SOLAR HOT WATER EVALUATION

OLBRICH BOTANICAL GARDENS

3330 Atwood Avenue
Madison, Wisconsin 53704

June 23, 2015

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SOLAR EVALUATION AT OLBRICH BOTANICAL GARDENS:

Non-Potable Water Usage:
The botanical gardens uses an estimate range of 2,000 to 6,500 gallons per day of low temperature hot water(75 deg F) for plant irrigation(RO water) and plant fertilizer usage. Refer to Figure 1 attached for flow chart of water uses. Currently, this non-potable water is tempered by gas-fired water heaters. This study evaluates the potential for using solar hot water collectors to reduce the fossil fuel energy usage.

Hot Water Reheat:
The hot water heating system at the botanical gardens employs a hot water reheat system to temper the air for space heating. During the summer, late spring and early fall months, the reheat load is primarily used to provide better temperature and humidity control for the VAV forced air system. Removing this hot water heating load from the hot water boiler system in the summer will allow eliminating the use of fossil fuel and also allow summer maintenance and shutdown on the boiler system.

Potable Water Usage:
The botanical gardens uses an estimate range of 130 to 180 gallons per day of high temperature hot water(110 deg F) for hand washing, showers and cleaning. Currently, this potable water is tempered by gas-fired water heaters. This study evaluates the potential for using solar hot water collectors to reduce the fossil fuel energy usage.

Proposed Hot Water Solar System:
The proposed hot water solar system would consist of either a 10 collector panels(400 SF) or 20 collector panels(800 SF) with an approximately 200 to 400 gallon storage tank and arranged in a drain back configuration on the roof above the mechanical room. The solar panels would be arranged on a 20-foot sloped support system over the proposed mechanical equipment - refer to Figure 2 attached. The solar storage tank would be located in the Head house area supported above 7-feet high to avoid interfering with the traffic in the Head house.

Estimated Energy and Cost Savings:
Estimated existing low and high hot water and reheat energy usage is 2,714 to 6,790 therms per year with an estimated energy cost range of $ 2,171 to $ 5,432 per year at $ 0.80/therm.

The 400 SF solar system(ten 4x10 ft collectors) is estimated to save 1,050 - 1,148 therms/year at an estimated energy cost savings of $ 840 to $ 920 per year.

The 800 SF solar system(twenty 4x10 ft collectors) is estimated to save 1,651 - 2,001 therms/year at an estimated energy cost savings of $ 1,320 to $ 1,600 per year.

