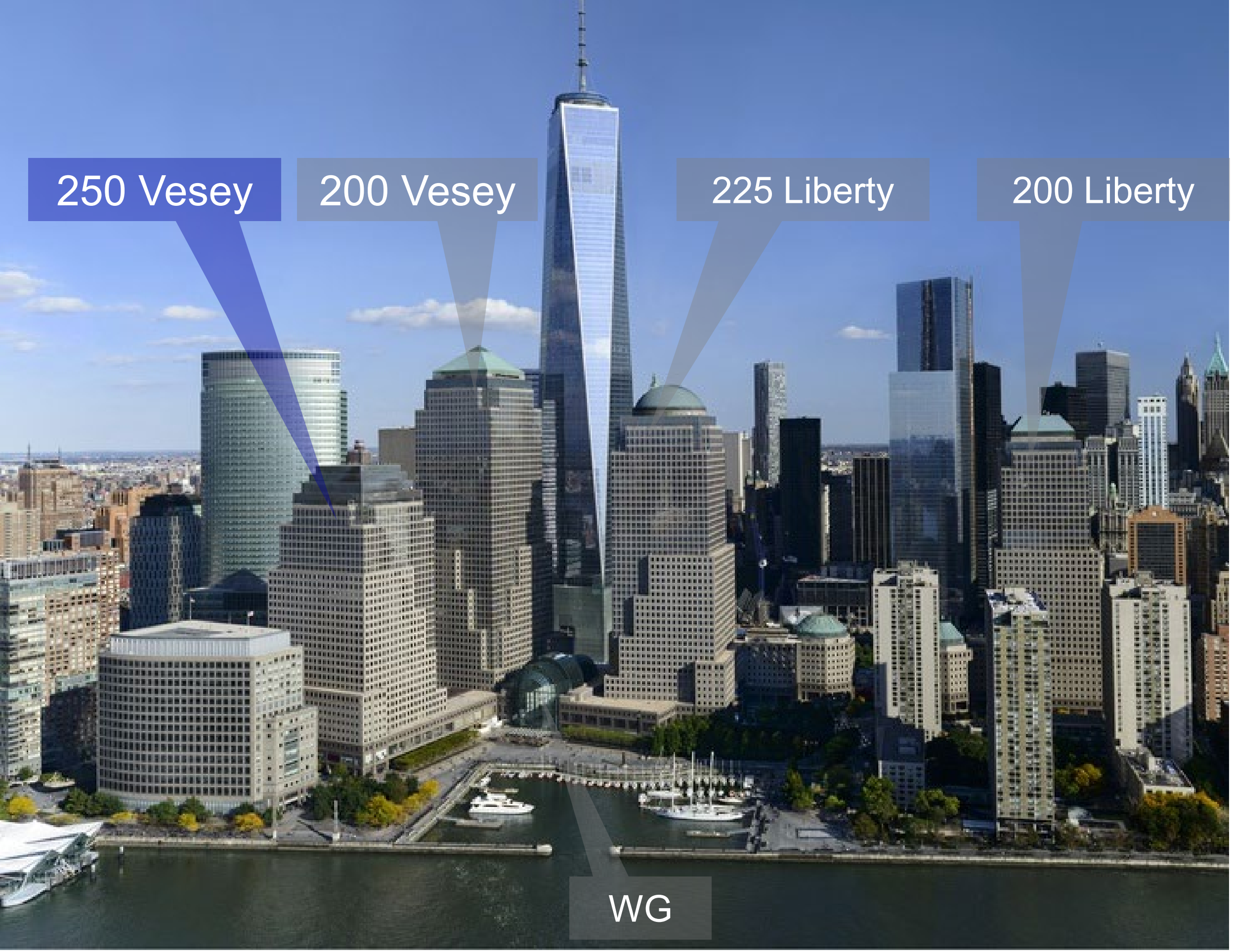
Brookfield Place

CHW Optimization



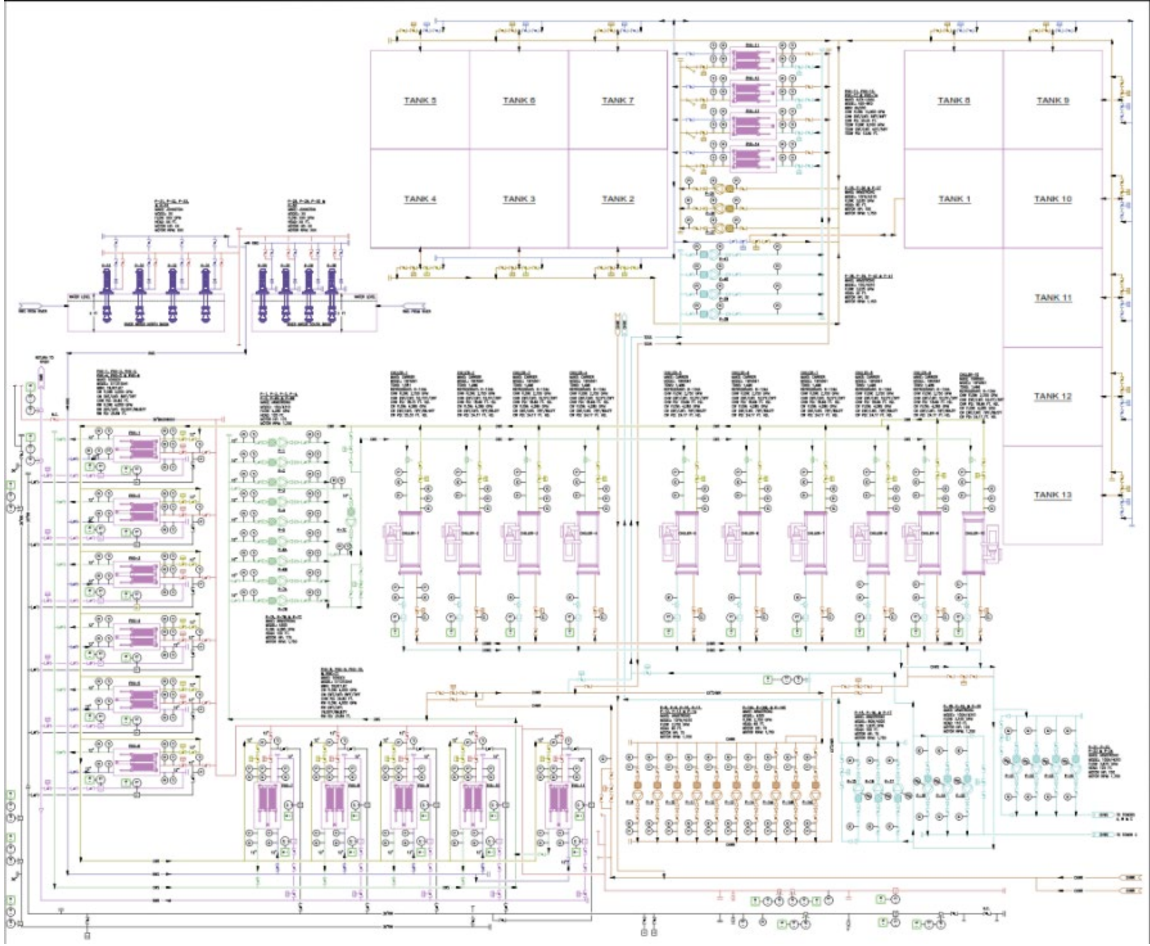
14 Acre, 5-building, 8M Sq Ft, mixed use complex on the Hudson River in Lower Manhattan.

- *200 Liberty - 1.6M SF*
- *225 Liberty - 2.5M SF*
- *200 Vesey – 2.3M SF*
- *250 Vesey – 1.6M SF*
- *Winter Garden Atrium*

- *Plant is in basement of 250 Vesey*

EXISTING PLANT

- *Built in early/mid 1980s*
- *15,000 Ton Plant*
    - *(10) 1,500 Ton Constant Speed Chillers*
- *River Water Heat Rejection via 11 titanium PFHXs and 8 VT pumps*
- *47 CW/TES/CHW Pumps*
- *(13) 280,000 Gallon TES Tanks*
    - *Roughly 30,000 Ton-hrs +/-*
- *Three CHW distribution loops*
    - *Building A, B Winter Garden*
    - *Building C*
    - *Building D*



