Welcome

High Performance Mechanicals for Houses That Work

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The EEBA High Performance Builder Designation

- The Houses That Work Building Science workshop
- The HERS Associate Course
- **The High Performance Mechanical Systems course**

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Today's Agenda

- What's different in high performance homes?
- The building science connection to mechanical systems
- The right decisions in the right order for all systems
  - The right size
  - Integrated design
  - Elements of design for proper heating and cooling
  - Review of equipment alternatives for heating and cooling
  - Controls
  - Commissioning of HVAC systems
  - Hot water heating technologies
  - Indoor environmental quality
    - Ventilation
    - Filtration
    - Humidity control
  - Solar
  - Next steps

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Mechanical Systems for High Performance Homes

Choices, Opportunities, Risks, Challenges

Cooling	Filtration
Heating	Plumbing
Hot Water	Controls
Ventilation	Solar
Dehumidification	

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House Systems - What's changed?

What impact might these have?

The original 1200-1500 sq.ft. starter home

Modest AC expectations

Simple water heating expectations

3/4 Ton

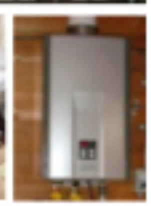
30000 BTUs

The new 1200-1500 sq.ft. starter home

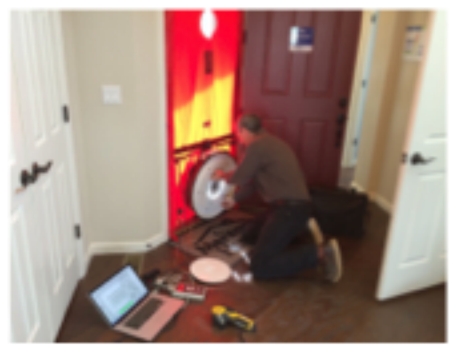
Higher AC expectations

Much higher water heating expectations

2.5 Ton



180 MBH



Tighter buildings ..... More exhaust appliances

Larger windows....

Opened less

Lower sensible loads ..... Higher latent loads

More lights, appliances and hot water

Advanced Systems .... Higher expectations

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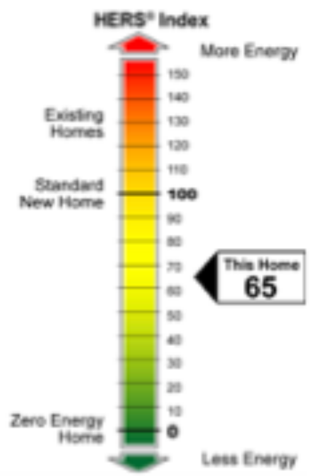
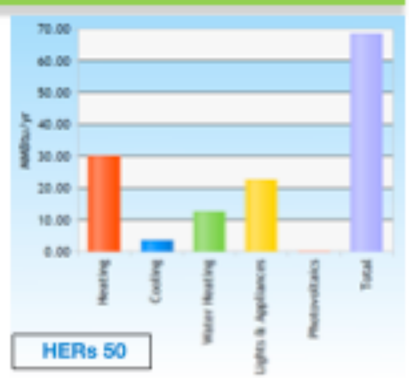
HERS Ratings

Home Energy Rating System

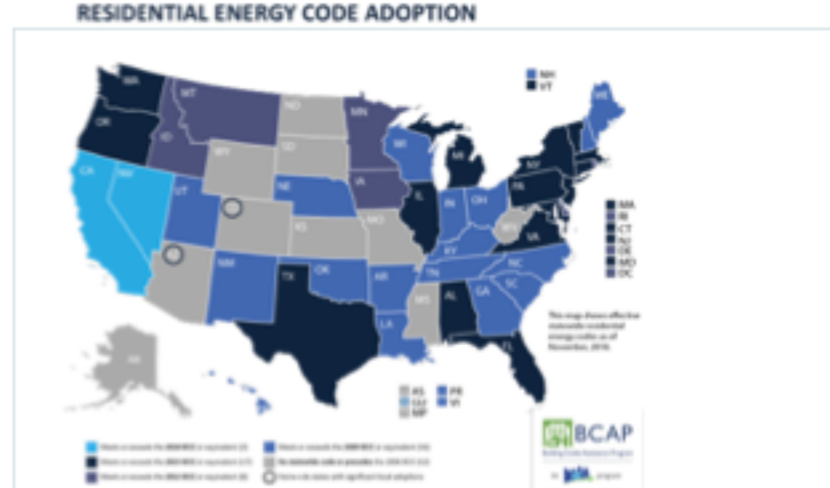


RESNET
HERS
INDEX

New Mechanical Priorities



RESIDENTIAL ENERGY CODE ADOPTION



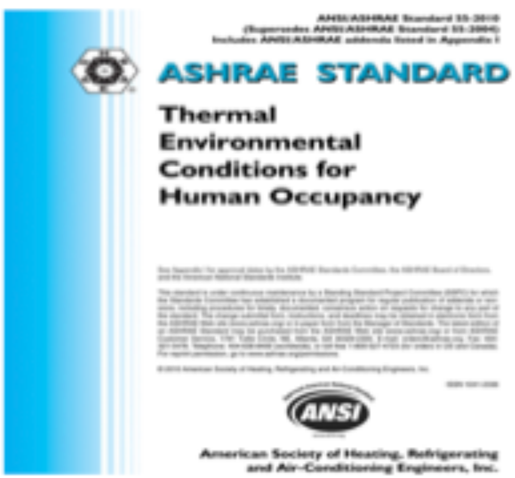
Are we ready for the changes?

Be Aware ....

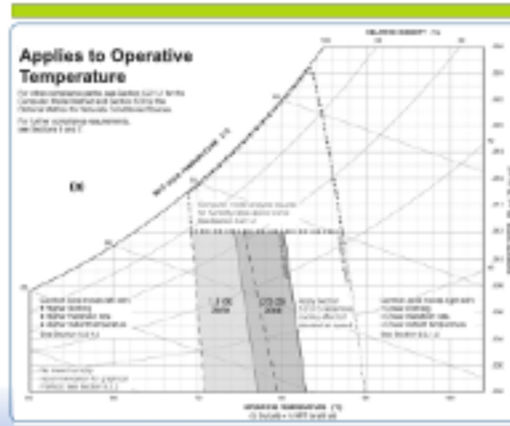
- Energy Efficiency ≠ Comfort
- Builders typically have more comfort complaints than high bill complaints
- If you can't provide comfort, energy efficiency could be set back 20 years
- We need to remember comfort fundamentals

Let's Start by Defining Comfort

- Air temperature
- Humidity
- Air speed - drafts
- Surrounding surface temperatures
- Gender, age, activities of occupants
- Metabolic rate & clothing



Comfort - Finding the Sweet Spot



Operative temperature:

- The average of the ambient air and the **mean radiant** temperatures, weighted by their respective heat transfer coefficients.

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The Comfort Challenge

The human body transfers heat by:

- 15% humidity / perspiration
- 35% convection / conduction to the air
- 50% radiation to surrounding surfaces

Which ones do we measure and control?

Comfort - Finding the Sweet Spot

Thermostats respond to air temperatures

Human **Thermal Comfort** Responds to the Operative Temperature

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The Comfort Challenge

Do you have the tools, equipment and knowledge to respond?

Can we meet their Comfort Expectations?

Residential Single-Zone and Multi-Zone Systems

Minimum / Maximum Recommended Values for Comfort and Safety

Comfort Item	Heating Season	Cooling Season
Thermostat setpoint (design)	70°F	75°F
Relative humidity (RH)[1]	30% RH maximum (20 – 30% RH is desirable)	55% RH maximum (25 – 50% RH is desirable)
Dry-bulb temperature at the thermostat	Setpoint temperature ±2°F	Setpoint temperature ±3°F (single-zone) Setpoint temperature ±2°F (multi-zone)
Dry-bulb temperature in any conditioned room	Setpoint temperature ±2°F	Setpoint temperature ±3°F (single-zone) Setpoint temperature ±2°F (multi-zone)
Room-to-room temperature differences (i.e., same level)	4°F maximum	6°F maximum (single-zone) 4°F maximum (multi-zone)
Floor-to-floor temperature differences (i.e., different levels)	4°F maximum	6°F maximum (single-zone) 4°F maximum (multi-zone)
Floor temperature (slab floors or floors over unconditioned space)	65°F minimum at 4' above the floor for 70°F thermostat setting [not applicable near outside walls]	—
Air filtration – MINIMUM EFFECTIVENESS[3]	MERV[2] rating of 4 – 6 [Standard disposable media filter]	MERV[2] rating of 4 – 6 [Standard disposable media filter]
Air filtration – BETTER EFFECTIVENESS[3]	MERV[2] rating of 8 – 11 [1-2" residential pleated filter]	MERV[2] rating of 8 – 11 [1-2" residential pleated filter]
Ventilation (outdoor air introduced into the occupied space)	0.35 air changes per hour (ACH) [for any infiltration-ventilation combination]	0.35 air changes per hour (ACH) [for any infiltration-ventilation combination]
Air circulation within room[4]	Size and location of supply outlets selected for optimum heating performance / low resistance return path required for every room	Size and location of supply outlets selected for optimum cooling performance / low resistance return path required for every room

ACCA Comfort Guidelines

Comfort - A starting point

Parameter	Setting	Range
Temperature		
Summer	75 ºF	+/- 3 ºF
Winter	72 ºF	+/- 3 ºF
Humidity		
Summer	50%	+/- 5%
Winter	35%	+/- 5%
Foot Comfort	63 ºF	+/- 3 ºF

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Heating and Cooling Systems

Fuel choices

- Electric
- Gas
- Oil
- Wood
- Solar
- Combinations

Distribution choices

- Central Forced air
- Radiant
  - In-floor
  - Baseboard
- Ductless
- Space heaters

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The Current Realities…

- Equipment designed at+10% to 25% for a condition that lasts less than 50 hrs per year.
- Ducts that deliver just 80% to 85% of required flow to spaces.
- Windows that change from energy gain to energy loss in minutes
- Homeowners who expect +/- 1 ºF, 3% RH

1) Get heating & cooling capacity right

Heat Flow Formulas:

Conduction heat flow (through walls, ceilings, floors)

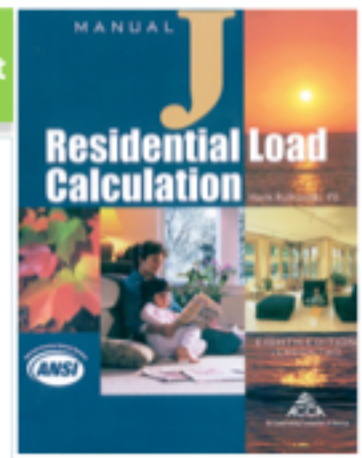
= (Surface Area x Temp. Diff.) / R-value

Radiant flow (through glass)

= Surface area x Solar incidence x Solar Heat Gain Coefficient

Heat flow by air (via air leakage or ventilation) - Sensible

= Volume of air (CFM) x Temp. Diff. x 1.1



Conduction Heat Flow

HF = Exposed area x Temp. difference / R-Value

Heat flow through 1000' attic floor =
1000 x (135 - 75) / R-30 = 2000 BTU/hr

At R-40
1000 x (135 - 75) / R-40 = 1500 BTU/hr

Heat flow through 1000' of wall =
1000 x (95 - 75) / R-10 = 2000 BTU/hr

Get the Size Right

- Do Room-by-Room heat loss & gain calculation

Based on:

- Design Day - Winter, Summer
- Conduction losses through enclosure
- Air leakage through enclosure
- Energy losses through ducts in unconditioned space

SECOND FLOOR PLAN

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Design Conditions

Condition	ASHRAE 99.6%
Winter, design dry bulb (F)	12.9°F
Summer, dry bulb / Coincident Dew Point	93.9 / 67
Summer Dew Point / Coincident Dry Bulb	75.3 / 82
Degree days-heating	4203
Degree days-cooling	1228
Precipitation	41"
Solar incidence - South, Aug	120 btu/hr/ft2
Solar incidence - West, Aug	160 btu/hr/ft2

