ITEM NO.
4.C.

INFORMATIONAL MEMORANDUM
Tukwila Metropolitan Park District

TO: **Tukwila Pool MPD Board President**

FROM: **Rick Still, Parks and Recreation Director**

DATE: **June 13, 2012**

SUBJECT: **Solar Energy Slideshow – presentation and discussion**

ISSUE
McKinstry will be presenting a brief slideshow on solar energy information.

FINANCIAL IMPACT
No financial impact at this time.

BACKGROUND
McKinstry has conducted additional research on solar options for the Tukwila Pool. The attached Power Point presentation is an overview of their findings as it relates to the Tukwila Pool.

DISCUSSION
The Tukwila Pool uses natural gas as the energy source for heating the building air, the pool water and the domestic water. The annual utility costs for gas is approximately $80,000 (Slide 2). From the Investment Grade Audit performed in February and March of this year, McKinstry has been able to calculate a breakdown of the $80,000 in natural gas that is being consumed: approximately $60,000 to heat the building air and approximately $20,000 for heating water (pool water $17,000 & domestic water $3,000). If Solar Thermal were able to replace natural gas use 100%, the savings would be approximately $20,000 per year or over a ten-year payback for construction cost of approximately $210,000 to $240,000, plus structural support costs. It is not possible to efficiently heat the building air with solar thermal due to the requirement of heating the boiler water to 180 degrees to heat the air (Slide 3). Solar can heat up to the needed 105 degrees for pool water and domestic water. However, solar thermal use will always need to be supplemented with the natural gas operated heat source due to the cost benefit ratio or "sweet spot". The sweet spot is determined by finding the most efficient use the space available on the roof for collector units, the cost for the purchase and installation of the collector units and the annual savings or payback years.

There are two systems described in the attached presentation, Evacuated Tube (Slide 4) and Flat Panel (Slide 5). A comparison of three different vendors' calculations for the size, weight, operational period, solar fraction total, construction cost, annual savings and simple payback are shown on Slide 6. The economic drivers or decisions points are presented (Slide 7 & 8) to describe the pros and cons of each system. The roof is not capable of supporting the solar thermal systems without a structural support system; this would be an additional cost, to distribute the weight load to the load bearing walls. The ongoing maintenance to clean the tubes/panels and roof quarterly and the additional maintenance cost for the additional pumps, heat exchangers and motors would be estimated at approximately $3,000 annually. Further research on manufacture

recommendations for maintenance and a discussion with other system owners would help solidify the maintenance costs. Benchmarks of other pools are shown on Slide 9.

From the three scenarios on Slide 5, the construction cost divided by the annual utility savings provides a payback range of approximately 28 years to 99 years. This does not meet the 15-year payback criteria for this project – nor does allow us to defer some current CIP projects so they could be constructed later with the savings from solar thermal efficiencies, therefore it is not being recommended for this capital program.

RECOMMENDATION

Staff recommends removing the solar thermal project from the items "being pursued" project list.

ATTACHMENTS

1. Solar Slideshow
   - Exhibit A Solar Industries
   - Exhibit B SCHUCO Energy
   - Exhibit C Apricus solar hot water
   - Exhibit D Solar Heating air vs. water

Tukwila Pool

Solar Thermal Information

Andrew Williamson | June 13, 2012

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Discussion Points

- Solar Options at the Tukwila Pool
- What are the major economic drivers?
  - Savings
  - Construction Costs
  - Structural Considerations
  - Ongoing Maintenance
- Benchmarks from the Industry
- How Tukwila Pool compares to these benchmarks

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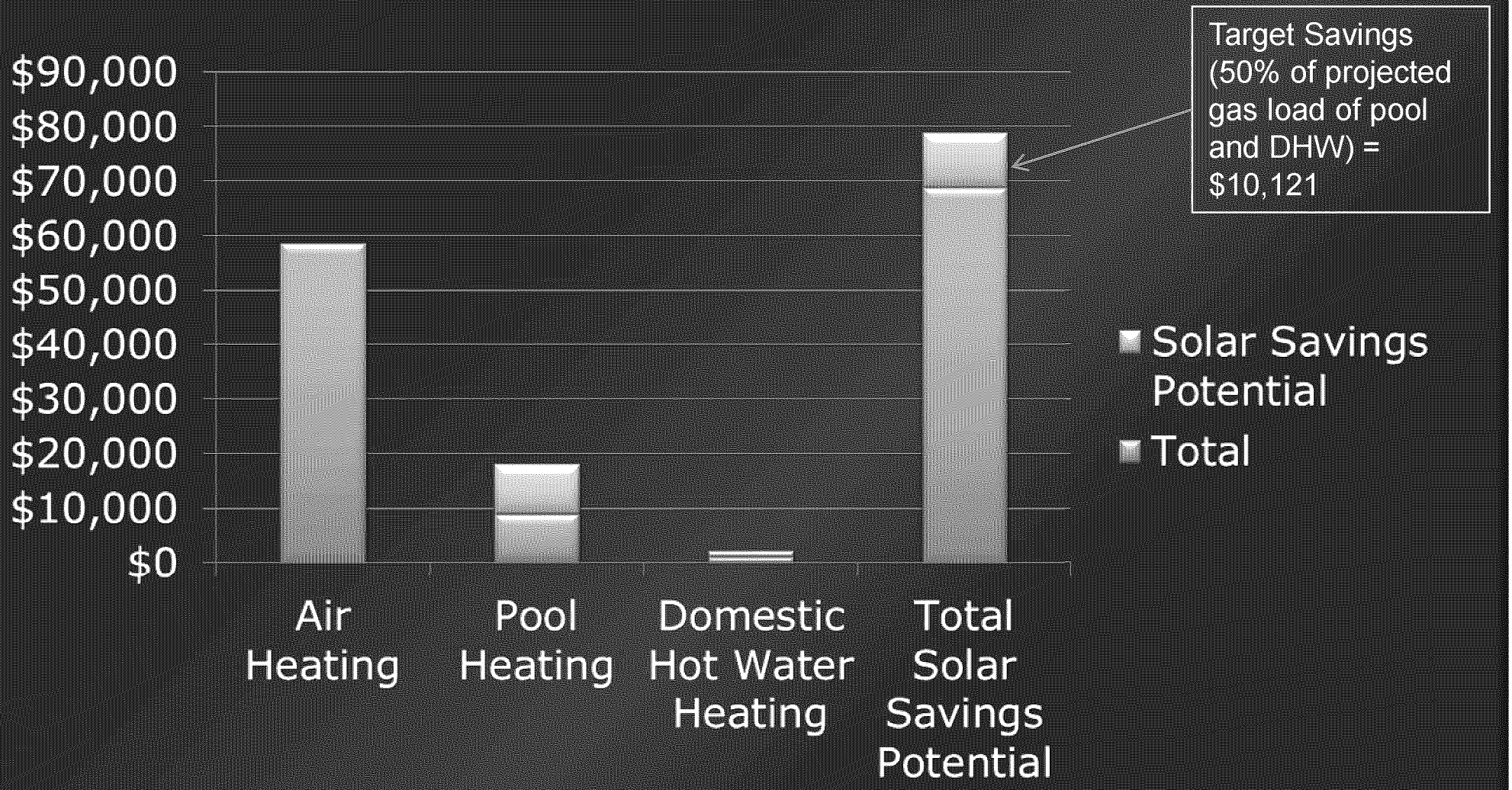
Natural Gas Use Comparison

