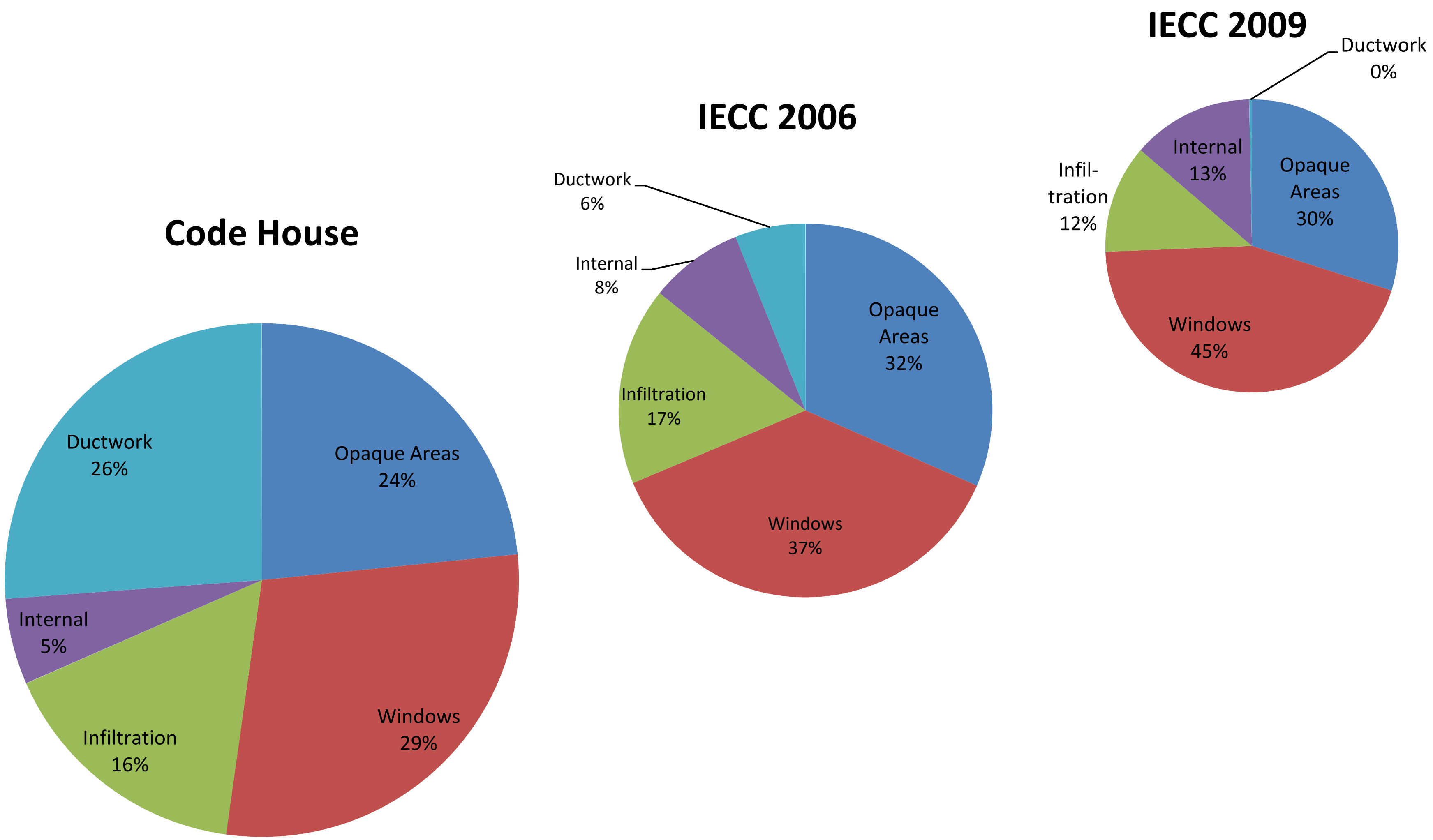
Evolution with Code Changes



Enclosure: Key Factors to Consider

- Insulation values
- Window specification
- Air tightness
- External and internal shading

Enclosure: Insulation Values

- Walls
- Ceilings
- Floors

Enclosure: Windows

Ⓐ ***U-Factor*** *measures how well a product prevents heat from escaping a home or building. U-Factor ratings generally fall between 0.20 and 1.20. The lower the U-Factor, the better a product is at keeping heat in. U-Factor is particularly important during the winter heating season. This label displays U-Factor in U.S. units. Labels on products sold in markets outside the United States may display U-Factor in metric units.*

Ⓑ ***Solar Heat Gain Coefficient*** *(SHGC) measures how well a product blocks heat from the sun. SHGC is expressed as a number between 0 and 1. The lower the SHGC, the better a product is at blocking unwanted heat gain. Blocking solar heat gain is particularly important during the summer cooling season.*

Ⓒ ***Visible Transmittance*** *(VT) measures how much light comes through a product. VT is expressed as a number between 0 and 1. The higher the VT, the higher the potential for daylighting.*

Ⓓ ***Air Leakage*** *(AL) measures how much outside air comes into a home or building through a product. AL rates typically fall in a range between 0.1 and 0.3. The lower the AL, the better a product is at keeping air out. AL is an optional rating, and manufacturers can choose not to include it on their labels. This label displays AL in U.S. units. Labels on products sold in markets outside the United States may display AL in metric units.*

