CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Acceptance Requirements #2:

Based on Retro-commissioning Failure Modes

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team October 2011

This report was prepared by the California Statewide Utility Codes and Standards Program and funded by the California utility customers under the auspices of the California Public Utilities Commission.

Table of Contents

List of Tables and Figures

1. Introduction

This report is a part of the California Investor-Owned Utilities (IOUs) Codes and Standards Enhancement (CASE) effort to develop technical and cost-effectiveness information for proposed regulations on building energy efficiency design practices and technologies.

This report investigates the potential for improvements or additions to current Title 24 Nonresidential Acceptance Requirements, which are targeted inspections and functional tests meant to improve compliance with specific code measures and thereby ensure energy savings. Specifically, this measure investigated building system faults identified through retro-commissioning (RCx) projects and identified ways these findings may inform revised or new acceptance tests. The outcome of this measure includes new acceptance test requirements, and modifications to current test requirements for the 2013 Title 24 rulemaking cycle.

Specifically, based on this research we tentatively propose one new acceptance test for Supply Air Temperature (SAT) Reset Controls, and one revised test to account for Condenser Water Supply Temperature (CWST) Reset Controls on water-cooled chillers served by a cooling tower. SAT reset saves energy by adjusting the supply air temperature during periods of low load, typically based on outside air temperature. CWST reset saves energy by lower chiller condenser entering supply water temperature during times of low cooling load, allowing the chiller to operate more efficiently at part load.

Throughout 2010 and early 2011, the CASE Team (Team) evaluated costs and savings associated with each code change proposal. The Team engaged industry stakeholders to solicit feedback on the code change proposals, energy savings analyses, and cost estimates. The contents of this report were developed with feedback from building departments, contractors organizations, and other related industries and the California Energy Commission (CEC) into account.

The main approaches, assumptions and methods of analysis used in this proposal have been presented for review at three public stakeholder meetings hosted by the IOUs. At each meeting, the CASE Team asked for feedback on the proposed language and analysis. Following each meeting, the CASE Team sent participants a summary of what was discussed at the meeting and a summary of outstanding questions and issues. A record of the Stakeholder Meeting presentations, summaries and other supporting documents can be found at www.calcodesgroup.com. Stakeholder meetings were held on the following dates and locations:

- First Stakeholder Meeting: May 20, 2010, California Lighting Technology Center, UC Davis, CA
- Second Stakeholder Meeting: December 7, 2010, San Ramon Conference Center, San Ramon, CA
- Third Stakeholder Meeting: April 6, 2010, Webinar

2. Overview

2.1 *Measure Title*

Acceptance Requirements Topic #2: New and Revised Acceptance Requirements based on Retro-commissioning (RCx) Failure Modes

2.2 *Description*

This measure proposes new or revised acceptance tests or acceptance testing procedures for the Energy Efficiency Standards for Nonresidential Buildings (Part 6, Title 24).

Acceptance Testing requirements consist of targeted inspection checks and tests to determine whether specific building systems, controls, and equipment were not only installed properly, but also function as specified by the building plans and as required by the Title 24 Standards. The acceptance test process generally includes conducting a visual inspection, reviewing certification requirements, and performing functional tests. These requirements currently apply to both new construction and significant retrofits.

Currently, a total of twenty-one acceptance tests exist for major building systems, including envelope, mechanical (HVAC), and indoor and outdoor lighting. This measure proposes one new test and one change to an existing test. This measure relies upon data from a dataset of building failures collected from building retro-commissioning (RCx) by PECI. By investigating and sorting for the most common and energy-consuming building failures, new tests were developed which will target and prevent these common failures.

2.3 *Type of Change*

This measure proposes mandatory requirements. Acceptance tests are mandatory for any installed system which has an associated test, and the tests must be completed and documented via the Acceptance Forms before a Certificate of Occupancy can be issued by a building department.

This measure does not affect prescriptive or performance compliance, nor will it affect modeling performance calculations.

This measure would require changes to the three sections of the Standards which pertain to the acceptance requirements - Chapter 10 of the Nonresidential Compliance Manual (NRCM), Appendix A of the NRCM, and Reference Nonresidential Appendix NA7. Chapter 10 contains general directions and rationale for the Requirements, Appendix A of the NRCM contains the Acceptance Forms, and Appendix NA7 contains specific instructions for carrying out the tests.

Changes include changes to the instructions and directions, forms, and scope of compliance. They also include two new tests.

2.4 *Energy Benefits*

The proposed new acceptance tests will create electric, demand, and natural gas savings, in kWh/yr, kW, and therms/yr respectively. These energy savings are obtained by ensuring that equipment are installed and operate as designed and as specified by code, thereby improving compliance with the code.

Energy savings are presented for each acceptance test analyzed, and for each prototype building (see Methodology and Analysis Results for methodology). Savings are normalized to a per-square-foot basis for comparison across buildings and scaling to statewide savings projections.

Yearly energy savings use TDV (Time Dependent Valuation) to apply a valuation of the present value monetary savings.

The following table summarizes the average yearly savings from each measure. Section 4 discusses savings analysis and results in more detail.

	Weighted Average Electricity Savings		**Weighted Average Natural Gas Savings**		**Weighted Average Demand Savings**		**Weighted Average TDV Cost Savings**	
	kWh / sf	**kWh / bldg***	**Therms / sf**	**Therms / bldg ***	**kW / sf**	**kW / bldg ***	**$ / sf**	**$ / bldg ***
Supply Air Temperature Reset (Acceptance & Measure)	0.5	5,000	0.051	510	0.008	8	$1.40	$14,000
Condenser Water Supply Temperature Reset (Acceptance)	0.058	6,200	0	0	0	0	$0.12	$12,200

*Representative model for SAT Reset is10,000 square foot building. Representative models for CWST Reset are 67,500 square foot and 117,000 square foot buildings.

The savings from these measures will result in, at most, the following yearly statewide savings. Section 4 discusses savings analysis and results in more detail.

	Statewide Power Savings (MW/yr)	**Statewide Electricity Savings (GWh/yr)**	**Statewide Natural Gas Savings (Million Therms/yr)**	**Total TDV Cost Savings (Million $)**
Supply Air Temperature Reset (Acceptance & Measure)	52	34	3	$90
Condenser Water Supply Temperature Reset (Acceptance)	0.0	1.2	0.0	$2.4

2.5 *Non-Energy Benefits*

Non-energy benefits include improved operation and reduced need for maintenance for functioning systems. This will decrease maintenance costs, increase the building value, and improve comfort and air quality (IAQ) due to properly functioning HVAC systems.

2.6 *Environmental Impact*

This proposed measure does not have any anticipated adverse environmental impacts, neither to air nor water quality, nor to materials or equipment.

The reduction in energy use is anticipated to create emissions reductions from reduced power generation. This includes reductions in CO_2, CO, SO_X, NO_X, and PM_{10}.

These impacts, on a per-building basis, are summarized in the table below:

	NO_X (lbs/bldg)	**SO_X (lbs/bldg)**	**CO (lbs/bldg)**	**PM_{10} (lbs/bldg)**	**CO_2 (lbs/bldg)**
CWST Reset	1.0	5.9	1.4	0.5	3,600
SAT Reset	1.3	5.1	1.3	0.42	3,500

*Representative model for SAT Reset is10,000 square foot building. Representative models for CWST Reset are 67,500 square foot and 117,000 square foot buildings.

2.7 *Technology Measures*

This measure does not require any new technology or equipment, beyond that which is already commonly used for Acceptance Tests.

The Acceptance Tests currently require the use of a number of measurement tools, including:

- Airflow measurement probes / anemometer
- Fan flowmeter
- Digital manometer
- Reference CO_2 probe
- Differential pressure gauge
- Static pressure sensor
- Hydronic manometer
- Temperature probe
- Light meter (illuminance or foot-candle)
- Amperage meter / power meter
- Logging light meter

These tools are already in use and should be readily available to contractors and other test practitioners. Therefore no additional costs or concerns for availability are assigned to these tools in this analysis.

2.7.1 Useful Life, Persistence, and Maintenance

Acceptance requirements are meant to ensure compliance with the codes, and therefore increase the persistence of savings for measures. For simplicity of this analysis, the energy savings of each proposed acceptance test are considered as a comparison of a properly functioning measure (properly tested) vs. an installed measure that is not properly functioning (not tested or improperly tested).

Additional maintenance is expected to ensure the proper functioning of the tested equipment, and the savings are expected to persist for the lifetime of the equipment that is tested. In actual practice, the energy savings for acceptance requirements depend on the manner in which the tests are carried out and results verified, and on the building maintenance practice.

The effectiveness of the acceptance requirements depends greatly on whether they are performed correctly or at all. Therefore, the key concerns related to persistence of savings are test effectiveness and compliance. These concerns are being addressed separately in another complementary code proposal: Acceptance Requirements #1: PIER Study, Effectiveness and Compliance.

2.8 *Performance Verification of the Proposed Measure*

Ideally, the acceptance requirements themselves verify proper installation and operation; they are a means of performance verification. However, as noted, the effectiveness of the acceptance tests varies greatly, and the performance of the energy-consuming building components depends on those tests. The tests are verified by means of completion of the Acceptance Forms, the signing of those forms by the "Responsible Person" (who is licensed as a contractor, engineer, or otherwise able and authorized to accept responsibility for the building's construction under Division 3 of the Buildings and Professions Code) and submittal of those forms to the Building Departments as a prerequisite for a Certificate of Occupancy.

The effectiveness of the acceptance requirements is being addressed separately in another complementary code proposal: Acceptance Requirements #1: PIER Study, Effectiveness and Compliance.

Energy performance and persistence of savings is guaranteed for code measures by the acceptance tests themselves, which improve compliance with the code measure. In this analysis, we assume that the energy savings and improved performance from the acceptance tests will persist through the non-residential analysis period of 15 years as defined by the CEC. Improved performance and incremental energy savings can be maintained by periodic follow up testing and maintenance.

2.9 *Cost Effectiveness*

The following table shows average costs and savings results using the California Energy Commission (CEC) Life Cycle Cost (LCC) Methodology. To obtain energy savings, SAT Reset was modeled in a previous CASE analysis in one building type across 16 climate zones while CWST Reset was modeled in two building types across 5 climate zones. The LCC methodology compares the additional first and maintenance costs, against the energy cost savings, considering useful measure life and periodic maintenance.

