

CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Solar Water Heating

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team

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1. Purpose

Through Codes and Standards Enhancement (CASE) Studies, the California Investor Owned Utilities (IOUs) provide standards and code-setting bodies with the technical and cost-effectiveness information required to make informed judgments on proposed regulations for promising energy efficiency design practices and technologies.

The IOUs and their consultants began evaluating potential code change proposals in the fall, 2009. Throughout 2010, the CASE Team evaluated energy savings and costs 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. This Draft CASE Report presents a code change proposal for solar hot water systems for residential low-rise, single-family buildings and introduces a new proposal for commercial buildings, specifically restaurants.

The contents of this report, including cost and savings analyses and proposed code language, were developed taking feedback from industry and the California Energy Commission (CEC) into account. This is a Draft version of the CASE Report. A final version will be released in summer/fall 2011.

DRAFT

2. Overview

2.1 Measure Title

Solar Water Heating – Residential and Specialty Commercial

2.2 Description

This proposed measure increases the prescriptive required minimum fraction of water heat to be provided by solar water heating systems for individual dwelling units (i.e. single-family housing) with electric resistance (storage and instantaneous) water heaters using Package C. The solar fraction required will be equal across climate zones, at .7. The measure also introduces an option for individual dwelling units where the solar fraction is unable to be calculated. In addition to changing the requirements, this code change proposal addresses several limitations of the language, format and representation of the existing code in the standards document and the compliance manual, e.g. placing the requirement in a more central location in the standard and compliance manual, and clarifying language that seems to be remnant from previous code cycles. While natural gas is preferred over electric for water heating from a resource consumption perspective, the current documentation of the solar fraction requirement for residential buildings using Package C [§151f, TABLE 151-B] (particularly in cases of natural gas non-availability) provides inconsistent guidance and should be clarified.

The proposed measure also introduces a required minimum fraction of water heating provided by solar water heating systems for new construction full service restaurants with natural gas storage water heaters, and conditioned and unconditioned floor area of at least 12,600 sq. feet. The solar fraction will be equal across climate zones, at .25, except for Climate Zone 1, which is exempt.

The proposed measure introduces to Part 11 of Title 24 a minimum fraction of water heat to be provided by solar water heating systems for new construction quick service restaurants with electric storage water heaters, and conditioned and unconditioned floor area of at least 1,600 sq. feet. The solar fraction required is equal across climate-zones, except for Climate Zone 1, which is exempt.

The code change proposal also addresses the current limitations of how solar water heating is calculated for both prescriptive and performance compliance. The current method for calculating solar fraction is the software program F-chart, and provides an annual value and is a separate calculator instead of being integrated into any existing building performance software programs. This measure proposes the use of an hourly model of solar fraction to increase precision and to align with the California Energy Commission's (CEC) Time-Dependent Valuation (TDV) of energy calculations. The measure also proposes integration of solar modeling into the Residential Alternative Calculation Method (ACM) while changing it from an "optional capability" to a "minimal capability," thereby simplifying and making consistent the solar inputs for the compliance analyst. This could make solar thermal a more broadly applied measure, while also improving enforcement and error checking. Finally, the measure proposes a new definition and differentiation of restaurant occupancy types—"quick service" and "full service."

2.3 Type of Change

This proposed measure would change the prescriptive approach for residential Package C in Part 6 of Title 24 for electric resistance water heaters. The measure would change the prescriptive approach in Part 6 of Title 24 for natural gas storage water heaters in full service restaurants. The measure would also change the prescriptive approach in Part 11 of Title 24 for electric water heaters in quick service restaurants. This measure would modify the calculation procedures and assumptions used in making performance calculations using the Residential Alternative Calculation Method (ACM) Manual. The change would also modify the language and visual representation of the solar fraction requirement in the residential standard, compliance manual and compliance forms.

2.4 Energy Benefits

The proposed measure results in energy savings and demand reduction beyond 2008 Title 24 Code. All yearly energy savings are multiplied against the 2013 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 residential non-envelope measures, the TDV period of analysis is 30 years at a 3% discount rate. For nonresidential non-envelope measures, the TDV period of analysis is 15 years at a 3% discount rate. For the nonresidential non-envelope cost-effectiveness calculations for this analysis the Part 11 of Title 24 or “Reach Code” TDV multipliers were used (see Appendix A for more details).

Residential: Single Family – Electric Resistance Water Heating, Package C (Climate Zone Average)

	Electricity Savings (kwh/yr)	Demand Savings (kw)	Natural Gas Savings (Therms/yr)	TDV Electricity Cost Savings	TDV Gas Cost Savings
Per Prototype Building	2,700	.30	N/A	\$10,480	N/A
Savings per square foot	1.00	.0001	N/A	\$3.90	N/A

Commercial: Restaurant - Natural Gas Storage Water Heating¹ (Climate Zone Average)

	Electricity Savings (kwh/yr)	Demand Savings (W)	Natural Gas Savings (Therms/yr)	TDV Electricity Cost Savings	TDV Gas Cost Savings

¹ The natural gas water heating system saves a significant amount of natural gas, but uses a small amount of electricity, for the collector and heat exchange pumps, hence the negative electricity cost savings values.

Per Prototype Building	(530)	(.12)	1,650	(\$1,18)	\$23,630
Savings per square foot	(.04)	(.00005)	.13	(.09)	\$1.90

Commercial: Restaurant - Electric Storage Water Heating ² (Climate Zone Average)

	Electricity Savings (kwh/yr)	Demand Savings (kw)	Natural Gas Savings (Therms/yr)	REACH TDV Electricity Cost Savings	TDV Gas Cost Savings
Per Prototype Building	10,580	2.10	N/A	\$26,290	N/A
Savings per square foot	7.05	.0008	N/A	\$17.90	N/A

2.5 Non-Energy Benefits

We found little evidence to suggest there are substantive non-energy benefits. Increased property value may be likely, however, further research would be needed to quantify the benefit.

2.6 Environmental Impact

Emissions Factors

	NOX	SOX	CO	PM10	CO2
Per Prototype Building (Residential)	0.47	2.60	0.60	0.20	1,560
Per Prototype Building (Commercial Natural Gas)	16.2	10.5	4.80	1.60	18,650
Per Prototype Building (Commercial Electric)	1.7	10.0	2.40	0.80	6,130

Material Increase (I), Decrease (D), or No Change (NC): (All units are lbs/year) ³

	Mercury	Lead	Copper	Steel	Plastic	Others (Identify)

² These are averages of Climate Zone 13 and 15. The measure in Climate Zone 1 was cost-ineffective and therefore not included in these calculations.
³ Calculated based on one product from one manufacturer, Enerworks, divided by the life expectancies. Not representational of full market.

Per Prototype Building (Residential)	NC	.01	1.14	18.4	.95	Aluminum – 1.70 USP Propylene Glycol - 3.5
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Water Consumption:

	On-Site (Not at the Powerplant) Water Savings (or Increase) (Gallons/Year)
Per Prototype Building (Residential)	+ 40gallons / Year

Water Quality Impacts:

Comment on the potential increase (I), decrease (D), or no change (NC) in contamination compared to the base case assumption, including but not limited to: mineralization (calcium, boron, and salts), algae or bacterial buildup, and corrosives as a result of PH change.

	Mineralization (calcium, boron, and salts)	Algae or Bacterial Buildup	Corrosives as a Result of PH Change	Others
Impact (I, D, or NC)	NC	NC	NC	NC
Comment on reasons for your impact assessment	Measure does not involve technology which impacts water quality.			

2.7 Technology Measures

Measure Availability:

Over the past several decades, availability of solar water heating systems has increased worldwide. Between 2000 and 2009, the number of solar thermal collector companies more than tripled, and sales nearly doubled (EIA 20011). Solar Rating and Certification Corporation (SRCC) currently rates 48 different solar water heating systems.

In California, system and contractor availability is strong, with manufacturers generally supplying the systems to the contractors. California Solar Initiative Thermal Program (CSI Thermal), as of February 1st, 2011, listed 25 different contractors across 9 of the 16 climate zones, having installed tanks with electric backup from 11 different manufacturers in residential single family buildings. For natural gas, in the same data set, there have been 7 different contractors across 6 Climate Zones, having installed natural gas tank systems from 11 different manufacturers in multi-family and commercial buildings.

Useful Life, Persistence, and Maintenance:

Compared to standard storage water heaters, solar water heating systems with utility back up are more complex, with many components and varying life expectancies. With proper installation and

maintenance, however, systems are expected to maintain persistent savings over time. The table below summarizes the useful life of each component (Stakeholder Interviews 2010/2011):

Component	Life Expectancy (years)
Collector	20
Auxiliary and Auxiliary / Solar Combined Tank	10
Solar Tank	15
Motor and Pump	10
Controller	20
Heat Transfer Fluid	3

2.8 Performance Verification of the Proposed Measure

No additional performance verification such as diagnostic testing or acceptance tests will be required for compliance with this measure.