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Lets do a one room example

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Conductive Heat Loss/ Gain

- 2 exposed walls
- One exposed ceiling
- One window

Radiant Heat Gain (Cooling)

- Solar gain through window
- Internal loads
- Air leakage & ventilation

Participants complete the example on your worksheet

Assume 10' high ceilings, Assume window SHGC = 0.3

Remember the Heat Flow Formulas

Conduction heat flow (through walls, ceilings, floors)

= (Surface Area x Temp. Diff.) / R-value

Radiant flow (through glass)

= Surface area x Solar incidence x **S**olar **H**eat **G**ain **C**oefficient

Heat flow by air (via air leakage or ventilation) - Sensible

= Volume of air (CFM) x Temp. Diff. x 1.1

HVAC Sizing

Component	Surface area	x	Temp. Diff.	/	R-value	= BTUs/Hr
Ceiling: Winter Summer	150 sq.ft.				R30	
Walls: Winter Summer	250 sq.ft.				R15	
Windows: Winter Summer	20 sq.ft.				R3	

HVAC Sizing

Component	Surface area	x	Temp. Diff.	/	R-value	= BTUs/Hr
Ceiling: Winter Summer	150 sq.ft.		 60 20		R30	 300 100
Walls: Winter Summer	250 sq.ft.		 60 20		R15	 1000 333
Windows: Winter Summer	20 sq.ft.		 60 20		R3	 400 133

Solar gain (South) = 20 x 120 x 0.3 SHGC = 720 BTUs/hr

Solar gain (West) = 20 x 160 x 0.3 SHGC = 960 BTUs/hr

HVAC Sizing

Air leakage / ventilation heat loss - winter

= CFM x temp. difference x 1.1

= 60 x 60 x 1.1= 3960 BTUs/hr

Air leakage / ventilation heat gain - summer

= CFM x temp. difference x 1.1

= 60 x 20 x 1.1= 1320 BTUs/hr - sensible only

Definition - 1.1 is the product of the specific heat (0.24 BTU x Air Density x minutes in an hour (60))

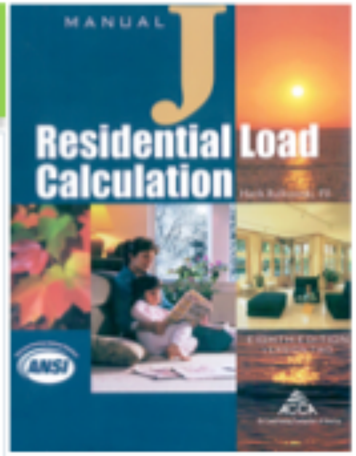
Proper Manual J Calculations

- Numerous software packages exist
- All rely on proper data input and appropriate assumptions

Common Errors:

- Fudging design day conditions
- Using default values for air tightness, windows, insulation
- Using improper ventilation rates

Don't tolerate oversizing, Manual J compliant programs have safety factors built in already



Impact of Improper Sizing

Short cycling

Poor humidity control

Poor temperature control

Noise

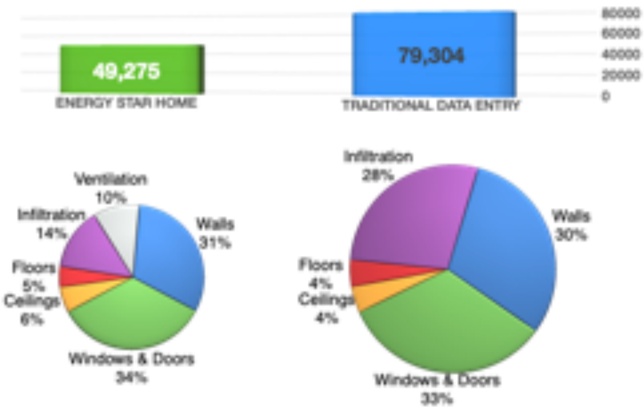
Extra cost for equipment & duct work

Possibly higher energy bills

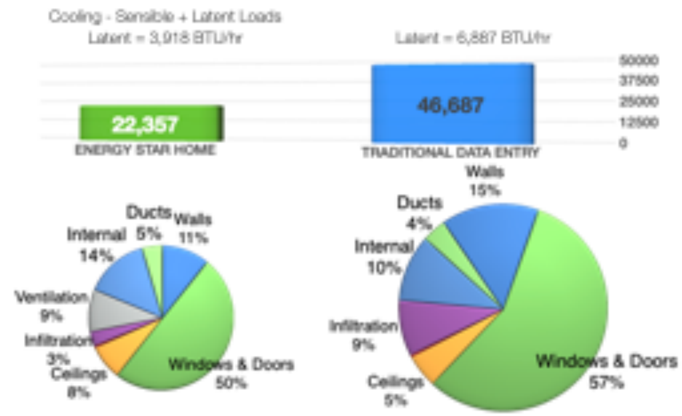
One example of poor sizing - Cold Climate CZ 7

Parameter	Actual	Traditional
Design Temp (W) Design Temp (S)	-15 ºF 91 ºF	Its cold here: -22 ºF Its getting hotter: 97 ºF
Indoor Design (W) Indoor Design (S)	70 ºF 75 ºF	People are picky: 72 ºF 72 ºF
Orientation	North Front	Worst Case - East Front
Windows	From NFRC label U=0.28, SHGC=0.28 Overhangs used	Default U=0.41, SHGC=0.32 Overhangs not used
Air tightness	Actual 2.0 ACH50	Default 7.0 ACH50
Insulation	R50 ceilings R25 walls R 15 foundation	R44 ceilings R19 walls R 10 foundation
Ventilation	ERV - 75 CFM	Exhaust fans - 75 CFM

Heating Loads- HP Home Versus Standard



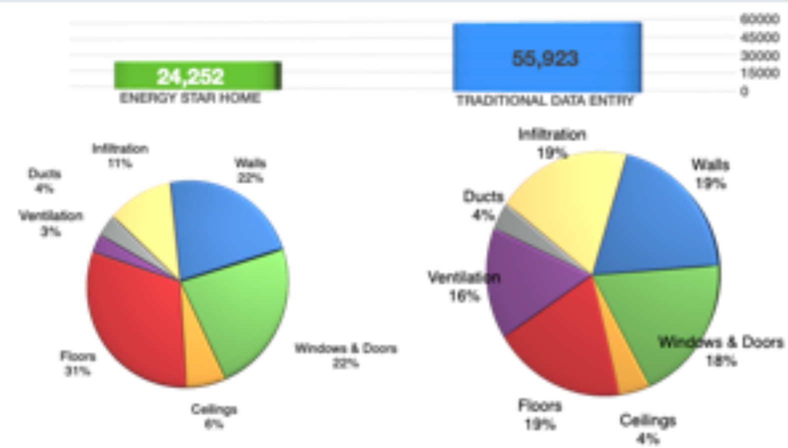
Cooling Loads- HP Home Versus Standard



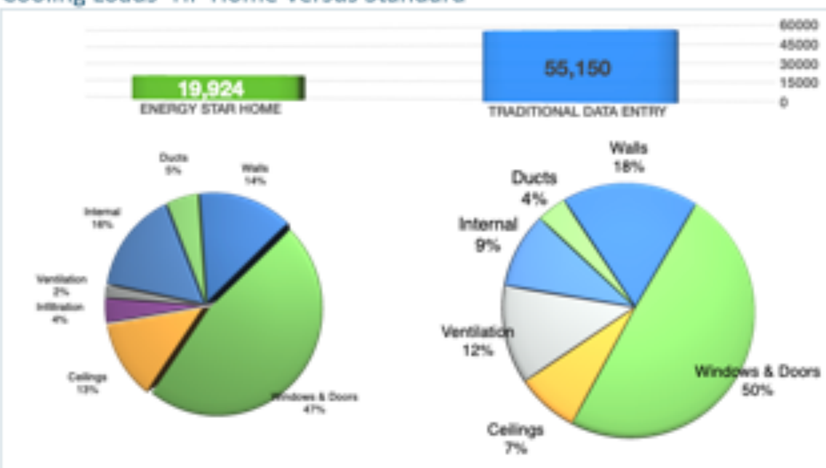
Another example of poor sizing - Climate Zone 3

Parameter	Actual	Traditional
Design Temp (W) Design Temp (S)	36 ºF 91 ºF	Its cold here: 26 ºF Its getting hotter: 97 ºF
Indoor Design (W) Indoor Design (S)	70 ºF 75 ºF	People are picky: 72 ºF 72 ºF
Orientation	North Front	Worst Case - East Front
Windows	From NFRC label U=0.28, SHGC=0.22 Overhangs used	Default U=0.40, SHGC=0.40 Overhangs not used
Air tightness Duct Leakage	Actual 3.0 ACH50 < 3 cfm/100 ft2	Default 7.0 ACH50 Average
Insulation	R38 ceilings R18 walls R 8 ducts	R28 ceilings R10 walls R 6 ducts
Ventilation	ERV - 75 CFM	Supply Only - 180 CFM

Heating Loads- HP Home Versus Standard

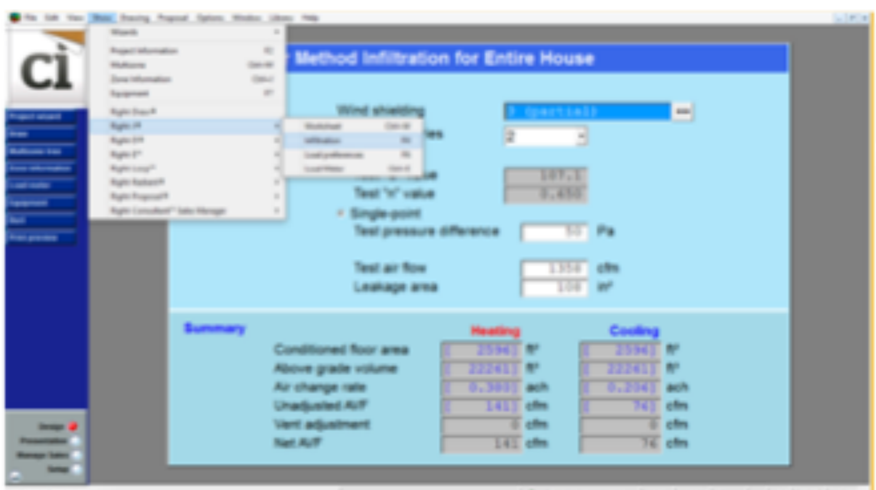


Cooling Loads- HP Home Versus Standard



Share important information

- Insulation levels
  - Wall and attic insulation levels
  - Foundation insulation
- Window data - use NFRC ratings
  - Solar heat gain coefficients - (this is usually the most important summer variable)
  - U values
- House Air leakage - (this is often the single biggest winter variable)
  - Provide blower door test values



Approved Software Guides Better Inputs

2) Select the right equipment

- Use manufacturer's technical manuals to match:
  - Required heat output
  - Required cooling output
    - Sensible & latent (moisture) loads
  - Fan / airflow delivery capacity and static pressure

Good System Selection

Heating and cooling systems come in specific sizes

(2, 2.5, 3 ton, or 45, 70, 90 Thousand BTUs for example)

- For heating it is acceptable to select a system that is within 110% -125% of the design load - slightly oversized
- For cooling choose a system that is between 90% - 110% of design load
- Other issues:
  - Equipment location (garage, attic, crawl...)
  - Blower type (ECM, PSC, HV...)
  - Filtration needs

