2016 TITLE 24, PART 6
NONRESIDENTIAL

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 nonresidential 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 code 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

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NONRESIDENTIAL
HVAC AND PLUMBING
APPLICATION GUIDE

CONTENTS

CHAPTER 1

INTRODUCTION

The Benefits of Efficiency

Cost Savings

Energy efficient commercial buildings create real savings for owners every month in the form of reduced utility bills. For many businesses, reducing monthly expenses results in a more profitable business and, with low maintenance costs, energy efficient design and construction may provide persistent savings to the owner.

Increased Comfort

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

Progress Toward Energy Efficiency Goals

Efficient equipment selection, proper installation, commissioning, and similar provisions of the Energy Standards are getting California closer to its Zero Net Energy (ZNE) goal. Efficiency measures in plumbing design and controls paired with the water flow reductions mandated by CALGreen Standards contribute energy savings through the water-energy nexus.

Rooftop HVAC Installation

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 nonresidential Energy Standards. It also contains information on the associated commissioning, acceptance testing and Home Energy Rating System (HERS) processes.

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 principles and commissioning and other quality assurance processes.

Technology Systems & Compliance Strategies

In Chapter 4, technologies that are commonly used for compliant buildings, and discussions about systems and controls applications are included. This chapter also includes insight into designing to accommodate crossover with other building codes.

Navigating the Compliance Strategy

Requirements related to nonresidential HVAC & plumbing systems are discussed in Chapter 5, along with applications for common project scenarios.

Recommendations, Resources and Coordination

Chapter 6 contains discussion around using energy simulation software and finding help with compliance when the project warrants it.

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 • Duplexes • Low-rise residential building envelope • Climate specific design • Insulation • Cool Roofs • Single Family Solar Ready including Solar Zone • 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 Code Ace.	

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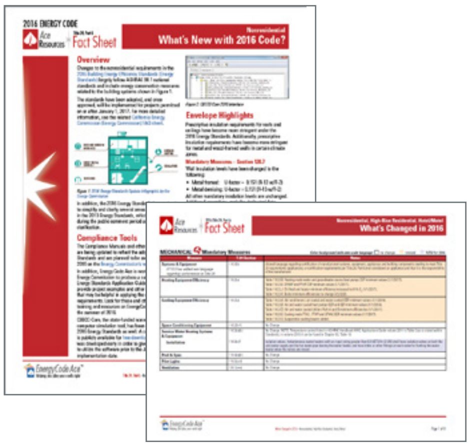


What's New and What's Changed Fact Sheets

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.

New Mandatory Efficiency Requirements

The 2016 Energy Standards changed the mandatory efficiency language for heating, cooling and other related equipment in Tables 110.2 A-K to reference Title-20 regulations.

Section 120.2 outlining HVAC Controls includes both minor changes and significant ones. Table 120.2-A, which is entirely new in the 2016 Standards, outlines when DDC is required at the zone. In addition, space conditioning systems with DDC to the zone level are now required to have optimum start/stop controls.

In addition, §110.3(c)7 now requires isolation valves for instantaneous water heaters with an input rating greater than 6.8 kBTU/hr (2kw). Isolation valves are required on both the cold water supply and the hot water pipe leaving the water heater, and hose bibs or other fittings on each valve for finishing the water heater when the valves are closed.

New Prescriptive Requirements

The 2016 Energy Standards updated the thresholds for Direct Expansion (DX) units, greater than 65,000 Btuh to have 2 stages of mechanical cooling. Language also was updated to include all DX cooling units, chilled water, and evaporative cooling systems with more than ¼ horsepower fans to include variable speed drives.

Energy Management Control Systems (EMCS) were added to §120.2 (a) to allow for a path to compliance with this technology if it meets requirements for each thermostat in the areas controlled.

New prescriptive control requirements were added in §140.4(n) to shut off or setback mechanical systems when operable windows or doors are opened to a directly conditioned space for more than 5 minutes. This new control requirement adds complexity to architectural systems interacting with HVAC systems requiring sensors at active windows. For instance a classroom window system with the casement windows below and awning windows above require sensors at each individual opening. This may be coordinated with security system sensors to trigger control of the HVAC systems.

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.

Find recorded decoding talks here: energycodeace.com/content/decoding-talks/

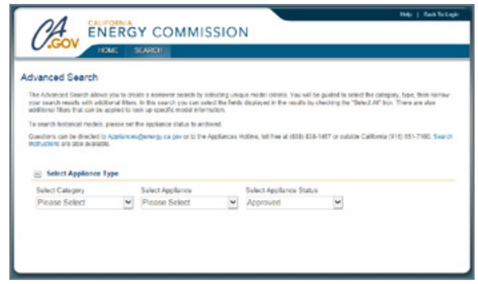
Finding Compliant Products

HVAC and Domestic Hot Water (DHW) Equipment

Locating compliant products for HVAC equipment is fairly straightforward for smaller manufactured equipment because they are regulated by the State's Appliance Efficiency Standards (Title 20) and technically can't be sold or installed in the state without meeting minimum efficiency standards. As you move into larger custom HVAC units and built up systems, the minimum efficiency requirements are defined in the Energy Standards in §110.2. Minimum efficiency requirements for water heating equipment is in §110.3

HVAC Controls

Mechanical controls that are dictated by the design choices are outlined in the Energy Standards in §120.2 and will vary based on the type of equipment. For example, the thermostat controls would be different for a single zone air conditioner versus a built up system with direct digital controls (DDC). Standard §120.2(b) would have the designer install automatic demand shed controls, when DDC is present, that would allow a temperature setback in times of grid stress as outlined in §120.2(h). These two systems would require very different specifications to adhere to the requirements between the single zone system and the DDC demand shed controlled system. This small example shows the potential coordination between energy code decision making, design specification, contractor purchasing, acceptance testing requirements, and commissioning requirements. Controls are one of the major items under the commissioning purview that have significant impacts on the long term operation and efficiency of the building.



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/Login.aspx

Title 24, Part 6 Essentials Training

Offered in traditional classroom and virtual formats, participants learn about navigating key nonresidential 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 – Nonresidential Standards for Plans Examiners and Building Inspectors
- Title 24, Part 6 Essentials – Nonresidential Standards for Energy Consultants
- Title 24, Part 6 Essentials – Nonresidential Standards for Architects

Find dates for upcoming classes: energycodeace.com/training


INDUSTRIAL COLD
SUPPLY
DOMESTIC HOT WATER
DOMESTIC HOT WATER RETURN
DANGER

CHAPTER 2

COMPLIANCE PROCESS

The following is an overview of the compliance process for nonresidential HVAC, plumbing, and commissioning requirements. Additional information and resources, including the 2016 Nonresidential 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, project 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

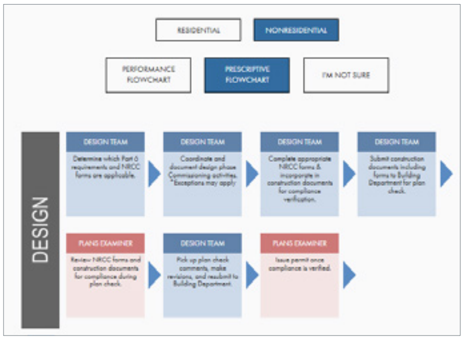
All nonresidential buildings that are regulated occupancies must be designed and built to comply with the mandatory measures of Title 24, Part 6. For HVAC, domestic hot water, and plumbing, there are a number of mandatory elements for minimum equipment efficiency, minimum ventilation, controls, insulation, commissioning and verification testing among others. Mandatory measures are further detailed in Chapter 5 of this guide.

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:

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 projects where design elements are unable to meet prescriptive requirements (for example window to wall ratios above 40%). New construction projects commonly follow the performance approach because of the flexibility allowed by trading efficiency options between the envelope, mechanical, and lighting systems.

Distribution System



The Navigator Ace™ is your roadmap to energy code 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/

For resources on non-regulated commissioning activities and best practice applications, private non-profit groups like the California Commissioning Collaborative provide guidance through their website: cacx.org/index.html

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.

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 in 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 certificate of compliance forms (NRCC) 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 do not need to be registered for nonresidential projects.

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 and 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 Certificate Of Compliance forms during construction. Coordination will be required between installers, designers, HERS Raters, the Commissioning Authority (CxA), Acceptance Test Technicians (ATT), and building inspectors to properly install and verify compliant installation. During construction, Certificates of Installation (NRCI) are completed in preparation for inspection.

Step 6: Test and Verify Compliance

When a HERS Rater, Acceptance Test Technician and/or Commissioning Authority are required by Title 24, Part 6, early coordination is encouraged to understand when inspections and testing are necessary during the construction process and incorporated into the schedule. Many system inspections are time sensitive as inspections may be infeasible after walls or other barriers are installed.

Commissioning

Once building systems become functional, a designated CxA must properly commission the building systems for newly constructed buildings with a conditioned floor area (cfa) of 10,000 ft^2 or larger. They also must ensure facility managers receive building system manuals and training on how to maintain and operate the building and its energy features. More in depth discussion on commissioning requirements is included in Chapter 4 of this guide.

Home Energy Rating System (HERS)

Title 24, Part 6 requires field testing and verification of certain systems, as well as registration of Certificates of Verification 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 California Energy Commission (Energy Commission) can be found on their website at energy.ca.gov/HERS/providers.html

Acceptance Testing

Once a certain number of Acceptance Test Technicians (ATTs) have been certified, Title 24, Part 6 will require that Certified Acceptance Test Technicians (ATTs) review and test mechanical systems, hydronic systems, and control installations to ensure controls operate as required by the Energy Standards. Until the threshold is met, the test is still required but does not have to be performed by a certified technician.

ATTs trained and certified through an approved curriculum provider will:

- Perform a construction inspection to ensure that what has been installed is consistent with the Certificates of Compliance, Certificates of Installation, and associated documentation as approved by the local jurisdiction.
- Test installations to ensure controls are positioned and calibrated to operate in compliance with the Energy Standards including the approved certificates and associated documentation.
- Check that all necessary set points or schedules are in place as required by the Energy Standards including the approved certificates and associated documentation.
- Fill out required Certificates of Acceptance and submit these to the general contractor or the identified responsible person (i.e., engineer, architect, commissioning agent) who will be responsible for submitting them to the enforcement agency.

Visit energy.ca.gov/title24/attcp for information on ATT certification providers, and notification of when certified ATTs will be required.

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. These include the final commissioning documents, operations manuals, and documentation that training has occurred if required.

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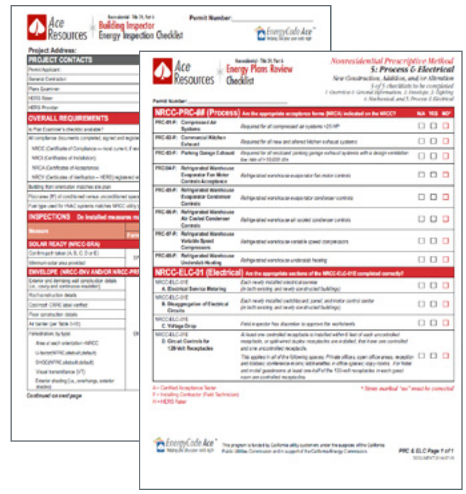

Plans Examiners and Building Inspector Checklists

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/

Nonresidential 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.

Form Naming Convention

Nonresidential → NRCC-PLB-02-E

Document Category

CXR = Commissioning Design Review
ELC = Electrical
ENV = Envelope
LTI = Indoor Lighting
LTO = Outdoor Lighting
LTS = Sign Lighting
MCH = Mechanical
PLB = Plumbing (DHW)
PRC = Covered Process
PRF = Performance approach
SRA = Solar Ready
STH = Solar Thermal

Document Type

Certificates of...
CC = Compliance
CI = Installation
CA = Acceptance
CV = Verification

Primary User

E = Enforcement agency
H = HERS Rater
F = Field Technician (Contractor)
. . Acceptance Test Tech

Certificates of Compliance

The Certificate of Compliance (NRCC) documents the building features required to comply with Title 24, Part 6, for nonresidential, high-rise residential, and hotel/motel buildings. These features will vary depending on the particular project and the compliance approach used. NRCCs are submitted to the building department as part of the building permit application (See Step 3 of the compliance process description).

Certificates of Installation

The Certificate of Installation (NRCI) documents that the building features actually installed in the field match those required in the Certificates of Compliance. NRCIs must be completed and signed by the installer or builder responsible for installing different building components. (See Step 5 of the compliance process description).

Certificates of Acceptance

The Certificate of Acceptance (NRCA) certifies that the building systems and equipment, as installed in the field, function and perform the way they were designed. NRCAs must be completed and signed by the test technician performing the acceptance test. See Step 6 of the compliance process description. For some lighting and mechanical tests, the Certificate of Acceptance must be completed and signed by a certified Acceptance Test Technician, as well as a "responsible person" who may be the technician, but needs to be someone who takes reasonability for the performed tests such as an employer or contractor. Note that until the threshold is met, the test is still required but does not have to be performed by a certified technician.

Certificates of Verification

The Certificate of Verification (NRCV) is used to document nonresidential HERS Measures, and is completed by a HERS Rater. The NRCV is most commonly used to document duct sealing, a prescriptive measure, but is also used to document nonresidential HERS measures for projects pursuing the performance path. These must be registered in the HERS registry.

Compliance Documents

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

Click here to access the forms: energy.ca.gov/2015publications/CEC-400-2015-033/appendices/forms/

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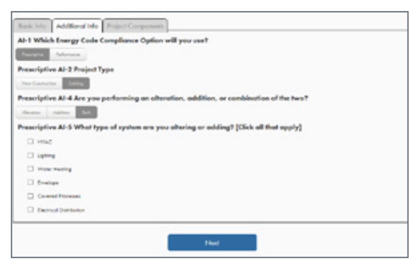


The Forms Ace aids in determining which compliance forms are applicable to your specific project.

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

CHAPTER 3

CONCEPTS & PRINCIPLES

Integrated Design & Construction Principles

The requirements of the Energy Standards reach most of the main components of the architectural, mechanical, plumbing, electrical, lighting and process systems. They also involve substantial coordination with Title 24 Part 11, commonly referred to as CALGreen.

Compliance with the Energy Standards involves a significant team effort including:

- Identifying, understanding, and applying the requirements,
- Completing documentation,
- Going through the permit process,
- Installing per permitted documentation, and
- Undergoing on-site verification during construction.

The key to success is an integrated design and construction process which requires deep coordination of the team members working toward the energy efficiency goals. Coordination of mandatory elements, prescriptive or performance approach, acceptance testing, and commissioning requirements during construction is required to achieve a final certificate of occupancy.

Building System Interactions

Part of the reason the Energy Standards are so complicated is because building science, and the way the systems interact is complicated. Integrated design and construction is critical to energy efficiency because it breaks down silos created by the typical design and construction process. Typically, responsibility for the envelope, mechanical, electrical, lighting and plumbing systems is divided among team members, and during construction is divided out further by component (insulation, fenestration, doors, etc.). However, in order to achieve deeper energy efficiency, the interactions between these systems must be understood and considered during design and construction. Chapter 6 uses the nonresidential performance form (NRCC-PRF-01-E) to discuss how these interactions affect compliance.

Rooftop Unit

Commissioning Fact Sheet

This Fact Sheet breaks down the Commissioning process as it applies to Title 24, Part 6, triggers at a glance.

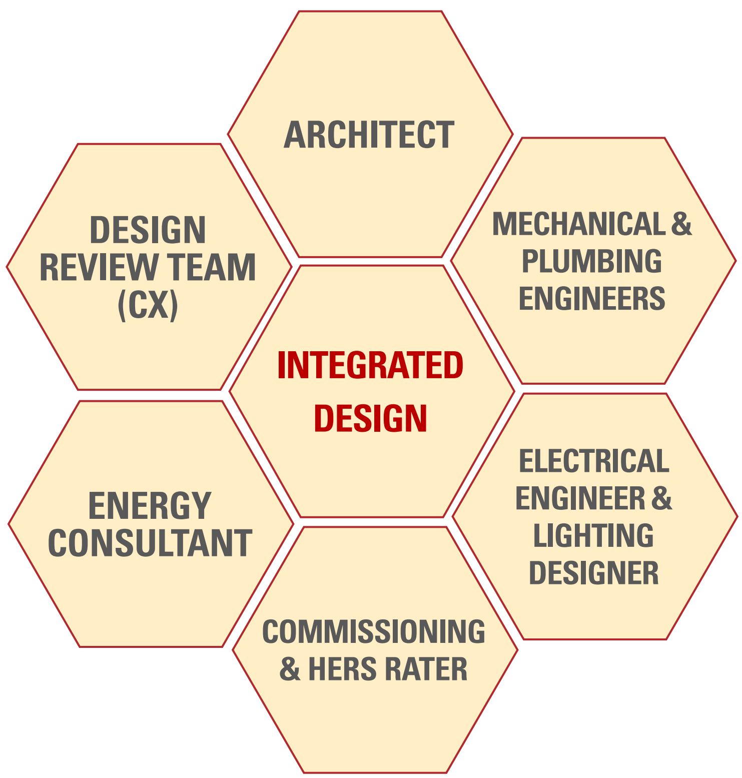
Find it here: energycodeace.com/content/resources-fact-sheets

Design Review Kickoff

The Energy Standards work toward addressing the necessary team coordination in §120.8. Well before a construction permit is issued, starting in schematic design, all newly constructed nonresidential buildings that are conditioned (not including high rise residential and hotel/motel occupancies) will be required to conduct a design review kickoff meeting per the commissioning requirements. During the design review kick off meeting the team should establish clear roles for compliance requirements, scheduling the Construction Document level design review, and state in the design schedule when construction documentation must be completed. At this early stage of every project, the design team players should have coordination items clearly identified as well as an initial path for attaining compliance. As the project progresses into design development there should be regular check-in sessions, compliance checks, and performance models created (if that pathway is chosen) to help the design team stay on track to a compliant design. All of these elements can be included in the design schedule during the design review kickoff.

Design Review

In the construction document phase of the project, a design review is required for all nonresidential newly constructed conditioned projects as part of documenting compliance with the Energy Standards. The design review forms will be completed, normally by a engineer, architect, or the designated Commissioning Authority (CxA). By reviewing each item on the NRCC-CXR-02/03/04-E forms, envelope, HVAC, and plumbing systems in the project (that require compliance) will be verified as compliant prior to permit application.



