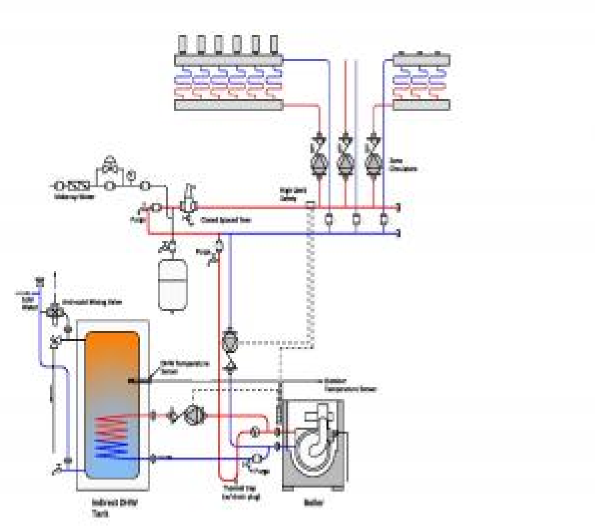
Condensing Boilers

Last Updated: 01/23/2015

Scope



Choose the highest performing boiler that project funding will allow to meet the design heating load of the project. The highest performance boilers are sealed-combustion, direct vent boilers, which have efficiencies exceeding 95% AFUE. These are also the safest boilers to install within a home because they draw combustion air from and release combustion byproducts directly to the outdoors.

Calculate the heating load for the home and properly size the boiler and distribution system to meet this load. Look at the boiler's output rating and if the design load is equal to or lower than the equipment's lowest output rating, consider alternative heating equipment options that better match the design load of the home.

Select a boiler with a modulating burner for increased efficiency.

Install in accordance with relevant standards including **ACCA Standard 5: HVAC Quality Installation Specification** and the **ACCA's Technician's Guide for Quality Installations** and **ACCA Standard 9: HVAC Quality Installation Verification Protocols**.

Set equipment control setting to optimize system efficiency. See the Building America report **Condensing Boilers – Control Strategies for Optimizing Performance** for guidance (Arena 2012).

For condensing boilers, install an outdoor reset control to match system output to actual load and recommend that homeowners not use a night-time temperature setback strategy. Select settings for the boiler reset curve and flow rates to optimize the performance of the system and to ensure that the return temperatures are low enough to promote condensing (**Arena 2012**).

Design an efficient zoned distribution system with a compact piping layout, insulated pipes, and correctly sized equipment for the radiators, baseboards, convectors, or radiant floor loop system. For hydro coil forced-air heating systems, design a compact duct layout following ACCA's **Manual D** duct sizing guidelines and install ducts properly in accordance with ACCA Manual D for maximum airflow and efficiency.

If you are participating in an energy-efficiency program, select a boiler whose efficiency complies with the requirements for your climate zone, as described below.

To determine your climate zone, see the International Energy Conservation Code (IECC) climate zone map on the Climate tab.

Zero Energy Ready Home Notes

The U.S. Department of Energy's Zero Energy Ready Home program allows builders to choose a prescriptive or performance path. The prescriptive path requires builders to meet or exceed the minimum HVAC efficiencies listed in Exhibit 2 of the DOE Zero Energy Ready Home **National Program Requirements**. The DOE Zero Energy Ready Home performance path allows builders to select a custom combination of measures for each home that is equivalent in performance to the minimum HERS index of a modeled target home that meets the requirements of Exhibit 2 as well as the mandatory requirements of Zero Energy Ready Home Exhibit 1. See the Compliance tab for specific program details.

ENERGY STAR Certified Homes Notes

The ENERGY STAR Certified Homes program allows builders to choose a prescriptive or performance path. The ENERGY STAR prescriptive path requires builders to meet the minimum HVAC efficiencies listed in Exhibit 1 of the **National Program Requirements** for ENERGY STAR Certified Homes. The ENERGY STAR performance path allows builders to select a custom combination of measures for each home that is equivalent in performance to the minimum HERS index of a modeled reference home that meets the requirements of ENERGY STAR Exhibit 1 as well as the mandatory requirements of Exhibit 2. See the Compliance tab for specific program details.

Description

According to the U.S. Energy Information Administration (EIA), up to 11 % of existing households use some form of hot water or steam heat. Boilers produce hot water that can be used to heat homes through several different distribution methods. The hot water can be sent through plastic pipe loops in the floor for radiant floor heat or through a metal radiator mounted along the wall or a baseboard radiator mounted near the floor. Hot water can also be directed from a combustion tank water heater to a coil in an air handler equipped with a fan to blow air across the coil and through supply air ducts to the home. Most combustion boilers are fueled by natural gas. **Fuel oil**, propane, and wood are other fuel sources used in locations where natural gas is not readily available. The hot water for a boiler may be heated or preheated by a solar thermal water heating system, a ground-source (geothermal) heat pump, or an air-source heat pump. The boiler may heat water in a tank or it may be a tankless (or instantaneous) wall-hung model. Some boilers provide heat for a potable hot water tank in addition to providing hot water to room heaters; this is referred to as indirect water heating. Some newer, very efficient models combine space heating, water heating, and heat recovery ventilation.

For best performance, the heating system should be properly sized to match the heating design load of the home, as described below. If the home is constructed with high levels of insulation and air sealing, a smaller heating system can often be installed. When equipment is oversized, it can "short cycle" or turn on and off repeatedly before the demand is met, which can have negative impacts on energy use, comfort, and equipment durability.

The **International Mechanical Code** classifies boilers based on vent type - direct, mechanical, or atmospheric. The **National Fuel Gas Code** puts vented combustion appliances (furnaces and boilers) in four categories based on flue vent pressures, flue gas temperatures (relates to condensing or noncondensing), and vent pipe materials. (See **Gas Boilers** for a more complete description of these categories.) The lowest efficiency boilers are atmospherically vented Category I boilers, which may or may not be equipped with a small induced draft fan to start the draft but still rely primarily on high temperatures in the vent stack to draw flue gases up and out the chimney. Category I boilers typically have annual fuel utilization efficiencies (AFUE) of under 80%. Higher efficiency Category III boilers are referred to as forced draft or power vented because they are equipped with a forced-draft fan at the start of the combustion chamber to push combustion air through the chamber and out the vent. Because this fan is operating whenever the boiler is firing, Category III boilers have positive pressure in the vent stack. The stack temperature on a Category III combustion appliance is above 140°F.

