Zero Specifications:

Optimized Comfort System
Zero Energy Ready Home Spec

- Optimized Duct Location
- RH Control In Hot/Humid Climates
• Quality HVAC Installation:
  – High efficiency
  – Properly designed and installed
  – Combined with a duct system that’s insulated, sealed, and balanced

... Maintain comfort with less energy.

• Ducts in Conditioned Space:
Zero Specifications
Optimized Comfort System:
Quality HVAC Installation
Basic Concept

Energy moves from more to less.

90° F - Outside

90° F

40° F

Cooler with Ice
Energy moves from more to less.

105°F

70°F
Energy moves from more to less.
• **Heating Load** varies for each hour of the year.

• **Heating Peak Load**: Maximum energy lost in a single hour, which must be added back to maintain temperature.
• Cooling & heating equipment are “btu machines” that add or remove btu’s to offset the load
• Load = number of btu’s equipment has to remove or add
• Load independent of *type* of equipment used
Heating and cooling equipment generally two modes – on & off.

Equipment < Load

Equipment > Load
What We’re Trying to Avoid

Which boat would you want - the one with the **small** pump or the **big** pump?
Verify that the equipment capacity is right-sized relative to the heating and cooling load.
1. Air follows the path of least resistance.

Equal resistance, equal flow

Room A
Room B

Higher resistance, less flow

Room A
Room B
Factors that influence the airflow of the ducts:

- Duct Length
- Duct Size
- Duct Shape
- Duct Type
- Duct Turns
- Other Components (e.g., Filters)
What We Are Trying to Avoid
Verify that the ducts are balanced, insulated, tight, and installed without major defects.
Basic Concepts HVAC QI

**Design:**
1. Calculate Heating/Cooling Loads
2. Select Equipment that Meets Loads
3. Design Duct System that Gets Air from Equipment to Rooms and Back

**Commission:**
A. Check Airflow at Air Handler
B. Check Refrigerant Charge
C. Measure Airflow at Registers/Exhaust
Zero Specifications

Optimized Comfort System:

Ducts in Conditioned Space
Why Ducts in Conditioned Space?

• **Significant Thermal Losses:**
  – Thermal losses triple for ducts in unconditioned vs. conditioned space
  – Total thermal losses can range from 10-45%
  – Extensive unconditioned space penetrations

• **Significant Performance Impacts:**
  – IAQ
  – Comfort
  – Durability
• **Short Duct Run**
  up to 10’ of total length is permitted to be outside of the home’s thermal and air barrier boundary.

• **Jump Ducts**
  may be located in attics if all joints, including boot-to-drywall, are fully air sealed with mastic

• **Ductless HVAC system**
Ducts in Conditioned Space

- Ducts in Dropped Ceiling
- Ducts in Modified Attic Truss
- Ducts Between Floors
- Ducts in Unvented Crawl Space/Basement
- Ducts in Unvented Attic
- Ducts in Vented Attic
Ducts in Conditioned Floor Space Option 1: Dropped Ceiling

Issues:

• Architectural Integration
• Good Fit w/Simple Plans
• Longer Throws (ACCA Man T)
Ducts in Conditioned Floor Space Option 2: Modified Attic Truss

Issues:

• Design Integration
• Good Fit w/Narrow Plans
• Sealed Air Barrier Critical
Ducts in Conditioned Floor Space Option 3: Ducts Between Floors

**Issues:**

- Simple Installation
- Design Flexibility
- Cost-Effective
- Floor Registers Likely
Ducts in Conditioned Floor Space Option 3: Ducts Between Floors
Unvented Crawl Space/Basement

Ducts in unvented crawl space or basement

Issues:

• Simple Installation
• Design Flexibility
• Cost-Effective
• Floor Registers Likely
Ducts in Unvented Attic

Issues:

- CZ 5+, air impermeable plus a Class II VR or Class III VR in direct contact
- No Class I VR on attic floor
**Ducts in Unvented Attic Benefits**

- **Enhanced Performance:**
  - Ducts and air handler in conditioned space
  - Enable fire sprinklers that don’t undermine the thermal and air control layer

- **Cost Savings:**
  - Eliminate ~dozen thermal bypass air barrier details
  - Additional storage, especially in slab-on-grade homes
  - Eliminate need for soffit and roof vents
  - Enabling single- rather than dual-zone HVAC systems by eliminating the egregious attic interface
Ducts in Vented Attic: Dry CZs