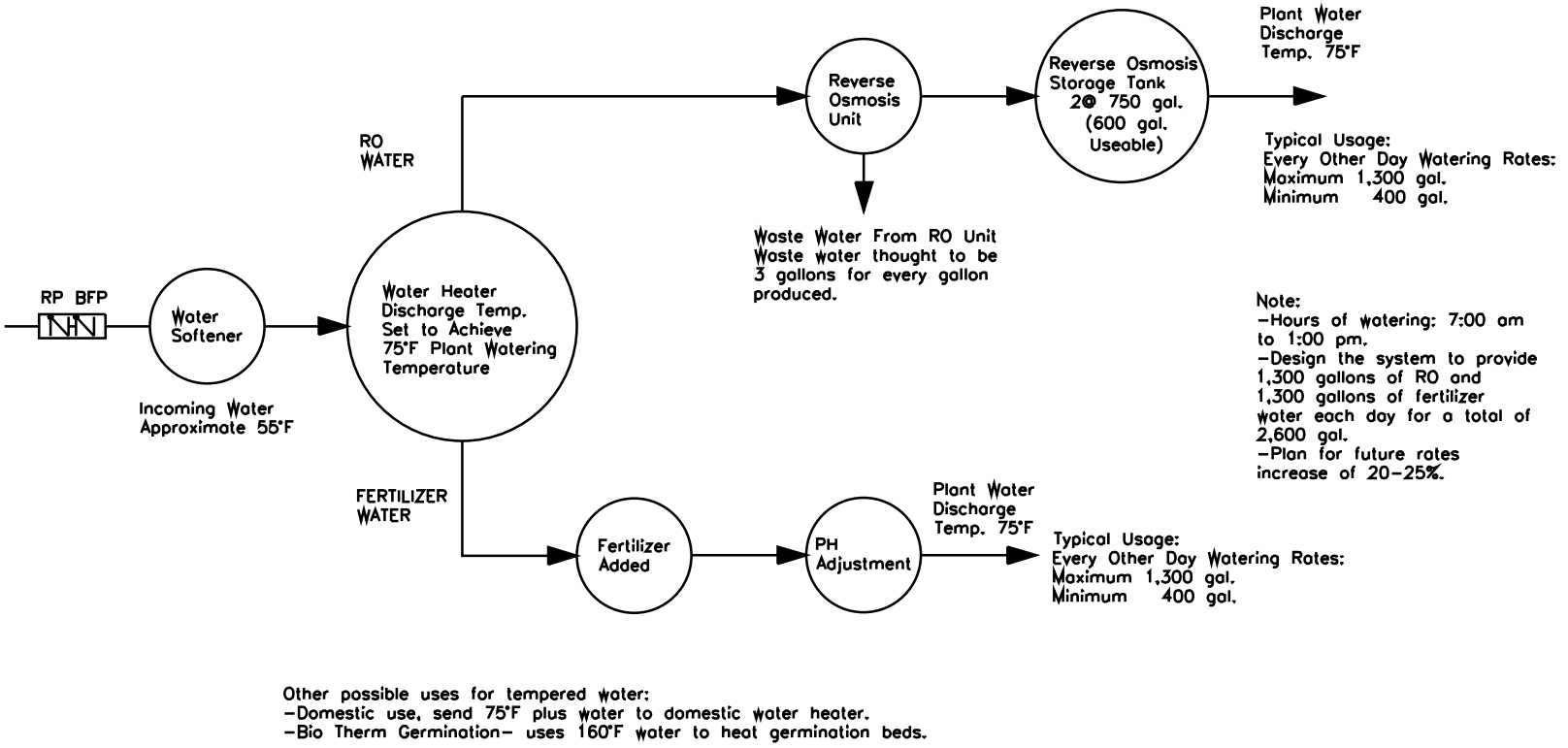
Estimated Solar System Costs:

The 400 SF solar system has an estimated construction cost of $ 62-72,000

The 800 SF solar system has an estimated construction cost of $ 116-136,000

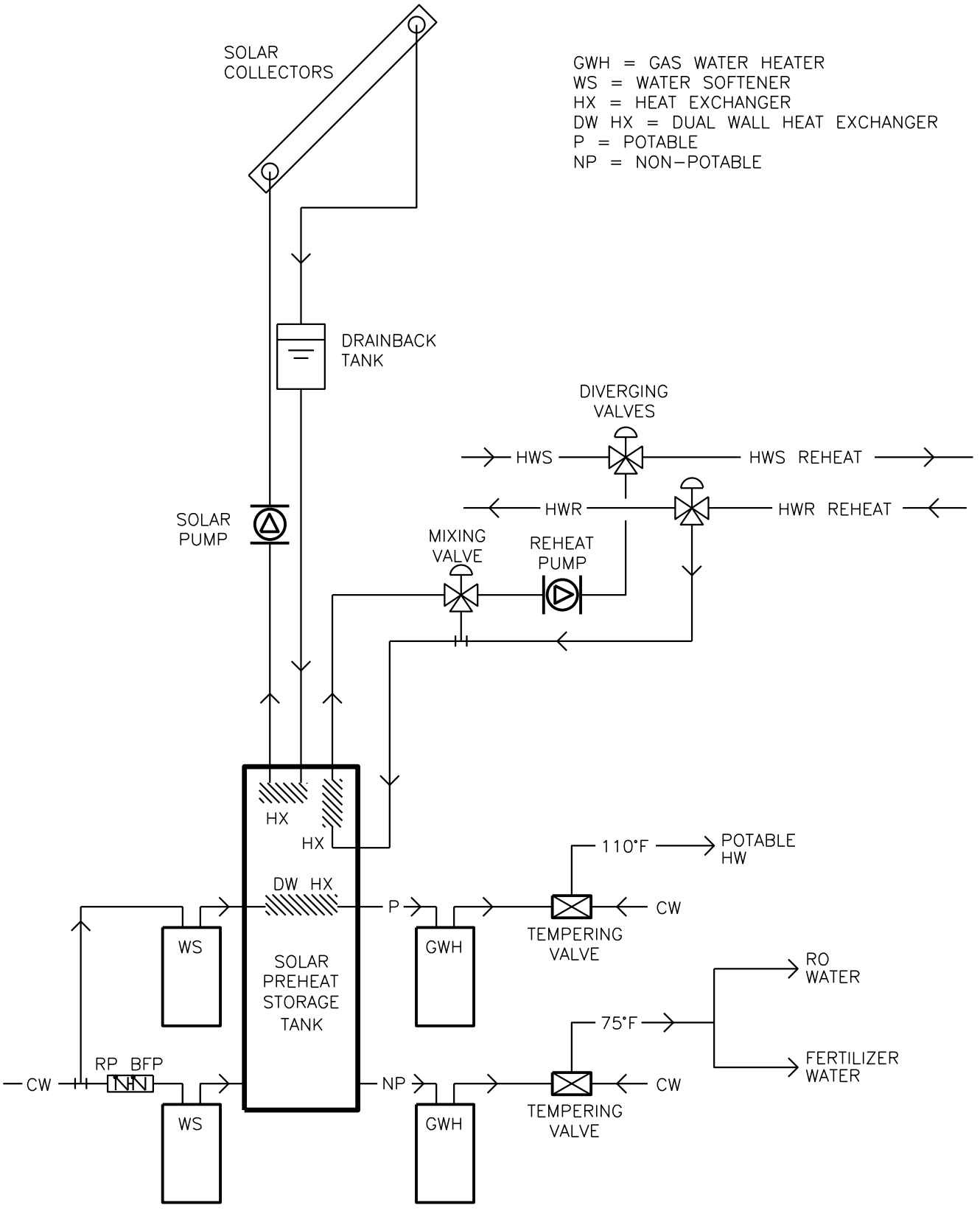
* * *

OLBRICH GARDEN– EXISTING LOW TEMPERATURE WATER USE



Other possible uses for tempered water:
–Domestic use, send 75°F plus water to domestic water heater.
–Bio Therm Germination– uses 160°F water to heat germination beds.