Use Manufacturer's Fan Specifications

[illegible] FURNACE COOLING AIRFLOW (CFM) AND POWER (WATTS) VS. EXTERNAL STATIC PRESSURE WITH FILTER

OUTDOOR UNIT SIZE (TONS)	AIRFLOW SETTING	DIP SWITCH SETTING					EXTERNAL STATIC PRESSURE				
		SW 1	SW 2	SW 3	SW 4		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.5	LOW (350 CFM/TON)	ON	ON	OFF	ON	CFM WATTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	NORMAL (400 CFM/TON)	ON	ON	OFF	OFF	CFM WATTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	HIGH (450 CFM/TON)	ON	ON	ON	OFF	CFM WATTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3.0	LOW (350 CFM/TON)	OFF	ON	OFF	ON	CFM WATTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	NORMAL (400 CFM/TON)	OFF	ON	OFF	OFF	CFM WATTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	HIGH (450 CFM/TON)	OFF	ON	ON	OFF	CFM WATTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	LOW (350 CFM/TON)	ON	OFF	OFF	ON	CFM WATTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	NORMAL (400 CFM/TON)	ON	OFF	OFF	OFF	CFM WATTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	HIGH (450 CFM/TON)	ON	OFF	ON	OFF	CFM WATTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	LOW (350 CFM/TON)	OFF	OFF	OFF	ON	CFM WATTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	NORMAL (400 CFM/TON)	OFF	OFF	OFF	OFF	CFM WATTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	HIGH (450 CFM/TON)	OFF	OFF	ON	OFF	CFM WATTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Preferred furnace choices

- Sealed combustion chamber
- Venting system decoupled from house pressures
- Efficiencies of 90%+
- High efficiency blower motors - ECM
- Two/multi stage heating

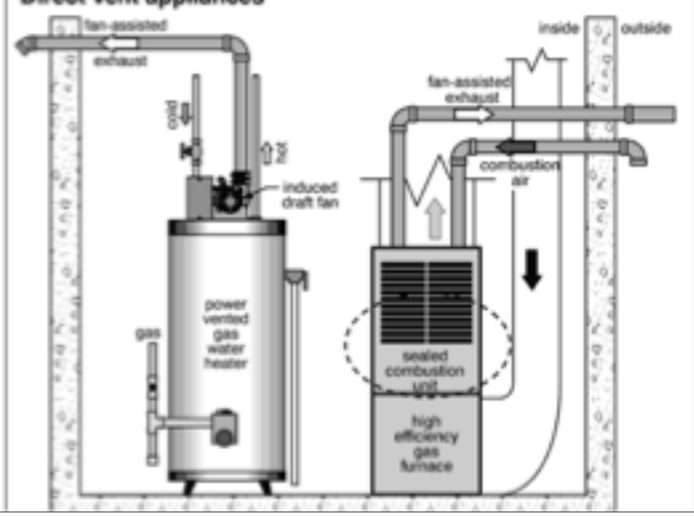
Preferred air handler choices

- Heat pump
- SEER 16+
- High efficiency blower motor - ECM
- Two/multi stage cooling

Preferred AC choices

- Outdoor condenser matched to indoor coil
- SEER ratings of 16+
- High efficiency blower motors - ECM
- Two - stage cooling
- Dehumidification cycles
- Heat pump

Direct vent appliances



New Realities in HVAC Design & Performance

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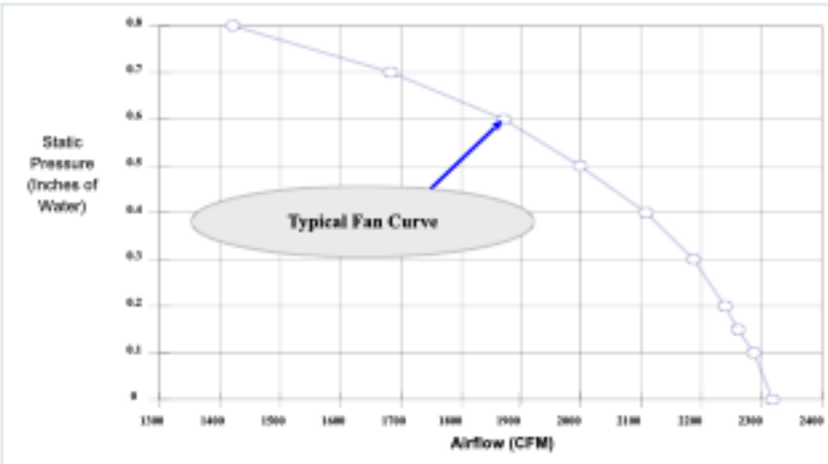
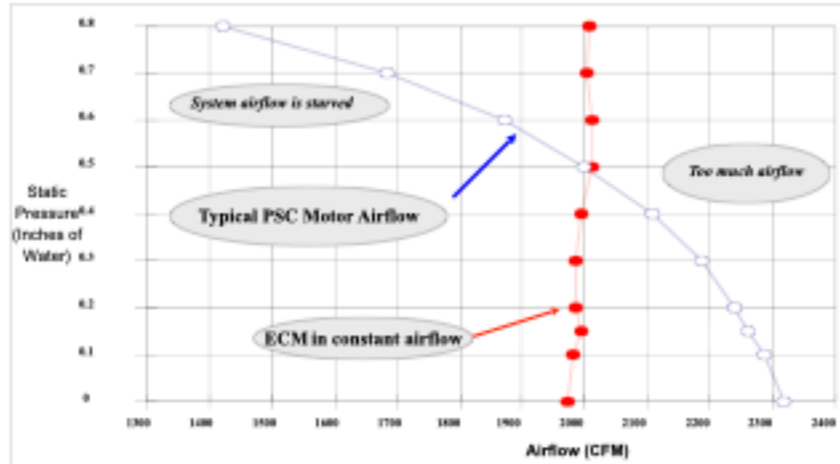
High Performance homes need more efficient motors!

- Capable of meeting small loads, part loads and full loads!
- Use 1/5 of original PSC motor types.
- Run efficiently at a variety of speeds (Modulation)
- Equipment lasts longer
- Enables balanced temperatures throughout home
- Enhances Ventilation "Effectiveness"

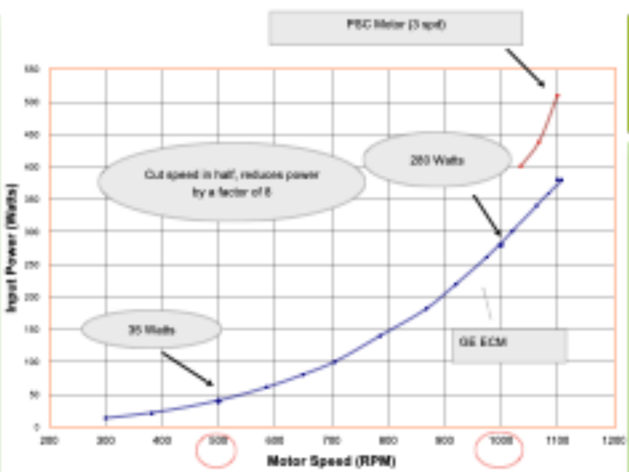
Airflow and Fan Curves



ECM Product Features: Constant Airflow

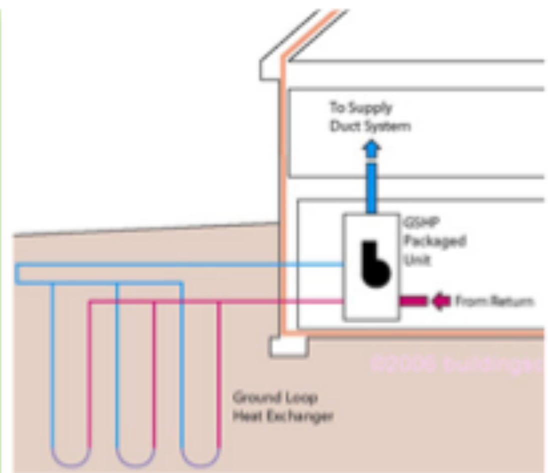


ECM Product Features: Efficiency



What about Heat Pumps?

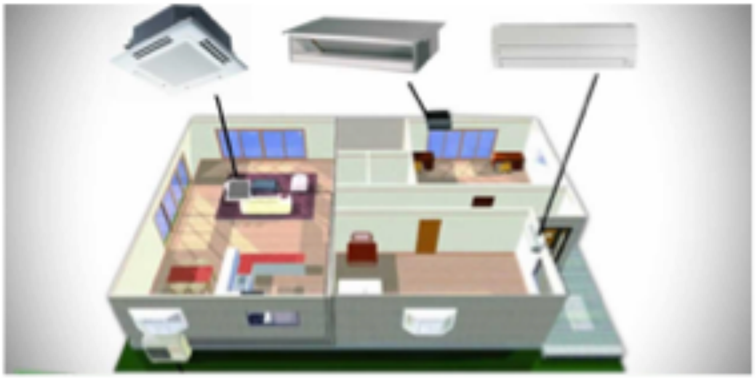
- Heat pumps are hard to overlook
- COPs of 3 to 4
- Be mindful of rating points and operating conditions – cold weather
- Water, ground or air source
- Specifically useful in High Performance Homes



MUZ-HM24NA2

Outdoor unit model			MUZ-HM24NA2
Capacity Rated (Minimum-Maximum)	Cooling *1	Btu/h	22,500 (5,800 ~ 22,500)
	Heating 47 *1	Btu/h	26,000 (5,400 ~ 26,000)
Capacity Rated (Maximum)	Heating 17 *2	Btu/h	18,500 (18,500)
Power consumption Rated (Minimum-Maximum)	Cooling *1	W	2,575 (275 ~ 2,575)
	Heating 47 *1	W	2,445 (265 ~ 2,445)
Power consumption Rated (Maximum)	Heating 17 *2	W	2,245 (2,245)
EER *1 [SEER] *3	Cooling		8.6 [18.0]
HSPF IV *4	Heating		8.5
COP	Heating *1		3.05
Power factor	Cooling (208/230)	%	99/99
	Heating (208/230)	%	99/99

Select Heat pumps for both Cooling & Heating Capacity



New Opportunities with Heat Pumps - Zoning

In High Performance Homes they can provide all Heating and Cooling Needs

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Thank You

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End of Module 1

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Welcome

High Performance Mechanicals for Houses That Work
Module 2

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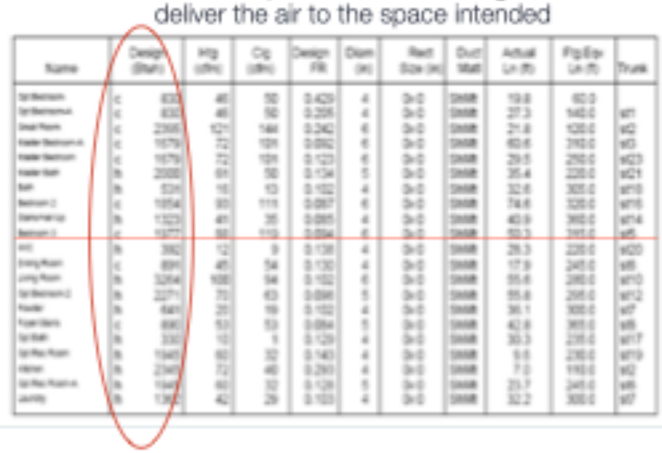
3) Design the Distribution (ducts) correctly

ACCA Duct Design

Manual D provides a duct sizing schedule to deliver the air to the space intended



HVAC by Design

- Properly size system
- Optimize duct layout

Example- Duct Design for Bedroom #3

		Design BTUs	Design CFM	Design Friction	Dia.
Bed #3	Heat	3872	88	1.01	5"
	Cool	1977	119	0.09	6"

The air required is calculated by the formula:

$$CFM = \frac{BTU/hr}{1.1 \times \text{Temp. rise across furnace}}$$

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Heat & Air Distribution BTU/hr Carrying Capacity