Life cycle costs and savings are presented on a per-square-foot basis, and also for each prototype building considered (for prototype building data, please see the Methodology section).

a	b	c	d	e	f		g	
Measure Name	Measure Life (Yrs)	Initial Measure Costs Relative to Base Case ($/sf) *	PV of Additional Testing & Maintenance Costs (PV$/sf)	PV of Total Costs (PV $/sf)	TDV of Energy Savings ($)		LCC Savings ($)	
					$/sf	$/bldg	$/sf	$/bldg
SAT Reset Controls Measure + Test	15	$0.08	$0.14	$0.22	$1.40	$14,000	$1.18	$11,800
CWST Reset Controls Test	15	$0	$0.03	$0.03	$0.12	$12,200	$0.09	$9,300

* Acceptance costs are primarily based on labor costs, which are not anticipated to change significantly after code adoption.

2.10 *Analysis Tools*

The proposed acceptance tests will be mandatory requirements, and therefore would not be subject to whole building performance modeling or calculations.

Nonetheless, it will be necessary to ensure that building systems and equipment which undergo an acceptance test receive performance energy "credit" in the code compliance process, typically via building modeling software. The building elements covered in the proposed acceptance tests have been reviewed to ensure that current building performance software is able to model them and properly account for the energy savings they will provide.

2.11 *Relationship to Other Measures*

This measure is being submitted in coordination with another measure related to acceptance testing: Acceptance Requirements #1: Effectiveness and Compliance, Based on PIER Study.

In 2010-2011, a PIER (Public Interest Energy Research) study, carried out by PECI, investigated the effectiveness of current acceptance tests via surveys, observations, and site visits at facilities across California. The purpose of this study was to improve compliance with the tests, as compliance is low for many reasons. This study recommends specific improvements to the acceptance testing forms, instruction language, and code compliance process.

In this proposal for new and revised acceptance tests, we have considered the findings of the PIER study in order to ensure any new acceptance requirements will be simple and easy to comply with.

3. Methodology

As acceptance tests are a compliance method, not efficiency measures unto themselves, the methodology for calculating costs and savings is slightly modified from typical measure analysis. Though compliance methods are typically not required to prove cost-effectiveness, we wish to present an analysis to estimate the impact that the test method will have on measure cost-effectiveness.

3.1 *Acceptance Test Selection and Development*

This section provides details on the CASE team review of retro-commissioning (RCx) data to select potential new acceptance tests for measure development.

The Portland Energy Conservation, Inc. (PECI) California Retro-commissioning (RCx) Programs were designed to focus solely on buildings 100,000 square feet and larger with central air handling units. Thus, the measures investigated during this project typically apply only to large commercial buildings and generally do not cover unitary HVAC equipment.

PECI used the RCx program Measure Summary Report (MSR) data as the sample to identify measures. This MSR is a compilation of all the measures identified during the RCx programs that PECI implemented on behalf of PG&E, SCE, and SDG&E during the 2006-2009 utility program cycle. This includes over 800 distinct measures (70 measure categories) identified in 125 buildings over eight building types. The buildings included in the programs were:

- 1 college/university
- 5 hospitals and medical centers
- 19 hotels
- 1 K-12 school
- 82 large offices
- 10 large retail
- 6 miscellaneous
- 1 medical lab

The MSR data includes information such as:

- Building name
- Occupancy type
- Climate zone
- Zip code
- Year constructed
- Control system (DDC, pneumatic, hybrid)
- Conditioned floor area
- Annual kWh and therm usage

- Failure mode
- Annual kWh, kW, and therm impact of the finding

The analysis tasks were as follows.

Step 1: Review RCx datasets to determine suitability of measures

This step involved sorting and filtering the RCx programs' data. As mentioned above, PECI used the RCx programs MSR data to determine the most prevalent measures in the large commercial buildings included in the PECI programs. PECI then aggregated the measures and counted the occurrence of each type across the programs. They then sorted the measures in descending order of occurrence to show which measures occurred most often. The most common measure was "Reduce equipment runtime" with 126 occurrences. On the other end of the scale, fourteen measures had only one occurrence each.

This data was then filtered to eliminate data that are (1) not representative of projected new construction projects in California and (2) not appropriate for 2013 Title 24. PECI performed this step by manually reviewing each measure with regard to these two criteria. These RCx programs only include existing buildings, so some of the findings did not apply to new construction. Some of the measure recommendations represented small capital improvement projects that IOU programs promote, such as adding a variable frequency drive (VFD) to a pump, fan, or chiller. The CASE team also eliminated these from further analysis, as they are not appropriate for considering as new acceptance requirements.

Step 2: Review RCx data to gauge level of savings

This step involved determining the energy impacts of the measures after initial sorting. This was necessary to rank the measures by energy impact, to consider for preliminary energy modeling analysis, as explained in the next step.

As part of the RCx programs, the energy impacts of the measures were calculated and recorded in the MSR data. The RCx providers calculated the energy savings expected as a result of addressing the measures, using a combination of energy simulation, spreadsheet calculations, trended data, and spot measurements. PECI engineers then reviewed the savings calculations and work with the providers to revise the estimates as needed to ensure accuracy. The utility program managers also reviewed the savings calculations and recommend changes as needed. This rigorous review process helped these programs achieve an excellent realization rate, which meant the savings were valid and defensible.

The MSR data contains the calculated annual kWh, kW, and therm impacts of the measures. However, the RCx programs primarily focus on electric consumption impacts (kWh/yr savings). The CASE team focused on the median savings rather than the average savings because averages tend to be distorted based on outliers in the data.

Step 3: Review RCx datasets to determine frequency of measures

Using the results of Steps 1 and 2, the CASE team truncated the list of measures to eliminate those with an occurrence frequency within the lowest 20th percentile. In other words, the measures that make up the top 80th percentile, based on the frequency of occurrence, continued to the next analysis step for consideration as new acceptance requirements.

There are 813 total occurrences of measures across 70 measures categories. The 80th percentile of 813 measures is 650 measures. Sorting the dataset by frequency of occurrence shows the top 20 categories compose 652 measures. The remaining 50 categories account for 161 measures. This is the 20th percentile and lower. These 50 measure categories were removed from further consideration.

After removing measures not applicable for testing, sorting according energy savings, and sorting according to frequency, the CASE team arrived at the list to the 18 items shown in Table 1.

Table 1: Key RCx Failure Modes

Measure Type	Occurrence	% of total	Cumulative	Electric savings, kWh/sf
Reduce equipment runtime	126	15%	15%	0.06
Reset duct static pressure setpoint	56	7%	33%	0.15
Optimize airside economizer – general	49	6%	45%	0.18
Supply air temperature reset	35	4%	49%	0.12
Reduce lighting schedule	35	4%	54%	0.08
Chilled water supply temperature reset	32	4%	58%	0.12
Adjust damper control	29	4%	61%	0.08
Condenser water supply temperature reset	25	3%	64%	0.19
Revise air handling unit control sequence	20	2%	67%	0.07
Optimum start/stop	17	2%	69%	0.10
Reduce DSP setpoint / relocate sensor	14	2%	71%	0.23
Controls sequence revisions	14	2%	72%	0.06
Add occupancy sensor	12	1%	74%	0.16
Chiller staging	12	1%	75%	0.07
Boiler lockout	12	1%	77%	0.03
Calibrate sensor	10	1%	78%	0.04
Trim pump impeller	9	1%	79%	0.05
Adjust outside air minimum flow setpoint	9	1%	80%	0.01

Finally, each mode was reviewed once again for suitability for a new or revised acceptance test. Nine of the eighteen modes listed in Table 1 are already addressed by existing acceptance tests. Furthermore, five measures were better addressed by design phase decisions or proper maintenance rather than acceptance testing.

Two of the remaining measures (Boiler lockout, Optimum start/stop) were considered for preliminary savings analysis but are not currently addressed in the nonresidential energy modeling software for compliance purposes nor in the nonresidential Alternate Calculation Method (ACM) Approval Manual for energy modeling software. Boiler lockout controls cannot be modeled using the DOE-2 engine, and building operational and occupancy schedules for Title 24 compliance are preset and cannot be modified by the modeler. Therefore, these measures would not be analyzed or credited during building performance or prescriptive compliance, and therefore cannot be tested at this time (Statewide Utilities Codes and Standards Program 2011 CASE Initiative, 2010b).

A summary of the suitability criteria and decisions is as follows in Table 2:

Table 2: Acceptance Test Suitability of RCx Failure Modes

Measure Type	Already in Acceptance Requirement	Design or Maintenance Concern	Not Addressed in NR ACM
Reduce equipment runtime	-	X	-
Reset duct static pressure set point	X	-	-
Optimize airside economizer – general	X	-	-
Supply air temperature reset	-	-	-
Reduce lighting schedule	X	-	-
Chilled water supply temperature reset	X	-	-
Adjust damper control	X	-	-
Condenser water supply temperature reset	-	-	-
Revise air handling unit control sequence	-	X	X
Optimum start/stop	-	-	X
Reduce DSP set point / relocate sensor	X	-	-
Controls sequence revisions	-	X	-
Add occupancy sensor	-	X	-
Chiller staging	-	X	-
Boiler lockout	-	-	X
Calibrate sensor	-	X	-
Trim pump impeller	-	X	X
Adjust outside air minimum flow set point	X	-	-

Based upon these results, the two acceptance test measures chosen for final savings and costs analysis are Supply Air Temperature (SAT) Reset Controls and Condenser Water Supply Temperature (CWST) Reset Controls. These measures are not covered by an existing acceptance requirement, and can be reviewed with a simple inspection and functional test. The energy savings from these measures can be attributed to a building during the prescriptive or performance compliance process and software.

SAT reset saves energy by adjusting the supply air temperature during periods of low load, typically based on outside air temperature. A 2003 PIER VAV Design Guide indicated that the highest savings from SAT Reset occurred when supply air is linearly reset between 65 °F and 55 °F up to 70 °F outside air (Hydeman & Stein, 2007, 72).

By reducing the condenser water supply temperature (temperature of water exiting the cooling tower) during times of low cooling load and low ambient wetbulb temperature, the chiller operates more efficiently at lower head pressure. Savings can be particularly significant for chillers with VFDs.

However, this measure can significantly increase cooling tower fan power and reduce chiller capacity to a level insufficient to meet load, if improperly applied.