2.9 Cost Effectiveness

We began our cost-effectiveness analysis by examining all 16 climate zones, given the climate sensitivity of the measure. We first performed this analysis for residential solar systems with electric back up and commercial solar systems with natural gas back up. Then, for the commercial solar systems with electric back up, we modeled the three least-cost effective climate zones from these other two analyses.

The numbers below in column C and E are representative of costs which are equal across climate zones, but column F contains the averages from the climate zones of the respective number of climate zones modeled (Commercial Electric is the average of the two cost-effective climate zones). The LCC equals the sum of each row, rather than the average LCC savings across climate zones. As mentioned in Section 2.4, residential water heating measures are evaluated over a 30 year period of analysis and using base code TDV, and nonresidential water heating measures are evaluated over a 15 year period of analysis, using base code TDV for the large restaurant measure (natural gas back up), and using reach code TDV for the quick service restaurant measure (electric back up).

BASE TDV

A	B	C	E	F	g
Measure Name	Measure Life (Years)	Additional Costs ¹ – Current Measure Costs (Relative to Basecase) (\$)	PV of Additional ³ Maintenance Costs (Savings) (Relative to Basecase) (PV\$)	PV of ⁴ Energy Cost Savings – Per Proto Building (PV\$)	LCC Savings Per Prototype Building (\$) Climate Zone Average
		Per Proto Building	Per Proto Building	Climate Zone Average	(c+e)-f Based on Current Costs
Residential Electric	30	\$5,710	\$4,110	\$10,480	\$660
Commercial – Natural Gas	15	\$17,860	\$3,090	\$22,440	\$1,490

REACH TDV

A	B	C	E	F	g
Measure Name	Measure Life (Years)	Additional Costs ¹ – Current Measure Costs (Relative to Basecase) (\$)	PV of Additional ³ Maintenance Costs (Savings) (Relative to Basecase) (PV\$)	PV of ⁴ Energy Cost Savings – Per Proto Building (PV\$)	LCC Savings Per Prototype Building (\$) Climate Zone Average
		Per Proto Building	Per Proto Building	Climate Zone Average	(c+e)-f Based on Current Costs
Commercial – Electric	15	\$24,190	\$1,650	\$26,880	\$1,040

2.10 Analysis Tools

Thermal Energy System Specialists (TESS) provided water heating hourly energy usage numbers in order to align with hourly TDV, and therefore provide a more precise assessment of energy costs. The software used is called TRNSYS, (Transient Energy System Simulation Tool) from which F-Chart is based. While a more fully integrated TRNSYS modeling tool would be ideal for compliance purposes, we believe an integration of F-Chart into compliance software is sufficient.

2.11 Relationship to Other Measures

This CASE proposes solar water heating requirements for *single family* homes. This CASE is related to three other solar water heating measures: 1) The multifamily SWH CASE proposes solar water heating and solar ready requirements for *multifamily* homes. 2) The Commercial Solar Ready CASE proposes solar ready requirements for PV systems in *commercial* buildings, 3) PV and SWH “solar ready” requirements for *single family* homes. These CASEs were developed collaboratively, with each CASE addressing distinct areas of the code.

3. Methodology

For the three separate components of this measure, we used the same basic methodology, with slight variations. The sections below describe the factors for selecting the base case systems and the proposed standards case systems, and data that informed the cost-effectiveness calculation.

3.1 Single Family Residential Buildings

As mentioned above, in this code change proposal for the residential sector, we examined individual dwelling unit buildings exclusively. A separate proposal in this code cycle addressed residential multi-family buildings.

3.1.1 Base Case System Selection:

While the current code contains a prescriptive requirement in Package C for a 25% solar fraction for homes with electric resistance water heating, market research suggests that many single family homes with electric water heaters are not being built with solar hot water systems. For example, the Residential Appliance Saturday Survey (RASS) 2009 database (KEMA 2010) indicates in a statewide survey covering all the investor owned utility service area including electric only areas, there were no homes built after 2001 with a solar water heater and electric backup. For the base case we therefore selected a standard electric resistance water heater with an 80-gallon tank and a 0.9 energy factor, instead of a solar system w/ electric backup with a 25% solar fraction. This represents an extremely conservative approach for a cost-effectiveness analysis, because our analysis assumes the full cost of the solar hot water system, despite the fact that a 25% solar fraction is already the minimum prescriptive requirement.

3.1.2 Proposed Standards Case System Selection:

With a wide range of systems in the marketplace, we initially selected four system types to model costs and energy savings. We modeled these systems across all 16 climate zones due to the variation in TDV and the climate-dependent energy consumption of solar water heating systems. As more field data became available, we focused our analysis on the most commonly installed system, an active indirect system w/ glycol freeze protection (CSI Thermal). This system was modeled with a 74 sq. ft flat plate collector and one 120 gallon tank with electric backup and a 0.9 energy factor. This size of system was based on estimates that this would provide the optimal solar fraction. It should be noted that a 1.5 to 2.0 gallon / sq. ft. ratio is needed to prevent the system from overheating (DOE 2010, Stakeholder Meeting 2010/2011).

It should also be noted that the standards for small federally regulated water heaters (Residential ACM Manual, Appendix B, Pg. 16) have a $0.97 - (.00132 \times V)$ energy factor requirement, as of January 20, 2004, however the energy factor used in modeling was 0.9, reflective of the values used by SRCC.

3.1.3 Calculation of Costs:

The three main costs of both systems are the energy costs, installation costs, and maintenance and replacement costs over the 30-year period of analysis for residential buildings.

The base case energy costs were calculated by the following equation:

Equation 1: $Energy\ Costs = \sum (Hourly\ ideal\ energy\ delivered\ to\ load\ (TESS\ 2011) / Energy\ Factor * TDV\ (CEC\ 2011\ v3))$

The proposed standards system energy costs were calculated using a similar approach:

Equation 2: $Energy\ Costs = \sum (Hourly\ energy\ consumption\ (TESS\ 2011) * TDV\ (CEC\ 2011\ v3))$

The inputs for calculating the hourly energy use and their sources are as follows:

- Prototype building size: 2,700 (Residential ACM manual, CEC 2008)
- Gallons Per Day: 56.5 (Residential ACM Manual, CEC 2008)
- Hourly Draw Schedule (Residential ACM Manual, CEC 2008)
- Inlet Water Temperatures: (NREL algorithm)
- Outlet Water temperature: 135 (Residential ACM manual, CEC 2008)
- Pipe size (OG 300 specification, SRCC 2011)
- Pipe insulation (Use OG 300 specification, SRCC 2011)
- System Orientation Due South (Residential ACM manual, CEC 2008)
- System Tilt 4:12 (Residential ACM manual, CEC 2008)

Installation and replacement for the base case were sourced from RSMeans (2010) for California. Using this methodology the installation costs for the Base Case system total \$1,495. See Table 1 for the replacement costs. There was assumed to be no maintenance.

Table 1 Maintenance and Replacement Costs: Base Case System

	Material + Warranty Cost Per Unit (\$)	Labor Rate (\$)	Labor Time	Labor Cost (\$)	Total Cost Overhead & Profit (\$)	Replacements / Maintenance per building life	PV Replacements / Maintenance per building life (\$)
Auxiliary Tank (80 gal)	\$1,080	\$35	5.0	\$170	\$1,500	1	\$1,110

Installation, maintenance and replacements costs for the proposed Standards case system were derived from a variety of sources. For installation costs, we first determined the total costs for electric back up tank systems with 74 to 80 sq. ft. collectors from the California Solar Initiative - Thermal public database (2011).⁴ To determine a state-weighted average, given the different material and labor rates

⁴ The database included both new and retrofit installations, and while there was a cost differential between types, this differences was deemed statistically insignificant using T-Test methods at 95% confidence interval.

in different parts of the state, we first multiplied these installation costs by the estimated percentages of the totals costs that equal labor and materials (20%, 80% respectively) for residential systems as determined by the Itron (2009). We then multiplied these labor and material costs by a respective normalizing conversion factor for each city based on population using data from the American Community Survey 2006 – 2008 (Census 2010) and cost data from RSMMeans data (2010). See Appendix B.

Using this methodology, the installation costs for the Proposed Case system are \$7,200. See Table 2 for the maintenance and replacement costs, derived from Stakeholder Interviews (2010/2011) and Stakeholder Meetings (2010/2011), and weighted for California rates as well using RSMMeans data (2010). See Appendix C for more details.

