# Indoor Air Quality and HVAC design strategies for high performance homes

Greg Davenport
and
Lucas Howard

MITSUBISHI ELECTRIC
COOLING & HEATING

Panasonic


HITACHI
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Panasonic
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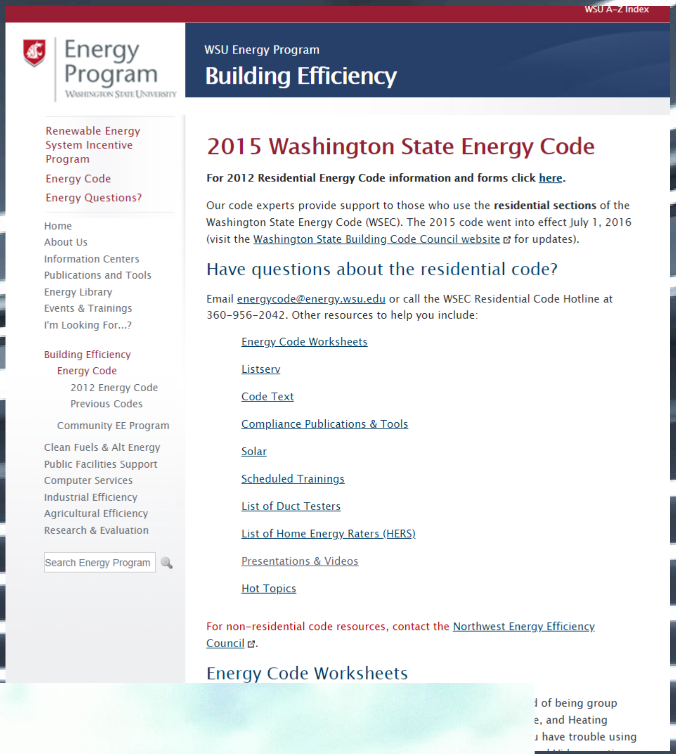
MITSUBISHI AHシリーズ


SEATTLE WA

Panasonic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Washington State University

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Renewable Energy System Incentive Program
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2015 Washington State Energy Code

**For 2012 Residential Energy Code information and forms click here.**

Our code experts provide support to those who use the **residential sections** of the Washington State Energy Code (WSEC). The 2015 code went into effect July 1, 2016 (visit the Washington State Building Code Council website for updates).

Have questions about the residential code?

Email energycode@energy.wsu.edu or call the WSEC Residential Code Hotline at 360-956-2042. Other resources to help you include:

- Energy Code Worksheets
- Listserv
- Code Text
- Compliance Publications & Tools
- Solar
- Scheduled Trainings
- List of Duct Testers
- List of Home Energy Raters (HERS)
- Presentations & Videos
- Hot Topics

For non-residential code resources, contact the Northwest Energy Efficiency Council.

Energy Code Worksheets

# Indoor Air Quality Specialist

# Who are you?

Have you ever tested a home?

Do you work for a utility/program implementer?

Do you design systems for heating and cooling?

Too much or too little humidity

design temperature is below 25°F?

# Part 1
# What you don't see can kill you

Why don’t builders spend more time talking to potential home buyers about indoor air quality and healthy homes?

How many builders talk about indoor air quality with potential home buyers?

Millions more people suffer from disease caused by poor indoor air quality

Millions of people [illegible] every year from poor indoor air quality

The New York Times

ASIA PACIFIC

## Study Links Polluted Air in China to 1.6 Million Deaths a Year

点击查看本文中文版 | Read in Chinese

By DAN LEVIN AUG. 13, 2015

BEIJING — Outdoor air pollution contributes to the deaths of an estimated 1.6 million people in China every year, or about 4,400 people a day, according to a newly released scientific paper.

# B.C. fire smoke: Is Seattle's air worse than China's?

By Daniel DeMay, SeattlePI Updated 6:02 pm PDT, Thursday, August 3, 2017



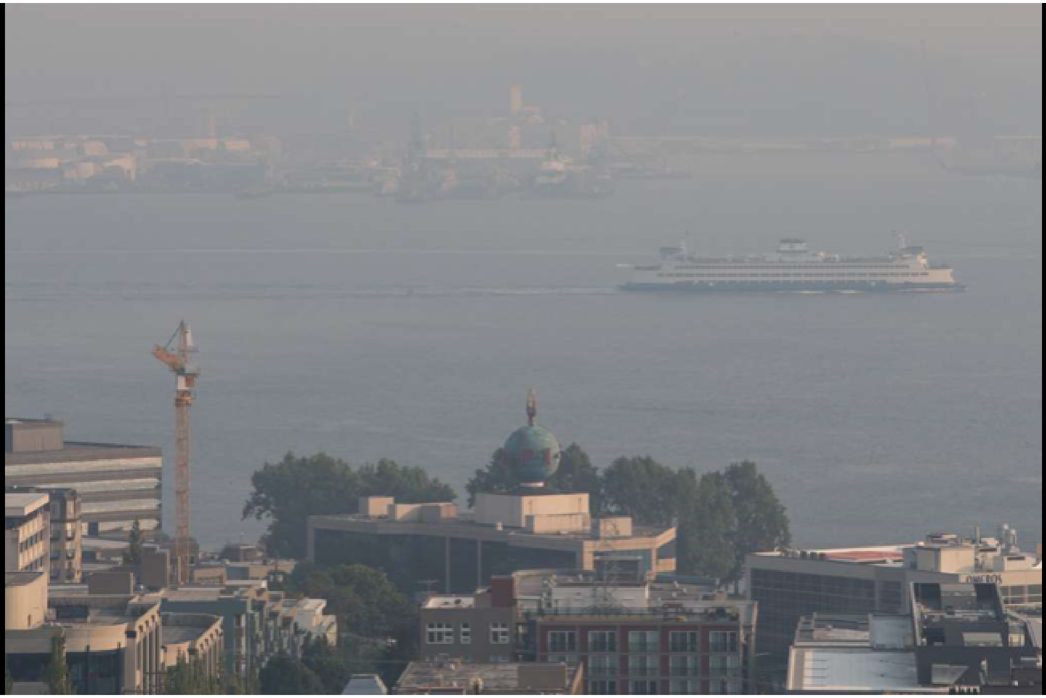

Photo: GRANT HINDSLEY, SEATTLEPI.COM



A ferry makes its way through smoke from wildfires in British Columbia covering Seattle on Wednesday, Aug. 2, 2017.

# We spend approximately 90% of our time indoors

World Health Organization

## Global Health Observatory (GHO) data

# Mortality from household air pollution


### Situation and trends

In 2012, household air pollution was responsible for 4.3 million deaths, and 7.7% of the global mortality

CDC

**439 People per year in the US die from non fire related CO**

# COMBUSTION RISKS THAT MAY AFFECT IAQ

- Gas Heating
- Gas Hot Water
- Gas cooking
- Gas fireplaces/BBQs
- Automobile exhaust in garage or near windows
- Forest fires
- Wood/pellet stoves
- Depressurization
- Also hobbies and workshops can cause risks

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Bringing Science Solutions to the World

For decades, no one worried much about the air quality inside people's homes unless there was secondhand smoke or radon present. Then scientists at the U.S. Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) made the discovery that the aggregate health consequences of poor indoor air quality are as significant as those from all traffic accidents or infectious diseases in the United States. One major source of indoor pollutants in the home is cooking.

# RESEARCH NEWS
BERKELEY LAB

lab a-z index | phone book

search: go

**May 24, 2007**

news releases | receive our news releases by email | science@berkeley lab

## Berkeley Lab, EPA Studies Confirm Large Public Health And Economic Impact of Dampness and Mold:

***They estimate that number of asthma cases attributable to exposure in home is 4.6 million, at $3.5 billion annual cost***

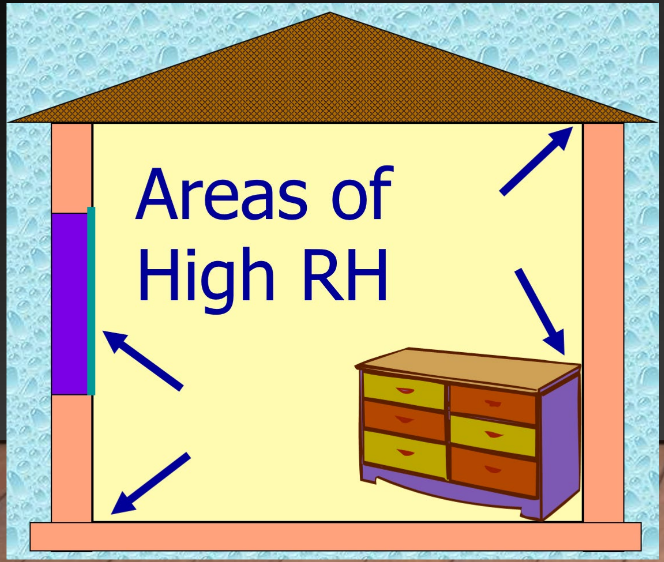
Contact: Allan Chen, (510) 486-4210, a_chen@lbl.gov

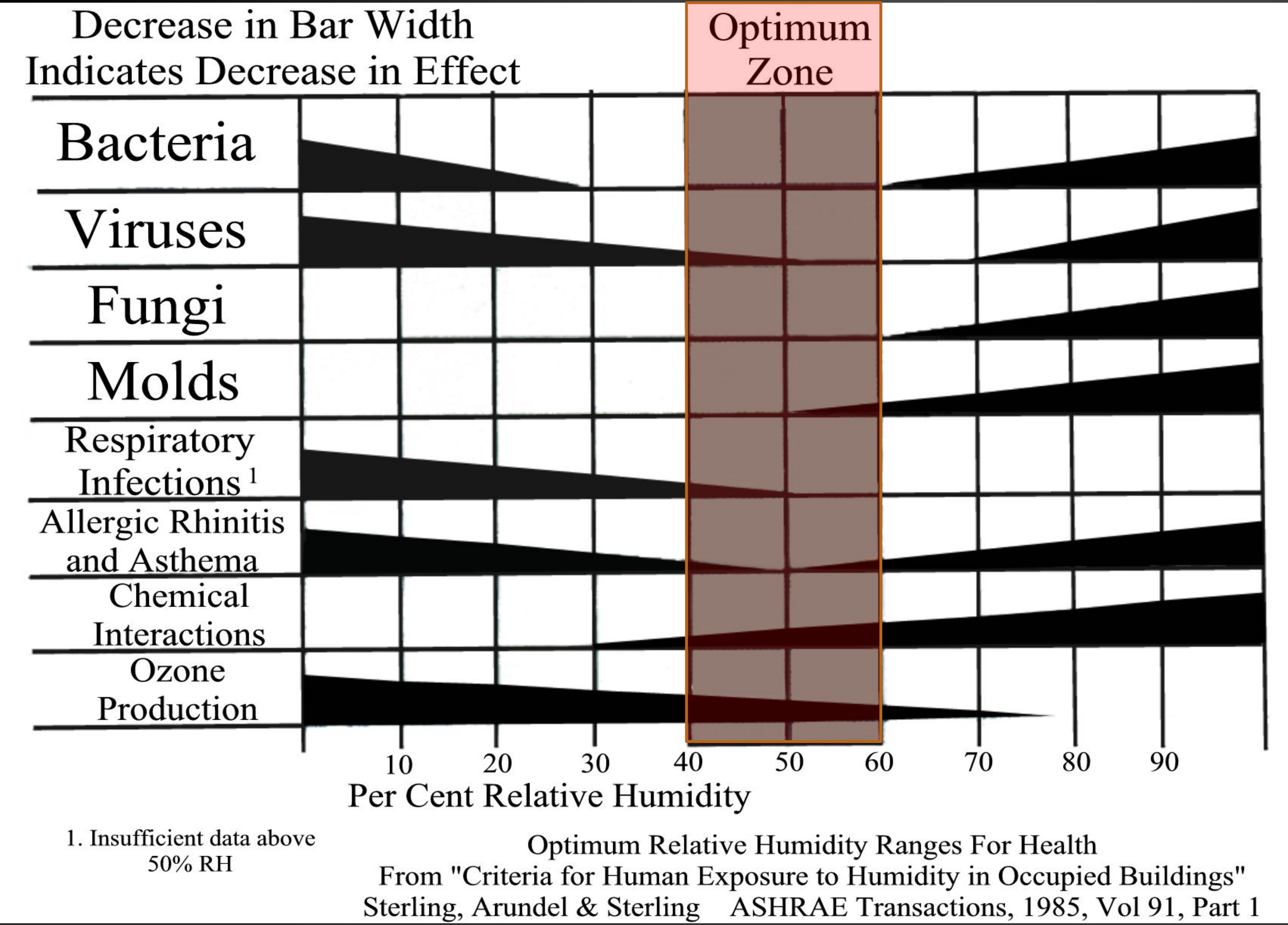
## HIDDEN MOLD

*Mold growing on the back side of wallpaper.*

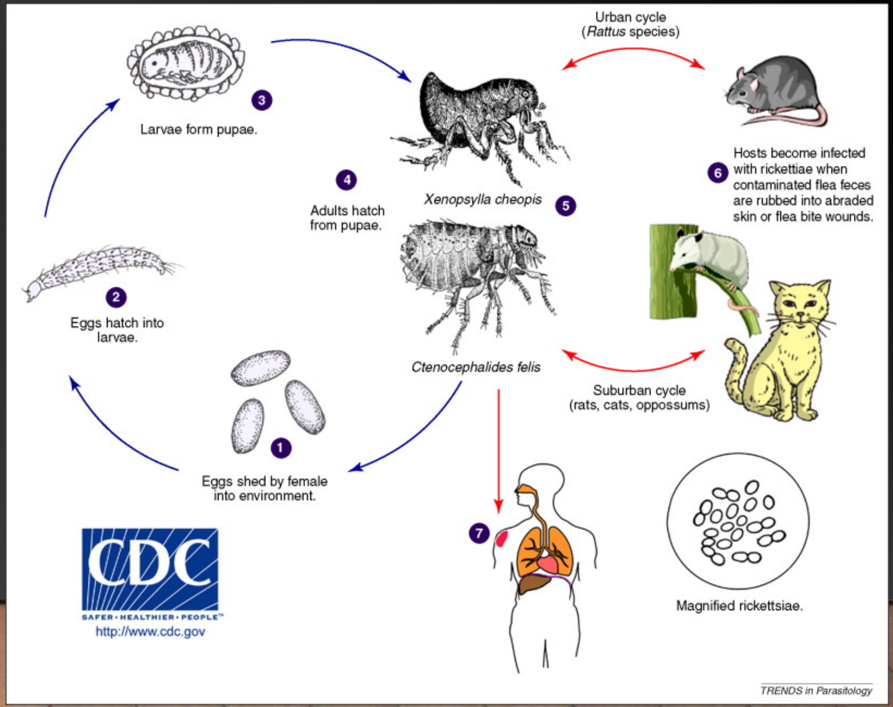
# WHAT IS RH AND WHERE CAN I GET SOME?

- Relative humidity (RH) is the ratio of the amount of water vapor in the air at a specific temperature to the maximum amount that the air could hold at that temperature, expressed as a percentage




Decrease in Bar Width
Indicates Decrease in Effect
Optimum
Zone
Bacteria
Viruses
Fungi
Molds
Respiratory
Infections 1
Allergic Rhinitis
and Asthema
Chemical
Interactions
Ozone
Production
10 20 30 40 50 60 70 80 90
Per Cent Relative Humidity
1. Insufficient data above
50% RH
Optimum Relative Humidity Ranges For Health
From "Criteria for Human Exposure to Humidity in Occupied Buildings"
Sterling, Arundel & Sterling ASHRAE Transactions, 1985, Vol 91, Part 1


VENT
ME


Urban cycle
(*Rattus* species)
3 Larvae form pupae.
4 Adults hatch from pupae.
*Xenopsylla cheopis*
5
6 Hosts become infected with rickettiae when contaminated flea feces are rubbed into abraded skin or flea bite wounds.
2 Eggs hatch into larvae.
*Ctenocephalides felis*
Suburban cycle
(rats, cats, oppossums)
1 Eggs shed by female into environment.
7
Magnified rickettsiae.
CDC
SAFER·HEALTHIER·PEOPLE™
http://www.cdc.gov
TRENDS in Parasitology

A Section 508–conformant HTML version of this article
is available at http://dx.doi.org/10.1289/ehp.1510037.

Research

# Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments

*Joseph G. Allen,[1] Piers MacNaughton,[1] Usha Satish,[2] Suresh Santanam,[3] Jose Vallarino,[1] and John D. Spengler[1]*

[1]Exposure, Epidemiology, and Risk Program, Department of Environmental Health, Harvard T.H. Chan School of Public Health, Boston, Massachusetts, USA; [2]Psychiatry and Behavioral Sciences, SUNY-Upstate Medical School, Syracuse, New York, USA; [3]Industrial Assessment Center, Center of Excellence, Syracuse University, Syracuse, New York, USA

BACKGROUND: The indoor built environment plays a critical role in our overall well-being because of both the amount of time we spend indoors (~90%) and the ability of buildings to positively or negatively influence our health. The advent of sustainable design or green building strategies reinvigorated questions regarding the specific factors in buildings that lead to optimized conditions for health and productivity.

RESULTS: On average, cognitive scores were 61% higher on the Green building day and 101% higher on the two Green+ building days than on the Conventional building day ($p < 0.0001$). VOCs and $CO_2$ were independently associated with cognitive scores.

CONCLUSIONS: Cognitive function scores were significantly better under Green+ building conditions than in the Conventional building conditions for all nine functional domains. These findings have wide-ranging implications because this study was designed to reflect conditions that are commonly encountered every day in many indoor environments.

# Indoor Environmental Quality (IEQ)

## Priorities

- Indoor Air Quality (IAQ)
  - Minimal pollutants
  - Odor Free
- Comfortable
  - Temperature
  - Relative Humidity
  - Draft Free
  - Quiet
  - Effective lighting
  - Aesthetically pleasing

# Household IAQ Risks

Toxic building materials

Particulate Matter

Mold

Tobacco smoke

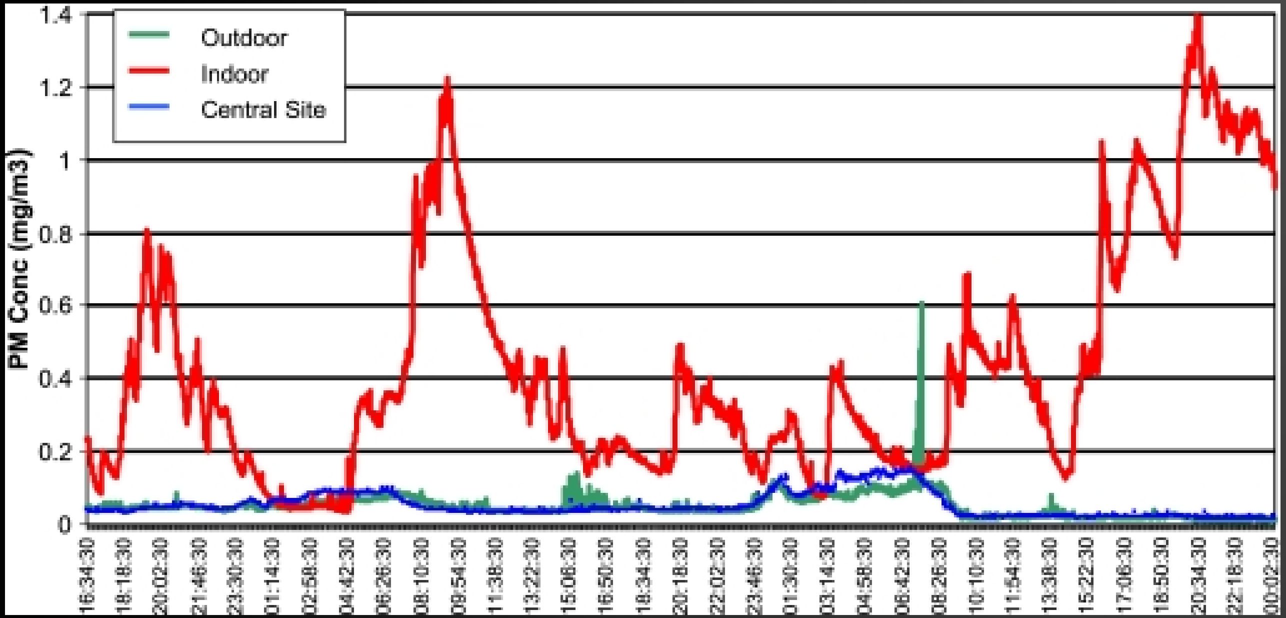
Outdoor air – … quality or forest fires

Depressurization and/or improper ventilation

Radon

# Pollutants Defined

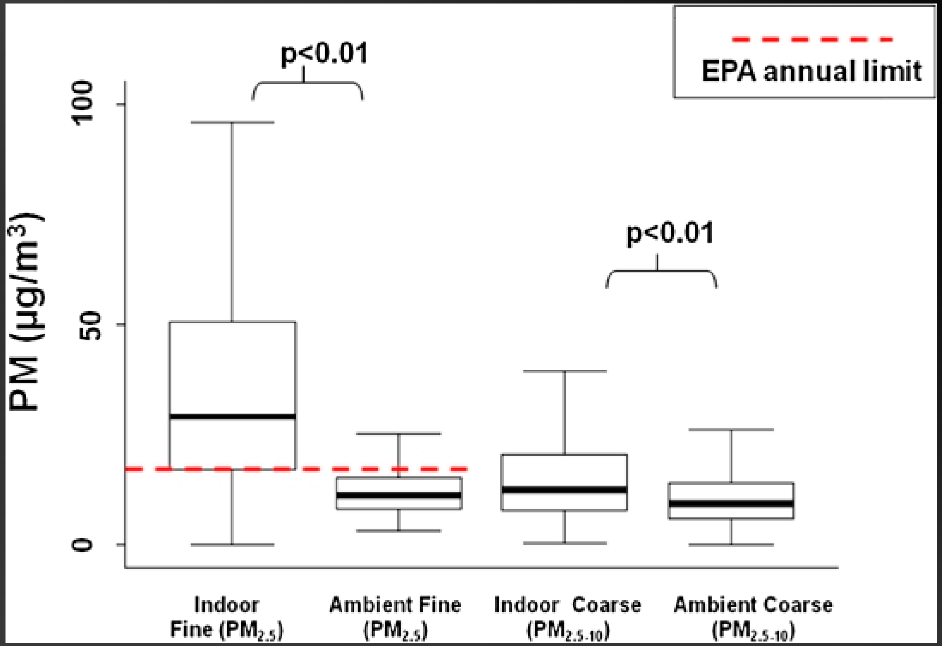
- VOC's = Volatile Organic Compounds
- Mold
- PM = Particle Matter
  - Generally measured in micrometers
- PM2.5 = Particle matter 2.5 micrometers or less
  - Pollutant of most concern in the average home
- Ultra fine particles = Particle matter 1.0 micrometers or less
- Small enough to be absorbed by organs and the blood steam




**Women who work within the home have a 54% higher death rate from cancer than those that work outside the home.**

**International Conference on Indoor Air Quality and Climate, Toronto, 1990.**

**Numerous indoor air pollutants have been directly tied to causing or increasing the risk of asthma developing in children**




Graphic data coutesy of the National Center for Biotechnology Information
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3266016/

Cooking on both gas and electric burners produces fine and ultrafine particles. These particles are small enough to enter the lungs, bloodstream and other organs.