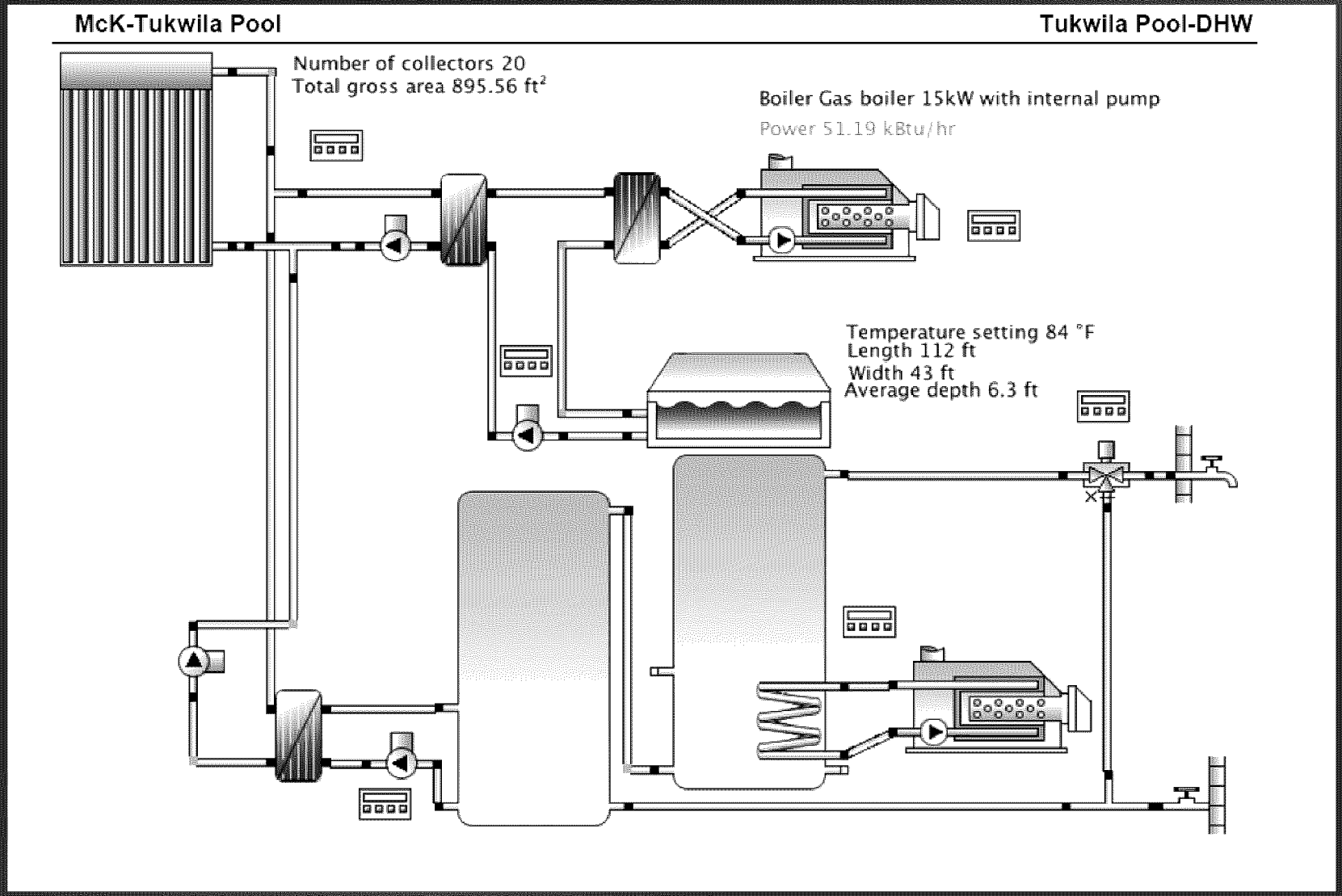


Solar Thermal: Heating Water vs. Air

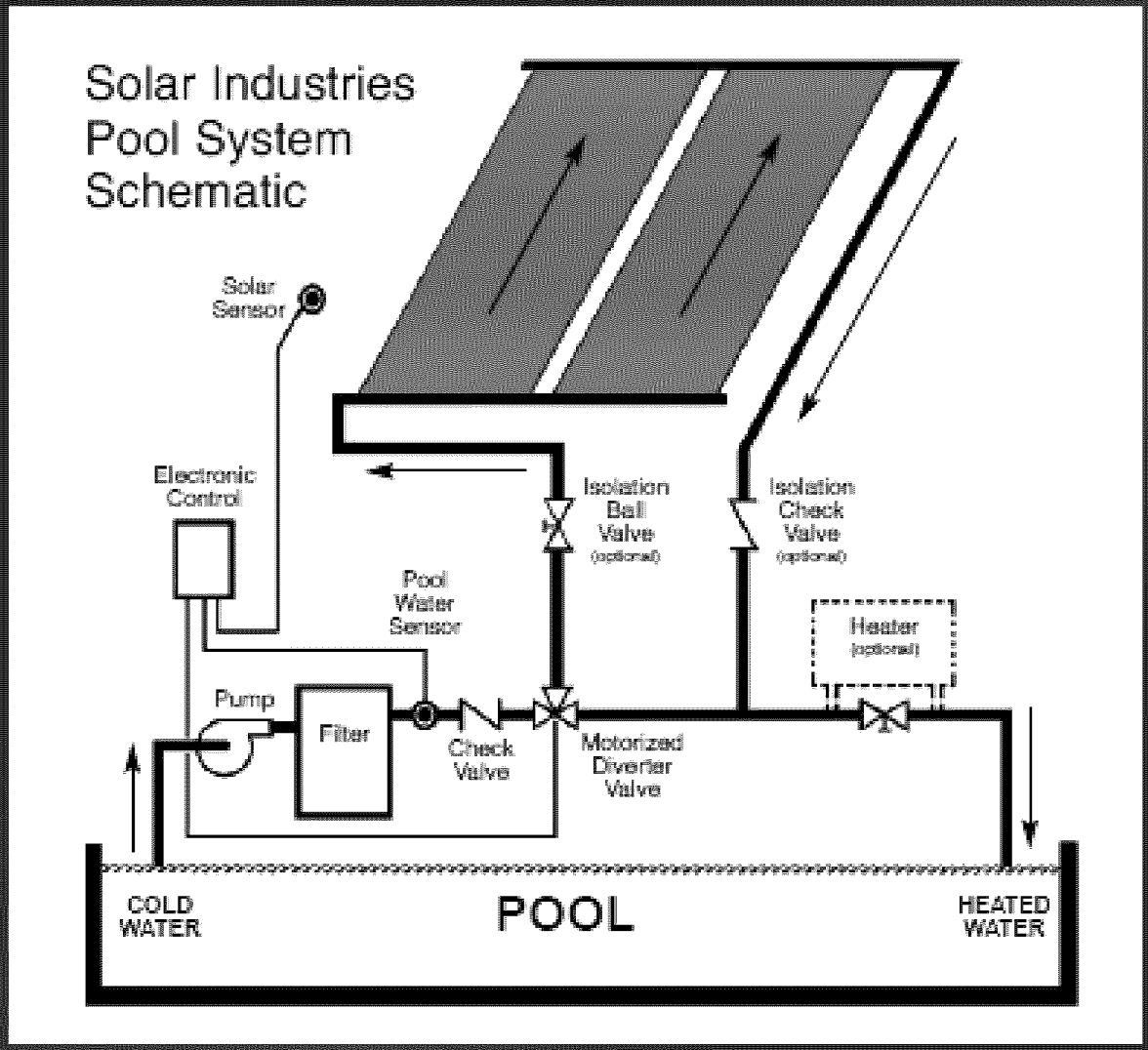
- To achieve higher temperatures needed for airside heating, the flow through the solar collect will need to be decreased.
- Lower output from solar collectors during winter months (more clouds), when airside heating load is greatest.
- Highest output from solar collectors during summer months, when airside heating load is lowest.
- More solar collectors increases initial cost, which takes away from other capital improvement items.
- Increasing winter and shoulder month production, results in a greater increase in over-production in the summer.
- To compensate for over-production, collectors would need to either be isolated (maintenance issue) or another source would be needed for heat rejection (exhaust air). Thermal energy cannot be sold back to the utility.
- Solar sizing software is designed to maximize output to meet water load (generally constant over year), without over-production.

- ADDING SOLAR COLLECTORS BEYOND PEAK SUMMER LOAD DECREASED THE RETURN ON INVESTMENT.

Evacuated Tube Schematic



Flat Panel Schematic



Vendor Comparison

System	Collector Area (ft^2)*	Collector Weight (lb)**	Annual Operation	Solar Fraction Total	Total Cost ($)	Annual Savings (Therms)	Annual Savings	Simple Payback (Years)
Flat Plate	4,096	5,300	May - Oct	53.0%	210K	6,808	$7,497	28
Evacuated Tube #1	1,527	7,900	All Year	53.9%	240K	2,802	$3,086	78
Evacuated Tube #2	896	4,600	All Year	61.3%	217K	1,993	$2,195	99

* Available Roof Area = 9,500 ft^2

**Mounting Weight Not Included in first cost – Structural upgrades could account for an additional TBD of cost

***It is assumed that all 3 options will require structural improvements to the existing roof

****McKinstry has solicited feedback from 3 vendors in the industry to provide this detail. The vendors referred to in the table above include: Apricus, Gen-con Solar and NW Mechanical

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Economic Drivers

- System Comparison
  - Flat Plate
    - Show better payback
    - Lower production per panel area
    - Drain-back system only operational in summer months
    - Better weight per sq ft – Will Still Impact Structural
    - Pool water circulated directly through solar collectors
  - Evacuated Tube
    - Longer payback
    - Better production per panel area
    - Operational all year – requires freeze protection (glycol solution)
    - More weight per sq ft – Bigger Structural Impact
    - Pool water isolated from collectors through heat exchangers

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Economic Drivers

- Construction Costs
  - McKinstry takes into account ALL costs of the project.
    - Pricing is inclusive of all Audits, Site Evaluation, Construction Management, Site Supervision, Contingencies, Taxes and Measurement and Verification
- Structural Considerations
  - Due to the nature of the layout of the pre-stressed tendons, the joists are sensitive to incoming point loads and would require significant analysis to determine whether or not there is reserve capacity to support incoming loads
  - Option to support solar array from the load bearing walls. This would require a steel framed platform.
  - Added structure is not a part of the construction cost identified
- Ongoing maintenance needed to upkeep solar systems
  - Ongoing maintenance will be required for all additional pumps, heat exchangers and motors. Estimate for ongoing costs would not require significant day-to-day maintenance beyond quarterly cleaning of roof and exterior of tubes. Maintenance cost for heat exchangers typically run about $1,000 /year if evacuated tube technology is implemented.