Issues:
- R-8 duct insulation min.
- Ductwork buried min. 3.5” blown-in insulation
- Total duct leakage ≤ 3 CFM25 per 100 ft² CFA
- Air Handler must be inside conditioned space
**Ducts in Vented Attic: Humid CZs**

**Issues:**
- R-8 duct insulation min.
- 1.5” minimum of ccSPF encapsulating ducts
- Ductwork buried min. 2” blown-in insulation
- Total duct leakage ≤ 3 CFM25 per 100 ft² CFA
- Air Handler must be inside conditioned space

**Buried Encapsulated Ducts (BEDs) (~R-25)**

- Blown-in Insulation
- Closed-Cell Foam
- R-8 Duct
- Truss Lower Chord
Buried Encapsulated Duct (BED)

Ducts buried under loose-fill insulation

R-8 ducts encapsulated in 1.5” ccSPF

R-8 flex duct encapsulated in 1.5” ccSPF

Duct boot connection encapsulated in 1.5” ccSPF

Drywall ceiling

Truss lower chords
Zero Specifications:
Comprehensive IAQ System
Zero Energy Ready Home Spec

- Radon
- Low Emission Materials
- Combustion Safety
- High MERV Filter

Complete IAQ System
Why IAQ is NOT A La Carte?

- 2000 SF Home
- 8.5’ Ceilings
- 3 ACH50 Air Tightness
- 200 cfm Exhaust (e.g. dryer, range hood)

- 5 Pa depressurization
Indoor Air Quality as a System

- Source Control
- Dilution
- Filtration

Practices & Product Selection That Limit:
- Moisture
- Radon
- Chemicals
- Combustion By-Products
- Biological Contaminants

HVAC Quality Installation System
Source Control: Moisture

Moisture Control System

- **Moisture Vapor:**
  - Air Sealing
  - Air Barriers

- **Bulk Moisture:**
  - Water-Managed Roofs
  - Water-Managed Walls/Openings
  - Water Managed Foundation/Site
  - Water Managed Materials

- **Dehumidification**
  [Warm-Humid Climates]
Source Control: Moisture Dehumidification in Warm-Humid CZs

- All of Alaska in Zone 7 except for the following Boroughs in Zone 8:
  - Bethel
  - Bellingham
  - Fairbanks N. Star
  - Nome
  - North Slope

- Northwest Arctic
- Southeast Fairbanks
- Wade Hampton
- Yukon-Koyukuk

Warm-Humid Below White Line

Zone 1 includes
- Hawaii, Guam,
- Puerto Rico,
- and the Virgin Islands
Equipment with sufficient latent capacity to maintain indoor relative humidity (RH) ≤ 60%:

- Additional dehumidification system(s), OR
- A central HVAC system equipped with additional controls to operate in dehumidification mode.

Dust mites in the billions at 60% RH or high
Note: these maps indicate average risk by county. However, **High levels of Radon can be found in any home.**
Source Control: Radon
Radon Resistant Construction

Required for Moisture Control:

A. Gas Permeable Layer
   (min. 4” clean gravel)
B. Plastic Sheeting
   (under slab)
C. Sealing and Caulking
   (all openings in concrete floor)
D. Vent Pipe
   (3 or 4 inch PVC pipe)
E. Junction Box
   (if fan needed later)

Radon Test Kits Not Required
Source Control: Biological Contaminants

Pests
Corrosion-proof rodent/bird screens for openings (e.g., copper or stainless steel mesh)

**Exception:** clothes dryer vent
Source Control: Biological Contaminants/Moisture
Foundation Sealing

Sealed Sump Pump
Air Sealing
Source Control: Combustion By-Products
Power/Direct Vent Equipment

Power Vented Water Heater
Direct-Vent Furnace
Source Control: Combustion By-Products
Certified Fireplaces & Stoves

- Vented to outdoors
- Adequate Combustion and Ventilation Air
- Gas fireplace power or direct vented
- Meet Specified Standards
CO Alarm in each bedroom area

