DANIEL MEYER POOL

RENEWABLE ENERGY ASSESSMENT

City of Ashland
Daniel Meyer Pool
Ashland, OR

Submitted to:
City of Ashland
Robertson Sherwood Architects

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ACRONYM GLOSSARY

ACRONYM	DEFINITION
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
Btu	British Thermal Unit
CFM	Cubic Feet per Minute
COP	Coefficient of Performance
DD	Design Development
DEQ	Department of Environmental Quality
EEM	Energy Efficiency Measure
EER	Energy Efficiency Ratio
ER	Electric Resistance
ETO	Energy Trust of Oregon
EUI	Energy Use Intensity
GET	Green Energy Technology
GHI	Global Horizontal Irradiance
HP	Heat Pump
HVAC	Heating, Ventilation, and Air Conditioning
kWh	Kilowatt-hour
kBtu	KiloBtu (1,000 Btus)
m	Meter
MBH	MegaBtu per hour (1,000 Btu/hr)
MMBtu	Metric Million Btu (equal to 1,000 kbtu)
ML	Measure Life
NG	Natural Gas
NREL	National Renewable Energy Laboratory
PV	Photovoltaic
ROM	Rough Order of Magnitude
s	Second
SD	Schematic Design
SHGC	Solar Heat Gain Coefficient
SHW	Solar Hot Water
SP	Simple Payback
TMY3	Typical Meteorological Year version 3
TSRF	Total Solar Resource Fraction

DISCLAIMER

The energy consumption and associated costs presented in this report are not intended to be interpreted as predictive in nature. Systems West has taken all reasonable actions under the supervision of a registered professional engineer to ensure all energy model and/or analysis inputs are within an acceptable range of accuracy for the given design phase of the project. The primary intent of energy modeling and affiliated analysis is to provide a comparative investigation of alternative design options in order to provide relative energy savings, relative simple payback potential and/or percent improvement of the proposed design over applicable code baselines.

Typical project characteristics that cause variance between modeled and actual energy use include but are not limited to: abnormal weather conditions; inconsistencies in equipment, systems, or occupancy schedules; discrepancies between specified and in-situ equipment efficiencies; and changes in internal loads. Energy modeling is not able to take these divergencies into account prospectively. A retrospective analysis that includes model calibration based on post-upgrade/construction utility data is required for the statistical precision of a prognostic model.

1. EXECUTIVE SUMMARY

PROJECT DESCRIPTION

Built in 1986, the existing Daniel Meyer Pool in Ashland, Oregon currently includes a 25-yard by 15-yard outdoor heated pool operating on a year-round schedule. The pool's heating equipment is currently supplied by natural gas and consumes roughly 20,000 therms per year of fossil fuel energy while emitting 117 tons of CO_2 annually. In addition to increasing the volume and surface area of the pool, the City of Ashland is interested in understanding the most effective way for the project to reduce carbon emissions and incorporate a renewable energy system compliant with the State of Oregon's Green Energy Technology (GET) requirements.

Prior to the energy analysis, the design team outlined four primary strategies to reduce carbon emissions:

- Electrification of pool heating equipment. Refer to the Appendix for a pool heating system matrix of the following four options. Note: Options 2 and 3B allow for complete electrification of pool heating equipment
  - Option 1: Natural gas (NG) boilers
  - Option 2: Electric resistance (ER) boilers
  - Option 3A: HP chiller with NG boiler back-up
  - Option 3B: HP chiller with ER boiler back-up
- Installation of a solar PV array
- Installation of a solar thermal hot water array
- Installation of a direct-use geothermal heating system[1]

CONCLUSIONS AND RECOMMENDATIONS

Based on the energy analysis, Systems West developed three primary recommendations to help enhance the design decisions associated with emissions reduction and GET system selection for Daniel Meyer Pool. This section summarizes each recommendation by its correlating analysis goal.

Goal 1: Optimize the carbon emissions reduction path for the project. The analysis has determined that the most cost-effective way to reduce carbon emissions on site is to electrify the pool heating equipment. Even while considering the increase in the proposed pool size, Option 2, the ER boiler system, will allow for the pool's annual CO_2 emission to drop from 117 to 28 tons. Option 3B, the HP chiller with electric-boiler back-up, will reduce annual emissions even further, to just 14 tons per year.

As the Appendix further outlines, the incremental payback for considering Option 3B over Option 2 is less than 5 years. Conversely, simple paybacks for the PV, SHW, and geothermal options range from 15 to 80 years. In other words, utilizing a heat pump chiller heating system

[1] This study did not explore closed-loop geothermal systems (i.e. ground-source heat pumps) since this technology is not compatible with a pool heating system. This is primarily due to the lack of sink/source cycling with the ground interface.

option demonstrates the most cost-effective path for reducing carbon emissions compared to an ER boiler baseline.

Due primarily to the magnitude of the winter and nighttime pool heating loads, the only option that has the potential to eliminate all site and source carbon emissions, i.e., for the project to be carbon-neutral, is the direct-use geothermal heating system. However, as further described in this report, the cost for integrating this system at this site is cost prohibitive, with capital costs ranging from $2.1 to $3.4 Million.

> *Recommendation:* Select an electric-source heating system as the basis of design for pool heating. Prioritize the investment in the HP chiller before considering exceeding the 1.5% GET budget for the project.

Goal 2: Determine a cost-effective solution for a renewable energy system that meets and/or exceeds Oregon's GET requirements. Due to the excessive capital costs of integrating a direct-use geothermal system, the project should focus consideration on either PV or SHW arrays for the GET renewable system. The analysis shows comparable paybacks for the minimum GET-sized arrays, each in the range of 19-23 years depending on the baseline heating system. However, PV systems have an effective useful life of 25 years, while SHW systems are generally closer to 20 years; therefore, a PV system is a better investment for this project since the break-even point is more likely to occur before the system needs to be replaced.

Furthermore, PV systems outperform SHW systems as arrays increase in area. As the size of the PV array increases beyond the minimum GET requirement, the simple payback tends to shorten due to economy of scale and the fact that the City of Ashland will credit PV production up to 100% of annual electrical consumption. Conversely, the SHW systems show longer simple paybacks as the array size increases due to the inability of the system to offset nightly and winter pool heating loads.

> *Recommendation:* Pursue a PV array system to conform with the State of Oregon's 1.5% for GET in Public Buildings requirement. As mentioned in the previous recommendation, the owner should prioritize investment in the HP chiller before they consider exceeding the 1.5% GET budget for the project. Systems West estimates the minimum size GET PV array to be roughly 23-kW and 1,600-ft^2 based on a $75,000 budget.