Commissioning & Acceptance Testing

These performance assurance processes are required in §120.8 (commissioning) and throughout other sections of the Energy Standards (acceptance testing). Chapter 13 of the Nonresidential Compliance Manual includes a summary of acceptance tests. The equipment that needs on-site installation verification and/or acceptance tests will be identified in the compliance forms noting the appropriate testing agency. This helps identify testing required for the construction team. It also helps define the project budget for testing.

Defining and Responding to Owner Requirements

For projects with conditioned floor area (cfa) greater than 10,000 ft^2 (see Table below) the building owner must complete an Owner's Project Requirements (OPR) document. The OPR typically outlines what the project intent is, how the owner wants the project delivered, and what standards of design should be used according to the site use allowed by the authority having jurisdiction. The OPR also dictates goals for the project including energy code compliance details, reach goals (% beyond code) if any, and compliance requirements with other standards such as the California Mechanical Code, Green Building Standards, and others that apply to the project. The OPR is ideally developed by the owner or facility manager, but in many cases its development is facilitated by the commissioning professional and/ or design team.

The design team is responsible for developing the Basis of Design (BOD) which is in response to the OPR. The BOD dictates how the design team will execute the design, the criteria for sizing equipment, type of equipment, ventilation rates, controls required, and a host of other elements that will shape the project.

The OPR and BOD documents together provide a roadmap for designers in the early stages of a project. These documents may evolve throughout the design to capture changes due to adjustments in the owner's needs, design challenges, and construction cost. In the concept and schematic design phases, choices are made for system types, technology used, control requirements, code triggers, and permit application requirements. From these decisions the compliance path can be chosen, permit issues identified, HERS and commissioning processes developed, and design started. Chapter 4 in this guide discusses system selection related to a project's compliance strategy.

Including Commissioning in the Construction Documents

Per the table below, all newly constructed nonresidential projects are required to address commissioning in the construction documents.

Commissioning Requirements	CFA		When
	<10kft²	≥ 10k ft2	
Owner's Project Requirements (OPR) (§120.8(b))		X	Pre-Design
Basis of Design (BOD) (§120.8(c))		X	Draft during Schematic Design, update as necessary
Design Review (§120.8(d))	X	X	Preliminary at 50% Design / Final at 90% Design
Commissioning specifications in Construction Docs (CD) ((§120.8(e))	X	X	Draft at 50% Design / Final at 90% Design
Commissioning Plan (§120.8(f))		X	Draft at 90% Design / Final during Construction
Functional Performance Tests (§120.8(g))		X	Construction
Operation & Maintenance (O&M) Training (§120.8(h))		X	Occupancy
Commissioning Report (§120.8(i))		X	Draft during Construction / Final during Occupancy

Commissioning Requirements in Title 24, Part 6

If the project has cfa less than 10,000 ft², this requirement can be met by including everything in the plans and specifications necessary to satisfy the design review. If the project has a conditioned floor area (cfa) of 10,000 ft² or greater, this will likely be done in the form of commissioning specifications. Commissioning specifications are extremely important, as they will communicate to bidding subcontractors what will be expected during construction phase commissioning activities. Multiple trades including mechanical, plumbing, electrical, testing and balancing (TAB), controls, etc. will need to participate in functional performance testing and commissioning, and these trades need to include this participation in their bids.

Drafting the Commissioning Plan

Projects that require a commissioning plan will draft one towards the end of design, and it will be finalized in the early phases of construction. The plan outlines what to expect during commissioning activities, what equipment will be tested and the roles and responsibilities of team members to the owner, designers and construction team members. The plan builds upon the commissioning specifications, but is typically more specific to the project because subcontractors have been selected by the time it is finalized. Chapter 12 of the Nonresidential Compliance Manual does a good job of explaining what must be included in the commissioning plan for compliance with the Energy Standards.

Value Engineering and Substitutions

There are a couple periods during bidding and construction that have notable impacts on energy code compliance that often go unnoticed. The first is value engineering or contractor substitutions. This common practice in the construction process has traditionally been a challenge for compliance since it requires careful attention to the design intent by contractors. Therefore, when contractors present an alternate to what is proposed in the design, it is up to the responsible designer to make sure the product or practice can still meet the Energy Standards.

Each small component of the building may face substitution and requires careful consideration of how the substitution may affect compliance in the submittal approval process. If substitutions impact code compliance, these substitutions must be documented for the approval agency via the certificate of compliance (NRCC).

Code in Practice

If storefront glass with a high performance product is substituted for a less expensive alternative without equal energy performance it may be accepted based on the material specification but could have enormous impacts on energy code compliance, daylighting potential, load calculations, and possibly HVAC equipment.

Functional Performance Testing

For nonresidential projects with conditioned floor area greater than or equal to 10,000 ft², the CxA will manage and oversee the functional performance test required by the energy code. In coordination with the acceptance testing technician (ATT) and the installing contractors, the equipment will be tested upon startup, verified, and adjusted if needed to meet the requirements of the Energy Standards.

Documentation, Training, & Operations Manual Handover

If required in §120.8, the CxA assigned to the project is responsible for collecting the documentation for the equipment installed and developing a systems manual tailored to the project, called the operations manual. This document includes a description of the facility, space, function, and operations information. It should include a list of equipment, maintenance needs, schedules of operations, and other information necessary to operate and maintain the mechanical equipment in addition to lighting and other regulated equipment. The operations manual is intended to be used like a quick reference guide for the building operator.

Systems operation training must be completed for nonresidential conditioned buildings greater than or equal to 10,000 ft^2 of conditioned floor area. Evidence of the training is documented by the commissioning agent. The design and construction team provide the building operators instruction and demonstration on how to start up the equipment, maintenance practices, interactions with building management systems, and other equipment elements necessary for daily operations.

A final commissioning report and systems manual will be provided to the building owner (or owner's representative) and operators when the building is handed over. The intent of the commissioning process is to make sure the building is operating as designed, and the people operating the building are trained in how to maintain the designed efficiency throughout the life of the building.

CHAPTER 4

TECHNOLOGY, SYSTEMS AND COMPLIANCE STRATEGIES

Choosing a System

Based on criteria for the project, such as available utilities, climate, operating schedules, etc., the design team must specify the appropriate HVAC equipment. Architectural loads often are a significant driver of system size, as mechanical system options can be limited depending on the cooling loads and distribution constraints associated with the building design. If cooling loads can be addressed through building design, this can open the door to efficient technologies such as chilled beams, radiant surfaces, and variable refrigerant volume systems depending on the project goals as defined by the Basis of Design (BOD) documentation process.

Mechanical system design also will be affected by the number of occupants, equipment present, the type of activity, or the air change rates required for fresh air or process in the space. The space load will drive the types of mechanical systems and the approach for space conditioning taking into consideration the ventilation criteria of the project.

For example, a 5,000 ft^2 building that is designed for an office space for 50 people will be very different than the same size space designed for an exercise area with an occupant density of 200 people at a high activity rate. The exercise space will require a high volume of outside air and likely would dictate an air based system. The office building may allow for a minimum outside air system combined with zonal cooling/ variable refrigerant volume systems or even allow for natural ventilation depending on the operable openings to the outside of the architectural design.

Most often the decisions are dictated by building configuration, maintenance requirements, building construction costs, and space restrictions for mechanical systems. These decisions are part of the commissioning process as developed by the design team.

System Technologies

High efficiency mechanical systems are evolving rapidly with the Energy Standards and changing technology. Units with variable refrigerant volume, heat recovery, chilled beams and thermal energy storage systems are just a handful of technologies that are changing the face of mechanical system design as we search for energy saving mechanical designs that are cost effective.

Direct Expansion (DX) HVAC Systems

This includes both rooftop "packaged" units and split systems. Split systems are the most common type of residential heating and cooling system in most of the U.S, but they are somewhat less common in commercial buildings. Split systems, which include both Variable Refrigerant Flow (VRF) mini-splits and traditional split systems, consist of an indoor section, which contains all heating components, as well as the supply fan and cooling coil. Split systems can use heat pumps, furnaces or hot water coils (supplied by a boiler) as their heat sources.

The outdoor section contains the compressor and condenser, with the condenser usually being air cooled, although larger or high efficiency units may have evaporative condensers. Packaged units, as the name implies, contain the same components as a split system, but the components are all housed in a single package, typically on the roof. Less commonly packaged units are located on a concrete pad adjacent to an exterior wall with ducting running in to and out of the building.

Heat pumps are a special category of packaged or split system in which the heating is accomplished exactly like the cooling for a standard split or packaged unit, but heating is supplied by reversing the flow of refrigerant, and "cooling" the outdoors during cold weather and capturing the condenser heat to warm the building. Heat pumps typically use ambient air as their heat sink/source, but more efficient units utilize either the ground or available bodies of water. All of these systems may be appropriate for smaller commercial buildings where individual room control is required, maintenance is limited, and plenty of space is allocated to mechanical systems. The typical application for split systems, packaged roof top systems, and individual heat pumps are classroom buildings or single story retail buildings with light loads.

Excluding the Variable Refrigerant Flow /Volume (VRF/VRV) systems, all of these system types fall into "simple mechanical systems" under the Energy Standards. The scale of these systems range from 2 tons of cooling up to 10 tons, but packaged units can get much larger.

Large Built Up System

Larger Built Up Systems or More Complex Variable Air Volume Packaged Systems

These systems fall into the category of "complex mechanical systems". Complex mechanical systems are those fan systems serving more than one thermostatically controlled zone, built up system, or other system that is not considered "unitary or packaged" listed under Table 110.2A, B, C or E. The larger built up or variable packaged systems can be scaled to any size cooling or heating load by the design engineers. The larger systems are tailored to constant loads and can be optimized for low part load operation or infrequently operated areas. Part load operation should be considered in the system selection process. Office buildings with fairly constant and predictable occupancy patterns require different design strategies than a highly variable occupancy like an auditorium, conference building, or even a movie theater. These highly variable occupancies require very responsive systems that can respond to a large influx of people to maintain indoor air quality and comfort conditions.

As with larger built up systems, chillers, cooling towers, boilers, and pumping distribution systems will travel a different path through the Energy Standard requirements than most large packaged systems. The largest systems with direct digital control will need to comply with the automatic demand shed control capability integrated into the energy management systems as outlined in §120.2(h).

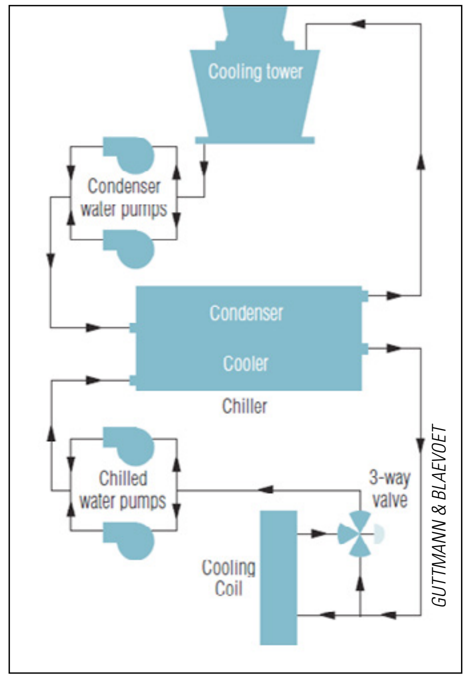
The air based built up systems have specialized requirements. For instance variable air volume systems commonly used to condition medium and large buildings (5,000ft^2 and above normally) have zone control designs that require temperature, airflow, and setback schedules down to the individual rooms in some cases that are serviced by a single air handler. The multiple zone controls need to communicate back to the air handlers for a number of conditions regulated by the Energy Standards. Items like:

- Minimum turndown ratio for VAV/Reheat terminals with DDC systems, §140.4 (c)
- Measurement of outside air to the zone §120.1 (e)
- Limit reheating or re-cooling of air §140.4 (d)

Hydronic Systems

Hydronic systems, like those with chilled water distribution or heating water, enter new territory for pipe insulation which don't apply to most ducted systems. Pipe insulation for heating and cooling systems need to show compliance with §120.3 and Table 120.3-A depending on the pipe size and temperature ranges.

When designing chilled water systems, there are a few sections in the Energy Standards to consider. Chilled water systems nearing the 300-ton cooling load need to consider the prescriptive limitation of air cooled chillers to this threshold. Above 300 tons water cooled chillers must be used unless it qualifies for an exception. One exception allows for air cooled chillers above the 300-ton limit when paired with off peak production with thermal energy storage tanks. Another exemption for this 300-ton limit is when water quality on the site cannot support water cooled equipment (§140.4(i)).



Hydronic System

Efficiency requirements for chillers also are unique compared to packaged or unitary equipment as the efficiency can change based on the chilled water temperatures, types of chillers applied, and part load operation. That's why both full load kW/ton and Integrated Part Load Values (IPLV) are listed in Table 110.2-D for chilled water systems.

Where cooling towers are applied in the central plant, §140.4(h) dictates the thresholds that require fan speed controls, tower water flow turndown, and other requirements mechanical design engineers should adhere to. Energy efficiency for cooling towers is dictated by §110.2 Table G. One new element that was introduced in the 2013 Energy Standards now regulates "blow down" or "bleed off" of cooling tower water (§110.2 (e)). The water use in cooling towers to produce the evaporative cooling effect has two primary losses associated with the process. Evaporation and water normally sent to the sewer system when water is replaced to reduce concentration of minerals in the cooling tower water. The 2016 Energy Standards carry similar language about documentation for maximum achievable cycles of concentration for water quality and flow based control systems in cooling towers above 150 tons. These requirements reduce the amount of water wasted during the cooling tower operations.

Combined Hydronic Heating and DHW Systems

When a building occupancy, such as a high-rise residential or hotel/motel dictates the need for domestic hot water, mechanical equipment for space heating may also be served through a combined hydronic system. In fact, when using the Performance approach, these building types may be compared to a system dependent upon hot water as the heating source (see Table 4 – HVAC system Map and Table 7 – System Descriptions on the next page) based on the number of floors associated with the building.

Building Type	Standard Design
Residential or hotel/motel guestrooms in a building with 3 or fewer floors	System 1 - PTAC
Residential or Hotel/motel guestrooms in a building with 4 or more floors	System 2 - FPFC
Warehouse and light manufacturing space types (per the Appendix 5.4A Schedule column) that do not include cooling in the proposed design	System 9 - HEATVENT
Covered Process	See Table 6 – System Map for Covered Processes
All other space types	See Table 5 – Nonresidential Spaces (Not Including Covered Processes)

Table 4 from the Nonresidential Alternative Calculation Method Reference Manual

System Type	Description	Detail
System 1 – PTAC	Packaged Terminal Air Conditioner	Ductless single-zone DX unit with hot water natural gas boiler
System 2 – FPFC	Four-Pipe Fan Coil	Central plant with terminal units with hot water and chilled water coils, with separate ventilation source
System 3 – PSZ	Packaged Single Zone	Single-zone constant volume DX unit with gas heating
System 4 – RESERVED		
System 5 – PVAV	Packaged VAV Unit	VAV reheat system; packaged variable volume DX unit with gas heating and with hot water reheat terminal units
System 6 – VAVS	Built-up VAV Unit	Variable volume system with chilled water and hot water coils, water-cooled chiller, tower and central boiler
System 7 – SZVAV	Packaged Single-Zone VA. Unit	Single-zone variable volume DX unit with variable speed drive and gas heating
System 8 – RESERVED		
System 9 – HEATVENT	Heating and Ventilation Only	Gas heating and ventilation
System 10 – CRAH	Computer Room Air Handler	Built-up variable volume unit with chilled water, no heating
System 11 – CRAC	Computer Room Air Conditioner	Packaged variable volume DX unit with no heating
System 12 – LAB	Laboratory HVAC System	For floor area < 50,00. ft^2: packaged variable volume system with 100% OA and minimum ventilation rate of 6 ACH For Floor Area>= 50,000 ft^2, built-up VAV (VAVS) with water-cooled chiller and central boiler
System 13 – KITCH	Kitchen HVAC System	Dedicated makeup air unit (MAU) – CHW if building is VAVS, DX otherwise. Dedicated exhaust fan.

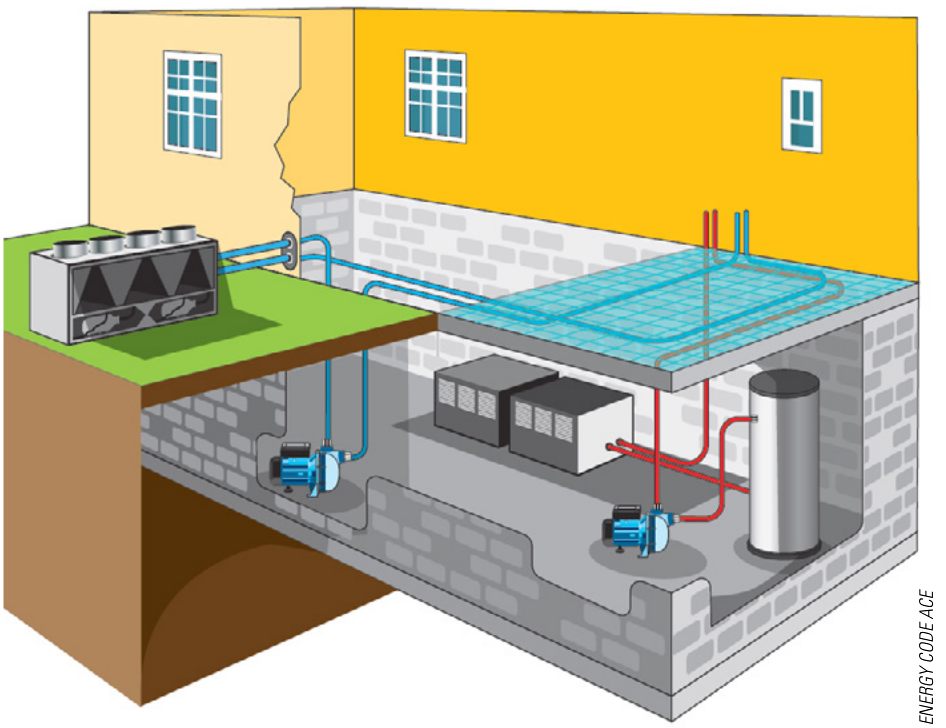
Table 7 from the Nonresidential Alternative Calculation Method Reference Manual

A four pipe fan coil system would typically be served with boilers that provide hot water to the fan coil units at each dwelling unit/hotel room through a looped system to and from the boiler. Additionally, the boiler could be used to provide domestic hot water, typically being tempered to prevent scalding and separated from the service hot water system to prevent cross contamination through various means (indirect storage tank served by the boiler; boiler with separate coil for space heating versus DHW; etc.). DHW could also be served by dedicated hot water equipment, and not combined with the hydronic space heating equipment.

