

STUDY OF SOLAR WATER HEATER ENERGY SAVINGS



June 28, 2021

A Study of Solar-Assisted Gas Water Heaters
for use in Single Family California Homes

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STUDY of solar water heater energy savings

A STUDY OF SOLAR-ASSISTED GAS WATER HEATERS FOR USE IN SINGLE FAMILY CALIFORNIA HOMES

OVERVIEW

Domestic solar water heating systems have long been used in the California market and incentivized by various programs. The technology has been supported by both regulators and utilities alike as a means of increasing energy efficiency while 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 incentive or a customized, complicated incentive program using an extensive online performance calculator. This study seeks to provide the data needed to structure and justify a deemed program for solar water heating technologies in single family homes.

PROJECT DESCRIPTION

Southern California Gas Company (SoCal Gas) initiated the 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. The annual energy savings were modeled using TRNSYS energy modeling and simulation software. The results provide annual energy savings relative to incumbent gas water heaters for a representative sample of current ICC-SRCC OG-300 certified solar domestic water heating systems using natural gas fueled backup water heaters.

Annual energy consumption of specified reference gas tank-type and tankless water heaters will also be modeled for comparison with the CPUC DEER Hot Water Calculator results and to determine comparative annual energy savings for solar water heating systems.

The work has been conducted by the Solar Rating & Certification Corporation (ICC-SRCC) in partnership with 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 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.

REFERENCE GAS WATER HEATER MODELING

Two reference water heaters are used for the purpose of assessing the energy savings estimated for each solar water heating system and to validate the results of the TRNSYS models in comparison with the DEER Calculator. The reference water heaters were selected from the CPUC DEER 2021 Water Heater Use Calculator, v4.2 with the parameters listed below.

Table 1: Reference Water Heater Characteristics

PARAMETER	GAS STORAGE	GAS TANKLESS
NAME - DEER CALCULATOR	Stor_UEF-Gas-050gal-MD-0.56UEF	Inst_UEF-Gas-lt200kBtuh-MD-0.81UEF
INDEX	196	163
NOM. VOLUME	50 gal	0 gal
UEF/DRAW	0.57 (Med)	0.81 (Med)
BURNER CAPACITY (Q_{CAP})	38.8 kBtu • h	141.2 kBtu • h
RECOVERY EFFICIENCY (H_{REC})	0.757	0.835
PILOT ENERGY (Q_{PILOT})	350 Btu • h	0
PILOT HEATING EFFICIENCY (H_{PILOT})	0.67	0
TANK HEAT LOSS (UA)	9.02 Btu/h • °F	0
CONDENSING FAN	No	No

Since the modeling assumptions and inputs utilized in the DEER 2021 Water Heater Energy Use Calculator are to be utilized for the annual energy consumption estimates of solar water heating systems, the methodology of the calculator has been reviewed and summarized below.

DEER2021 Water Heater Energy Use Calculator Methodology

The DEER 2021 Water Heater Energy Use Calculator v4.2 (“Calculator”) has been 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. It conducts hourly calculations of energy consumption for each water heater based on input parameters, a 45 gallon per day (gpd) water use profile, an ambient air temperature profile and other assumptions, which are listed below. Note that the 24-hour hot water draw profile results in a total consumption of 45 gallons per day and is shown in comparison to SRCC’s standard 64 gallon per day profile, which was previously used for the CSI Thermal Program. Since the scope of this project is limited to Single Family Residential water heaters, this discussion of the Calculator is limited to that application.

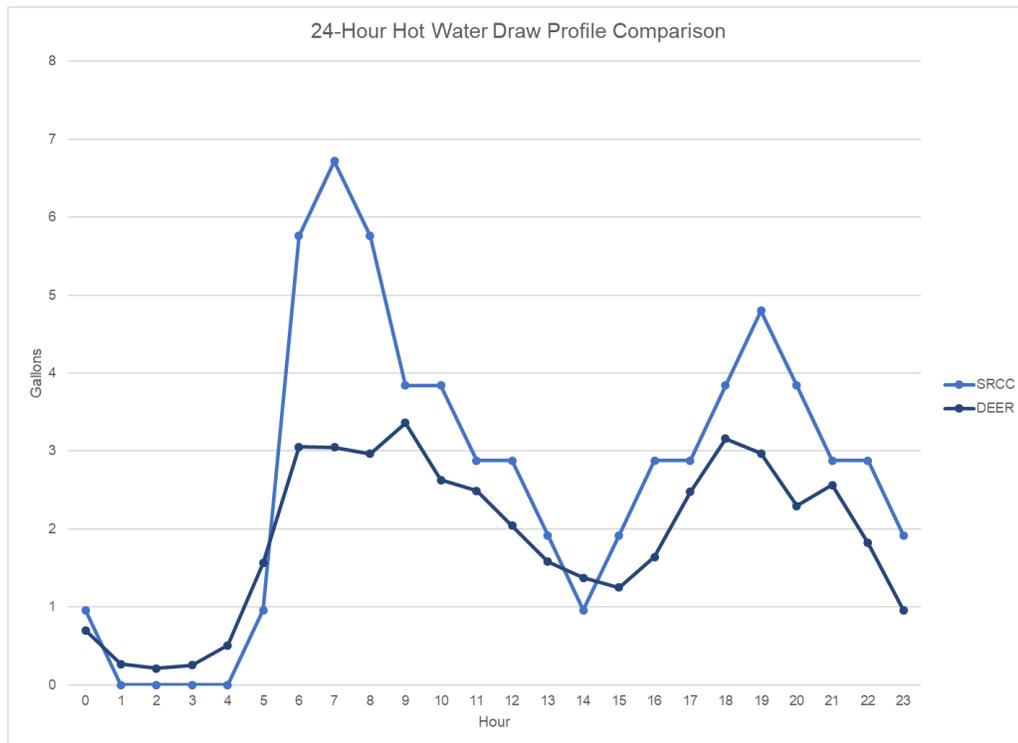
Table 2: DEER2021 Calculator Constants

VARIABLE	DESCRIPTION	VALUE
SETPPOINT TEMPERATURE (T_{SET})	Hot water setpoint temperature	135°F
TANK STRATIFICATION	Fully mixed, 1 node at setpoint temperature	135°F
CP/P	Specific heat/density of water	8.2 Btu/(gal • °F)

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

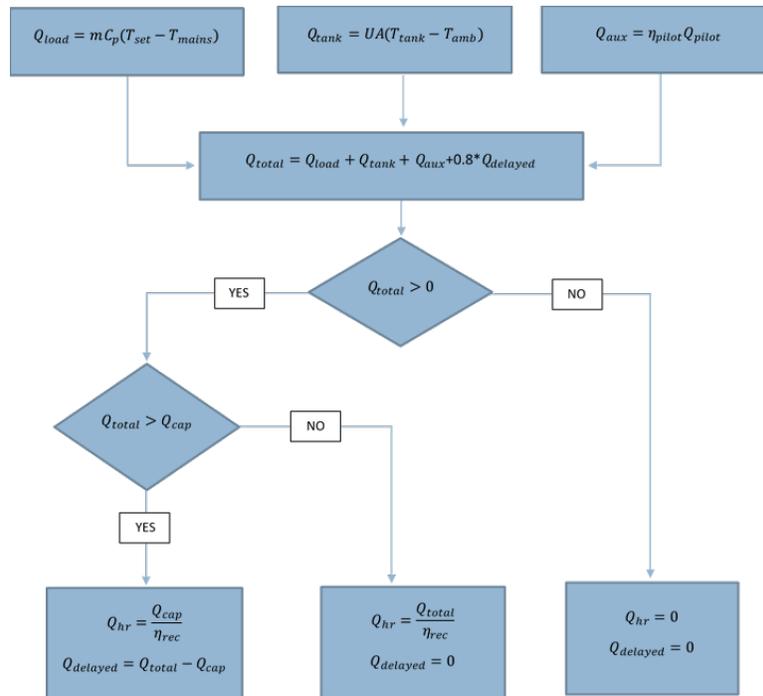
CACZ	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	49.5	48.7	48.6	49.0	50.5	52.0	53.2	54.0	54.1	53.4	52.2	50.8
2	53.7	52.3	52.1	52.8	55.6	58.4	60.8	62.3	62.5	61.2	58.9	56.2
3	54.5	53.4	53.3	53.8	55.8	57.8	59.6	60.7	60.8	59.9	58.2	56.2
4	55.7	54.1	54.0	54.8	57.7	60.7	63.3	64.9	65.0	63.7	61.2	58.3
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

Table 4: Hot Water Draw Profiles



Hourly Calculations – Gas Storage Water Heater

The CPUC Hot Water Calculator performs the following hourly calculation for storage gas water heaters over one complete year for each CA climate zone. The load energy (Q_{load}), tank losses (Q_{tank}), pilot energy (Q_{aux}) and delayed energy from the previous hour ($Q_{delayed}$) are added to obtain the total load for the hour (Q_{total}). This is then compared to the delivery capacity. If less than capacity, the energy consumed for the hour (Q_{hr}) is calculated by dividing by the recovery efficiency. If the load for the hour is greater than the capacity, it is capped at the capacity value and divided by the recovery efficiency to obtain the energy consumed for the hour. The remainder becomes the delayed energy for the next hour. If the total load is less than zero, the energy consumed for the hour is rounded to zero. The process is then repeated for the next hour. The total annual energy consumption is then the sum of each hourly value over the year.



Hourly Calculations – Gas Tankless Water Heater

The CPUC Hot Water Calculator performs the following hourly calculation for tankless gas water heaters over one complete year for each CA climate zone. The load energy (Q_{load}), tank losses (Q_{tank}), and delayed energy from the previous hour ($Q_{delayed}$) are added to obtain the total load for the hour (Q_{total}). This is then compared to the delivery capacity. If less than capacity, the energy consumed for the hour (Q_{hr}) is calculated by dividing by the recovery efficiency. If the load for the hour is greater than the capacity, it is capped at the capacity value and divided by the recovery efficiency to obtain the energy consumed for the hour. The remainder becomes the delayed energy for the next hour. If the total load is less than zero, the energy consumed for the hour is rounded to zero. The process is then repeated for the next hour. The total annual energy consumption is then the sum of each hourly value over the year.

