2016 TITLE 24, PART 6
RESIDENTIAL

HVAC AND PLUMBING

Energy Code Ace™

HELPING YOU PLAY YOUR CARDS RIGHT

This guide is designed to help builders and industry professionals become more familiar with the residential HVAC and plumbing portion of California's 2016 Building Energy Efficiency Standards (Title 24, Part 6).

The guide provides information on current technologies, design terms and principles, and best-practice approaches related to compliance with the Energy Standards.

This guide was developed and provided by Energy Code Ace, a sub-program of the California Statewide Codes & Standards Program, which offers free Energy Standards training, tools and resources for those who need to understand and meet the requirements of Title 24, Part 6 and Title 20.

To learn more, visit EnergyCodeAce.com

January 2017

Contributors:

Benningfield Group, Inc.

Gabel Associates, LLC

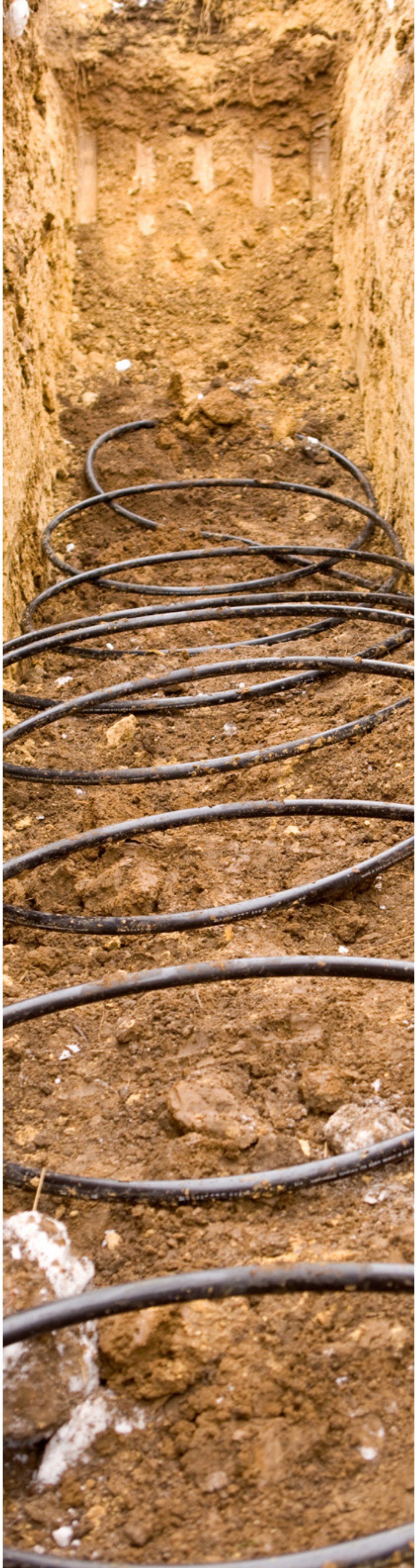
NORESCO

California Energy Commission

Wilkins Communications

McPherson Design

2017-05-12



RESIDENTIAL
HVAC AND PLUMBING
APPLICATION GUIDE

CONTENTS

CHAPTER 1

INTRODUCTION

The Benefits of Efficiency

Cost Savings

Energy efficient homes create real savings for homeowners, every month, in the form of reduced utility bills. For many families, reducing monthly expenses can result in a less stressful financial situation. With few maintenance costs, newly constructed homes that apply energy efficient design and construction can provide continuous long-term savings to the homeowner.

Increased Comfort

In addition to lowering operating costs for homeowners, the residential HVAC requirements of the Building Energy Efficiency Standards have the very tangible benefit of improving occupant comfort and indoor air quality. Meeting these standards requires careful design considerations, including load calculations to properly size equipment and ventilation calculations to provide acceptable levels of ventilation.

Progress Toward Energy Efficiency Goals

Water heaters that are used to provide hot water for our sinks and showers are the only permanent (non-plug-in) piece of equipment in our homes used 24 hours a day, 7 days a week, 365 days a year. Even small energy savings associated with these systems can multiply into BIG savings over the lifetime of that equipment. As we get closer to our Zero Net Energy goals in California, energy savings realized with domestic hot water (DHW) equipment, distribution and design are major factors in reaching those goals.

Electric Heat Pump Installed on a Residence

About this Guide

This is one of seven guides designed to help builders, designers, contractors, and others involved in the compliance process become more familiar with California's Building Energy Efficiency Standards (Energy Standards) as they apply to projects. It is designed to serve as a resource for industry professionals involved in the design, construction, or retrofit of California's buildings. The guides include compliance requirements and recommendations for implementing the Energy Standards in new construction, addition or renovation projects.

This application guide focuses on the heating, ventilation, air conditioning (HVAC), and plumbing requirements in the residential Energy Standards. It also contains information on the associated Home Energy Rating System (HERS) process.

Compliance Process Overview

Chapter 2 is an overview of the compliance process including the responsibilities, requirements, and documentation involved in each phase of the project, from design to final inspection.

Concepts & Principles

Chapter 3 is devoted to HVAC & plumbing concepts and principles that are relevant to compliance, such as integrated design and construction principles and energy efficient design considerations.

Technology Systems & Compliance Strategies

Chapter 4 includes technologies that are commonly used for compliant buildings, and discussions about systems and controls applications.

Navigating the Compliance Strategy

Requirements related to residential HVAC & plumbing systems are discussed in Chapter 5, along with a case study comparing performance and prescriptive compliance approaches.

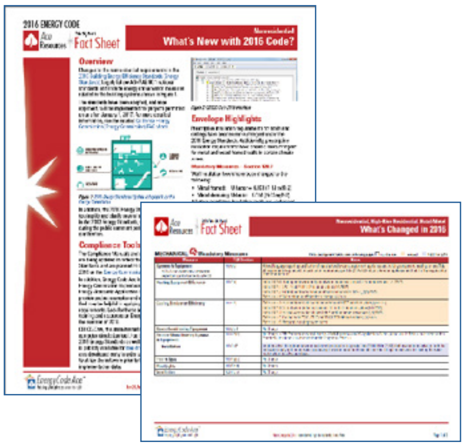
Recommendations, Resources and Coordination

Chapter 6 contains discussion around designing for compliance, field testing, and common alteration scenarios.

All seven guides can be found at EnergyCodeAce.com

APPLICATION GUIDE	WHAT'S COVERED
NONRESIDENTIAL ENVELOPE AND SOLAR READY AREAS	• Climate specific design • Insulation • Cool Roofs • Solar Zone • Fenestration • Compliance documentation details
NONRESIDENTIAL LIGHTING AND ELECTRICAL POWER DISTRIBUTION[1]	• Lighting design strategies • Controls • Electrical power distribution
NONRESIDENTIAL HVAC AND PLUMBING	• Mechanical Systems and Plumbing Systems • Commissioning, HERS Process & Acceptance Testing
NONRESIDENTIAL PROCESS EQUIPMENT AND SYSTEMS	• Process loads • Applicable products and systems such as kitchen hoods, parking garage ventilation, laboratory fume hoods, elevators and moving walkways, escalators, and compressors
RESIDENTIAL ENVELOPE AND SOLAR READY AREAS (Low Rise and Single Family)	• Single Family Homes, including duplexes • Low-rise residential building envelope • Climate specific design • Insulation • Cool Roofs • Single Family Solar-Ready including Solar Zones • Fenestration • Prescriptive vs. Performance compliance • Compliance documentation details
RESIDENTIAL LIGHTING[1] (Low Rise and Single Family)	• Lighting design strategies • Compliant Products • Controls
RESIDENTIAL HVAC AND PLUMBING (Low Rise and Single Family)	• HVAC terminology • Heating and cooling system types • Hot Water system types
1 Created by the California Lighting Technology Center (CLTC) in collaboration with Energy Standards Ace.	

Ace Resources™



What's New and What's Changed Fact Sheets

These two documents present 2016 Title 24, Part 6 updates at a glance.

Find both Fact Sheets here: energycodeace.com/content/resources-fact-sheets/

New in 2016: An Overview of Updates

The Energy Standards go through regular updates. The 2016 updates have enhanced, corrected, and evolved the requirements closer to the State's energy policy goals.

Mandatory Duct Requirements

Most of the changes to the 2016 Energy Standards for residential HVAC are very subtle. Many are just clarifications to the 2013 Energy Standards. One notable change is that the mandatory maximum duct leakage for new systems in single-family dwellings dropped from 6% to 5% of total system fan flow (see §150.0(m)11). A new three ton system, for example, would now have to leak no more than 60 cfm rather than 72 cfm. Also, R-4.2 insulation for ducts inside conditioned space is now the mandatory minimum (see §150.0(m)1).

Ducts in High Performance Attics (Prescriptive)

Ducts in high performance attics using prescriptive Options A or B have new insulation minimums. In climate zones 1, 2, 4, and 8 through 16, R-8 insulation is required. In climate zones 3, 5, 6 and 7, R-6 insulation is required. Ducts in high performance attics with ducts in conditioned space (Option C) must have R-6 insulation in all climate zones. See §150.1(c)9 of the Energy Standards for the definition of a high performance attic.

Whole House Fan Airflow Rates

The required airflow for whole house fans has been reduced to 1.5 cfm/ ft^2 of conditioned floor area. The size of the attic vent has also been reduced to 1ft^2 per 750 cfm of fan airflow.

Ace Training™

Title 24: Where We're Headed with the 2016 Standards

Offered in traditional classroom and virtual formats, this class presents what's new in the Title 24, Part 6 Energy Standards.

Find dates for upcoming classes: energycodeace.com/training

Decoding 2016 Title 24, Part 6: Let's Talk About What's New

A free, 2-hour interactive online event that discussed, reviewed and decoded the new 2016 code requirements for Title 24 Part 6.

Access the recorded talk here: energycodeace.com/content/decoding-talks/

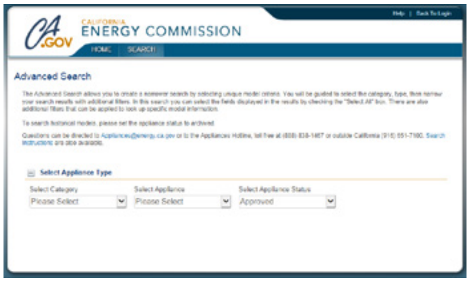
DHW Changes for 2016

There have been some major changes to prescriptive requirements regarding DHW under the 2016 Energy Standards for new homes, in which the standard water heater is no longer a gas tank type system, but a gas tankless (on-demand) water heater. This prescriptive change also effects the baseline system for projects using the performance approach to compliance. There are a series of options available for new homes that choose not to install a gas tankless unit, but they will trigger the need for HERS verified features (such as Quality Insulation Installation (QII), and DHW distribution systems).

When a tankless water heater is installed, there are new mandatory requirements for isolation valves on the distribution piping so that the system can be maintained properly. When a recirculation system is installed, only manual control pumps are prescriptively allowed, making any other control type require a performance calculation to show compliance. Electric resistance water heaters are no longer allowed prescriptively, and must be shown to work with a performance calculation.

Code in Practice

The new DHW requirements for a gas storage hot water heater in a new home trigger the need for HERS verified Quality Insulation Installation. This **must** be coordinated with the project designer and contractor at the beginning of a project. It is recommended that the DHW choice be decided before submittal to the building department and not left as an “in the field” decision.



Appliance Efficiency Database

This online database of products certified to the Energy Commission has a Quick Search function allowing users to search by product type, brand, or model.

Visit the database site here: cacertappliances.energy.ca.gov/Pages/Search/AdvancedSearch.aspx

Code in Practice

A builder, designer, owner, operator, or enforcing agency is **not** required to test any certified device to determine its compliance with minimum specifications or efficiencies adopted by the Energy Commission. Testing is the responsibility of the manufacturer.

Finding Compliant Products

Heating, cooling and DHW equipment, pumps, thermostats and controls must be certified to the Energy Commission before they can be installed. (Notice that certification *is* to the Energy Commission and not *by* the Energy Commission). Certified equipment will be listed in the Energy Commission's searchable on-line database. Certification requires that the product meets specific federal efficiency requirements. Certain features and functionality may also be required to obtain certification. For example, low leakage air handlers are required to have a maximum air leakage rate to be certified as such to the Energy Commission. If a low leakage air handler is specified on the Certificate of Compliance, only one that is on the Energy Commission's list of certified low leakage air handlers is allowed to be installed. It is very important that building designers specify on their plans that only certified equipment is to be used. It is even more important that installers confirm and document that the products they install are certified. Despite statewide enforcement and education efforts, it is often possible to purchase non-certified equipment in California, especially in the months after new, stricter requirements have gone into effect.

HVAC and DHW Products Regulated Under Title 20

- Heat pumps
- Air conditioners
- Furnaces
- Boilers
- Whole house fans
- Evaporative coolers
- Exhaust fans
- Water heaters and boilers

Products Regulated Under Title 24

- Ducts
- Sealants/Tapes

Code in Practice

In an example project, the CF1R stated that a tankless gas DHW unit (199,000 BTUH input) is to be installed with an energy factor of 0.85. During construction, it is decided to proceed with a Rinnai unit. Use of the Title 20 Appliance Efficiency Database can help assure that the units under consideration meet the necessary requirements and are also certified.

Filters

Manufacturer	Equals	Rinnai
Thermal Efficiency	Greater Than Or	85
Input BTUH	Equals	199000
Please Select		
Please Select		

Search Clear

Search Results 8 record(s) found

Export To: Excel CSV

		Manufacturer	Brand	Model Number	Measured Volume	Input BTUH	Thermal Efficiency	Regulatory Status
Select		Rinnai	Rinnai	REU-KB3237WDC-US	0.50000	199000	96	Federally-Regulated Commercial & Industrial Equipment
Select		Rinnai	Rinnai	(RC98HPi) REU-KA3237FFUD-US	0.00000	199000	96	Federally-Regulated Commercial & Industrial Equipment
Select		Rinnai	Rinnai	(RC98HPi) REU-KA3237FFUD-US	0.00000	199000	96	Federally-Regulated Commercial & Industrial Equipment
Select		Rinnai	Rinnai	REU-V2532WCD-US	0.50000	199000	85	Federally-Regulated Commercial & Industrial Equipment
Select		Rinnai	Rinnai	REU-V2532WC-US	0.50000	199000	85	Federally-Regulated Commercial & Industrial Equipment
Select		Rinnai	Rinnai	(RC98HPe) REU-KA3237WD-US	0.00000	199000	95	Federally-Regulated Commercial & Industrial Equipment
Select		Rinnai	Rinnai	(RC98HPe) REU-KA3237WD-US	0.00000	199000	95	Federally-Regulated Commercial & Industrial Equipment
Select		Rinnai	Rinnai	REU-KBD3237FFUDC-US	0.50000	199000	96	Federally-Regulated Commercial & Industrial Equipment


Hold
Inside
Set To
78°
76°
1:30 PM
Cool
Sun On
SET
HOLD
Fan
Auto On
System
Cool Off Heat

CHAPTER 2

COMPLIANCE PROCESS

The following is an overview of the compliance process for residential HVAC and plumbing requirements. Additional information and resources, including the 2016 Residential Compliance Manual and forms, may be found on the California Energy Commission (Energy Commission) website. energy.ca.gov/title24/2016standards/index.html

Step 1: Discuss and Define Energy-Related Project Goals

Designers, home owners and builders have the most opportunity to identify and pursue energy savings strategies at the beginning of a project. Early coordination of as many project team members as possible is recommended to clearly define energy-related project goals and understand potential opportunities and constraints. More detail on this step can be found in Chapter 3, where integrated design and construction principles are discussed.

Step 2: Determine and Design for...

Applicable Mandatory Measures

All residential buildings that are regulated occupancies must be designed and built to comply with the mandatory measures of Title 24, Part 6. Mandatory measures are discussed in Chapter 4 of this guide. Mandatory measures for residential HVAC and water heating primarily deal with minimum efficiencies (SEER, AFUE, etc.), required features (setback thermostats, etc.), design standards (load calculations, minimum airflow, etc.) and construction quality (duct leakage, etc.). Note that some minimum requirements may be higher for a particular project than the mandatory measures so that they meet the necessary prescriptive or performance requirements.

Applicable Performance or Prescriptive Requirements

In addition to meeting the mandatory requirements, buildings also must comply with additional requirements specified within the Energy Standards. Two approaches may be taken to meet these requirements:

Residential Thermostat

The Navigator Ace™ is your roadmap to Energy Standards compliance, illustrating the compliance process step by step from the big picture down to the fine details, including links to resources, tips, and tricks.

Find the tool here: energycodeace.com/content/navigator-ace/

CEC Blueprint, September/October 2015

The Q&A in this Blueprint clarifies who can be the "documentation author" and the "Responsible Person" on compliance documents.

Find it here: energy.ca.gov/2015publications/CEC-400-2015-031/CEC-400-2015-031.pdf

The **Performance Approach** provides one path to compliance. It requires using software approved by the California Energy Commission to create a whole building energy model, and requires expertise with the modeling software. The performance approach is best suited for new construction and when flexibility is desired for additions and alterations to existing construction. New construction projects commonly follow the performance approach because of the flexibility allowed by trading efficiency options between the envelope, mechanical, and lighting systems. This method allows for energy trade-offs between building systems (heating, cooling, water heating, etc.) and is thus considered more flexible.

The **Prescriptive Approach** does not require software or the same level of building modeling expertise as the Performance Approach. The prescriptive compliance approach is a valuable option for many projects, including retrofits, alterations, or single scope projects. The prescriptive approach is best suited for a more simplistic approach to smaller additions and alterations to existing construction in which flexibility is not an issue. The prescriptive approach sets strict limits on window area and orientation, for example. The prescriptive requirements also set the energy target for the performance approach.

Both the prescriptive and performance approaches are described in more detail in Chapter 5.

Local Energy Standards

There also may be local energy standards that the local jurisdiction will enforce in addition to Title 24, Part 6. These local energy standards may affect aspects of the project such as lighting, insulation, HVAC installations, and domestic hot water. Additionally, these local energy standards can require third-party inspections and building certifications. Being aware of local energy standards in the design phase of the project will reduce cost, time, and effort, as well as help to avoid extensive and costly change orders.

Step 3: Prepare and Submit Permit Application

Once the design requirements of the Energy Standards have been met, the permit applicant must ensure that the plans include all the documents that building officials will require for verifying compliance. Plans, specifications and certificates of compliance are submitted to the enforcement agency at the same time as a building permit application. There are some exceptions as to when plans are not required, and these can be found in §10-103 of Title 24, Part 6. If HERS verification is required for the project scope, Certificates of Compliance must be registered with a HERS Provider prior to permit application (with limited exceptions).

Step 4: Pass Plan Check and Receive Permit

Depending on the type of permit, the building department will issue a permit over the counter or require a plan check. If a plan check is required, a plans examiner must check that the design satisfies Title 24, Part 6 requirements, ensure that the plans are consistent with the information on the CF1R-Certificate of Compliance, and make certain that the plans contain the information to be verified during field inspection. A building permit is issued by the building department after plans are approved.

Step 5: Perform Construction

The construction team must follow the approved plans, specifications, and Certificates of Compliance (CF1Rs) during construction. Installers must provide Certificates of Installation for their scope of work. **Coordination will be required between installers, designers, HERS Raters, and building inspectors to properly install and verify compliant installation.** During construction, Certificates of Installation (CF2Rs) are completed in preparation for inspection.

Step 6: Test and Verify Compliance

When a HERS Rater is required by Title 24, Part 6, early coordination is encouraged to understand when inspections and testing are necessary during the construction process so that they can be incorporated into the schedule. Many inspections are time sensitive because the building component may be inaccessible after walls or other barriers are installed. This is especially true for residences incorporating HERS Verification of Existing Conditions or HERS-verified Quality Insulation Installation. (QII) as part of their compliance strategy.

Title 24, Part 6 requires field testing and verification of certain systems, as well as registration of Certificates of Compliance to a HERS Provider Registry database. Third party HERS Raters must be trained, tested and certified by a HERS Provider.

A list of providers approved by the Energy Commission can be found on their website at energy.ca.gov/HERS/providers.html

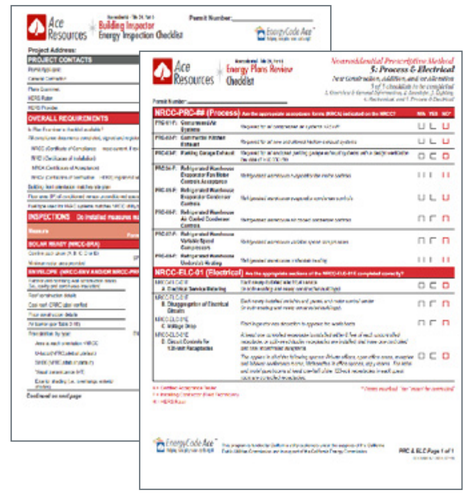
Step 7: Pass Building Inspection

The local authority having jurisdiction, often the building department, likely will require an inspection before finalizing the permit. Building inspections often are scheduled by the contractor with the building department on behalf of the building owner. Once all systems are installed and inspected, and completed compliance documentation has been verified, a Certificate of Occupancy will be issued by the local jurisdiction.