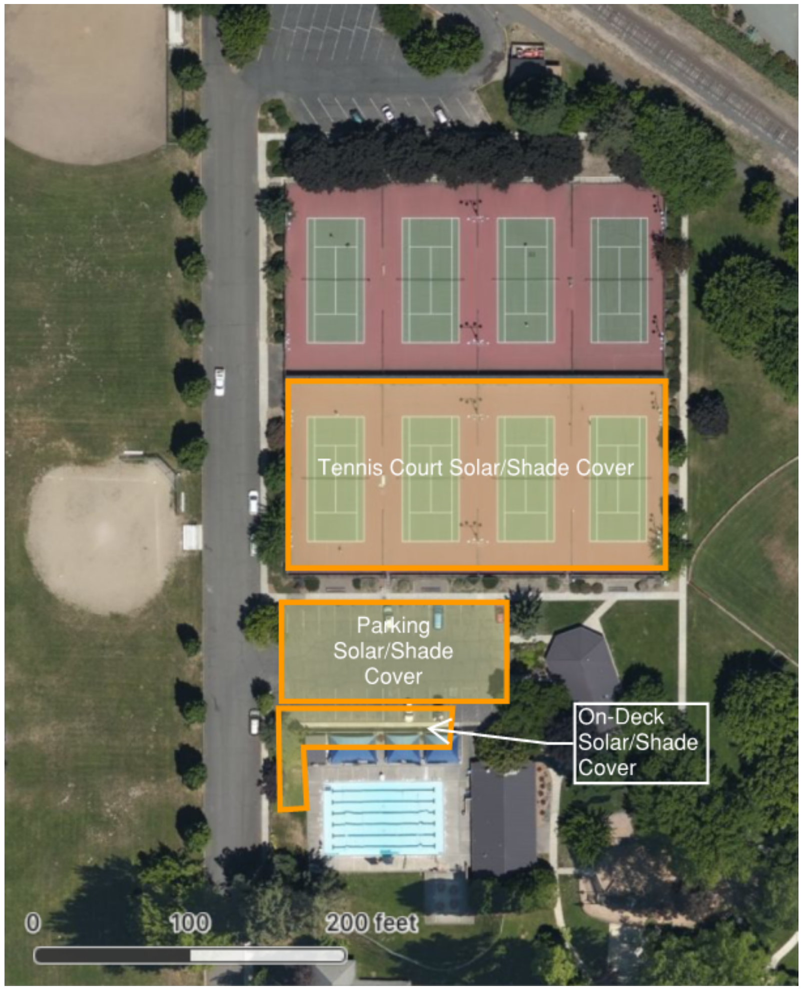
Goal 3: Determine the appropriate location for the panel array. The design team identified three locations for a solar array at the site, illustrated in Figure 1-1 and outlined in Table 1-1 below:

Table 1-1: Array Location Details

Array Location	Max Array Size (ft^2)	GET Min Array Size PV (ft^2)	GET Min Array Size SHW (ft^2)
Tennis Court	20,000	1,650	1,000
Parking Lot	9,000		
Pool Deck	2,200		

Each location exceeds the dimensions required for a minimum GET array for either a PV or SHW system. The analysis summary in the Results section outlines the total maximum production and associated payback for each array location assuming complete coverage. These results are informational and may be used by the owner to assess the potential production and capital costs associated with investment in PV beyond the GET requirement.

Figure 1-1: Array Location Map



Recommendation: The parking lot location seems to offer the best location for the PV array since locating the array on the pool deck may require tree cuttings on the southwest corner, and the tennis court will require taller overall mounting structures. If the owner does not intend to exceed the 1.5% GET Budget (assumed to be $75,000 for this analysis), the pool deck is equally as viable if panels are prioritized on the east side of the mapped location, away from trees. Further discussion regarding the maximum PV investment will dictate whether the array necessitates spillover into a combination of more than one location. Please refer to Figure 2-1 for guidance on the production and cost implications for the three maximum array sizes. Note that other factors such as proximity to utility equipment and ideal inverter location will also inform decisions on final array location.

2. RESULTS

Figure 2-1 on the following page provides a summary matrix of the analysis results. Refer to page 6 for further narrative and matrix details.

Figure 2-1: Analysis Results Matrix

Ashland Daniel Meyer Pool

Energy Efficiency Measure Analysis Summary

GET Assessment

SYSTEMS
WEST
ENGINEERS

	Annual Consumption of Baseline Options					
	Electric	NG	Other Fuel	EUI	CO_2	Energy Cost
	kwh	Therm	gallons	kbtu/sf/yr	Tons	$
Baseline System Option 2 (All Electric Boilers)	1,269,000	0	0	1,478	28	$132,653
Baseline System Option 3B (HP Chiller with Electric Boiler Backup)	632,000	0	0	736	14	$66,065

			Analysis Results - Option 2 Baseline (All Electric Boiler)							Analysis Results - Option 3B Baseline (HP Chiller w/ Electric Boiler)						
			Annual Energy/Emissions			Financial				Annual Energy/Emissions			Financial			
Analysis	EEM	EEM Description	Energy Reduction	CO_2 Reduction	Resulting CO_2 Emissions	Annual Energy Cost Savings	Measure Cost[1]	Simple Payback	Measure Life	Energy Reduction	CO_2 Reduction	Resulting CO_2 Emissions	Annual Energy Cost Savings	Measure Cost[1]	Simple Payback	Measure Life
			kwh	Tons	Tons	$/yr	$	yr	yr	kwh	Tons	Tons	$	$	yr	yr
PV	1	Tennis Court Array (400-kW Capacity Max)	571,000	13	15	$59,688	$977,000	16.4	33	571,000	13	1	$59,688	$977,000	16.4	33
PV	2	Parking Lot Cover Array (174-kW Capacity Max)	247,000	5	23	$25,820	$421,000	16.3	33	247,000	5	8	$25,820	$421,000	16.3	33
PV	3	Pool Deck Array (45-kW Capacity Max)	64,000	1	27	$6,690	$145,000	21.7	33	64,000	1	13	$6,690	$145,000	21.7	33
PV	4	Min GET Array (~23-kW Capacity)	33,000	1	27	$3,450	$75,000	21.7	33	33,000	1	13	$3,450	$75,000	21.7	33
SHW	5	Tennis Court Array (~20,000 ft^2 Array Max)	228,000	5	23	$23,834	$1,502,000	63.0	20	161,000	4	10	$16,830	$1,502,000	89.2	20
SHW	6	Parking Lot Cover Array (~9,000 ft^2 Array Max)	189,000	4	24	$19,757	$648,000	32.8	20	143,000	3	11	$14,948	$648,000	43.3	20
SHW	7	Pool Deck Array (~2,200 ft^2 Array Max)	84,000	2	26	$8,781	$166,000	18.9	20	80,000	2	12	$8,363	$166,000	19.9	20
SHW	8	Min GET Array (~1,000 ft^2 Array)	37,000	1	27	$3,868	$75,000	19.4	20	31,000	1	13	$3,241	$75,000	23.1	20
Geo	9	High Temperature Direct-Use Geothermal	1,269,000	28	0	$132,653	$3,422,000	25.8	50+	632,000	14	0	$66,065	$3,422,000	51.8	50+
Geo	10	Low Temperature Direct-Use Geothermal	246,000	5	23	$25,715	$2,124,000	82.6	50+	243,000	5	9	$25,402	$2,124,000	83.6	50+