ISSUE - TWO OPTIONS

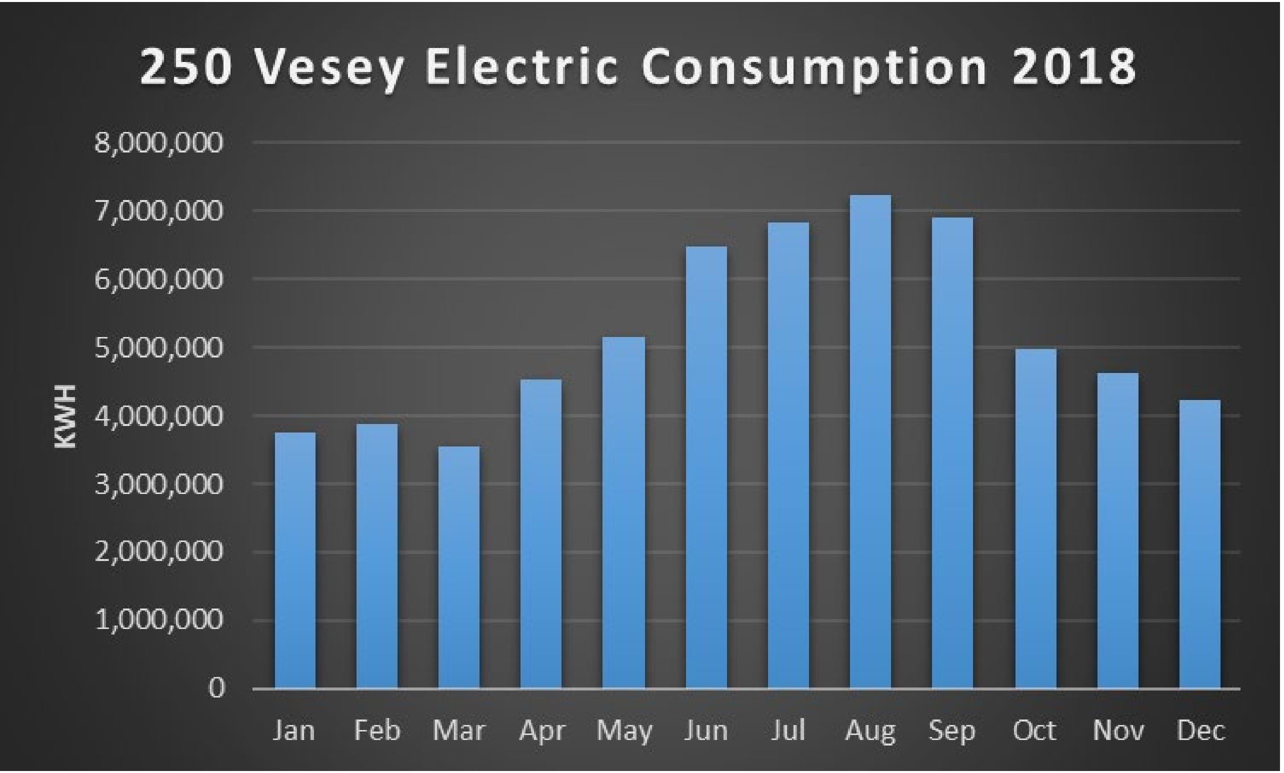
1. *Option 1 - $18MM*
   - *New Chiller*
   - *New Latent thermal storage (Ice)*
     - *Pros - New equipment*
     - *Cons – High capex, more invasive (Plant shutdown), rigging challenge, schedule challenge*
2. *Option 2 - $11MM*
   - *Rebuild existing chillers with VFDs*
   - *Optimized existing sensible thermal storage*
     - *Pros – No plant shutdown, lower capex, higher ROI, continue to use sensible TES, eliminate rigging issue, reduced schedule*
     - *Cons – No new equipment; however, compete overhaul*

