PERFORMANCE AND COMPETITIVE EVALUATION

Date	Job	Customer
2021/08/03	Atlanta Building	All Prospective Bidders

Climatic Data Location	Tower Tech Contact
United States	Travis Glover, Jr.
Georgia	(770) 490-3915
Atlanta	TGlover@SoutheastPump.com

Tower Tech Model	Opposition Model
TTXR-041950 [4 module(s)]	Evapco, AT (4 Cell), 420-124 [4 cell(s)]

Design GPM	Design HWT	Design CWT
3600.0 GPM	95.0 °F	85.0 °F

Design WBT	Min WBT (avg.)	Max WBT (avg.)
78.0 °F	34.48 °F	73.13 °F

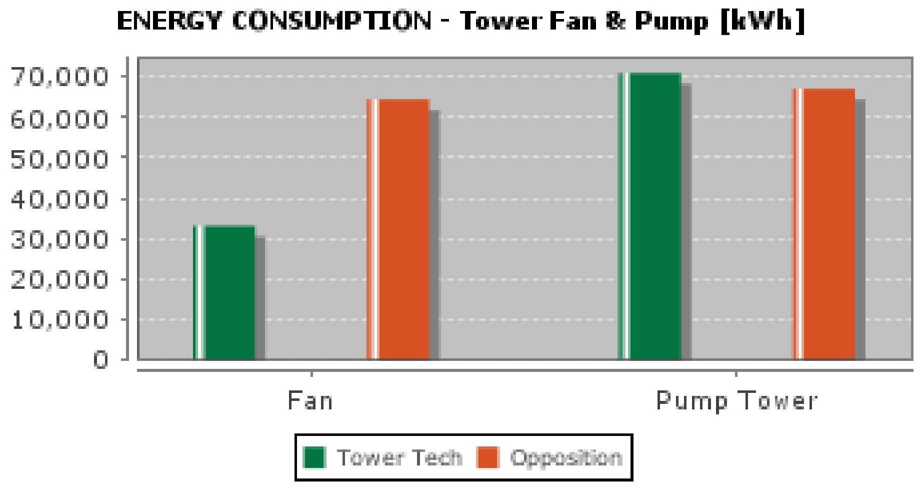
UNIT PRICES

Electricity	Sewer Disposal	Water	Chemical Usage
0.0989 ($/kWh)	20.98 ($/1000 gallons)	8.24 ($/1000 gallons)	2.25 ($/1000 gallons blowdown)

[3926]

ANNUAL ENERGY CONSUMPTION (kWh)

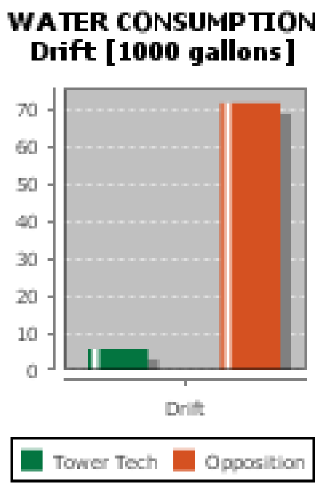
	Tower Tech	Opposition
Fan	33,075	64,505
Pump (Tower Only)	71,037	67,141

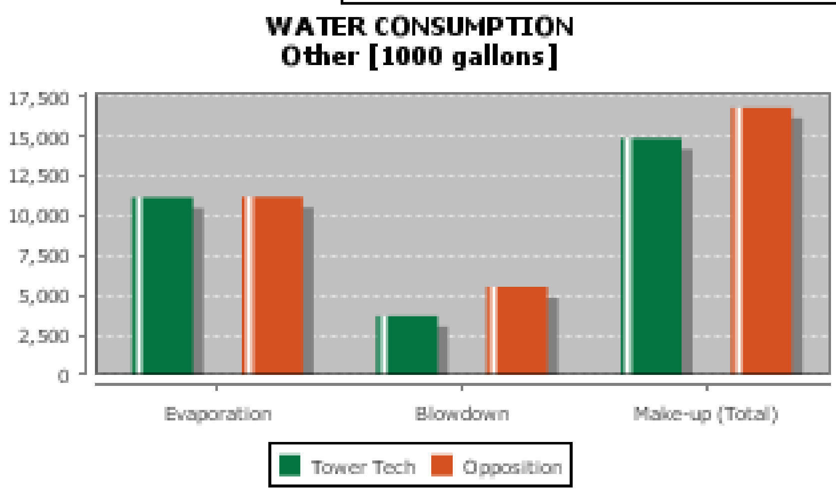


ANNUAL WATER CONSUMPTION (1000 gallons)

	Tower Tech	Opposition
Evaporation	11,179	11,229
Drift	6	72
Blowdown	3,720	5,543
Make-up	**14,905**	**16,843**

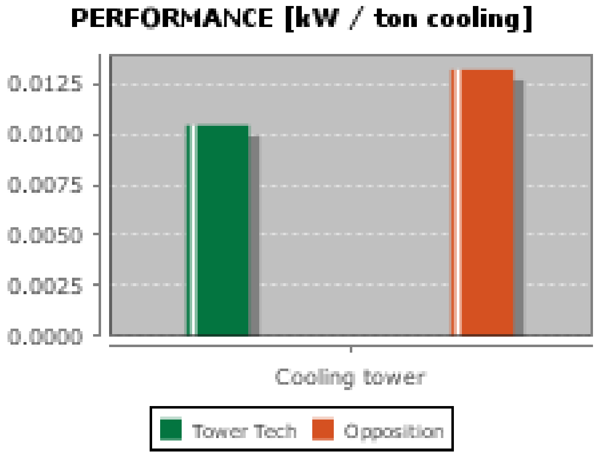
Estimated Annual Average Water Savings - 1,938,000 gallons





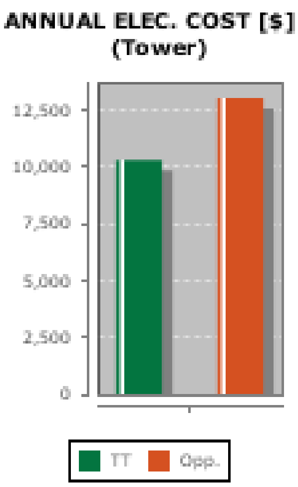
PERFORMANCE

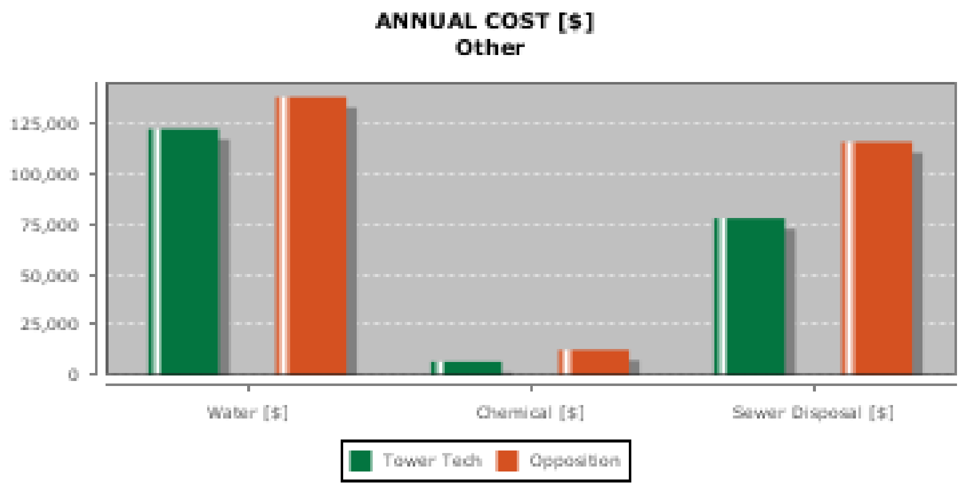
	Tower Tech	Opposition
Cooling Tower [kW / ton cooling]	.010	.013



ANNUAL OPERATING COST

	Tower Tech	Opposition
Fan Electricity	$3,271	$6,380
Pump Electricity	$7,026	$6,640
Electricity	$10,297	$13,020
Water	$122,814	$138,790
Sewer	$78,054	$116,284
Chemical	$6,511	$12,471
Total (Tower only)	**$217,676**	**$280,564**





SUMMARY

	Tower Tech	Opposition
Initial Capital Cost	$0	$0
Annual Operating Cost	$217,676	$280,564
Simple Payback	.00 year(s) *	

**(Tower Tech Initial Capital Cost - Opposition Initial Capital Cost) / (Opposition Annual Operating Cost - Tower Tech Annual Operating Cost)*