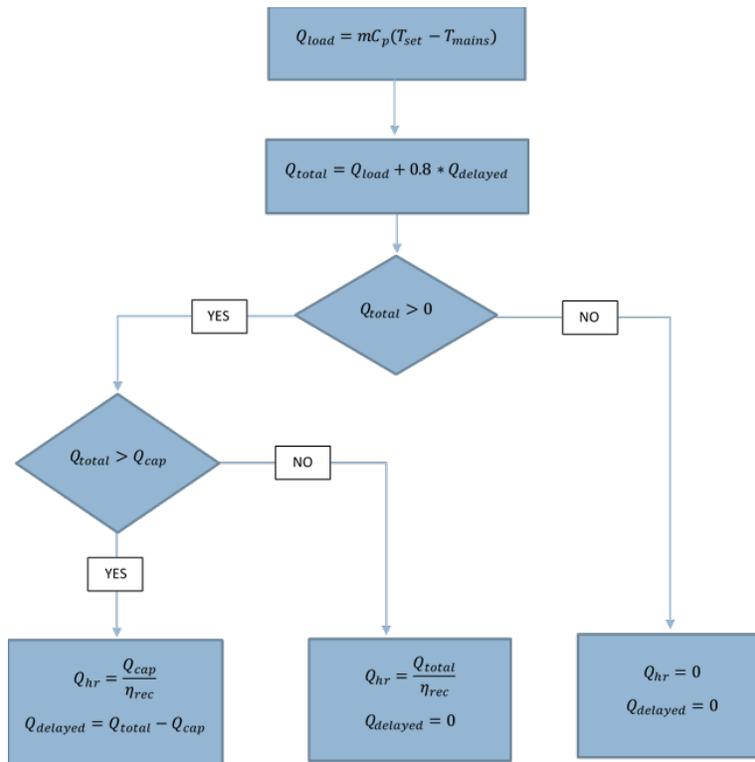


Table 5: Hourly Inputs to DEER Calculator for Gas Water Heaters

VARIABLE	DESCRIPTION	NOTES/SOURCE
$m(h)$	Mass of cold water from the mains entering the tank over the hour (h)	Hot water load table
T_{set}	Hot water setpoint temperature	135°F
$T_{mains}(h)$	Mains water temperature for the hour (h)	Water mains table
$T_{amb}(h)$	Ambient air temperature for the hour (h)	Ambient air table
UA	Tank loss	Constant for water heater
η_{pilot}	Pilot heating efficiency	Constant for water heater
Q_{pilot}	Pilot energy use	Constant for water heater
$Q_{delayed}(h-1)$	Delayed energy from the previous hour (h-1)	
Q_{cap}	Delivery capacity	Constant for water heater
C_p/ρ	Specific heat/density of water	8.2 Btu/(gal • F)
η_{rec}	Recovery efficiency	Constant for water heater

Table 6: Hourly Outputs from DEER Calculator for Gas Water Heaters

$Q_{hr}(h)$	Energy consumption for the hour (h)	Summed for total annual energy consumption
$Q_{delayed}(h)$	Delayed energy for the hour (h)	Used in calculation for next hour (h+1)

Modeling Result Comparison

Models of the reference water heaters listed were developed within the TRNSYS platform utilizing the inputs and assumptions of the DEER Calculator for Single Family Homes. The purpose of the modeling of the reference water heaters is to confirm and validate the new TRNSYS models in comparison to the DEER Calculator. The annual energy consumption of the two designated reference water heaters estimated by the DEER Water Heating Calculator and the new TRNSYS models is reported below. As is evident, the annual energy consumption of each reference water heater predicted by the new TRNSYS models mirrors the consumption reported by the DEER water heater calculator for the associated 45 gpd draw profile.

Table 7: Annual Energy Consumption for Reference Water Heaters in Single Family Homes

CACZ	STOR_UEF-GAS-050GAL-MD-0.56UEF (THERMS)		INST_UEF-GAS-LT200KBTUH-MD-0.81UEF (THERMS)	
	DEER 45	TRNSYS 45	DEER 45	TRNSYS 45
1	238	238	136	136
2	221	221	126	126
3	222	222	126	127
4	215	214	123	123
5	225	225	128	129
6	208	208	119	119
7	206	206	118	118
8	202	202	116	116
9	202	202	116	116
10	201	201	115	115
11	204	204	117	117
12	211	211	120	121
13	202	202	115	116
14	206	205	118	118
15	170	170	97	97
16	236	236	135	135

Similarly, the total energy contained in the hot water set by the 45 gpd DEER load profile, relative to the incoming water temperature, has been modeled using TRNSYS. The results are given below, compared to the results from the DEER calculator for each climate zone.

Table 8: Annual Energy Load in the 45 gpd DEER Hot Water Draw Pattern

CACZ	DEER 45 (THERMS)	TRNSYS 45 (THERMS)
1	113	113
2	105	105
3	106	106
4	102	102
5	107	107
6	99	99
7	98	98
8	97	97
9	97	97
10	96	96
11	98	98
12	101	101
13	96	96
14	98	98
15	81	81
16	113	113

SOLAR WATER HEATER MODELING

The primary objective of the project is the estimation of the annual energy consumption of several representative solar water heating systems using gas backup water heaters, consistent with the methodology used in the DEER Water Heating Calculator. This builds on the modeling work conducted for the two reference water heaters and applies similar TRNSYS models to representative solar water heaters. Those chosen systems consist of 10 pairs of systems (configurations), each pair made up of one system that uses a storage tank-type gas water heater and a second that uses a tankless gas water heater. Each pair is identical in design, aside from the backup water heater as shown in the table below. The schematics for each type are shown in detail in Appendix B. Additional information on the performance metrics reported for solar water heaters can be found in Appendix C.

For each system, the OG-300 certification number granted by ICC-SRCC is provided. Details on each certification can be found on the SRCC Rating Directory at www.solar-rating.org.

The same collector is used in each pair of systems, and it is listed along with the quantity to be installed in the system, OG-100 certification number, type and total area. The DOE Hot Water Draw Pattern specified for the determination of Uniform Energy Factor (UEF) is listed for each, per the [Solar Uniform Energy Factor Procedure for Solar Water Heating Systems \(ICC 900/SRCC 300 – 2020, Appendix A\)](#). The effective area is also provided, which normalizes the collector area in order to account for the variation in different solar thermal collector technologies. The result, provided in square meters, permits the thermal efficiency performance of different collectors to be compared on area basis. It does not, however, account for other system variations, such as total storage volume, heat exchanger effectiveness or control system logic.

Table 9: Representative Solar Water Heating System Pairs

CONFIG	MANUFACTURER	TYPE	OG-100 NO.	QTY	COLLECTOR(S)		
					TYPE*	TOTAL AREA (ft ²)	EFFECTIVE AREA (m ²)
A	Rheem	Pumped	2009057C	1	GFP	24.6	1.43
B	Rheem	Pumped	2009057B	1	GFP	32.8	1.95
C	Rheem	Pumped	2009057A	1	GFP	40.9	2.43
D	Heliodyne	ICS	10002030	1	ICS	25.7	1.29
E	Heliodyne	Pumped	2010115A	1	GFP	40.3	2.45
F	Heliodyne	Pumped	2010115C	2	GFP	53.9	3.25
G	GE Appliances	ICS	10002086	1	ICS	25.7	1.58
H	SunEarth	Pumped	2007032A	2	GFP	81.8	4.85
I	Heliodyne	Pumped	2010115A	1	GFP	40.3	2.45
J	GREENoneTEC	ICS	10001930	1	ICS	25.7	0.84

* GFP: Glazed Flat Plate, ICS: Integrated Collector Storage

Table 10: Individual Representative Solar Water Heating Systems

STORAGE GAS TANK-TYPE BACKUP			TANKLESS GAS BACKUP		
CONFIG	OG-300 NO.	MODEL	CONFIG	OG-300 NO.	MODEL
A1	30003878	RS65-24BP-2G	A2	30003879	RS65-24BP-TG
B1	30003884	RS65-32BP-2G	B2	30003886	RS65-32BP-TG
C1	30003885	RS65-40BP-2G	C2	30003887	RS65-40BP-TG
D1	30004228	HICS 200-G	D2	30004229	HICS 200-GT
E1	30004247	HPAS 1 410 G 80 AC D Z	E2	30004248	HPAS 1 410 G 80 AC S F
F1	2009036H	HPAK 016 2 406 G 80 ACD Z	F2	2010136E	HPAK 016 2 406 G 80 ACS F
G1	30004286	GT50C10BAM-G	G2	30004292	GT50C10BAM-TG
H1	2001001S	TE80P-120-2G	H2	2008024R	TE80P-120-TLG
I1	2011141B	HPAK 016 1 410 G 80 ACD Z	I2	2010136G	HPAK 016 1 410 G 80 ACS F
J1	30004078	Solpal Plus L-G	J2	30004079	Solpal Plus L-GT

TRNSYS Solar Water Heater Energy Use Calculator Methodology

Models were created using the TRNSYS energy software for each of the representative sample water heating systems in order to estimate the annual energy consumption of each. The models utilized the same assumptions for hot water draws, water mains temperatures, ambient air temperature, setpoint, tank stratification, and fluid setpoint as the DEER Water Heater Calculator and the associated TRNSYS models. To this, the models added the California Climate Zone v2 weather files to provide the beam, diffuse and longwave (infrared) radiation, ambient temperature and wind speed at the collector throughout the year for each location.

Each solar collector was modeled using an installation configuration similar that used to determine the SRCC OG-300 performance ratings. Each collector is assumed to be oriented due south and installed at the optimum slope determined for each climate zone, as shown below. The length of piping in the solar loop (from the collector to the tank or backup water heater) is assumed to be 25 feet in each direction, fully insulated.

The TRNSYS models operate to 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, along with the degree to which the energy requested is satisfied by the system.

Summaries of the results are shown graphically for CA Climate Zones 6 and 9 below, and the full dataset for each climate zone is provided in Appendix A. The annual energy savings are calculated relative to the same technology. Therefore, for solar water heaters with storage type backup water heaters, their savings are shown relative to the reference storage water heater. And for solar water heaters with tankless backups, the savings are relative to the tankless reference water heater. Results are also provided using the Coefficient of Performance (COP). This is calculated as the ratio of the load and Q_{aux} for each system.

It should be noted that actual energy savings will vary with both use and location. The analyses conducted assume an identical use profile repeatedly daily. Changes to the timing or total of hot water draws will impact actual savings. Other influences will include collector installation direction, angle and 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.