Category III and Category IV boilers are both forced draft (also referred to as power vented) appliances meaning that they are equipped with a combustion fan that is located before the burner to push air through the combustion chamber and out of the vent. The fan is continually operating when the burner is firing so the vent stack pressure is always positive.

Category IV boilers, like Category III boilers, vent their combustion exhaust gases directly outside through a sealed pipe so they cannot be back drafted. Category III and IV appliances should be installed as sealed-combustion/direct vent appliances, which means their combustion chamber is sealed off from the combustion appliance zone (CAZ), which is the room where the equipment is located, and they draw their combustion air from outside via a second vent pipe or concentric pipes that bring combustion air directly to the combustion chamber from outside. (See Figures 1, 2, and 3.) However, although manufacturers do not recommend it, they are sometimes installed as non-direct-vent appliances (where the exhaust pipe is installed but the pipe for incoming air is not installed so the boiler draws its combustion air from the CAZ). If this approach is taken, ample combustion air must be supplied to the CAZ; see **Combustion Furnaces** for more on calculating the amount of air needed in the CAZ for non-direct-vented appliances.

Category III boilers have efficiencies of 80% to 90%. For information on Category I and III vented combustion appliances, see **Gas-Fired Boilers** and **Oil-Fired Boilers**.

An important difference between Category III and Category IV boilers is that Category IV boilers are condensing boilers that have a second heat exchanger (or sometimes one extra-large heat exchanger), which allows the combustion gases to cool and condense, releasing more heat in the boiler rather than sending it up the flue as water vapor. Because the flue gases are cooler (<140°F), they can be vented through the wall or roof by means of a PVC pipe rather than a chimney. Condensing boilers are the most efficient type of boilers with AFUEs of 90% to 96%.

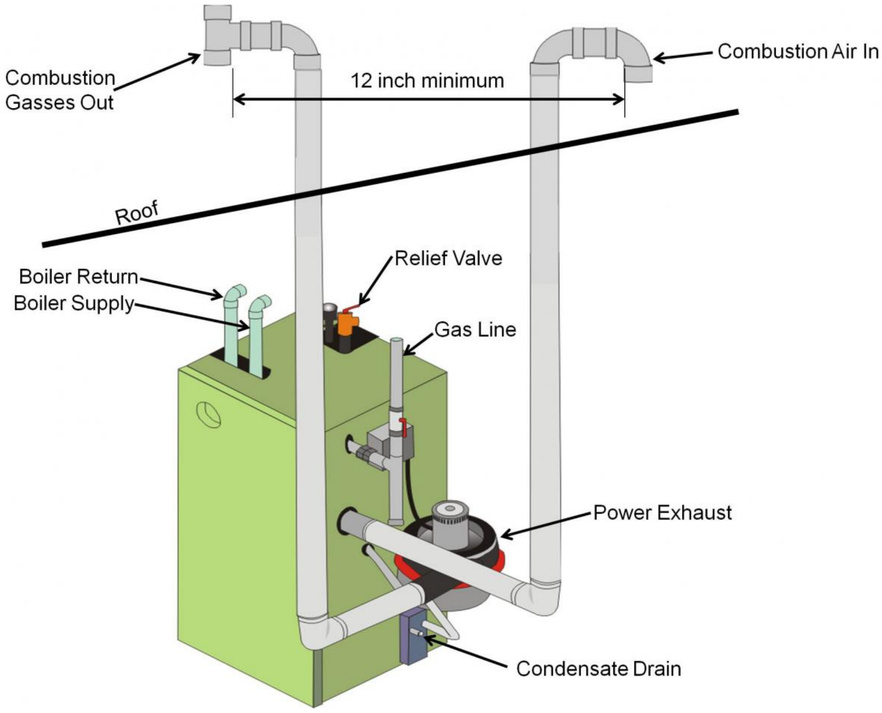


Figure 1. This gas-fired condensing boiler is installed as a direct vent appliance that receives combustion air directly from outdoors and vents combustion gases directly to the outdoors.

