CAPE ELIZABETH SOLAR THERMAL POOL HEATING AND PUMPING PROJECT

11/18/2016

Executive Summary

An analysis of the application of solar thermal energy was undertaken for the Cape Elizabeth High School Pool/Spa and associated electrical energy needs. These related documents describe the **rationale, data, references/resources, and conclusions** regarding the concurrent use of solar thermal and photovoltaic installations for this specific energy intensive segment of our study (**POOL, POOL PUMPS AND PV, SPA, SPA PUMPS, COMPRESSORS, ETC.**). The parametric data used in these documents are taken from the actual POOL and SPA known values. Other losses, financial, and unknown parameters are best estimates. The detailed calculations are shown on pages 4-10.

The town pays roughly **\$34,000** each year to (i) heat the water in the high school's swimming pool and (ii) purchase electricity to power existing pumps to circulate the pool water. This report recommends (i) heating the water with solar thermal panels that cost approximately \$27,000 and (ii) recommends supplying the electricity for the pumps with solar photovoltaic panels costing approximately \$80,000. **The total investment would be roughly \$107,000**.

If the town adopts the recommendations in this report, the town will pay roughly **§0** each year to heat and circulate the pool's water, a savings of **\$34,000** per year. The annual savings result in a payback period for the \$107,000 investment of approximately **three** year(s).

Conclusions:

- The initial data shown in the attached calculations show results which favor the adoption of solar thermal panels for the POOL (p.7) and associated PV water pumping (p.9),
- but discourage the application of solar energy, at this time, to the SPA and compressors (p.9 ff).
- The cost of the thermal panels and associated balance and engineering is approximately \$ 27,000. The payback time, after operational stability, is approximately one year (p.7, 8)).
- The cost of the associated pumping photovoltaic electrical power is approximately \$80,000 (\$2.55/installed watt)(p.4,9). This is highly recommended for the project.
- This is taken as part of the total PV costs of \$382,198.50 which is the PV including the SPA and compressors.
- This balance of \$302, 000 for the SPA and compressors is deemed a poor PV investment, and it should not be implemented (p.9).
- The proposed location of the panels for the POOL project is the rooftop of the pool area.
- There are no storage costs, since the pool itself is the water storage.

 A PPA could is recommended, since the costs of the buyout are only slightly over \$100,000.

Due to the near lack of financial incentives in Maine, financing calculations are less than adequate and should be revisited when adoption of the thermal section is nearer to reality. Perhaps the renewable energy attitudes and funding in Maine will become a reality once again. The data calculations/simulations should be run again as more financial information is made available.

The references that follow describe the rational, model, and sources for pages 4-10.

NOTES.

The solar water heating models calculate the thermal output of the system, assuming that it displaces electricity that would normally heat water in a conventional electric water heating system.

NREL System Advisor's detailed photovoltaic, PV Watts, solar water heating, and functional models, used for these calculations, can perform sub-hourly simulations for advanced analyses, but require sub-hourly weather data to do so.

The <u>solar water heating</u> model calculates the value of electricity saved by the system, assuming that heat from the system displaces heat that would be generated by a conventional electric water heater without the solar system.

References, Models, and Databases

This topic lists all of the performance models and describes the component-level models and databases used.

System Performance Models

The system models represent a complete renewable energy system and were developed by NREL using algorithms from partners listed below and the team.

Model Name	NREL Partner (if any)
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Detailed Photovoltaic Component models from Sandia National Laboratories and the University of Wisconsin

PVWatts

Solar Water Heating Modifications of Sunport Master Spreadsheet

Solar Water Heating University of Wisconsin

Component Performance Models

The detailed photovoltaic and wind power models include options for choosing a component performance model to represent part of the system.

Model Name	Component	Developer
Simple Efficiency Module Model	Photovoltaic module	NREL
CEC Performance Model with Module Data base	Photovoltaic module	University of Wisconsin
CEC Performance Model with User Entered Specifications	Photovoltaic module	Adapted by NREL

Sandia PV Array Performance Model with Module Database	Photovoltaic module	Sandia National Laboratories
Single Point Efficiency Inverter	Inverter	NREL
Sandia Performance Model for Grid Connected PV Inverters	Inverter	Sandia National Laboratories

Component Parameter Databases

Some of the component models use a library of input parameters to represent the performance characteristics of the component. The libraries listed below are owned by organizations other than NREL.