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Fine particles = 1.0 – 2.5 micrometers
Ultrafine particles < 1.0 micrometers

Original Articles

**Development of a standard capture efficiency test method for residential kitchen ventilation**

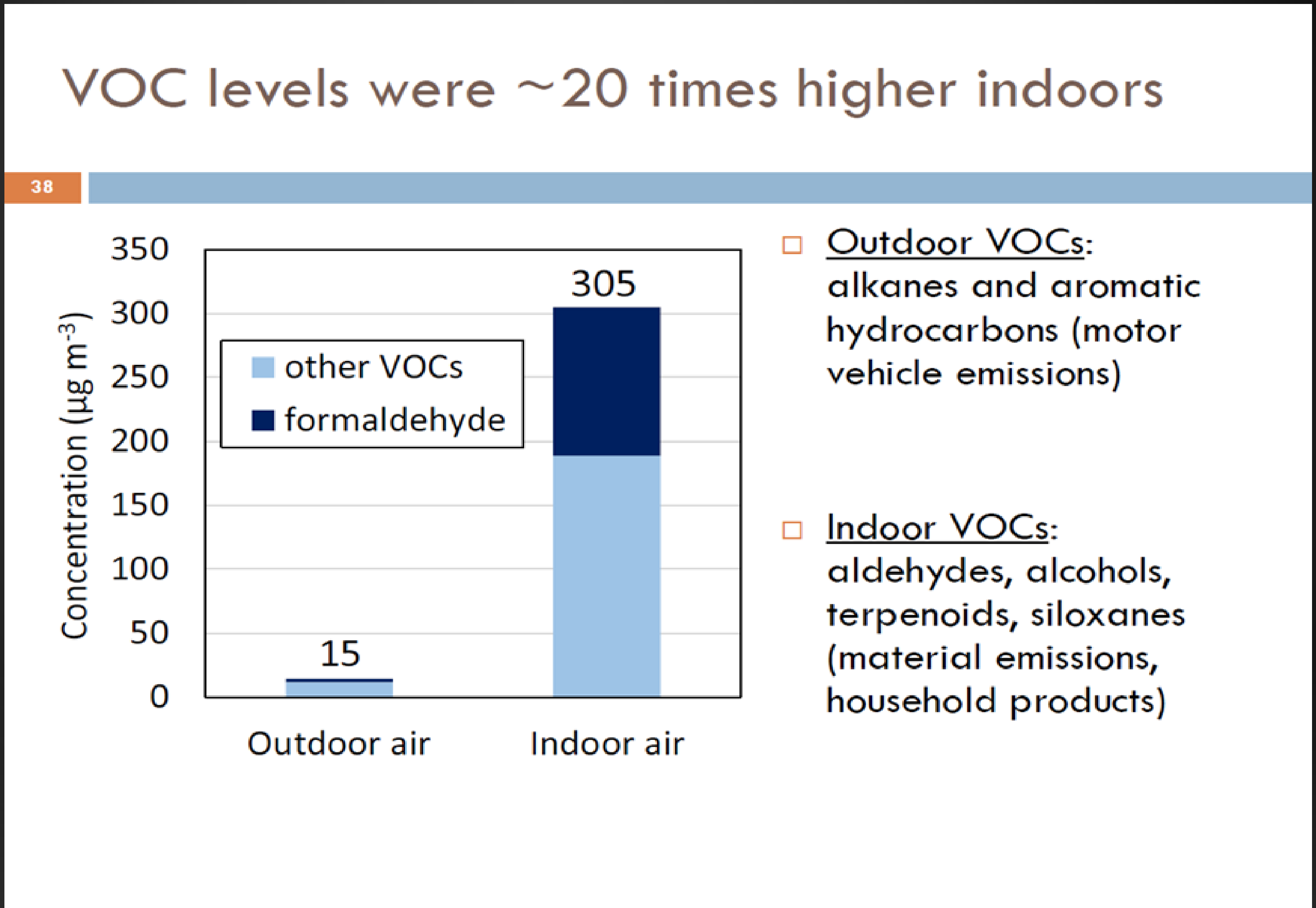
Yang-Seon Kim, Iain S. Walker & William W. Delp

Pages 176-187 | Received 17 Apr 2017, Accepted 06 Dec 2017, Accepted author version posted online: 02 Jan 2018, Published online: 05 Jan 2018

Recent research by LBL estimate that 10's of millions of Californians cooking with gas stoves are **<u>routinely exposed to pollutant levels that exceed federal standards for outdoor air.</u>**

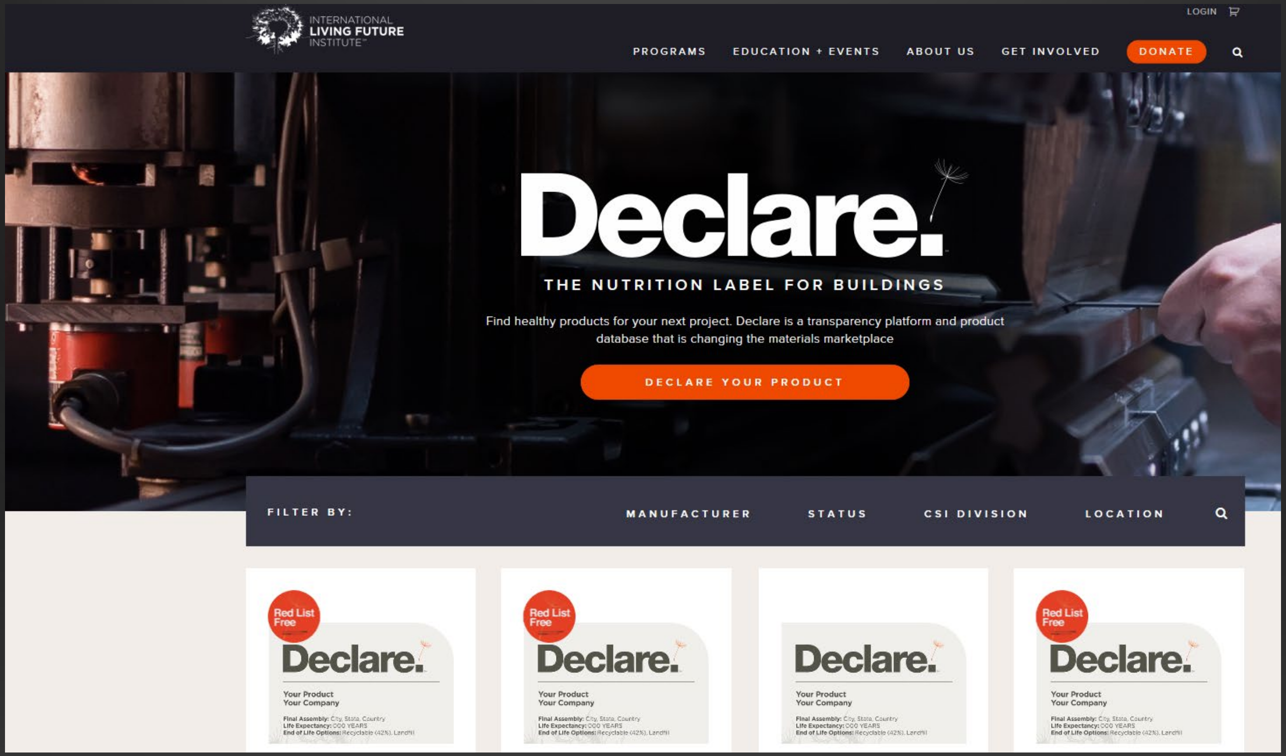
C:\Users\lh65488\Documents\Educational Materials\IAQ Ventilation Research\Pollution in the Home Kitchens Can Produce Hazardous Levels of Indoor Pollutants  Berkeley Lab.mht

# indoor air quality




EPA- indoor air quality 2x-5x more toxic than outdoor air

# Low toxicity building materials improve indoor air quality and health



# Part 2

# HVAC Design for High Performance Homes

# ACCA'S Residential
## Design Manuals

**System Process**

| | |
|---|---|
| Load Calculation | ACCA Manual J |
| Equipment Selection | **ACCA Manual S** |
| Duct Design | ACCA Manual D |
| Air Distribution | ACCA Manual T |
| Test, Adjust, and Balance | ACCA Manual B |

# Smart HVAC Design

## Design it right and prevent comfort problems

Do a Manual D and Manual T calculation every time if you have ducts

Do a room-by-room heating and cooling load calc every time (Manual J)

Don't oversize ASHP systems (Manual S)

**Check your turndown ratio to ensure good shoulder season performance**

Wrightsoft, Adtek, Acculoads, EnergyGauge, or SpecPro

Consider using well designed airshare or transfer system when possible

**Oversized ASHPs will have poor energy performance and comfort performance**

**Design a good ventilation system for improved comfort, health, and energy efficiency**

# What do ducts really do?

Distribute

heating and cooling

Unless you use a

Exhaust stale air

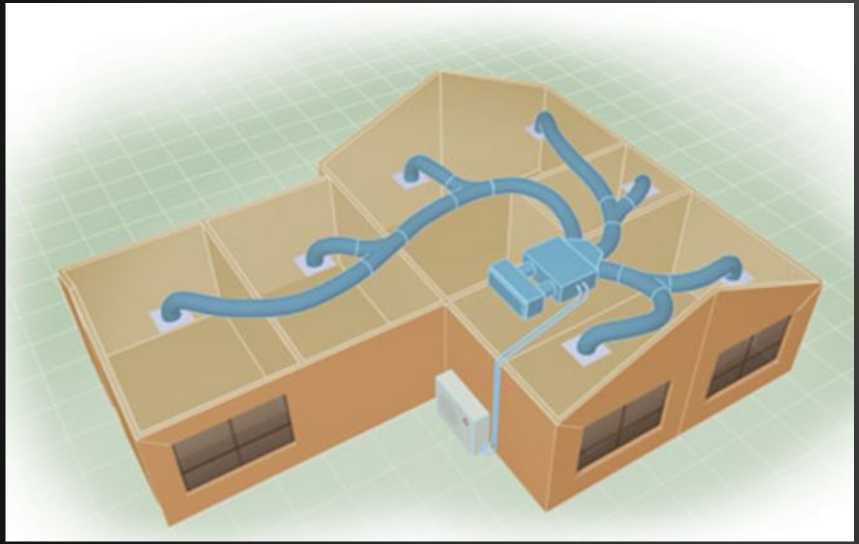
Supply fresh air

ductless heat pump system

Improve Comfort, IAQ, and health

# Ductwork for Space Conditioning

# Horizontal Ducted Systems



**Passive Home Project**

**Boise, Idaho**

**Affordable Home Builder**

Rhvac - Residential & Light Commercial HVAC Loads

Elite Software Development
Flourish
Pa

*Project Report*

### Design Data

| | | |
|---|---|---|
| Reference City: | | Boise AP, Idaho |
| Building Orientation: | | Front door faces Southwest |
| Daily Temperature Range: | | High |
| Latitude: | 43 | Degrees |
| Elevation: | 2838 | ft. |
| Altitude Factor: | 0.902 | |
| Elevation Sensible Adj. Factor: | 0.916 | |
| Elevation Total Adj. Factor: | 0.991 | |
| Elevation Heating Adj. Factor: | 0.960 | |

| | Outdoor Dry Bulb | Outdoor Wet Bulb | Outdoor Rel.Hum | Indoor Rel.Hum | Indoor Dry Bulb | Grains Difference |
|---|---|---|---|---|---|---|
| Winter: | 3 | 1 | n/a | n/a | 70 | n/a |
| Summer: | 95 | 64 | 18% | 30% | 75 | 7 |

### Check Figures

| | | | |
|---|---|---|---|
| Total Building Supply CFM: | 931 | CFM Per Square ft.: | 0.725 |
| Square ft. of Room Area: | 1,284 | Square ft. Per Ton: | 1,093 |
| Volume (ft³): | 11,074 | | |

### Building Loads

| | | | | |
|---|---|---|---|---|
| Total Heating Required Including Ventilation Air: | 11,753 | Btuh | 11.753 | MBH (Based On 0.960 Derating) |
| Total Sensible Gain: | 9,941 | Btuh | 88 | % |
| Total Latent Gain: | 1,363 | Btuh | 12 | % |
| Total Cooling Required Including Ventilation Air: | 11,304 | Btuh | 0.94 | Tons (Based On Sensible + Latent) |
| | | | 1.17 | Tons (Based On 77% Sensible Capacity) (and 0.916 Sensible Derating) |

### Notes

Rhvac is an ACCA approved Manual J and Manual D computer program.
Calculations are performed per ACCA Manual J 8th Edition, Version 2, and ACCA Manual D.
All computed results are estimates as building use and weather may vary.

# Manual J

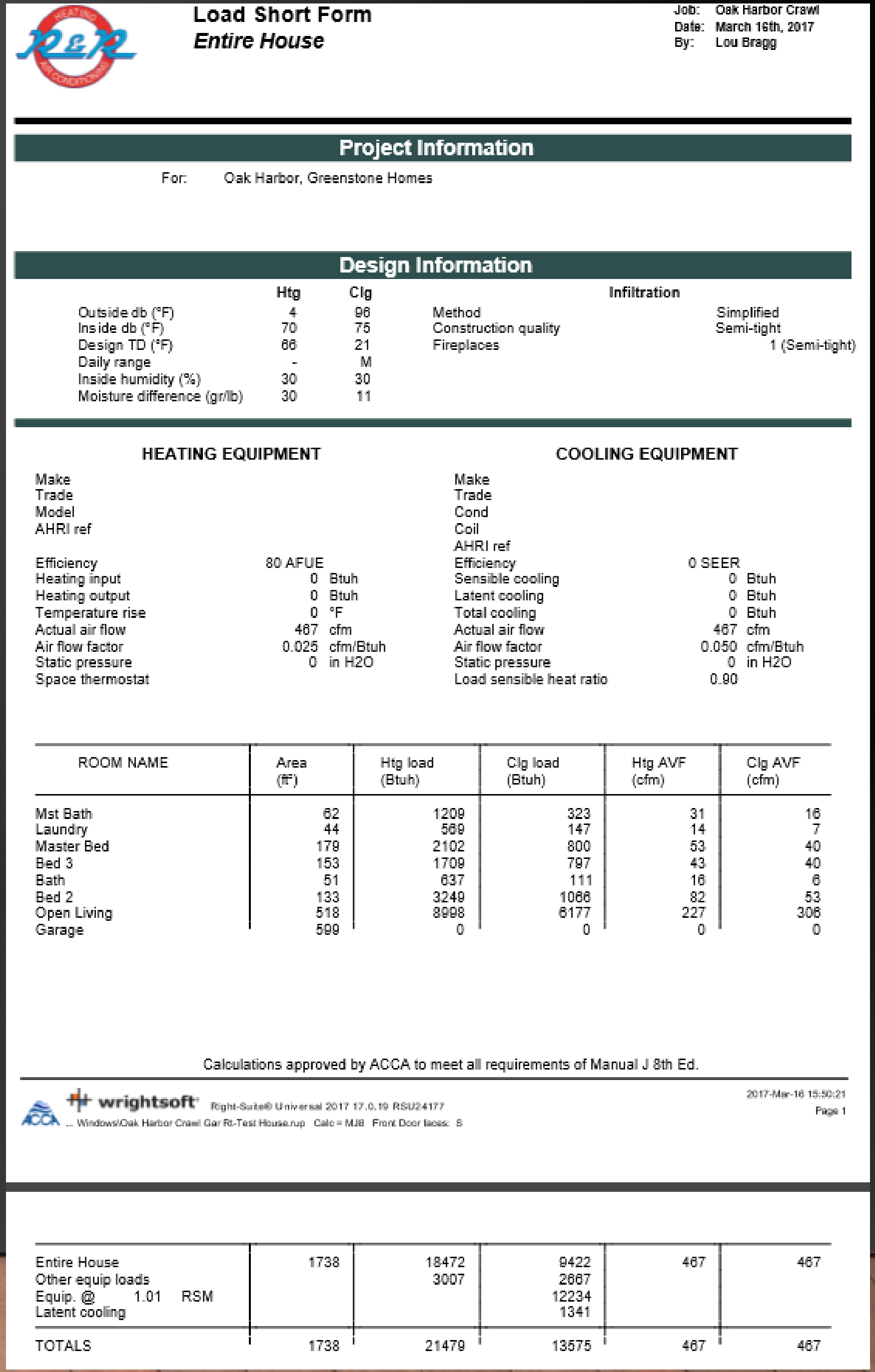
# Room by room heating and cooling load calculation

## Be sure to correctly account for

Air infiltration

Ventilation heating and cooling load

Latent removal when needed



**Load Short Form**
*Entire House*

Job: Oak Harbor Crawl
Date: March 16th, 2017
By: Lou Bragg

**Project Information**

For: Oak Harbor, Greenstone Homes

**Design Information**

| | Htg | Clg |
|---|---|---|
| Outside db (°F) | 4 | 96 |
| Inside db (°F) | 70 | 75 |
| Design TD (°F) | 66 | 21 |
| Daily range | - | M |
| Inside humidity (%) | 30 | 30 |
| Moisture difference (gr/lb) | 30 | 11 |

| Infiltration | |
|---|---|
| Method | Simplified |
| Construction quality | Semi-tight |
| Fireplaces | 1 (Semi-tight) |

**HEATING EQUIPMENT**

| | |
|---|---|
| Make | |
| Trade | |
| Model | |
| AHRI ref | |
| Efficiency | 80 AFUE |
| Heating input | 0 Btuh |
| Heating output | 0 Btuh |
| Temperature rise | 0 °F |
| Actual air flow | 467 cfm |
| Air flow factor | 0.025 cfm/Btuh |
| Static pressure | 0 in H2O |
| Space thermostat | |

**COOLING EQUIPMENT**

| | |
|---|---|
| Make | |
| Trade | |
| Cond | |
| Coil | |
| AHRI ref | |
| Efficiency | 0 SEER |
| Sensible cooling | 0 Btuh |
| Latent cooling | 0 Btuh |
| Total cooling | 0 Btuh |
| Actual air flow | 467 cfm |
| Air flow factor | 0.050 cfm/Btuh |
| Static pressure | 0 in H2O |
| Load sensible heat ratio | 0.90 |

| ROOM NAME | Area (ft²) | Htg load (Btuh) | Clg load (Btuh) | Htg AVF (cfm) | Clg AVF (cfm) |
|---|---|---|---|---|---|
| Mst Bath | 62 | 1209 | 323 | 31 | 16 |
| Laundry | 44 | 569 | 147 | 14 | 7 |
| Master Bed | 179 | 2102 | 800 | 53 | 40 |
| Bed 3 | 153 | 1709 | 797 | 43 | 40 |
| Bath | 51 | 637 | 111 | 16 | 6 |
| Bed 2 | 133 | 3249 | 1066 | 82 | 53 |
| Open Living | 518 | 8998 | 6177 | 227 | 306 |
| Garage | 599 | 0 | 0 | 0 | 0 |

Calculations approved by ACCA to meet all requirements of Manual J 8th Ed.

wrightsoft Right-Suite® Universal 2017 17.0.19 RSU24177
... Windows\Oak Harbor Crawl Gar Rt-Test House.rup Calc = MJ8 Front Door faces: S
2017-Mar-16 15:50:21
Page 1

| | | | | | |
|---|---|---|---|---|---|
| Entire House | 1738 | 18472 | 9422 | 467 | 467 |
| Other equip loads | | 3007 | 2667 | | |
| Equip. @ 1.01 RSM | | | 12234 | | |
| Latent cooling | | | 1341 | | |
| TOTALS | 1738 | 21479 | 13575 | 467 | 467 |

# Why is there a U turn in this ductwork?

# Audience Question #3

First to raise hand and answer correctly

Which is more energy efficient?