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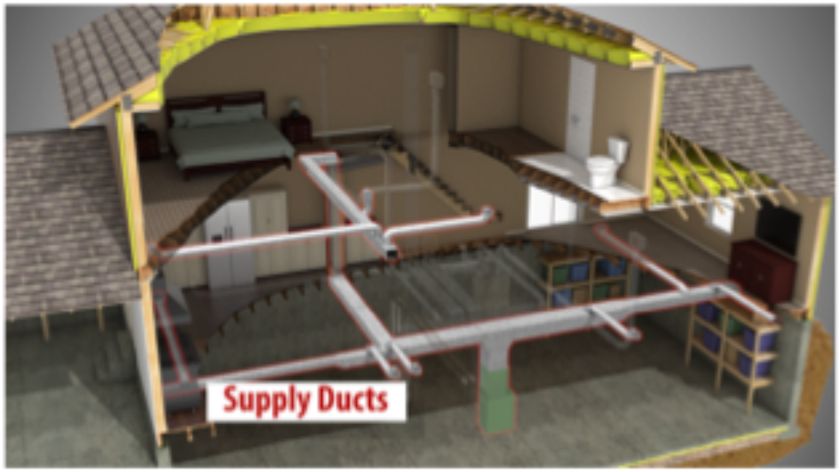
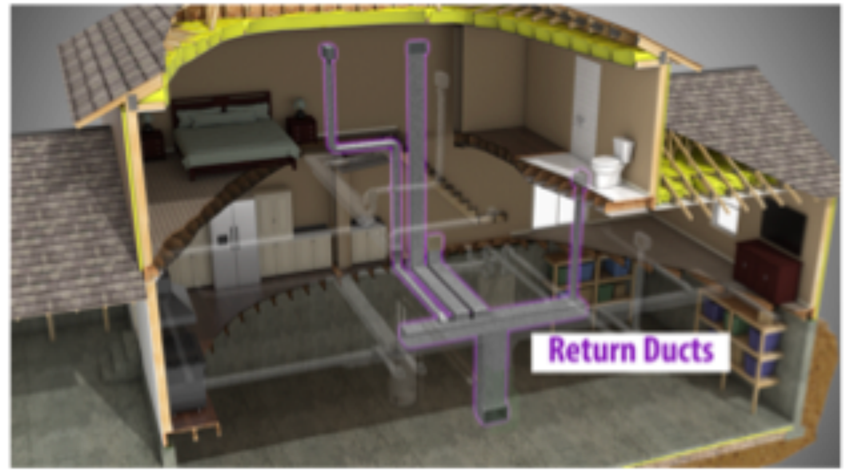
Duct size	Airflow CFM	25 °F Cooling	45 °F Heating	55 °F Heating
4"	30-40	800 -1100	1485 -1980	1815 - 2420
5"	50-60	1300 -1650	**2375 - 3960**	3025 - 3630
6"	90-110	2475 -3025	4455 - 5445	5445 - 6710

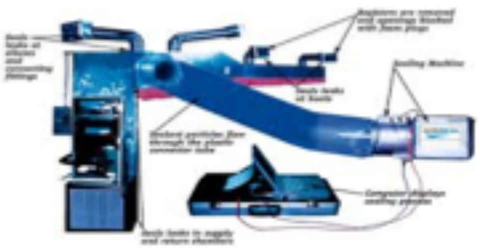




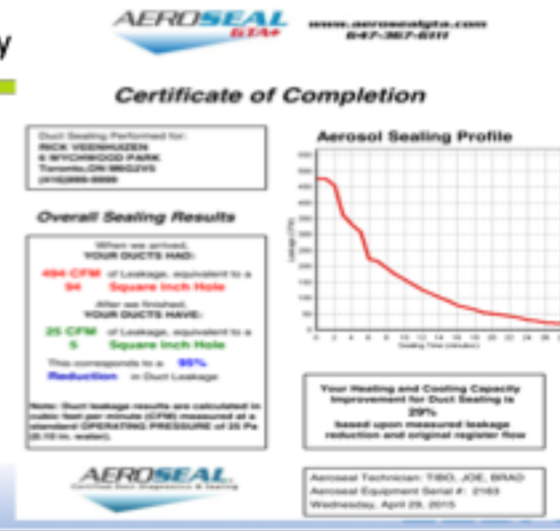
Change plans to get equipment & ducts in conditioned space

Ductwork needs to be sealed - what's the Goal?

Duct Sealing Technology



Duct Sealing Technology



Duct Sealing Results – my house

Room	Airflow Before CFM	Airflow After CFM
Master Bed	45	59
Master Bed	28	35
Master Bath	36	34
Bed 3	32	46
Bed 3	16	24
Bed 2	37	37
Main Bath	21	25
Bed1	35	42
Bed1	43	50
Family	32	46
Family	37	31
Family	10	15
Living	51	66
Dining	13	18
Kitchen	53	64
Office	36	49
Mudroom	13	13
Basement	42	48
Basement	39	48
Total	**619**	**750**

Ducts & equipment in conditioned space

4 Strategies

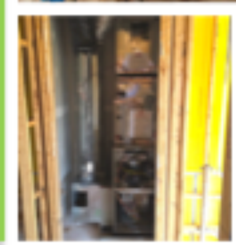
Ducts in the floor system

Dropped or raised ceilings

Condition the attic

Bury the ducts

OR … Ductless systems



Conduction Heat Flow - attics in summer

$$HF = \frac{\text{Exposed area} \times \text{Temp. difference}}{\text{R-Value}}$$

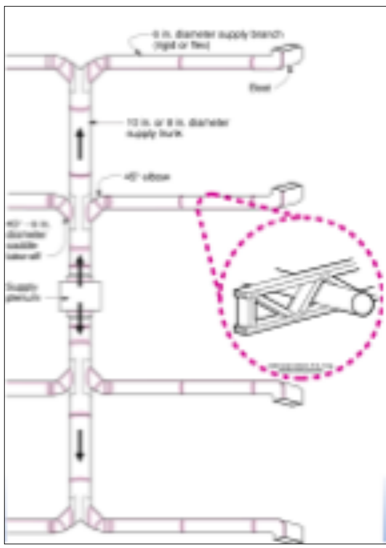
Heat flow through 1000′ attic floor =

1000 x (135 - 75) / R-30 = 2000 BTU/hr

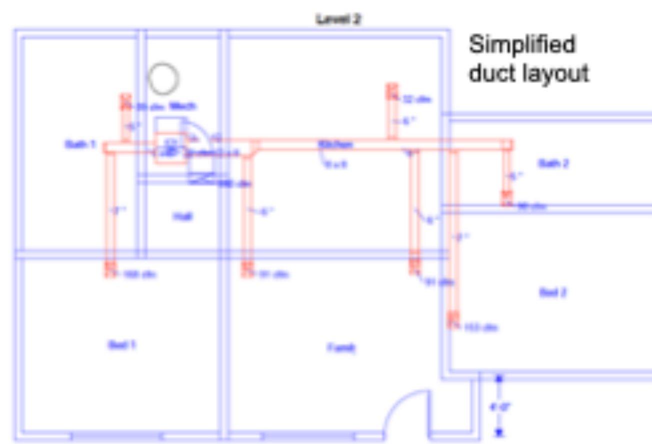
Heat flow through 100′ of 8″ dia. AC duct =

100 x 2 x (135 - 55) / R-8 = 2000 BTU/hr

Easy to service, quiet and efficient

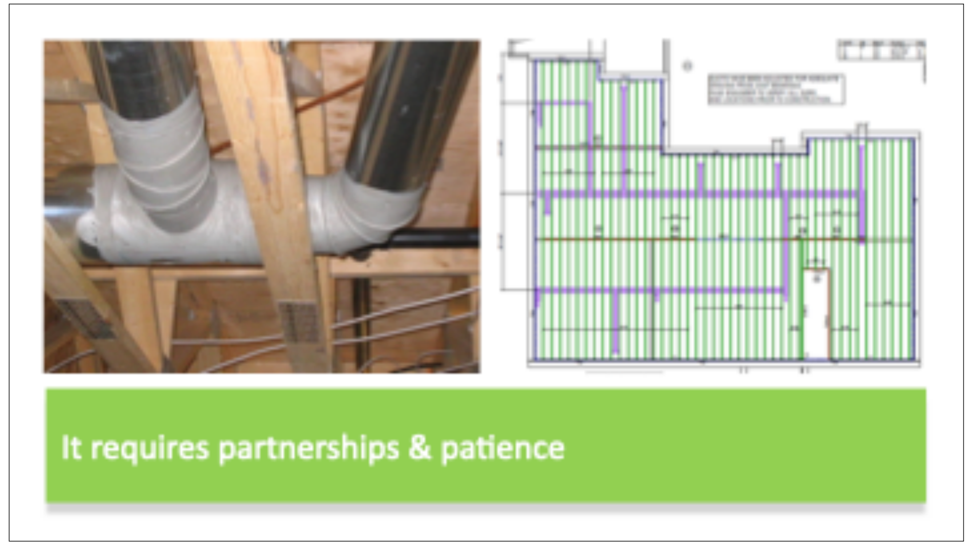


Efficient design and installation



Simplified duct layout

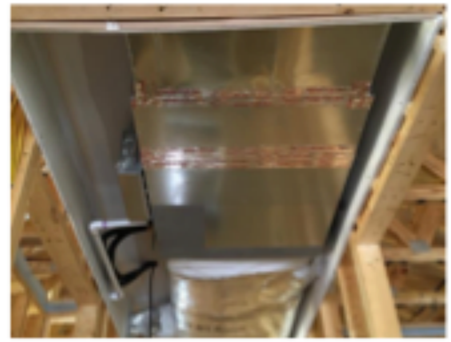

Layout Floors to Accommodate HVAC


It requires partnerships & patience

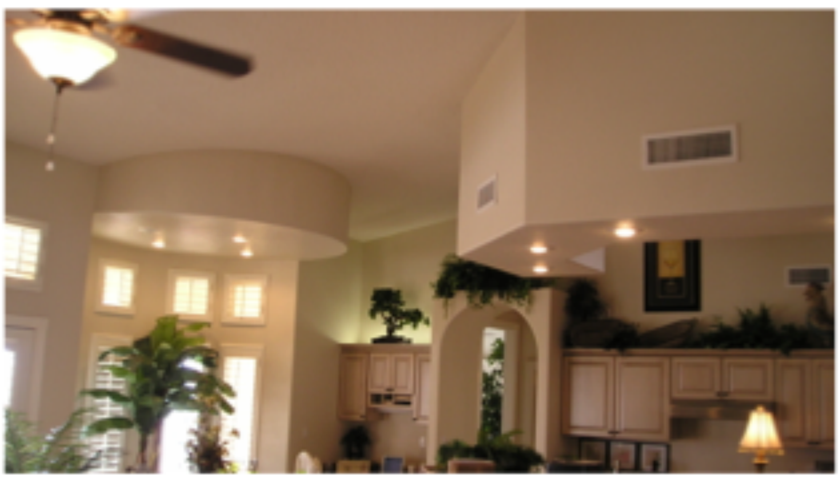

A dropped ceiling in the
hallway can be effective


Dropped or raised ceilings
Properly sized and located grilles "throw"
air to the perimeter windows and walls

Mini-Ducted Systems are an option

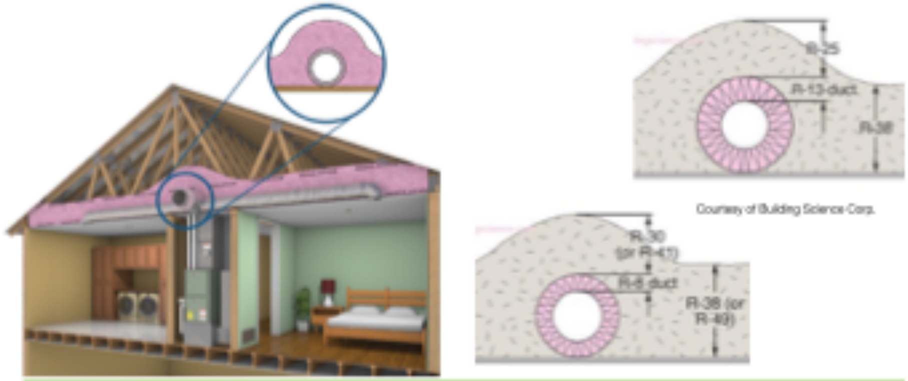


Ducted mini-split in a dropped ceiling



Conditioned attics are an option

It can raise the value of a home



Buried Ducts are an Option

New opportunities to eliminate ductwork all together

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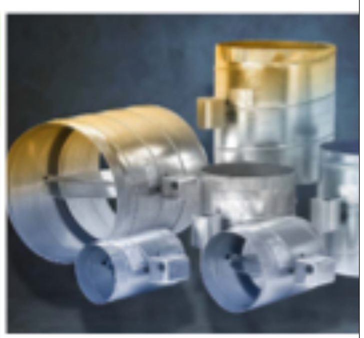
Zoning will become more important