[1] Opinion of Probable Incremental Costs

Assumptions:

Bldg Sqft	$/kWh	$lbsCO_2/kWh$	kbtu/kWh	$/Therm	$lbsCO_2/Therm$	kbtu/Therm	Other Fuel	Units	$/Unit	lbsCO2/Unit	kbtu/unit
2,930	$0.105	0.044	3.412	$0.888	11.684	100	Oil	gallons	$1.899	22.4	138,800

Heat Map Legend	
	Savings (decrease in energy use and/or energy cost)
	Penalty (increase in energy use and/or energy cost)

MATRIX DETAILS

Since the pool heating basis of design system is not yet finalized, the analysis considered savings and cost for each of the 10 EEMs compared to two electric heating system baselines:

1. All electric (ER) boilers (Option 2 outlined in Appendix)
2. HP chiller with ER boiler back up (Option 3B in Appendix)

As mentioned in the executive summary, the geothermal options offer the highest energy savings potential out of all the EEMs but also have capital costs associated with them that may generally be considered prohibitive. The matrix incorporates a heat map in the energy reduction field for each baseline to illustrate the options achieving the highest energy savings potential. Green results illustrate higher potential for energy savings and emissions reduction.

The matrix illustrates that the PV systems have the best balance of energy savings potential and cost effectiveness. Generally, in order for an EEM to be considered cost effective, the simple payback should occur within the expected measure life of the system. Depending on the size of the PV array that the project invests in, the PV systems are showing that they will pay for themselves within 50-70% of the effective useful life of the system.

Note that only the SHW and geothermal EEMs experienced a difference in savings between the two baselines. This is because these systems are highly interactive with the baseline heating system. Assuming an Option 2 baseline for example, the pool load is primarily served by the EEM (SHW or geothermal) with the entire resultant portion of the load being served by the electric boiler system. For Option 3B, the EEM is the primary heating source, with the HP chiller acting as a secondary system. When there is additional load that neither can meet, then the electric boiler backup system serves the resultant load. The varying levels of system interaction allows for only marginal savings in the Option 3B baseline vs. the Option 2 baseline; however, lower resultant site emissions are possible assuming the Option 3B baseline.

3. ANALYSIS ASSUMPTIONS

CROSSCUTTING ASSUMPTIONS

The energy analysis considered the hourly pool demand and the hourly offset potential from each renewable energy technology. Table 3-1 outlines the assumptions for modeling these metrics across all analysis scenarios.

Table 3-1: Cross-Cutting Assumptions and Sources

Metric	Assumption	Source	Notes
Outside air dry bulb temperature	°F modeled hourly	NREL TMY3 for Medford, OR	
Solar irradiance	GHI (w/m^2) modeled hourly	NREL TMY3 for Medford, OR	
Wind speed	m/s modeled hourly	NREL TMY3 for Medford, OR	
New pool volume	354,735 gallons	SD Report	
New pool surface Area	7,202 ft^2	SD Report	
Pool daily schedule	Uncovered 8am – 8pm Covered 8pm-8am	Engineering Assumption	Based on similar projects
Pool weekly schedule	7 days a week	Architect	
Pool annual schedule	Year-round operation	Architect	
Pool temperature setpoint	80°F	Engineering Assumption	Based on similar projects
Existing pool heat loss	1,600 MMBtu annually	Utility Billing	
New pool heat loss	4,000 MMBtu annually (Modeled Hourly)	ASHRAE Fundamentals	Proportional to increased pool volume
Pool heating system equipment capacity	2,900 MBH	Engineering Estimate	
Electric boiler performance	100% at all part loads	Engineering Estimate	
HP chiller performance	920 MBH and 3.4 COP @ 60°F OAT with relative linear regression to 530 MBH and 1.7 COP @ 15°F OAT	Equipment Specifications	AERMEC HP Chiller Basis of Design
Electricity rate	$0.105/kwh	Utility Billing	
Greenhouse gas emissions from electricity	0.044 lbs CO_2/kwh	Oregon DEQ	Link[2]
GET budget	$75,000	Architect	

SOLAR PV ANALYSIS ASSUMPTIONS

Systems West modeled the annual savings of the PV arrays by determining the direct electrical production based on TMY3 hourly solar irradiance resource. Table 3-3 outlines the assumptions for modeling the hourly SHW production for each of the 4 arrays:

1. Tennis Court: Assumes full panel coverage of a tennis court shading structure.

[2] https://www.oregon.gov/deq/aq/programs/Pages/GHG-Emissions.aspx

2. Parking Lot: Assumes full panel coverage of a parking lot shading structure.
3. Pool Deck: Assumes full panel coverage of the pool deck area.
4. Min GET Array: Assumes the smallest array that is required by the Oregon GET regulations.

Table 3-2: PV Analysis Assumptions and Sources

Metric	Assumption	Source	Notes
Tilt	12°	Engineering Assumption	
Orientation	180° Azimuth	Engineering Assumption	
Shading	0%	Engineering Assumption	TSRF study is required for proper shading estimates
Panel Type	Standard Efficiency photovoltaic	Engineering Assumption	Energy Model Default
System Losses	10%	Engineering Assumption	Energy Model Default
Array Operation	Year round	Engineering Assumption	
Inverter Efficiency	96%	Engineering Assumption	Energy Model Default
Array Capacity	14 W/ft^2	NREL estimate (benchmarked with installer ROMs)	
Equipment and Installation Costs	\$3.3-3.6/ft^2	NREL estimate (benchmarked with installer ROMs)	Does not Include Structural Costs
Effective Useful Life	33 years	NREL estimate (benchmarked with ETO)	

The financial analysis for the PV systems does not consider potential utility or government-funded incentives for renewable energy investments.

