High-Performance Mechanical Systems: Principles and Best Practices

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NEW DEMANDS ON MECHANICAL SYSTEMS:
PRINCIPLES AND BEST PRACTICES

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NEW DEMANDS ON MECHANICAL SYSTEMS:
PRINCIPLES AND BEST PRACTICES

- Part 1: Intro & the Five Things
- Part 2: Making a Case for High Performance
- Part 3: Basic Service Requirements
- Part 4. Key System Components
- Part 5: Systems That Make Sense

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=> Using building science and a systems approach to guide us towards more robust, high-performance mechanical systems!

OVERARCHING THEMES

- We can and must do better!
  - Challenge ourselves towards better performance
- Existing technology can get us there, but …
  - We need to reduce the focus on products.
  - We must embrace more robust systems.
  - We need improvement in design & execution.
- Together we must find more robust designs, technologies, and processes for the future.

KEEPING OUR EYE ON THE BALL

- Is it possible that we have over-invested in products and under-invested in good design and proper execution?

- Are we not being realistic about the process?
  - Are we investing in risky designs, systems, and materials and hoping for perfect execution?
  - Are we counting on perfect homeowner operation and maintenance?

A GROWING EPIDEMIC: NOTMYJOBITIS

THE FIVE THINGS

- How did we get here?
- What is driving these changes?
- What does it mean for building design and construction practices?

FIVE FUNDAMENTAL CHANGES

- Increase thermal resistance
  - more insulation => less heat flow => less drying!
- Changes in permeability of linings
  - while this may mean less wetting,
  - it also can lead to very slow drying!
- Increased water/mold sensitivity of materials
- Moisture storage and redistribution
- Complex 3-D airflow networks in buildings

FIVE KEY DRIVERS FOR CHANGE

- Demand for Increased Comfort
- Drive for Improved Energy Efficiency
- Interest in Low-Maintenance Homes
- Concerns for Indoor Air Quality
- Rising Cost of Housing

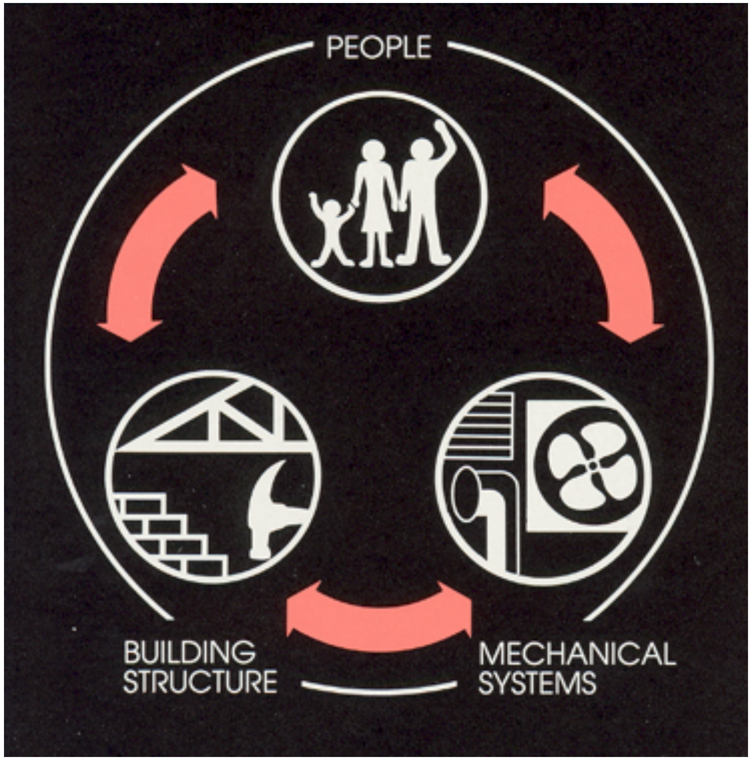
FIVE INEVITABLE TRENDS

- Building Airtightness
- Mechanical Ventilation
  - must include air distribution
- Exterior Control Layers
  - especially insulation and vented cladding
- Ducts in Conditioned Space
  - will drive use of conditioned crawl spaces/attics
- Active Pressure Management
  - integrated make-up air

FIVE CHANGES WE MUST EMBRACE

- Step Back & Take a Broader Systems View
- Demand Performance Over Prescriptive
- Use Building Science, Engineered Approach
- Place a Premium on Robust
- Focus on Total Cost of Ownership

2: A SYSTEMS-GUIDED, PERFORMANCE-BASED APPROACH



- A house is a dynamic system of interconnected parts and components.
- It is driven by the climate, site, indoor conditions, and the laws of physics.
- And depending on how it is designed, constructed, and operated, it may perform …
  - very well,
  - very poorly, or
  - anywhere in between!

Building America Strategy

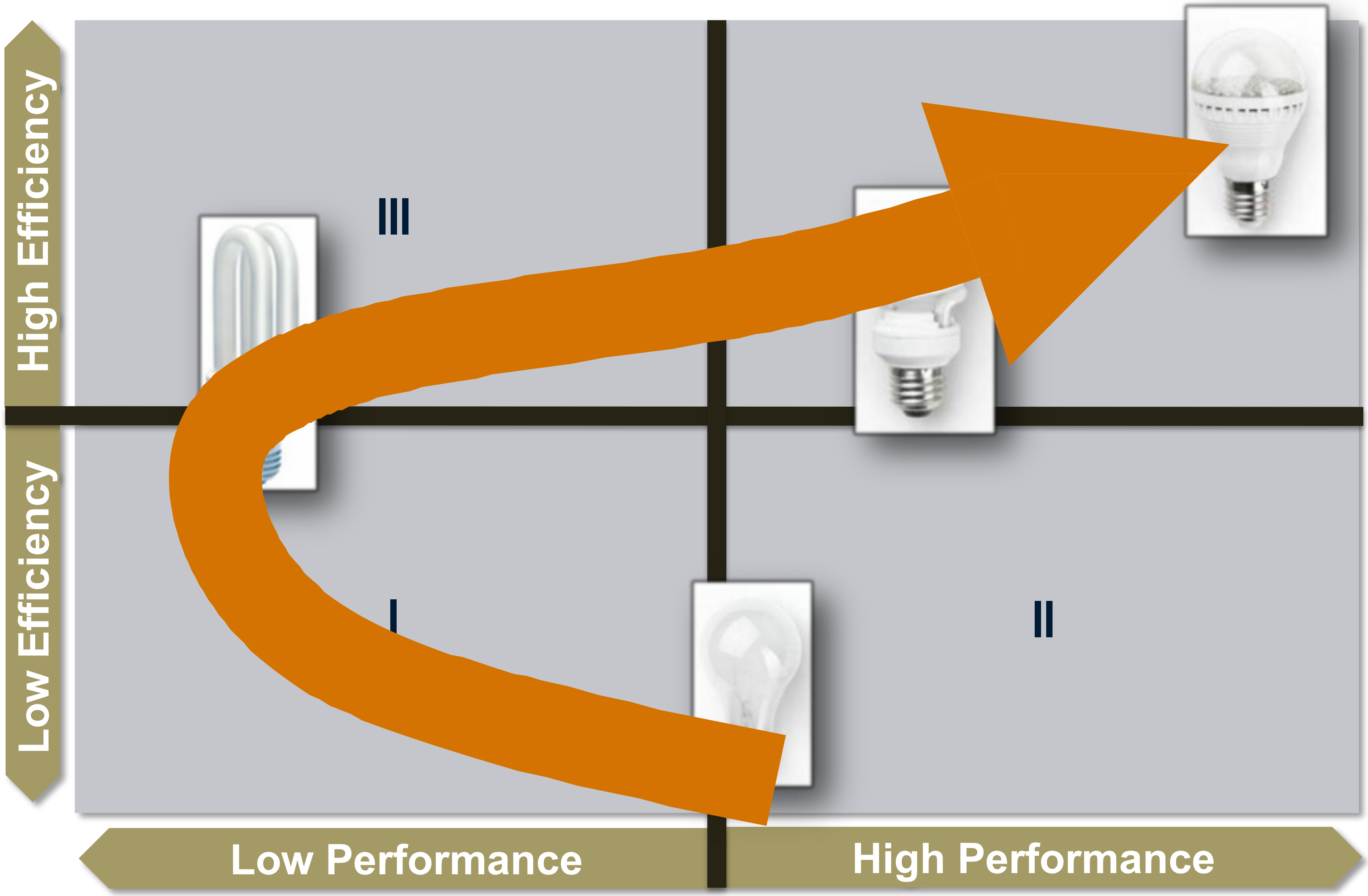
Ultra-High Efficiency

- Enclosure
- Low-Load HVAC
- Components

+ High-Performance

- Affordable
- Comfort
- Health
- Durability
- Renewable Readiness
- Water Conservation
- Disaster Resistance