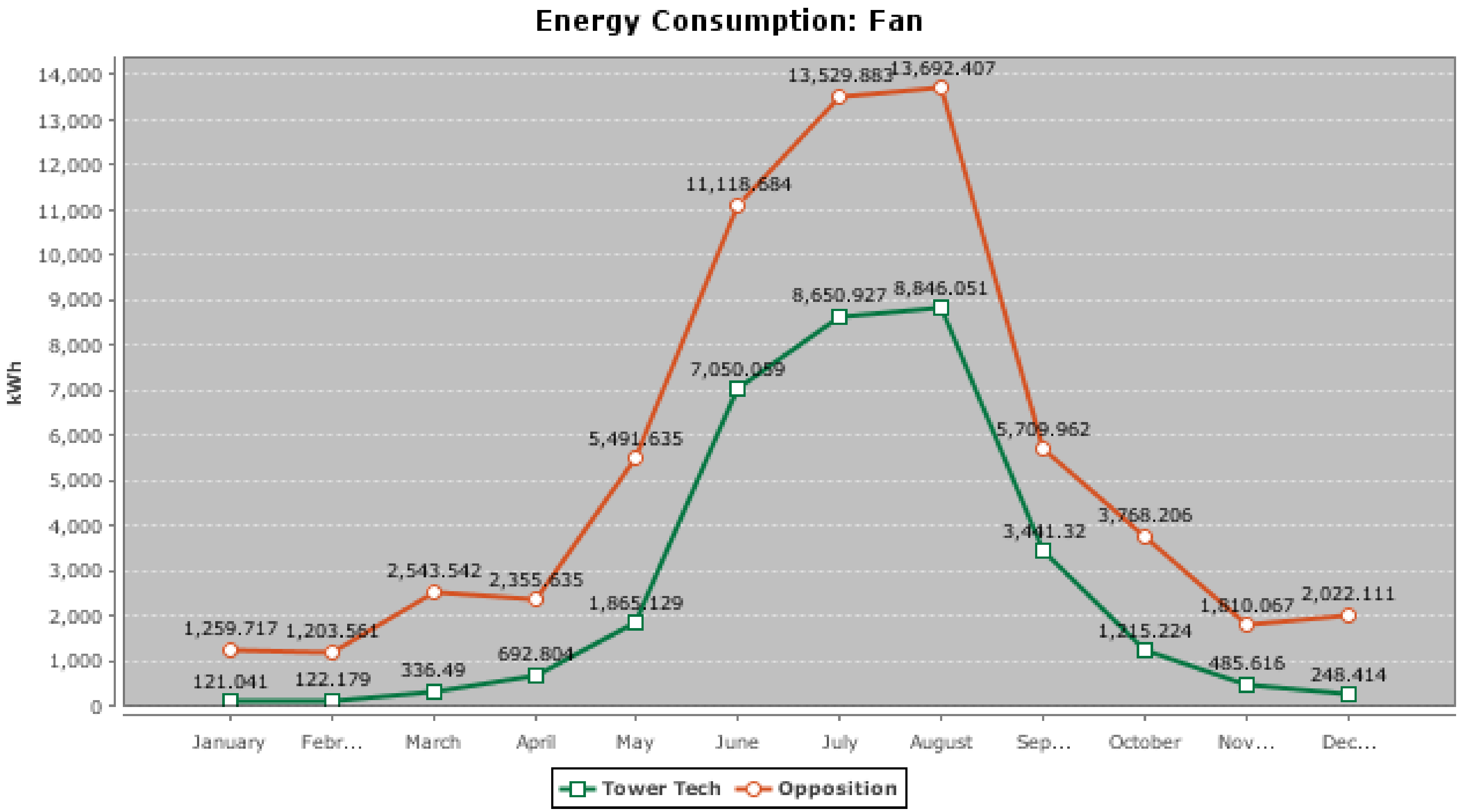
Annual Operating Costs include electricity, water, chemical & sewer disposal costs)

The future costs of replacing opposition towers throughout the outlook period are ignored in the simple payback calculation.

LIFE CYCLE COST

Outlook Period (Years) 20 year(s)

Tower Only	Tower Tech	Opposition
Total Operating Cost	$4,353,513	$5,611,277
Total Capital Cost for outlook period	$0	$0
Total Capital and Operating Cost for outlook period	$4,353,513	$5,611,277
Savings	$1,257,764	


Energy Consumption: Fan
kWh
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1,259.717
1,203.561
2,543.542
2,355.635
5,491.635
11,118.684
13,529.883
13,692.407
5,709.962
3,768.206
1,810.067
2,022.111
121.041
122.179
336.49
692.804
1,865.129
7,050.059
8,650.927
8,846.051
3,441.32
1,215.224
485.616
248.414
January
Febr...
March
April
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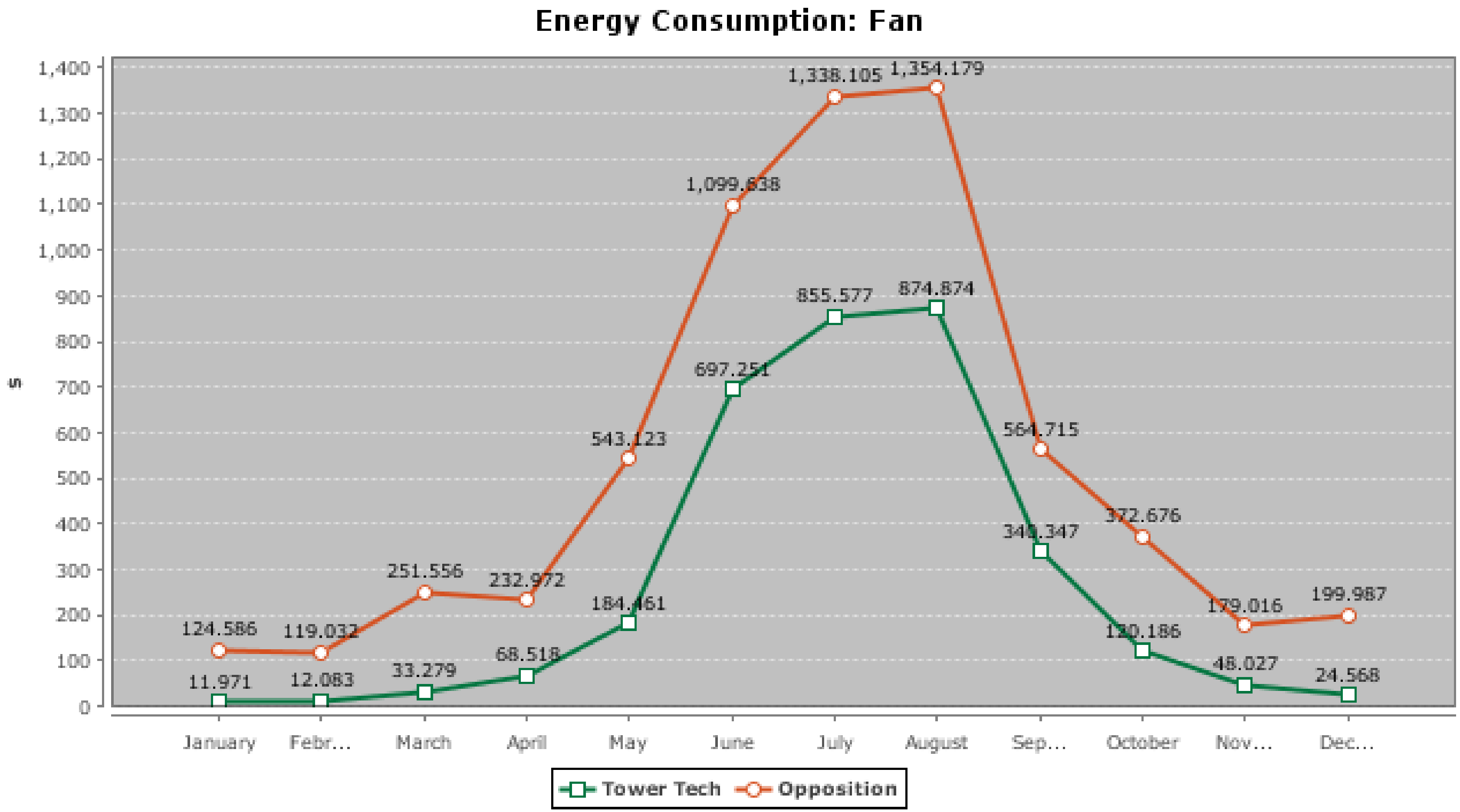
June
July
August
Sep...
October
Nov...
Dec...
Tower Tech
Opposition