In either case, the Energy Standards have both mandatory and prescriptive requirements for hot water heating equipment. When looking for the requirements for DHW systems associated with high-rise residential buildings and hotel/motel buildings, one must look to the residential portion of the Energy Standards. For hydronic space heating requirements, look to the nonresidential portion of the Energy Standards (see tables on the following pages). All other nonresidential occupancies are addressed in the nonresidential sections of the Energy Standards only.

California Building Standards Commission

Find the California Mechanical Code and other code Parts here: bsc.ca.gov/codes.aspx



Example of Combined Hydronic Heating and DHW System

The following tables provide code sections and summarize requirements for hydronic space heating. Building types are separated into these categories;

All = All builidng types

Nonres = Nonresidential

High-Rise = High-rise and Hotel/Motel

Building Type	Mandatory	
High-Rise	**§110.1**	Mandatory requirements for appliances (water heaters)
	§110.3	
All	(a)	Temperature controls
All	(b)	Meet Appliance Efficiency Regulations
All	(c)	1. Outlet temperature controls for service systems with >167,000 Btuh capacity. 2. Controls for hot water distribution systems 3. Temperature controls for public lavatories 4. Insulation for unfired storage and solar backup tanks 5. Recirculation loops to meet design criteria of 110.3(c)5A-F 6. State Buildings: 60% of energy provided from solar or recovered energy 7. Isolation valves for instantaneous systems >6.8 kBTUH (2kW)
	§120.3	
All	(a)	3. A-D General service water heating hot water pipe insulation requirements
All	(b)	Insulation protection
All	(c)	HW piping insulation thickness (Table 120.3-A)
	§120.8	Commissioning
Nonres	(d)-(e)	Nonresidential conditioned building of any size
All	(a)-(c);(f)-(i)	Nonresidential buildings ≥10,000 ft² conditioned space
	§120.9	
All	(a)-(c)	Boilers ≥2.5 MMBTUH (see Process Systems and Equipment Application Guide)
	§150.0	
High-Rise	(j)	Water system piping, tanks and insulation for piping and cooling system lines
High-Rise	(n)	1. Recirculation systems to meet §110.3(c)5 2. Solar thermal systems to be SRCC certified and rated (or other approved listing)

Building Type	Prescriptive	
All	**§140.4** (k)	Hydronic System Measures 1. Hydronic variable flow systems 2. Chiller isolation 3. Boiler isolation 4. Chilled and hot water temperature reset controls 5. Water-cooled AC and hydronic heat pump systems 6. Variable flow controls 7. Hydronic heat pump controls
	§140.5	
Nonres	(a)	There are no prescriptive measures, though the performance approach can be used for efficiency, fuel type, and size of equipment
High-Rise	(b)	Comply with §150.1(c)8 – residential section of the energy code
	§150.1	
High-Rise	(c)	8.B Centralized systems i. Minimum efficiency equipment per §110.1 and §110.3 ii. Recirculation system meeting §110.3(c)2 and 5, and has 2 recirculation loops (one loop per half of the building) when ≥9 dwelling units/hotel rooms iii. Solar hot water system (20% solar savings fraction (SSF) for CZ 1-9 / 35% SSF for CZ 10-16)

Building Type	Performance	
Nonres	**NR ACM**	Water heating 5.9.1: Baseline building shall have (1) gas storage water heater meeting min. efficiency and sized per Appendix 5.4A
High-Rise	**NR ACM**	Water Heating 5.9.1: Baseline building shall have gas instantaneous water heater for each dwelling unit; and (1) non-recirculating gas storage water heater for common areas; meeting min. efficiency and sized per Appendix 5.4A HVAC 5.1.2 (≥4 habitable stories). Baseline HVAC system would be a four pipe fan coil system using a boiler for space heating, and chiller for space cooling (≤3 habitable stories: PTAC units)

Control Applications

A change of occupancy type with mechanical system upgrades also may trigger more complex control systems, such as demand controlled ventilation with CO_2 sensors mounted in the occupied zone to control indoor air quality. It is extremely important to recognize these triggers, both mandatory and prescriptive, along the project's compliance path. The control requirements also adapt to the occupancy types.

A very unique example is the control requirements for hotel/motel applications that require occupant sensing thermostats or key card controls to shut off air conditioning when the room is unoccupied (§120.2 (e)4). This control requirement for this particular occupancy is also required to control lighting and plug loads (§130.1 (c)8).This is another example of a special coordination item with unique acceptance testing crossover for both mechanical and electrical.

HVAC controls are becoming a new resource for energy efficiency and as controls get better, less expensive, and require less maintenance they will be integrated into the Energy Standards in both prescriptive and mandatory requirements. The hotel/motel key card controls are one prime example of a control introduced in the 2013 Energy Standards that were immediately moved into the mandatory section because of their ability to provide energy savings. Improved control technology with multi-input sensors able to implement demand controlled ventilation, occupancy sensor for ventilation, and even controls tied to window sensors are required in a number of different combinations in the 2016 Energy Standards and likely will continue to expand.

Crossover with Other Building Codes

The efficiency measures outlined in the Energy Standards have many crossovers to other sections of the California Building Code. Appliances and an increasing list of mechanical system minimum efficiency requirements are dictated by Title 20 and must be referenced for certain types of mechanical equipment as noted in the mandatory requirements in §110.0 of the Energy Standards.

For a host of mechanical design requirements, the California Mechanical Code (CMC), Title 24, Part 4, must be referenced for instances of coordination. Just to name a few: ventilation, duct design, controls, filters, and a number of others that bear weight on the energy performance. The duct insulation requirements dictated by Title 24, Part 6 also have parallel specifications subject to Part 4 the California Mechanical Code.

As with many coordination items there are instances of conflicts between the codes. One example is the ventilation requirements of the CMC do not always match the requirements in the Energy Standards. Careful attention must be applied to compliance with each building code. As per §1.1.7.3 of the California Building Code, when the requirements of any other part of the California Building Standards code, Title-24, the most restrictive requirements shall prevail.

Code in Practice

Diving deeper into the ventilation example mentioned, let's investigate ventilation required for office space. The California Mechanical Code (CMC) has a different methodology for providing outside air to the space (CMC Table 402.1) than the Energy Standards (Table 120.1A). Using the CMC method only, a space could under ventilate the space significantly depending on occupant density. For example, with a 1,000 ft^2 office using the default occupancy from the CMC table the total outside air requirement would be 85 CFM where the Energy Standards method would require 150 CFM total. The Energy Standards require nearly double the CMC rate. In this instance the design needs to provide the worst case condition, 150 CFM.

TABLE 120.1-A MINIMUM VENTILATION RATES

TYPE OF USE	CFM PER SQUARE FOOT OF CONDITIONED FLOOR AREA
Auto Repair Workshops	1.50
Barber Shops	0.40
Bars, cocktail lounges, and casinos	0.20
Beauty shops	0.40
Coin-operated dry cleaning	0.30
Commercial dry cleaning	0.45
High-rise residential	Ventilation Rates Specified by the CBC
Hotel guest rooms (less than 500 ft²)	30 cfm/guest room
Hotel guest rooms (500 ft² or greater)	0.15
Retail stores	0.20
All others	0.15

TABLE 402.1
MINIMUM VENTILATION RATES IN BREATHING ZONE[1, 2]
[ASHRAE 62.1: TABLE 6-1]

OCCUPANCY CATEGORY[4]	PEOPLE OUTDOOR Air Rate R_P (cfm/person)	AREA OUTDOOR Air Rate R_A (cfm/ft²)	DEFAULT OCCUPANT Density[3] (people/1000 ft²)
OFFICE BUILDINGS			
Breakrooms	5	0.12	50
Occupiable storage rooms for dry materials	5	0.06	2
Office space	5	0.06	5
Main entry lobbies	5	0.06	10
Reception areas	5	0.06	30
Telephone/data entry	5	0.06	60

CHAPTER 5

NAVIGATING YOUR COMPLIANCE STRATEGIES

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 nonresidential buildings with HVAC and plumbing systems must meet a set of mandatory requirements. Mandatory requirements may not be traded off using either compliance approach described below.

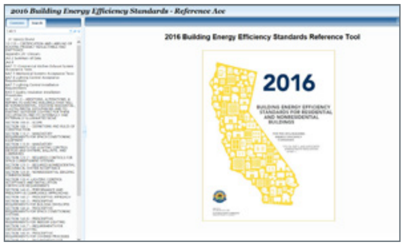
Prescriptive Approach

In general, 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 or exceed the requirement. The prescriptive approach is typically used for alteration or simple addition projects.

Performance Approach

The performance approach builds on the prescriptive approach by allowing energy allotments to be traded between building systems. This compliance approach requires using energy analysis software that has been approved by the Energy Commission. The performance approach is almost always used for newly constructed buildings and major renovations.

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

Identifying the Right Requirements

Understanding the Energy Standards requirements for each project is a complex decision tree starting with identifying project type: newly constructed, addition, alteration, and repair. Descriptions of these project types can be found in this chapter under "Define The Project Type." The next step is to determine the compliance approach for the scope, such as isolated envelope changes, lighting only compliance, HVAC and controls, or code required process elements.

Where to Find Applicable Requirements

The Energy Standards contain requirements for all newly constructed buildings, additions and alterations. The Energy Standards are divided into three general categories; mandatory requirements that apply to all buildings, nonresidential building requirements (including high-rise residential and hotel/motel buildings) and residential building requirements (including low-rise and single family residential buildings). The Title 24, Part 6 Building Energy Efficiency Standards are available from the Energy Commission and may be downloaded here:

Title 24, Part 6 Building Energy Efficiency Standards

The following table provides references to sections of the Energy Standards for nonresidential HVAC and plumbing requirements and is categorized by mandatory measures, prescriptive approach and performance approach. All code sections below are hyperlinked to the Reference Ace tool.

HVAC SYSTEMS	MANDATORY	PRESCRIPTIVE	PERFORMANCE
Newly Constructed			§140.1
Equipment Type & Efficiency	§110.0, §110.1, §110.2(a), §110.5	§140.4(a), §140.4(b), §140.4(c), §140.4(i), §140.4(j)	
Controls	§110.2(b), §110.2(c), §110.2(d), §120.2	§140.4(d), §140.4(f), §140.4(m), §140.4(n)	
Heat Rejection Equipment (Cooling Towers, Condensers)	§110.2(e)	§140.4(h)	
Low Leakage Air Handlers	§110.2(f)		
Boilers	§120.9		
Economizers		§140.4(e)	
Electric Resistance Heating		§140.4(g)	
Hydronic Systems		§140.4(k)	
Ventilation	§120.1		
Pipe Insulation	§120.3		
Distribution (Ducts)	§120.4	§140.4(l)	
Acceptance Tests	§120.5		
Commissioning	§120.8		

HVAC SYSTEMS	MANDATORY	PRESCRIPTIVE	PERFORMANCE
Additions, Alterations & Repairs			§140.1
Addition.		§141.0(a)1	§141.0(a)1
Alterations		§141.0(b)2, §141.0(b)2C-E	§141.0(b)3
Repairs		§141.0(c)	

DHW SYSTEMS	MANDATORY	PRESCRIPTIVE	PERFORMANCE
Newly Constructed			§140.1
Equipment Certification	§110.1, §110.3(a)		
Equipment Efficiency	§110.3(b)		
Controls	§110.3(c) 1-3		
Tank Insulation	§110.3(c)4		
Recirculation Loops	§110.3(c)5		
Isolation Valves	§110.3(c)7		
Pipe Insulation	§120.3		
Commissioning	§120.8		
Additions, Alterations & Repairs			
Additions		§141.0(a)1	§141.0(a)2
Alterations		§141.0(b)2, §141.0(b)2N	§141.0(b)3
Repairs		§141.0(c)	

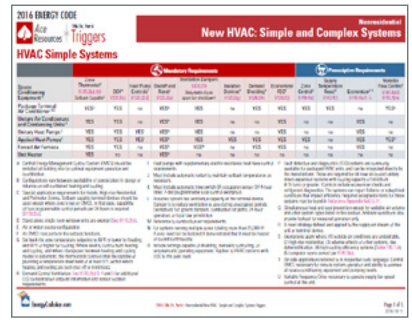
Note: See §100.0 Scope and Table 100.0-A Application of Standards for additional information on which sections of Title 24, Part 6 apply to any given project, in particular which code sections apply to conditioned versus unconditioned space.

Define the Project Type

Under Title 24, Part 6, project types are broken into four categories. Newly constructed, additions , alterations, or maintenance and repairs. A project's scope determines which portions of the HVAC requirements apply.

Nearly all nonresidential new construction, addition and renovation projects are mandated to demonstrate compliance with some aspect of the HVAC portion of Title 24, Part 6. The complexity of the Energy Standards requires different compliance paths and documentation depending on the scope of work involved. This section describes in general when a project is subject to, or "triggers", the HVAC requirements of the Energy Standards.

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:

- Nonresidential HVAC Alteration
- Nonresidential Small Commercial HVAC Alterations
- NR HVAC Controls

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

Code in Practice

A small atrium addition that is primarily glass would be difficult to make comply on its own because it would not comply with prescriptive window to wall ratio limitations. Envelope compliance may be achieved in this scenario using the performance path to trade off with lower installed lighting power beyond what's required by the Energy Standards or installing a high performance mechanical system that offsets the energy use from the envelope penalties.

Newly Constructed or Newly Conditioned

Newly constructed buildings must comply with the HVAC portions of Title 24, Part 6 if they contain conditioned space (directly or indirectly heated or cooled) regardless of whether or not that space is habitable (as defined by the Glossary in Joint Appendix 1). Institutional occupancies such as hospitals, prisons, and other "I" and "L" occupancies are not regulated by the Energy Standard (see §100.0 (a)1). Special conditions apply to buildings with unique process requirements such as refrigerated warehouses. Details on process system requirements in the Energy Standards are included in the Process Systems and Equipment Application Guide.

Addition

Addition is when conditioned floor area AND conditioned volume are added to an existing conditioned building. Addition projects have the option of demonstrating compliance by showing that either the addition alone meets the Energy Standards, or the building as a whole (existing plus addition) meets the Energy Standards.

Alteration

Replacement of mechanical equipment trigger the Energy Standards even when ducting and distribution systems remain. Other alterations may just involve extending ducts or adding a zone terminal unit that trigger the Energy Standards in different forms.

Maintenance and Repair

A repair is when a feature of the building is replaced or repaired that does not increase the energy use of that feature and is NOT considered an alteration. An example of this is when a fan fails within an air handler and it is replaced in kind without replacing the entire air handler. It would be considered an alteration and trigger code if the entire air handler was replaced. Maintenance or repair projects can be subject to Title 24, Part 6 if HVAC unit(s) or the cooling coils associated the HVAC unit(s) are replaced. If the scope of project's HVAC work consists only of adding or modifying ductwork in conditioned spaces, the local building department may or may not require a permit but mandatory measures will need to be met.

Compliance Requirements for HVAC Systems and Controls

The HVAC portion of Title 24, Part 6, like the rest of the Energy Standards, includes mandatory requirements that apply to all projects outlined in §110 and §120. Similar to other aspects of the Energy Standards, the owner and project team have the choice of demonstrating HVAC compliance using the prescriptive approach by adhering to specific requirements or by demonstrating compliance using the performance approach which uses an energy budget.

Mandatory Requirements

There are mandatory requirements that apply to all buildings, mandatory requirements that apply only to nonresidential buildings and mandatory requirements that vary by building or system type. Exceptions to the mandatory requirements exist and are listed in the Energy Standards.

As an example, all HVAC equipment installed in nonresidential buildings must meet or exceed the efficiency requirements outlined in Tables 110.2-A through 110.2-K. Minimum efficiency levels vary by equipment type (packaged HVAC units, boilers, chillers, cooling towers, etc.) and by equipment capacity.

The mandatory requirements for direct digital controls, thermostats, occupancy sensors, shut off controls and demand control ventilation are described below. In all cases, these controls are required for all newly constructed projects and most additions or alterations unless otherwise noted.

Thermostats

Thermostatic control of zone temperature by thermostats or a DDC system is required for all HVAC zones. Requirements for thermostats can be found in §120. This control may take the form of individual setback thermostats for smaller systems or DDC for larger systems. For those situations where DDC is not required, primarily smaller zones served by smaller single zone HVAC equipment, setback thermostats are required.

Regardless of whether zone temperatures are controlled by individual thermostats or a DDC system, the thermostatic controls must be capable of being programmed to set the cooling temperature to 85°F or higher, the heating temperature to 55°F or lower and must incorporate a deadband or range of temperature difference, of at least 5°F inside of which the heating and cooling is turned off or set to a minimum.

Direct Digital Controls (DDC)

Direct Digital Controls (DDC) monitor temperature, flow, pressure and other parameters within a building's zones and mechanical systems. DDC uses these measured values to control mechanical systems' operation in a manner that optimizes comfort and efficiency. DDC is required for all newly constructed projects that use multizone air handlers or central plants with design heating or cooling capacities of 300 kBtu/h or greater if those units serve more than three zones. For additions and alterations, DDC is required for any new air or water side equipment if the design heating or cooling loads are 300 kBtu/h or greater and the existing air handlers are already controlled by a DDC system. DDC is not required for simple single zone packaged units or multizone units smaller than the 300 kBtu/h capacity. Smaller units may be controlled using setback thermostats. Table 120.2-A in the Energy Standards describes when DDC must be used.

Building Status	Applications	Qualifications
Newly Constructed Buildings	Air handling system and all zones served by the system	Individual systems supplying more than three zones and with design heating or cooling capacity of 300 Btu/h and larger
Newly Constructed Buildings	Chilled water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design cooling capacity of 300 kBtu/h (87.9 kW) and larger
Newly Constructed Buildings	Hot water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design heating capacity of 300 kBtu/h (87.9 kW) and larger
Additions or Alterations	Zone terminal unit such as VAV box	Where existing zones served by the same air handling, chilled water, or hot water systems that have DDC

Code in Practice

Typical examples of systems that would be allowed to utilize individual setback thermostats include single zone packaged units or split systems serving individual school classrooms or similar units serving small retail spaces. In many cases, especially for buildings with large numbers of packaged single zone units such as big box stores or schools, DDC isn't required but is beneficial to the owner from maintenance and monitoring perspective.