3.2 *Per Measure Energy Savings Calculation Methodology*

3.2.1 Supply Air Temperature Reset Controls

For those efficiency measures which have a previous Codes and Standards Enhancement analysis, energy savings and costs have already been determined and are referenced in this report. These measures have been shown to be cost-effective. To verify the value of an acceptance test for these measures, we simply add the cost of performing the test to the previously determined measure cost, and re-calculate the measure life cycle cost. This approach applies to the Supply Air Temperature Reset acceptance test proposal. Supply Air Temperature Reset is a prescriptive code measure for mechanical space-conditioning systems supplying heated or cooled air to multiple zones (Section 144(f)), and analysis for this measure was recently done for the 2008 Building Standards by Taylor Engineering (Hydeman & Stein, 2007) on behalf of the Pacific Gas and Electric Company. This 2008 analysis is referenced here and provides the basis for the life-cycle cost analysis for SAT Reset Controls Acceptance.

Taylor Engineering calculated energy savings for this measure by building performance modeling. An overview of their modeling strategy is provided here, while a more detailed description of the model they used can be found in the original 2008 CASE report.

A 10,000 square foot, five zone office building was modeled in eQuest to evaluate annual energy performance of the proposed control sequences. The building was modeled in all climate zones, and prescriptive values were chosen for the envelope components. In order to simulate "real-life" building operation, five occupancy day schedules were modeled.

The building model is conditioned by a packaged VAV system with hot water reheats at VAV boxes. Room temperature set points during occupied / unoccupied hours were 75 °F / 82 °F for cooling and 70 °F / 64 °F for heating, respectively. System supply air temperature was fixed at 55 °F cooling in the base case, with a DOE-2 fan curve representing static pressure reset.

The standards case was identical to the base case, with the exception that cooling SAT reset control and heating SAT reset control were set according to the demands of the warmest and coolest zone, respectively. Cooling SAT reset from 55 °F up to 65 °F between 70 °F and 65 °F outside air temperature. Heating SAT reset down to a minimum of 75 °F.

Detailed base case and standards case modeling assumptions for SAT Reset Controls Acceptance can be seen in the Table A1 and Figures A1 and A2 in the Appendix.

3.2.2 Condenser Water Supply Temperature Reset Controls

The CWST Reset Controls measure does not have an accessible existing CASE analysis, so the analysis isolated the savings associated with performing the acceptance test, and calculated the cost of performing the test.

Savings are obtained by building energy modeling using EnergyPro v5.1, which uses the DOE-2.1E engine and is currently approved by the CEC for performance compliance with Title 24 (CEC, 2010b). Condenser water supply temperature reset is a performance energy-saving measure which is not prescriptive in the code, but is already addressed in the ACM and can be modeled by building performance software for compliance.

Energy savings for this acceptance test are obtained by building performance modeling using two prototype buildings (Office and Hotel). These buildings were chosen of different sizes and occupancies because the CWST Reset Measure will only affect water-cooled chilled water plants, typically used for large buildings or campuses; furthermore, the RCx measured data came primarily from office and hotel buildings. Prescriptive envelope components and default occupancies were applied to both building models.

Table 3: Building Modeling Parameters

Occupancy Type	Area (sq ft)	Number of Stories	Number of Zones	HVAC System
Office	117,000	6*	15*	Chilled Water Built-up Variable Air Volume with HW Reheat (NR ACM Standard HVAC System #4)
Hotel	67,500	3	15	Four-Pipe Fan Coil with Central Plant (NR ACM Standard HVAC System #5)

*Modeled as three floors with a 4x multiplier for the central floor.

The model office chilled water plant was run with either a water cooled centrifugal chiller or a water cooled screw chiller with cooling tower. Chiller size varied between 218-279 tons based on climate zone. The model hotel water plant was run with a water cooled scroll chiller with cooling tower; chiller size varied between 118-123 tons based on climate. In the base case, entering condenser water remains a constant 80 °F. In the standards case, entering condenser water temperature is reset down to 66 °F / 70 °F according to outdoor wet-bulb temperature. See Table 4 for base case and standards / acceptance test case parameters.

Table 4: CWST Reset Controls Modeling Assumptions

	Office				Hotel	
Parameter	**Base Case**	**Standards / Acceptance Case**	**Base Case**	**Standards / Acceptance Case**	**Base Case**	**Standards / Acceptance Case**
Chiller Type	Centrifugal	Centrifugal	Screw	Screw	Scroll	Scroll
Chiller Efficiency (COP)	5.5	5.5	4.9	4.9	4.45	4.45
Leaving Chilled Water Temperature (°F)	44	44	44	44	44	44
Entering Condenser Water Temperature (°F)	85	85	85	85	85	85
Condenser Setpoint Temperature (°F)	80	80	80	80	80	80
Tower Minimum Leaving Water Temperature (deg F)	-	66	-	66	-	70
Approach Temperature (°F)*	-	10	-	10	-	6
Cooling Tower Fan Power (hp)	30	30	30	30	15	15
Cooling Tower Fan Efficiency (%)	97%	97%	97%	97%	92%	92%

*Temperature between Outside Air Wetbulb Temperature and Cooling Tower Minimum Leaving Water Temperature

Modeling was done for six representative California climate zones (CZs) and cities, representing about 57% of CA population and 60% of new construction:

CZ 3 - North Coastal - Oakland

CZ 12 - North Inland - Sacramento

CZ 6 - South Coastal - Los Angeles AP/Torrance

CZ 9 – South Inland – Burbank

CZ 10 - South Inland - Riverside

CZ 16 - Mountain - Mount Shasta

Additional model parameter data can be seen in the Appendix, Table A2 and A3, and Figures A3 and A4.

3.2.3 Time Dependent Valuation and Test Effectiveness

All yearly energy savings are multiplied against the 2011 TDV (Time Dependent Valuation) values to determine the monetary value of the energy savings over the entire measure life cycle. The TDV values weight peak savings more heavily than off-peak savings to account for the real cost of energy to society. For nonresidential non-envelope measures, the TDV period of analysis is 15 years at a 3% discount rate. This period of analysis is appropriate for HVAC controls, as HVAC equipment will operate to or beyond 15 years. The energy savings achieved by acceptance testing are assumed to be maintained by regular yearly incremental maintenance.

To isolate the net energy savings from acceptance requirements for CWST Reset controls, we take into account the estimated effectiveness of the acceptance test at identifying building problems and at correcting them. PECI developed these factors in a 2003 study on behalf of the Air Conditioning and Refrigeration Technology Institute (PECI & Battelle Northwest Division, 2003, A-3).

The factors "Prevalence of Problems" and "Likelihood of Not Being Detected without Commissioning" describe how common a problem is when the particular equipment is present, and whether a problem would normally be identified if a system or equipment were not commissioned / tested. These factors are applied to the measure energy savings to account for the fact that (a) building equipment may or may not fail and therefore may or may not always benefit from acceptance testing, and (b) the test may not be able to always capture the necessary information to prevent the failure from occurring. These factors do not take compliance into account.

3.3 *Statewide Energy Savings Methodology*

The statewide energy savings associated with these proposed measures were calculated by multiplying the per unit estimate with the statewide estimate of new construction in 2014. Details on the method and data source of the new construction forecast are presented in sections 4.5 and 7.3.

3.4 *Costs Calculation Methodology*

The cost of acceptance tests consists mainly of the time for the technician to perform the test, and for the Responsible Person to review the test data and sign the forms. These are a one-time cost accrued at equipment installation.

New acceptance tests may require atypical tools or equipment which are not easily accessible to the technicians, incurring an additional cost to purchase this equipment. However, for the tests analyzed in this report, this was not the case and equipment costs were not considered. For SAT Reset, necessary equipment includes (a) drybulb temperature sensor(s). Necessary equipment to test CWST Reset may include a drybulb temperature sensor, relative humidity meter/sensor, sling psychrometer, amperage or power meter, tachometer, pressure gauge, and flow meter.

Stakeholder feedback obtained during IOU sponsored stakeholder meetings indicated that the installing contractor tends to perform the test and sign the forms as the Responsible Person. In the case of both acceptance test measures proposed in this report, the controls contractor would be likely to perform this function.

National average contractor rates were obtained from the RS Means 2010 database of both union and open shop labor rates. They were then adjusted upwards to California rates. In this case, the highest listed rates (sheet metal workers, electricians, plumbers) - $80 / hr including overhead and profit -

were used as a conservative assumption. A scalar of 1.068 is applied to adjust for California prices, creating an adjusted rate of $85/hr.[1]

Labor rates are multiplied by contractor time to perform the test and review the forms to obtain total test cost. The specific acceptance testing procedures add an incremental cost on top of normal installation, startup, and testing and balancing (TAB) procedures. Acceptance test time estimates (minimum and maximum) were obtained from Functional Testing Guides (FTGs) based on retro-commissioning procedures by Portland Energy Conservation, Inc. (PECI, 2003) and from stakeholder feedback.

Findings from the related Acceptance Testing CASE Study (#1: Based on PIER Study), and stakeholder feedback, indicate that it is typically necessary for two technicians to be on-site to perform the test (for example, the installing contractor to perform the test, and the controls contractor to manipulate the building energy management system). Given this trend, average test time is multiplied by two to account for this required coordination.

Table 5: Acceptance Test Time Estimates

	Minimum Test Time (hrs)	Maximum Test Time (hrs)	Forms Review Time (hrs)	Travel Time (hrs)	Average Total Time (hrs)	Labor Rate ($/hr)	Average Total Test Cost
SAT Reset Acceptance	0.5	2	2	2	5	$85	850
CWST Reset Acceptance	6	8	2	2	11	$85	$1870

Finally, a small incremental maintenance cost is assumed for the standards case to maintain the enhanced energy savings and performance due to acceptance testing over the life of the building. In the case of both of these measures, the building energy manager or maintenance staff is assumed to periodically revisit the controls set points to assure occupant comfort and performance.

Incremental maintenance labor costs and time are shown in Table 6, assuming the same labor rate. Yearly costs are discounted over the course of 15 years at 3% discount rate, as consistent with CEC's life cycle cost analysis method. These incremental costs are considered for both SAT Reset and CWST Reset.

---

[1] This scalar was obtained from RS Means City Cost Indexes for Labor / Installation for the largest metropolitan areas in California, weighted according to city population and scaled to statewide population (RSMeans 2010 City Cost Indexes, Cost Works, 2011).