Energy Consumption: Fan
$
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
1,338.105
1,354.179
1,099.638
855.577
874.874
697.251
543.123
564.715
372.676
345.347
251.556
232.972
184.461
124.586
119.032
179.016
199.987
120.186
11.971
12.083
33.279
68.518
48.027
24.568
January
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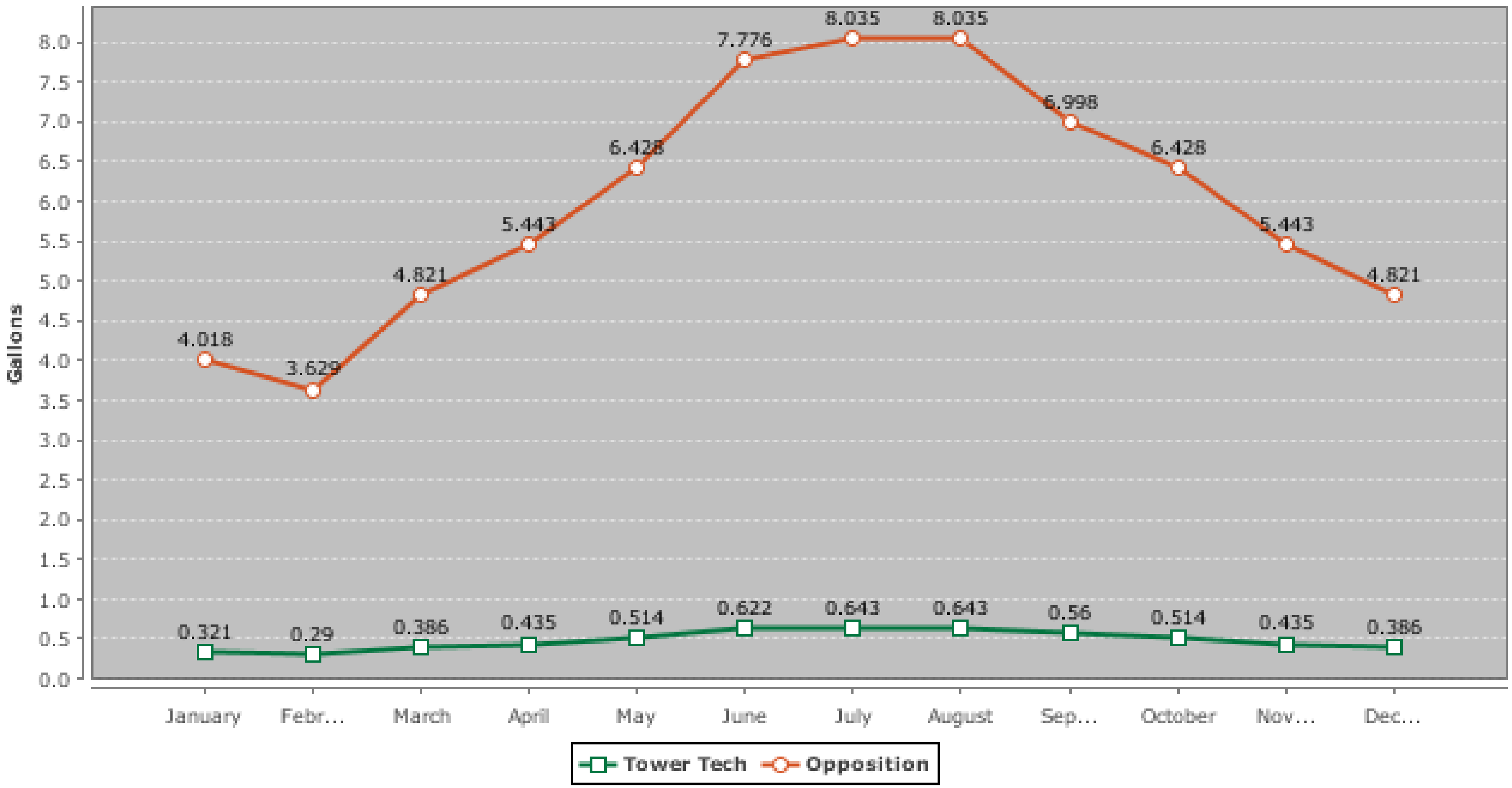
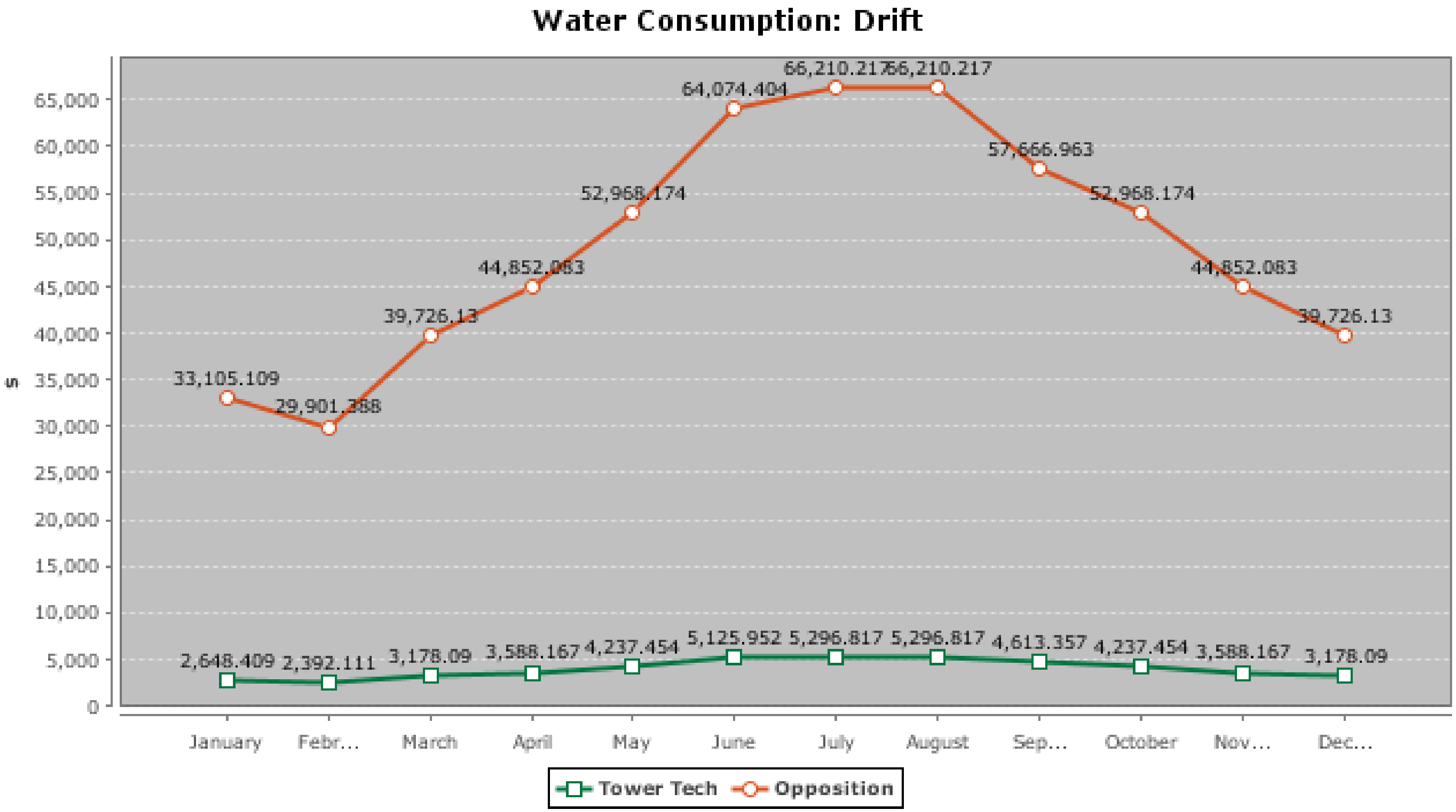
Dec…
Tower Tech
Opposition

