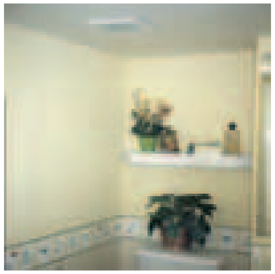
Healthy and Affordable Housing: Practical Recommendations for Meeting Your Ventilation Requirements

READ THIS

BEFORE YOU VENTILATE



Residential Ventilation:
Too Little, Too Much, or Just Right?

The Building America Experience

Building Your Home - Questions

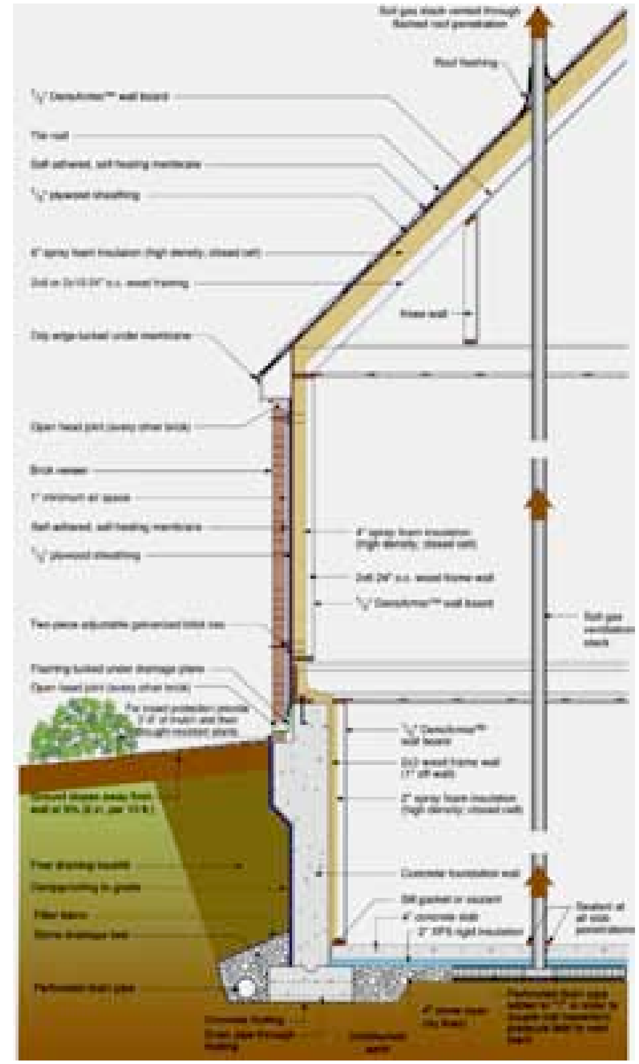
- How do you build the enclosure?
- How should you condition the enclosure?
- How should you ventilate the enclosure?
- How do you do the above and save energy?

These questions are inter-related, yet we attempt to answer them separately

- The Building America is an applied research program designed find answers
- Objective - Promote system engineering to improve home performance while reducing energy use

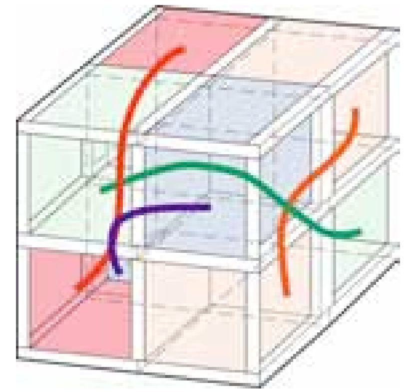
Context is Important

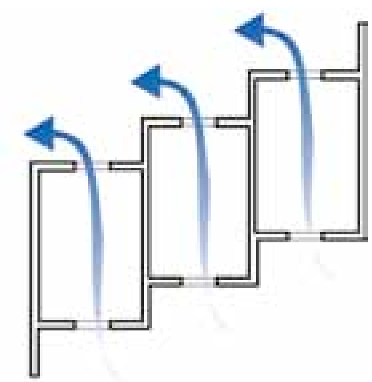
- What is the function of that home?
  - It is an environmental separator
  - It separates the inside from the outside
  - Creates conditions inside that the homeowner can control
  - Allows the homeowner to bring in the outside when desirable, but to exclude the outside when necessary



Context is Important

- In order to control the air, you must first enclose the air
  - An enclosure is constructed
  - This enclosure provides closure for all six sides of the cube
  - Openings in the enclosure should be intentional
    - Doors, Windows, Exhaust vents, Outside Air Intake

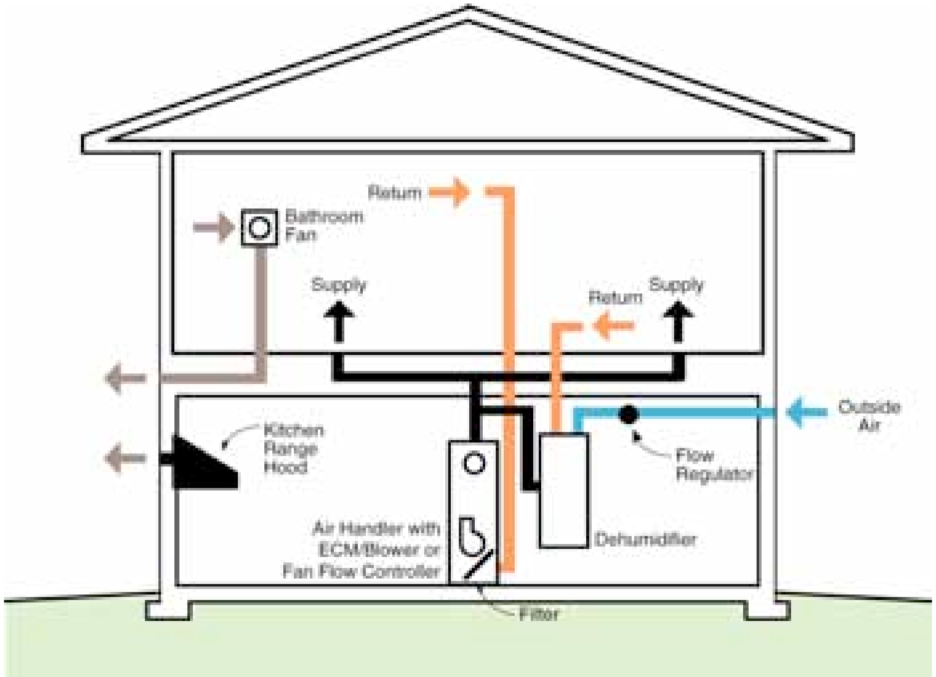




Staggering rooms or using wing walls increases ventilation through rooms oriented north to south

Context is Important

- Air brought into the the home can then be……..
  - Heated
  - Cooled
  - Humidified
  - Dehumidified
  - Cleaned, Filtered
  - Distributed, Mixed



- Energy is spent in the process

Indoor Air Quality Is More Than a Fan and a Filter

- The mechanical system matters…..
  - Just as we don’t want the HVAC system to be a contaminant source (drain pans, dirty filters)………….

Indoor Air Quality Is More Than a Fan and a Filter

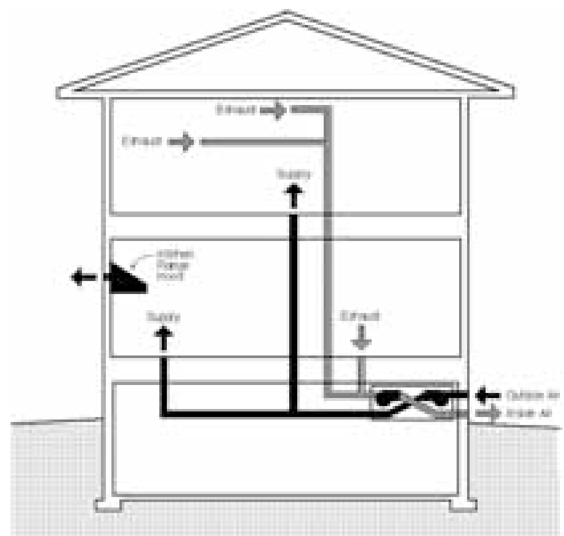
- The enclosure is part of the solution
  - We don’t want the enclosure to be the contaminant source (moldy buildings)

Different Systems for Different Climates

- Closure Design
- Conditioning System Design
- Ventilation System Design

How Do You Ventilate?

- How much outside air do you need?
- How do you distribute it throughout the house?
- How do you clean it?
- Do you add moisture or subtract moisture?



According to ASHRAE 62.2

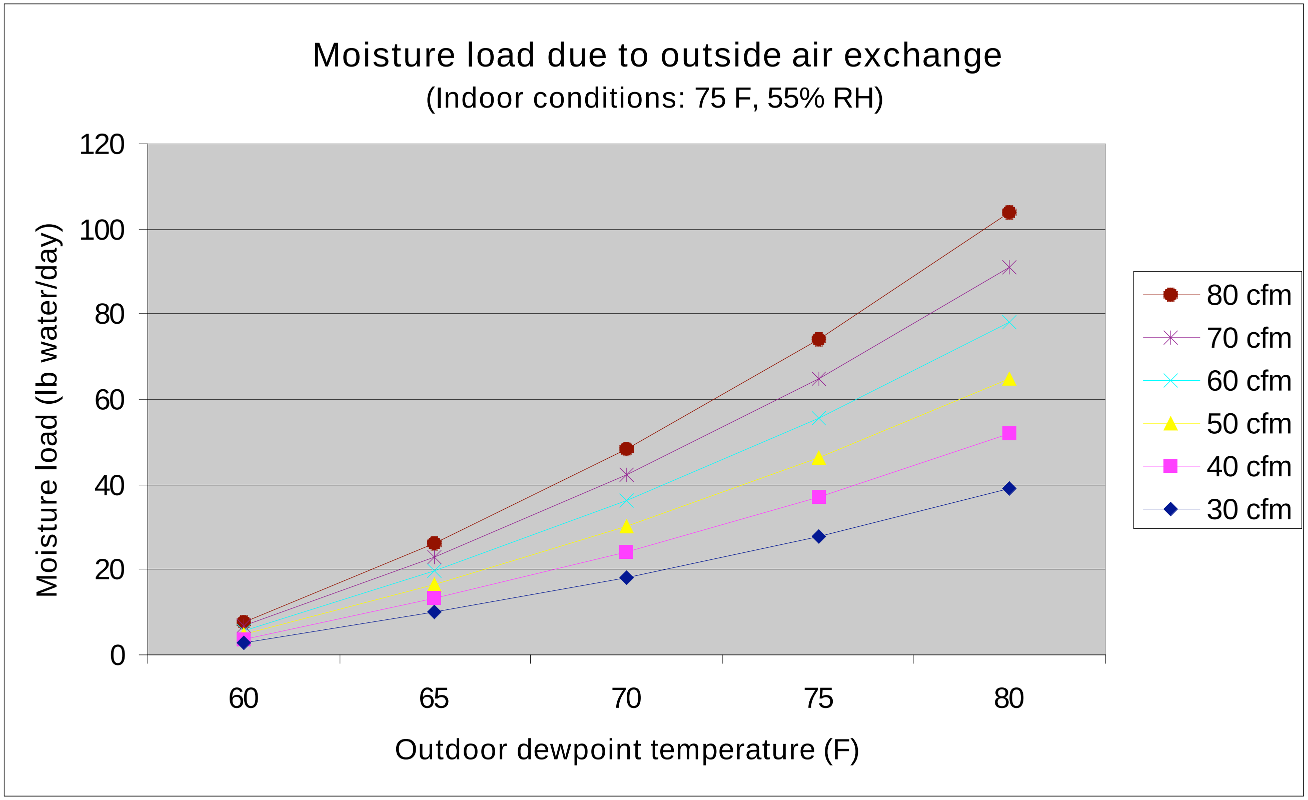
- The same amount everywhere, every climate
- Big houses need more air than smaller houses
- Selecting materials does not affect the rates under current thinking
  - This will change as we learn more in the future
- We assume the enclosure are equally leaky everywhere regardless of age