Step 8: Provide Documentation to Building Owners

Upon occupancy, the building owner must receive copies of the energy compliance documents along with instructions for operation and maintenance.

Ace Resources™



Plans Examiners and Building Inspector Checklists

Checklists for Plans Examiners and Building Inspectors are available for applicants to prepare for plan check and inspection as well as to guide department staff through Part 6 compliance verification

Find the checklists here.
energycodeace.com/content/resources-checklists/

Ace Training™

Title 24, Part 6 Essentials Training

Offered in traditional classroom and virtual formats, participants learn about navigating key residential Title 24, Part 6 building standards and compliance options for new construction, alterations and additions, and compliance related documents.
This course is available in several versions to fit project roles:

- Title 24 Part 6 Essentials – Residential Standards for Plans Examiners and Building Inspectors
- Title 24 Part 6 Essentials – Residential Standards for Energy Consultants
- Title 24 Part 6 Essentials – Residential Standards for AC Quality Installation Contractors

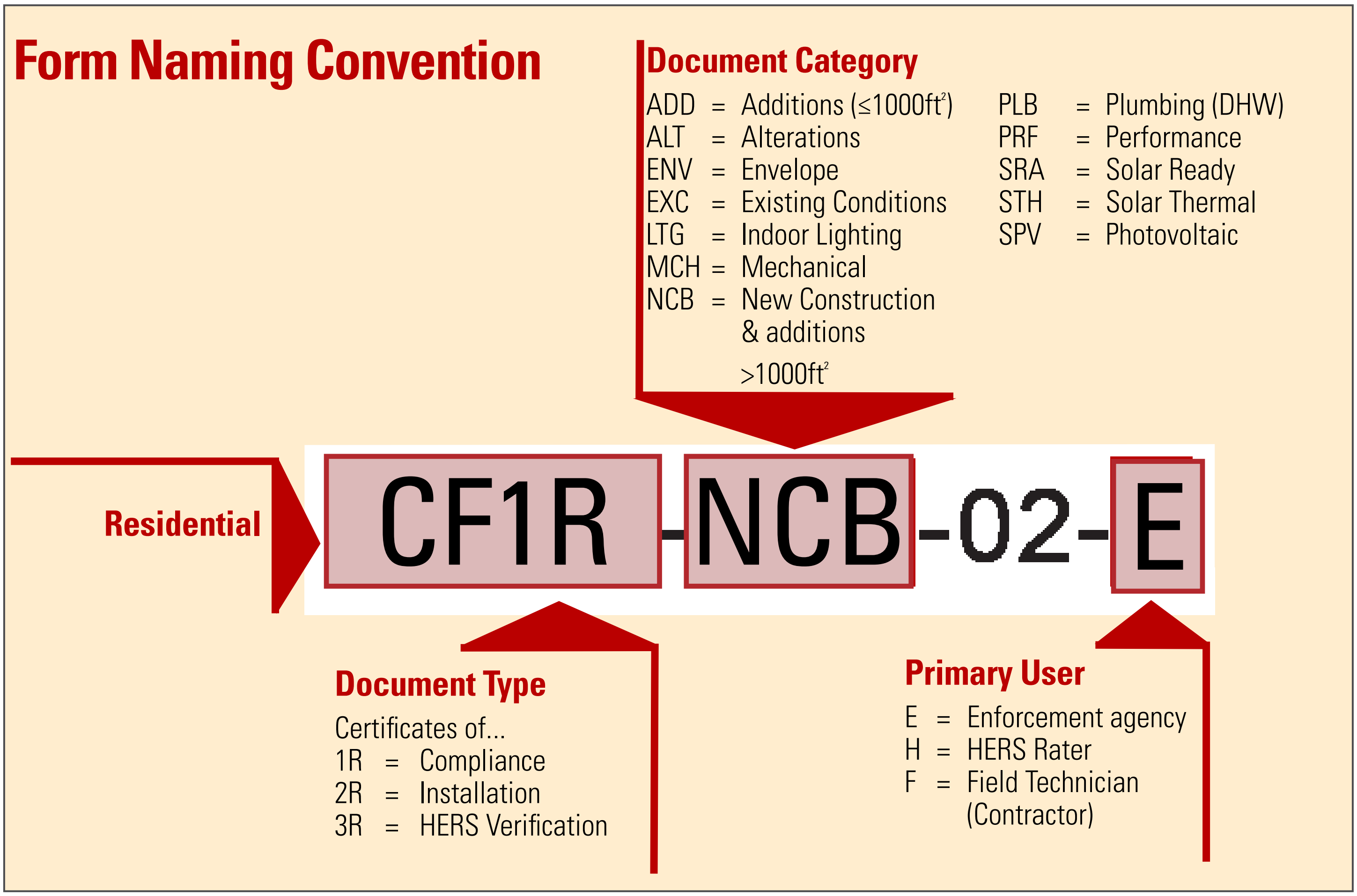
Find dates for upcoming classes: energycodeace.com/training

Residential HVAC and Plumbing Compliance Documents

The compliance process includes the completion of a set of forms to submit for review by a plans examiner within the authority having jurisdiction. Not all forms are required for all projects. Instructions for completing these forms are provided at the end for each form, except for the performance method forms which are filled out by the approved compliance software.

A Logical Pattern

The residential compliance documents follow a pattern as simple as 1 - 2 - 3. There is some logic to the numbering too.



Certificates of Compliance

The Certificate of Compliance (CF1R) verifies the building features required to comply with Title 24, Part 6, for low-rise residential buildings. These features will vary depending on the particular project and the compliance approach used. CF1Rs are submitted to the building department as part of the building permit application (see Step 3 of the compliance process description).

The CF1R will document what minimum features (HERS and non-HERS) are required to meet the Energy Standards. It is typically filled out and submitted with the permit application and checked as part of the plan check process.

These forms establish the "commitment" to provide code compliant equipment and installation. The performance approach allows flexibility to the prescriptive code requirements, whereas the prescriptive approach is considered more "rigid".

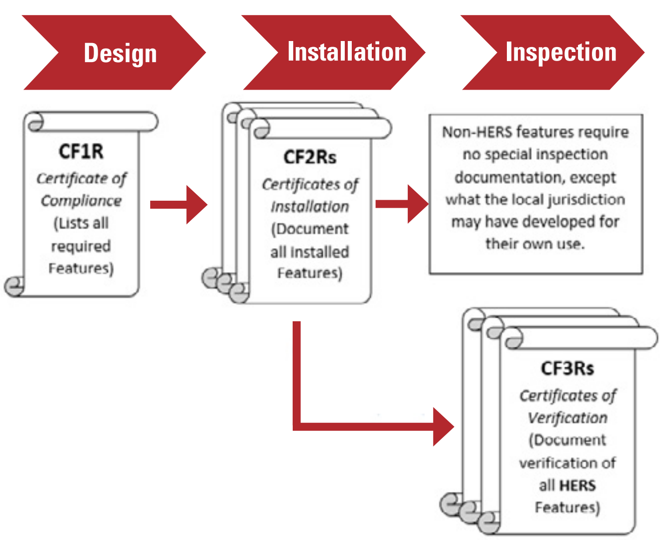
Certificates of Installation

The Certificate of Installation (CF2R) verifies that the low-rise residential building products and features actually installed in the field match those required in the Certificates of Compliance. CF2Rs must be completed and signed by the installer or builder responsible for installing regulated building components (see Step 5 of the compliance process description). There is one CF2R for each major feature or category of features. CF2Rs that end in "E" are for features that are inspected by the enforcement agency. CF2Rs that end in "H" are for features that are inspected by the HERS rater.

Whereas the installing contractor must sign off taking responsibility of installed features, anyone can be the "documentation author" to facilitate filling out the forms for the contractor. This could be the HERS rater, office staff, etc.

Certificates of Verification

The Certificate of Verification (CF3R) verifies compliance with HERS measures in the CF1Rs. CF3Rs must be completed and signed by a HERS rater (see Step 6 of the compliance process description). The CF3Rs are only required for HERS verified features. Non-HERS features are inspected by the local building inspector as needed, in conjunction with checking that the appropriate CF2Rs have been completed and signed by the installer (managed by HERS registry). There are usually no special compliance documents for these inspections, unless the local jurisdiction designed some for their own use.



Compliance Documents

Compliance Document forms can be found on the Energy Commission website.

Click here to access the forms: energy.ca.gov/2015publications/CEC-400-2015-032/appendices/forms/

Ace Forms™

The Forms Ace aids in determining which compliance forms are applicable to your specific project.

Find the tool here: energycodeace.com/content/forms-ace/


MIN
MAX
MIN
MAX

ALEX 'FLORSTEIN' FEDOROV

CHAPTER 3

CONCEPTS & PRINCIPLES

Integrated Design & Construction Principles

Although not intuitive, the main drivers for an efficient HVAC system in a home are actually the architecture of the home (size, shape, and configuration) and the envelope design. Too often homes are designed first, and then the HVAC system must be designed to fit the architecture. To maximize the contribution of the HVAC system to energy efficiency, the home should be designed in an integrative manner, with the HVAC system in mind - especially when determining placement of ducts in a ducted system. This allows much more flexibility in choosing the type of system, and also can result in appropriate sizing of equipment (and potentially overall project cost savings due to downsizing).

The role of the HVAC system is to supply heating and cooling to the home, primarily for occupant health and comfort. Energy efficiency, in terms of energy use per square foot starts with the building envelope. The building envelope will primarily determine the size of the equipment needed to maintain a constant temperature inside. Calculations will determine how much energy that the HVAC uses in the summer to cool and how much heat (energy) escapes the building in the winter. These calculations are called the heating and cooling loads of the home. In addition to using less energy, a 2,000ft^2 house with a very efficient building envelope will require a smaller HVAC system than a 2,000 ft^2 house with an inefficient building envelope. Reducing costs associated with heating and cooling (and lighting) is largely what efficient envelope design is all about. More detail on these concepts is provided in the Residential Envelope and Solar Ready Application Guide.

Design Considerations for HVAC Systems

Once the equipment size has been determined, based on heating and cooling loads, the HVAC system's ability to efficiently deliver heating and cooling is driven by four design considerations:

1. The rated efficiency of the equipment (energy required to provide a given amount of heating or cooling under *test* conditions).
2. The installed efficiency of the equipment (energy required to provide a given amount of heating or cooling under *actual* conditions).
3. The efficiency of the distribution system (how much heating or cooling is lost getting from the equipment to areas in the house).

Tankless Hot Water Heater


BLUEPRINT
California Energy Commission
Efficiency Division

In This Issue

New Computer Compliance Program Available

Filter Grille Area Requirements

Decerti cation of Energy Analysis and Comfort Solutions

CEC Blueprint, November 2015-February 2016

The Q&A in this Blueprint clarifies SEER/EER requirements set by the U.S. Department of Energy.

Find it here:
energy.ca.gov/2015publications/CEC-400-2015-046/CEC-400-2015-046.pdf

4. The efficiency of the system controls (the ability of the thermostat to turn the system on and off in a manner that requires the least amount of run time while maintaining a constant temperature in the home).

Each of the design considerations are discussed in more detail below.

Rated Equipment Efficiency

This is determined by how well the actual heating and cooling equipment is designed and manufactured. All certified equipment is tested to determine how much energy is required to add BTUs (heat) or remove BTUs (cool), and this information is provided by the manufacturer (see SEER/ EER/ AFUE/ HSPF in the glossary for details). This establishes the equipment's rated efficiency. Mandatory measures in the Energy Standards set the minimum requirements for rated equipment efficiency, but performance trade-offs could require substantially higher efficiencies if compliance is shown using the performance path.

Installed Equipment Efficiency

This is determined by how well the entire system is designed and installed in the home. Gas furnaces are pretty simple and are much less affected by installation issues (air flow, refrigerant charge, etc.) than heat pumps and air conditioners. Even so, the rated equipment efficiencies (and capacities, for that matter) can be dramatically reduced due to poor installation. Mandatory measures establish minimum installation requirements to ensure that poor installation does not discount efficiency from an otherwise excellent building envelope and HVAC equipment specification.

Distribution System Efficiency

This is determined by the type of distribution, ducted vs. non-ducted, and the quality of the installation. Non-ducted systems are essentially 100% efficient at delivering heating and cooling to the home; however, as discussed in Chapter 4, they may sacrifice temperature consistency (comfort). Ducted systems have historically been designed and installed very poorly and to blame for much of the energy being wasted in existing, older homes. Energy lost through leaks and conduction can be substantial, as can the fan energy required to push the air through the ducts. The mandatory measures set minimum requirements for airflow and fan watt draw, which together, help ensure properly sized ducts. Mandatory measures also set strict requirements for duct materials and sealing. Duct R-value is set by mandatory and prescriptive measures and is commonly upgraded for performance credits. There are also special performance credits for putting ducts in better locations, such as inside conditioned space and for having duct systems with less than typical surface area. By installing a certified low leakage air handler, a performance credit can be taken for extra tight ducts. With all of these requirements and options for compliance credit, the Energy Standards are emphasizing how important distribution is for an energy efficient HVAC system.

System Controls

There is not much flexibility in the Energy Standards for system controls. Digital setback thermostats are required by the mandatory measures on almost all common systems. Thermostats with demand control may be required in some situations. With some HVAC alterations, older non-setback thermostats are required to be upgraded to setback thermostats. These requirements are discussed in more detail in Chapter 5 of this Application Guide.

Basic HVAC Design Concepts

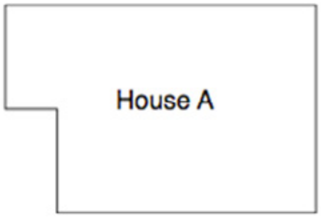
The following design concepts provide the foundation when selecting and designing a residential HVAC system in compliance with the Energy Standards.

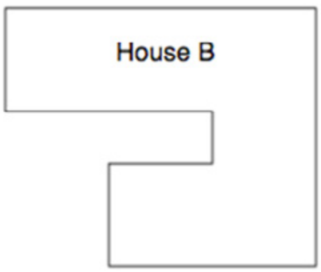
Heating

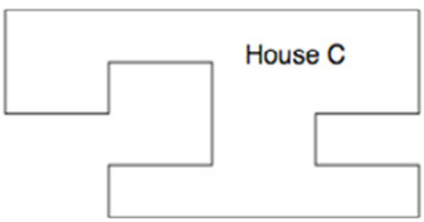
Think of heating as replacing heat energy (measured in BTUs) that is escaping from a warm house when the weather is cooler outside. A heater must be sized for the worst case condition of when no heat being added to the house from other internal sources, such as people, lights, equipment, or even some external sources such as solar gains. Once the size of the heater is determined (based on the building envelope) the Energy Standards will dictate the rated equipment efficiency, the installed system efficiency, the distribution efficiency and the system controls.

There are two basic fuel types that make up the vast majority of heating systems in California: electric and gas. Electric includes both electric resistance and heat pumps, but it can be very difficult to comply using electric resistance due to its extremely high cost per BTU. Gas includes natural gas and propane, both of which involve the combustion (burning) of a gas. The heat is then distributed to the air by a variety of methods. Wood, oil and coal are other options but are not discussed here due to the low numbers of systems being installed using these fuel types. Considerations for the two most common types, natural gas and electric heat pump systems, include the following:

Consideration	Natural Gas Heaters	Electric Heat pumps
Operating cost	Gas is cheaper per BTU.	Electricity is more expensive per BTU, but heat pumps can be efficient at moving heat from the outdoors to the indoors.
Availability	Natural gas is widely available, but not everywhere.	Electricity is available in all permitted homes that are subject to the Energy Standards.
Safety	Safe when systems are properly installed and maintained. Adherence to safety codes is important.	Safe when systems are properly installed and maintained. Adherence to safety codes is important.
Quality of heat	Gas heating provides warm air.	Heat pumps can supply air during heating that feels cool to the occupant because it is delivered at a temperature that is higher than the set temperature but lower than normal body temperature. Good distribution system design can minimize this.
Installation costs	Cost of gas piping and venting are important factors.	Electric systems are generally cheaper to install due to lack of gas piping and venting.
Equipment costs	A gas system with air conditioning is similar to heat pump equipment. If air conditioning is not needed, gas is substantially less expensive.	Similar to gas heating systems, except that it must also include air conditioning, which is not needed in all climate zones.
Environmental impacts	Gas systems produce greenhouse gases.	Greenhouse gases are produced from electricity generation, when not produced by wind, solar and hydro. On site renewables can offset consumption.







Code in Practice: Distribution

Consider the three conditioned footprints of single story houses shown above. They all have the exact same square footage and volume. House A might be able to be adequately heated by a single point heater such as a wall furnace or ductless mini-split heat pump. House B will need more precise distribution to achieve even temperature distribution in all rooms. House C will be a real challenge. It will probably need multiple zones and independent temperature sensors.

Cooling

Many people think that cooling a home is adding "coldness" to the home. It is more accurate to realize that cooling a home is really removing heat energy (in units of BTUs) from the home. This is heat that has come into the home primarily due to there being a warmer temperature outside and sun shining through fenestration (windows, etc.). heat energy enter the house through conduction (reduced by adding insulation), convection (reduced by sealing leaks) and radiation (reduced by shading and windows with lower solar heat gain coefficients - SHGC). Sizing air conditioning equipment must also account for "internal gains". This is heat put into the house from things such as people, lights, appliances, and cooking. In more humid climates, latent gains can be a significant load on the air conditioner. Fortunately, the vast majority of California is a dry enough climate that we do not need to worry about these. Once the size of the air conditioner is determined (based on the building envelope and assumptions about internal gains) the Energy Standards will dictate the requirements for rated equipment efficiency, the installed system efficiency, the distribution efficiency and the system controls, just like for heating systems.

Load Calculations And Equipment Sizing

Load calculations are required by the Energy Standards. Performing load calculations is an exercise in adding up all the conduction, convection, and radiation heat transfer through each and every exterior surface in the house. This must be done once for summer, when it is hotter outside than inside, and once for winter, when it is hotter inside than outside. The result is a rate of heat transfer (BTUs per hour) either into the home (cooling load) or out of the home (heating load). This can then be used to select an adequately sized piece of equipment to remove BTUs (cooling) or replace BTUs (heating). Heating and cooling equipment is rated in BTUs per hour.

As discussed below, to properly design a distribution system you need to know the heating and cooling loads for each room. It can be done by hand, or even with a spreadsheet, but most designers use specialized load calculation software, not to be confused with Energy Standards compliance software.

Distribution

Distribution represents the most challenging part of HVAC system design and one of the components most susceptible to poor installation. It is relatively easy to select a heater or air conditioner that will meet a home's design loads as discussed above, but getting the BTUs to (or removing them from) various parts of the house at the right rate and at the right time can be very tricky. Realize that as the sun passes through the sky, loads in different parts of the house fluctuate drastically. If parts of the house are architecturally different or isolated from the rest of the house, distribution becomes more important. If the house is really "chopped up" multiple controls (thermostats or temperature sensors) may be needed. Ducted systems are required to be designed according to ACCA Manuals J, S, and D by the California Mechanical Code, Part 4 and the California Green Code, Part 11. ACCA sets a suggested target for temperature variations within a house, but the real standard is homeowner expectation. An experienced HVAC designer should be consulted on this topic.

Designing Energy Efficient DHW Systems

DHW Considerations for New Homes

As our hot water heating needs have evolved to include bathrooms with large spa tubs, multi-head shower stalls, kitchens with prep sinks in addition to kitchen sinks, and potentially hydronic heating systems that utilize combined hydronic DHW systems, the design of these systems can become complex. When thinking about the energy efficiency of these designs, concerns about DHW equipment location, type and controls must be taken into account to take advantage of the technology that has evolved to meet these needs.

Location of Equipment

When contemplating placement of the DHW equipment, proximity to the hot water devices such as tubs or washing machine must be evaluated. The physical location of the equipment may be dictated by proximity to the gas supply and flue installation criteria. The layout of rooms within the home, such as having bathrooms on opposite sides of a home, impacts the length of time to receive hot water that may be solved with a recirculation system. While this will allow for immediate hot water, it requires use of additional energy. With California's drought woes, this is an important conversation. Multiple tankless water heaters at each location is another solution to this concern, but will require gas supply capable of handling the load, space for the equipment, and flue termination considerations.

Combined Hydronic Heating and DHW Systems

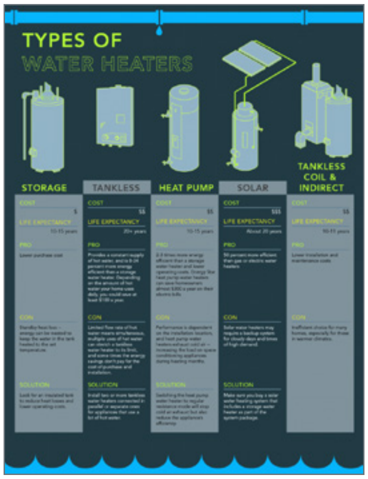
Combined hydronic heating and DHW systems use a central hot water source, such as a boiler, to meet both domestic hot water and space heating demand. Depending on the heating and domestic water heating loads, it may be appropriate to consider a combined system to serve both. With hydronic heating systems, type of equipment (i.e. dedicated boiler or a combined hydronic DHW unit) is important. Size of the heating load, in addition to the DHW needs, may help in determining the best equipment choices.