FIGURE 1



OLBRICH SOLAR HOT WATER PIPING SCHEMATIC

NTS

FIGURE 2

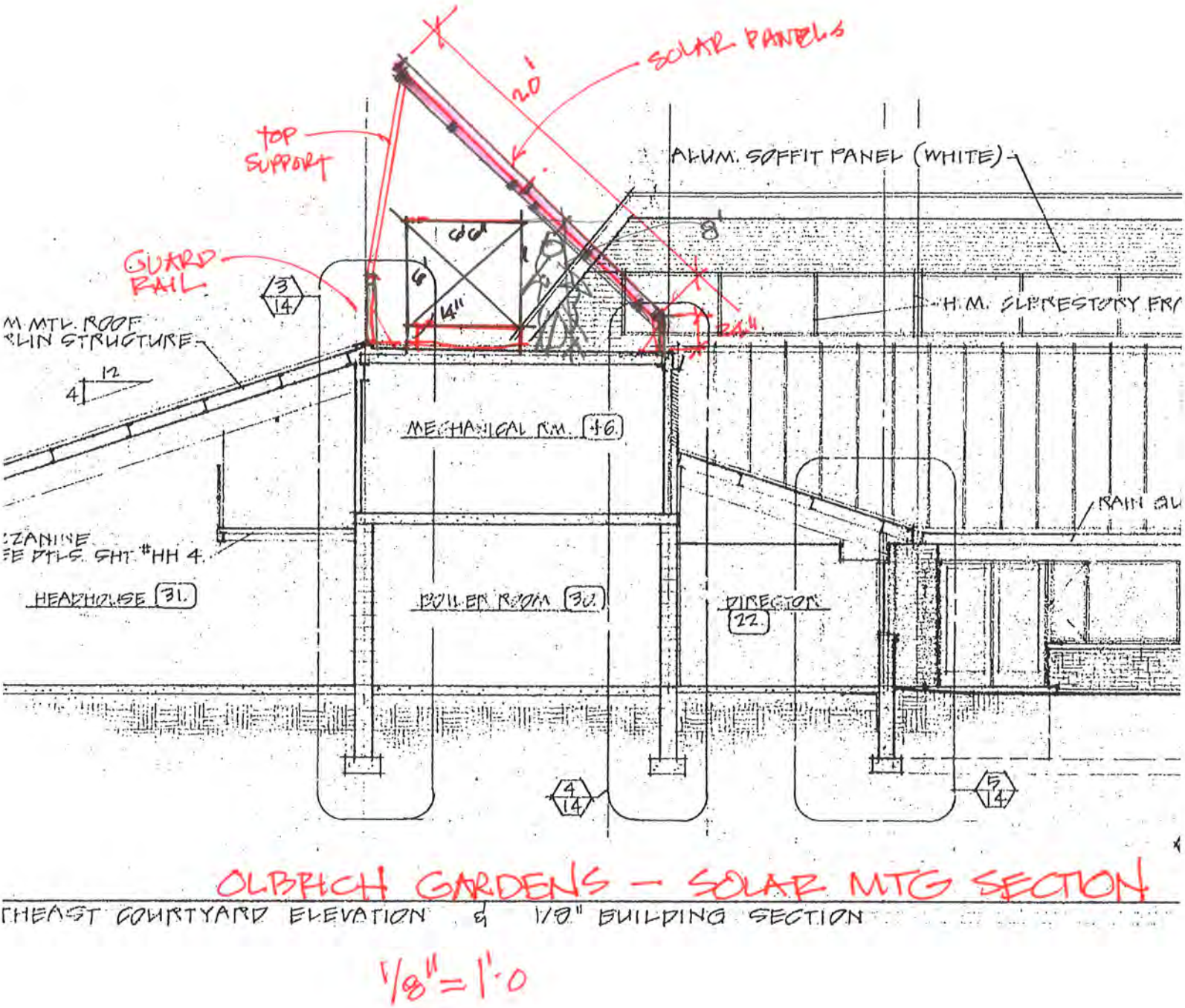

SOLAR PANELS
20'
TOP SUPPORT
ALUM. SOFFIT PANEL (WHITE)
GUARD RAIL
3/14
6"
14"
8'
24"
H.M. CLERESTORY FR
M. MTL. ROOF
RLIN STRUCTURE
12
4
MECHANICAL RM. 46.
RAIN GU
:ZANINE
E PTLS. SHT #HH 4.
HEADHOUSE 31.
BOILER ROOM 30.
DIRECTOR
22.
4/14
7/14
OLBRICH GARDENS - SOLAR MTG SECTION
THEAST COURTYARD ELEVATION & 1/8" BUILDING SECTION
1/8"=1'-0

FIGURE 3

PROPOSED AIR-COOLED CHILLER UNITS - FUTURE

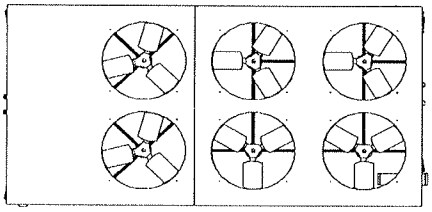
LC 54 TON UNIT

CLEARANCES	
LOCATION	LC 54 TON
REAR	48"
FRONT	48"
LEFT SIDE	36"
RIGHT SIDE	36"
TOP	UNOBSTRUCTED

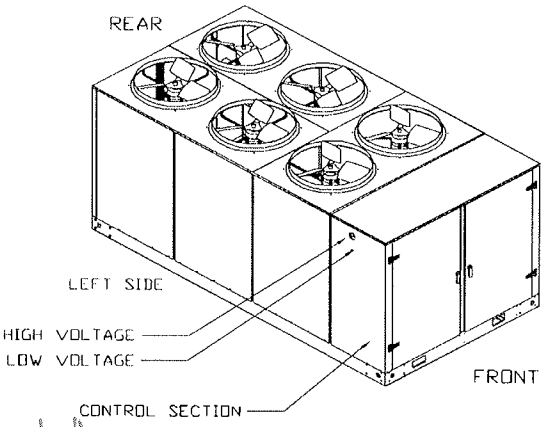
CONNECTION SIZES			
UNIT SIZE	CIRCUIT	PIPE SIZE	PIPE TYPE
LC 054	WATER IN	4"	GROOVED IPS*
	WATER OUT	4"	GROOVED IPS*