Bringing in Humid Air Can Be a Problem

- Humidity is not a pollutant-but can create one
  - It takes energy to dry air
  - This energy used to come from building inefficient enclosures and using inefficient equipment
  - Now with good glass, good insulation, good lights, good appliances, we don't have enough heat available to run the A/C to dehumidify

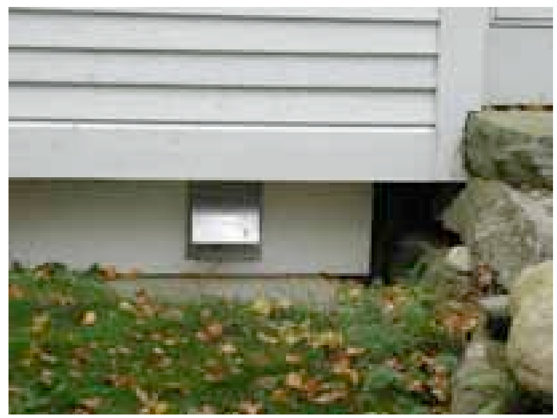
Bringing in Too Much Humid Air is a Problem

- Over-Ventilating Energy Efficient Buildings during spring, summer, and fall leads to mold



Bringing in Outside Air Can Be Expensive in Terms of Energy

- We do not want to bring in more than we need
- If we build a perfectly tight enclosure and eliminate uncontrolled air leakage,the above is possible



Establish Enclosure Tightness

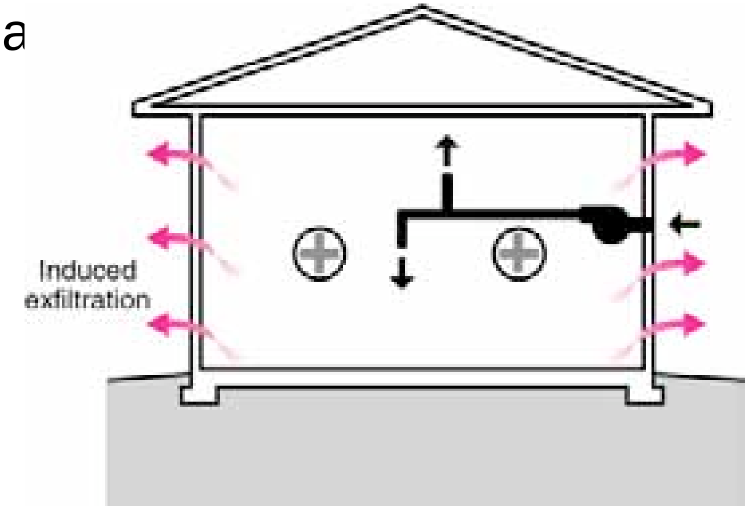
- Same metric everywhere
  - What metric?
- Not too tight, not too leaky, just right (depends on ventilation system choice
  - Trial and error
- Between 2 and 3 ach@ 50 Pa
  - Leakier than the Canadian R-2000
  - Tighter than the typical American home
  - Achievable- Over 16,000 built to this standard under this program

Establish Enclosure Tightness

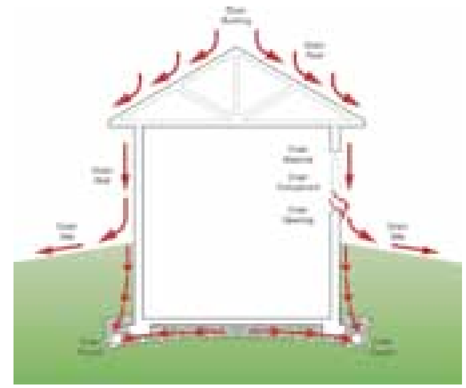
- On energy side, not much difference between 1 ach@ 50 Pa and 3 ach@ 50 Pa
- The controlled ventilation number we use (ASHRAE 62.2) dominates
- Any tighter standard cannot be practically achieved by the current industry, trade, and technology basis

Establish Enclosure Tightness

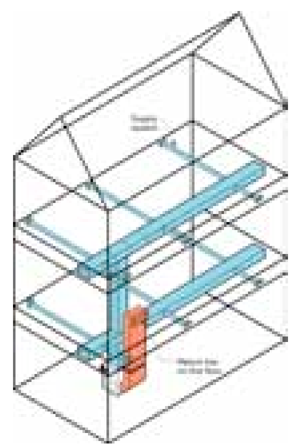
- Supply ventilation at 62.2 rates is able to achieve positive pressurization (between 1 and 2 Pa) when enclosures are constructed to this tightness metric
  - .25 cfm/sq. ft. of enclosure area as tested under pressurization at 50 Pa
  - 2.5 inches of holes/100 sq. ft. of enclosure area (at 10 Pa-CGSB method)
  - 1.25 inches of holes/100 sq. ft. of enclosure area (at 4 Pa - ASTM method)

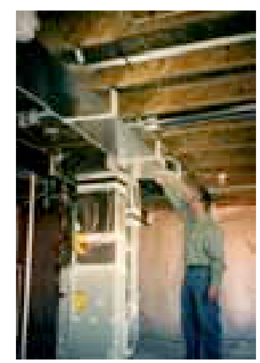


Other Criteria



- Practice Source Control
  - Moisture metric
    - Design to exclude water
    - Design to dry should it get wet
  - Combustion Appliances
    - Uncoupled from the conditioned space
    - Dedicated combustion air
    - Power-vent exhaust of combustion products
  - Spot Ventilation
    - Baths, kitchens, points of pollution generation
  - Control Duct Leakage
    - All ducts must be tight
    - Duct must be located within the conditioned space so they don't leak to the outside





Purposes of Mechanical Ventilation

Point-source ventilation - Remove Pollutants

- exhaust fans: kitchen, bath, laundry, trash rooms

Whole-building ventilation - Dilute Pollutants

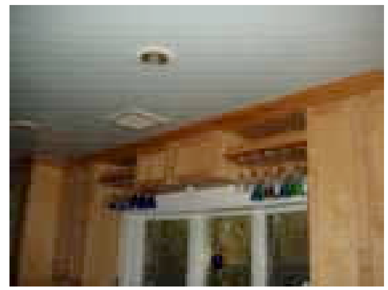
- supply, exhaust, or balanced fans distributing to all rooms

How Much Do you Need?

- ASHRAE 62.2
  - 7.5 cfm per person based on number of bedrooms plus one
  - plus .01 cfm per sq. ft.
    - Example- A three bedroom 1500 sq. ft. house would take ;
      - 7.5 x 4 plus 1,500 x .01 = 45 CFM
    - Example - A three bedroom 10,000 sq. ft. house would take:
      - 7.5 x 4 plus 10,000 x .01 = 175 CFM

Dealing With Specific Pollutant Sources

- Provide exhaust fans at pollutant generation location that can be run when required
  - Example - Bathroom Fan
    - Kitchen exhaust hood
    - Fan in Trash room
- These fans have off-on switches and/or timers



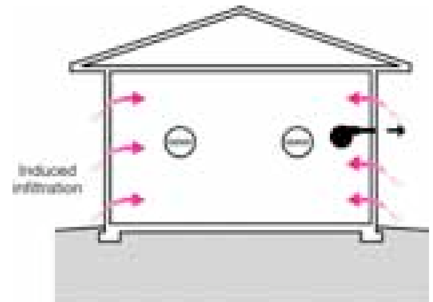
Dealing With Temporary Occupancy Loads

- Design system to boost the existing supply ventilation - approximately twice required amount
  - Example - The 1,500 sq. ft. house that required 45 CFM continuously, would have the ability to be boosted to 90 CFM
  - Example - The 10,000 sq. ft. house that required 175 CFM continuously, would have the ability to be boosted to 350 CFM

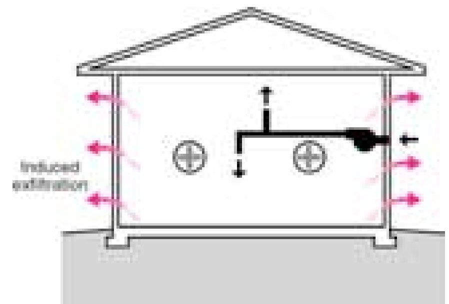
Controlled Ventilation - Options

Requires Airtight building envelope and ducts

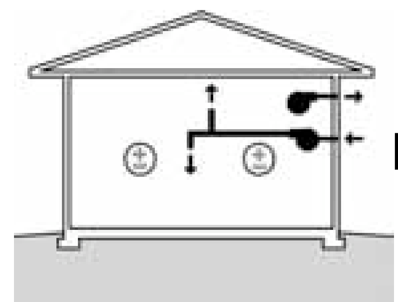
- Exhaust ventilation
  - single- or multi-point
- Supply ventilation
  - single- or multi-point
  - integrated with central system fan
- Balanced ventilation
  - single- or multi-point
  - integrated with central system fan
  - with or without heat or energy recovery



Exhaust



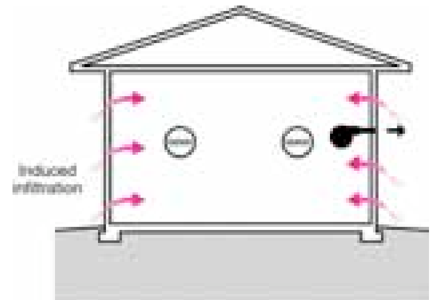
Supply



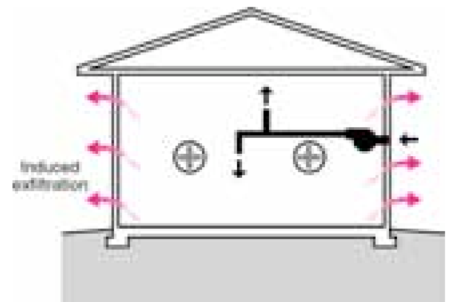
Balanced

Controlled Ventilation - Options

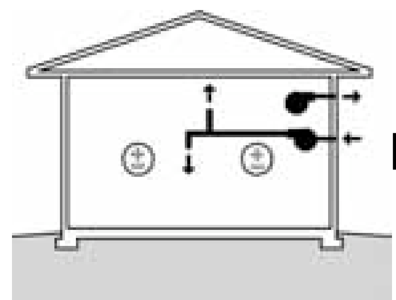
- Exhaust, supply, and balanced ventilation systems were tested, none of the systems were independently fully ducted because of the high installation cost
- All of the ventilation systems tested provided adequate air exchange and ventilation air distribution as long as there was periodic whole-house mixing provided by the central air distribution system.
- Only those systems that utilized periodic whole-house mixing provided by recycling of the central air distribution system fan showed excellent ventilation air distribution, as determined by multizone age-of-air and air change rate measurements