Ⓔ ***Condensation Resistance*** *(CR) measures how well a product resists the formation of condensation. CR is expressed as a number between 1 and 100. The higher the number, the better a product is able to resist condensation. CR is an optional rating, and manufacturers can choose not to include it on their NFRC labels.*

NFRC
National Fenestration Rating Council®
CERTIFIED

World's Best Window Co.
Millennium 2000+
Vinyl-Clad Wood Frame
Double Glazing • Argon Fill • Low E
Product Type: **Vertical Slider**

ENERGY PERFORMANCE RATINGS

U-Factor (U.S./I-P)	Solar Heat Gain Coefficient
Ⓐ **0.35**	Ⓑ **0.32**

ADDITIONAL PERFORMANCE RATINGS

Visible Transmittance	Air Leakage (U.S./I-P)
Ⓒ **0.51**	Ⓓ **0.2**
Condensation Resistance	
Ⓔ **51**	

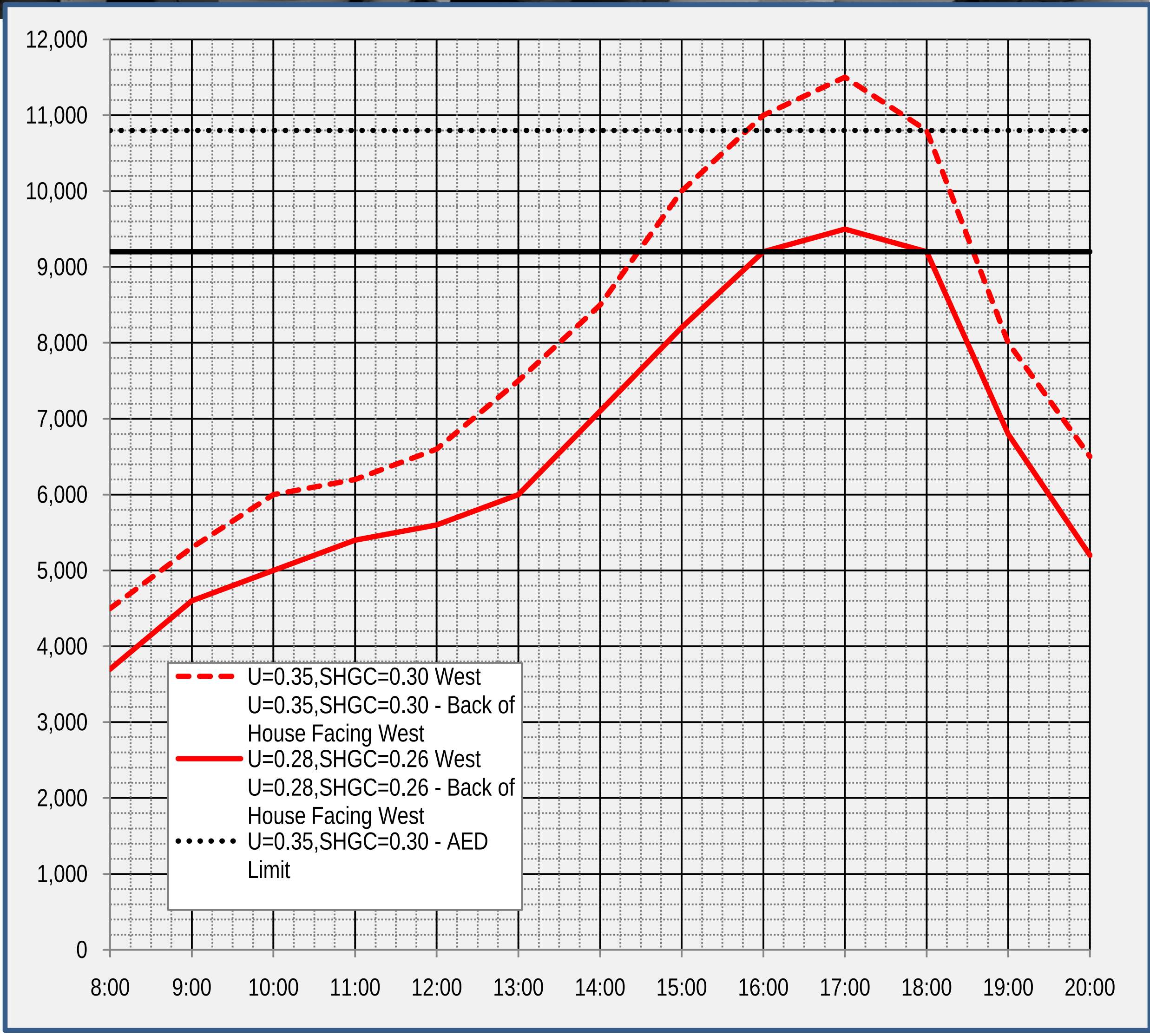
Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. Consult manufacturer's literature for other product performance information. www.nfrc.org

Enclosure: Windows

- Orientation
- Size
- Thermal conductivity
- Solar Heat Gain Coefficient (SHGC)

Impact of Window Specification on Peak Cooling Load

- U= 0.35 SHGC= 0.30 versus U= 0.28 SHGC = 0.26
- When buildings are well insulated and air sealed windows are more critical



Enclosure: Air Tightness

The target ventilation and infiltration rate must be accurately represented in the data input

In humid climates, the impact on the latent cooling load can be significant.