When designing combined systems, the following considerations are applicable:

- Fuel type (gas or electric)
- Distribution type (non-recirculated and recirculated, PEX piping, point of use)
- Equipment location and configuration (single central system, multiple equipment, combined hydronic system)

Assuming any number of different types of systems are being looked at for a particular house, further considerations can be made, such as:

- Reliability and durability of equipment
- Availability of qualified service technician
- Ease of use and maintenance
- Noise (condensing water heaters and boilers have fans)
- Cost (both first cost and operating costs)



Water Heater Infographic

ENERGY.GOV is a great resource. The Energy Saver 101 Water Heater Infographic is a quick reference to the pro's and con's of changing DHW types. It goes into detail on a variety of water heater related topics.

Find it here:
energy.gov/energysaver/water-heating

DHW for Additions and Alterations to Existing Homes

When contemplating DHW changes to a home, installation limitations and cost of converting the DHW type can limit choices.

- If the existing home has an electric resistance DHW heater, there may not be natural gas provided at the water heater location and there may be no flue. Because it would likely be cost prohibitive to pipe gas to the unit and provide a flue that goes straight up to the roof, it may be appropriate to use the existing water heater type. Requirements for this scenario are included in §150.2(b)1Giib.
- Solar assisted DHW is always cost effective with resistance DHW. Payback is usually 2-15 years!
- If considering a heat pump DHW system, location of the unit is important. Since this system type works by using heat from the surrounding air to heat water, the temperature of the space in which the water heater unit is housed must be within a certain range (varies by manufacturer), and there has to be enough air space to draw in. When considering a heat pump, consider replacing the entire HVAC system as well as the DHW system with the heat pump. This could be an opportunity to implement a combined hydronic heating and DHW system discussed above.
- If the existing home has a tank gas system, then the limitations on installing a tankless would include providing gas piping sized to the gas demand (which may even require an upgrade of the gas meter), a 120 volt receptacle, revising the flue type, and providing a condensate drain (since this is a condensing type of system) to the outside.
- If a new tankless water heater unit is desired in addition to the existing water heater, which is typically considered to reduce water run time to remote bathrooms far from central DHW, then installation concerns are similar to those listed above.
- Adding a recirculation pump to a home, which is often a method used to reduce water run time, requires that a "manual pump" control be used for prescriptive compliance or triggers the need for a performance calculation. A recirculation pump can be installed at the central water heater unit, or at the point of use (i.e. kitchen, bathroom, laundry sink location) which will impact the ability to insulate all of the hot water piping associated with the recirculated water (only hot water piping "accessible" needs to be insulated). Be aware that there is a significant cost associated with installing new piping, especially to distant end uses.

Resource Highlight: Building America Solution Center

Although not specific to California's Energy Standards, the US Department of Energy's Building America Solutions Center includes a library of resources for designing and building energy efficient residential structures.

Visit the website here: https//basc.pnnl.gov

CHAPTER 4

TECHNOLOGY, SYSTEMS AND COMPLIANCE STRATEGIES

Selecting an HVAC System Type

Selecting what kind of system to install in a home requires some basic considerations such as fuel type, equipment locations and number of zones.Assuming that a number of different types of systems are being looked at for a particular house, further considerations can be made, such as reliability, noise and temperature control (how much variation in temperature between rooms is acceptable). In addition, both first cost and operating costs must be considered. Operating costs are a direct reflection of equipment efficiency and fuel type.

All system types can be made to comply with the Energy Standards, in most cases. Using the performance approach, most any deficiency due to the equipment can be traded off against improving other features. Some system types are inherently more efficient than others, but there may be trade-offs in comfort or first costs. All systems come in a range of efficiencies, the minimum of which is constrained by the mandatory measures (which usually align with federal minimums).

Heating Systems

There are a variety of different products available to meet the requirements of the Energy Standards. As long as you stay away from electric resistance heating of any kind (except as an emergency back up to another type of heat), most types of systems have the potential to be efficient and comfortable when properly sized, designed and installed. The trickiest part is getting the best bang for your buck. Experience shows that focusing on good design and excellent installation almost always results in happy building occupants.

Split System Gas Furnace

The gas furnace split system is the most common residential heating and cooling system. It consists of an indoor unit with a fan and gas furnace heat exchange connected to a duct system to distribute warm air throughout the house. Cooling can be easily integrated by installing a cooling coil in the ductwork immediately above the heating coil which is connected to an outdoor condensing unit.

This type of system:

- Gas heat has low operating cost.
- Air conditioning is easily integrated and uses the same distribution system.
- Compliance is straightforward, and can comply prescriptively.

Ductless System

Ductles Mini Split System, outside unit

Split System Electric Heat Pump

The electric heat pump split system is very similar to the furnace split system with the exception that there is no furnace heating coil, and the refrigerant cooling coil becomes a heating coil as well by the addition of a reversing valve in the outdoor unit. The system will normally include an electric resistance backup heating coil, because heating capacity drops at low outdoor air temperatures. Electric resistance backup operation is relatively expensive.

This type of system:

- Provides relatively economical heating where gas is not available.
- Has air conditioning that is integrated and uses the same distribution system.
- Is relatively straight forward for demonstrating compliance and can comply prescriptively.
- Will normally incur a penalty when doing performance compliance.
- Will have significantly degraded heating performance at low outdoor air temperatures (below 30°F to 40°F).

Ductless Mini-splits

Ductless mini-split systems use one or more outdoor condensing units connected by refrigerant lines to fan coil units installed in the rooms of the home. Each indoor unit includes a fan and a heat pump coil. Each fan-coil unit is controlled individually allowing good temperature control and energy performance. The system does not utilize a duct system, potentially offering space savings in the home.

This type of system:

- Provides good comfort and energy performance.
- Will have significantly degraded heating performance at low outdoor air temperatures (below 30°F to 40°F).
- Is relatively straight forward for demonstrating compliance and can comply prescriptively.

Ground Source Heat Pump

This is a heat pump system where heat is drawn from, or rejected to, a water loop that circulates water through ground loops. This allows the water loop to be kept at a moderate temperature, even when the outdoor air temperature is very hot or cold. Also, this allows the heat pump to operate with good efficiency all the time. However, the ground loop adds significant system cost, and the system is generally limited to new construction. Space for the ground loop may not always be available.

This type of system:

- Provides good heating and cooling performance, and economical heating where gas is not available.
- Requires ground loop piping that can be expensive to install.
- Has air conditioning that is integrated and uses the same distribution system.
- Is relatively straight forward for demonstrating compliance and can comply prescriptively.

Hot Water Baseboard Heating

Hot water baseboard heating relies on a gas boiler to provide hot water which is pumped to convectors in each room. Each pump is controlled by a thermostat, with the amount of hot water pumped to the room controlling the amount of heat provided. Baseboard heating can offer better control because of multiple pumps and thermostats. However, the system cannot be integrated with cooling, and a separate cooling system must be installed. There is also no fan, so air cleaning cannot be provided.

This type of system:

- Has low operating cost when gas is used to heat the water.
- Can be difficult to install with air conditioning. Installation of a separate cooling system can be expensive.
- Compliance is straightforward, and can comply prescriptively.
- Can provide very good comfort.

Baseboard Electric Heater

Electric baseboard heating uses convectors in each room which are heated by electric resistance. The system cannot be integrated with cooling, and a separate cooling system must be installed. There is also no fan, so air cleaning cannot be provided. Electric resistance heat is not allowed under the prescriptive compliance path, so performance compliance is required. The system is relatively inexpensive, and if heating loads are low, can be a viable option.

This type of system:

- Can be difficult to install with air conditioning. Installation of a separate cooling system can be expensive.
- Cannot comply prescriptively, so compliance must be shown using the performance path.
- Can have very high heating costs, so the system is appropriate only when heating loads are very low.
- Has very low installation cost.

Electric Resistance Central Furnace

The electric resistance furnace split system is very similar to the gas furnace split system with the exception that the heating coil is heated by electric resistance. Cooling can be easily integrated by installing a cooling coil in the ductwork immediately above the heating coil. Electric resistance heat is not allowed under the prescriptive compliance path, so performance compliance is required. The system is relatively inexpensive, and if heating loads are low, can be a viable option.

This type of system:

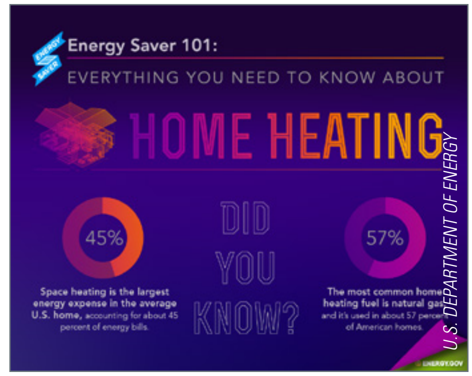
- Cannot comply prescriptively, so compliance must be shown using the performance path.
- Can have very high heating costs, so the system is appropriate only when heating loads are very low.
- Has relatively low installation cost, unless the duct system is extensive.

Forced Air Hydronic System

The forced air hydronic system is also known as a combo system. It is similar to a gas furnace split system except that the heating coil is a hot water coil with the hot water being provided by the domestic water heater and a pump. The system is typically used for smaller residences, and reduces costs by having a single gas line and flue system. Cooling is integrated in the same way as with furnace systems.

This type of system:

- Has low operating cost when gas is used to heat the water.
- Is easy to add air conditioning to.
- Compliance is straightforward, and can comply prescriptively.

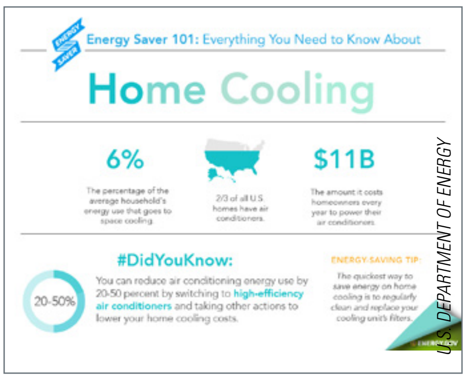


Energy Saver 101 Home Heating Infographic

The U.S. Department of Energy (DOE) has created this resource showing heating system types, pros and cons, and maintenance tips.

Find it here: energy.gov/articles/energy-saver-101-infographic-home-heating

Raidant Hydronic System



Energy Saver 101 Home Cooling Infographic

This DOE resource shows how an air conditioner works, tips for choosing a system and common problems.

Find it here:
energy.gov/articles/energy-saver-101-infographic-home-cooling

Radiant Hydronic System

Radiant hydronic heating is very similar to hot water baseboard heating, except that instead of using convectors the hot water is pumped through tubing embedded in the floor. Temperature control is similar to the baseboard system with multiple thermostats and pumps. In addition, the warm floor can provide equal comfort at lower air temperatures, potentially offering additional energy savings. However, the system cannot be integrated with cooling, and a separate cooling system must be installed. There is also no fan, so air cleaning cannot be provided.

This type of system:

- Has low operating cost when gas is used to heat the water.
- Can be difficult to install with air conditioning. Installation of a separate cooling system can be expensive.
- Compliance is straightforward, and can comply prescriptively.
- Can provide very good comfort.

Cooling Systems

Residential cooling systems fall into two basic types, but there are a variety of product variations. By far the most common type is direct expansion cooling, usually as part of a split system but also available as ductless mini-split systems. Evaporative cooling is the other type, and offers low operating costs, but water consumption is an issue. Equipment sizing is particularly important for DX cooling systems, as oversized systems will operate poorly, waste energy and deliver less comfortable conditions. As always, good design and excellent installation almost always results in happy building occupants.

Central Ducted Split Systems

Central ducted split systems are the most common type of residential cooling system. They rely on the fan in a central air handler/heating system to move air over the cooling coil and through a duct system to the rooms of the home. The coil is a direct expansion (DX) type connected to an outdoor condensing unit. The DX coil may also be part of a heat pump system.

This type of system:

- Air conditioning is integrated and uses the heating distribution system.
- Compliance is straightforward, and can comply prescriptively.

Ductless Mini-Splits

Ductless mini-split systems use one or more outdoor condensing units connected by refrigerant lines to fan coil units installed in the rooms of the home. Each indoor unit includes a fan and a DX cooling coil. Each fancoil unit is controlled individually allowing good temperature control and energy performance. The system can be cooling only or can provide heating when configured as a heat pump. The system does not utilize a duct system, potentially offering space savings in the home.

This type of system:

- Provides good comfort and energy performance.
- Can be installed as a cooling only system.
- Compliance is straightforward, and can comply prescriptively.

Evaporative Coolers

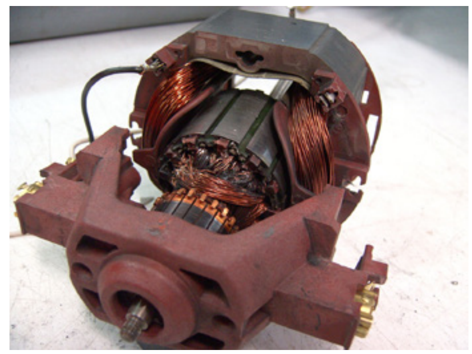
Evaporative cooling systems use the evaporation of water to cool the air that is then distributed by a duct system to the rooms of the house. These system offer low operating cost since no electric cooling is needed, but water consumption can be high. These systems are good for locations with low humidity as they can add moisture to the space. The system may not be able to provide air as cold as a DX system, so high airflows may be needed, which can be a disadvantage.

This type of system:

- Has very low operating cost.
- Can have high water consumption.
- Can be used with any compliance option.

Motors

There are two basic types of electric motors used in air handlers to drive the fans that move the air through the ducts. An electronically commutated motor (ECM) is different than a standard permanent split capacitor (PSC) motor in that it has an on-board microprocessor. They were originally referred to as "integrated control motors." The microprocessor controls the motor's rotational speed in response to torque against the motor's drive shaft. This torque comes from changes in resistance to airflow such as the evaporator coil getting wet from condensation or the filter getting dirtier over time. The motor senses this increased resistance and responds by increasing its speed, which increases watt draw, to maintain a constant airflow. They are naturally more efficient than standard PSC motors, but this ability to compensate for increased resistance also improves overall system performance (e.g., cooling energy use of the condenser).



Electronically Commutated Motor (ECM)

There are no specific requirements or performance credits for electric motors in the Energy Standards. The motor's efficiency is accounted for in rated efficiency of the equipment; however, air handlers with ECM motors are more likely to pass the mandatory air flow and fan watt draw requirements. While definitely not a remedy for undersized ducts, ECM motors can reduce the negative impacts somewhat.

HVAC Energy Efficiency Improvement Strategies

Air Balancing

The Energy Standards address total system fan flow very well by making air flow and fan watt draw mandatory measures in new ducted systems with air conditioning (see section §150.0(m)13). This helps ensure that the system is providing space conditioning to the entire space in a manner that is cost effective and energy efficient. What it does not address however is how that air is distributed to each room. This is referred to as the "air balance" of a system. Even though this is much more of a comfort issue than an efficiency issue, it can be the single biggest cause of homeowner dissatisfaction with a system. For a home to have even temperature distribution that most home owners expect, the conditioned air must be delivered to each room at a rate proportional to that rooms heating or cooling load. In other words, if the room accounts for 12% of the homes cooling load, it should be getting 12% of the total system cooling mode fan flow. Sometimes the proportion changes between heating and cooling flows. For example, a room might need 12% of the cooling airflow, but 15% of the heating airflow. Usually, because cooling airflow is almost always set to a higher fan speed, the ducts are sized for cooling flows and any seasonal imbalances can be addressed by slight adjustments in the supply registers.

Programmable Thermostat

Control Strategies

The Energy Standards are very specific on the minimum requirements for thermostats. (See mandatory measures, §110.2). These simple thermostats turn single-stage heating or cooling equipment on or off, based on the indoor setpoint temperature, and the temperature of the room in which the thermostat (and its temperature sensor) are located. The oldest and most common type uses a mercury thermometer. In California, it is illegal to sell, install, or dispose of mercury thermostats as solid waste. For more info on state laws visit: thermostat-recycle.org/statelaws

A few manufacturers (including Honeywell, White-Rodgers, and Cadet) make single operation, non-programmable thermostats. However, California law requires that permitted heating or cooling equipment installations use programmable thermostats. Therefore, non-programmable thermostats can only be installed in systems that would otherwise require programmable thermostats as part of maintenance repairs that do not require a permit, such as replacing a mercury thermostat. Non-programmable thermostats are allowed on some simple systems, such as wall furnaces (see §110.2(c)).

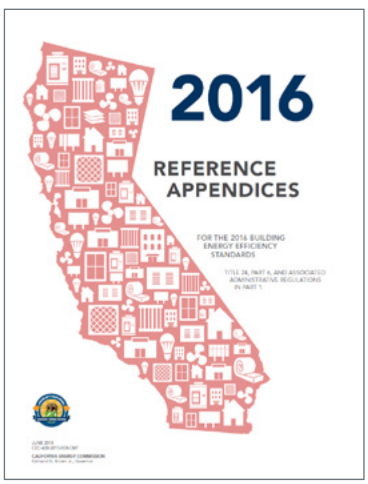
Programmable thermostats, also called setback thermostats, are digital devices intended to save energy. Energy savings are made possible by allowing users to schedule times that space conditioning is automatically reduced because occupants are away or sleeping.

Not much has changed in basic thermostats over the past 20 years. They are still too hard to program, have too small of a screen and too few buttons. One of the biggest advances in thermostat usability is in the new Wi-Fi based "smart thermostats". These allow users to program them using much more intuitive interfaces on a computer, tablet or smart phone. Also, the ability to monitor and control them remotely has been very popular.

Qualifying programmable setback thermostats are required in all new systems and for all alterations that trigger duct sealing. Some situations require an upgraded type of thermostat that has the ability to be remotely controlled by utilities. It does not require that this remote control be activated, just that they have that capability to be remotely controlled in case the occupants choose to participate in a special program. These are called demand response thermostats. The required features are detailed in Joint Appendix 5.

Thermostat location is not specifically addressed by the Energy Standards, but it is addressed by the California Mechanical Code. The problem with determining a good thermostat location is that there are dozens of terrible places to put a thermostat, but no perfect place to put one. Usually a reasonable place to locate a thermostat is in an interior hallway near the return grille. Some guidelines are:

1. Do not locate a thermostat on an exterior wall.
2. Make sure that the hole behind the thermostat is completely sealed against airflow.
3. Never locate a thermostat where direct sunlight may hit it.
4. Never locate a thermostat where a supply register will blow directly on it.
5. Consider a thermostat's ability to effectively turn a system ON when the system is not running. Separately, consider a thermostat's ability to effectively turn a system OFF when the system is running. Sometimes these result in two different optimum locations. Decide which is more important.



2016 Reference Appendices

Joint Appendix 5 (JA5) includes requirements for an Occupant Controlled Smart Thermostat (OCST)

Find it here: energy.ca.gov/2015publications/CEC-400-2015-038/CEC-400-2015-038-CMF.pdf

Zoning

Zonal control refers to the ability to independently control separate zones in a single home. For smaller homes, this is usually accomplished by using motorized zone dampers on a single system. If not designed correctly, these can have a very negative impact on system airflow when one or more zone dampers are closed. To prevent this, the Energy Standards requires that the system pass the minimum air-flow test in all operating modes. In other words, the system airflow must not drop below the requirement no matter how many zone dampers are open or closed at any given time. This can result in ducts that are much larger than a normal system. There are some exceptions to this requirement, such as installing a dual speed or variable speed condenser. Most zoned systems have two zones, usually upstairs and downstairs. Refer to Section 4.5 of the Residential Compliance Manual or §150.0(m)13B and C of the Energy Standards for a detailed discussion of zoning systems.

Duct Locations and Insulation

There are three basic places where ducts are commonly located in a home. In order of worst to best, they are:

1. Vented attic
2. Vented crawlspace
3. Conditioned space

What makes one location better or worse than another is how different the temperature is between the inside and outside of the ducts. This directly affects conductive losses and gains. Return leaks are another problem made worse by more extreme temperature differences. Substantial return leaks in a hot attic will increase the return air temperature, which reduces capacity and efficiency of air conditioning equipment. Another factor is whether supply air leaks occur inside or outside the conditioned shell of the home. If they are located inside the conditioned shell, they will help to condition the home. If they are located outside the conditioned shell, that air and the energy used to heat or cool it is wasted.

DHW Equipment

There are multiple considerations when designing a compliant DHW system, including selecting equipment, designing distribution and implementing controls.

Utility Source (Fuel Type)

The utility source (electricity, natural gas, propane) available at the home typically dictates the type of DHW system being installed.

Electricity

In general, electricity is an expensive energy source for California, BUT very efficient (there is no flue loss associated with this DHW system type). When used in conjunction with a PV system, it can be very attractive. Being aware of restrictions in the Energy Standards is important (see Chapter 5) when installing a water heater using electric resistance. Heat pump water heaters use much less electricity to heat the same amount of water making them a smart choice when using electricity, but can be much more expensive to buy and install.