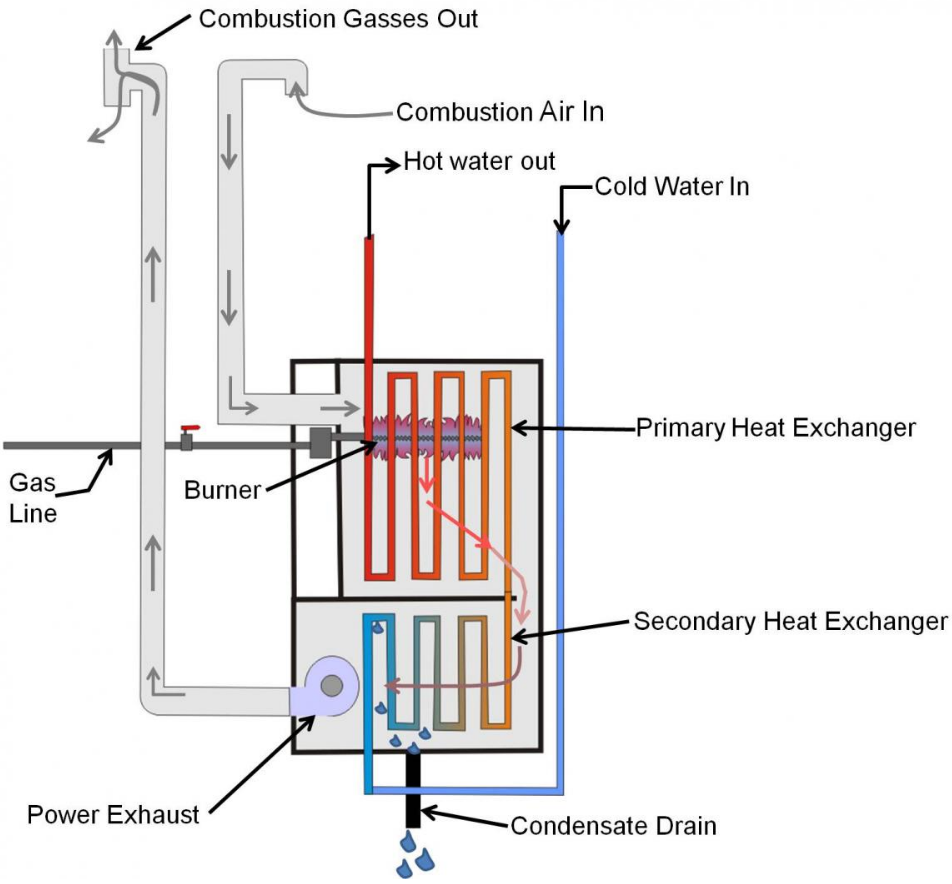


Figure 2. Condensing boilers have primary and secondary heat exchangers. Hot combustion gases heat the water in the primary heat exchanger. Any residual heat in the combustion gases is transferred to the cool water returning from the house and entering the secondary heat exchanger. The cooled combustion gases condense, releasing moisture to the condensate drain before the gases are exhausted up the vent.

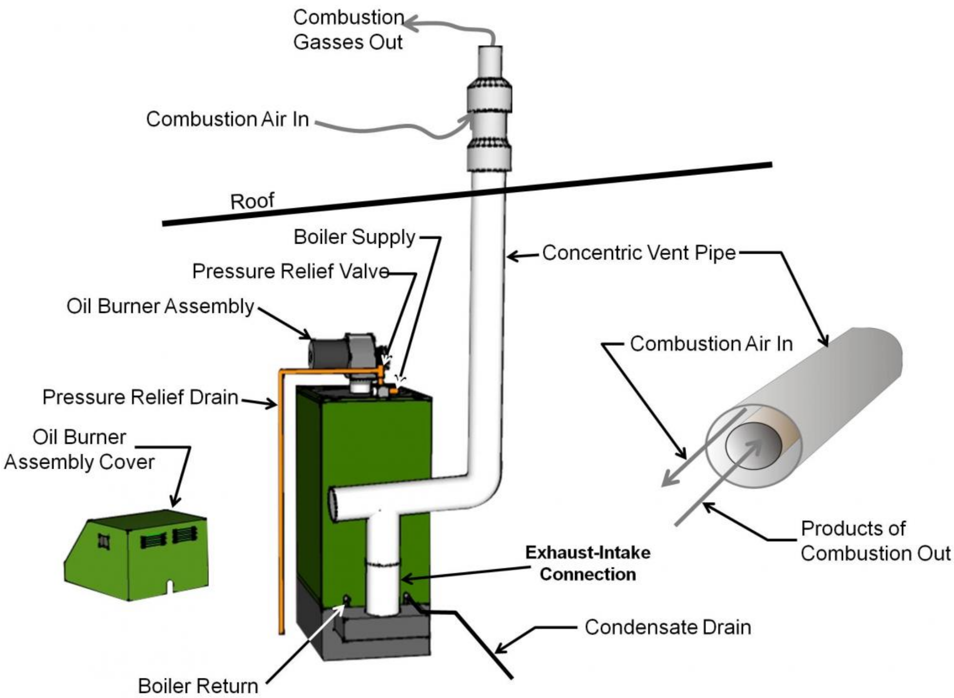


Figure 3. This Category IV oil-fired condensing boiler uses a concentric (double walled) vent pipe to directly vent combustion air in from outside and directly vent exhaust gases outside.

Low flue vent temperatures allow the water vapor (a by-product of combustion) to condense before or as it enters the vent pipe. This condensate water is highly acidic (pH of 2) and could be dirty if the fuel is dirty or if the boiler needs servicing. If the vent pipe exists through a side wall rather than through the ceiling, the horizontal portion of the pipe should be installed at a slight upward angle so that any condensate water drains back to a condensate drain line rather than going out the vent. The condensate drain line should be directed to a sewer or septic system. However check local codes to see if pretreatment of the condensate is required. Some jurisdictions require that the condensate be passed through a neutralizer containing calcium carbonate or a similar material to raise its pH before disposal. Such pretreatment is recommended whether required by code or not.

The design of the piping distribution system can reduce energy usage and improve comfort because they allow for zoning. In general, distribution systems such as parallel or primary-secondary piping arrangements perform better than the simpler series piping where all heat emitters are connected to a single pipe loop. For more information on distribution, see **Gas-Fired Boilers**.

Boiler Controls

While older boilers are either on or off, newer boilers with multi-stage or modulating burners have adjustable output to better match heating loads. This reduces the number of on-off cycles (and cycling losses) and allows the boiler to operate for longer hours at lower firing rates, which improves efficiency. Non-modulating boilers have efficiencies of 85% to 90%. Boilers that operate in modulation mode rather than just on-off can improve average boiler efficiency by up to 8%. Higher-efficiency models are also equipped with electronic controllers that can increase equipment life, improve boiler efficiency, and enhance comfort, by adjusting boiler water temperature, creating time-delay relays, performing automatic post-purge, preventing warm-weather boiler operation, controlling the position of mixing valves, and controlling pump speeds. These controls can increase the efficiency of noncondensing boilers by 10% or more and reduce idle losses to 0.3%. Condensing gas boilers that are fully modulating and have advanced controls can achieve efficiencies ranging from 92% to 96%.

There are many settings that can be adjusted on a modern boiler to improve the efficiency and comfort performance of the equipment, these adjustments may provide better performance than the default factory settings.

An outdoor reset control, which matches the system output to the actual outdoor temperature conditions, will improve comfort for owners of both condensing and non-condensing equipment by preventing extreme spikes in indoor temperature when the outdoor temperatures are warmer than design conditions. If you install an outdoor reset, recommend that homeowners do not use a night-time temperature setback strategy unless special controls have been installed that can override the reset control. Locate the outdoor sensor where it will not be exposed to a heat source such as direct sunlight or a dryer exhaust vent.