SOLAR HOT WATER ANALYSIS ASSUMPTIONS

Systems West modeled the annual production of the solar hot water arrays by determining the portion of the hourly pool heating load that each array would be able to serve based on the TMY3 hourly solar irradiance resource. The relationship between production and array size is nonlinear. As the array size/capacity increases, the technology experiences a diminished returns phenomenon since the hours at the highest capacity (most sunlight) do not align with the hours of highest pool load (nighttime and uncovered).

Table 3-3 outlines the assumptions for modeling the hourly SHW production for each of the 4 arrays:

1. Tennis Court: Assumes full panel coverage of a tennis court shading structure.
2. Parking Lot: Assumes full panel coverage of a parking lot shading structure.
3. Pool Deck: Assumes full panel coverage of the pool deck area.

4. Min GET Array: Assumes the smallest array that is required by the Oregon GET regulations.

Table 3-3: SHW Analysis Assumptions and Sources

Metric	Assumption	Source	Notes
Tilt	12°	Engineering Assumption	
Orientation	180° Azimuth	Engineering Assumption	
Shading	0%	Engineering Assumption	TSRF study is required for proper shading estimates
Panel Type	Unglazed	Engineering Assumption	Basis: Heliocol HC-40
Panel Dimensions	4' x 10.5'	Manufacturer Specs	Basis: Heliocol HC-40
Array Operation	April through October	Engineering Assumption	See discussion below
Equipment and Installation Costs	$74/ft^2	NREL estimate (benchmarked with installer ROMs)	Does not Include Structural Costs
Effective Useful Life	20 years	NREL (benchmarked with ETO)	

As the table outlines, this analysis assumed unglazed solar collectors as the basis of design. The analysis team performed preliminary analysis between unglazed and glazed collectors and found that unglazed collectors in this case provide better payback in all array sizes since they perform at higher efficiency and are less expensive than glazed models.

This analysis assumed that the unglazed collectors would be inoperable during winter months (November through March). Glazed collector systems often use a freeze-resistant mixture of glycol or employ a method that drains liquid from the collectors to prevent damage from freezing. Simple direct circulation unglazed collector systems lack sophisticated freeze protection. Due to the low solar resource in the winter months, this reduced operation of the unglazed collectors still provided similar annual production as well as better payback compared to the glazed collectors.

The financial analysis for the SHW systems does not consider potential utility or government-funded incentives for renewable energy investments.

DIRECT-USE GEOTHERMAL ASSUMPTIONS

The amount of energy that a direct-use geothermal system can offset for pool heating is directly related to both the water temperature and pumping flowrate potential of the hydrothermal well. This analysis therefore considered two scenarios for the geothermal system at Daniel Meyer Pool:

1. High-Temperature Well: Assumed to produce enough heat to directly serve the entire annual load of the pool (for all hours of the year).

2. Low-Temperature Well: Assumed to serve a portion of the annual heating load of the pool (low-load hours may be served completely but high-load hours will require the associated baseline heating system to operate).

Table 3-4 below outlines the analysis assumptions for modeling the hourly energy production and associated capital costs for each geothermal scenario.

Table 3-4: Geothermal Analysis Assumptions and Sources

Metric	Assumption	Source	Notes
High-temperature well depth	1,500 meters	NREL geothermal resource map for Ashland (Confirmed via geothermal well contractor interviews)	Link[3]
High-temperature well water temperature	>130°F		
Low-temperature well depth	1,000 meters		
Low-temperature well water temperature	100°F		
Equipment and Installation Costs	Logarithmic trend based on well depth	2016 Geothermics publication (Confirmed via geothermal well contractor interviews)	Link[4] (see discussion below for more detail regarding measure costs)
Effective Useful Life	50+ years	Energy Trust of Oregon	

The analysis results presented in Figure 2-1 provide best-case energy production from the respective wells. According to discussions with the geothermal well contractors, the general temperature water found in wells around the Ashland area is between 55°F-70°F at depths of less than 400m. There are sources to the north and near the foothills where hot springs are available; however, reasonable depth hydrothermal pools have not been found in the vicinity of the Daniel Meyer Pool. The assumed temperature in the analysis for each well are theoretical, with major uncertainty regarding the permeability and water quality of the aquifer below the Daniel Meyer Pool site. In addition to the cost of drilling for hydrothermal wells, the water systems typically require substantial treatment due to high sulfur and mineral content, which is not considered in this analysis. Measure costs for each well include the following components that quantify the total completed well construction costs:

- Drilling
- Equipment rental
- Cementing
- Fuel
- Casing and tubulars
- Mud logging
- Air compressors
- Welding

[3] https://maps.nrel.gov/geothermal-prospector

[4] Maciej Z. Lukawski, Rachel L. Silverman, Jefferson W. Tester, *Uncertainty analysis of geothermal well drilling and completion costs*, Geothermics, Volume 64, 2016, Pages 382-391.

- Inspection
- Engineering
- Wellhead equipment

Additionally, the analysis assumes ideal water pumping flowrates provided by each well. Total energy production from each geothermal scenario depends on the available flow rate of the extraction and injection wells. To provide best-case energy production for the analysis, Systems West assumed that the flow rate from each well (high-temperature and low-temperature) matched the rate required by the baseline heating systems for the pool. Actual energy production for each well will vary on actual flow rates and water temperature, which requires a substantial technical feasibility study by a geotechnical expert and/or contractor.

4. APPENDIX

The following table was developed previously by the design team as a resource for mapping the different heating system options for comparison of attributes.