Code in Practice: Heat Pump Domestic Hot Water

Many times, when a home installs a PV system, the Homeowners ask for all the gas appliances to be replaced with electric resistance. While electric resistance DHW unit are difficult to make work with the Energy Standards, heat pump DHW are a nice solution.

Natural Gas

Natural gas is less expensive to use in California, but has become an issue of concern for greenhouse gas emissions. In addition, not all homes or neighborhoods have natural gas available, so there may be situations when natural gas water heating equipment is not the appropriate choice.

Propane Gas

In most situations, propane gas has become the most expensive energy source, making it an expensive choice over the lifetime of the water heater. However, since propane can be installed in many locations when natural gas is not available, it is often considered if electricity is not the primary utility source being used (i.e. gas stove, space heating systems). Propane gas is a source that requires additional maintenance, since it can contain minerals or contaminants that clog the unit.

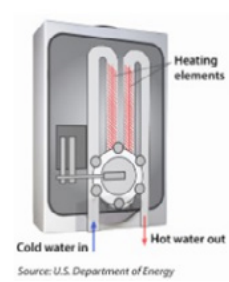
The following illustrations show options for differing energy sources.

Utility Type: Electricity

Electric Resistance Examples

ENERGY CODE ACE

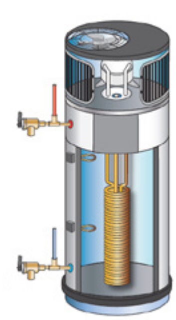
Tank



U.S. DEPARTMENT OF ENERGY

Tankless

Heat Pump Examples

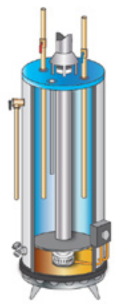


ENERGY CODE ACE

Tank (which can also be used for combine hydronic)

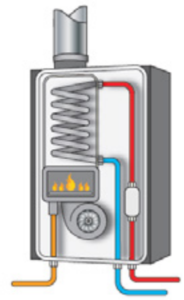
Utility Type: Natural Gas or Propane

Examples



ENERGY CODE ACE

Tank (which can also be used for combine hydronic)



ENERGY CODE ACE

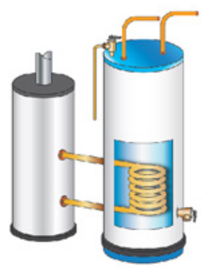
Tankless

Utility Type: Solar Hot Water

Examples

ENERGY CODE ACE

Tank

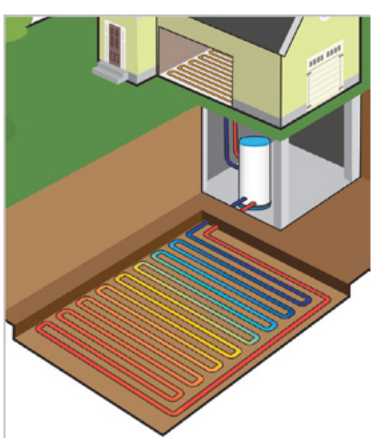


ENERGY CODE ACE

Combined Hydronic with Storage Tank

Utility Type: Goethermal

Examples



ENERGY CODE ACE

Subterranean Storage

Tank or Tankless

When considering whether to install a tank or tankless system, it comes down to space available, size of utility service, and maintenance schedule.

A tank system needs space, but requires a relatively small gas and/or electric service draw, the drawback being that the system uses a continual amount of energy to keep the water at a consistent temperature so that it can be used at any time. Any flow rate can be accommodated (such as a bathroom sink). A tank system has a "sacrificial anode rod" that is designed to protect the tank, and extends the life of the DHW unit, especially if maintained properly.

A tankless system saves energy overall, since it is only engaged upon use, but the amount of energy needed for that minimal amount of use is high because it heats the flow of water as it passes over the source. It is important to pick the correct flow rate (GPM), for the use. Low flow is less expensive and requires low energy source, but limits how fast the water goes through the unit which may be appropriate for bathroom sinks (0.5 GPM each) but not a tub (typically 3 GPM each). Another consideration for tankless systems, is they typically engage for over 0.5 GPM flow draw which is the maximum flow requirement for a bathroom sink. Continual maintenance is a must for tankless systems, which if ignored, can reduce the lifetime of an expensive DHW system choice.

Low Efficiency Versus High Efficiency

Installation criteria, and the noise associated with high efficiency units, should be considered when deciding energy factor of the unit (the higher the energy factor, the higher the efficiency).

Low efficiency (which in turns means a low energy factor, but cannot be lower than the minimum energy factor required by the Federal requirements) is less expensive, and does not dictate additional installation factors such as a condensate drain, or specialized flue. With no pump or fan, which is typically required for high efficiency units, it is very quiet.

High efficiency DHW units minimize heat loss through the flue by blowing the hot exhaust gas into the heating elements (requiring a fan), which is desired because it reduces wasted energy. In turn, as the flue gas gets colder, it produces condensation (acidic water) which must be drained to somewhere through a drain sloped to the outside. This also requires a specialized flue that can handle this "wet" flue gas.

Size of Equipment

Physical size (such as a 50 gallon or 75 gallon tank) and energy input (BTUH or wattage) dictate the amount of water available for use. A large family getting ready at the same time in the morning may desire a large tank or equipment with higher energy input (recovery factor) to handle their hot water needs.

Multiple Water Heaters or Just One

Where the water using features of a home impact how long it takes for hot water to get there, the Residential Compliance Manual does a great job reviewing the impact of the home's design on the water heating system. As a home is added to, it may make more sense to provide tankless DHW to service those new locations. Installation concerns, such as discussed in the previous chapter for additions and alterations, must be considered.

DHW Equipment Controls

A timer used at the water heater that is programmed to the homeowners hot water heating requirements such as showers in the morning through last load of laundry at bedtime, can be a way to improve energy savings when pursuing the performance path to compliance. There are timers that can be simple or complex, but many have the look and feel of a programmable thermostat. As water heaters have become more efficient with minimum standby loss, there has been discussion surrounding the effectiveness of a timer as an energy savings measure.

Gas DHW

There are a few things that need to be in place for this to happen smoothly and safely. The pilot light for the water heater has to be able to turn on and off, for the timer to work, or be able to reduce the temperature settings of the tank. There are many aftermarket options depending on the functionality of the gas water heater, but be sure to follow manufacturer's directions for the controls and not void the warranty. There are even DHW units that have a timer integrated.

Electric DHW

These units are easier, since there is no pilot light to work around.

DHW Distribution

Length of Pipe

Heat loss associated with the piping has a two-fold effect: it reduces the temperature of the water getting to its destination, and it heats up the air around it (usually the home, which if summertime, then requires the AC system to work even harder). If the length of pipe is minimized (and insulation is used on the pipe), then the heat loss is minimized. This goes back to the design of the home, and whether the location of bathrooms and kitchen is centralized in proximity of the DHW unit. Additional compliance credit can be achieved by seeking a HERS verified "point of use" or "compact design" when using the performance path to compliance.

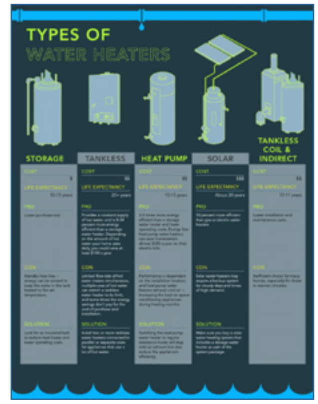
Copper or Cross-linked polyethylene (PEX)

Copper is the time tested product used for decades, which in part because of long time use, allows for flexibility when selecting connections and installation features. Copper resists corrosion and is not affected by being exposed to ultraviolet rays (sun light) and is durable.

PEX is relatively new to the market (compared to copper) and some building departments do not allow it to be used for potable water (so verify before using in your location), but is very flexible and very adaptable to low and high temperatures and does not corrode, though it cannot be installed outside since it is affected by ultraviolet rays. PEX piping is used for manifold systems (parallel piping) which can reduce size and length of pipe, hence reducing heat loss, if installed properly. Additional compliance credit can be achieved by seeking HERS verified "parallel piping" when using the performance path to compliance.

Insulation

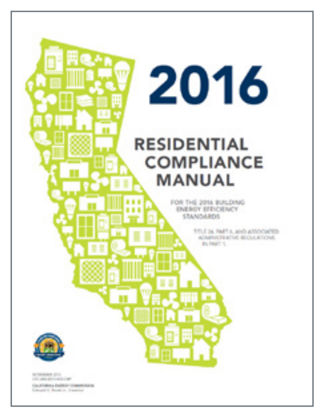
Pipe insulation, or pipes buried in wall, roof, or floor insulation helps prevent heat loss as hot water flows through the pipes. Each code cycle requires more and more hot water pipe insulation to mitigate this heat loss, and §150.0(j)2A includes requirements in the 2016 Energy Standards. If not required by §150.0(j)2A for a specific project scenario, it is recommended that all trunk piping be insulated. Additional compliance credit can



Water Heater Infographic

ENERGY.GOV is a great resource. The Energy Saver 101 Water Heater Infographic is a quick reference to the pro's and con's of changing water heater types. It goes into detail on a variety of water heater related topics.

Find it here:
energy.gov/energysaver/water-heating



2016 Residenital Compliance Manual

Chapter 5 does a great job of discussing impact of home design on water heating systems.

Find it here:
energy.ca.gov/title24/2016standards/residential_manual.html

be achieved by seeking HERS verified "pipe insulation" in which all trunk and branch piping is insulated by the installer and then inspected in the field by a HERS rater. This compliance credit is available to projects pursuing the performance path to compliance for DHW systems.

Recirculation DHW Systems

Recirculation DHW systems are becoming more popular because they save water, but they can also save energy if designed with that objective in mind. It's obvious that the longer the faucet runs waiting for the water to be hot, the more water will be wasted going down the drain. Recirculation systems provide immediate hot water, saving water, but may not save energy due to energy required for the pump, the DHW heater maintaining the temperature within the pipes, and the heat loss associated with the pipes being transferred to the conditioned space (may require more cooling/AC). There are a couple options to minimize energy consumption in recirculation systems:

Integrated Loop

Locate the pump at the furthest point of use with controls with the hot water being recirculated back to the DHW unit via the cold water piping. This is typical for retrofits, since re-piping the existing hot water system will not be required.

Dedicated/Closed Loop

Recirculation pump is at the central DHW unit and there is a specific hot water line that is plumbed to the furthest fixture. This is typically used when recirculated systems are integrated while designing the home.

Recirculation Systems: Control, no control, how to control?

Not including controls: This is not recommended from an energy use point of view. In fact, if no controls are used for a recirculation system, this must be shown to work with a performance calculation at a *huge* penalty. Don't do it!

Timer

This is very much like the programmable timer talked about for the DHW heater itself. You program what time you get up, when you go to work, when you come home and go to bed so that the pump is only working when you are home. But, we are still wasting energy for a system that is working away hoping you will use hot water at any moment of the day you are home. And just like programming a thermostat, is it programmed to the homeowner's schedule properly. A performance calculation will be required to get compliance credit for this control type.

Occupancy Sensor

This seems like a nice compromise, but what if the occupant went in to the bathroom to just get a towel and the occupancy sensor turns on the pump because you entered the space? Now we are wasting energy for hot water that is not needed. A performance calculation will be required to get compliance credit for this control type.

Manual Control or "Push Button"

This control technology results in a conscious choice by the homeowner, who presses a button when they want hot water, which tells the pump to turn on. This type of system can always be installed, and does not require any special performance calculation for compliance.

California Energy Commission Online Resource Center

The Online Resource Center provides Energy Standards compliance resources including:

- Energy Commission contact information
- Trainings and Events
- Energy Standards language and documents
- Links to External Resources

Call the Hotline at:

- Toll-Free in California: 800-772-3300
- Outside California: 916-654-5106

Find the webpage here: energy.ca.gov/title24/orc/


POWER
REMOTE

CHAPTER 5

NAVIGATING YOUR COMPLIANCE STRATEGY

Compliance Requirements

There are two basic steps to comply with the Energy Standards:

1. Meet all mandatory requirements by installing required systems, equipment and devices, and ensure that they perform all functions required by the Energy Standards.
2. Select your method of compliance by choosing either the Performance Approach or the Prescriptive Approach.

Mandatory Requirements

All residential buildings must meet a set of mandatory requirements for minimum equipment efficiencies, distribution and controls. Examples of HVAC and DHW building components addressed by mandatory measures include minimum equipment efficiencies, ducts and pipe insulation, HERS measures, and controls.

Prescriptive Approach

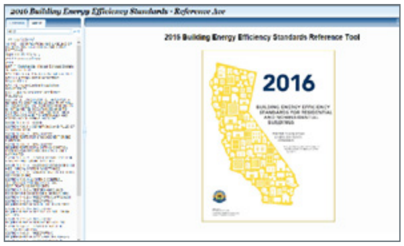
The Prescriptive Approach is considered the most direct path to compliance. It is a set of prescribed performance levels for various building components, where each component must meet the required minimum efficiency.

Performance Approach

The Performance Approach allows energy allotments to be traded off between building components, such as DHW, HVAC or the building envelope. The "proposed" home's simulated energy use is compared to a "standard" home, which is essentially the same home, but with the prescriptive energy features. This allows credit for features that are better than prescriptive levels (aka performance credits) to offset features that are worse than prescriptive levels (e.g., more glass area). This compliance approach requires using energy analysis software that has been approved by the Energy Commission.

Ductless Mini-Split System, Indoor Unit

Ace Reference™



The Reference Ace™ tool helps you navigate the Standards, Compliance Manual and Reference Appendices using key word search capabilities, hyperlinked tables and related sections.

Find the tool here: energycodeace.com/content/reference-ace-2016-tool

Navigating Title 24, Part 6

The following tables provide references to sections of the Energy Standards for residential HVAC system and DHW requirements, categorized by mandatory measures, prescriptive approach and performance approach. Requirements are based on project type (newly constructed, alteration, addition) and descriptions of these project types are included on the following page. When exceptions pertain to any sections, they will be noted in the Energy Standards for that specific section.

HVAC SYSTEMS	MANDATORY	PRESCRIPTIVE	PERFORMANCE
Newly Constructed			
Equipment Type & Efficiency	§110.2, §110.5	§150.1(c)6, §150.1(c)7, §150.1(c)10	§150.1(b)
Equipment Sizing	§150.0(h)	§150.1(c)12	§150.1(b)
Controls	§150.0(i)		§150.1(b)
Refrigerant Line Insulation	§150.0(j)		
Distribution (Ducts)	§150.0(m)		
Ventilation	§150.1(c)9	§140.4(e)	
Alterations			
Equipment Type & Efficiency	§150.2(b)	§150.2(b)1C,	§150.1(b)
150.2(b)1F (alt only)	§150.2(b)2		
Equipment Sizing	§150.2(b)	§150.2(b)1C	§150.2(b)2
Controls	§150.2(b)	§150.2(b)1C	
150.2(b)1F (alt only)	§150.2(b)2		
Distribution (Ducts)	§150.2(b)	§150.2(b)1D, E	§150.2(b)2
Ventilation	§150.2(b)		
Additions			
Equipment Type & Efficiency	§150.2(a)		§150.2(a)2
Equipment Sizing	§150.2(a)		§150.2(a)2
Controls	§150.2(a)		§150.2(a)2
Distribution (Ducts)	§150.2(a)		§150.2(a)2
Ventilation	§150.2(a)	§150.2(a)1	§150.2(a)2

DHW SYSTEMS	MANDATORY	PRESCRIPTIVE	PERFORMANCE
Newly Constructed			
DHW Equipment	§110.3(b), §150.0(j)	§150.1(c)8	§150.1(b)
DHW Installation	§110.3(c), §150.0(n)	§150.1(c)8	§150.1(a)2
Alterations			
DHW Equipment	§150.2(b), §110.3(b), §150.0(j)	§150.2(b)1G	§150.2(b)2
DHW Installation	§150.2(b), §110.3(c), §150.0(n)	§150.2(b)1G	§150.2(b)2
Additions			
DHW Equipment	§150.2(a), §110.3(b), §150.0(j)	§150.2(a)1D	§150.2(a)2
DHW Installation	§150.2(a), §110.3(c), §150.0(n)	§150.2(a)1D	§150.2(a)2

Note: See §100.0 Scope and Table 100.0-A Application of Energy Standards for additional information on which sections of Title 24, Part 6 apply to any given project, in particular which code sections apply to conditioned versus unconditioned space.

Define the Project Type

The scope of the project will determine the scope of the HVAC and DHW systems regulated by the Energy Standards. Requirements may be triggered based on classifying the project as newly constructed or new construction (addition, alteration or repair).

Newly Constructed Homes

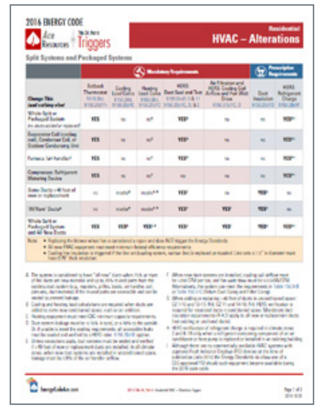
A newly constructed home is a home that has never been used or occupied for any purpose. Everything is new from the ground up, including the HVAC and DHW systems. A complete HVAC system or DHW system replacement in an existing home, although the system is entirely new, would be considered an alteration (see New Construction in Existing Buildings below).

New Construction in Existing Buildings

The Energy Standards differentiate between "newly constructed buildings" and "new construction in existing buildings". New construction in existing buildings includes additions, alterations, and repairs (§100.0(e)3). "Construction" is probably not the best choice of words in the context of HVAC and DHW systems. Replacing a furnace or water heater is not really considered "construction". Perhaps it's better to think of this as "new work in existing buildings".

Systems installed in newly constructed homes are generally held to a higher standard than systems being worked on in existing homes. However the extent of the work being done in an existing home may trigger the same requirements as systems in newly

Ace Resources™



Trigger Sheet resources can help identify relevant code sections in the Energy Standards, based on the scope of the project.

Trigger Sheets are available for the following HVAC related topics:

- Residential HVAC Changeouts

Find the resource here: energycodeace.com/content/resources-trigger-sheets/

constructed buildings. It's important to realize that an HVAC system includes all of the heating and cooling equipment, the distribution system (e.g., ducts, plenums, fittings and registers), and the controls (same concept applies to DHW systems).

Additions vs. Alterations

A project is an "addition" if it creates newly conditioned floor area and volume on an existing building. A project is an "alteration" to an existing home if is not an addition (i.e., does not create newly conditioned floor area and volume).

From an HVAC system perspective, it doesn't really matter whether the project is defined as an addition or alteration. It matters how much of the system (equipment, distribution system and controls) is being added or replaced. An HVAC system can have the same exact requirements in a newly constructed home, an addition and an alteration if the entire system is new. An HVAC system can have the exact same requirements in an addition or alteration if only parts of the system are new. What determines the requirements for an HVAC system is whether the system is entirely or partially new. A partially new system is called an "altered HVAC system" (see below).

Entirely New HVAC Systems

When more than 75% of the ducts in a system, by length, are new AND the air handler is new, the entire system will have to meet all of the requirements as though it was installed in a newly constructed home: duct leakage, air flow and fan efficacy. The exception is when any of the ducts are not accessible.

Exceptions

The duct leakage requirement does not apply if:

1. The first is when any part of the duct system is not accessible.
   OR
2. The second is when the air handler is not new and it can be demonstrated by using smoke that the ducts are sealed but the old air handler is leaky.

(Substantially) New Duct System.

The distribution system can have its own designation (new or altered) and its own requirements. When more than 75% of the ducts in a system, by length, are new, the resulting duct system will have to meet the duct leakage requirements as though it was installed in a newly constructed home.

Note that the new ducts must be properly sized according to ACCA Manual D or equivalent. This can be tricky if the existing ducts are severely undersized. If so, consideration should be given to replacing all of the ducts.

Altered HVAC Systems

Work done to an existing HVAC system that triggers requirements can be as simple as replacing a furnace to as complicated as installing a totally new central heating and air system in a house that previously had a wall furnace (aka, a "cut-in").

As previously discussed, if work done to an existing HVAC system is extensive enough, it may have to meet the mandatory and prescriptive requirements similar to a completely new system. This includes lower allowed duct leakage and air flow and fan watt draw requirements that simple change-outs are not subject to. Essentially, if so much of the duct system is new or replaced that there is opportunity for a complete redesign of the ducts (75% of ducts are new or replaced and are all accessible) it is reasonable to expect them to meet the requirements of a new system. If only parts of the system are new or replaced and it does not meet the definition of entirely new HVAC system or new duct system, this is referred to as an "altered HVAC system".

Because studies have shown that duct leakage and poor refrigerant charging is so prevalent in existing homes, the Energy Commission has determined that it is cost effective to address these when work is being done to a system. Therefore, the Energy Standards require that ducts be sealed in all climate zones and refrigerant charge be checked in some climate zones when major components (air handler, condenser, coil, and more than 40 feet of ducts) are added or replaced.