Table 2 Maintenance and Replacement Costs: Standards Case System

	Material + Warranty Cost Per Unit (\$)	Labor Rate (\$)	Labor Time	Labor Cost (\$)	Total Cost Overhead & Profit (\$)	Replacements / Maintenance per building life	PV Replacements/ Maintenance per building life (\$)
Collector (74 sq. ft.)	\$1,500	\$35	13	\$450	\$2,420	1	\$1,340
Solar & Auxiliary Combined Tank (120 gal)	\$1,080	\$35	6	\$200	\$1,50	3	\$2,510
Motor & Pump	\$420	\$35	1.75	\$60	\$570	3	\$740
Controller	\$175	\$35	2.5	\$90	\$340	1	\$190
Heat Transfer Fluid Check	-	\$35	0.5	\$20	\$20	20	\$90
Heat Transfer Fluid Check & Replace	\$105	\$35	2	\$70	\$175	9	\$1,040
						Total	\$5,910

The cost-effectiveness of the proposed Standards case system was determined by calculating the difference between life-cycle costs (energy costs + installation costs + NPV (maintenance & replacement)).

The final component of the methodology was the calculation of the annual solar fraction. The solar fraction was calculated using **Equation 3**, as derived from SRCC (2011)

$$\text{Equation 3: Annual Solar Fraction} = 1 - \text{Energy Factor (EF)} / \text{Solar Energy Factor (SEF)}$$

Where: EF = 0.9 for a standard electric auxiliary tank.

$$\text{Solar Energy Factor} = Q_{del} / (Q_{aux} + Q_{par})$$

Where:

QDEL = Energy delivered to the hot water load (TESS 2011)

QAUX = Annual amount of energy used by the auxiliary water heater or backup element with a solar system operating, (Btu/year) (TESS 2011)

QPAR = Parasitic energy: Annual amounts of AC electrical energy used to power pumps, controllers, shutters, trackers, or any other item needed to operate the SDHW system, (Btu/year). (TESS 2011)

3.2 Non-Residential Buildings

In determining the potential applications for solar water heating systems in the commercial sector, we first examined the non-residential (non-hotel/motel)⁵ building types with the greatest hot water demand. The ACM Manual formula for calculating hot water demand (Btu/hr/sq ft.) indicates that restaurants surpass others by an order of magnitude, so we selected this occupancy type for our analysis. We also analyzed electric and natural gas water heating separately, given their differences in efficiencies and utility costs.

It is important to note that while the building prototype is specified in the Residential ACM, with both gallons per day of hot water and sq. footage defined, the Non-Residential ACM applies a different approach: it specifies Btu/h of hot water per person by occupancy type and the number of people per 1,000 sq. ft. Multiplying these values together provides the standard recovery load, in Btu/hr/sq.ft. Since prototype building square footage by occupancy is not specified, however, we therefore had to develop our own value for analysis. Instead of researching and defining the prototype size, we instead used the approach of determining square footage thresholds for cost-effectiveness. These thresholds were determined by the results of the LCC analysis. To calculate energy use and costs, instead of using the Residential ACM standard recovery load and hourly profiles, we utilized the gallons per day metric, and ASHRAE hourly profiles for hot water demand used by the California Solar Thermal Initiative (see Appendix D). Once we determined the threshold of gallons per day for cost-effectiveness, we plugged this value into the ACM formula for Standard Recovery Load Btu/h/sq. ft. to determine the resulting square footage (see Appendix E).

3.2.1 Base Case System Selection:

The base case for quick service restaurants with a standard electric storage water heater is an 80-gallon tank found in a small restaurant or coffee shop (Food Service Technology Center 2010). The tank was estimated to have a 0.9 energy factor (SRCC 2011). For full service restaurants with a natural gas storage water heater, the base case is a 400,000 Btu/hr rated, 100 gallon tank (Wallace & Fisher 2007). The tank was estimated to have a 0.74 operating efficiency based on a 0.80 thermal efficiency (FSTC 2011).

⁵ A separate CASE report in this code cycle is addressing non-residential hotel and motel buildings.

3.2.2 Proposed Standards Case System Selection:

For restaurants with electric water heating we modeled costs and energy savings of the most commonly installed system according to CSI Thermal (2011) and California Center for Sustainable Energy – Solar Hot Water Pilot Program (CCSE) database (2010): an active indirect system w/ glycol freeze protection.⁶ For sizing the system, we first used the same specifications as the residential system given the comparable hot water demand. However, this sizing of 80 Sq. ft. and a 120 gallon tank proved to be cost-ineffective. We therefore determined that a larger, two-tank system was needed (a 300 gallon solar tank, and an 80 gallon electric storage back up) and sized with 200 sq. ft. of collectors. The energy factor of the tank was estimated to be 0.9 for the reasons mentioned in above in section 3.1.2. The collector sizing was determined to be limited by the available roof space of this prototype restaurant (Stakeholder Meetings 2010/2011).

Using the results from the residential modeling, we chose to model these systems across the 3 least cost-effective climate zones. Cost-effectiveness in these climate zones can be assumed to demonstrate cost-effectiveness across all climate zones.

For restaurants with natural gas heating, the proposed Standards case system is a two-tank system (350 gallon solar tank, and a 100 gallon natural gas boiler) with 0.80 thermal efficiency. This results in the same operating efficiency as the base case (FSTC 2011).

For the solar system, we modeled two types of active indirect systems, drain-back and glycol freeze protection and immersed and external heat exchangers, with 240 sq. ft. of flat-plate collectors. Sizing was also limited by available roof space of this prototype restaurant. Once we determined the external heat exchanger glycol system had the most savings, we also modeled this system with unglazed and evacuated tube collector, though the flat plate collector proved to result in the most savings.

3.2.3 Calculation of Costs:

The three main costs of both systems are the energy costs, installation costs, and the post-installation costs (maintenance and replacement) of the 15-year useful building life.

Energy Costs:

The base case energy costs were calculated by the following equation:⁷

Equation 4: $Energy\ Costs = \sum (Hourly\ ideal\ energy\ delivered\ to\ load\ (TESS\ 2011) / Energy\ Factor / Operating\ Efficiency * TDV\ (CEC\ 2011\ v3))$

The proposed standards system energy costs were calculated using a similar approach:

Equation 5: $Energy\ Costs = \sum (Hourly\ energy\ consumption\ (TESS\ 2011) * TDV\ (CEC\ 2011\ v3))$

⁶ Given the constraint of available roof space, we limited the maximum system size to this number of collectors.

Where:

Hourly Energy Consumption - Electric = Collector Pump + PV Controller + Electric Auxiliary (TESS 2011)
 Hourly Energy Consumption - Natural Gas = Collector Pump + Heat Exchanger Pump + Natural Gas Auxiliary (TESS 2011)

The inputs for calculating the hourly energy use and their sources are as follows:

- Prototype building size:

Given that there are no prototypes for building square footage by type specified in the non-residential ACM (CEC 2008a), as mentioned above, we tested for square footage thresholds and the corresponding gallons per day using the non-residential ACM Manual Table N-2 (CEC 2008a) to show cost-effectiveness. To calculate the corresponding square footages, we used assumptions from the ACM Manual, as indicated in the following formulas:

Equation 6: $Sq. ft. = Gallons / day * 1 / Gallons / day / sq. ft$

Where:

Equation 7: $Gallons / day / sq. ft = (Standard Recovery Load / day / 1,000 sq. ft) * 1 / (total degrees raised * Btu/degree per gallon)$

Where:

Equation 8: $Standard Recovery Load / day / 1,000 sq. ft. = (\sum (people/sq. ft. \& Btu/h/person (ACM, Table N2-5)) * occupancy load profile for year (ACM, Table N2-5)) / (days in a year)$

- Gallons Per Day:
 1. Electric Water Heating: 250 gallons per day (estimate)
 2. Natural Gas Water Heating: 2,000 gallons per day (Karas and Fisher 2007).
- Hourly Draw Schedule / Occupancy Load Profile
 1. Electric Water Heating: ASHRAE, from CSI Thermal, Food Service B (2011a)
 2. Natural Gas Water Heating: ASHRAE, from CSI Thermal, Food Service A. (2011a)
- Inlet Water Temperatures: (NREL algorithm)
- Outlet Water temperature: (Karas and Fisher 2007)
- Pipe size (OG 300 specification)
- Pipe insulation (Use OG 300 specification)
- System Orientation Due South (Residential ACM manual)
- System Tilt 4:12 (Residential ACM manual)

Installation & Post-Installation costs

Installation, maintenance and replacement costs for the base case and for proposed standard case system for both electric water heating and natural gas were sourced from CSI Thermal and CCSE (2010), RSMMeans (2010), Census (2010) and Stakeholder Meetings (2010/2011). One key additional

modification to the methodology for the system w/ natural gas back up, was that since there was a smaller sample of these exact sized systems in the CSI Thermal and CCSE, we used regression analysis to estimate the costs (see Appendix F). It is important to note that when developing the appropriate regression methodology, we took into consideration feedback from stakeholders (2010/2011) and other sources (RSMMeans 2010). There was input from stakeholders suggesting that several linear curves are an accurate reflection of how costs increase when increasing collector size.