Table 6: Incremental Maintenance Costs

	Yearly Maintenance Time (hrs)	Yearly Maintenance Cost	Present Value (PV) Yearly Maintenance Cost (r=3%, n=15)
SAT Reset Acceptance & Measure	0.5	$43	$510
CWST Reset Acceptance	1	$85	$1,020

For SAT Reset Acceptance, the costs of performing the test and additional maintenance (Tables 5 and 6) are added to the measure first cost, estimated at between $400 and $800 (Hydeman & Stein, 2007).

This first cost is not considered for CWST Reset Acceptance; only the incremental cost and energy savings benefit of performing the test are considered, as this measure is not prescriptively required by the code and does not have a previous CASE measure analysis.

4. Analysis and Results

4.1 *Energy and Cost Savings*

The following tables demonstrate the weighted average site energy and cost savings from these measures, calculated as described in the Methodology section.

Table 7: Weighted Average Site Energy Savings

	Electric Savings (kWh / sf-yr)	**Peak Demand Savings (kW / sf-yr)**	**Gas Savings (Therms / sf-yr)**	**Total Energy Savings (kBtu / sf-yr)**
SAT Reset Acceptance & Measure	0.5	0.008	0.051	4.4
CWST Reset Acceptance *	0.058	0.000	0.000	0.2

*Includes test effectiveness factor of 71% for CWST Reset to isolate savings from acceptance test. See PECI & Battelle Northwest Division, 2003.

Detailed tables showing savings for each climate zone and building type are available in the Appendix (Tables A4, A5, and A6). For SAT Reset Controls, highest savings occur in CZ 1, CZ 3, and CZ 5 – mild, wet, coastal climates. Lowest savings occur in CZ 14, CZ 15, and CZ 16 – mountain regions with hot summers and cold winters. For CWST Reset Controls, highest savings occur in CZs 9, 10 and 12 – dry inland areas. Lowest savings occur in CZ 3 and 6 – mild and wet coastal areas. On a per-ton or per-sq-ft basis, the highest CWST savings came from the modeled screw chillers, with lower savings from centrifugal and lowest from scroll.

All costs are considered over a period of 15 years at 3% discount rate.

Table 8: Average Costs Savings

	Total Cost Savings (PV TDV $ / sf)
SAT Reset Acceptance & Measure	$1.40
CWST Reset Acceptance	$0.12

*Includes test effectiveness factor of 71% for CWST Reset. See PECI & Battelle Northwest Division, 2003.

Table 9: Average Per-Test Costs

	Average Acceptance Test Cost (PV $)	Present Value of Yearly Incremental Maintenance Cost ($)	Materials and Installation Cost (PV $)	Total Present Value Incremental Measure Cost (PV $)	Total Present Value Cost (PV $ / sf) *
SAT Reset Acceptance & Measure	$850	$510	$800	$2,200	$0.22
CWST Reset Acceptance	$1,870	$1,020	N/A	$2,900	$0.03

*Representative model for SAT Reset is 10,000 square foot building. Representative models for CWST Reset are 67,500 square foot and 117,000 square foot buildings.

4.2 *Cost Effectiveness*

The cost-effectiveness of a measure depends on its ultimate life cycle cost. Costs and TDV cost value of life cycle energy savings are compared to determine whether the measure will have total negative life cycle cost (positive savings). For acceptance tests, the cost of the test is based on the time spent to conduct the inspection and test for each system, and therefore is fixed no matter the building size.

Table 10: Measure Cost-Effectiveness (Life Cycle Cost)

	Approximate Total PV Incremental Cost (PV $)	Approximate Average TDV Savings (TDV $)	Approximate Net Per-Building Life Cycle Cost Savings ($)	Per-Sq Ft Life Cycle Cost Savings ($/sf) *
SAT Reset Acceptance & Measure	$2,200	$14,000	$11,800	$1.18
CWST Reset Acceptance	$2,900	$12,200	$9,300	$0.09

*Representative model for SAT Reset is10,000 square foot building. Representative models for CWST Reset are 67,500 square foot and 117,000 square foot buildings.

For a feasibility check, we calculate the break-even building size for which these acceptance test measures will be cost-effective. SAT Reset Controls Acceptance & Measure will conservatively be cost-effective for any building or building zone greater than 1,500 square feet (air conditioning system greater than approximately 4 tons of cooling). Therefore it is anticipated that this measure will remain cost-effective when combined with an acceptance test.

For CWST Reset Controls Acceptance, the measure will conservatively be cost-effective for any building greater than approximately 13,000 square feet or chilled water system greater than approximately 13 tons. Water-cooled chillers and cooling towers are far larger than this, so it is anticipated that this test will be cost-effective in all installed cases.

4.3 *Recommended Modeling Approach*

No new modeling rules or algorithms are proposed, and no new recommendations are made for the ACM Manuals. SAT Reset Control and CWST Reset Control are already addressed by the ACM in detail, in sections 2.5.3.10 and 2.5.3.16-17 respectively.

4.4 *Statewide Savings Estimates*

Adding new acceptance tests will not create new savings due to new measures installed; rather, they will ensure energy savings from installed equipment will persist. The energy savings presented for SAT Reset have already been accounted due to the measure's addition to the 2008 code, and are presented here for informational purposes only. The energy savings due to CWST Reset Acceptance attempt to isolate the extra energy savings that the test will accrue by increasing the rate of proper equipment installation, without accounting for the savings from requiring a prescriptive measure. As there is little concrete data on current and future acceptance test compliance rates, the energy savings in this report should be considered as a maximum bound.

The maximum energy and energy cost savings potential for these measures are 0.56 kWh/sf, 0.008 kW/sf, 0.05 therms/sf, and $1.52/sf. Applying these unit estimates to the 2014 statewide estimate of new construction of 183.3 million square feet per year (HMG 2010) results in first year statewide energy savings of 35 GWh, 50 MW, 3 MMTherms, and $93 million in gross cost savings.

Savings included factors to account for actual instance of equipment installation (18.9% for CWST Reset, 32% for SAT Reset), based on data from 2003 CBECS indicating equipment prevalence (CBECS 2003). Table 11 show savings estimates. Detailed savings data is available in tables A6, A7, and A8 in the Appendix.

Yearly statewide savings for Supply Air Temperature Reset (Measure + Test) are higher than the estimates prepared for the 2008 code (Hydeman & Stein, 2007) due to increased new construction forecasts from 157.8 million square feet in 2008 to 183.3 million square feet in 2014. See the new construction data in Table A9 in the Appendix.

Table 11: Statewide Savings Estimates

	Electric Savings (GWh)	**Peak Demand Savings (MW)**	**Gas Savings (MMTherms)**	**TDV Cost Savings (Million $)**
SAT Reset Acceptance & Measure	34	52	3.1	$91
CWST Reset Acceptance *	1.2	0.0	0.0	$2.4

*Includes test effectiveness factor of 71% for CWST Reset to isolate savings from acceptance test. See PECI & Battelle Northwest Division, 2003.

5. Recommended Language for the Standards Document, ACM Manuals, and the Reference Appendices

Language recommendations apply to the Nonresidential Standards, the Nonresidential Compliance Manual, the Nonresidential Reference Appendices, and the Nonresidential Certificates of Acceptance.

5.1 *Standards*

The following changes are recommended for the Standards (additions underlined, ~~deletions struck out~~):

SECTION 125 – REQUIRED NONRESIDENTIAL MECHANICAL SYSTEM ACCEPTANCE

(a) Before an occupancy permit is granted the following equipment and systems shall be certified as meeting the Acceptance Requirements for Code Compliance, as specified by the Reference Nonresidential Appendix NA7. A Certificate of Acceptance shall be submitted to the enforcement agency that certifies that the equipment and systems meet the acceptance requirements:

1. Outdoor air ventilation systems shall be tested in accordance with NA7.5.1

2. Constant volume, single zone unitary air conditioning and heat pump unit controls shall be tested in accordance with NA7.5.2.

3. Duct systems shall be tested in accordance with NA7.5.3 where either:

A. They are new duct systems that meet the criteria of Sections 144(k)1, 144(k)2, and 144(k)3; or

B. They are part of a system that meets the criteria of Section 149(b)1D.

4. Air economizers shall be tested in accordance with NA7.5.4.

EXCEPTION to Section 125(a)4: Air economizers installed by the HVAC system manufacturer and certified to the Commission as being factory calibrated and tested are not required to be field tested per NA7.5.4.2.

5. Demand control ventilation systems required by Section 121(c)3 shall be tested in accordance with NA7.5.5

6. Supply fan variable flow controls shall be tested in accordance with NA7.5.6.

7. Hydronic system variable flow controls shall be tested in accordance with NA7.5.7 and NA7.5.9.

8. Boiler or chillers that require isolation controls per Section 144(j)2 or 144(j)3 shall be tested in accordance with NA7.5.7.

9. Hydronic systems with supply water temperature reset controls shall be tested in accordance with NA7.5.8.

10. Automatic demand shed controls shall be tested in accordance with NA7.5.10.

11. Fault Detection and Diagnostics (FDD) for Packaged Direct-Expansion Units shall be tested in accordance with NA7.5.11.

12. Automatic fault detection and diagnostics (FDD) for air handling units and zone terminal units shall be tested in accordance with NA7.5.12.

13. Distributed Energy Storage DX AC Systems shall be tested in accordance with NA7.5.13.

14. Thermal Energy Storage (TES) Systems shall be tested in accordance with NA7.5.14.

15. Supply air temperature reset controls shall be tested in accordance with NA7.5.15.

16. Water-cooled chillers served by cooling towers with condenser water reset controls shall be tested in accordance with NA7.5.16.

5.2 *Reference Appendices*

These two tests, NA7.5.16 and NA7.5.17, are additions to the Reference Appendices, and so not underlined here as is typical for sake of clarity.

Nonresidential Appendix NA7

Appendix NA7 – Acceptance Requirements for Nonresidential Buildings

…

NA7.5 Mechanical Systems Acceptance Tests

…

NA7.5.16 Supply Air Temperature Reset Controls (Certificate of Acceptance Form MECH-16A)

NA7.5.16.1 Construction Inspection

Prior to functional testing, verify and document the following:

- Reset controls have been installed per Standards §144(f)(2).
- Reset schedule, including high and low setpoint limits and equipment lockout temperatures, is available and documented in the building plans. Reset schedule resets temperature by at least 25% of the difference between the design supply air temperature and design room air temperature.
- Sensors used to control supply air temperature have been calibrated, or read accurately against a calibrated temperature standard. Attach a copy of the calibration certificate or field verification results.
- If applicable, duct static pressure reset controls are disabled during testing to prevent any unwanted interaction.
- Controls for outside air damper or economizer operation are disabled during testing to prevent any unwanted interaction.
- Document current supply air temperature.