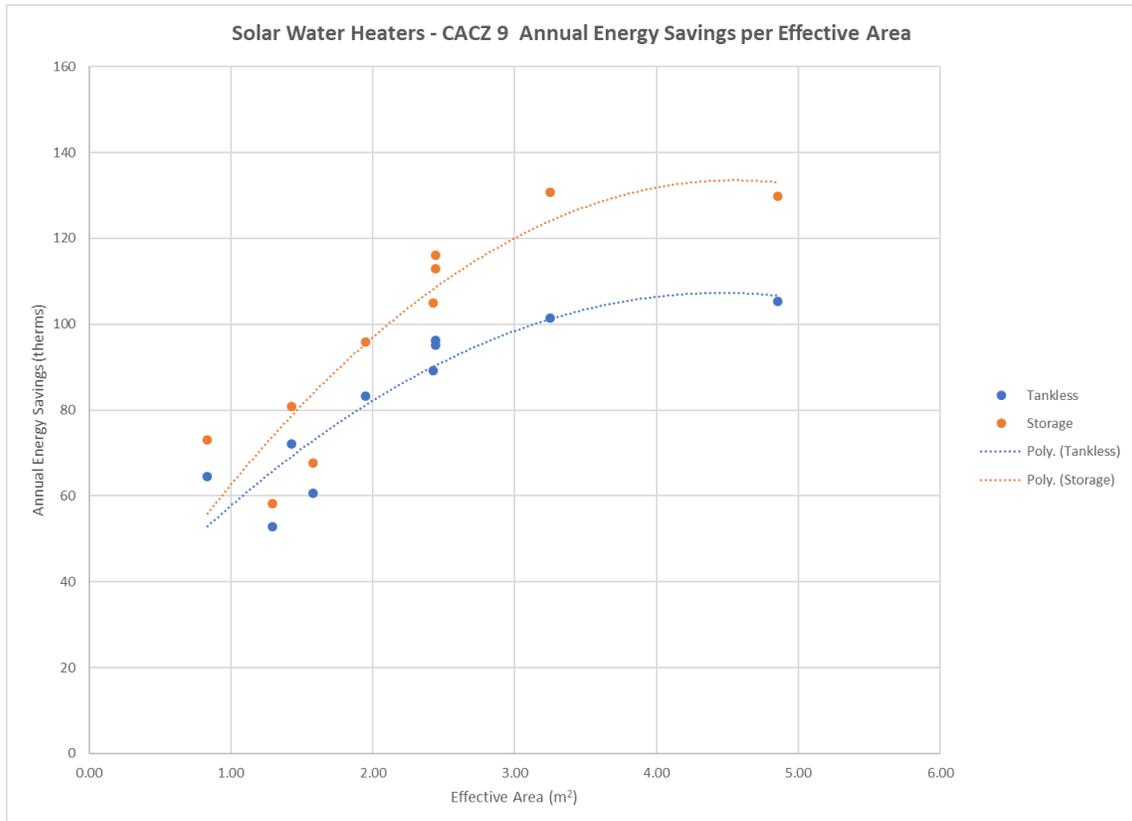
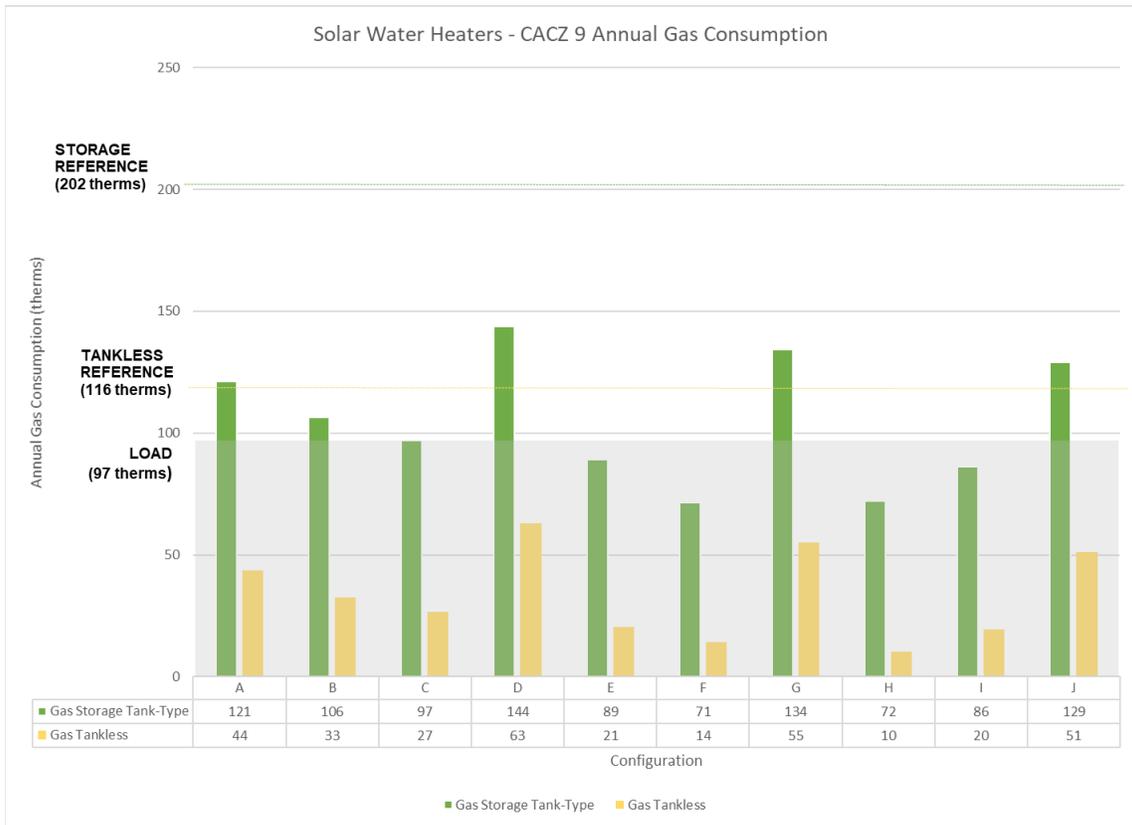
While the absolute savings for any given project and installation will vary, models of this type can be used to compare the performance and savings associated with different technologies and system types. By comparing these technologies on a consistent basis – with the same installation, usage and environmental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

Table 11: Solar Water Heater Annual Results for CA Climate Zone 9

CONFIG	LOAD (therms)	A _G (ft ²)	A _{EFF} (ft ²)	GAS STORAGE TANK-TYPE				GAS TANKLESS			
				OG-300 No.	Q _{aux} (therms)	AES (therms)	COP	OG-300 No.	Q _{aux} (therms)	AES (therms)	COP
A	99	25	15.4	30003878	129	79	0.8	30003879	48	71	2.1
B	99	33	21.0	30003884	113	95	0.9	30003886	35	84	2.8
C	99	41	26.1	30003885	103	105	1.0	30003887	28	91	3.5
D	99	26	13.9	30004228	149	59	0.7	30004229	65	54	1.5
E	99	40	26.3	30004247	94	115	1.1	30004248	21	98	4.8
F	99	54	35.0	2009036H	76	132	1.3	2010136E	13	106	7.7
G	99	26	17.0	30004286	140	69	0.7	30004292	57	62	1.7
H	99	82	52.2	2001001S	75	133	1.3	2008024R	9	110	10.7
I	99	40	26.3	2011141B	93	115	1.1	2010136G	20	99	5.0
J	99	26	9.0	30004078	133	75	0.7	30004079	53	67	1.9
REF	99	0			208		0.5		119		0.8

Table 12: Solar Water Heater Annual Results for CA Climate Zone 9

CONFIG	LOAD (therms)	A _G (ft ²)	A _{EFF} (ft ²)	GAS STORAGE TANK-TYPE				GAS TANKLESS			
				OG-300 No.	Q _{aux} (therms)	AES (therms)	COP	OG-300 No.	Q _{aux} (therms)	AES (therms)	COP
A	97	25	1.43	30003878	121	81	0.8	30003879	44	72	2.2
B	97	33	1.95	30003884	106	96	0.9	30003886	33	83	3.0
C	97	41	2.43	30003885	97	105	1.0	30003887	27	89	3.6
D	97	26	1.29	30004228	144	58	0.7	30004229	63	53	1.5
E	97	40	2.44	30004247	89	113	1.1	30004248	21	95	4.7
F	97	54	3.25	2009036H	71	131	1.4	2010136E	14	101	6.7
G	97	26	1.58	30004286	134	68	0.7	30004292	55	61	1.8
H	97	82	4.85	2001001S	72	130	1.3	2008024R	10	105	9.4
I	97	40	2.44	2011141B	86	116	1.1	2010136G	20	96	4.9
J	97	26	0.84	30004078	129	73	0.7	30004079	51	65	1.9
REF	97	0			202		0.5		116		0.8



Uniform Energy Factor (UEF)

The Uniform Energy Factor (UEF) metric was also modeled in the TRNSYS platform for each solar water heating system based on the [Solar Uniform Energy Factor Procedure for Solar Water Heating Systems \(ICC 900/SRCC 300 – 2020, Appendix A\)](#). The specification establishes the appropriate DOE Draw Pattern based on the total gross solar collector area of the system. The DOE 24-hour test is then simulated based on the DOE test specification coupled with the weather and irradiance profiles in the SUEF specification. The results are provided in the table below.

Table 13: Solar Water Heater UEF Results

CONFIG	A _G (ft ²)	A _{EFF} (ft ²)	GAS STORAGE			GAS TANKLESS		
			OG-300 NO.	UEF DRAW	UEF	OG-300 NO.	UEF DRAW	UEF
A	25	15.4	30003878	Low	1.00	30003879	Low	1.68
B	33	21.0	30003884	Low	1.22	30003886	Low	2.66
C	41	26.1	30003885	Medium	1.64	30003887	Medium	999
D	26	13.9	30004228	Low	1.02	30004229	Low	1.90
E	40	26.3	30004247	Medium	1.57	30004248	Medium	999
F	54	35.0	2009036H	Medium	2.17	2010136E	Medium	999
G	26	17.0	30004286	Low	1.15	30004292	Low	2.44
H	82	52.2	2001001S	High	2.81	2008024R	High	999
I	40	26.3	2011141B	Medium	1.57	2010136G	Medium	999
J	26	9.0	30004078	Low	1.14	30004079	Low	2.13
REF	0	0		Medium	0.56		Medium	0.81

Per the ENERGY STAR Residential Water Heater Specification, v4.0, any solar water heating system with a gas backup qualifies for certification under the program if the UEF value is 1.80 or higher. Those qualifying are formatted with bold text.

Because the UEF metric for solar water heaters is highly non-linear, the value associated with some systems will become extremely large for some system types. Any value over 999 is truncated and reported as 999. A comparison of the SUEF values and annual energy savings for a given climate zone shows that those reporting 999 have very low annual energy consumption values.

Electrical Energy Consumption Results

Some 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. This energy consumption is unique to solar water heaters and therefore must be accounted for in the calculation of net energy savings. In these calculations, it is referred to as parasitic energy (Q_{par}).

Peak electrical energy use is of concern in each climate zone on particular times of the day and year. Therefore, the average hourly electrical energy consumption was modeled on a monthly basis for each system

and each climate zone. An example is provided below for the month of September in each climate zone for system 2001001S.