Water Consumption: Drift





Water Consumption: Drift
$
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
33,105.109
29,901.388
39,726.13
44,852.083
52,968.174
64,074.404
66,210.217
66,210.217
57,666.963
52,968.174
44,852.083
39,726.13
2,648.409
2,392.111
3,178.09
3,588.167
4,237.454
5,125.952
5,296.817
5,296.817
4,613.357
4,237.454
3,588.167
3,178.09
January
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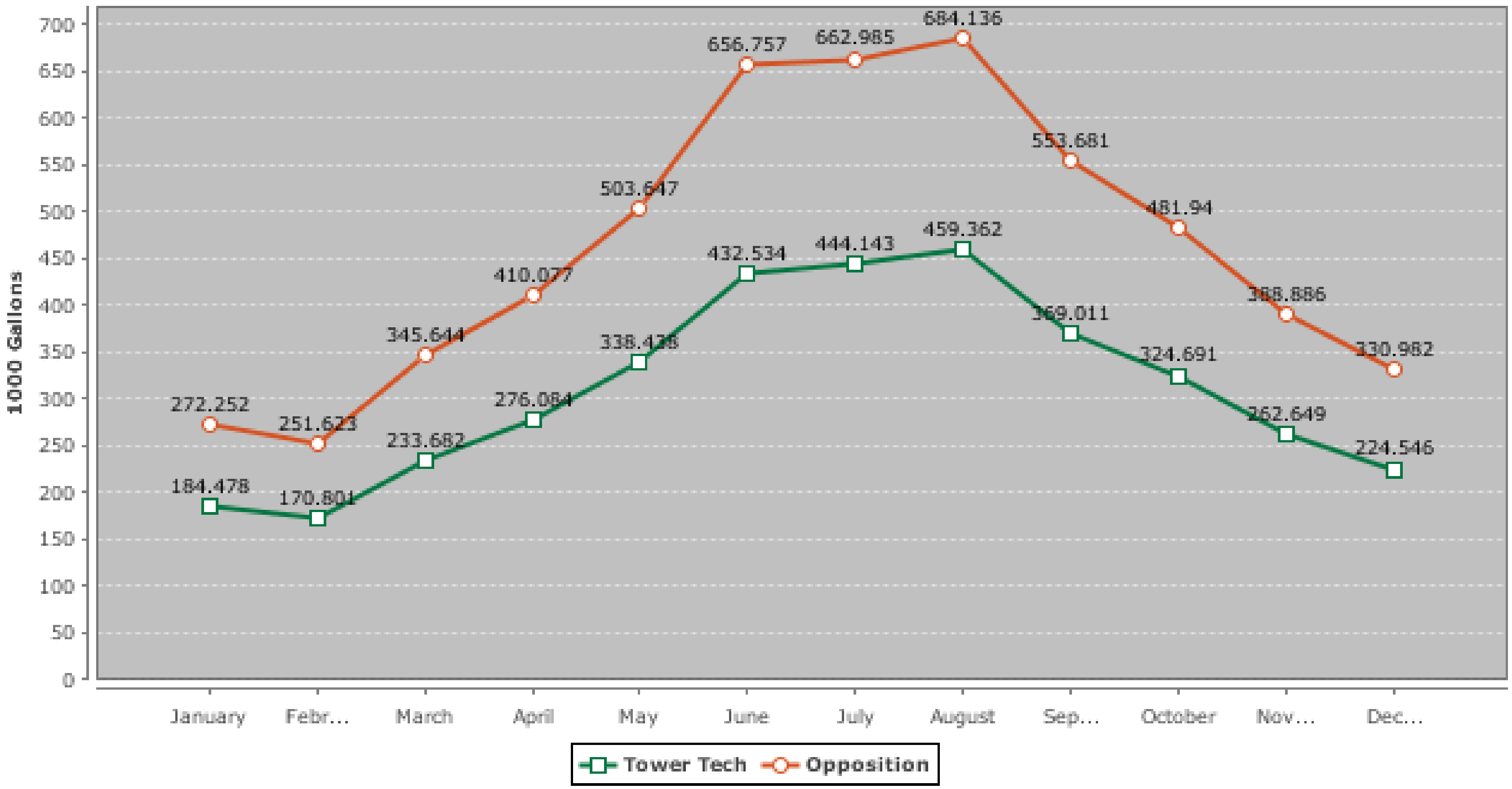
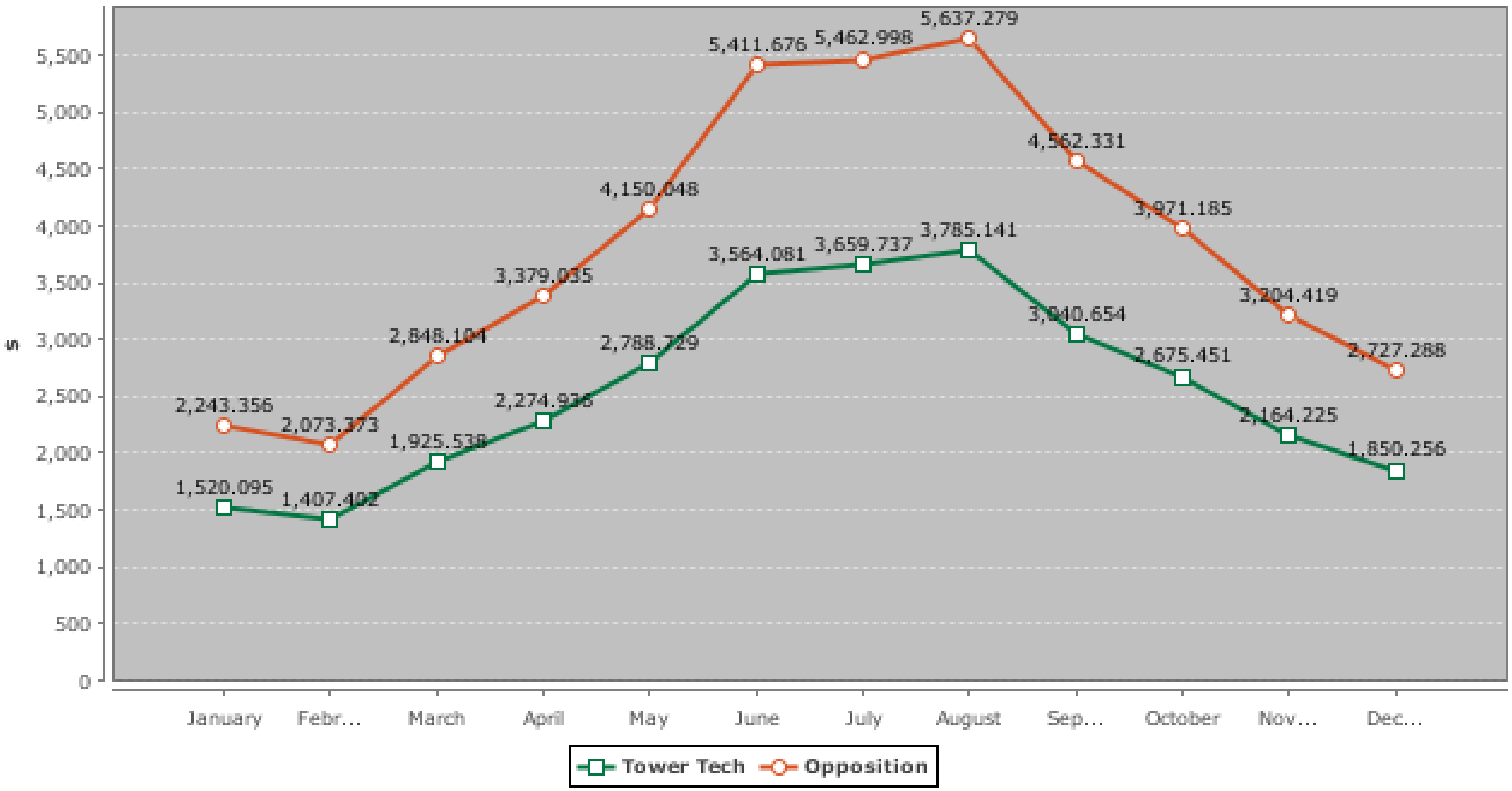
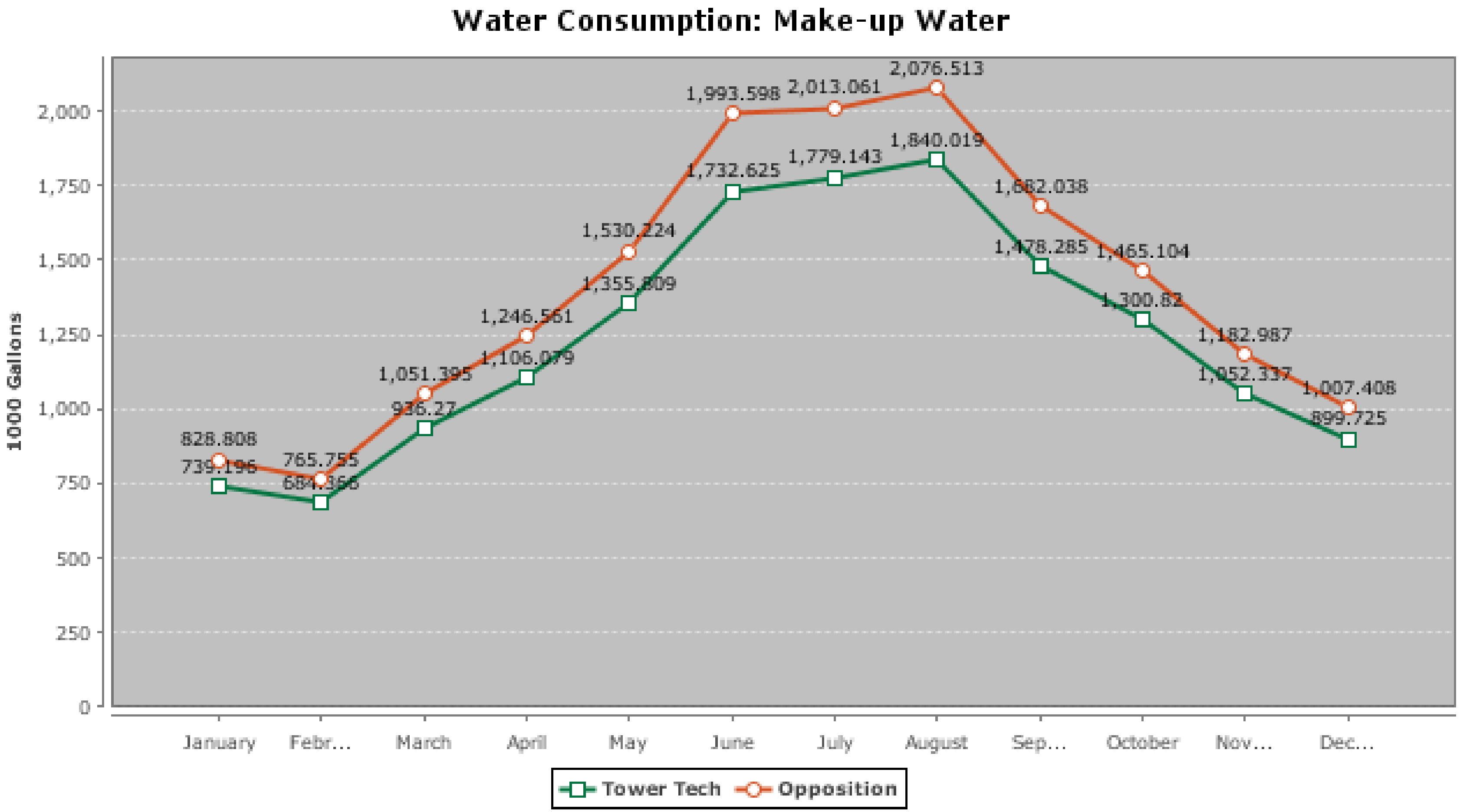
October
Nov...
Dec...
Tower Tech
Opposition