Repairs

The Energy Standards define a repair as the reconstruction or renewal for the purpose of maintenance of any component, system, or equipment of an existing building. Repairs shall not increase the preexisting energy consumption of the repaired component, system, or equipment. Replacement of any component, system, or equipment for which there are requirements in the Standards is considered an alteration and not a repair. Generally, if the work being done does not normally require a permit, then it can safely be deemed a repair. If, however, any of the work requires a permit for any reason then it should be treated as an alteration and will trigger the appropriate requirements. If no permit is required then the Energy Standards do not apply.

Defining a repair gets more complicated when dealing with "refrigerant containing devices". In climate zones 2 and 8-15, adding or replacing a refrigerant containing device in an existing system will trigger the prescriptive requirement for refrigerant charge verification, among others. Refrigerant containing devices include compressors, TXVs, refrigerant lines, filter/driers, etc. Replacing these components could certainly be considered "reconstruction or renewal for the purpose of maintenance" and therefore replacing just those components are generally referred to as repairs in the industry. However, if the local authority having jurisdiction requires a permit for these types of component replacements, or if the work is part of a larger scope requiring a permit (such as a furnace replacement), then the project would need to demonstrate compliance with requirements as part of the permitting process.

Examples of DHW repairs include replacing components (i.e. anode rod, thermostat, flue, tank insulation). As with HVAC repairs, DHW repairs do not trigger requirements and no documentation is required.

Mandatory Requirements

Residential projects must first meet all applicable mandatory measures for minimum HVAC requirements and DHW requirements. Mandatory measures ensure that minimum requirements are met regardless of the compliance approach.

Mandatory HVAC Requirements

Heating and cooling load calculations (§150.0(h)1)

Refer to Section 4.2.1.3 of the 2016 Residential Compliance Manual for a discussion of the minimum requirements for sizing heating equipment. Acceptable load calculation methodologies include the ASHRAE Handbooks, SMACNA Manuals, and ACCA Manual J. The latter is the most commonly used method and is the most widely available as a variety of software applications designed to assist in the process. It is designed to be used by contractors for smaller higher volume projects (e.g., single family homes, remodels, additions, etc.).

Code in Practice

Consider a 2,000 square foot house built in the 70's. The most common sizing practice of the day was 500 square feet per ton, so this house was originally built with a 4 ton system, even though load calculations could easily have justified a 3 ½ ton system. Thanks to utility rebate programs and other renovations, the home has upgraded ceiling insulation, windows, permanent external shading (patio covers) on the south and west sides and infiltration control. Load calculations now would easily justify a 3 ton system. Since the upgrades the homeowners have noticed a general improvement in energy costs and comfort, except that the temperature differential between upstairs and downstairs has gotten worse and the system cycles on and off frequently. Several times the coil has frozen up, requiring service calls. Now, the system has stopped working, apparently due to a failed condenser.

Standard practice for an HVAC contractor in this situation would be to replace the system with the same size equipment and try to upsell them on high efficiency equipment. It is very time consuming to do load calculations on a home, so it is rarely done in this type of situation; however, there are some obvious indications that smaller equipment should definitely be considered. The fact that improvements have been made to the house that substantially reduce cooling load calculations should be the first clue. Short cycling of the AC, coil freezing and more noticeable stratification of temperatures are also important signs of equipment oversizing and duct undersizing. The recommendation for this house would be to reduce tonnage per mandatory load calculations and increase airflow.

Code in Practice:
Examples of Classifying HVAC Addition, Alterations and Repairs

1. A home is getting a large master suite addition. A new ducted split system is being installed to serve just the addition.
   - Project classification: addition
   - HVAC system classification: entirely new
2. A home is getting a large master suite addition. The existing system is getting new larger equipment. New ducts are being run to the addition. The ducts serving the existing house are not being changed and make up more than 25% of the total duct system, by length.
   - Project classification: addition
   - HVAC system classification: altered
3. An existing home currently only has a wall furnace. They are upgrading to central heat and air (commonly referred to as a "cut-in").
   - Project classification: alteration
   - HVAC system classification: entirely new
4. An existing home has a ducted split system with all of the ducts in the crawlspace. A skunk got into the ducts and chewed them all up. The home owner is having all of the ducts replaced, but none of the equipment (commonly referred to as a "reduct")
   - Project classification: alteration
   - HVAC system classification: new duct system (the system must be sealed to 5% leakage, unless it can be shown by using smoke that the ducts are sealed and the existing air handler is the cause of the leakage)
5. An existing two story home has a single package unit on the roof and old, rusty, uninsulated sheet metal ducts in the attic. The homeowner wants to replace as much of the ducts as possible. The ducts serving the first floor are not accessible.
   - Project classification: alteration
   - HVAC system classification: altered (even if more than 75% of the ducts are replaced, the fact that some are not accessible, exempts them from the new duct system sealing requirement)
6. An existing home with a ducted split system in the attic is being remodeled. It is getting all new equipment and ducts. They are leaving the existing supply registers and sheet metal register boots.
   - Project classification: alteration
   - HVAC system classification: entirely new (more than 75% of the ducts are being replaced and register boots are considered accessible)
7. An existing HVAC system is diagnosed with a stuck TXV. The technician will replace it.
   - Project classification: repairor alteration (depends on whether a permit is required for this work by the local authority having jurisdiction)
   - HVAC system classification: repair or alteration (depends on whether a permit is required for this work by the local authority having jurisdiction)
8. The same system as #7 is also getting a new furnace.
   - Project classification: alteration
   - HVAC system classification: altered (duct sealing and refrigerant charge if in CZ 2, 8-15)

Design conditions (§150.0(h))

Refer to Section 4.2.1.3 of the 2016 RCM for a discussion of the minimum requirements for sizing heating equipment. As mentioned in Chapter 3 of this Guide, cooling load calculations are done in the summer, when it is hotter outside than inside, and heating load calculations are done in the winter when it is hotter inside than outside. This implies that there are four temperatures being considered: inside and outside, for summer and winter. These are called the:

- Summer indoor design temperature,
- Summer outdoor design temperature,
- Winter indoor design temperature, and
- Winter outside design temperature.

The indoor temperatures are the temperatures that the equipment is designed to maintain inside the home during the respective season. The energy standards require designers to use 68°F for winter heating loads and 75°F for summer cooling loads. These are set by the Energy Standards to prevent people from designing to irresponsible temperatures or personal preferences far outside the norm. The outside design temperatures are set based on historical weather data for the location of the home. They are listed in Reference Joint Appendix JA2. Because not every single city in California is on the list and because there are spaces in between the cities that may have micro-climates, designers are allowed some flexibility in what outdoor design conditions they use. In the long run, a few degrees will have relatively little impact on the overall load calculations.

Outdoor Condensing Unit

Outdoor Condensing Units (§150.0(h))

Section 4.3.1.3 of the RCM discusses the requirement for outdoor condensing units to have a clearance of no less than 5 feet from a dryer vent. Outdoor condensers work by expelling heat (collected from inside the house) to the outside. They rely on good air circulation. Dryer vents expel hot, moist air full of particulates (dryer lint). Having a dryer vent blow directly on an outdoor condensing unit is a bad idea. The lint will build up on the condenser coils and the warm moist air makes it even harder to expel the heat.

Central Forced Air Heating Furnaces (§150.0(h))

The Energy Standards require central forced air heating furnaces to be installed to operate at or below the manufacturer's maximum inlet-to-outlet temperature rise specifications. Temperature rise in a furnace is the temperature difference between the return air and the supply air measured right at the furnace. Excessive temperature rise in a furnace indicates low airflow or an over specification firing rate. This reduces efficiency and could result in damage to the equipment. To ensure efficient operation and longevity of the furnace, installation per manufacturer's specification is critical.

Ductwork in Attic

Thermostats (§150.0(i))

This section in the Energy Standards refers to requirements in §110.2(c). Section 110.2(c) requires a programmable setback thermostat for unitary heating and cooling equipment. There are also thermostat requirements in §110.2(b) for heat pumps with supplementary electric resistance heaters to avoid supplementary heater operation when the load can be met by the heat pump.

Refer to Chapter 4.5 of the 2016 RCM for a discussion of the minimum requirements for thermostats and other controls.

Code in Practice

An existing home is replacing the old 50-gallon gas water heater with a new 50-gallon gas water heater meeting minimum efficiency and **no other** work is being done to the home. The compliance documents required:

Certificate of Compliance

- CF1R-ALT-05-E

Certificate of Installation

- CF2R-ALT-05-E


BLUEPRINT
California Energy Commission
Efficiency Division

CEC Blueprint, November 2015-February 2016

The Q&A in this Blueprint clarifies that all-in-one piping systems can be used to meet pipe insulation requirements in §150.0(j)2.

Find it here:
energy.ca.gov/2015publications/CEC-400-2015-046/CEC-400-2015-046.pdf

Ductwork & Filtration (§150.0(m))

There are many requirements that regulate factory and field fabricated duct systems, all of which are listed in §150.0(m). Duct insulation, labeling and damper requirements are also found in this section. Air filtration is required for systems that use more than 10 feet of ductwork to distribute the conditioned air. Requirements for filter efficiency and pressure drop are located in this section as well.

Demonstration of a minimum airflow of 350cfm/ton of cooling capacity and a maximum of fan efficacy of 0.58w/cfm for the AHU is required by this section. These requirements must be field verified by a HERS Rater.

Ventilation (§150.0(o))

This mandatory measure requires compliance with ventilation requirements in ASHRAE Standard 62.2, and does not allow operable windows to provide the whole building ventilation airflow per the Energy Standards. In addition, the whole building requirement requires field verification per Residential Appendix 3.7. Additions less than 1,000ft^2 are exempt from only the whole building ventilation airflow requirements of §150.2(a). More details can be found in Chapter 4.6 of the Residential Compliance Manual.

Mandatory DHW Requirements

Requirements For Newly Constructed Homes (§150.0(n))

When building a new home, no matter what type of DHW system is being installed the following features need to be in place, so that when the homeowner replaces their DHW system in the future, they can upgrade to a gas tankless unit. Being able to convert an existing home to gas tankless can be cost prohibitive. Since the least expensive time to install these features into a home is while it is being built, the Energy Standards require these features at construction.

- A 120V electrical receptacle that is within 3 feet from the water heater and accessible to the water heater with no obstructions; and
- A Category III or IV vent, or a Type B vent with straight pipe between the outside termination and the space where the water heater is installed; and
- A condensate drain that is no more than 2 inches higher than the base of the installed water heater, and allows natural draining without pump assistance, and
- A gas supply line with a capacity of at least 200,000 Btu/hr.

In addition, there are distribution requirements per §150.0(j)2:

- Hot water pipe insulation: 1" diameter or less hot water piping to be insulated with 1" thick pipe insulation (per Table 120.3-A) at the following locations:
  1. The first 5 feet (1.5 meters) of hot and cold water pipes from the storage tank.
  2. All piping with a nominal diameter of 3/4 inch (19 millimeter) or larger.
  3. All piping associated with a domestic hot water recirculation system regardless of the pipe diameter.
  4. Piping from the heating source to storage tank or between tanks.
  5. Piping buried below grade.
  6. All hot water pipes from the heating source to the kitchen fixtures.
  7. The pipe insulation can be installed after installation, or a pre-insulated product can be used. This applies to both copper and PEX hot water piping.

Note that for pipes greater than 1" in diameter, more insulation is required. Refer to Table 120.3-A for requirements. Also note that Section 609.11 of the 2016 Plumbing Code now requires all DHW pipes to be insulated.

Equipment (§110.3(b))

DHW units must meet minimum efficiency requirements. Depending on how much energy a unit is using, it may be considered an "appliance". All Appliances must meet the minimum efficiency requirements of Title 20, and be certified to the Energy Commission (see Chapter 1).

Installation (§110.3(c)7)

If the DHW heater is to be a tankless unit, and the input rating (how much energy it is drawing) exceeds 6.8 kBtuh (2 kW) then isolation valves and other fittings such as hose bibs will be required for both the cold and hot water piping leaving the water heater so that it can be flushed regularly to retain its high efficiency and not be replaced before it should, which can happen if not maintained per manufacturer's requirements.

Prescriptive Approach

The prescriptive approach is a set of minimum performance levels. This can be applied to various HVAC and DHW components, where each component of the proposed design must meet all of the prescriptive requirements. When using the prescriptive approach, building components are treated separately and cannot be traded-off with other features. Prescriptive compliance is dependent upon the project scope; newly constructed, addition or alteration. Since the prescriptive requirements set the baseline used for the performance compliance path, it is important to be cognizant of what the baseline is using to set the TDV budget.

Prescriptive HVAC Requirements

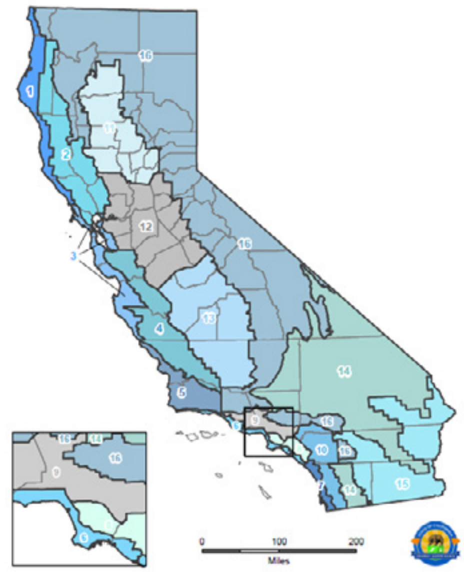
The prescriptive approach is rarely used for newly constructed homes. Its use as a compliance option is most common for smaller additions and alterations, including new HVAC system installations in existing homes.

Alterations (§150.2(b))

The prescriptive package for HVAC systems in Table 150.1-A shows applicable requirements for equipment efficiencies, excluding any electric resistance.

When more than 40 feet of ductwork is being installed, requirements for duct sealing and insulation are triggered (§150.2(b)1D&E). The Energy Standards require duct leakage testing to show compliance with leakage rates, and the allowed leakage rates are different for entirely new or replacement duct systems versus extensions to existing systems. It can be difficult to meet duct leakage rates in the field on extensions to existing systems, because some ductwork is not accessible as part of the alteration project, and the inaccessible ducts are not explicitly required to be sealed. Ductwork constructed, insulated or sealed with asbestos, common in homes built prior to the 1980's, is also exempt. However, duct leakage is a significant loss of system efficiency, so all reasonable attempts to seal existing ductwork should be made. The duct insulation requirements vary somewhat by climate zone as shown in Table 150.2-A.

Climate zones 2 and 8-15 require refrigerant charge verification by a HERS rater and all the features and requirements that go along with it as specified in §150.2(b)1F. This includes set-back thermostat and HERS verified minimum airflow of 300.



California Climate Zones

California has widely varying climate conditions across the state, resulting in a division of 16 Climate Zones. The Energy Commission has established typical weather data, prescriptive packages and energy budgets for each geographic area, which are defined by zip code.

California's Building Climate Zone Areas can be found here: energy.ca.gov/maps/renewable/building_climate_zones.html

Code in Practice

The owner of an existing home is replacing one (1) existing gas tank water heater, and will also add a new gas tankless water heater for the master bathroom. No recirculation pumps will be added for either system. How do you show compliance?

The prescriptive method can be used since they are adding one (1) gas tankless water heater to a home that only has one (1) water heater to begin with.

Adding a gas tankless water heater in this situation is allowed as explained in the Energy Commission Blueprint for March-April 2016, link below.

Certificate of Compliance

- CF1R-ALT-05-E for altered DHW

Certificate of Installation

- CF2R-ALT-05-E for altered DHW

CEC Blueprint, March-April 2016

This issue details that (1) additional natural gas or propane instantaneous water heater can be installed prescriptively. If additional storage or electric water heaters are added, the performance approach must be used.

Find it here: http://www.energy.ca.gov/2016publications/CEC-400-2016-003/CEC-400-2016-003.pdf

Additions (§150.2(a))

To comply prescriptively, new HVAC systems installed in additions must meet the same requirements defined in §150.1(c) and Table 150.1-A for new buildings, as well as all applicable mandatory measures per §150.2(a), with some exceptions. Additions less than or equal to 1,000 ft^2 are exempt from the prescriptive ventilation cooling requirement in §150.1(c)12.

If a residential addition is to be heated or cooled by an existing HVAC system already conditioning the existing residence, the existing space heating or cooling equipment is exempt from the Energy Standards. However, if ducts are extended from the existing system to serve the addition this is considered an alteration, and both the extended ducts and the altered existing duct system must meet the applicable requirements of §150.2(b)1D.

Prescriptive DHW Requirements

As we get closer to 2020 (California's goal of zero net energy for all new homes), the energy requirements of a home are going to get tighter and tighter. As a result, DHW requirements for new construction have gone through a big change in the 2016 Energy Standards cycle. For the first time, equipment type (tank versus tankless) is defined within the prescriptive minimum, not just equipment fuel type, efficiency and installation requirements. The baseline prescriptive water heater has changed from a 50 gallon storage gas water heater to a tankless gas water heater, and that tankless gas water heater now sets the standard design water heating energy budget for the Performance Approach. Storage gas water heaters are still available prescriptively, but only with additional energy-efficiency measures installed, as explained below.

New Single-Family Home (§150.1(c)8)

Equipment

There are three prescriptive water heater options for new residences:

1. One (1) tankless gas or propane water heater with 200,000 Btuh maximum input; OR
2. One (1) 55 gallon or less storage gas or propane water heater with 105,000 Btuh maximum input, plus:
    - HERS-verified Quality Insulation Installation (QII) per RA3.5;

    AND one of the following:

    - Compact hot water distribution system (HERS verified), OR
    - All hot water pipes insulated and verified by HERS rater ;

    OR
3. One (1) storage gas water heater larger than 55 gallons with 105,000 Btuh maximum input. QII is not required since the federal requirements for larger water heaters have reduced the energy loss associated with the units, but this prescriptive water heater option will still require one of the following:
    - Compact hot water distribution system (HERS verified), OR
    - All hot water pipes insulated and verified by HERS rater

Distribution

If a recirculation system is installed in a single family residence, the only prescriptive option is a demand recirculation system with manual pump control. Any other type of recirculation pump control (i.e. no control, motion sensor, timer) will require using the Performance Approach.

Alterations (§150.2(b)1G)

Since tankless gas water heaters often cannot be installed easily in existing homes, storage tank water heaters are allowed prescriptively when replacing existing equipment. The requirements for altered and added water heaters take into consideration the number of existing water heaters in a residence and whether or not the building has a natural gas connection.

Equipment

When replacing a water heater in an existing home, the same type of water heater can usually be installed as long as it meets the mandatory requirements (i.e. minimum efficiency, tank insulation). If the building has a natural gas or propane connection, then to comply prescriptively the replacement water heater must be natural gas or propane, or some equivalent water heating system as determined by the Energy Commission (§150.2(b)1Giic). Electric resistance water heaters, or an Energy Commission equivalent, can only be installed if natural gas is not connected to the building. Storage electric resistance replacement water heaters cannot exceed 60 gallons (trying to reduce electric load impact at peak load conditions). If the water heating changes from a gas system to electric resistance even though gas is available, or if the replaced electric resistance water heater is to exceed 60 gallons, then compliance must be shown using the Performance Approach. Other energy features will be required to offset the additional energy use.

Distribution

Hot water piping insulation must meet the same requirements as a new home, except that only "accessible" piping needs to be insulated. If a recirculation pump is to be added along with or after the new water heater has been installed, then controls and insulation of all "accessible" hot water piping must also be done. If the controls are not push button demand, then compliance must be shown using the Performance Approach.

Adding a Water Heater to an Existing Home (§150.2(a))

When adding a water heater to an existing home, there are different requirements depending on if it is in conjunction with an addition to the home or not, and how many water heaters are already existing.

Equipment

1. Only one (1) existing water heater in the home:
   - Adding a water heater without an addition (i.e., without adding square footage to the home): One (1) gas tankless system can be added in this situation without triggering additional measures (see Blueprint sidebar, opposite page). If a tank system, non-gas system, or more than one (1) additional water heater is desired, then a performance calculation will be required to show that the project meets the Energy Standards.
   - Adding DHW in conjunction with an addition: When adding onto a home, one (1) water heater is allowed to be added with no penalty, as long as it meets the prescriptive requirements for a new water heater. If a third DHW is added, then the Performance Approach will be required.
2. Two (2) or more existing water heaters in the home:
   - Adding DHW without an addition (i.e., without adding square footage to the home). The Performance Approach will need to be used.
   - Adding DHW in conjunction with an addition. The Performance Approach will need to be used.

Heat Pump

Climate Zone	Minimum Required Energy Factor
1	2.75
2	2.75
3	2.75
4	2.80
5	2.75
6	2.33
7	2.50
8	2.33
9	2.33
10	2.33
11	2.50
12	2.80
13	2.50
14	2.50
15	2.33
16	3.00 plus a solar water heating system with solar savings fraction ≥0.4

Heat Pump EF for Alterations Only

Distribution

When adding new water heating equipment, hot water piping associated with the new system must meet all of the same hot water piping requirements as a new DHW system.

