Commercial-in-Confidence

TRNSYS modelling of solar hot water systems

Summary Report

Report: AU2011-124-P v.1

Provided by

SOLEM CONSULTING

Client: Heliodyne Inc.

Richmond, CA

Sept 2011

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The analysis is based on information supplied by Heliodyne Inc. and manufacturer data.

1 OVERVIEW

Heliodyne Inc. has commissioned SOLEM Consulting Pty Ltd to simulate the performance of a range of commercial solar thermal systems using the TRNSYS simulation environment. It is the aim of this study to determine the impact on annual system performance for a range of flow rates through two collector models, and two storage tank stratification configurations. The collectors tested were the Heliodyne GOBI 410 001 and Schuco CTE 220 CH 2 / CH 5. All system parameters between each comparative test of the collectors remained constant to ensure fair comparison of the results.

The data output presented in the summary report

- Energy balance breakdown (all energy gains and losses) monthly and annually.
- Solar yield from collector hourly, monthly and annually
- Average collector efficiency, monthly and annually.
- Fraction of load energy provided by solar collectors
- Plot of flow rate against annual energy saved
- Plot of flow rate against annual solar yield

2 SIMULATION DETAILS

Each simulation was undertaken using the TRNSYS simulation environment. The study was broken down into 6 simulation groups. These groups contained multiple simulations only varying the flow rate and corresponding pump electrical demand and pipe diameter. The details of each simulation group are provided in the tables below.

Table 1 Simulation overview

Simulation number	Details
Simulation 1 Base case	Heliodyne Gobi 410 001 collectors, 6 collectors per array with 4 arrays. All collectors in parallel. 1 simulation. This is the current standard installation practice by Heliodyne.
Simulation 2 parametric run	Schuco CTE 220 CH2 collectors, 16 collectors per array with 2 arrays. 7 corresponding sets of flow rate, electrical pump demand and pipe diameter were simulated. 7 simulations.
Simulation 3 parametric run	Heliodyne Gobi 410 001 collectors, 8 collectors per array and 3 arrays. 6 corresponding sets of flow rate, electrical pump demand and pipe diameter were simulated. 6 simulations.
Simulation 4	Repeat of simulation 1 except with a perfectly stratified storage tank. 1 simulation.
Simulation 5 parametric run	Repeat of simulation 2, except with a perfectly stratified storage tank. 7 simulations.
Simulation 6 parametric run	Repeat of simulation 3 except with a perfectly stratified storage tank. 6 simulations.

The corresponding sets of flow rate, pump electrical demand are given in Table 2 and Table 3 below.

Table 2 Hydraulic specifications for Simulation 2 and 5: Schuco CTE 220 CH2 collector

Simulation	Specific flow rate [GPM/ft^2]	Total flow rate [GPM]	Pipe size [Inch]	Speed [ft/s]	Estimated Head loss through 200' of pipe [ft]	16 collector array head loss [ft]	Recommended Pump:	Pump power [W]	Collector Area [m^2]
a	0.0057	5.3	3/4"	3.85	19.24	4.84	UP-26-96	205	86.08
b	0.0093	8.6	1"	3.5	13.52	4.84	UP-26-96	205	86.08
c	0.013	12	1"	4.9	24.21	4.84	UP-26-96	205	86.08
d	0.0167	15.5	1 1/4"	4.05	15.2	4.84	UP 43-75	215	86.08
e	0.02	18.5	1 1/4"	4.83	20.72	4.84	Up 32-160	400	86.08
f	0.0228	21	1 1/2"	4.84	12.17	4.84	UPS 32-80	220	86.08
g	0.0259	24	1 1/2"	4.34	15.38	4.84	UPS 32-160	400	86.08

Table 3 Hydraulic specifications for Simulation 3 and 6: Heliodyne Gobi 410 001 collector

Simulation	Specific flow rate [GPM/ft^2]	Total flow rate [GPM]	Pipe size [Inch]	Speed [ft/s]	Estimated Head loss through 200' of pipe [ft]	8 collector array head loss [ft]	Recommended Pump:	Pump power [W]	Collector Area [m^2]
Base	0.031	30	2"	NA	NA	NA	NA	250	89.52
a	0.004	5.5	3/4"	4.7	20.52	0.17	UP 26-96	205	119.36
b	0.008	10.3	1"	4.1	18.53	0.57	UPS 26-64	185	119.36
c	0.011	14.1	1 1/4"	3.7	12.88	1.04	UPS 26-64	185	119.36
d	0.014	18.5	1 1/4"	4.8	20.72	1.74	UPS 32-80	200	119.36
e	0.018	23.1	1 1/2"	4.2	14.38	2.67	UPS 32-80	200	119.36
f	0.022	28.3	2"	2.3	6.06	3.93	UPS 32-80	200	119.36

2.1 Assumptions

The assumptions used to develop the simulation model are shown in Table 4 below. These were provided by Heliodyne. Solem used generalised assumptions where data was unable and kept these consistent between all simulations to ensure comparable results.