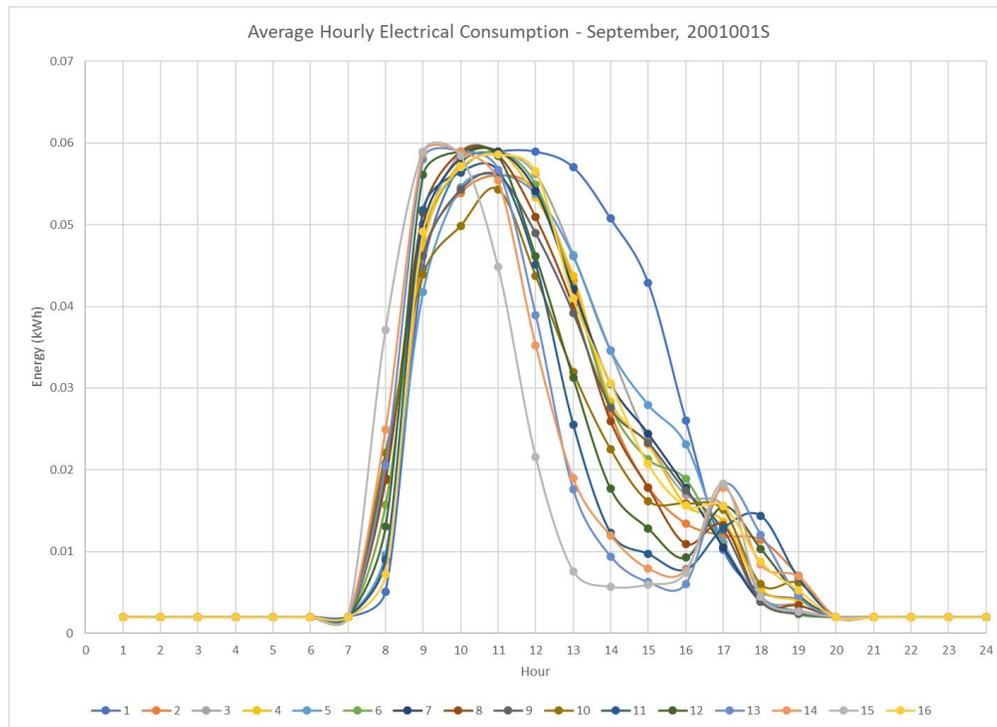


Figure 1: September Average Hourly Electrical Consumption per Climate Zone - SWH System 2001001S

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 backups in California single-family homes. The conditions and assumptions were modeled after those used in the CPUC DEER Hot Water Calculator. Models of reference storage and tankless gas water heaters were created in the TRNSYS energy modeling software platform in order to compare the annual energy consumption results with those generated by the DEER Calculator. Using similar assumptions and inputs, the results were virtually identical.

TRNSYS models were then created for 20 solar water heating systems using the same assumptions and inputs as the reference water heaters. The annual energy consumption for each system in each CA climate zone was reported for comparison with the reference water heaters. Various other measures of performance, including COP, effective area and annual energy savings were also reported. Additional modeling was conducted to produce a Uniform Energy Factor rating for each solar water heating system per the methodology used by the U.S. EPA's ENERGY STAR® Residential Water Heater Specification. A final set of models provided the average hourly parasitic energy load for each solar water heating system by month and climate zone. The parasitic energy draw represents the total additional electrical energy consumed by the various solar water heaters in order to operate their pumps, sensors and controllers.

Appendix A: Solar Water Heater Annual Energy Dataset

The following table details the individual annual energy ratings for each solar water heating system in each CA climate zone derived from the TRNSYS modeling described in this report. Each associated parameter is also described below:

Configuration: Solar water heater configuration pair

Backup: Backup water heater installed in the solar water heating system (gas storage or gas tankless)

OG-300 Number: Certification number associated with the solar water heating system from the ICC-SRCC OG-300 program. Certification information available at www.solar-rating.org. Note that performance values provided in the OG-300 program use a different set of assumptions than those used for this study, which are specific to California.

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

Q_Delivered (Q_{DEL}): Total annual energy imparted by the hot water heater and delivered to meet the load in therms. Energy measured as the difference in temperature between the delivered hot water and the input water temperature, multiplied by the density and specific heat of water.

Q_Required (Q_{LOAD}): Total annual energy contained within the DEER hot water load for each CA climate zone. Energy measured as the difference in temperature between the requested hot water draw pattern and the input water temperature, multiplied by the density and specific heat of water.

Q_Parasitics (Q_{PAR}): Total annual energy consumed by electrical components within the solar water heating system. Includes circulating pumps, controls and sensors. Note that some systems are passive, not requiring any additional electrical energy. Reported in kWh and equivalent gas therms.

Q_Auxilliary_Gas (Q_{AUX}): Total annual energy output of the auxiliary gas water heater in therms.

Eff_Aux_Gas (η_{AUX}): Gas auxiliary water heater efficiency.

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

Gas_Therm: Total quantity of gas consumed by the solar water heating system to meet the 45 gpd DEER load in the specified climate zone.

Elec_kWh: Total additional electrical power consumed by the solar water heating system to operate and meet the load in the specified climate zone.

Config.	Backup	OG-300 No.	CACZ	Q_Delivered	Q_Required	Q_Parasitics	Q_Aux_Gas	Eff_Aux_Gas	EffectiveArea	Gas_Therms	Elec_kWh
A	Storage	30003878	1	113.15	113.22	5.16	132.62	0.744	1.43	178.2	151.4
A	Storage	30003878	2	105.29	105.34	5.06	107.06	0.741	1.43	144.5	148.3

A	Storage	30003878	3	105.56	105.59	5.31	108.66	0.741	1.43	146.6	155.8
A	Storage	30003878	4	102.32	102.35	5.34	100.98	0.740	1.43	136.4	156.6
A	Storage	30003878	5	107.19	107.22	5.28	105.44	0.741	1.43	142.3	155.0
A	Storage	30003878	6	99.23	99.25	5.52	95.15	0.739	1.43	128.8	161.8
A	Storage	30003878	7	98.12	98.14	5.49	93.89	0.739	1.43	127.1	161.1
A	Storage	30003878	8	96.56	96.58	5.51	88.93	0.738	1.43	120.6	161.7
A	Storage	30003878	9	96.50	96.51	5.25	89.41	0.738	1.43	121.2	154.0
A	Storage	30003878	10	96.09	96.11	5.34	87.15	0.737	1.43	118.2	156.7
A	Storage	30003878	11	97.58	97.62	4.87	95.32	0.739	1.43	129.0	142.9
A	Storage	30003878	12	100.57	100.60	5.13	97.41	0.739	1.43	131.7	150.5
A	Storage	30003878	13	96.35	96.38	5.14	89.25	0.738	1.43	121.0	150.8
A	Storage	30003878	14	98.31	98.33	5.40	86.58	0.737	1.43	117.4	158.4
A	Storage	30003878	15	80.99	81.00	5.24	61.25	0.729	1.43	84.0	153.7
A	Storage	30003878	16	112.97	113.03	5.05	120.26	0.743	1.43	161.9	148.2
A	Tankless	30003879	1	113.22	113.22	5.29	68.46	0.835	1.43	82.0	155.1
A	Tankless	30003879	2	105.34	105.34	5.15	48.63	0.835	1.43	58.2	151.0
A	Tankless	30003879	3	105.59	105.59	5.40	49.24	0.835	1.43	59.0	158.5
A	Tankless	30003879	4	102.35	102.35	5.41	44.21	0.835	1.43	52.9	158.6
A	Tankless	30003879	5	107.22	107.22	5.36	45.49	0.835	1.43	54.5	157.3
A	Tankless	30003879	6	99.25	99.25	5.58	39.80	0.835	1.43	47.7	163.7
A	Tankless	30003879	7	98.14	98.14	5.57	39.26	0.835	1.43	47.0	163.2
A	Tankless	30003879	8	96.58	96.58	5.56	35.55	0.835	1.43	42.6	163.2
A	Tankless	30003879	9	96.51	96.51	5.31	36.34	0.835	1.43	43.5	155.8
A	Tankless	30003879	10	96.11	96.11	5.39	34.52	0.835	1.43	41.3	158.2
A	Tankless	30003879	11	97.62	97.62	4.86	42.82	0.835	1.43	51.3	142.5
A	Tankless	30003879	12	100.60	100.60	5.17	42.58	0.835	1.43	51.0	151.7
A	Tankless	30003879	13	96.38	96.38	5.11	37.82	0.835	1.43	45.3	150.0
A	Tankless	30003879	14	98.33	98.33	5.38	34.11	0.835	1.43	40.8	157.7
A	Tankless	30003879	15	81.00	81.00	5.10	20.03	0.835	1.43	24.0	149.5
A	Tankless	30003879	16	113.03	113.03	5.14	57.95	0.835	1.43	69.4	150.7
B	Storage	30003884	1	113.16	113.22	5.19	123.35	0.743	1.95	166.0	152.3
B	Storage	30003884	2	105.30	105.34	4.97	96.09	0.739	1.95	130.0	145.6
B	Storage	30003884	3	105.56	105.59	5.25	97.39	0.739	1.95	131.7	154.1
B	Storage	30003884	4	102.33	102.35	5.20	89.90	0.738	1.95	121.8	152.4
B	Storage	30003884	5	107.19	107.22	5.19	93.07	0.739	1.95	126.0	152.3
B	Storage	30003884	6	99.23	99.25	5.42	83.31	0.736	1.95	113.1	159.0
B	Storage	30003884	7	98.13	98.14	5.40	82.14	0.736	1.95	111.6	158.5