When installing an outdoor reset control with a noncondensing boiler, choose settings so that the return temperature to the boiler is no lower than 140°F to prevent condensing. However, when selecting the outdoor reset curve set points for a condensing boiler, choose settings so that the temperature of the water returning to the boiler is below 130°F. This ensures that the return temperatures are low enough to promote condensing, which will greatly increase the energy efficiency of the system (see **Arena 2012** for more details). To ensure the return temperature is below 130°F, the supply temperature will likely have to be reduced to below the factory setting. Make sure the heat emitters used (baseboards, radiators, etc.) are properly sized based on the average temperature in the distribution loop. If undersized, they won't release enough heat to the space and the water will return to the boiler at too high a temperature, preventing condensing. Radiant floor systems are typically set up to run at lower temperatures when installed, so they do not require additional adjustment to the boiler's supply temperature.

If you are specifying toe kick heaters in homes that have condensing boilers with outdoor reset controls, make sure the toe kick model specified is capable of operating at low temperatures. Many of the toe kick heaters currently available will not operate below a supply temperature of 140°F. A properly designed and configured condensing hydronic system will have return temperatures below 130°F most of the year, leaving the occupants without heat in rooms with toe kick heaters.

In highly insulated, energy-efficient homes with correctly sized equipment, nighttime setback can cause comfort issues and customer complaints. A boiler that is correctly sized to meet the home's design heating load will not have enough capacity to recover from the setback in a reasonable amount of time, especially if the system is designed with an outdoor reset control. Outdoor reset controls match the boiler's supply temperature to the heating load based on the current outdoor conditions, severely hindering the system's ability to raise the temperature in the space. If the boiler was set up with an outdoor reset control and no capability to override it, advise homeowners not to set their thermostat temperature back during nighttime hours. This is also recommended if the home is highly energy efficient and the boiler was sized to meet the design heating load.

If you know that the homeowner will employ a setback strategy or if you would like to provide that capability, you can install controls to speed up temperature recovery such as 1) a boost control that automatically raises the boiler output target temperature if heating demand is not satisfied within a set number of minutes, 2) an indoor sensor that works with the outdoor reset control to compensate for lags in response based on interior temperature, or 3) a simple manual override switch. Oversizing the heat emitters and possibly the boiler may be necessary to meet the additional load induced during periods of setback recovery.

If the boiler is oversized compared to the design load, oversizing the heat emitters will help reduce short cycling of the boiler. This may be the only option in situations where the smallest boilers are too large for the design load or there are several zones, each of which has very small loads compared to the boiler's capacity. In these cases, oversizing the emitters will reduce cycling, improve response time, and increase efficiency. Note that many manufacturers set a maximum temperature difference between the boiler's supply and return to protect the heat exchanger. Oversizing the heat emitter will result in an increase in the delta T, so make sure that you do not oversize to the point that the manufacturer's limit is exceeded. If installing a non-condensing boiler, make sure that increasing the emitter does not result in return water temperatures below 140°F.

For both condensing and noncondensing boilers, a warm weather shutoff turns off the boiler when the temperature setting is exceeded by the outdoor temperature. Boilers commonly come from the factory with the shutoff set between 68°F and 72°F. In locations with large day-night temperature swings or in spring and fall in homes that use a setback, if the shutoff is set too low, warm midmorning outside temperatures could prevent the heat from coming on even if it is still cold inside. Make sure the warm weather shutoff setting is no lower than the desired indoor winter temperature. For example, if 70°F is the normal setting, the warm weather shutoff should be no lower than 70°F.

Make sure your system includes an automatic post purge control, which keeps the system pump on for several minutes after the boiler stops firing to disperse the heat still residing in the mass of the boiler.

Some boiler manufacturers have started offering controls that can limit the boiler's maximum input. This can be especially useful if the boiler is used for both space heating and domestic hot water and one load is significantly less than the other. This limit reduces cycling in situations where the boiler's maximum firing rate is significantly higher than the demand, for example if when the water heater is calling for heat but the space heater is not.

Heat dumping is a strategy that diverts excess boiler heat to the domestic hot water (DHW) tank after the space heating demand is satisfied. Studies have shown this technique can greatly improve overall system efficiency (**Butcher 2011**).

See the Building America report **Condensing Boilers – Control Strategies for Optimizing Performance** for additional guidance on setting boiler controls.

How to Select and Install a Boiler

1. Choose the highest performing boiler that project funding will allow to meet the design heating load of the project. If you are participating in an energy-efficiency program, select a boiler that complies with the requirements for your climate zone, as described in the Compliance tab.
2. Install in accordance with relevant standards including **ACCA Standard 5: HVAC Quality Installation Specification** and the **ACCA's Technician's Guide for Quality Installations** and **ACCA Standard 9: HVAC Quality Installation Verification Protocols**.
3. Design an efficient distribution system that allows for zoning.
4. Properly size the boiler by first calculating the heating load of the home. Calculate heat load as described in the **ASHRAE Fundamentals Handbook**. Many software products are also available that can guide you through the calculations, and several boiler manufacturers include sizing guidelines or software on their web sites. If the design load is equal to or lower than the selected boiler's lowest output rating, consider alternative low-load heating equipment options that better match the design load of the home.
5. Install the boiler as a direct-vent installation where combustion air is piped directly to the boiler combustion chamber from outside. If the boiler must use the CAZ for combustion air, verify that required combustion air is provided in the CAZ and perform a combustion safety test after installation. See methods for calculating and providing combustion air in the guide **Combustion Furnaces**.
6. Select appropriate vent piping in accordance with the **National Fuel Gas Code** (see the Compliance tab).

7. Set the equipment control settings to optimize system efficiency as described above and in **Arena 2012**.
8. If your boiler heats a hydro coil for forced air heating, see Sizing Heating/Cooling System Distribution.
9. After the boiler is installed and before the initial filling, fill the system with water plus a cleaning solution. Allow this to circulate for several hours to remove grease, oil, and chemicals from solder and flux. Drain then fill with clean water. If the city water is corrosive, include an initial treatment. If properly installed, the boiler should operate indefinitely without needing additional water or cleaning.
10. For condensing boilers, ensure that condensate drains properly to the sewer or directly outdoors. Because the condensate is highly acidic, follow local code requirements regarding pretreatment of condensate before disposing to the sewer. Protect the condensate line from freezing. Provide a secondary (emergency) drain pan constructed of durable material.
11. Verify correct boiler operation by testing the outdoor reset control, and evaluating the boost control if one is installed.

Ensuring Success

Choose a Category IV high-efficiency, sealed-combustion, direct-vent system whenever possible.