Table 4 Assumptions used to develop simulation model

Parameter	**UNIT**	**Heliodyne systems**	**Schuco Systems**
Collector parameters			
a0	-	0.75	0.736
a1	W/[m^2 K]	-3.6857	-3.3951
a2	W/[m^2 K^2]	-0.00548	-0.0094
Efficiency equation type	inlet, average or outlet	inlet	inlet
test flow rate	L/[hr]	299	258
Collector azimuth	Degree from South in West direction	0	0
Collector slope	degree from horizontal	35	35

Total collector area	m^2	89.52, 119.36	86.08
IAM 1 b0	-	0.078[1]	0.081
IAM 2 b1	-	0.086	0.001
Area per collector	m^2	3.73	2.69
Number of collectors in series		harp design (all in parallel): 4 parallel arrays of 6 each	2 parallel arrays of 16 each
Daily hot water demand (peak)	L/day	15,000	15,000
Cold water inlet temperature	DegC	15	15
Solar Pump		See Table 2	See Table 3
Pumping speed	Constant or variable	constant	constant
HX pump		See Table 2	See Table 3
Pumping speed	Constant or variable	constant	constant
Pipe			
Pipe length each way	m	30.5	30.5
Pipe diameter	mm	See Table 2	See Table 3
Pipe thickness	mm	3	3
Pipe thermal conductivity	W/[m K]	394	394
Insulation thickness	Mm	25.4	25.4
Conductivity of insulation	W/[m K]	0.037	0.037
Is exposed to the ambient temperature?	Y or N	Y	Y
Pipes within system		Solar pipe HX Pipe Hot water pipe	Solar pipe HX Pipe Hot water pipe
Solar Fluid			
Fluid density	kg/m^3	1053	1053
Fluid specific heat	kJ/[kg K]	3.525	3.525
Fluid thermal conductivity	W/[m K]	0.441	0.441
Fluid viscosity	Kg /[m s]	1.55E-03	1.55E-03
Boiling point of fluid	degC	104	104
Tank Fluid[2]			
Fluid density	$kg/[m^3]$	980	980
Fluid specific heat	kJ /[kg C]	4.19	4.19
Fluid thermal conductivity	W/[m K]	0.613	0.613
Fluid viscosity	kg/[m s]	8.55E-04	8.55E-04
Boiling point of fluid	degC	100	100
Heat exchanger			
Heat exchanger type	-	Double-wall Flat Plate, Counter Flow	Double-wall Flat Plate, Counter Flow
Constant effectiveness	-	0.55	0.55
Controller			
Temperature difference ON	K	10 (18 deg F)	10 (18 deg F)
Temperature difference OFF	K	2.7 (5 deg F)	2.7 (5 deg F)

[1] IAM data provided by SRCC data sheet
[2] Provided by SOLEM

Height of temperature sensor in tank from bottom	m	0.5	0.5
Tank			
Volume	m^3	7.38	7.38
Tank Height	m	3.13	3.13
Top Loss Coefficient	W/ [m^2 K]	1.67[3]	1.67[3]
Bottom Loss Coefficient	W/ [m^2 K]	1.67[3]	1.67[3]
All other loss Coefficients	W/ [m^2 K]	1.67[3]	1.67[3]
Ports in tank			
Height of inlet from HX to tank	m	2.63	2.63
Height of outlet from tank to HX	m	0.5	0.5
Height of cold water inlet to tank	m	0.5	0.5
Height of hot water outlet from tank to load	m	3.13	3.13
Inline gas booster			
Capacity	kW	500	500
Output temperature set point	degC	60	60
Overall loss coefficient	W/[K]	5	5
Firing efficiency	-	0.8	0.8
Temperature exposed to	degC	25	25
Climatic zone		**Sacramento CA (TMY2)**	**Sacramento CA (TMY2)**

Stratification

Two configurations of the storage tank were used to study the performance variation due to improved thermal stratification. The minimal stratification (mixed) tank was configured with 10 thermal temperature nodes (layers) and a fixed port (inlet) location for the return from the solar collectors (via the heat exchanger). This enables a limited stratification of the storage tank. The second configuration simulates a greater stratification. 20 thermal temperature nodes are used and a variable height of the return from the solar collectors. The variable height simulates the use of a diffuser or stratification pipe within the tank. Water enters the tank at a height which has the same temperature as the entering water to minimise disturbance (mixing) of the thermal layers.