Performance Approach

The performance approach is considered the most flexible compliance method, and it can be used to analyze and demonstrate compliance for buildings that do not comply easily with the prescriptive method. In the performance approach, the proposed building is analyzed using Energy Commission approved compliance software, and its estimated annual energy use is compared to a "standard design" baseline energy use. This method allows "trade-offs" when a prescriptive requirement can't be met and another system can make up the deficit, allowing the project to comply in total. While the prescriptive options set the baseline for all performance calculations, the performance method does **not** allow for any mandatory features to be traded.

HVAC System Trade-offs Allowed

Equipment Efficiency Upgrades: Because the prescriptive HVAC requirements are pretty minimal, any upgrades in efficiency will result in a performance credit; however, equipment efficiency upgrades should be made after all reasonable envelope upgrades. Envelope upgrades will reduce load, resulting in smaller equipment. It is better to have smaller base-efficiency equipment than larger high-efficiency equipment. Also, consider that air conditioners installed with higher-than-minimum efficiency ratings will require a HERS rater to verify.

Compliance Credits

Besides upgrading equipment efficiency, there are some special performance-only credits that can be applied to HVAC:

Supply duct location – The standard design building (the house that sets the performance baseline, which the proposed house has to meet) has its ducts in an unconditioned attic. Locating the ducts somewhere where there is less temperature difference between the inside and outside of the ducts will result in less heat conduction through the ducts and get a performance credit. The best credit comes from putting ducts in conditioned space because not only is there less conduction, but the leaked air stays inside the building shell. Be aware that architecturally this can be difficult to do.

Superior fan efficacy and airflow – The mandatory minimum fan efficacy and airflow are 0.58 watts/cfm and 350 cfm/ton. Proper airflow across the evaporator coil is one of the most under appreciated performance criteria among installers and designers. The manufacturer's expanded data tables (which can be a challenge to understand) for a given coil/condenser match will show a definite correlation between system airflow and both cooling capacity and efficiency. Reducing airflow reduces both. This is why the Energy Standards have recently made proper airflow and fan watt draw mandatory for all new ducted systems with air conditioning. Proper airflow is a direct result of proper duct design; however it can also be achieved by forcing the air through an undersized duct system. This is typically done by upsizing the fan motor in the air handler, which will result in very high fan energy consumption and negate most of the benefit of proper airflow. To prevent this, proper fan efficacy (watts/cfm) must also be verified. Better energy performance would be a lower watts/cfm and a high cfm/ton. Unfortunately, these are numbers that are not easy to predict at the design stage. Unlike efficiency ratings, you can't simply pick a piece of equipment that will meet this requirement. ACCA

CEC Blueprint, March-April 2016

Still valid under the 2016 Energy Standards, this Blueprint clarifies compliance options for residential water heating.

Find it here: energy.ca.gov/2016publications/CEC-400-2016-003/CEC-400-2016-003.pdf

ACCA Manuals D, J, and S

The Indoor Environment & Energy Efficiency Association (ACCA) Manuals are available for purchase on the ACCA website. The can be used to properly size ducts and fittings for correct airflow.

Find them here: https://acca.org/standards/technical-manuals

Manual D (in conjunction with Manuals J and S) will allow you to specify a design cfm at a given static pressure. This helps size ducts and fittings to achieve the target airflow. If a careful design is done and the system installed correctly, the target cfm should be fairly easy to achieve. Fan efficacy is less intuitive and less well documented and may not necessarily correlate directly to improved airflow (i.e., improving airflow 10% may not improve fan watt draw by 10%). The trick is for the energy consultant modeling the system to pick values that provide adequate performance credit but are also reasonably achievable. No one can quite predict what the fan watt draw of a system will be until it is installed and turned on. This may lead to having to go back and rerun the performance report with the actual fan efficacy because it ended up being lower than expected.

Supply duct surface area and buried ducts – The performance software has the ability to model multiple duct conditions for different duct sections. These sections are quantified by surface area. This allows a compliance credit for having a duct system that has substantially less surface area than the standard house and systems that have ducts located in a variety of ideal locations, including buried under loose fill ceiling insulation.

Low leakage air handler (LLAH) – A large portion of allowable duct leakage is assumed to come from the air handler (furnace, fan coil, etc.). An LLAH is an air handler that has been tested to have a leakage rate substantially lower than typical air handlers. Not only should this make it easier to pass the mandatory duct leakage requirement, it makes it more likely that a substantially lower final leakage rate could be achieved. When a low leakage air handler is specified, the performance software allows the user to specify a target leakage lower than the normal minimum. Again, the trick is taking a reasonable credit without specifying a number that cannot be achieved. Experienced installers should be consulted to determine what a reasonable target might be. Similar to fan watt draw, if the target is not met the designer may have to revise the performance run to use the final tested number. Any compliance deficit that might result from this will have to be made up with other features, which can be difficult at this late stage.

DHW System Trade-offs Allowed

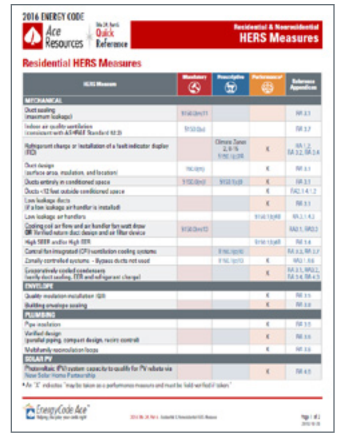
Compliance Credits

There are several options that exceed prescriptive requirements that can be traded for credit within the Performance Approach:

1. HERS verified QII (if not being used as an alternative to a gas tank system)
2. HERS verified compact hot water distribution system (if not being used as an alternative to a gas tank system)
3. HERS verified insulated hot water pipes (if not being used as an alternative to a gas tank system)
4. Solar hot water panels
5. High efficiency gas tankless system (exceeding mandatory equipment efficiencies)
6. Combined hydronic DHW and space heating systems
7. Geothermal heat pump systems

These compliance credits can be traded against any other TDV energy use in the home that has prescriptive requirements (i.e. windows, HVAC system). The table below concentrates on DHW systems and the considerations to contemplate when deciding to use the prescriptive method versus performance.

Ace Resources™



HERS Measures Resource

The performance compliance credits described here involve verification by a HERS Rater. This Energy Code Ace resource summarizes HERS measures in the 2016 Energy Standards

Find the checklists here: energycodeace.com/content/resources-fact-sheets

DHW System Choices			
Electric resistance tank	**Electric resistance tankless**	**Prescriptive**	**Performance**
Inexpensive installation High electricity use.	Hidden installation cost can be the electrical panel since these can have a large amp draw.	**New home or adding DHW:** Must use performance method. **Altered DHW:** Only allowed prescriptively if there is no natural gas connection to the house.	New home or adding DHW: Can be traded, but with equivalent TDV energy, which can be very difficult.
Heat pump tank	**Combined hydronic heat pump**	**Prescriptive**	**Performance**
A more expensive DHW choice, but allows for electricity as the utility source. Has installation requirements that may limit location.	These are becoming more popular as a whole house system. Installation must be designed.	**New home, adding DHW:** Must use performance method. **Altered DHW:** See table provided for heat pump DHW.	Heat pump water heaters are a good solution to a home that doesn't have gas, or desires to be PV dependent.
Gas tank	**Gas tankless**	**Prescriptive**	**Performance**
The higher the efficiency, the more likely it will be a condensing DHW in which installation features will mimic gas tankless systems.	The DHW of choice in this code cycle. Installation features such as flue type, condensate drain, gas piping able to handle the Btuh input, and 120 volt outlet nearby.	**New Home:** (1) gas tankless **Altered DHW.** If the house has natural gas or propane, either a tank or tankless gas water heater (or Energy Commission equivalent) is required prescriptively **Adding (1)DHW:** (1) gas tankless. **Adding more than (1)DHW:** Must use performance method.	New home: Trading the prescriptive baseline of (1) gas tankless DHW with equivalent TDV energy features, or improving TDV energy associated with DHW system such as solar hot water. Add/Alt DHW. go beyond prescriptive allowances.

DHW System Choices		
Combined hydronic with solar hot water panels	**Prescriptive**	**Performance**
Combined hydronic systems are attractive because they reduce the amount of equipment that is being used for space heating and DHW. When packaged with a solar panel system, energy savings can be a double whammy.	There are no prescriptive requirements for combined hydronic systems, though DHW source will need to meet prescriptive requirements.	Can always be used for performance TDV credit.
Electric tank with PV	**Prescriptive**	**Performance**
As many homeowners are installing PV panels, the desire to install only electric using systems is attractive. The Energy Standards do not look any differently upon a home using electric resistance DHW with or without PV systems. Not all homes can take credit for PV systems in a performance calculation.	See restrictions regarding electric resistance DHW.	There is some PV performance TDV credit allowed, but it is limited to certain climate zones and other minimum requirements
Solar hot water panels with any DHW type	**Prescriptive**	**Performance**
Solar hot water panels can always be modeled for TDV credit in a performance calculation. Installation costs may exceed PV panels due to hot water supply and return piping, pumps and storage tank, but the pay back over the years with reduced utility cost for a system used every day of the year can add up quickly.	Solar hot water panels have no prescriptive requirements.	Can always be used for performance TDV credit.
Geothermal heat pump	**Prescriptive**	**Performance**
Geothermal systems are not always an option, since it depends on location and land available. These systems must be designed, and installation is very pricey.	Since these systems utilize heat pump DHW, performance method will be required.	Can always be used for performance TDV credit.

Case Study: Habitat for Humanity San Joaquin, Dream Creek Subdivision

Prescriptive Versus Performance in Practice

Both the prescriptive and performance methods have advantages, depending on the particular building being analyzed. This case study evaluates the features of one particular residence to assess the pros and cons of the different compliance approaches when applied in the real world.

The case study residence for this section is a remarkable building designed to far exceed the 2008 Energy Standards that were in effect when it originally went for permit – so much so, that it still complies with the much tougher 2016 Energy Standards! The home is in the Habitat for Humanity San Joaquin, Dream Creek subdivision in Stockton, and it is a PG&E ZNE (zero net energy) production builder demonstration project.

An important goal of the project was to show that it is possible to achieve ZNE goals cost-effectively as a result of paying careful attention to construction details and how all building systems work together. The project team concentrated on the following areas:

- Adaptive and efficient architectural design
- Advanced framing and high performance envelope
- High performance heating, ventilation, and air conditioning (HVAC)
- Water heating
- Water conservation
- Lighting
- Solar electricity

This guide concentrates primarily on energy-efficient HVAC systems and water heating, but all these features work together to make the home as sustainable and energy efficient as possible.

NOTE: All architectural details on the following page depict the ZNE Demonstration Home, Habitat for Humanity, Dream Creek Subdivision, Stockton, CA. Designed by George H. Koertzen, Habitat for Humanity San Joaquin County, CA.

Project Team

Project Manager:

George Koertzen, Habitat for Humanity

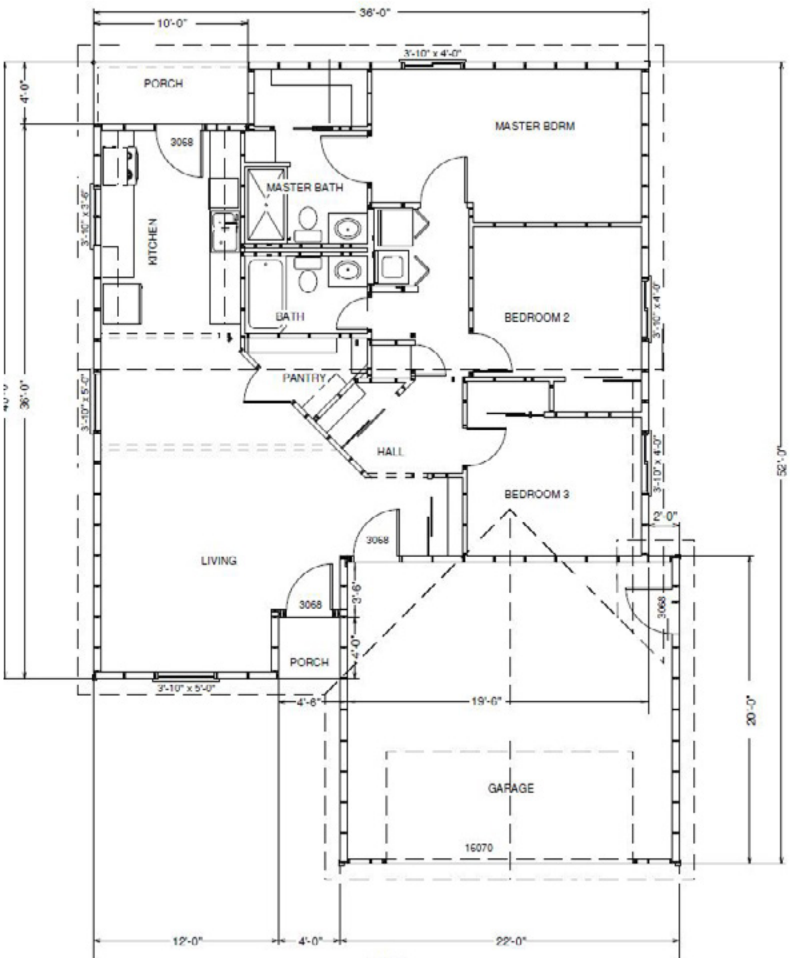
Consultants:

Ann Edminster, Design AVEnues LLC

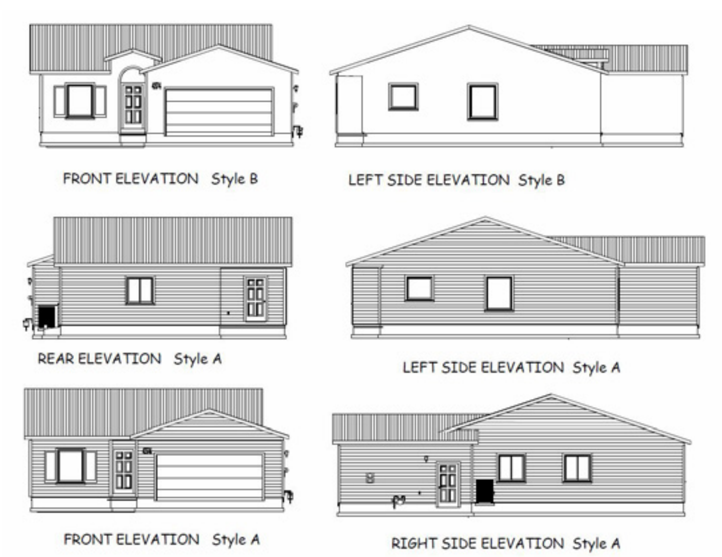
Rick Chitwood, Chitwood Energy Management

Steve Easley, Steve Easley & Associates

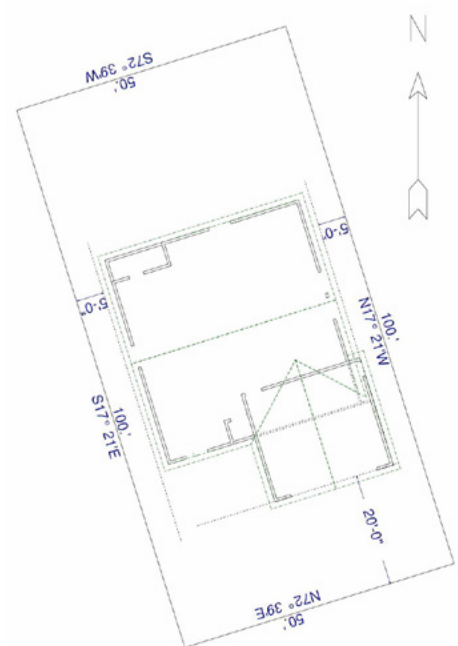
Special thanks go to George Koertzen and Habitat for Humanity San Joaquin for allowing access to the project drawings and technical information, and to Rick Chitwood of Chitwood Energy Management, for bringing Dream Creek to our attention and sharing his photos of advanced construction details.



Floor Plan



Elevations



Plot Plan

CEC Blueprint Listserv

Users of the Energy Standards can stay up to date on Energy Commission clarifications and interpretations by signing up for the Blueprint listserv.

Sign up here:
energy.ca.gov/efficiency/blueprint/

Prescriptive vs Performance Method Compliance Analysis

The following tables and discussion compare the HVAC and DHW features of the case study residence with the applicable prescriptive requirements and the performance method standard design assumptions for climate zone 12 to assess compliance options in practice.

This first section considers the proposed HVAC system and how it compares to the prescriptive requirements and the performance method standard design.

Non-HERS HVAC Measures

HVAC FEATURES	CASE STUDY	PRESCRIPTIVE	PERFORMANCE
New Low-Rise Residential Buildings	ZNE Demonstration Home Dream Creek Subdivision Stockton, CA	Package A Climate Zone (CZ) 12 (§150.1 Table 150.1-A)	2016 Residential ACM Reference Manual (Section 2.4)
Fuel Types	Space Heating: Electricity Space Cooling: Electricity	Space Heating: Electricity Space Cooling: Electricity	
Equipment Type	Ducted mini split heat pump	Ducted mini split heat pump	Ducted mini split heat pump
Heating efficiency	10.3 HSPF	Meet or exceed current Federal minimum: HSPF≥8.2	Standard design set at current Federal minimum: HSPF = 8.2
Cooling efficiency	15.1 SEER, 11.2 EER Note that EER is not federally regulated for central split system heat pumps.	Meet or exceed current Federal minimum: SEER ≥14.0	Standard design set at current Federal minimum efficiency for central split heat pump. SEER = 14.0; plus Federal minimum EER for air conditioners with output ≥ 45,000 Btu/hr and < 65,000 Btu/hr: EER=11.7
Distribution	R-8 ducts in conditioned space, ducts sealed and tested for leakage	R-6 ducts in conditioned space, ducts sealed and tested for leakage	R-8 ducts in high performance vented attic, ducts sealed and tested for leakage

The fuel types and basic equipment types for the proposed system are important for compliance. In this case study, the proposed system is a ducted electric mini split heat pump that provides both space heating and cooling, so there is only one fuel type and one equipment type. Electric resistance space heating is not allowed as the primary heat source prescriptively, so the prescriptive requirements for any primary electric space heating are based on heat pumps. The performance method standard design for systems with electric space heating and cooling assumes an electric split system heat pump.

Energy Standards requirements for minimum space heating and cooling efficiencies match the current U.S. Department of Energy minimum requirements set forth in the Federal appliance efficiency standards when applicable and are also published in the California Energy Commission Appliance Efficiency Regulations. The case study ducted mini split heat pump has an AHRI-rated space heating efficiency of 10.3 HSPF compared to the minimum prescriptive HSPF and the performance standard design HSPF, both of which equal 8.2. Thus, the case study HSPF complies prescriptively and would provide a performance method compliance credit.

On the cooling side, the proposed ducted mini split heat pump has an AHRI-rated SEER of 15.1 and EER of 11.3. Central split heat pumps have a minimum federal cooling efficiency requirement of 14 SEER, but no minimum EER requirement. Prescriptive Package A only requires cooling equipment to meet the minimum SEER, so the SEER for the case study heat pump complies prescriptively. The proposed 15.1 SEER would provide a performance method compliance credit, but the high SEER would have to be HERS verified. The performance method standard design also includes an 11.7 EER, even though EER is not federally regulated for central split heat pumps, but the compliance software allows input of SEER alone which then calculates a default EER. There's also an option to take performance method compliance credit for an EER higher than 11.7, but it requires HERS verification.

The proposed distribution system is another important part of any HVAC system. The case study house has R-8 ducts in conditioned space, and the ducts have been sealed and tested for leakage. Both the duct location and duct leakage have been HERS-verified. Prescriptive Package A has an option that allows R-6 ducts in conditioned space, which also requires the HERS-verified duct location and leakage, so the proposed ducts comply prescriptively. The performance method standard design assumes sealed and tested R-8 ducts in a high performance attic with HERS-verified duct leakage, so the case study HERS-verified ducts in conditioned space would provide a performance compliance credit.

Code in Practice: Mini Split Heat Pump Efficiencies

Heating and cooling efficiency ratings for mini split heat pumps can be found in the AHRI directory, and the values shown for the case study ducted mini split heat pumps are AHRI-rated.

However, the Energy Commission has determined that there have been problems with efficiency testing protocols for ductless heat pumps, including ductless mini split heat pumps. As a result, minimum efficiency assumptions are currently required for Title 24 Energy Standards compliance with those systems. This may change once additional research is done to document appropriate efficiency ratings, so stay tuned!