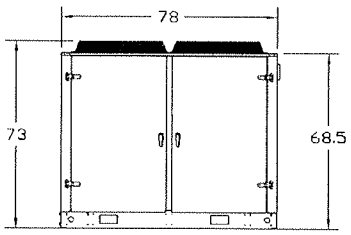
* IPS IRON PIPE SIZE

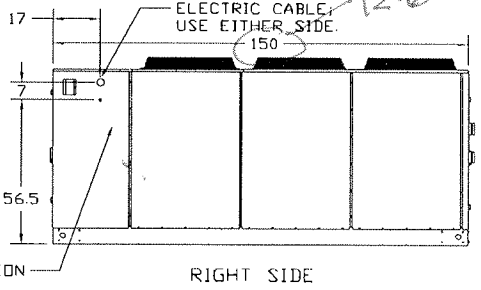
POWER CONNECTIONS			
UNIT SIZE	CIRCUIT	CONDUIT SIZE	HOLE SIZE
LC 054	HIGH VOLTAGE	2 1/2"	3"
	LOW VOLTAGE	1/2"	7/8"

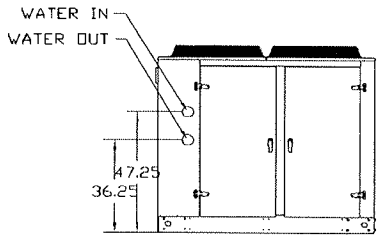


TOP









Olbrich Gardens Solar Hot Water Summary

Site Considerations:

The most available space for solar hot water collectors close to the water heating mechanicals is a small section of flat EPDM roof, adjacent to the greenhouse dome. Currently, there are multiple air handlers monopolizing a majority of the space; however it would be possible to site panels just south of the existing equipment. The plan for future removal of the HVAC equipment also presents further opportunity for doubling the available space for equipment. The flat roof area has 45 ft east to west and 18 ft north to south available, with an orientation within 10 degrees of true south (Fig.1). The site would require a large steel structure anchored directly to the concrete roof deck below, as well as support the collectors around the existing roof top units. Another option is to move the remaining roof top units to the north a few feet to make for additional clearances. The available space would be sufficient for up to ten (10) 4X10' flat plate collectors, but have potential to have a second row above that to provide up to 20 total collectors (240 sq ft). A (10) collector array would require approximately 44 ft East to West, and 8 ft North to South, and have a height of 10 ft, whereas the (20) collector array would have a height of approximately 18 ft. The adjacent roof line is 11 ft high for comparison purposes (highlighted in yellow in Fig.2).

Figure 1 – Aerial photo provided by Google Earth showing Olbrich Garden roof area available for possible solar hot water collector sites (highlighted in red)

Figure 2 – Photo on flat roof area looking East. Note presence of roof top units but space is available to go above existing and future rooftop equipment if desired.

Building demands vs available collector space

There are 4 major loads that are ideal temperature ranges for solar water heating: 1) Irrigation/fertilizer 2) RO water for irrigation 3) Hot Water Reheats during the summer and 4) domestic for the building.

After conversations with staff and considering future boiler replacement plans, it was determined that making the Reheat demand a primary load for the solar would be ideal, with secondary options for the other watering needs.

When modelling using Retscreen vers 4, a (10) 4X10 collector array can provide 80% of the reheat demand from May to September the high end demand estimate of 720MBH/day (see attached summary from the model). If the larger 20 collector array were installed 100% of the reheat demand could be supplied from the solar, with additional hot water available for the other loads. When adding the additional demands the 10 and 20 collector arrays can meet from 30-75% of the demand, depending

on the high or low end of the estimated daily loads. The average energy offset by the 10 collector array would be 40%, and 66% for the 20 collector array. Controls for delivering the energy to the reheats as a primary demand would be recommended with either setting for the summer months.

Table 1. Solar hot water system energy offset annually for all building loads (#1-4)

System	Low end (%)	High end (%)	Gallons of storage
(10) 4X10 collector	1,050 therms (48%)	1,148 therms (32%)	187 gal
(20) 4X10 collector	1,651 therms (76%)	2,001 therms (55%)	375 gal

*assumes 80% water heater efficiency

System storage sizing and recommended system type

The available space best fit for solar storage tanks and balance of system components is near the back loading dock, adjacent to the overhead steel platform that leads into the mezzanine mechanical room. There is over 150 sq ft of floor space that would more than accommodate a single designated solar storage tank, and necessary pumps. A drain-back system design would be preferred to allow for system shutdown when necessary, and the existing site is conducive to allowing drainage from the collectors to the drain-back tank. The recommended storage for a 10 collector array would be 160-175 gallons, and 320-380 gallons for the 20 collector array. The typical 1:1 ratio (gallon of storage : square ft of collector) can be reduced somewhat because of the large consistent volume of process water demands at the site.