Library Name	Component	Owner
CEC Modules	PV module	California Energy Commission
Sandia Inverters	Inverter	Sandia National Laboratories
Sandia Modules	PV module	Sandia National Laboratories

Online Financial Model Data

System Advisor can automatically download data from the following online databases to populate values on its financial model input pages.

Database Name Type of Data Database Manager

OpenEl U.S. Utility Rate Database Retail electricity prices and rate structures NREL and Illinois State University

Online Renewable Resource and Weather Data Sources

System Advisor can automatically download renewable energy resource and weather data from the following online databases.

Database Name	Type of Resource Data	Database Manager	
National Solar Radiation Database	Solar and Meteorological	NREL	

Solar Resource Files

NREL System Advisor comes with a database of weather files for the solar performance models.

The solar resource files are in the CSV format and contain data from:

- •National Solar Resource Database (NSRDB): TMY3 (1991-2005) and TMY2 (1961-1990)
- •Solar and Wind Energy Resource Assessment Programme (SWERA)
- •The ASHRAE International Weather for Energy Calculations Version 1.1 (IWEC)
- •Canadian Weather for Energy Calculations (CWEC)

DETAILS OF SOLAR POOL CALCULATIONS

THERMAL SOLAR DESIGN FOR POOL

Conversion factors:

```
1 gal H<sub>2</sub>O = 3.79 kg

1 gal/min = 227.27 kg/hr.

1 hp = 746 watts

1 gal = 0.0038 m<sup>3</sup>

°C = 5/9(°F - 32)
```