Exhaust



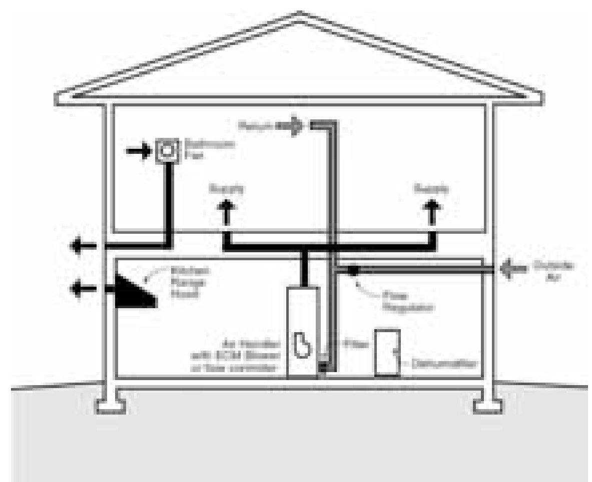
Supply



Balanced

What System Got it Right?
Central-Fan-Integrated Supply Ventilation

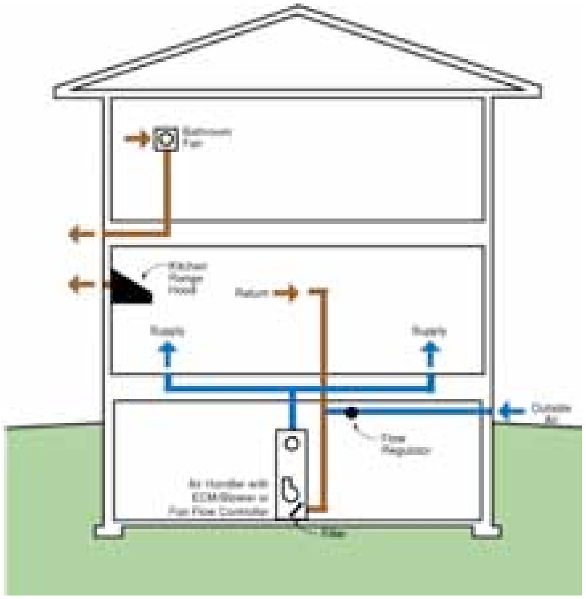
- Requires airtight building envelope and ducts
- Properly sized duct extending from an outside fresh air source to the air handler return
  - low pressure drop wall cap
  - insulated duct (R-4 to 6)
  - accessible outside air filter
  - balancing damper
  - optional motorized damper



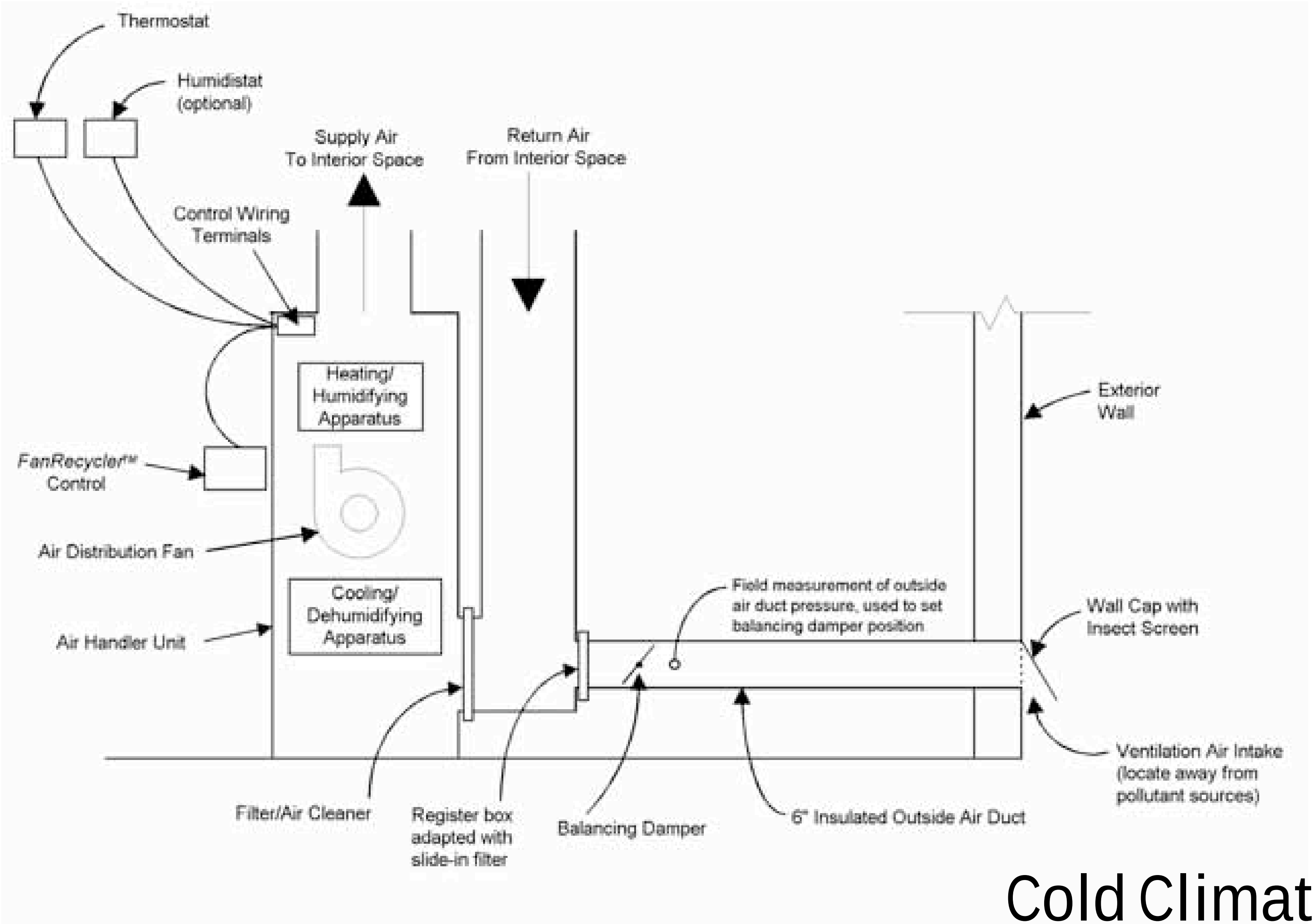
- Fan recycling control
  - assures distribution of fresh air when there is no thermostat demand

Fan Recycling Application

- Activates the central system fan for a selectable ON time if it has been inactive for a selectable OFF time
  - Improved comfort control by periodic mixing
  - Improved indoor air quality by periodic full distribution of ventilation air

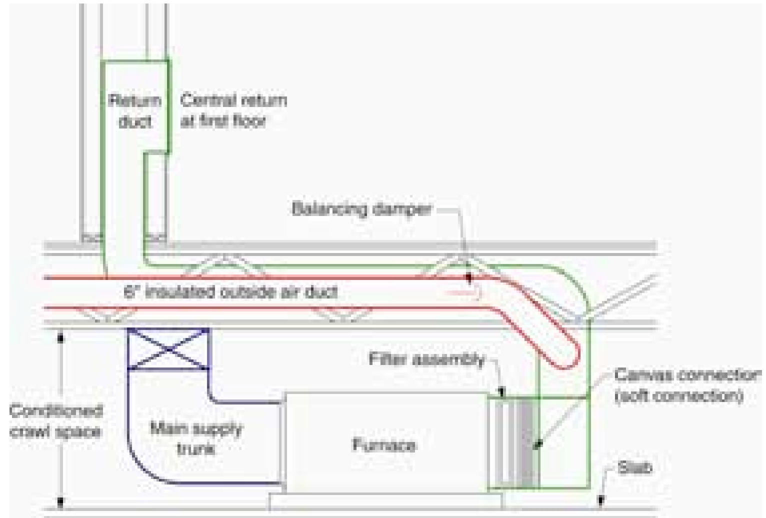


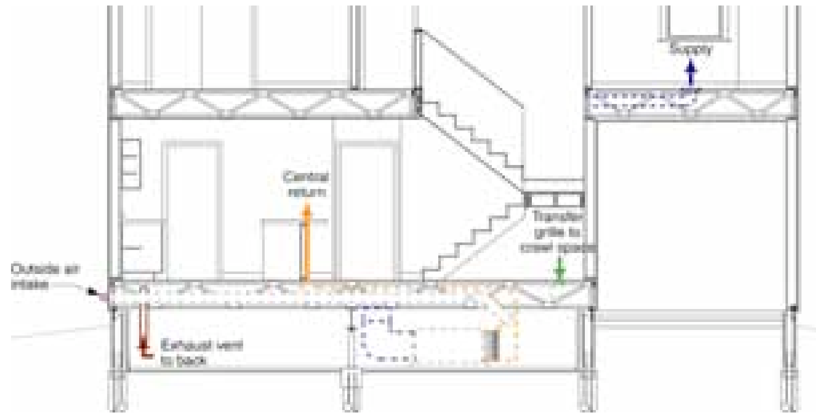
Cold Climate



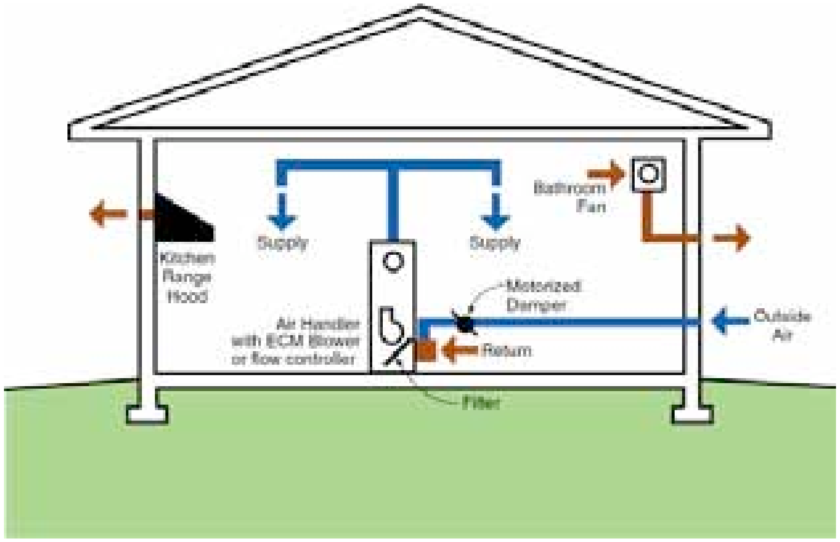
CENTRAL-FAN-INTEGRATED SUPPLY VENTILATION SYSTEM
Installation Configuration 1