Water Consumption: Blowdown



Water Consumption: Blowdown





Water Consumption: Make-up Water
1000 Gallons
2,000
1,750
1,500
1,250
1,000
750
500
250
0
828.808
739.196
765.755
684.366
1,051.395
936.27
1,246.561
1,106.079
1,530.224
1,355.809
1,993.598
1,732.625
2,013.061
1,779.143
2,076.513
1,840.019
1,682.038
1,478.285
1,465.104
1,300.82
1,182.987
1,052.337
1,007.408
899.725
January
Febr...
March
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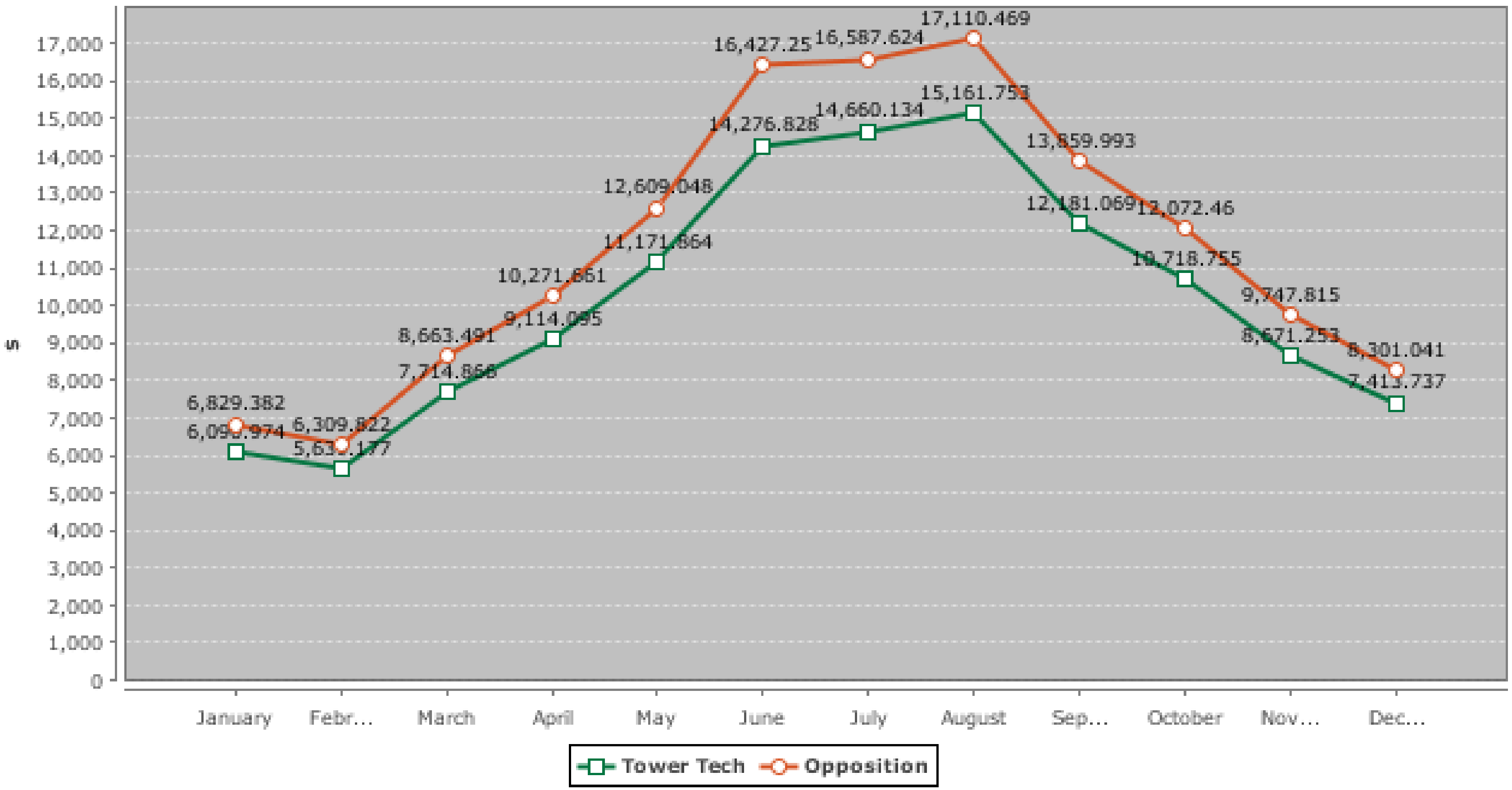
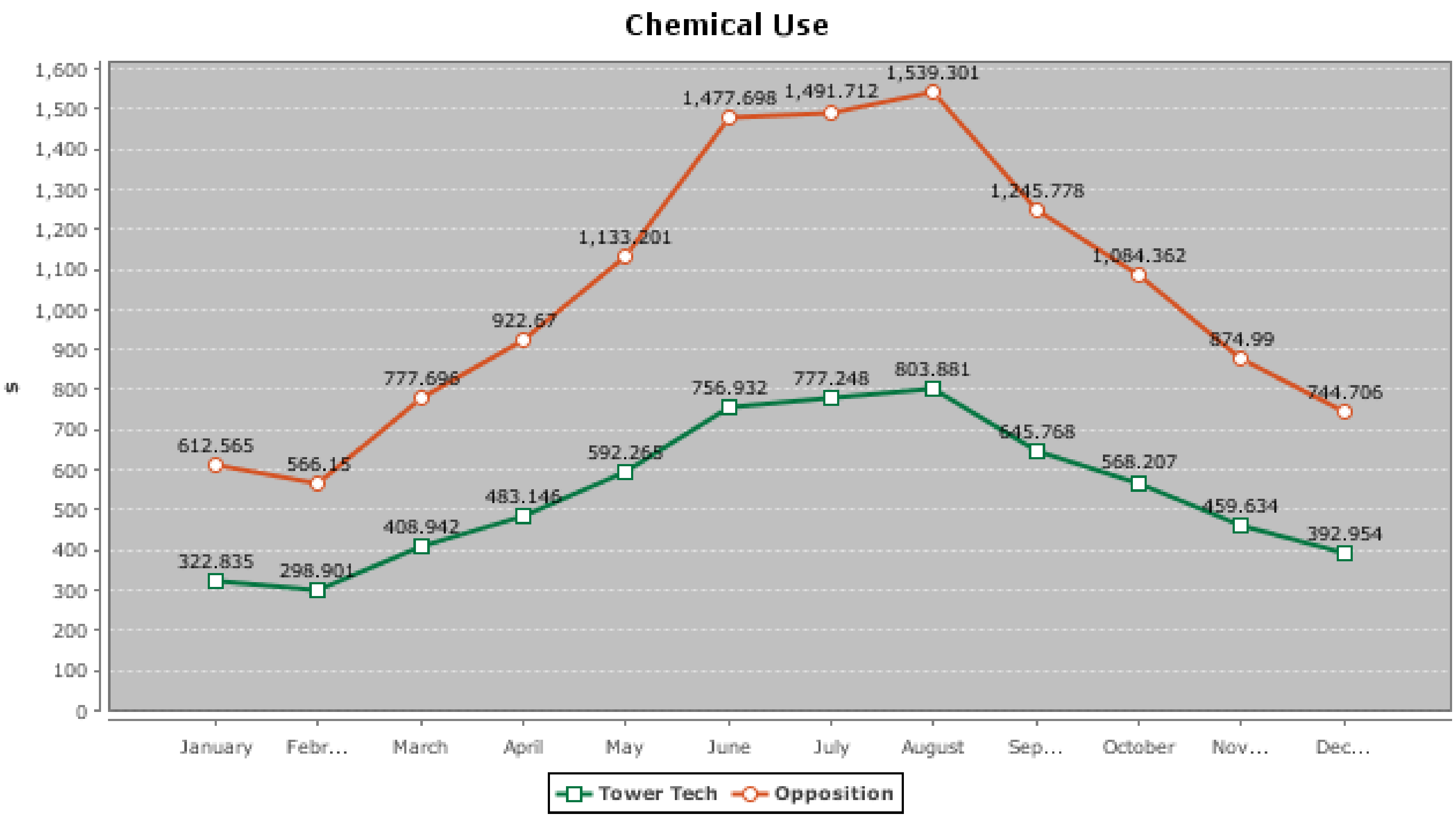
Sep...
October
Nov...
Dec...
Tower Tech
Opposition