Ducts in conditioned space or

Insulated ducts running outside of conditioned space


# Manual D – Duct design

2018 IECC allows buried ducts

better than ductwork over insulation

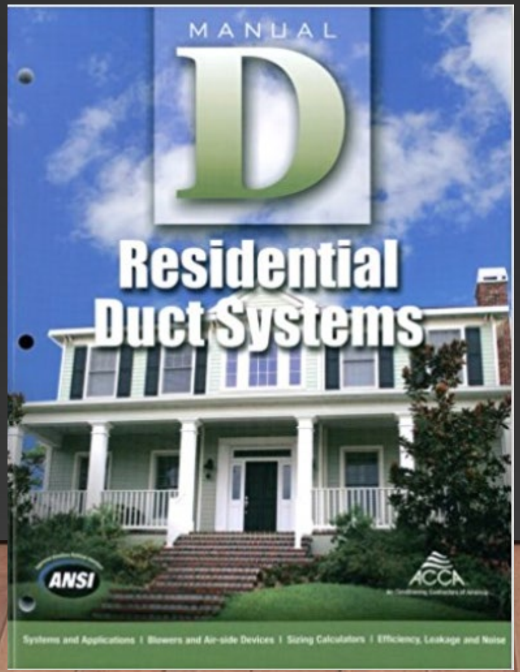
still not as good as ducts in conditioned space

Mini splits can eliminate and/or reduce the need for space conditioning ductwork

All space conditioning ductwork and HRV ductwork needs to have properly designed ductwork

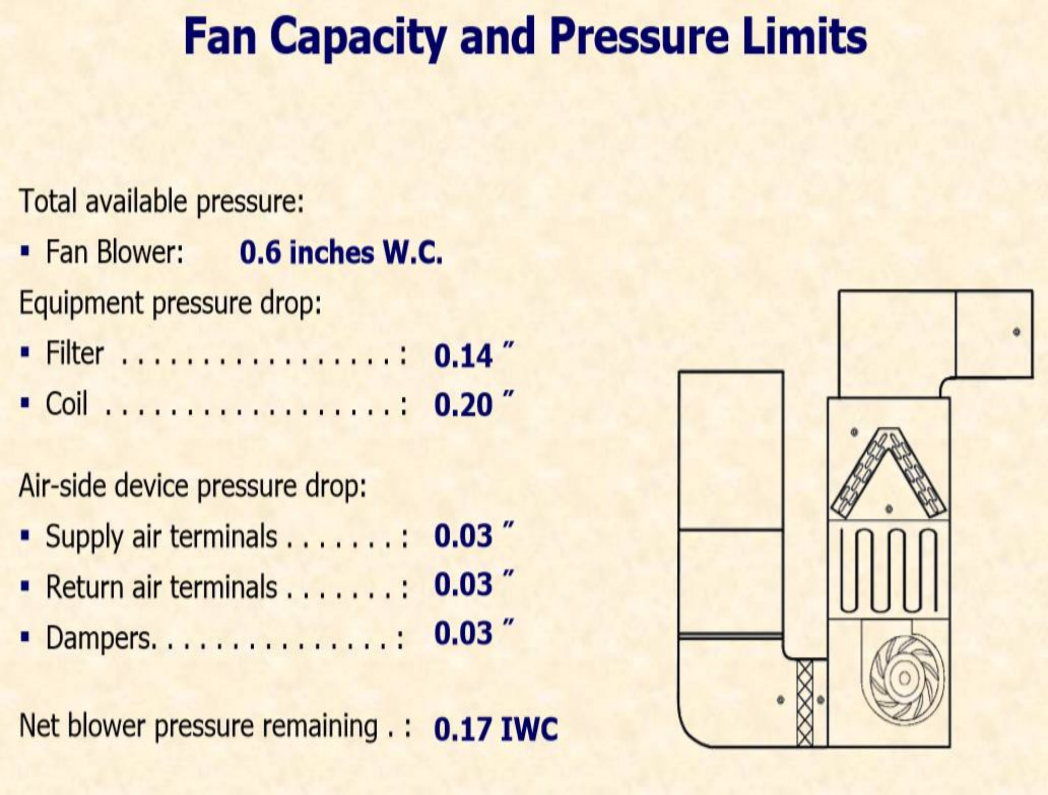
Ductwork should be designed to prevent condensation problems (warm humid air inside of ducts hitting cold surfaces)

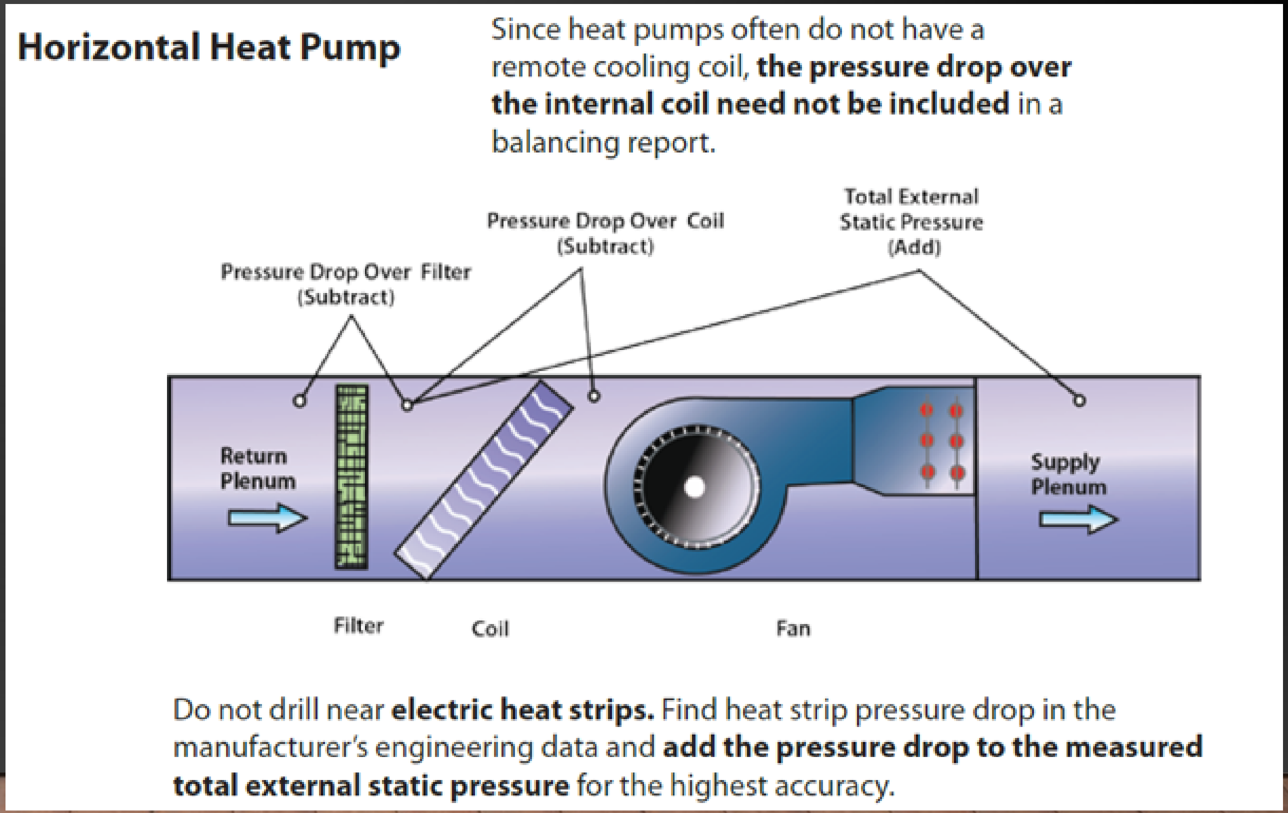
All ventilation ductwork needs to be properly designed



# INPUTS & DATA REQUIRED TO PERFORM A MANUAL D

## Total External Static Pressure (ESP)

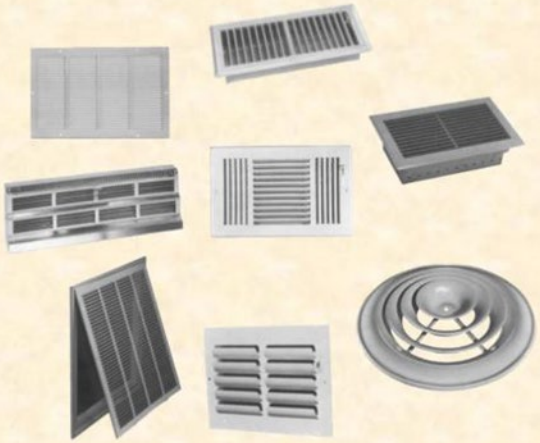


# MANUAL T – AIR TERMINAL DEVICE SELECTION

Manual T: Air Distribution Basics

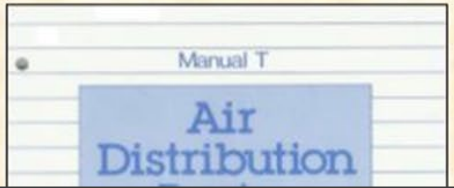
- Room by room load data is used to select air terminal devices.



## Air Terminal Device Selection

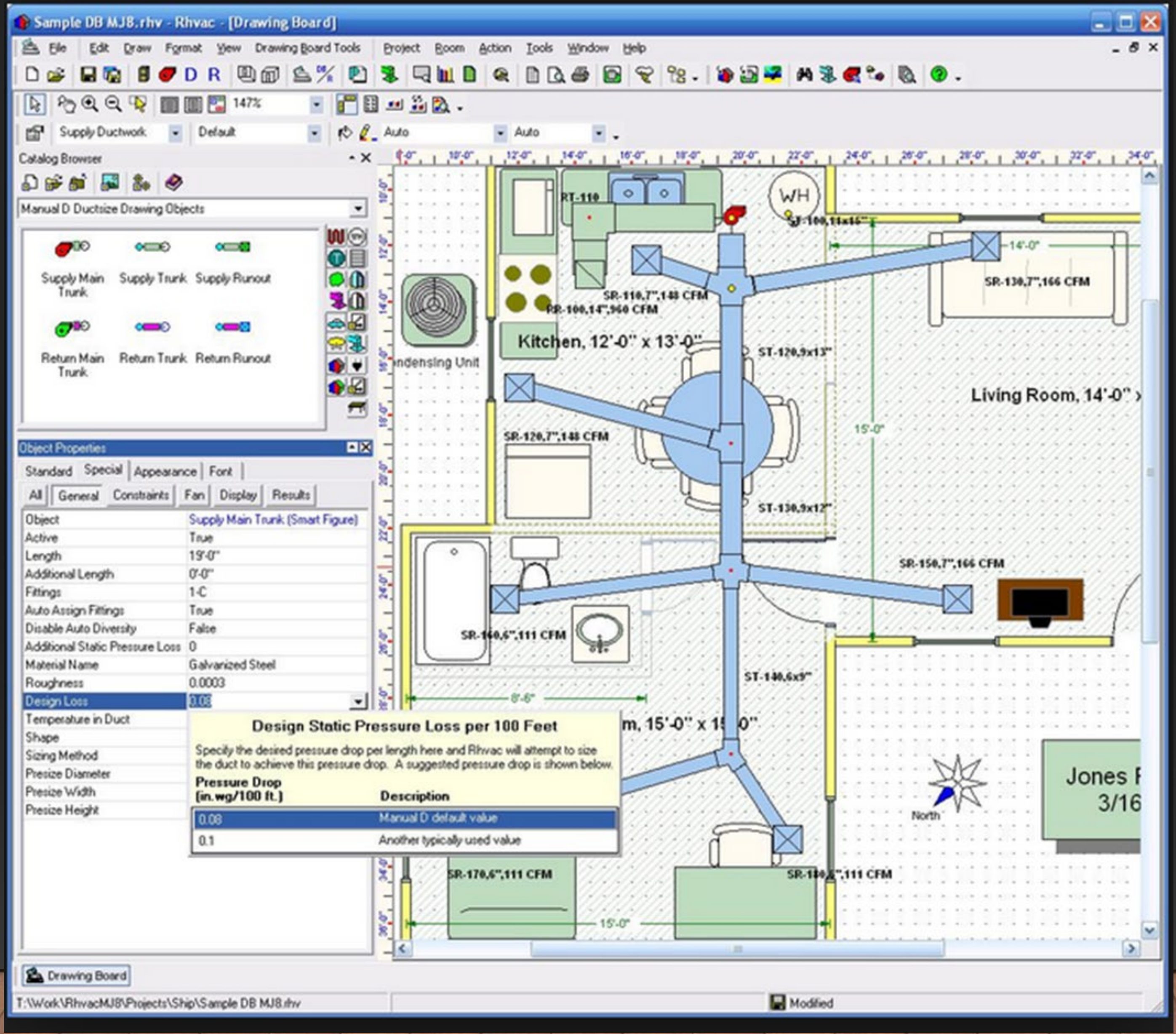
Manual T: Air Terminal Devices

- Use manufacture data to select based on:
  - Size
  - Btuh capacity
  - CFM
  - Pressure drop
  - Velocity
  - Throw
  - Spread.



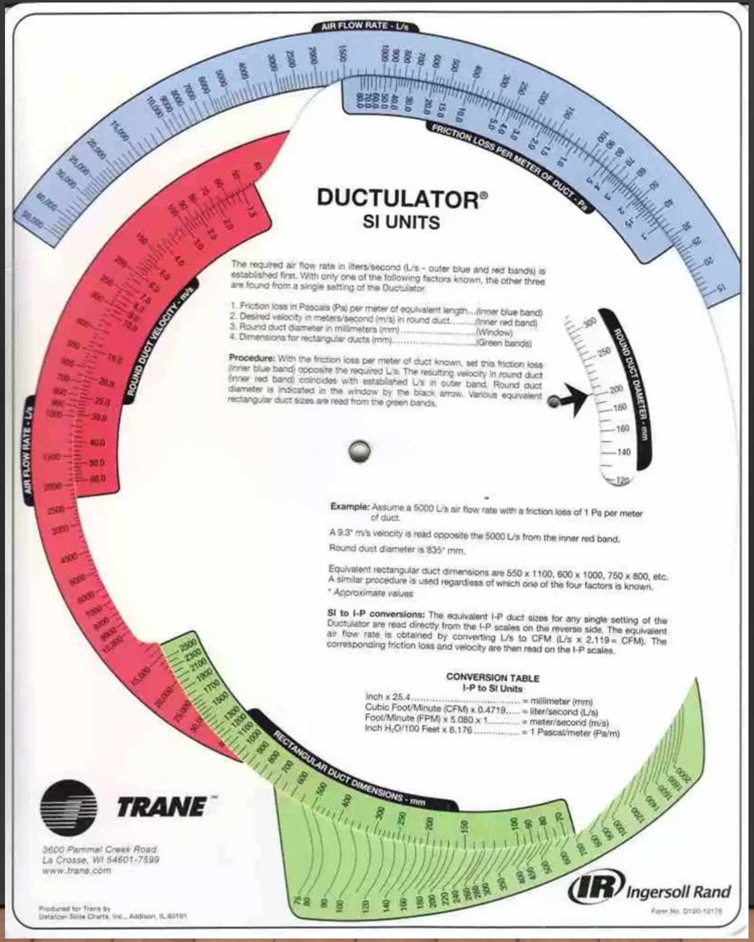

| NOMINAL SIZE | FREE AREA SQ. IN. | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Heating BTU/h | 3045 | 4565 | 6090 | 7610 | 9515 |
| | | Cooling BTU/h | 855 | 1280 | 1710 | 2135 | 2670 |
| | | C.F.M. | 40 | 60 | 80 | 100 | 125 |
| 2¼" x 12" | 21 | T.P. Loss | .009 | .015 | .027 | .037 | .050 |
| | | Vert. Throw (ft.) | 3 | 4 | 5 | 6 | 8 |
| | | Vert. Spread (ft.) | 6 | 8 | 10 | 11 | 14 |
| | | Face Velocity | 280 | 420 | 565 | 705 | 880 |
| 2¼" x 14" | 24 | T.P. Loss | .006 | .010 | .021 | .031 | .042 |
| | | Vert. Throw (ft.) | 3 | 4 | 4.5 | 5.5 | 8 |
| | | Vert. Spread (ft.) | 6 | 8 | 9 | 11 | 14 |
| | | Face Velocity | 245 | 365 | 490 | 610 | 760 |
| 4" x 10" | 32 | T.P. Loss | | .008 | .021 | .026 | .032 |
| | | Vert. Throw (ft.) | | 3 | 4 | 5 | 7 |
| | | Vert. Spread (ft.) | | 6 | 8 | 9 | 12 |
| | | Face Velocity | | 265 | 355 | 445 | 555 |

# MANUAL D LOAD SOFTWARE



# MANUAL D – SUPPLEMENTAL TOOLS

## DUCTULATOR



# What is in your ductwork?



# DUMB DUCT DESIGN

RANGE HOOD CAPTURE EFFICIENCY - ASTM E3087-17

# Smart Duct Design

Use a good duct design tool

Ducts should be as straight as possible

Soft turns over hard turns

Make sure your static pressure matches your ductwork

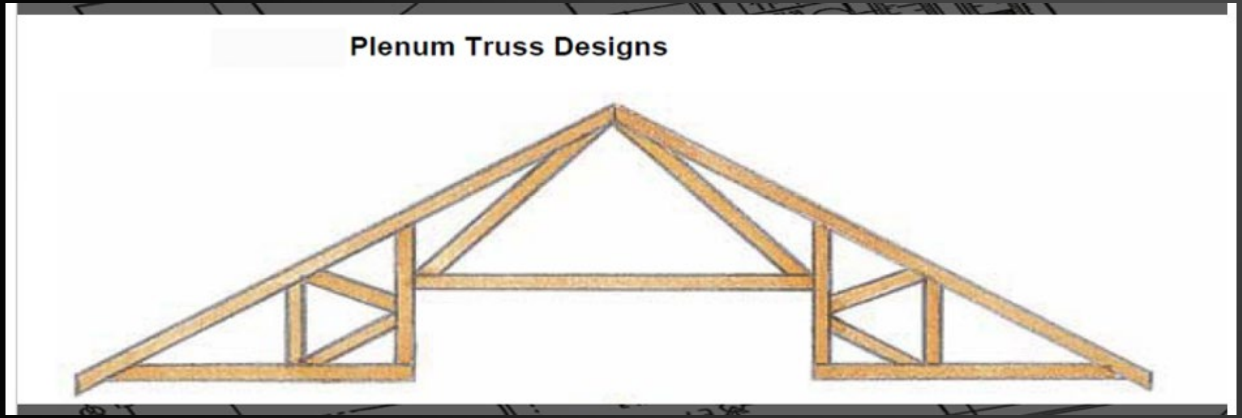
Use dampers and good duct terminations

Air needs a return path in order to move through the home

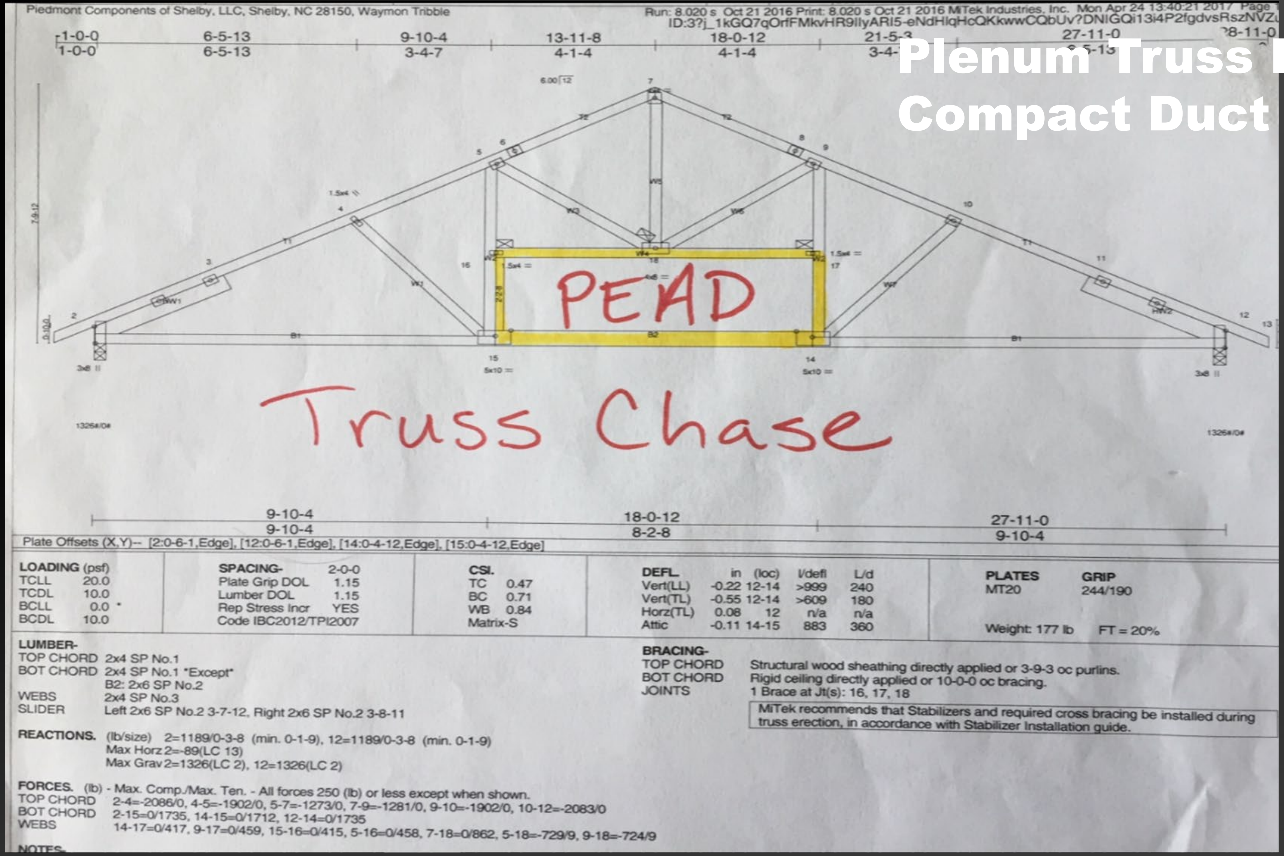
Use stack effect to your advantage for heating and cooling