NA7.5.16.2 Functional Testing

- If system is single-duct, or has zone-level reheat, Steps 1-3 are performed once at the main supply fan. If system is dual-duct, Steps 1-3 are performed for each duct or “deck” downstream of the main supply fan.

- Check to make sure that chilled/hot water coils, if used, are not already fully open and calling for maximum cooling/heating. If this is the case, reverse Steps 1 and 2 as necessary to allow system to operate within its bounds of operation and not be forced to meet an impossible setpoint.
- If zone feedback is used to reset, identify any zones with unusually high loads ("rogue zones") prior to and during performing the test. If possible, exclude those zones from the reset sequence.

Step 1: Override reset control variable to its maximum value to drive supply temperature downward (for example, temporarily replace outside temperature signal with a high fixed temperature value for outside air temperature, or temporarily override zone damper signals to imitate all zones calling for maximum cooling). If the reset control variable input cannot be modified, then change the limit of the variable around the currently occurring value (for example, modify the reset schedule to create an outside air setpoint high limit below the current outside air temperature).

Verify and document the following:

- Supply air temperature setpoint is reset to meet the appropriate value.
- Actual supply air temperature changes to meet setpoint.
- Verify that supply air temperature is within +/-2 degree F of the control setpoint.

Step 2: Override reset control variable to its minimum value to drive supply temperature upward. If the reset control variable input cannot be modified, then change the limit of the variable around the currently occurring value.

Verify and document the following:

- Supply air temperature setpoint is reset to meet the appropriate value.
- Actual supply air temperature changes to meet setpoint.
- Verify that supply air temperature is within +/-2 degree F of the control setpoint.

Step 3: Restore reset control variable to automatic control, and/or restore the high and low limits of the reset control variable. Remove all system overrides initiated during test.

Verify and document the following:

- Supply air temperature setpoint is reset to meet the appropriate value.
- Actual supply air temperature changes to meet setpoint.

NA7.5.16 Condenser Water Supply Temperature Reset Controls (Certificate of Acceptance Form MECH-17A)

NA7.5.16.1 Construction Inspection

Prior to functional testing, verify and document the following:

- Condenser water supply temperature control sequence, including condenser water supply high and low limits, is available and documented in the building documents.

- Cooling tower fan control sequence, including tower design wetbulb temperature and approach, is available and documented in the building documents.
- Temperature, pressure, and flow gauges and sensors are installed where appropriate.
- All ambient dry bulb temperature, relative humidity, and pressure sensors used by controller have been calibrated, or read accurately against a standard calibrated sensor. Attach a copy of calibration certificate or field verification results.
- All cooling tower fan motors are operational.
- All cooling tower fan speed controls (e.g. VSDs) are installed, operational, and connected to cooling tower fan motors.
- Document current outdoor ambient air dry bulb and wet bulb temperatures, entering condenser water supply temperature, and leaving chilled water temperature readings from the control system.

NA7.5.16.2 Functional Testing

- The system cooling load must be sufficiently high to run the test. If necessary, artificially increase the evaporator load to perform the functional tests, or wait until a time of stable chiller operation. If necessary, reverse Steps 1 & 2 in the test based on atmospheric conditions and buildings loads.
- If testing in cold ambient conditions, ensure that freeze protection controls are installed and functional to prevent equipment damage.
- If the actual control sequence differs significantly from that implied by the tests, attach a description of the control sequence, a description of the tests that were done to verify the system operates according to the sequence, and the test results.

Step 1: Using the desired reset strategy, change the reset control variable to its minimum value to drive condenser water supply temperature downward towards lower limit (for example, temporarily replace signal of outdoor air wetbulb temperature to a low fixed value). If the reset control variable input cannot be modified, then change the limit of the variable around the currently occurring value (for example, adjust the sequence to set the maximum outdoor air wetbulb temperature to below the current temperature). Allow time for the system to stabilize.

Verify and document the following:

- Condenser water supply temperature setpoint changes to meet appropriate value.
- Actual condenser water supply temperature changes to meet setpoint.
- Cooling tower fan(s) stage properly and/or adjust speed according to fan schedule, to meet lower condenser water supply setpoint.

Step 2: Using the desired reset strategy, override reset control variable towards its maximum value to drive condenser water supply temperature upward to high limit. If the reset control variable input cannot be modified, then change the limit of the variable around the currently occurring value. Allow time for the system to stabilize.

Verify and document the following:

- Condenser water supply temperature setpoint changes to meet appropriate value.
- Actual condenser water supply temperature changes to meet setpoint.
- Cooling tower fan(s) stage properly and/or adjust speed according to fan schedule, to meet higher condenser water supply setpoint.

Step 3: Restore all controls and equipment to original settings, and/or restore the high and low limits of the reset control variable. Remove all system overrides initiated during test.

Verify and document the following:

- Condenser water supply temperature setpoint is reset to the appropriate value.
- Cooling tower fan(s) and chiller(s) return to normal operation.

5.3 *Compliance Manual*

Under development.

5.4 *Certificates of Acceptance (Forms)*

MECH-16A: NA 7.5.15 - Supply Air Temperature Reset Controls Acceptance

Under development.

MECH-17A: NA 7.5.16 – Condenser Water Supply Temperature Reset Controls Acceptance

Under development.

6. Bibliography and Other Research

California Energy Commission. 2008a. *2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2008-001-CMF. December 2008. Available from http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.PDF

California Energy Commission. 2008b. *Nonresidential Alternative Calculation Method (ACM) Approval Manual for the 2008 Building Energy Efficiency Standards.* CEC-400-2008-003-CMF. December 2008. Available from http://www.energy.ca.gov/2008publications/CEC-400-2008-003/CEC-400-2008-003-CMF.PDF

California Energy Commission. 2009. *Reference Appendices for the 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2008-004-CMF. Revised June 2009. Available from http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-004-CMF.PDF

California Energy Commission. 2010a. *2008 Building Energy Efficiency Standards Nonresidential Compliance Manual.* CEC-400-2008-017-CMF-Rev 1. Revised July 2010. Available from http://www.energy.ca.gov/2008publications/CEC-400-2008-017/CEC-400-2008-017-CMF-REV1.PDF

California Energy Commission. 2010b. List of Approved Computer Programs for the 2008 Building Energy Efficiency Standards. Available from http://www.energy.ca.gov/title24/2008standards/2008_computer_prog_list.html.

Energy Design Resources. 2009. *Chilled Water Plant Design Guide.* Design Guide: CoolTools Chilled Water Plant. December 2009. Available from http://energydesignresources.com/media/2305/EDR_DesignGuidelines_CoolToolsChilledWater.pdf

Heschong Mahone Group, Inc. 2005. *Evaluation of Nonresidential Acceptance Requirements: Final Report.* Prepared for Pacific Gas and Electric Company. July 2005.

Heschong Mahone Group, Inc. 2010. *NonRes Construction Forecast by BCZ v7*. Developed by Heschong Mahone Group with data sourced from Abrishami, Moshen at the California Energy Commission (CEC). August, 2010.

Hydeman, Mark (PE) and Stein, Jeff (PE). 2007. *DDC to the Zone Level Measure 5: Supply Air Temperature Reset"*. 2007 Workshop Report: PG&E Codes and Standards Enhancement (CASE) Initiative. Taylor Engineering. February 27, 2007.

Available from http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2007-02-26-27_workshop/supporting/2007-02-15_REPORT_DDC_TO_THE_ZONE_LEVEL.PDF

Portland Energy Conservation, Inc. and Battelle Northwest Division. 2003. *Methods for Automated And Continuous Commissioning of Building Systems: Final Report.* ARTI-21CR/610-30040-01. Prepared for the Air-Conditioning and Refrigeration Technology Institute under ARTI 21-CR Program Contract Number 610-30040. April 2003.

Available from http://www.osti.gov/bridge/servlets/purl/810800-vomrED/native/810800.pdf

Portland Energy Conservation, Inc. 2003. "Functional Testing and Design Guides." http://www.peci.org/ftguide/index.htm. Portland, WA: Portland Energy Conservation, Inc.

[RSMeans] Cost Works. 2011. Cost Books Online. http://meanscostworks.com/. Norcross, GA: Reed Construction Data.

Statewide Utilities Codes and Standards Program 2011 CASE Initiative. 2010a. *Memorandum to Stakeholders re: First Stakeholder Meeting, May 20 2010, California Lighting Technology Center.* Notes for Stakeholder Meeting for Acceptance Testing and Design-Phase Commissioning Topics. May 2010. Available from http://www.h-m-g.com/T24/AcceptanceTestingCommissioning/NotesAT_CXMeeting052010Final.pdf

Statewide Utilities Codes and Standards Program 2011 CASE Initiative. 2010b. *Memorandum to Stakeholders re: Stakeholder Meeting 2, December 07 2010, San Ramon.* Notes for Stakeholder Meeting for Acceptance Testing and Design-Phase Commissioning Topics. December 2010. Available from http://www.h-m-g.com/T24/AcceptanceTestingCommissioning/Notes_ATDPCx_Meeting_120710.pdf

7. Appendices

7.1 *Appendix A: Tables and Figures*

Table A1: Base Case Modeling Assumptions - SAT Reset

Hydeman & Stein, 2007.