Tower Tech Outperform™

Water Consumption: Make-up Water





Chemical Use
$
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
612.565
566.15
777.696
922.67
1,133.201
1,477.698
1,491.712
1,539.301
1,245.778
1,084.362
874.99
744.706
322.835
298.901
408.942
483.146
592.265
756.932
777.248
803.881
645.768
568.207
459.634
392.954
January
Febr…
March
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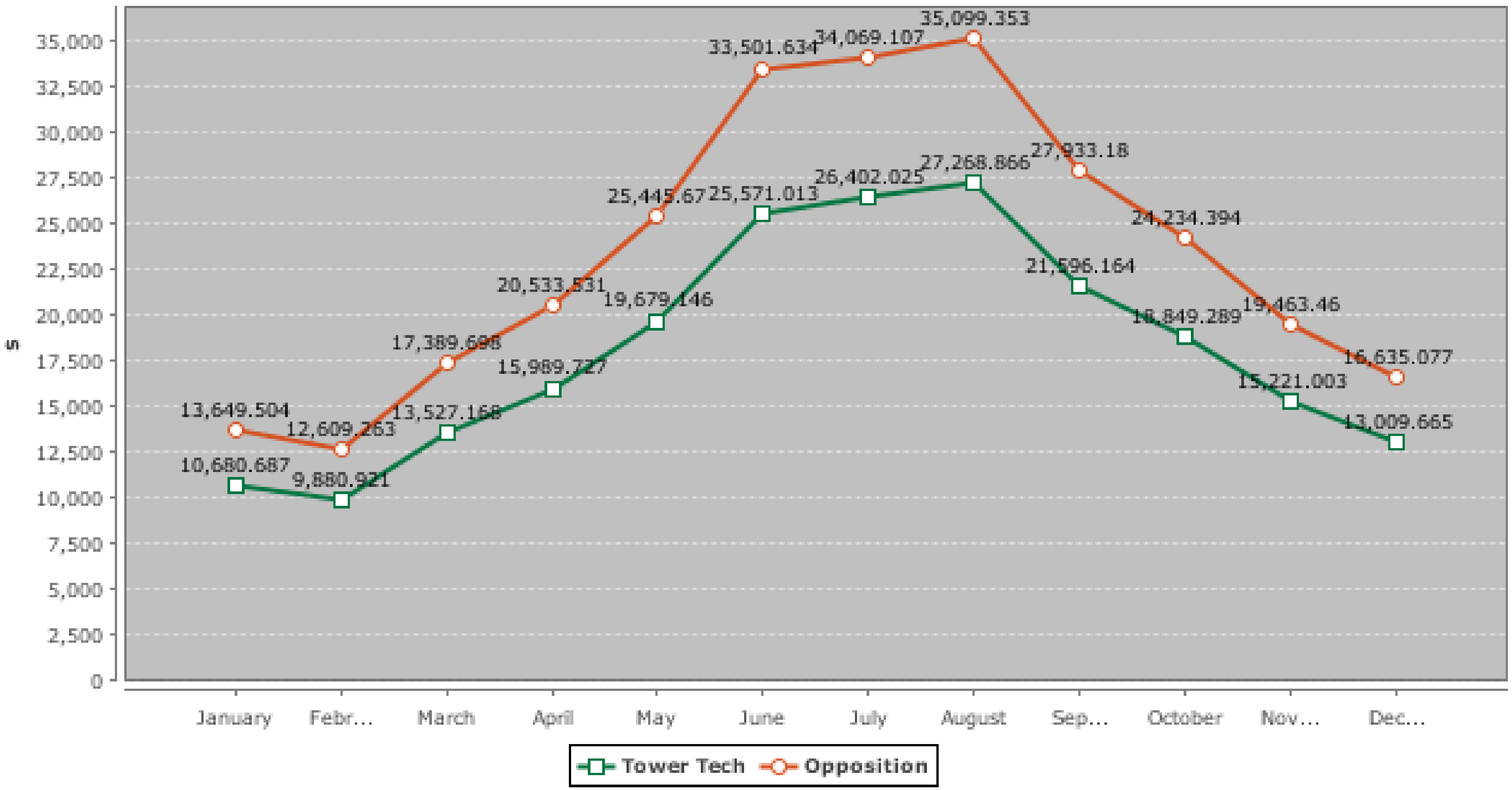
October
Nov…
Dec…
Tower Tech
Opposition

Total Cost



Total Cost
$
35,000
32,500
30,000
27,500
25,000
22,500
20,000
17,500
15,000
12,500
10,000
7,500
5,000
2,500
0
January
Febr...
March
April
May
June
July
August
Sep...
October
Nov...
Dec...
13,649.504
12,609.263
17,389.698
20,533.531
25,445.67
33,501.634
34,069.107
35,099.353
27,933.18
24,234.394
19,463.46
16,635.077
10,680.687
9,880.921
13,527.168
15,989.727
19,679.146
25,571.013
26,402.025
27,268.866
21,596.164
18,849.289
15,221.003
13,009.665
Tower Tech
Opposition

PACE APPENDIX

This appendix provides the PACE user with a technical description of the general methodology of a PACE simulation in order to best interpret the inputs and results.

A. Weather profiles

The weather profiles contained in the PACE database are based on the 5 years' *Integrated Surface Hourly Observations* from the *National Oceanic and Atmospheric Administration*. Weather profiles can either be based on a typical day for each month (hourly-monthly) or on a frequency basis.

Hourly monthly profiles are available for average wet bulb and average dry bulb temperatures as well as for maximum wet bulb temperatures with coincident dry bulb temperatures.