B	Storage	30003884	8	96.57	96.58	5.37	77.10	0.735	1.95	104.9	157.5
B	Storage	30003884	9	96.50	96.51	5.08	78.03	0.735	1.95	106.2	149.0
B	Storage	30003884	10	96.10	96.11	5.15	75.84	0.734	1.95	103.3	151.1
B	Storage	30003884	11	97.58	97.62	4.63	86.42	0.737	1.95	117.2	135.9
B	Storage	30003884	12	100.57	100.60	4.93	87.73	0.738	1.95	119.0	144.7
B	Storage	30003884	13	96.35	96.38	4.86	80.16	0.736	1.95	109.0	142.5
B	Storage	30003884	14	98.32	98.33	5.10	75.92	0.734	1.95	103.4	149.5
B	Storage	30003884	15	80.99	81.00	4.81	52.63	0.725	1.95	72.6	140.9
B	Storage	30003884	16	112.97	113.03	4.97	109.76	0.742	1.95	148.0	145.7
B	Tankless	30003886	1	113.22	113.22	5.29	59.63	0.835	1.95	71.4	155.0
B	Tankless	30003886	2	105.34	105.34	4.96	39.37	0.835	1.95	47.2	145.5
B	Tankless	30003886	3	105.59	105.59	5.28	39.41	0.835	1.95	47.2	154.7
B	Tankless	30003886	4	102.35	102.35	5.18	35.02	0.835	1.95	41.9	151.9
B	Tankless	30003886	5	107.22	107.22	5.23	34.44	0.835	1.95	41.3	153.4
B	Tankless	30003886	6	99.25	99.25	5.42	29.49	0.835	1.95	35.3	159.0
B	Tankless	30003886	7	98.14	98.14	5.41	29.05	0.835	1.95	34.8	158.7
B	Tankless	30003886	8	96.58	96.58	5.34	25.71	0.835	1.95	30.8	156.8
B	Tankless	30003886	9	96.51	96.51	5.04	27.13	0.835	1.95	32.5	147.9
B	Tankless	30003886	10	96.11	96.11	5.10	25.43	0.835	1.95	30.5	149.4
B	Tankless	30003886	11	97.62	97.62	4.55	35.78	0.835	1.95	42.8	133.4
B	Tankless	30003886	12	100.60	100.60	4.87	35.10	0.835	1.95	42.0	142.7
B	Tankless	30003886	13	96.38	96.38	4.74	30.89	0.835	1.95	37.0	139.2
B	Tankless	30003886	14	98.33	98.33	4.99	25.66	0.835	1.95	30.7	146.3
B	Tankless	30003886	15	81.00	81.00	4.57	14.23	0.835	1.95	17.0	134.2
B	Tankless	30003886	16	113.03	113.03	4.98	48.95	0.835	1.95	58.6	146.2
C	Storage	30003885	1	113.17	113.22	5.13	116.61	0.742	2.43	157.1	150.6
C	Storage	30003885	2	105.30	105.34	4.75	89.26	0.738	2.43	121.0	139.3
C	Storage	30003885	3	105.57	105.59	5.09	89.94	0.738	2.43	121.9	149.4
C	Storage	30003885	4	102.33	102.35	4.98	82.92	0.736	2.43	112.6	146.0
C	Storage	30003885	5	107.20	107.22	5.02	84.73	0.737	2.43	115.0	147.1
C	Storage	30003885	6	99.23	99.25	5.22	75.47	0.734	2.43	102.8	153.2
C	Storage	30003885	7	98.13	98.14	5.20	74.46	0.734	2.43	101.4	152.6
C	Storage	30003885	8	96.57	96.58	5.14	69.54	0.732	2.43	95.0	150.7
C	Storage	30003885	9	96.50	96.51	4.83	71.09	0.733	2.43	97.0	141.7
C	Storage	30003885	10	96.10	96.11	4.87	69.19	0.732	2.43	94.5	142.8
C	Storage	30003885	11	97.58	97.62	4.39	81.22	0.736	2.43	110.4	128.7
C	Storage	30003885	12	100.58	100.60	4.66	82.17	0.736	2.43	111.6	136.6

C	Storage	30003885	13	96.35	96.38	4.58	74.87	0.734	2.43	102.0	134.2
C	Storage	30003885	14	98.32	98.33	4.80	69.43	0.732	2.43	94.8	140.9
C	Storage	30003885	15	80.99	81.00	4.39	48.32	0.722	2.43	67.0	128.8
C	Storage	30003885	16	112.98	113.03	4.81	103.04	0.740	2.43	139.2	140.9
C	Tankless	30003887	1	113.22	113.22	5.20	53.49	0.835	2.43	64.1	152.4
C	Tankless	30003887	2	105.34	105.34	4.69	34.20	0.835	2.43	41.0	137.4
C	Tankless	30003887	3	105.59	105.59	5.06	33.50	0.835	2.43	40.1	148.4
C	Tankless	30003887	4	102.35	102.35	4.90	29.62	0.835	2.43	35.5	143.8
C	Tankless	30003887	5	107.22	107.22	5.00	27.85	0.835	2.43	33.3	146.7
C	Tankless	30003887	6	99.25	99.25	5.16	23.36	0.835	2.43	28.0	151.4
C	Tankless	30003887	7	98.14	98.14	5.15	23.17	0.835	2.43	27.7	151.1
C	Tankless	30003887	8	96.58	96.58	5.04	20.09	0.835	2.43	24.1	147.9
C	Tankless	30003887	9	96.51	96.51	4.73	22.09	0.835	2.43	26.5	138.8
C	Tankless	30003887	10	96.11	96.11	4.77	20.73	0.835	2.43	24.8	139.8
C	Tankless	30003887	11	97.62	97.62	4.29	31.79	0.835	2.43	38.1	125.8
C	Tankless	30003887	12	100.60	100.60	4.57	30.78	0.835	2.43	36.9	134.0
C	Tankless	30003887	13	96.38	96.38	4.46	26.83	0.835	2.43	32.1	130.7
C	Tankless	30003887	14	98.33	98.33	4.67	20.69	0.835	2.43	24.8	136.9
C	Tankless	30003887	15	81.00	81.00	4.14	11.91	0.835	2.43	14.3	121.3
C	Tankless	30003887	16	113.03	113.03	4.77	43.51	0.835	2.43	52.1	140.0
D	Storage	30004228	1	113.13	113.22	-	143.01	0.745	1.29	191.9	-
D	Storage	30004228	2	105.26	105.34	-	124.38	0.743	1.29	167.3	-
D	Storage	30004228	3	105.54	105.59	-	122.73	0.743	1.29	165.1	-
D	Storage	30004228	4	102.30	102.35	-	117.11	0.743	1.29	157.7	-
D	Storage	30004228	5	107.16	107.22	-	121.22	0.743	1.29	163.1	-
D	Storage	30004228	6	99.21	99.25	-	110.60	0.742	1.29	149.1	-
D	Storage	30004228	7	98.11	98.14	-	108.76	0.741	1.29	146.7	-
D	Storage	30004228	8	96.55	96.58	-	105.97	0.741	1.29	143.0	-
D	Storage	30004228	9	96.48	96.51	-	106.56	0.741	1.29	143.8	-
D	Storage	30004228	10	96.08	96.11	-	105.45	0.741	1.29	142.3	-
D	Storage	30004228	11	97.56	97.62	-	111.89	0.742	1.29	150.8	-
D	Storage	30004228	12	100.54	100.60	-	113.80	0.742	1.29	153.4	-
D	Storage	30004228	13	96.33	96.38	-	104.91	0.741	1.29	141.6	-
D	Storage	30004228	14	98.29	98.33	-	106.01	0.741	1.29	143.1	-
D	Storage	30004228	15	80.98	81.00	-	79.93	0.736	1.29	108.7	-
D	Storage	30004228	16	112.91	113.03	-	136.23	0.745	1.29	183.0	-
D	Tankless	30004229	1	113.22	113.22	-	78.54	0.835	1.29	94.1	-

D	Tankless	30004229	2	105.33	105.34	-	65.16	0.835	1.29	78.0	-
D	Tankless	30004229	3	105.59	105.59	-	62.69	0.835	1.29	75.1	-
D	Tankless	30004229	4	102.35	102.35	-	59.50	0.835	1.29	71.3	-
D	Tankless	30004229	5	107.22	107.22	-	60.59	0.835	1.29	72.6	-
D	Tankless	30004229	6	99.25	99.25	-	54.48	0.835	1.29	65.2	-
D	Tankless	30004229	7	98.14	98.14	-	53.41	0.835	1.29	64.0	-
D	Tankless	30004229	8	96.58	96.58	-	51.72	0.835	1.29	61.9	-
D	Tankless	30004229	9	96.51	96.51	-	52.47	0.835	1.29	62.8	-
D	Tankless	30004229	10	96.11	96.11	-	51.67	0.835	1.29	61.9	-
D	Tankless	30004229	11	97.61	97.62	-	57.89	0.835	1.29	69.3	-
D	Tankless	30004229	12	100.59	100.60	-	57.66	0.835	1.29	69.1	-
D	Tankless	30004229	13	96.37	96.38	-	51.83	0.835	1.29	62.1	-
D	Tankless	30004229	14	98.33	98.33	-	51.86	0.835	1.29	62.1	-
D	Tankless	30004229	15	80.99	81.00	-	36.13	0.835	1.29	43.3	-
D	Tankless	30004229	16	113.03	113.03	-	73.17	0.835	1.29	87.6	-
E	Storage	30004247	1	113.18	113.22	5.19	111.01	0.742	2.44	149.7	152.1
E	Storage	30004247	2	105.31	105.34	4.72	83.26	0.736	2.44	113.1	138.5
E	Storage	30004247	3	105.57	105.59	5.04	83.52	0.737	2.44	113.4	147.9
E	Storage	30004247	4	102.34	102.35	4.91	76.91	0.735	2.44	104.7	144.1
E	Storage	30004247	5	107.20	107.22	4.97	77.85	0.735	2.44	105.9	145.8
E	Storage	30004247	6	99.24	99.25	5.15	68.60	0.732	2.44	93.7	150.9
E	Storage	30004247	7	98.13	98.14	5.13	68.01	0.732	2.44	92.9	150.6
E	Storage	30004247	8	96.57	96.58	5.06	63.06	0.730	2.44	86.4	148.3
E	Storage	30004247	9	96.51	96.51	4.75	65.03	0.731	2.44	89.0	139.2
E	Storage	30004247	10	96.10	96.11	4.78	63.06	0.730	2.44	86.4	140.2
E	Storage	30004247	11	97.59	97.62	4.35	75.80	0.734	2.44	103.2	127.6
E	Storage	30004247	12	100.58	100.60	4.62	76.45	0.735	2.44	104.1	135.4
E	Storage	30004247	13	96.36	96.38	4.51	69.40	0.732	2.44	94.8	132.2
E	Storage	30004247	14	98.32	98.33	4.70	63.02	0.730	2.44	86.4	137.7
E	Storage	30004247	15	81.00	81.00	4.28	43.36	0.718	2.44	60.4	125.6
E	Storage	30004247	16	112.99	113.03	4.78	97.08	0.739	2.44	131.3	140.2
E	Tankless	30004248	1	113.22	113.22	5.13	47.76	0.835	2.44	57.2	150.5
E	Tankless	30004248	2	105.34	105.34	4.50	28.96	0.835	2.44	34.7	132.1
E	Tankless	30004248	3	105.59	105.59	4.84	27.96	0.835	2.44	33.5	141.9
E	Tankless	30004248	4	102.35	102.35	4.68	24.44	0.835	2.44	29.3	137.2
E	Tankless	30004248	5	107.22	107.22	4.78	21.84	0.835	2.44	26.2	140.2
E	Tankless	30004248	6	99.25	99.25	4.93	17.29	0.835	2.44	20.7	144.6