	Case #	Basecase
HVAC System	System Type	PVAVS
	Sizing Ratio	1
	Fan Control	VSD
	Air Flow	min Fan ratio = 0.1, max Fan ratio = 1.1
	Fan Eff	SA Fan 53%, RA Fan 53%
	Fan Performance Curve	Perfect fan curve
	Fan static pressure	3.5"
	OA ratio	Default (calc. from zone OA CFM)
	Economizer	differential drybulb, max temperature limit = 59
	Cooling EIR	0.36 (9.5 EER)
	Min SAT	55. °F
	Max Cooling SAT Reset Temp	59. °F
	Cooling SAT temp control	Constant
	Heating SAT temp control	Constant
	Heating Coil	No coil at packaged unit, only hot water reheating coil at each zone
	RH Coil Vavle	3-way valve
	Min Heating Reset Temp	75. °F
Zone (each)	Thermostat	Proportional
	Throttling Range	.1 °F
	Cooling Min Flow Ratio	30%
	Cooling Max Flow Ratio	100%
	Heating Min Flow Ratio	30%
	Heating Max Flow Ratio	30%
	Cooling setpoint	75. °F
	Heating setpoint	70. °F
	Cooling setpoint unoccuppied	82. °F
	Heating setpoint unoccuppied	64. °F
Boiler Plant	Boiler HIR	1.25
	Design HWST	180 °F
	Design HW loop dT	40 °F
	HW loop pump control	one speed pump
Building Envelope	Exterior wall U value	R-13 (code)
	Roof U value	R-19 (code)
	WWR	40%
	Glass Type	U = 0.47, SHGC = 0.31 (nonnorth), 0.47 (north)
	Area	100 ft by 100 ft, 15 ft perimeter zone depth
Building Internal Load	Occpancy	100 sf/person
	Lighting	1.3 w/sf
	Equipment	1.5 w/sf
	Schedule	Occupied 7:00 ~19:00 M-F, Unoccupied other days

Figure A1: eQuest parametric run inputs - SAT Reset

Hydeman & Stein, 2007.

Parametric Runs Comparison Listing

Component	Referenc...	Keyword	Array Idx	Baseline	TempResetBase
HVAC Sy...	Core Sys...	COOL-C...	N/A	CONSTANT	WARMEST
HVAC Sy...	Core Sys...	HEAT-CO...	N/A		COLDEST
HVAC Sy...	Core Sys...	COOL-MI...	N/A		55.000
HVAC Sy...	Core Sys...	COOL-MA...	N/A		65.000
HVAC Sy...	Core Sys...	HEAT-MI...	N/A		75.000
HVAC Sy...	Core Sys...	COOL-SE...	N/A		55.000
HVAC Sy...	Core Sys...	MIN-FLO...	N/A		
Thermal ...	EL1 Core...	MIN-FLO...	N/A	0.300	0.300
HVAC Sy...	Core Sys...	SIZING-...	N/A	1.250	1.250
Thermal ...	EL1 Core...	THERMO...	N/A	PROPORT...	PROPORTIONAL
Thermal ...	EL1 Core...	CMIN-FL...	N/A		
Thermal ...	EL1 Core...	HMIN-FL...	N/A		
Thermal ...	EL1 Core...	MIN-CFM...	N/A	0.300	0.300
Thermal ...	EL1 Core...	CMIN-CF...	N/A		
Thermal ...	EL1 Core...	HMIN-CF...	N/A		
HVAC Sy...	Core Sys...	REHEAT-...	N/A	100.000	100.000

Figure A2: Zone Layout for eQuest Model - SAT Reset

Hydeman & Stein, 2007.

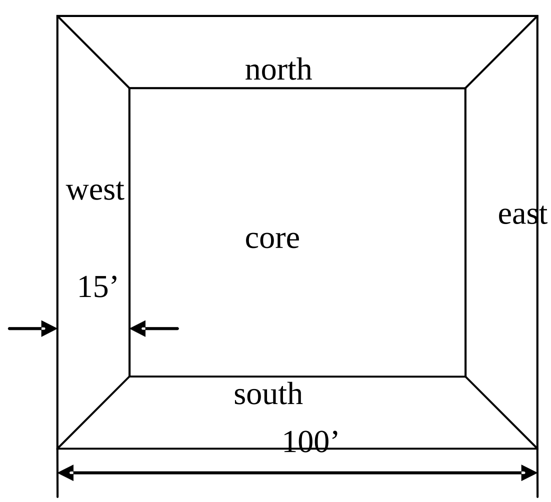

Table A2: Detailed Description of EnergyPro Models – CWST Reset

The information presented in this table is the same between the "base case" and "standard case" for all parameters unless noted.

Parameter		Office Model		Hotel Model
Dimensions	Size	117,000 sq ft		67,500 sq ft
	Dimensions	130 (N/S) x 150 (W/E)		150 x 150
	Floors	6		3
HVAC System	Distribution Type	Built-up VAV		1^{st} Floor: Built-up Single Zone $2^{nd}/3^{rd}$ Floor: 4-Pipe Fan Coil
	Total Design CFM	60,000 cfm		36,000 cfm
	Fan Type	VSD Blow-Through		CAV Blow-Through
	Fan Efficiency	1.25 W/cfm		0.8 W/cfm
	Economizer	Fixed Temp Integrated Drybulb		1^{st} Floor: Diff Temp Int Drybulb $2^{nd}/3^{rd}$ Floor: Fixed Temp Int Drybulb
	Economizer Lockout Setpoint	75 F		75 F
	Heating	HHW		HHW
	Heating SAT	105 F		105 F
	Heating SAT Temp Control	Constant		Constant
	Cooling	CHW		CHW
	Cooling SAT	55 F		55 F
	Cooling SAT Temp Control	Warmest Zone		Constant
Hot Water Plant	Size	1000 MMBTUH		2000 MMBTUH
	HIR / Recovery Efficiency	1.33 / 75%		1.43 / 70%
	Design HW Loop dT	30 F		30 F
	HW Loop Pump Control	One Speed / 3 Way Valves		Variable Speed
Chilled Water Plant	Chiller Size	See table A3		See table A3
	Chiller Type	Screw	Centrifugal	Scroll
	Chiller EIR/COP	0.20 / 4.9	0.18 / 5.5	0.224 / 4.45
	Chilled Water Supply Temperature	44 F		44 F
	Entering Condenser Water Temperature	85 F		85 F
	Cooling Tower	See table A3		See table A3
	Cooling Tower EIR	0.0102		0.0250

Parameter		Office Model	Hotel Model
	Cooling Tower Fan Size	30 hp	15 hp
	Cooling Tower Fan Speed Control	VSD	VSD
	CTW Temperature Setpoint	80 F	80 F
	CT Design Wetbulb	65 F	65 F
Envelope	Type	Wood Frame, Low-Slope Roof (Prescriptive Table 143-A of Standards)	Wood Frame, Low-Slope Roof (Prescriptive Tables 143-A, 143-B of Standards)
	WWR	30%	27%
Zone	Distribution Type	VAV Box w/Reheat	-
	Minimum Flow Ratio	30%	-
	Winter / Summer Temperature Setpoint	70 F / 78 F	70 F / 78 F
	Thermostat Type	Reverse Action	-
	Occupancy	Complete Building Office	1st Floor: Hotel Function Area 2nd/3rd Floor: Hotel/Motel Guest Room
	Occupant Density	100 sf/occupant	1st Floor: 15 sf/occupant 2nd/3rd Floor: 200 sf/occupant
	Lighting Power Density	0.85 W/sf	1st Floor: 1.5 W/sf 2nd/3rd Floor: 0.5 W/sf
	Schedule	Occupancy: 7am – 6pm M-F Fans: 5am – 8pm M-S	Occupancy: 24 / 7 Fans: 24 / 7

Table A3: Chiller and Cooling Tower Modeled Size – CWST Reset

Building Model Type	Area (sq ft)	Climate Zone	Chiller Type	Chiller Size (tons)	Cooling Tower Size (tons)
Office	117000	3	Centrifugal	235	282
Office	117000	3	Screw	235	282
Hotel	67000	3	Scroll	120	150
Office	117000	6	Centrifugal	245	294
Office	117000	6	Screw	245	294
Hotel	67000	6	Scroll	120	150
Office	117000	9	Centrifugal	218	265
Office	117000	9	Screw	218	262
Hotel	67000	9	Scroll	123	145
Office	117000	10	Centrifugal	224	270
Office	117000	10	Screw	224	270
Hotel	67000	10	Scroll	118	147
Office	117000	12	Centrifugal	278	328
Office	117000	12	Screw	278	328
Hotel	67000	12	Scroll	120	150
Office	117000	16	Centrifugal	279	329
Office	117000	16	Screw	279	329
Hotel	67000	16	Scroll	120	150

Figure A3: Zone Layout for EnergyPro Office Model – CWST Reset

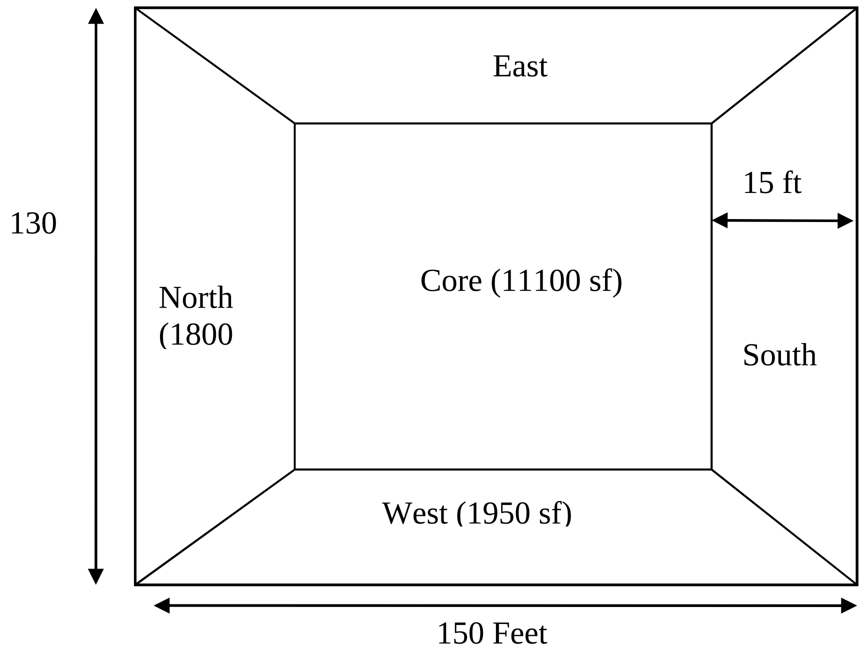

Figure A4: Zone Layout for EnergyPro Hotel Mode – CWST Reset

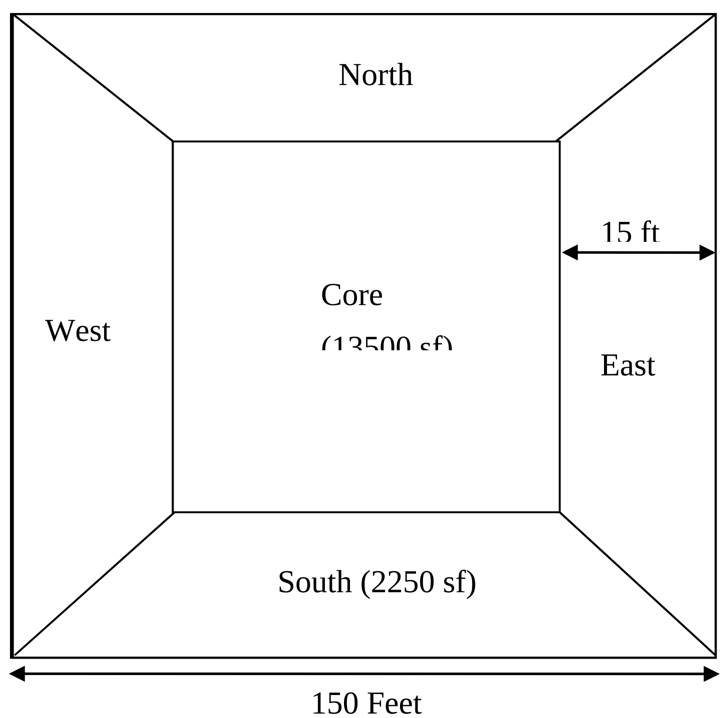

Table A4: SAT Reset Comprehensive Energy Savings Estimates

Hydeman & Stein, 2007.