Enclosure: Air Tightness

Blower Door is a Critical Tool

HVAC contractors need proof

Enclosure: Internal and External Shading

Questions?

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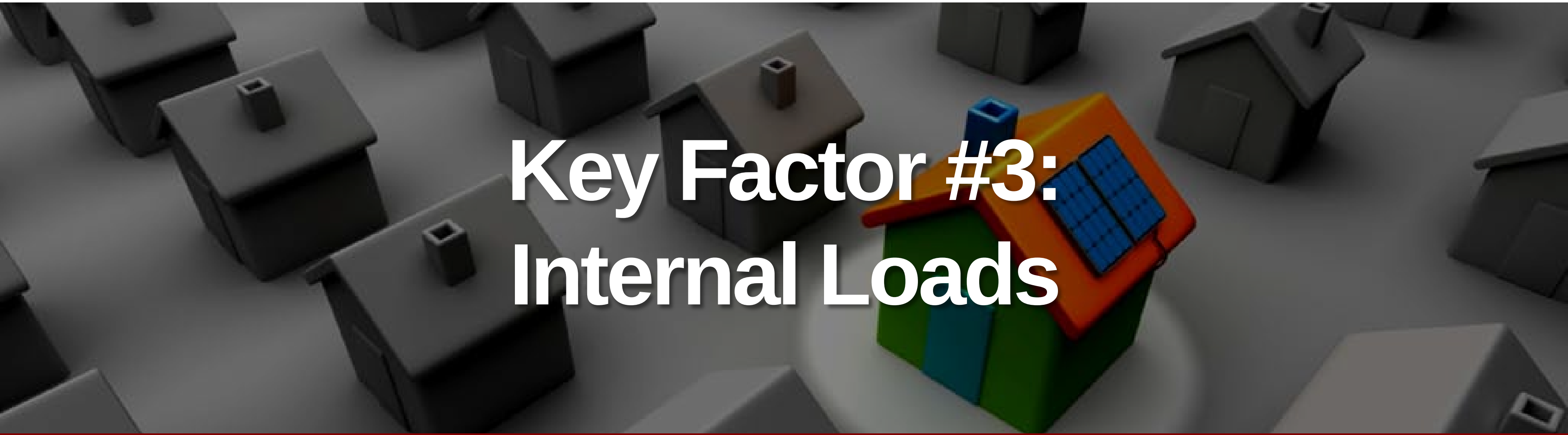

Key Factor #3: Internal Loads

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Internal Loads

- # of occupants
- Electronics
- Lighting
- Appliances

Internal Loads

- System location
- Ductwork
  - Location
  - Insulation value
  - Leakage

What Happens When You "Fudge" the Numbers?

Intentional or accidental manipulation of the design parameters can lead to large variations in the load

Case Study: Examples of Numbers Gone Wrong

- Two Climate Zones
  - CZ2 Orlando FL
  - CZ5 Chicago IL
- Two Houses
  - 2223 ft^2 slab-on-grade
  - 2223 ft^2 on full basement
- Multiple runs through WrightSoft with common errors/safety factors
  - Altered outdoor/indoor design conditions
  - De-rated insulation, window performance, shading characteristics
  - Exaggerated infiltration and ventilation
  - Combined all safety factors for a grossly exaggerated load

Fudge Factor #1 – Design Conditions

Baseline	Manipulated
Outdoor Design Conditions 93°Fdb 76°Fwb Temp Cooling 42°F Temp Heating	*Outdoor Design Conditions* 96°Fdb 79°Fwb Temp Cooling 30°F Heating
Indoor Design Conditions 75°F Temp 50%RH Cooling 70°F Temp 30% RH Heating	*Indoor Design Conditions* 70°F Temp 30% RH Cooling 75°F Temp 50%RH Heating

Results - Orlando Manipulated Outdoor/Indoor Design Conditions

	Baseline Load	Manipulated Load	Change In Load Btu/h	Change In Load %
Heating Load	23,600 Btu/h	37,800 Btu/h	14,100 Btu/h	60 %
Sensible Cooling	16,600 Btu/h	22,900 Btu/h	6,300 Btu/h	38 %
Latent Cooing	4,100 Btu/h	7,100 Btu/h	3,000 Btu/h	73 %
Total Cooling	20,700 Btu/h	30,100 Btu/h	9,400 Btu/h	45 %

Fudge Factor #2 – Manipulating Thermal Enclosure Design

Chicago Building Component Manipulations	
Baseline	**Manipulated**
Windows U = 0.35, SHGC = 0.5 *Walls* R19 *Attic* R38 Full credit for eaves, 50% exterior bug screens, light colored blinds at 45 degrees closed	*Windows* U = 0.45 SHGC = 0.5 *Walls* R17 *Attic* R30 No credit for eaves, no bug screens, no blinds