Load

The hot water load simulated was 15,000L (3,962 Gal) per day drawn from the tank with an approximated ASHRAE residential average. The load was drawn over a 30 minute period at the beginning of each period. This is done to produce the intermittent load nature of a real system allowing stratification to occur.

[3] Provided by SOLEM based upon previous experience.

Table 5 Daily Load Pattern

Hour of day	Percent drawn
0	6%
8	9%
10	16%
12	14%
14	15%
17	17%
20	23%

The cold water delivery was assumed to be 15°C (59°F) and the hot water delivery temperature was 60°C (140°F).

Heat exchanger

A constant effectiveness heat exchanger is utilised to separate the solar fluid and the hot water fluid in the tank. The effectiveness simulated was 0.55 as specified by Heliodyne.

3 RESULTS

This section presents the results of the study. The annual results are presented in the report and the hourly and monthly results are presented in the spreadsheet accompanying the report. The first section provides an explanation of the terms used to describe the results.

3.1 Terms

Solar Yield: This is the energy captured by the solar thermal collector. This is also known as useful solar gain or useful gain.

Solar Pipe Loss: This is the total energy lost through the pipework in the solar thermal system. It includes the pipe work connecting the collectors to the heat exchanger and the pipe work connecting the heat exchanger to the storage tank.

Tank loss: This is the loss of energy from the storage tank. It includes losses from the side, top and bottom of the tank.

Solar pump electrical energy consumption: The energy supplied to the pump in the solar loop and the heat exchange loop summed together.

Energy provided by the solar system: The energy provided to the hot water load by the solar thermal system. It is measured at the load side of the storage tank and account for all the losses in the system.

Gas consumption: The chemical energy content of the gas supplied to the inline instant gas burner. This is the purchased energy provided to the gas burner.

Hot water load energy: The hot water load that is required to be met by the solar system and the gas burner.

Collector efficiency: The percentage of energy in the solar radiation converted into useful solar yield.

Fraction of saving: This is the per cent reduction in gas consumption due to the energy provide by the solar thermal system.

3.2 Annual results

Table 6 Simulation 1 results – Heliodyne collector with mixed tank and height flow rate

Simulation	Solar Yield [MJ]	Solar Pipe Loss [MJ]	Tank Loss [MJ]	Solar pump Electrical consumption [MJ]	Energy provided by solar system [MJ]	Gas Consumption [MJ]	Hot water load energy [MJ]	Collector efficiency [-]	Fraction of saving [-]
Sim 1	374,830	7,828	8,909	5,460	358,163	842,968	1,027,075	58.5%	34.0%

Table 7 Simulation 2 results – Schuco collector with mixed tank and parametric run of varying flow rates

Simulation	Solar Yield [MJ]	Solar Pipe Loss [MJ]	Tank Loss [MJ]	Solar pump Electrical consumption [MJ]	Energy provided by solar system [MJ]	Gas Consumption [MJ]	Hot water load energy [MJ]	Collector efficiency [-]	Fraction of saving [-]
Sim 2a	330,905	4,236	5,690	5,576	322,801	887,210	1,027,075	53.7%	30.6%
Sim 2b	356,720	4,593	7,463	5,389	345,628	858,635	1,027,075	57.9%	32.8%
Sim 2c	366,858	4,433	8,242	5,261	354,832	847,105	1,027,075	59.6%	33.7%
Sim 2d	371,774	5,251	8,682	5,387	358,301	842,763	1,027,075	60.4%	34.1%
Sim 2e	373,543	5,284	8,993	9,853	360,857	839,564	1,027,075	60.7%	34.0%
Sim 2f	374,748	6,191	9,109	5,343	359,573	841,173	1,027,075	60.8%	34.2%
Sim 2g	374,925	6,240	9,283	9,568	360,672	839,814	1,027,075	60.9%	34.0%

Table 8 Simulation 3 results – Heliodyne collector with mixed tank and parametric run of varying flow rates

Simulation	Solar Yield [MJ]	Solar Pipe Loss [MJ]	Tank Loss [MJ]	Solar pump Electrical consumption [MJ]	Energy provided by solar system [MJ]	Gas Consumption [MJ]	Hot water load energy [MJ]	Collector efficiency [-]	Fraction of saving [-]
Sim 3a	399,085	4,987	6,713	5,297	378,807	817,198	1,027,075	62.3%	36.1%
Sim 3b	446,624	5,670	9,372	4,500	431,753	750,979	1,027,075	69.7%	41.3%
Sim 3c	461,349	6,691	10,157	4,409	444,313	735,256	1,027,075	72.0%	42.5%
Sim 3d	469,678	6,651	10,731	4,668	451,906	725,774	1,027,075	73.3%	43.2%
Sim 3e	474,223	7,806	11,084	4,567	454,623	722,395	1,027,075	74.0%	43.5%
Sim 3f	476,785	10,108	11,332	4,463	454,353	722,743	1,027,075	74.4%	43.5%