E	Tankless	30004248	7	98.14	98.14	4.92	17.62	0.835	2.44	21.1	144.4
E	Tankless	30004248	8	96.58	96.58	4.80	14.68	0.835	2.44	17.6	140.7
E	Tankless	30004248	9	96.51	96.51	4.49	17.13	0.835	2.44	20.5	131.8
E	Tankless	30004248	10	96.11	96.11	4.50	15.75	0.835	2.44	18.9	132.0
E	Tankless	30004248	11	97.62	97.62	4.10	27.30	0.835	2.44	32.7	120.2
E	Tankless	30004248	12	100.60	100.60	4.37	26.03	0.835	2.44	31.2	128.2
E	Tankless	30004248	13	96.38	96.38	4.23	22.48	0.835	2.44	26.9	124.1
E	Tankless	30004248	14	98.33	98.33	4.42	15.37	0.835	2.44	18.4	129.6
E	Tankless	30004248	15	81.00	81.00	3.85	8.70	0.835	2.44	10.4	112.8
E	Tankless	30004248	16	113.03	113.03	4.59	38.27	0.835	2.44	45.8	134.6
F	Tankless	2010136e	1	113.22	113.22	7.86	39.21	0.835	3.25	47.0	230.6
F	Tankless	2010136e	2	105.34	105.34	7.10	22.97	0.835	3.25	27.5	208.3
F	Tankless	2010136e	3	105.59	105.59	7.76	20.72	0.835	3.25	24.8	227.5
F	Tankless	2010136e	4	102.35	102.35	7.73	17.73	0.835	3.25	21.2	226.6
F	Tankless	2010136e	5	107.22	107.22	7.92	14.20	0.835	3.25	17.0	232.2
F	Tankless	2010136e	6	99.25	99.25	8.12	10.77	0.835	3.25	12.9	238.1
F	Tankless	2010136e	7	98.14	98.14	8.01	11.05	0.835	3.25	13.2	235.0
F	Tankless	2010136e	8	96.58	96.58	7.90	8.72	0.835	3.25	10.4	231.8
F	Tankless	2010136e	9	96.51	96.51	7.01	11.90	0.835	3.25	14.3	205.6
F	Tankless	2010136e	10	96.11	96.11	7.17	11.16	0.835	3.25	13.4	210.2
F	Tankless	2010136e	11	97.62	97.62	6.55	22.51	0.835	3.25	27.0	192.2
F	Tankless	2010136e	12	100.60	100.60	6.92	20.63	0.835	3.25	24.7	203.1
F	Tankless	2010136e	13	96.37	96.38	6.81	18.08	0.835	3.25	21.7	199.7
F	Tankless	2010136e	14	98.33	98.33	7.61	9.60	0.835	3.25	11.5	223.2
F	Tankless	2010136e	15	81.00	81.00	6.09	7.20	0.835	3.25	8.6	178.5
F	Tankless	2010136e	16	113.03	113.03	7.41	31.13	0.835	3.25	37.3	217.2
F	Storage	2009036h	1	113.19	113.22	7.99	101.50	0.740	3.25	137.1	234.3
F	Storage	2009036h	2	105.31	105.34	8.11	70.74	0.733	3.25	96.5	237.8
F	Storage	2009036h	3	105.58	105.59	8.63	70.82	0.733	3.25	96.6	253.0
F	Storage	2009036h	4	102.34	102.35	8.70	64.15	0.730	3.25	87.8	255.3
F	Storage	2009036h	5	107.21	107.22	8.96	63.41	0.730	3.25	86.9	262.7
F	Storage	2009036h	6	99.24	99.25	9.17	55.22	0.726	3.25	76.1	268.8
F	Storage	2009036h	7	98.14	98.14	9.07	54.68	0.726	3.25	75.3	266.0
F	Storage	2009036h	8	96.58	96.58	9.08	49.62	0.723	3.25	68.7	266.4
F	Storage	2009036h	9	96.51	96.51	8.23	51.61	0.724	3.25	71.3	241.4
F	Storage	2009036h	10	96.11	96.11	8.49	49.57	0.723	3.25	68.6	248.9
F	Storage	2009036h	11	97.59	97.62	7.48	64.94	0.731	3.25	88.9	219.3

F	Storage	2009036h	12	100.59	100.60	7.85	64.46	0.730	3.25	88.3	230.3
F	Storage	2009036h	13	96.36	96.38	7.78	58.19	0.728	3.25	80.0	228.1
F	Storage	2009036h	14	98.33	98.33	8.73	49.91	0.723	3.25	69.0	256.1
F	Storage	2009036h	15	81.00	81.00	7.54	33.94	0.707	3.25	48.0	221.1
F	Storage	2009036h	16	113.00	113.03	8.20	85.11	0.737	3.25	115.5	240.4
G	Storage	30004286	1	113.14	113.22	-	137.70	0.745	1.58	184.9	-
G	Storage	30004286	2	105.26	105.34	-	117.71	0.743	1.58	158.5	-
G	Storage	30004286	3	105.54	105.59	-	115.88	0.742	1.58	156.1	-
G	Storage	30004286	4	102.31	102.35	-	110.11	0.742	1.58	148.5	-
G	Storage	30004286	5	107.17	107.22	-	113.93	0.742	1.58	153.5	-
G	Storage	30004286	6	99.22	99.25	-	103.33	0.741	1.58	139.5	-
G	Storage	30004286	7	98.11	98.14	-	101.54	0.740	1.58	137.2	-
G	Storage	30004286	8	96.55	96.58	-	98.57	0.740	1.58	133.3	-
G	Storage	30004286	9	96.48	96.51	-	99.36	0.740	1.58	134.3	-
G	Storage	30004286	10	96.08	96.11	-	98.11	0.740	1.58	132.7	-
G	Storage	30004286	11	97.56	97.62	-	105.28	0.741	1.58	142.1	-
G	Storage	30004286	12	100.55	100.60	-	106.79	0.741	1.58	144.1	-
G	Storage	30004286	13	96.33	96.38	-	97.80	0.740	1.58	132.2	-
G	Storage	30004286	14	98.29	98.33	-	98.18	0.740	1.58	132.8	-
G	Storage	30004286	15	80.98	81.00	-	72.58	0.733	1.58	99.0	-
G	Storage	30004286	16	112.92	113.03	-	129.58	0.744	1.58	174.2	-
G	Tankless	30004292	1	113.22	113.22	-	73.32	0.835	1.58	87.8	-
G	Tankless	30004292	2	105.33	105.34	-	59.06	0.835	1.58	70.7	-
G	Tankless	30004292	3	105.59	105.59	-	56.30	0.835	1.58	67.4	-
G	Tankless	30004292	4	102.34	102.35	-	53.14	0.835	1.58	63.6	-
G	Tankless	30004292	5	107.21	107.22	-	53.68	0.835	1.58	64.3	-
G	Tankless	30004292	6	99.25	99.25	-	47.69	0.835	1.58	57.1	-
G	Tankless	30004292	7	98.14	98.14	-	46.65	0.835	1.58	55.9	-
G	Tankless	30004292	8	96.58	96.58	-	44.93	0.835	1.58	53.8	-
G	Tankless	30004292	9	96.51	96.51	-	45.94	0.835	1.58	55.0	-
G	Tankless	30004292	10	96.10	96.11	-	45.01	0.835	1.58	53.9	-
G	Tankless	30004292	11	97.61	97.62	-	52.33	0.835	1.58	62.7	-
G	Tankless	30004292	12	100.59	100.60	-	51.73	0.835	1.58	62.0	-
G	Tankless	30004292	13	96.36	96.38	-	46.00	0.835	1.58	55.1	-
G	Tankless	30004292	14	98.32	98.33	-	45.15	0.835	1.58	54.1	-
G	Tankless	30004292	15	80.98	81.00	-	30.30	0.835	1.58	36.3	-
G	Tankless	30004292	16	113.03	113.03	-	67.14	0.835	1.58	80.4	-

H	Storage	2001001s	1	113.20	113.22	4.69	96.28	0.739	4.85	130.3	137.7
H	Storage	2001001s	2	105.32	105.34	4.14	70.32	0.733	4.85	96.0	121.3
H	Storage	2001001s	3	105.58	105.59	4.49	69.52	0.732	4.85	94.9	131.6
H	Storage	2001001s	4	102.34	102.35	4.35	63.55	0.730	4.85	87.1	127.6
H	Storage	2001001s	5	107.21	107.22	4.41	62.25	0.730	4.85	85.3	129.4
H	Storage	2001001s	6	99.25	99.25	4.61	54.31	0.726	4.85	74.9	135.2
H	Storage	2001001s	7	98.14	98.14	4.60	53.79	0.725	4.85	74.2	134.9
H	Storage	2001001s	8	96.58	96.58	4.48	49.70	0.723	4.85	68.8	131.3
H	Storage	2001001s	9	96.51	96.51	4.15	52.23	0.724	4.85	72.1	121.7
H	Storage	2001001s	10	96.11	96.11	4.17	50.94	0.724	4.85	70.4	122.3
H	Storage	2001001s	11	97.60	97.62	3.81	65.21	0.731	4.85	89.2	111.8
H	Storage	2001001s	12	100.59	100.60	4.05	64.99	0.731	4.85	89.0	118.8
H	Storage	2001001s	13	96.37	96.38	3.97	59.13	0.728	4.85	81.2	116.5
H	Storage	2001001s	14	98.33	98.33	4.18	51.24	0.724	4.85	70.8	122.7
H	Storage	2001001s	15	81.00	81.00	3.64	36.47	0.711	4.85	51.3	106.9
H	Storage	2001001s	16	113.01	113.03	4.22	83.95	0.737	4.85	114.0	123.9
H	Tankless	2008024r	1	113.22	113.22	4.62	34.46	0.835	4.85	41.3	135.5
H	Tankless	2008024r	2	105.34	105.34	3.91	19.69	0.835	4.85	23.6	114.7
H	Tankless	2008024r	3	105.59	105.59	4.29	17.12	0.835	4.85	20.5	125.7
H	Tankless	2008024r	4	102.35	102.35	4.13	14.44	0.835	4.85	17.3	121.2
H	Tankless	2008024r	5	107.22	107.22	4.19	10.70	0.835	4.85	12.8	122.8
H	Tankless	2008024r	6	99.25	99.25	4.36	7.75	0.835	4.85	9.3	128.0
H	Tankless	2008024r	7	98.14	98.14	4.35	7.94	0.835	4.85	9.5	127.6
H	Tankless	2008024r	8	96.58	96.58	4.20	6.00	0.835	4.85	7.2	123.2
H	Tankless	2008024r	9	96.51	96.51	3.89	8.57	0.835	4.85	10.3	114.1
H	Tankless	2008024r	10	96.11	96.11	3.88	8.00	0.835	4.85	9.6	113.8
H	Tankless	2008024r	11	97.62	97.62	3.58	19.43	0.835	4.85	23.3	105.1
H	Tankless	2008024r	12	100.60	100.60	3.82	17.41	0.835	4.85	20.9	112.1
H	Tankless	2008024r	13	96.38	96.38	3.71	15.34	0.835	4.85	18.4	108.7
H	Tankless	2008024r	14	98.33	98.33	3.91	7.44	0.835	4.85	8.9	114.7
H	Tankless	2008024r	15	81.00	81.00	3.28	5.04	0.835	4.85	6.0	96.3
H	Tankless	2008024r	16	113.03	113.03	4.05	27.56	0.835	4.85	33.0	118.9
I	Tankless	2010136g	1	113.22	113.22	7.80	47.83	0.835	2.44	57.3	228.8
I	Tankless	2010136g	2	105.34	105.34	7.86	28.38	0.835	2.44	34.0	230.6
I	Tankless	2010136g	3	105.59	105.59	8.42	27.21	0.835	2.44	32.6	247.1
I	Tankless	2010136g	4	102.35	102.35	8.44	23.81	0.835	2.44	28.5	247.6
I	Tankless	2010136g	5	107.22	107.22	8.85	20.83	0.835	2.44	25.0	259.5