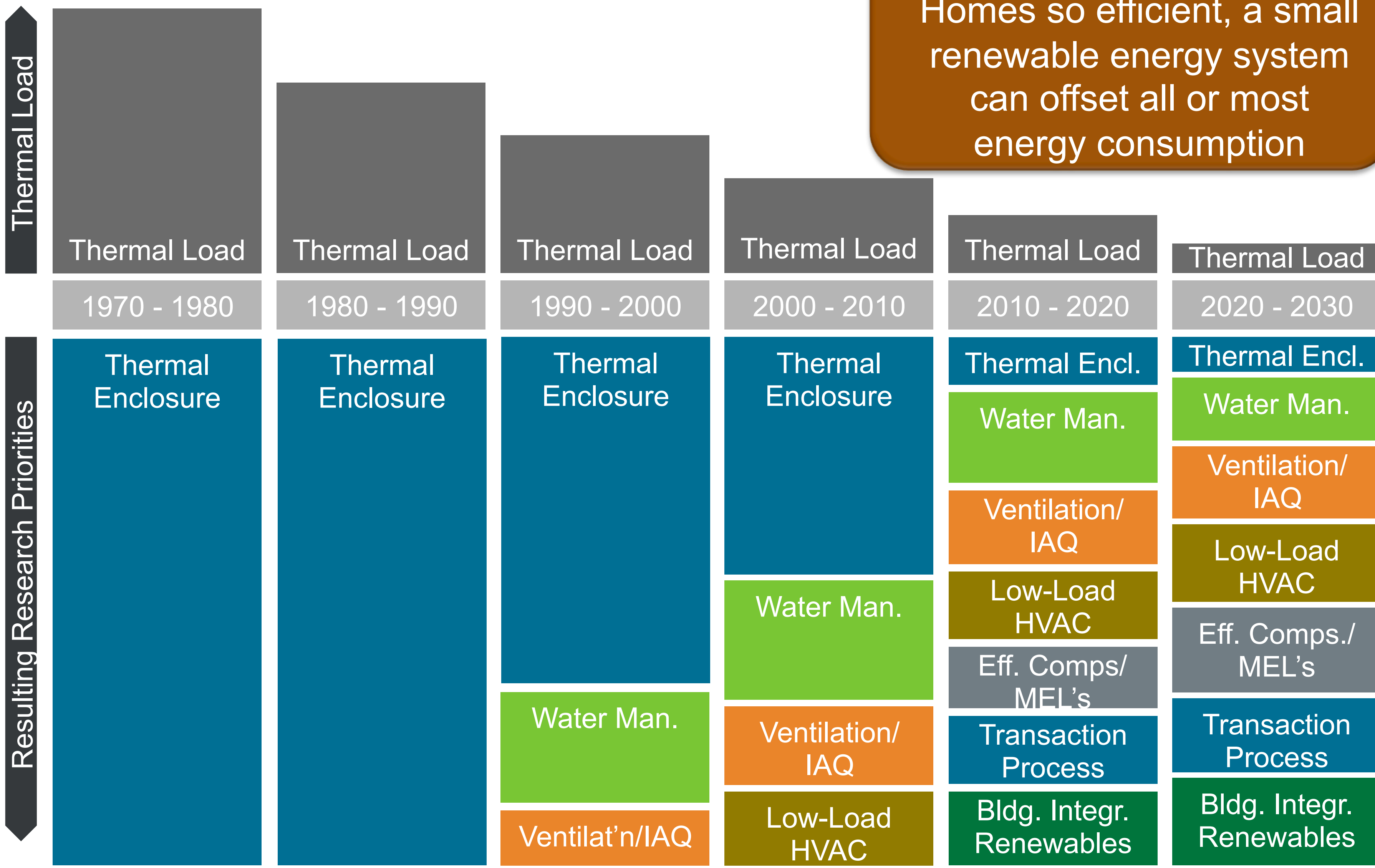
Efficiency + Performance Example



Building America Strategy

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

Goal:
Homes so efficient, a small renewable energy system can offset all or most energy consumption



HIGH-PERFORMANCE HOUSING: MAKING THE CASE FOR ROBUST

- Robust
  - Strong, healthy, and hardy in constitution
  - Built, constructed, or designed to be sturdy, durable, or hard-wearing
  - A system that is able to recover from unexpected conditions during operation

- Things that seem to work regardless what your subs, nature, or client throw at them!

HIGH-PERFORMANCE HOUSING: MAKING THE CASE FOR ROBUST

- Fragile
  - Easily broken; not having a strong structure
  - Unlikely to withstand severe stresses and strains

- Things that make perfect sense on paper, but seem to be “too fickle” to handle the real life situations they encounter.

HIGH-PERFORMANCE HOUSING: MAKING THE CASE FOR ROBUST

- When push comes to shove; will your home's response be robust or fragile?
  - Climate extremes
  - Abnormal interior conditions
  - Execution errors
  - Unusual operations
  - Neglected maintenance

HIGH-PERFORMANCE HOUSING: MAKING THE CASE FOR ROBUST

- Robust: Don’t think of it as a thing, but more of a conceptual way of evaluating new designs, systems, materials, execution, and operation.

- There are a number of ways to think of robust.
  - It is idiot proof, bullet proof, and unlikely to fail.
  - If it fails, it won’t hurt anything else.
  - If it fails, it will be easy to repair or replace.
  - If it fails, there is a planned back-up or redundancy.

MAKING THE CASE FOR ROBUST

- It appears that some designs, systems, materials, and operations are falling short of our performance expectations.

- I believe our mechanical systems are lagging way behind the rest of the high-performance house …
  - in both the technology and delivery system.

MAKING THE CASE FOR ROBUST

- We must ensure our high-performance houses meet our expectations today and in the future?

- High-performance houses will push our current approach. Therefore, we must …
  - design and engineer (not just build) our homes.
  - build forgiveness/tolerance into all systems.
  - build redundancy into critical materials.
    - or make it easy to repair and/or replace key components
  - develop a more predictable delivery system.
  - provide continuous feedback to the occupant.

QUICK TRUE-FALSE QUIZ: SYSTEMS

- You should never pressurize a house in MN.
- Hydronic distribution is inherently more efficient than force-air distribution.
- Particle arrestance is best with a new filter.
- All ventilation must be balanced (per Code).
  - The (whole house) residential mechanical ventilation system must always be balanced.
- In the U.S., domestic hot water is 20% of residential energy consumption.

THE MODERN MECHANICAL CONUNDRUM

- Has typical single zone gas force-air heating and cooling hit the end of the road?
  - continues to be difficult to match peak load
  - part-load can be ineffective and inefficient
  - poor zone comfort for high-performance homes
- Should ventilation (fresh air for people) be an independent system?
  - limited mixing in airtight homes
  - need better distribution to all habitable spaces.

THE MODERN MECHANICAL CONUNDRUM

- Can we justify two independent, high-end, sealed combustion, condensing plants for space and water heating?
  - We probably need to move towards integrated space and water heating systems.
- How are we going to manage pressures (both negative and positive) in our new, airtight homes?
  - Active pressure management is needed now.