The installation costs for the Base Case electric storage water heater is \$1,600. The installation costs for the Base Case natural gas storage water heater is \$10,241. The installation costs for the Proposed Standards Case solar system with electric storage back up is \$23,800. The installation cost for the Proposed Standards Case natural gas storage water heater is \$28,000. Table 3, 4, 5, and 6 summarize the maintenance and replacement costs for these systems. Table 7 summarizes the building prototype used in this analysis.

Table 3: Maintenance and Replacement Costs: Base Case System Commercial Electric Storage

	Material + Warranty Cost Per Unit	Labor Rate	Labor Time	Labor Cost	Total Cost O&P (Per unit)	Replacements/ Maintenance per building life	PV Replacements/ Maintenance per building life (\$)
Auxiliary Tank (80 Gal)	\$1,080	\$53	5	\$267	\$1,610	1	\$1,530

Table 4: Maintenance and Replacement Costs: Proposed Standards System Commercial Solar System w/ Electric Storage Back up

	Material + Warranty Cost Per Unit	Labor Rate	Labor Time	Labor Cost	Total Cost O&P (Per unit)	Replacements/ Maintenance per building life	PV Replacements/ Maintenance per building life (\$)
Auxiliary Tank (80 gal)	\$1,080	\$53	5	\$270	\$1,610	1	\$1,530
Motor & Pump	\$420	\$53	1.75	\$90	\$610	1	\$455
Controller	\$180	\$53	2.5	\$130	\$395	0	-
Heat Transfer Fluid Check	0	\$53	0.5	\$30	\$30	10	\$140
Heat Transfer Fluid Replace	\$105	\$53	2	\$110	\$210	5	\$820
						Total	\$2,945

Table 5: Maintenance and Replacement Costs: Base Case System Commercial Natural Gas Storage

	Material + Warranty Cost Per Unit	Labor Rate	Labor Time	Labor Cost	Total Cost O&P (Per unit)	Replacements / Maintenance per building life	PV Replacements / Maintenance per building life (\$)
Auxiliary Tank (100 Gal, 400 GPH)	\$7,500	\$53	20	\$1,070	\$10,140	1	\$ 7,550

Table 6 : Maintenance and Replacement Costs: Proposed Standards System Commercial Natural Gas Storage

	Material + Warranty Cost Per Unit	Labor Rate	Labor Time	Labor Cost	Total Cost O&P (per unit)	Replacements / Maintenance per building life	PV Replacements / Maintenance per building life (\$)
Auxiliary Tank (100 Gal, 400 GPH)	\$7,500	\$53	20	\$1,070	\$10,140	1	\$7,550
Heat Transfer Fluid Check	0	\$53	0.5	\$30	\$20	10	\$140
Heat Transfer Fluid Replace	\$110	\$53	2	\$110	\$210	5	\$1,750
						Total	\$9,400

Table 7: Prototype Size

	Occupancy Type (Residential, Retail, Office, etc)	Area (Square Feet)	Number of Stories
Prototype 1	Residential Low Rise - Individual Dwelling Unit	2,700 Sq. Ft.	2
Prototype 2	Commercial – Restaurant, electric storage water heater	1,600 Sq. Ft	1
Prototype 3	Commercial – Restaurant, natural gas storage water heater	12,600 Sq. Ft.	1

4. Analysis and Results

Our analysis resulted in several conclusions. First, installing and utilizing solar water heating with an electric resistance backup water heater in residential, individual unit dwellings saves a significant amount of energy in all 16 climate zones. Moreover, the most common system, an active indirect system with glycol freeze protection is cost-effective.

Table 8 summarizes the energy savings, energy cost savings, incremental cost and the life-cycle cost savings for the Standards Case for residential buildings with electric resistance water heating, as well as the corresponding solar fraction achieved by the solar system.

Table 8 ORIGINAL Proposed Standards Case Results: Residential Solar w/ Electric Resistance back up

Climate Zone	Annual Energy Savings (kWh)	30 Year PV BASE TDV Energy Cost Savings (\$)	Incremental Measure Cost (installation and PV maintenance and replacement) (\$)	Life Cycle Cost Savings (\$)	Solar Fraction
1	2,920	\$11,390	\$9,820	\$1,570	0.64
2	3,300	\$12,540	\$9,820	\$2,720	0.77
3	3,320	\$12,650	\$9,820	\$2,830	0.77
4	3,340	\$12,750	\$9,820	\$2,930	0.79
5	3,590	\$13,650	\$9,820	\$3,830	0.84
6	3,430	\$12,560	\$9,820	\$2,740	0.84
7	3,450	\$13,160	\$9,820	\$3,340	0.86
8	3,370	\$12,380	\$9,820	\$2,560	0.84
9	3,330	\$12,150	\$9,820	\$2,330	0.84
10	3,350	\$12,120	\$9,820	\$2,300	0.85
11	3,170	\$12,020	\$9,820	\$2,200	0.77
12	3,150	\$12,030	\$9,820	\$2,210	0.75
13	2,980	\$11,330	\$9,820	\$1,510	0.75
14	3,550	\$12,740	\$9,820	\$2,920	0.87
15	3,050	\$10,910	\$9,820	\$1,090	0.89
16	3,530	\$12,920	\$9,820	\$3,100	0.75

Stakeholder feedback regarding these results suggested that most of these solar fractions were too high and would result in systems overheating. To address this concern, we decreased the solar fraction to .7 while also inserting a requirement for system to have overheating protection per the Solar Rating Certification Corporation and/or the CSI-Thermal Handbook. Table 9 and the code language reflect the results of this change.

Table 9 AMENDED Proposed Standards Case Results: Residential Solar w/ Electric Resistance back up

Climate Zone	Annual Energy Savings (kWh)	30 Year PV BASE TDV Energy Cost Savings (\$)	Incremental Measure Cost (installation and PV maintenance and replacement) (\$)	Life Cycle Cost Savings (\$)	Solar Fraction
1	3,180	\$12,240	\$10,200	\$2,040	0.70
2	2,730	\$10,710	\$9,630	\$1,080	0.70
3	2,710	\$10,650	\$9,630	\$1,020	0.70
4	2,680	\$10,540	\$9,630	\$910	0.70
5	2,620	\$10,370	\$9,430	\$940	0.70
6	2,580	\$10,620	\$9,310	\$1,310	0.70
7	2,550	\$10,590	\$9,210	\$1,380	0.70
8	2,570	\$10,590	\$9,210	\$1,380	0.70
9	2,580	\$10,570	\$9,210	\$1,360	0.70
10	2,570	\$10,570	\$9,210	\$1,360	0.70
11	2,720	\$10,610	\$9,630	\$980	0.70
12	2,760	\$10,650	\$9,630	\$1,020	0.70
13	2,730	\$10,510	\$9,630	\$880	0.70
14	2,620	\$10,660	\$9,630	\$1,030	0.70
15	2,380	\$9,810	\$9,100	\$710	0.70
16	2,800	\$10,850	\$9,630	\$1,220	0.70

The second conclusion is that installing and utilizing solar water heating with 200 sq. feet of flat-plate collectors with an electric storage backup water heater in commercial restaurants 1,600 sq. ft. large (with 250 gallons per day hot water demand) is cost-effective over the base case, an electric storage water heater, when using Reach Code TDV, in every climate zone except for Climate Zone 1. Table 9 summarizes the energy, energy cost savings and the life-cycle cost savings for the Standards Case for restaurants with electric storage water heating, as well as the corresponding solar fraction achieved by the solar system.

Table 10 Proposed Standards Case Results: Commercial Solar w/ Electric Storage back up (REACH TDV)

Climate Zone	Annual Energy Savings (kWh)	15 Year PV REACH TDV Energy Cost Savings (\$)	Incremental Measure Cost (installation and PV maintenance and replacement)	Life Cycle Cost Savings (\$)	Solar Fraction
1	8,280	\$23,140	\$23,800	(\$660)	0.38
13	10,150	\$26,580	\$23,800	\$2,780	0.54
15	11,010	\$27,170	\$23,800	\$3,370	0.67

Third, installing and utilizing solar water heating with a natural gas backup water heater in restaurants 12,600 sq. ft. or larger is cost-effective over the base case, a natural gas storage water heater, in every climate zone, except Climate Zone 1. Table 11 summarizes the energy, energy cost savings and the life-cycle cost savings for the Standards Case for restaurants with natural gas water heating, as well as the corresponding solar fraction achieved by the solar system using Equation 10.