CO Alarm

Combined CO & Smoke Alarm

Enforceable policy in Multi-family buildings

Source Control: Combustion By-Products
Certified CO Alarms

- CO Alarm
- Combined CO & Smoke Alarm

UL Listed
Source Control: Combustion By-Products
Attached Garage Isolation

Exhaust Fan
Optional

Air Sealing & Gasketed Door
Source Control: Combustion By-Products
Attached Garage Isolation

No Air Handler in the Garage

Picture Source: Construction Instruction
Source Control: Chemicals
Low Formaldehyde Pressed Wood

MDF & Particleboard

Sample Industrial Board Bundle Tag for Particleboard
Certified to 0.20 PPM Standard. Tag Size 4" x 5"

CONFORMS TO PARTICLEBOARD
FORMALDEHYDE EMISSION REQUIREMENTS
OF BOTH ANSI A208.1-1999, TABLE B
AND HUD 24 CFR 3280

MILL 000

COMPANY LOCATION
PRODUCTION DATE/SHIFT
Source Control: Chemicals
Low Formaldehyde Cabinets

- Visit www.kcma.org
- Follow Industry Professional link to Environmental Stewardship Program
Health Hazards of VOCs
VOLATILE Organic Compounds

Immediate
- Eye & Respiratory Tract Irritation
- Headaches
- Dizziness
- Visual Disorders
- Memory Impairment

Up to 6 years
- Eye, Nose, and Throat Irritation
- Headaches
- Loss of Coordination
- Nausea
- Damage to Liver, Kidney, and Central Nervous System
- Cancer
**Source Control: Chemicals**

**Low VOC Paints**

*Interior paints and finishes, including 90% or more of such products applied to interior surfaces of homes, shall be certified low-VOC or no-VOC by one of the following:*

- Green Seal Standard GS-11, OR
- Greenguard Certification for Paints and Coatings, OR
- Master Painters Institute (MPI) Green Performance Standards GPS-1 or GPS-2, OR
- A third-party low-emitting product list based on CA Section 01350, e.g., the CHPS List at chps.net/manual/lem_table.htm.
Carpets and carpet adhesives shall be labeled with, or otherwise documented as meeting, the Carpet & Rug Institute (CRI) Green Label Plus or Green Label testing program criteria. Carpet cushion (i.e., padding) shall similarly be certified to meet the CRI Green Label testing program criteria.
Low emission materials and products are rapidly evolving, gaining market share & recognition

Standards, labels, certification agencies can be challenging to navigate

To help partners identify sources and spec products, a new IAP resources is available:

How to Find Indoor airPLUS Compliant Low-Emission Products

**Source Control: Chemicals**

**Identifying Low-Emission Solutions**

**How to Find Indoor airPLUS Compliant Low-Emission Products**

<table>
<thead>
<tr>
<th>Cabinetry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement: Use Cabinetry made with component materials (plywood, particleboard, MDF) that are certified to comply with the appropriate standards above; OR registered brands or products produced in plants certified under the Kitchen Cabinet Manufacturers Association’s (KCMA) Environmental Stewardship Certification Program (ESP 05-12); OR GREENGUARD or GREENGUARD Gold Certification for Cabinetry.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Meet at least one standard below</th>
<th>How to find compliant products</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCMA’s Environmental Stewardship Program (ESP 05-12)</td>
<td>Look for the KCMA-ESP label on cabinets (often sink bases), product packaging, and/or spec sheets. For a list of KCMA certified manufacturers that produce compliant cabinets, visit: <a href="http://www.kcma.org/Member/ESP_Certified_Manufacturers">http://www.kcma.org/Member/ESP_Certified_Manufacturers</a>. Note: Manufacturers listed in the link above can be used as a resource, but partners should request confirmation from the manufacturer or supplier that the product lines they are using are indeed compliant.</td>
</tr>
</tbody>
</table>
Three Options:

- Exhaust-Only
- Supply-Only
- Balanced

ASHRAE 62.2 2010 Continuous Ventilation Rate:

\[7.5 \text{ cfm} \times (\# \text{ bedrooms} + 1) + [0.01 \times \text{Sq. Ft.}]\]

2,000 sq. ft., 3 Bedroom Home Example:

\[7.5 \times (3+1) + [0.01 \times 2,000] = [30 + 20] = 50 \text{ cfm}\]
Meeting WHMV Requirements