Code in Practice

DCV controls are normally required if the HVAC system has an economizer based on the occupant density. If you're using Energy Commission approved software the "Default" occupancy rates listed in the Nonresidential Manual Table 4-14 are applied. The "Default" occupant densities for conference rooms, movie theaters, gymnasiums, and other spaces with large occupant loads trigger DCV controls. The "Default Occupancy Design Conditions" may differ from estimated or even fire code occupancies.

Building Status	Applications	Qualifications
Additions or Alterations	Air handling system or fan coil	Where existing air handling system(s) and fan coil(s) served by the same chilled or hot water plant have DDC
Additions or Alterations	New air handling system and all new zones served by the system	Individual systems with design heating or cooling capacity of 300 kBtu/h and larger and supplying more than three zones and more than 75 percent of zones are new
Additions or Alterations	New or upgraded chilled water plant	Where all chillers are new and plant design cooling capacity is 300 kBtu/h (87.9 kW) and larger
Additions or Alterations	New or upgraded hot water plant	Where all boilers are new and plant design heating capacity is 300 kBtu/h (87.9 kW) and larger

Table 120.2-A DDC Applications and Qualifications

Demand Control Ventilation (DCV)

Demand Control Ventilation (DCV) systems vary the quantity of ventilation air introduced into a space to maintain a measured concentration of CO_2 of 1000 ppm or less. If no device exists measuring the CO2 concentrations of the outside air, 400 parts per million (ppm) will be assumed. The standards require regulated spaces to be maintained less than or equal to 600 ppm plus the baseline outside air concentration. If the assumed 400 ppm for outside air is used adding the 600 ppm the sensor setpoint will be equal to or less than 1000 ppm. DCV systems are required for spaces with high occupancy levels such as conference rooms, movie theatres, and other spaces with design occupancies of 40 ft²/person or less. It is important to note that DCV controls are designed to control ventilation only utilizing CO2 concentrations as a proxy for indoor air quality. Using this metric the ventilation control will not be able to manage odors, contaminants, or other pollutant management in the space.

Table 120.1-A of the Energy Standards lists the baseline ventilation rates that are required regardless of CO_2 concentration during those periods that a space is occupied. The baseline ventilation rates for spaces range from 0.15 cfm/ft² – 0.20 cfm/ft² for most office, education or retail buildings to 0.4 cfm/ft² for barber shops and beauty parlors and even higher for dry cleaning and auto repair shops.

Occupancy Sensors and Shut-off Controls

Most owners and designers are familiar with the requirement that occupancy sensors be used to control lighting power in certain scenarios. However, occupancy sensors also can meet the automatic shut off requirements of §120.2(e) which mandates that all HVAC system controls be capable of shutting off the system during periods when the zone is not occupied. In addition to occupancy sensors, an automatic time switch with a manual override or a manually operated four-hour timer can be used to meet this requirement. Another automatic shut off requirement is made for spaces with high occupant densities such as classrooms, meeting rooms, conference spaces and others, the Energy Standard require that the cooling setpoint be raised by 2°F and the heating setpoint be lowered by 2°F during periods of nonuse. Additional exceptions exist and are described in §120.2(e).

Prescriptive Requirements

Using the prescriptive approach requires that, in addition to the mandatory requirements, a project adhere to specific equipment sizing, efficiency, and controls.

The prescriptive requirements vary by climate zone and equipment size, and similar to the mandatory requirements listed above, exceptions to the prescriptive requirements exist to account for special situations. Energy Standards §140.4 describes prescriptive compliance for space conditioning equipment and calculation of heating, cooling and ventilation loads. Examples of prescriptive requirements for nonresidential buildings include:

- Design load calculations must follow ASHRAE methods
- Safety factors and cool down/warm up factors are limited to 10-30%
- Duct leakage must not exceed 6% of air flow
- Fan power (W/cfm) is limited for most systems
- Variable speed drives are required for most supply and return fans
- All newly installed DX units over 5.4 tons installed in existing or newly constructed buildings must have at least 3 stages of cooling
- DX units 20 tons and over must have at least 4 stages of cooling
- Controls must minimize reheating and recooling of supply air
- Multizone units must utilize temperature reset controls
- Air side or water economizers are required for systems > 4.5 tons
- Economizer limit controls are mandated and vary by climate zone
- Economizers must utilize fault detection and diagnostics (FDD) systems which provide notification of improper operation
- Electric resistance heating is prohibited
- Requirements for heat rejection equipment such as fan speed control and cooling tower flow turndown
- Minimum chiller efficiency and restrictions on air-cooled chillers
- Requirements for hydronic systems such as variable flow and hot water/ chilled water temperature reset
- HVAC system shut-off (interlock with operable windows/ doors)

A few of these prescriptive requirements allow trade-offs (see Code in Practice sidebar), which are described in §140.4.

Code in Practice

An example of a prescriptive tradeoff would be trading the prescriptive requirement for an economizer with increasing efficiency of the cooling system as described in §140.4(e). For example, if an existing split DX unit is being replaced in a retail store, and there is difficulty redesigning the duct system to bring in outside air, the new unit could increase efficiency and not install an economizer. The required increase in efficiency depends on climate zone and varies between 30%-70%. Although a 30% increase in efficiency is reasonably achievable, 65% or more is not, so the application of this exception does have limitations

Performance Approach

This discussion focuses on the HVAC aspects of the performance approach, but it is important to remember that the advantage of the performance approach is that compliance with the Energy Standards can be achieved by trading off efficiency levels between a building's envelope, HVAC, lighting and water heating systems.

The performance approach to compliance requires whole building energy modeling using certified simulation programs approved by the California Energy Commission.

While approved simulation programs may differ in their interfaces and support structure, the general process that each simulation tool follows is the same. All approved energy simulation software programs create two energy models of a project building; the proposed model which represents the building as designed, and the baseline or standard model which assumes the proposed building is designed following the mandatory and prescriptive requirements.

Code in Practice

The Performance Approach allows efficiency tradeoffs between HVAC, lighting, water heating and envelope components. However, a project must still comply with mandatory requirements. For example, the weighted average U-factor of a metal framed wall is required to be 0.151 or less (R-13 cavity + R-2 continuous). A metal framed wall with R13 cavity insulation alone is NOT allowed, even if very efficient HVAC systems are utilized which reduce the TDV energy below the energy budget.

Code in Practice

Time Dependent Valuation or TDV is a concept that accounts for the energy required at the power plant and transmission and distribution losses. TDV energy calculations assign a higher value to energy saved during utility peak periods when the grid and power plants are near their capacity. As a result of TDV, a kWh saved at 4:00 P.M. in July has more value than a kWh saved at 4:00 A.M. in October.

Time Dependent Valuation (TDV)

The TDV energy consumption of the baseline model represents the allowed energy budget for the project, which the proposed project must meet. If the proposed building uses an amount of TDV energy less than or equal to the baseline building's TDV energy, and the proposed building meets the mandatory requirements, the proposed design complies with the Energy Standards. While in principle this sounds straight forward, as with all models there are cautions associated with energy modeling in general, and modeling for compliance in particular that should be understood by the design team and the owner. Chapter 5 highlights several important assumptions and limitations associated with the implementation of the performance path and the associated software packages.

Above Code Benchmark

The performance approach provides a benchmark for exceeding code requirements in "Reach Codes" such as CALGreen (Title 24, Part 11) Tier 1 & 2, LEED®, or utility incentive programs.

CALGreen Tier 1 Local Jurisdiction Requirements

energy.ca.gov/title24/2016standards/ordinances/

LEED Certification

usgbc.org/certification

Savings By Design Incentive Program

savingsbydesign.com/

Compliance Requirements for DHW Systems and Controls

Domestic hot water (DHW) requirements of Title 24, Part 6 are dependent upon building occupancy type and also vary greatly between offices and high water users like hotels, motels, and high-rise residential buildings covered under the nonresidential Energy Standards.

1. High-rise residential and hotel/motel occupancies, regulated under the nonresidential Energy Standards, must meet the domestic hot water system requirements of §150.1(c)8.
2. Nonresidential occupancies (i.e. office, warehouse, retail) have mandatory requirements for minimum efficiency for water heating equipment outlined in §110.1, §110.3 and §120.3.

When designing a DHW system, there are three main topics that must be addressed:

1. Equipment: There are three main types of domestic hot water heaters including storage, instantaneous and indirect. Gas or oil firing, heat pump, electric resistance, solar thermal, geothermal, and even wood or coal burning resources can provide heat.
2. Distribution systems: There are two main types of distribution systems, recirculation and non-recirculation.
3. Controls: Controls are focused on water temperature in the tank, at the fixture, on/off control of pumps, and other parts of the system.

For each of these topics, there are mandatory requirements. Prescriptive requirements apply to some topics. When using the performance method, be aware of additional requirements that may affect the design.

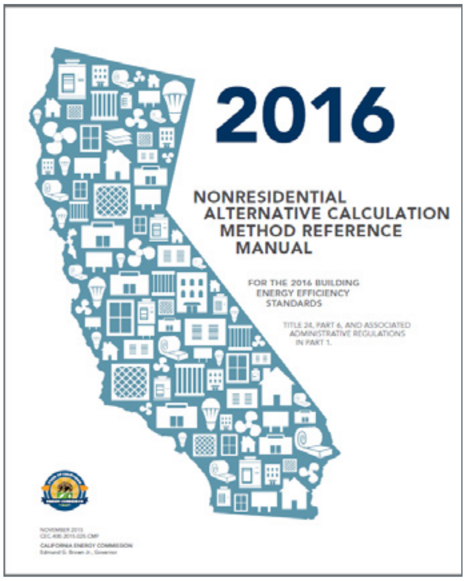
DHW Equipment

Mandatory requirements in §110.3(a) dictate that any equipment selected must be certified per Title 20 requirements (Appliance Efficiency Regulations). The efficiency levels for each type of equipment are listed depending on fuel source like natural gas, propane, heat pump, and dictates limitations on electric resistance heating.

The Energy Standards dictate insulation levels for hot water storage tanks and backup tanks for solar thermal systems to mitigate energy loss through the tank walls as much as possible. If insulation is completely external to the tank, it must be at least R-12. If insulation is a combination of internal and external insulation, then the combined total must be at least R-16. Alternatively, the tank must have a heat loss of less than 6.5 Btu/h/ft² when the temperature difference between the water and the air is 80°F. This is measured, for example, when the tank storage temperature is 140°F for hot water and the outside air temperature falls below 60°F.

New in the 2016 Energy Standards, instantaneous water heaters with an input rating greater than 6.8 kBtu/h (2 kW) shall have isolation valves on both the cold water supply and the hot water pipe leaving the water heater, and hose bibbs or other fittings on each valve for flushing the water heater when the valves are closed.

High-rise residential and hotel/motel buildings in climate zones 1 through 9 have an additional requirement to include a solar thermal collection systems with a minimum Solar Savings Fraction (SSF) of 20% which increased to 35% in climate zones 10 through 16. This element may be traded off for other building features in the performance approach.



The Energy Commission publishes the Alternative Calculation Method Reference Manual to aid with compliance and compliance software.

Find the manual here: energy.ca.gov/2015publications/CEC-400-2015-025/CEC-400-2015-025-CMF.pdf

Distribution Systems

Non-recirculating distribution systems only have requirements for insulation on the piping as specified in §120.3. See the piping section of this guide for details on pipe insulation requirements.

Recirculating distribution systems have a number of mandatory requirements in §110.3. Recirculating DHW systems are most common in multifamily and hotel/motel applications, but can be found in any building type. Requirements include:

- Air release valve or vertical pump installation. Alternatively, the recirculating pump must be installed vertically on the return line, or it must have an automatic air release valve. The air release valve must be installed on the inlet side of the pump, within 4 feet of the pump, and on top of a vertical riser at least 12 inches long. The valve must be accessible for maintenance and repair.
- Backflow prevention for recirculation loop. A check valve or equivalent device shall be installed between the recirculating pump and the water heating equipment to prevent water flowing backwards in the recirculating loop.
- Equipment for pump priming. A hose bibb must be installed between the pump and the water heating equipment to be used to bleed air out of the pump after pump replacement. There also must be an isolation valve installed between the hose bibb and the water heating equipment.
- Pump isolation valves. Isolation valves are required on both sides of the pump. One of these may be the valve included in the pump priming requirement. The valves are allowed to be part of the flange that attaches the pump to the pipe.
- Cold water supply and recirculation loop connection to hot water storage tank. Storage water heaters and boilers must be plumbed in accordance with the manufacturer's instructions. The cold water piping and recirculating loop piping shall not be connected to the hot water storage tank drain port.
- Cold water supply backflow prevention. A check valve must be installed on the cold water supply line between the hot water system and the closest tee on the cold water supply line. Expansion tank requirements from the California Plumbing Code, §608.3, must be met.

Controls

Service water heating systems must be supplied with automatic temperature control. Depending on the intended use of the hot water, the system must be able to control the water to a temperature between 75°F and 195°F. Temperatures above 140°F are used only for commercial laundry or commercial dish washing applications. The specific temperatures are provided in a table from the 2011 ASHRAE Handbook – HVAC Applications.

If the DHW system has a total rated heating capacity of 167,000 Btu/h or more and has outlets which must supply water at a temperature higher than service water temperatures as listed in the ASHRAE handbook, then it shall have separate remote heaters, heat exchangers, or boosters to supply the outlet with the higher temperature.

- DHW systems must include controls that limit the hot water temperature at fixtures in public lavatories to no more than 110°F.
- DHW systems with circulating pumps or electrical heat trace systems must have controls that are able to automatically turn them off.

Using the Performance Approach for DHW Systems

When compliance with Title 24, Part 6 is being shown using the performance approach, the Standard Design model will use a gas fired water heater if natural gas is selected as a heating source. If the project heating source is electricity, then an electric DHW system is allowed with minimal penalty. If the proposed design includes a recirculation system, the performance baseline building will include a similar control system described in the prescriptive sections.

Due to the baseline system choice of natural gas, if an electric water heater is being used in the design, a performance penalty is likely to result even with supplemental solar thermal collection. If this performance penalty causes the design to fail compliance, the water heater can be excluded from the performance approach, showing compliance through the prescriptive path for the DHW system only. Using the prescriptive method, there is no penalty for an electric DHW system, even if natural gas is available.

Case Study: Phocus Office and Warehouse

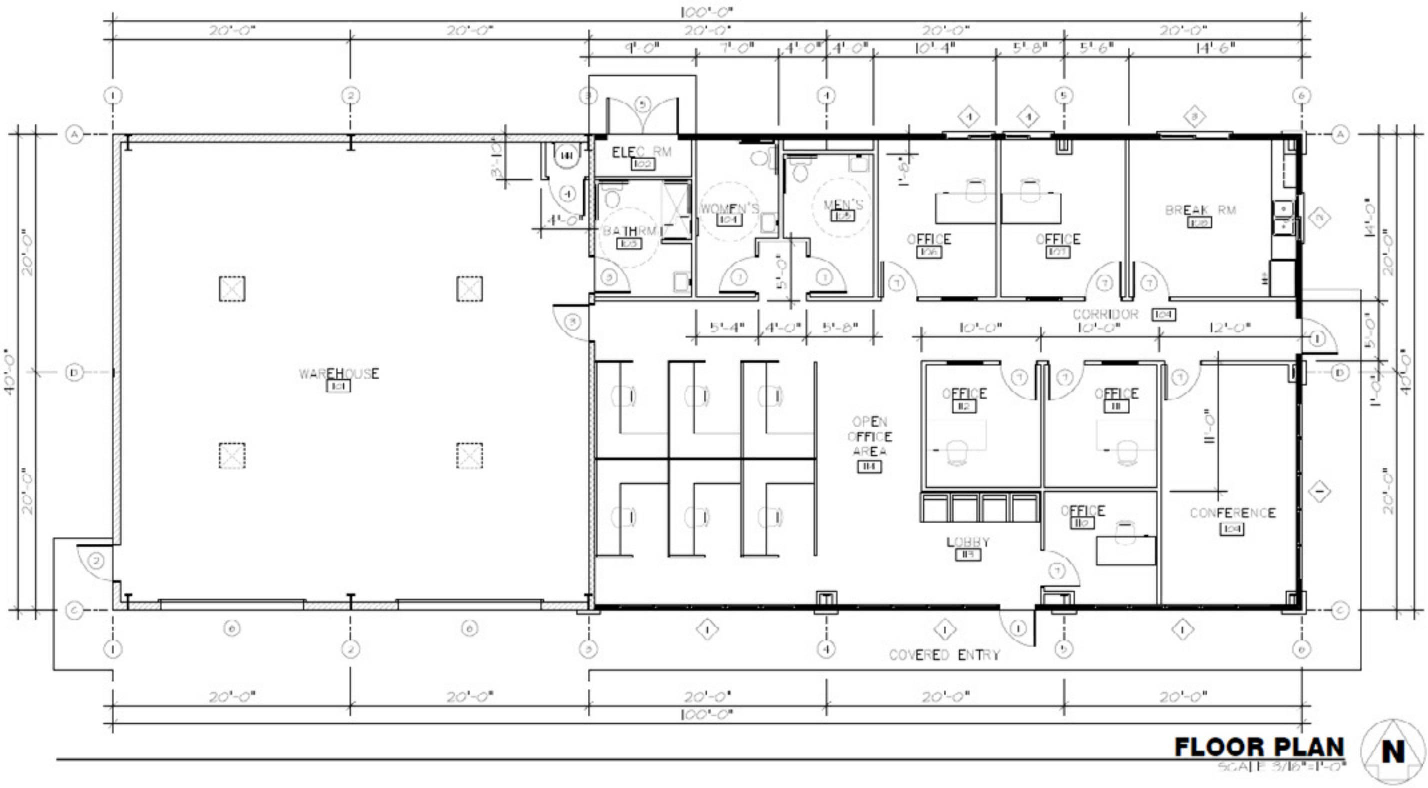
The case study project, Phocus Office and Warehouse in Valencia (climate zone 9) is a sample project created for training purposes and was used to provide a basis for comparison of the prescriptive and performance approaches. The building consists of 2,370 ft² of conditioned space, including offices, conference rooms, an employee lounge and support spaces, plus 1,630 ft² of unconditioned warehouse space (see floor plan and elevations on facing page). The discussion below compares Prescriptive prescriptive versus performance approaches to achieve compliance with the Energy Standards. An important tool in this comparison are the tables on the following pages listing the proposed building features and comparing them to the applicable mandatory measures and prescriptive requirements versus the performance method standard design assumptions.