	POOL WATER HEATING SYSTEM COMPARISON CHART			
	All systems are to are assumed to have a peak capacity of 3,000,000 BTU per hour, and will meet pool water heating load requirements of 8,640,000,000 BTU over the course of one year			
	OPTION 1	**OPTION 2**	**OPTION 3A**	**OPTION 3B**
	Description			
	New natural-gas fired 3MBH pool heater with 97% efficiency proposed by the pool contractor to replace the older heater.	Four (4) new 300kW all-electric pool heaters at 97% efficiency, with new 1400amp 480v electrical service upgrade.	New 268kW Heat Pump Chiller unit requiring a new 600amp 480v Electrical service upgrade, with new back-up natural-gas fired 3MBH boiler.	New 268kW Heat Pump Chiller unit with back-up from (4) new 300kW all-electric pool heaters at 97% efficiency, with new 1400amp 480v electrical
	Annual Power/Fuel Requirements			
Power		2,610,556 kWh	738,182 kWh	738,182 kWh
Nat. Gas	89,072 Therms		13,732 Therms	402,417 kWh
	Power/Fuel Rates			
Power		Use & Demand Charges	Use & Demand Charges	Use & Demand Charges
Nat. Gas	$0.90184/Therm		$0.90184/Therm	
	Annual Power/Fuel Costs			
Power		$274,188	$88,056	$88,056
Nat. Gas	$80,329		$12,384	$50,149
	TOTAL Annual Power/Fuel Costs			
	$80,329	**$274,188**	**$100,440**	**$138,205**
	Added Capital Costs and Project Costs			
	$0.00	$101,844	$534,441	$599,748
	Equipment priced in Base Estimate and Project Budget	Equipment cost differential and electrical service	Equipment cost differential and electrical service	Equipment cost differential and electrical service
	Simple Payback			
	Lowest Cost	**240% Energy Cost Increase**	**25% Energy Cost Increase**	**74% Energy Cost Increase**
	No Payback	**No Payback**	**2.7yr Payback over Option 2**	**4.4yr Payback over Option 2**
	Gas Only Heating	All-Electric Heating	Electric/Gas Back-up Heating	Electric/Elect. Back-up Heating

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[1] This study did not explore closed-loop geothermal systems (i.e. ground-source heat pumps) since this technology is not compatible with a pool heating system. This is primarily due to the lack of sink/source cycling with the ground interface.

system option demonstrates the most cost-effective path for reducing carbon emissions compared to an ER boiler baseline.

Due primarily to the magnitude of the winter and nighttime pool heating loads, the only option that has the potential to eliminate all site and source carbon emissions (i.e., for the project to be carbon-neutral) is the direct-use geothermal heating system. However, as further described in this report, the cost for integrating this system at this site is cost prohibitive, with capital costs ranging from $2.1 to $3.4 Million.[2]

> *Recommendation:* Select an electric-source heating system as the basis of design for pool heating. Prioritize the investment in the HP chiller before considering exceeding the 1.5% GET budget for the project.

Goal 2: Determine a cost-effective solution for a renewable energy system that meets and/or exceeds Oregon's GET requirements. Due to the excessive capital costs of integrating a direct-use geothermal system, the project should focus consideration on either PV or SHW arrays for the GET renewable system. The analysis shows comparable paybacks for the minimum GET-sized arrays, each in the range of 50-60 years depending on the baseline heating system. However, PV systems have an effective useful life of 33 years, while SHW systems are generally closer to 20 years; therefore, a PV system is a better investment for this project since they will maintain annual cost benefits for over a decade longer than SHW systems.

Furthermore, PV systems outperform SHW systems as arrays increase in area. As the size of the PV array increases beyond the minimum GET requirement, the simple payback tends to shorten due to economy of scale and the fact that the City of Ashland will credit PV production up to 100% of annual electrical consumption. Conversely, the SHW systems show longer simple paybacks as the array size increases due to the inability of the system to offset nightly and winter pool heating loads.

> *Recommendation:* Pursue a PV array system to conform with the State of Oregon's 1.5% for GET in Public Buildings requirement. As mentioned in the previous recommendation, the owner should prioritize investment in the HP chiller before they consider exceeding the 1.5% GET budget for the project. Systems West estimates the minimum size GET PV array to be roughly 23-kW and 1,600-ft^2 based on a $75,000 budget.

Goal 3: Determine the appropriate location for the panel array. The design team identified three locations for a solar array at the site, illustrated in Figure 1-1 and outlined in Table 1-1 below:

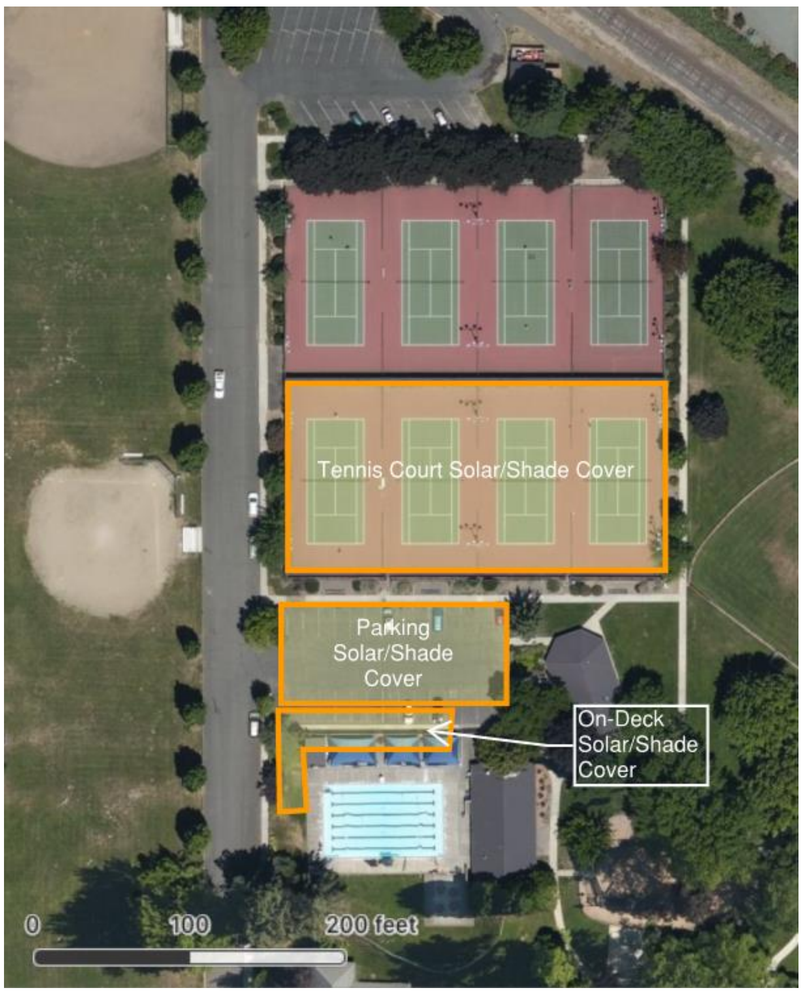
[2] These capital costs do not include associated structural improvements necessary for a direct-use geothermal system.

Table 1-1: Array Location Details

Array Location	Max Array Size (ft^2)	GET Min Array Size PV (ft^2)	GET Min Array Size SHW (ft^2)
Tennis Court	20,000	1,650	1,000
Parking Lot	9,000		
Pool Deck	2,200		

Each location exceeds the dimensions required for a minimum GET array for either a PV or SHW system. The analysis summary in the Results section outlines the total maximum production and associated payback for each array location assuming complete coverage. These results are informational and may be used by the owner to assess the potential production and capital costs associated with investment in PV beyond the GET requirement.