Table 9 Simulation 4 results – Heliodyne collector with stratified tank

Simulation	Solar Yield [MJ]	Solar Pipe Loss [MJ]	Tank Loss [MJ]	Solar pump Electrical consumption [MJ]	Energy provided by solar system [MJ]	Gas Consumption [MJ]	Hot water load energy [MJ]	Collector efficiency [-]	Fraction of saving [-]
Sim 4	381,567	6,269	7,436	5,600	367,283	831,741	1,027,075	59.6%	34.9%

Table 10 Simulation 5 results Schuco collector with stratified tank and parametric run of varying flow rates

Simulation	Solar Yield [MJ]	Solar Pipe Loss [MJ]	Tank Loss [MJ]	Solar pump Electrical consumption [MJ]	Energy provided by solar system [MJ]	Gas Consumption [MJ]	Hot water load energy [MJ]	Collector efficiency [-]	Fraction of saving [-]
Sim 5a	335,039	3,896	4,040	5,686	328,306	880,435	1,027,075	54.4%	31.1%
Sim 5b	361,725	4,017	5,951	5,455	351,970	850,853	1,027,075	58.7%	33.4%
Sim 5c	372,625	3,759	6,663	5,349	362,130	838,166	1,027,075	60.5%	34.4%
Sim 5d	378,359	4,308	7,054	5,502	366,761	832,377	1,027,075	61.4%	34.9%
Sim 5e	380,658	4,221	7,306	10,070	370,178	828,137	1,027,075	61.8%	34.8%
Sim 5f	381,953	4,809	7,391	5,453	369,359	829,156	1,027,075	62.0%	35.1%
Sim 5g	382,593	4,737	7,499	9,772	371,172	826,858	1,027,075	62.1%	35.0%

Table 11 Heliodyne collector with stratified tank and parametric run of varying flow rates

Simulation	Solar Yield [MJ]	Solar Pipe Loss [MJ]	Tank Loss [MJ]	Solar pump Electrical consumption [MJ]	Energy provided by solar system [MJ]	Gas Consumption [MJ]	Hot water load energy [MJ]	Collector efficiency [-]	Fraction of saving [-]
Sim 6a	405,467	4,576	4,848	5,513	387,978	805,873	1,027,075	63.3%	36.9%
Sim 6b	453,938	5,002	7,808	4,616	440,440	740,312	1,027,075	70.8%	42.1%
Sim 6c	469,045	5,786	8,556	4,503	453,627	723,844	1,027,075	73.2%	43.4%
Sim 6d	478,038	5,701	9,090	4,766	461,996	713,407	1,027,075	74.6%	44.2%
Sim 6e	483,220	6,558	9,381	4,668	465,745	708,709	1,027,075	75.4%	44.5%
Sim 6f	486,551	8,331	9,580	4,574	466,808	707,377	1,027,075	75.9%	44.7%

3.3 Collector efficiency

The average collector efficiency is given in Table 12 below.

Table 12 Annual average collector efficiency for each simulation.

Schuco			**Heliodyne**		
Flow rate [GPM]	**Sim 2 mixed**	**Sim 5 Stratified**	**Flow rate [GPM]**	**Sim 3 mixed**	**Sim6 Stratified**
5.3 [a]	53.7%	54.4%	5.5 [a]	50.7%	51.4%
8.6 [b]	57.9%	58.7%	10.3 [b]	55.5%	56.0%
12.0 [c]	59.6%	60.5%	14.1 [c]	56.8%	57.3%
15.5 [d]	60.4%	61.4%	18.5 [d]	57.6%	58.0%
18.5 [e]	60.7%	61.8%	23.1 [e]	58.0%	58.4%
21.0 [f]	60.8%	62.0%	28.3 [f]	58.2%	58.6%
24.0 [g]	60.9%	62.1%	30.0 [base]	58.5%	59.6%

3.4 Annual solar yield

Figure 1, Figure 2, and Figure 3 below show the flow rate plotted against the total annual solar yield. It is presented with both collectors on the same plot in Figure 1. For the purpose of clarity Figure 2 and Figure 3 show the identical plot as Figure 1 however the collectors separated into individual plots.