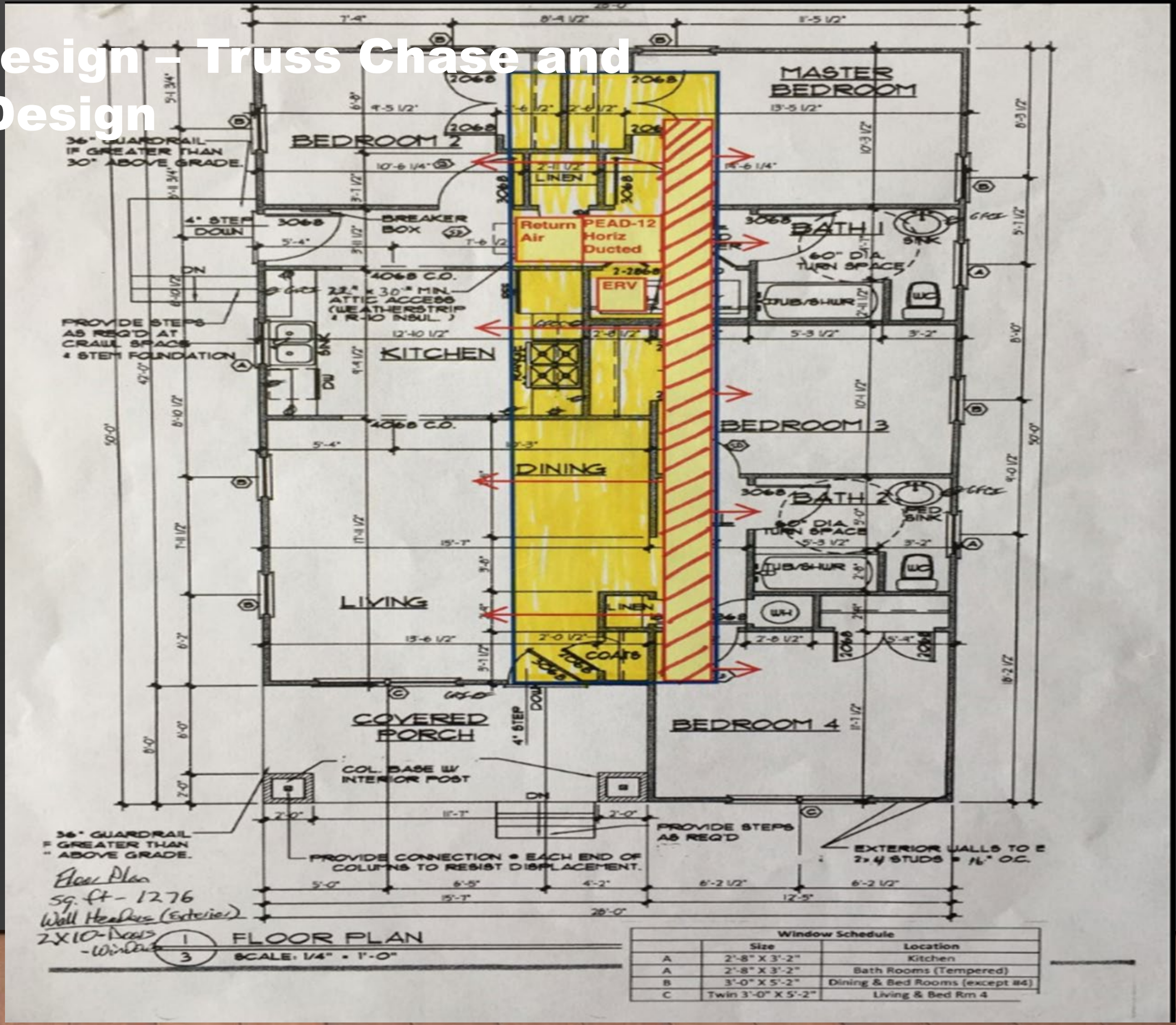
# DUCT INSIDE THE ENVELOPE!
# LESS DUCT - SOFFITS

# DUCT INSIDE THE ENVELOPE!
# PLENUM TRUSS DESIGN AND OPEN WEB TRUSS




# PLENUM TRUSS DESIGN
# TRUSS CHASE AND COMPACT DUCT DESIGN

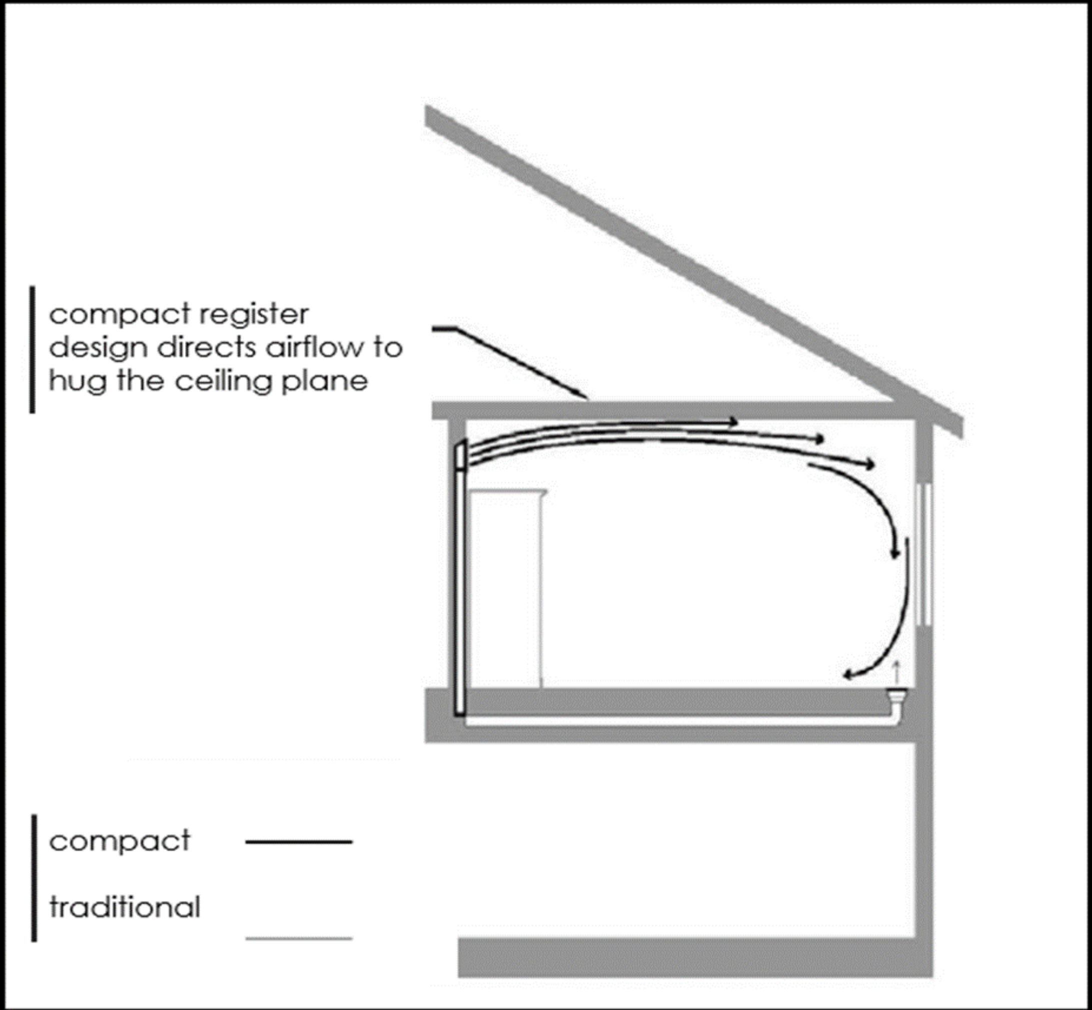



Plenum Truss Design – Truss Chase and Compact Duct Design

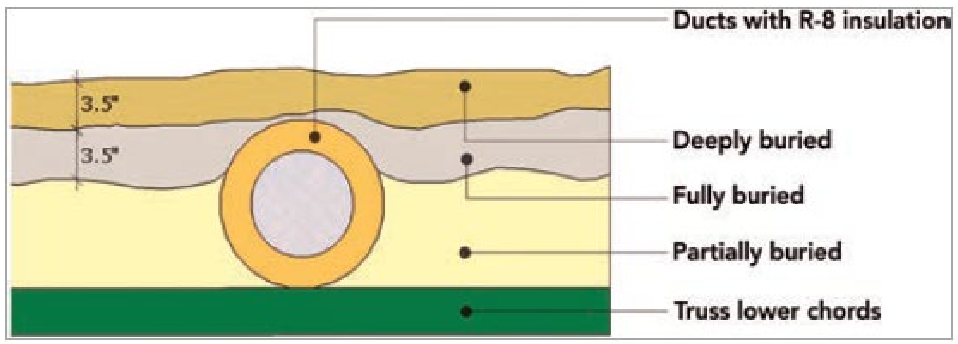
# COMPACT DUCT DESIGN

Compact duct design



# BURIED DUCTS – YES OR NO?

- Be careful! A problem with buried ducts is condensation on the outside of the duct insulation, especially in hot, humid climates during the cooling season.
- Buried ducts must be well sealed and insulated
- Encapsulating the attic ducts in closed-cell spray foam insulation will help overcome condensation.
- Use caution if considering buried ducts.




A buried, unfoamed duct installation

ILLUSTRATION: COURTESY STEVEN WINTER ASSOCIATES


BUILD
BETTER
Performance Construction Roundtable
Habitat for Humanity
of York County
MITSUBISHI
ELECTRIC
COOLING & HEATING

# Dupont Load Calculation

## Project Report

### General Project Information

| | |
|---|---|
| Project Title: | Habatit For Humanity |
| Designed By: | Benny Etter |
| Project Date: | Wednesday, March 16, 2016 |
| Client Name: | Habatit For Humanity |
| Client Address: | 341 Walnut St |
| Client City: | Rock Hill SC |
| Company Name: | Airtek Of York County |
| Company Representative: | Benny Etter |
| Company Address: | 2366 Anderson Rd |
| Company City: | Rock Hill SC 29704 |

### Design Data

| | | |
|---|---|---|
| Reference City: | | Rock Hill, South Carolina |
| Building Orientation: | | Front door faces North |
| Daily Temperature Range: | | Medium |
| Latitude: | 34 | Degrees |
| Elevation: | 470 | ft. |
| Altitude Factor: | 0.983 | |
| Elevation Sensible Adj. Factor: | 1.000 | |
| Elevation Total Adj. Factor: | 1.000 | |
| Elevation Heating Adj. Factor: | 1.000 | |
| Elevation Heating Adj. Factor: | 1.000 | |

| | Outdoor Dry Bulb | Outdoor Wet Bulb | Outdoor Rel.Hum | Indoor Rel.Hum | Indoor Dry Bulb | Grains Difference |
|---|---|---|---|---|---|---|
| Winter: | 23 | 21.39 | 80% | n/a | 70 | n/a |
| Summer: | 94 | 74 | 40% | 50% | 75 | 31 |

### Check Figures

| | | | |
|---|---|---|---|
| Total Building Supply CFM: | 708 | CFM Per Square ft.: | 0.593 |
| Square ft. of Room Area: | 1,195 | Square ft. Per Ton: | 821 |
| Volume (ft³) of Cond. Space: | 9,600 | | |

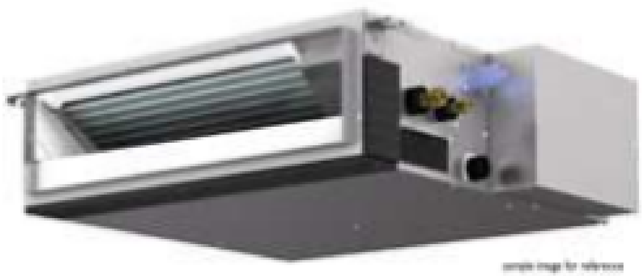
### Building Loads

| | | | | |
|---|---|---|---|---|
| Total Heating Required Including Ventilation Air: | 15,802 | Btuh | 15.802 | MBH |
| Total Sensible Gain: | 15,315 | Btuh | 88 | % |
| Total Latent Gain: | 2,153 | Btuh | 12 | % |
| Total Cooling Required Including Ventilation Air: | 17,468 | Btuh | 1.46 | Tons (Based On Sensible + Latent) |

# Mitsubishi Equipment Selection

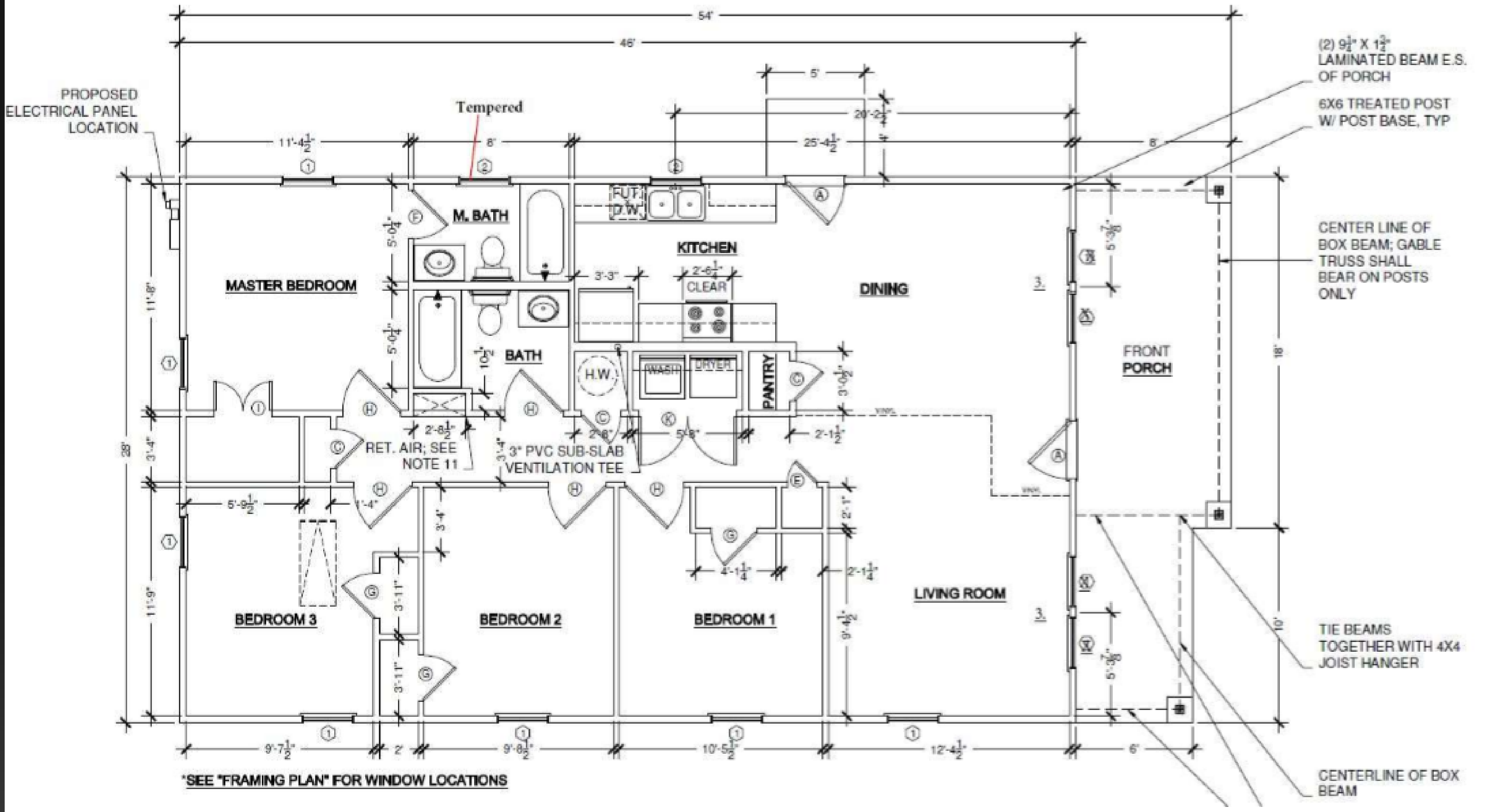
- 9,000 Btu MSZ for Great Room
- 9,000 Btu SEZ for Bedrooms