Table 11 Proposed Standards Case Results: Commercial Solar w/ Gas Storage back up (BASE TDV)

Climate Zone	Annual Energy Savings (Therms)	15 Year PV BASE TDV Energy Cost Savings (\$)	Incremental Measure Cost (installation and PV maintenance and replacement)	Life Cycle Cost Savings (\$)	Solar Fraction
1	1,440	\$19,490	\$20,950	(\$1,460)	0.18
2	1,650	\$22,240	\$20,950	\$1,290	0.25
3	1,610	\$21,680	\$20,950	\$730	0.24
4	1,670	\$22,540	\$20,950	\$1,590	0.25
5	1,690	\$23,080	\$20,950	\$2,130	0.25
6	1,610	\$22,110	\$20,950	\$1,160	0.25
7	1,620	\$22,580	\$20,950	\$1,630	0.26
8	1,630	\$22,310	\$20,950	\$1,360	0.26
9	1,650	\$22,540	\$20,950	\$1,590	0.26
10	1,670	\$22,840	\$20,950	\$1,890	0.27
11	1,680	\$22,570	\$20,950	\$1,620	0.26
12	1,640	\$21,980	\$20,950	\$1,030	0.25
13	1,590	\$21,300	\$20,950	\$350	0.26
14	1,810	\$24,810	\$20,950	\$3,860	0.28
15	1,660	\$22,730	\$20,950	\$1,780	0.31
16	1,780	\$24,290	\$20,950	\$3,340	0.24

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

Part 6

RESIDENTIAL STANDARDS:

Subchapter 8

SECTION 151 – PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES

Section 151(b)1

- (b) **Performance Standards.** A building complies with the performance standard if the combined depletable TDV energy use for water heating Section 151(b)1 and space conditioning Section 151(b)2 is less than or equal to the combined maximum allowable TDV energy use for both water heating and space conditioning, even if the building fails to meet either the water heating or space conditioning budget alone.
1. **Water heating budgets.** The water heating budgets for each climate zone shall be the calculated consumption of energy from depletable sources required for water heating in buildings in which the requirements of Section 151(a) and of Section 151(f)8A for systems serving individual dwelling units or of Section 151(f)8C for systems serving multiple dwelling units are met. To determine the water heating budget, use an approved calculation method.
- (f) **Prescriptive Standards/ Component Packages.** Buildings that comply with the prescriptive standards shall be designed, constructed, and equipped to meet all of the requirements of one of the packages of components shown in TABLE 151-B **Error! Reference source not found.** or TABLE 151-D for the appropriate climate zone shown in FIGURE 101-A. In TABLE 151-B **Error! Reference source not found.** and TABLE 151-D, a NA (not allowed) means that feature is not allowed in a particular climate zone and a NR (no requirement) means that there is no prescriptive requirement for that feature in a particular climate zone. Installed components shall meet the following requirements:
-
8. **Domestic Water-heating systems.** Water heating systems shall meet the requirements of either A, B, ~~or C~~ or D and meet the requirements of E and F, or shall meet the requirements of Section 151(b)1.
 - A. For systems serving individual dwelling units, a single gas or propane storage type water heater with an input of 75,000 Btu per hour or less and no recirculation pumps, and that meets the tank insulation requirements of Section 150(j) and the requirements of Sections 111 and 113 shall be installed.
 - B. For systems serving individual dwelling units, a single gas or propane instantaneous water heater with an input of 200,000 Btu per hour or less and no recirculation pumps or storage tank, and that meets the requirements of Sections 111 and 113 shall be installed.
 - C. For systems serving multiple dwelling units, a central water heating system that has gas or propane water heaters, boilers or other water heating equipment that meet the minimum efficiency requirements of Sections 111 and 113 and a water heating recirculation loop that meets the requirements of Section 113(c)2 and Section 113(c)5 shall be installed.
 - D. For systems serving individual dwelling units, electric-resistance water heating may be installed as the main water heating source in Package C only if natural gas is unavailable and only if the water heater is located within the building envelope and is served by a solar water heating system that has a calculated solar fraction no less than .7 and follows freeze and overheat protection guidelines of SRCC and/or CSI Thermal Handbook, or a system having the following characteristics:
 1. Collector rating : Collectors shall have a SRCC OG-100 rating of having a Y intercept no less than 0.706 and a slope no less than $- .865 \text{ btu/hr ft}^2 \text{ } ^\circ \text{ F}$
 2. Collector type: collector shall be a glazed flat-plate collector.

3. Collector size and orientation: Collectors shall be at least the area specified below by Climate Zone, facing within 45° of due South, having a tilt angle between 14.02°(3:12) and 22.62° (5:12)° from horizontal. Over 90% of collector area shall be unshaded for at least 8 hours on the equinox.

<u>Climate Zone</u>	<u>Collector Sq. Ft.</u>
<u>1</u>	<u>55</u>
<u>2</u>	<u>36</u>
<u>3</u>	<u>36</u>
<u>4</u>	<u>30</u>
<u>5</u>	<u>30</u>
<u>6</u>	<u>30</u>
<u>7</u>	<u>30</u>
<u>8</u>	<u>30</u>
<u>9</u>	<u>30</u>
<u>10</u>	<u>36</u>
<u>11</u>	<u>36</u>
<u>12</u>	<u>36</u>
<u>13</u>	<u>36</u>
<u>14</u>	<u>18</u>
<u>15</u>	<u>18</u>
<u>16</u>	<u>36</u>

4. Solar Storage tank: internal volume of at least 2 gallons per 1 sq. ft. of collector and insulated according to Section 113(c)4.
 5. Freeze protection: as specified in CSI Thermal Handbook
 6. Overheat protection: as specified as by SRCC guidelines, or if not available, as specified by CSI Thermal Handbook
 7. Pump. Pumps shall have an electronically commutated motor.
- E. All hot water pipes from the heating source to the kitchen fixtures shall be thermally insulated as specified by Section 150(j)2.
- F. All buried hot water piping shall be insulated to meet the requirements of Section 150(j)2 and be installed in a waterproof and non-crushable casing or sleeve that allows for installation, removal and replacement of the enclosed water piping. The internal cross-section or diameter of the casing or sleeve shall be large enough to allow for insulation of the hot water piping.

TABLE 151-B COMPONENT PACKAGE C

Climate Zone	1, 16	3	4	5	6	7	8, 9	10	2, 11-13	14	15
BUILDING ENVELOPE											
Insulation minimums ¹											
Ceiling	R49	R38	R38	R38	R38	R38	R38	R49	R49	R49	R49
Wood-frame walls	R29	R25	R25	R25	R21	R21	R21	R25	R29	R29	R29
“Heavy mass” walls	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
“Light mass” walls	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Below-grade walls	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Slab floor perimeter	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7
Raised floors	R30	R30	R30	R30	R21	R21	R21	R30	R30	R30	R21
Concrete raised floors	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radiant Barrier	NR	NR	REQ	NR	NR	NR	REQ	REQ	REQ	REQ	REQ
Roofing Products	See TABLE 151-C, COMPONENT PACKAGE D										
FENESTRATION											
Maximum U-factor ²	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Maximum Solar Heat Gain Coefficient (SHGC) ³	NR	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Maximum total area	14%	14%	14%	16%	14%	14%	14%	16%	16%	14%	16%
Maximum West facing area	NR	NR	5%	NR	NR	5%	5%	5%	5%	5%	5%
THERMAL MASS ⁴	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ
SPACE-HEATING ⁵											
Electric-resistant allowed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
If gas, AFUE =	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
If heat pump, HSPF ⁶ =	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
SPACE-COOLING											
SEER =	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
If split system, Refrigerant charge measurement or charge indicator display	NR	NR	NR	NR	NR	NR	REQ	REQ	REQ	REQ	REQ
Central Forced Air Handler:	See TABLE 151-C, COMPONENT PACKAGE D										
DUCTS											
Duct sealing	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ
Duct Insulation	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8
WATER HEATING											
Either prescriptive requirements in §151(f)8F or SOLAR FRACTION of:	<u>0.70</u>	<u>0.70</u>	<u>0.70</u>	<u>0.70</u>	<u>0.70</u>	<u>0.70</u>	<u>0.70</u>	<u>0.70</u>	<u>0.70</u>	<u>0.70</u>	<u>0.70</u>
WATER-HEATING	System shall meet Section 151(f)8 or Section 151(b)1 ⁷										

Footnote requirements to TABLE 151-B **Error! Reference source not found.** and TABLE 151-D.

1 The R-values shown for ceiling, wood frame wall and raised floor are for wood-frame construction with insulation installed between the framing members. For alternative construction assemblies, see Section 151(f)1A.