Climate Zone	Electrical Energy Savings [kWh/yr]	Electrical Peak Demand Reduction [kW]	TDV Electrical Cost Savings [$]	Natural Gas Energy Savings [Therms/yr]	TDV Gas Cost Savings [$]	TDV Total Cost Savings [$]	TDV Total Cost Savings Normalized [$/sf]
CZ01	8,900	0.0	$17,000	700	$9,200	$26,000	$2.6
CZ02	5,100	0.0	$7,000	610	$8,300	$15,000	$1.5
CZ03	7,500	0.0	$12,000	600	$8,200	$21,000	$2.1
CZ04	6,500	0.0	$9,000	560	$7,700	$17,000	$1.7
CZ05	8,600	0.0	$13,000	650	$8,700	$22,000	$2.2
CZ06	7,400	0.0	$11,000	500	$6,800	$18,000	$1.8
CZ07	7,400	0.0	$11,000	460	$6,300	$17,000	$1.7
CZ08	6,100	0.0	$8,000	450	$6,200	$15,000	$1.5
CZ09	5,400	0.0	$7,000	460	$6,300	$14,000	$1.4
CZ10	4,900	0.0	$6,000	480	$6,500	$13,000	$1.3
CZ11	3,700	0.0	$4,000	590	$8,100	$12,000	$1.2
CZ12	4,900	0.0	$6,000	640	$8,800	$15,000	$1.5
CZ13	3,800	0.0	$4,000	570	$7,900	$12,000	$1.2
CZ14	2,100	0.0	$1,000	460	$6,300	$8,000	$0.8
CZ15	1,800	0.0	$2,000	330	$4,600	$6,000	$0.6
CZ16	2,200	0.0	$3,000	410	$5,400	$8,000	$0.8
Minimum	1,800	0.0	$1,000	330	$4,600	$6,000	$0.6
Maximum	8,900	0.0	$17,000	700	$9,200	$26,000	$2.6
Wtd Avg	5,200	0.0	$7,000	520	$7,100	$14,000	$1.4

Table A5: CWST Reset Per Model Energy Savings Estimates

Model Data								Energy Savings			TDV Savings		
Bldg	SF	CZ	Pop %	Chiller Type	Chiller Size	COP	CT Size	kWh Total	kWh / Ton	kWh / SF	TDV Total	TDV / Ton	TDV / SF
Office	117000	3	9.7%	Centrifugal	235	5.5	282	6,617	28.16	0.057	$13,707	$ 58.33	$ 0.12
Office	117000	3	9.7%	Screw	235	4.9	282	11,341	48.26	0.097	$23,363	$ 99.42	$ 0.20
Hotel	67000	3	9.7%	Scroll	120	4.45	150	1,023	8.52	0.015	$ 4,291	$ 35.76	$ 0.06
Office	117000	6	8.1%	Centrifugal	245	5.5	294	8,376	34.19	0.072	$15,180	$ 61.96	$ 0.13
Office	117000	6	8.1%	Screw	245	4.9	294	14,348	58.56	0.123	$26,300	$107.35	$ 0.22
Hotel	67000	6	8.1%	Scroll	120	4.45	150	1,132	9.43	0.017	$ 4,559	$ 38.00	$ 0.07
Office	117000	9	15.6%	Centrifugal	218	5.5	265	9,078	41.64	0.078	$15,180	$ 69.63	$ 0.13
Office	117000	9	15.6%	Screw	218	4.9	262	15,309	70.23	0.131	$26,179	$120.09	$ 0.22
Hotel	67000	9	15.6%	Scroll	123	4.45	145	4,174	33.94	0.062	$10,961	$ 89.12	$ 0.16
Office	117000	10	7.5%	Centrifugal	224	5.5	270	11,053	49.34	0.094	$19,522	$ 87.15	$ 0.17
Office	117000	10	7.5%	Screw	224	4.9	270	17,597	78.56	0.150	$32,016	$142.93	$ 0.27
Hotel	67000	10	7.5%	Scroll	118	4.45	147	6,802	57.65	0.102	$17,808	$150.92	$ 0.27
Office	117000	12	6.4%	Centrifugal	278	5.5	328	7,103	25.55	0.061	$12,915	$ 46.46	$ 0.11
Office	117000	12	6.4%	Screw	278	4.9	328	11,793	42.42	0.101	$21,851	$ 78.60	$ 0.19
Hotel	67000	12	6.4%	Scroll	120	4.45	150	4,877	40.65	0.073	$14,068	$117.23	$ 0.21
Office	117000	16	1.6%	Centrifugal	279	5.5	329	8,287	29.70	0.071	$15,019	$ 53.83	$ 0.13
Office	117000	16	1.6%	Screw	279	4.9	329	10,244	36.72	0.088	$22,902	$ 82.09	$ 0.20
Hotel	67000	16	1.6%	Scroll	120	4.45	150	3,705	30.87	0.055	$11,757	$ 97.98	$ 0.18

		Energy Savings			TDV Savings			Net Savings		
		kWh Total	kWh / Ton	kWh / SF	TDV Total	TDV / Ton	TDV / SF	$ Total	$ / Ton	$ / SF
Measure Savings	**Straight Avg**	8,500	40	0.080	$17,100	$ 85	$ 0.17	$ 14,100	$ 69	$ 0.14
	Avg Pop-Weighted	8,700	42	0.082	$17,100	$ 86	$ 0.17	$ 14,100	$ 70	$ 0.14
	Wt Avg Centrifugal	8,500	36	0.073	$15,300	$ 65	$ 0.13	$ 12,300	$ 52	$ 0.10
	Wt Avg Screw	14,100	60	0.120	$25,900	$ 111	$ 0.22	$ 22,900	$ 98	$ 0.20
	Wt Avg Scroll	3,500	29	0.053	$10,000	$ 83	$ 0.15	$ 7,000	$ 59	$ 0.11
Acceptance Test Isolated Savings	**Straight Avg**	6,100	29	0.057	12,200	$ 61	$ 0.12	$ 10,100	$ 49	$ 0.10
	Avg Pop-Weighted	6,200	30	0.058	12,200	$ 62	$ 0.12	$ 10,100	$ 50	$ 0.10
	Wt Avg Centrifugal	6,100	26	0.052	10,900	$ 47	$ 0.09	$ 8,800	$ 37	$ 0.07
	Wt Avg Screw	10,100	43	0.086	18,500	$ 79	$ 0.16	$ 16,300	$ 70	$ 0.14
	Wt Avg Scroll	2,500	21	0.037	7,100	$ 60	$ 0.11	$ 5,000	$ 42	$ 0.08

Table A6: SAT Reset Statewide Energy Savings Estimates, 2008 New Construction Forecast

Hydeman & Stein, 2007.

Climate Zone	Electrical Energy Savings [kWh/yr]	Electrical Peak Demand Reduction (kW)	Natural Gas Savings [Therms/yr]	TDV Cost Savings [$]	Nox [lbs/yr]	CO2 [lbs/yr]	CO [lbs/yr]	PM10 [lbs/yr]
CZ01	100,000	-	8,000	$300,000	100	200,000	50	0
CZ02	300,000	-	39,000	$1,000,000	500	800,000	200	50
CZ03	4,200,000	-	338,000	$11,800,000	4,800	8,900,000	2,000	600
CZ04	2,700,000	-	229,000	$7,000,000	3,200	5,800,000	1,300	400
CZ05	600,000	-	43,000	$1,500,000	600	1,200,000	250	100
CZ06	2,400,000	-	164,000	$5,900,000	2,500	4,800,000	1,050	300
CZ07	1,300,000	-	80,000	$3,000,000	1,300	2,500,000	550	150
CZ08	3,100,000	-	228,000	$7,600,000	3,300	6,300,000	1,400	400
CZ09	1,700,000	-	143,000	$4,300,000	2,000	3,700,000	800	250
CZ10	2,000,000	-	199,000	$5,400,000	2,700	4,700,000	1,050	300
CZ11	500,000	-	85,000	$1,700,000	1,000	1,600,000	400	100
CZ12	3,200,000	-	422,000	$9,900,000	5,200	8,700,000	2,000	600
CZ13	600,000	-	97,000	$2,000,000	1,200	1,900,000	450	150
CZ14	1,100,000	-	238,000	$4,100,000	2,700	4,000,000	950	300
CZ15	500,000	-	86,000	$1,600,000	1,000	1,600,000	350	100
CZ16	200,000	-	40,000	$800,000	500	700,000	150	50
Total	25,000,000	-	2,400,000	$68,000,000	32,400	58,000,000	13,000	3,900

Table A7: SAT Reset Statewide Energy Savings Estimates, 2014 New Construction Forecast

CZ	kWh/yr	kW	Therms/yr	TDV $	NRNC Statewide Wt Avg CZ			
					GWh	MW	Mmtherms	TDV M$
1	8,900	7.8	700	$ 26,000	0.1	0.1	0.0	$ 0.4
2	5,100	9.7	610	$ 15,000	0.7	1.3	0.1	$ 2.0
3	7,500	9.2	600	$ 21,000	3.9	4.7	0.3	$ 11
4	6,500	8.4	560	$ 17,000	2.1	2.7	0.2	$ 5.5
5	8,600	8.8	650	$ 22,000	0.5	0.6	0.0	$ 1.4
6	7,400	8.1	500	$ 18,000	3.6	3.9	0.2	$ 8.7
7	7,400	9.0	460	$ 17,000	4.7	5.7	0.3	$ 11
8	6,100	9.5	450	$ 15,000	3.6	5.6	0.3	$ 8.8
9	5,400	9.1	460	$ 14,000	6.3	10.6	0.5	$ 16
10	4,900	9.1	480	$ 13,000	1.7	3.1	0.2	$ 4.4
11	3,700	7.6	590	$ 12,000	0.6	1.3	0.1	$ 2.1
12	4,900	8.6	640	$ 15,000	4.4	7.6	0.6	$ 13
13	3,800	8.8	570	$ 12,000	1.5	3.5	0.2	$ 4.8
14	2,100	6.1	460	$ 8,000	0.2	0.5	0.0	$ 0.6
15	1,800	8.8	330	$ 6,000	0.1	0.3	0.0	$ 0.2
16	2,200	6.4	410	$ 8,000	0.2	0.6	0.0	$ 0.8
				TOTAL	34	52	3.1	$ 91

Note: Includes factor of 32% to account for multizone AHU systems in new construction. See CBECS.