Cold Climate

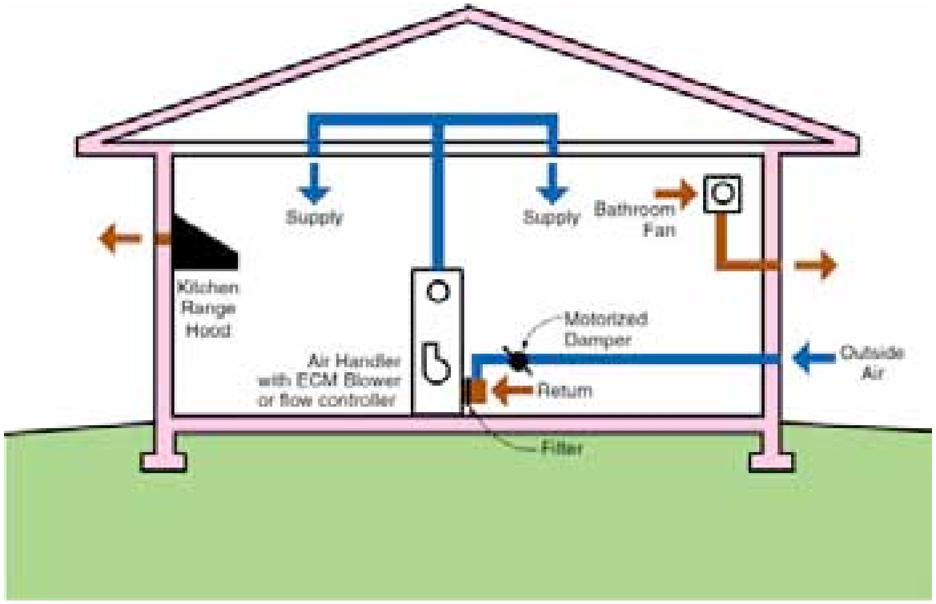




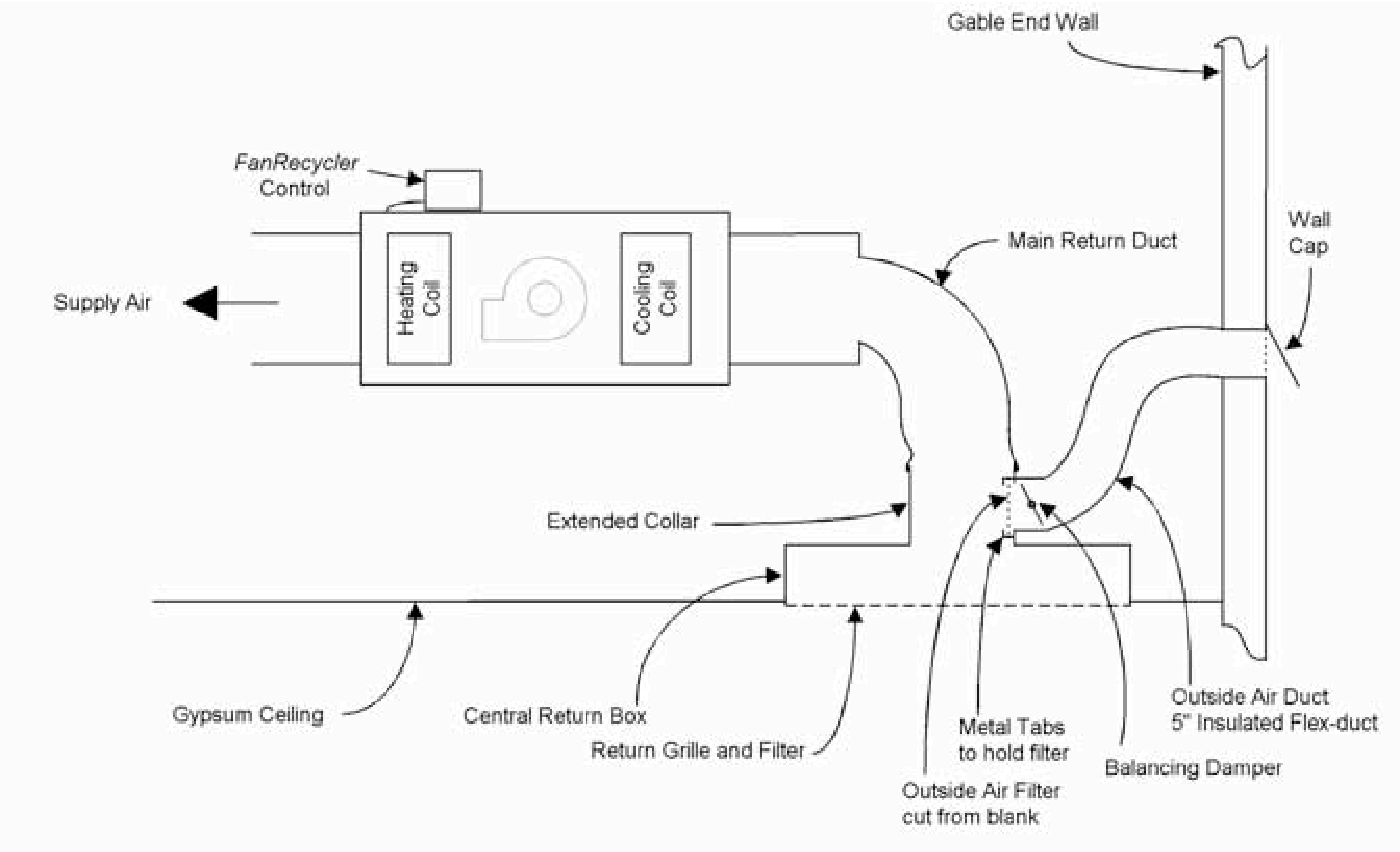
Cold Climate



Mixed Dry Climate



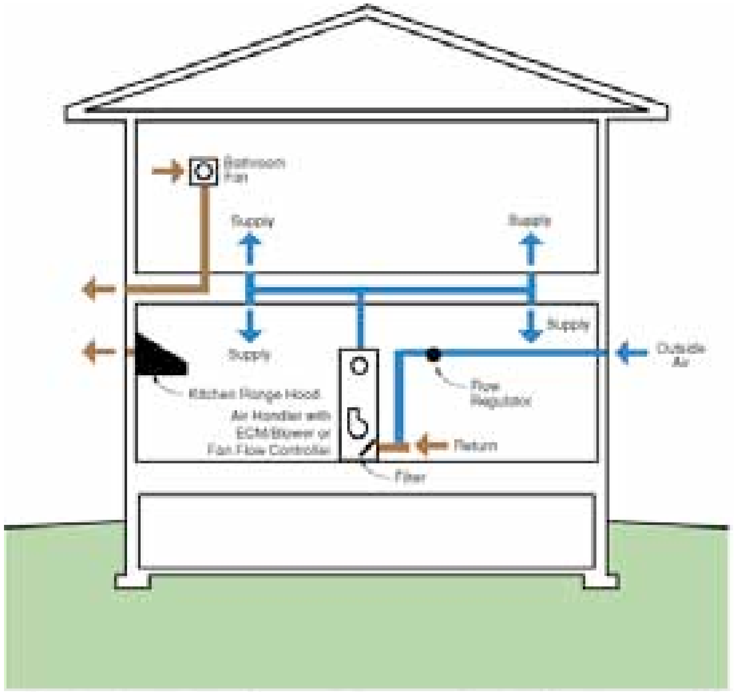
Hot Dry Climate



INSTALLATION CONFIGURATION 2

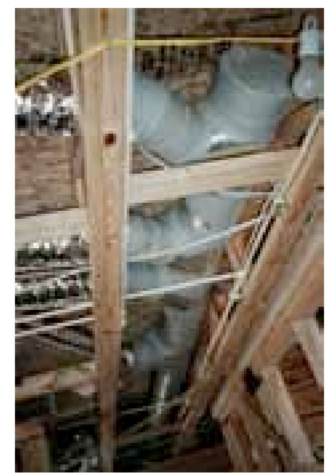
Hot Dry Climate

Hot Dry Climate



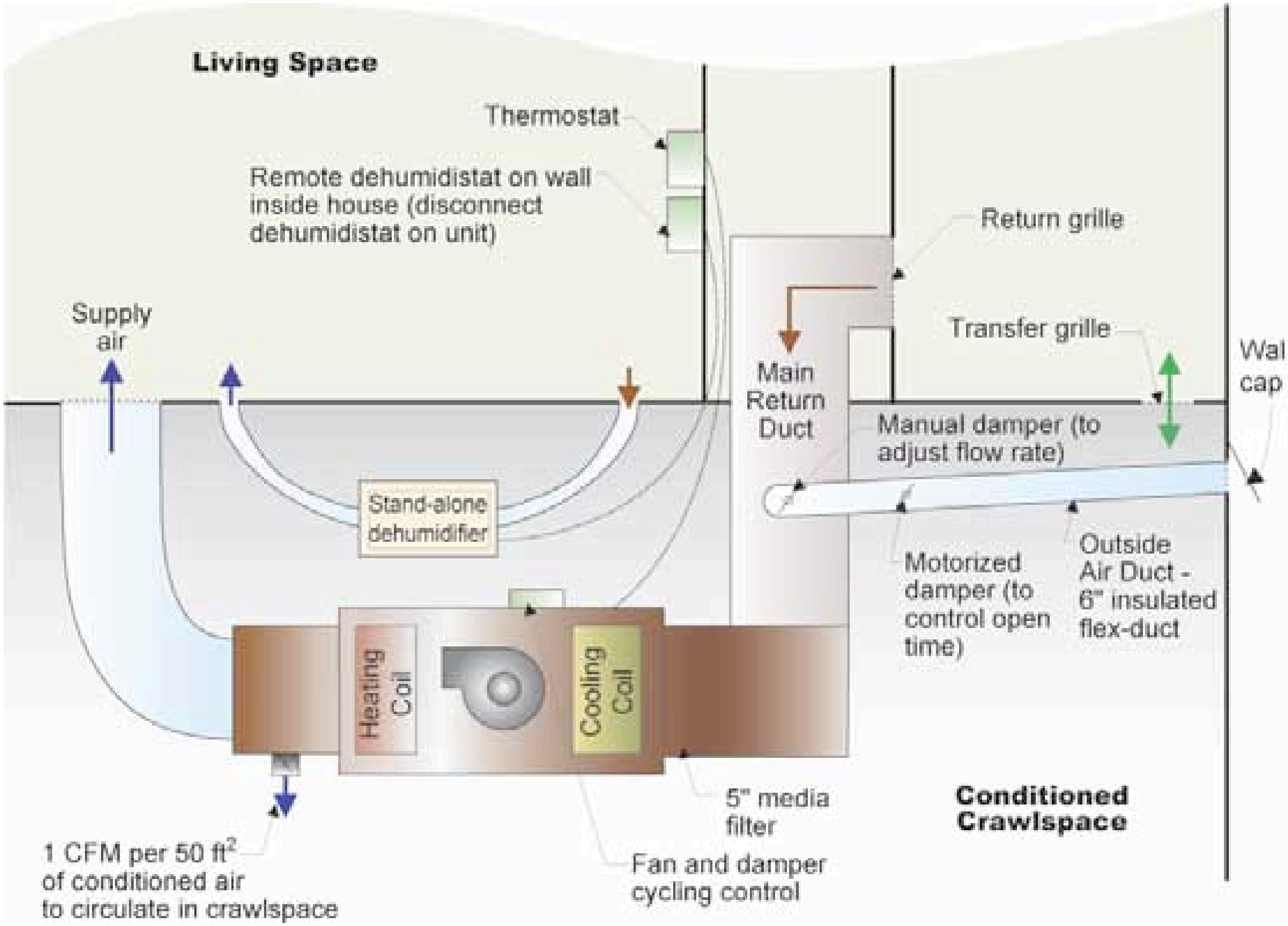
Supply Ventilation System Integrated with Heating and A/C