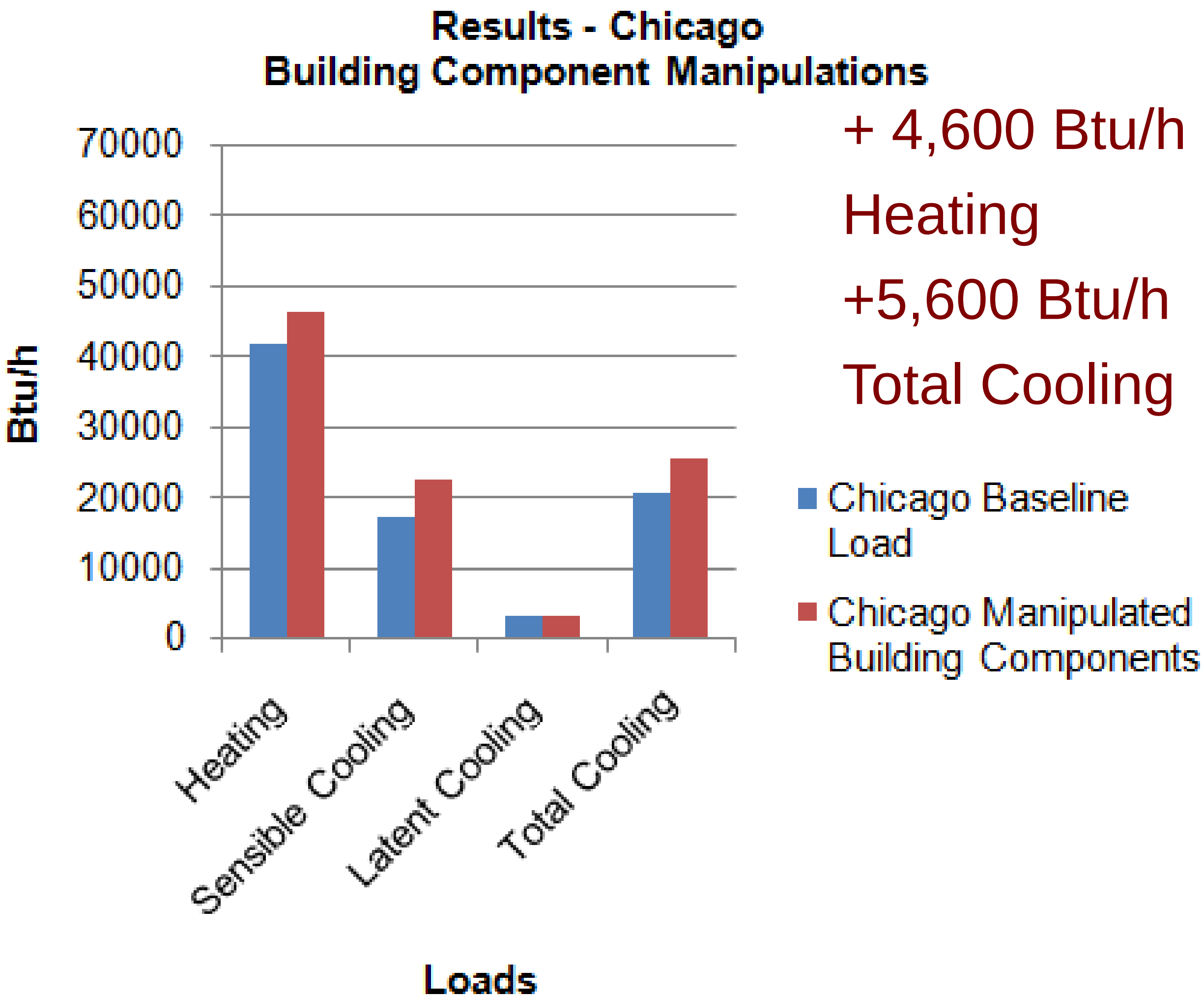



Fudge Factor #2 – Manipulating Thermal Enclosure Design

Results - Chicago Building Component Manipulations

	Baseline Load	Manipulated Load	Change In Load Btu/h	Change In Load %
Heating Load	41,700 Btu/h	46,300 Btu/h	4,600 Btu/h	11%
Sensible Cooling	17,400 Btu/h	22,400 Btu/h	5,000 Btu/h	28 %
Latent Cooing	3,200 Btu/h	3,200 Btu/h	0 Btu/h	0 %
Total Cooling	20,600 Btu/h	25,700 Btu/h	5,100 Btu/h	24 %