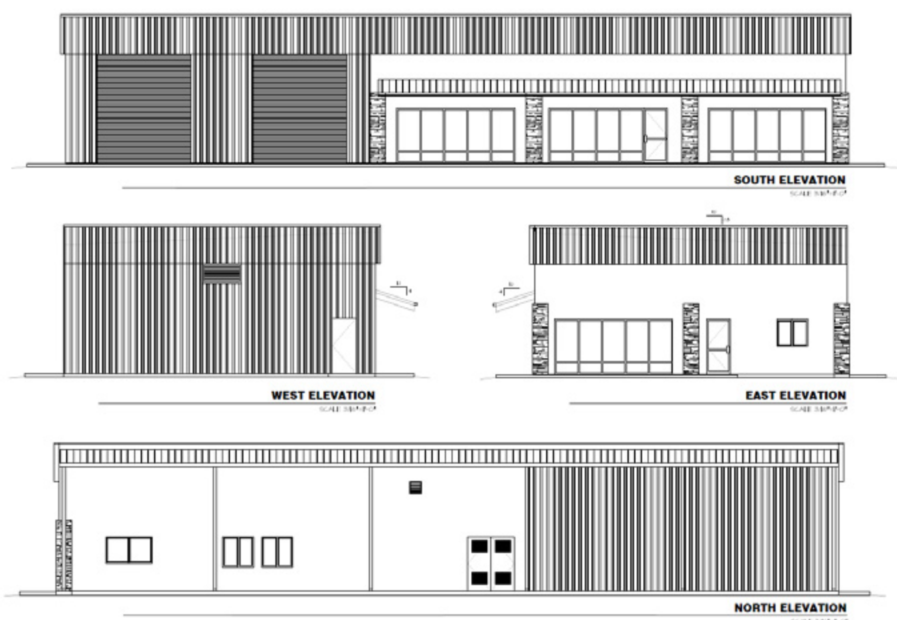
Integrated Design Project Delivery: Benefits of the Commissioning Process

Integrated design encourages team members to work together and that leads to a more effective design process. Below is a snapshot of a typical project team for this kind of building:

Team Member	Role
Architect	Architect (Prime Contractor), Coordinate Cx Design Review
MEP	Mechanical & Plumbing Engineers
Lighting Design	Electrical & Lighting Engineer
Certified Energy Analyst	Energy Consultant

The Phocus project is exempt from many of the commissioning requirements required by the Energy Standards because it only has 2,370 ft² of conditioned space, and most commissioning requirements only apply to buildings with more than 10,000 ft² of conditioned space. The size allows the design team to provide a streamlined set of commissioning documents easy to prepare under the integrated design approach. The typical Design Phase Design Review documentation required for this scope of work is indicated on page 46.





Phocus Office and Warehouse, Valencia CA
Floor Plan and Elevations

Commissioning Form	Title
NRCC-CXR-02-E	Commissioning – Commissioning Documents
NRCC-CXR-03-E	Construction Documents
NRCC-CXR-05-E	Commissioning – Design Review Signature Page

Prescriptive vs Performance In Practice

Compliance with the Energy Standards can be achieved in two comprehensive steps; 1) meet all the applicable mandatory measures and; 2) choose the best compliance path based on the scope of the project, considering the advantages and disadvantages for both the prescriptive and performance compliance paths. In this case study we will explore the application of satisfying the mandatory measures and the pros and cons of both the prescriptive and performance compliance paths when analyzing nonresidential buildings.

Prescriptive compliance for HVAC and service water heating in nonresidential buildings requires meeting all of the specific requirements defined in Energy Standards sections §140.4 (HVAC) and §140.5 (service water heating). Systems that do not meet all of the applicable prescriptive requirements do not comply prescriptively, and must either be changed to meet all prescriptive measures or must show compliance using the performance approach.

Performance compliance requires that mechanical and water heating systems are modeled together with the building envelope, and sometimes also indoor lighting, in specialized software approved by the California Energy Commission. The compliance software uses the building information to calculate the proposed energy use and compare it to a standard design energy budget. Both the standard design energy budget and proposed design energy use include TDV energy for space-conditioning, indoor lighting, mechanical ventilation, service water heating and covered process loads.

The standard design system energy budget for a proposed building is calculated by applying the mandatory and prescriptive requirements to the proposed building design according to the rules defined in the 2016 Nonresidential Alternative Calculation Method Reference Manual (ACM Manual). To comply with the Energy Standards using the performance approach, the proposed annual compliance total TDV energy use must be less than that for the standard design.

Prescriptive vs Performance Method Compliance Analysis

HVAC – Simple System

The Phocus office and warehouse building has conditioned space with heating and cooling being supplied to the private offices, restrooms, conference and break rooms. Both the warehouse and electrical/mechanical spaces are unconditioned. The system type utilized is a rooftop packaged single zone (PSZ) system which is considered a 'simple system'. When considering mandatory measures or prescriptive compliance, the Energy Standards assume the same type of system as is proposed in most cases. However, the performance method takes a different approach and sets the standard design HVAC system based on the building occupancy, the conditioned floor area, and the number of habitable stories as defined in the 2016 Nonresidential Alternative Calculation Method Reference Manual (ACM Manual) Table 5 for nonresidential spaces:

Building Area	Floors	Standard Design	Description
≤ 10,000 ft²	1 floor	PSZ	Packaged Single Zone
	>1 floor	PVAV	Packaged VAV Unit
10,000 ft² – 150,000 ft²	Any	PVAV	Packaged VAV Unit
>150,000 ft²	1 floor	SZVAV	Single-zone VAV Unit
	>1 floor	VAVS	Built-up VAV Unit

2016 Nonresidential Alternative Calculation Method Reference Manual (ACM Manual) Table 5: HVAC System Map for Nonresidential Spaces, highlighting Phocus case study standard design system.

The Phocus case study building is one story with less than 10,000 ft² of conditioned space, so the performance compliance path assumes a packaged single zone system in the standard design energy budget. In this case, the performance method standard design system type matches the proposed system, so there is no performance method credit or penalty for system type.

The mandatory requirements are the first step to seeking performance or prescriptive compliance. Once the mandatory requirements are satisfied the HVAC system is then analyzed according to the compliance path chosen. The space-conditioning system for this project met all of the mandatory requirements which included:

- Equipment efficiency
- Duct insulation
- Ventilation
- System controls

Equipment efficiency is based on Federal standards mandated by the U.S. Department of Energy minimum requirements set forth in the Federal appliance efficiency standards and also published in the California Energy Commission Appliance Efficiency Regulations. The Energy Standards §110.2(a) outlines the efficiency standards for various equipment types. The Phocus project packaged single zone system had to meet the mandatory minimum 11.2 EER and 12.9 IEER efficiencies for space cooling and 78% AFUE for space heating. The performance standard design assumes these same minimum efficiencies. The proposed HVAC system has an 81% AFUE for the gas furnace so it complies prescriptively and would be a performance compliance credit. The proposed cooling EER and IEER just meet the cooling minimums, so they would comply prescriptively and be neither a credit nor a penalty for performance.

There are no mandatory insulation requirements for ducts in directly conditioned space, so the proposed R-4.2 ducts in conditioned space comply prescriptively. Since there is no prescriptive requirement, there is no performance method credit or penalty for this particular duct design.

In terms of ventilation, all enclosed habitable spaces for this project have to meet the minimum ventilation requirements according California Building Code requiring either natural or mechanical ventilation (§120.1(b)). This case study assumes mechanical ventilation by way of a non-integrated fixed temperature economizer to regulate the outdoor air flow into the building. Note that the prescriptive approach would require an integrated economizer, so having the non-integrated economizer makes it impossible for this building to comply prescriptively. The performance standard design assumes an integrated differential dry bulb economizer which is more energy efficient than the proposed system, so that will result in a cooling energy compliance penalty in the performance approach.

The use of a PSZ system with an economizer also triggers mandatory demand control ventilation (DCV) because some of the spaces being served have occupant density less than 40 ft^2 per person (§120.1(c)3). DCV allows the outdoor air quantity to be adjusted based on real-time ventilation needs. When using DCV, coupling it with CO_2 sensors is not only part of this mandatory HVAC control but in the high occupant density lobby, conference and break rooms the CO_2 sensors help to maintain the concentrations of CO_2 at healthy levels.

System controls are the last of the mandatory measures for the HVAC system and require that new HVAC systems not controlled by Energy Management Control Systems (EMCS) have at the minimum occupant controlled smart thermostat (OCST) with setback capability. Code compliance also requires that occupants be able to program at least four (4) temperature setpoints points within a 24-hour period, allowing for maximum occupant comfort and energy efficiency. The Phocus case study includes OCST technology versus an EMCS to satisfy this requirement primarily for its cost effectiveness and ease of maintenance. Installing smart thermostats for this project was the best approach. The OCST specified also fulfilled the automatic shut off requirements during periods of non-use while also automatically restarting to maintain specified (code compliant) heating and cooling set points. These controls are neither a credit nor a penalty for performance compliance.

The HVAC system design for this project was closely matched to the baseline system as it is a packaged single zone system suppling both heating and cooling to the conditioned spaces. The proposed heating and sensible cooling output capacities comply prescriptively, and would be neither credits nor penalties in the performance method.

Overall, the proposed HVAC system meets prescriptive requirements for everything except the non-integrated economizer, but that one exception means that the system does not comply prescriptively. The system meets all mandatory measures, so it can be analyzed for compliance using the performance approach. Most of the system features will be neutral for performance compliance, but the non-integrated economizer will result in somewhat higher than standard cooling energy use, while the 81% furnace AFUE will reduce proposed heating energy relative to the 78% AFUE standard design.

Important Note on Performance Method Standard Design:

The standard design used in the Performance Approach sets the baseline TDV energy budget for the building. However, the features of the actual proposed building may be better or worse than the standard design assumptions and still comply with the Energy Standards, as long as the compliance energy total for the proposed design is less than or equal to the standard design and the proposed building meets all applicable mandatory measures.

Phocus Office and Warehouse Building Case Study Compared to Mandatory and Prescriptive HVAC Requirements and Performance Method Standard Design

HVAC FEATURES	CASE STUDY	MANDATORY	PRESCRIPTIVE	PERFORMANCE
Newly Constructed Nonresidential Buildings	Phocus Office and Warehouse Building, Valencia, CA, Climate Zone 9	2016 Building Energy Efficiency Standards (§110.0, §110.1, §110.2(a), §110.5, §120.4)	2016 Building Energy Efficiency Standards (§140.4)	2016 Nonresidential ACM Reference Manual (Sections 5.1.2 and 5.7, Tables 4, 5 and 7)
Total Conditioned Floor Area (CFA):	2,370 ft²	2,370 ft²	2,370 ft²	2,370 ft²
Number of Habitable Stories:	1	1	1	1
Fuel Types:	Space Heating: Natural Gas Space Cooling: Electricity	No mandatory fuel type requirements	Space Heating: Natural Gas Space Cooling: Electricity	Space Heating: Natural Gas Space Cooling: Electricity
Equipment Type:	Packaged single zone (PSZ) system: Gas furnace with 75,000 Btu/hr output, DX cooling with 93,000 Btu/hr total output, 65,100 sensible output, plus non-integrated fixed temperature economizer, single phase	Meet or exceed mandatory requirements for proposed HVAC system type	PSZ system with gas furnace and DX cooling allowed, maximum output capacities based on loads and allowing safety factors, integrated economizer required for total cooling output ≥ 54,000 Btu/hr, single phase	PSZ system (based on CFA and # habitable stories), modeled with gas furnace and DX cooling with integrated differential dry bulb economizer, single phase, output capacities autosized by software based on loads (no compliance credit allowed for undersizing proposed system)
Heating efficiency:	81% AFUE	Meet or exceed current Federal minimum: AFUE ≥ 78%:	Meet or exceed current Federal minimum: AFUE ≥ 78%	Standard design set at current Federal minimum: AFUE = 78%
Cooling efficiency:	11.2 EER, 12.9 IEER	Meet or exceed current Federal minimum: EER ≥ 11.2	Meet or exceed current Federal minimum: EER ≥ 11.2	Standard design set at current Federal minimum efficiency for packaged single zone system EER = 11.2; plus Federal minimum EER for air conditioners with output ≥ 65,000 Btu/hr and < 135,000 Btu/hr: EER=11.2; IEER = 12.9
Distribution:	R-4.2 ducts in conditioned space	No duct insulation required for ducts in conditioned space	No duct insulation required for ducts in conditioned space	R-4.2 ducts in conditioned space

Domestic Hot Water

The Phocus office and warehouse building domestic hot water (DHW) system is very simple in design, but it meets all the mandatory requirements for water heaters in newly constructed buildings as discussed earlier in this guide. Under the 2016 Energy Standards the only prescriptive requirements for DHW are to meet the mandatory requirements for the particular type of water heating system being installed.

The MEP designer opted to specify a manufacturer-certified 40 gallon gas water heater, rated at 40,000 Btu/hr, with an energy factor of 0.70, and a standard, non recirculating distribution system. Looking at the table comparing mandatory and prescriptive requirements to the performance standard design assumptions for this system, you will see that most of the mandatory water heating system features are neither a credit nor a penalty for performance method compliance. The main exception to that is the water heater efficiency which is rated as an energy factor. DHW systems have to meet the applicable Appliance Efficiency Regulations as detailed in §110.1.

The minimum energy factor for a 40 gallon gas water heater is calculated using the equation EF=0.675– (0.0015 x V), where V is the tank volume, or EF = 0.615. The proposed water heater is substantially higher efficiency than the baseline, so the water heater would comply prescriptively and would provide a compliance credit in the performance method.

Phocus Office & Warehouse Building Case Study Compared To Mandatory and Prescriptive DHW Requirements and Performance Method Standard Design

DHW FEATURES	CASE STUDY	MANDATORY	PRESCRIPTIVE	PERFORMANCE
Newly Constructed Nonresidential Buildings	Phocus Office and Warehouse Building, Valencia, CA, Climate Zone 9	2016 Building Energy Efficiency Standards (§110.1, §110.3(b), §110.3(c) 1-3)	2016 Building Energy Efficiency Standards (§140.5(a))	2016 Nonresidential ACM Reference Manual (Section 5.9.1)
Fuel Types:	Natural Gas	No mandatory fuel type requirements	Natural Gas	Natural Gas
Equipment Type:	One 40 gallon gas water heater with 40,000 Btu/hr input	Meet or exceed mandatory requirements for proposed water heater type (small storage gas)	Meet or exceed mandatory requirements for proposed water heater type (small storage gas)	One 40 gallon gas water heater with maximum input for a small storage gas water heater
Tank Type:	Tank	Tank	Tank	Tank
Btu/hr Input:	40,000 Btu/hr	Small storage gas input defined as: ≤ 75,000 Btu/hr	Small storage gas input defined as: ≤ 75,000 Btu/hr	Standard design input rating is autosized
Efficiency:	0.70 EF	Meet or exceed current Federal minimum for a 40 gallon gas water heater: EF ≥ 0.615	Meet or exceed current Federal minimum for a 40 gallon gas water heater: EF ≥ 0.615	Non recirculating standard distribution, no controls
Controls:	Non recirculating standard distribution, no controls	Non recirculating standard distribution, no controls required	Non recirculating standard distribution, no controls required	Non recirculating standard distribution, no controls required

The Building Envelope Summary for Performance

Since the building envelope is included in the performance compliance analysis along with the HVAC and water heating systems, it is important to understand the building envelope characteristics. The performance approach space heating and space cooling energy use results from a combination of building envelope and mechanical system features.

The project envelope features include a building on a slab-on-grade foundation, with metal framed walls and a mix of storefront and manufactured windows. It was designed to meet or exceed most of the prescriptive envelope requirements, except for the prescriptive exterior wall U-factor of 0.062 versus the proposed 0.090, and the area-weighted prescriptive U-factor for fenestration for this design is 0.374 versus the proposed area-weighted fenestration U-factor of 0.430.

Building envelope features:

- 2,370 ft^2 total conditioned floor area
- 1,630 ft^2 total unconditioned floor area
- 70 ft^2 manufactured high performance fenestration with dual pane argon-fill low-e glass and vinyl frame, NFRC-rated U-factor of 0.34 and SHGC of 0.27;
- 441 ft^2 storefront fixed windows and glass doors with dual pane argon-fill low-e glass and thermal break metal frame, center of glass U-factor of 0.28 and SHGC of 0.27, NA6 calculated U-factor=0.445 and SHGC=0.312; 5' overhangs shading south-facing storefront windows and doors, total fenestration window to wall area ratio equals 20.5%, no west-facing fenestration
- Standing seam metal roof with R-30 insulation (U-factor=0.041), CRRC-rated cool roof with Aged Solar Reflectance = 0.69 and Thermal Emittance = 0.83
- Typical exterior walls 2x6 metal framed, R-21 cavity insulation plus R-5 continuous insulation (U-factor=0.090)
- Demising partitions next to unconditioned warehouse 2x6 metal framed, R-21 cavity insulation (U-factor=0.149)
- Uninsulated Slab on grade (F-factor=0.730)

Case Study Performance Method Results

Using EnergyPro 7.1 Energy Commission-approved energy compliance software to analyze the proposed building envelope, HVAC and water heating systems, the Phocus building complies with Title 24 Part 6 Energy Standards using the performance approach.

The first page of the NRCC-PRF-01-E Certificate of Compliance form lists general project information and the compliance results. Section B: Compliance Results for Performance Components compares the standard and proposed design TDV energy use for each energy component and for the compliance total and calculates their TDV energy use compliance margins.. Column 5 of this section also shows the Percent Better than Standard value for each energy component and for the compliance total. When evaluating the compliance results for each energy component as compared to the compliance total, the TDV energy use compliance margin is more helpful than the percent better than the standard design for the component. However, the compliance total percent better than standard is important as an assessment of overall building performance and is used for some incentive programs.