Figure 1-1: Array Location Map



Recommendation: The parking lot location seems to offer the best location for the PV array since locating the array on the pool deck may require tree cuttings on the southwest corner, and the tennis court will require taller overall mounting structures. If the owner does not intend to exceed the 1.5% GET Budget (assumed to be $75,000 for this analysis), the pool deck is equally as viable if panels are prioritized on the east side of the mapped location, away from trees. Further discussion regarding the maximum PV investment will dictate whether the array necessitates a specific location or spillover into a combination of locations. Please refer to Figure 2-1 for guidance on the production and cost implications for the three maximum array sizes. Note that other factors such as proximity to utility equipment and ideal inverter location will also inform decisions on final array location.

2. RESULTS

Figure 2-1 on the following page provides a summary matrix of the analysis results. Refer to page 6 for further narrative and matrix details.

Figure 2-1: Analysis Results Matrix

Ashland Daniel Meyer Pool

Energy Efficiency Measure Analysis Summary

GET Assessment

SYSTEMS WEST ENGINEERS

	Annual Consumption of Baseline Options					
	Electric	NG	Other Fuel	EUI	CO_2	Energy Cost
	kwh	Therm	gallons	kbtu/sf/yr	Tons	$
Baseline System Option 2 (All Electric Boilers)	1,269,000	0	0	1,478	28	$132,653
Baseline System Option 3B (HP Chiller with Electric Boiler Backup)	632,000	0	0	736	14	$66,065

Analysis Results - Option 2 Baseline (All Electric Boiler)

Analysis	EEM	EEM Description	Annual Energy/Emissions: Energy Reduction (kwh)	CO_2 Reduction (Tons)	Resulting CO_2 Emissions (Tons)	Financial: Annual Energy Cost Savings ($/yr)	Measure Cost[1] ($)	Simple Payback (yr)	Measure Life (yr)
PV	1	Tennis Court Array (400-kW Capacity Max)	571,000	13	15	$59,688	$3,539,000	59.3	33
PV	2	Parking Lot Cover Array (174-kW Capacity Max)	247,000	5	23	$25,820	$1,245,000	48.2	33
PV	3	Pool Deck Array (45-kW Capacity Max)	64,000	1	27	$6,690	$309,000	46.2	33
PV	4	Min GET Array (~23-kW Capacity)	33,000	1	27	$3,450	$198,000	57.4	33
SHW	5	Tennis Court Array (~20,000 ft^2 Array Max)	228,000	5	23	$23,834	$4,064,000	170.5	20
SHW	6	Parking Lot Cover Array (~9,000 ft^2 Array Max)	189,000	4	24	$19,757	$1,471,000	74.5	20
SHW	7	Pool Deck Array (~2,200 ft^2 Array Max)	84,000	2	26	$8,781	$330,000	37.6	20
SHW	8	Min GET Array (~1,000 ft^2 Array)	37,000	1	27	$3,868	$197,793	51.1	20
Geo	9	High Temperature Direct-Use Geothermal	1,269,000	28	0	$132,653	$3,422,000	25.8	50+
Geo	10	Low Temperature Direct-Use Geothermal	246,000	5	23	$25,715	$2,124,000	82.6	50+

Analysis Results - Option 3B Baseline (HP Chiller w/ Electric Boiler)

Analysis	EEM	EEM Description	Annual Energy/Emissions: Energy Reduction (kwh)	CO_2 Reduction (Tons)	Resulting CO_2 Emissions (Tons)	Financial: Annual Energy Cost Savings ($)	Measure Cost[1] ($)	Simple Payback (yr)	Measure Life (yr)
PV	1	Tennis Court Array (400-kW Capacity Max)	571,000	13	1	$59,688	$3,539,000	59.3	33
PV	2	Parking Lot Cover Array (174-kW Capacity Max)	247,000	5	8	$25,820	$1,245,000	48.2	33
PV	3	Pool Deck Array (45-kW Capacity Max)	64,000	1	13	$6,690	$309,000	46.2	33
PV	4	Min GET Array (~23-kW Capacity)	33,000	1	13	$3,450	$198,000	57.4	33
SHW	5	Tennis Court Array (~20,000 ft^2 Array Max)	161,000	4	10	$16,830	$4,064,000	241.5	20
SHW	6	Parking Lot Cover Array (~9,000 ft^2 Array Max)	143,000	3	11	$14,948	$1,471,000	98.4	20
SHW	7	Pool Deck Array (~2,200 ft^2 Array Max)	80,000	2	12	$8,363	$330,000	39.5	20
SHW	8	Min GET Array (~1,000 ft^2 Array)	31,000	1	13	$3,241	$197,793	61.0	20
Geo	9	High Temperature Direct-Use Geothermal	632,000	14	0	$66,065	$3,422,000	51.8	50+
Geo	10	Low Temperature Direct-Use Geothermal	243,000	5	9	$25,402	$2,124,000	83.6	50+

[1] Opinion of Probable Incremental Costs

Assumptions:

Bldg Sqft	$/kWh	$lbsCO_2$/kWh	kbtu/kWh	$/Therm	$lbsCO_2$/Therm	kbtu/Therm	Other Fuel	Units	$/Unit	lbsCO2/Unit	kbtu/unit
2,930	$0.105	0.044	3.412	$0.888	11.684	100	Oil	gallons	$1.899	22.4	138,800

Heat Map Legend
Savings (decrease in energy use and/or energy cost)
Penalty (increase in energy use and/or energy cost)

MATRIX DETAILS

Since the pool heating basis of design system is not yet finalized, the analysis considered savings and cost for each of the 10 EEMs compared to two electric heating system baselines:

1. All electric (ER) boilers (Option 2 outlined in Appendix)
2. HP chiller with ER boiler back up (Option 3B in Appendix)

As mentioned in the executive summary, the high temperature geothermal options offer the highest energy savings potential out of all the EEMs but also have capital costs associated with them that may generally be considered prohibitive. The matrix incorporates a heat map in the energy reduction field for each baseline to illustrate the options achieving the highest energy savings potential. Green results illustrate higher potential for energy savings and emissions reduction.

The matrix illustrates that the PV systems generally have the best balance of energy savings potential, measure life, and cost compared to the SHW systems. Although the smaller PV system sizes have comparable simple paybacks to the SHW systems, they have longer effective useful equipment lives which allow for a higher yield of the total payback before systems need to be replaced.