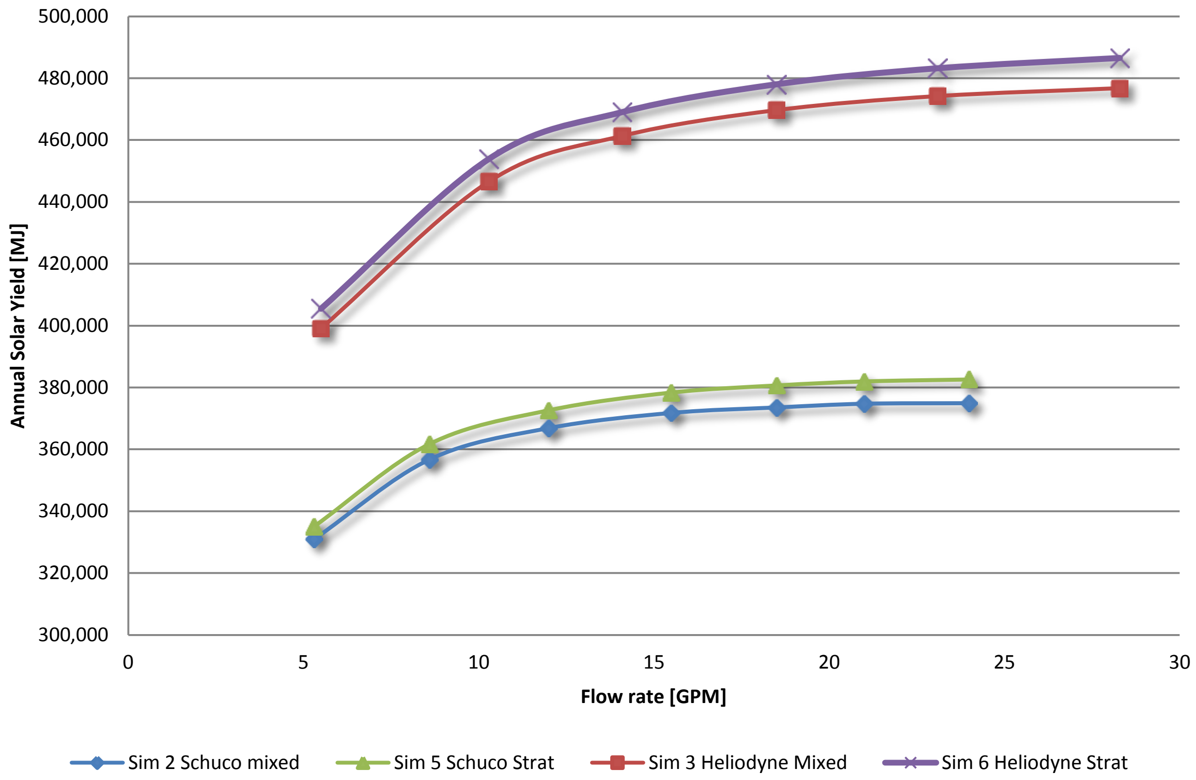

Figure 1 Flow rate plotted against annual solar yield for both collectors

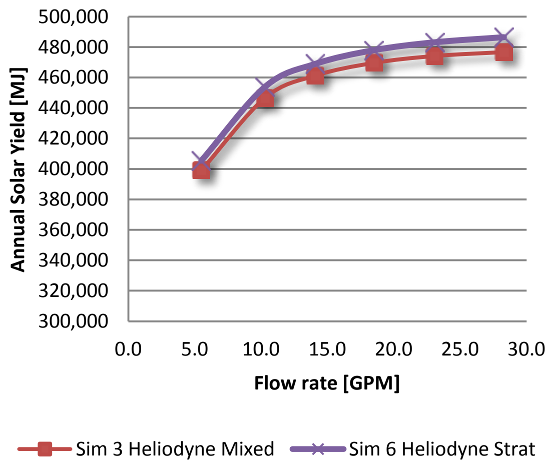

Figure 2 Flow rate plotted against annual solar yield for Heliodyne collectors

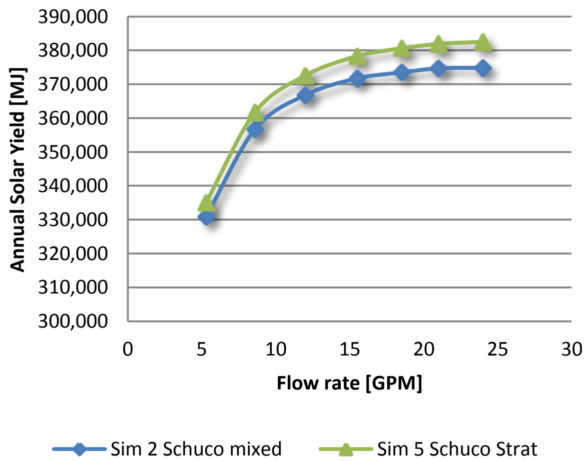

Figure 3 Flow rate plotted against annual solar yield for Schuco collectors

3.5 Annual fraction of saving

The fraction of energy saved by use of the solar thermal system is plotted in Figure 4, Figure 5, and Figure 6 below. It is presented with both collectors on the same plot in. For the purpose of clarity Figure 5 and Figure 6 shows the identical result as Figure 4 except with each collector separated into individual plots.