Other Pools

- Snohomish Aquatics Center
  - New Construction Pool
    - Structural can be built in
    - Center Cost $21.3 million with lazy river, 10 lane swimming pool, water slide and shallow side, hot tub and a wave pool. This is a much larger pool and load.
- North Kitsap Community Pool
  - Installation cost similar to our project approximately $110,000
  - Payback range is close to 15 years (very similar to our numbers) without structural improvements
  - This is not inclusive of design, taxes, contingencies, etc. Tukwila numbers are “turn-key”.
- Bainbridge Aquatics Center
  - Project cost shared with public was for only equipment
  - Costs were not inclusive of design, audit, labor for installation and structural review.
  - Large amount of risk for structural considerations. Cost of material was $70,000

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Exhibit D

Solar Thermal: Heating Water vs. Air

		Spring	Summer	Fall	Winter		Spring	Summer	Fall	Winter	
A	Collector Max Output (BTU / Day):	30,000	40,000	30,000	10,000		30,000	40,000	30,000	10,000	per Solar Rep
B	Cost per Collector:		$6,000					$4,500			Budget Price
C	Total Collectors:		35					70			Variable
D	Installed Cost:		$210,000					$315,000			= B x C
E	Solar Maximum Output (BTU / Day):	1,050,000	1,400,000	1,050,000	350,000		2,100,000	2,800,000	2,100,000	700,000	= A x C
F	Air Heating Load (BTU / Day):	902,691	325,327	890,358	1,332,518		902,691	325,327	890,358	1,332,518	Estimated
G	Water Heating Load (BTU / Day):	1,120,824	1,112,695	1,104,208	1,096,285		1,120,824	1,112,695	1,104,208	1,096,285	Estimated
H	Total Load (BTU / Day):	2,023,516	1,438,022	1,994,566	2,428,802		2,023,516	1,438,022	1,994,566	2,428,802	= F + G
I	Solar Contribution:	52%	97%	53%	14%		104%	195%	105%	29%	= E / H
J	Therms Saved:	958	1,278	958	319		1,023	1,015	1,008	639	Conversion
K	Annual Natural Gas Savings:		$3,869					$4,058			J * Gas Rate

- Air and water heating loads are approximated for daylight hours only to match solar production periods.
- Air heating would not be available during winter months in a drainback system (flat plate). Typical operation Nov - Apr.
- Additional annual maintenance costs (~$3,000): Cleaning roof & tubes - $2,000; Pumps & heat exchangers - $1,000.
- Additional panels requires more structural modifications. Depending on the size of the array, could be $25K - $75K.

In illustration above, doubling the system size results in less than 5% increase in energy savings. An additional investment of $105,000 gains $189 in savings.

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ENERGY SMART POOLS

Solar Heating Analysis

U.S. Department of Energy — May 22, 2012

Seattle, Wa

Exhibit A

Annual Energy/Water Savings Analysis:

Solar Pool Heating System Energy Savings		$6,427

Annual Energy/Water Cost Analysis:

Pool Heating Costs without Solar Pool Heating System		$23,747
Pump Motor Electrical Cost		0
Ventilation Motor Electrical Cost (indoor only)		0
Water Consumption/Cost Due to Evaporation	136,026 gals.	102
Total Annual Energy & Water Costs		$23,849
Pool Heating Costs with Solar Pool Heating System Only		$17,319
Pump Motor Electrical Cost		0
Ventilation Motor Electrical Cost (indoor only)		0
Water Consumption/Cost Due to Evaporation	136,026 gals.	102
Total Annual Energy & Water Costs		$17,421

System Cost/Payback Analysis:

Solar Pool Heating System Cost	$99,999
Payback	15.55

Organization
Contact
Address
City, St Zip
Phone

Default ID Generic
Type Owner Unknown
Type Pool Indoor
Weather Site WASHINGTON, SEATTLE
Windspeed % 15 Shading Factor % 0

	Mon	Day	Sun	Mon	Tue	Wed	Thur	Fri	Sat
Open	1	1	08:00AM	08:00AM	08:00AM	08:00AM	08:00AM	08:00AM	08:00AM
Close	12	31	8:00PM	8:00PM	8:00PM	8:00PM	8:00PM	8:00PM	8:00PM

General Pool Data		Indoor Pool Data		Pool Cover Data		Solar Heating Data	
Pool Area	4816			Cover Type	Bubble/Solar	Collector Type	Unglazed
Pool Temp (F)	82	Room Temp (F)	84	System	Manual	Eff Y-Intercept	0.8580
Activity Level	Low	Room Humidity %	65	Cover R-Value	1.5	Efficiency Slope	- 3.4200
Pool Htr Fuel	Natural Gas	Vent Htr Fuel	Natural Gas	Pool Area Covered %	100	Collector Sqft	3840
Fuel Cost	$1.000	Fuel Cost	$1.000	Installed Cost	$4,816	Installed Cost	$99,999
Pool Heater Eff %	75	Vent Heater Eff %	75	Water Cost $/k gal	$0.75		
Pump Motor HP	0.00	Vent Motor HP	0.00	Pump Motor Hrs/day	24.0		
Pump Motor Eff %	85	Vent Motor Eff %	85	Vent Motor Hrs/day	16.1		
Pump Run Hrs/day	24.0	Vent Run Hrs/day	24.0				
Pump Motor Load %	80	Vent Motor Load %	80				

Comments

ENERGY SMART POOLS

Solar Heating Analysis Summary

Prepared for:

Seattle, Wa

ANNUAL SUMMARY INFORMATION
based on the data YOU provided.

Installing a Solar Heating will:

Lower energy costs by: 26.9 % or $6,427

Current energy & water costs	$23,849
Projected energy costs w/Solar Heating	$17,422
Savings per year	$6,427

The estimated cost of a Solar Heating system is $99,999.
The payback period to realize a return on your investment is 15.55 years.

BE AN ENERGY SMART CONSUMER!
RSPEC! AND **YOU** CAN MAKE A DIFFERENCE!

RSPEC!, EE-531, U.S. Department of Energy, 1000 Independence Avenue, S.W., Washington, D.C. 20585-0001 (202) 586-8034 Fax: (202) 586-8134

ENERGY SMART POOLS

Solar Heating Analysis Part I - Uncovered

U.S. Department of Energy — May 22, 2012

Seattle, Wa

ANNUAL SYSTEM TOTALS

POOL HEATING	Htg. Loads (10^6BTU's)	Energy Use (10^6BTU's)	Htg. Fuel Use therms	Costs $
Outside Air	589	786	7,864	7,864
Evaporation	1,191	1,588	15,882	15,882
Convection				
Radiation				
Solar Gain				
Solar Heating System	-482	-642	-6,427	-6,427
Totals	1,298	1,731	17,319	$17,319

MOTORS	Energy Use (10^6BTU's)	Mot. Elec. Use kwh	Costs $
Pump Motors	0	0	0
Vent. Fan Motors	0	0	0
Totals	0	0	$0

WATER USE	Water Gallons	Costs $
Evaporation Totals	136,026	$102

GRAND TOTAL COSTS $17,421

Annual Pool Solar Heating System Savings

	Htg. Loads (10^6BTU's)	Energy Use (10^6BTU's)	Htg. Fuel Use therms	Costs $
Annual Savings	482	642	6,427	$6,427

Pool Solar Heating System Payback

Type of System	Cost/Sq.Ft.	Total Cost	Payback Years
Unglazed	26.04	99,999	15.5

Organization
Contact
Address
City, St Zip
Phone

Default ID Generic
Type Owner Unknown
Type Pool Indoor
Weather Site WASHINGTON, SEATTLE
Windspeed % 15 Shading Factor % 0

	Mon	Day	Sun	Mon	Tue	Wed	Thur	Fri	Sat
Open	1	1	08:00AM	08:00AM	08:00AM	08:00AM	08:00AM	08:00AM	08:00AM
Close	12	31	8:00PM	8:00PM	8:00PM	8:00PM	8:00PM	8:00PM	8:00PM

General Pool Data

Pool Area	4816
Pool Temp (F)	82
Activity Level	Low
Pool Htr Fuel	Natural Gas
Fuel Cost	$1.000
Pool Heater Eff %	75
Pump Motor HP	0.00
Pump Motor Eff %	85
Pump Run Hrs/day	24.0
Pump Motor Load %	80