Table A8: CWST Reset Statewide Energy Savings Estimates

Model Data			Energy Savings			NR NC Statewide		NR NC State Wt Avg CZ		
Bldg	SF	CZ	kWh / SF	kWh / SF TEST	TDV/SF TEST	GWh Measure	GWh TEST ONLY	GWh Measure	GWh TEST ONLY	TDV TEST ONLY (M$)
Office	117000	3	0.057	0.040	$ 0.08	0.90	0.64			
Office	117000	3	0.097	0.069	$ 0.14	1.55	1.10	0.17	0.12	$ 0.27
Hotel	67000	3	0.015	0.011	$ 0.05	0.24	0.17			
Office	117000	6	0.072	0.051	$ 0.09	1.07	0.77			
Office	117000	6	0.123	0.088	$ 0.16	1.84	1.31	0.20	0.14	$ 0.28
Hotel	67000	6	0.017	0.012	$ 0.05	0.25	0.18			
Office	117000	9	0.078	0.055	$ 0.09	2.81	2.00			
Office	117000	9	0.131	0.093	$ 0.16	4.73	3.38	0.62	0.44	$ 0.84
Hotel	67000	9	0.062	0.044	$ 0.12	2.25	1.61			
Office	117000	10	0.094	0.067	$ 0.12	0.99	0.71			
Office	117000	10	0.150	0.107	$ 0.20	1.57	1.12	0.23	0.16	$ 0.33
Hotel	67000	10	0.102	0.072	$ 0.19	1.06	0.76			
Office	117000	12	0.061	0.043	$ 0.08	1.67	1.19			
Office	117000	12	0.101	0.072	$ 0.13	2.77	1.98	0.41	0.29	$ 0.63
Hotel	67000	12	0.073	0.052	$ 0.15	2.00	1.43			
Office	117000	16	0.071	0.051	$ 0.09	0.21	0.15			
Office	117000	16	0.088	0.063	$ 0.14	0.26	0.19	0.04	0.03	$ 0.07
Hotel	67000	16	0.055	0.039	$ 0.13	0.17	0.12			
							TOTAL	**1.7**	**1.2**	**$ 2.4**

Note: Includes test effectiveness factor of 71% to isolate savings from acceptance test (PECI & Battelle Northwest Division, 200)3. Includes factor of 19% to account for prevalence of chilled water plants in new construction (CBECS).

Table A9: Statewide New Construction Estimates, All Building Types, 2014

Source: NonRes Construction Forecast by BCZ v7, HMG 2010

New Construction	
CZ	**MSF**
1	0.44
2	4.03
3	15.95
4	10.00
5	1.94
6	14.99
7	19.63
8	18.12
9	36.15
10	10.47
11	5.31
12	27.52
13	12.38
14	2.40
15	0.99
16	2.99
TOTAL	183.33

7.2 *Appendix B: Condenser Water Reset as a Prescriptive Measure*

During the three stakeholder meetings held for this measure (5-20-11, 12-7-10, 4-6-10) stakeholders noted that condenser water reset controls are not a prescriptive part of the code, and therefore different from other acceptance tests which typically do. Stakeholders proposed that the CASE team investigate the feasibility of proposing condenser water reset as a prescriptive code measure for water-cooled chillers. Title 24 (Section 144(h)) requires cooling towers and other heat rejection equipment have the ability to turn down fan speed to 2/3 or less and have controls to adjust the leaving fluid temperature, enabling condenser water reset strategies.

The CASE team briefly investigated the extra costs of designing and programming a condenser water reset strategy. An industry poll indicated that most chillers currently on the market would be able to experience savings from condenser water reset and could operate at low condenser water temperatures, particularly Path B chillers. These comments indicated that optimized condenser water reset control was not common in the market but becoming more and more so. Cost premiums for implementing the controls could be minimal, depending on the complexity of the plant and equipment already at the site.

Cost research indicated that the extra cost of enabling condenser water reset varied greatly and depended primarily on extra time spent on designing and programming the controls, with small costs from additional sensors (e.g. relative humidity). The cost estimate was in the low thousands of dollars, indicating it could be cost-effective based on the modeled energy savings. The CEC presented this measure at an August 17, 2011 pre-rulemaking workshop. See costs and savings estimates presented in table B1, based on most recent analysis:

Table B1: Cost-Effectiveness, Condenser Water Reset Controls

Condenser Water Reset Controls Prescriptive Measure	Weighted Average Savings (kWh/yr)		Weighted Average TDV Savings (PV $)		Installation and Materials Cost (PV $)		Testing and Maintenance Cost (PV $)		Life Cycle Cost Savings ($)	
	kWh/sf	kWh/bldg	$/sf	$/bldg	$/sf	$/bldg	$/sf	$/bldg	$/sf	$/bldg
	0.08	8,700	$0.17	$17,100	$0.01	$900	$0.029	$2,900	$0.13	$13,300

However, during this research the CASE team received feedback from other stakeholders that condenser water reset was not ready to be a prescriptive code measure, based on poor implementation in actual design practice, and significant potential drawbacks. While condenser water reset controls can obtain significant and cost-effective plant savings, it is difficult to both write a control sequence that optimizes operation at all possible load and operating conditions, and difficult to ensure that the sequence and savings persist over time. Furthermore, an improperly implemented sequence could create significant operational problems and failures (chiller tripping or surging) or an energy penalty (excessive condenser water pump and cooling tower fan energy).

With these comments in mind, the CASE team interviewed engineering design firms, retrocommissioning providers, chiller manufacturers, and incentive program reviewers on the feasibility and prevalence of condenser water reset in current design practice. The responses varied greatly, but most interviewees agreed that condenser water reset was a difficult and subtle control sequence to implement, and relatively rare in current design practice. Even when implemented by a knowledgeable and conscientious engineer, the control sequence could fail (and frequently did, based on the experience of one retrocommissioning provider) due to adjustments by facility staff or unforeseen load or weather conditions. As noted above, such failures could be significant, and could incur an energy penalty that would offset code savings. A number of manufacturer proprietary "black box" control systems exist on the market, but these are costly and only developed after years of research. Most interviewees supported additional research to design a set of example condenser water reset sequences that could be applied by design engineers. Detailed records of stakeholder feedback has been provided to the CEC, but are not reproduced here for privacy

Given this feedback, the CASE team is not pursuing this measure for additional research for the 2013 update to Title 24.

7.3 ***Appendix C: Non-Residential Construction Forecast Details***

7.3.1 Summary

The Non-Residential construction forecast dataset is data that is published by the California Energy Commission's (CEC) demand forecast office. This demand forecast office is charged with calculating the required electricity and natural gas supply centers that need to be built in order to meet the new construction utility loads. Data is sourced from Dodge construction database, the demand forecast office future generation facility planning data, and building permit office data.

All CASE reports used the statewide construction forecast for 2014. The TDV savings analysis is calculated on a 15 or 30 year net present value, so it is correct to use the 2014 construction forecast as the basis for CASE savings.

7.3.2 Additional Details

The demand generation office publishes this dataset and categorizes the data by demand forecast climate zones (FCZ) as well as building type (based on NAICS codes). The 16 climate zones are organized by the generation facility locations throughout California, and differ from the Title 24 building climate zones (BCZ). The Heschong Mahone Group (HMG) has reorganized the demand forecast office data using 2000 Census data (population weighted by zip code) and mapped FCZ and BCZ to a given zip code. The construction forecast data is provided to CASE authors in BCZ in order to calculate Title 24 statewide energy savings impacts. Though the individual climate zone categories differ between the demand forecast published by the CEC and the construction forecast, the total construction estimates are consistent; in other words, HMG has not added to or subtracted from total construction area.

The demand forecast office provides two (2) independent data sets: total construction and additional construction. Total construction is the sum of all existing floor space in a given category (Small office, large office, restaurant, etc.). Additional construction is floor space area constructed in a given year (new construction); this data is derived from the sources mentioned above (Dodge, Demand forecast office, building permits).

Additional construction is an independent dataset from total construction. The difference between two consecutive years of total construction is not necessarily the additional construction for the year because this difference does not take into consideration floor space that was renovated, or repurposed.

In order to further specify the construction forecast for the purpose of statewide energy savings calculation for Title 24 compliance, HMG has provided CASE authors with the ability to aggregate across multiple building types. This tool is useful for measures that apply to a portion of various building types' floor space (e.g. skylight requirements might apply to 20% of offices, 50% of warehouses and 25% of college floor space).

The main purpose of the CEC demand forecast is to estimate electricity and natural gas needs in 2022 (or 10-12 years in the future), and this dataset is much less concerned about the inaccuracy at 12 or 24 month timeframe.

It is appropriate to use the CEC demand forecast construction data as an estimate of future years construction (over the life of the measure). The CEC non-residential construction forecast is the best publicly available data to estimate statewide energy savings.

7.3.3 Citation

"NonRes Construction Forecast by BCZ v7"; Developed by Heschong Mahone Group with data sourced August, 2010 from Abrishami, Moshen at the California Energy Commission (CEC)