3. BASIC SERVICE (MEP) SYSTEMS

- Mechanical System
  – HVAC will be the primary focus for today!
- Electrical System
  – Limited discussion on this one for today!
- Plumbing System
  – Some discussion as it overlaps HVAC!

BASIC SERVICE REQUIREMENTS

- Comfortable Interior Conditions
- Healthy Indoor Air
- Convenient Warm Water
- Limited Building Enclosure Impacts
- Affordability of Systems

INTERIOR SPACE CONDITIONS

- Thermal Comfort (operative temperature)
  - Heating
  - Cooling
  - Humidity
  - Airflow

Note: Acoustical comfort is important, too.

INTERIOR SPACE CONDITIONS

- ASHRAE Comfort Zones
  - Notice the newer humidity limits

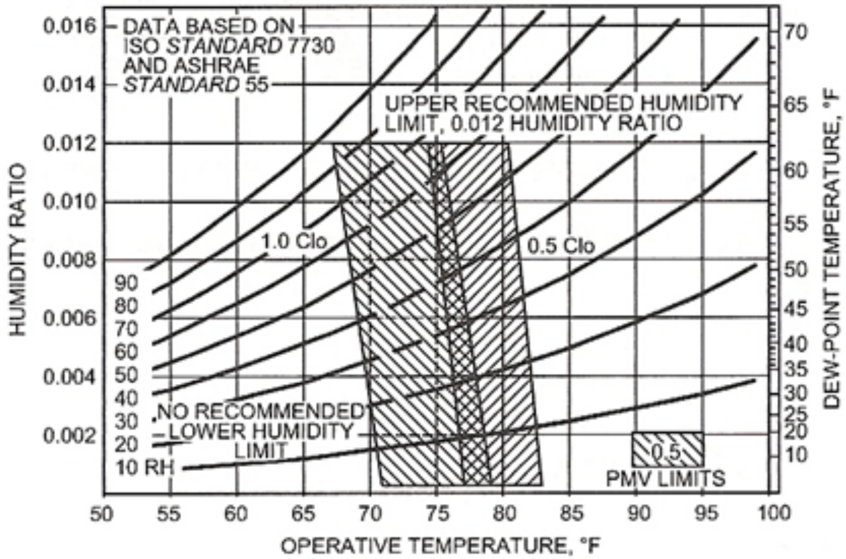


Fig. 5 ASHRAE Summer and Winter Comfort Zones
[Acceptable ranges of operative temperature and humidity with air speed ≤ 40 fpm for people wearing 1.0 and 0.5 clo clothing during primarily sedentary activity (≤1.1 met).]

INDOOR ENVIRONMENTAL QUALITY

- Safe pollutant levels
  - Avoid, encapsulate, and point source control
  - Then general ventilation
- Manage fine particulates
  - Whole house
  - Kitchen range
- Protection against biologicals
  - Humidity control
  - Particle filtration

DOMESTIC HOT WATER

- Safe
  - No backdrafting
  - No scalding
- Comfortable
  - Proper temperature
- Convenient
  - Quick delivery

BUILDING ENCLOSURE IMPACTS

- Manage Pressures
- Mitigate Pollutants
- Prevent Critter Entry

BUILDING ENCLOSURE: PRESSURE

- Optimal Pressures (House wrt Outdoors)

	Winter	Summer
– Building Enclosure	-	+
– Garage Gases	+ (or =)	= (or +)
– Radon (Soil Gases)	+	= (or +)
– Combustion Safety	+ (or =)	+
– Exterior Pollutants	+	+

BUILDING ENCLOSURE: POLLUTANTS

- Soil Gases
  – Radon, water vapor, etc.
- Garage Gases/Particulates
  – Engine by-products, stored chemicals, etc.
- Structural Cavities
  – VOCs, particulates, mold, etc.

BUILDING ENCLOSURE: CRITTERS

- Screens on ventilation hoods
- Filters (inline) on intake air
- Quality dampers
  - Exhaust side of ventilation
  - Kitchen range hood
  - Clothes dryer

AFFORDABILITY OF SYSTEMS

- Pay Me Now or Pay Me Later!
  - Initial (capital) costs
  - Operational (energy) costs
  - Ongoing Maintenance costs
  - Time to replacement
- But Think Beyond Costs
  - Comfort
  - Convenience
  - Competitive edge

4. MECHANICAL SYSTEMS

- Space Conditioning Components
  - Heating
  - Cooling
  - Filtration
  - Humidification/Dehumidification
- Ventilation (whole house & spot)
- Other Key Components
  - Make-Up Air (MUA)
  - Domestic Hot Water

SPACE HEATING

- Fuel Costs
- Key Parts of the System
  - Delivery Approach
    - Forced air
    - Hydronic
  - Plant Choices
  - Controls
- System Costs

SPACE HEATING: FUEL COSTS

- Cost per Delivered Million Btu
  - NG = 10.0 x \$/therm / efficiency

    10.0 x \$0.80 / 0.65 = \$ 12.31

    10.0 x \$0.80 / 0.94 = \$ 8.51
  - LPG = 11.0 x \$/gallon / efficiency

    11.0 x \$1.65 / 0.94 = \$ 19.31
  - Elec = 293 x \$/kWh / COP

    293 x \$0.12 / 1.0 = \$ 32.23

    293 x \$0.12 / 3.2 = \$ 10.07

    293 x \$0.07 / 3.2 = \$ 6.41

SPACE HEATING: COMMON SYSTEMS

- Gas Forced Air
- Electric or Gas Radiant
- Air Source Heat Pump (ASHP)
- Ground Source Heat Pump (GSHP)

SPACE HEATING: GAS FORCED-AIR

- Traditional Single (or Dual) Zone Furnace
  - Most common system used for the past several decades
  - Easily adapted for space cooling
- Current Challenges
  - Proper sizing
  - Poor part-load efficiency
  - Poor space by space comfort and control

SPACE HEATING: RADIANT

- Infloor or Room Radiators/Convectors
  - Electric radiant tends to inexpensive to install and provides easy zoning controls, but quite expensive to operate.
    - high potential for space by space heating comfort
  - Hot water has lost market share, in general, but has seen a small resurgence with high-end clients for comfort-focused spaces.

SPACE HEATING: ASHP

- Traditional Split System
  - Uses an outside compressor/condenser unit with and indoor evaporator coil
  - Provides heating and cooling with a reversing valve to switch the condenser and evaporator
- Ductless or Ducted Mini-splits
  - Similar outdoor unit, but indoor units are located within each space or a unit with limited ducting
  - Improved capacity and high part-load efficiency

SPACE HEATING: GSHP

- Indoor unit looks similar to and functions like an ASHP (or GFA system with an AC coil).
- There must be an outside loop-field
- With desuperheater it can provide hot water
- With proper installation and operation, the GSHP can be efficient and provide competitive operational costs.
- However, initial costs continue to be high.

SPACE COOLING

- To AC or not to AC?
- Natural ventilation can work many days!
  - However, it might have outdoor IAQ issues including pollen, mold spores, and particulates.
  - It can contribute indoor moisture and mold issues, especially with cooler interior surfaces
    - especially materials with soil contact.

SPACE COOLING

- Traditional AC on a GFA Unit
  – Very common, but has similar sizing, zoning, and part-load efficiency issues.
- Ductless (or Ducted) Mini-splits
  – Improved part-load efficiency and better zoning.
- Room (or window) AC Units

SPACE HUMIDIFICATION

- In some instances it is necessary for winter-time comfort in cold climates, especially in
  - houses with very low moisture loads and/or
  - houses with high winter ventilation rates.
- But frequently it can be managed without intentional humidification.
  - If not, it should be a steam humidifier system
  - Or wetted drum/pad w/ exceptional maintenance
  - Or cool mist using clean, distilled water

SPACE DEHUMIDIFCATION

- This is critical in low-load homes, as typical air-conditioning doesn't work.
  - Many times you have latent loads without a sensible load
  - Frequently you need moisture removal under part-load conditions
- It takes 15 to 20 minutes to wet the coil to the point that condensate is being removed.
  - About the same to re-evaporate, though much shorter if the fan runs continuously.