- Air handler with ECM/blower runs continuously (or operated based on time of occupancy) pulling outside air into the return system
- A flow regulator provides fixed outside air supply quantities independent of air handler blower speed
- House forced air duct system provides circulation and tempering
- Point source exhaust is provided by individual bathroom fans and a kitchen range hood
- In supply ventilation systems, and with heat recovery ventilation, pre-filtration is recommended as debris can affect duct and fan performance reducing air supply
- Kitchen range hood provides point source exhaust as needed
- Outside air duct should be insulated and positioned so that there is a fall/slope toward the outside to control any potential interior condensation. Avoid using long lengths of flex duct that may have a dip that could create a reservoir for condensation.
- Mixed return air temperatures (return air plus outside air) should not be allowed to drop below 50°F at the design temperature in order to control condensation of combustion gases on heat exchanger surfaces

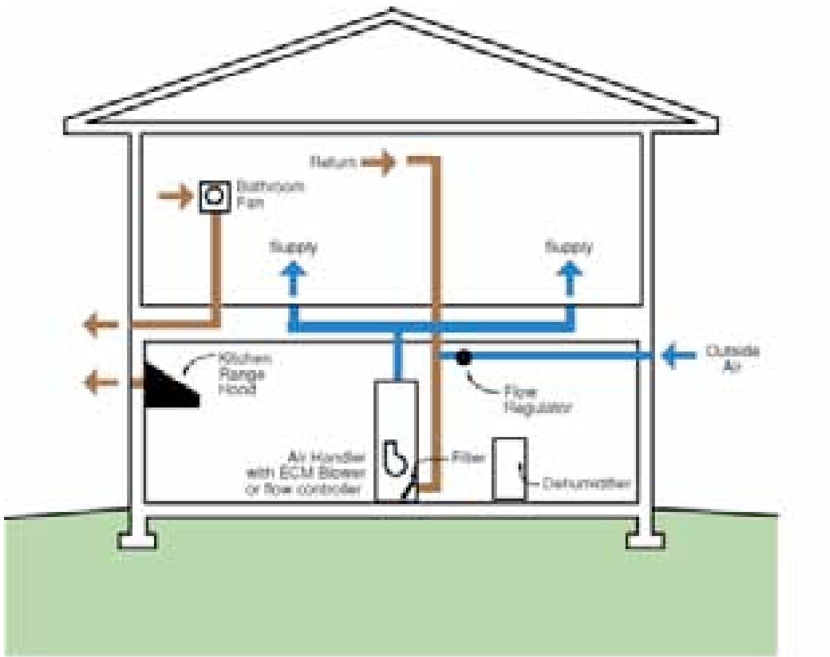


Mixed Humid Climate

U.S. Department of Energy Building America Program Partner



Mixed Humid Climate



Supply Ventilation System Integrated with Heating and A/C

- Air handler and motorized damper operated based on time of occupancy by a flow controller pulling outside air into the return system
- Flow controller should not allow air handler to run for 15 minutes after coil becomes de-energized to prevent re-evaporation of condensate from coil and drain pan
- A motorized damper prevents excessive outside air supply during long blower duty cycles
- House forced air duct system provide circulation and tempering
- Point source exhaust is provided by individual bathroom fans and a kitchen range hood
- In supply ventilation systems, pre-filtration is recommended as debris can affect duct and fan performance reducing air supply
- Kitchen range hood and bathroom fans provide point source exhaust as needed
- Exhaust fans should not run continuously
- Outside air supply is controlled by a motorized damper. Closing the outside air damper during unoccupied periods will allow the flow controller to periodically mix the interior air without bringing in outside air helping the dehumidifier control interior RH — humid air is brought to the dehumidifier. The cooling function of the A/C can also be shutdown during this time (i.e. A/C on blower only operation).
- Outside air supply should have an override for periods when outside air is poor, i.e. smoke from fires

Hot Humid Climate

U.S. Department of Energy Building America Program Partner

Fan Cycling in Extreme Climates

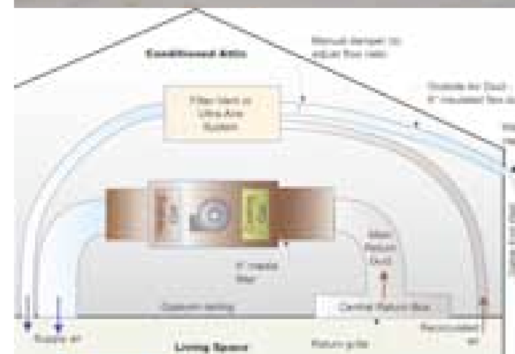
- Hot Humid Climates
  - We found we need supplemental humidity control
  - No system would work without supplemental humidity control with our more efficient building enclosures
- Very Cold/Severe Cold Climates
  - Concerns for making the heat exchangers too cold
  - Leads to corrosion from condensation of the products of combustion
  - The mixed temperature of the outside air and the inside air needs to stay above 50 degrees

Central-fan-integrated supply with fan recycling, damper, and dehumidifier

- Air handler unit in conditioned space closet, placed on platform high enough to place dehumidifier underneath

- Dehumidifier controlled by dehumidistat in conditioned space

- Normal cycling of air handler and fan recycling distributes ventilation air and dehumidified air