- WHMV Fan Efficiency
  - For an example home of 4 BR and 2500 SF in CZ5:
    - \( Q_{fan} = 0.01 \times A_{floor} + 7.5 \times (Nbr + 1) \)
    - \( = 0.01 \times (2500) + 7.5 \times (5) = 63 \text{ cfm} \)

<table>
<thead>
<tr>
<th>CZ 1-2</th>
<th>CZ 3, 4 (except Marine)</th>
<th>CZ 4 Marine, 5-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.8 cfm/W</td>
<td>2.8 cfm/W</td>
<td>1.2 cfm/W</td>
</tr>
<tr>
<td>No heat exchange</td>
<td>No heat exchange</td>
<td>HX with 60% SRE</td>
</tr>
</tbody>
</table>

- \( 63 \text{ cfm} / (1.2 \text{ cfm/W}) = 53 \text{ Watts BALANCED w/ 60% SRE} \)
Dilution: Whole-House Ventilation

Exhaust-Only Ventilation
Dilution: Whole-House Ventilation
Supply-Only Ventilation
Dilution: Whole-House Ventilation
Balanced Ventilation

ERV or HRV
Simple Thru-Wall ERV

- 90+% Heat Recovery
- 20-30% Humidity Recovery
- 1.4 – 2.8 W for 10/18/22 CFM
Dilution: Whole-House Ventilation
Ventilation Challenge: Persistence
Dilution:
Spot Ventilation

• **Kitchen:**
  – 100 CFM Intermittent
  – 5 ACH Continuous

• **Bathrooms:**
  – 50 CFM Intermittent
  – 20 CFM Continuous
Filtration:
High-MERV HVAC Filter

8 MERV Filter Minimum
Verifying Homes – Indoor airPLUS

• 1-page checklist
• Builder or Rater may verify
• Permissible methods:
  – Visual verification on site during construction
  – Reviewing photos taken during construction
  – Checking documentation
  – Equivalent methods as appropriate
• Sampling permitted per RESNET protocol
Zero Specifications:
Efficient Components System
Zero Energy Ready Home Spec

Efficient Components System

ENERGY STAR:
- Appliances
- Exhaust Fans
- Ceiling Fans
- Water Heating*

Efficient:
- Lighting
- Hot Water Distribution
- Equipment*

* Target only
Components and MEL’s are increasingly larger part of total energy use in low-Load homes (~50%).
Zero Energy Ready Home requires:

- **ENERGY STAR Certified Appliances**: refrigerators, dishwashers, clothes washers
- **ENERGY STAR Certified Fans**: bathroom ventilation, ceiling fans
- **ENERGY STAR Certified Lighting**: Min. 80% of fixtures or lamps (CFL or LED)
- **WaterSense Hot Water Distribution**

*Only where installed by builder*
Zero Energy Ready Home Target Home also specifies **ENERGY STAR Water Heating:**

<table>
<thead>
<tr>
<th>Water Heater Type</th>
<th>Target Home Water Heater’s Energy Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas/Propane ≤ 55 gallons</td>
<td>EF = 0.67</td>
</tr>
<tr>
<td>Gas/Propane &gt; 55 gallons</td>
<td>EF = 0.77</td>
</tr>
<tr>
<td>Electric Systems</td>
<td>EF = 2.0</td>
</tr>
<tr>
<td>Heating Oil</td>
<td>EF = 0.60</td>
</tr>
</tbody>
</table>
Zero Energy Ready Home Target Home also specifies **High-Efficiency Space Conditioning**:

<table>
<thead>
<tr>
<th>HVAC Equipment</th>
<th>Target Home Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hot Climates (IECC Zones 1,2)</td>
</tr>
<tr>
<td>AFUE</td>
<td>80%</td>
</tr>
<tr>
<td>SEER</td>
<td>18</td>
</tr>
<tr>
<td>HPSF</td>
<td>8.2</td>
</tr>
<tr>
<td>Geo Heat Pump</td>
<td>ENERGY STAR EER/COP</td>
</tr>
</tbody>
</table>
Water Efficient System Context

• **Indoor Fixtures**
  - Plumbing Fixtures
  - Appliances and Other Equipment

• **Distribution**
  - Service Pressure
  - Metering (for Multi-Family Homes)
  - Leak Prevention
  - Hot Water Distribution

• **Outdoor**
  - Landscape Design
  - Irrigation (if installed)
Efficient Hot Water Distribution

• “Must Have” for zero net-energy ready homes
• Based on EPA WaterSense Specifications:
  – No more than 0.5 gallons of water in any piping/manifold between the hot water source and any hot water fixture.
  – No more than 0.6 gallons of water shall be collected from the hot water fixture before hot water delivered.
  – Timer- and temperature-based recirculating systems shall not be used to meet the criteria.
Built for when water was free and energy was cheap!