SPACE DEHUMIDIFCATION

- In our climate, it might be possible to downsize the AC and consider reheat to force longer run times.
  - Variable capacity AC can help, too!

- But for best summer humidity control, consider a whole house dehumidifier.

SPACE DEHUMIDIFCATION

- Whole House Dehumidification
  - Since ventilation does not equal humidity control, it is critical to provide systematic dehumidification.
  - Independent control for indoor humidity for condensation, mold, and dust mites
  - Aid in summer comfort
  - Might be able to use a smart, variable output AC with combi space heating.

SPACE FILTRATION

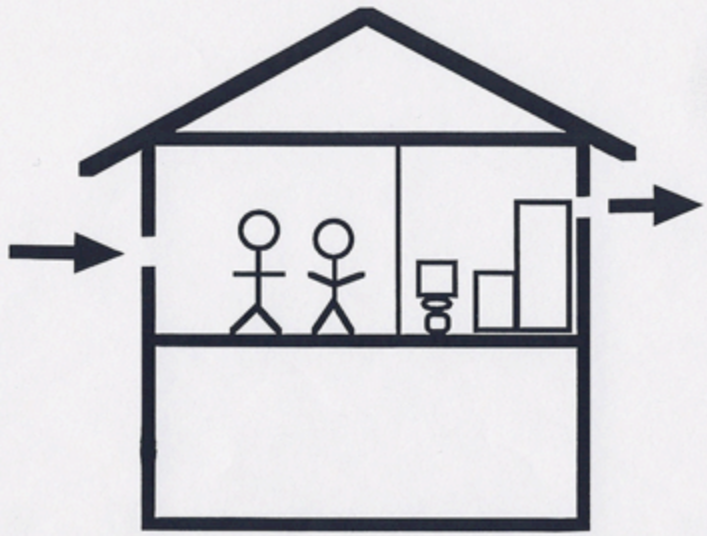
- Pleated media filter
- Electrostatic
- Electronic
- Turbulence

GETTING ON THE SAME PAGE

- For today's discussion, we are going to separate out four specific types of air:
  - Ventilation Air
  - Make-Up Air
  - Combustion Air
  - Circulation Air

VENTILATION AIR

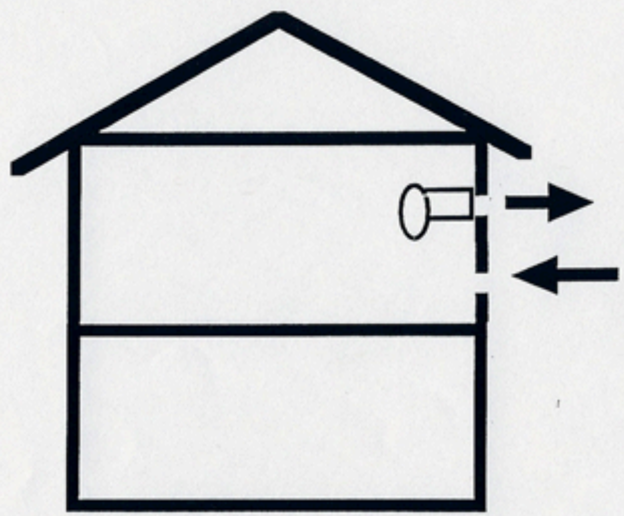
- **Ventilation Air**
  - Replacement, by direct or indirect means, of air in habitable rooms with fresh, outdoor air.



  - Ventilation air is intended to meet metabolic needs, manage indoor air pollutants, and control winter moisture.

MAKE-UP AIR

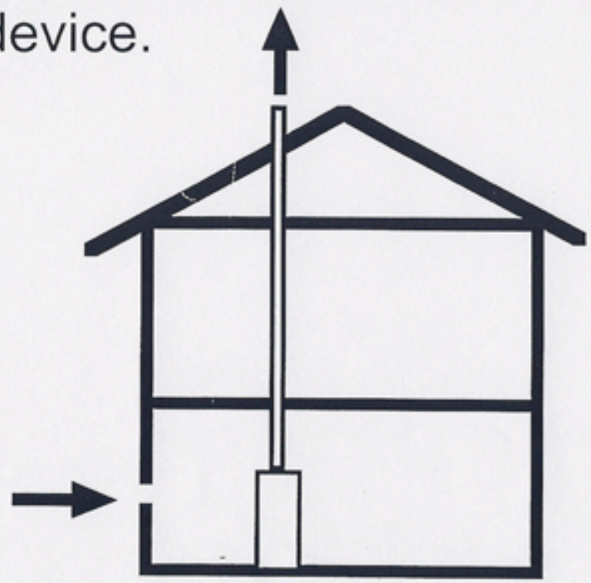
- **Make-Up Air**
  - Outdoor air needed to replace indoor air removed by mechanical exhaust device(s).



  - Makeup air is intended to limit the negative pressure in the home when exhaust devices are in operation.

COMBUSTION AIR

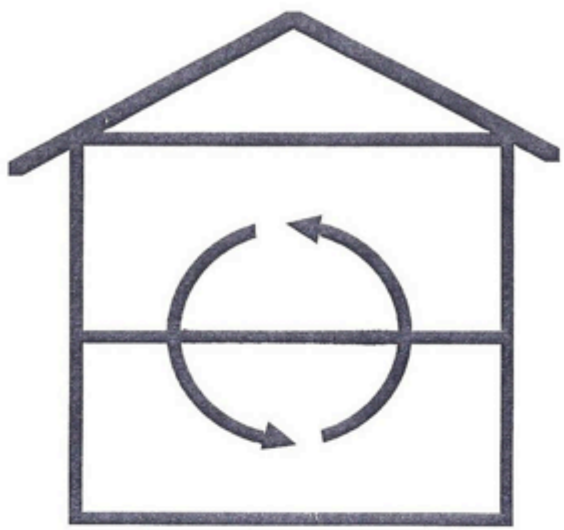
- **Combustion Air**
  - Air from the home (or directly from the outdoors) required to meet the combustion and dilution needs of a vented combustion device.



  - Combustion air is intended to ensure proper combustion and venting of combustion by-products.

CIRCULATION AIR

- **Circulation Air**
  - Air taken from the home and recirculated back to the home using mechanical means.



  - Circulation air is intended to mix the indoor air for improved comfort and to provide more uniform indoor conditions.

VENTILATION BASICS

- A methodical and systematic way of looking at ventilation air (that does include a bit on circulation and make-up air, too).
  - Air in & air out
  - Building pressures
  - Internal flows
  - System operation

VENTILATION 101

- (Bad) Air Out
  - Where is exhaust air picked up?
  - How is air being exhausted (% mechanical)?
- (Good) Air In
  - Where is intake air supplied?
  - How is air being supplied (% mechanical)?
  - Does this air need to be conditioned?

=> ***Ventilation effectiveness*** is all about the "concentration gradient"!

VENTILATION 201

- Resultant House Pressure
  - If the mechanically exhausted and supplied air are not equal …
    - or the exhaust and supply air are not well connected
  - What will be the change in the house pressure?
    - too negative may impact venting, radon, garages
    - too positive can impact winter moisture migration

=> ***Pressure change*** can be profound in tight homes, especially with higher ventilation rates.

VENTILATION 301

- Internal Flow Path(s)
  - What is the path from the supply location to the exhaust location?
  - Does the fresh air flow through the occupied zone?

=> ***Ventilation efficiency*** is all about getting fresh air to people with the lowest possible energy consumption!

VENTILATION 401

- System Controls & Operation
  - Is there a clear indicator when the system is operating properly?
  - Can the ventilation rate be easily increased or decrease as needed or desired?
  - Is the fresh air being distributed to all habitable spaces?
  - Can the system be shut down for maintenance?

=> ***Occupant role*** cannot be an afterthought!