sample image for reference



sample image for reference

# York County Habitat - Dupont Plan

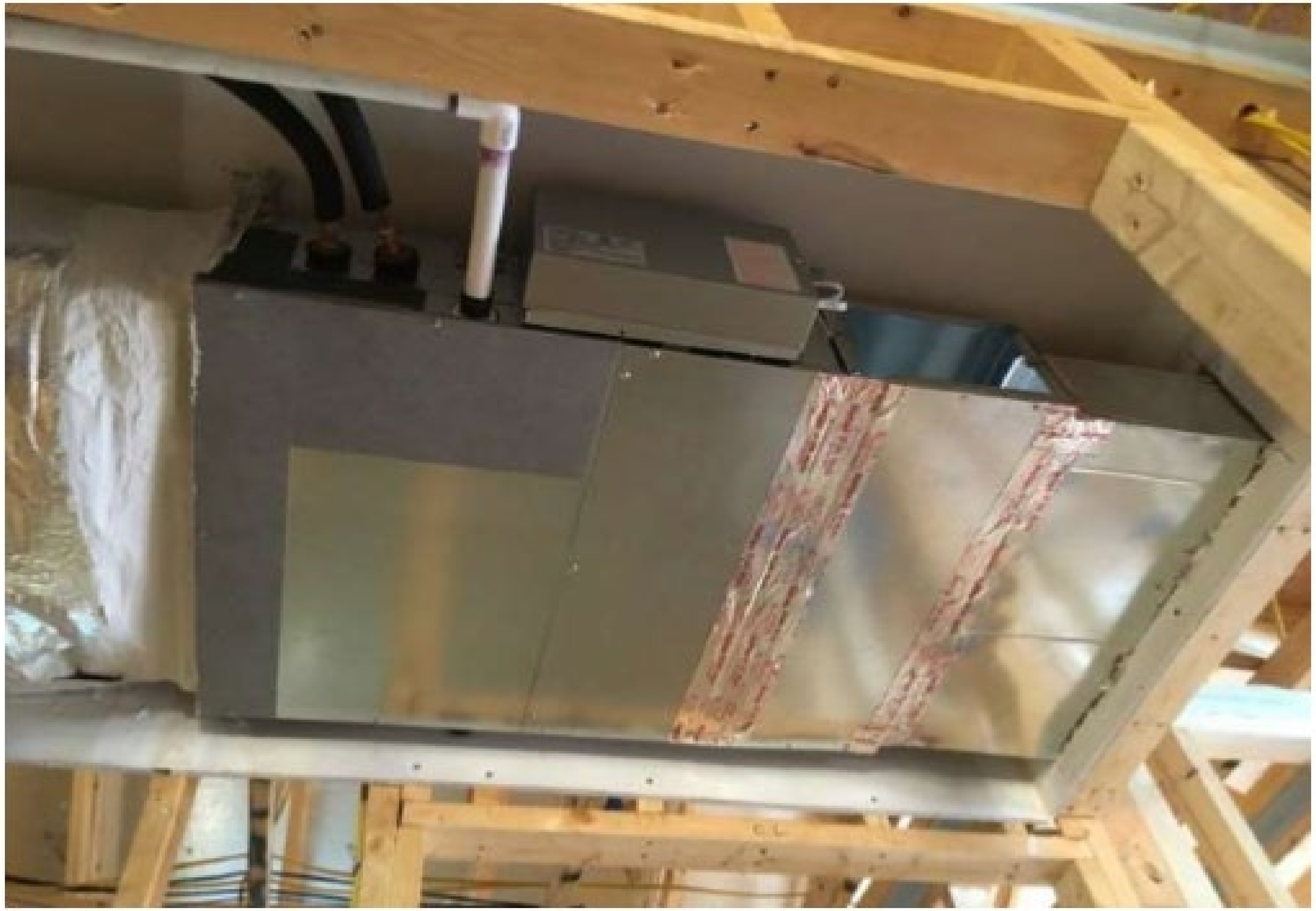


# Construction Site Tour

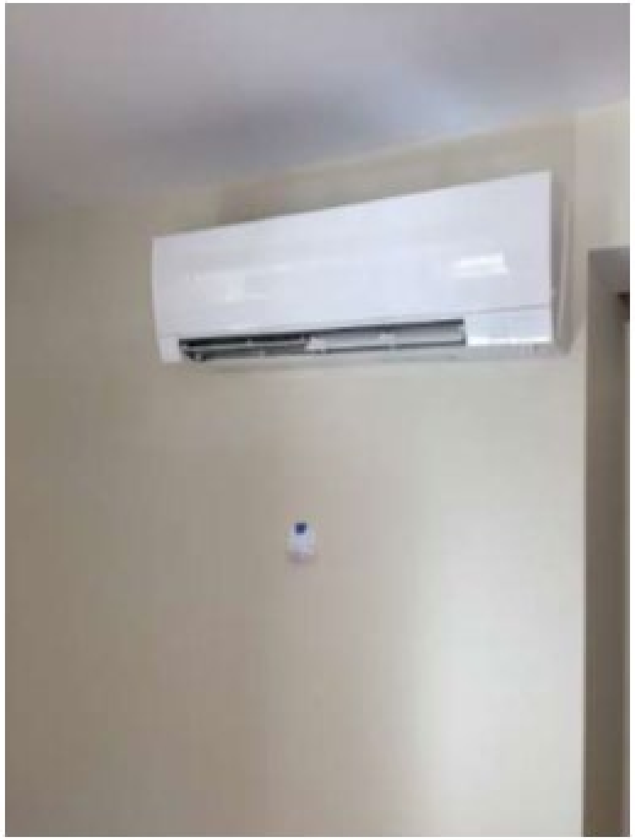
# Mitsubishi System Design

# SEZ in Dropped Hallway Chase

# SEZ with filter box



# Indoor Units



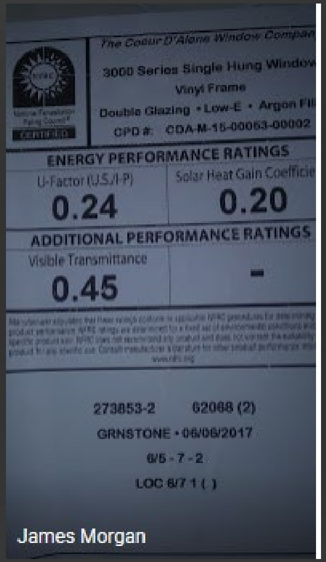
# ERV/HRV Rough-In

# Construction Site Tour

# Construction Site Tour

# High performance shell






# Energy efficient heating and cooling



ENERGY STAR


# Room by room heating and cooling load calculation Manual J

## Heating load 21,479 BTU

## Cooling load 13,875 BTU

## Bedroom 3 only 1,709 BTU

**Load Short Form**
***Entire House***

Job: Oak Harbor Crawl
Date: March 16th, 2017
By: Lou Bragg

**Project Information**

For: Oak Harbor, Greenstone Homes

**Design Information**

| | Htg | Clg |
|---|---|---|
| Outside db (°F) | 4 | 96 |
| Inside db (°F) | 70 | 75 |
| Design TD (°F) | 66 | 21 |
| Daily range | - | M |
| Inside humidity (%) | 30 | 30 |
| Moisture difference (gr/lb) | 30 | 11 |

| Infiltration | |
|---|---|
| Method | Simplified |
| Construction quality | Semi-tight |
| Fireplaces | 1 (Semi-tight) |

**HEATING EQUIPMENT**

| | |
|---|---|
| Make | |
| Trade | |
| Model | |
| AHRI ref | |
| Efficiency | 80 AFUE |
| Heating input | 0 Btuh |
| Heating output | 0 Btuh |
| Temperature rise | 0 °F |
| Actual air flow | 467 cfm |
| Air flow factor | 0.025 cfm/Btuh |
| Static pressure | 0 in H2O |
| Space thermostat | |

**COOLING EQUIPMENT**

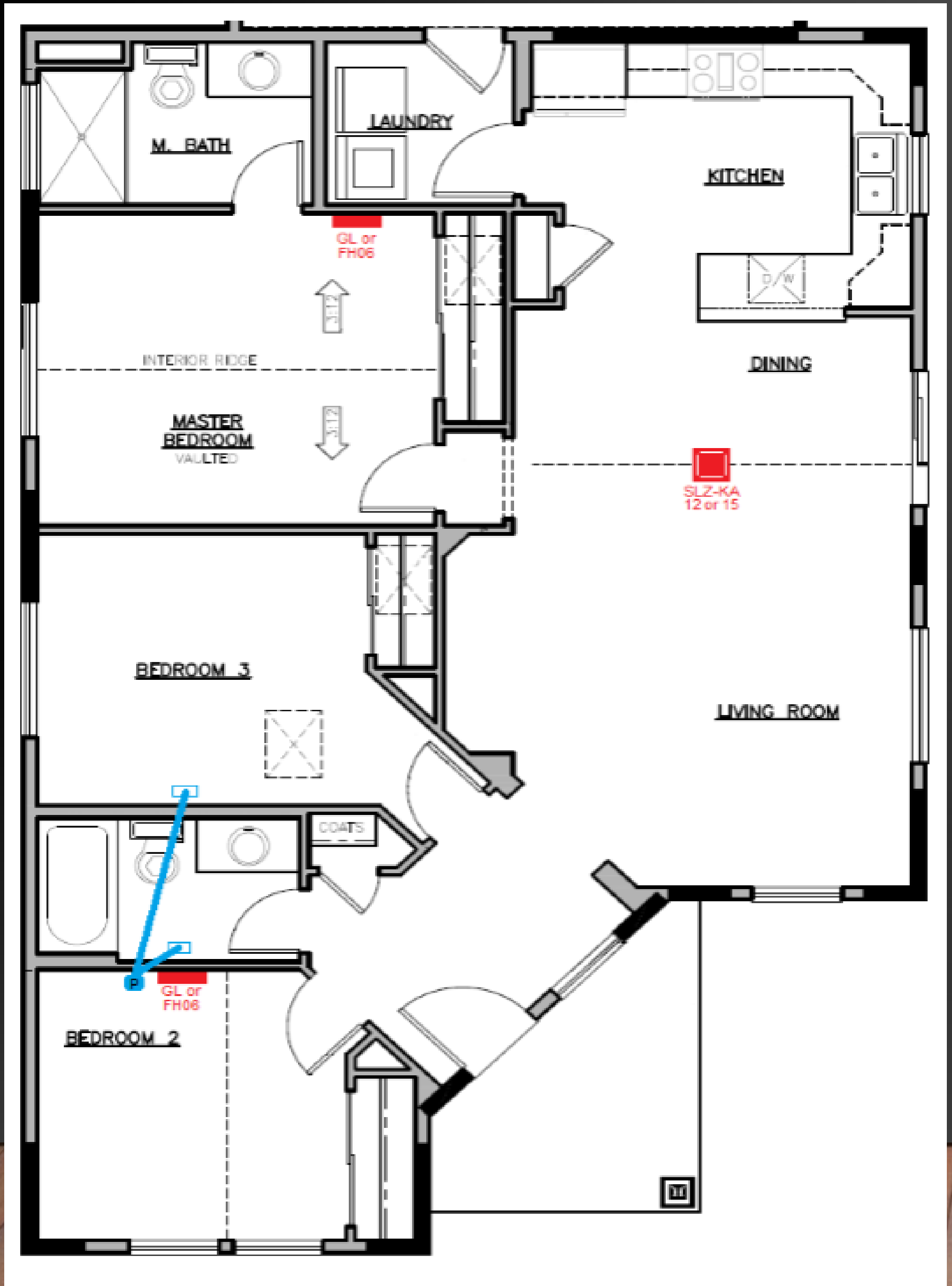
| | |
|---|---|
| Make | |
| Trade | |
| Cond | |
| Coil | |
| AHRI ref | |
| Efficiency | 0 SEER |
| Sensible cooling | 0 Btuh |
| Latent cooling | 0 Btuh |
| Total cooling | 0 Btuh |
| Actual air flow | 467 cfm |
| Air flow factor | 0.050 cfm/Btuh |
| Static pressure | 0 in H2O |
| Load sensible heat ratio | 0.90 |

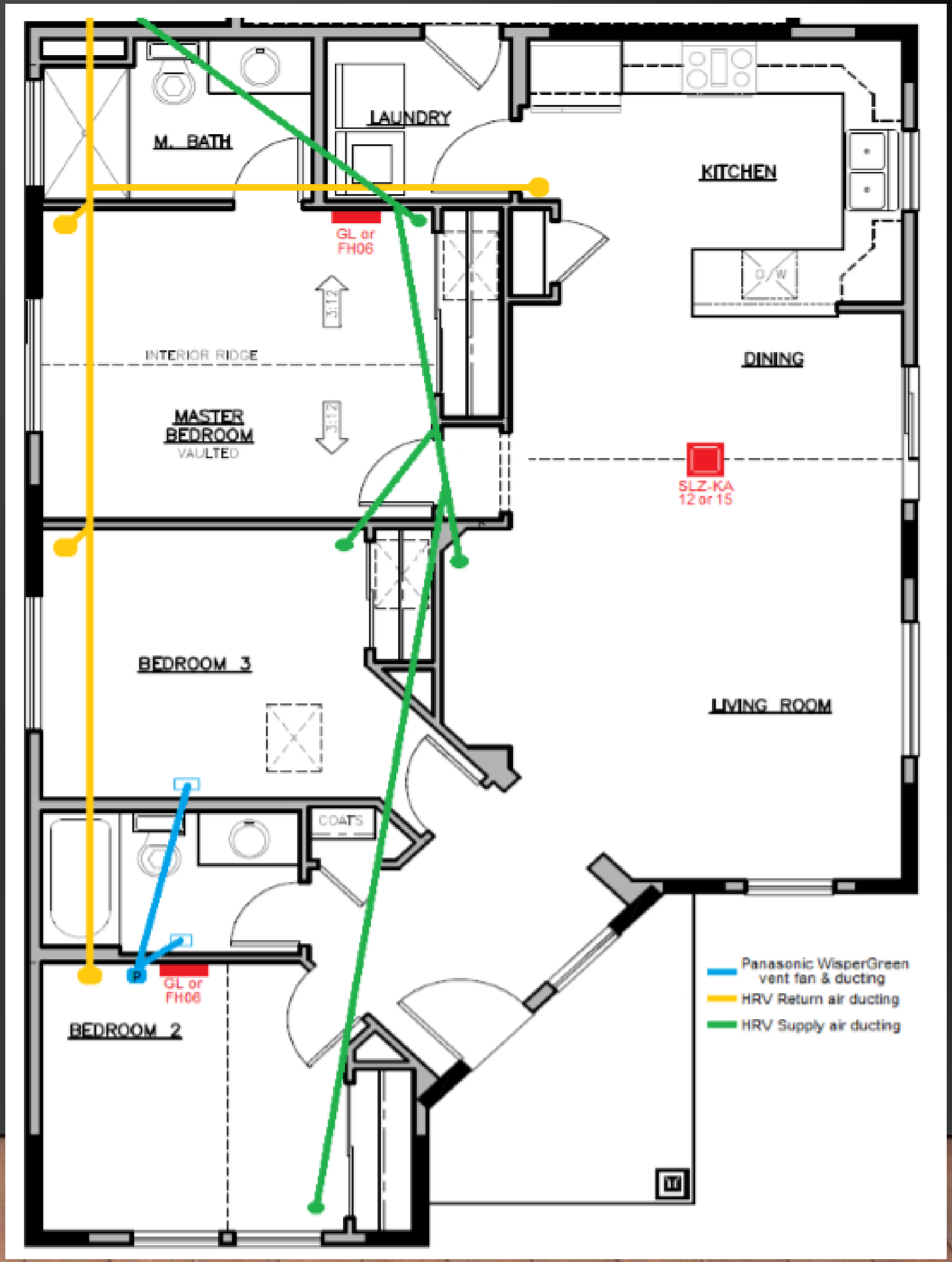
| ROOM NAME | Area (ft²) | Htg load (Btuh) | Clg load (Btuh) | Htg AVF (cfm) | Clg AVF (cfm) |
|---|---|---|---|---|---|
| Mst Bath | 62 | 1209 | 323 | 31 | 16 |
| Laundry | 44 | 569 | 147 | 14 | 7 |
| Master Bed | 179 | 2102 | 800 | 53 | 40 |
| Bed 3 | 153 | 1709 | 797 | 43 | 40 |
| Bath | 51 | 637 | 111 | 16 | 6 |
| Bed 2 | 133 | 3249 | 1066 | 82 | 53 |
| Open Living | 518 | 8998 | 6177 | 227 | 306 |
| Garage | 599 | 0 | 0 | 0 | 0 |

Calculations approved by ACCA to meet all requirements of Manual J 8th Ed.

wrightsoft Right-Suite® Universal 2017 17.0.19 RSU24177
... Windows/Oak Harbor Crawl Gar Rt-Test House.rup Calc = MJ8 Front Door faces: S
2017-Mar-16 15:50:21
Page 1

| | | | | | |
|---|---|---|---|---|---|
| Entire House | 1738 | 18472 | 9422 | 467 | 467 |
| Other equip loads | | 3007 | 2667 | | |
| Equip. @ 1.01 RSM | | | 12234 | | |
| Latent cooling | | | 1341 | | |
| TOTALS | 1738 | 21479 | 13575 | 467 | 467 |


M. BATH
LAUNDRY
KITCHEN
GL or FH06
DINING
INTERIOR RIDGE
MASTER BEDROOM
VAULTED
SLZ-KA 12 or 15
BEDROOM 3
LIVING ROOM
COATS
GL or FH06
BEDROOM 2


M. BATH
LAUNDRY
KITCHEN
GL or FH06
DINING
INTERIOR RIDGE
MASTER BEDROOM
VAULTED
SLZ-KA 12 or 15
BEDROOM 3
LIVING ROOM
COATS
GL or FH06
BEDROOM 2
Panasonic WisperGreen vent fan & ducting
HRV Return air ducting
HRV Supply air ducting

# High performance Fresh Air system

## Heat recovery whole home ventilation fan plus whole home filter for healthy indoor air quality


# INDOOR AIR QUALITY AND VENTILATION BEST PRACTICES

Keep the chemicals out of the living space

Supply fresh air to bedrooms for improved sleep quality

Charcoal filtration

Whole home fresh air system to meet ASHRAE 62.2 requirements

Always run kitchen fans when cooking

Less toxic building materials

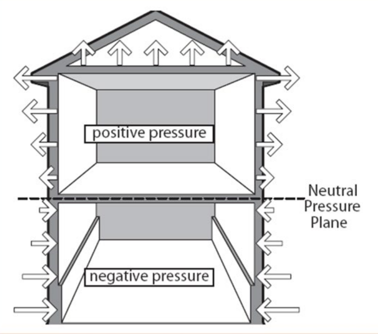
Always run bath fans when bathing

# Natural Ventilation

Driving Force = Pressure difference (ΔP)

- Temperature difference
- Stack effect
- Wind

**Stack Effect**



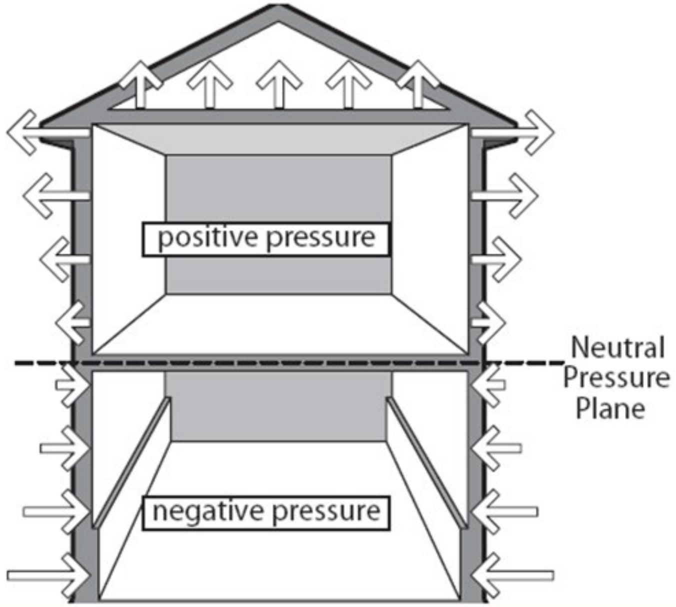

The stack effect is caused by the relative buoyancy of warmer air. Warmer air's upward force exerts an outward pressure. Airflow, through holes in the home's top, creates suction at lower levels, pulling air in. Arrows indicate the direction and intensity of air pressure.

ΔP varies seasonally

# Natural Ventilation

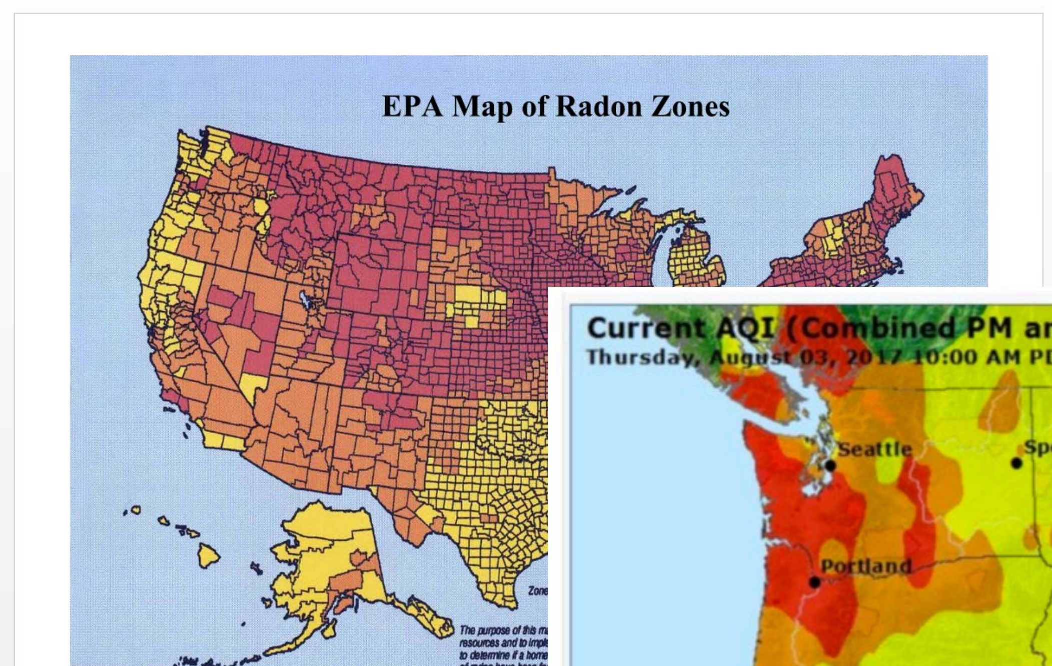
## Air out = Air in

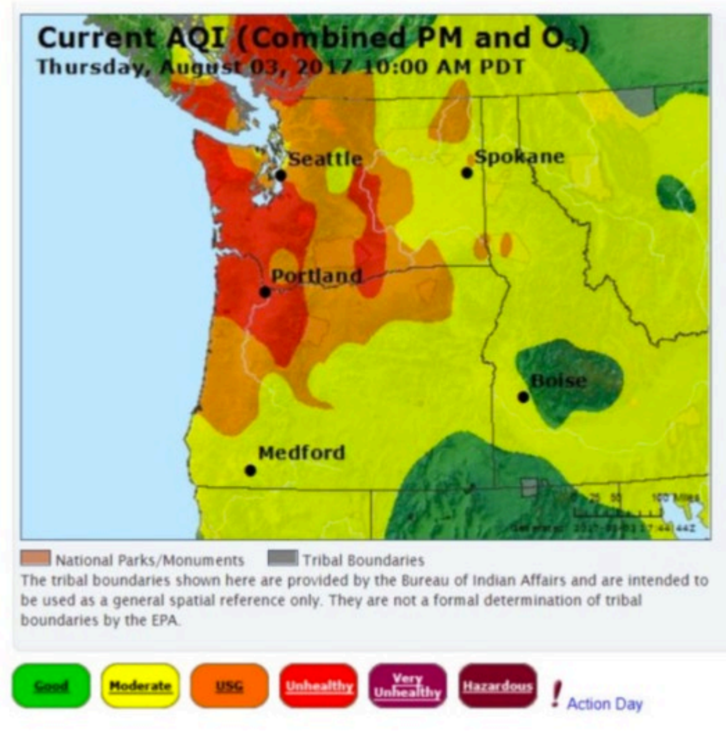
**Stack Effect**



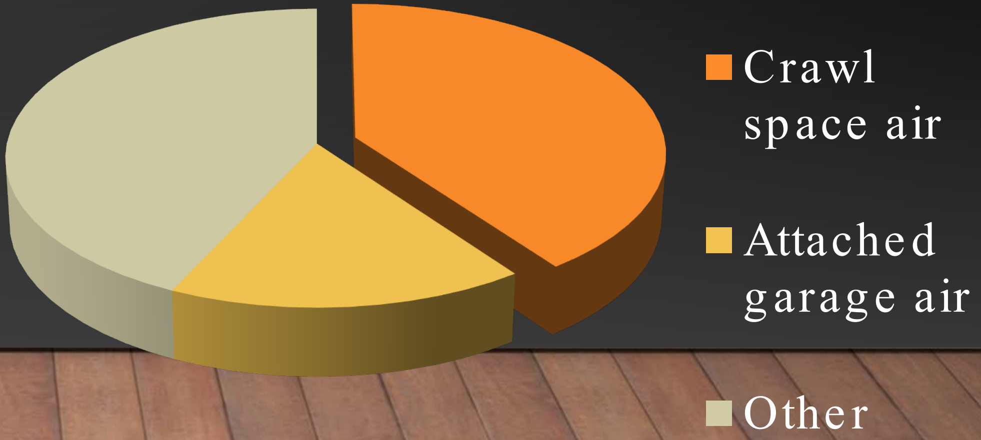

The stack effect is caused by the relative buoyancy of warmer air. Warmer air's upward force exerts an outward pressure. Airflow, through holes in the home's top, creates suction at lower levels, pulling air in. Arrows indicate the direction and intensity of air pressure.