A frequency profile presents the weather data in terms of hours of the year that a certain wet bulb temperature is experienced. The wet bulb temperatures are presented in 2 °F increments along with the mean coincident dry bulb temperatures.

B. Load profile & Usage factors

The variation of the cooling load that the cooling tower is required to dissipate throughout the year is governed by the load profile and usage factors. A load profile for a specific application consists of a load factor and required water outlet temperature table. Each load factor represents the fraction of the maximum cooling load that the cooling tower must dissipate at a given calculation instant, thus

$$Load\ factor = {}^{Instantaneous\ cooling\ load}\!/\!_{Maximum\ cooling\ load}$$

The additional usage factor is specified for each day of the week and it is used to compensate for the variation of the cooling load on a daily basis. This is especially useful for example school applications where the cooling requirements are drastically less over weekends. The usage factor adjusts the instantaneous cooling load after the load factor has been considered. Thus the instantaneous cooling load can be determined as follows

$$Instantaneous\ cooling\ load = Usage\ factor \times Load\ factor \times Maximum\ cooling\ load$$

It is important to notice that the usage factor is considered together with the load factor, thus if the load factor at 14:00-15:00 is 0.5 for a typical day in January and the usage factor for Saturdays is 0.5, then the instantaneous cooling load will be 0.25 times (0.5 x 0.5) the maximum cooling load for 14:00-15:00 of typical Saturday in January.

C. Water flow rate strategy

The maximum cooling load is determined from the maximum flow rate and the range.

$$Maximum\ cooling\ load\ (tons) = 0.033 \times Maximum\ flow\ rate\ (gpm) \times Range(°\mathrm{F})$$

In order to realise the required instantaneous cooling load one can either vary the flow rate or adjust the range. The choice between these two options is governed by the cooling strategy or application type.

The following options for water flow rate strategies are available:

1. Chiller Constant Flow Rate & Cooling Tower Constant Flow Rate

This strategy assumes that the water flow rate to the cooling tower remains constant throughout the year and the cooling load is adjusted by varying the range proportionally with the load profile.

$$Instantaneous\ flow\ rate = Maximum\ flow\ rate$$

$$Number\ of\ active\ chillers = Maximum\ number\ of\ chillers$$

$$Number\ of\ active\ cooling\ towers = Maximum\ number\ of\ cooling\ towers$$

$$Instantaneous\ range = Usage\ factor \times Load\ factor \times Maximum\ range$$

2. Chiller Constant Flow Rate & Cooling Tower Variable Flow Rate

This strategy assumes that the water flow rate through each chiller remains constant, but the flow rate through a cooling tower can vary. Thus the flow rate can vary stepwise by shutting down chillers. The required flow rate through each chiller is

$$Flow\ rate\ per\ chiller = {}^{Maximum\ flow\ rate}\!/_{Maximum\ number\ of\ chillers}$$

Thus the following flow rates are possible in the case where 1500 gpm runs to 3 chillers

Number of active chillers	Instantaneous flow rate	Flow rate per chiller
3	1500 gpm	500 gpm
2	1000 gpm	500 gpm
1	500 gpm	500 gpm

The stepped water flow rate is then distributed to the maximum number of cooling towers while the flow rate per cooling tower is above the lower limit. The lower flow rate limit per cooling tower is as follow

$$Tower\ Tech\ lower\ flow\ rate\ limit = Number\ of\ nozzles\ per\ tower\ \times Minimum\ flow\ per\ nozzle$$

$$Opposition\ tower\ lower\ flow\ rate\ limit = Minimum\ flow\ rate\ in\ CTI\ data$$

The minimum flow per nozzle for Tower Tech is as follows

Dry bulb temperature	**Minimum flow per nozzle**
Below 25 °F	200 gpm
Between 25 and 32 °F	150 gpm
Above 32 °F	100 gpm

Tower Tech's Variable Flow Rotary Spray nozzle allows the flow rate to be reduced to 100 gpm through each nozzle while still effectively distributing the water over the fill area, whereas the lower flow rate limit for opposition towers are assumed to be the minimum flow rate presented in the CTI data. In cases of low temperature this flow rate is increased to reduce the chances of freezing, as shown in the table.

The upper flow rate limit per cooling tower is as follow

$$Tower\ Tech\ upper\ flow\ rate\ limit = Number\ of\ nozzles\ per\ tower\ \times 300\ gpm$$

$$Opposition\ tower\ upper\ flow\ rate\ limit = Maximum\ flow\ rate\ in\ CTI\ data$$

The flow rate is fixed at the lower limit in cases where only one cell is active and the flow is below the lower limit. Multiple cell towers can shut down cells individually in order to accommodate the required instantaneous flow rate.

The strategy flow diagram is shown in Figure 1.

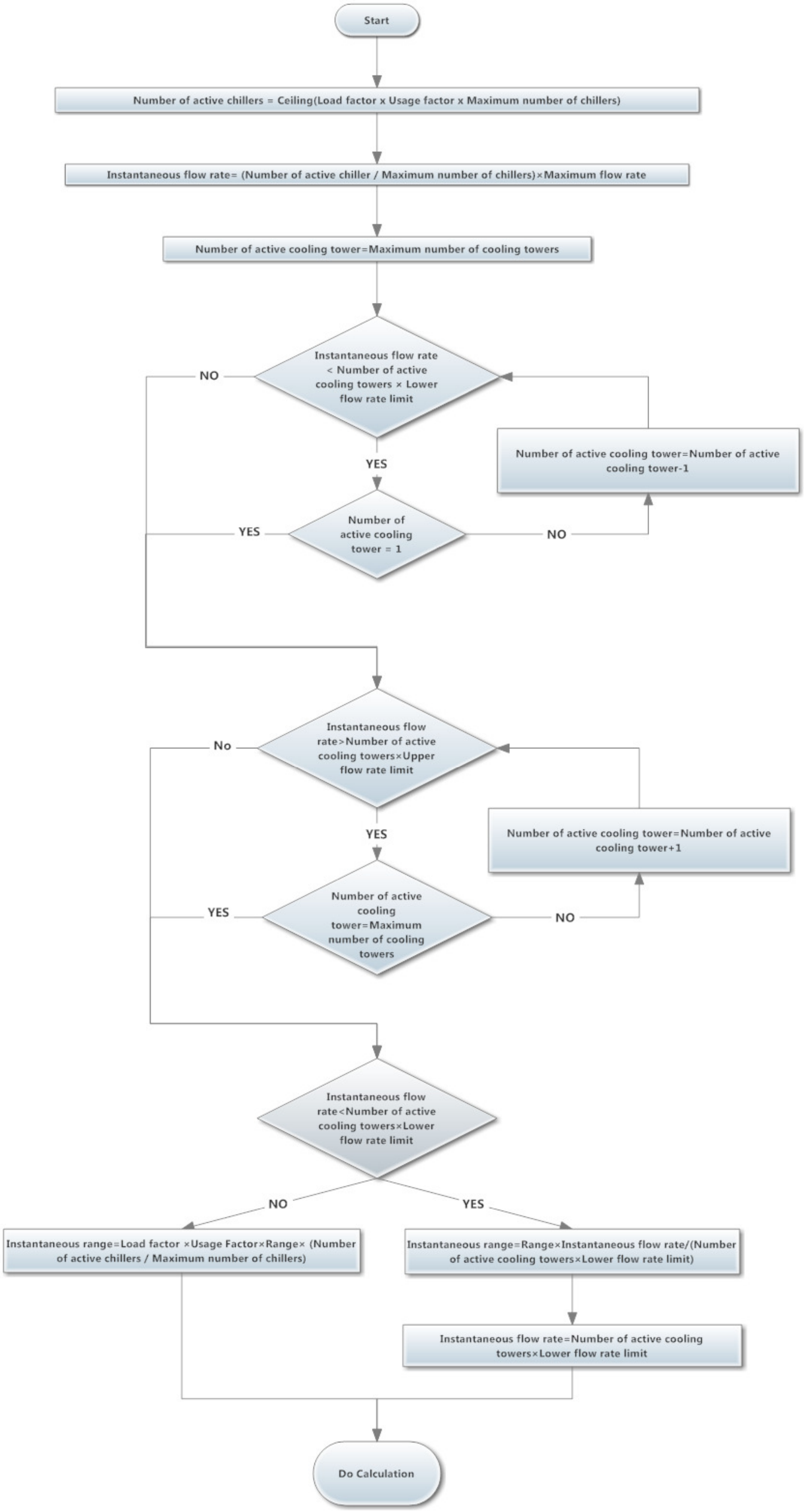


Figure 1: Chiller Constant Flow Rate & Cooling Tower Variable Flow Rate

3. Industrial

This strategy distributes the instantaneous water flow rate to the maximum number of cooling towers / cells while the flow rate per cooling tower is above the lower limit. The lower flow rate limit per cooling tower is as stated in the previous section. This strategy is shown in Figure 2.