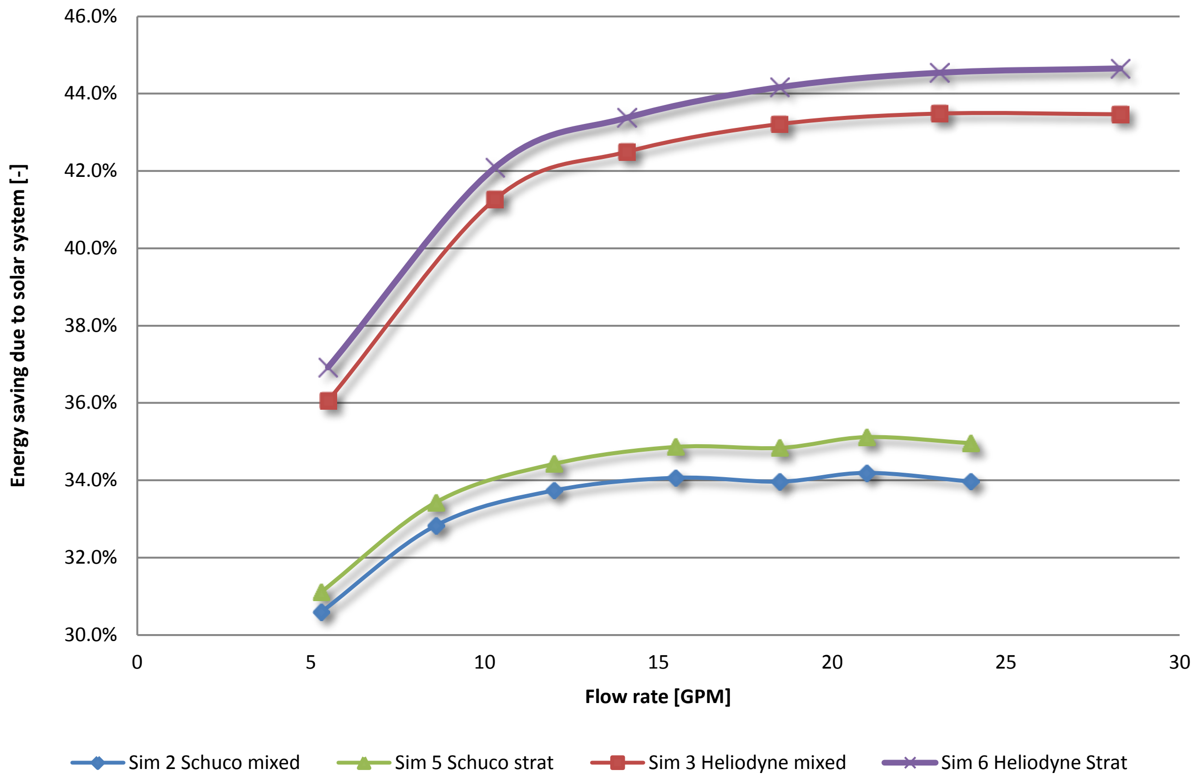

Figure 4 Flow rate plotted against annual energy saved

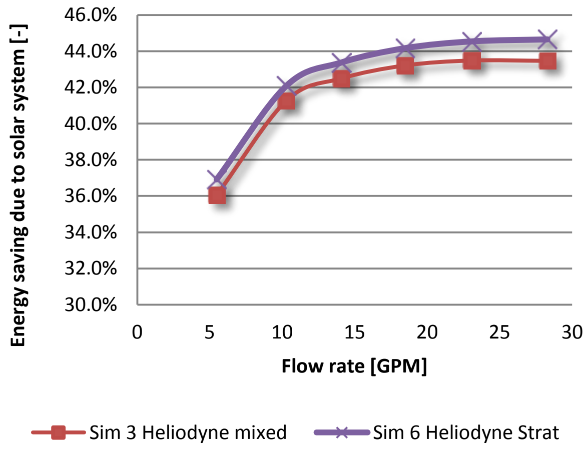

Figure 5 Flow rate plotted against annual energy saved for Heliodyne collectors

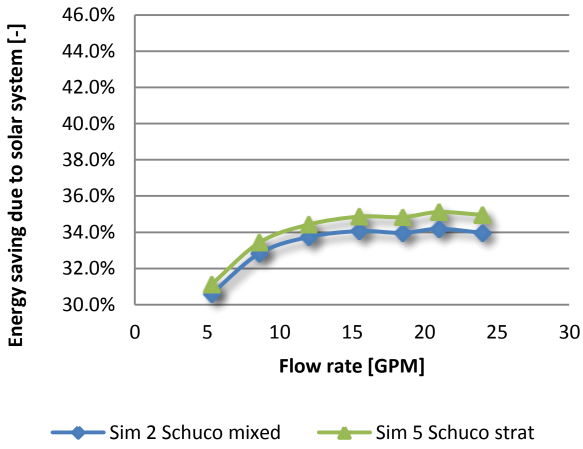

Figure 6 Flow rate plotted against annual energy saved for Schuco collectors

4 DISCUSSION AND CONCLUSIONS

A brief set of conclusions have been drawn from these results and a presented below.

The annual performance of the Heliodyne system is relatively unaffected by flow rate down to 14.1 GPM or 0.0146 GPM/ft^2. This is 47% of the currently used flow rate. The annual performance of the Schuco system is relatively unaffected by flow rate down to 12 GPM or 0.013 GPM/ft^2. At the lowest flow rate of 5.5 GPM both collectors drop in annual collector efficiency of 7-8% and a drop in the annual saving of 4%.

In this study, the stratification of the tank shows an overall improvement of just 1% for both collector systems. It should be noted stratification is dependent on the characteristic of the load and under different situations the effect of improved stratification may be greater. While the variable load pattern is used in these simulations, the large load of 15,000L of water being drawn through the 7,380L tank does reduce the effect of stratification as the storage tank is purged of charge completely and thus not storage hot water overnight.

The results show a negative energy loss from the storage tank during the summer months in a number of simulations of the fully stratified systems. This means that the tank actually gains energy during those months rather than losses energy. This is due to the configuration of the system. The cold water inlet temperature is set to a constant temperature of 15°C. Before this water enters the tanks, it can drop down about 1°C when the ambient temperature is