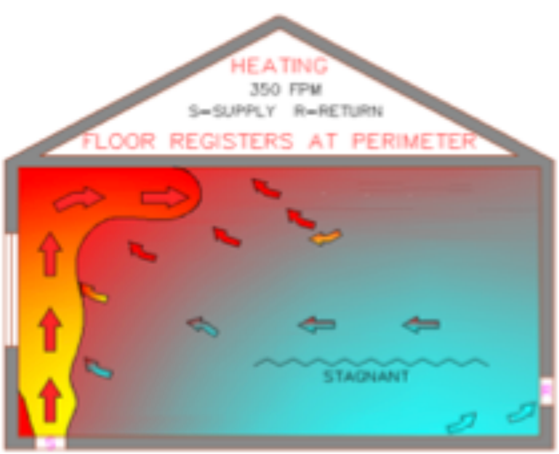
- Matching seasonal or intermittent loads
  - Example – kitchens, large windows
- Accurate delivery of part loads
- Making best use of equipment capacity

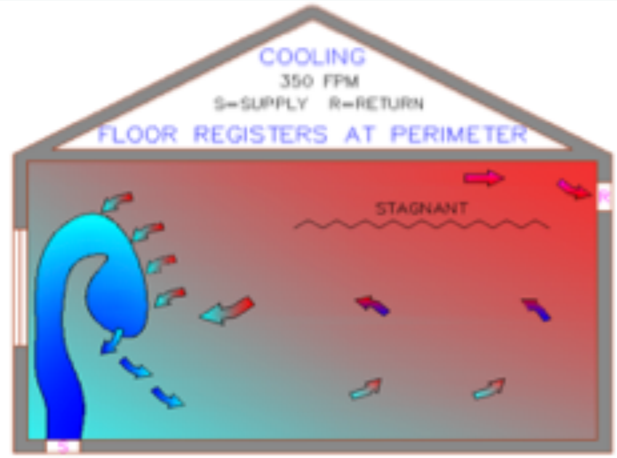
It's easier than ever:

- ECM fans
- Multi- stage equipment
- Static pressure controls

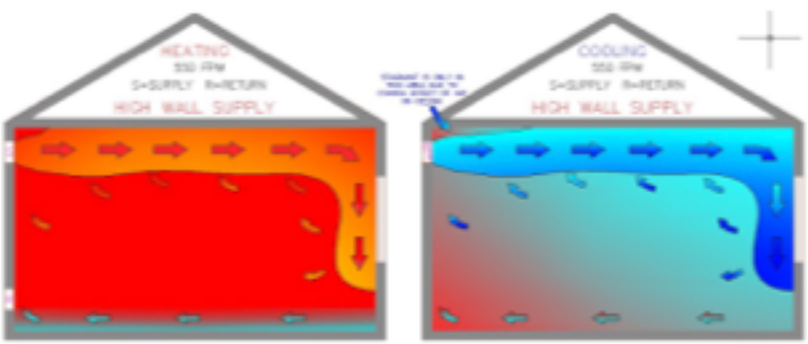
Distribution of Air

Properly sized and located grilles "throw" air to the perimeter windows and walls

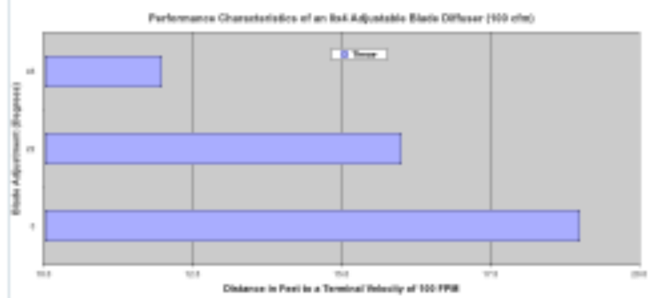




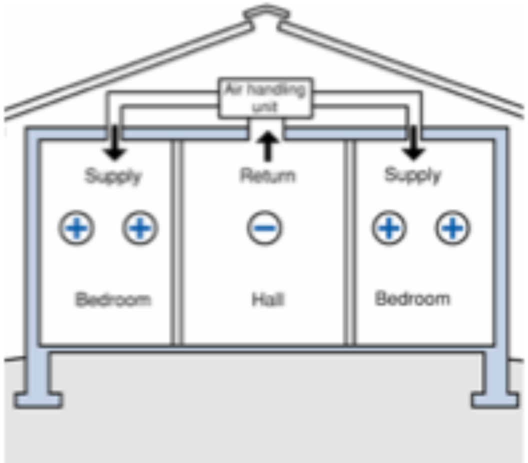
Choose Proper Diffusers with Velocity and "Throw" in Mind



Diffuser selection affects performance



Return Air Paths



Graphics Courtesy of Building Science Corp.

Return Path Options

- Limit room pressures to < 3 Pa
- Individual returns, jump ducts, transfer grilles
- Jump ducts and transfer grilles address privacy, code issues, and "whistling"

Test to validate if you still need them

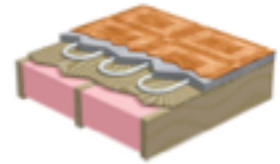
Return Options

Heating / Cooling Equipment Options Summary

Will there be new directions?

- Duct-less systems
- Forced air with zoning
- **Hot water based systems**

There are new choices to consider



- Low loads present Opportunities & Challenges

Integrated Mechanical Systems

- Invest in one good heat source
- Invest in multiple fuel choices
  - Gas
  - Electric
  - Heat pump
  - Solar
- Priority controls
- Great flexibility, adjustments to:
  - Air flow
  - Water flow
  - Water temperature

Combination Systems

Use approved / matched systems

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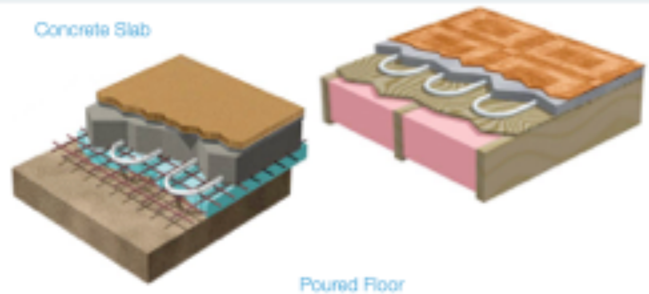
Advantages of Hydronic Heating Pipes

A ½"pipe delivers the same amount of heat as an 8" x 8"duct.

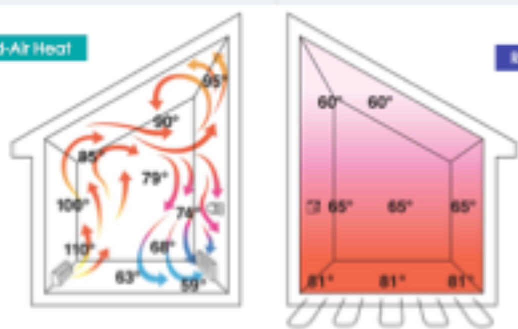
Radiant heating options



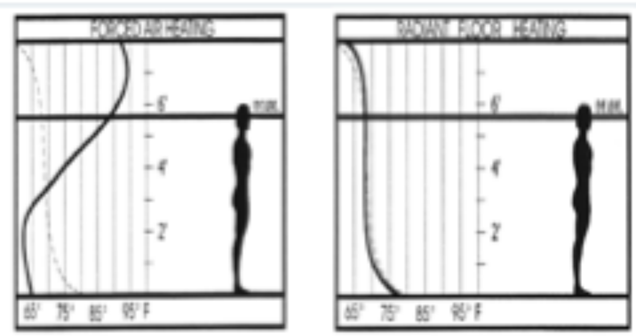
Radiant panels

Temperature Gradients

Forced Air vs. Radiant Floor Temperature Distribution



Forced Air vs Radiant Heating Curves
- A good comfort match



Radiant in-Floor Heat

- Heat surfaces, not air
- Lower noise
- Comfort on concrete floors
- Ideal for basements & "floor warming"
- Requires additional systems for AC, humidity control and filtration

Controls

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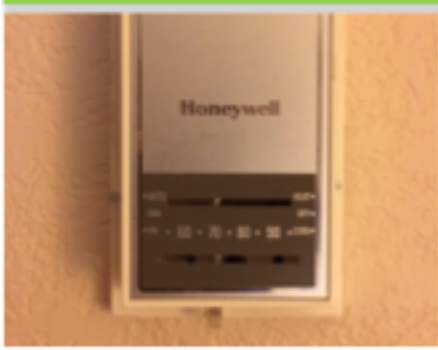
Remember the good old days of controls?



Much Smarter Controls

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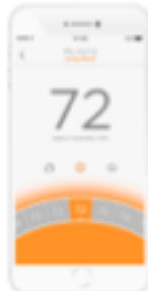
- Programming & integrating functions
  - Fan cycles
  - Humidification
  - Dehumidification
  - Ventilation

Value Proposition to Builders

- Anticipates changes
- Real time diagnostics
- Simplifying choices
- Consistent messages
- Responding to buyer trends
- Learns proper sizing



Verification / Commissioning

What can we test?

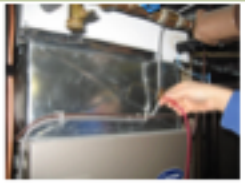
Whole house air leakage
Air leakage from garage, attic etc.
Duct leakage
Room to room pressures
Ventilation & air handler air flows
Air handler performance
Temperature & RH Monitoring
Thermal performance

Simple Testing Can Help

- Verify performance before the Design Day
- 4-5 measurements
- Matched to the design
- Matched to manufacturer's specifications

Test for Performance



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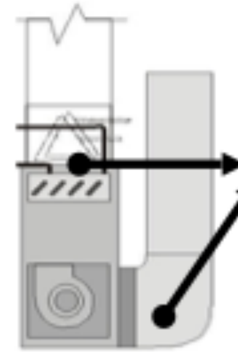
1) Duct pressures

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2) Airflow at air handler


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3) Airflow at diffusers

		Design BTU	Design CFM	Design Friction	Dia.
Bed-3	Heat	1700	31	0.1	4"
	Cool	1366	49	0.1	5"

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4) Refrigerant Verification

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- The right tools
- The right conditions
- The right skills
- New resources are available

5) Temperature rises

For proper cooling, air off the coil should be 4-6 ºF below desired Dew Point

EPA's Indoor air PLUS Program
An excellent opportunity for builders & HVAC contractors

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- Moisture control
- HVAC: heating, cooling, ventilation, filtration
- Combustion and garage isolation
- Commissioning the building
- Radon control
- Pest barriers
- Healthy building materials

ENERGY STAR

+

look for

The ENERGY STAR HVAC Checklist

ENERGY STAR Certified Homes, Version 3 (Rev. 07)
HVAC System Quality Installation Contractor Checklist [1]

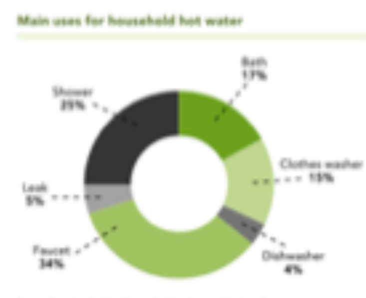
Hot Water

Expectations have changed

Hot Water Expectations have Changed

Hot Water Usage Relevance

- Hot water use is still on its way up
- Wait times are an issue
  - Waste of water
  - Perception of energy waste



Regulations have changed

Minimum 2015 Requirements		Example EF
Gas	Storage: <55 US gal. EF = 0.675 – (gal x 0.0015) >55 US gal. EF = 0.8012 – (gal x 0.00078)	40 US gal = 0.62 60 US gal = 0.75
	Tankless: EF = 0.82–(gal x 0.0019)	Typical = 0.80
Oil	EF = 0.68–(gal. x 0.0019)	50 gal = 0.585
Electric	<55 gal. EF = 0.960–(gal x 0.0003) >55 gal. EF = 2.057–(gal x 0.00113)	40 gal = 0.95 60 gal = 1.98

Hot water is flexible

- In-floor
- Air handlers
- Towel warmers
- Radiant panels
- DHW
- Storage

- Oil
- Gas
- Electric
- Wood
- Solar
- Reclaim

What's the Right Choice?