Fudge Factor #2 – Manipulating Thermal Enclosure Design



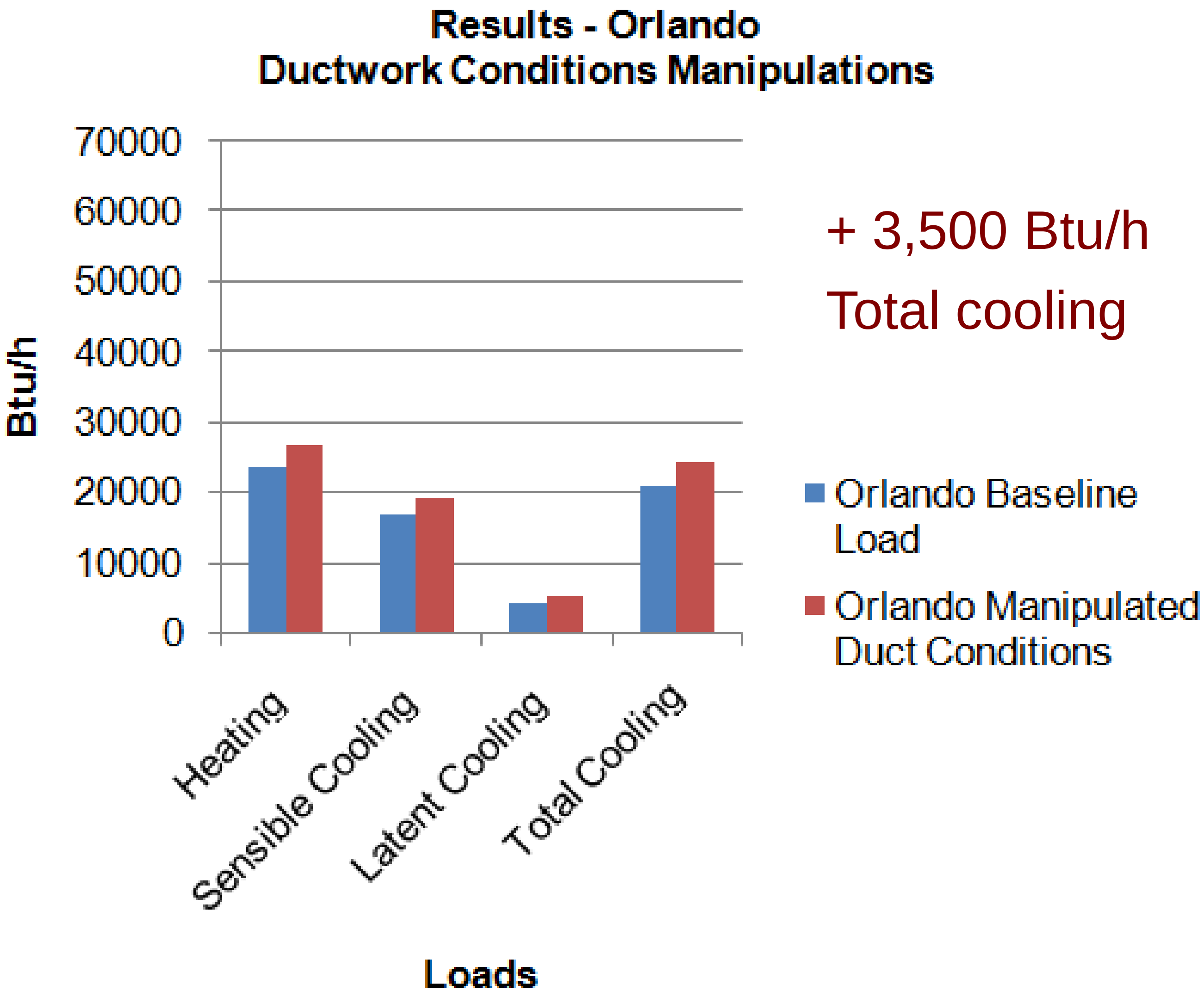
+ 4,600 Btu/h Heating

+5,600 Btu/h Total Cooling

Fudge Factor #3 – Ductwork Conditions

Orlando Ductwork Conditions Manipulations	
Baseline	**Manipulated**
Tightness level Supply = 0.06 cfm/ft^2 *Tightness level Return* = 0.06 cfm/ft^2 *Insulation* = R8	*Tightness level Supply* = 0.12 cfm/ft^2 *Tightness level* Return = 0.24 cfm/ft^2 *Insulation* = R6