# Natural Ventilation?



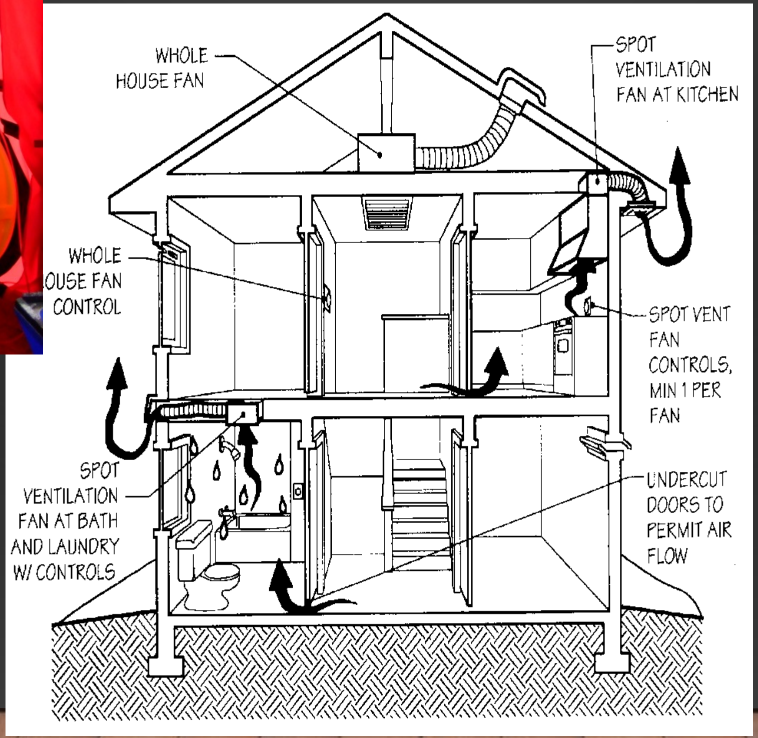

## Outside “Fresh” Air



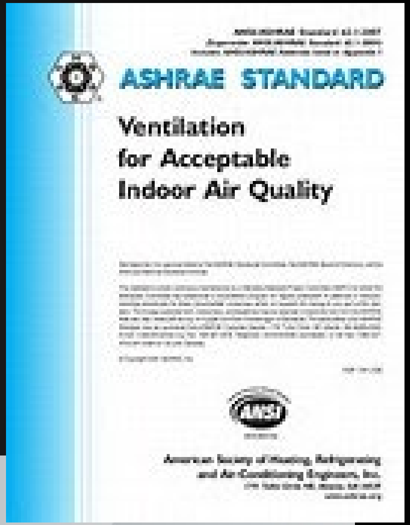
# ASHRAE 62.2

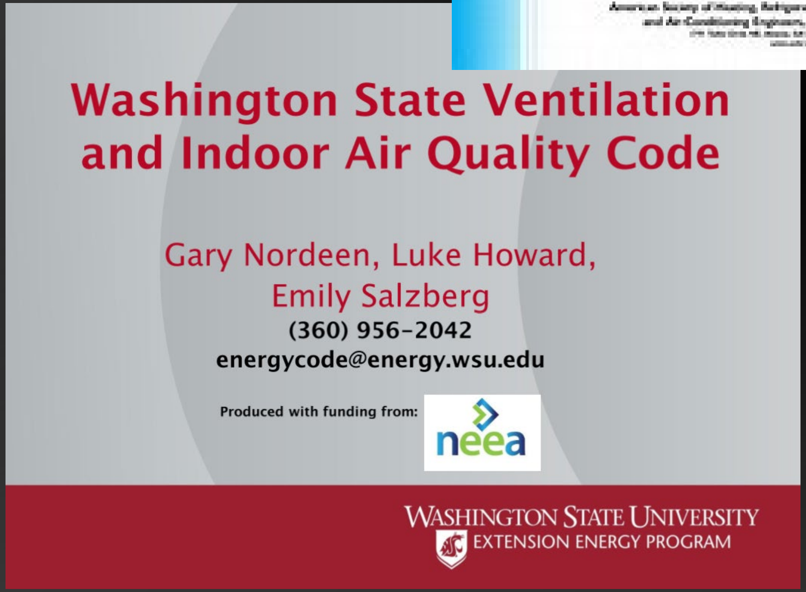
Most states now mandate local and whole house mechanical ventilation by code.

Build tight




Ventilate right

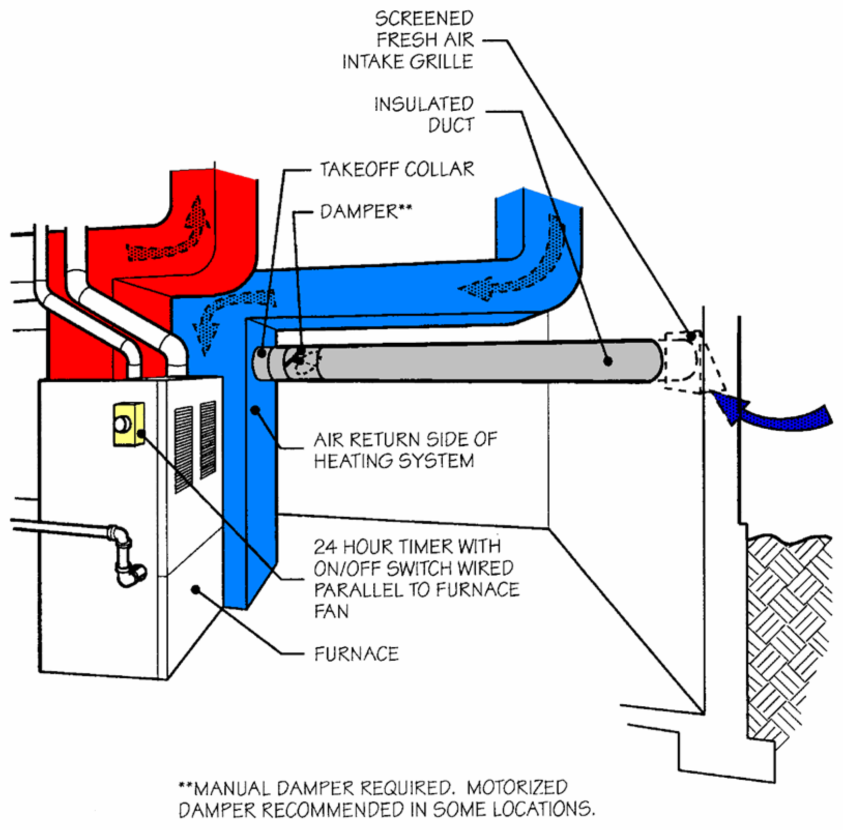


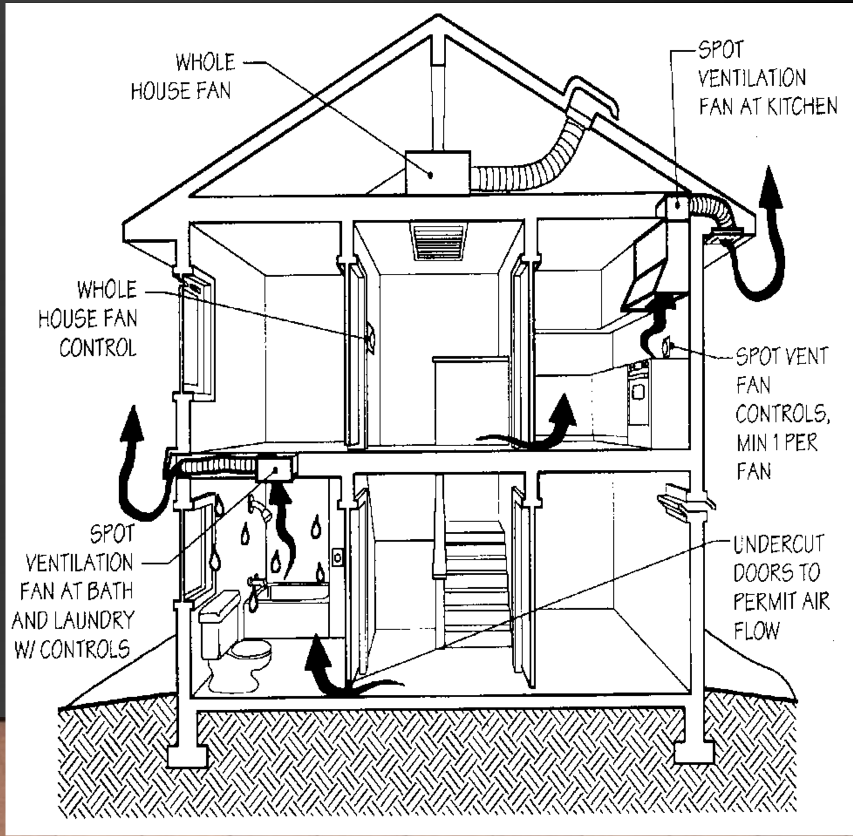
# Common Whole House Ventilation System Types

Supply Integrated with

Central Forced Air

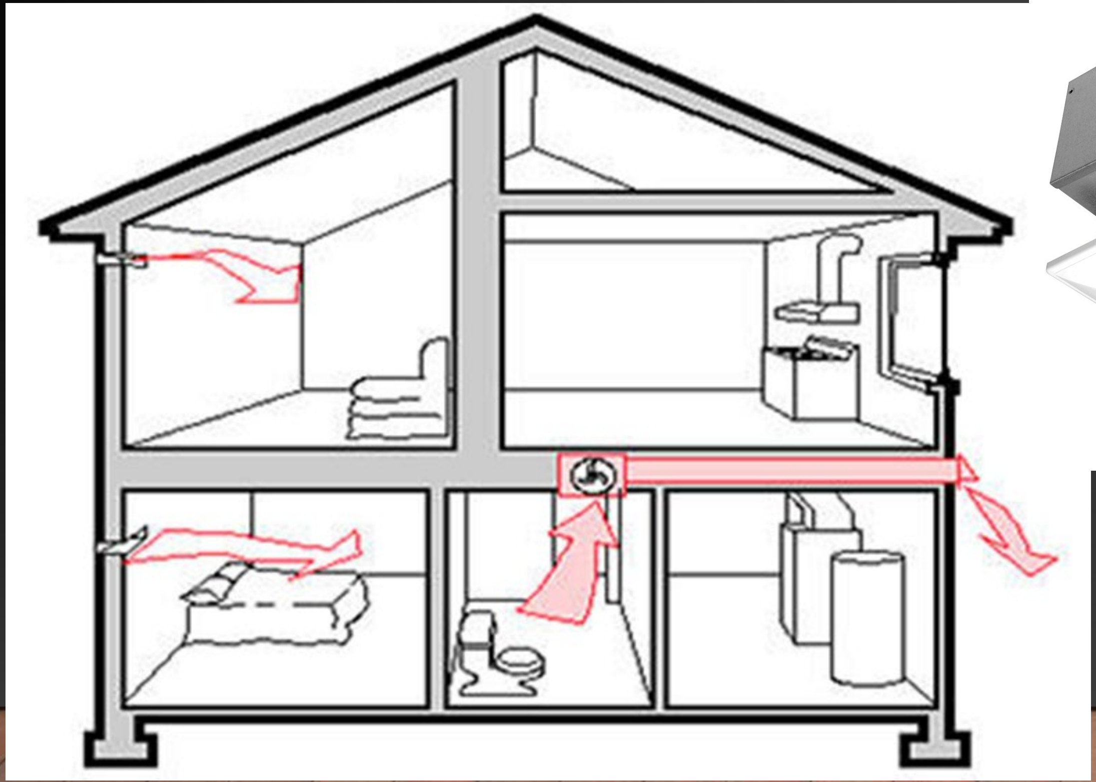



Exhaust Only



# WHOLE HOUSE VENTILATION SYSTEM EFFECTIVENESS

Exhaust Only Systems



# LOCAL EXHAUST VENTILATION

**Baths***

50 cfm intermittent

- 80 cfm in Oregon

- 20 cfm continuous

Condensation sensor on fan?

**Kitchens**

- 100 cfm intermittent
- 25 cfm continuous
- Systems over 400cfm must provide makeup air

*some states require local exhaust in utility/laundry rooms

# AVOIDING DEPRESSURIZATION

## SOURCES OF NEGATIVE PRESSURE IN A HOME ARE

Range hoods

Exhaust fans

Dryers

Central Vacuum

Bad HVAC system design

# Make Up Air

In the US, the construction industry has long recognized the need for adequate makeup air for exhaust systems. Beginning in 2009 and in every version since, the International Residential Code (IRC) has required that makeup air be provided for kitchen hood exhaust systems with capacity of 400 cfm or greater.

When an exhaust fan operates without sufficient makeup air, some undesirable results can occur:

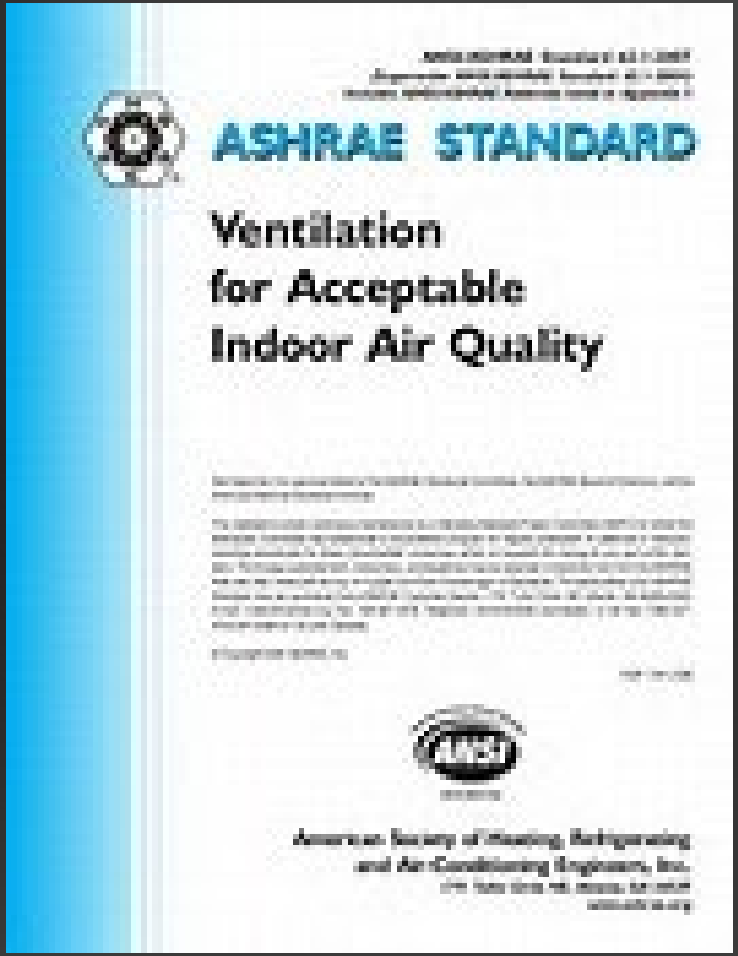
**The exhaust system will not work to its intended capacity**

Kitchen hood exhaust systems are sized to remove cooking-generated heat, odors and contaminants based on the cooking equipment's dimensions and heat rating. Inadequate makeup air can prevent a kitchen hood exhaust system from adequately removing contaminants.

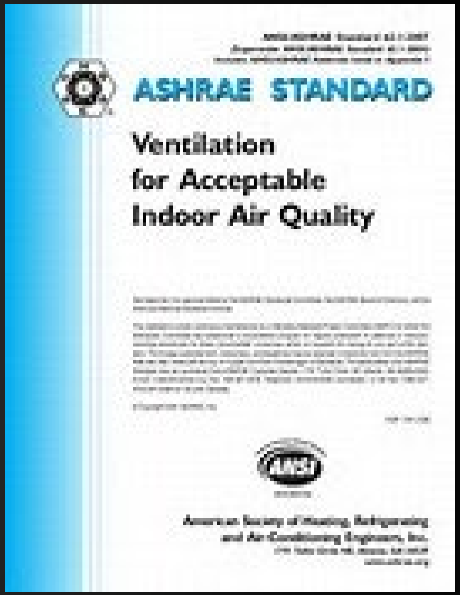
**Backdrafting of chimneys and appliance vents**

Insufficient makeup air will result in depressurization in the home. Depressurization works to halt the flow of hearth and appliance combustion products from exiting the home. This "backdrafting" can result in a dangerous accumulation of harmful gases in the home. Studies by the Building Performance Institute (BPI) and Residential Energy Services Network (RESNET) have shown that as little as **5 Pa (0.02" w.g.)** depressurization can cause backdrafting.

# WHOLE HOUSE MECHANICAL VENTILATION



# WHOLE HOUSE MECHANICAL VENTILATION INTERMITTENT OPERATION




| DWELLING UNIT FLOOR AREA (square feet) | NUMBER OF BEDROOMS | | | | |
|---|---|---|---|---|---|
| | 0 - 1 | 2 - 3 | 4 - 5 | 6 - 7 | > 7 |
| | Airflow in CFM | | | | |
| < 1,500 | 30 | 45 | 60 | 75 | 90 |
| 1,501 - 3,000 | 45 | 60 | 75 | 90 | 105 |
| 3,001 - 4,500 | 60 | 75 | 90 | 105 | 120 |
| 4,501 - 6,000 | 75 | 90 | 105 | 120 | 135 |
| 6,001 - 7,500 | 90 | 105 | 120 | 135 | 150 |
| > 7,500 | 105 | 120 | 135 | 150 | 165 |

For SI: 1 square foot = 0.0929 $m^2$, 1 cubic foot per minute = 0.0004719 $m^3/s$.

**Table M1507.3.3(2)**
**Intermittent Whole-House Mechanical Ventilation Rate Factors[a, b]**

| Run-Time Percentage in Each 4-Hour Segment | 25% | 33% | 50% | 66% | 75% | 100% |
|---|---|---|---|---|---|---|
| Factor[a] | 4 | 3 | 2 | 1.5 | 1.3 | 1.0 |

a For ventilation system run time values between those given, the factors are permitted to be determined by interpolation.
b Extrapolation beyond the table is prohibited.