HERS-Verified HVAC Measures[1]

HVAC FEATURES	CASE STUDY	PRESCRIPTIVE	PERFORMANCE
New Low-Rise Residential Buildings	ZNE Demonstration Home Dream Creek Subdivision Stockton, CA	Package A Climate Zone (CZ) 12 (§150.1 Table 150.1-A)	2016 Residential ACM Reference Manual (Section 2.4)
Minimum airflow	Mandatory 350 cfm/ton	Mandatory 350 cfm/ton	Mandatory 350 cfm/ton
Fan efficacy watts/cfm	Mandatory 0.58 watts/cfm	Mandatory 0.58 watts/cfm	Mandatory 0.58 watts/cfm
Indoor air quality (IAQ) mechanical ventilation	Mandatory	Mandatory	Standard design models mandatory minimum ventilation
Duct sealing and reduced duct leakage	Yes	Mandatory for new residences with ducted HVAC systems	Standard design assumes mandatory minimum requirements
Duct location in conditioned space	Yes	Yes	Standard design assumes ducts in attic, so verified ducts in conditioned provides compliance credit
Refrigerant charge	No	Required for CZ 2, and 8-15	Assumed in standard design for CZ 2 and 8-15
Whole house fan	No	Required for CZ 8-14	Assumed in standard design for CZ 8-14
SEER	Mandatory for SEER > minimum for performance method compliance	Not required	Mandatory for compliance credit for SEER > minimum in Performance Approach

1 HERS-verified Measures. Note that some of the HVAC and DHW HERS verifications in the case study are new measures in the 2016 Energy Standards which were not available or needed for compliance at the time this building actually went for permit under the 2008 Energy Standards. They are included in this case study performance method analysis to be consistent with the 2016 code.

There are mandatory, prescriptive, and performance method HERS measures for HVAC systems. Mandatory HERS measures must be implemented for all compliance paths, but do not provide any performance method compliance credit. Prescriptive HERS measures are required to show compliance using Package A, but they are not required when showing performance method compliance. Some HERS verifications are triggered by higher than average equipment efficiency or improved duct location, and they can result in performance method credits. Mandatory HVAC HERS-verified measures for the case study house include minimum airflow, fan efficacy cfm/W, duct sealing and reduced duct leakage, and Indoor Air Quality (IAQ) mechanical ventilation.

As mentioned above, the case study building has ducts in conditioned space, so the duct location must be HERS-verified for prescriptive compliance or to gain a performance method compliance credit. The prescriptive method also requires a HERS-verified refrigerant charge and whole house fan for climate zone 12, but the case study HVAC system does not include those measures. To comply prescriptively, a building must meet all applicable requirements from Package A, so this system does not comply prescriptively as designed. However, the building can be analyzed using the Performance Approach. The performance standard design assumes the energy saving from the HERS-verified refrigerant charge and whole house fan, so energy savings from more efficient measures such as the proposed ducts in conditioned space would need to compensate for energy losses from those less efficient measures.

The final type of HERS measure for the case study is the performance method requirement for verification of any SEER that is higher than the minimum requirement. The current minimum SEER is 14.0 and the case study ducted mini split heat pump has a SEER of 15.1, so that high SEER must be HERS-verified to provide compliance credit. Alternatively, the Energy Standards always give the performance option to model the minimum SEER required for a particular type of equipment as long as the actual installed system is the same type and meets or exceeds the efficiency assumed in the performance method analysis. In this case, a minimum 14.0 SEER could be modeled without being HERS-verified, but it would not provide any performance compliance credit.

DHW Measures

DHW FEATURES	CASE STUDY	PRESCRIPTIVE	PERFORMANCE
New Low-Rise Residential Buildings	ZNE Demonstration Home Dream Creek Subdivision Stockton, CA	Package A Climate Zone (CZ) 12 (§150.1 Table 150.1-A)	2016 Residential ACM Reference Manual (Section 2.9)
Fuel Type	Natural Gas	Natural Gas	Natural Gas
Tank Type	Tankless	Tankless	Tankless
Btu/hr Input	150,000 Btu/hr	≤ 200,000 Btu/hr	200,000 Btu/hr
Efficiency	0.82 EF	Meet or exceed current Federal minimum energy factor: EF ≥ 0.82	Standard design assumes current Federal minimum energy factor: EF = 0.82
Distribution	HERS compact design with 12' longest hot water pipe run	Standard (no recirculation system)	Standard (no recirculation system)
Controls	No recirculation, so no controls installed	No recirculation, so no controls required	No recirculation, so no controls assumed

The case study house has a tankless gas water heater with 150,000 Btu/hr input and 0.82 energy factor. Tankless gas water heaters with 200,000 Btu/hr input or less are characterized as "small instantaneous gas water heaters" in the federal appliance efficiency standards, and they are required to have energy factors of at least 0.82.

The case study water heater meets that requirement and complies prescriptively per §150.1(c)8Ai. The performance method standard design matches the prescriptive requirement with a tankless gas water heater with 200,000 Btu/hr input and 0.82 energy factor, and there is no performance credit or penalty for the proposed equipment type in this case. Note that although the proposed water heater only has 150,000 Btu/hr input versus 200,000 Btu/hr input, both are in the same small instantaneous gas water heater category so the reduced input does not result in a performance method compliance credit.

Water heating distribution affects energy use, and in this case the water heater was located near the center of the house so that the longest hot water pipe run is only 12 feet long. This saves energy by limiting potential heat loss through the pipes. To gain compliance credit in the 2016 Energy Standards the compact design must be HERS-verified. HERS-verified compact distribution exceeds the energy performance of the standard non-recirculating distribution assumed in both the prescriptive standards and in the performance method standard design. Thus the distribution system complies prescriptively and gives a performance compliance credit.

HVAC and DHW Compliance Analysis Summary

Checking the case study residence against the prescriptive requirements and performance method standard design shows that the water heating system would comply prescriptively and would allow a performance compliance credit for its HERS compact distribution. The HVAC system complies with every prescriptive requirement except for the HERS-verified refrigerant charge and whole house fan. The prescriptive compliance option can only be used if a project meets every applicable prescriptive requirement so that leads to completing a full performance method compliance analysis. Not meeting every prescriptive measure results in a performance compliance penalty, but it may be traded against energy savings from features such as the more efficient HSPF, SEER and duct location.

Envelope and Solar PV Summary for Performance

A performance method compliance analysis for a low-rise residential building must include the proposed building envelope as well as the HVAC and DHW systems, and it can also include compliance credit for solar PV. Here's a summary of those features being modeled for the case study residence:

Building envelope:

- 1,236 ft² total conditioned floor area
- High performance fenestration with dual pane argon-fill low-e glass and vinyl frame, NFRC-rated U-factor of 0.28 and SHGC of 0.20, total fenestration area equals 7.9 percent of conditioned floor area
- Vented attic with R-42 ceiling insulation installed with a wood framed raised heel truss to maximize insulation performance, plus attic radiant barrier, but no CRRC-rated cool roof
- Typical exterior walls 2x6 wood framed with advanced wall framing, R-21 cavity insulation plus R-5 continuous insulation (U-factor=0.044)
- Demising partitions next to unconditioned garage 2x6 wood framed with advanced wall framing, R-21 cavity insulation (U-factor=0.057)
- Raised floor over crawl space: 4x6 wood frame, 32"on center with R-21 cavity insulation (U-factor=0.035)
- HERS-verified quality insulation installation (QII)
- Solar photovoltaic (PV) system: 2.8 kW PV system installed

Case Study Performance Method Results

Using the CBECC-Res 2016.2.0 Energy-Commission-approved energy compliance software to analyze the proposed building envelope, HVAC and water heating systems, and solar PV contribution, the case study building complies with the Energy Standards using the Performance Approach. Similar results could be achieved using other Energy-Commission-approved compliance software.

The first page of the performance method CF1R-PRF-01 form lists general project information and the compliance results, including the important statement that the "Building Complies with Computer Performance", plus notes that the building includes HERS measures and other special features, followed by the energy use summary:

CERTIFICATE OF COMPLIANCE - RESIDENTIAL PERFORMANCE COMPLIANCE METHOD — **CF1R-PRF-01**

Project Name: Habitat for Humanity, ZNE Demonstration — **Calculation Date/Time:** 22:43, Mon, Jul 18, 2016 — **Page 1 of 8**

Calculation Description: Title 24 Analysis — **Input File Name:** H4H Residence_CBECC-Res 2016.2.0-857.ribd16

GENERAL INFORMATION					
01	Project Name	Habitat for Humanity, ZNE Demonstration			
02	Calculation Description	Title 24 Analysis			
03	Project Location	Dream Creek Subdivision			
04	City	Stockton	05	Standards Version	Compliance 2017
06	Zip Code		07	Compliance Manager Version	BEMCmpMgr 2016.2.0 (592)
08	Climate Zone	CZ12	09	Software Version	CBECC-Res 2016.2.0 (857)
10	Building Type	Single Family	11	Front Orientation (deg/Cardinal)	163
12	Project Scope	Newly Constructed	13	Number of Dwelling Units	1
14	Total Cond. Floor Area (ft^2)	1236	15	Number of Zones	1
16	Slab Area (ft^2)	0	17	Number of Stories	1
18	Addition Cond. Floor Area	N/A	19	Natural Gas Available	Yes
20	Addition Slab Area (ft^2)	N/A	21	Glazing Percentage (%)	7.9%

COMPLIANCE RESULTS	
01	Building Complies with Computer Performance
02	This building incorporates features that require field testing and/or verification by a certified HERS rater under the supervision of a CEC-approved HERS provider.
03	This building incorporates one or more Special Features shown below

ENERGY USE SUMMARY				
04	05	06	07	08
Energy Use (kTDV/ft^2-yr)	Standard Design	Proposed Design	Compliance Margin	Percent Improvement
Space Heating	14.37	6.89	7.48	52.1%
Space Cooling	22.11	29.34	-7.23	-32.7%
IAQ Ventilation	1.64	1.64	0.00	0.0%
Water Heating	15.32	14.50	0.82	5.4%
Photovoltaic Offset	----	-12.08	12.08	----
Compliance Energy Total	53.44	40.29	13.15	24.6%

Page 1 of CF1R-PRF-01-E for Habitat for Humanity Case Study House.

The compliance energy total of all the different components shows that the proposed building saves energy as compared to the standard design energy budget, and exceeds Energy Standards requirements by 24.6 percent.

The energy use summary shows that the proposed design saves energy compared to the standard design for space heating and water heating, but loses energy on space cooling. The solar PV system provides a large photovoltaic offset compliance credit. Cooling energy use is a dominant feature of climate zone 12, where the building is located, and it is the largest single component of energy use for both the standard and proposed designs. The losses on space cooling are mostly because the building does not have a CRRC-rated cool roof and because the standard design assumes both roof and ceiling insulation even for buildings with ducts in conditioned space.

Note that the positive heating compliance margin and negative cooling compliance margin in this case are not primarily driven by the efficiency of the HVAC equipment or system. They are mostly due to the differences between the prescriptive and proposed envelope components. However, anything above the minimum prescriptive or mandatory HVAC assumptions in the standard design will result in a performance credit but not necessarily a positive compliance margin. In this case study the overall compliance margin is 24.6 percent better than the standard design when taking credit for the higher than minimum 15.1 SEER and 10.2 HSPF, but it goes down to only 18.1 percent better than the standard design when minimum efficiency 14.0 SEER and 8.2 HSPF are modeled:

COMPLIANCE RESULTS	
01	Building Complies with Computer Performance
02	This building incorporates features that require field testing and/or verification by a certified HERS rater under the supervision of a CEC-approved HERS provider.
03	This building incorporates one or more Special Features shown below

ENERGY USE SUMMARY				
04	05	06	07	08
Energy Use (kTDV/ft^2-yr)	Standard Design	Proposed Design	Compliance Margin	Percent Improvement
Space Heating	14.37	8.42	5.95	41.4%
Space Cooling	22.11	31.27	-9.16	-41.4%
IAQ Ventilation	1.64	1.64	0.00	0.0%
Water Heating	15.32	14.50	0.82	5.4%
Photovoltaic Offset	----	-12.08	12.08	----
Compliance Energy Total	**53.44**	**43.75**	**9.69**	**18.1%**

Performance results using minimum SEER and HSPF equipment.

CHAPTER 6

RECOMMENDATIONS, RESOURCES AND COORDINATION

Installing and Testing to Meet Code Requirements

Many features are relatively easy to design and install, especially if it is simply a matter of purchasing the right make and model, such as windows or equipment. Some energy features, however, are based on quality of design and installation. You don't know that they are going to pass until they are tested using diagnostic equipment. Sometimes additional work and retesting may be required and this greatly impacts the cost effectiveness of the feature. The following suggestions are intended to help you achieve compliance on the first attempt. In all cases, an experienced installer and HERS rater are very important.

Duct Sealing

Focus equally on all parts of the system. When the system is running, the pressure is greatest near the air handler and leakage will be the worst here, but during the leakage test the whole system is under the same pressure and all leaks have equal value toward passing the test regardless of where they are located in the system. Take the time to seal around the register boots. Pre-seal all sheet metal fittings. Use proper tape. Focus on sealing the inner liner, not the vapor barrier. The vapor barrier is not intended to hold pressure.

Airflow and Fan Watt Draw

Use a qualified designer that is experienced using a good duct sizing methodology like ACCA Manual D. Do not use rules of thumbs to size ducts - rules of thumb have typically been derived by trial and error, usually have no scientific basis and are often wrong. Trust the calculations – Manual J has gone through a very rigorous ANSI review process. Avoid sharp bends in the ducts – this creates static pressure losses that were probably not accounted for in the duct sizing calculations. Use properly sized sheet metal fittings to turn the air whenever possible (hard elbows, angled register boots) rather than flex duct – it is harder to quantify the static pressure losses of flex duct in the calculations. Consider upsizing the evaporator coil – the coil is usually the largest single static pressure drop and upsizing it is a relatively inexpensive way to reduce this. Manufacturer's specs will usually show that this improves efficiency and capacity, plus it will have much less resistance to airflow. Make sure to use a condenser coil match with

Solar Domestic Hot Water System

CEC Blueprint, March-April 2016

This Q&A describes a scenario where the project does not pass fan watt draw testing and recommends ways to improve fan efficacy.

Find it here:
energy.ca.gov/2016publications/CEC-400-2016-003/CEC-400-2016-003.pdf

an AHRI rating, which indicates that the manufacturer has had their equipment tested for its compatibility with different size condensers. On large projects, if a condenser/coil match is desired that has not been tested, some manufacturers will test the combination upon request. Consider bar-type registers instead of standard stamped face registers – they are generally have a much lower static pressure drop. Install the largest return duct, filter and grille that will fit. You cannot oversize these. If one large return will not fit, use multiple returns. They can be spread around the house, but do not need to be.

Compliant DHW Designs

When designing a DHW system, looking at the DHW placement in conjunction with the locations of bathrooms, laundry rooms and kitchen can be an opportunity to implement a compact design, or point of use distribution system. If the home has bathrooms on opposite sides of the building, multiple DHW units may be a good solution to energy efficiency, water conservation, and homeowner satisfaction with instant hot water from the tap.

As homeowners become more conscious of the energy efficiency, DHW should be at the top of the list. This is the one piece of equipment used every day of the year, morning through night, in every home. The DHW type chosen that works best for the home design, with cost of installation in mind, can impact the energy use of a home tremendously, and should be thoroughly researched.

HVAC Alteration Scenarios

Basic Process for Prescriptive HVAC Alterations

Most HVAC alterations will require some HERS verification. The basic process to ensure compliance for these is as follows:

1. HVAC contractor bids project after being contacted by homeowner
2. Project is entered into online HERS registry by anyone, but it is best if done by HVAC contractor. Registry tells them what tests and forms are required (Note: this should be done whether the contractor wins the bid or not because it helps determine what tests are required, which can have a substantial impact on project cost.)
3. If contractor wins bid, CF1R-ALT-02 can be generated and signed online. If not, they can delete or abandon project in registry.
4. Contractor takes CF1R to building department to get permit
5. Contractor installs equipment
6. Contractor completes and signs CF2Rs online. The registry tells them exactly which ones are needed. Note that all mandatory measures are now listed on the appropriate CF2R forms. Signing a CF2R form is acknowledgment that the mandatory measures were followed. Process cannot be completed until all appropriate forms are signed.
7. HERS rater is assigned to project through the registry by whoever enters the project and completes the HERS Tests
8. HERS rater completes and signs CF3Rs online
9. Building department can look on registry to ensure that all tests are completed and all forms have been signed, then they can perform their inspections
10. Permit closed.

Common HVAC Alteration Scenarios

A common scenario in California is replacing an air conditioner or furnace once the existing equipment has reached the end of its useful life (needs to be replaced). Below are a couple examples of common projects and how the Energy Standards are followed:

Replacement of AC

The air conditioning unit that serves a 2,300ft^2 house in Sacramento (CZ12) stops blowing cold air. The HVAC contractor inspects the system and determines that the compressor has failed due to old age and contaminants in the refrigerant lines. The furnace was replaced within the last four years. The contractor recommends that the condenser and evaporator coil both be replaced, even though the evaporator coil is still in reasonably good condition. This is often required by the manufacturer of the condenser to ensure that the condenser will work correctly with the coil. The HERS registry will indicate that this project will require sealed ducts (to 15%) and refrigerant charge verification. The contractor includes these in the bid. After getting the permit, the contractor replaces the equipment, seals the ducts and charges the equipment with refrigerant. They decide not to do sampling and call the rater to come perform the HERS tests. They do not have to be present during the tests, but since they do not know for sure that the system will pass the tests, they opt to be there in case they need to make corrections. Upon passing the tests, all CF2Rs and CF3Rs are completed and signed online. The Building department is notified and performs their inspections. Upon completion of all inspections, the permit is closed.

Replacement of furnace

In Truckee (CZ16), the furnace in a vacation cabin needs to be replaced because it is an old open combustion type furnace that is prone to back drafting. Because they are sealing the house up to reduce infiltration, they decide to replace the furnace with a newer, much safer sealed combustion furnace. Replacing an air handler (a furnace is an air handler) will trigger the requirements for duct sealing in all climate zones. The process is similar to the previous example except that refrigerant charge is not required because the AC system is not being altered.

"Re-duct"

Another situation that may occur is that the equipment is still okay but the ducts are in such bad shape that they need to be replaced. Sometimes ducts can get water in them or can be severely damaged by animals. When more than 75% of the ducts are being replaced in a system, there is a good opportunity to hit the 6% target as required of a duct system in a new home. However, because the air handler is not being replaced and older air handlers can leak close to 6% on their own, there is an exception to the 6% requirement. If it doesn't pass and it can be shown with theatrical smoke that no observable leakage is coming from the ducts, the project qualifies for the exception.

"Cut in"

A common situation that occurs in older homes that have wall furnaces or floor furnaces is that the owner wants to upgrade to central heating and air conditioning. New supply registers must be cut into the ceiling or floor (hence the name), new ducts must be designed, installed and sealed, and new equipment must be set. Because the system is essentially entirely brand new, it triggers all of the requirements of a system in a new home: air flow, fan watt draw, 6% duct sealing, and refrigerant charge (in CZ's 2, 8-15).

The HERS registry will guide the contractor through all of the compliance requirements, including which tests are required and which forms are filled out.

CEC HERS Provider Page

HERS Registries are created and maintained by HERS Providers. Certified Providers can be found on the CEC's website.

Sign up here: energy.ca.gov/HERS/

Upgrading to Central Heating and Air

In homes that have non-central systems, such as wall furnaces and window air conditioners, upgrading to central heat and air (sometimes referred to as a "cut-in") can be very appealing and can substantially increase the value of a home. A well designed ducted system will distribute heating and cooling to all parts of the home evenly and provide much better comfort control, but be aware that your energy costs are likely to go up substantially. This is due to the inherent energy losses in a ducted system through convection and leakage. The only way to really prevent this is to somehow keep the ducts inside conditioned space, which can be very challenging.

Reducing System Size During an HVAC Alteration

When replacing an existing component the standard practice is to replace "like for like" in terms of size, however, it is very common that some energy upgrades have been made to a home since the existing system was originally sized. This often means that smaller equipment is very likely a good idea. Oversized equipment is not only more expensive to operate, it will likely create comfort problems. Unless you are talking about ducts, bigger is not better for HVAC equipment. Air conditioners and heat pumps are far more susceptible to oversizing problems than furnaces.

In some cases downsizing a condenser by ½ ton can solve comfort problems as well as reduce operating costs. Downsizing a condenser alone usually does not require changing the size of other equipment (air handler and coil). Because optimal airflow is based on cfm per ton of the condenser, downsizing the condenser can bring a system into compliance, improve efficiency and improve comfort without changing anything else in a system that previously had oversized equipment and undersized ducts.

Research and direct experience shows that the average existing home in California has lots of room for improvement, whether it's equipment sizing, duct leakage, refrigerant charge, or airflow. For existing homes, it's fairly safe to assume that the equipment is larger than it needs to be, the ducts leak more than they should, the refrigerant charge could use some adjusting, and the ducts are probably undersized. So much so, that the Energy Standards require that many of these items be addressed when major work is being done to the system.

Deciding On Equipment Change-Out vs. Complete New System

As discussed in a previous section, many older homes in California have equipment that is oversized and ducts that are undersized. If major work is being done to a system, this is the best time to consider a completely new system, new ducts, fittings and equipment. Even new supply registers may be in order because typically, they too are undersized and/or located in less than optimal locations. Things to consider when deciding whether to replace some or all of the system:

- Are all of the ducts accessible. If not, inaccessible ducts are extremely difficult to replace.
- What is the condition of the existing ductwork. Old flex duct may be damaged or have a deteriorating vapor barrier. Old sheet metal ducts may be very leaky, rusty, and poorly insulated. Old rigid fiberglass ducts may be damaged or deteriorating and extremely dirty.
- Are the ducts substantially undersized for the airflow needed for the new equipment. If so, replacement with properly sized ducts may be a good option. If only marginally undersized, substantial improvement can sometimes be gained from only increasing the return ducts and filter grilles and perhaps a better type of supply register (bar-type vs. stamped face.)