Fudge Factor #3 – Ductwork Conditions



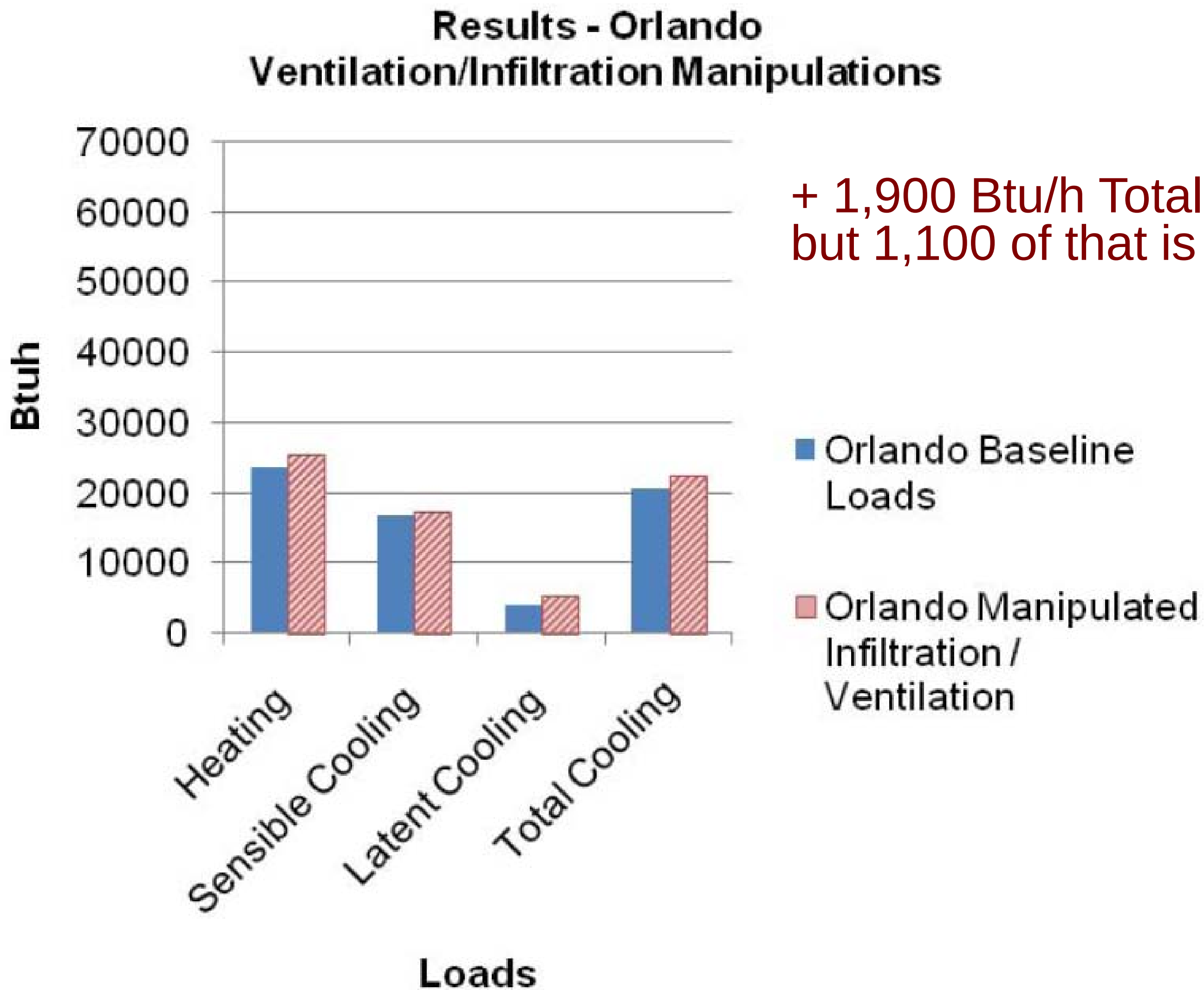
+ 3,500 Btu/h

Total cooling

Fudge Factor #4 – Ventilation / Air Infiltration

Baseline	Manipulated
Heating season infiltration = 0.19 ACHn (5.04 ACH50) Cooling season infiltration = 0.10 ACHn (2.65 ACH50) Ventilation balanced 60 cfm to meet ASHRAE standard 62.2 without energy or heat recovery	Heating season infiltration = 0.43 ACHn (11.39 ACH50) Cooling season infiltration = 0.23 ACHn (6.09 ACH50) Ventilation exhaust only 100 cfm

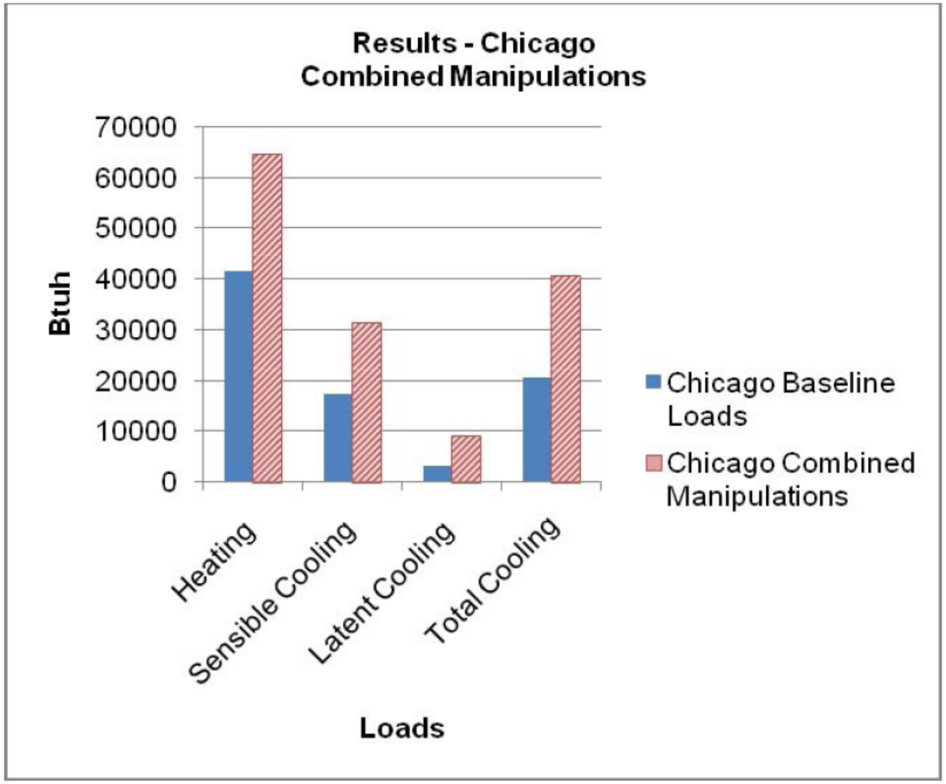
Fudge Factor #4 – Ventilation / Air Infiltration



