CAPE ELIZABETH SOLAR THERMAL POOL HEATING AND PUMPING PROJECT

11/6/2016

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. 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 initial data shown in the attached calculations show results which favor the adoption of solar thermal panels and associated water pumping but discourage the application of solar energy, at this time, to the SPA and compressors. The cost of the thermal panels and associated balance and engineering is approximately $ 27,000, with debt arbitrarily set at 50%. The cost of the associated pumping photovoltaic electrical power is approximately $80,000 ($2.35/installed watt). The proposed location of the panels is the rooftop of the pool area.

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.

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 can perform sub-hourly simulations for advanced analyses, but require sub-hourly weather data to do so.

The solar water heating 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)
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
OpenEI 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)

THERMAL SOLAR DESIGN FOR POOL

Conversion factors:

1 gal H_2O = 3.79 kg

1 gal/min = 227.27 kg/hr.

1 hp = 746 watts

1 gal = 0.0038 m^3

$^{\circ}C = 5/9(^{\circ}F - 32)$

NEEDS FOR SOLAR THERMAL DESIGN FOR POOL

POOL

1. Total capacity of water in pool and ancillary storage; **250,000 gal = 947,000 kg= 3598.6 m^3**

   (a) Separate size of storage(if available)

2. Flow rate of water during use; **350 gpm = 79544.5 kg/hr**

3. Desired temperature of water; **82F = 27.8C**

4. Power (V, A, phases, PF)/hp/flow design of water pump(s); **208 V, 3ϕ**

   2-15 hp = 22380 W

   1-10 hp = 7460 W

   1-5hp = 3730 W