D. Performance calculator

The heat transfer required at every calculation instance can be expressed in terms of Number of Transfer Units. This is a governed by the ambient conditions (dry bulb, wet bulb temperatures as well as atmospheric pressure), cooling load (water inlet temperature, water outlet temperature and water flow rate) and air flow rate. The ambient conditions are all located in PACE's climate database and the water outlet temperature comes from the required water outlet temperature table in the load profile. The water flow rate and range is governed by the given application type as explained in the previous section. The water inlet temperature can then be determined as follow

$$Water\ inlet\ temperature = Required\ water\ outlet\ temperature + Instantaneous\ range$$

The air flow rate can then be determined on an iterative basis by means of the relevant cooling tower model.

E. Opposition cooling tower model

The opposition cooling tower's performance is described in PACE with the following model

$$Number\ of\ Transfer\ Units = c_1 \left(\frac{Water\ flow\ rate}{Air\ flow\ rate}\right)^{c_2}$$

where the Number of Transfer Units describes the heat transfer capabilities of the cooling tower and c_1 and c_2 are coefficients that are determined for each model from the given manufacturer's performance tables. All of the opposition cooling towers are assumed to be operating with a variable frequency drive on the fan, which allows the air flow rate to vary dynamically in order to achieve the required cooling load.

Opposition towers that have multiple cells are modelled as singe cell units and the number of cells are taken into account when the maximum number of cooling towers are calculate, thus

$$Maximum\ number\ of\ cooling\ towers = Number\ of\ units \times Number\ of\ cells\ per\ unit$$

F. Tower Tech cooling tower model

Tower Tech's cooling tower's performance is described by a more complex mathematical model since we have more in depth knowledge of how our cooling tower operates at various conditions. Tower Tech's towers are also modelled with variable frequency driven fans.

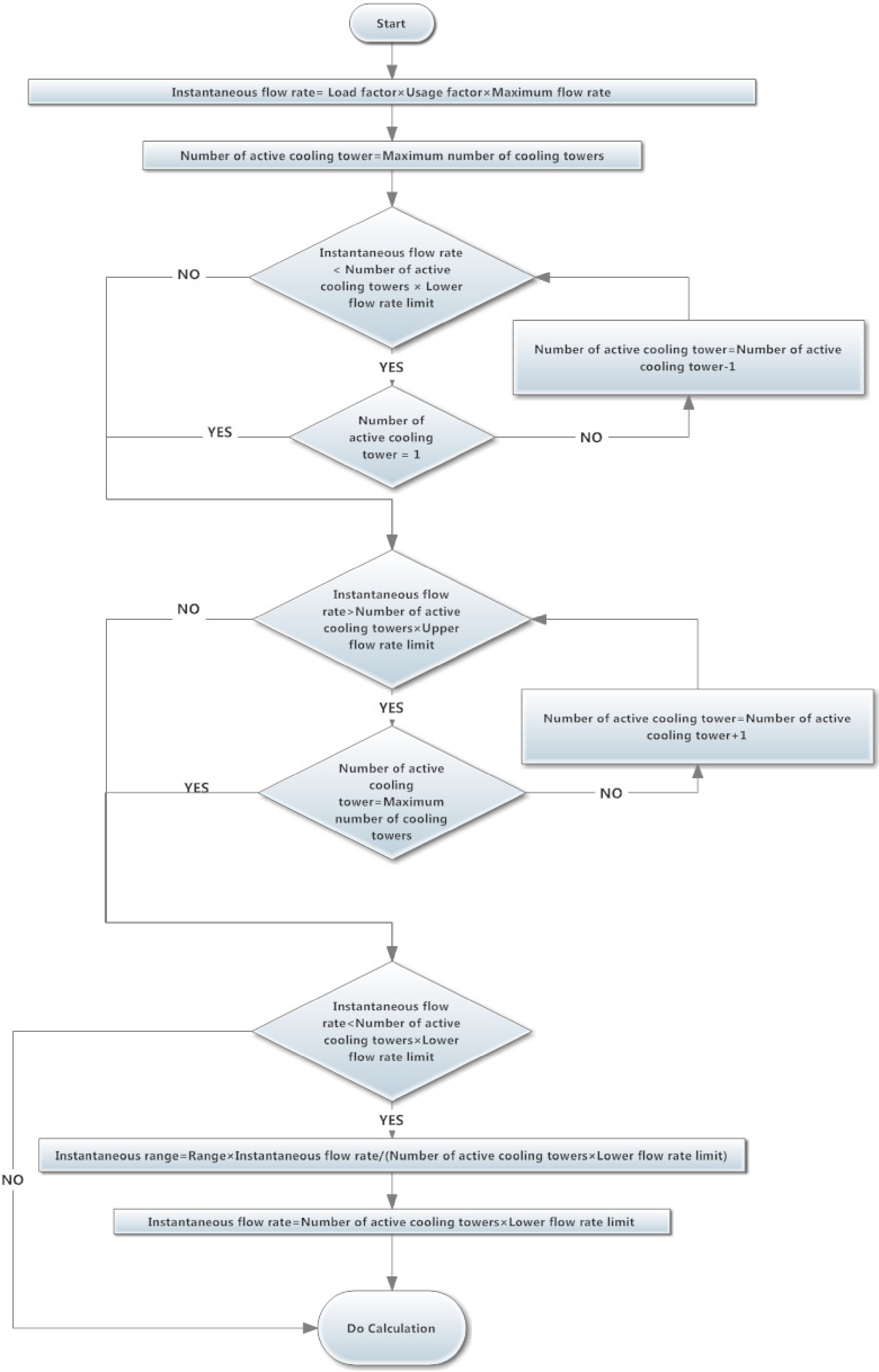


Figure 2: Industrial Strategy

G. Results

1. Energy consumption

➢ *Fan*

The fan energy consumption can be calculated from the fan power, which is calculated by means of the affinity fan laws. Thus the instantaneous fan power at any off design point can be expressed as follows

$$Instantaneous\ fan\ power = Design\ fan\ power \left(\frac{Instantaneous\ fan\ power}{Design\ air\ flow\ rate}\right)^3$$

This is then used to determine the instantaneous fan energy consumption as follows

$$Instantaneous\ fan\ energy\ consumption = \frac{Instantaneous\ fan\ power}{Fan\ motor\ efficiency}$$

➢ *Pump (Tower Only)*

The instantaneous pump power that is required by the cooling tower is calculated as follows

$$Instantaneous\ pump\ power = \frac{0.188 \times Instantaneous\ water\ flow\ rate \times Cooling\ tower\ head}{Pump\ efficiency}$$

The cooling tower head is in most cases taken as the static head or pump height. The energy consumption is then calculated

$$Instantaneous\ pump\ energy\ consumption = \frac{Instantaneous\ pump\ power}{Pump\ motor\ efficiency}$$

➢ *Pump (System excluding Cooling Tower)*

The instantaneous pump power that is required by system is calculated as follows

$$Instantaneous\ pump\ power = \frac{0.188 \times Instantaneous\ water\ flow\ rate \times System\ head}{Pump\ efficiency}$$

where the system head is

$$System\ head = Maximum\ system\ head \left(\frac{Instantaneous\ water\ flow\ rate}{Maximum\ water\ flow\ rate}\right)^2$$

This is then used to calculate the instantaneous pump energy consumption related to the system.

2. Water consumption

➢ *Evaporation*

The water consumption related to evaporation is determined from the inlet and outlet air humidity ratios and the air flow rate

$$Evaporation\ water\ loss = Air\ flow\ rate \times (Air\ outlet\ humidity\ ratio - Air\ inlet\ humidity\ ratio)$$

➢ *Drift*

The water consumption related to drift is determined as follow

$$Drift\ water\ loss = Instantaneous\ water\ flow\ rate \times Drift\ loss\ percentage$$

where the drift loss percentage is governed by the drift eliminator's performance.

➢ *Blowdown*

The water consumption related to blowdown is determined as follow

$$Blowdown = \frac{Evaporation}{Cycles\ of\ concetration - 1} - Drift$$

where the cycles of concentration relate to the accumulation of dissolved chemicals in the cooling water.

➢ *Make-up*

The total make-up water required is the calculated as follow

$$Make - up\ water = Evaporation\ loss + Drift\ loss + Blowdown\ loss$$