# WHOLE HOUSE MECHANICAL VENTILATION CONTINUOUS OPERATION

2013

**VENTILATION RATES FOR ALL GROUP R PRIVATE DWELLINGS, SINGLE AND MULTIPLE**
**(Continuously Operating Systems)**

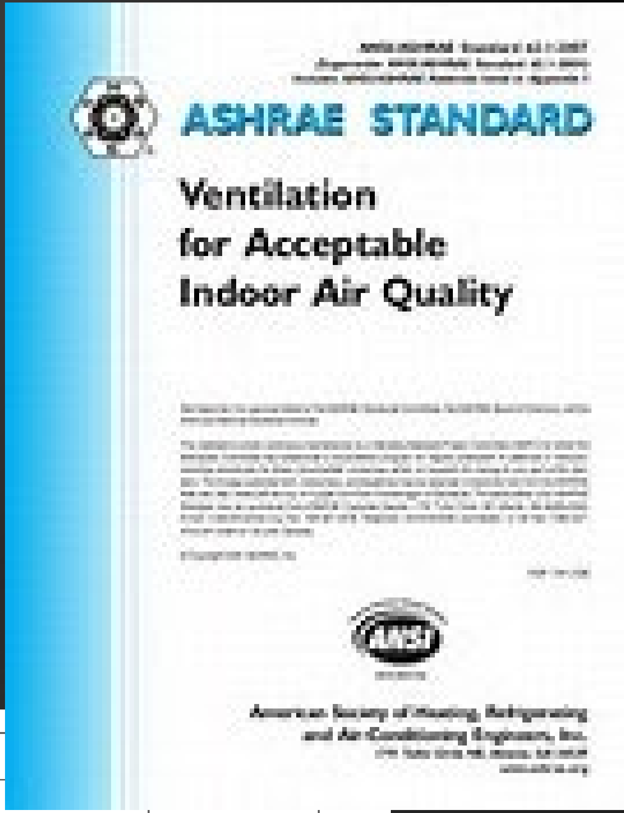
| Floor Area (ft$^2$) | Bedrooms[a] | | | | |
|---|---|---|---|---|---|
| | 0-1 | 2-3 | 4-5 | 6-7 | >7 |
| <500 | 30 | 40 | 45 | 55 | 60 |
| 500 - 1000 | 45 | 55 | 60 | 70 | 75 |
| 1001 - 1500 | 60 | 70 | 75 | 85 | 90 |
| 1501 - 2000 | 75 | 85 | 90 | 100 | 105 |
| 2001 - 2500 | 90 | 100 | 105 | 115 | 120 |
| 2501 - 3000 | 105 | 115 | 120 | 130 | 135 |
| 3001 - 3500 | 120 | 130 | 135 | 145 | 150 |
| >3500 | 135 | 145 | 150 | 160 | 165 |

a. Ventilation rates in table are minimum outdoor airflow rates measured in cfm.

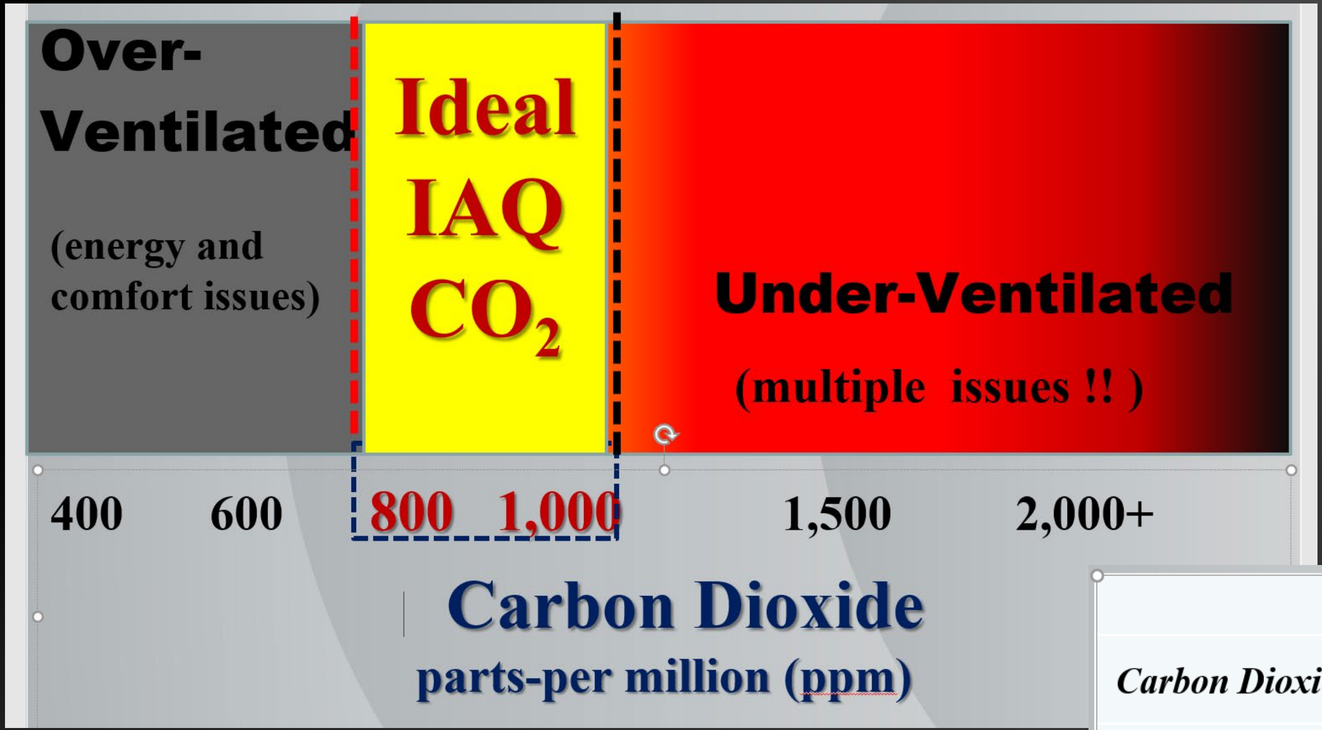
2010

| DWELLING UNIT FLOOR AREA (square feet) | NUMBER OF BEDROOMS | | | | |
|---|---|---|---|---|---|
| | 0 - 1 | 2 - 3 | 4 - 5 | | |
| | Airflow in CFM | | | | |
| < 1,500 | 30 | 45 | 60 | 75 | 90 |
| 1,501 - 3,000 | 45 | 60 | 75 | 90 | 105 |
| 3,001 - 4,500 | 60 | 75 | 90 | 105 | 120 |
| 4,501 - 6,000 | 75 | 90 | 105 | 120 | 135 |
| 6,001 - 7,500 | 90 | 105 | 120 | 135 | 150 |
| > 7,500 | 105 | 120 | 135 | 150 | 165 |

For SI: 1 square foot = 0.0929 m$^2$, 1 cubic foot per minute = 0.0004719 m$^3$/s.



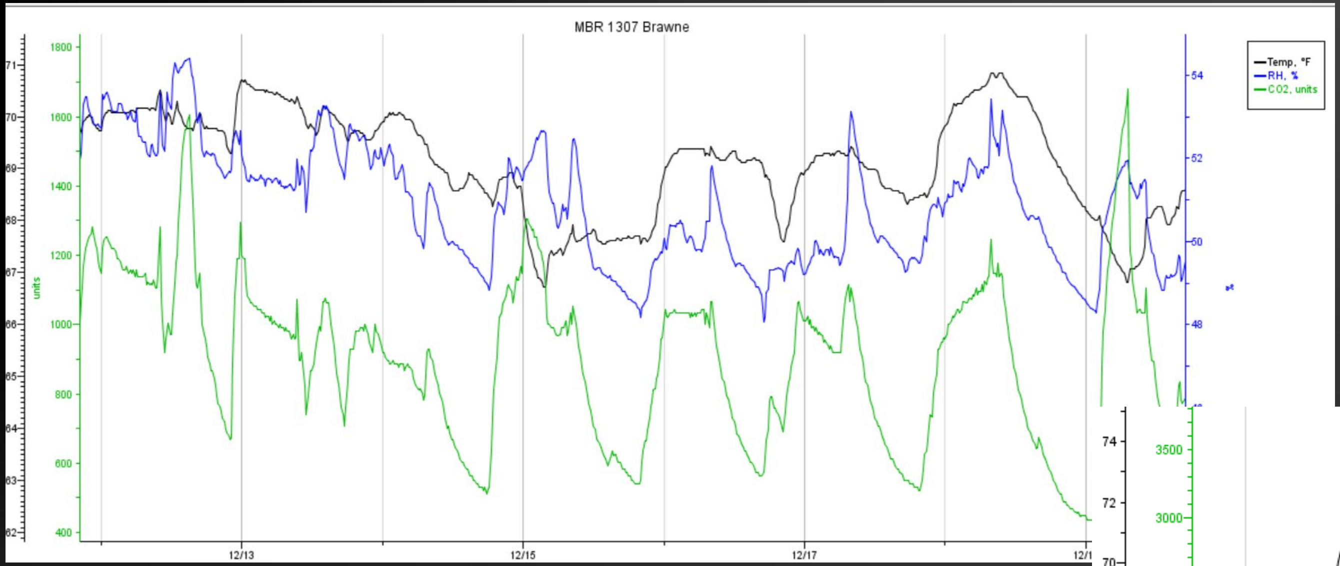
# WHOLE HOUSE VENTILATION SYSTEM EFFECTIVENESS

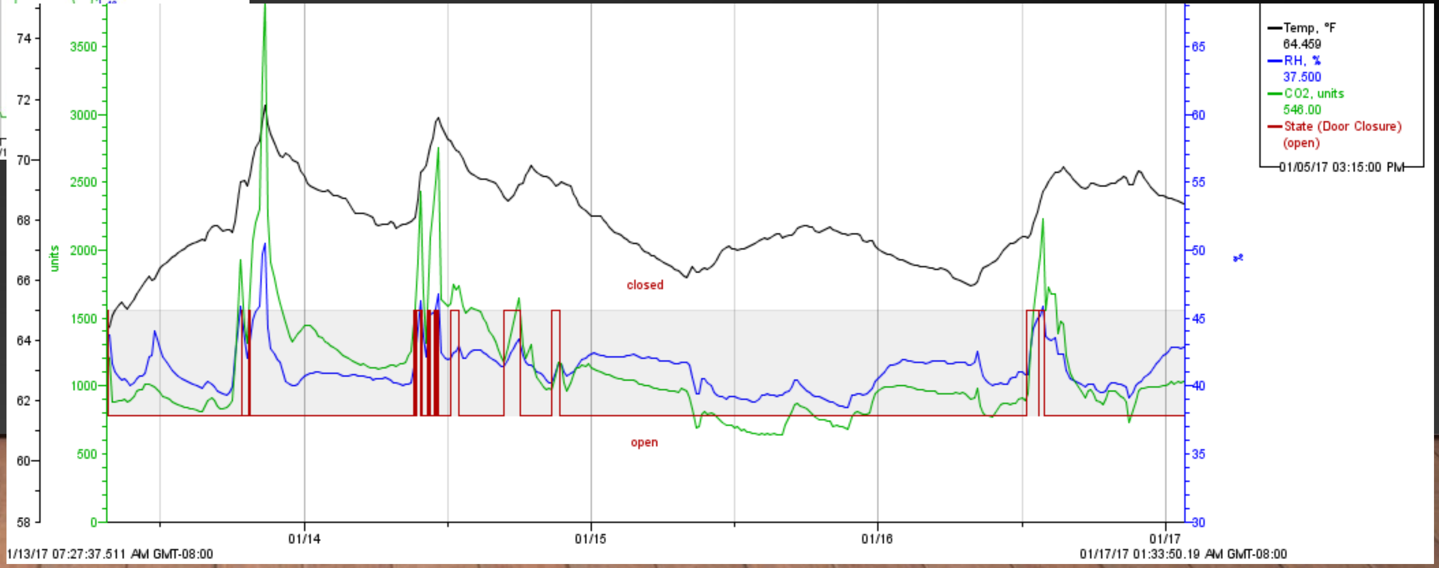



| Carbon Dioxide and Ventilation Rate | | |
|---|---|---|
| *Carbon Dioxide (ppm)* | *Outside Air (cfm/person* | *IAQ Assumption* |
| 2,400 | 5 cfm | Unacceptable |
| 1,400 | 10 cfm | Poor |
| 1,000 | 15 cfm | ASHRAE Standard 62 |
| 800 | 20 cfm | |
| 600 | 25 cfm | Acceptable |
| 400 (and above) | | Outdoor Air |

# WHOLE HOUSE VENTILATION SYSTEM EFFECTIVENESS

Exhaust Only Systems

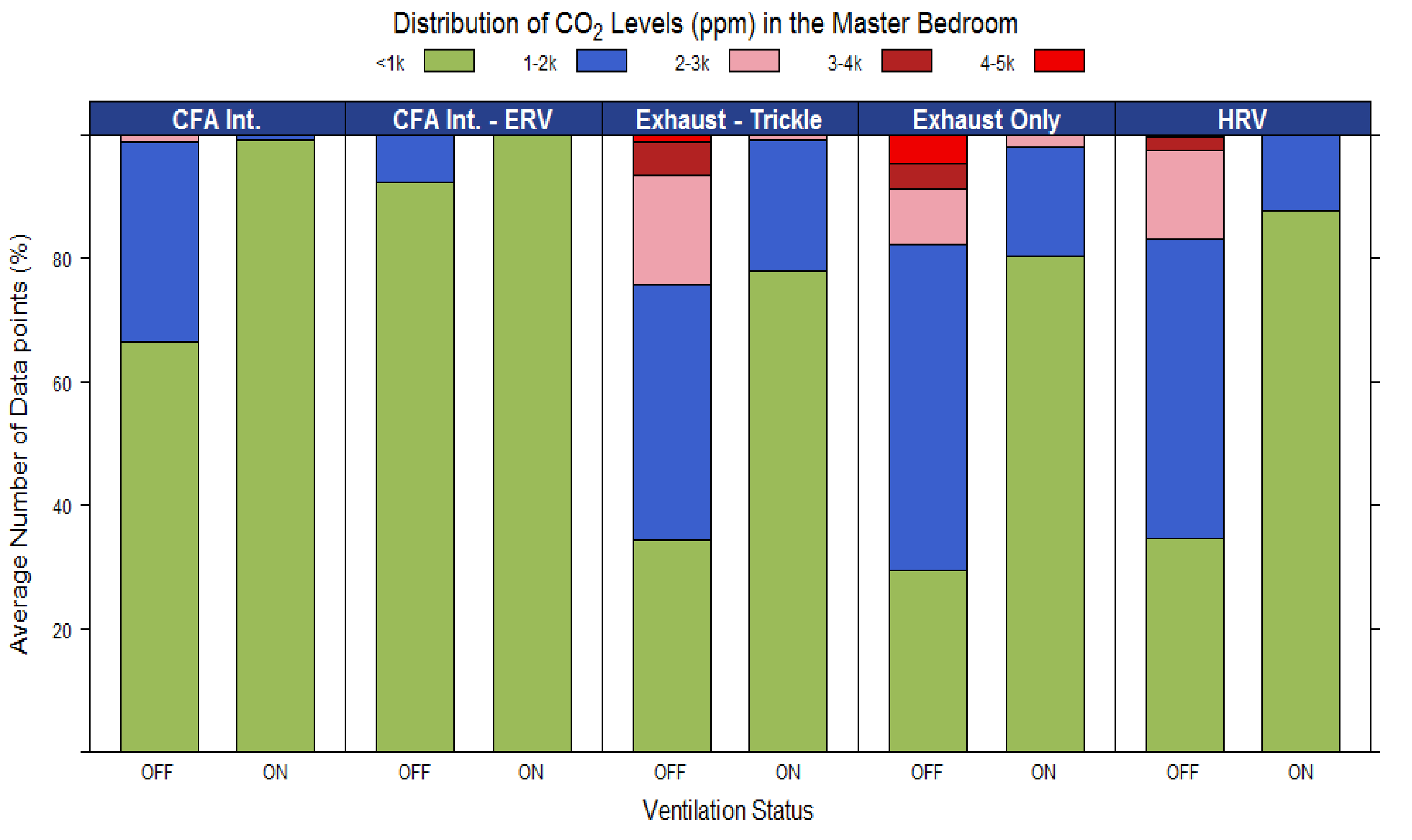


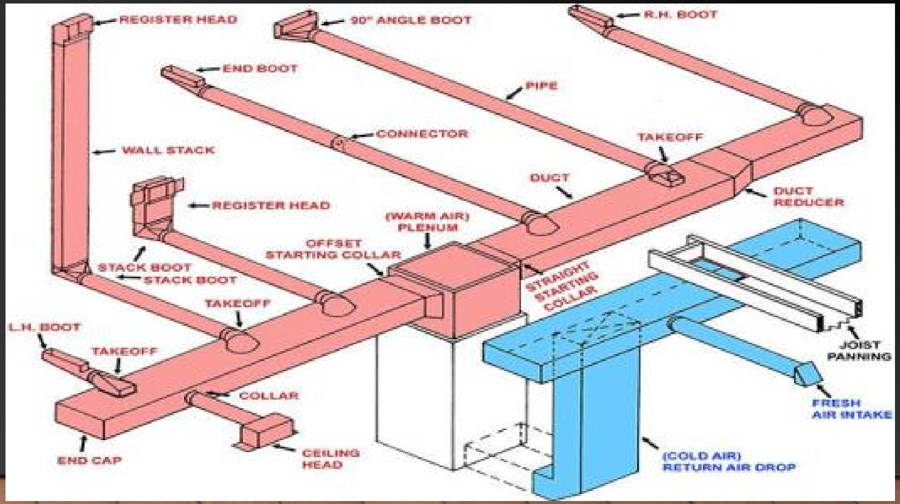



# High Performance Ventilation

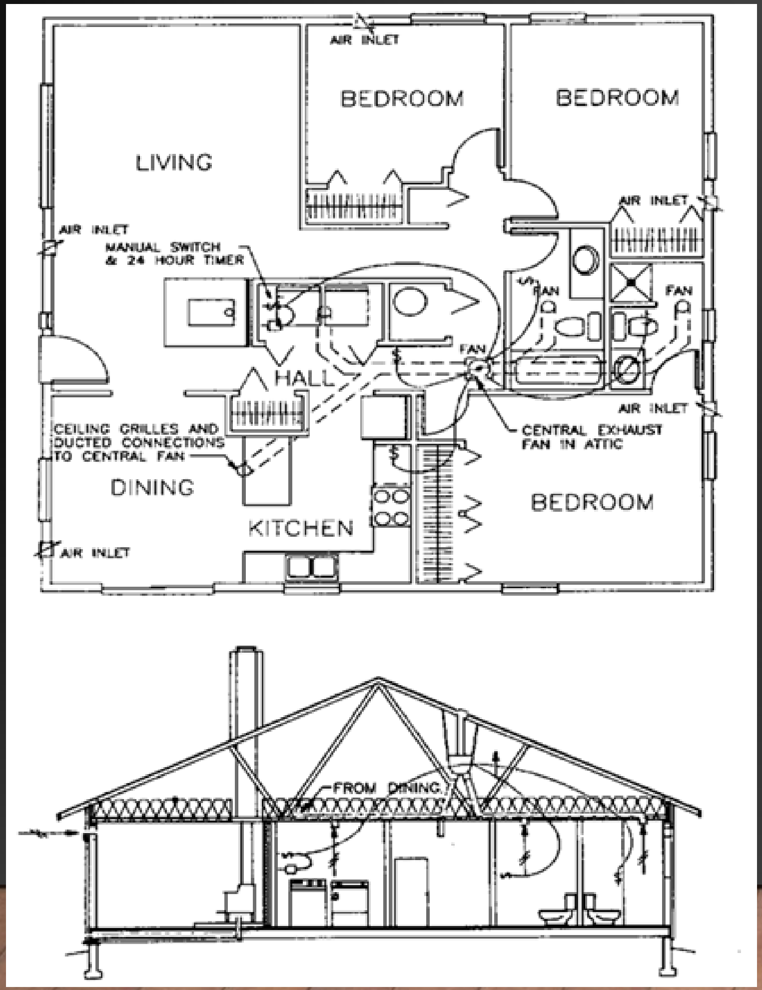
# WHOLE HOUSE VENTILATION SYSTEM EFFECTIVENESS