A QUALITY VENTILATION SYSTEM SHOULD:

- Provide a continuous, baseline ventilation.
- Have additional capacity available, when needed.
- Remove exhaust air from areas with highest contaminants.
- Provide the outdoor (fresh) air as clean as possible.
- Supply outdoor (fresh) air to all habitable rooms.
- Not impose serious pressure imbalances on the home.
- Have acceptable thermal and acoustical comfort.
- Be easy to operate and maintain.
- Be cost effective to install and operate.
  - Adapted from the R-2000 Design Guidelines (CHBA – 1994?)

SYSTEM DESIGN & BEST PRACTICES

- Ventilation Flow Rates
- Ventilation Distribution
- Ventilation System Design

VENTILATION RATES

- How much ventilation do you need?
  - Trick question …
    - nobody knows for sure and every house, occupant, and situation would have a very different answer.
- However, …
  - Generally more is better for indoor air quality
    - unless there are external source issues
    - or a serious moisture penalty (generally summer)
  - Generally less is better for energy efficiency
    - unless ventilation also serves as an economizer

VENTILATION RATES

- An important building physics factoid:
  - 1 cfm of exhaust ≠ 1 cfm of balanced ventilation
    - When you turn on a 100 cfm exhaust fan you will get approximately 60 to 70 cfm of new outdoor air.
    - When you turn on a 100 cfm balanced ventilation system you will get 100 cfm of new outdoor air.
  - No codes or standards deal with this difference at this time, but it has clear air exchange, air quality, and energy impacts.

VENTILATION RATES: ASHRAE 62.2-'16

- Whole House Mechanical Ventilation
  Q_v = 0.03 x Floor Area + 7.5 (Bedrooms +1)

- Source Point Ventilation
  - Kitchen
    - on demand: 100 cfm or
    - continuous: 5 ACH
  - Full bath:
    - on demand: 50 cfm or
    - continuous: 20cfm

VENTILATION RATES: BSC-1501

- Whole House Mechanical Ventilation
  $Q_v = 0.01 \times \text{Floor Area} + 7.5\ (\text{Bedrooms} + 1)$

- $Q_{fan} = Qv * Cs$

System Coefficient	Distributed	Not Distributed
Balanced	0.75	1.0
Not Balanced	1.0	1.25

- Source point ventilation similar to ASHRAE

VENTILATION RATES: MN-REC ’15

- Total Ventilation

  Q_{tv} = (0.02 x conditioned floor area)

  + (15 x (bedrooms +1))

- Continuous Ventilation

  Q_{cv} = total ventilation / 2 (but not less than 40 cfm)

- Intermittent Ventilation

  total ventilation – continuous ventilation

- Source point ventilation similar to ASHRAE

MN REC'15: VENTILATION RATES

- The building shall be provided with a balanced mechanical ventilation system that is +/-10 percent of the system's design capacity and meets the requirements of Section R403.5.5, which establishes the continuous and total mechanical ventilation requirements … .
  - Exception: Kitchen and bath fans that are not included as part of the mechanical ventilation system are exempt from these requirements.

VENTILATION DISTRIBUTION: MN-REC ’15

- Ventilation (outdoor) air shall be delivered to each habitable space by a forced-air circulation system, separate duct system, or individual inlets.
  - This is currently unique to MN,
  - But increasingly important as houses get much tighter …
    - because stack and wind forces don’t provide internal air movement and mixing.

VENTILATION DISTRIBUTION: MN-REC '15

- When the ventilation air is being distributed via the forced air system …
  - If the outdoor air is supplied directly to the forced air circulation system, provide a flow rate of 0.15 cfm x conditioned floor area.
  - If the outdoor air is supplied directly to the forced air circulation system, provide a flow rate of 0.075 cfm x conditioned floor area.

VENTILATION SYSTEM DESIGN

- Step 1. Ventilation Type
  - Exhaust-Only
  - Balanced Supply & Exhaust
  - Supply-Only

VENTILATION SYSTEM DESIGN

- Step 2. Exhaust Approach
  – Source => pick-ups in key source points
  – General => pick-ups from central living spaces
  – Volume => pick-up from return duct

VENTILATION SYSTEM DESIGN

- Step 3. Fresh Air Distribution
  – Forced-air circulation system
  – Separate duct system
  – Individual inlets

VENTILATION SYSTEM DESIGN

- Step 4. With or Without Heat Recovery
  - No heat recovery
  - Heat recovery
    - heat recovery ventilator (HRV)
    - energy (enthalpy) recovery ventilator (ERV)
    - heat pumps (to air or water)

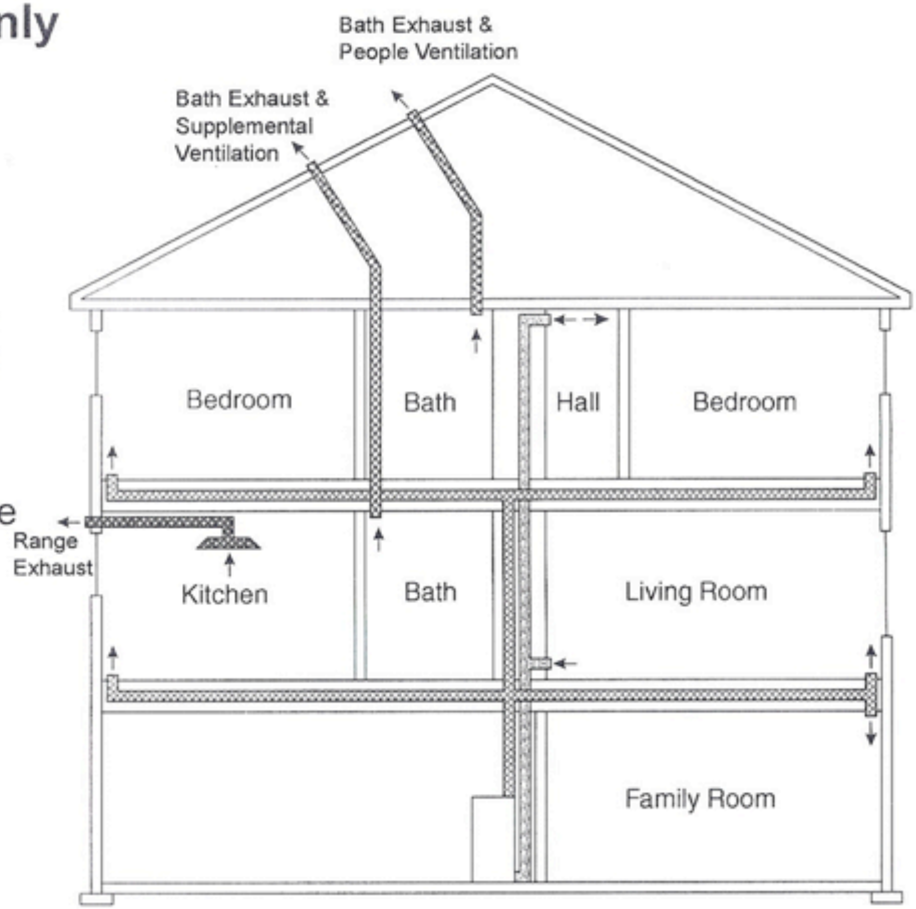
GENERAL VENTILATION DESIGN

- Step 5. Controls
  - Continuous should be continuous
    - but could be turned off when there is no occupancy or windows are wide open
    - does need a shut-off for maintenance
  - Intermittent (high speed or additional fan)
    - generally occupant controlled
    - frequently in source point areas

DECENTRALIZED EXHAUST-ONLY

- 1. Decentralized Exhaust-Only
  - source point approach
  - no heat recovery
  - with forced air