Indoor Pool Data

Room Temp (F)	84
Room Humidity %	65
Vent Htr Fuel	Natural Gas
Fuel Cost	$1.000
Vent Heater Eff %	75
Vent Motor HP	0.00
Vent Motor Eff %	85
Vent Run Hrs/day	24.0
Vent Motor Load %	80

Pool Cover Data

Cover Type	Bubble/Solar
System	Manual
Cover R-Value	1.5
Pool Area Covered %	100
Installed Cost	$4,816
Water Cost $/k gal	$0.75
Pump Motor Hrs/day	24.0
Vent Motor Hrs/day	16.1

Solar Heating Data

Collector Type	Unglazed
Eff Y-Intercept	0.8580
Efficiency Slope	- 3.4200
Collector Sqft	3840
Installed Cost	$99,999

Comments

ENERGY SMART POOLS
Solar Heating Analysis Part I - Uncovered

U.S. Department of Energy — May 22, 2012

Seattle, Wa

Average Evaporation Rate (lbs./hr.)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12:00 am - 8:00 am	112	112	112	112	112	112	112	112	112	112	112	112
8:00 am - 4:00 pm	145	145	145	145	145	145	145	145	145	145	145	145
4:00 pm - 12:00 am	129	129	129	129	129	129	129	129	129	129	129	129

Average Outside Air Required (10^3 cfm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12:00 am - 8:00 am	2.02	1.90	2.23	2.09	2.17	2.45	2.81	3.27	2.78	2.37	2.13	1.96
8:00 am - 4:00 pm	2.80	2.50	2.74	2.92	3.19	3.39	3.70	4.21	3.76	3.90	2.84	2.77
4:00 pm - 12:00 am	2.20	2.30	2.37	2.42	2.55	3.19	3.57	3.54	3.26	2.95	2.36	2.52

Average Outside Air Heating Losses (10^6 BTU's)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
12:00 am - 8:00 am	25	20	25	21	9	0	0	0	10	21	22	22	181
8:00 am - 4:00 pm	32	24	26	23	10	0	0	0	9	29	26	30	214
4:00 pm - 12:00 am	26	23	24	21	9	0	0	0	10	24	23	28	193
Totals	84	69	77	67	30	0	0	0	30	75	73	81	589

Average Evaporation Losses (10^6 BTU's)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
12:00 am - 8:00 am	29	27	29	28	29	28	29	29	28	29	28	29	345
8:00 am - 4:00 pm	38	35	38	36	38	36	38	38	36	38	36	38	448
4:00 pm - 12:00 am	33	31	33	32	33	32	33	33	32	33	32	33	397
Totals	100	94	100	97	100	97	100	100	97	100	97	100	1,191

Average Convection Losses (10^6 BTU's)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
12:00 am - 8:00 am													
8:00 am - 4:00 pm													
4:00 pm - 12:00 am													
Totals													

Average Radiation Losses (10^6 BTU's)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
12:00 am - 8:00 am													
8:00 am - 4:00 pm													
4:00 pm - 12:00 am													
Totals													

Total Monthly Pool Losses (10^6 BTU's)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Total Load													

Average Direct Solar Gain (10^6 BTU's)

8:00 am - 4:00 pm	

Net Total Monthly Pool Load (10^6 BTU's)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Total Load	100	94	100	97	100	97	100	100	97	100	97	100	1,191

Pool Solar Heating System Analysis

Available Output from Solar Heating System (10^6 BTU's)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Totals	0	19	28	36	50	54	98	88	68	30	5	0	482

Net Savings from Solar Heating System (10^6 BTU's)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Totals	0	19	28	36	50	54	98	88	68	30	5	0	482

Net Monthly Pool Load After Solar Heating System (10^6 BTU's)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Totals	100	75	72	61	50	42	2	12	28	69	91	100	709

Questionnaire for Solar Pool Heating Projects

Exhibit B

Date:

Schuco customer information:

Company: Tel.: Fax:

Contact person: e-mail:

Project data:

Project name: Tukwila Pool

Project address: 4414 South 144th Street Project Budget: $____

Type of installation ☐ New construction ☒ Retrofit

Type of Pool: ☒ Indoor ☐ Outdoor

☒ Public ☐ Private

Collector Location: ☒ Pitched Roof ☐ Flat Roof ☐ Wall Mount ☐ Ground Mount ☐ Other: ____

Solar Fraction Desired: 55 % (amount of conventional fuel offset by solar energy)

Roof Type (if collectors are roof mounted)

☐ Composition ☐ S-Tile ☐ Flat Tile ☐ Metal Corrugated ☐ Metal Standing Seam ☐ Tar & Gravel

☐ EPDM Ballasted ☒ EPDM Non-ballasted ☐ Other: ____

Roof Structure: ☐ wood framed ☐ steel framed ☒ concrete

Roof Height: 1 stories

Attic Space: ☐ finished ☐ unfinished ☐ accessible ☐ inaccessible

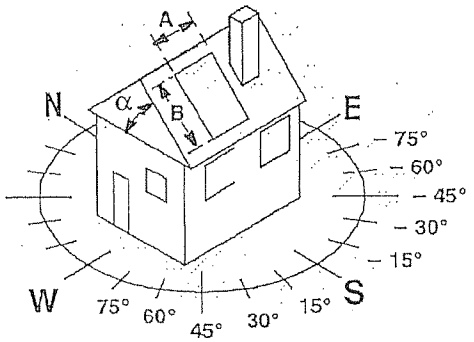
Solar Exposure

Roof incline "α": 5 degrees or Pitch: ____ / 12 (Rise / Run)

Angle from south: 0 degrees

Size of available installation surface "A" = 74 ft x "B" = 128 ft

Shading: ☒ none ☐ partial explain: ____ (attach pathfinder survey)



Swimming pool – Use Profile

When in use: ☒ All year round ☐ Seasonally from to (month)

Pool Cover: ☐ Without cover ☒ Covered 8 hours per day

Pool Size:

Pool Shape: Rectangle Round, Square, Rectangle, Kidney, Other

Surface Area: 4,850 sq. ft. Average depth: 6.3 feet gallons: 250,000

Pool Temperature:

Desired pool temperature setpoint: 84.5 °F

Pool Building (if indoors)

Type of construction: (conventional or high percentage of glazing)

Indoor Air Heating: ☐ No ☒ Yes, temperature setpoint = 86 °F

Make-up Water Temperature 55 °F

Humidity Control: ☐ No ☒ Yes, set at 50 % R.H. Ventilation Control: ☐ No ☒ Yes

Other Remarks: Natural gas heat, no mechanical cooling

Pool shading (if outdoor)

Shading: ☐ none ☐ partial, explain: _____

Existing Pool Heater Fuel:

Type of Fuel: ☒ Nat. Gas ☐ Propane ☐ Oil ☐ Electricity ☐ Steam ☐ Other _____

Fuel costs: 0.99/therm $/ unit (therm, gallon, KWh, CCF, etc.)

Existing Pool Heating Equipment

Heater Type: ☐ Direct fired stand alone Heater

☒ Integrated with boiler (heated by external boiler and connected via a heat exchanger)

☐ Heat Pump

Heater manufacturer: DeDeitrich Year of manufacture: 2003 Heater type and model: GTE 518A

Heater output: 3739 BTU/hr Combustion Type: ☐ Condensing ☒ Non-Condensing ☐ Don't know

Annual Fuel Consumption: (applicable only if pool heating system is metered independently)

Fuel oil: _____ gallons Gas: 50,000 therms cubic feet or therms

Filter:

Pool Circulation Pipe Size: 8" in Pump Rating: 20 hp Filter Type DE (sand, DE, cartridge)

Filter Size: unknown sq. ft. Pool Filter Pump: 208/3 Volts Pool Filter Operating Hours: 8760 hours/year

---

Location for Solar Heat Exchanger

Room height: 15 feet Room size: 42 feet times 10 feet

Door width: 6 feet Door height: 7 feet

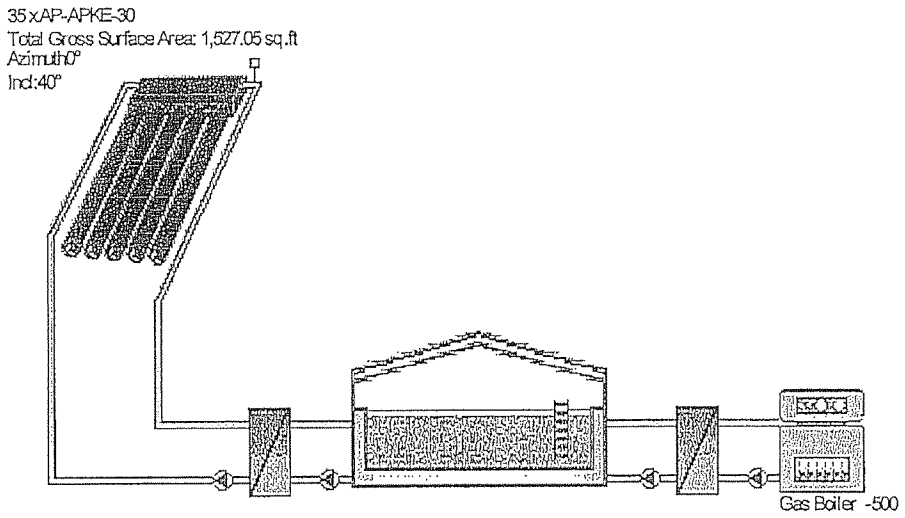
Approximate distance of pipe run from solar collectors to Solar Heat Exchanger: 50 feet

