STUDY OF SOLAR WATER HEATER ENERGY SAVINGS IN COMMERCIAL BUILDINGS

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A Study of Solar-Assisted Gas Water Heaters for use in Commercial California Buildings

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STUDY of solar water heater energy savings in COMMERCIAL BUILDINGS

A STUDY OF SOLAR-ASSISTED GAS WATER HEATERS FOR USE IN COMMERCIAL CALIFORNIA BUILDINGS

OVERVIEW

Domestic solar water heating systems have long been installed in a wide range of building types throughout the California's climate zones. The technology has been supported by both regulators and utilities as a means of increasing energy efficiency of water heating systems and reducing greenhouse gas emissions. The Southern California Gas Company requested performance modeling to support a potential incentive program for solar water heaters within existing incentive program structures for energy efficient technologies. This differs from the approaches used commonly in the past that either used a flat rebate or a complicated customized incentive structure using an online calculator to predict energy savings. This study seeks to provide the data needed to structure and justify a deemed program for solar water heating technologies installed in several types of commercial buildings. It builds on previous, similar studies conducted for single-family and multi-family buildings.

PROJECT DESCRIPTION

Southern California Gas Company (SoCalGas) initiated this project to develop estimated annual energy savings for a range of solar water heating systems for the purpose of designing and establishing a deemed energy efficient rebate program. Task 1 focused exclusively on the application of solar thermal water heaters to single-family homes. Task 2 expanded to study the use of solar water heaters in multi-family buildings. Task 3 extended the study further to several other commercial applications where solar thermal water heaters are well-suited. They are listed below with the associated Database for Energy Efficiency Resources (DEER) building type codes for each. Multi-family Housing is again included for the purposes of comparison and to provide some small updates to the results that will be explained further below.

- Dormitories (EUD)
- Laundromats (RtS)
- Hotels (Htl)
- Motels (Mtl)
- Office (OfL)
- Quick Service Restaurants (RFF)
- Meal Service Restaurants (RSD)

- Nursing Homes (Nrs)
- Primary Schools (EPr)
- Secondary Schools -Jr/Sr. High (ESe)
- Multi-Family Housing (MFM)

The performance of several solar water heater designs for each building in each California Climate Zone were modeled using the Transient System Simulation Tool (TRNSYS) software package. The results provide annual energy consumption for each building type and application, all added to an existing backup water heater fueled by natural gas. For each, a reference water heater fueled only by natural gas was also analyzed to estimate annual energy consumption. The annual energy savings were calculated for each case by taking the difference between the annual energy consumption for the solar water heating system and the corresponding reference water heater and accounting for the increased electrical parasitic power consumption of the solar water heating systems.

For all analyses, an updated version of TRNSYS code used in the CSI Thermal Commercial & Multifamily Residential Incentive Calculator was used. This online, public calculator was developed for the California Solar Initiative (CSI) Program by contractors Energy Solutions and Thermal Energy System Specialists (TESS). The thermal analysis engine at the heart of the calculator was created using the TRNSYS program.

This study was conducted by the Solar Rating & Certification Corporation (ICC-SRCC) and Thermal Energy System Specialists (TESS). ICC-SRCC is an accredited certification body specializing in compliance assessment of solar heating and cooling products. It certifies solar thermal collectors under the OG-100 program and domestic solar thermal water heating systems under the OG-300 program. TESS is an engineering consulting company specializing in the modeling and analysis of energy systems.

REPRESENTATIVE SYSTEMS

Data on the types and sizes of solar water heating systems installed in the various commercial building types through the CSI Program was analyzed to select appropriate representative systems for the analysis of solar water heaters to follow. In most cases the system specified was based on a combination of the median and average size, as established by the number of collectors, storage tank volume and auxiliary gas water heater size (tank-type). A demand benchmark parameter and value were selected for each, which was then used to establish the Hot Water Draw value using the methodology established within the CSI Thermal Program. The total daily Hot Water Draw value is used in the system modeling to scale the associated hot water draw profile. The values for each representative system are given in Table 1.

The solar thermal collectors and heat exchanger configurations used for the CSI Thermal commercial installations were also reviewed. Both were found to be very similar to those used in the previous Multi-Family Study published by ICC-SRCC dated January 5, 2022.

Table 1: Representative Systems for Each Building Category

BUILDING TYPE	DRAW PROFILE	DEMAND BENCHMARK	HOT WATER DRAW (GPD)	QTY COLLECTORS	SOLAR STORAGE VOLUME (GAL)	AUXILIARY GAS WATER HEATER VOLUME (GAL)
DORMITORY	EUD	96 persons	1248	15	900	240
LAUNDROMAT	RtS	1250 pounds	2500	20	1200	360
HOTEL	Htl	80 units	1200	15	900	500
MOTEL	Mtl	80 units	1200	15	900	500
OFFICE	OfL	250 persons	250	8	120	250
QUICK SERVICE RESTAURANT	RFF	700 meals	490	10	600	120
MEAL SERVICE RESTAURANT	RSD	1500 meals	3600	30	1800	240
NURSING HOME	Nrs	30 beds	540	5	300	240
JR/SENIOR HIGH SCHOOL	ESe	1000 students	1800	4	240	240
PRIMARY SCHOOL	EPr	500 students	900	4	240	240
MULTIFAMILY	MFM	40 units	1600	15	1200	500

REVIEW OF COMMERCIAL BUILDING HOT WATER LOAD CURVES

The project began with a review of two primary sources of system-level hot water draw patterns ("load curves"), the DEER Hot Water Energy Use Calculator v.5.0 and the CSI Thermal Program (as documented in the CSI Thermal Incentive Calculator User Guide). The objective was to select the most appropriate draw pattern to be used in subsequent analyses for each building type.

DEER2021 Water Heater Energy Use Calculator

The DEER 2023 Water Heater Energy Use Calculator v5.0 ("Calculator") was developed to provide a common methodology to estimate the energy savings associated with a range of water heating technologies compared to common legacy water heaters for various building types in the California climate zones. For each building type, it conducts hourly calculations of energy consumption by a selected water heater based on specific input parameters, and a hot water draw profile scaled by total daily hot water consumption. The total daily hot water consumption is then specified for each building type and application. Together they can be used to establish the specific hot water draw pattern associated with each building type and application included.

CSI Thermal Program

The CSI Thermal incentive program also utilized a normalized draw profile, scalable using a Demand Benchmark appropriate for each building type. The original basis for the profile shape and multipliers were found in the ASHRAE Handbook.

COMPARISON

In most cases, the building type and application designations were very similar between the DEER and CSI sources. However, there were notable exceptions. For example, the CSI Thermal program differentiated between men's, women's, and average dormitories whereas the DEER calculator only specifies one dormitory type. For schools, CSI provides separate elementary, junior high and senior high types, each in 10-month and 12-month operation sub-types. DEER only includes Primary and Secondary School types. Finally, CSI makes no distinction between hotels and motels, whereas DEER has separate draws for both.

In the comparison, a test case consisting of an indirect solar water heating system with an external supply side heat exchanger and drainback freeze protection was modeled for each climate zone and hot water load profile. Solar tank volume and auxiliary tank volume were as listed in Table 1 for each. A single collector flat plate glazed collector type with 4.9 square feet of gross area (OG-100 2007032A) was used in an array of the size specified in Table 1. The hot water draw profiles were scaled according to the daily hot water draw in Table 1.

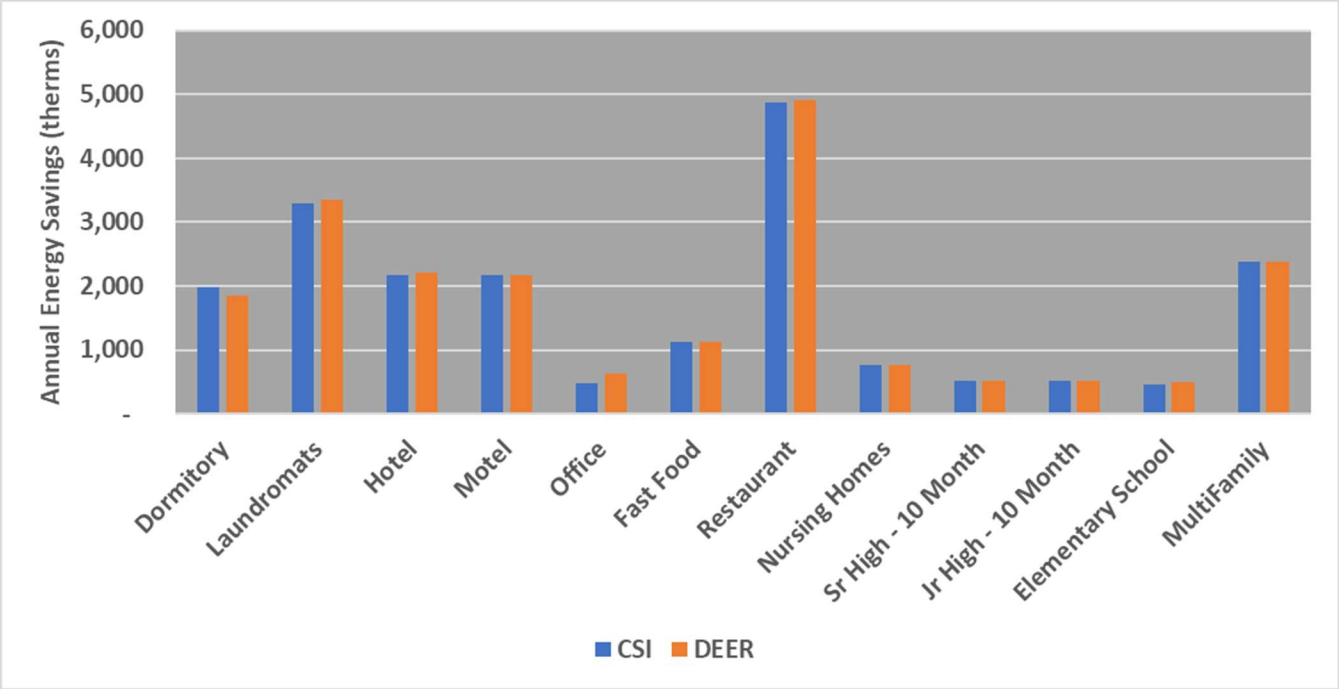

Figure 1: Comparison of Annual Energy Savings Using CSI and DEER Load Profiles in CACZ9

As shown in Figure 1 for Climate Zone 9, the results of the annual system output were extremely similar for all building types modeled using the test system. All were +/- 2%, except for Dormitories at 7%, Elementary Schools at 9% and Offices at 32%. Results in other California climate zones showed similar patterns.

Because the annual energy savings results were found to be similar for the DEER and CSI hot water load patterns, the DEER load curves were selected for use in the analysis to be consistent with other measures in California.

BASELINE WATER HEATER

For each representative system, a baseline water heater was assumed for the purpose of calculating the Annual Energy Savings for each solar water heater. For each, the baseline water heater is assumed to be a

tank-type gas water heater, of the size specified in Table 1 for the auxiliary gas water heater. Each is assumed to have an overall efficiency of 82%. The thermostat setpoint of the baseline water heater, with and without a solar water heater, is assumed to be 135°F. The TRNSYS model of the baseline water heater assumed the tank to be stratified vertically with 10 temperature nodes.

MODEL UPDATES

The TRNSYS models used by the CSI Thermal Commercial Calculator were updated for the purposes of this study as described in the subsections below.

TRNSYS Engine

Since the initial creation of the CSI Thermal Calculator, new editions of the TRNSYS modeling software have been released. The original calculator was ported from version 17 to version 18 of the TRNSYS engine. The impact of the update to the latest TRNSYS engine was studied in more detail in the ICC-SRCC Multi-Family Study dated January 5, 2022. That analysis found that the difference between the results provided by each was minimal and attributable to updates in the modeling of pump energy imparted to the fluid.

Hot Water Load

A daily hot water draw schedule was created for each hour of the day over a full year for each building type to be modeled. For each, the shape of the draw profile was established by normalizing the DEER hot water draw profile for each building as listed below. To get the hourly fraction for each building, the average daily hot water draw volume was first calculated by summing the 8,760 hourly draw volumes and dividing by 365 days per year. The normalized hourly values (the Hourly DHW fraction) were then calculated for each building by dividing the hourly draw volumes by the average daily hot water draw volume. In this way, the day-to-day and hour-to-hour water draw variations inherent to the DEER profiles can be maintained but the building draw profiles may be scaled up or down to match the desired building average daily water draw profile.

- Dormitories: EUD Profile
- High Schools: ESe Profile
- Hotel: Htl Profile
- Motel: Mtl Profile
- Nursing Home: Nrs Profile
- Office: OfL Profile
- Quick Service Restaurant: RFF Profile
- Meal Service Restaurant: RSD Profile
- Coin-Op Laundry: RtS Profile
- Primary Schools: EPr Profile

This normalized hot water draw profile was then multiplied by the average daily hot water draw for each building type, given in Table 1. These average daily draws were established for each representative system using the scaling factors established in the CSI Thermal program based on the demand benchmark value for each. So while the shape of the draw profile was derived from the DEER Hot Water Calculator, the

amplitude was adjusted to the size of the representative system using the CSI Thermal scaling factors. As with the previous single-family and multi-family studies conducted by ICC-SRCC, the flow was assumed to be constant for each hour, such that the prescribed hourly draw volume is attained.

Note that for some building types, the draw profile varies throughout the week and throughout the year. For example, the DEER draw profile for Dormitories showed reduced consumption on weekends and during the summer months as depicted in Figure 2.

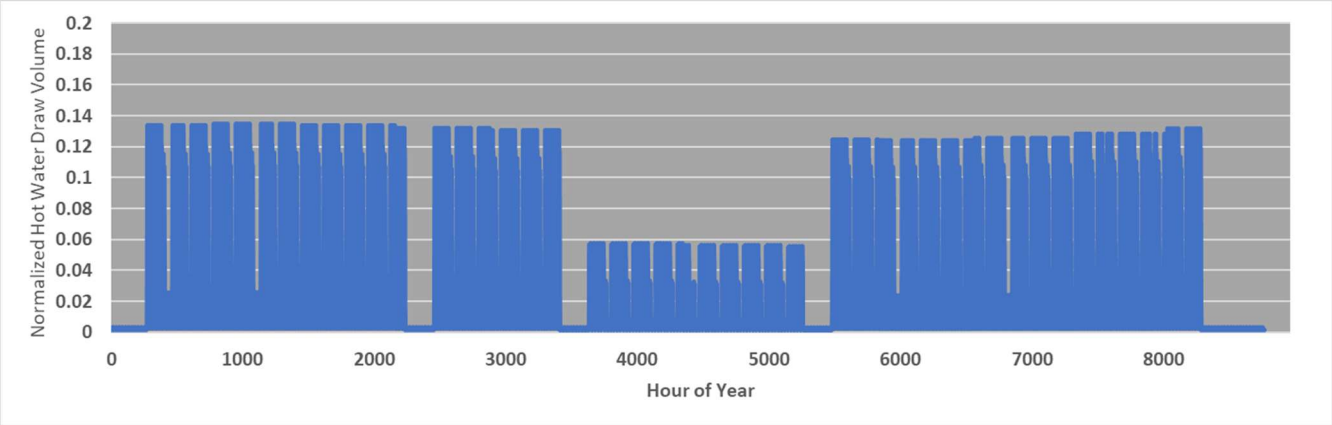

Figure 2: Normalized Hourly Hot Water Draw Profile for Dormitories (EUD)

Constants and Other Assumptions

Several constants and assumptions used in the TRNSYS model were updated to correspond to those used in the DEER Calculator and the previous studies for single-family and multi-family residential construction. The key assumptions used in modeling for the sensitivity analyses and subsequent larger sample modeling are shown in Table 2. The TRNSYS Model can analyze several other cases that were not utilized in this study. They include collector tracking, solar tanks with auxiliary heating devices, concentrating collectors, tankless backup water heaters, parallel and series collector connections, multiple solar tanks and single-tank systems.