Major site concerns to note:

-Solar hot water delivery to the system is at 3 separate locations with different temperature safety requirements. Limiting high water temperatures with mixing valves at each use will be more efficient than limiting the entire solar storage tank temperatures to 75-120F

-The timing for construction of the solar hot water system should coordinate with either the boiler upgrades or the HVAC remodel. The presence of the rooftop units as well as other piping work occurring when the boiler is upgrade provide ideal times to gain efficiencies from overlapping work, and coordination for solar roof work.

-The mix of potable and non-potable end uses for the water can be separated with internal or external heat exchangers but definitely has to be considered.

Estimated Construction Budgets and Applicable Incentives

System Size	Turn-key construction costs
(10) 4'X10's (400 sq ft)	$62,000 to $72,000
(20) 4'X10's (800 sq ft)	$116,000 to $136,000

Currently Focus on Energy's Renewable Energy Competition Incentive Program (RECIP) is open for grant applications. The due date is March 20th, 2015, with another projected application opening in the fall of

2015, and January 2016. Solar hot water projects can qualify for up to $1.00 per therm offset, or equivalent to approximately **$1,200** or **$2,000** for the (10) or (20) collector projects respectively

SOLAR LOAD SUMMARY

DATE: June 23, 2015

PROJECT: **Olbrich Botanical Gardens - Solar Load Estimates**
H1207

TO: Paul Stauffer City of Madison - Facility Engineering
Adam Gusse H&H Solar Energy Services

FROM: Mike Hein HEIN Engineering Group

NON-POTABLE LOADS:	**low**	**high**
Irrigation Watering: 1,300 gallons/day x (75 - 55 deg F) x 8.33 lbs/gal =		217 MBH/day
400 gallons/day x (75 - 55 deg F) x 8.33 lbs/gal =	67 MBH/day	
RO Waste: 3,900 gallons/day x (75 - 55 deg F) x 8.33 lbs/gal =		650 MBH/day
1,200 gallons/day x (75 - 55 deg F) x 8.33 lbs/gal =	200 MBH/day	
Fertilizer Water: 1,300 gallons/day x (75 - 55 deg F) x 8.33 lbs/gal =		217 MBH/day
400 gallons/day x (75 - 55 deg F) x 8.33 lbs/gal =	67 MBH/day	
Hot Water Reheat: 3,500 CFM min x (70 - 55 deg F) x 1.085 x 12 hr/d = (summer only; May - Sept)	360 MBH/day	720 MBH/day
NON POTABLE TOTAL DAILY LOADS	694 MBH/day	1,804 MBH/day

POTABLE LOADS:

Hot Water Usage:

Visitors (winter): 100 peo/day x 0.5 gal/peo	=	50 gal/day
Visitors (summer): 200 peo/day x 0.5 gal/peo	=	100 gal/day
Employees: 10 peo x 2.0 gal/day	=	20 gal/day
Shower - employees: 4 peo x 10 gal/shwr	=	40 gal/day
Food Prep: 10 peo x 1.0 gal/peo	=	10 gal/day
Maintenance:	=	10 gal/day

Low DHW estimate: 130 gal/day x (110 - 55 deg F) x 8.33 lbs/gal =	60 MBH/day	
High DHW estimate: 180 gal/day x (110 - 55 deg F) x 8.33 lbs/gal =		82 MBH/day
NON POTABLE + POTABLE TOTAL DAILY LOADS =	754 MBH/day	1,886 MBH/day
=	2,714 Therm/yr	6,790 Therm/yr
COST SAVINGS @ $0.80/THERM & 0.85 EFF =	$ 2,171/yr	$ 5,432/yr

* * *

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17 Applegate Court, Suite 200
Madison, WI 53713
Phone: (608) 288-9260
Fax: (608) 288-9282
email: hein@chorus.net

Technology **Solar water heater**

Load characteristics

Application **Reheat Load for Summer**

⊙ Hot water

	Unit	Base case	Proposed case
Load type		HVAC Reheats	
Daily hot water use	gal/d	2,750	2,750
Temperature	°F	70	70
Operating days per week	d	7	7