   TOTAL ELECTRICAL (POOL) = 33570 W = 33.57 kW

5. Other: **40 ton unit, 208 V, 3ϕ, 2-35 hp compressors = 52220 W = 52.22 kW**

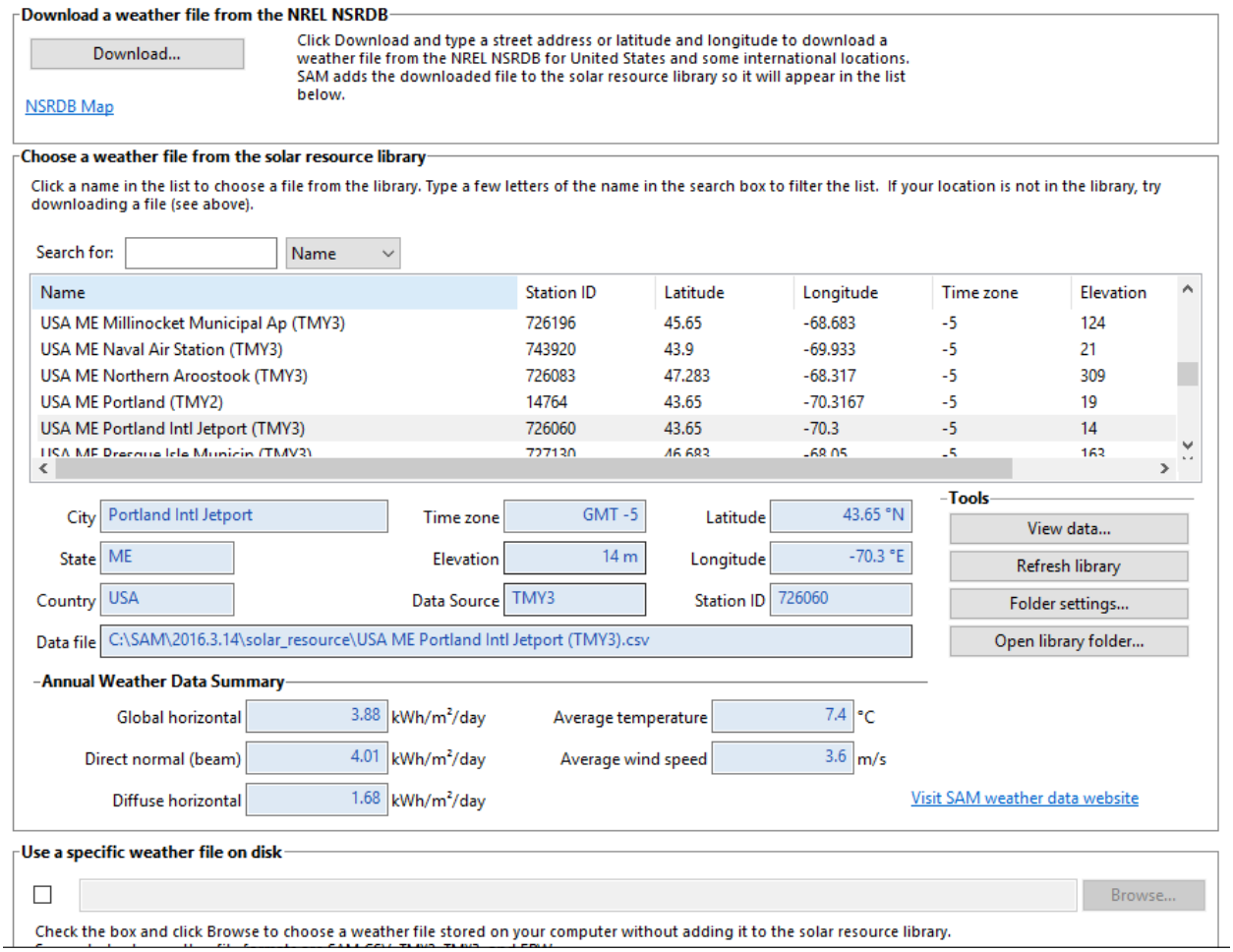
SPA

1. **10,000 gal = 37,900 kg = 144 m^3**

2. **2-7.5 hp = 22389 W= 22.389 kW, 208V, 3ϕ**

3. **Water 102 F = 38,9C, space 84F = 28.9C**

JVM 10/18/2016


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 below.
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 letters of the name in the search box to filter the list. If your location is not in the library, try downloading a file (see above).
Search for:
Name
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
City Portland Intl Jetport
Time zone GMT -5
Latitude 43.65 °N
State ME
Elevation 14 m
Longitude -70.3 °E
Country USA
Data Source TMY3
Station ID 726060
Data file C:\SAM\2016.3.14\solar_resource\USA ME Portland Intl Jetport (TMY3).csv
Tools
View data...
Refresh library
Folder settings...
Open library folder...
Annual Weather Data Summary
Global horizontal 3.88 kWh/m²/day
Average temperature 7.4 °C
Direct normal (beam) 4.01 kWh/m²/day
Average wind speed 3.6 m/s
Diffuse horizontal 1.68 kWh/m²/day
Visit SAM weather data website
Use a specific weather file on disk
Browse...
Check the box and click Browse to choose a weather file stored on your computer without adding it to the solar resource library.

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

Tilt	30 deg	Diffuse sky model	Isotropic
Azimuth	180 deg	Irradiance inputs	Beam and Diffuse
Total system flow rate	22.1 kg/s	Albedo	0.2 0..1
Working fluid	Glycol	Total system collector area	32 m2
Number of collectors	8	Rated system size	18.704 kW

Shading

Shading losses: Edit shading... | Open 3D shade calculator...

Curtailment and Availabilty

Edit losses...