Table 2: TRNSYS Model Constants, Assumptions and Parameters

PARAMETER	DESCRIPTION	VALUE
SETPOINT TEMPERATURE	Backup water heater setpoint temperature	135°F
TANK STRATIFICATION LEVEL	Stratified	10 nodes
RECIRCULATION PUMP FLOW	Flow rate of hot water recirculation pump	GPD/1000 +0.5 in GPM
RECIRCULATION DUTY CYCLE	Hot water recirculation system run-time.	100%
RECIRCULATION PUMP POWER	Power consumed by the recirculation pump is a function of the total daily hot water consumption.	1/25 + GPD/50,000 (hp)
INDOOR AMBIENT TEMPERATURE	Indoor air temp in vicinity of tank (°F)	T_{amb}+1/3*(72°F-T_{amb})
COLLECTOR SHADING FACTOR	Measure of the degree of shading on the collector	1.0
COLLECTOR INSTALLATION SLOPE	Angle of the plane of the collector with respect to horizontal.	30 degrees, Fixed
COLLECTOR AZIMUTH	Fixed installation direction of the collector.	Due South (180°), Fixed
GLYCOL CONCENTRATION	Concentration of polypropylene glycol used in the solar loop of Configurations 14 & 16	40%
AVERAGE FLUID TEMPERATURE FOR FLUID PROPERTIES	Fluid properties are assumed to be fixed and are based on the average temperature given.	40°C (104°F)

SOLAR COLLECTOR THERMAL CAPACITANCE	Thermal capacitance of the solar collectors is assumed to be a fixed value.	10 kJ/m^2°K
COLLECTOR LOOP FLOWRATE	Collector flowrate GPM=1 gpm/collector x Number of Collectors (assuming all collectors are series connected)	1 gpm/collector
NODES PER COLLECTOR	Number of isothermal nodes per collector along the flow path.	50
NODES PER PIPE	Number of isothermal nodes per length of piping along the flow path.	10

Mains Water Temperatures

The mains water temperatures throughout the year and for each climate zone were updated to match those used in the DEER Calculator, as shown in Table 3.

Table 3: Monthly Water Mains Temperature for CA Climate Zones (F)

CACZ	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	49.5	48.7	48.6	49.0	50.5	52.0	53.2	54.0	54.1	53.4	52.2	50.8
2	53.7	52.3	52.1	52.8	55.6	58.4	60.8	62.3	62.5	61.2	58.9	56.2
3	54.5	53.4	53.3	53.8	55.8	57.8	59.6	60.7	60.8	59.9	58.2	56.2
4	55.7	54.1	54.0	54.8	57.7	60.7	63.3	64.9	65.0	63.7	61.2	58.3
5	53.6	52.7	52.7	53.1	54.8	56.5	58.0	58.9	59.0	58.2	56.8	55.1
6	58.9	57.8	57.7	58.2	60.4	62.6	64.5	65.7	65.8	64.9	63.0	60.9
7	60.2	59.3	59.2	59.7	61.5	63.2	64.8	65.8	65.9	65.1	63.5	61.8
8	60.7	59.5	59.4	59.9	62.3	64.7	66.7	68.0	68.1	67.0	65.1	62.8
9	60.2	58.7	58.6	59.3	62.1	64.9	67.4	68.9	69.1	67.8	65.4	62.7
10	59.9	58.2	58.0	58.9	62.2	65.5	68.3	70.1	70.3	68.8	66.0	62.8
11	55.8	52.8	52.6	54.0	59.8	65.5	70.5	73.6	73.9	71.3	66.5	60.9
12	55.6	53.5	53.3	54.3	58.4	62.5	66.1	68.3	68.5	66.7	63.2	59.3
13	57.0	54.0	53.8	55.2	60.8	66.3	71.1	74.2	74.5	72.0	67.3	61.9
14	55.2	52.2	51.9	53.4	59.2	65.0	70.0	73.2	73.5	70.9	66.0	60.4
15	68.4	65.5	65.3	66.6	72.2	77.7	82.4	85.5	85.7	83.3	78.6	73.3
16	45.3	42.7	42.4	43.7	48.7	53.8	58.1	60.9	61.1	58.9	54.6	49.8

Weather Data

TRNSYS models make use of weather files for each California Climate Zone providing typical parameters such as ambient temperature, relative humidity, wind speed and solar irradiance on one-minute increments for an entire year. The most recent weather files specified by the California Public Utilities Commission (CPUC) are the CZ2022 Typical Weather files produced by the California Measurement Advisory Council (CALMAC) that represent a 20-year period of record in each climate zone. The CZ2022 files were evaluated for use in the TRNSYS models. Initial results for Multi-Family Homes in each climate zone showed a significant decrease in overall energy savings compared with the results obtained using the previous CZ2018 data files in some of the climate zones. A closer examination of the solar irradiance data provided in the CZ2022 files revealed that both the tilted and horizontal surface values were lower for some climate zones, with the peak values

plateauing at a level significantly below the earlier dataset. The solar irradiance waveforms are shown in Figure 3 along with those from the CZ2018 files. The shape shown does not appear to correspond to real-world conditions, as exemplified by the CZ2018 irradiance curves (labeled RV2 in Figure 2). Lacking any available explanation for the "clipped" solar irradiance profiles, the CZ2018 data files were selected for use in the subsequent TRNSYS modeling over the CZ2022 files.

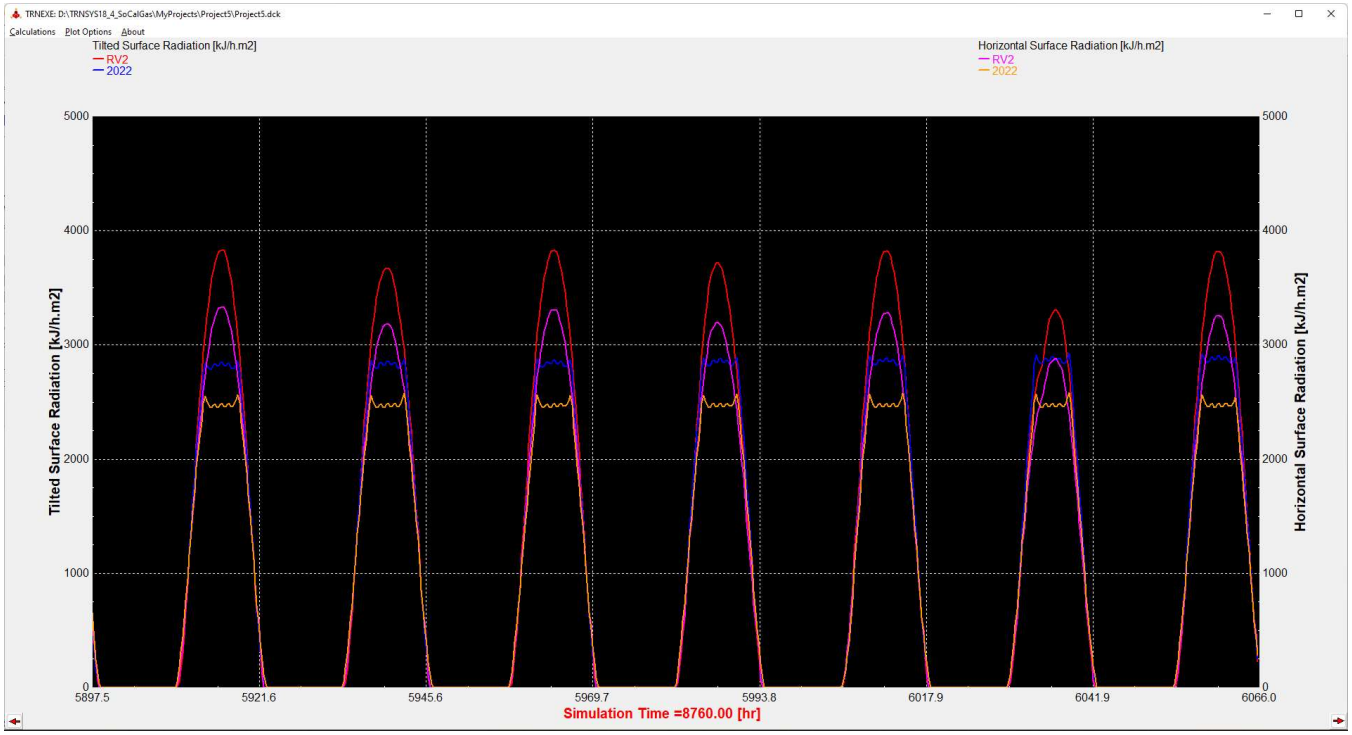

Figure 3: CZ2022 Solar Irradiance Waveform for CACZ13

MODELING OF SOLAR WATER HEATERS IN COMMERCIAL BUILDINGS

The primary objective of this project is the estimation of the annual energy consumption for a larger sample of representative solar water heating systems using gas backup water heaters, consistent with the methodology used in the CSI Thermal Calculator. The updated version of the model using the v18 TRNSYS engine was used for all modeling that follows.

A total of 40 discrete systems were modeled for each building type in each of the (16) California Climate Zones over a period of one year. Four different solar water heating system configurations, shown in Table 4, were modeled with each of the 10 most popular solar thermal collectors still in production (which were also utilized in the previous Multi-Family study published by ICC-SRCC on January 5, 2022). The solar water heater system configurations varied the heat exchanger type (external/immersed) and location (supply side/load side) with two different freeze protection measures (glycol/drainback). The schematics for each are shown in detail in Appendix B. The 40 discrete systems modeled were obtained by apply the 10 different types of collectors to each of the solar water heater configurations.

Table 4: Solar Water Heating System Configurations for TRNSYS Modeling

SWH CONFIG	HEAT EXCHANGER	FREEZE PROTECTION
14	External Supply Side Heat Exchanger	Glycol
16	Immersed Supply Side Heat Exchanger	Glycol
18	External Supply Side Heat Exchanger	Drainback
102	Immersed Load Side Heat Exchanger	Drainback

Each SWH configuration used the same components, as specified in Table 5, except for the specific solar thermal collectors, which are listed in Table 6 and the tank sizes in Table 1. For the calculation of energy savings, the gas and electric consumption of each solar water heating system is compared to the gas consumption of the existing commercial storage water heater installed without solar collectors. In all cases it is assumed that a continuously operating recirculation pump is installed on the building's plumbing system (100% duty cycle) with a flowrate as specified in Table 5. Where glycol is used as the fluid in the solar loop, it is assumed to have a concentration of polypropylene glycol of 40%. For drainback systems, water is used as the working fluid in the solar loop. Fluid properties are assumed to be constant in the models and are based on a 40°C (104°F) average fluid temperature.

Table 5: System Components

COMPONENT	SPECIFICATION
SOLAR TANK (NO HX)	Volume per Table 1 (actual volume 90% of nominal), vertical with a L/D ratio of 2.608, R12.5 insulation (50% losses).
SOLAR TANK (W./IMMERSED IN-TANK HX)	Volume per Table 1 (actual volume 90% of nominal), Hx surface area = 0.1 ft^2/gal, 11.02 m coil length, R12.5 insulation (50% losses)
DRAINBACK TANK	Vol= 10 + 2 x Number of Collectors (gallons), heat loss coefficient 3 kJ/hm^2K, rectangular shape with the height 2/3 the side length
EXTERNAL HEAT EXCHANGER	0.4 effectiveness for double-wall type, 0.5 for single-wall type
SOLAR AND HX PUMPS	30 W/gpm, 90% motor efficiency, 60% overall efficiency
GAS STORAGE WATER HEATER	Commercial gas storage water heater with 82% overall efficiency and volume per Table 1.
CONTROLLER	Differential temperature controller with a 20°F turn-on and 5°F turn-off dead band. Temperature sensors are located 1/3 of the height from the bottom of the solar storage tank and on the outlet line of the solar collector array.
SOLAR THERMAL COLLECTORS	See Table 6.
PIPING	Type L copper sized to maintain 4 ft/s or less velocity at peak flow. Total length = 50' + 5' x Number of Collectors (divided equally between supply and return lines).
PIPE INSULATION	¾" thick insulation with k=0.04 W/m°K

Arrays of identical solar thermal collectors connected in series were modeled for each configuration and collector combination. The collectors were mounted at the ideal slope and azimuth for each location (slope of ~30-35 degrees from horizontal) and oriented due South (180 degrees) on fixed (non-tracking) mounts). Each array used in each solar water heater configuration is made up of identical collectors drawn from the list in Table 6. The collectors used in the TRNSYS models include (8) glazed flat plate models and (2) evacuated glazed tube models. Each collector was certified under the ICC-SRCC OG-100 program, providing the measured collector performance data required for system modeling.

Table 6: Solar Thermal Collectors for Commercial System Modeling

	SINGLE COLLECTOR

INDEX	OG-100 NO.	MFG	MODEL	TYPE*	GROSS AREA (M^2)	EFFECTIVE AREA (M^2)
1	10001803	SunEarth	TRB-40	GFP	3.804	2.35
2	2010115a	Heliodyne	410 001	GFP	3.740	2.33
3	2007032a	SunEarth	EP-40	GFP	3.800	2.18
4	10001912	Heliodyne	410 001+	GFP	3.913	2.5
5	10002008	SolAqua	4X10H	GFP	3.720	2.28
6	2010115d	Heliodyne	408 001	GFP	2.993	1.86
7	2007032d	SunEarth	EP-32	GFP	3.051	1.75
8	10001804	SunEarth	TRB-32	GFP	3.050	1.88
9	2009042b	Jiangsu Sunrain	TZ58/1800-30R	ET	5.241	2.28
10	10001893	Jiangsu Micoe	SZ58/1800-30HA	ET	4.858	2.21

* Glazed Flat Plate (GFP), Evacuated Tube (ET)

Effective area (TESS, 2019) was calculated from the gross area, thermal efficiency at a standard operating condition, and an estimate of the incidence angle modifier impact for each collector. The effective area metric normalizes the collector area to account for variations in different solar thermal collector technologies (glazed flat plate and evacuated tube) and for variations in thermal performance of similar collectors. The result, provided in square meters, permits the thermal efficiency performance of different collectors to be compared on an area basis. It does not, however, account for other system parameters, such as total storage volume, heat exchanger effectiveness or control system logic which are addressed in the full system modeling. More information on the effective area metric can be found in Appendix C.