Percent of month used

Month	Base case	Proposed case
January	0%	0%
February	0%	0%
March	0%	0%
April	0%	0%
May	50%	50%
June	90%	90%
July	100%	100%
August	100%	100%
September	75%	75%
October	0%	0%
November	0%	0%
December	0%	0%

Supply temperature method		User-defined	
Water temperature - minimum	°F	55	
Water temperature - maximum	°F	55	

	Unit	Base case	Proposed case	Energy saved
Heating	MWh	12.9	12.9	0%

Resource assessment

Solar tracking mode		Fixed
Slope	°	45.0
Azimuth	°	0.0

Show data

Solar water heater

Type	Glazed

Manufacturer		Alternate Energy Technologies	
Model		Alternate Energy AE-40	
Gross area per solar collector	ft²	39.78	
Aperture area per solar collector	ft²	37.47	
Fr (tau alpha) coefficient		0.71	
Fr UL coefficient	(W/m²)/°C	4.91	
Temperature coefficient for Fr UL	(W/m²)/°C²	0.000	
Number of collectors		10	8
Solar collector area	ft²	397.83	
Capacity	kW	24.37	
Miscellaneous losses	%		
Balance of system & miscellaneous			
Storage		Yes	
Storage capacity / solar collector area	gal/ft²	1	
Storage capacity	gal	187.3	
Heat exchanger	yes/no	Yes	
Heat exchanger efficiency	%	85.0%	
Miscellaneous losses	%	1.0%	
Pump power / solar collector area	W/m²		
Electricity rate	$/kWh		
Summary			
Electricity - pump	MWh	0.0	
Heating delivered	MWh	10.3	
Solar fraction	%	80%	

Technology		**Solar water heater**

Load characteristics

All Loads (converted g/day to account for temp dif.) including RC

Application

○
⊙ Hot water

	Unit	Base case	Pro
Load type		All Loads (Low End)	
Daily hot water use	gal/d	3,800	
Temperature	°F	70	
Operating days per week	d	7	

☐ **Percent of month used**

Supply temperature method		User-defined
Water temperature - minimum	°F	55
Water temperature - maximum	°F	55

	Unit	Base case	Pro
Heating	MWh	51.0	

Resource assessment

Solar tracking mode		Fixed
Slope	°	45.0
Azimuth	°	0.0

☐ **Show data**

Solar water heater

Type		Glazed
Manufacturer		Alternate Energy Technologies
Model		Alternate Energy AE-40
Gross area per solar collector	ft²	39.78
Aperture area per solar collector	ft²	37.47
Fr (tau alpha) coefficient		0.71
Fr UL coefficient	(W/m²)/°C	4.91
Temperature coefficient for Fr UL	(W/m²)/°C²	0.000
Number of collectors		10
Solar collector area	ft²	397.83

Capacity	kW	24.37
Miscellaneous losses	%	

Balance of system & miscellaneous

Storage		Yes
Storage capacity / solar collector area	gal/ft²	1
Storage capacity	gal	187.3
Heat exchanger	yes/no	Yes
Heat exchanger efficiency	%	85.0%
Miscellaneous losses	%	1.0%
Pump power / solar collector area	W/m²	
Electricity rate	$/kWh	

Summary

Electricity - pump	MWh	0.0
Heating delivered	MWh	24.6
Solar fraction	%	48%

Technology	**Solar water heater**

Load characteristics

Application	○ Same as previous but with 20 collectors
	⊙ Hot water

	Unit	Base case	Proposed case
Load type		All Loads (Low End)	
Daily hot water use	gal/d	3,800	3,800
Temperature	°F	70	70
Operating days per week	d	7	7

☐ **Percent of month used**

Supply temperature method		User-defined
Water temperature - minimum	°F	55
Water temperature - maximum	°F	55

	Unit	Base case	Proposed case	Energy saved
Heating	MWh	51.0	51.0	0%

Resource assessment

Solar tracking mode		Fixed
Slope	°	45.0
Azimuth	°	0.0

☐ **Show data**

Solar water heater

Type		Glazed
Manufacturer		Alternate Energy Technologies
Model		Alternate Energy AE-40
Gross area per solar collector	ft²	39.78
Aperture area per solar collector	ft²	37.47
Fr (tau alpha) coefficient		0.71
Fr UL coefficient	(W/m²)/°C	4.91
Temperature coefficient for Fr UL	(W/m²)/°C²	0.000