Pipe chase available: ☐ Yes ☒ No Pipes will be run: ☒ inside building ☐ outside building

Other:

Please provide photographs of the following:

- Proposed Collector Mounting Location
- Proposed Solar Heat Exchanger Location
- Existing Pool Heating Equipment



Results of Annual Simulation

Installed Collector Power:	338.84 kBtu/hr	
Collector Surface Area Irradiation:	632.62 MBtu	442.49 kBtu/sq.ft
Energy Produced by Collectors:	250.20 MBtu	175.01 kBtu/sq.ft
Energy Produced by Collector Loop:	243.48 MBtu	170.30 kBtu/sq.ft
Energy Swimming Pool Solar System:	243.48 MBtu	
Energy from Auxiliary Heating:	207 MBtu	

Natural Gas (H) Savings:	**10,271.2 cu.yd**
Natural Gas (H) Savings:	**2,802.29 therm**
CO2 Emissions Avoided:	**36,610.10 lbs**
Swimming Pool Solar Fraction:	**53.9 %**
System Efficiency:	**38.2 %**

Basic Data

Climate File

Location:	SEATTLE SEATTLE-TACOMA INTL A
Climate Data Record:	"SEATTLE SEATTLE-TACOMA INTL A"
Total Annual Global Radiation:	4.23 MBtu
Latitude:	47.45 °
Longitude:	122.3 °

Indoor Pool

Pool Area:	4941.002 sq.ft
Auxiliary Heating:	Yes

System Components

Collector Loop

Manufacturer:	Apricus Co., Ltd.
Type:	AP-APKE-30
Number:	35.00
Total Gross Surface Area:	1527.05 sq.ft
Total Active Solar Surface Area:	1429.75 sq.ft
Tilt Angle:	40 °
Azimuth:	0 °

Auxiliary Heating

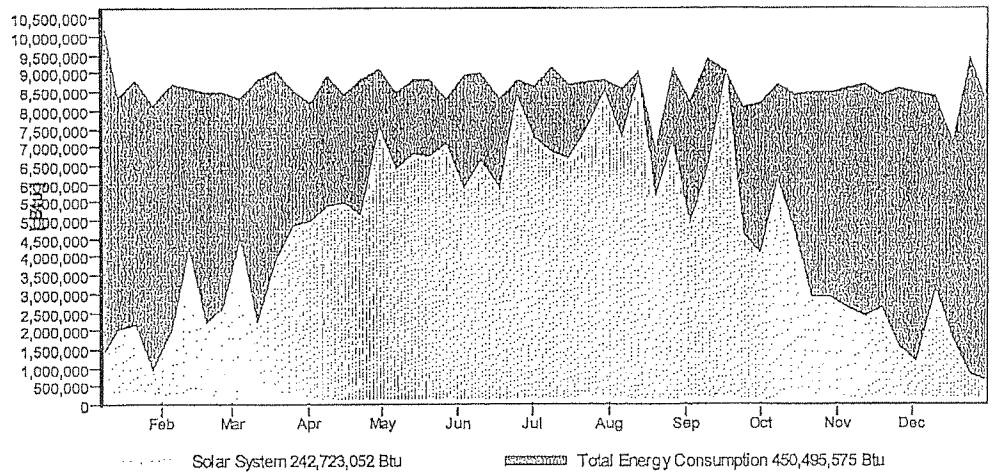
Manufacturer:	T*SOL Database
Type:	Gas Boiler -500
Nominal Output:	3.74 MBtu/hr


Original T*SOL Database

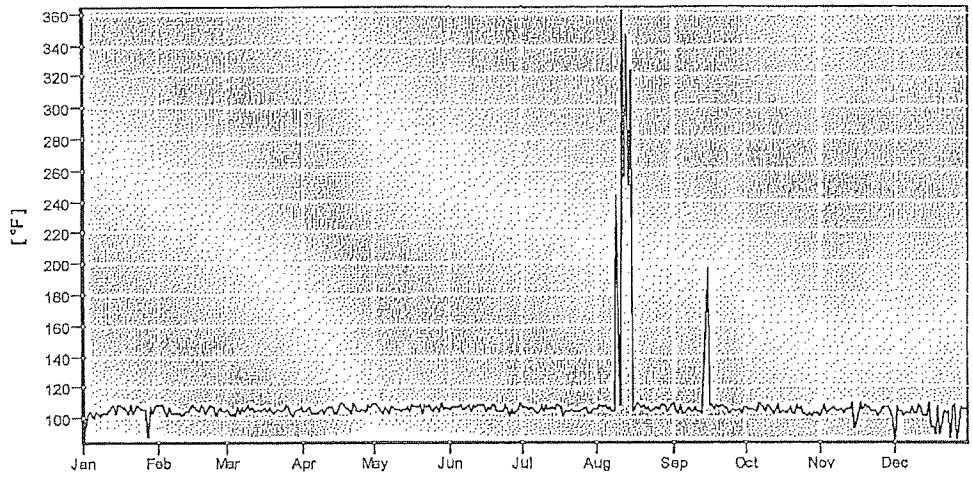

With Test Report


Solar Keymark

Solar Energy Consumption as Percentage of Total Cosumption

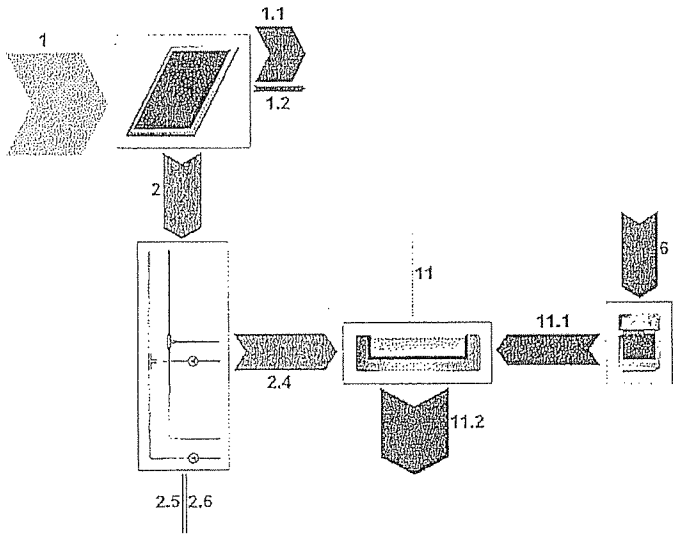


Daily Maximum Collector Temperature



These calculations were carried out by T*SOL Expert 4.4 - the Simulation Programme for Solar Thermal Heating Systems. The results are determined by a mathematical model calculation with variable time steps of up to 6 minutes. Actual yields can deviate from these values due to fluctuations in climate, consumption and other factors.The Schematic System Diagram above does not represent and cannot replace a full technical drawing of the solar system.

Energy Balance Schematic



Legend

1	Collector Surface Area Irradiation	6,782 therm
1.1	Optical Collector Losses	3,706 therm
1.2	Thermal Collector Losses	405 therm
2	Energy from Collector Array	2,511 therm
2.5	External Piping Losses	6,120 kBtu
2.6	Internal Piping Losses	631 kBtu
2.4	Solar Energy to Swimming Pool	2,444 therm
11.2	Swimming Pool Losses	4,510 therm
11	Swimming Pool Irradiation	0 kBtu
6	Final Energy	2,369 therm
11.1	Supplementary Energy to Swimming Pool (From Final Energy)	2,078 therm

Glossary

1 Collector Surface Area Irradiation
Energy Irradiated onto Tilted Collector Area (Active Solar Surface)

1.1 Optical Collector Losses
Reflection and Other Losses

1.2 Thermal Collector Losses
Heat Conduction and Other Losses

2 Energy from Collector Array
Energy Output at Collector Array Outlet (i.e. Before the Piping)

2.1 Solar Energy to Storage Tank
Energy from Collector Loop to Storage Tank (Minus Piping Losses)

2.2 Solar Energy to Preheating Tank
Collector Array Energy Minus Piping Losses

2.3 Solar Energy to Buffer Tank
Energy from Collector Loop to Buffer Tank (Minus Piping Losses)

2.4 Solar Energy to Swimming Pool
Energy from Collector Loop to Swimming Pool (Minus Piping Losses)

2.5 External Piping Losses
External Piping Losses

2.6 Internal Piping Losses
Internal Piping Losses

3.1 Tank Losses
Heat Losses via Surface Area

3.2 Circulation Losses
Circulation Piping Losses

3.3 Preheating Tank to Tank
Heat from Preheating Tank to Tank

3.4 Tank to Space Heating
Heat from Tank to HT/LT Heating. For tanks with circulation, there is a solar contribution and a contribution from the temperature mix in the tank.