Note that the effective area values in this report include an update to the parameter made since the previous Multi-Family Housing Report was published by ICC-SRCC on January 5, 2022. The update was made to improve the accuracy of the results for tubular collector types. Therefore, results for MFM building types are also included in this report to provide the latest data and for the purpose of comparison with the other commercial building types. The change to the effective areas was minimal, as shown in Table 7.

Table 7: Comparison of Effective Area from Multi-Family to Commercial Building Report

OG-100 NO.	MULTI-FAMILY REPORT VALUES (m^2)	CORRECTED COMMERCIAL BUILDING VALUES (m^2)	CHANGE
10001803	2.39	2.35	-1.7%
2010115A	2.36	2.33	-1.3%
2007032A	2.19	2.18	-0.5%
10001912	2.53	2.5	-1.2%
10002008	2.32	2.28	-1.7%
2010115D	1.89	1.86	-1.6%
2007032D	1.76	1.75	-0.6%
10001804	1.91	1.88	-1.6%
2009042B	2.45	2.28	-6.9%

10001893	2.39	2.21	-7.5%

TRNSYS Solar Water Heater Energy Use Calculation Methodology

Models were created using the TRNSYS simulation software for each of the representative sample water heating systems to estimate the annual energy consumption of each. The models utilized updated versions of the CSI Thermal Commercial Calculator, modified to use v18 of TRNSYS as described in the preceding sections. The selected draw profiles and total daily hot water load specified in Table 1 were used to establish the hourly hot water draws for each building type. As with the preceding Single-Family and Mutli-Family Studies published by ICC-SRCC (June 28, 2021, and January 5, 2022, respectively) the backup water heater setpoint was 135°F. CALMAC CZ2018 weather files were used to provide the beam, diffuse and longwave (infrared) radiation, ambient temperature, and wind speed at the collector throughout the year for each location (see Weather Data section above for more information on weather file selection). Given the height of installation, a solar shade factor of 1.0 (no shading) was assumed for each system.

The TRNSYS models solve the energy balance equations for the system on one-minute timesteps, utilizing the instantaneous weather and hot water demand conditions described. The cumulative energy consumed (gas and electricity as applicable) is reported for the entire year for each of the 40 solar water heaters (10 collectors x 4 configurations) and the reference storage water heater for each building.

The total annual energy content in the hot water load is shown for each building type and climate zone in Table 8. The hot water load varies by climate zone since the incoming water temperature varies by location. Therefore, the energy required to achieve the same hot water temperature varies.

The models provide detailed datasets yielding the annual gas consumption for each building/system type/location combination. Additional information on the performance metrics reported for solar water heaters can be found in Appendix C.

Table 8: Annual Hot Water Load (therms) for Each Commercial Building Type

CACZ	EUD	RTS	HTL	MTL	OFL	RFF	RSD	NRS	ESE	EPR	MFM
CZ1	3,158	6,313	3,031	3,031	631	1,237	9,091	1,364	4,561	2,281	5,243
CZ2	2,941	5,867	2,816	2,816	587	1,150	8,449	1,267	4,254	2,127	4,884
CZ3	2,947	5,885	2,825	2,825	589	1,154	8,475	1,271	4,259	2,129	4,898
CZ4	2,858	5,700	2,736	2,736	570	1,117	8,207	1,231	4,136	2,068	4,749
CZ5	2,991	5,977	2,869	2,869	598	1,172	8,607	1,291	4,322	2,161	4,969
CZ6	2,770	5,530	2,655	2,655	553	1,084	7,964	1,195	4,005	2,003	4,610
CZ7	2,739	5,470	2,626	2,626	547	1,072	7,877	1,182	3,958	1,979	4,560
CZ8	2,696	5,381	2,583	2,583	538	1,055	7,748	1,162	3,899	1,950	4,489
CZ9	2,695	5,374	2,580	2,580	537	1,053	7,739	1,161	3,900	1,950	4,482
CZ10	2,685	5,350	2,568	2,568	535	1,049	7,703	1,156	3,887	1,943	4,463
CZ11	2,732	5,422	2,602	2,602	542	1,063	7,807	1,171	3,965	1,982	4,526
CZ12	2,812	5,596	2,686	2,686	560	1,097	8,058	1,209	4,073	2,037	4,666
CZ13	2,697	5,353	2,570	2,570	535	1,049	7,709	1,156	3,913	1,957	4,465
CZ14	2,752	5,461	2,621	2,621	546	1,070	7,864	1,180	3,994	1,997	4,556

CZ15	2,268	4,495	2,158	2,158	450	881	6,473	971	3,295	1,648	3,769
CZ16	3,160	6,285	3,017	3,017	629	1,232	9,051	1,358	4,579	2,290	5,230

RESULTS FOR SOLAR WATER HEATERS IN COMMERCIAL BUILDINGS

The following sections detail the results of the modeling conducted using the TRNSYS models described above for the representative solar water heating systems installed on each commercial building type in each of California's Climate Zones (CACZ). In each case, the solar water heaters are installed as an addition to the existing gas water heater. Energy savings are assessed by comparing the annual energy consumption before and after the addition of the solar water heating system in each climate zone. Hot water loads are prescribed for each building type and scaled for each representative system as described above.

Table 9 provides a summary of the annual energy savings associated with each building type in each CA Climate Zone. Each entry provides an average of the energy savings across the 40 solar water heating systems modeled.

Table 9: Average Annual Energy Savings for Each Building Type (therms)

CACZ	EUD	RTS	HTL	MTL	OFL	RFF	RSD	NRS	ESE	EPR	MFM*
CZ1	1,385	2,432	1,629	1,611	540	902	3,599	567	371	350	1,754
CZ2	1,740	3,153	2,098	2,056	632	1,086	4,642	729	485	458	2,264
CZ3	1,723	3,135	2,088	2,051	634	1,104	4,617	725	469	442	2,252
CZ4	1,778	3,263	2,166	2,119	639	1,113	4,805	753	488	460	2,342
CZ5	1,886	3,382	2,254	2,212	692	1,200	4,968	780	516	489	2,425
CZ6	1,813	3,313	2,202	2,154	651	1,153	4,862	763	505	478	2,376
CZ7	1,828	3,265	2,169	2,122	647	1,136	4,788	752	502	475	2,339
CZ8	1,842	3,388	2,244	2,189	648	1,155	4,970	780	517	488	2,427
CZ9	1,842	3,355	2,220	2,155	636	1,123	4,919	772	511	483	2,405
CZ10	1,894	3,484	2,296	2,225	653	1,153	5,105	801	534	505	2,493
CZ11	1,721	3,250	2,069	1,992	580	1,010	4,772	742	482	454	2,319
CZ12	1,796	3,371	2,180	2,098	621	1,067	4,957	775	502	474	2,414
CZ13	1,830	3,490	2,201	2,108	602	1,053	5,116	795	523	492	2,484
CZ14	1,986	3,770	2,420	2,329	669	1,184	5,524	861	569	537	2,689
CZ15	1,908	3,702	2,280	2,165	579	1,028	5,384	837	565	537	2,622
CZ16	1,694	3,110	2,060	2,015	620	1,070	4,587	719	458	431	2,231

*Multi-family housing results using corrected effective area values, compared with previous Mutli-Family Housing Study. See Effective Area Section for more information.

Table 10 provides a similar summary, normalized with respect to the effective area of the solar array associated with each solar water heating system modeled. The results are given in units of therms per square meter (therms/m^2).

Table 10: Normalized Average Annual Energy Savings with Array Effective Area for Each Building Type (therms/m²)

CACZ	EUD	RTS	HTL	MTL	OFL	RFF	RSD	NRS	ESE	EPR	MFM*
CZ1	3.98	5.23	4.68	4.63	2.91	3.89	5.16	4.88	3.99	3.76	5.03
CZ2	5.00	6.79	6.02	5.91	3.42	4.70	6.66	6.28	5.22	4.93	6.50
CZ3	4.95	6.75	6.00	5.89	3.43	4.77	6.62	6.24	5.05	4.76	6.46
CZ4	5.11	7.02	6.22	6.09	3.46	4.81	6.89	6.49	5.25	4.95	6.72
CZ5	5.42	7.28	6.47	6.35	3.75	5.19	7.13	6.72	5.55	5.26	6.96
CZ6	5.21	7.13	6.32	6.19	3.52	4.99	6.98	6.57	5.43	5.14	6.82
CZ7	5.25	7.03	6.23	6.09	3.50	4.91	6.87	6.47	5.40	5.12	6.71
CZ8	5.30	7.29	6.45	6.29	3.51	5.00	7.13	6.71	5.56	5.25	6.96
CZ9	5.30	7.22	6.38	6.20	3.45	4.87	7.06	6.65	5.50	5.20	6.90
CZ10	5.45	7.50	6.60	6.40	3.54	5.00	7.32	6.90	5.75	5.43	7.15
CZ11	4.95	6.99	5.95	5.74	3.14	4.37	6.85	6.40	5.18	4.88	6.66
CZ12	5.17	7.25	6.27	6.04	3.36	4.63	7.11	6.67	5.40	5.10	6.93
CZ13	5.27	7.51	6.34	6.08	3.26	4.56	7.34	6.85	5.62	5.29	7.13
CZ14	5.71	8.11	6.96	6.71	3.63	5.13	7.93	7.42	6.12	5.78	7.72
CZ15	5.49	7.97	6.58	6.25	3.15	4.46	7.73	7.21	6.08	5.78	7.53
CZ16	4.87	6.69	5.92	5.79	3.36	4.63	6.58	6.19	4.93	4.64	6.40

*Multi-family housing results using corrected effective area values, compared with previous Mutli-Family Housing Study. See Effective Area Section for more information.

It should be noted that while every effort was made to approximate common conditions in the buildings modeled, actual energy savings will inevitably differ for each real-world installation. Differences between the timing or volumes of the actual hot water draws compared to the modeled hot water draws will impact actual savings. Other influences will include collector installation direction, angle, shading, piping length, size and insulation, control mode and pump speed. And of course, actual weather conditions will vary daily and annually compared with the typical weather conditions used for modeling.

While the absolute savings will vary, models of this type can be used to compare the relative performance and savings associated with different technologies and system types for a given building type. By comparing these technologies on a consistent basis – with the same installation, usage and environmental conditions, the relative attributes can be studied.

Additional Electrical Energy Consumption Results

Most types of solar water heaters make use of electrical controls and pumps. This additional energy consumption is generally small, but is irregular, since pumps turn on and off throughout the day depending on the demand, control strategy and weather conditions. This energy consumption is unique to solar water heaters and therefore must be accounted for in the calculation of net energy savings. Because it is a net savings, it does not include electrical energy consumption associated with the auxiliary water heater in a stand-alone configuration, used for reference. Therefore, the energy consumed by recirculation pumps, used in both solar and reference water heating systems, is not included. Average annual results are provided in Table 11 in units of kWh for each building type.

Table 11: Average Annual Parasitic Electrical Energy Use by Building Type (kWh)

CACZ	EUD	RTS	HTL	MTL	OFL	RFF	RSD	NRS	ESE	EPR	MFM*
CZ1	1174	1832	1358	1379	503	766	2849	480	335	317	1416
CZ2	1231	2009	1467	1462	508	804	3086	514	343	327	1522
CZ3	1268	2065	1515	1517	532	846	3185	531	355	337	1571
CZ4	1297	2138	1563	1556	536	852	3293	548	365	347	1625
CZ5	1311	2130	1557	1557	551	880	3281	544	363	346	1611
CZ6	1328	2189	1604	1601	546	889	3382	563	376	357	1666
CZ7	1326	2165	1584	1582	540	876	3346	557	374	355	1647
CZ8	1329	2214	1613	1603	538	883	3413	567	377	358	1679
CZ9	1261	2096	1521	1505	495	813	3224	536	355	337	1587
CZ10	1292	2172	1568	1545	510	836	3335	553	362	344	1638
CZ11	1189	2034	1414	1380	459	735	3118	513	338	322	1530
CZ12	1241	2105	1488	1451	487	776	3231	534	352	335	1587
CZ13	1244	2159	1483	1438	469	756	3305	541	358	340	1619
CZ14	1334	2310	1620	1579	519	850	3539	581	381	363	1735
CZ15	1254	2263	1501	1441	429	712	3441	563	368	349	1686
CZ16	1234	2030	1478	1469	512	814	3125	520	343	326	1539

*Multi-family housing results using corrected effective area values, compared with previous Mutli-Family Housing Study. See Effective Area Section for more information.

Peak electrical energy use is of concern in each climate zone at times of the day and year. Therefore, the average net parasitic electrical energy consumption was modeled on an hourly basis for each system and each climate zone throughout the year. An example is provided in Figure 4 for the month of September in each climate zone for system configuration 18 with collector 10001803. It is also shown for all building types in September in CACZ9 for system configuration 18 with collector 10001803 in Figure 5.

As shown, relatively little variation is observed between the parasitic draws between climate zones for a given building type. The energy consumption was parallel to the availability of solar irradiation and fell to zero overnight. Comparing the consumption by building type for a single climate zone shows that shape of the parasitic load was comparable, while the amplitude scaled with the normalized annual energy savings.