Verify that the boiler is not oversized for the home's heating load.

For Category IV boilers, ensure that the horizontal portion of the exhaust vent pipe slopes slightly toward the boiler. Ensure that the condensate line drains to a sewer or outdoors. If condensate is drained to outdoors then protect the drain from freezing by either insulation or heat tape. Also ensure that a drain pan is installed under the boiler as a backup measure.

After installation, inspect to verify the following in accord with **ACCA Standard 5: HVAC Quality Installation Specification** and the **ACCA's Technician's Guide for Quality Installations** and **ACCA Standard 9: HVAC Quality Installation Verification Protocols**. These standards address quality installation and commissioning requirements for vapor compression cooling systems, heat pumps, and combustion and hydronic heating systems.

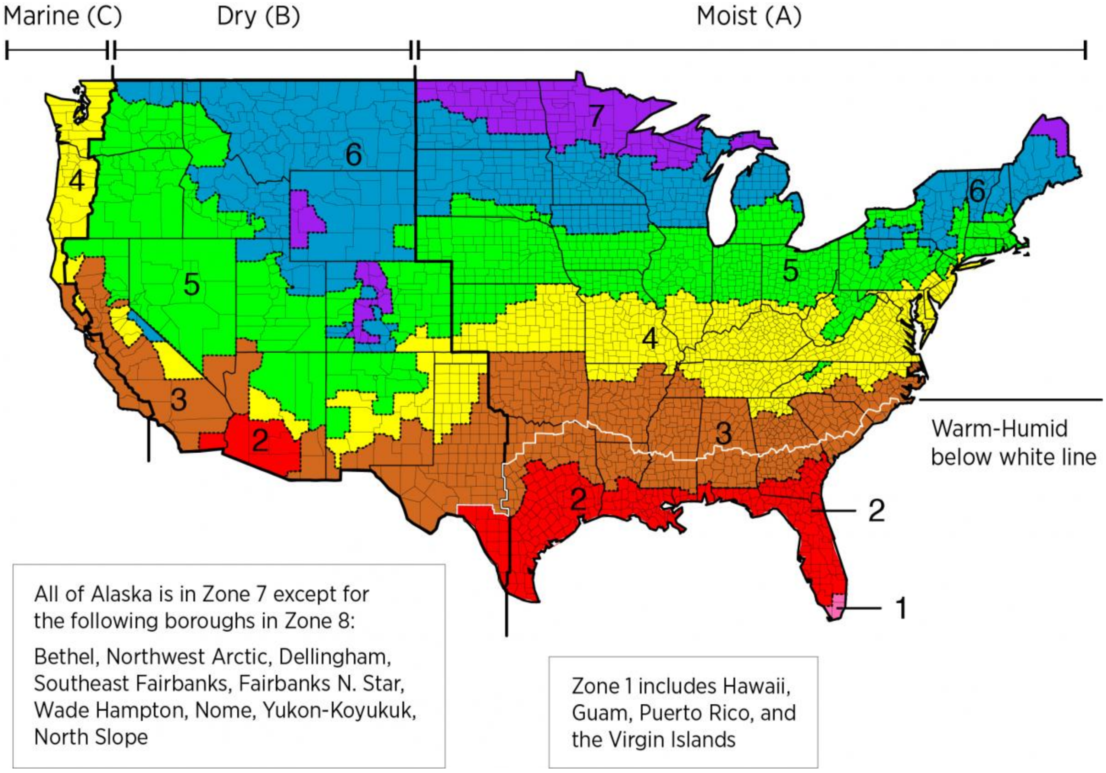
- Verify that any baseboard emitters installed are large enough to deliver the capacity needed.
- Ensure a minimum of a 20°F temperature differential between the supply and return temperatures under design conditions.
- Ensure that the temperature setting on the boiler reset curve is below the boiler's high limit setting.
- Verify that the warm weather shutoff is high enough to prevent no-heat situations during the swing seasons.
- Verify that the outdoor reset sensor has been placed away from any exhaust vents including kitchen, bath, dryer, and mechanical system vents and that it will not be in direct sunlight during any portion of the day.

Climate

ENERGY STAR makes mandatory direct vent or mechanically drafted combustion appliances in all climate zones except IECC Climate Zones 1 through 3 where naturally drafted appliances are allowed. Where naturally drafted appliances are allowed, a combustion safety test must be performed. ENERGY STAR allows gas and oil furnaces and boilers to be >=80% AFUE in Climate Zones 1, 2, and 3. In Climate Zones 4-8, ENERGY STAR requires that gas furnaces be >=90% AFUE, oil furnaces be >=85% and ENERGY STAR labeled, and boilers be >=85% and ENERGY STAR labeled.

The DOE Zero Energy Ready Home program allows >=80% furnaces and boilers in Climate Zones 1 and 2 only. In Climate Zones 3 and 4 (except marine climate zone 4), furnaces and boilers must have an AFUE of >=90% and in Climate Zones 5 through 8 (plus marine climate zone 4), furnaces and boilers must have an AFUE >=94%.

To determine your climate zone, see the International Energy Conservation Code (IECC) climate zone map.



IECC Climate Zone Map

Training

Right and Wrong Images

None Available

CAD

None Available

Compliance

2009 and 2012 IRC

Comply with all relevant sections of the applicable International Residential Code, including pertinent sections of Chapter 13: General Mechanical System Requirements, Chapter 14: Heating and Cooling Equipment, Chapter 20 Boilers and Water Heaters, Chapter 21 Hydronic Piping, Chapter 22 Special Piping and Storage Systems, and Chapter 24 Fuel Gas.

2009 IECC

403.1 Each heating and cooling system should have its own thermostat.

403.2 Ducts - Insulate supply ducts in attics to at least R-8 and all other ducts to at least R-6. Duct tightness shall be verified as described in 403.2.2 Sealing.

403.3 Mechanical system piping capable of carrying fluids >105°F or < 55°F must be insulated to at least R-3.

403.6 Heating equipment sizing shall be in accordance with Section M1401.2 of the International Residential Code.

2012 IECC

R403.1 Each heating and cooling system should have its own thermostat. If the primary heating system is a forced-air furnace at least one thermostat must be programmable.