Constant loss: 0.0 %
Hourly losses: None
Custom periods: None

Collector

◉ Enter user-defined parameters
○ Choose from library

User-defined collector

Collector area	4 m2
FRta	0.7
FRUL	3.85 W/m2.C
Incidence angle modifier	0.2
Test fluid	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	2.98	0.34	0.685
TiSUN LLC TiSUN FM-W S 4	2007054A	Glazed Flat-Plate	2.55	0.17	0.733
TiSUN LLC TiSUN FA 2 5	2007052C	Glazed Flat-Plate	10.1	0	0.732
TiSUN LLC TiSUN FA 2 6	2007052D	Glazed Flat-Plate	12.1	0	0.731
TiSUN LLC TiSUN FA 2 3	2007052B	Glazed Flat-Plate	6.1	0	0.726
TiSUN LLC TiSUN FA 2 4	2007052A	Glazed Flat-Plate	8.08	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	3598.6 m3	Heat exchanger effectiveness	0.75 0..1
Solar tank height to diameter ratio	0.5	Outlet set temperature	55 C
Solar tank heat loss coefficient (U value)	1 W/m2.C	Mechanical room temperature	27 C
Solar tank maximum water temperature	28 C		

Piping and Pumping

Total piping length in system	20 m	Pump power	33570 W
Pipe diameter	0.019 m	Pump efficiency	0.85 0..1
Pipe insulation conductivity	0.03 W/m.C		
Pipe insulation thickness	0.006 m		

Advanced

Use custom mains profile	☐	Use custom set temperatures	☑
Hourly custom mains profile	Edit data... C	Hourly custom set temperatures	Edit data... C

Direct Capital Costs

Number of Collectors	8	Collector cost	600.00 $/m2	$ 19,200.00
		Storage cost	0.00 $/m3	$ 0.00
			Balance of system	$ 4,000.00
			Installation cost	$ 2,000.00
			Contingency 0 %	$ 0.00
			Total direct cost	$ 25,200.00

Indirect Capital Costs

	% of Direct Cost	Non-fixed Cost	Fixed Cost	Total
Engineer, Procure, Construct	5 %	$ 1260.00	$ 0.00	$ 1,260.00
Project, Land, Miscellaneous	0 %	$ 0.00	$ 0.00	$ 0.00

Sales tax of 0 % applies to 100 % of direct cost $ 0.00

Total indirect cost $ 1,260.00

Total Installed Costs

Total Installed Cost excludes financing costs (if any, see Financing Page)

Total installed cost $ 26,460.00

Total installed cost per capacity ($/Wt) $ 1.41

Operation and Maintenance Costs

	First year cost		Escalation rate (above inflation)
Fixed annual cost	0	$/yr	0 %
Fixed cost by capacity	50	$/kW-yr	0 %
Variable cost by generation	0	$/MWh	0 %

In Value mode, SAM applies both inflation and escalation to the first year cost to calculate out-year costs. In Schedule mode, neither inflation nor escalation applies. See Help for details.

System Performance Degradation

Degradation rate 0.5 %/year

Applies to the system's total annual AC output.

In Value mode, the degradation rate applies to the system's total annual kWh output for the previous year starting in Year 2. In Schedule mode, each year's rate applies to the Year 1 value. See Help for details.

Project Term Debt

Debt percent	50 %	Net capital cost	$ 26,460.00	The weighted average cost of capital (WACC) is displayed for reference. SAM does not use the value for calculations.
Loan term	30 years	Debt	$ 13,230.00	
Loan rate	5 %/year	WACC	5.70 %	For a project with no debt, set the debt percent to zero.

Analysis Parameters

Analysis period	30 years	Inflation rate	2.5 %/year
		Real discount rate	5.5 %/year
		Nominal discount rate	8.14 %/year

Tax and Insurance Rates

Federal income tax rate	30 %/year	**Property Tax**	
State income tax rate	7 %/year	Assessed percentage	100 % of installed cost
		Assessed value	$ 26,460.00
Sales tax	0 % of total direct cost	Annual decline	0 %/year
Insurance rate (annual)	1 % of installed cost	Property tax rate	1 %/year

Salvage Value

Net salvage value	0 % of installed cost	End of analysis period value	$ 0

Depreciation

Federal			State		
○ No depreciation			○ No depreciation		
◉ 5-yr MACRS			◉ 5-yr MACRS		
○ Straight line	12	years	○ Straight line	12	years
○ Custom	Edit...	percentages	○ Custom	Edit...	percentages

The depreciable basis is the sum of total installed cost from the System Costs page and total construction financing cost from the Financing page, less the sum of investment-based incentives (IBI) and 50% of any investment tax credits (ITC).