Below is a copy of the compliance results from the NRCC-PRF-1 Certificate of Compliance for this project. The compliance total TDV energy use for the proposed design is less than that for the standard design, so the Phocus case study complies with Title 24 using the performance approach. This building complies by 4.2 percent better than standard using the performance compliance path. The compliance results show a compliance penalty for space heating, and compliance credits for space cooling, indoor fans and domestic hot water. The compliance credit for water heating is expected since the proposed water heater is more energy efficient that the standard design assumption, while the results for space heating and space cooling show how the energy use or savings from building envelope characteristics is traded against the energy compliance features of the mechanical system.

Project Name:	Phocus Office	NRCC-PRF-01-E	Page 1 of 19
Project Address:	2020 Vision Court Valencia 91354	Calculation Date/Time:	22:48, Mon, Oct 17, 2016
Compliance Scope:	NewEnvelopeAndMechanical	Input File Name:	Phocus Office-Warehouse Case Study T24 EP7.1 Gas DHW 10-17-16.cibd16x

A. PROJECT GENERAL INFORMATION					
1.	Project Location (city)	Valencia	**8.**	Standards Version	Compliance2016
2.	CA Zip Code	91354	**9.**	Compliance Software (version)	EnergyPro 7.1
3.	Climate Zone	9	**10.**	Building Orientation (deg)	(S) 180 deg
4.	Total Conditioned Floor Area in Scope	2,370 ft²	**11.**	Permitted Scope of Work	NewEnvelopeAndMechanical
5.	Total Unconditioned Floor Area	1,630 ft²	**12.**	Building Type(s)	Nonresidential
6.	Total # of Stories (Habitable Above Grade)	1	13	Gas Type	NaturalGas
7.	Total # of dwelling units	0			

B. COMPLIANCE RESULTS FOR PERFORMANCE COMPONENTS (Annual TDV Energy Use, kBtu/ft ^{2}-yr)				**§ 140.1**
		BUILDING COMPLIES		
1. Energy Component	**2. Standard Design (TDV)**	**3. Proposed Design (TDV)**	**4. Compliance Margin (TDV)**	**5. Percent Better than Standard**
Space Heating	3.27	5.02	-1.75	-53.5%
Space Cooling	84.60	83.54	1.06	1.3%
Indoor Fans	106.71	97.92	8.79	8.2%
Heat Rejection	--	--	--	--
Pumps & Misc.	--	--	--	--
Domestic Hot Water	6.38	4.04	2.34	36.7%
Indoor Lighting	47.55	47.55	--	0.0%
COMPLIANCE TOTAL	**248.51**	**238.07**	**10.44**	**4.2%**
Receptacle	79.70	79.70	0.0	0.0%
Process	--	--	--	--
Other Ltg	--	--	--	--
TOTAL	**328.21**	**317.77**	**10.4**	**3.2%**

Performance Method Compliance Results for Phocus Office and Warehouse Case Study: Packaged Single Zone Gas/Electric HVAC, Storage Gas Water Heater, Form NRCC-PRF-01-E, Page 1 of 19, Energy Commission approved software version EnergyPro 7.1

Case Study Performance vs Prescriptive: Storage Electric Water Heater

As an exercise, suppose that the client for the Phocus case study wanted to use a 40 gallon storage electric resistance water heater, instead of a 40 gallon storage gas water heater. The electric water heater has an energy factor of 0.95 and 4500 watts input (18,772 Btu/hr). Replacing the water heater gives a substantial DHW compliance penalty in the performance method compliance results:

B. COMPLIANCE RESULTS FOR PERFORMANCE COMPONENTS (Annual TDV Energy Use, kBtu/ft ^{2}-yr)				§ 140.1
BUILDING COMPLIES				
1. Energy Component	2. Standard Design (TDV)	3. Proposed Design (TDV)	4. Compliance Margin (TDV)	5. Percent Better than Standard
Space Heating	3.27	5.02	-1.75	-53.5%
Space Cooling	84.60	83.54	1.06	1.3%
Indoor Fans	106.71	97.92	8.79	8.2%
Heat Rejection	--	--	--	--
Pumps & Misc.	--	--	--	--
Domestic Hot Water	5.96	10.85	-4.89	-82.0%
Indoor Lighting	47.55	47.55	--	0.0%
COMPLIANCE TOTAL	**248.09**	**244.88**	**3.21**	**1.3%**
Receptacle	79.70	79.70	0.0	0.0%
Process	--	--	--	--
Other Ltg	--	--	--	--
TOTAL	**327.79**	**324.58**	**3.2**	**1.0%**

Performance Method Compliance Results for Phocus Office and Warehouse Case Study: Packaged Single Zone Gas/Electric HVAC, Storage Electric Water Heater, Form NRCC-PRF-01-E, Page 1 of 19, Energy Commission approved software version EnergyPro 7.1

Note that the standard design input rating is autosized as in the analysis with a gas water heater, but the proposed design TDV energy use for the electric water heater is more than twice as much that for the gas water heater. This is because the DHW standard design assumes a storage gas water heater as the baseline for performance compliance in all nonresidential buildings even when the proposed system is electric (see 2016 Nonresidential ACM Manual Section 5.9.1.2 "Water Heater Type and Size").

Although you might not expect it based on the performance results below, any manufacturer-certified electric resistance water heater that meets all applicable mandatory measures complies with the Energy Standards using the prescriptive approach. There may be some situations where it will make sense to show separate prescriptive compliance for service water heating even while using the performance approach for other building components.

Winery Case Study, 3-D View. The Winery uses a complex system using both VRF and VAV systems so that we can highlight system choices, code triggers, and modeling limitations to compliance. DHW and HVAC hot water systems for VAV system (hot water reheat).

Case Study: Winery

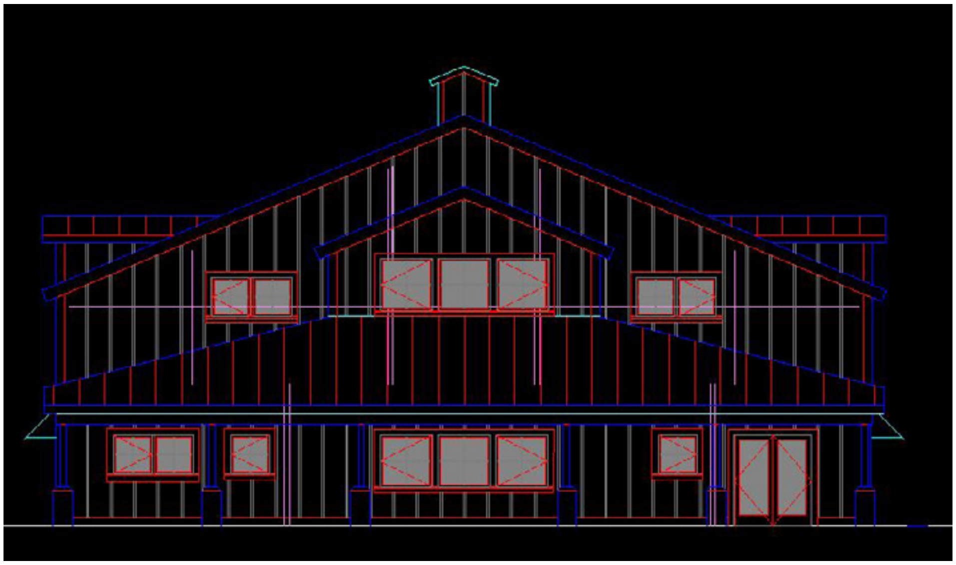
As we continue our discussion on integrated design and its effectiveness when employed as a first-line defense mechanism to meeting the Energy Standards it is important that we also discuss more complicated HVAC systems, coined as 'Complex Systems'. Complex systems from the modeling simulation viewpoint have inherent challenges that can best be mitigated using integrated design principles. In the next case study, we will evaluate a Winery project that proposes using two different types of complex systems: variable refrigerant flow (VRF) and variable air volume (VAV) systems. The VRF system has some modeling limitations as opposed to the VAV system. We will discuss these challenges as we evaluate the Title 24 requirements for each of these system types.

The Winery project is new construction and the scope for Title 24 compliance includes the building envelope, HVAC and water heating. Like the Phocus case study, the Winery is a sample project developed for training purposes and will be used here to evaluate compliance options, concentrating on mechanical systems and service water heating.

Project Scope - Winery, Sonoma CA

The Winery is a new two-story nonresidential winery building in Sonoma California, in climate zone 2. This 9,000 ft^2 building has 3,893 ft^2 of conditioned space and 5,077 ft^2 of unconditioned space. It houses several private offices, convention space, a tasting room, a chemical storage area, as well as a fermentation room along with a separate area for post-production wine storage.

For the purposes of our study, let's assume that the Energy Consultant plans to use the performance compliance path which requires a whole building simulation, including the building envelope.



Winery Case Study, Front Elevation

A Typical Project Team for this Kind of Building

Team Member	Role
Architect	Architect (Prime Contractor), Coordinate Cx Design Review
MEP	Mechanical & Plumbing Engineers
Lighting Design	Electrical & Lighting Engineer
Certified Energy Analyst (CEA)	Energy Consultant

The Building Envelope Summary for Performance

These building envelope features that would be part of the performance compliance analysis.

- 3,893 ft² total conditioned floor area
- 5,077 ft² total unconditioned floor area
- 323 ft² storefront windows and glass doors with dual pane argon-fill low-e glass and thermal break metal frame, center of glass U-factor of 0.29 and SHGC of 0.39, NA6 calculated U-factor=0.453 and SHGC=0.42; total fenestration window to wall area ratio (WWR) equals 13.6%, west-facing fenestration WWR equals 7.3%
- 2,343 ft² typical wood framed rafter roof with R-30 ceiling insulation and metal standing seam, but no CRRC-rated cool roof (U-factor=0.034)
- 556 ft² structural insulated panel (SIPS) roof with R-36 insulation, but no CRRC-rated cool roof (U-factor=0.029)
- Typical exterior walls structural insulated panels with R-14 (U-factor=0.062)
- Demising partitions next to unconditioned tank room structural insulated panels with R-30, (U-factor=0.062)
- Slab on grade (F-factor=0.730)

The Winery Design

VRF and VAV Complex System Design

The project requirements are centered around the many aspects of wine making. Temperature control and ventilation are the top two concerns. Temperature control in wine making is the top priority for fermentation and wine storage. The two types of complex systems proposed are the best fit for this project because of the custom zonal temperature control capabilities that these system types provide. The integrated design approach is favorable for early design discussions because it allows the Energy Consultant, Architect and Mechanical Engineer to discuss the code triggers associated with commissioning and other building features of that pose design limitation. The mechanical consultant in the schematic design phase would provide detailed explanation as to why VRF and or VAV systems were the best fit for this project.

The VRF system by design provides economically precise individual comfort control to targeted spaces (zones) providing maximum comfort to the occupants. By design VRF systems can be designed with many configurations with the benefits of offering a wide variety of applications including spot heating and cooling for targeted application. VRF systems move refrigerant to the zone heated or cooled. The nature of the on-demand benefits of the VRF system allows for spaces in the same thermal envelope to be cooled while other spaces are being heated or vice versa. The zonal level control allows the designer to better manage the heating and cooling needs of the uses based on occupancy use of the space.

A VAV system provides heating, ventilation and cooling. The ventilation is not supplied at a constant rate but rather varies depending on systems design, and the same is true for the heating and cooling capabilities of the system. The simplest VAV systems control ventilation from a single supply source while varying the airflow to each zone based on the temperature in the rooms in the zone.

As we delve into a few of the particulars of each of these systems we will focus on the Energy Standards mandatory, prescriptive and performance requirements in addition to the software modeling limitations for each of these complex systems and discuss how they have an impact on the whole building performance simulation.

Integrated Design Project Delivery: Benefits of the Commissioning Process

As mentioned in the Phocus Warehouse and Office Building case study, integrated design creates much needed synergy amongst the team members that allows for a more effective design process. This holds true for the Winery project given specificity of the temperature and ventilation requirements and the challenges complex systems present.

This building is exempt from many of the commissioning requirements required by the Energy Standards because it only has 3,898 ft^2 of conditioned space, and most commissioning requirements only apply to buildings with 10,000 ft^2 or more of conditioned space. Similar to the Phocus project the size allows the design team to provide a streamlined set of commissioning documents easy to prepare under the integrated design approach.

Below is typical Design Phase Design Review documentation required for this scope of work:

Commissioning Form	Title
NRCC-CXR-02-E	Commissioning – Commissioning Documents
NRCC-CXR-03-E	Construction Documents
NRCC-CXR-05-E	Commissioning – Design Review Signature Page

The Performance Compliance Path: Software Modeling Limitations, VRF vs. VAV

Since the Performance Approach involves a whole building simulation, it provides the benefit of energy tradeoffs between building features, such as the mechanical system and the building envelope.

Because the Winery project has less than 10,000 ft^2 of conditioned floor area and two habitable stories, the standard design system that both the VRF and VAV system are being benchmarked against in the 2016 Nonresidential ACM Manual is a packaged VAV system with a boiler and reheat capability (see highlighted 2016 Nonresidential ACM Manual Table 5 below). When considering performance compliance, it is important to understand that the number of habitable stories can make a big difference in the standard design system, even for buildings with the same conditioned floor area.

Building Area	Floors	Standard Design	Description
≤ 10,000 ft²	1 floor	PSZ	Packaged Single Zone
	>1 floor	PVAV	Packaged VAV Unit
10,000 ft² – 150,000 ft²	Any	PVAV	Packaged VAV Unit
>150,000 ft²	1 floor	SZVAV	Single-zone VAV Unit
	>1 floor	VAVS	Built-up VAV Unit

2016 Nonresidential Alternative Calculation Method Reference Manual (ACM Manual) Table 5: HVAC System Map for Nonresidential Spaces, highlighting the Winery case study standard design system.

VRF systems are highly efficient and have the capability to reduce heating and cooling energy of a building because of the ability to target the specific heating and cooling needs on a zonal level. The VRF system as mentioned earlier has its own inherent set of modeling limitations imposed by the California Energy Commission. Although the state-approved simulation software can model these types of complex systems as designed, the Energy Commission restricts the modeling approach for VRF systems because they have concerns about the efficiency testing methodology that manufacturers are using to determine efficiencies for these complex systems. Consequently, for Title 24 energy compliance, VRF systems must be modeled as split DX heat pump systems using only minimum efficiencies thus not allowing any performance credit to be taken even if the equipment efficiencies from the manufacturer are better than the minimum values.

The packaged VAV system however, is approved by the Energy Commission to be modeled as designed in the state-approved software and the benefits that this system design provides are accurately captured, providing the ability to provide energy credit under the performance compliance path should the equipment efficiencies exceed the minimum requirements, helping aid in a better compliance margin should other building features be less energy efficient which results in energy penalties.

Both the VRF and VAV systems had several benefits for the Winery and fit the criteria of the Owner's Project Requirements however, given the other building features being considered the Energy Consultant provided two simulation models demonstrating the impact on energy compliance that the two system designs would deliver.

Winery Case Study Compared to Mandatory and Prescriptive HVAC Requirements and Performance Method Standard Design: VRF System

HVAC FEATURES	CASE STUDY	MANDATORY	PRESCRIPTIVE	PERFORMANCE
Newly Constructed Nonresidential Buildings	Winery, Sonoma, CA Climate Zone 2	2016 Building Energy Efficiency Standards (§110.0, §110.1, §110.2(a), §120.4)	2016 Building Energy Efficiency Standards (§140.4)	2016 Nonresidential ACM Reference Manual (Sections 5.1.2, 5.7, Tables 4,5, and 7)
Total Conditioned Floor Area (CFA):	3,893 ft^2	3,893 ft^2	3,893 ft^2	3,893 ft^2
Number of Habitable Stories:	2	2	2	2
Fuel Types:	Space Heating: Electricity Space Cooling: Electricity	No mandatory fuel type requirements	Space Heating: Electricity Space Cooling: Electricity	Space Heating: Natural Gas Space Cooling: Electricity
Equipment Type (4 small systems all ≤ 36,000 Btu/hr cooling output):	VRF (Modeled as a minimum efficiency Split DX Heat Pump)	Meet or exceed mandatory requirements for proposed HVAC system type	Meet requirements for Split DX Heat Pump	Packaged VAV DX unit with gas furnace and hot water reheat (based on CFA and # of habitable stories)
Heating Efficiency (Split Heat Pump):	8.2 HSPF	Meet or exceed current Federal minimum: 8.2 HSPF	Meet or exceed current Federal minimum: 8.2 HSPF	Standard design set at current Federal minimum for a gas furnace: AFUE = 78%
Cooling efficiency:	14 SEER (Split DX) 12.2 EER (Split DX)	Meet or exceed current Federal minimum: SEER ≥ 14.0 (Split DX) EER ≥ 12.2 (Split DX)	Meet or exceed current Federal minimum: SEER ≥ 14.0 (Split DX) EER ≥ 12.2 (Split DX)	Standard design set at current Federal minimum efficiency for air conditioners with output < 45,000 Btu/hr: SEER=14.0, EER = 12.2
Supply Fans (1 fan per system, each fan ≤ 1205 cfm and ≤ 0.8 hp):	Constant volume, largest of 4 fans has 1,205 cfm design airflow and 0.8 hp	Meet applicable mandatory measures	Proposed fans under prescriptive 25 hp limit	Standard design assumes a variable flow, variable speed drive fan, supply cfm autosized to meet loads
Distribution:	R-8 ducts in conditioned space	No duct insulation required for ducts in conditioned space	No duct insulation required for ducts in conditioned space	R-8 ducts in conditioned space

Winery Case Study Compared to Mandatory and Prescriptive HVAC Requirements and Performance Method Standard Design: PVAV System

HVAC FEATURES	CASE STUDY	MANDATORY	PRESCRIPTIVE	PERFORMANCE
Newly Constructed Nonresidential Buildings	Winery, Sonoma, CA Climate Zone 2	2016 Building Energy Efficiency Standards (§110.0, §110.1, §110.2(a), §110.5, §120.4)	2016 Building Energy Efficiency Standards (§140.4)	2016 Nonresidential ACM Reference Manual (Sections 5.1.2, 5.7, Tables 4,5, and 7)
Total Conditioned Floor Area (CFA):	3,893 ft²	3,893 ft²	3,893 ft²	3,893 ft²
Number of Habitable Stories:	2	2	2	2
Fuel Types:	Space Heating: Natural Gas Space Cooling: Electricity	No mandatory fuel type requirements	Space Heating: Natural Gas Space Cooling: Electricity	Space Heating: Natural Gas Space Cooling: Electricity
Equipment Type (2 identical systems installed):	Packaged variable air volume (PVAV) system: Gas furnace with 135,000 Btu/hr output, PVAV DX cooling with 136,000 Btu/hr total output, 95,200 Btu/hr sensible output, plus integrated differential temperature economizer, three phase, Reheat boiler with 185,000 Btu/hr input	Meet or exceed mandatory requirements for proposed HVAC system type	Packaged VAV DX unit with gas furnace and hot water reheat	Packaged VAV DX unit with gas furnace and hot water reheat (based on CFA and # of habitable stories), equipment output capacity autosized to meet loads, plus integrated differential temperature economizer, three phase
Gas Furnace Heating Efficiency:	78% AFUE	Meet or exceed current Federal minimum: AFUE ≥ 78%	Meet or exceed current Federal minimum: AFUE ≥ 78%	Meet or exceed current Federal minimum: AFUE ≥ 78%
Reheat Boiler Efficiency:	85% AFUE	Meet or exceed current Federal minimum: AFUE ≥ 82%	Meet or exceed current Federal minimum: AFUE ≥ 82%	Meet or exceed current Federal minimum: AFUE ≥ 82%
PVAV DX Cooling Efficiency:	11.0 EER 12.7 IEER	Meet or exceed current Federal minimum: EER ≥ 11.0, IEER ≥ 12.4	Meet or exceed current Federal minimum: EER ≥ 11.0, IEER ≥ 12.4	Standard design set at current Federal minimum efficiency for DX air conditioners with output ≥ 135,000 Btu/hr and < 240,000 Btu/hr EER=11.0; IEER = 12.4
Supply Fans:	Variable speed drive, 3,400 cfm design airflow, 0 cfm minimum airflow, 1.5 hp	Meet applicable mandatory measures	Proposed fans under prescriptive 25 hp limit	Standard design assumes a variable flow, variable speed drive fan, supply cfm autosized to meet loads
Distribution:	R-8 ducts in conditioned space	No duct insulation required for ducts in conditioned space	No duct insulation required for ducts in conditioned space	R-8 ducts in conditioned space

Prescriptive vs Performance Method Compliance Analysis

The prescriptive versus performance comparison tables give information on the proposed VRF and PVAV systems, and then show prescriptive requirements for each feature as well as describing the performance standard design assumptions defined in the 2016 Nonresidential ACM and used as the baseline in the Energy Commission approved compliance software. It is interesting to note that since the standard design system type is based on the building conditioned floor area and number of habitable stories, both the VRF and PVAV systems are compared to the same PVAV system in the Performance Approach, even though the two proposed systems are quite different from each other. This can make it hard to predict ahead of time what sort of compliance results may emerge from any performance analysis.