403.2 Ducts - Insulate supply ducts in attics to at least R-8 and all other ducts to at least R-6. Duct tightness shall be verified as described in 403.2.2 Sealing. The air handler shall have a manufacturer's designation showing air leakage is no more than 2% of the design air flow rate when tested in accordance with ASHRAE 193.

R403.3 Mechanical system piping capable of carrying fluids >105°F or < 55°F must be insulated to at least R-3. Piping insulation exposed to weather must be protected from damage cause by sunlight, moisture, equipment, and wind. The protection cannot be provided by adhesive tape.

403.6 Heating and cooling equipment shall be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J or other approved heating and cooling calculation methods.

ACCA Standards

***ACCA Manual S. Residential Equipment Selection**, ANSI/ACCA 3-Manual S-2004, provides information on how to select and size heating and cooling equipment to meet Manual J loads based on local climate and ambient conditions at the building site. Manual S covers sizing strategies for all types of cooling and heating equipment, as well as comprehensive manufacturers' performance data on sensible, latent, or heating capacity for various operating conditions.

ACCA Manual D: Residential Duct Systems, ANSI/ACCA 1-Manual D-2011, provides ANSI-recognized duct sizing principles and calculations that apply to all duct materials; the system operating point (supply cfm and external static pressure) and airway sizing for single-speed and multi-speed (ECM) blowers; a method for determining the impact of duct friction and fitting pressure drop on blower performance and air delivery; and equivalent length data.

ACCA Manual J: Residential Load Calculation, ANSI/ACCA 2-Manual J-2011, provides information for calculating heating and cooling loads for equipment sizing for single-family detached homes, small multi-unit structures, condominiums, town houses, and manufactured homes.

ACCA Standard 5: HVAC Quality Installation Specification, ANSI/ACCA 5 QI-2010, details nationally recognized criteria for the proper installation of residential and commercial HVAC systems, including forced air furnaces, boilers, air conditioners, and heat pumps. The Standard covers aspects of design, installation, and distribution systems, as well as necessary documentation. The Technician's Guide for Quality Installation, produced by ACCA, explains the HVAC Quality Installation (QI) Specification and provides detailed procedures for the steps technicians must complete and document to show compliance with the HVAC QI Specification.

***ACCA Standard 9: HVAC Quality Installation Verification Protocols**, ANSI/ACCA 9 QIVP-2009, specifies the protocols to verify the installation of HVAC systems in accordance with ACCA Standard 5. The protocols provide guidance to contractors, verifiers, and administrators who participate in verification efforts using independent objective and qualified third parties to ensure that an HVAC installation meets the requirements in Standard 5.

National Fuel Gas Code (NFPA-5 2012)

The products of combustion from a gas-fired furnace (non-condensing) are vented out of the building using specific types of vent pipes made up of different materials depending on the flue gas temperatures, as specified in ANSI Z223.1, the National Fuel Gas Code (NFPA-5 2012), "Table 12.5.1 Type of Venting System to Be Used." Table 2 shows appropriate venting materials for residential vented combustion appliances, excerpted from the NFPA Table 12.5.1.

Table 2. Acceptable Venting Types for Different Combustion Appliance Types, excerpted from NFPA 54 2012, the National Fuel Gas Code, Table 12.5.1.

Appliance	Type of Venting System	NFPA Section Location
Listed Category 1 Appliances	Type B Gas Vent	12.7
Listed appliances equipped with draft hood	Chimney	12.6
Appliances listed for use with Type B gas vent	Single-wall metal pipe	12.8
	Listed chimney lining system for gas venting	12.6.1.3
	Special gas vent listed for these appliances	12.5.4
Category III appliances Category IV appliances	As specified or furnished by manufacturers of listed appliances	12.5.2 12.5.4
Listed combination gas- and oil-burning appliances	Type L vent Chimney	12.7 12.6
Direct vent appliances		12.3.5

See the National Fuel Gas Code for additional relevant requirements.

U.S. Department of Energy Zero Energy Ready Home

The U.S. Department of Energy's Zero Energy Ready Home program allows builders to choose a prescriptive or performance path. The DOE Zero Energy Ready Home prescriptive path requires builders to meet or exceed the minimum HVAC efficiencies listed in Exhibit 2 of the National Program Requirements, as shown below. The DOE Zero Energy Ready Home performance path allows builders to select a custom combination of measures for each home that is equivalent in performance to the minimum HERS index of a modeled target home that meets the requirements of Exhibit 2 as well as the mandatory requirements of Zero Energy Ready Home Exhibit 1.

Exhibit 2: DOE Zero Energy Ready Home Target Home [7, 20]

HVAC Equipment[21]			
	Hot Climates (2012 IECC Zones 1,2) [22]	**Mixed Climates** (2012 IECC Zones 3, 4 except Marine)	**Cold Climates** (2012 IECC Zones 4 Marine 5,6,7,8)
AFUE	80%	90%	94%
SEER	18	15	13
HSPF	8.2	9	10[23]
Geothermal Heat Pump	ENERGY STAR EER and COP Criteria		
ASHRAE 62.2 Whole-House Mechanical Ventilation System	1.4 cfm/W; no heat exchange	1.4 cfm/W; no heat exchange	1.2 cfm/W; heat exchange with 60% SRE
Insulation and Infiltration			
• Insulation levels shall meet the 2012 IECC and achieve Grade 1 installation, per RESNET standards. • Infiltration[24] (ACH50): 3 in CZ's 1-2 | 2.5 in CZ's 3-4 | 2 in CZ's 5-7 | 1.5 in CZ 8			

The DOE Zero Energy Ready Home prescriptive path requires builders to meet or exceed the minimum HVAC efficiencies listed in Exhibit 2. The DOE Zero Energy Ready Home performance path allows builders to select a custom combination of measures for each home that is equivalent in performance to the minimum HERS index of a modeled target home that meets the requirements of Exhibit 2 as well as the mandatory requirements of Zero Energy Ready Home Exhibit 1.

Zero Energy Ready Home Notes:

(7) State energy code specifications that exceed the DOE Zero Energy Ready Home National Program Requirements always take precedence and shall be used instead of DOE Zero Energy Ready Home specifications to determine DOE Zero Energy Ready Home compliance.