I	Tankless	2010136g	6	99.25	99.25	8.96	16.40	0.835	2.44	19.6	262.9
I	Tankless	2010136g	7	98.14	98.14	8.80	16.69	0.835	2.44	20.0	258.2
I	Tankless	2010136g	8	96.58	96.58	8.84	13.78	0.835	2.44	16.5	259.2
I	Tankless	2010136g	9	96.51	96.51	7.98	16.25	0.835	2.44	19.5	233.9
I	Tankless	2010136g	10	96.11	96.11	8.22	14.87	0.835	2.44	17.8	241.2
I	Tankless	2010136g	11	97.62	97.62	7.24	27.02	0.835	2.44	32.4	212.4
I	Tankless	2010136g	12	100.60	100.60	7.64	25.53	0.835	2.44	30.6	224.0
I	Tankless	2010136g	13	96.37	96.38	7.55	22.24	0.835	2.44	26.6	221.5
I	Tankless	2010136g	14	98.33	98.33	8.56	14.64	0.835	2.44	17.5	251.0
I	Tankless	2010136g	15	81.00	81.00	7.11	8.40	0.835	2.44	10.1	208.6
I	Tankless	2010136g	16	113.03	113.03	7.99	37.72	0.835	2.44	45.2	234.5
I	Storage	2011141b	1	113.18	113.22	7.79	112.90	0.742	2.44	152.2	228.6
I	Storage	2011141b	2	105.31	105.34	8.63	81.95	0.736	2.44	111.3	253.0
I	Storage	2011141b	3	105.58	105.59	8.95	83.28	0.736	2.44	113.1	262.4
I	Storage	2011141b	4	102.34	102.35	9.27	75.44	0.734	2.44	102.7	271.9
I	Storage	2011141b	5	107.20	107.22	9.35	77.26	0.735	2.44	105.1	274.3
I	Storage	2011141b	6	99.24	99.25	9.54	68.14	0.732	2.44	93.1	279.7
I	Storage	2011141b	7	98.13	98.14	9.41	67.42	0.732	2.44	92.1	275.9
I	Storage	2011141b	8	96.58	96.58	9.62	61.80	0.729	2.44	84.7	282.3
I	Storage	2011141b	9	96.51	96.51	8.91	62.75	0.730	2.44	86.0	261.5
I	Storage	2011141b	10	96.10	96.11	9.23	60.38	0.729	2.44	82.9	270.6
I	Storage	2011141b	11	97.59	97.62	8.22	73.26	0.734	2.44	99.9	240.9
I	Storage	2011141b	12	100.58	100.60	8.67	73.44	0.734	2.44	100.1	254.3
I	Storage	2011141b	13	96.36	96.38	8.65	66.43	0.731	2.44	90.9	253.6
I	Storage	2011141b	14	98.32	98.33	9.65	60.09	0.729	2.44	82.5	283.1
I	Storage	2011141b	15	81.00	81.00	8.81	39.62	0.714	2.44	55.5	258.5
I	Storage	2011141b	16	112.99	113.03	8.61	96.16	0.739	2.44	130.1	252.6
J	Storage	30004078	1	113.14	113.22	-	132.94	0.744	0.84	178.6	-
J	Storage	30004078	2	105.27	105.34	-	113.26	0.742	0.84	152.6	-
J	Storage	30004078	3	105.54	105.59	-	111.20	0.742	0.84	149.9	-
J	Storage	30004078	4	102.31	102.35	-	105.05	0.741	0.84	141.8	-
J	Storage	30004078	5	107.17	107.22	-	108.74	0.741	0.84	146.7	-
J	Storage	30004078	6	99.22	99.25	-	98.57	0.740	0.84	133.3	-
J	Storage	30004078	7	98.11	98.14	-	96.41	0.739	0.84	130.4	-
J	Storage	30004078	8	96.55	96.58	-	93.65	0.739	0.84	126.8	-
J	Storage	30004078	9	96.48	96.51	-	95.30	0.739	0.84	128.9	-
J	Storage	30004078	10	96.08	96.11	-	93.76	0.739	0.84	126.9	-

J	Storage	30004078	11	97.56	97.62	-	102.55	0.740	0.84	138.5	-
J	Storage	30004078	12	100.54	100.60	-	103.11	0.740	0.84	139.3	-
J	Storage	30004078	13	96.33	96.38	-	94.26	0.739	0.84	127.6	-
J	Storage	30004078	14	98.29	98.33	-	95.65	0.739	0.84	129.4	-
J	Storage	30004078	15	80.98	81.00	-	70.96	0.733	0.84	96.8	-
J	Storage	30004078	16	112.93	113.03	-	125.47	0.744	0.84	168.8	-
J	Tankless	30004079	1	113.22	113.22	-	68.93	0.835	0.84	82.6	-
J	Tankless	30004079	2	105.33	105.34	-	55.30	0.835	0.84	66.2	-
J	Tankless	30004079	3	105.58	105.59	-	52.47	0.835	0.84	62.8	-
J	Tankless	30004079	4	102.34	102.35	-	49.03	0.835	0.84	58.7	-
J	Tankless	30004079	5	107.21	107.22	-	49.28	0.835	0.84	59.0	-
J	Tankless	30004079	6	99.24	99.25	-	43.79	0.835	0.84	52.4	-
J	Tankless	30004079	7	98.13	98.14	-	42.42	0.835	0.84	50.8	-
J	Tankless	30004079	8	96.57	96.58	-	40.96	0.835	0.84	49.1	-
J	Tankless	30004079	9	96.50	96.51	-	42.71	0.835	0.84	51.2	-
J	Tankless	30004079	10	96.10	96.11	-	41.47	0.835	0.84	49.7	-
J	Tankless	30004079	11	97.60	97.62	-	50.28	0.835	0.84	60.2	-
J	Tankless	30004079	12	100.58	100.60	-	48.91	0.835	0.84	58.6	-
J	Tankless	30004079	13	96.35	96.38	-	43.34	0.835	0.84	51.9	-
J	Tankless	30004079	14	98.32	98.33	-	43.22	0.835	0.84	51.8	-
J	Tankless	30004079	15	80.98	81.00	-	29.28	0.835	0.84	35.1	-
J	Tankless	30004079	16	113.02	113.03	-	63.75	0.835	0.84	76.3	-

Appendix B: Solar Water Heating System Configuration Schematics

The solar water heating systems selected for modeling and study consist of 10 pairs, each made up of one that uses a storage tank-type and a second that uses a tankless gas water heater. The configuration used in each pair is identical in design, aside from the installed backup water heater. The configuration schematics are shown below. In each, the rectangle with dashed lines indicates the location of the storage or tankless backup gas water heater.

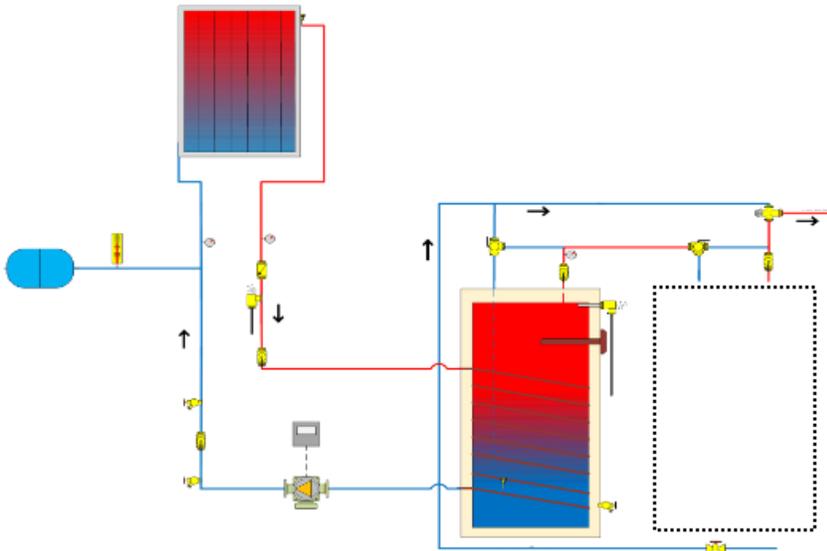


Figure 2: System Schematics for Configurations A, B, C (different collector for each)