High Efficiency vs Smaller Equipment

Realize that base-efficiency equipment today would have been considered super high efficiency not too long ago. The technology to squeeze even more efficiency out of equipment is getting more complex and more expensive. Generally, speaking the more complicated equipment is, the more likely it is to have problems and the more expensive it is to repair. It is better to invest money in improving the load of the house before investing in higher efficiency equipment. Reducing the load can result in smaller, less efficient equipment being able to do the job just as well and as cheaply as larger more efficient equipment.

Adding Conditioned Space

When adding condition space on to a house, there are several options with regard to the HVAC system.

1. Ducts can be extended off the existing system to serve the addition. This assumes that the existing system can handle the added heating and cooling load of the addition. If less than 40’ of duct is added or replaced, this will not trigger the duct sealing requirement.
2. The size of the existing system can be increased and new ducts can be run to serve the addition. Replacing equipment without replacing more than 75% of the ducts is a change out alteration and will trigger duct sealing and possibly refrigerant charge verification, depending on the climate zone. If all of the equipment and more than 75% of the ducts are replaced, all of the requirements triggered for newly constructed housed could be triggered. There is an exception to the duct sealing requirement if any of the ducts are not accessible.
3. A completely new system could be installed dedicated solely to the addition, which would trigger all of the requirements of a system being installed in a new home.

DHW Performance Scenarios

The following water heating system scenarios all use the Habitat for Humanity case study residence in Chapter 4 as a starting point. The case study house has one minimum efficiency (EF=0.82) tankless gas water heater with HERS-verified compact distribution, resulting in a water heating compliance margin of 0.82 kTDV/ft²-yr better than the water heating standard design as shown in the performance method Energy Use Summary:

ENERGY USE SUMMARY				
04	05	06	07	08
Energy Use (kTDV/ft²-yr)	Standard Design	Proposed Design	Compliance Margin	Percent Improvement
Space Heating	14.37	6.89	7.48	52.1%
Space Cooling	22.11	29.34	-7.23	-32.7%
IAQ Ventilation	1.64	1.64	0.00	0.0%
Water Heating	15.32	14.50	0.82	5.4%
Photovoltaic Offset	----	-12.08	12.08	----
Compliance Energy Total	53.44	40.29	13.15	24.6%

HERS FEATURE SUMMARY
The following is a summary of the features that must be field-verified by a certified HERS Rater as a condition for meeting the modeled energy performance for this computer analysis. Additional detail is provided in the building components tables below.
Building-level Verifications: • High Quality Insulation Installation (QII) • IAQ mechanical ventilation Cooling System Verifications: • Minimum Airflow • Verified SEER • Fan Efficacy Watts/CFM HVAC Distribution System Verifications: • Duct Sealing • Ducts located entirely in conditioned space confirmed by duct leakage testing Domestic Hot Water System Verifications: • Compact Design

WATER HEATING SYSTEMS					
01	02	03	04	05	06
Name	System Type	Distribution Type	Water Heater	Number of Heaters	Solar Fraction (%)
DHW Sys 1 - 1/1	DHW	(HERS req'd) Compact Distribution System	DHW Heater 1	1	.0%

WATER HEATERS									
01	02	03	04	05	06	07	08	09	10
Name	Heater Element Type	Tank Type	Tank Volume (gal)	Energy Factor/Efficiency	Input Rating/Pilot	Tank Insulation R-value (Int/Ext)	Standby Loss (Fraction)	Heat Pump Type	Tank Location or Ambient Condition
DHW Heater 1	Gas	Small Instantaneous	NA	0.82 EF	200,000 Btu/hr	0	0	NA	NA

Performance Method Compliance Results for Habitat for Humanity Case Study Residence with 0.82 EF tankless gas water heater, compact distribution, plus QII, excerpts from Form CF1R-PRF-01 highlighting the water heating system, Energy Commission approved software version CBECC-Res 2016.2.0 (857)

The building envelope includes quality insulation installation (QII) which is sometimes part of prescriptive water heating compliance, and the compliance energy total for the proposed building overall exceeds the Energy Standards by 24.6 percent. Information on the proposed water heating system can be found in several parts of the CF1R-PRF-01-E, including those shown above.

One 60% EF 50 Gallon Tank Water Heater with Compact Distribution, plus QII

This scenario replaces the 0.82 EF tankless gas water heater from the case study with a 0.60 EF 50 gallon gas water heater with 40,000 Btu/hr input, but keeps the same HERS-verified compact distribution system and QII credits. Per Energy Standards §150.1(c)8Aii, the proposed small storage tank water heater complies with prescriptive package A when combined with QII and compact distribution. The performance method Energy Use Summary shows that the water heating energy use by itself goes from having a positive compliance margin of 0.82 kTDV/ft²-yr to a negative one of -6.33 kTDV/ft²-yr. None of the other energy use components change, so the net result is a proposed compliance energy total that is 11.2 percent better than standard rather than the 24.8 percent better with the tankless water heater.

ENERGY USE SUMMARY				
04	05	06	07	08
Energy Use (kTDV/ft²-yr)	Standard Design	Proposed Design	Compliance Margin	Percent Improvement
Space Heating	14.37	6.89	7.48	52.1%
Space Cooling	22.11	29.34	-7.23	-32.7%
IAQ Ventilation	1.64	1.64	0.00	0.0%
Water Heating	15.32	21.65	-6.33	-41.3%
Photovoltaic Offset	----	-12.08	12.08	----
Compliance Energy Total	53.44	47.44	6.00	11.2%

HERS FEATURE SUMMARY
The following is a summary of the features that must be field-verified by a certified HERS Rater as a condition for meeting the modeled energy performance for this computer analysis. Additional detail is provided in the building components tables below.
Building-level Verifications: • High Quality Insulation Installation (QII) • IAQ mechanical ventilation Cooling System Verifications: • Minimum Airflow • Verified SEER • Fan Efficacy Watts/CFM HVAC Distribution System Verifications: • Duct Sealing • Ducts located entirely in conditioned space confirmed by duct leakage testing Domestic Hot Water System Verifications: • Compact Design

WATER HEATING SYSTEMS					
01	02	03	04	05	06
Name	System Type	Distribution Type	Water Heater	Number of Heaters	Solar Fraction (%)
DHW Sys 1 - 1/1	DHW	(HERS req'd) Compact Distribution System	DHW Heater 1	1	.0%

WATER HEATERS									
01	02	03	04	05	06	07	08	09	10
Name	Heater Element Type	Tank Type	Tank Volume (gal)	Energy Factor/Efficiency	Input Rating/Pilot	Tank Insulation R-value (Int/Ext)	Standby Loss (Fraction)	Heat Pump Type	Tank Location or Ambient Condition
DHW Heater 1	Gas	Small Storage	50	0.6 EF	40,000 Btu/hr	0		NA	NA

Performance Method Compliance Results for Habitat for Humanity Case Study Residence with 0.60 EF 50 gallon gas water heater, compact distribution, plus QII, excerpts from Form CF1R-PRF-01 highlighting the water heating system, Energy Commission approved software version CBECC-Res 2016.2.0 (857)

The substantial change is the result of reducing the water heater efficiency from 0.82 EF to 0.60 EF, even though each of those values is the minimum mandatory efficiency for the particular water heater type in the federal appliance efficiency standards. This is why prescriptive compliance for a small storage gas water heater requires QII and compact design or HERS-verified hot water pipe insulation, but tankless gas water heaters with 200,000 Btu/hr input or less comply prescriptively with standard distribution and standard insulation (see below).

One 82% EF Gas Tankless Water Heater with Standard Distribution, no QII

This scenario models the case study 0.82 EF tankless gas water heater with standard distribution and no QII to show baseline tankless gas water heater compliance meeting prescriptive package A. The performance method Energy Use Summary shows the water heating proposed design is exactly the same as the water heating standard design of 15.32 kTDV/ft^2-yr, since this particular water heating system is used in the 2016 Residential ACM Reference Manual to set the standard design water heating energy budget:

ENERGY USE SUMMARY

04	05	06	07	08
Energy Use (kTDV/ft^2-yr)	Standard Design	Proposed Design	Compliance Margin	Percent Improvement
Space Heating	14.37	10.19	4.18	29.1%
Space Cooling	22.11	30.44	-8.33	-37.7%
IAQ Ventilation	1.64	1.64	0.00	0.0%
Water Heating	15.32	15.32	0.00	0.0%
Photovoltaic Offset	----	-12.08	12.08	----
Compliance Energy Total	53.44	45.51	7.93	14.8%

HERS FEATURE SUMMARY

The following is a summary of the features that must be field-verified by a certified HERS Rater as a condition for meeting the modeled energy performance for this computer analysis. Additional detail is provided in the building components tables below.

Building-level Verifications:
- IAQ mechanical ventilation

Cooling System Verifications:
- Minimum Airflow
- Verified SEER
- Fan Efficacy Watts/CFM

HVAC Distribution System Verifications:
- Duct Sealing
- Ducts located entirely in conditioned space confirmed by duct leakage testing

Domestic Hot Water System Verifications:
- -- None --

WATER HEATERS

01	02	03	04	05	06	07	08	09	10
Name	Heater Element Type	Tank Type	Tank Volume (gal)	Energy Factor/Efficiency	Input Rating/Pilot	Tank Insulation R-value (Int/Ext)	Standby Loss (Fraction)	Heat Pump Type	Tank Location or Ambient Condition
DHW Heater 1	Gas	Small Instantaneous	NA	0.82 EF	200,000 Btu/hr	0	0	NA	NA

Performance Method Compliance Results for Habitat for Humanity Case Study Residence with 0.82 EF tankless gas water heater, standard distribution, no QII, excerpts from Form CF1R-PRF-01 highlighting the water heating system, Energy Commission approved software version CBECC-Res 2016.2.0 (857)

Compared to the original case study with the same tankless gas water heater, the proposed compliance energy total here has gone down from 24.6 to 14.8 percent better than the Energy Standards because of the savings lost by removing the compact design and QII energy-efficiency measures. It is interesting that this is still better than the performance method results of the prescriptively complying storage gas water heating system from the previous scenario.

One 60% EF 50 Gallon Tank Water Heater with Standard Distribution, no QII

A main advantage of using the Performance Approach is to analyze the energy compliance of building features that do not meet prescriptive requirements, so here are the compliance results of the case study house with the 0.60 EF small storage gas water heater, but this time with standard distribution and no QII:

ENERGY USE SUMMARY				
04	05	06	07	08
Energy Use (kTDV/ft^2-yr)	Standard Design	Proposed Design	Compliance Margin	Percent Improvement
Space Heating	14.37	10.19	4.18	29.1%
Space Cooling	22.11	30.44	-8.33	-37.7%
IAQ Ventilation	1.64	1.64	0.00	0.0%
Water Heating	15.32	22.44	-7.12	-46.5%
Photovoltaic Offset	----	-12.08	12.08	----
Compliance Energy Total	53.44	52.63	0.81	1.5%

HERS FEATURE SUMMARY

The following is a summary of the features that must be field-verified by a certified HERS Rater as a condition for meeting the modeled energy performance for this computer analysis. Additional detail is provided in the building components tables below.

Building-level Verifications:
- **IAQ mechanical ventilation**

Cooling System Verifications:
- **Minimum Airflow**
- **Verified SEER**
- **Fan Efficacy Watts/CFM**

HVAC Distribution System Verifications:
- **Duct Sealing**
- **Ducts located entirely in conditioned space confirmed by duct leakage testing**

Domestic Hot Water System Verifications:
- **-- None --**

WATER HEATERS									
01	02	03	04	05	06	07	08	09	10
Name	Heater Element Type	Tank Type	Tank Volume (gal)	Energy Factor/Efficiency	Input Rating/Pilot	Tank Insulation R-value (Int/Ext)	Standby Loss (Fraction)	Heat Pump Type	Tank Location or Ambient Condition
DHW Heater 1	Gas	Small Storage	50	0.6 EF	40,000 Btu/hr	0		NA	NA

Performance Method Compliance Results for Habitat for Humanity Case Study Residence with 0.60 EF 50 gallon gas water heater, standard distribution, no QII, excerpts from Form CF1R-PRF-01 highlighting the water heating system, Energy Commission approved software version CBECC-Res 2016.2.0 (857)

This time, the water heating energy use has a negative compliance margin of -7.12 kTDV/ft^2-yr and the proposed space heating and cooling energy use have gone up substantially due to no QII, but the overall compliance energy total still shows the house complying with the Title 24 Energy Standards by 1.5 percent.

One 62% EF 50 Gallon Tank Water Heater, Pipe Insulation, Solar Hot Water

Increasing energy factor, adding HERS-verified hot water pipe insulation, and installing a solar water heating system are other performance method alternatives to reduce water heating energy use and improve overall energy compliance without requiring QII or compact design. In this example, the case study residence is modeled with a 50 gallon gas water heater with the energy factor increased from 0.60 EF to 0.62 EF, plus HERS-verified hot water pipe insulation, and a solar hot water system with a 50% solar fraction. This set of water heating measures improved the water heating compliance margin from a negative -7.12 kTDV/ft^2-yr to a positive 0.44 kTDV/ft^2-yr, and allowed the building overall to exceed the Energy Standards by 15.7 percent instead of only 1.5 percent.

See the next page for details.

ENERGY USE SUMMARY				
04	05	06	07	08
Energy Use (kTDV/ft^2-yr)	Standard Design	Proposed Design	Compliance Margin	Percent Improvement
Space Heating	14.37	10.19	4.18	29.1%
Space Cooling	22.11	30.44	-8.33	-37.7%
IAQ Ventilation	1.64	1.64	0.00	0.0%
Water Heating	15.32	14.88	0.44	2.9%
Photovoltaic Offset	----	-12.08	12.08	----
Compliance Energy Total	53.44	45.07	8.37	15.7%

REQUIRED SPECIAL FEATURES

The following are features that must be installed as condition for meeting the modeled energy performance for this computer analysis.

- **PV System: 2.8 kWdc**
- **Raised heel truss**
- **Ceiling has high level of insulation**
- **Floor has high level of insulation**
- **Advanced wall framing included (see opaque surface constructions)**
- **Non-standard duct location (any location other than attic)**
- **Solar water heating credit, single family building Special feature and additional documentation**
- **Pipe insulation, all lines**

The following is a summary of the features that must be field-verified by a certified HERS Rater as a condition for meeting the modeled energy performance for this computer analysis. Additional detail is provided in the building components tables below.

Building-level Verifications:
- **IAQ mechanical ventilation**

Cooling System Verifications:
- **Minimum Airflow**
- **Verified SEER**
- **Fan Efficacy Watts/CFM**

HVAC Distribution System Verifications:
- **Duct Sealing**
- **Ducts located entirely in conditioned space confirmed by duct leakage testing**

Domestic Hot Water System Verifications:
- **Pipe Insulation, All Lines**

WATER HEATING SYSTEMS					
01	02	03	04	05	06
Name	System Type	Distribution Type	Water Heater	Number of Heaters	Solar Fraction (%)
DHW Sys 1 - 1/1	DHW	(HERS req'd) Pipe Insulation, All Lines	DHW Heater 1	1	50.0%

WATER HEATERS									
01	02	03	04	05	06	07	08	09	10
Name	Heater Element Type	Tank Type	Tank Volume (gal)	Energy Factor/Efficiency	Input Rating/Pilot	Tank Insulation R-value (Int/Ext)	Standby Loss (Fraction)	Heat Pump Type	Tank Location or Ambient Condition
DHW Heater 1	Gas	Small Storage	50	0.62 EF	40,000 Btu/hr	0		NA	NA

Performance Method Compliance Results for Habitat for Humanity Case Study Residence with 0.62 EF 50 gallon gas water heater, HERS-verified hot water pipe insulation, 50. solar fraction, no QII, excerpts from Form CF1R-PRF-01 highlighting the water heating system, Energy Commission approved software version CBECC-Res 2016.2.0 (857)

CHAPTER 7

APPENDIX

Glossary

Efficiency Terms

EER – Energy Efficiency Ratio describes the efficiency of a DX cooling system. It is the cooling provided (measured in Btu) divided by the electricity consumed (in Watt-hrs) at a given set of indoor and outdoor temperatures. Cooling systems have a rated EER that is measured at a specific set of temperatures as defined by a rating standard. These temperatures are 95°F outdoor temperature with an indoor temperature of 80°F and 50% relative humidity. Actual operating EER can be determined, and will vary as conditions vary. The electricity consumption included in the EER includes that used by the refrigerant compressor, the condenser unit fan, the indoor fan and the controls.

SEER – Seasonal Energy Efficiency Ratio is a rating value that defines the expected efficiency of a DX cooling system (including the cooling performance of a heat pump system) over the full cooling season. It is calculated by measuring the EER of the system at 8 different outdoor temperatures, ranging from 65°F to 104°F. Each of the eight EER values are weighted based on the expected frequency of that temperature occurring and the associated cooling load at each temperature to calculate the SEER. Because typical operating conditions are weighted more than extreme conditions, the SEER is intended to represent the actual operating efficiency of a cooling system better than the rated EER.

AFUE – Annual Fuel Utilization Efficiency is a measure of the efficiency of gas, propane or oil fired combustion appliances, such as furnaces, boilers and water heaters. It is the heat delivered by the appliance divided by the fuel energy supplied, both values expressed in the same units (typically Btus) and expressed as a percentage. The heat energy supplied value is reduced by including various losses in the system. The AFUE is a rating value that is intended to represent the overall annual efficiency of the unit. The operating efficiency of the system will vary based on actual conditions. Any electricity consumption by the appliance, such as for a combustion fan or for controls, is not included in the AFUE value.

HSPF – Heating Seasonal Performance Factor describes the heating efficiency of heat pump systems. It represents the total heating provided over the heating season divided by the electricity used by the system. The units are the same as for EER or SEER, Btu/

Ground Pipe Looping for Ground Source Heat Pump

Watt-hr. The HSPF is determined at a series of specified conditions, and the results are then combined, similar to the weighting procedure used to determine SEER.

Btu – British Thermal Unit is a unit of energy that is commonly used to describe heating or cooling energy. A Btu is the amount of energy needed to heat up (or cool down) one pound of water by 1°F.

Btuh – Btu per hour is used to describe the rate at which heating or cooling is being provided. A particular piece of equipment will have a rated capacity in Btuh that describes how much heating or cooling the unit can do. Btuh is also used to describe how much heating or cooling is being provided by an operating piece of equipment at a given time, and also to describe the amount of heating or cooling a house needs.

Ton is a unit of cooling capacity. It is equal to 12,000 Btuh, so the numbers are typically easier to grasp quickly. A typical home air conditioner may have a rated capacity of 60,000 Btuh, equal to 5 tons.

cfm – Cubic feet per minute is used to describe the flowrate of a fan, such as that in the indoor unit of a residential heating and air conditioning system. The indoor unit for a 5 ton air conditioner will have a flowrate of around 2,000 cfm.

Condenser – A condenser is part of a cooling system that rejects heat removed from the conditioned space. On a split system air conditioning system the condenser is in the outdoor unit. However, packaged units also include a condenser section. Heat is rejected by the condenser because when the refrigerant is compressed, it gets hot. It is then pumped through the outdoor coil, where a fan blows outdoor air over the hot coil, cooling it down by transferring heat to the outdoor air.

Coil – A coil is a length of tubing arranged in a serpentine or circular pattern, allowing a considerable length of tubing to be packed into a relatively small space. These coils are used for exchanging heat between the air on one side with the fluid in the tubes. Coils are used in multiple places in HVAC systems, typically including cooling coils and furnace coils in air handlers, condenser coils in the outdoor units of air conditioned systems, and various forms of heat exchanger or heat recovery systems. Note that some modern coils, notably furnace coils, have evolved beyond tubing configurations to more complex shapes.

Air handler – An air handling unit is a set of components in a single package which always includes a fan to move air. Air handlers typically also include heating and cooling coils, mixing dampers for economizer control, temperature controls, and filters. The air handler in a residential forced air HVAC system will typically include the fan, filters, furnace or heat pump heating coil, and air conditioning coil.

Airflow Concepts

Static pressure – Air moves through a duct system due to pressure differences, moving from a location of high pressure to one of lower pressure. The pressure that causes the air to move is the static pressure. As a duct system becomes longer, has smaller cross section, and has more obstructions, the static pressure needed to achieve a given flow rate (cfm) increases. The static pressure needed to move air through the duct system is provided by the fan. The static pressure that will be needed to move air through the system is a key parameter to be considered when selecting a fan.

Velocity – Velocity is a technical term which is generically called speed. As used when discussing HVAC systems, as a fluid moves through a system, it will have a rate of movement which is called its velocity. The fluids might be air through a duct, or water or refrigerant through a pipe. Velocity is typically measured in feet per minute (fpm or ft/min) or feet per second (fps or ft/s).

Fan Efficacy – Work output divided by power input. For fans, the efficacy is measured in air flow rate (cfm) per power input (Watt), therefore the unit for fan efficacy is (cfm/W). Like the miles per gallon rating, higher is better.