3.5 Tank to Standby Tank
Heat from Tank to DHW Standby Tank

3.5 Tank to Solar Standby Tank
Heat from Tank to Solar Standby Tank

3.6 From Tank to Appliances
Heat from Tank to Appliances

4.1 Tank Losses
Heat Losses via Surface Area

5.1 Buffer Tank Losses
Heat Losses via Surface Area

5.2 Buffer Tank to Heating
Heat from Buffer Tank to HT/LT Heating

6 Final Energy
Final Energy Current into System. This can flow in as natural gas, oil or electricity (not including solar energy) taking efficiency levels into account

6.1 Supplementary Energy to Tank
Supplementary Energy (e.g. Boiler) to Tank

6.2 From Continuous Flow Water Heater

Glossary

Heat from Continuous Flow Water Heater to Appliances

6.3 Auxiliary Energy Losses
Auxilary Heating Losses (e.g. Boiler Losses)

6.4 Supplementary Energy to Space Heating
Supplementary Energy (e.g. Boiler) to HT/LT Heating

6.5 Heating Element
Energy from Heating Element

6.6 Continuous-Flow Water Heater to Standby Tank
Heat forStandby Tank via Continuous-Flow Water Heater

7 Solar Standby Tank to DHW Standby Tank
Heat from Solar Standby Tank to DHW Standby Tank

7.1 Solar Standby Tank Losses
Solar Standby Tank Heat Losses

8.1 Standby Tank Losses
Standby Tank Heat Losses

8.2 Circulation Losses
Circulation Piping Losses

8.3 To Standby Tank
Heat to Standby Tank

9 DHW Energy via Standby Tank
Heat from Standby Tank to DHW Appliances

9 DHW Energy via Tank
Heat for DHW Appliances from Tank

9.1 DHW Energy via Continuous Flow Water Heater
Heat from DHW Appliances via Continuous Flow Water Heater (Excluding Solar Energy)

10.1 Heat to HT Heating
Heat to High Temperature Heating

10.2 Heat to LT Heating
Heat to Low Temperature Heating

11 Swimming Pool Irradiation
Energy Irradiated onto Swimming Pool

11.1 Supplementary Energy to Swimming Pool (From Final Energy)
Supplementary Energy to Swimming Pool, e.g. from Boiler or Auxiliary Heating

11.2 Swimming Pool Losses
Swimming Pool Losses, i.e. Evaporation, Radiation and Heat Conduction

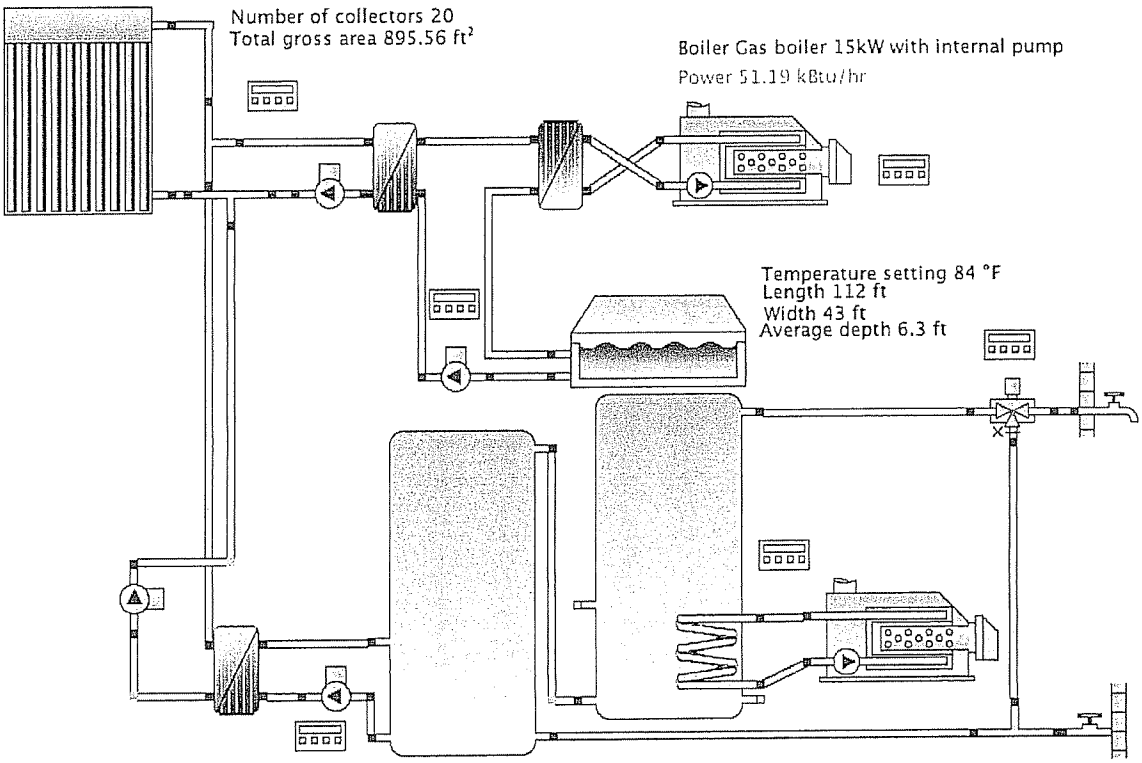
Notes

1. Any tank deviations result from the temperature differences at simulation start and end.
2. Burner losses are not shown separately in the schematic.

Professional Report

Exhibit C

McK-Tukwila Pool **Tukwila Pool-DHW**



Location of the system

USA
WA Seattle
Longitude: -122.3°
Latitude: 47.53°
Elevation: 70 ft

This report has been created by:

Frank Pokorny
6 Sycamore Way
06405 Branford, CT

Professional Report

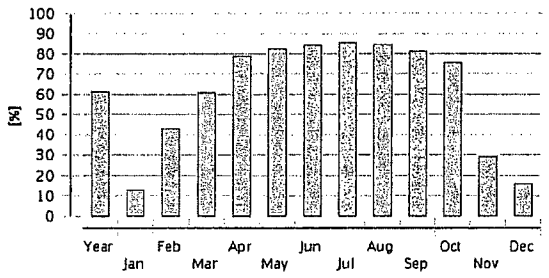
System overview (annual values)

Total fuel and/or electrical energy consumption of the system [Etot]	144,148 kBtu
Total energy consumption [Quse]	273,365.6 kBtu
System performance (Quse / Etot)	1.9
Comfort demand	Energy demand covered

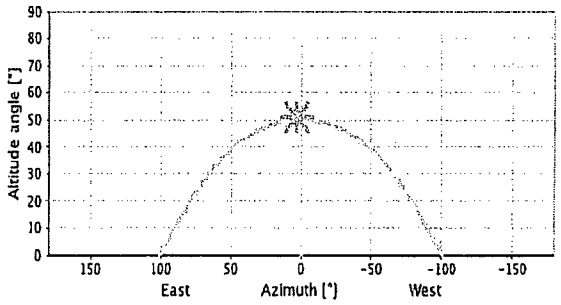
Overview solar thermal energy (annual values)

Collector area	895.6 ft²
Solar fraction total	61.3%
Total annual field yield	179,392.9 kBtu
Collector field yield relating to gross area	200.3 kBtu/ft²/Year
Collector field yield relating to aperture area	279.9 kBtu/ft²/Year
Max. fuel savings	196,480.9 ft³: [Natural gas H]
Max. energy savings	199,333.3 kBtu
Max. reduction in CO2 emissions	29,826.7 pound

Solar fraction: fraction of solar energy to system [SFn]



Horizon line



Meteorological data-Overview

Average outdoor temperature	53.6 °F
Global irradiation, annual sum	389.9 kBtu/ft²
Diffuse irradiation, annual sum	187.1 kBtu/ft²

Professional Report

Component overview (annual values)

Boiler 1	Gas boiler 15kW with internal pump	
Power	kBtu/hr	51.19
Total efficiency	%	88.1
Energy from/to the system [Qaux]	kBtu	58,787.7
Fuel and electrical energy consumption [Eaux]	kBtu	66,707.7
Energy savings solar thermal	kBtu	23,829.1
CO		