Input Time Series Load Data

Electric Load Data

Energy usage: Edit data... kW

Normalize supplied load profile to monthly utility bill data

Scaling factor (optional): 1

Monthly energy usage: Edit values... kWh

View load data...

Monthly Load Summary

	Energy (kWh)	Peak (kW)
Jan	25,415.11	46.14
Feb	22,835.96	46.12
Mar	25,201.86	47.77
Apr	24,737.45	56.53
May	26,684.73	58.68
Jun	29,219.67	69.53
Jul	32,255.26	71.41
Aug	31,188.28	70.87
Sep	27,258.54	68.01
Oct	25,595.31	51.36
Nov	24,607.17	47.10
Dec	25,465.73	46.08
Annual	320,465.09	71.41

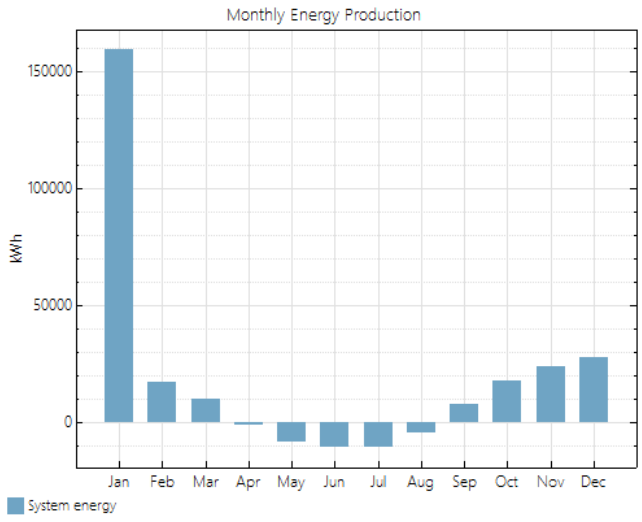
Annual Adjustment

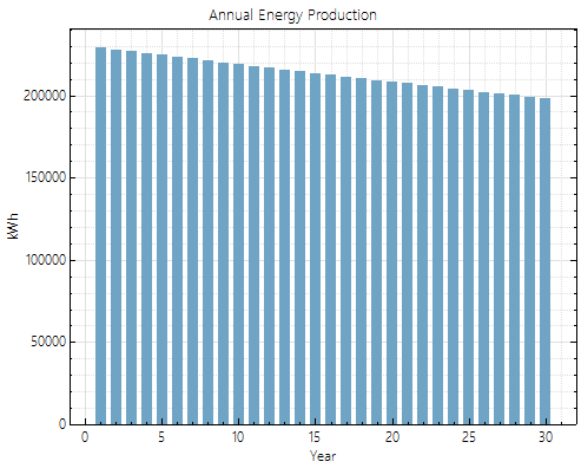
Load growth rate: Value 0 %/yr

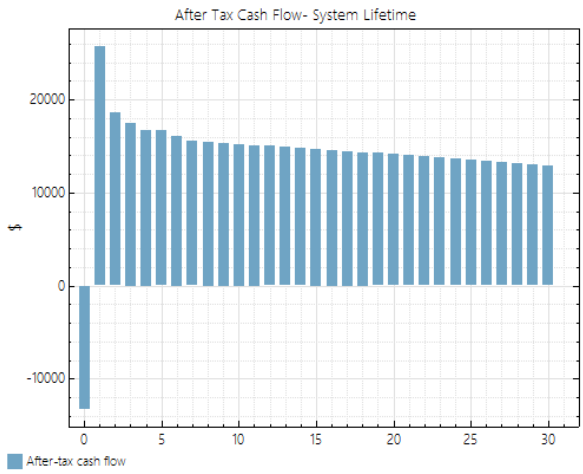
In Value mode, the growth rate applies to the previous year's annual kWh load starting in Year 2. In Schedule mode, each year's rate applies to the Year 1 kWh value. See Help for details.