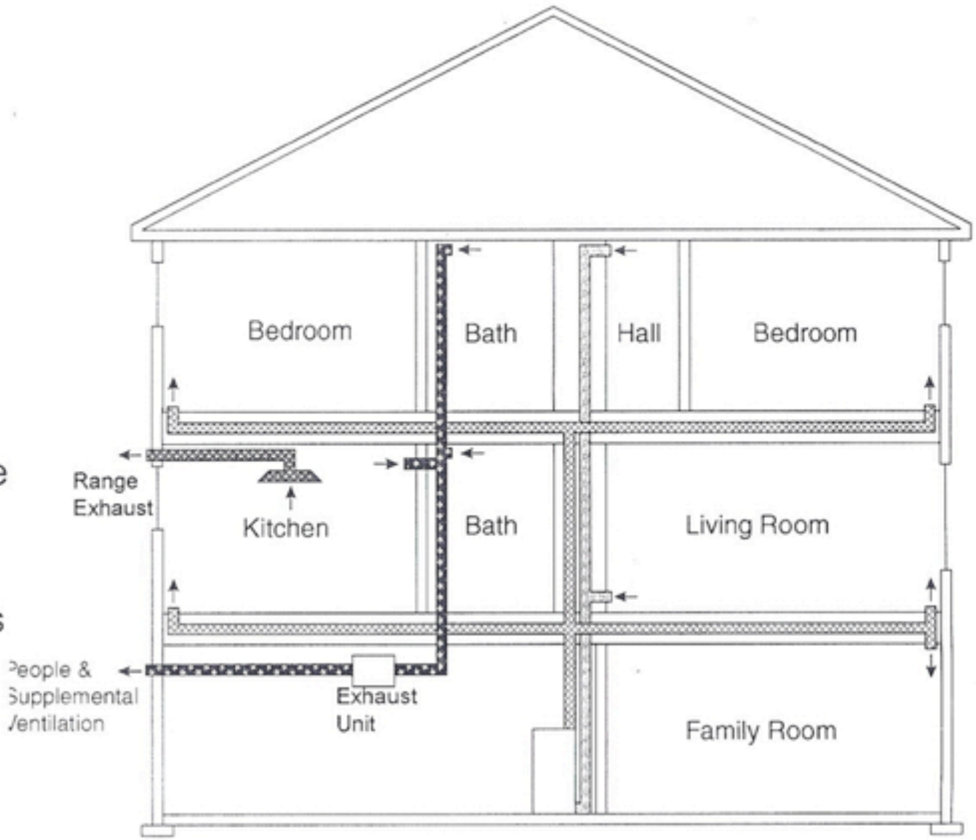
  – This option will depressurize the home and may cause undesired infiltration.
  – The force-air fan must run intermittently to provide adequate distribution of fresh air.
  – All RVS fans must have flow measured and verified.
  – Controls for people ventilation must be clearly marked in a central location.
  – Continuous venting to the roof may cause ice dams.



CENTRALIZED EXHAUST-ONLY

- **3. Centralized Exhaust-Only**
  - source point approach
  - no heat recovery
  - with forced-air

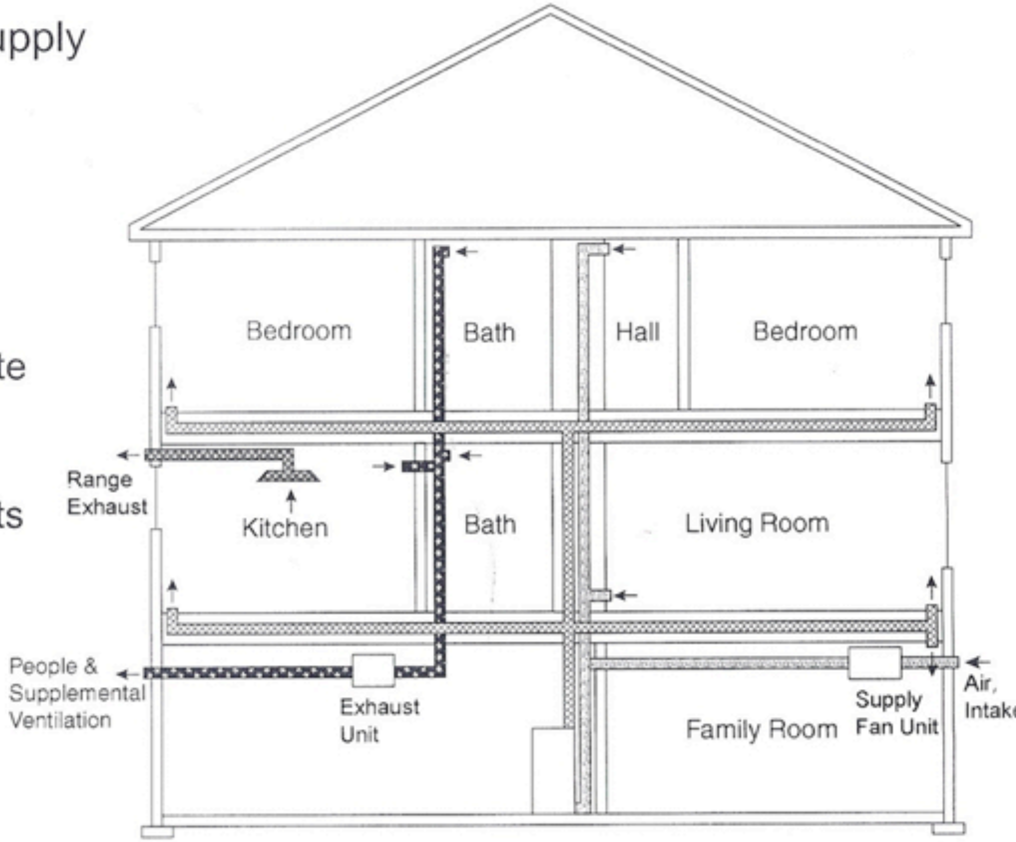
– This option will depressurize the home and may cause undesired infiltration.
– The force-air fan must run intermittently to provide adequate distribution of fresh air.
– This fan must meet both people and total ventilation requirements
– All RVS fans must have flow measured and verified.
– Controls for people ventilation must be clearly marked in a central location.



BALANCED W/O HEAT RECOVERY

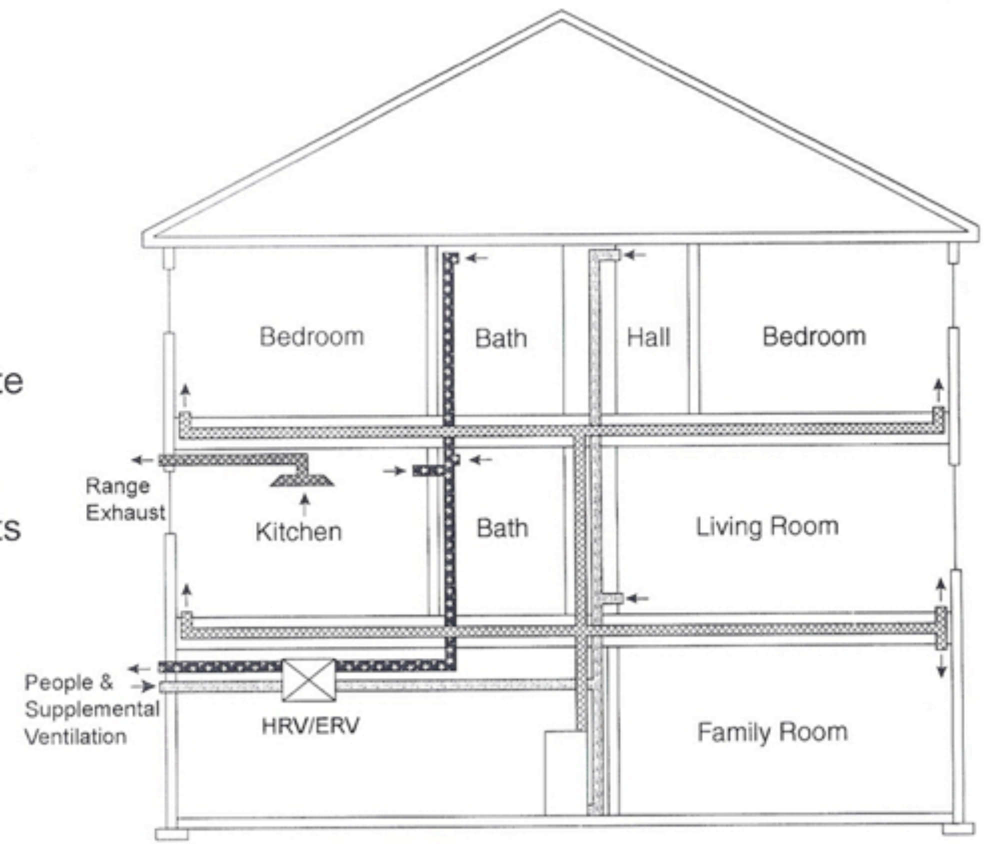
- **4. Balanced**
  - separate exhaust and supply
  - source point approach
  - without heat recovery
  - with forced-air

- The force-air fan must run intermittently to provide adequate distribution of fresh air.
- This fan must meet both people and total ventilation requirements
- All RVS fans must have flow measured and verified.
- Controls for people ventilation must be clearly marked in a central location.
- Supply air may need to be tempered by preheat or blending.