The VRF system modeling limitations imposed by the Energy Commission required that this equipment be modeled as a split DX heat pump system. This system type has two main components: an indoor heat pump unit and an outdoor condensing unit. Pay attention to how the heating fuel and system type switches from electric heat pumps in the proposed design to natural gas furnaces and reheat boilers in the standard design, with the corresponding changes in efficiency ratings from an 8.2 HSPF to a 78% AFUE furnace. It is not necessary to assume a PVAV system as the baseline to comply prescriptively. The system type and efficiency for air conditioning are more consistent between the proposed system, the prescriptive requirements and the performance standard design than for space heating. The performance standard design assumes the same mandatory minimum cooling efficiency values as are required prescriptively.

Below is the Certificate of Compliance report for the VRF system modeled as a split DX system.

Project Name:	Winery	NRCC-PRF-01-E	Page 1 of 19
Project Address:	Road Sonoma 95476	Calculation Date/Time:	18:13, Mon, Oct 17, 2016
Compliance Scope:	NewEnvelopeAndMechanical	Input File Name:	Winery (VRF) - modeled as split dx EP7.1 10-17-16.cibd16x

A. PROJECT GENERAL INFORMATION					
1.	Project Location (city)	Sonoma	8.	Standards Version	Compliance2016
2.	CA Zip Code	95476	9.	Compliance Software (version)	EnergyPro 7.1
3.	Climate Zone	2	10.	Building Orientation (deg)	(N) 341 deg
4.	Total Conditioned Floor Area in Scope	3,893 ft²	11.	Permitted Scope of Work	NewEnvelopeAndMechanical
5.	Total Unconditioned Floor Area	5,077 ft²	12.	Building Type(s)	Nonresidential
6.	Total # of Stories (Habitable Above Grade)	2	13	Gas Type	NaturalGas
7.	Total # of dwelling units	0			

B. COMPLIANCE RESULTS FOR PERFORMANCE COMPONENTS (Annual TDV Energy Use, kBtu/ft ²-yr)				§ 140.1
		BUILDING COMPLIES		
1. Energy Component	2. Standard Design (TDV)	3. Proposed Design (TDV)	4. Compliance Margin (TDV)	5. Percent Better than Standard
Space Heating	21.82	45.62	-23.80	-109.1%
Space Cooling	151.97	74.88	77.09	50.7%
Indoor Fans	65.83	63.82	2.01	3.1%
Heat Rejection	--	--	--	--
Pumps & Misc.	1.81	--	1.81	--
Domestic Hot Water	11.18	6.26	4.92	44.0%
Indoor Lighting	105.20	105.20	--	0.0%
COMPLIANCE TOTAL	**357.81**	**295.78**	**62.03**	**17.3%**
Receptacle	220.37	220.37	0.0	0.0%
Process	137.03	137.03	0.0	0.0%
Other Ltg	--	--	--	--
TOTAL	**715.21**	**653.18**	**62.0**	**8.7%**

Performance Method Compliance Results for Winery: VRF System modeled as Split DX Heat Pumps, Tankless Gas Water Heater, Form NRCC-PRF-01-E, Page 1 of 19, Energy Commission approved software version EnergyPro 7.1

The Winery modeled with a VRF system complies with Title 24 with a positive compliance margin of 62.03 kBtu/ft²-yr of TDV energy or a compliance total of 17.3% better than the standard design. Most of the energy saved is for space cooling which is the combination of the cooling equipment and the cooling-related components of the building envelope. The proposed space heating on the other hand is using a lot more energy than the standard design and is receiving a penalty as the proposed TDV energy use is 23.80 kBtu/ft²-yr more than the standard design. As with the space cooling, the space heating results from the interactions of the heating equipment with the building envelope and operating conditions.

As you'll notice in the comparison table for the PVAV system, the proposed design is very similar to the standard design. Below are the compliance results for each of the energy components designed as part of the proposed VAV system for this project:

B. COMPLIANCE RESULTS FOR PERFORMANCE COMPONENTS (Annual TDV Energy Use, kBtu/ft ^{2}-yr)				§ 140.1
BUILDING COMPLIES				
1. Energy Component	2. Standard Design (TDV)	3. Proposed Design (TDV)	4. Compliance Margin (TDV)	5. Percent Better than Standard
Space Heating	21.82	21.79	0.03	0.1%
Space Cooling	151.97	131.51	20.46	13.5%
Indoor Fans	65.82	44.22	21.60	32.8%
Heat Rejection	--	--	--	--
Pumps & Misc.	1.81	0.84	0.97	53.6%
Domestic Hot Water	11.18	6.26	4.92	44.0%
Indoor Lighting	105.20	105.20	--	0.0%
COMPLIANCE TOTAL	**357.80**	**309.82**	**47.98**	**13.4%**
Receptacle	220.37	220.37	0.0	0.0%
Process	137.04	137.04	0.0	0.0%
Other Ltg	--	--	--	--
TOTAL	**715.21**	**667.23**	**48.0**	**6.7%**

Performance Method Compliance Results for Winery: Packaged VAV System, Tankless Gas Water Heater, Form NRCC-PRF-01-E, Page 1 of 18, Energy Commission approved software version EnergyPro 7.1

The Winery with the packaged VAV system also complies with Title 24 with a comfortable compliance margin of 47.98 kBtu/ft²-yr of TDV energy, or a compliance total 13.4 percent better than standard. It is interesting that the compliance margin for the packaged VAV system as designed ended up somewhat worse than the VRF system modeled as a minimum efficiency split DX heat pump system. Perhaps because the proposed PVAV system is almost identical to the standard design system, none of the energy components is out of compliance on its own, but the space cooling compliance margin is not as large as for the VRF system.

The VAV system modeled was favorable in terms of energy compliance in that many of the HVAC features were in line with the mandatory, prescriptive and performance requirements. The packaged VAV system concept designed included a DX chiller to cool the whole building, and a boiler supplies hot water to all zones. Also, the system design includes zonal terminal units with hot water reheat to each of the zones.

Winery Case Study Compared to Mandatory & Prescriptive DHW Requirements and Performance Method Standard Design

DHW FEATURES	CASE STUDY	MANDATORY	PRESCRIPTIVE	PERFORMANCE
Newly Constructed Nonresidential Buildings	Winery, Sonoma, CA Climate Zone 2	2016 Building Energy Efficiency Standards (§110.1, §110.3(b), §110.3(c) 1-3)	2016 Building Energy Efficiency Standards (§140.5)	2016 Nonresidential ACM Reference Manual (Section 5.9.1)
Fuel Types:	Natural Gas	No mandatory fuel type requirements	Natural Gas	Natural Gas
Equipment Type:	0.100 gallons with 185,000 Btu/hr input	Meet or exceed mandatory requirements for proposed water heater heating type (small instantaneous gas)	Meet or exceed mandatory requirements for proposed water heater heating type (small instantaneous gas)	One 40 gallon gas water heater with maximum input for a small storage gas water heater
Tank Type	Tankless	Tankless	Tankless	Tank
Btu/hr Input:	185,000 Btu/hr	Small instantaneous gas input defined as: ≤ 200,000 Btu/hr	Small instantaneous gas input defined as: ≤ 200,000 Btu/hr	Standard design input rating is autosized
Efficiency	0.84 EF	Meet or exceed current Federal minimum for a 0.100 gallon instantaneous gas water heater: EF≥0.82	Meet or exceed current Federal minimum for a 0.100 gallon instantaneous gas water heater: EF≥0.82	Standard design set at 2004 Federal minimum for a 40 gallon gas water heater: EF=0.59
Controls:	Non recirculating standard distribution, no controls	Non recirculating standard distribution, no controls	Non recirculating standard distribution, no controls	Non recirculating standard distribution, no controls

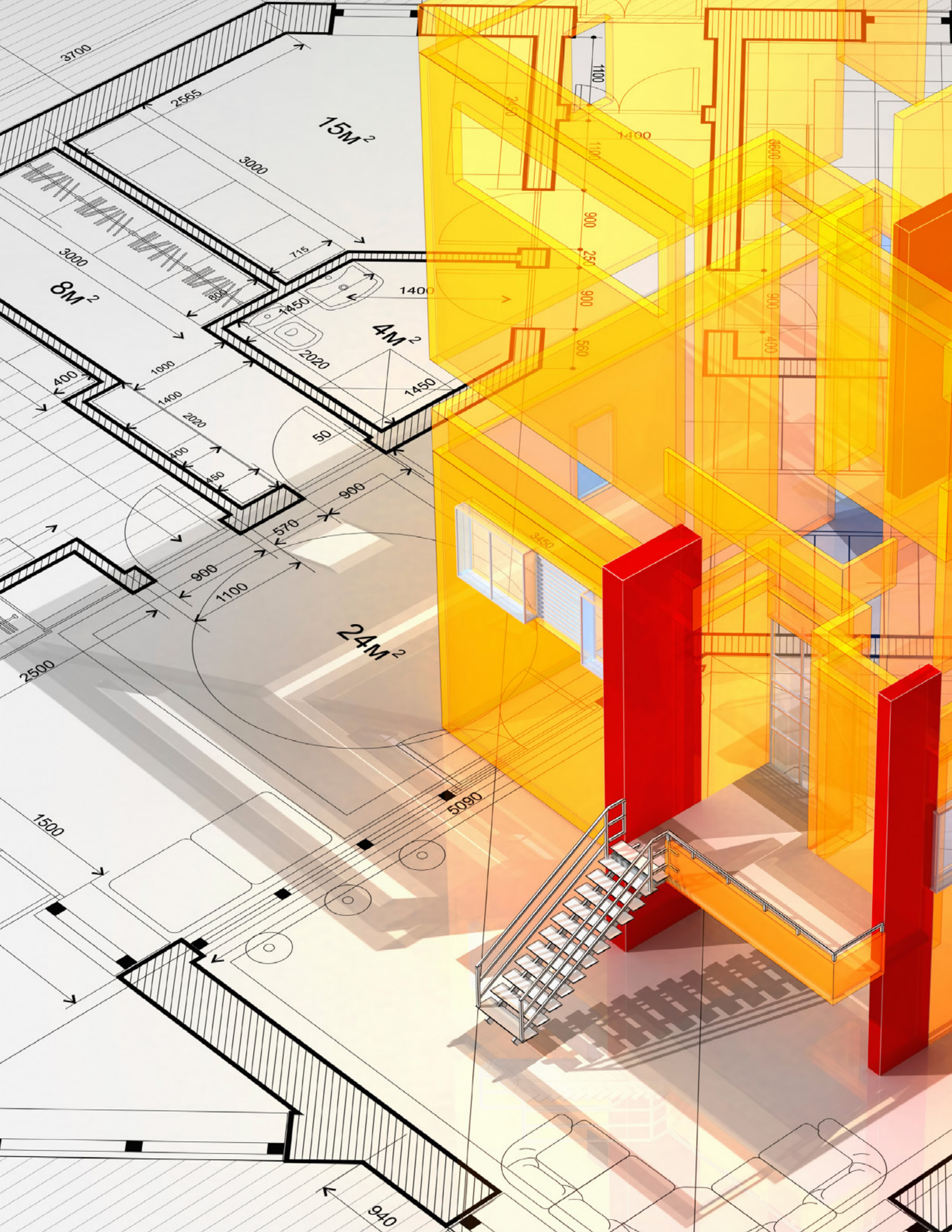
Domestic Hot Water

Looking at the prescriptive versus performance comparison table for water heating you'll see that the domestic hot water (DHW) for this project was provided by an instantaneous gas water heater with an energy factor of 0.84 which is better than the mandatory and prescriptive minimum energy factor of 0.82 for this type of system. The standard design water heater is a storage gas water heater with an energy factor of 0.59, the same as for the Phocus case study. One reason tankless water heaters are more energy efficient is that water is heated on demand rather than stored in a tank, so there is no need to heat and then reheat the same tank full of water before using it.

The project site has natural gas available which was ideal because the mandatory and prescriptive requirements have to match that of the proposed design and in this case natural gas is the ACM benchmark. Instantaneous gas water heaters are highly efficient, and the difference between the 0.59 standard design and 0.84 proposed design energy factors results in an energy credit under the performance compliance method, as shown in the excerpt from the compliance results below:

Domestic Hot Water	11.18	6.26	4.92	44.0%
Indoor Lighting	105.20	105.20	--	0.0%
COMPLIANCE TOTAL	357.80	309.82	47.98	13.4%

The proposed energy use for the instantaneous gas water heater is 4.92 kBtu/ft²-yr less than the standard design that assumes a storage gas water heater. That's about 10% of the compliance total energy savings of 47.98 kBtu/ft²-yr, and it's an energy saving that is relatively easy to achieve.



3700
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900
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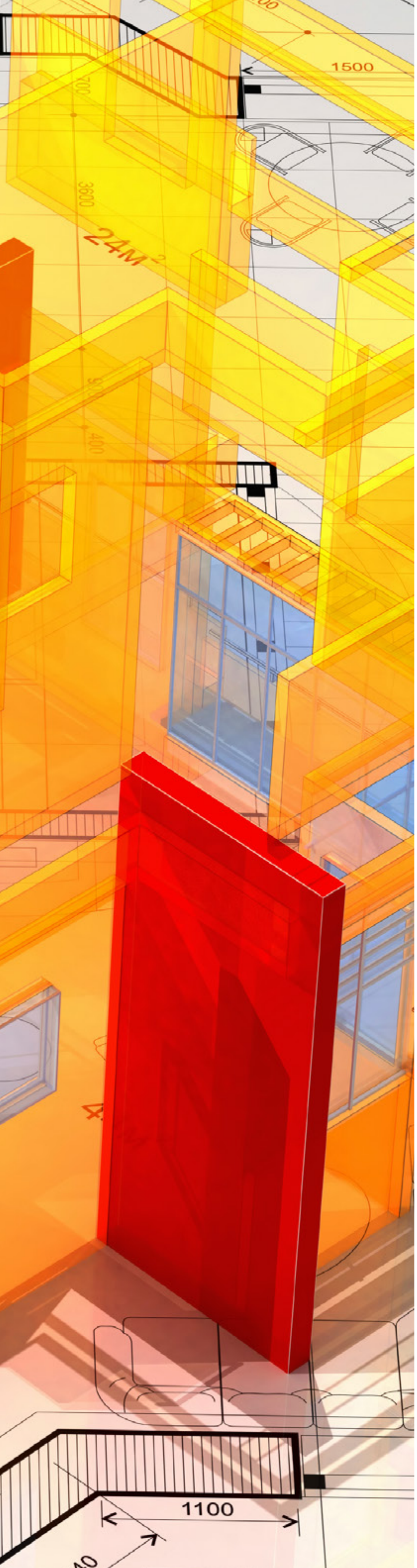


CHAPTER 6

RECOMMENDATIONS, RESOURCES AND COORDINATION

Using Energy Simulation Software for the Performance Approach

Using the performance approach to compliance requires the use of approved energy simulation software. A list of these certified compliance tools are maintained on the Energy Commission's website: energy.ca.gov/title24/2016standards/2016_computer_prog_list.html.

Software Assumptions and Limitations

The simulation software is sophisticated, and capable of simulating many energy related scenarios and there are numerous assumptions and limitations associated with its use.

- While §110.2 of the Energy Standards defines minimum required efficiencies for most HVAC components and system types, there is no mandated system type (VAV, packaged VAV, Split heat pump, etc.) that must be used for a proposed project or building type. However the performance approach does assume a specific system type based on the occupancy and square footage of the building and adopts the prescriptive minimum efficiency of that equipment. The system type assumed for the baseline system is not always the same as the proposed design. Table 4 from the 2016 Nonresidential Alternative Calculation Method (ACM) Reference Manual summarizes the HVAC system types that are assumed as a baseline for any project using the performance compliance approach.