+ 1,900 Btu/h Total cooling but 1,100 of that is Latent

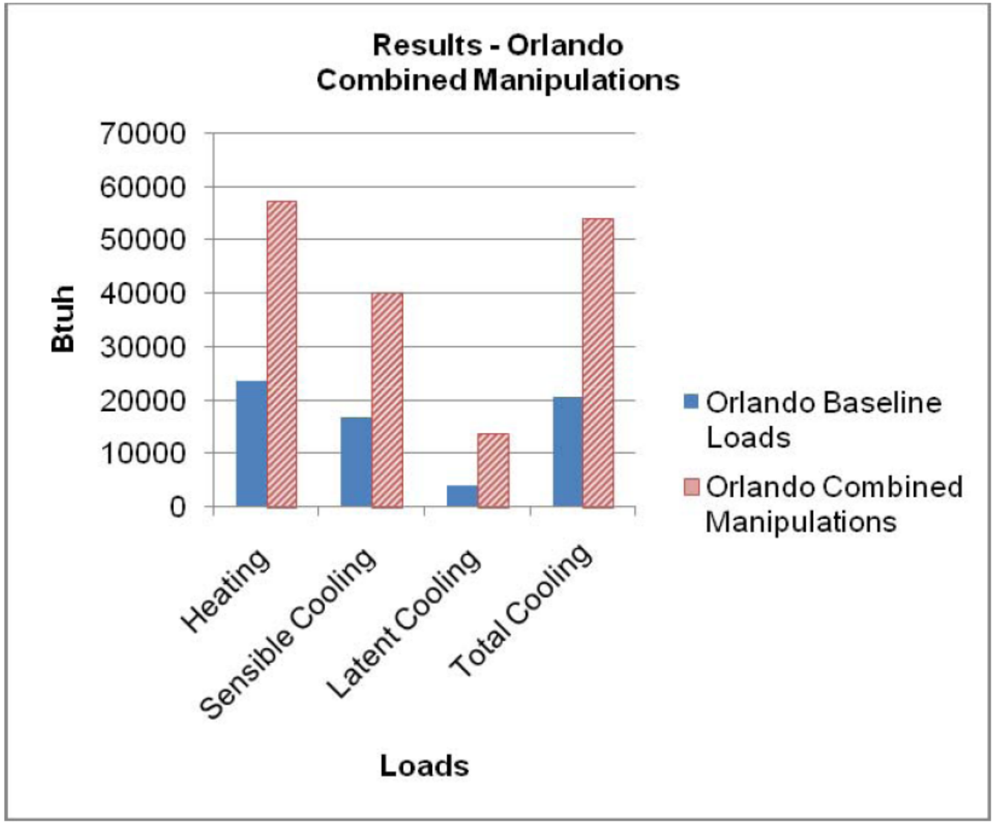
Combined "Safety Factors" - Chicago

	Baseline Load	Manipulated Load	Change In Load Btu/h	Change In Load %
Heating Load	41,700 Btu/h	64,700 Btu/h	23,000 Btu/h	55 %
Sensible Cooling	17,400 Btu/h	31,600 Btu/h	14,200 Btu/h	82 %
Latent Cooing	3,200 Btu/h	9,100 Btu/h	5,900 Btu/h	184 %
Total Cooling	20,600 Btu/h	40,600 Btu/h	20,000 Btu/h	97 %



Combined "Safety Factors" - Orlando

	Baseline Load	Manipulated Load	Change In Load Btu/h	Change In Load %
Heating Load	23,600 Btu/h	57,200 Btu/h	33,600 Btu/h	142 %
Sensible Cooling	16,600 Btu/h	40,200 Btu/h	23,600 Btu/h	142 %
Latent Cooing	4,100 Btu/h	13,900 Btu/h	9,800 Btu/h	239%
Total Cooling	20,700 Btu/h	54,000 Btu/h	33,300 Btu/h	161 %



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Questions?