The heavy mass wall R-value in parentheses is the minimum R-value for the entire wall assembly if the wall weight exceeds 40 pounds per square foot. The light mass wall R-value in brackets is the minimum R-value for the entire assembly if the heat capacity of the wall meets or exceeds the result of multiplying the bracketed minimum R-value by 0.65. Any insulation installed on heavy or light mass walls must be integral with, or installed on the outside of, the

exterior mass. The inside surface of the thermal mass, including plaster or gypsum board in direct contact with the masonry wall, shall be exposed to the room air. The exterior wall used to meet the R-value in parentheses cannot also be used to meet the thermal mass requirement.

- 2 The installed fenestration products shall meet the requirements of Section 151(f)3.
- 3 The installed fenestration products shall meet the requirements of Section 151(f)4.
- 4 If the package requires thermal mass, the thermal mass shall meet the requirements of Section 151(f)5.
- 5 Thermostats shall be installed in conjunction with all space-heating systems in accordance with Section 151(f)9.
- 6 HSPF means "heating seasonal performance factor."
- 7 ~~Electric resistance water heating may be installed as the main water heating source in Package C only if the water heater is located within the building envelope and a minimum of 25 percent of the energy for water heating is provided by a passive or active solar system.~~
- 8 As an alternative under Package E in climate zone 1, glazing with a maximum 0.57 U-factor and a 92% AFUE furnace or an 8.4 HSPF heat pump may be substituted for the Package E glazing U-factor requirement. All other requirements of Package E must be met.
- 9 As an alternative under Package E in climate zone 16, glazing with a maximum 0.57 U-factor and a 90% AFUE furnace or an 8.4 HSPF heat pump may be substituted for may be substituted for the Package E glazing U-factor requirement. All other requirements of Package E must be met.
- 10 A supplemental heating unit may be installed in a space served directly or indirectly by a primary heating system, provided that the unit thermal capacity does not exceed 2 kilowatts or 7,000 Btu/hr and is controlled by a time-limiting device not exceeding 30 minutes.

RESIDENTIAL MANUAL:

- 5.1.3 Water Heater Types:
 - Add: Solar Water Heater w/ electric resistance storage backup
 - Add: Solar Water Heater w/electric resistance instantaneous backup
 - Add: Solar Water Heater w/ natural gas storage backup
- 1-18-1 Package C
 - "Electric resistance water heating may only be used with Package C if the water heater is located within the building envelope and a .7 solar fraction of the energy for water heating is provided by a passive or active solar system as specified in Table 151-B COMPONENT Package C."

TABLE 151-B COMPONENT PACKAGE C

Climate Zone	1, 16	3	4	5	6	7	8, 9	10	2, 11-13	14	15
BUILDING ENVELOPE											
Insulation minimums ¹											
Ceiling	R49	R38	R38	R38	R38	R38	R38	R49	R49	R49	R49
Wood-frame walls	R29	R25	R25	R25	R21	R21	R21	R25	R29	R29	R29
“Heavy mass” walls	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
“Light mass” walls	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Below-grade walls	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Slab floor perimeter	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7	R7
Raised floors	R30	R30	R30	R30	R21	R21	R21	R30	R30	R30	R21
Concrete raised floors	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radiant Barrier	NR	NR	REQ	NR	NR	NR	REQ	REQ	REQ	REQ	REQ
Roofing Products											
FENESTRATION											
Maximum U-factor ²	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Maximum Solar Heat Gain Coefficient (SHGC) ³	NR	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Maximum total area	14%	14%	14%	16%	14%	14%	14%	16%	16%	14%	16%
Maximum West facing area	NR	NR	5%	NR	NR	5%	5%	5%	5%	5%	5%
THERMAL MASS⁴	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ
SPACE-HEATING ⁵											
Electric-resistant allowed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
If gas, AFUE =	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
If heat pump, HSPF ⁶ =	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
SPACE-COOLING											
SEER =	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
If split system, Refrigerant charge measurement or charge indicator display	NR	NR	NR	NR	NR	NR	REQ	REQ	REQ	REQ	REQ
Central Forced Air Handler:											
DUCTS											
Duct sealing	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ
Duct Insulation	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8
WATER HEATING											
Either prescriptive requirements in §151(f)8F or SOLAR FRACTION of:	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
WATER-HEATING	System shall meet Section 151(f)8 or Section 151(b)4 ⁷										

Footnote requirements to TABLE 151-B **Error! Reference source not found.**and TABLE 151-D.

1 The R-values shown for ceiling, wood frame wall and raised floor are for wood-frame construction with insulation installed between the framing members. For alternative construction assemblies, see Section 151(f)1A.

The heavy mass wall R-value in parentheses is the minimum R-value for the entire wall assembly if the wall weight exceeds 40 pounds per square foot. The light mass wall R-value in brackets is the minimum R-value for the entire assembly if the heat capacity of the wall meets or exceeds the result of multiplying the bracketed minimum R-value by

- 0.65. Any insulation installed on heavy or light mass walls must be integral with, or installed on the outside of, the exterior mass. The inside surface of the thermal mass, including plaster or gypsum board in direct contact with the masonry wall, shall be exposed to the room air. The exterior wall used to meet the R-value in parentheses cannot also be used to meet the thermal mass requirement.
- 2 The installed fenestration products shall meet the requirements of Section 151(f)3.
 - 4 The installed fenestration products shall meet the requirements of Section 151(f)4.
 - 4 If the package requires thermal mass, the thermal mass shall meet the requirements of Section 151(f)5.
 - 5 Thermostats shall be installed in conjunction with all space-heating systems in accordance with Section 151(f)9.
 - 6 HSPF means "heating seasonal performance factor."
 - ~~7 Electric resistance water heating may be installed as the main water heating source in Package C only if the water heater is located within the building envelope and a minimum of 25 percent of the energy for water heating is provided by a passive or active solar system.~~
 - 8 As an alternative under Package E in climate zone 1, glazing with a maximum 0.57 U-factor and a 92% AFUE furnace or an 8.4 HSPF heat pump may be substituted for the Package E glazing U-factor requirement. All other requirements of Package E must be met.
 - 9 As an alternative under Package E in climate zone 16, glazing with a maximum 0.57 U-factor and a 90% AFUE furnace or an 8.4 HSPF heat pump may be substituted for may be substituted for the Package E glazing U-factor requirement. All other requirements of Package E must be met.
 - 10 A supplemental heating unit may be installed in a space served directly or indirectly by a primary heating system, provided that the unit thermal capacity does not exceed 2 kilowatts or 7,000 Btu/hr and is controlled by a time-limiting device not exceeding 30 minutes.
 - 5-1.5. pg. 5-5
 - Revise: "~~So~~ Solar water heating is also required if electric resistance water heater is installed (using prescriptive package C)."

PART 6 & PART 11

NON RESIDENTIAL STANDARDS

DEFINITIONS AND RULES OF CONSTRUCTION

- **NONRESIDENTIAL FUNCTION AREA OR TYPE OF USE**

Dining is a room or rooms in a restaurant or hotel/motel (other than guest rooms) where meals that are served to the customers will be consumed.

Full-Service Dining is....[to be filled in]

Quick-Service Dining is....[to be filled in]

Restaurant is a room, area, or building that is a food establishment as defined in Section 27520 of the Health and Safety Code.

Full-Service Restaurant is....[to be filled in]

Quick-Service Restaurant is....[to be filled in]

PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES

PART 6

- Add: (a) Nonresidential Occupancies. Buildings with building category designated as “full-service restaurant” or area category as “full-service dining” and a total square footage (conditioned floor area & non-conditioned floor area) of 12,600 or greater may install a natural gas water heater if the water heater is located within the building envelope and 25% of the energy for water heating is provided by a passive or active solar system, and follows freeze and overheat protection guidelines of SRCC and/or CSI Thermal Handbook
- Exception: When indoor lighting and mechanical plans are both submitted for construction in an existing building envelope.

PART 11

- Buildings with building category designated as “quick service restaurant” or area category as “quick service dining” and a total square footage (conditioned floor area & non-conditioned floor area) of 1,600 or greater may install an electric storage water heater if the water heater is located within the building envelope and a minimum of 50% percent of the energy for water heating is provided by a passive or active solar system.
- Exception: When indoor lighting and mechanical plans are both submitted for construction in an existing building envelope.

Exception: Where building is located in Climate Zone 1.

A service water heating system installed in this building type and all nonresidential buildings complies with this section if it also complies with the applicable requirements of Part 6, Sections (111,113 and 123).