  Regardless of the type of HVAC system(s) that is proposed for a project, the reference simulation that is used to create the energy budget will utilize the rules in Table 4 to define the type of HVAC system for the base case.
- Energy simulation software is estimating the energy use of a building that is not yet built or renovated, and it is developing this estimate to ensure compliance with the Energy Standards. The simulation makes many assumptions that are not always editable by the user and may not represent the intended or envisioned operation of a given building. For example, the simulation software assumes default set-points and hours of occupancy for thermostats, lighting, receptacle and occupancy schedules. Receptacle loads (computers, copiers, printers, etc,) and operation of shades and blinds cannot be changed in the simulations. Number of people in the building can be varied over a fairly narrow range.

- The simulation is not allowed to account for any benefits or penalties associated with shade trees, localized shading by adjacent structures or microclimates. Only structures permanently attached to a building are allowed to be included in the analysis. For example, a building surrounded by other tall buildings or in a forest that is heavily shaded is considered fully exposed by the simulation tool as if it was on an open, flat plane of ground.
- Compliance with Title 24, Part 6 is determined using a TDV energy budget that places a higher value on energy saved during utility peak periods (e.g. hot summer afternoons). As a result, saving one kWh of electricity at 3:00 A.M. will not reward the energy budget in the same way that saving that same kWh of electricity at 3:00 P.M. in July. This meets the public policy goal of encouraging off peak energy use instead of peak period use, but it also means that users should be careful in how they interpret simulation results modified by the TDV multipliers.
- Certain system and/or equipment types are not currently defined in the Nonresidential ACM Reference Manual, which means that for the purposes of compliance, the presumed benefits and/or penalties of those system types are not fully captured by the simulation. The following system types are not currently defined in the ACM: chilled beams, variable refrigerant flow (VRF), ground source heat pumps, underfloor and/or displacement ventilation systems and most absorption chillers but may be added in subsequent version of the software. It is up to the user to keep up on equipment system supported). The Energy Commission outlines the “Alternative Calculation Methods” approach for compliance with systems outside the current approved software in §10-109 (e).
- Human comfort, which can be influenced by air movement, radiant surface temperatures, air temperature and even an occupant’s perceived control over their environment, is not accounted for in the simulation. For this reason, only some of the benefits of radiant heating/cooling, natural ventilation, ceiling fans and other less common HVAC components are captured by the simulation.

Interpreting Energy Simulation Reports

For these reasons and others, users and consumers of information generated by energy simulation compliance programs in compliance mode should treat the results as an accurate measure of compliance, but not as a perfect measure of the eventual energy consumption of the project. It should be noted that most approved energy simulation tools can be run in a "non-compliance" mode that may be useful for design purposes or to predict actual energy use more closely.

The results of these "non-compliance" simulations cannot be used to demonstrate adherence to the Title 24, Part 6 Energy Standards except through exceptional methods submitted through the California Energy Commission as outlined in §10-109(e).

The simple statement taken at face value, "Building Complies", explains very little other than the software inputs representing the project meet or beat the Energy Standards. The fact that the results show the building complies could be either by design or accident.

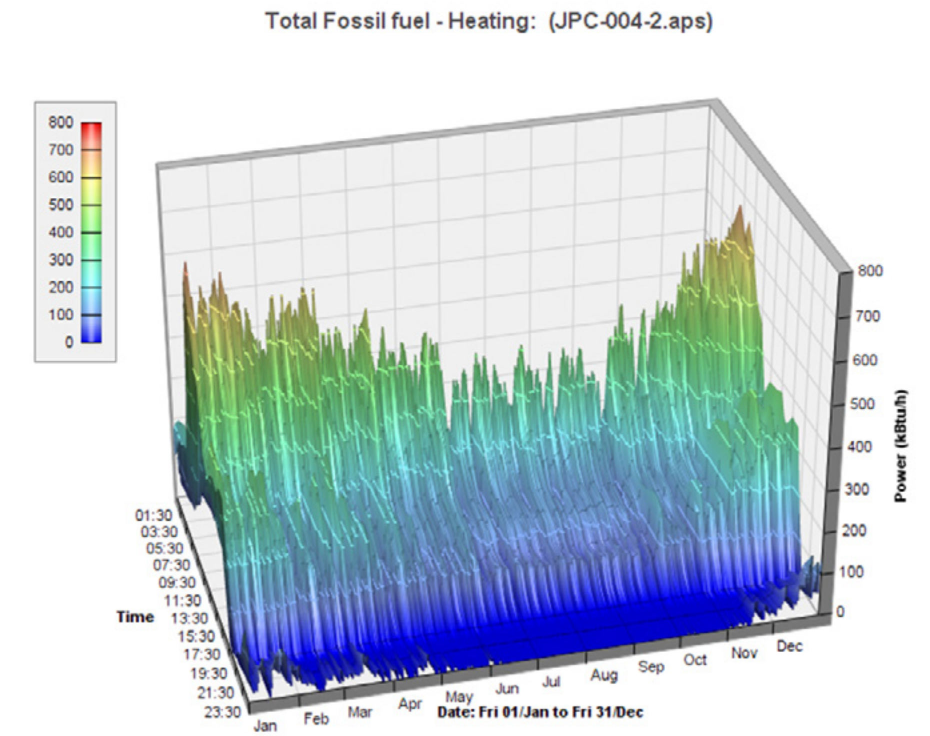
The components represent the impact of the design on those systems that use energy resulting in a TDV adjusted Energy Use Intensity (EUI). The TDV multipliers differ by hour for electricity use throughout the day and by month, vary by climate zone and grid region, and significantly change depending on the fuel types used. The following sections summarize the energy end uses reported by the simulation software and are intended to explain how various systems in a building interact.

B. COMPLIANCE RESULTS FOR PERFORMANCE COMPONENTS				§ 140.1
BUILDING COMPLIES				
1. Energy Component	2. Standard Design (TDV)	3. Proposed Design (TDV)	4. Compliance Margin (TDV)	5. Percent Better than Standard
Space Heating	15.1	11.1	4.0	26.5%
Space Cooling	109.4	79.0	30.4	27.8%
Indoor Fans	59.0	67.8	-8.8	-14.9%
Heat Rejection	--	--	--	--
Pumps & Misc.	0.8	--	0.8	--
Domestic Hot Water	--	--	--	--
Indoor Lighting	118.3	91.5	26.8	22.7%
COMPLIANCE TOTAL	**302.6**	**249.4**	**53.2**	**17.6%**
Receptacle	225.2	225.2		0.0%
Process	140.1	140.1		0.0%
Process Ltg	--	--		--
TOTAL	**667.9**	**614.7**		**8.0%**

NRCC-PRF-01-E from an example project. Much information can be gathered by interpreting each of the energy components.

Space Heating

Space heating is the resultant energy use as the heating system keeps the interior space temperature from dropping too low due to heat loss through the envelope. Keep in mind that internal gains (lights, people, plug loads), as well as envelope construction (sun penetration through glazing), contribute heat to the space and can influence heating demand over the course of the year. Some variables that can impact the space heating numbers include, but are not limited to: wall construction/insulation, glazing construction, and heating system efficiency.

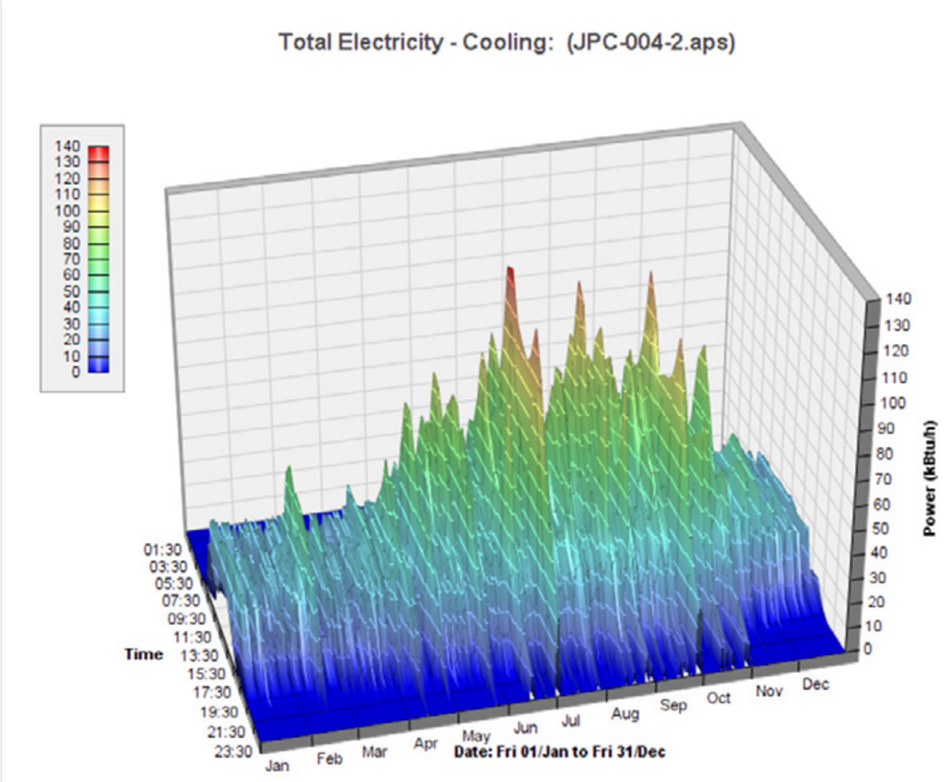


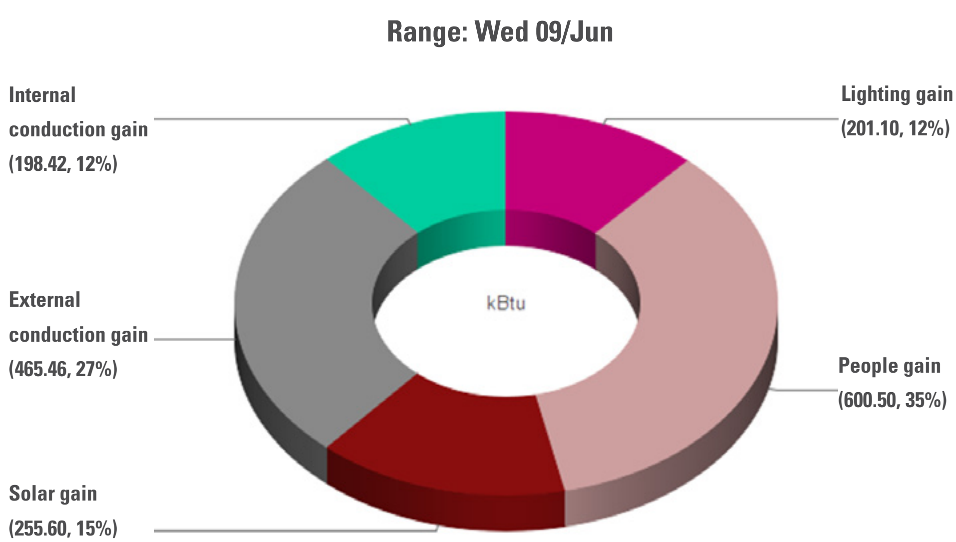
Heating Load Profile - CA CZ 4

Space Cooling

The resultant energy use of the cooling system keeps the interior space temperature from rising too high due to heat gain through the envelope, people, lighting, plug loads and any other miscellaneous process that introduces heat to the space. Some variables impact cooling energy in spaces that have very little to do with the architecture of the building. Process loads in the space like computer or IT equipment can generate significant cooling loads that run around the clock.

In commercial kitchens, exhaust air for stoves and other cooking equipment usually drives the need for space cooling. In spaces like auditoriums, with very little glass normally for performances, the cooling load is generated from the high density of people in the space. It's important to understand the loads in the space and the impacts on the performance models and specific compliance paths (see example cooling load profile on the next page).

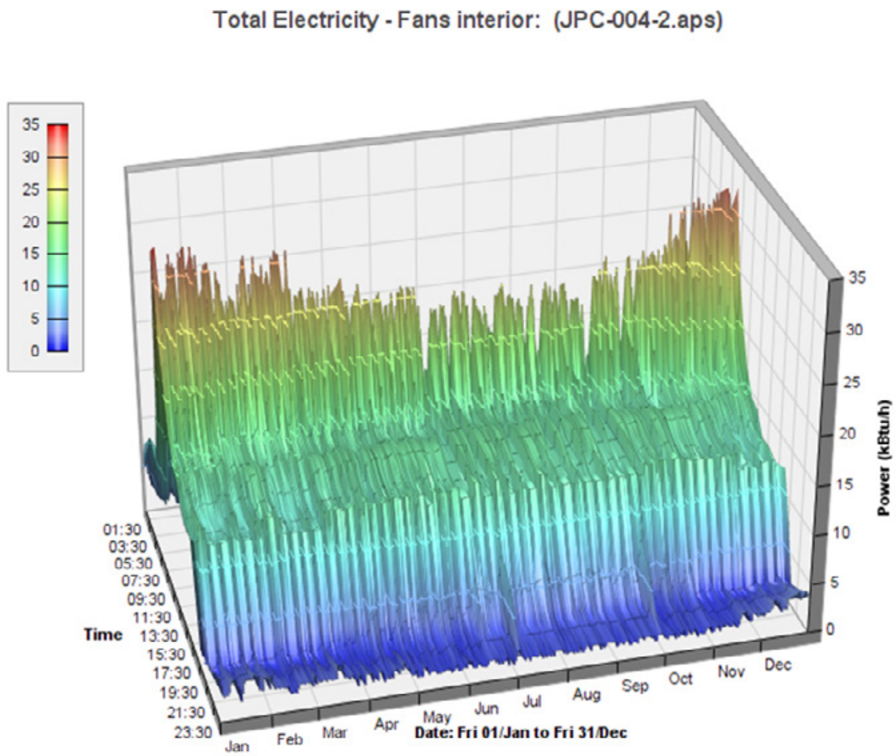




The two illustrations above show a breakdown of a Cooling Load Profile - CA CZ 4

Indoor Fans

Similar to the cooling and heating energy use profile, fan energy is heavily impacted by the internal loads, architectural design, and perhaps the process elements in the building. Where high heating or cooling loads are present, and an air based system is selected in the design, the fan energy will be impacted in the compliance approach. Fan energy use changes as heating and cooling loads change, but system type and design also have an impact. Low pressure drop duct design, low leakage air handlers, ductless systems, and water based systems like radiant floors, radiant panel walls or ceilings, and chilled beams all have the potential to reduce fan power and energy consumption.



Fan Load Profile - CA CZ 4

Heat Rejection

Heat rejection in the performance model is tied to evaporatively cooled air handlers and packaged units, water source heat pumps, and central plants with cooling towers but can also apply to geothermal plants. Heat rejection from DX units is reported in the cooling category only. This is important in interpreting the results when the proposed system is water cooled and the baseline system is DX. In this example a water cooled system will show a negative compliance margin in the heat rejection component but a higher margin for cooling since the energy for heat rejection in the baseline is included in the cooling category. The combined TDV for both cooling and heat rejection should be considered when interpreting the results. The heat rejection category can be reduced with low approach temperature cooling towers, cooling tower fan design, or geothermal field efficiency. There are limitations in the current performance modeling tools to fully model the effectiveness of geothermal field designs but the energy use can be approximated.

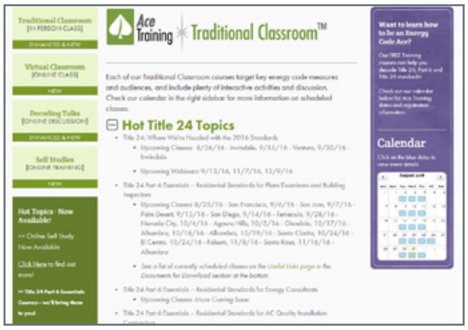
Pumps and Miscellaneous

The category titled “Pumps & Misc” normally just includes the pumping power associated with central plant equipment including hot water, chilled water, and pumps associated with cooling tower or condenser water. Strategies for reducing pumping power can take the form of reducing heating and cooling loads as well as designing low pressure drop piping systems with variable speed drives.

Domestic Hot Water

This category normally covers just the domestic hot water systems along with controls and pumps if any.

Energy used to heat potable water for “domestic” use (sanitation, food preparation, drinking, personal hygiene) to a higher temperature through use of a hot water heating appliance (water heaters, boilers, heat exchangers). High-rise residential and hotel/motel occupancies have mandatory and prescriptive requirements that will dictate the energy budget, efficiency, control criteria, and recirculation design. All other nonresidential occupancies have mandatory requirements that dictate efficiency and controls. Strategies for reducing this energy category center around the efficiency of the DHW source, solar thermal systems to offset demand, and the controls for recirculation systems if any are present.



Energy Code Ace Trainings

Energy Code Ace offers trainings in a variety of formats including in person classroom, virtual classroom, online decoding talks and online self studies.

Visit the web page to for more information: energycodeace.com/content/training-ace/

Finding Help With Energy Compliance

This Application Guide brings together a host of resources and experience to create a pathway for understanding Energy Standards, the purpose of the standards, and how to apply them. Each project requires an evaluation of the code triggers, mandatory measures, prescriptive or performance compliance paths, and the testing and verification process that may apply to the project.

Some projects become complex, and may require additional resources, such as training, or even a specialist to help navigate the Energy Standards.

Available Training

Training is available in many forms for understanding the Energy Standards. The Investor Owned Utilities (IOU's), the California Energy Commission, and other entities like HERS Providers and the California Association of Building Energy Consultants (CABEC) regularly offer classes. Classes are offered in many formats from online training sessions, videos, hands on inspection training, and others. Each team member should keep up to date with the Energy Standards requirements as they are updated every three years.

Find Qualified Experts

Design and construction professionals have a responsibility to know their role in compliance, but increasing complexity of the Energy Standards requires dedicated experts in most cases. Qualified energy consultants can help navigate compliance strategies along with seasoned commissioning authorities to help verify operations post construction. Acceptance Testing Technicians are quickly coming into the market to serve the testing requirements within the Energy Standards. All of these professionals are in high demand and new providers are coming into an expanding market. Below are some links for finding qualified professionals to help document compliance with the Energy Standards:

CABEC Certified Energy Analyst

cabec.org/cea.

California Commissioning Collaborative

cacx.org/resources/selecting.html

California Energy Commission- ATT Certification Providers

energy.ca.gov/title24/attcp/