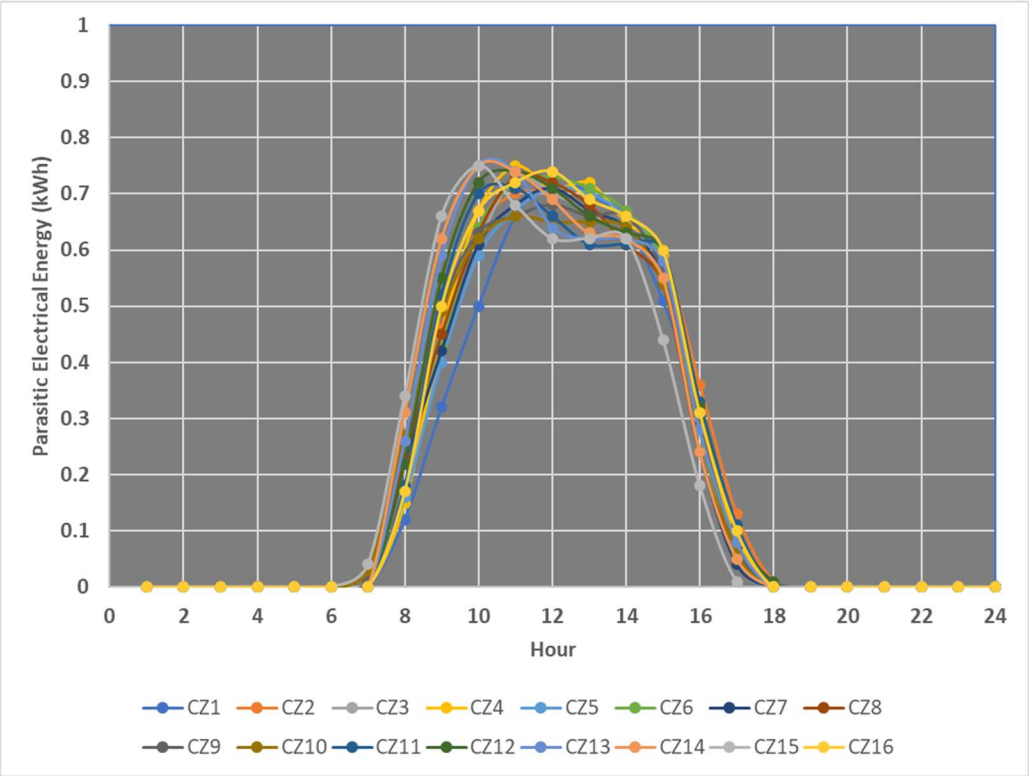

Figure 4: Dormitory Hourly Parasitic Electrical Energy in September for Config. 18 & Collector 10001803

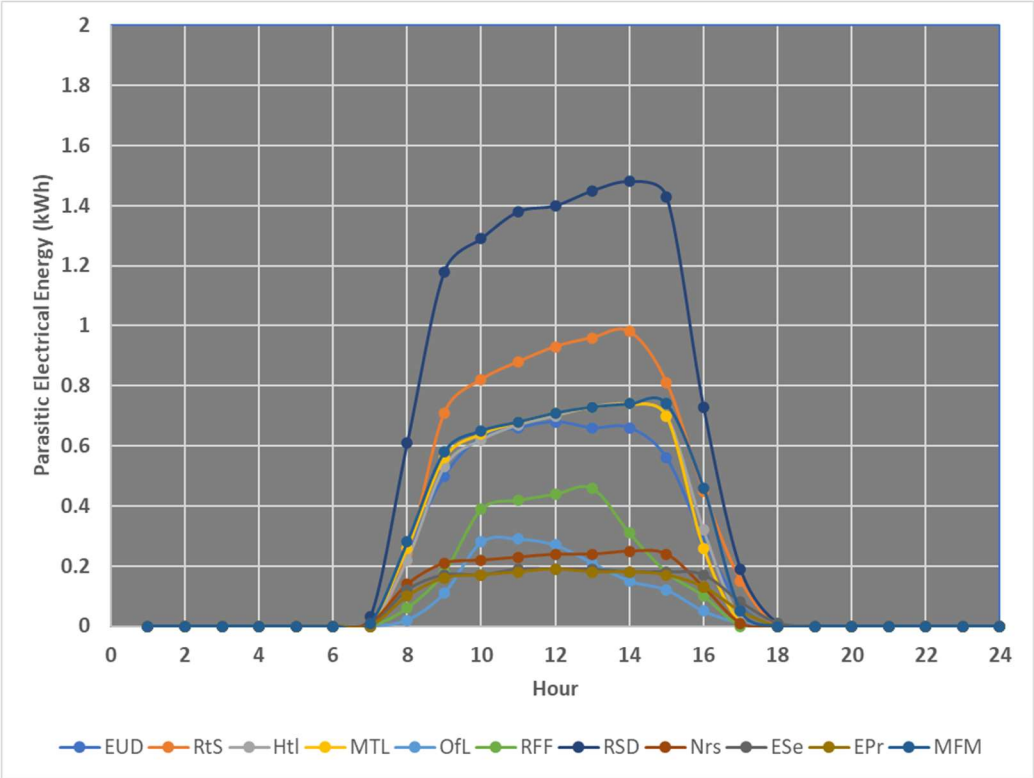

Figure 5: Hourly Parasitic Electrical Energy in September for Config. 18 & Collector 10001803 in Climate Zone 9

SUMMARY

A project was undertaken by the Solar Rating & Certification Corporation (ICC-SRCC) and Thermal Energy System Specialists (TESS) to model the energy savings associated with several representative types of solar water heating systems with gas backup water heaters in several types of commercial California buildings. The conditions and assumptions were modeled using an updated version of the TRNSYS model used in the CSI Thermal Multifamily Hot Water Calculator. Hot water loads were compared between the CSI Thermal Program and the DEER Hot Water Calculator, yielding extremely similar results.

TRNSYS models were then created for 40 solar water heating systems (10 different collectors x 4 different solar water heater configurations) scaled with a hot water load for each building. A representative system was created for each building type based on the most prevalent systems installed for each under the CSI Thermal Program. The annual energy savings for each system in each CA climate zone and each building was reported along with the additional parasitic

Analysis revealed a linear relationship between annual energy savings and total collector effective area for each configuration, in much the same way as the previous Multi-Family Study published by ICC-SRCC dated January 5, 2022. This again indicated the potential to use the effective area of the arrays as a parameter for estimating the annual energy savings for each building type, albeit with different multipliers for each.

The annual additional parasitic electrical energy consumption for each solar water heating system in each climate zone was also calculated. The parasitic electrical energy draw consists of the total electrical energy consumed by the solar water heaters to operate electrical components such as pumps, sensors and differential controllers. The results generally peaked and plateaued between 10 AM and 3 PM with modest variation between the 16 CA Climate Zones, and more significant differences between the building types.

Appendix A: Solar Water Heater Annual Energy Commercial Building Dataset

The following table details the individual annual energy savings and additional parasitic energy consumption for each solar water heating system in each CA climate zone and each building type derived from the TRNSYS modeling described in this report.

Each associated parameter is also described below:

Configuration (Config): Solar water heater system layout varying the heat exchanger type and location and freeze protection method. See Table 6 for index numbers and descriptions.

Backup: Backup water heater installed in each solar water heating system intended to provide the additional heat required to meet the hot water load not met by the solar array. Also known as auxiliary water heater.

CACZ: California Climate Zone as specified by the California Energy Center (CEC)

Annual Energy Savings: Total annual energy saved by using the specified solar water heating system compared to the annual energy consumed by the reference water heater in a standalone configuration (without solar), for a given CA Climate Zone (see Appendix C).

Hot Water Draw Pattern: Volumetric hot water demand over 24-hours for a given building.

Hot Water Load: Ideal energy input required to raise the temperature of the incoming water to the hot water setpoint and satisfy the volumetric demand associated with the building over one year for a given location.

Effective Area (A_{EFF}): Normalized collector area based on performance at a specific, standardized rating condition in units of square meters (see Appendix C).

Additional Annual Parasitic Energy Consumption (kWh): Total additional electrical power consumed by the solar water heating system to operate and meet the load in the specified climate zone.

Reference Water Heater: Conventional commercial gas-fired storage water heater used as the reference (base) water heater for calculating energy savings.

Annual Energy Savings

DORMITORY (EUD) ANNUAL ENERGY SAVINGS PER CA CLIMATE ZONE (THERMS)																	
Config.	Collector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	10001803	396	517	499	519	554	540	538	552	546	571	511	535	555	606	606	485
18	2010115a	392	513	495	516	551	535	534	548	542	567	507	531	551	601	602	482
18	2007032a	356	470	454	472	504	491	490	502	497	520	465	486	504	552	553	441
18	10001912	413	538	519	541	576	562	560	574	568	594	532	557	577	631	631	505
18	10002008	383	501	484	503	538	523	521	535	529	553	495	518	537	587	588	470
18	2010115d	324	426	411	427	456	443	441	454	450	470	420	439	456	499	499	400
18	2007032d	293	389	376	391	415	405	403	414	411	430	385	401	417	456	458	365
18	10001804	326	428	413	429	458	446	444	456	452	472	423	441	458	501	502	402
18	2009042b	379	488	474	493	516	513	509	522	516	537	488	510	529	575	571	465
18	10001893	376	486	471	491	515	511	507	520	514	536	487	508	527	573	569	463

14	10001803	390	509	491	512	545	531	529	544	537	562	503	526	546	596	597	478
14	2010115a	387	505	487	507	541	527	525	539	533	558	499	522	542	592	592	474
14	2007032a	352	464	449	467	498	486	484	497	491	514	460	481	498	546	547	436
14	10001912	407	530	511	533	567	554	551	565	559	585	525	548	569	621	621	498
14	10002008	377	493	476	496	529	514	513	527	521	545	487	510	529	578	579	463
14	2010115d	320	421	406	422	451	438	437	449	444	464	416	434	451	493	493	395
14	2007032d	291	386	373	388	412	403	401	412	408	427	382	399	414	453	454	363
14	10001804	322	423	408	425	453	441	439	452	446	467	418	436	453	495	496	397
14	2009042b	377	485	471	491	513	510	507	520	514	535	486	508	527	572	568	463
14	10001893	374	483	467	488	512	507	503	516	511	533	483	505	523	569	566	459
16	10001803	356	467	451	469	499	486	484	498	493	515	462	483	501	547	548	438
16	2010115a	352	462	445	463	494	480	479	493	488	510	457	477	496	541	543	433
16	2007032a	325	430	415	432	460	448	446	459	454	475	425	444	461	503	505	403
16	10001912	373	488	472	491	522	510	508	522	516	539	484	506	525	573	574	459
16	10002008	343	451	435	452	482	469	467	481	476	498	446	466	484	527	530	423
16	2010115d	296	390	376	391	416	405	403	415	412	431	386	402	419	456	458	366
16	2007032d	273	362	350	364	386	376	375	385	383	400	359	374	389	424	426	339
16	10001804	298	393	380	395	419	409	407	419	415	434	389	406	422	460	462	369
16	2009042b	363	468	454	474	495	492	489	502	496	516	469	490	508	551	549	446
16	10001893	359	465	451	470	493	489	486	499	493	514	466	487	505	550	547	442
102	10001803	368	483	464	484	516	501	499	512	508	531	477	499	516	564	564	452
102	2010115a	364	478	460	480	511	497	494	507	503	526	472	494	511	558	559	448
102	2007032a	334	442	426	443	473	459	458	470	465	487	437	457	472	517	518	414
102	10001912	385	503	484	505	537	524	521	534	529	554	498	521	539	588	588	472
102	10002008	355	467	450	468	499	485	482	496	491	514	461	482	500	545	546	437
102	2010115d	303	400	385	400	427	414	412	424	421	439	395	413	427	467	466	375
102	2007032d	278	369	356	370	393	383	381	391	388	406	365	381	394	432	432	346
102	10001804	305	402	388	403	430	417	415	427	423	442	398	415	430	470	469	378
102	2009042b	366	469	455	474	496	492	488	500	495	515	470	492	508	551	546	447
102	10001893	362	466	451	471	493	489	485	496	492	512	467	488	505	548	544	443

LAUNDROMAT (RTS) ANNUAL ENERGY SAVINGS PER CA CLIMATE ZONE (THERMS)

Config.	Collector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	10001803	2671	3470	3447	3589	3740	3648	3599	3735	3700	3847	3566	3701	3832	4150	4076	3412
18	2010115a	2638	3431	3406	3547	3700	3605	3557	3693	3659	3804	3524	3656	3788	4102	4032	3371
18	2007032a	2448	3191	3177	3306	3446	3353	3313	3437	3401	3534	3282	3402	3524	3816	3753	3137
18	10001912	2805	3639	3622	3769	3919	3834	3782	3923	3884	4035	3739	3886	4014	4353	4256	3585
18	10002008	2575	3348	3324	3461	3611	3516	3470	3601	3569	3710	3438	3567	3696	4001	3936	3288
18	2010115d	2197	2858	2835	2953	3079	3000	2959	3072	3045	3166	2933	3045	3156	3414	3367	2809
18	2007032d	2034	2651	2639	2747	2860	2786	2751	2854	2824	2936	2727	2829	2930	3171	3120	2609
18	10001804	2218	2882	2860	2978	3102	3027	2985	3098	3070	3191	2960	3072	3184	3444	3395	2834
18	2009042b	2738	3496	3487	3623	3706	3695	3629	3758	3722	3852	3636	3768	3900	4193	4101	3482
18	10001893	2694	3462	3457	3591	3675	3661	3593	3723	3686	3819	3605	3733	3864	4162	4077	3447

14	10001803	2629	3418	3396	3536	3682	3595	3546	3681	3643	3788	3514	3647	3776	4089	4020	3360
14	2010115a	2595	3377	3353	3493	3641	3551	3502	3636	3600	3743	3470	3601	3730	4040	3974	3318
14	2007032a	2413	3147	3131	3260	3396	3305	3266	3388	3352	3483	3234	3352	3472	3759	3698	3092
14	10001912	2763	3587	3570	3716	3862	3779	3728	3868	3827	3977	3689	3832	3961	4293	4205	3533
14	10002008	2534	3296	3271	3408	3554	3462	3416	3547	3512	3652	3386	3512	3639	3938	3878	3237
14	2010115d	2170	2826	2802	2921	3043	2966	2926	3039	3010	3131	2902	3013	3122	3378	3330	2777
14	2007032d	2014	2627	2615	2722	2833	2759	2726	2828	2799	2909	2703	2804	2903	3142	3092	2585
14	10001804	2192	2851	2828	2947	3068	2994	2953	3066	3037	3158	2929	3041	3150	3408	3360	2804
14	2009042b	2716	3474	3464	3599	3683	3670	3605	3734	3698	3828	3614	3743	3875	4167	4077	3459
14	10001893	2674	3444	3440	3573	3656	3642	3574	3704	3665	3798	3586	3715	3845	4142	4059	3428
16	10001803	2454	3182	3159	3289	3421	3340	3295	3419	3387	3520	3273	3395	3519	3802	3744	3132
16	2010115a	2418	3138	3113	3242	3375	3291	3247	3370	3339	3471	3226	3346	3469	3748	3693	3086
16	2007032a	2249	2917	2895	3017	3143	3053	3017	3132	3098	3218	2989	3098	3209	3465	3411	2867
16	10001912	2587	3352	3334	3470	3602	3525	3477	3607	3570	3710	3452	3582	3708	4009	3941	3304
16	10002008	2359	3057	3031	3158	3289	3203	3161	3282	3252	3380	3139	3256	3376	3645	3593	3005
16	2010115d	2047	2657	2635	2745	2857	2785	2748	2852	2827	2939	2730	2834	2938	3173	3128	2614
16	2007032d	1904	2475	2459	2562	2667	2593	2562	2660	2631	2734	2541	2636	2730	2948	2901	2436
16	10001804	2070	2686	2665	2776	2886	2817	2779	2884	2857	2970	2761	2866	2970	3208	3162	2644
16	2009042b	2614	3339	3324	3460	3536	3523	3460	3587	3547	3672	3470	3594	3721	3996	3913	3325
16	10001893	2588	3334	3328	3459	3537	3526	3460	3587	3548	3676	3476	3600	3727	4014	3935	3322
102	10001803	2581	3362	3335	3476	3607	3517	3466	3600	3566	3704	3459	3589	3711	4009	3925	3306
102	2010115a	2546	3321	3292	3432	3565	3471	3420	3554	3522	3658	3415	3543	3665	3959	3879	3264
102	2007032a	2365	3085	3065	3192	3316	3224	3182	3304	3270	3396	3174	3288	3401	3673	3605	3032
102	10001912	2714	3531	3509	3656	3787	3702	3648	3787	3749	3891	3632	3772	3894	4211	4106	3478
102	10002008	2486	3240	3211	3346	3478	3383	3335	3465	3435	3567	3331	3455	3575	3859	3785	3183
102	2010115d	2132	2778	2752	2870	2982	2903	2862	2974	2948	3062	2859	2964	3070	3314	3260	2733
102	2007032d	1976	2579	2562	2670	2770	2697	2662	2762	2735	2841	2653	2750	2848	3074	3021	2537
102	10001804	2154	2804	2780	2897	3007	2932	2890	3001	2974	3090	2887	2994	3099	3345	3290	2760
102	2009042b	2685	3426	3417	3554	3622	3613	3548	3677	3632	3759	3571	3700	3824	4101	4005	3419
102	10001893	2641	3394	3391	3523	3597	3588	3518	3648	3604	3731	3542	3668	3794	4081	3989	3386