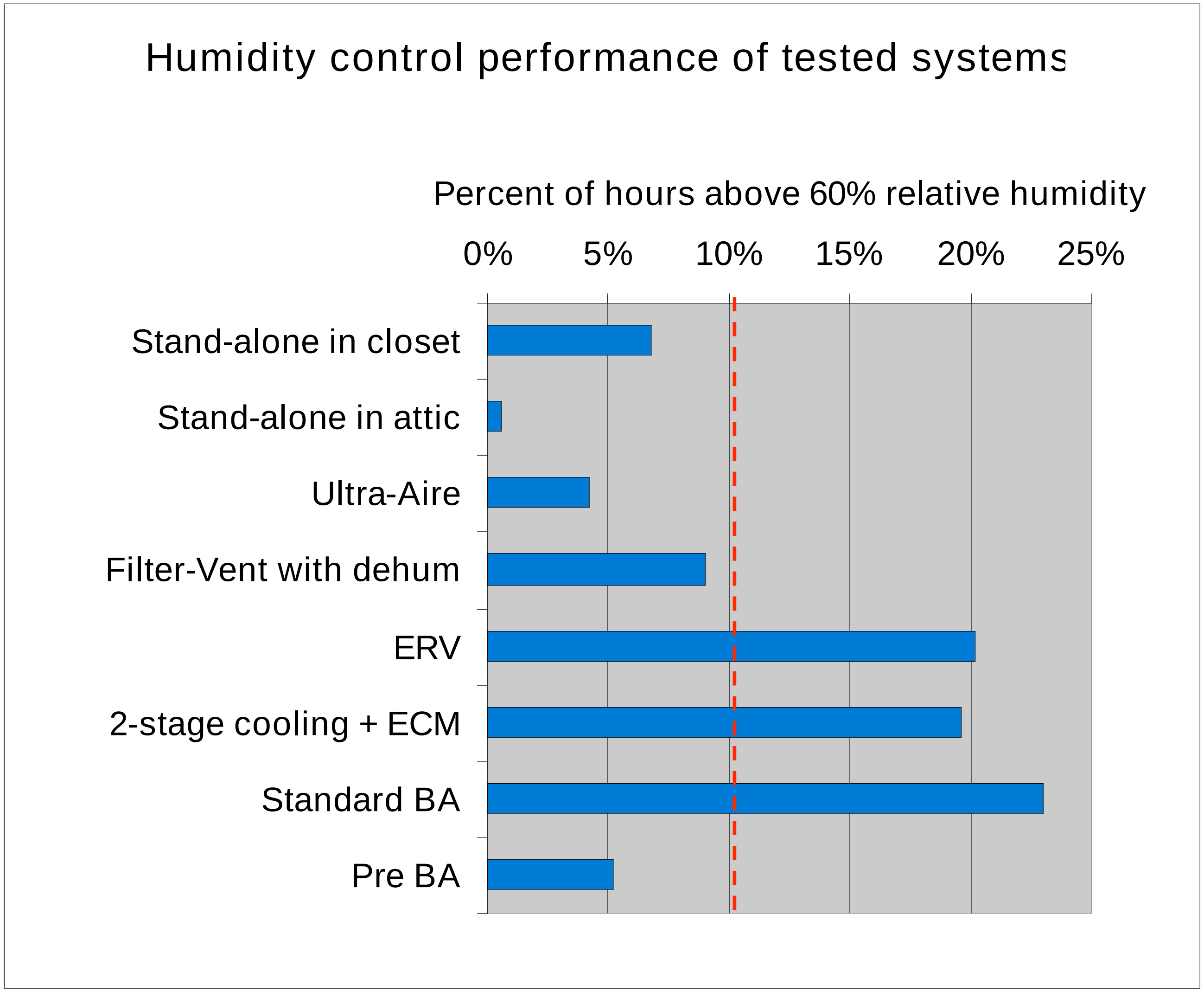


Hot Humid Climate

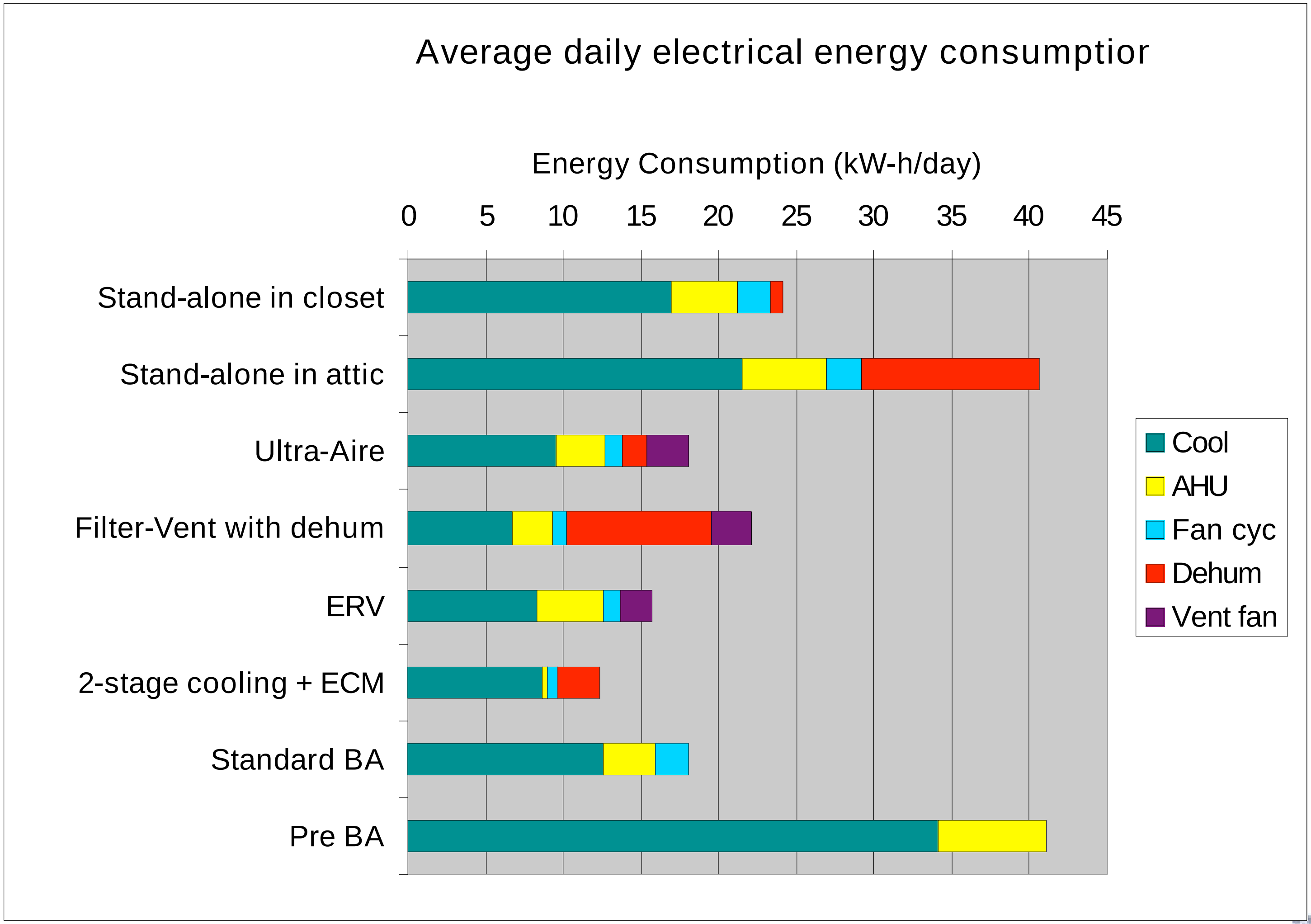
Systems Tested – Houston, TX USA

STAND-ALONE IN CLOSET	
19803 Ash.,	2 story, 2386 ft^2
19902 Ash.,	2 story, 2397 ft^2
STAND-ALONE IN ATTIC	
19950 Ash.,	2 story, 2397 ft^2
2731 Sun.,	2 story, 2448 ft^2
ULTRA-AIRE	
19915 Ash.,	1 story, 2100 ft^2
19938 Ash.,	2 story, 2448 ft^2
19923 Ash.,	2 story, 2397 ft^2
FILTER-VENT + STAND-ALONE	
19934 Ash.,	1 story, 1830 ft^2
19922 Ash.,	1 story, 2100 ft^2
19954 Ash.,	2 story, 2386 ft^2
ERV	
19926 Ash.,	1 story, 1830 ft^2
19942 Ash.,	1 story, 2197 ft^2
19930 Ash.,	2 story, 2448 ft^2
2-STAGE + ECM AHU	
19422 Col.,	1 story, 2197 ft^2
ENERGY EFFICIENT REFERENCE	
2802 Sun.,	2 story, 2386 ft^2
2814 Sun.,	1 story, 2197 ft^2
19906 Ash.,	2 story, 2386 ft^2
STANDARD REFERENCE	
19622 Her.,	2 story, 2448 ft^2
4818 Cot.,	1 story, 2197 ft^2
6263 Clear.,	2 story, 3300 ft^2