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- Fuel access?
- Number of people?
- Patterns of use?
- Space / location limits?
- Climate zone?
- Efficiency of the home?
- Other mechanicals?
- Expectations of clients?
- Other?

Water Heaters

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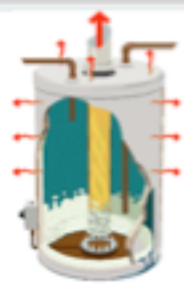

Traditional Tank
EF < 0.60

Tankless = +0.80

Condensing
water heater =0.86

High Efficiency Condensing Gas Storage Water Heater

Strengths

- Direct vent / sealed combustion
- EFs 0.86+ possible
- Very quick recovery times
- Similar foot print as existing storage
- Similar operational characteristics
- Quiet venter motors
- Well suited for "Combo" space & water heating applications

High Efficiency Condensing Gas Storage Water Heater

Design / Installation Considerations

- Vent lengths to outside
- Electric power required
- Typically taller unit
- Access to condensate drainage
- Be sure to compare efficiency ratings against alternatives with similar capacities

Tankless Water Heaters

Strengths

- Low stand-by losses
- EFs from 0.80 to high 0.90's possible
- Wall installation frees up floor space
- Continuous supply of hot water
- Great flexibility
  - Point of use temperature controls
  - Locate supplementary units near point of use
  - Combo space & water heating capabilities
- Safe operation with direct venting
- New technologies reduce wait times - recirc. and internal storage tanks

Heat Pump Water Heaters

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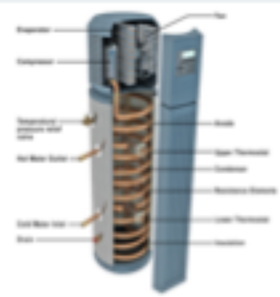
Strengths

- Very high EFs – 2.30+ possible
- Similar foot print as existing storage
- Provides cooling & dehumidification to the space
- Electric back-up
- Particularly useful in "Net zero-energy" homes to complement solar thermal & solar PV.



Solar Thermal Water Heaters

- A great preheat strategy for tankless, storage water heaters & HPWHs – increases their capacity
- 50-60% of annual hot water needs are easily provided
- Excess hot water can be used to heat swimming pools
- Requires freeze protection & annual maintenance

Indoor Environmental Quality

Understanding IAQ

Lets start with outside air

Lets start with outside air

SMOG
Ozone
+
Fine dust

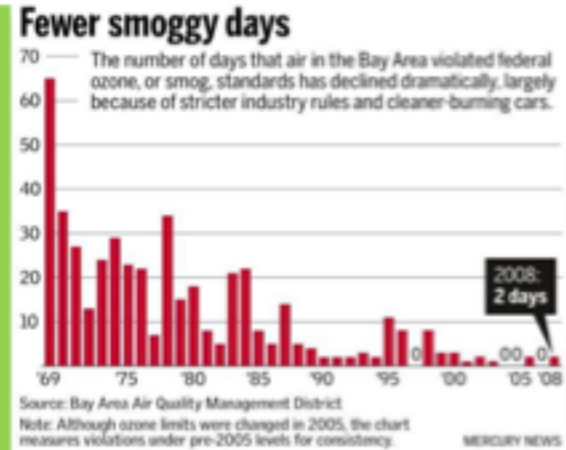
Improvements since the Clean Air Act - 1970's

Current state of indoor air quality control

What could be measured

What devices could be controlled to impact air quality

What impact might be expected



What's Changed since the 1970's

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- What's changed - why is IAQ a bigger issue?
- The Building Science Connection
- Where does ventilation fit into your decision criteria?

Common Pollutants

Building related

Carpet, paints, stains and cabinets

Occupant related

Lifestyle, hobbies, pets and cleaning

Indoor Air Quality is Important to our Clients

20% of households have someone with asthma, allergies or respiratory problems

…poor IAQ may cost 10's of billions annually in lost productivity
EPA

Air cleaners are a $1.2 Billion industry

IAQ…Why is it a bigger issue than ever?

Change in the **way we build**
-Tighter
-More chemicals
-Air conditioning

Change in the **way we live**
-90% of time indoors
-Don't open windows
-More moisture

Change in **products we use**
-Carpets &furnishings
-Cleaners & hygiene
-More "stuff" inside

What is good indoor air ?

Is as fresh and clean as outdoor air

Has no odors (use your nose)

Has fewer pollutants

Healthier to breathe

(The right temperature and humidity)

IAQ Control Strategies

1. **Remove Pollutants**
2. **Source control**
   "Seal" or Isolate
   If you can't remove it find a way to isolate or seal it
3. **Ventilate**
   Dilute pollutants with "fresh" outdoor air
   Point source removal
4. **Filter**

Thank You

High Performance Mechanicals for Houses That Work

End of Module 2

EEBA

Welcome

High Performance Mechanicals for Houses That Work
Module 3

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IAQ Defined

3. DEFINITIONS

acceptable indoor air quality: air toward which a substantial majority of occupants express no dissatisfaction with respect to odor and sensory irritation and in which there are not likely to be contaminants at concentrations that are known to pose a health risk.

This standard does not address specific pollutant concentration levels. It also does not address certain potential pollutant sources such as unvented combustion space heaters and contamination from outdoor sources or from episodic occupant-controlled events such as painting, smoking, cleaning, or other high-polluting events. For information on resi-

ASHRAE STANDARD

Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

Ventilation

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Ventilation - a system or means of providing fresh air.

Webster New Collegiate Dictionary

We used to ventilate with windows, now we don't

All homes need Capacity for Mechanical Ventilation

- To remove common pollutants
- To ensure good indoor air quality for occupants
- To control moisture

Benjamin Franklin

"I am certain that no air is so unwholesome as air in a closed room that has been often breathed and not changed."

We have always needed Ventilation

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"Light and air as means of preserving the health of the occupants of tenements are just as necessary as running water. Dr. H. M. Biggs, an eminent authority on tuberculosis, testified before the Tenement House Commission

The New York Times
Published: October 13, 1901

The Code Connection

IRC Section 303.4
Where the air infiltration rate of a dwelling unit is less than 5 air changes per hour when tested with a blower door at a pressure of 0.2 inch w.c. (50Pa) in accordance with Section N1102.4.1.2, the dwelling unit shall be provided with a whole-house ventilation in accordance with Section M1507.3

Ventilation & IAQ Systems

ASHRAE 62.2 - 2010 - a minimum

Based on occupants & size of home
CFM = (# of beds + 1) x 7.5 + (0.01 x sq.ft.)
OR

Floor Area (sq. ft)	Number of Bedrooms			
	0-1	2-3	4-5	6-7
<1500	30	45	60	75
1501 - 3000	45	60	75	90
3001 - 4500	60	75	90	105
4501 - 6000	75	90	105	120

ASHRAE 62.2 - 2016: Increased Continuous CAPACITY

Based on occupants & size of home
CFM = (# of beds + 1) x 7.5 + (0.03 x sq.ft.)
OR

Floor Area (sq. ft)	Number of Bedrooms			
	0-1	2-3	4-5	6-7
<1500	60	75	90	105
1501 - 3000	90	105	120	135
3001 - 4500	120	135	150	175
4501 - 6000	165	180	195	210

Local Exhaust Ventilation

ASHRAE 62.2 Minimum Exhaust Flow Rate

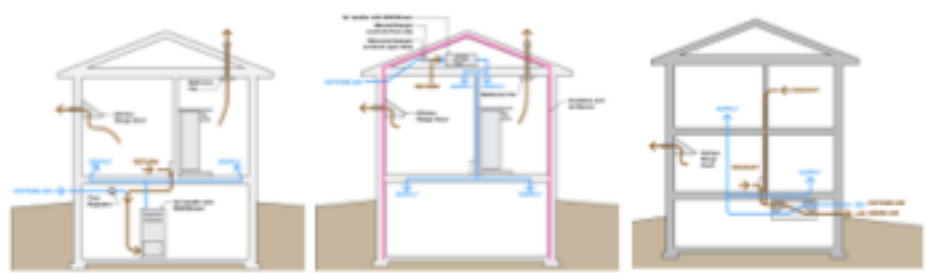
	Continuous	Intermittent
Kitchen	60 CFM	100 CFM
Bathroom	20 CFM	50 CFM

HVI Kitchen Range Exhaust Flow Rate

Location of Range	Recommended per Linear Ft of Range	Minimum per Linear Ft of Range
Against a Wall	100 CFM	40 CFM
In an Island	150 CFM	50 CFM

For Gas Ranges recommend 100 CFM / 10,000 BTUs of burner capacity

Ventilation Strategies



Exhaust Supply Balanced

Ventilation Options

Efficient & quiet exhaust fans

Damper Controlled fresh air intakes

Timer or occupancy controls

Control Strategies for "Continuous" Exhaust

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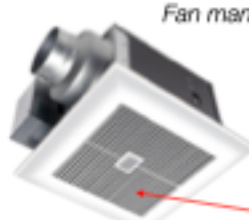
Fan manufacturers have many new, helpful control strategies

- Continuous Low
- High speed occupancy
- Cycle timed



Exhaust fan performance

The importance of Balanced Ventilation

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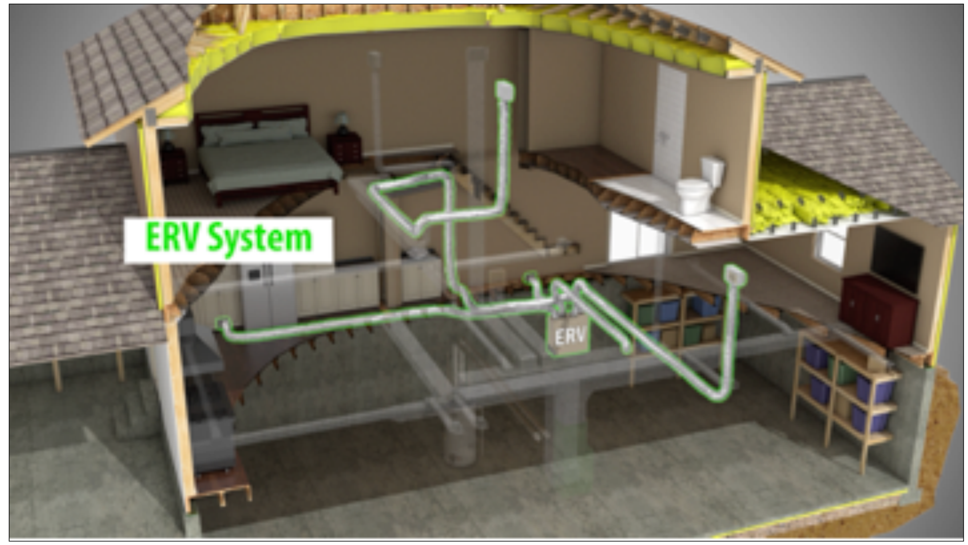
- Air in = air out
- An opportunity for energy recovery
- An opportunity for filtering and distributing fresh air
- Lowers HERs scores
- Lowers heating and cooling loads

Construction Instruction®
Building Science for Everyone, Everywhere

Energy Recovery Ventilator
(ERV) in an Attic
Summer



HRV / ERV Installation Opportunities

- In attics or basements
- Exhaust from areas of poor air quality
- Supply air to bedrooms and main living areas
- Ducting can be independent of other systems OR
- Combine with heating and cooling distribution systems

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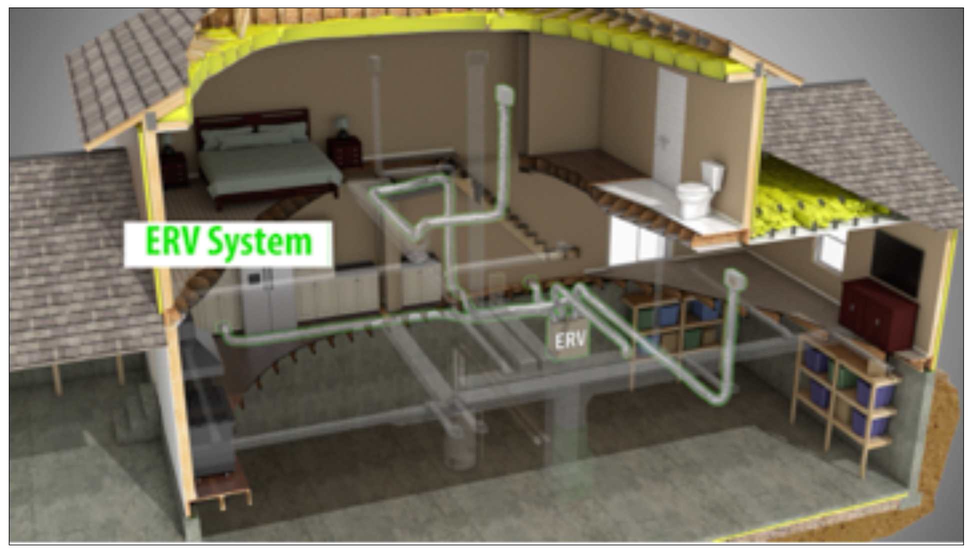
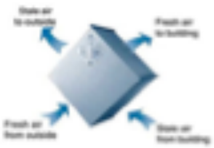


HRV's - ERV's what's the difference?