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Wrap Up

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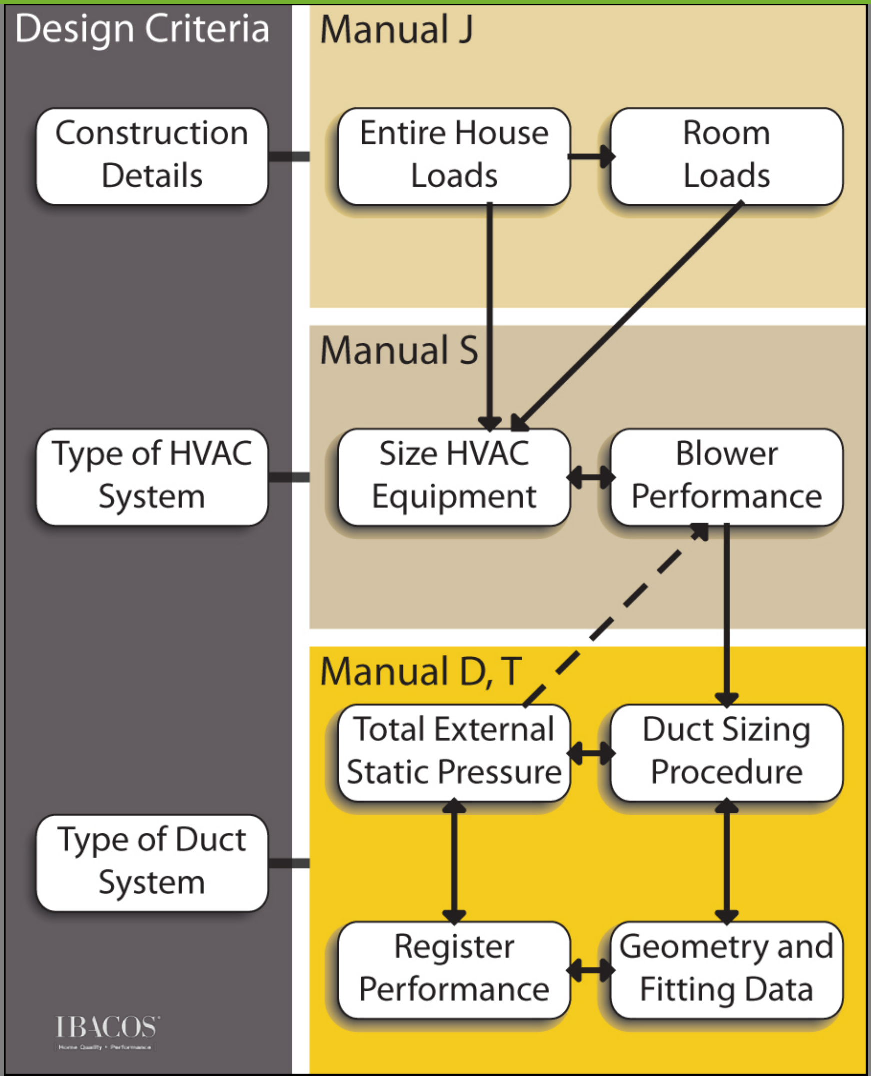
Resources

- IBACOS – Building America "Guide to Heating and Cooling Load Calculations for High Performance Homes"
- Air Conditioning Contractors of America – *Manual J Residential Load Calculation Eighth Edition*

Big Picture: We Just Covered Step 1 of 3

Iterative Process

1. Load calculations
2. Equipment selection and sizing
3. Duct and register sizing



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Thank you for joining us!

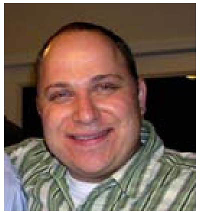
More Questions?

Arlan Burdick

Building Performance Specialist

406-548-7472

aburdick@ibacos.com

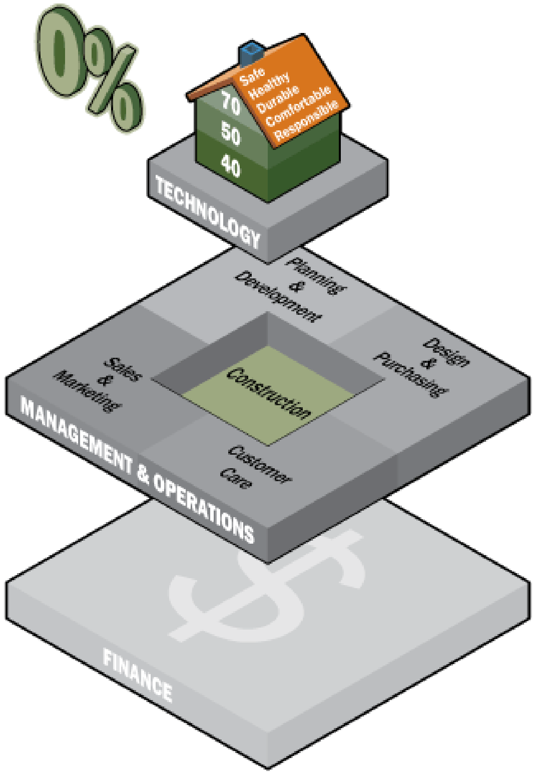


Anthony Grisolia

Services Manager

412-915-4061

agrisolia@ibacos.com



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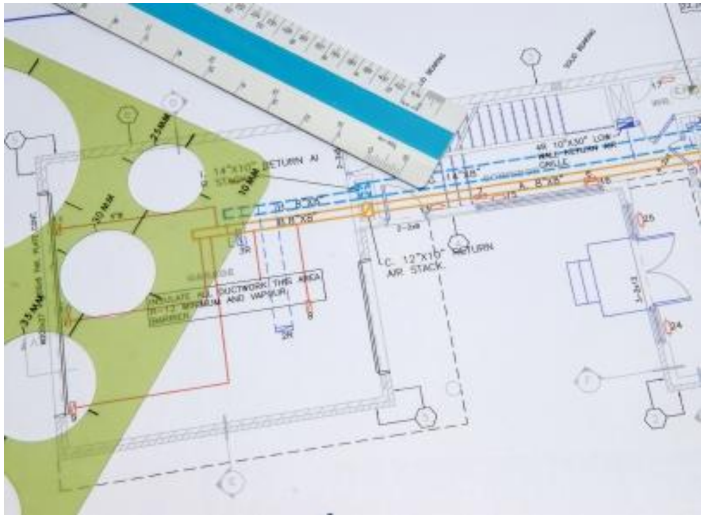

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