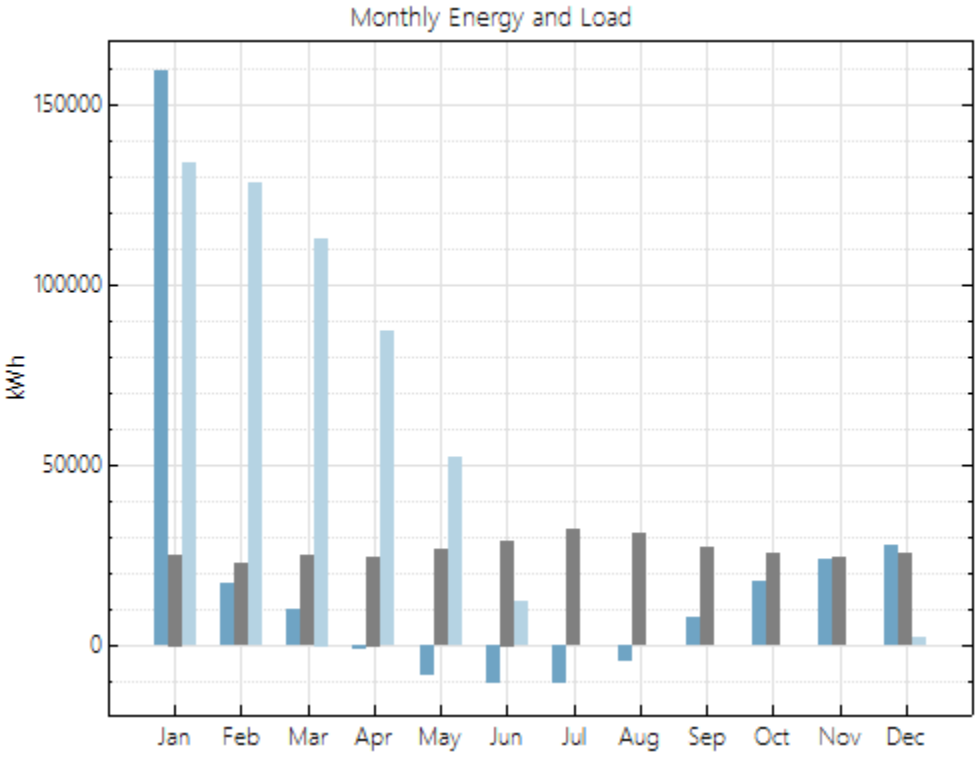
Summary | Graphs | Data | Cash flow | Time series | Profiles | Statistics | Heat map | PDF / CDF | Notices

Metric	Value
Annual energy saved (year 1)	229,092 kWh
Solar fraction (year 1)	0.01
Aux with solar (year 1)	31,453,026.0 kWh
Aux without solar (year 1)	31,820,626.0 kWh
Capacity factor (year 1)	139.8%
Levelized COE (nominal)	0.82 ¢/kWh
Levelized COE (real)	0.63 ¢/kWh
Electricity bill without system (year 1)	$38,456
Electricity bill with system (year 1)	$11,197
Net savings with system (year 1)	$27,259
Net present value	$169,213
Payback period	1.0 years
Net capital cost	$26,460
Equity	$13,230
Debt	$13,230




Annual Energy Production
kWh
200000
150000
100000
50000
0
0
5
10
15
20
25
30
Year


After Tax Cash Flow- System Lifetime
$
20000
10000
0
-10000
0
5
10
15
20
25
30
After-tax cash flow


Monthly Energy and Load
kWh
150000
100000
50000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

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

	$		$/Wdc		
Balance of system equipment	0.00		0.57		$ 85,500.00
Installation labor	0.00	+	0.15	=	$ 22,500.00
Installer margin and overhead	0.00		0.75		$ 112,500.00
				Subtotal	$ 358,500.00

Contingency

Contingency	0	% 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 Costs

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 installed cost per capacity	$ 2.55/Wdc