NON RESIDENTIAL MANUAL

- 4.7 Service Water Heating
 - Service Water Heaters in Restaurants
 - Buildings with building category designated as “full-service restaurant” or area category as “full-service dining” and a total square footage (conditioned floor area & non-conditioned floor area) of 12,600 or greater may install a natural gas water heater if the water heater is located within the building envelope and 25% of the energy for water heating is provided by a passive or active solar system, and follows freeze and overheat protection guidelines of SRCC and/or CSI Thermal Handbook

COMPLIANCE FORMS

RESIDENTIAL

- CF-1R – Certificate of Compliance - Residential New Construction (page 4 of 5) Water Heating:
 - Add: electric resistance water heating with solar fraction requirement and reference to Solar Water Heating and CF-SR (Solar Water Heating Calculation).
- CF-6R-MECH-01 – Domestic Hot Water (DHW) (page 1 of 2):
 - Add: electric resistance water heating with solar fraction requirement
- CF-6R-MECH-02 - Solar Domestic Hot Water Systems (SDHW) (page 1 of 1):
 - Revise: “Net Solar Fraction”

RESIDENTIAL ACM MANUAL

- Integrating Hourly Solar Water Heating Hourly Modeling Calculation

6. Bibliography and Other Research

[CEC] California Energy Commission. 2008. Residential Alternative Calculation Method (ACM) Approval Manual for the 2008 Building Energy Efficiency Standards. December 2008.

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7. Appendices

APPENDIX A

TDV Part 11 of Title 24 (Reach Code) Multipliers

	Electricity	Gas	Propane
Res 30yr	1.259	1.331	1.152
Non-Res 15yr	1.253	1.375	1.197
Non-Res 30yr	1.27	1.354	1.182

APPENDIX B

Population Weighting for Plumbing Labor and Materials

Metro Region	Population (millions) American Community Survey, Census 2007-2009)	Plumbing Labor		State/City Ratio	Plumbing Material		State/City Ratio
		Location Factor (*US Rate) RS Means	Weighted Loc. Factor (Pop. Location Factor)		Location Factor (*US Rate)	Weighted Loc. Factor	
Alhambra	0.086	96.3	8.282	1.096	93.4	8.032	1.067
Anaheim	0.334	112.9	37.709	0.934	100.1	33.433	0.995
Bakersfield	0.318	94.2	29.956	1.120	100.1	31.832	0.995
Berkeley	0.108	123.2	13.306	0.856	93.4	10.087	1.067
Eureka	0.027	102.4	2.765	1.030	93.3	2.519	1.068
Fresno	0.472	107.8	50.882	0.979	100.2	47.294	0.994
Inglewood	0.116	96.3	11.171	1.096	93.4	10.834	1.067
Long beach	0.463	96.3	44.587	1.096	93.4	43.244	1.067
Los Angeles	3.75	112.9	423.375	0.934	100.2	375.750	0.994
Marysville	2007-2009 Population unavailable	-	-	-	-	-	-
Modesto	0.204	107.8	21.991	0.979	100.1	20.420	0.995
Mojave	2007-2009 Population unavailable	-	-	-	-	-	-
Oakland	0.362	136.1	49.268	0.776	100.2	36.272	0.994
Oxnard	0.176	112.9	19.870	0.934	100.1	17.618	0.995
Palm Springs	0.039	96.3	3.756	1.096	93.3	3.639	1.068
Palo Alto	0.063	122.3	7.705	0.863	93.4	5.884	1.067
Pasadena	0.138	96.3	13.289	1.096	93.4	12.889	1.067
Redding	0.091	98.7	8.982	1.069	100.1	9.109	0.995
Richmond	0.099	119.7	11.850	0.881	93.4	9.247	1.067
Riverside	0.302	112.9	34.096	0.934	100.1	30.230	0.995
Sacramento	0.447	110.8	49.528	0.952	100.1	44.745	0.995
Salinas	0.144	108.2	15.581	0.975	93.4	13.450	1.067
San Bernardino	0.208	96.4	20.051	1.094	93.3	19.406	1.068
San Diego	1.25	113.3	141.625	0.931	100.2	125.250	0.994
San Francisco	0.798	165.1	131.750	0.639	100.2	79.960	0.994
San Jose	0.905	138.5	125.343	0.762	100.1	90.591	0.995
San Luis Obispo	0.048	96.4	4.627	1.094	93.4	4.483	1.067
San Mateo	0.093	137.1	12.750	0.770	93.4	8.686	1.067
San Rafael	0.054	132.9	7.177	0.794	93.4	5.044	1.067
Santa Ana	0.328	96.3	31.586	1.096	93.3	30.602	1.069
Santa Barbara	0.086	112.9	9.709	0.934	100.1	8.609	0.995

Santa Cruz	0.055	108.2	5.951	0.975	100.1	5.506	0.995
Santa Rosa	0.153	132.1	20.211	0.799	93.3	14.275	1.069
Stockton	0.286	98.8	28.257	1.068	100.1	28.629	0.995
Susanville	2007-2009 Population unavailable	-	-	-	-	-	-
Vallejo	0.114	112	12.768	0.942	100.1	11.411	0.995
Nan nyus	2007-2009 Population unavailable	-	-	-	-	-	-
TOTAL	12.117		1409.752			1198.981	
	Population (millions)						
California	36	105.501			99.647		
Weighted	23.883	Weighted			Weighted		
Rest of State	12.117	100.00			100.00		

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APPENDIX C

Replacement & Maintenance Costs		Residential Solar Hot Water w/ Electric Storage Backup	
Costs are for Active Indirect Glycol System, the most common system across sizes. Data points for Drainback were limited, though generally suggests it is a slightly higher cost systems. Thermospyhpon, ICS are less expensive by difficult to model. Active Direct Water systems are less expensive, but less prevalent.			
Overall Assumptions		Source	
Building Life (years)	30	CEC TDV	
Collector Size (Sq. Ft)	80		
Labor Rates (See Tab)	35	RS Means 11	
Labor O&P (See tab)	63%	RS Means 11	
Material O&P	12%	RS Means 11	
Labor	20%	Itron 2009	
Material	80%	Itron 2009	
Component Assumptions			
Component	Life Expectancy / Frequency	Number of Implementations During Building Life	Cost Per Replacement
Collector	20	1	\$ 2,419.03
Solar & Auxiliary Tank	10	2	\$ 1,936.24
Motor and Pump	10	2	\$ 572.13
Controller	20	1	\$ 338.12
Heat Transfer Fluid Check	1	20	\$ 17.44
Heat Transfer Fluid Check & Replacement	3	9	\$ 175.25

Replacement & Maintenance Costs		Commercial Solar Hot Water w/ Electric Storage Backup	
Costs are for Active Indirect Glycol System, the most common system across sizes. Data points for Drainback were limited, though generally suggests it is a slightly higher cost systems. Thermospyhpon, ICS are less expensive by difficult to model. Active Direct Water systems are less expensive, but less prevalent.			
Overall Assumptions		Source	
Building Life (years)	15	CEC TDV	
Collector Size (Sq. Ft)	200		
Labor Rates (See Tab)	53.4	RS Means 11	
Labor O&P (See tab)	49%	RS Means 11	
Material O&P	12%	RS Means 11	
Labor	20%	Itron 2009	
Material	80%	Itron 2009	
Component Assumptions			
Component	Life Expectancy / Frequency	Number of Implementations During Building Life	Cost Per Replacement
Collector	20	0	\$ 2,717
Auxiliary Tank	10	1	\$ 1,610
Solar Tank	15	0	\$ 4,135
Motor and Pump	10	1	\$ 612
Controller	20	0	\$ 395
Heat Transfer Fluid Check	1	10	\$ 27
Heat Transfer Fluid Check & Replacement	3	5	\$ 212

APPENDIX D

Below are the daily hot water demand load profiles for “full service” (Type A) and “quick service” (Type B) restaurants from which new occupancy loads were derived.

Profiles for Restaurants

	Food Services (Type A)	Food Service (Type B)
Hour	gph/unit	gph/unit
1	-	0.08
2	-	0.06
3	-	0.04
4	-	0.04
5	-	0.02
6	-	0.02
7	-	0.02
8	-	0.01
9	0.02	0.02
10	0.03	0.04
11	0.04	0.02
12	0.04	0.03
13	0.05	0.05
14	0.17	0.05
15	0.08	0.03
16	0.03	0.04
17	0.02	0.04
18	0.07	0.05
19	0.20	0.07
20	0.10	0.05
21	0.09	0.05
22	0.04	0.05
23	0.01	0.05
24	-	0.05

Day of Week	Food Services (Type A)	Food Service (Type B)
Sunday	1	1
Monday	1	1
Tuesday	1	1
Wednesday	1	1
Thursday	1	1
Friday	1	1
Saturday	1	1
Month of Year	Food Services (Type A)	Food Service (Type B)
January	1	1
February	1	1
March	1	1
April	1	1
May	1	1
June	1	1
July	1	1
August	1	1
September	1	1
October	1	1
November	1	1
December	1	1

Source: California Solar Thermal Initiative. 2011a, originally from ASHRAE HVAC Applications 2007 section 49.18, figure 24.