Professional Report

Pool Pool	**Indoor pool**	
Pool type		Indoor pool
Length	ft	112
Width	ft	43
Average depth	ft	6.3
Energy from/to the system [Quse]	kBtu	222,833.2
External heat exchanger Pool heat exchanger	**Plate heat exchanger, small**	
Transfer capacity	W/K	5,000
External heat exchanger Solar loop heat exchanger	**VPM 30, 35 W**	
Transfer capacity	W/K	30,000
External heat exchanger 4	**Plate heat exchanger, medium size**	
Transfer capacity	W/K	10,000
Pump Solar loop pump	**Pump Eco, large**	
Circuit pressure drop	psi	3.42
Flow rate	gpm	15.9
Fuel and electrical energy consumption [Epar]	kBtu	424.2
Pump Pool pump	**Pump Eco, large**	
Circuit pressure drop	psi	5.115
Flow rate	gpm	22
Fuel and electrical energy consumption [Epar]	kBtu	1,494.5
Pump 4	**Pump Eco, small**	
Circuit pressure drop	psi	2.077
Flow rate	gpm	15.9
Fuel and electrical energy consumption [Epar]	kBtu	52.5
Pump 6	**Pump Eco, large**	
Circuit pressure drop	psi	3.679
Flow rate	gpm	15.9
Fuel and electrical energy consumption [Epar]	kBtu	424.2
Storage tank 1	**300gal US universal tank**	
Volume	gal	300
Height	ft	7.22
Material		Enameled steel
Insulation		Flexible polyurethane foam
Thickness of insulation	in	4
Heat loss	kBtu	7,268.9
Connection losses	kBtu	4,627.2

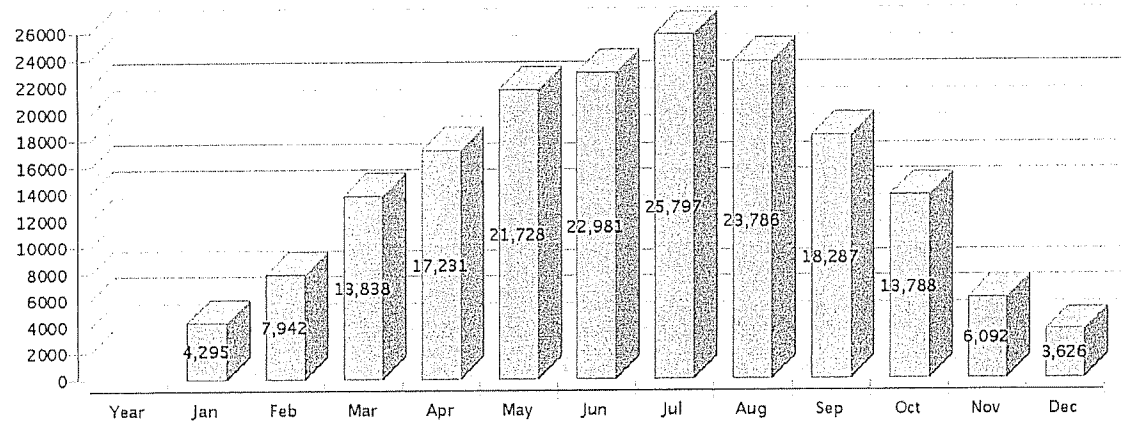
Professional Report

Storage tank 3	480gal US universal tank	
Volume	gal	480
Height	ft	7.22
Material		Enameled steel
Insulation		Flexible polyurethane foam
Thickness of insulation	in	4
Heat loss	kBtu	1,153.3
Connection losses	kBtu	249.7

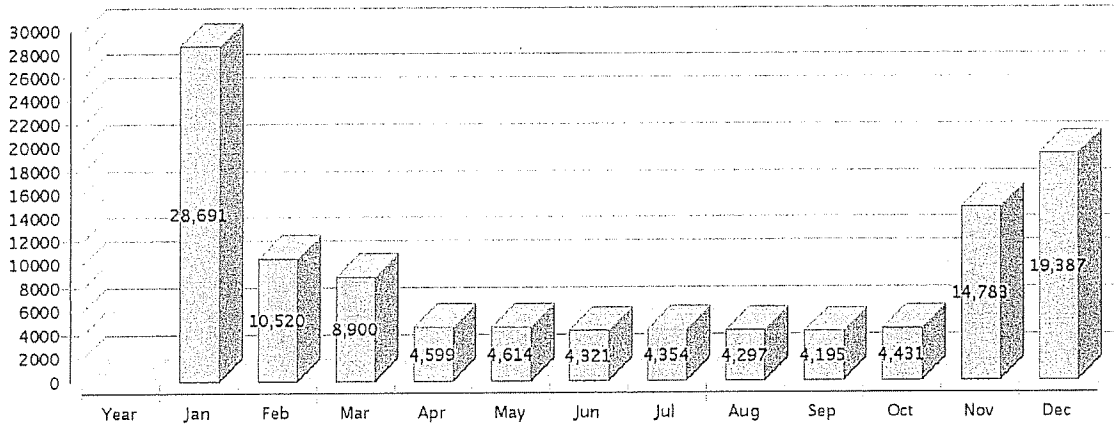
Loop

Solar loop		
Fluid mixture		Water
Fluid concentration	%	33.3
Fluid domains volume	gal	35.6
Pressure on top of the circuit	psi	58.016

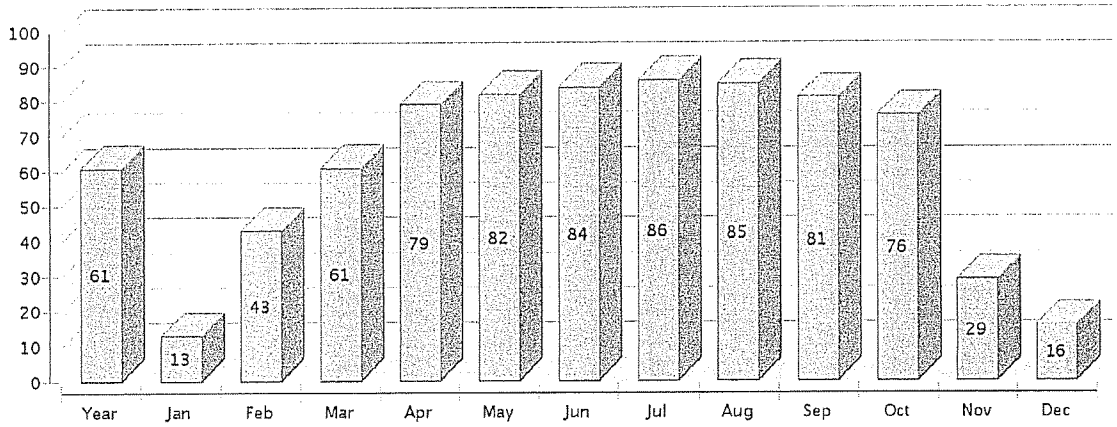
Solar thermal energy to the system [Qsol] kBtu



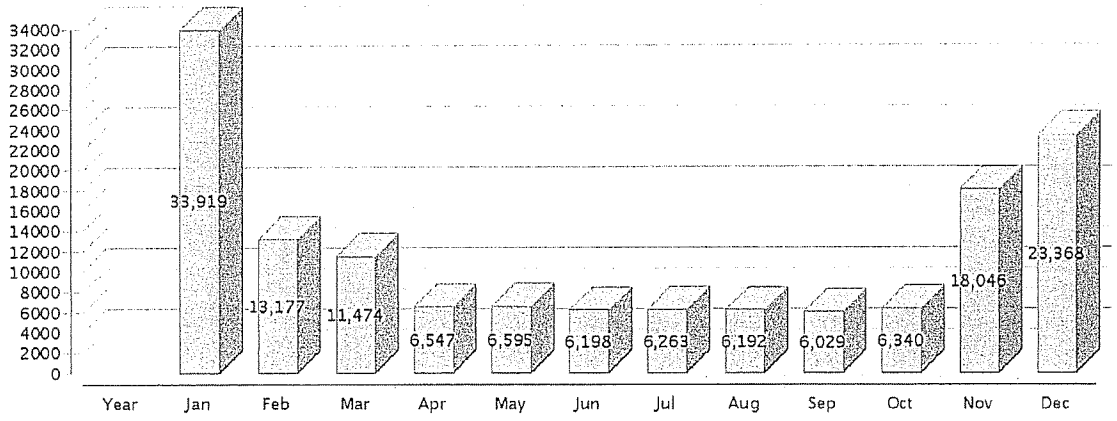
Heat generator energy to the system (solar thermal energy not included) [Qaux] kBtu