NEEDS FOR SOLAR THERMAL DESIGN FOR POOL

POOL

- Total capacity of water in pool and ancillary storage; 250,000 gal = 947,000 kg= 3598.6 m³
 - (a) Separate size of storage(if available)
- 2. Flow rate of water during use; 350 gpm = 79544.5 kg/hr
- Desired temperature of water; 82F = 27.8C
- 4. Power (V, A, phases, PF)/hp/flow design of water pump(s); 208 V, 36

```
2-15 hp = 22380 W

1-10 hp = 7460 W

1-5hp = 3730 W

TOTAL ELECTRICAL (POOL) = 33570 W = 33.57 kW
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5. Other: 40 ton unit, 208 V, 36, 2-35 hp compressors = 52220 W = 52.22 kW

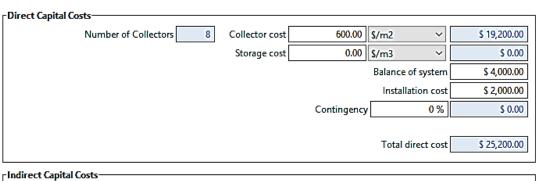
SPA

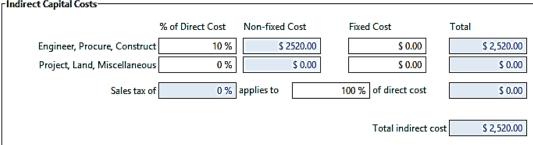
- 1, 10,000 gal = 37,900 kg = 144 m³
- 2. 2-7.5 hp = 22389 W= 22.389 kW, 208V, 36
- 3. Water 102 F = 38,9C, space 84F = 28.9C

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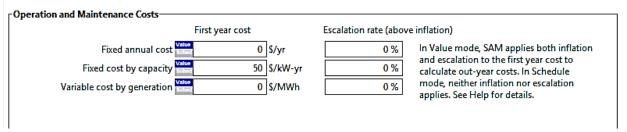
Download a weather file from the NREL NSRDB						
Download Click Download and type a street address or latitude and longitude to download a weather file from the NREL NSRDB for United States and some international locations. SAM adds the downloaded file to the solar resource library so it will appear in the list						
NSRDB Map						
Choose a weather file from the solar resource library—						
Click a name in the list to choose a file from the library. Type a few I downloading a file (see above).	etters of the name ir	the search box to t	ilter the list. If yo	ur location is not in t	the library, try	
Search for: Name V						
Name	Station ID	Latitude	Longitude	Time zone	Elevation ^	
USA ME Millinocket Municipal Ap (TMY3)	726196	45.65	-68.683	-5	124	
USA ME Naval Air Station (TMY3)	743920	43.9	-69.933	-5	21	
USA ME Northern Aroostook (TMY3)	726083	47.283	-68.317	-5	309	
USA ME Portland (TMY2)	14764	43.65	-70.3167	-5	19	
USA ME Portland Intl Jetport (TMY3)	726060	43.65	-70.3	-5	14	
IISA ME Drazque Isla Municin (TMVR)	777130	VE 285	-69 NS	-5	163	
				-Tools		
City Portland Intl Jetport Time zone	GMT -5	Latitude	43.65 °N	View	data	
State ME Elevation	14 m	Longitude	-70.3 °E	Refresi	h library	
Country USA Data Source	TMY3	Station ID 72	26060	Folders	ettings	
Data file C:\SAM\2016.3.14\solar_resource\USA ME Portland Intl	Jetport (TMY3).csv			Open libra	ary folder	
-Annual Weather Data Summary-				_		
Global horizontal 3.88 kWh/m²/day	Average temp	erature	7.4 °C			
Direct normal (beam) 4.01 kWh/m²/day	Average win	d speed	3.6 m/s			
Diffuse horizontal 1.68 kWh/m²/day			7	/isit SAM weather da	ta website	
Use a specific weather file on disk						
					Browse	
Check the box and click Browse to choose a weather file stored on	your computer with	out adding it to the	solar resource lib	orary.		

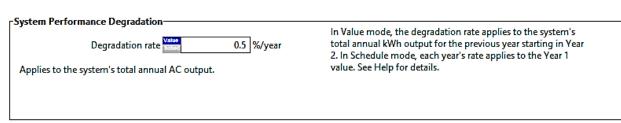
Hot Water Draw					
Hourly hot water draw profile Edit data kg/hr Scale draw profile to average daily usage ✓					
Total annual hot water draw 6.96811e+008 kg/year Average daily hot water usage 1.90907e+006 kg/day					
System					
	deg	Diffuse sky mo	del Isotronic		~
	deg	_	uts Beam and D	iffura	<u> </u>
	, -	_		$\overline{}$	•
Total system flow rate 22.1	_	Albe		0.2 01	
Working fluid Glycol	To:	tal system collector a	rea	32 m2	
Number of collectors 8		Rated system s	ize 1	8.704 kW	
-Shading		-Cur	tailment and Av	ailabilty—	
	D shade calculator		Edit losses	Constant lo	ss: 0.0 %
Shauling losses Late shauling	D 3riade Calculatoriii		Luit iosses	Hourly loss	
				Custom per	riods: None
-Collector					
_	Г	-User-defined collect	or		
Enter user-defined parameters			Collector area		4 m2
○ Choose from library			FRta		0.7
			FRUL		3.85 W/m2.C
		Incidence	angle modifier		0.2
		meidenee	Test fluid	CI_I	<u> </u>
				Glycol	
			Test flow		0.06 kg/s
Search for: Name					
Name	SRCC Number	Type	Area	IAM	FRta