(20) Use the 2012 IECC Climate zone map.

(22) DOE recommends, but does not require, that cooling systems in hot-humid climates utilize controls for immediate blower shutoff after condenser shutoff, to prevent re-evaporation of moisture off the wet coil.

(23) Air source heat pumps with electric resistance backup cannot be used in homes qualified in Climate Zones 7 & 8 using the Prescriptive Path.

Washington and California residents – please see the **DOE Zero Energy Ready Home website for state-specific requirements**
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ENERGY STAR Version 3 (Rev 07)

The ENERGY STAR Certified Homes program allows builders to choose a prescriptive or performance path.

The ENERGY STAR prescriptive path requires builders to meet the minimum HVAC efficiencies listed in Exhibit 1. The ENERGY STAR performance path allows builders to select a custom combination of measures for each home that is equivalent in performance to the minimum HERS index of a modeled reference home that meets the requirements of Exhibit 1 as well as the mandatory requirements of ENERGY STAR Exhibit 2.

Exhibit 1: ENERGY STAR Reference Design

Hot Climates (2009 IECC Zones 1,2,3)[10]	**Mixed and Cold Climates** (2009 IECC Zones 4,5,6,7,8)[10]
Cooling Equipment (Where Provided)[11]	
• Cooling equipment shall meet the following applicable efficiency levels:	
• ≥ 14.5 SEER / 12 EER ENERGY STAR qualified AC, **OR;** • Heat pump (See Heating Equipment)	• ≥ 13 SEER AC, **OR;** • Heat pump (See Heating Equipment)
Heating Equipment[11]	
• Heating equipment shall meet the following applicable efficiency levels:	

• ≥ 80 AFUE gas furnace, **OR;**
• ≥ 80 AFUE oil furnace, **OR;**
• ≥ 80 AFUE boiler, **OR;**
• ≥ 8.2 HSPF / 14.5 SEER / 12 EER air-source heat pump, ENERGY STAR qualified with electric backup or ENERGY STAR qualified dual-fuel backup heating, **OR;**
• Ground-source heat pump, any product type, ENERGY STAR qualified:
	• ≥ 90 AFUE gas furnace, ENERGY STAR qualified, **OR;**
	• ≥ 85 AFUE oil furnace, ENERGY STAR qualified, **OR;**
	• ≥ 85 AFUE boiler, ENERGY STAR qualified, **OR;**
	• Air-source heat pump[12], ENERGY STAR qualified with efficiency as follows:
	  ◦ *CZ 4:* ≥ 8.5 HSPF / 14.5 SEER / 12 EER with electric backup, **OR;**
	  ◦ *CZ 5:* ≥ 9.25 HSPF / 14.5 SEER / 12 EER with electric backup, **OR;**
	  ◦ *CZ 6:* ≥ 9.5 HSPF / 14.5 SEER / 12 EER with electric backup, **OR;**
	• Air-source heat pump, ENERGY STAR qualified, ≥ 8.2 HSPF / 14.5 SEER / 12 EER with ENERGY STAR qualified dual-fuel backup, **OR;**
	• Ground-source heat pump, any product type, ENERGY STAR qualified[13]

When sizing the furnace, the listed output heating capacity should be between 100% and 140% of the design total heat loss or the next larger nominal size if a larger size is dictated by the cooling system selection.

Follow the criteria in the ENERGY STAR HVAC System Quality Installation Contractor and Rater Checklists.

HVAC System Quality Installation Rater Checklist, 10. Combustion Appliances:
10.1 Furnaces, boilers, and water heaters located within the home's pressure boundary are mechanically drafted or direct-vented. As an exception, naturally drafted equipment is allowed in Climate Zones 1-3. For naturally drafted furnaces, boilers, and water heaters, the Rater has followed RESNET or BPI combustion safety test procedures and met the selected standard's limits for depressurization, spillage, draft pressure, and CO concentration in ambient air, as well as a CO concentration in the flue of ? 25 ppm.

ENERGY STAR Footnotes:

(36) Raters shall use either the Building Performance Institute's (BPI's) Combustion Safety Test Procedure for Vented Appliances or RESNET's Interim Guidelines for Combustion Appliance Testing & Writing Work Scope and be BPI-certified or RESNET-certified to follow the protocol. If using RESNET's worst-case depressurization protocol to evaluate fireplaces, the blower door shall not be set to exhaust 300 CFM to simulate the fireplace in operation, but the remainder of the protocol shall be followed.

(8) Heating and cooling loads shall be calculated, equipment shall be selected, and duct systems shall be sized according to the latest editions of ACCA Manuals J, S, & D, respectively, 2009 ASHRAE Handbook of Fundamentals, or other methodology approved by the Authority Having Jurisdiction. The HVAC system design shall be completed for the specific configuration (e.g., plan, elevation, option, and orientation) of the home to be built except as permitted herein.
For each house plan with multiple configurations (e.g., orientations, elevations, options), the loads shall be calculated for each potential configuration. If the loads across all configurations vary by ? 25%, then the largest load shall be permitted to be used for equipment selection for all configurations, subject to the over-sizing limits of ACCA Manual S. Otherwise, the contractor shall group the load for each configuration into a set with ? 25% variation and equipment selection shall be completed for each set of loads.

For each house plan with multiple configurations, the room-level design airflows shall be calculated for each potential configuration. If the design airflows for each room vary across all configurations by ? 25% or 25 CFM, then the average room-level design airflow shall be permitted to be used when designing the duct system. Otherwise, the contractor shall group the room-level design airflow for each configuration into a set with ? 25% or 25 CFM variation and the duct design shall be completed for the average airflow of that set.

In alignment with ASHRAE 62.2-2010, these ENERGY STAR guidelines do not address unvented combustion space heaters.

Many states have adopted state- or region-specific ENERGY STAR Certified Homes criteria - Please see the **ENERGY STAR Certified Homes website for regional specifications**.

More Info.

Case Studies

1. **[DOE Zero Energy Ready Home Case Study: Ithaca Neighborhood Housing Services, Ithaca, New York]**
   Author(s): PNNL
   Organization(s): PNNL
   Publication Date: October, 2013
   Case study of a DOE Zero Energy Ready Home in Ithaca, NY, that scored HERS 50 without PV. These 1,160 ft2 affordable town houses have R-20 advance framed walls, R-52 blown cellulose in attic, radiant heat with 92.5 AFUE boiler, and triple-pane windows.