Heat Recovery Ventilation

- Allows transfer of sensible heat or temperature difference



Poly or Aluminum Core

Energy Recovery Ventilation

- Allows both sensible and latent transfer
- Moisture transfer
  - Reduces cooling loads in humid climates
  - Avoids over-drying in winter

Permeable Core

ERV Technology

All houses, old or new, tight or loose need it

- Properly sized
- Controlled
- Measured flow
- Integrated

The important design and installation detail

- Reduce heating, cooling and latent loads
- Proper duct sizing
- Measure and balance flows

Ventilation Impact on Heat / Cool Loads

75 CFM of ventilation will increase HVAC loads

Cold Weather

At -20 °F

- Ventilation adds 7300 BTUs to heating loads
- Ventilation can remove up to 7 gallons of water per day

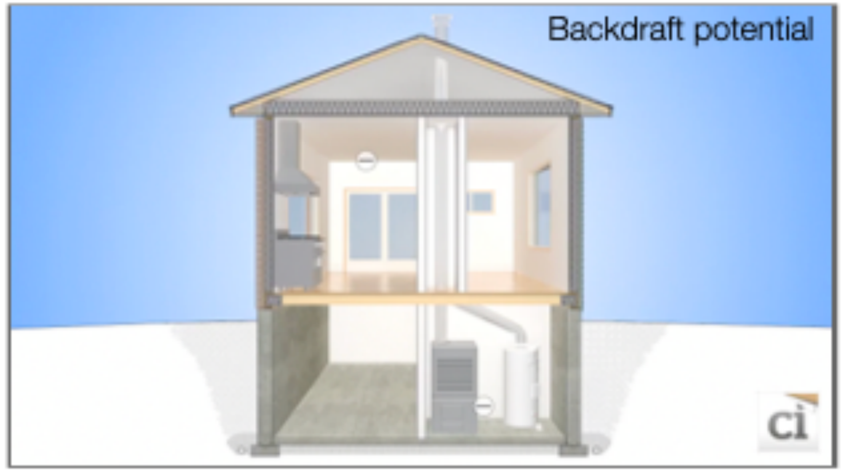
Hot Weather

At 105 °F and dry outside

- Ventilation adds 2500 BTUs (1/5 of a ton) to cooling loads
- At 95 °F and humid
- Ventilation adds 4500 BTUs (just over 1/3 of a ton) to cooling loads
- 2/3 of this load is latent (moisture)

These loads can be reduced by up to 70% through the use of heat / energy recovery technology

Make-Up Air



Two issues

1. Backdrafting of "spillage susceptible combustion appliances
   - 3 to 5 Pa limit
2. Proper operation of the exhaust appliance
   - 25 to 50 Pa limit
   - Know the fan curves of the exhaust appliances

Codes set a prescriptive limit of 400 CFM

Ventilation Impact on combustion appliances
Testing for depressurization

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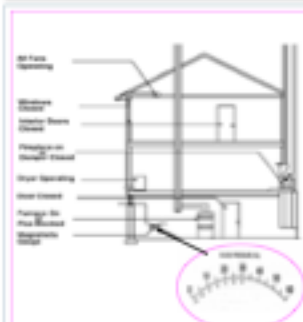

- Specific concern with natural draft appliances; wood burning fireplaces, gas log sets
- Tight houses with large exhausts can cause negative pressure
- Chimneys can overcome -5 Pa (-0.02"w.g.) pressure
- Test and provide make-up air if required

M1503.4 Makeup air required.

Exhaust hood systems capable of exhausting in excess of 400 cubic feet per minute (0.19 m^3/s) shall be mechanically or naturally provided with makeup air at a rate approximately equal to the exhaust air rate. Such makeup air systems shall be equipped with not less than one damper. Each damper shall be a gravity damper or an electrically operated damper that automatically opens when the exhaust system operates. Dampers shall be accessible for inspection, service, repair and replacement without removing permanent construction or any other ducts not connected to the damper being inspected, serviced, repaired or replaced.

M1503.4.1 Location.

Kitchen exhaust makeup air shall be discharged into the same room in which the exhaust system is located or into rooms or duct systems that communicate through one or more permanent openings with the room in which such exhaust system is located. Such permanent openings shall have a net cross-sectional area not less than the required area of the makeup air supply openings.

What about make-up air?

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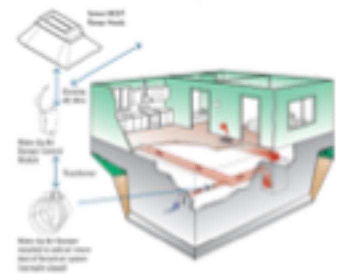
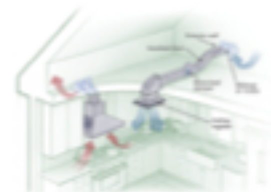
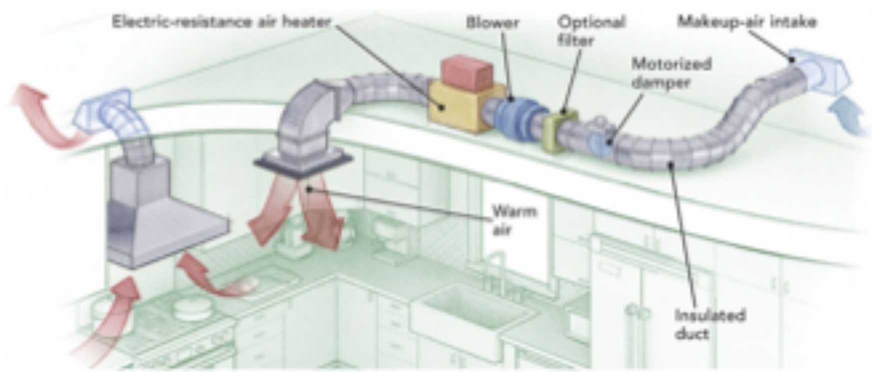
Fan manufacturers have new, helpful strategies



Over 400 CFM ??





What about make-up air?

Filtration

- Final IAQ strategy
- Simple, easy, cost effective
- Clean Air Delivery Rate 1200

Filtration Options

1" – 4" Pleated Filters
- MERV 8-12
- May restrict air flow

1" Electrostatic
- MERV 6-10
- Simple, washable
- May restrict air flow

Electronic Filter
- No MERV ratings
- Good at removing small particles
- Needs cleaning every 6-8 weeks
- May give off small amounts of ozone

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Filtration

Filtration is the 4th of IAQ strategies: Remove, Seal, Ventilate, then Filter

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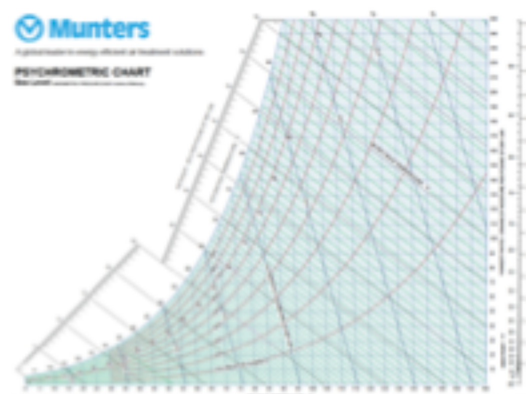
- Filtration at the furnace works and is cost effective
- Commonly located in the return duct of the air handler
- Choose a filter with a rating of MERV 13 or better
- The better the filter, the more it restricts air flow, understand the appliance needs

Psychrometrics

Understanding the Physics of Air:

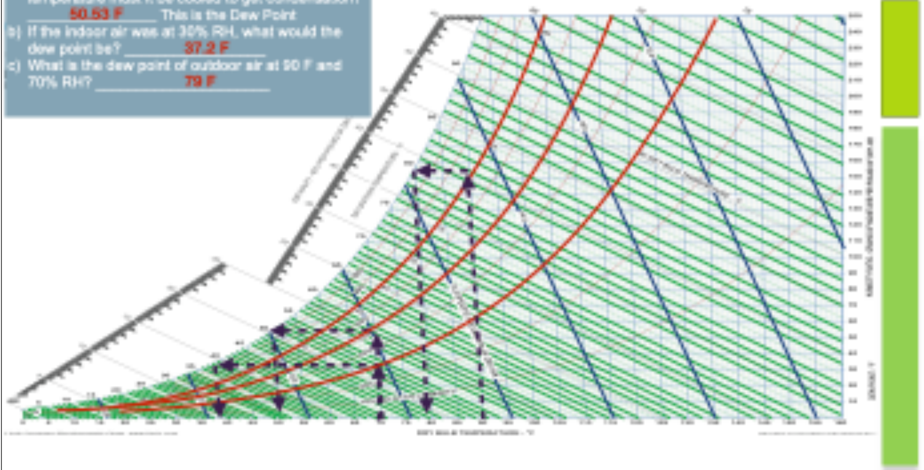
Psychrometric Exercise



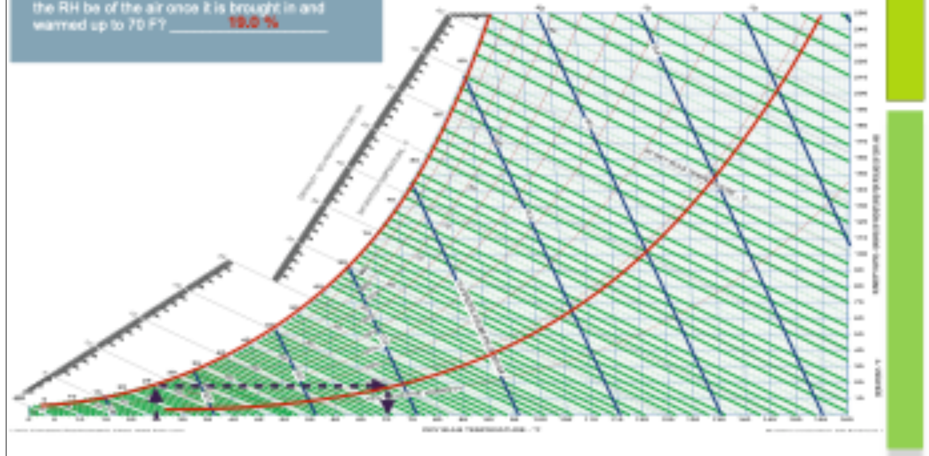
a) If indoor air is at 70 F and 50% RH, to what temperature must it be cooled to get condensation? ___50.53 F___ This is the Dew Point

b) If the indoor air was at 30% RH, what would the dew point be? ___37.2 F___

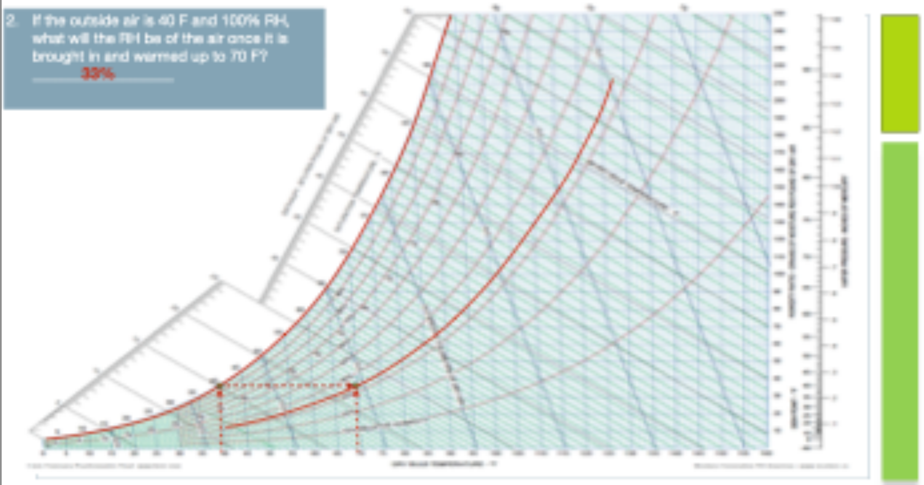
c) What is the dew point of outdoor air at 90 F and 70% RH? ___79 F___