APPENDIX E

Hot Water Demand determined by T24 ACM Manual 2.6.1.1, 2-115

Standard Recovery Load in Btu/hr per 1,000 Sq. ft. (SRL) x Hourly load multiplier for the nth hour (Fwhp(n) = 38,847,789 Annual Btu / 365 days = 106,432 Btu/day / 80 degree temp. difference (RES ACM Inlet Water Temp Avg) * 8.33Btu/Deg = 159 GPD

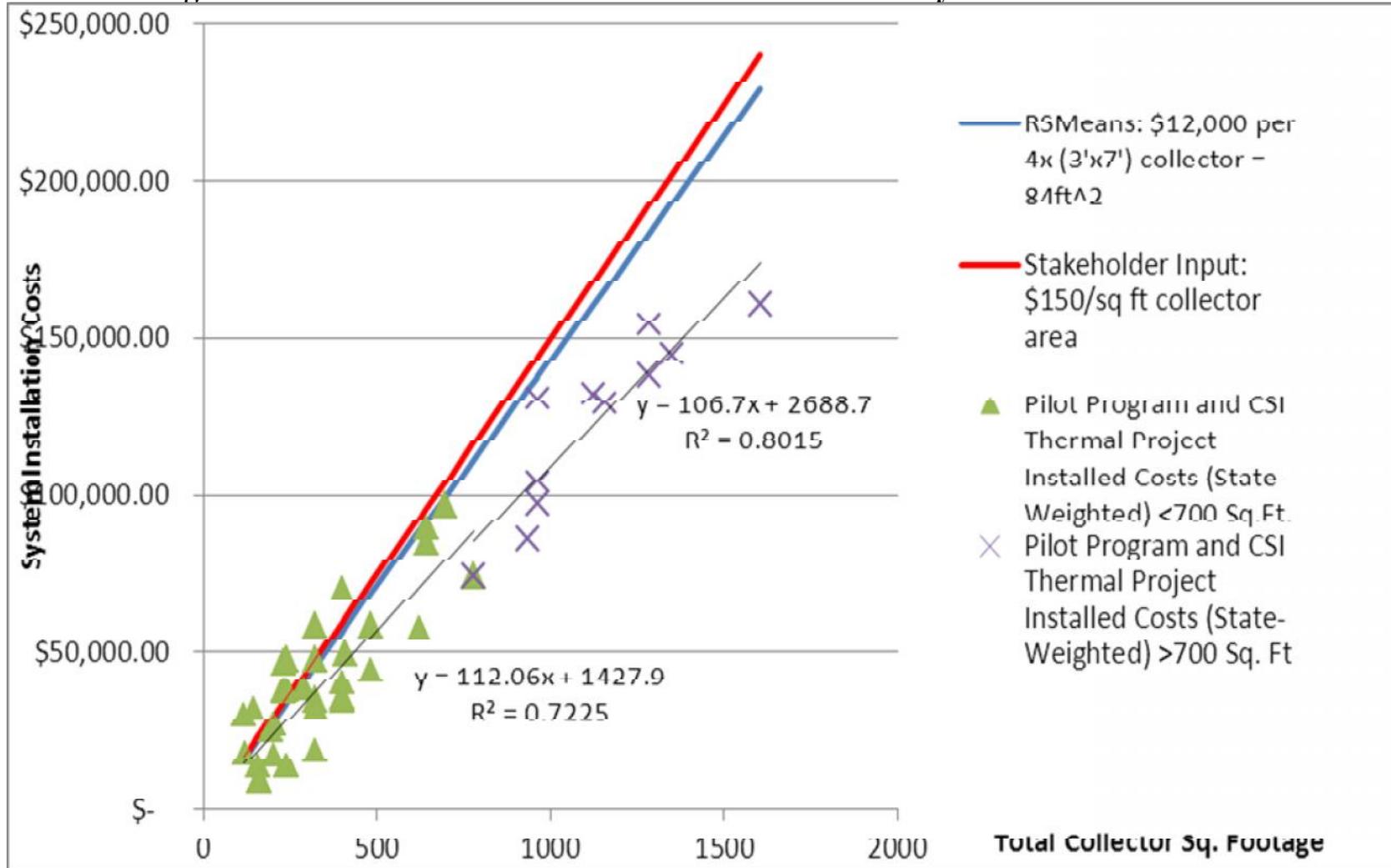
Where: Standard Recovery Load in Btu/hr per 1,000 Sq. ft. - Restaurants = 16,470
= 45 people per 1,000 Sq. Ft. x 366 Hot Water Btu/h per person

250 GPD (Cost Effective Threshold for Commercial Electric) / 159 GPD = 1.57 * 1,000 Sq. Ft. = 1,570 Sq. Ft. Round to 1,600 Sq. Ft.

2,000 GPD (Cost Effective Threshold for Commercial Natural Gas) / 159 GPD = 12.58 * 1,000 Sq. Ft. = 12,580 Sq. Ft. Round to 12,600 Sq. Ft.

APPENDIX F

Statewide Avg. Installation Costs vs. Collector Size: Active Indirect Glycol



APPENDIX G

Commercial Buildings Energy Consumption Survey
 National Building Data
 Released: June 2006
<http://www.eia.doe.gov/emeu/cbecs/>

Table B11. Selected Principal Building Activity: Part 1, Number of Buildings for Non-Mall Buildings, 2003

	Number of Buildings (thousand)							
	All Buildings*	Principal Building Activity						
		Education	Food Sales	Food Service	Health Care		Lodging	Retail (Other Than Mall)
				Inpatient	Outpatient			
All Buildings*	4,645	386	226	297	8	121	142	443
Building Floorspace (Square Feet)								
1,001 to 5,000	2,552	162	164	202	N	56	38	241
5,001 to 10,000	889	56	44	65	N	38	21	97
10,001 to 25,000	738	60	Q	23	Q	19	38	83
25,001 to 50,000	241	48	Q	Q	Q	Q	23	14
50,001 to 100,000	129	39	Q	Q	Q	3	11	Q
100,001 to 200,000	65	16	Q	N	Q	Q	7	4
200,001 to 500,000	25	5	N	Q	2	Q	4	Q
Over 500,000	7	Q	N	N	1	N	Q	Q
Year Constructed								
Before 1920	330	12	Q	32	Q	Q	Q	37
1920 to 1945	527	26	Q	34	Q	Q	11	66
1946 to 1959	562	78	Q	30	Q	Q	17	62
1960 to 1969	579	60	Q	Q	1	Q	25	59
1970 to 1979	731	58	Q	46	2	14	25	90
1980 to 1989	707	44	33	46	2	18	21	44
1990 to 1999	876	75	56	66	0	36	30	68
2000 to 2003	334	32	Q	Q	Q	Q	6	17

Table A6. Building Size, Floorspace for All Buildings (Including Malls), 2003

	Total Floorspace (million square feet)								
	All Buildings	Building Size							
		1,001 to 5,000 Square Feet	5,001 to 10,000 Square Feet	10,000 to 25,000 Square Feet	25,001 to 50,000 Square Feet	50,001 to 100,000 Square Feet	100,001 to 200,000 Square Feet	200,001 to 500,000 Square Feet	Over 500,000 Square Feet
All Buildings	71,658	6,922	7,033	12,659	9,382	10,291	10,217	7,494	7,660
Principal Building Activity									
Education	9,874	409	399	931	1,756	2,690	2,167	1,420	Q
Food Sales	1,255	409	356	Q	Q	Q	Q	N	N
Food Service	1,654	544	442	345	Q	Q	N	Q	N
Health Care	3,163	165	280	313	157	364	395	514	973
Inpatient	1,905	N	N	Q	Q	Q	Q	467	973
Outpatient	1,258	165	280	312	Q	206	Q	Q	N
Lodging	5,096	99	160	631	803	841	930	1,185	Q
Mercantile	11,192	771	1,173	2,409	1,291	1,505	1,677	462	1,905
Retail (Other Than Mall)	4,317	638	725	1,284	578	Q	524	Q	Q
Enclosed and Strip Malls	6,875	Q	448	1,124	713	1,234	1,153	Q	1,752
Office	12,208	1,382	938	1,887	1,506	1,209	1,428	1,493	2,365
Public Assembly	3,939	336	518	1,077	301	474	868	Q	Q
Public Order and Safety	1,090	122	Q	Q	Q	Q	Q	Q	Q
Religious Worship	3,754	416	744	1,235	930	Q	Q	Q	N
Service	4,050	1,034	722	1,021	560	Q	Q	Q	Q
Warehouse and Storage	10,078	895	868	2,064	1,043	1,494	1,162	1,322	Q
Other	1,738	Q	Q	Q	Q	Q	Q	Q	Q
Vacant	2,567	239	Q	Q	471	Q	Q	Q	Q

Released: June 2006
<http://www.eia.doe.gov/emeu/cbecs/>