2. **[DOE Zero Energy Ready Home Case Study: Palo Duro Homes, Albuquerque, New Mexico]**
   Author(s): PNNL
   Organization(s): PNNL
   Publication Date: September, 2013
   Case study about a DOE 2014 Housing Innovation Award winner.

References and Resources*

1. **[ACCA Manual D—Residential Duct Systems]**
   Author(s): Air Conditioning Contractors of America
   Organization(s): Air Conditioning Contractors of America
   Publication Date: December, 2013
   Standard outlining industry procedure for sizing residential duct systems.

2. **[ACCA Manual J - Residential Load Calculation]**
   Author(s): Air Conditioning Contractors of America
   Organization(s): Air Conditioning Contractors of America
   Publication Date: January, 2011
   Standard covering equipment sizing loads for single-family-detached homes, small multi-unit structures, condo-miniums, town houses and manufactured homes.

3. **[ACCA Manual S - Residential Equipment Selection]**
   Author(s): Air Conditioning Contractors of America
   Organization(s): Air Conditioning Contractors of America
   Publication Date: April, 2013
   Standard covering sizing strategies for all types of cooling and heating equipment, as well as how to use comprehensive manufacturer's performance data on sensible, latent, or heating capacity for various operating conditions.

4. **[ACCA Standard 5: HVAC Quality Installation Specification]**
   Author(s): Air Conditioning Contractors of America
   Organization(s): Air Conditioning Contractors of America
   Publication Date: January, 2010
   Standard providing a universally accepted definition for quality installation across a broad spectrum of the HVAC industry.

5. **[ACCA Standard 9: HVAC Quality Installation Verification Protocols]**
   Publication Date: January, 2009
   Document detailing the requirements, roles, and obligations for participants in an organized effort, ensuring that HVAC installations comply with the ANSI/ACCA 5 QI – 2007 (HVAC Quality Installation Specification) QI Standard.

6. **[ASHRAE Handbook – Fundamentals]**
   Author(s): ASHRAE
   Organization(s): ASHRAE
   Publication Date: January, 2013
   Guidebook covering basic principles and data used in the HVAC&R industry.

7.

Boilers, Baseboard Radiation, Finned Tube (Commercial) Radiation, and Indirect-Fired Water Heaters
Author(s): Air-Conditioning Heating and Refrigeration Institute
Organization(s): Air-Conditioning Heating and Refrigeration Institute
Publication Date: April, 2009
This directory contains the I=B=R Ratings for cast-iron, steel, aluminum and copper boilers, baseboard and finned tube radiation, indirect-fired water heaters, effective as of the date of this publication.

8. Controls and Safety Devices for Automatically Fired Boilers
Author(s): American Society of Mechanical Engineers
Organization(s): American Society of Mechanical Engineers
Publication Date: January, 2012
Standard covering requirements for the assembly, installation, maintenance, and operation of controls and safety devices on automatically operated boilers directly fired with gas, oil, gas-oil, or electricity, having fuel input ratings under 12,500,000 Btu/hr.

9. EIA Residential Energy Consumption Survey 2009
Author(s): EIA
Organization(s): EIA
Publication Date: January, 2009
Federal statistics about national energy consumption in residential homes.

10. Heat Pumps and Hydronics – A Great Team for High-Performance Homes
Author(s): Butler
Organization(s): Energy Vanguard
Publication Date: January, 2011
Article discussing the advantages of using heat pumps instead of furnaces in high-performance homes.

11. How to Perform a Heat-Loss Calculation Part I
Author(s): Holladay
Organization(s): Green Building Advisor
Publication Date: April, 2012
Website blog with guidance about calculating heat-loss.

12. International Fuel Gas Code
Author(s): ICC
Organization(s): ICC
Publication Date: January, 2012
Standard document with information about the international fuel gas code.

13. International Mechanical Code
Author(s): ICC
Organization(s): ICC
Publication Date: January, 2009
Code containing 2009 ICC language for mechanical draft systems.

14. Manual B - Balancing and Testing Air and Hydronic Systems
Author(s): Air Conditioning Contractors of America
Organization(s): Air Conditioning Contractors of America
Publication Date: January, 2009
Standard technical manual with information about HVSC balancing, testing air and hydronic systems.

15. Measure Guideline: Condensing Boilers – Optimizing Efficiency and Response Time During Setback Operation
Author(s): Arena
Organization(s): CARB
Publication Date: February, 2014
Report providing step-by-step instructions for heating contractors and hydronic designers for selecting the proper control settings to maximize system performance and improve response time when using a thermostat setback.

16. Modern Hydronic Heating for Residential and Light Commercial Buildings
Author(s): Siegenthaler
Organization(s): Delmar CENGAGE Learning
Publication Date: January, 2012
Book with indepth information about hydronic systems for residential and commercial buildings.

17.

Mortgage Industry National Home Energy Rating Systems Standards
Author(s): RESNET
Organization(s): RESNET
Publication Date: January, 2013
Standards aimed to ensure that accurate and consistent home energy ratings are performed by accredited home energy rating Providers through their Raters nationwide.

18. **NFPA 54: National Fuel Gas Code**
Author(s): National Fire Protection Association
Organization(s): National Fire Protection Association
Publication Date: January, 2012
Code outlining minimum safety requirements for the design and installation of fuel gas piping systems in homes and other buildings.

19. **Performance of Combination Hydronic Systems**
Author(s): Butcher
Organization(s): ASHRAE
Publication Date: December, 2011
Article investigating how a linear input/output relationship can be used as a simple model of the performance of a combination hydronic heating system over heating only, DHW only, and combined loads.

20. **Technician's Guide for Quality Installation**
Author(s): Air Conditioning Contractors of America
Organization(s): Air Conditioning Contractors of America
Publication Date: January, 2010
The Technician's Guide equips practitioners with the knowledge to properly implement all of the measurement procedures required in the HVAC QI Specification.

*Publication dates are shown for formal documents. Dates are not shown for non-dated media. Access dates for referenced, non-dated media, such as web sites, are shown in the measure guide text.