2. If the outside air is 25 F and 100% RH, what will the RH be of the air once it is brought in and warmed up to 70 F? ___19.0 %___



2. If the outside air is 40 F and 100% RH, what will the RH be of the air once it is brought in and warmed up to 70 F? ___33%___

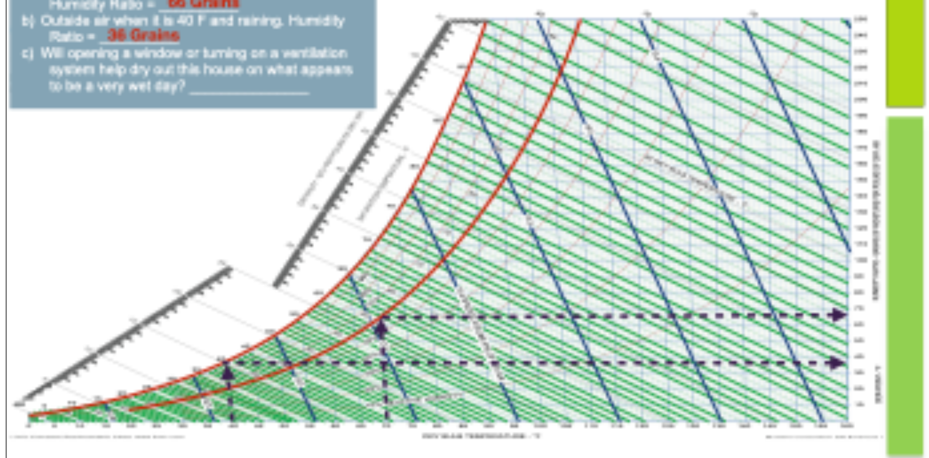


3. Which airstream has more moisture in it:

a) House inside air that is at 70 F and 60% RH Humidity Ratio = ___66 Grains___

b) Outside air when it is 40 F and raining. Humidity Ratio = ___36 Grains___

c) Will opening a window or turning on a ventilation system help dry out this house on what appears to be a very wet day? ______________

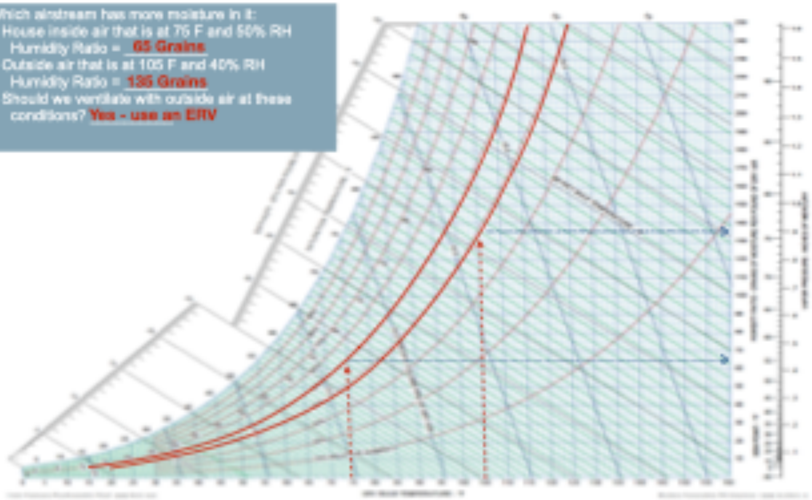


4. Which airstream has more moisture in it:

a) House inside air that is at 75 F and 50% RH
   Humidity Ratio = 65 Grains

b) Outside air that is at 105 F and 40% RH
   Humidity Ratio = 135 Grains

c) Should we ventilate with outside air at these conditions? Yes - use an ERV



Dehumidification

The importance of Dehumidification

Sensible loads are down:
- Better windows
- Better walls
- Better ceilings

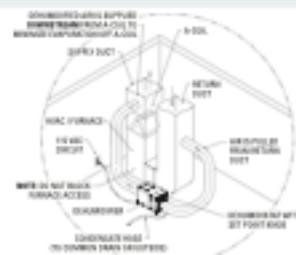
Latent loads are up:
- More time indoors
- More plumbing
- More consistent ventilation

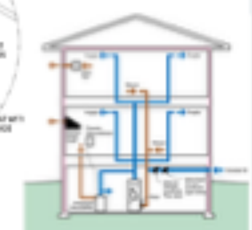
HVAC design must include dehumidification, to supplement air conditioning

Dehumidification Strategies

Strategies:
- 2 stage AC units with humidity controls
- ERVs for ventilation
- Portable dehumidifiers
- Whole house dehumidifiers

Whole House System Advantages:
- High moisture removal capacity
- Up to 120 pints per day
- Can be integrated with AC controls
- May allow downsizing of AC system by 1/2 to 1 ton
- Filtered and drained near the central system





Critical Dehumidification Applications

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- Basements in cold climates for spring and fall
- In hot, humid climates to supplement AC & ventilation loads
- In various climates to aid drying of construction moisture

Whole House Dehumidification will become normal

What's Next?
in HVAC Concepts

Net Zero / Low Load Homes

Typical Specifications

- R50 – R70 Ceilings
- R25 – R35 Walls
- R20 – R30 Basements
- R10 – R15 Under slab
- Triple – glazed windows
- < 1.0 ACH tightness
- Optimized framing

Net-Zero Mechanicals

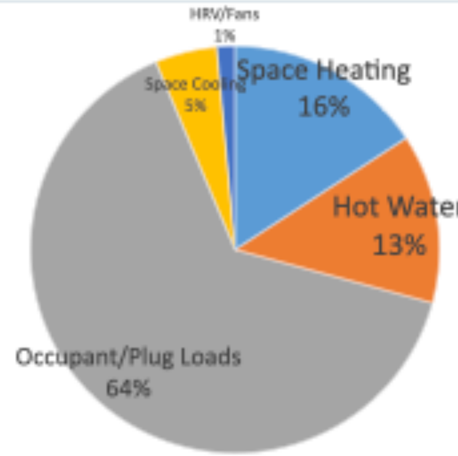
Minimum Specifications

- High Efficiency ERV / HRV
- ECM fan motors
- High efficiency furnace
- Heat pump
- High efficiency water heater
- ENERGY STAR appliances
- LED lights

BIG Questions??
Which fuels?
What's the back-up plan?
What's the control plan?

2030 OBJECTIVE

Average Zero Energy Ready Home uses 40 to 50 MilBTUs/yr



Then

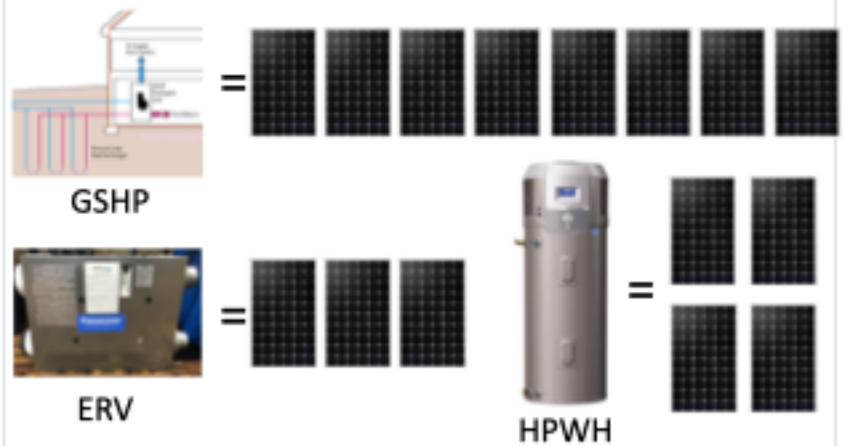
Solar is specified by its peak generation capacity in kWs

A typical Zero Energy project might have a 7-10 kW capacity system

Actual annual output depends on location, orientation, pitch

The goal is to generate that 40 - 50 milBTUs per year
Cost = $25,000 - $30,000

Optimizing the Trade offs to Solar to Get to Zero - One Example

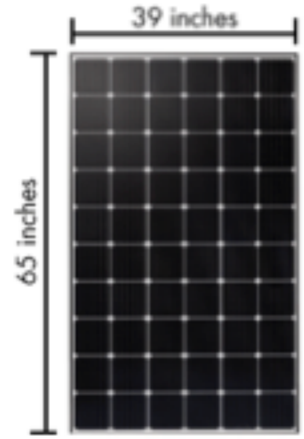


Renewables

They will be normal

Design for roof areas that face SE to West

Work with a solar company to optimize pitch, orientation, efficiency



One Panel Example

At 20% efficient
= 265 watts
= 320 kWh / yr generated
= 1.1 MilBTUs/ yr

At $3 / watt
= $800 installed
= $725 / milBTUs / yr

What did we accomplish?

- Safer
- Healthier
- Comfortable
- Durable
- More efficient
- More affordable

The Elegance of High Performance

The same things that make houses more energy efficient also make them:

- More Durable
- Healthier
- Quieter
- Controllable & Comfortable

Dozens of valuable consumer benefits

What should be on your To Do List?

- Recalibrate sizing
- Look for integrated solutions
- Measure & Test

What Should I Be Doing By Now				
Tasks	**Done**	**This Year**	**3-5 Yrs**	**5-10 Yrs**
All furnaces, waters & gas fireplace DV, PV and/or sealed comb.	☐	☐	☐	☐
94%+ furnaces with ECM / Variable output heating & fan motors	☐	☐	☐	☐
HE water heating – 0.82+ Energy factor	☐	☐	☐	☐
Heat Recovery or Energy Recovery ventilation	☐	☐	☐	☐
Energy Star rated, quiet bath and kitchen fans	☐	☐	☐	☐
"Warm floor" heating where it is needed most –ie. basements	☐	☐	☐	☐
Smaller, properly sized duct work with proper grille selection	☐	☐	☐	☐
18+ SEER AC with dehumidification cycle	☐	☐	☐	☐
Sealed duct work	☐	☐	☐	☐
Dehumidification in basements	☐	☐	☐	☐
MERV 10+ filter effectiveness	☐	☐	☐	☐
High HSPF Air source of ground source heat pumps	☐	☐	☐	☐
Zoned systems	☐	☐	☐	☐
Integrated / remote access / diagnostic controls	☐	☐	☐	☐
Integrated heating and hot water systems	☐	☐	☐	☐
Solar ready homes	☐	☐	☐	☐
Solar water heating	☐	☐	☐	☐
Solar photovoltaics	☐	☐	☐	☐

Key Concepts & Opportunities

- Not if… but when
- Respect the science
- Respect the comfort challenge
- Get the sizing right
- Try new strategies & technologies
- Test for success
- Strategic Partners are key

The EEBA High Performance Builder Certification

- The Houses That Work Building Science workshop
- The HERS Associate Course
- **The High Performance Mechanical Systems course**

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Thank You

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