HOTEL (HTL) ANNUAL ENERGY SAVINGS PER CA CLIMATE ZONE (THERMS)

Config.	Collector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	10001803	1768	2284	2272	2355	2465	2397	2363	2444	2420	2503	2212	2352	2346	2604	2414	2237
18	2010115a	1743	2256	2243	2327	2436	2368	2333	2414	2392	2476	2195	2332	2330	2583	2405	2208
18	2007032a	1616	2099	2085	2168	2261	2191	2166	2245	2227	2307	2098	2203	2232	2446	2330	2054
18	10001912	1860	2389	2386	2465	2585	2516	2480	2555	2517	2598	2268	2412	2398	2682	2440	2339
18	10002008	1700	2202	2187	2271	2375	2306	2274	2355	2334	2418	2163	2293	2299	2538	2385	2154
18	2010115d	1477	1917	1902	1980	2063	2007	1978	2053	2038	2115	1949	2033	2086	2267	2200	1880
18	2007032d	1370	1781	1769	1841	1916	1861	1837	1908	1892	1962	1820	1892	1949	2111	2063	1747
18	10001804	1493	1936	1922	2000	2082	2028	1999	2074	2058	2135	1967	2054	2106	2288	2217	1899
18	2009042b	1857	2354	2350	2432	2499	2478	2435	2514	2487	2564	2284	2424	2420	2670	2458	2334
18	10001893	1845	2358	2359	2439	2510	2489	2443	2522	2490	2568	2284	2424	2420	2684	2462	2338

14	10001803	1755	2266	2255	2340	2447	2383	2348	2430	2404	2488	2203	2341	2338	2594	2409	2219
14	2010115a	1730	2238	2226	2310	2417	2351	2317	2399	2375	2459	2186	2320	2321	2571	2402	2190
14	2007032a	1605	2084	2070	2154	2245	2177	2151	2231	2211	2291	2087	2190	2222	2433	2320	2039
14	10001912	1847	2373	2369	2451	2566	2501	2465	2542	2504	2587	2259	2403	2391	2672	2435	2323
14	10002008	1687	2183	2168	2253	2355	2290	2258	2339	2318	2401	2152	2279	2289	2523	2379	2135
14	2010115d	1470	1907	1894	1971	2053	2000	1971	2046	2030	2106	1942	2026	2080	2259	2194	1871
14	2007032d	1365	1776	1762	1835	1909	1853	1830	1900	1886	1956	1815	1887	1943	2104	2057	1742
14	10001804	1486	1927	1914	1992	2073	2021	1992	2067	2051	2127	1962	2046	2099	2281	2213	1891
14	2009042b	1851	2350	2344	2428	2494	2475	2433	2512	2483	2561	2279	2420	2415	2668	2454	2329
14	10001893	1843	2358	2360	2441	2512	2493	2446	2526	2491	2569	2281	2423	2416	2684	2458	2338
16	10001803	1636	2114	2100	2182	2272	2215	2183	2263	2244	2325	2113	2225	2252	2467	2350	2072
16	2010115a	1609	2082	2067	2149	2239	2180	2150	2229	2211	2292	2089	2194	2228	2436	2331	2040
16	2007032a	1489	1923	1905	1985	2066	2004	1980	2055	2038	2113	1946	2027	2080	2255	2189	1882
16	10001912	1728	2228	2219	2302	2397	2340	2307	2388	2363	2446	2187	2320	2325	2568	2404	2187
16	10002008	1567	2025	2007	2089	2176	2117	2088	2166	2150	2228	2042	2136	2182	2375	2288	1983
16	2010115d	1382	1790	1775	1848	1922	1872	1846	1916	1902	1973	1829	1903	1962	2122	2079	1756
16	2007032d	1285	1663	1649	1718	1788	1735	1714	1779	1764	1830	1699	1764	1821	1967	1929	1631
16	10001804	1399	1811	1797	1871	1944	1896	1869	1940	1925	1997	1851	1926	1985	2148	2101	1778
16	2009042b	1780	2259	2250	2336	2394	2377	2337	2418	2390	2468	2233	2367	2372	2601	2428	2240
16	10001893	1786	2289	2289	2373	2434	2420	2375	2457	2426	2506	2248	2388	2389	2639	2443	2274
102	10001803	1693	2182	2172	2246	2350	2288	2254	2322	2285	2351	2060	2179	2177	2431	2220	2123
102	2010115a	1667	2154	2141	2219	2320	2257	2224	2294	2261	2329	2042	2165	2163	2412	2213	2099
102	2007032a	1549	2002	1989	2067	2153	2092	2065	2140	2119	2194	1965	2085	2090	2302	2167	1960
102	10001912	1784	2258	2273	2319	2461	2386	2353	2408	2348	2409	2110	2227	2218	2493	2233	2203
102	10002008	1625	2101	2086	2167	2260	2198	2166	2241	2217	2290	2017	2142	2142	2376	2202	2053
102	2010115d	1421	1842	1829	1902	1980	1928	1900	1972	1957	2029	1874	1956	2004	2180	2115	1809
102	2007032d	1323	1715	1703	1772	1843	1791	1769	1835	1819	1886	1752	1819	1877	2028	1985	1683
102	10001804	1439	1863	1850	1924	2000	1951	1922	1993	1978	2050	1892	1977	2022	2202	2131	1830
102	2009042b	1821	2288	2291	2358	2431	2411	2373	2437	2392	2456	2185	2305	2309	2555	2333	2259
102	10001893	1809	2291	2304	2366	2448	2423	2382	2447	2400	2466	2206	2325	2331	2587	2362	2268

MOTEL (MTL) ANNUAL ENERGY SAVINGS PER CA CLIMATE ZONE (THERMS)

Config.	Collector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	10001803	1756	2252	2242	2319	2428	2358	2319	2389	2352	2422	2118	2245	2232	2497	2274	2194
18	2010115a	1731	2225	2213	2293	2400	2327	2290	2363	2331	2403	2102	2231	2220	2479	2268	2170
18	2007032a	1600	2067	2054	2132	2223	2152	2124	2201	2180	2257	2029	2147	2149	2369	2224	2023
18	10001912	1847	2332	2346	2394	2539	2455	2418	2475	2417	2482	2164	2287	2272	2557	2289	2271
18	10002008	1687	2172	2157	2238	2339	2267	2232	2309	2285	2360	2078	2208	2199	2443	2255	2123
18	2010115d	1470	1904	1889	1965	2044	1987	1957	2030	2016	2088	1923	2011	2049	2232	2144	1867
18	2007032d	1362	1768	1755	1825	1895	1838	1814	1882	1868	1937	1799	1871	1920	2079	2020	1733
18	10001804	1487	1922	1909	1984	2063	2009	1977	2051	2035	2108	1940	2031	2065	2252	2158	1887
18	2009042b	1859	2340	2340	2409	2486	2453	2411	2477	2427	2493	2202	2325	2316	2573	2334	2305
18	10001893	1851	2344	2352	2414	2503	2463	2422	2481	2431	2498	2217	2339	2333	2594	2350	2306

14	10001803	1742	2238	2227	2304	2412	2341	2303	2374	2337	2408	2100	2225	2213	2479	2255	2178
14	2010115a	1717	2210	2197	2277	2382	2310	2274	2347	2314	2389	2086	2214	2201	2462	2250	2153
14	2007032a	1588	2051	2038	2117	2205	2137	2110	2188	2165	2240	2015	2134	2133	2352	2210	2005
14	10001912	1834	2318	2331	2379	2523	2438	2400	2459	2400	2466	2144	2266	2250	2536	2267	2253
14	10002008	1674	2158	2140	2221	2320	2249	2215	2293	2269	2344	2062	2193	2182	2427	2238	2107
14	2010115d	1463	1895	1879	1956	2035	1979	1949	2023	2007	2079	1913	2000	2041	2223	2136	1855
14	2007032d	1356	1760	1747	1819	1887	1832	1808	1876	1861	1929	1793	1864	1912	2072	2012	1725
14	10001804	1480	1915	1899	1976	2056	2001	1970	2044	2028	2100	1931	2020	2057	2244	2150	1875
14	2009042b	1851	2330	2329	2398	2477	2443	2404	2464	2415	2479	2187	2308	2298	2554	2314	2291
14	10001893	1847	2336	2347	2406	2499	2459	2418	2478	2422	2485	2205	2326	2319	2584	2334	2296
16	10001803	1629	2096	2082	2162	2250	2190	2158	2235	2213	2291	2053	2179	2182	2404	2260	2053
16	2010115a	1602	2065	2050	2129	2217	2156	2124	2202	2182	2259	2034	2155	2162	2378	2247	2021
16	2007032a	1480	1904	1886	1963	2042	1977	1953	2027	2009	2081	1918	1999	2043	2217	2138	1862
16	10001912	1720	2207	2199	2279	2372	2312	2278	2353	2319	2396	2113	2242	2237	2488	2297	2160
16	10002008	1559	2008	1990	2070	2154	2093	2063	2139	2121	2197	1999	2108	2127	2326	2219	1965
16	2010115d	1377	1782	1766	1838	1910	1858	1831	1901	1886	1955	1815	1889	1942	2100	2047	1747
16	2007032d	1279	1654	1638	1706	1772	1718	1696	1761	1747	1811	1685	1749	1801	1945	1900	1620
16	10001804	1396	1804	1789	1862	1932	1882	1855	1925	1909	1979	1837	1912	1965	2126	2068	1769
16	2009042b	1780	2249	2240	2324	2381	2360	2319	2395	2361	2434	2164	2293	2289	2525	2324	2226
16	10001893	1789	2283	2284	2360	2426	2404	2360	2431	2386	2454	2176	2302	2300	2558	2337	2252
102	10001803	1637	2039	2058	2095	2236	2158	2127	2178	2112	2177	1915	2015	2009	2253	2028	1992
102	2010115a	1611	2023	2038	2077	2215	2137	2105	2158	2098	2162	1899	1999	1995	2236	2020	1973
102	2007032a	1495	1919	1911	1973	2068	2005	1978	2038	2008	2069	1821	1923	1923	2138	1979	1863
102	10001912	1717	2087	2119	2150	2294	2221	2189	2232	2147	2212	1959	2059	2053	2306	2047	2052
102	10002008	1571	1994	1998	2045	2167	2097	2066	2120	2075	2137	1875	1978	1975	2207	2012	1939
102	2010115d	1381	1788	1774	1844	1920	1870	1842	1910	1896	1964	1769	1871	1884	2070	1965	1754
102	2007032d	1284	1661	1649	1714	1782	1731	1710	1773	1759	1824	1680	1759	1791	1948	1885	1628
102	10001804	1399	1808	1795	1866	1940	1893	1864	1932	1916	1984	1782	1887	1898	2088	1975	1775
102	2009042b	1777	2162	2190	2230	2337	2292	2259	2308	2240	2302	2062	2164	2166	2398	2165	2147
102	10001893	1772	2183	2209	2253	2355	2317	2281	2333	2264	2331	2099	2203	2209	2449	2214	2168

OFFICE (OFL) ANNUAL ENERGY SAVINGS PER CA CLIMATE ZONE (THERMS)

Config.	Collector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	10001803	561	648	654	654	714	667	664	662	647	664	590	631	612	681	580	636
18	2010115a	554	645	651	650	711	664	659	658	645	662	588	628	609	678	579	631
18	2007032a	523	626	627	631	688	643	639	642	635	649	573	613	594	661	576	609
18	10001912	581	657	667	667	722	677	673	671	653	671	601	641	622	692	584	652
18	10002008	543	638	643	644	704	657	652	653	642	659	582	623	603	672	578	623
18	2010115d	494	607	602	611	663	623	618	624	619	635	558	599	581	648	572	588
18	2007032d	464	578	570	583	629	591	589	597	596	612	540	581	564	625	564	561
18	10001804	500	611	608	616	669	628	623	629	623	638	562	602	584	651	573	593
18	2009042b	609	667	677	677	728	689	685	680	663	679	610	650	631	694	588	667
18	10001893	610	669	682	682	734	693	688	683	665	682	614	655	634	701	591	673

14	10001803	559	647	653	653	713	666	662	660	645	663	589	630	611	680	580	635
14	2010115a	552	644	649	650	710	663	658	657	643	661	587	627	608	678	579	630
14	2007032a	520	625	624	629	686	641	636	641	633	648	572	612	593	660	576	607
14	10001912	578	656	665	666	720	675	671	669	650	669	599	639	620	691	583	650
14	10002008	541	638	642	643	702	655	651	652	640	658	581	622	603	671	578	622
14	2010115d	493	608	602	612	663	623	619	625	620	635	559	600	582	649	573	589
14	2007032d	463	578	569	583	629	591	589	597	596	613	541	581	565	625	565	561
14	10001804	500	612	608	617	669	629	623	629	623	638	562	603	585	653	574	594
14	2009042b	607	667	676	677	728	688	684	680	662	678	610	650	631	694	589	666
14	10001893	608	669	681	682	733	692	686	681	663	680	613	654	633	701	589	672
16	10001803	547	645	648	651	710	665	661	660	648	665	589	630	610	681	586	631
16	2010115a	539	641	643	646	706	660	657	656	645	662	585	626	607	678	585	625
16	2007032a	504	613	608	618	671	629	626	631	626	641	565	606	588	652	578	595
16	10001912	571	658	664	666	724	678	674	672	656	674	600	642	621	693	588	648
16	10002008	527	631	632	637	695	650	647	648	640	656	578	620	600	670	583	615
16	2010115d	485	600	594	606	656	617	613	620	615	632	556	597	580	646	575	582
16	2007032d	452	566	557	572	616	580	578	588	586	603	533	572	559	617	563	550
16	10001804	491	605	600	611	662	623	619	625	619	636	559	600	583	651	576	588
16	2009042b	602	667	677	677	730	690	685	681	665	680	610	651	631	696	592	665
16	10001893	607	672	683	685	736	695	690	685	667	684	616	657	636	704	592	674
102	10001803	554	638	645	650	701	661	658	656	637	657	584	627	608	678	581	629
102	2010115a	546	635	640	645	698	657	654	653	634	654	581	623	605	675	579	624
102	2007032a	516	615	616	623	675	634	631	633	620	639	565	605	588	654	572	599
102	10001912	574	650	660	663	711	674	670	667	646	666	594	637	617	688	584	645
102	10002008	536	629	632	638	691	650	647	646	630	649	576	617	600	668	577	616
102	2010115d	493	603	599	609	658	621	617	621	612	631	555	598	579	648	570	585
102	2007032d	464	575	567	582	625	590	587	595	589	608	537	577	561	623	561	558
102	10001804	500	607	605	615	663	626	623	626	616	634	559	601	583	651	572	591
102	2009042b	609	665	678	678	726	691	686	681	662	678	607	650	630	695	590	667
102	10001893	615	663	681	682	727	691	685	680	658	677	607	651	632	698	592	667