Copper L piping:
- 1” = 5.53 ounces/ft
- ¾” = 3.22 ounces/ft
- ½” = 1.55 ounces/ft

Stored Volume: 306 gallons
10’ branch
Wait Time: 1 – 1.5 minutes
2 GPM showerhead
Hot Water Distribution Options

- Core Plumbing Layout (wet wall)
- Manifold System
- Demand Pumping System
Core Plumbing Layout
Manifold Plumbing System

10’ Max
Demand Pumping System

- Demand Pump
- Dedicated Return
- Sensor or Controls

Diagram showing the components of a demand pumping system, including water heater, remote receiver, and dedicated return line.
1. **Initiate Operation:**
   Turn on any occupant-controlled or occupancy sensor-based recirculation systems, if present.

2. **Container Placement:**
   Locate bucket or flow measuring bag pre-marked for 0.6 gallons under the hot water fixture. Only need to test fixture with greatest stored volume of hot water.

3. **Turn on Hot Water Over Digital Thermometer:**
   Record starting temperature.

4. **Final Measurement:**
   When water reaches 0.6 gallons in container, record temperature again. A minimum increase of 10°F is required to pass the test.
Zero Specifications:
Solar Ready System
Zero Energy Ready Home Spec

Solar Ready System

DOE ZERH PV-Ready Checklist = ZERO ENERGY READY HOME U.S. DEPARTMENT OF ENERGY
Solar Ready Encouraged

Solar Ready Required

Average Daily Solar Radiation Per Month

ANNUAL

kWh/m²/day

10 to 14
8 to 10
7 to 8
6 to 7
5 to 6
4 to 5
3 to 4
2 to 3
0 to 2
none

Encouraged
Required
Screen for RERH Applicability

- **Renewable Energy Ready Checklists**
  - Determine applicability by zip code
  - In this Mid-Atlantic example, solar resources = 4.8 kWh/m²/day
Not required in areas lacking access to significant solar resources:

- Tree Shading
- Tall Buildings
- Available South Facing Roof
Documentation of the maximum allowable dead load and live load ratings of the existing roof (Rec DL.: 6 lbs./sq. ft.)

**Conduit** to run DC wire from roof to inverter

**Dedicated Area** for installing inverter and balance of system

**Conduit** to run AC wire from inverter location to electric panel

**Circuit Breaker** designated and/or installed for use by the PV system in the electric panel
Integrated Renewable Energy

PV Mounted on Roof

PV Integrated into Front or Rear Porch Roof Directly on Porch Framing
Benefits:

- Cost
- Appearance
- Maintenance
- Daylighting

PV Integrated into Front or Rear Porch Roof Directly on Porch Framing
Integrated Renewable Energy
smartflower™ POP, made in Austria
Verifying Homes – RERH

- RERH checklist for DOE ZERH Home
  - builder or rater may verify
Zero Specifications:
Summary
Stepping up to ZERH Summary…

<table>
<thead>
<tr>
<th>Solar Ready</th>
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<tbody>
<tr>
<td>EPA Indoor Air Package</td>
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<tr>
<td>Ducts in Condit. Space</td>
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<tr>
<th>HVAC QI with WHV</th>
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<th>HVAC QI + HRV</th>
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<tbody>
<tr>
<td>Water Management</td>
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<td>Water Management</td>
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<tr>
<td>Independent Verification</td>
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<tbody>
<tr>
<td>HERS 85-90</td>
<td>HERS 70-80</td>
<td>HERS 65-75</td>
<td>HERS 55-65</td>
<td>HERS 48-55</td>
<td>HERS 35-45</td>
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<table>
<thead>
<tr>
<th>IECC 2009</th>
<th>IECC 2012</th>
<th>ENERGY STAR v3</th>
<th>ENERGY STAR v3.1</th>
<th>ZERH</th>
<th>PHIUS+</th>
</tr>
</thead>
</table>