BALANCE W/ HEAT RECOVERY

- **6. Balanced**
    - source point approach
    - with heat recovery
    - with forced-air

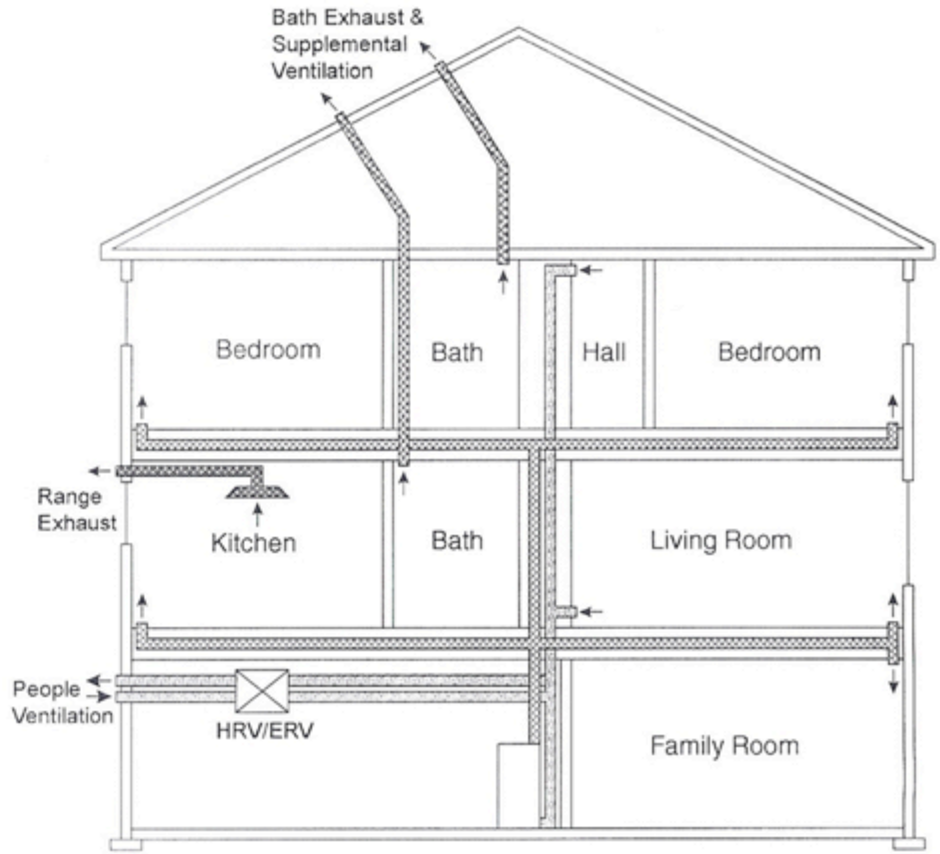


– The force-air fan must run intermittently to provide adequate distribution of fresh air.
– This fan must meet both people and total ventilation requirements
– All RVS fans must have flow measured and verified.
– Controls for people ventilation must be clearly marked in a central location.
– Airflow must be adjusted for defrost & low temp. reduction.

BALANCE W/ HEAT RECOVERY

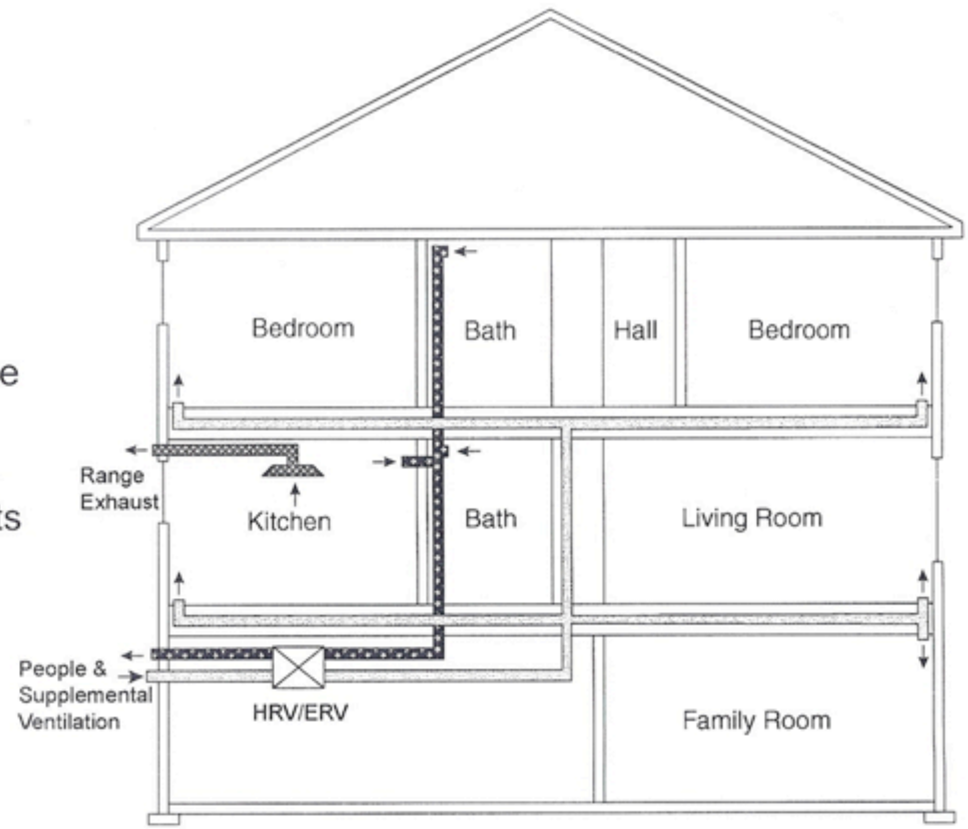
- **8. Balanced**
  - volume approach
  - with heat recovery
  - with forced-air

  - The force-air fan must run continuously to meet ventilation requirements and provide adequate distribution of fresh air.
  - This fan might meet the people ventilation requirements only
  - All RVS fans must have flow measured and verified.
  - Controls for people ventilation must be clearly marked in a central location.
  - Airflow must be adjusted for defrost & low temp. reduction.



BALANCED W/ HEAT RECOVERY

- **10. Balanced**
  - source point approach
  - with heat recovery
  - without forced-air



- The ventilation fan must run continuously to provide adequate distribution of fresh air
- This fan must meet both people and total ventilation requirements
- All RVS fans must have flow measured and verified.
- Controls for people ventilation must be clearly marked in a central location.
- Airflow must be adjusted for defrost & low temp. reduction.

BALANCED VENTILATION: WHY???

- Whole building energy efficiency?
- Ventilation effectiveness and/or efficiency?
- Potential for heat recovery?
- Possible pressure concerns?

BALANCED VENTILATION

- Generally a good idea, but …
- In reality, it is virtually impossible to be balanced (within 10%) at all times.
  - Multiple fans/speeds is a control nightmare
  - HRVs (and most ERVs) have defrost cycles
  - If connected to a forced air system, is it with circulation fan on or fan off?
    - Is the ventilation fan on low or high?