Note that only the SHW and geothermal EEMs experienced a difference in savings between the two baselines. This is because these systems are highly interactive with the baseline heating system. Assuming an Option 2 baseline for example, the pool load is primarily served by the EEM (SHW or geothermal) with the entire resultant portion of the load being served by the electric boiler system. For Option 3B, the EEM is the primary heating source, with the HP chiller acting as a secondary system. When there is additional load that neither can meet, then the electric boiler backup system serves the resultant load. The varying levels of system interaction allows for only marginal savings in the Option 3B baseline vs. the Option 2 baseline; however, lower resultant site emissions are possible assuming the Option 3B baseline.

3. ANALYSIS ASSUMPTIONS

CROSSCUTTING ASSUMPTIONS

The energy analysis considered the hourly pool demand and the hourly offset potential from each renewable energy technology. Table 3-1 outlines the assumptions for modeling these metrics across all analysis scenarios.

Table 3-1: Cross-Cutting Assumptions and Sources

Metric	Assumption	Source	Notes
Outside air dry bulb temperature	°F modeled hourly	NREL TMY3 for Medford, OR	

Metric	Assumption	Source	Notes
Solar irradiance	GHI (w/m^2) modeled hourly	NREL TMY3 for Medford, OR	
Wind speed	m/s modeled hourly	NREL TMY3 for Medford, OR	
New pool volume	354,735 gallons	SD Report	
New pool surface Area	7,202 ft^2	SD Report	
Pool daily schedule	Uncovered 8am – 8pm Covered 8pm-8am	Engineering Assumption	Based on similar projects
Pool weekly schedule	7 days a week	Architect	
Pool annual schedule	Year-round operation	Architect	
Pool temperature setpoint	80°F	Engineering Assumption	Based on similar projects
Existing pool heat loss	1,600 MMBtu annually	Utility Billing	
New pool heat loss	4,000 MMBtu annually (Modeled Hourly)	ASHRAE Fundamentals	Proportional to increased pool volume
Pool heating system equipment capacity	2,900 MBH	Engineering Estimate	
Electric boiler performance	100% at all part loads	Engineering Estimate	
HP chiller performance	920 MBH and 3.4 COP @ 60°F OAT with relative linear regression to 530 MBH and 1.7 COP @ 15°F OAT	Equipment Specifications	AERMEC HP Chiller Basis of Design
Electricity rate	$0.105/kwh	Utility Billing	
Greenhouse gas emissions from electricity	0.044 lbs CO_2/kwh	Oregon DEQ	Link[3]
GET budget	$75,000	Architect	

SOLAR PV ANALYSIS ASSUMPTIONS

Systems West modeled the annual savings of the PV arrays by determining the direct electrical production based on TMY3 hourly solar irradiance resource. Table 3-2 outlines the assumptions for modeling the hourly PV production for each of the 4 arrays:

1. Tennis Court: Assumes full panel coverage of a tennis court shading structure.
2. Parking Lot: Assumes full panel coverage of a parking lot shading structure.
3. Pool Deck: Assumes full panel coverage of the pool deck area.

[3] https://www.oregon.gov/deq/aq/programs/Pages/GHG-Emissions.aspx

4. Min GET Array: Assumes the smallest array that is required by the Oregon GET regulations.

Table 3-2: PV Analysis Assumptions and Sources

Metric	Assumption	Source	Notes
Tilt	12°	Engineering Assumption	
Orientation	180° Azimuth	Engineering Assumption	
Shading	0%	Engineering Assumption	TSRF study is required for proper shading estimates
Panel Type	Standard Efficiency photovoltaic	Engineering Assumption	Energy Model Default
System Losses	10%	Engineering Assumption	Energy Model Default
Array Operation	Year round	Engineering Assumption	
Inverter Efficiency	96%	Engineering Assumption	Energy Model Default
Array Capacity	14 W/ft^2	NREL estimate (benchmarked with installer ROMs)	
Equipment and Installation Costs	\$3.3-3.6/ft^2	NREL estimate (benchmarked with installer ROMs)	See Appendix B for additional structural costs.
Effective Useful Life	33 years	NREL estimate (benchmarked with ETO)	

The financial analysis for the PV systems does not consider potential utility or government-funded incentives for renewable energy investments.

SOLAR HOT WATER ANALYSIS ASSUMPTIONS

Systems West modeled the annual production of the solar hot water arrays by determining the portion of the hourly pool heating load that each array would be able to serve based on the TMY3 hourly solar irradiance resource. The relationship between production and array size is nonlinear. As the array size/capacity increases, the technology experiences a diminished returns phenomenon since the hours at the highest capacity (most sunlight) do not align with the hours of highest pool load (nighttime and uncovered).

Table 3-3 outlines the assumptions for modeling the hourly SHW production for each of the 4 arrays:

1. Tennis Court: Assumes full panel coverage of a tennis court shading structure.
2. Parking Lot: Assumes full panel coverage of a parking lot shading structure.
3. Pool Deck: Assumes full panel coverage of the pool deck area.
4. Min GET Array: Assumes the smallest array that is required by the Oregon GET regulations.

Table 3-3: SHW Analysis Assumptions and Sources

Metric	Assumption	Source	Notes
Tilt	12°	Engineering Assumption	
Orientation	180° Azimuth	Engineering Assumption	
Shading	0%	Engineering Assumption	TSRF study is required for proper shading estimates
Panel Type	Unglazed	Engineering Assumption	Basis: Heliocol HC-40
Panel Dimensions	4' x 10.5'	Manufacturer Specs	Basis: Heliocol HC-40
Array Operation	April through October	Engineering Assumption	See discussion below
Equipment and Installation Costs	$74/ft^2	NREL estimate (benchmarked with installer ROMs)	See Appendix B for additional structural costs.
Effective Useful Life	20 years	NREL (benchmarked with ETO)	

As the table outlines, this analysis assumed unglazed solar collectors as the basis of design. The analysis team performed preliminary analysis between unglazed and glazed collectors and found that unglazed collectors in this case provide better payback in all array sizes since they perform at higher efficiency and are less expensive than glazed models.

This analysis assumed that the unglazed collectors would be inoperable during winter months (November through March). Glazed collector systems often use a freeze-resistant mixture of glycol or employ a method that drains liquid from the collectors to prevent damage from freezing. Simple direct circulation unglazed collector systems lack sophisticated freeze protection. Due to the low solar resource in the winter months, this reduced operation of the unglazed collectors still provided similar annual production as well as better payback compared to the glazed collectors.

The financial analysis for the SHW systems does not consider potential utility or government-funded incentives for renewable energy investments.