QUICK SERVICE RESTAURANT (RFF) ANNUAL ENERGY SAVINGS PER CA CLIMATE ZONE (THERMS)

Config.	Collector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	10001803	951	1124	1151	1150	1254	1200	1180	1195	1156	1185	1036	1094	1076	1218	1035	1110
18	2010115a	938	1117	1143	1142	1246	1191	1171	1188	1151	1179	1030	1088	1070	1211	1034	1101
18	2007032a	879	1082	1096	1104	1199	1143	1128	1150	1122	1151	1004	1061	1046	1175	1028	1058
18	10001912	993	1146	1179	1177	1278	1227	1204	1217	1171	1200	1055	1114	1094	1240	1039	1139
18	10002008	917	1105	1126	1128	1230	1174	1157	1175	1141	1170	1020	1078	1062	1198	1032	1086
18	2010115d	816	1035	1038	1055	1134	1087	1073	1098	1083	1114	968	1025	1014	1136	1015	1009
18	2007032d	763	981	977	1004	1068	1025	1013	1043	1036	1067	935	991	983	1093	997	957
18	10001804	827	1043	1049	1063	1145	1098	1083	1108	1090	1120	974	1031	1019	1143	1018	1018
18	2009042b	1029	1152	1190	1186	1278	1240	1219	1225	1184	1210	1064	1123	1103	1236	1047	1157
18	10001893	1029	1155	1194	1191	1282	1246	1223	1229	1184	1213	1068	1127	1106	1246	1047	1162

14	10001803	947	1124	1150	1150	1254	1200	1180	1196	1156	1186	1036	1094	1077	1220	1036	1109
14	2010115a	934	1117	1142	1142	1245	1190	1172	1188	1151	1180	1030	1088	1072	1213	1036	1100
14	2007032a	873	1080	1093	1103	1196	1141	1126	1148	1122	1150	1003	1060	1046	1176	1030	1056
14	10001912	989	1146	1178	1177	1278	1227	1205	1218	1171	1200	1055	1114	1095	1242	1041	1138
14	10002008	912	1104	1125	1127	1229	1173	1156	1175	1141	1170	1020	1078	1062	1199	1034	1085
14	2010115d	814	1036	1038	1057	1134	1089	1074	1100	1084	1116	971	1027	1017	1140	1018	1010
14	2007032d	762	982	977	1005	1068	1026	1013	1044	1037	1068	937	992	985	1096	1000	957
14	10001804	825	1045	1049	1066	1145	1100	1085	1110	1092	1123	977	1034	1022	1147	1021	1020
14	2009042b	1026	1154	1190	1189	1280	1242	1220	1228	1185	1212	1066	1126	1107	1240	1049	1158
14	10001893	1029	1159	1197	1195	1285	1250	1226	1232	1186	1215	1071	1130	1110	1252	1049	1165
16	10001803	910	1104	1124	1128	1227	1174	1158	1175	1142	1171	1021	1079	1063	1199	1038	1084
16	2010115a	895	1095	1113	1117	1215	1162	1146	1166	1134	1164	1014	1072	1057	1191	1037	1074
16	2007032a	830	1043	1045	1066	1143	1094	1081	1107	1091	1122	978	1034	1023	1142	1023	1016
16	10001912	958	1131	1159	1159	1260	1209	1190	1204	1163	1193	1042	1102	1084	1227	1043	1118
16	10002008	871	1078	1091	1100	1192	1140	1125	1146	1121	1151	1001	1059	1045	1174	1033	1054
16	2010115d	782	1005	1002	1028	1092	1053	1038	1068	1059	1091	951	1008	1000	1116	1013	979
16	2007032d	728	939	931	964	1016	979	967	1000	995	1029	911	963	961	1062	984	916
16	10001804	794	1016	1014	1039	1105	1065	1051	1079	1069	1101	958	1015	1007	1124	1016	991
16	2009042b	1008	1145	1181	1179	1271	1232	1213	1222	1181	1208	1060	1119	1100	1232	1051	1147
16	10001893	1017	1154	1193	1191	1282	1247	1224	1233	1186	1215	1066	1127	1107	1249	1050	1159
102	10001803	934	1109	1134	1139	1232	1183	1164	1180	1133	1162	1024	1082	1066	1206	1022	1095
102	2010115a	920	1102	1124	1130	1224	1174	1156	1173	1128	1158	1018	1075	1059	1199	1021	1085
102	2007032a	863	1066	1077	1091	1178	1126	1111	1133	1101	1129	990	1047	1034	1162	1014	1042
102	10001912	976	1131	1161	1166	1255	1209	1187	1201	1146	1174	1042	1101	1083	1227	1027	1123
102	10002008	900	1090	1108	1117	1210	1158	1141	1159	1120	1149	1008	1065	1050	1186	1018	1070
102	2010115d	804	1025	1025	1047	1119	1076	1062	1089	1069	1100	961	1018	1008	1131	1009	999
102	2007032d	751	968	961	993	1050	1011	999	1030	1021	1052	927	982	977	1086	991	944
102	10001804	816	1034	1037	1057	1130	1088	1073	1099	1077	1107	967	1025	1014	1138	1011	1009
102	2009042b	1026	1149	1187	1186	1272	1236	1215	1222	1175	1201	1063	1123	1105	1236	1043	1155
102	10001893	1030	1155	1195	1194	1281	1245	1223	1230	1181	1210	1070	1130	1110	1250	1052	1163

MEAL SERVICE RESTAURANT (RSD) ANNUAL ENERGY SAVINGS PER CA CLIMATE ZONE (THERMS)

Config.	Collector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	10001803	3962	5125	5090	5303	5497	5362	5281	5487	5436	5645	5241	5460	5626	6087	5915	5051
18	2010115a	3912	5064	5027	5239	5435	5293	5215	5419	5370	5577	5179	5395	5561	6017	5856	4988
18	2007032a	3627	4702	4678	4871	5047	4903	4837	5026	4974	5167	4829	5014	5177	5592	5468	4633
18	10001912	4161	5383	5355	5573	5767	5641	5557	5768	5710	5928	5485	5724	5877	6378	6149	5309
18	10002008	3819	4938	4901	5107	5301	5156	5082	5283	5234	5436	5056	5261	5432	5870	5726	4864
18	2010115d	3272	4229	4204	4372	4547	4420	4355	4522	4475	4650	4345	4509	4671	5038	4946	4169
18	2007032d	3027	3928	3913	4066	4222	4098	4044	4197	4151	4314	4038	4184	4329	4674	4578	3872
18	10001804	3304	4265	4243	4412	4584	4462	4395	4564	4515	4690	4386	4552	4714	5084	4991	4208
18	2009042b	4089	5208	5194	5399	5508	5485	5385	5580	5525	5715	5398	5609	5784	6219	6009	5195
18	10001893	4025	5156	5153	5353	5467	5441	5337	5534	5475	5666	5355	5560	5734	6176	5987	5145

14	10001803	3908	5051	5020	5228	5422	5290	5212	5414	5361	5568	5172	5385	5552	6008	5856	4976
14	2010115a	3856	4988	4955	5162	5357	5221	5144	5345	5294	5499	5107	5318	5485	5935	5794	4912
14	2007032a	3579	4637	4613	4803	4983	4841	4776	4964	4908	5099	4760	4941	5106	5515	5400	4568
14	10001912	4106	5306	5282	5498	5692	5568	5487	5696	5635	5852	5423	5652	5811	6302	6099	5235
14	10002008	3765	4865	4830	5032	5227	5087	5013	5209	5159	5360	4985	5186	5354	5789	5661	4790
14	2010115d	3236	4185	4160	4328	4500	4381	4315	4482	4432	4606	4299	4459	4619	4988	4899	4124
14	2007032d	2998	3892	3879	4033	4185	4068	4015	4166	4118	4279	3998	4147	4289	4634	4540	3837
14	10001804	3268	4223	4200	4368	4538	4424	4358	4524	4471	4647	4340	4503	4664	5034	4945	4165
14	2009042b	4056	5171	5158	5363	5471	5450	5352	5546	5489	5679	5366	5570	5748	6181	5981	5156
14	10001893	3998	5128	5125	5325	5439	5417	5312	5508	5447	5641	5332	5534	5709	6151	5969	5115
16	10001803	3623	4670	4636	4829	5006	4884	4814	4998	4950	5142	4791	4979	5145	5552	5448	4606
16	2010115a	3569	4602	4567	4757	4937	4810	4742	4924	4878	5068	4720	4906	5070	5472	5373	4536
16	2007032a	3316	4272	4240	4416	4589	4451	4397	4566	4515	4690	4371	4535	4688	5056	4962	4205
16	10001912	3819	4927	4897	5099	5275	5160	5086	5278	5225	5426	5051	5250	5418	5855	5725	4862
16	10002008	3481	4482	4446	4631	4809	4679	4615	4793	4746	4931	4595	4774	4935	5322	5229	4415
16	2010115d	3032	3913	3884	4042	4201	4089	4031	4184	4141	4304	4018	4168	4316	4655	4574	3856
16	2007032d	2820	3648	3624	3772	3921	3805	3758	3900	3857	4007	3736	3874	4008	4324	4238	3593
16	10001804	3068	3956	3929	4088	4245	4137	4078	4232	4188	4351	4065	4217	4366	4708	4626	3901
16	2009042b	3884	4943	4919	5121	5221	5196	5101	5291	5234	5415	5122	5314	5488	5891	5727	4928
16	10001893	3850	4945	4937	5133	5234	5215	5114	5305	5244	5431	5140	5332	5507	5928	5772	4933
102	10001803	3765	4877	4844	5041	5230	5100	5021	5217	5170	5366	4993	5189	5340	5780	5595	4801
102	2010115a	3711	4815	4777	4975	5166	5032	4954	5148	5105	5298	4930	5120	5275	5708	5540	4736
102	2007032a	3447	4469	4439	4621	4798	4666	4605	4779	4730	4910	4581	4752	4904	5300	5174	4398
102	10001912	3961	5125	5100	5303	5494	5369	5288	5488	5432	5637	5219	5454	5571	6050	5771	5053
102	10002008	3622	4696	4655	4849	5037	4903	4829	5019	4976	5166	4807	4991	5151	5566	5419	4617
102	2010115d	3127	4048	4018	4185	4347	4231	4167	4329	4286	4450	4161	4315	4463	4818	4729	3988
102	2007032d	2900	3762	3741	3892	4040	3931	3876	4023	3979	4131	3865	4004	4143	4473	4388	3705
102	10001804	3161	4087	4059	4224	4386	4275	4210	4372	4328	4493	4203	4359	4507	4865	4775	4030
102	2009042b	3953	5029	5012	5209	5302	5286	5187	5377	5317	5500	5213	5413	5571	5982	5769	5023
102	10001893	3899	4990	4985	5179	5283	5265	5159	5350	5288	5472	5189	5382	5544	5970	5774	4984

NURSING HOME (NRS) ANNUAL ENERGY SAVINGS PER CA CLIMATE ZONE (THERMS)

Config.	Collector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	10001803	620	800	794	826	859	837	825	855	849	880	813	848	871	945	920	787
18	2010115a	611	791	784	816	849	826	814	845	838	870	804	838	861	934	910	776
18	2007032a	565	730	726	755	784	761	752	780	773	802	745	775	799	863	844	718
18	10001912	651	839	835	868	901	880	867	899	890	923	846	890	903	987	951	827
18	10002008	596	771	764	795	827	805	793	824	817	848	784	817	841	911	889	756
18	2010115d	515	665	660	687	714	694	685	710	704	731	680	708	731	789	774	654
18	2007032d	476	615	611	635	660	640	633	656	651	676	630	654	676	729	715	605
18	10001804	521	671	666	693	720	701	691	717	711	738	687	714	738	796	781	661
18	2009042b	644	821	816	847	863	858	842	872	865	896	845	879	903	973	939	818
18	10001893	637	816	814	844	863	857	840	871	862	893	841	875	899	971	939	813

14	10001803	617	796	791	823	855	835	823	853	845	877	811	845	867	942	917	782
14	2010115a	609	786	780	812	845	824	812	843	834	866	801	834	858	930	907	772
14	2007032a	562	728	724	753	781	758	750	778	771	800	743	772	796	861	842	715
14	10001912	649	836	832	864	897	878	865	897	887	920	841	886	898	983	947	822
14	10002008	594	766	760	791	823	802	791	821	813	844	781	813	838	906	886	752
14	2010115d	515	664	659	686	713	695	685	711	704	731	680	707	731	789	774	653
14	2007032d	476	616	611	636	660	641	633	657	651	676	631	655	676	730	716	606
14	10001804	520	670	666	693	720	702	692	718	711	738	687	714	738	797	781	660
14	2009042b	645	822	817	849	865	860	844	875	867	898	845	880	902	973	940	818
14	10001893	639	818	817	848	867	861	844	875	865	896	843	879	900	974	941	815
16	10001803	562	724	718	747	775	756	746	774	767	796	740	769	793	856	839	711
16	2010115a	553	713	707	735	764	744	734	762	755	784	728	757	781	843	827	700
16	2007032a	512	658	651	678	705	683	675	701	695	721	670	696	718	774	759	645
16	10001912	593	764	760	789	819	800	789	818	810	840	781	812	836	904	883	752
16	10002008	539	693	687	715	743	723	713	740	734	762	708	736	760	819	803	680
16	2010115d	474	611	605	630	655	637	628	652	646	671	626	650	672	724	712	600
16	2007032d	441	567	562	585	609	590	583	605	599	622	580	602	622	670	658	557
16	10001804	480	618	613	638	662	645	636	660	654	679	633	658	680	733	720	608
16	2009042b	611	775	771	802	818	813	799	828	819	847	799	830	855	918	892	771
16	10001893	610	782	780	810	828	824	808	838	828	857	809	840	864	933	906	779
102	10001803	595	767	763	793	824	804	792	822	814	844	759	805	811	891	847	754
102	2010115a	586	757	753	782	813	793	782	811	803	833	752	798	804	883	844	743
102	2007032a	543	702	697	724	753	732	723	750	743	771	713	744	762	828	807	688
102	10001912	626	806	803	834	865	847	835	863	852	881	780	828	831	921	859	792
102	10002008	572	738	733	762	793	772	761	790	783	812	741	782	793	866	835	724
102	2010115d	496	641	636	662	688	671	661	686	680	705	657	683	705	762	748	630
102	2007032d	461	594	592	615	639	621	614	636	630	654	609	633	654	706	693	585
102	10001804	502	647	643	669	694	678	668	693	686	712	664	690	713	769	755	637
102	2009042b	628	795	792	822	838	836	821	850	841	869	801	845	856	930	886	792
102	10001893	621	792	792	822	839	836	820	850	839	868	803	845	858	933	891	790