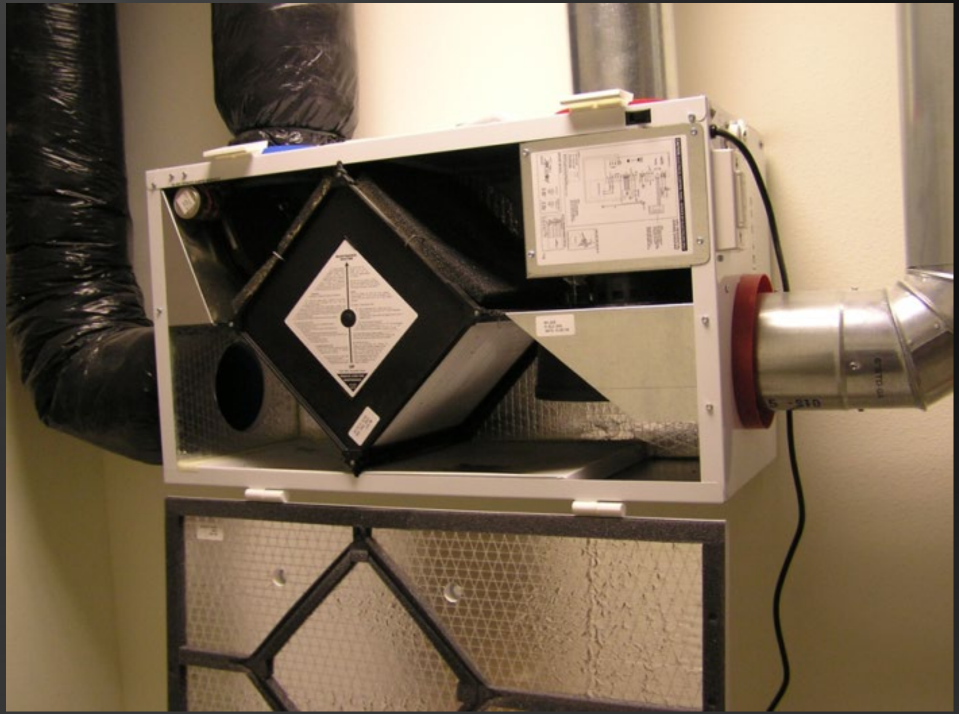
## Central Integrated Supply Systems



# Not-So-Common Whole House Ventilation System Types



# Benefits of an HRV/ERV

Whole home balanced ventilations systems may help with

New airtight high performance homes need mechanical ventilation to provide fresh air

HRV/ERV's reduce cost of space conditioning and improve the energy efficiency of the envelope

Good ventilation improves indoor air quality and health

Balanced ventilation reduces risk of pressurization or de-pressurization on envelope

They are not the whole answer

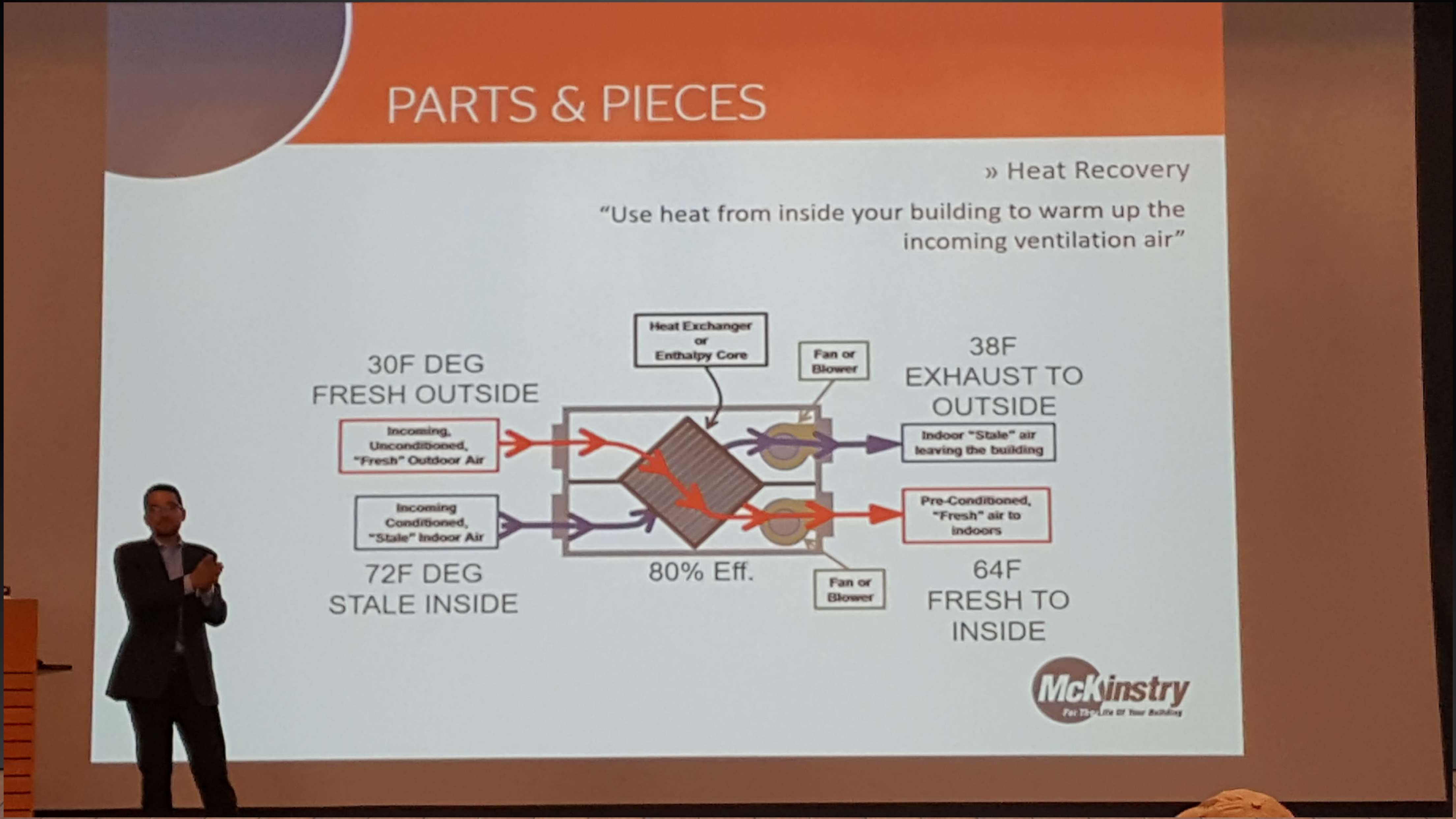
# HRV/ERVs are a great choice for ventilation

HRV/ERVs will not work for distribution of heating and cooling

HRV/ERVs must have good duct design

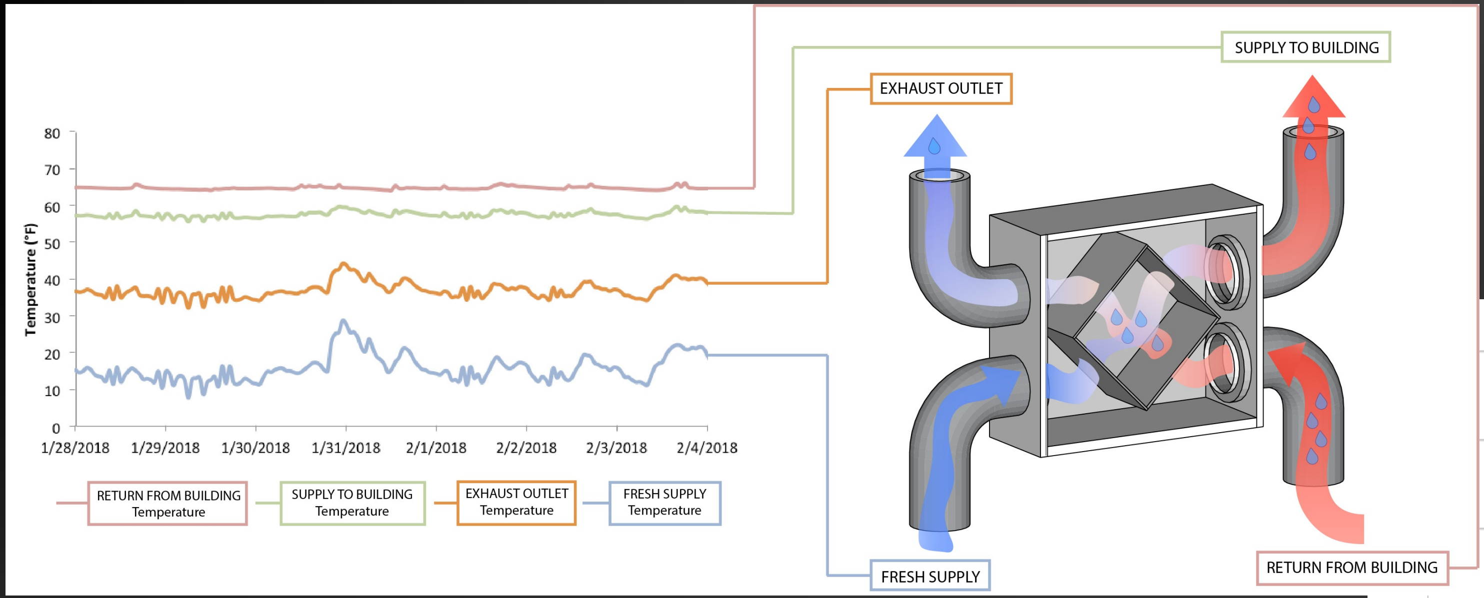
Spot HRV/ERVs can be a great choice for a smaller home

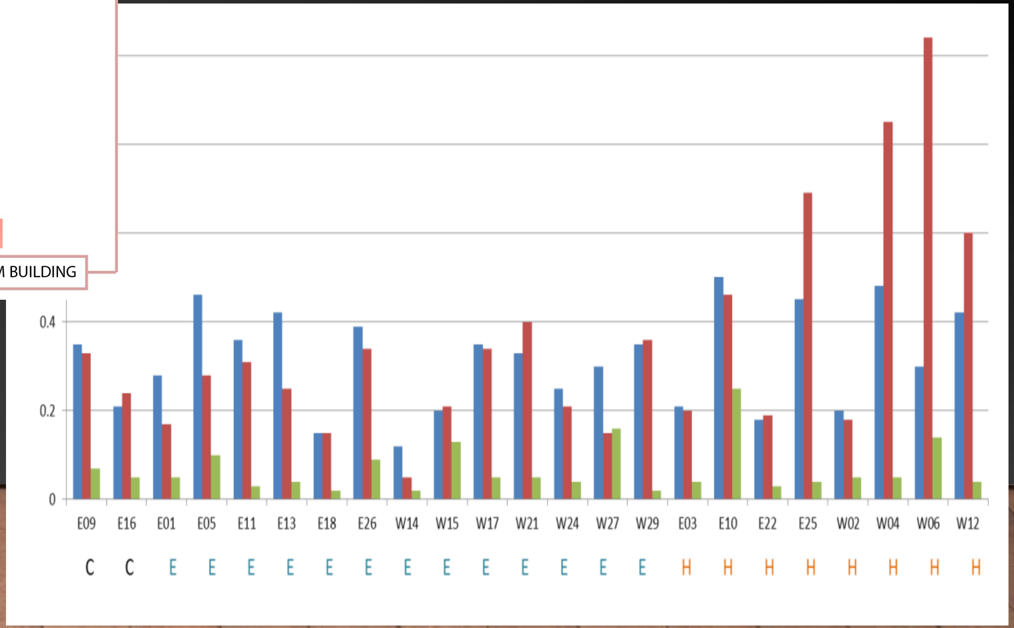
Whole Home HRV/ERVs are a great choice for larger homes


PARTS & PIECES
» Heat Recovery
"Use heat from inside your building to warm up the incoming ventilation air"
Heat Exchanger or Enthalpy Core
Fan or Blower
30F DEG FRESH OUTSIDE
Incoming, Unconditioned, "Fresh" Outdoor Air
Incoming Conditioned, "Stale" Indoor Air
72F DEG STALE INSIDE
80% Eff.
38F EXHAUST TO OUTSIDE
Indoor "Stale" air leaving the building
Pre-Conditioned, "Fresh" air to indoors
Fan or Blower
64F FRESH TO INSIDE
McKinstry

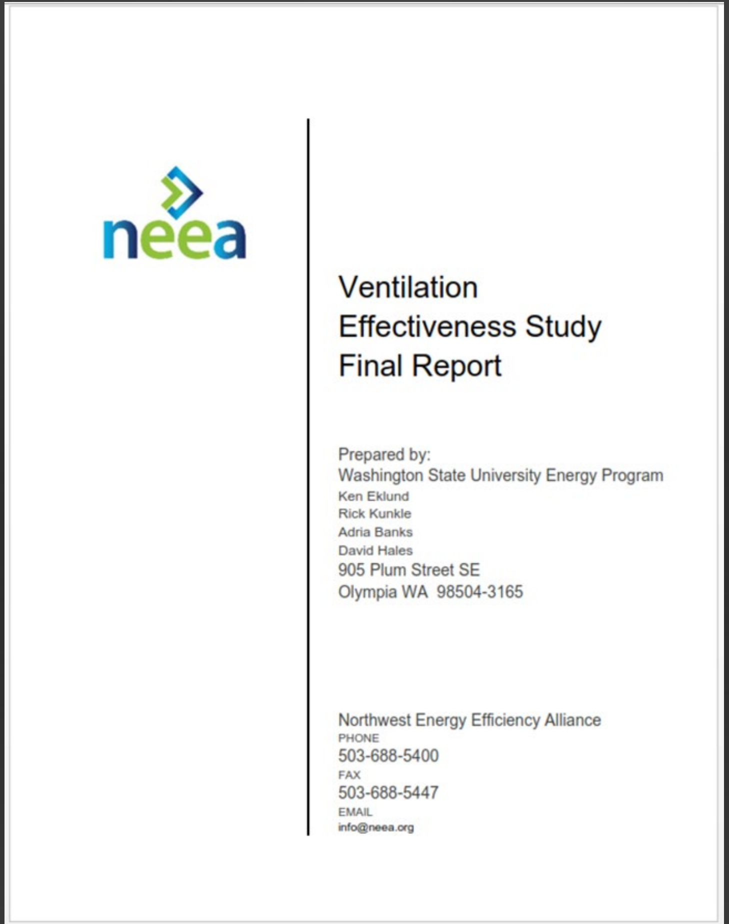
# WHOLE HOUSE VENTILATION SYSTEM EFFECTIVENESS

## Balanced System



# WHOLE HOUSE VENTILATION SYSTEM EFFECTIVENESS STUDY



neea

Ventilation
Effectiveness Study
Final Report

Prepared by:
Washington State University Energy Program
Ken Eklund
Rick Kunkle
Adria Banks
David Hales
905 Plum Street SE
Olympia WA 98504-3165

Northwest Energy Efficiency Alliance
PHONE
503-688-5400
FAX
503-688-5447
EMAIL
info@neea.org

HTTPS://CONDUITNW.ORG/PAGES/FILE.ASPX?RID=2585

# HRV/ERV BEST PRACTICES

HRVs are recommended in the Pacific NW.

Any HRV/ERV return air grills near kitchen should have pre-filters

Different climates may need an ERV to help manage humidity too.

All HRV/ERV ductwork should be in conditioned space.

Exhaust ventilation for bathrooms, kitchens and laundry room is best.

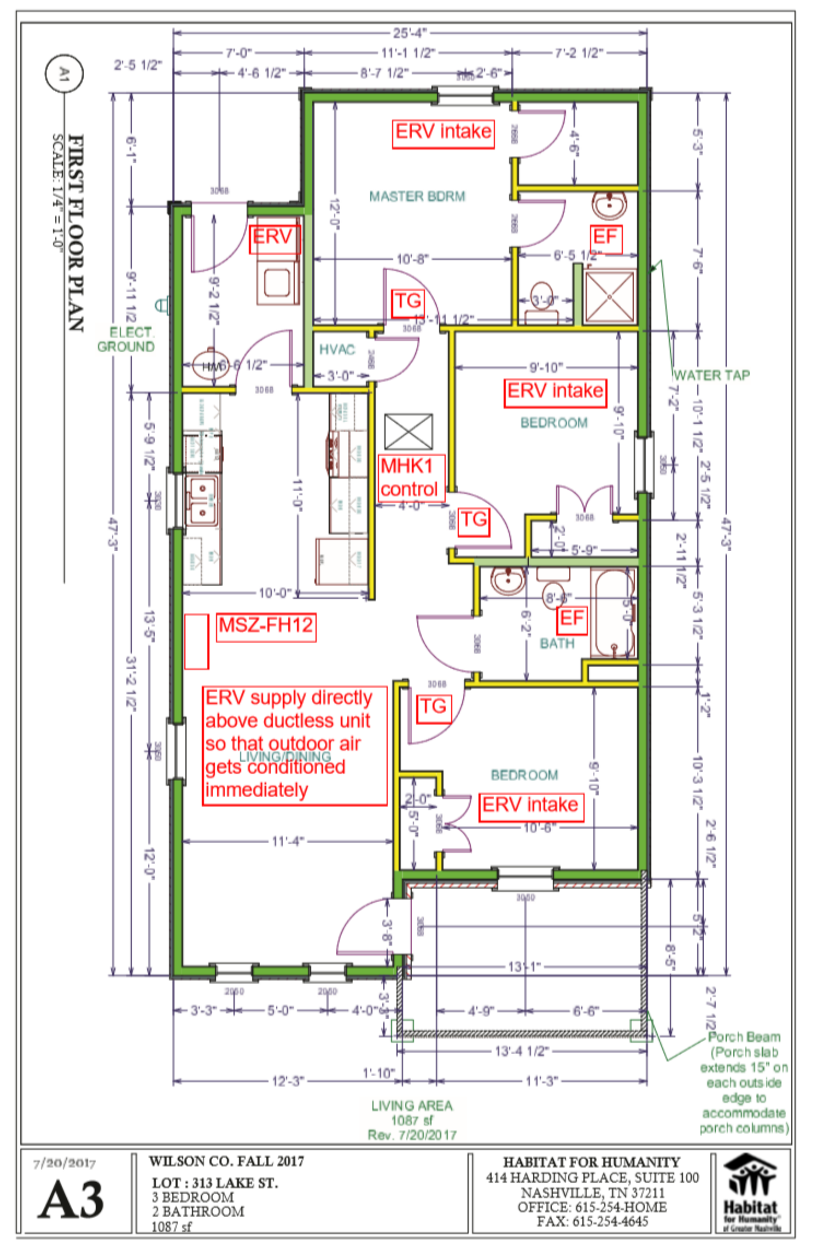
Supply fresh air to all bedrooms from HRV/ERV

If you are using an HRV for bathroom and/or kitchen ventilation, make sure you have controls for boost mode

Be sure and have return air pathways in each room supplied by HRV/ERV

# Part 3

# Case Studies


FIRST FLOOR PLAN
SCALE: 1/4" = 1'-0"
ERV intake
MASTER BDRM
ERV
EF
TG
HVAC
ELECT GROUND
WATER TAP
ERV intake
BEDROOM
MHK1 control
TG
EF
BATH
MSZ-FH12
ERV supply directly above ductless unit so that outdoor air gets conditioned immediately
LIVING/DINING
TG
BEDROOM
ERV intake
Porch Beam (Porch slab extends 15" on each outside edge to accommodate porch columns)
LIVING AREA
1087 sf
Rev. 7/20/2017
7/20/2017
A3
WILSON CO. FALL 2017
LOT : 313 LAKE ST.
3 BEDROOM
2 BATHROOM
1087 sf
HABITAT FOR HUMANITY
414 HARDING PLACE, SUITE 100
NASHVILLE, TN 37211
OFFICE: 615-254-HOME
FAX: 615-254-4645


3M


3M
3"
N36TAT
3"

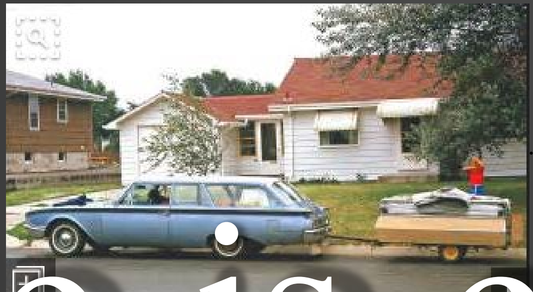

3M
All Weather
Flashing Tape 8067

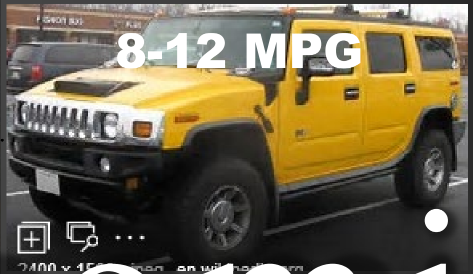
energy vanguard

HVAC DESIGN | HVAC Load Calculations | HVAC Design Protocols | Code Compliance | S

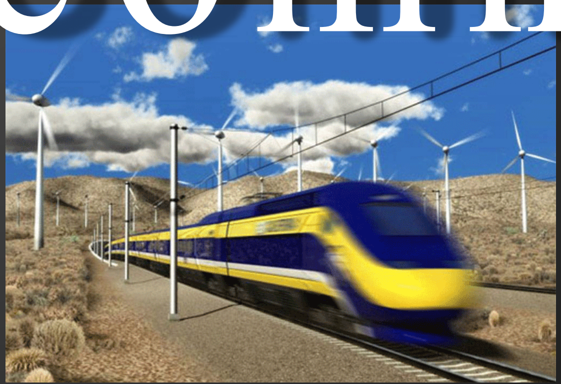
# HVAC Design

# Change is coming!











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