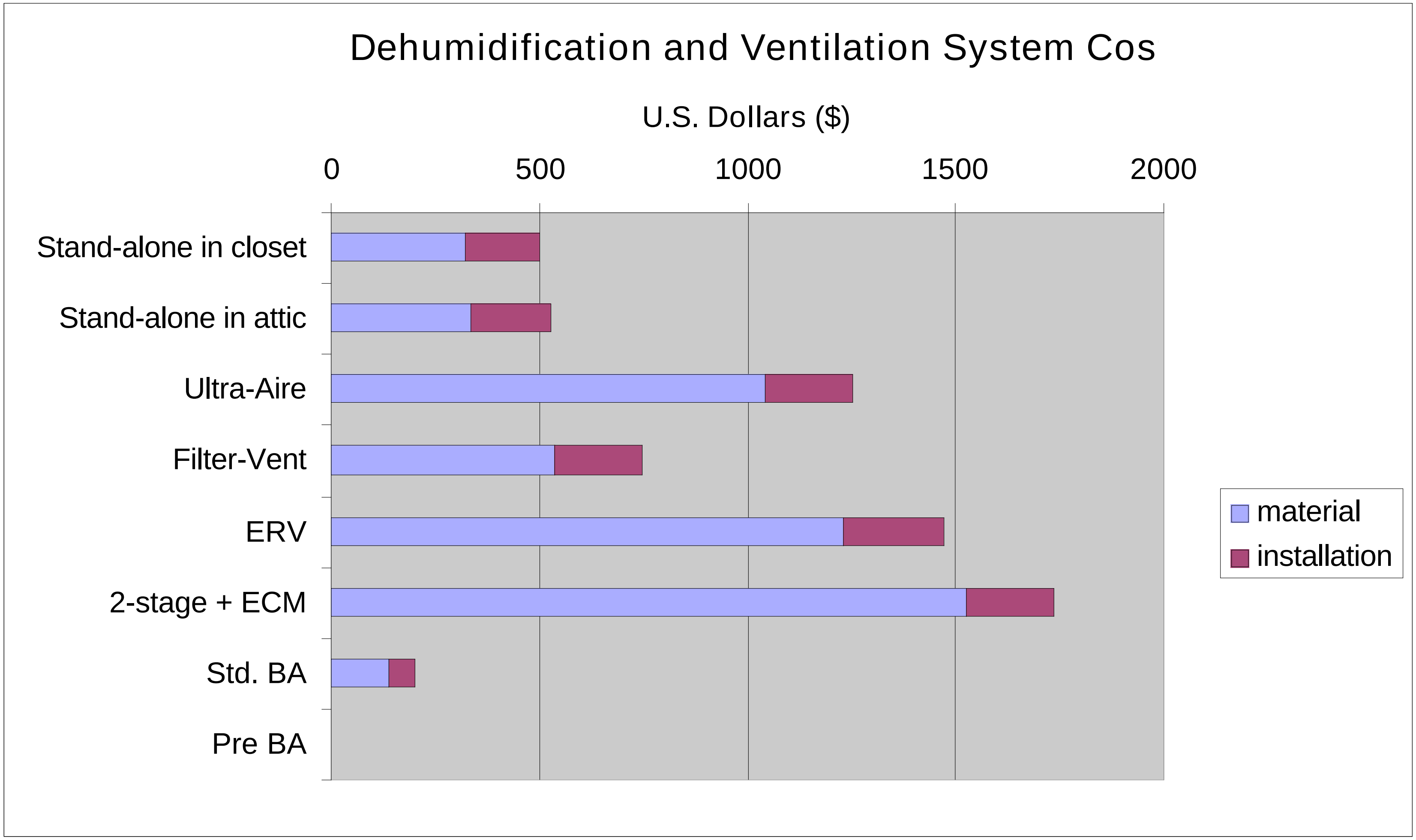
System Humidity Control Performance

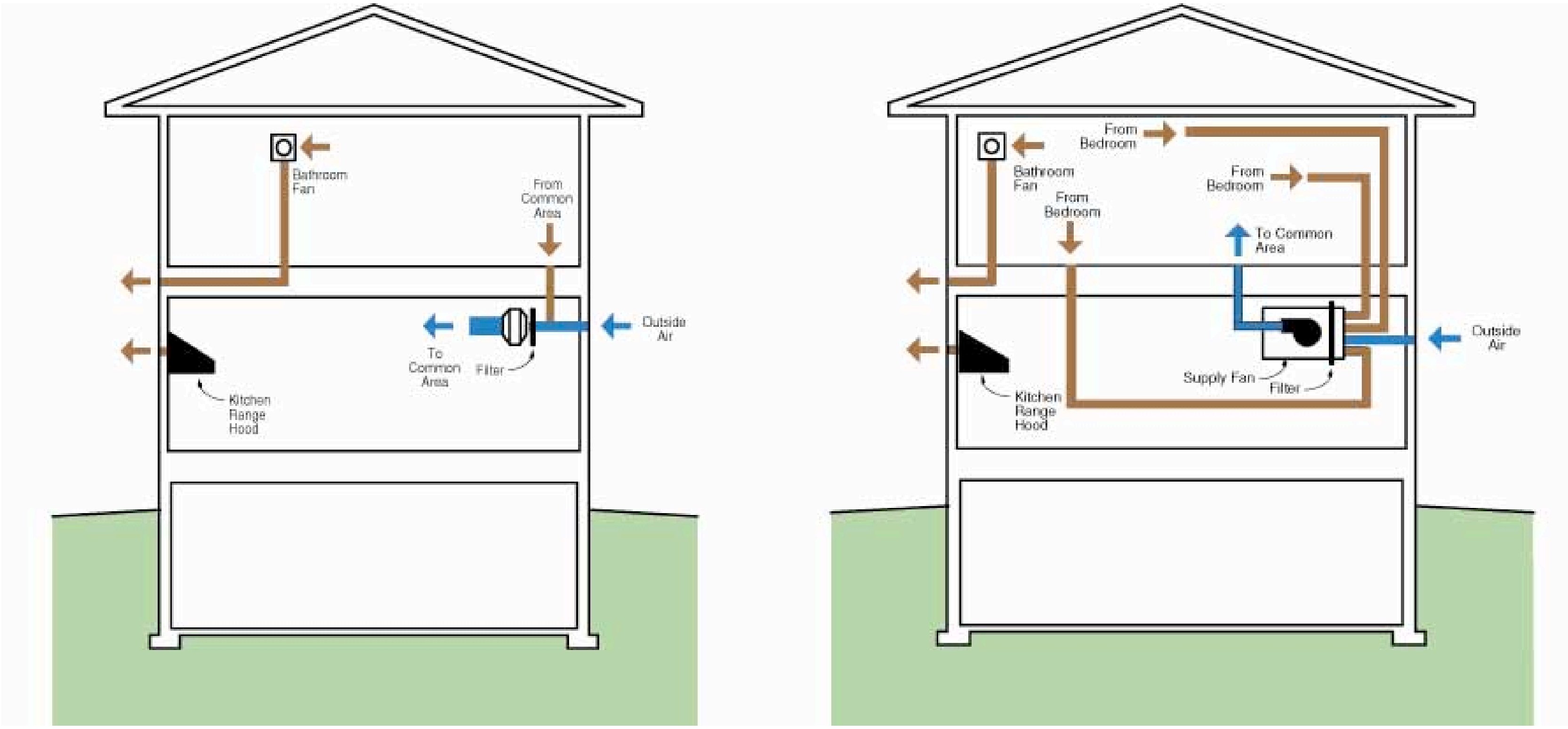


Total Cooling, Heating Fan, Ventilation, and Dehumidification Energy Consumption



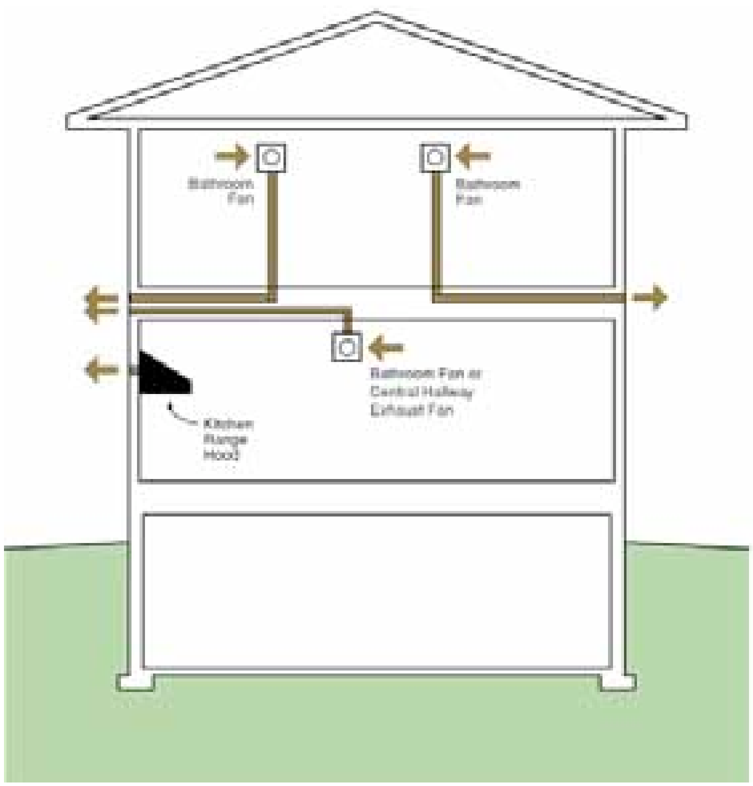
System's Material and Installation Cost

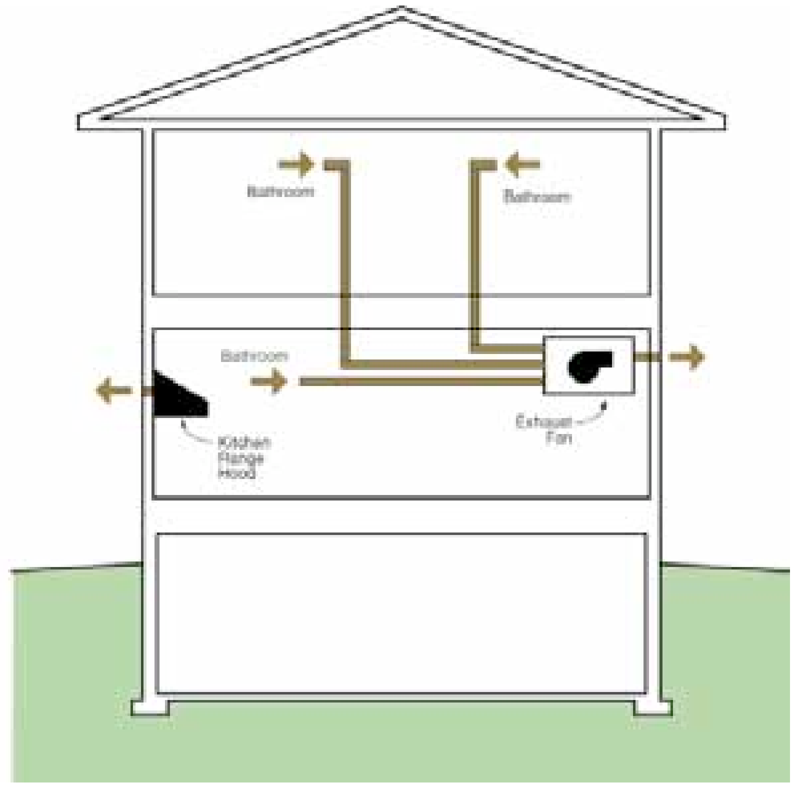




•Continuously operating supply with central fan recycling for distribution and mixing
•Limitations: Forgiving envelope, low interior RH

Supply
Very Cold Climate



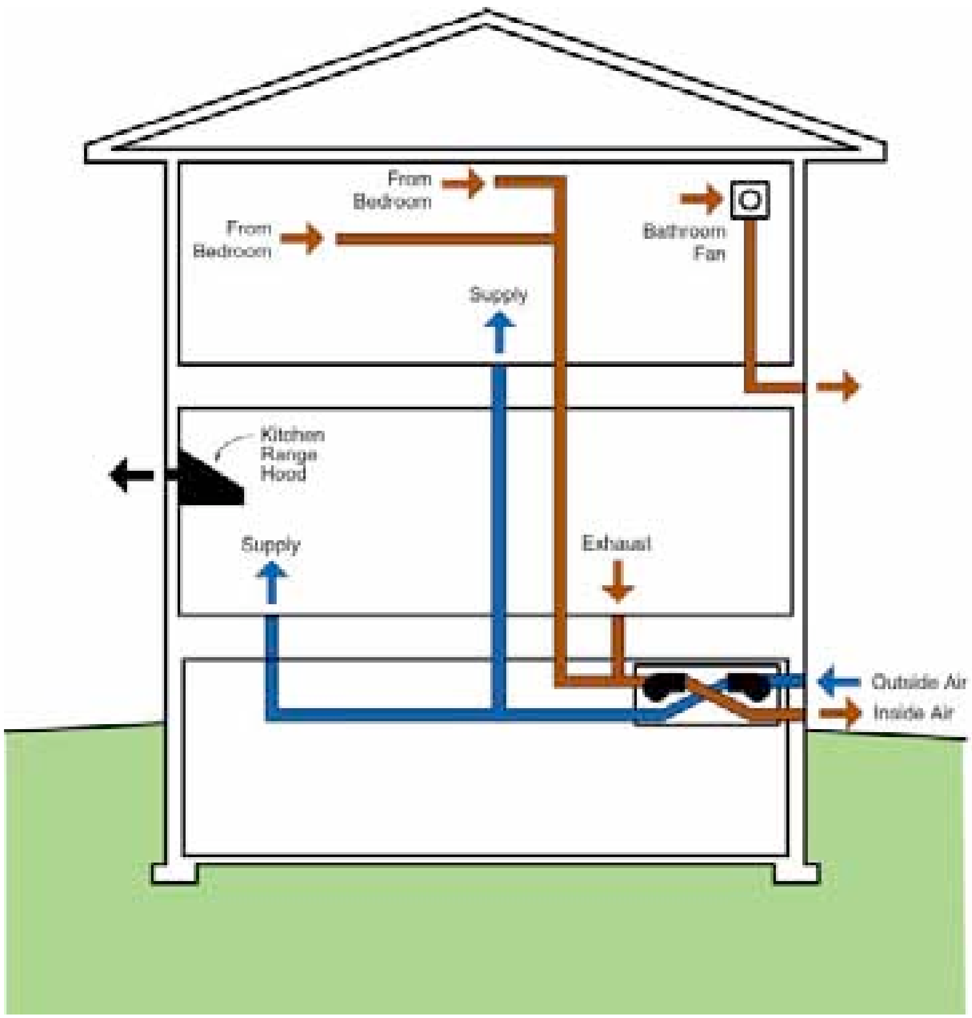


- Continuously operating exhaust with central fan recycling for distribution and mixing (sealed combustion space/DHW heating)

Exhaust
Very Cold Climates

• Balanced heat recovery ventilation with central fan recycling for distribution and mixing or

•Fully-ducted multi-point HRV system



Balanced
Very Cold Climates

Fan Recycling Advantage

- Better than running the fan continuously @ full speed
  - about 60% less fan energy consumed
  - less wear on fan components
  - less moisture re-evaporation off of wet cooling coil
  - no moisture condensation in cool supply ducts
  - provides effectively the same whole-house mixing benefit
- Better than timer-motor type controls
  - no overlapping, or short-cycling operation of the fan
  - all of the above advantages apply

Ventilation Strategies Compared

- Base 1: No mechanical ventilation
  - SLA=0.0005, ELA=108 in^2
- Base 2: Multi-point supply ventilation
  - 40 cfm continuous, no infiltration
- Cen Fan1: Central-fan-integrated supply vent
  - 60 cfm intermittent at 33%
  - SLA=0.0002, ELA=44 in^2
  - ducts in unconditioned space
- Cen Fan2: Central-fan-integrated supply vent
  - same as Cen Fan1 except ducts in conditioned space

Ventilation System Cost Estimates

- Central-fan-integrated system
  - $320: $65 fan recycling control, $65 motorized damper, $30 duct parts, $160 labor

- Multi-point supply system
  - $1,200: $650 supply fan with filter and four inlet ports (outside air and recirculation air) and one outlet port, $150 ducts and grilles, $400 labor

Energy Costs Comparisons

- Central-fan-integrated ventilation compared to uncontrolled infiltration
  - $22 to $47 savings with ducts in conditioned space
  - $3 to $27 cost with ducts in unconditioned space

- Central-fan-integrated ventilation compared to multi-point supply ventilation
  - $50 more (Chicago) to $33 less (Orlando) for ducts in conditioned space

Why Central-Fan-Integrated Ventilation Works

- Effective central-fan-integrated ventilation:
  - air tight ducts or ducts in conditioned space
  - fan recycling control
  - 5” to 9” insulated fresh air duct to return air side of central fan
  - air filtration
  - balancing damper for flow adjustment
  - motorized damper
  - relay for exhaust fan to create balanced system (optional)

Whole House
How Much Did the Whole System Improvements Cost?