SECONDARY (JR/SR HIGH) SCHOOL (ESE) ANNUAL ENERGY SAVINGS PER CA CLIMATE ZONE (THERMS)

Config.	Collector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	10001803	422	551	533	554	589	574	571	589	580	608	546	569	593	646	642	519
18	2010115a	419	548	529	550	586	570	567	585	577	604	542	565	589	642	638	516
18	2007032a	376	497	481	500	530	518	515	530	524	549	493	513	534	584	581	468
18	10001912	439	573	554	576	611	597	594	612	603	631	568	592	616	672	667	540
18	10002008	408	535	516	537	571	556	553	570	563	589	529	551	574	626	623	503
18	2010115d	343	451	435	453	480	467	464	479	475	497	446	464	485	528	525	424
18	2007032d	308	408	394	410	434	424	420	433	430	450	405	421	440	479	477	384
18	10001804	344	453	437	455	482	470	466	481	476	499	448	466	487	530	527	427
18	2009042b	396	511	497	517	539	537	532	548	540	562	513	534	556	603	595	489
18	10001893	394	510	496	516	539	535	530	546	539	561	511	532	554	602	593	487

14	10001803	415	542	524	545	579	565	562	579	571	597	537	559	583	635	631	511
14	2010115a	412	538	520	541	575	560	557	575	567	593	533	555	579	630	627	507
14	2007032a	372	491	475	494	524	512	509	524	518	542	487	507	527	577	574	462
14	10001912	433	563	545	567	601	588	585	602	593	621	559	582	607	661	656	531
14	10002008	402	525	507	528	561	547	544	561	553	579	520	542	564	615	612	494
14	2010115d	339	445	430	447	474	462	459	474	469	491	440	458	478	521	518	419
14	2007032d	306	405	391	407	430	421	418	431	426	447	402	418	436	475	473	381
14	10001804	341	447	432	449	476	464	462	476	471	493	443	461	480	524	520	422
14	2009042b	394	508	494	514	536	534	529	545	537	559	510	531	553	600	592	486
14	10001893	391	506	491	512	535	531	526	542	535	557	507	528	550	597	589	483
16	10001803	378	496	479	498	529	515	513	529	523	547	492	512	534	581	579	467
16	2010115a	374	491	474	493	523	510	507	523	517	542	486	506	528	575	573	462
16	2007032a	345	455	440	458	485	473	470	485	480	503	451	469	489	532	531	428
16	10001912	396	518	501	521	552	540	537	554	547	572	515	536	558	608	605	489
16	10002008	365	479	463	481	511	497	495	510	505	529	475	494	515	561	559	451
16	2010115d	313	411	397	413	437	426	423	437	433	454	408	424	443	482	480	387
16	2007032d	288	380	367	382	404	395	392	404	401	419	377	392	410	445	444	358
16	10001804	315	415	400	416	441	430	427	441	437	457	411	427	447	485	484	390
16	2009042b	380	490	477	496	517	515	511	526	519	540	492	513	534	579	572	469
16	10001893	375	487	473	493	514	511	507	522	515	537	489	509	530	576	569	465
102	10001803	394	517	499	519	552	538	534	550	544	569	512	534	555	606	601	487
102	2010115a	391	513	495	515	548	533	530	546	540	564	508	530	551	601	596	482
102	2007032a	356	471	455	473	503	490	488	502	496	519	467	486	505	552	549	443
102	10001912	412	538	519	542	574	561	557	574	566	593	534	557	579	632	626	507
102	10002008	381	501	483	503	535	520	517	533	527	551	496	517	538	586	582	471
102	2010115d	323	426	411	427	454	441	438	452	448	468	421	439	457	498	495	401
102	2007032d	294	390	377	392	414	405	402	414	410	429	386	402	419	457	454	367
102	10001804	325	428	413	429	456	444	441	455	450	471	424	441	459	501	497	403
102	2009042b	384	493	479	499	520	518	513	527	520	541	495	516	536	581	572	472
102	10001893	380	490	476	496	518	514	509	524	517	539	492	513	532	578	569	468

PRIMARY SCHOOL (EPR) ANNUAL ENERGY SAVINGS PER CA CLIMATE ZONE (THERMS)

Config.	Collector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	10001803	396	517	499	519	554	540	538	552	546	571	511	535	555	606	606	485
18	2010115a	392	513	495	516	551	535	534	548	542	567	507	531	551	601	602	482
18	2007032a	356	470	454	472	504	491	490	502	497	520	465	486	504	552	553	441
18	10001912	413	538	519	541	576	562	560	574	568	594	532	557	577	631	631	505
18	10002008	383	501	484	503	538	523	521	535	529	553	495	518	537	587	588	470
18	2010115d	324	426	411	427	456	443	441	454	450	470	420	439	456	499	499	400
18	2007032d	293	389	376	391	415	405	403	414	411	430	385	401	417	456	458	365
18	10001804	326	428	413	429	458	446	444	456	452	472	423	441	458	501	502	402
18	2009042b	379	488	474	493	516	513	509	522	516	537	488	510	529	575	571	465
18	10001893	376	486	471	491	515	511	507	520	514	536	487	508	527	573	569	463

14	10001803	390	509	491	512	545	531	529	544	537	562	503	526	546	596	597	478
14	2010115a	387	505	487	507	541	527	525	539	533	558	499	522	542	592	592	474
14	2007032a	352	464	449	467	498	486	484	497	491	514	460	481	498	546	547	436
14	10001912	407	530	511	533	567	554	551	565	559	585	525	548	569	621	621	498
14	10002008	377	493	476	496	529	514	513	527	521	545	487	510	529	578	579	463
14	2010115d	320	421	406	422	451	438	437	449	444	464	416	434	451	493	493	395
14	2007032d	291	386	373	388	412	403	401	412	408	427	382	399	414	453	454	363
14	10001804	322	423	408	425	453	441	439	452	446	467	418	436	453	495	496	397
14	2009042b	377	485	471	491	513	510	507	520	514	535	486	508	527	572	568	463
14	10001893	374	483	467	488	512	507	503	516	511	533	483	505	523	569	566	459
16	10001803	356	467	451	469	499	486	484	498	493	515	462	483	501	547	548	438
16	2010115a	352	462	445	463	494	480	479	493	488	510	457	477	496	541	543	433
16	2007032a	325	430	415	432	460	448	446	459	454	475	425	444	461	503	505	403
16	10001912	373	488	472	491	522	510	508	522	516	539	484	506	525	573	574	459
16	10002008	343	451	435	452	482	469	467	481	476	498	446	466	484	527	530	423
16	2010115d	296	390	376	391	416	405	403	415	412	431	386	402	419	456	458	366
16	2007032d	273	362	350	364	386	376	375	385	383	400	359	374	389	424	426	339
16	10001804	298	393	380	395	419	409	407	419	415	434	389	406	422	460	462	369
16	2009042b	363	468	454	474	495	492	489	502	496	516	469	490	508	551	549	446
16	10001893	359	465	451	470	493	489	486	499	493	514	466	487	505	550	547	442
102	10001803	368	483	464	484	516	501	499	512	508	531	477	499	516	564	564	452
102	2010115a	364	478	460	480	511	497	494	507	503	526	472	494	511	558	559	448
102	2007032a	334	442	426	443	473	459	458	470	465	487	437	457	472	517	518	414
102	10001912	385	503	484	505	537	524	521	534	529	554	498	521	539	588	588	472
102	10002008	355	467	450	468	499	485	482	496	491	514	461	482	500	545	546	437
102	2010115d	303	400	385	400	427	414	412	424	421	439	395	413	427	467	466	375
102	2007032d	278	369	356	370	393	383	381	391	388	406	365	381	394	432	432	346
102	10001804	305	402	388	403	430	417	415	427	423	442	398	415	430	470	469	378
102	2009042b	366	469	455	474	496	492	488	500	495	515	470	492	508	551	546	447
102	10001893	362	466	451	471	493	489	485	496	492	512	467	488	505	548	544	443

MULTIFAMILY HOUSING (MFH) ANNUAL ENERGY SAVINGS PER CA CLIMATE ZONE (THERMS)

Config.	Collector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	10001803	1911	2474	2459	2558	2660	2596	2559	2655	2632	2730	2520	2628	2699	2931	2847	2429
18	2010115a	1887	2445	2429	2527	2631	2565	2527	2623	2601	2699	2491	2597	2670	2898	2820	2399
18	2007032a	1742	2265	2252	2343	2435	2367	2337	2426	2404	2496	2320	2411	2483	2690	2629	2224
18	10001912	2005	2594	2584	2685	2789	2728	2689	2786	2759	2861	2632	2750	2812	3066	2956	2551
18	10002008	1840	2385	2367	2464	2565	2498	2463	2557	2535	2631	2432	2534	2608	2827	2758	2339
18	2010115d	1583	2048	2034	2116	2203	2145	2114	2193	2175	2257	2103	2183	2258	2439	2397	2011
18	2007032d	1461	1894	1887	1962	2040	1983	1957	2030	2010	2085	1948	2020	2088	2258	2216	1863
18	10001804	1598	2065	2052	2135	2221	2165	2134	2214	2193	2276	2122	2203	2278	2461	2416	2030
18	2009042b	1958	2499	2491	2588	2640	2632	2583	2676	2648	2736	2579	2685	2757	2971	2871	2488
18	10001893	1935	2480	2477	2574	2629	2618	2568	2662	2634	2724	2565	2667	2741	2959	2868	2472

14	10001803	1894	2454	2437	2538	2636	2573	2536	2632	2609	2707	2502	2608	2679	2907	2830	2410
14	2010115a	1869	2425	2407	2506	2606	2540	2504	2599	2578	2675	2472	2576	2648	2873	2800	2379
14	2007032a	1727	2243	2228	2321	2411	2346	2316	2403	2383	2473	2297	2385	2461	2664	2611	2202
14	10001912	1989	2575	2563	2665	2766	2706	2667	2765	2738	2840	2616	2733	2795	3044	2940	2532
14	10002008	1824	2365	2345	2443	2540	2475	2440	2533	2513	2607	2414	2514	2587	2803	2737	2319
14	2010115d	1572	2035	2020	2104	2189	2130	2098	2179	2162	2244	2089	2168	2243	2424	2384	1999
14	2007032d	1453	1885	1878	1951	2030	1976	1949	2021	2001	2077	1938	2009	2077	2246	2206	1854
14	10001804	1588	2053	2038	2122	2206	2150	2118	2198	2181	2264	2108	2188	2264	2445	2405	2018
14	2009042b	1952	2494	2484	2582	2634	2627	2578	2673	2645	2733	2573	2677	2752	2966	2867	2482
14	10001893	1931	2481	2475	2570	2625	2614	2563	2657	2632	2723	2565	2667	2738	2956	2870	2471
16	10001803	1795	2321	2304	2398	2490	2430	2395	2486	2465	2557	2373	2469	2544	2752	2694	2279
16	2010115a	1769	2289	2271	2364	2457	2396	2361	2451	2431	2523	2340	2435	2510	2715	2660	2246
16	2007032a	1640	2122	2106	2194	2281	2215	2187	2271	2250	2334	2170	2253	2326	2512	2464	2082
16	10001912	1890	2443	2430	2528	2621	2564	2527	2621	2596	2693	2496	2598	2672	2896	2823	2403
16	10002008	1725	2229	2211	2302	2393	2331	2298	2386	2367	2456	2279	2371	2446	2643	2592	2187
16	2010115d	1501	1940	1926	2004	2085	2030	2001	2076	2059	2137	1992	2068	2139	2308	2271	1906
16	2007032d	1393	1805	1794	1867	1942	1886	1861	1932	1913	1985	1851	1920	1985	2143	2105	1773
16	10001804	1518	1961	1947	2026	2105	2053	2023	2099	2080	2159	2014	2091	2162	2333	2295	1928
16	2009042b	1901	2426	2415	2513	2563	2553	2507	2599	2571	2659	2506	2605	2681	2885	2800	2413
16	10001893	1886	2426	2422	2517	2571	2561	2511	2604	2574	2664	2514	2611	2688	2900	2819	2414
102	10001803	1846	2387	2373	2468	2564	2503	2466	2559	2537	2631	2429	2537	2598	2828	2746	2344
102	2010115a	1820	2359	2342	2436	2533	2471	2434	2526	2505	2599	2402	2506	2570	2795	2720	2314
102	2007032a	1688	2187	2174	2261	2351	2287	2259	2342	2322	2409	2237	2323	2396	2593	2541	2145
102	10001912	1940	2506	2496	2594	2691	2634	2595	2690	2664	2762	2513	2655	2684	2944	2826	2464
102	10002008	1776	2300	2282	2374	2469	2407	2372	2462	2442	2534	2348	2444	2515	2726	2663	2256
102	2010115d	1534	1986	1970	2051	2132	2080	2049	2126	2109	2189	2040	2118	2189	2365	2323	1951
102	2007032d	1423	1841	1835	1907	1981	1929	1904	1972	1954	2028	1894	1964	2029	2193	2154	1811
102	10001804	1551	2004	1990	2071	2150	2101	2069	2147	2128	2209	2060	2139	2210	2388	2344	1972
102	2009042b	1928	2449	2444	2539	2587	2582	2535	2625	2597	2683	2522	2636	2693	2911	2812	2441
102	10001893	1905	2436	2435	2526	2582	2573	2523	2614	2587	2675	2512	2622	2682	2907	2811	2427

Appendix B: Solar Water Heating System Configuration Schematics

The solar water heating systems selected for modeling and study consist of 40 separate combinations consisting of 4 configurations modeled with 10 different collector arrays. Two of the four configurations use drainback freeze protection and two use glycol. For heat exchangers, two use immersed heat exchangers in the solar tank and two use external heat exchangers. Schematics for the four configurations are shown below.