Number of collectors		20	11
Solar collector area	ft²	795.67	
Capacity	kW	48.73	
Miscellaneous losses	%		
Balance of system & miscellaneous			
Storage		Yes	
Storage capacity / solar collector area	gal/ft²	1	
Storage capacity	gal	374.7	
Heat exchanger	yes/no	Yes	
Heat exchanger efficiency	%	85.0%	
Miscellaneous losses	%	1.0%	
Pump power / solar collector area	W/m²		
Electricity rate	$/kWh		
Summary			
Electricity - pump	MWh	0.0	
Heating delivered	MWh	38.7	
Solar fraction	%	76%	

Technology	**Solar water heater**

Load characteristics

Application	High End Loads with 10 Collectors
	⊙ Hot water

	Unit	Base case	Proposed case
Load type		All Loads (High End)	
Daily hot water use	gal/d	6,300	6,300
Temperature	°F	70	70
Operating days per week	d	7	7

☐ **Percent of month used**

Supply temperature method		User-defined
Water temperature - minimum	°F	55
Water temperature - maximum	°F	55

	Unit	Base case	Proposed case	Energy saved
Heating	MWh	84.6	84.6	0%

Resource assessment

Solar tracking mode		Fixed
Slope	°	45.0
Azimuth	°	0.0

☐ **Show data**

Solar water heater

Type		Glazed
Manufacturer		Alternate Energy Technologies
Model		Alternate Energy AE-40
Gross area per solar collector	ft²	39.78
Aperture area per solar collector	ft²	37.47
Fr (tau alpha) coefficient		0.71
Fr UL coefficient	(W/m²)/°C	4.91

Temperature coefficient for Fr UL	$(W/m^2)/°C^2$	0.000	
Number of collectors		10	18
Solar collector area	ft^2	397.83	
Capacity	kW	24.37	
Miscellaneous losses	%		
Balance of system & miscellaneous			
Storage		Yes	
Storage capacity / solar collector area	gal/ft^2	1	
Storage capacity	gal	187.3	
Heat exchanger	yes/no	Yes	
Heat exchanger efficiency	%	85.0%	
Miscellaneous losses	%	1.0%	
Pump power / solar collector area	W/m^2		
Electricity rate	$/kWh		
Summary			
Electricity - pump	MWh	0.0	
Heating delivered	MWh	26.9	
Solar fraction	%	32%	

Technology	**Solar water heater**

Load characteristics

Application

- ○ High End Loads with 20 Collectors
- ⊙ Hot water

	Unit	Base case	Proposed case
Load type		All Loads (High End)	
Daily hot water use	gal/d	6,300	6,300
Temperature	°F	70	70
Operating days per week	d	7	7

☐ **Percent of month used**

Supply temperature method		User-defined
Water temperature - minimum	°F	55
Water temperature - maximum	°F	55

	Unit	Base case	Proposed case	Energy saved
Heating	MWh	84.6	84.6	0%

Resource assessment

Solar tracking mode		Fixed
Slope	°	45.0
Azimuth	°	0.0

☐ **Show data**

Solar water heater

Type		Glazed	
Manufacturer		Alternate Energy Technologies	
Model		Alternate Energy AE-40	
Gross area per solar collector	ft²	39.78	
Aperture area per solar collector	ft²	37.47	
Fr (tau alpha) coefficient		0.71	
Fr UL coefficient	(W/m²)/°C	4.91	
Temperature coefficient for Fr UL	(W/m²)/°C²	0.000	
Number of collectors		20	18

Solar collector area	ft²	795.67
Capacity	kW	48.73
Miscellaneous losses	%	

Balance of system & miscellaneous

Storage		Yes
Storage capacity / solar collector area	gal/ft²	1
Storage capacity	gal	374.7
Heat exchanger	yes/no	Yes
Heat exchanger efficiency	%	85.0%
Miscellaneous losses	%	1.0%
Pump power / solar collector area	W/m²	
Electricity rate	$/kWh	

Summary

Electricity - pump	MWh	0.0
Heating delivered	MWh	46.9
Solar fraction	%	55%