DIRECT-USE GEOTHERMAL ANALYSIS ASSUMPTIONS

The amount of energy that a direct-use geothermal system can offset for pool heating is directly related to both the water temperature and pumping flowrate potential of the hydrothermal well. This analysis therefore considered two scenarios for the geothermal system at Daniel Meyer Pool:

1. High-Temperature Well: Assumed to produce enough heat to directly serve the entire annual load of the pool (for all hours of the year).
2. Low-Temperature Well: Assumed to serve a portion of the annual heating load of the pool (low-load hours may be served completely but high-load hours will require the associated baseline heating system to operate).

Table 3-4 below outlines the analysis assumptions for modeling the hourly energy production and associated capital costs for each geothermal scenario.

Table 3-4: Geothermal Analysis Assumptions and Sources

Metric	Assumption	Source	Notes
High-temperature well depth	1,500 meters	NREL geothermal resource map for Ashland (Confirmed via geothermal well contractor interviews)	Link[4]
High-temperature well water temperature	>130°F		
Low-temperature well depth	1,000 meters		
Low-temperature well water temperature	100°F		
Equipment and Installation Costs	Logarithmic trend based on well depth	2016 Geothermics publication (Confirmed via geothermal well contractor interviews)	Link[5] (see discussion below for more detail regarding measure costs). See Appendix B for additional structural costs.
Effective Useful Life	50+ years	Energy Trust of Oregon	

The analysis results presented in Figure 2-1 provide best-case energy production from the respective wells. According to discussions with the geothermal well contractors, the general temperature water found in wells around the Ashland area is between 55°F-70°F at depths of less than 400m. There are sources to the north and near the foothills where hot springs are available; however, reasonable depth hydrothermal pools have not been found in the vicinity of the Daniel Meyer Pool. The assumed temperature in the analysis for each well are theoretical, with major uncertainty regarding the permeability and water quality of the aquifer below the Daniel Meyer Pool site. In addition to the cost of drilling for hydrothermal wells, the water systems typically require substantial treatment due to high sulfur and mineral content, which is not considered in this analysis. Measure costs for each well include the following components that quantify the total completed well construction costs:

- Drilling
- Equipment rental
- Cementing
- Fuel
- Casing and tubulars
- Mud logging
- Air compressors
- Welding
- Inspection

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[4] https://maps.nrel.gov/geothermal-prospector

[5] Maciej Z. Lukawski, Rachel L. Silverman, Jefferson W. Tester, *Uncertainty analysis of geothermal well drilling and completion costs*, Geothermics, Volume 64, 2016, Pages 382-391.

- Engineering
- Wellhead equipment

Additionally, the analysis assumes ideal water pumping flowrates provided by each well. Total energy production from each geothermal scenario depends on the available flow rate of the extraction and injection wells. To provide best-case energy production for the analysis, Systems West assumed that the flow rate from each well (high-temperature and low-temperature) matched the rate required by the baseline heating systems for the pool. Actual energy production for each well will vary on actual flow rates and water temperature, which requires a substantial technical feasibility study by a geotechnical expert and/or contractor.

4. APPENDIX A – HEATING SYSTEM MATRIX

The following table was developed previously by the design team as a resource for mapping the different heating system options for comparison of attributes.

	POOL WATER HEATING SYSTEM COMPARISON CHART			
	All systems are to are assumed to have a peak capacity of 3,000,000 BTU per hour, and will meet pool water heating load requirements of 8,640,000,000 BTU over the course of one year			
	OPTION 1	**OPTION 2**	**OPTION 3A**	**OPTION 3B**
	Description			
	New natural-gas fired 3MBH pool heater with 97% efficiency proposed by the pool contractor to replace the older heater.	Four (4) new 300kW all-electric pool heaters at 97% efficiency, with new 1400amp 480v electrical service upgrade.	New 268kW Heat Pump Chiller unit requiring a new 600amp 480v Electrical service upgrade, with new back-up natural-gas fired 3MBH boiler.	New 268kW Heat Pump Chiller unit with back-up from (4) new 300kW all-electric pool heaters at 97% efficiency, with new 1400amp 480v electrical
	Annual Power/Fuel Requirements			
Power		2,610,556 kWh	738,182 kWh	738,182 kWh
Nat. Gas	89,072 Therms		13,732 Therms	402,417 kWh
	Power/Fuel Rates			
Power		Use & Demand Charges	Use & Demand Charges	Use & Demand Charges
Nat. Gas	$0.90184/Therm		$0.90184/Therm	
	Annual Power/Fuel Costs			
Power		$274,188	$88,056	$88,056
Nat. Gas	$80,329		$12,384	$50,149
	TOTAL Annual Power/Fuel Costs			
	$80,329	**$274,188**	**$100,440**	**$138,205**
	Added Capital Costs and Project Costs			
	$0.00	$101,844	$534,441	$599,748
	Equipment priced in Base Estimate and Project Budget	Equipment cost differential and electrical service	Equipment cost differential and electrical service	Equipment cost differential and electrical service
	Simple Payback			
	Lowest Cost	**240% Energy Cost Increase**	**25% Energy Cost Increase**	**74% Energy Cost Increase**
	No Payback	**No Payback**	**2.7yr Payback over Option 2**	**4.4yr Payback over Option 2**
	Gas Only Heating	All-Electric Heating	Electric/Gas Back-up Heating	Electric/Elect. Back-up Heating

5. APPENDIX B – MEASURE COST SUMMARY

Daniel Meyer Pool Solar/Shade Cover Capital Cost Options **April 2022**

	PV Array Capacity	PV Array $	Support Structure*	Area	Cost /sf	*** Comparative Structure Costs	Cost /sf	Site Development Costs	Est Conting., GC, OH&P	Total Direct Construction	Comments
									22%		
Minimum GET Array	23 kW	$75,000	Custom steel frame shade structures	1,650 sf	56.00	92,400.00	5.00	8,250.00	22,143.00	$122,793.00	drain to deck
Pool Deck Array	45 kW	$145,000	Custom steel frame shade structures	2,200 sf	56.00	123,200.00	5.00	11,000.00	29,524.00	$163,724.00	drain to deck
Parking Lot Cover Array **	174 kW	$421,000	Cantilevered custom steel structures	9,000 sf	60.00	540,000.00	15.00	135,000.00	148,500.00	$823,500.00	stormwater management, parking lot repaving/striping
Tennis Court Array	400 kW	$977,000	Pre-engineered metal bulding	20,000 sf	90.00	1,800,000.00	15.00	300,000.00	462,000.00	$2,562,000.00	stormwater management, tennis court/site repair, site utilities

* Refer to report for more information
** assumes drive aisle is covered
*** Structure only costs