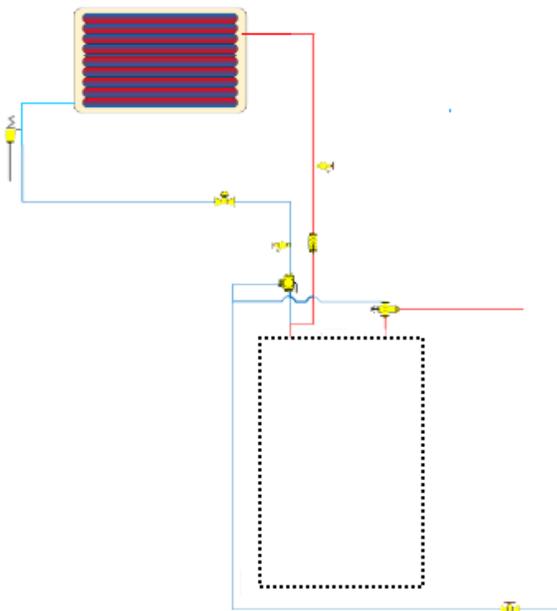


Figure 3: System Schematic for Configuration D

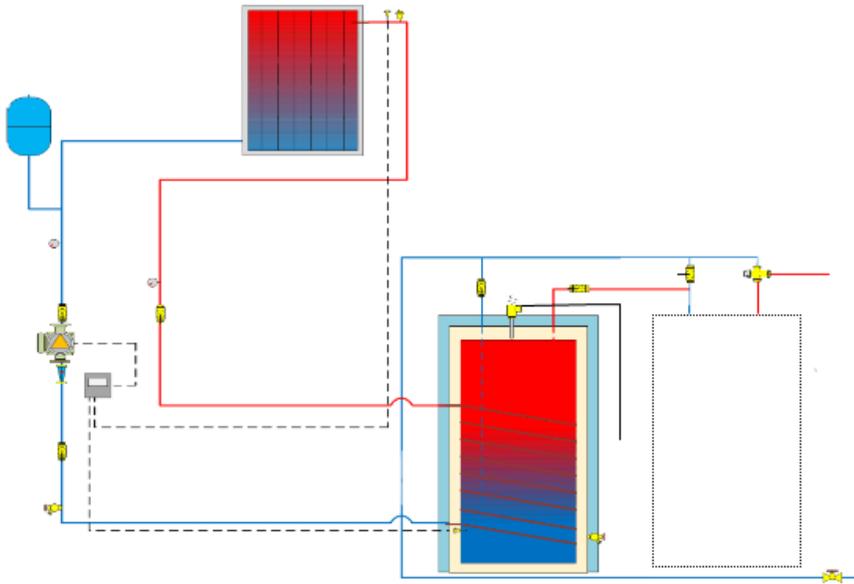


Figure 4: System Schematic Configuration E

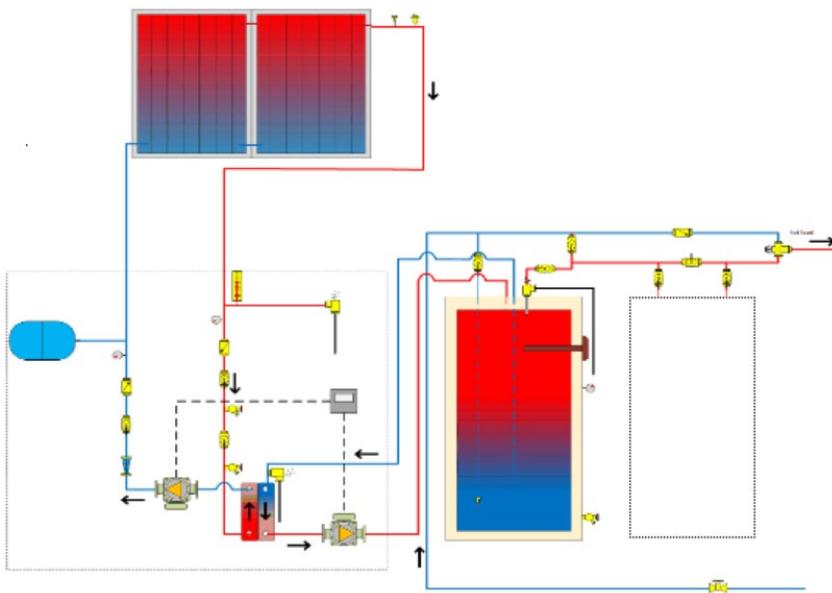


Figure 5: System Schematic Configuration F

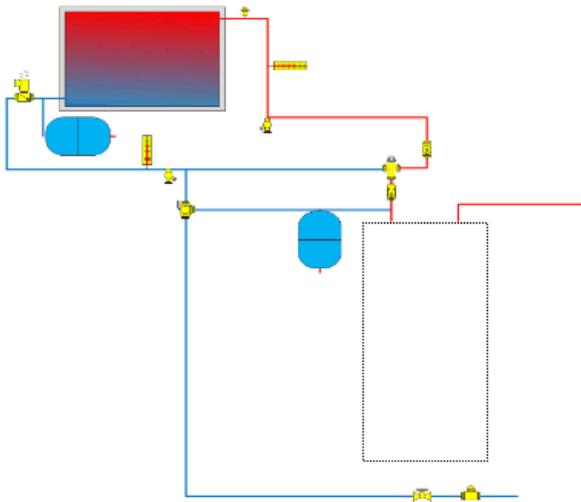


Figure 6: System Schematic Configuration G

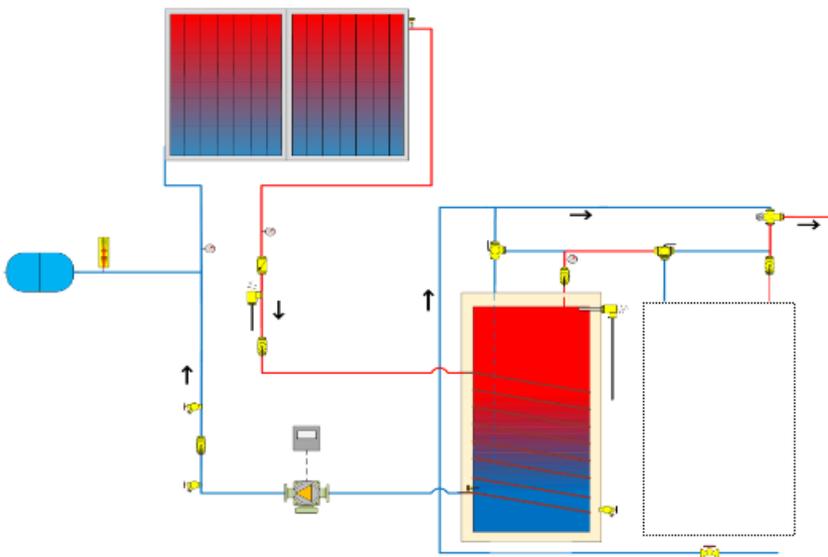


Figure 7: System Schematic Configuration H

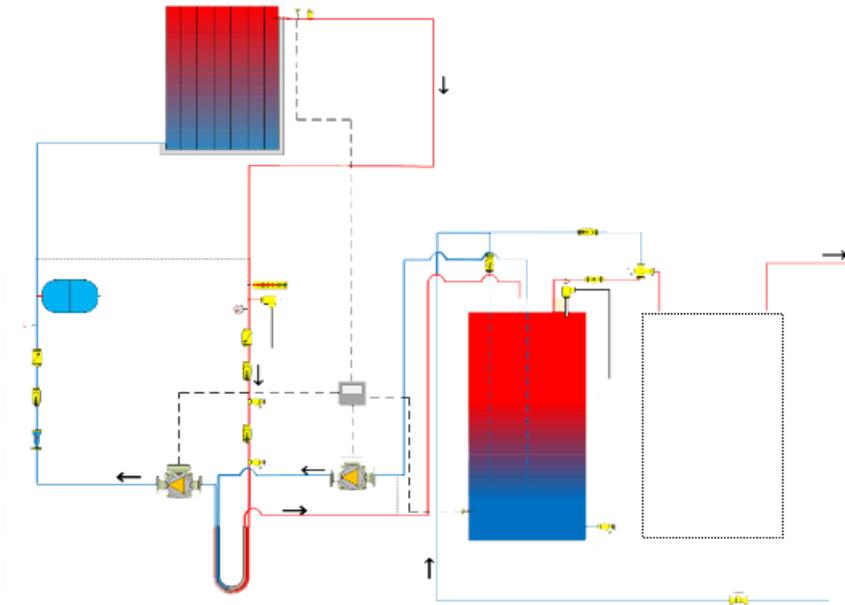


Figure 8: System Schematic Configuration I

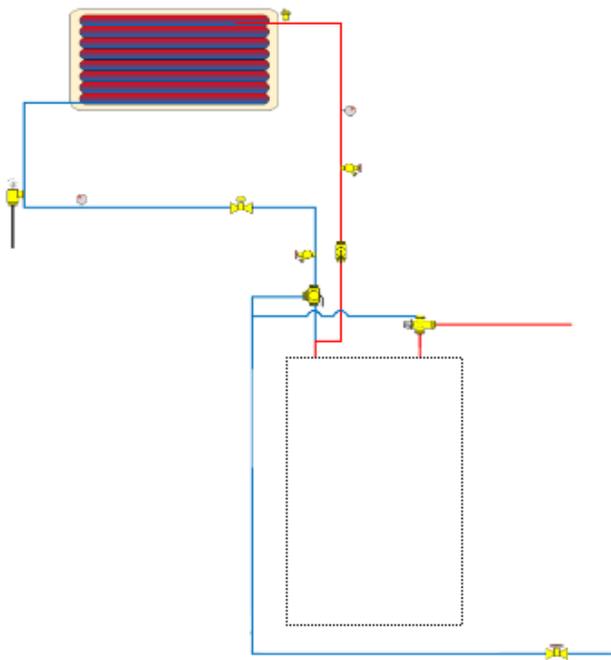


Figure 9: System Schematic Configuration J

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.

The results provided can be processed as desired to produce any or all metrics described below. Note that the metric will vary with the assumptions used. So, for example, the Solar Fraction value published with each OG-300 certification is based on the 64 gallon per day hot water load, ambient temperature profile, incoming water temperature assumptions, and installation details. Solar Fraction calculated using the performance data in this report would differ since it is based on the assumptions and load established in the DEER Hot Water Heater Calculator.

The available solar water heater performance metrics include the following:

Solar Fraction (SF). This metric describes the ratio of the energy contained within hot water that was derived from solar sources over a set period of time. Typically, this is reported on an annual basis.

$$SF = 1 - \left(\frac{Q_{AUX} + Q_{PAR}}{Q_{DEL}} \right)$$

Coefficient of Performance (COP). This metric is the ratio of the energy obtained in the hot water delivered to the load to the fuel energy consumed over a set period of time. Or put more simply, “what you get compared to what you paid for.”

$$COP = \frac{Q_{LOAD}}{Q_{AUX}}$$

Effective Area (A_{EFF}). Effective area is a metric developed to normalize the area associated with a collector in order 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 a given 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.

Solar Uniform Energy Factor (SUEF). The Solar Uniform Energy Factor is a metric developed for consistency with the Uniform Energy Factor metric established by the U.S. Department of Energy. The UEF metric is determined for traditional water heaters using First-Hour and 24-Hour test methods contained in [10 CFR 430, Subpart B, Appendix E](#). The DOE method did not address solar water heaters. Therefore, a new specification contained within Appendix A of the ICC 900/SRCC 300-2020 standard expands the methodology to address solar. Typically, Solar UEF is determined by means of energy modeling using software such as TRNSYS. SUEF is a non-linear metric.

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 of time. The appropriate reference water heater for these calculations must be determined by the user. The user must also 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.

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