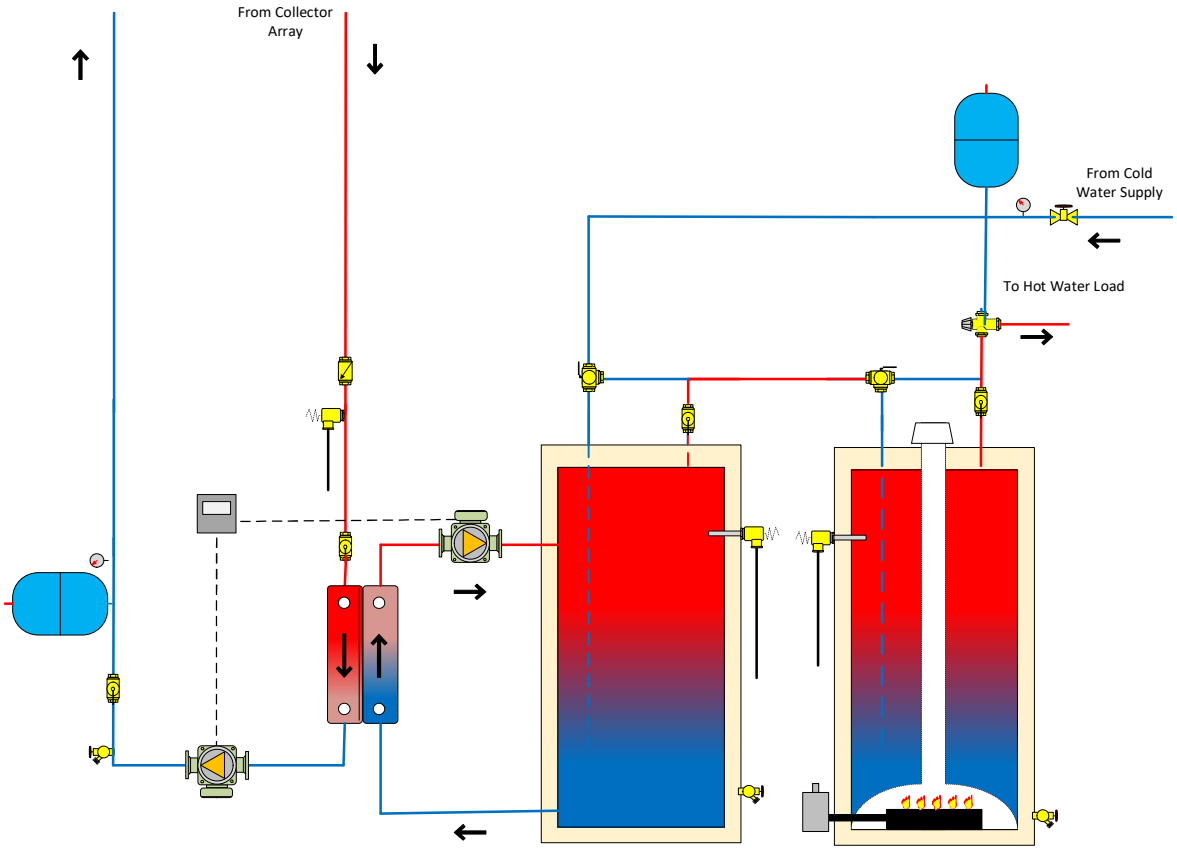

Figure B1: System Configuration 14 - External Supply Side Heat Exchanger with Glycol Freeze Protection

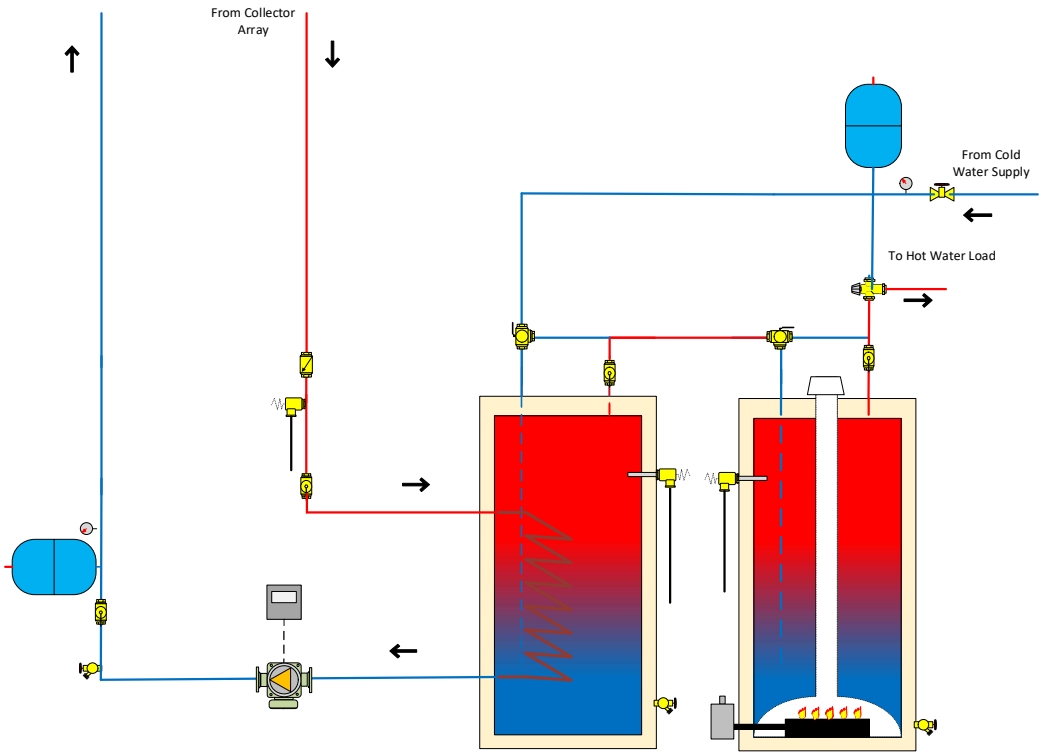

Figure B2: System Configuration 16 - Immersed Supply Side Heat Exchanger with Glycol Freeze Protection

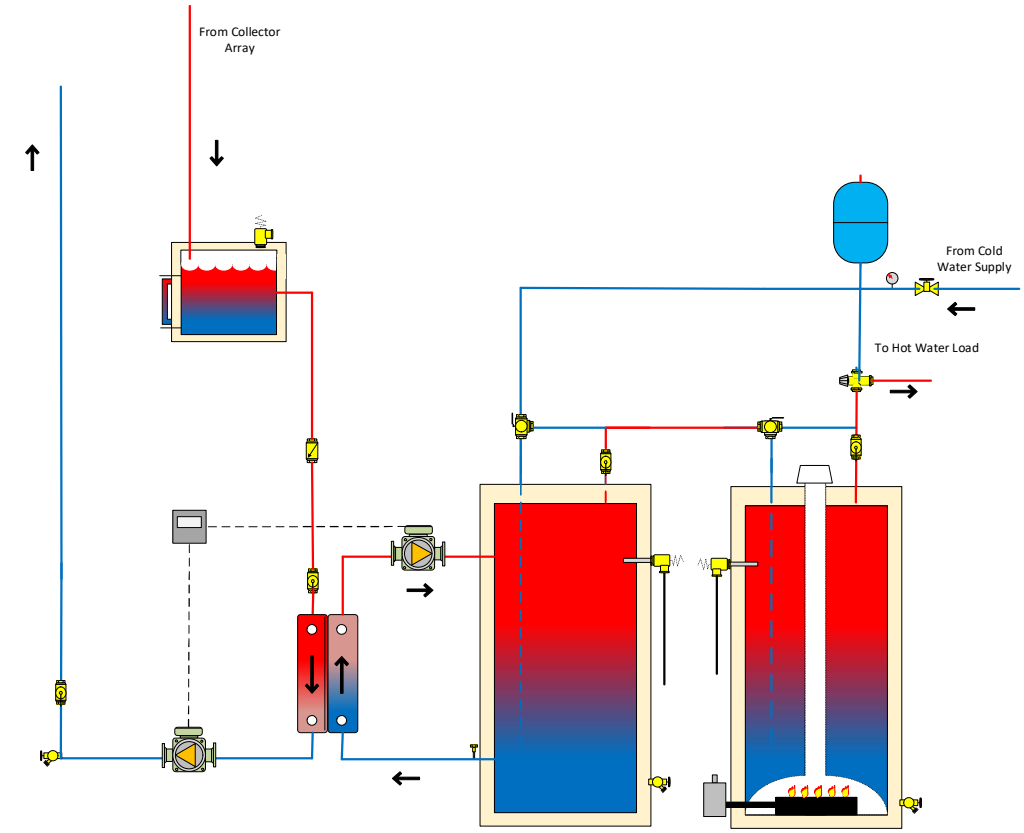

Figure B6: System Configuration 18 - External Supply Side Heat Exchanger with Drainback Freeze Protection

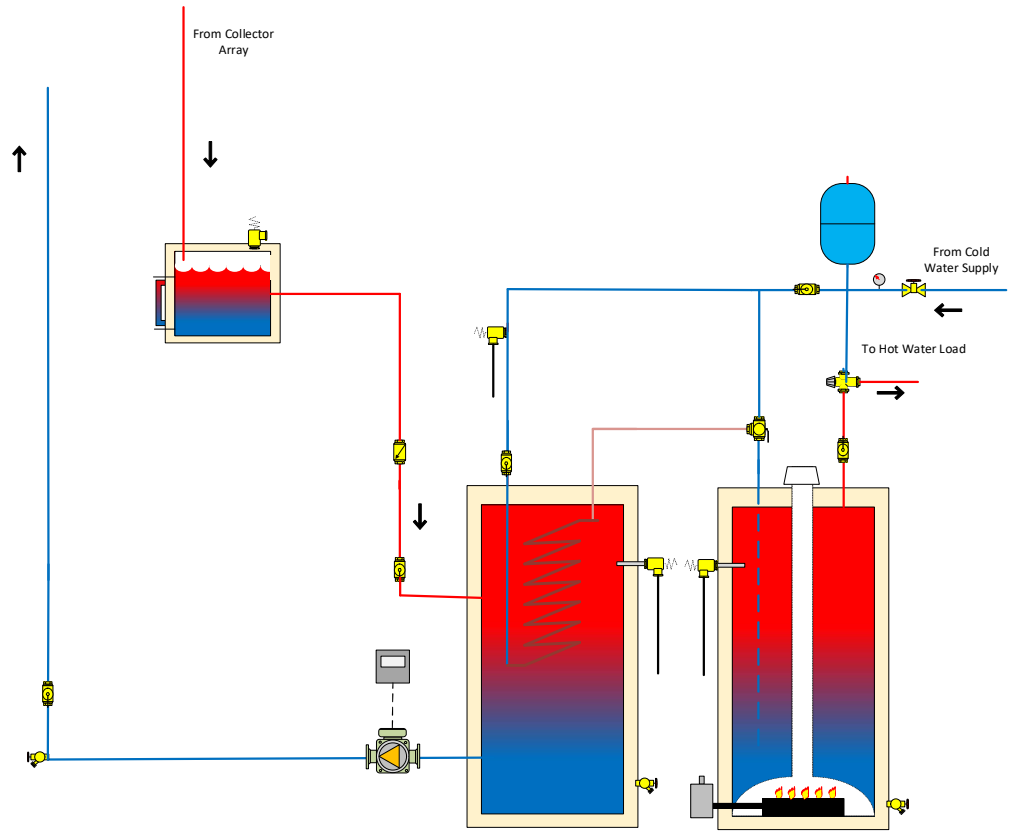

Figure B4: System Configuration 102 - Immersed Load Side Heat Exchanger with Drainback Freeze Protection

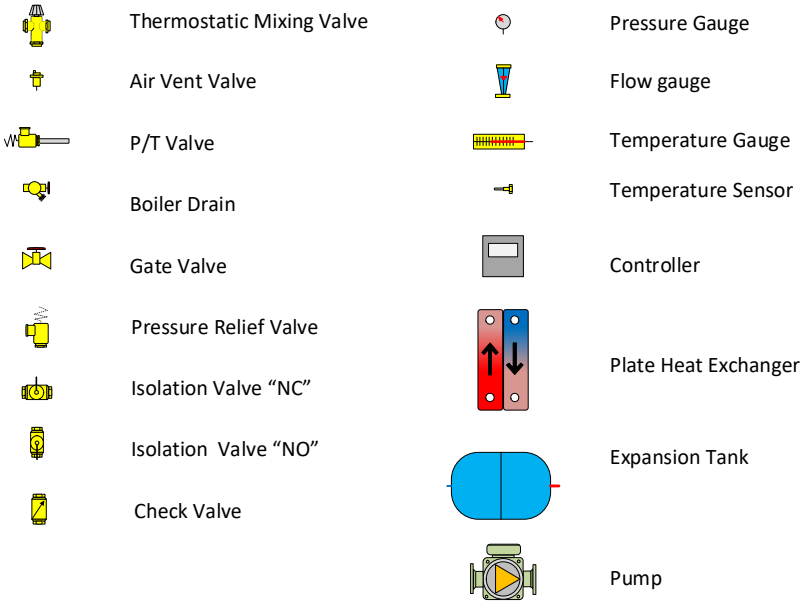

Figure B5: Schematic Symbol Legend

Appendix C: Solar Water Heating System Performance Metrics

Solar water heating systems differ from traditional, fuel-only water heaters in that they utilize a time-dependent solar energy source. Typically, these systems utilize two fuel sources, where the solar portion is irregular but prioritized. Backup water heaters consuming fuels such as natural gas, make up the difference between the solar energy supply and the hot water energy demand. As a result, the metrics used to describe the performance of solar water heaters are somewhat different from those used for traditional water heaters.

Note that the metric will vary with the assumptions used. Variations in parameters such as the collector mounting angle and azimuth, annual hot water load, setpoint temperature, building size, storage tank volume, heat exchanger configuration and freeze protection mechanism will all have impacts on the overall annual energy savings observed in the real world.

The solar water heater performance metrics provided in this analysis include the following:

Effective Area (A_{EFF}). Effective area (TESS, 2019) is a metric developed to normalize the area associated with a collector to account for the variation in different solar thermal technologies. It permits the thermal efficiency performance of different collectors to be compared on an area basis. The effective area is calculated for the collectors in each system based on a specific rating condition. The actual gross collector area (A_G) is measured using the length and width of the projected area exposed to solar radiation, as established in the ISO 9806 standard.

For this study of SWH systems in a warm climate, the standard conditions were assumed to be an incident solar radiation of 800 W/m^2, an inlet temperature to ambient temperature difference of 20°C, and a flow rate equal to the test flow rate for the collector. In equation form the effective area can be calculated for glazed flat plate collectors as:

$$A_{eff} = A_g \, \eta_{nom} \, \overline{IAM_T}$$

And for evacuated tube collectors as:

$$A_{eff} = A_g \, \eta_{nom} \, \overline{IAM}_T \, \overline{IAM}_L$$

Where the variables are defined as:

Ag	The gross area of the collector as provided on the collector test report.
η_{nom}	The efficiency of the collector at an irradiance of 800 W/m^2, an inlet temperature 20°C above the ambient temperature, and with a fluid flow rate equal to the published test flow rate.
$\overline{IAM}_T$	The average transverse incidence angle modifier from 0 degrees to 60 degrees.
$\overline{IAM}_L$	The average longitudinal incidence angle modifier from 0 degrees to 60 degrees.

Annual Energy Savings. The Annual Energy Savings is the difference between the energy consumed by the solar water heater and a reference water heater over a period. The user must determine whether the calculation will include parasitic electrical energy or only the energy consumed by the gas auxiliary water heater. If including parasitic electrical energy, it must be converted to a gas equivalent in therms. The conversion is 29.3297 kWh/therm.

$$AES = Q_{REF} - Q_{AUX} - Q_{PAR}$$