low. As the load draws 15,000L per day from the 7,380L storage tank, the tanks has two complete water changes per day and 46% of this being after 5pm when little solar is available. This configuration leads to a purging of the energy collected throughout the day and leaves an uncharged (cold) tank. During summer when the ambient temperature rises sufficiently high enough the next day before the tank is charged by the solar, energy is transferred into the tank by the ambient, this energy is actually greater than the energy lost during the solar production.

5 APPENDIX 1 COLLECTOR CERTIFICATES

SOLAR COLLECTOR CERTIFICATION AND RATING	CERTIFIED SOLAR COLLECTOR	
	SUPPLIER:	**Heliodyne, Inc.** 4910 Seaport Avenue Richmond, CA 94804 USA
	MODEL:	GOBI 410 001
	COLLECTOR TYPE:	Glazed Flat-Plate
SRCC OG-100	CERTIFICATION#:	2010115A

COLLECTOR THERMAL PERFORMANCE RATING

Kilowatt-hours Per Panel Per Day				Thousands of BTU Per Panel Per Day			
CATEGORY (Ti-Ta)	CLEAR DAY	MILDLY CLOUDY	CLOUDY DAY	CATEGORY (Ti-Ta)	CLEAR DAY	MILDLY CLOUDY	CLOUDY DAY
A (-5 °C)	16.9	12.8	8.7	A (-9 °F)	57.6	43.5	29.5
B (5 °C)	15.4	11.2	7.1	B (9 °F)	52.4	38.4	24.4
C (20 °C)	13.1	9.1	5.1	C (36 °F)	44.7	30.9	17.2
D (50 °C)	9.0	5.2	1.7	D (90 °F)	30.7	17.7	5.7
E (80 °C)	5.3	2.1	0.0	E (144 °F)	18.2	7.0	0.0

A- Pool Heating (Warm Climate) **B**- Pool Heating (Cool Climate) **C**- Water Heating (Warm Climate) **D**- Water Heating (Cool Climate) **E**- Air Conditioning

Original Certification Date: 28-MAR-11

COLLECTOR SPECIFICATIONS

Gross Area: 3.732 m^2 40.17 ft^2
Dry Weight: 43.5 kg 96. lb
Test Pressure: 1103. KPa 160. psig

Net Aperture Area: 3.47 m^2 37.33 ft^2
Fluid Capacity: 5.1 liter 1.3 gal

COLLECTOR MATERIALS

Frame: Aluminum
Cover (Outer): Tempered glass
Cover (Inner):

Pressure Drop

Flow		ΔP	
ml/s	gpm	Pa	in H_2O
20.00	0.32	41.93	0.17
50.00	0.79	121.0	0.5
80.00	1.27	219.43	0.88