Solar fraction: fraction of solar energy to system [SFn] %



Total fuel and/or electrical energy consumption of the system [Etot] kBtu



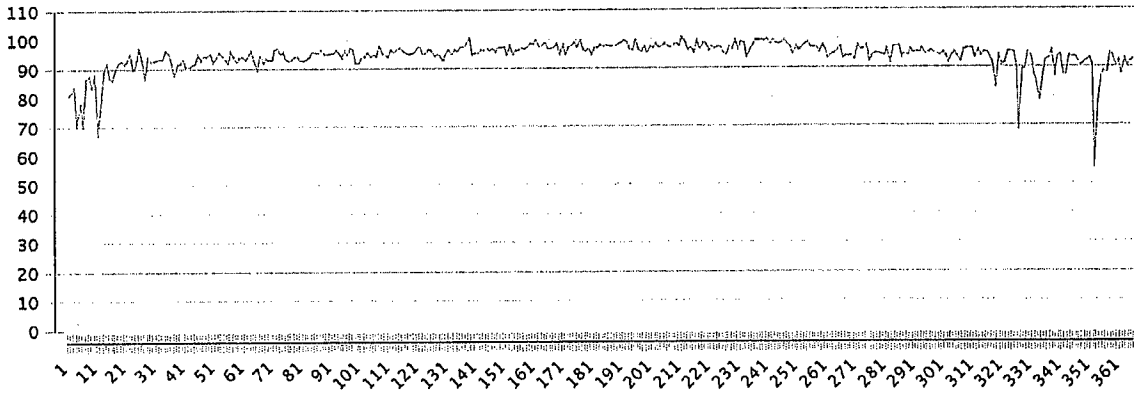
Professional Report

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Solar thermal energy to the system [Qsol]												
kBtu	179393	4295	7942	13838	17231	21728	22981	25797	23786	18287	13788	6092	3626
Heat generator energy to the system (solar thermal energy not included) [Qaux]												
kBtu	113093	28691	10520	8900	4599	4614	4321	4354	4297	4195	4431	14783	19387
Heat generator fuel and electrical energy consumption [Eaux]												
kBtu	141753	33762	13016	11270	6337	6362	5966	6018	5955	5817	6144	17889	23215
Solar fraction: fraction of solar energy to system [SFn]												
%	61.3	13	43	60.9	78.9	82.5	84.2	85.6	84.7	81.3	75.7	29.2	15.8
Total fuel and/or electrical energy consumption of the system [Etot]												
kBtu	144148	33919	13177	11474	6547	6595	6198	6263	6192	6029	6340	18046	23368
Irradiation onto collector area [Esol]												
kBtu	387214	10155	17120	30333	38542	48530	50470	55412	49861	37552	27299	13031	8910
Electrical energy consumption of pumps [Epar]												
kBtu	2395	157	161	204	211	233	232	245	237	212	196	156	153
Heat loss to indoor room (including heat generator losses) [Qint]												
kBtu	39535	3388	3071	3422	3297	3386	3248	3333	3308	3195	3301	3214	3373
Heat loss to surroundings (without collector losses) [Qext]												
kBtu	10597	3662	1084	782	184	176	158	133	125	136	154	1663	2340
Total energy consumption [Quse]												
kBtu	273366	31107	16957	21106	20293	24760	25765	28602	26540	20990	16700	19296	21250

Professional Report

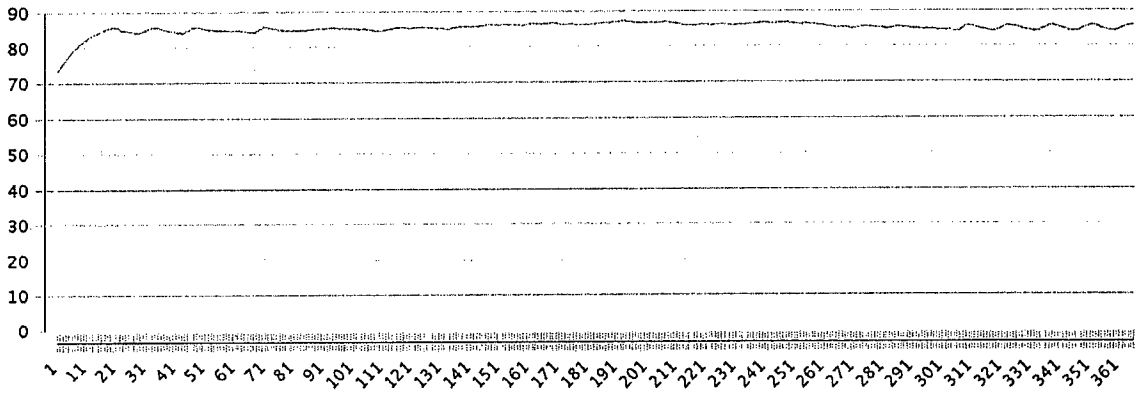
Collector North America

Daily maximum temperature [°F]



Pool Pool

Temperature [°F] - Daily average



Professional Report

Energy flow diagram

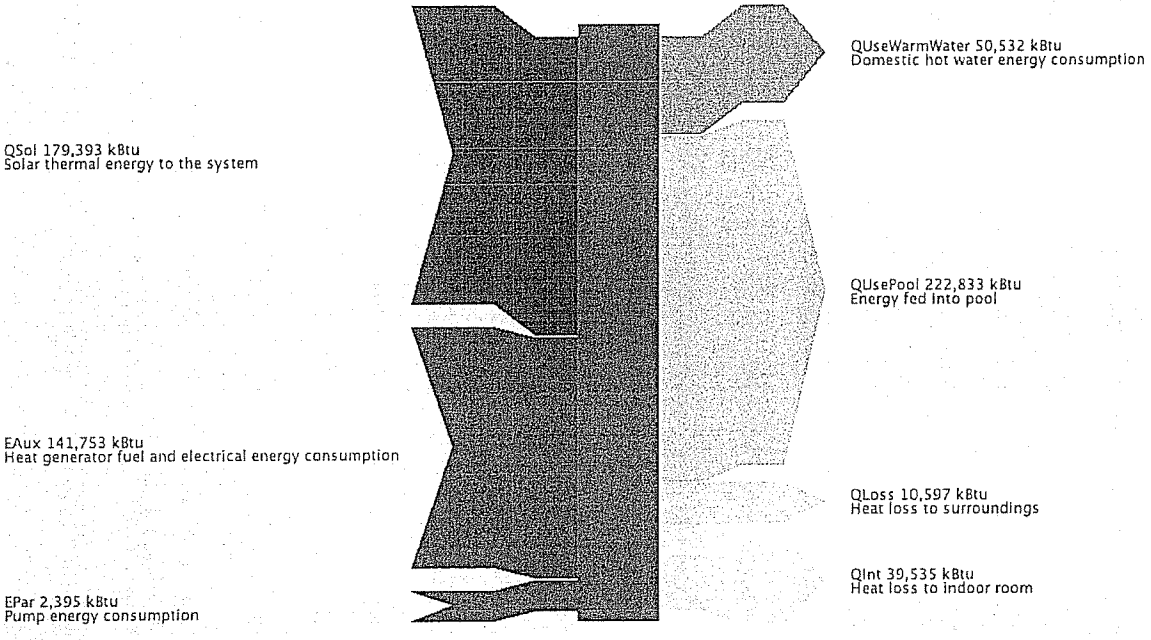


Exhibit D

Solar Thermal: Heating Water vs. Air

		Spring	Summer	Fall	Winter		Spring	Summer	Fall	Winter	
A	Collector Max Output (BTU / Day):	30,000	40,000	30,000	10,000		30,000	40,000	30,000	10,000	per Solar Rep
B	Cost per Collector:	$6,000					$4,500				Budget Price
C	Total Collectors:	35					70				Variable
D	Installed Cost:	$210,000					$315,000				= B x C
E	Solar Maximum Output (BTU / Day):	1,050,000	1,400,000	1,050,000	350,000		2,100,000	2,800,000	2,100,000	700,000	= A x C
F	Air Heating Load (BTU / Day):	902,691	325,327	890,358	1,332,518		902,691	325,327	890,358	1,332,518	Estimated
G	Water Heating Load (BTU / Day):	1,120,824	1,112,695	1,104,208	1,096,285		1,120,824	1,112,695	1,104,208	1,096,285	Estimated
H	Total Load (BTU / Day):	2,023,516	1,438,022	1,994,566	2,428,802		2,023,516	1,438,022	1,994,566	2,428,802	= F + G
I	Solar Contribution:	52%	97%	53%	14%		104%	195%	105%	29%	= E / H
J	Therms Saved:	958	1,278	958	319		1,023	1,015	1,008	639	Conversion
K	Annual Natural Gas Savings:	$3,869					$4,058				J * Gas Rate

- Air and water heating loads are approximated for daylight hours only to match solar production periods.
- Air heating would not be available during winter months in a drainback system (flat plate). Typical operation Nov - Apr.
- Additional annual maintenance costs (~$3,000): Cleaning roof & tubes - $2,000; Pumps & heat exchangers - $1,000.
- Additional panels requires more structural modifications. Depending on the size of the array, could be $25K - $75K.

In illustration above, doubling the system size results in less than 5% increase in energy savings. An additional investment of $105,000 gains $189 in savings.