Thermo Dynamics Ltd. Micro-Flo S32-P	2009007A	Glazed Flat-Plate		0.34	0.685
TISUN LLC TISUN FM-W S 4	2007054A	Glazed Flat-Plate		0.17	0.733
TISUN LLC TISUN FA 2 5	2007052C	Glazed Flat-Plate Glazed Flat-Plate		0	0.732
TISUN LLC TISUN FA 2 6 TISUN LLC TISUN FA 2 3	2007052D 2007052B	Glazed Flat-Plate		0	0.731 0.726
TISUN LLC TISUN FA 2 4	2007052A	Glazed Flat-Plate		0	0.708
TrendSetter Solar Products Inc. Trendsetter TS-22-S	2007029B	Tubular	3.16	-0.09	0.355
TrendSetter Solar Products Inc. Trendsetter TS-30-S	2007029A	Tubular	4.02	-1.29	0.355
Tsinghua Solar Systems Ltd. Tsinghua Solar SLU-1500 12	2007034Ai	Tubular	1.28	-1.8	0.3
<					>
-Solar Tank and Heat Exchanger					
Solar tank volume 3	598.6 m3	Heat ex	hanger effective	eness	0.75 01
Solar tank height to diameter ratio	0.5	O	utlet set temper	ature	55 C
Solar tank heat loss coefficient (U value)	1 W/m2.C	Mechanic	al room temper	ature	27 C
Solar tank maximum water temperature	28 C				
-Piping and Pumping					
Total piping length in system	20 m		Pump p	ower	33570 W
	0.019 m		Pump effici	ency	0.85 01
Pipe insulation conductivity	0.03 W/m.C		•		
					
ripe insulation thickness	0.006 m				
-Advanced					
UtEI- 🗆					
Use custom mains profile		Use cus	om set tempera	tures 🗸	





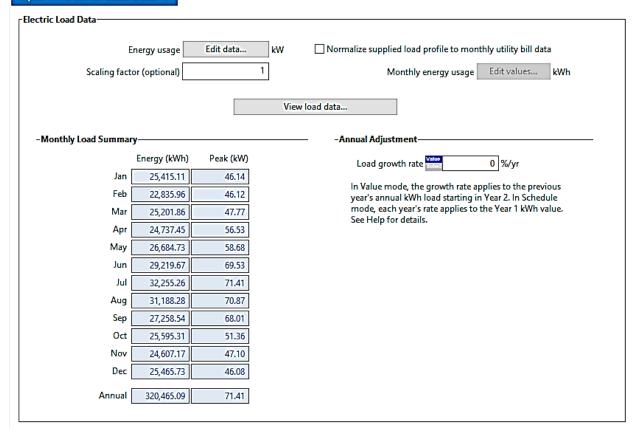
Total Installed Costs Total Installed Cost excludes financing costs (if any, see Financing Page) Total installed cost \$27,720.00 Total installed cost per capacity (\$/\text{Wt}) \$1.48





Project Term Debt						
Debt percent		0 %	Net capital cost	\$ 27,720.00		verage cost of capital (WACC) reference. SAM does not use
Loan term		0 years	Debt	\$ 0.00	the value for ca	
Loan rate		0 %/year	WACC	0.00 %		
Loannate		o wyear	WACC	0.00	For a project wire to zero.	th no debt, set the debt percent
Analysis Parameters						
Ana	llysis period	0 years		Inflation rate	0 %/y	ear
				Real discount rate	0 %/y	ear
			1	Nominal discount rate	0.00 %/y	ear
Tax and Insurance Rates—						
Federal incor	ne tax rate	0 %/year	-Prop	erty Tax———	400	
State incor	me tax rate	0 %/year		Assessed percentage		f installed cost
State medi	ine tax rate			Assessed value	\$ 27,	720.00
	Sales tax	0 % of total direct	cost	Annual decline	0 %/y	ear
Insurance rat	e (annual)	1 % of installed co	st	Property tax rate	1 %/y	ear
−Salvage Value						
-	vage value	0 % of installed co	st	End of analysis perio	d value	\$ 0
- Depreciation -						
Federal			Sta	te		
No depreciation			• 1	No depreciation		
○ 5-yr MACRS			0	5-yr MACRS		_
Straight line		7 years	0:	Straight line		7 years
○ Custom	Edit	percentages	0	Custom	Edit	percentages
The depreciable basis is the sum of investment-based					inancing cost fro	m the Financing page, less the

Input Time Series Load Data 🗸



CE PV COST FOR POOL/SPA NEEDS (\$80,000 NECESSARY FOR POOL PUMPING)

Direct Capital Costs					
Module 1 units 150.0 kWdc,	/unit	150.0 kWdc	0.71	\$/Wdc ~	\$ 106,500.00
Inverter 1 units 136.4 kWac/	/unit	136.4 kWac	0.21	\$/Wdc ~	\$ 31,500.00
	s		\$/Wdc		
Balance of system equipment	0.00		0.57		\$ 85,500.00
Installation labor		+	0.15	=	\$ 22,500.00
Installer margin and overhead	0.00		0.75		\$ 112,500.00
-Contingency—				Subtotal	\$ 358,500.00
-contingency		Contingency	(% of subtotal	\$ 0.00
				Total direct cost	\$ 358,500.00
Indirect Capital Costs					
	% of direct cost		\$/Wdc	\$	
Permitting and environmental studies	0		0.06	0.00	\$ 9,000.00
Engineering and developer overhead	0	+	0.00 +	0.00 =	\$ 0.00
Grid interconnection	0		0.00	0.00	\$ 0.00
Land purchase	0	+	0.00	0.00	\$ 0.00
Land prep. & transmission	0		0.00	0.00	\$ 0.00
-Sales Tax Sales tax basis, percent of direct cost	82 %	Sales tax rate	5	.0 %	\$ 14,698.50
				Total indirect cost	\$ 23,698.50
-Total Installed Cost					
				Total installed cost	\$ 382,198.50
			Total install	ed cost per capacity	\$ 2.55/Wdc