BALANCED VENTILATION

- Also keep in mind all of the other things that aren't balanced?
  - Clothes dryer
  - Kitchen hood/exhaust
  - Other exhaust fans (not part of the ventilation)
- In super-tight homes this might be a reason to keep the ventilation balanced or perhaps increase the supply over exhaust!

BALANCED VENTILATION

- Furthermore, …
  - It may be undesirable to be balanced at all times.
    - ie. when other exhausting devices are operating
  - Balanced total ventilation could be more expensive to install and operate due to …
    - equipment and/or controls
    - oversized/underutilized HRV/ERV
  - May lead to poor system performance
    - increased operation and maintenance issues

VENTILATION TYPE: MN-REC '15

- An HRV or ERV intended to comply with both the continuous and total ventilation rate requirements shall meet the rated design capacity of the continuous ventilation rate specified in Section R403.5.3 under low capacity and meet the total ventilation rate specified in Section R403.5.2 under high capacity.
  - Exception: The balanced HRV/ERV system may include exhaust fans to meet the intermittent ventilation rate. Surface mounted fans shall have a maximum 1.0 sone per HVI Standard 915.

BALANCED HRV/ERV CONTINUOUS W/ INTERMITTENT EXHAUST

- This is a fortuitous exception and good opportunity for …
  – improved code compliance and
  – best ventilation practices.

BALANCED HRV/ERV CONTINUOUS W/ INTERMITTENT EXHAUST

- I would consider this option for:
  - Homes that are large and/or low occupancy
  - Homes with high-production source points
  - Homes with long runs to source points
  - Homes with "iffy" wintertime enclosures

BALANCED HRV/ERV FOR BOTH CONTINUOUS AND INTERMITTENT

- I would recommended this option for:
  - Smaller, high occupancy homes
  - Extremely tight homes
  - Zero energy ready homes

HEAT RECOVERY – GOOD IDEA???

- From an energy perspective it is a must!
  - Though it might only be cost effective for the continuous ventilation.
- However, must include the occupant into this decision.
- Probably better as an incentive, rather than as a requirement.

HRV OR ERV???

- This is not quite as simple as it sounds!
- Strictly from an energy perspective …
  - Generally use an HRV in heating only climates
  - Generally use an ERV in cooling or mixed climates
- But from an indoor humidity perspective …
  - HRV can over-dry a leaky or low H2O load home
  - ERV may not dry down a tight & high H2O load home
- Cost, complexity, and maintenance of these systems vary widely.

VENTILATION SUMMARY

- Balanced continuous ventilation with an HRV/ERV.
- Intermittent ventilation can be balanced or exhaust-only.
- But don't forget the distribution!

OTHER: MAKE-UP AIR

- As houses get tighter and the exhaust flows get bigger, this gets dicey in a hurry!

- Pressure Triangle
  - If we know the house tightness and exhaust flow,
  - It is easy to predict the resultant pressure.
  - For example: 2200 SF House at 2 ACH@50Pa
    - 150 cfm causes -6 Pa
    - 300 cfm causes -18 Pa

DESIRABLE HOUSE PRESSURES (DRAFT)

- Optimal Pressure (House wrt Outdoors)

	Winter	Summer
– Building Enclosure	-	+
– Garage Gases	+ (or =)	= (or +)
– Radon (Soil Gases)	+	= (or +)
– Combustion Safety	+ (or =)	+
– Exterior Pollutants	+	+

OTHER: MAKE-UP AIR

- How much for how long?

- Key equipment concerns
  - Ventilation
    - This can be minimized by using a balanced ventilation strategy for both continuous and intermittent.
  - Kitchen range
  - Clothes dryer

OTHER: WATER HEATING

- Combustion Safety
  - Must be power-vented
  - Preferably two-pipe direct power-vented
- Type
  - Storage tank
  - Tankless

OTHER: WATER HEATING

- Storage Tank
  - Provides instant access to hot water
  - Gives buffer capacity for widely varying draws
  - Easier maintenance

- Definitely would go this way for combination space and water heating
  - Condensing sealed combustion (90+% CAE)

OTHER: WATER HEATING

- Tankless
  - Should be a modulating unit
  - Predictable draws
  - Good water quality

OTHER: WATER HEATING

- Delivery system is very important.
- Insulate the pipes.
- No more than ½ gallon between source (water heater or recirc line) and any fixture.

5. BASE (MINIMUM) SYSTEM

- High-efficiency gas furnace (90% AFUE)
- High-efficiency air-conditioning (13 SEER)
- Deep-pleated media filter (MERV 8)
- Ducted ERV for continuous ventilation rate
- Exhaust-only spot ventilation
  - must meet total ventilation, plus range vent
- Ductless/condensing clothes dryer
- High-EF storage water heater (0.65 EF)

SYSTEMS THAT MAKE SENSE: GOOD

- High-efficiency gas furnace (94+% AFUE)
- High-efficiency air-conditioning (15+ SEER)
- Deep-pleated media filter (MERV 10+)
- Ducted ERV for continuous ventilation rate
- Exhaust-only spot ventilation
  - must meet total ventilation, plus range vent
- Blended make-up air for clothes dryer/range
- High-EF storage water heater (0.68+ EF)

SYSTEMS THAT MAKE SENSE: BETTER

- Multi-head ducted VRF mini-split ASHP
  - High efficiency heating and air-conditioning
- Deep-pleated media filter (MERV 10+)
- Ducted ERV for continuous ventilation rate
- Exhaust-only spot ventilation
  - must meet total ventilation, plus range vent
- Blended make-up air for clothes dryer/range
- High-EF storage water heater (0.68+ EF)

SYSTEMS THAT MAKE SENSE: BETTER

- Integrated space and water heating system
  - 92% CAE condensing, storage-tank hot water
  - Fan-coil with ECM motor & 3 row hot water coil
  - Deep-pleated media filter (MERV 10+)
- ASHP (17+ SEER) using fan-coil unit
- Fully ducted two-speed ERV
  - continuous & total ventilation rate
- Tempered make-up air for dryer & range
- On-demand recirc hot water distribution

SYSTEMS THAT MAKES SENSE: ???

- Ground-source heat pump (COP 3.6+)
  - Water to air
  - Desuperheater for hot water (DHW + radiant)
  - Zoned cooling designed for dehumidification
- Deep pleated media filter (MERV 10+)
- Fully-ducted, two-speed ERV
- Tempered make-up air for dryer & range
- On-demand recirc hot water distribution

FINAL NOTES & CAUTIONS

- High-performance houses will require new enclosure strategies and systems:
  - Higher insulation levels
  - Improved water, air, and vapor control layers
  - Better drying strategies
  - More robust delivery systems

FINAL NOTES & CAUTIONS

- High-performance enclosures will demand a new approach to the mechanical systems:
  - Integrated systems approach to low-load HVAC +DHW
  - Increased attention to indoor air quality
    - source control
    - ventilation
    - filtration
    - distribution
  - Improved make-up air solutions

MUST HAVE RESOURCES

- BSI-039: The Five Things
  - Joseph Lstiburek
- BSI-022: The Perfect HVAC
  - John Straube
- BSI-016: Top Ten Issues in Ventilation
  - Armin Rudd
- BSI-017: Solving IAQ Problems
  - Joseph Lstiburek
- BSD-113 Ground Source Heat Pumps
  - John Straube

HIGH PERFORMANCE ENCLOSURES: PRINCIPLES AND BEST PRACTICES

- Your New Partners
  - Home Energy Raters
  - Home Performance Consultants
  - Other Resources
    - Building America

HIGH PERFORMANCE ENCLOSURES: PRINCIPLES AND BEST PRACTICES

- DOE Building America Resources
  - General Energy Information (EERE)
  - DOE Zero Energy Ready Home (ZERH)
    - Tour of Zero
  - Top Innovations "Hall of Fame"
  - Building America Solution Center

Your one stop shop => BASC.energy.gov

- Discussion & Questions

Contact Information

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