Absorber Material: Tube - Copper / Plate - Aluminum
Absorber Coating: Selective coating
Insulation Side: Foam
Insulation Back: foam

TECHNICAL INFORMATION

Efficiency Equation [NOTE: Based on gross area and (P)=Ti-Ta]				Y INTERCEPT	SLOPE
SI Units:	η= 0.750	-3.68570 (P)/I	-0.00548 $(P)^2/I$	0.752	-4.023 W/m^2.°C
IP Units:	η= 0.750	-0.64924 (P)/I	-0.00054 $(P)^2/I$	0.752	-0.709 Btu/hr.ft^2.°F

Incident Angle Modifier [(S)=1/cosθ - 1, 0°<θ<=60°]

Kτα = 1	-0.078 (S)	-0.086 $(S)^2$
Kτα = 1	-0.17 (S)	Linear Fit

Test Fluid: Water
Test Flow Rate: 22.2 ml/s.m^2 0.0328 gpm/ft^2

REMARKS:

September, 2011
Certification must be renewed annually, For current status contact:
SOLAR RATING & CERTIFICATION CORPORATION
400 High Point Drive, Suite 400 ♦ Cocoa, Florida 32926 ♦ (321) 213-6037 ♦ Fax (321) 821-0910

SOLAR COLLECTOR CERTIFICATION AND RATING	CERTIFIED SOLAR COLLECTOR	
SRCC OG-100 CERTIFIED	SUPPLIER:	**Schuco USA LLLP** 240 Pane Road New ington, CT 06111 USA
	MODEL:	Performance Collector CTE 220 CH 2 / CH 5
	COLLECTOR TYPE:	Glazed Flat-Plate
SRCC OG-100	CERTIFICATION#:	2009017A

COLLECTOR THERMAL PERFORMANCE RATING

Kilowatt-hours Per Panel Per Day				Thousands of BTU Per Panel Per Day			
CATEGORY (Ti-Ta)	CLEAR DAY	MILDLY CLOUDY	CLOUDY DAY	CATEGORY (Ti-Ta)	CLEAR DAY	MILDLY CLOUDY	CLOUDY DAY
A (-5 °C)	12.4	9.4	6.4	A (-9 °F)	42.3	32.0	21.8
B (5 °C)	11.4	8.4	5.4	B (9 °F)	38.9	28.6	18.4
C (20 °C)	9.8	6.8	3.9	C (36 °F)	33.4	23.2	13.3
D (50 °C)	6.8	3.9	1.4	D (90 °F)	23.1	13.4	4.6
E (80 °C)	3.9	1.5	0.0	E (144 °F)	13.3	5.2	0.0

A- Pool Heating (Warm Climate) **B-** Pool Heating (Cool Climate) **C-** Water Heating (Warm Climate) **D-** Water Heating (Cool Climate) E- Air Conditioning

Original Certification Date: 07-FEB-11

COLLECTOR SPECIFICATIONS

Gross Area:	2.690 m^2	28.95 ft^2	**Net Aperture Area:**	2.50 m^2	26.91 ft^2
Dry Weight:	48.0 kg	106. lb	**Fluid Capacity:**	2.2 liter	0.6 gal
Test Pressure:	1500. KPa	218. psig			

COLLECTOR MATERIALS

Frame:	Aluminum
Cover (Outer):	Tempered glass
Cover (Inner):	Tempered glass

Pressure Drop

Flow		ΔP	
ml/s	gpm	Pa	in H_2O
20.00	0.32	4578.55	18.40
50.00	0.79	20249.3	81.4
80.00	1.27	46483.60	186.82

Absorber Material:	Tube - Copper / Plate - Aluminum	**Insulation Side:**	No
Absorber Coating:	Selective coating	**Insulation Back:**	fiber

TECHNICAL INFORMATION

Efficiency Equation [NOTE: Based on gross area and (P)=Ti-Ta]				**Y INTERCEPT**	**SLOPE**
SI Units:	η= 0.736	-3.39510 (P)/I	-0.00940 $(P)^2/I$	0.741	-4.021 W/m^2.°C
IP Units:	η= 0.736	-0.59805 (P)/I	-0.00092 $(P)^2/I$	0.741	-0.708 Btu/hr.ft^2.°F

Incident Angle Modifier [(S)=1/cosθ - 1, 0°<θ<=60°]

Kτα = 1	-0.081 (S)	0.001 $(S)^2$
Kτα = 1	-0.08 (S)	Linear Fit

Test Fluid: Water

Test Flow Rate: 19.3 ml/s.m^2 0.0284 gpm/ft^2

REMARKS:

September, 2011

Certification must be renew ed annually, For current status contact:

SOLAR RATING & CERTIFICATION CORPORATION

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