System Improvements

• Leak Free Construction	+$ 250 to 500
• Tight Ducts in Conditioned Space	+$ 250 to 500
• Upgrade Combustion Appliances	+$ 250 to 500
• Addition of Ventilation System	+$ 250 to 500
Incremental Cost	+$ 1, 250 to 2,250

System Savings due to trade-offs

• Smaller Mechanical Systems	-$ 1, 250 to 2,250
Total Incremental Cost	+$ 0

Typical Energy Savings -$ 250 to 500

U.S. Department of Energy Building America Program Partner

What Did We Learn?

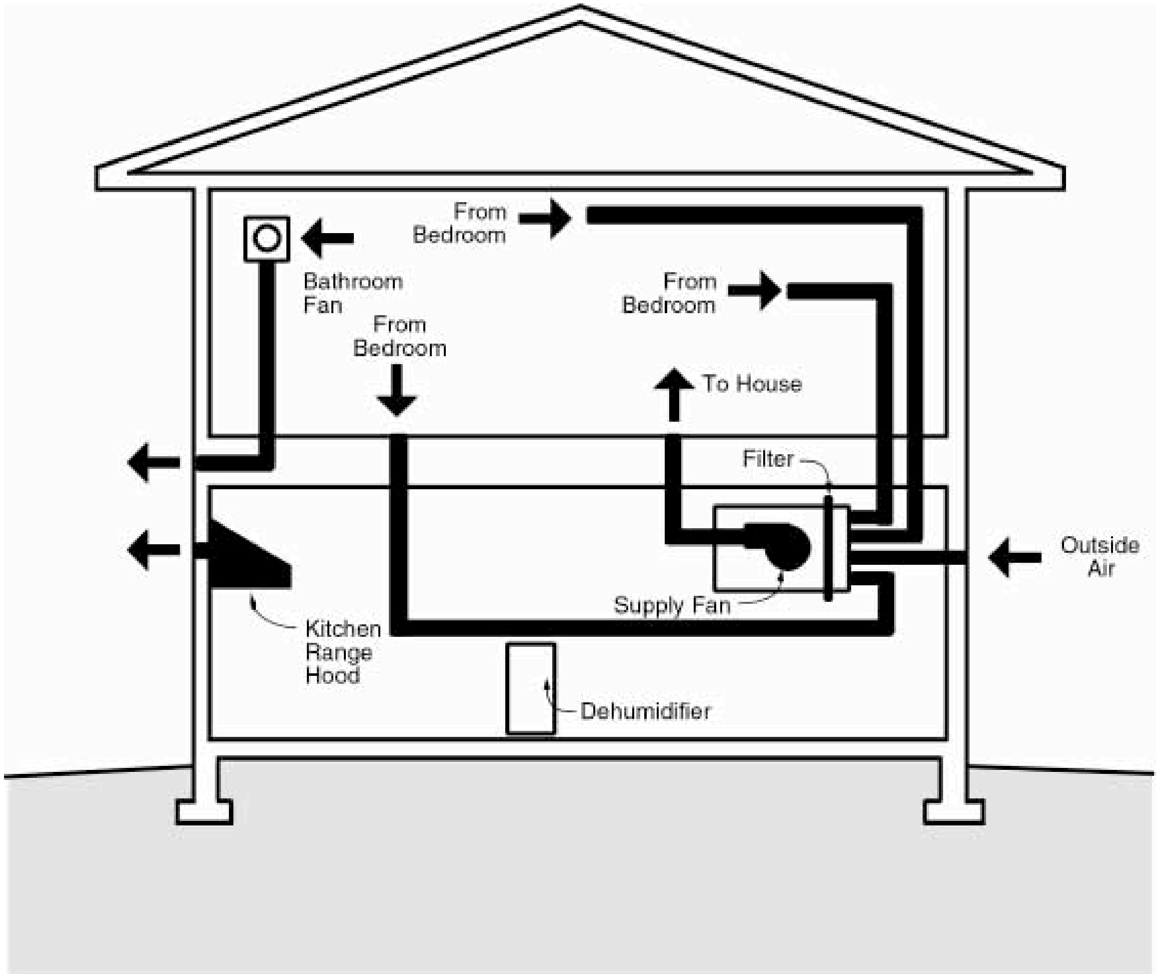
- If you have a lousy enclosure, a positive pressure cannot fix it in the south, and a negative pressure cannot fix it in the north
- If you have a leak-free enclosure, supply, exhaust, or balanced ventilation will work
  - That is, don't worry about pressurization of depressurization if you design your building enclosure to dry
- 30 to 70 cfm does not change system

Where Are We Going Next?

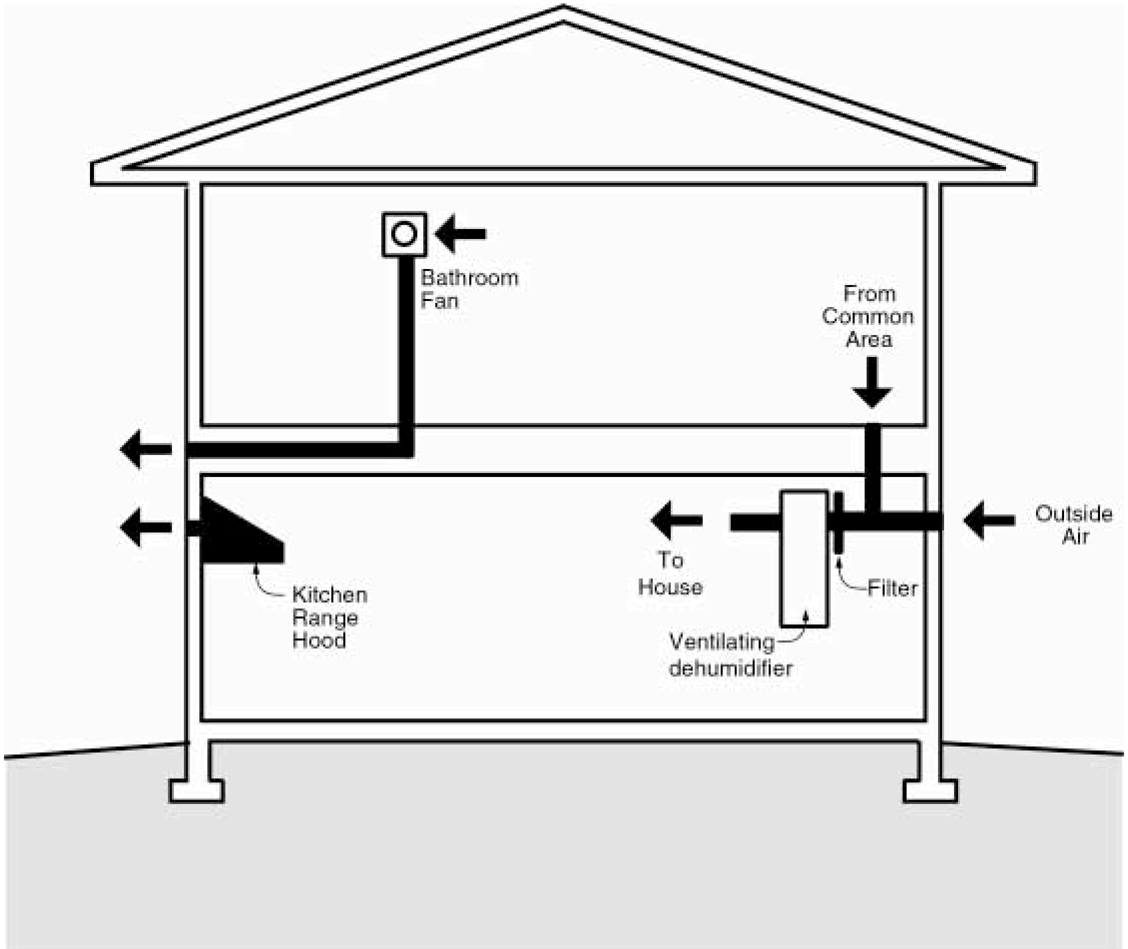
- We move to stand alone systems that are non-integrated with the heating and cooling system. This system will provide filtration at its return and will periodically distribute and mix the air.

- We will use a small efficient fan to bring in outside air that will only be passively connected to the main air handler and will have its own controls. This fan will have a carbon and particle filter in front of it to remove pollen and ozone.

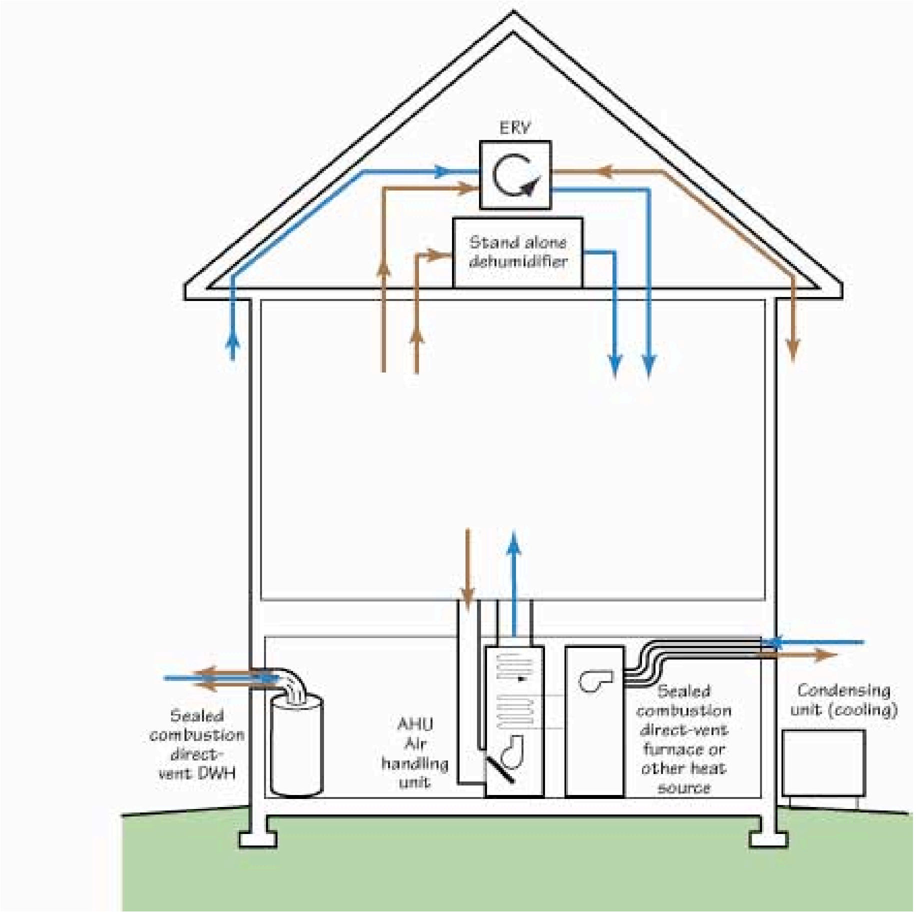
- We will use a separate dehumidification system that will only be passively connected to the main air handler and will its their own controls.



Non-Integrated Supply



Non-Integrated Supply



Non-Integrated Balanced