CHW PLANT OPTIMIZATION

1. *Chiller Refurbishment with new tubes and VFDs on seven chillers*
2. *Chiller Plant Controls Optimization – Work with your new controls system*
   - *Benefits/Scope*
     - *No Black Box Controls Optimization*
     - ***Personnel Training** to Ensure Success*
     - *Primary Pump VFDs*
     - ***TES Optimization***
     - *Improve load DT*
3. *Preliminary Analysis*
   - *Existing Average Plant kW/Ton = 1.2*
   - *Proposed Average Plant kW/Ton = 0.75*

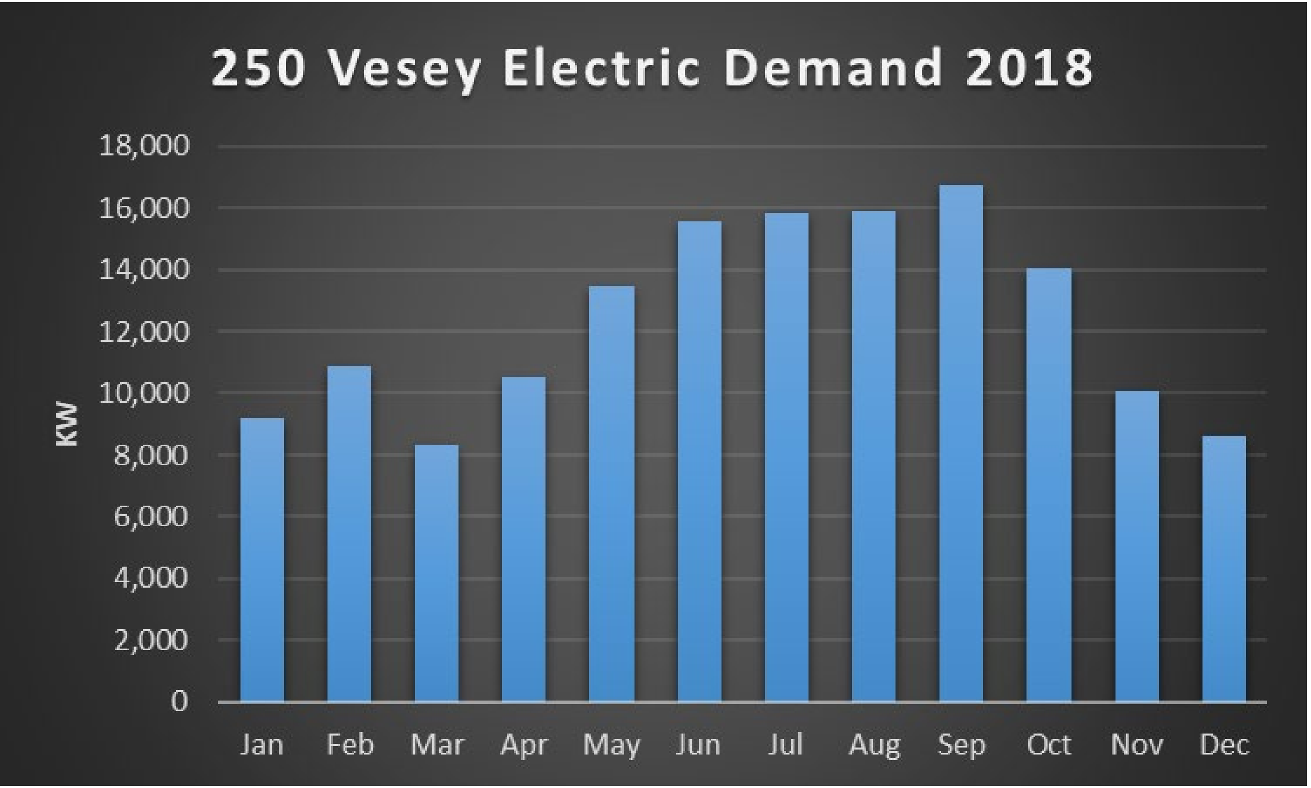
Option	Optimization and Chiller Rebuild
Energy Savings (kWh)	6,937,594
Peak Power Reductions (kW)	3,281
First Cost ($)	(11,489,000)
Estimated Rebate ($)	3,280,695
Net CapEX ($)	(8,208,305)
Annual Energy Savings ($)	1,290,355
Simple Payback (Years)	(6.26)

ENERGY – ELECTRIC - USAGE



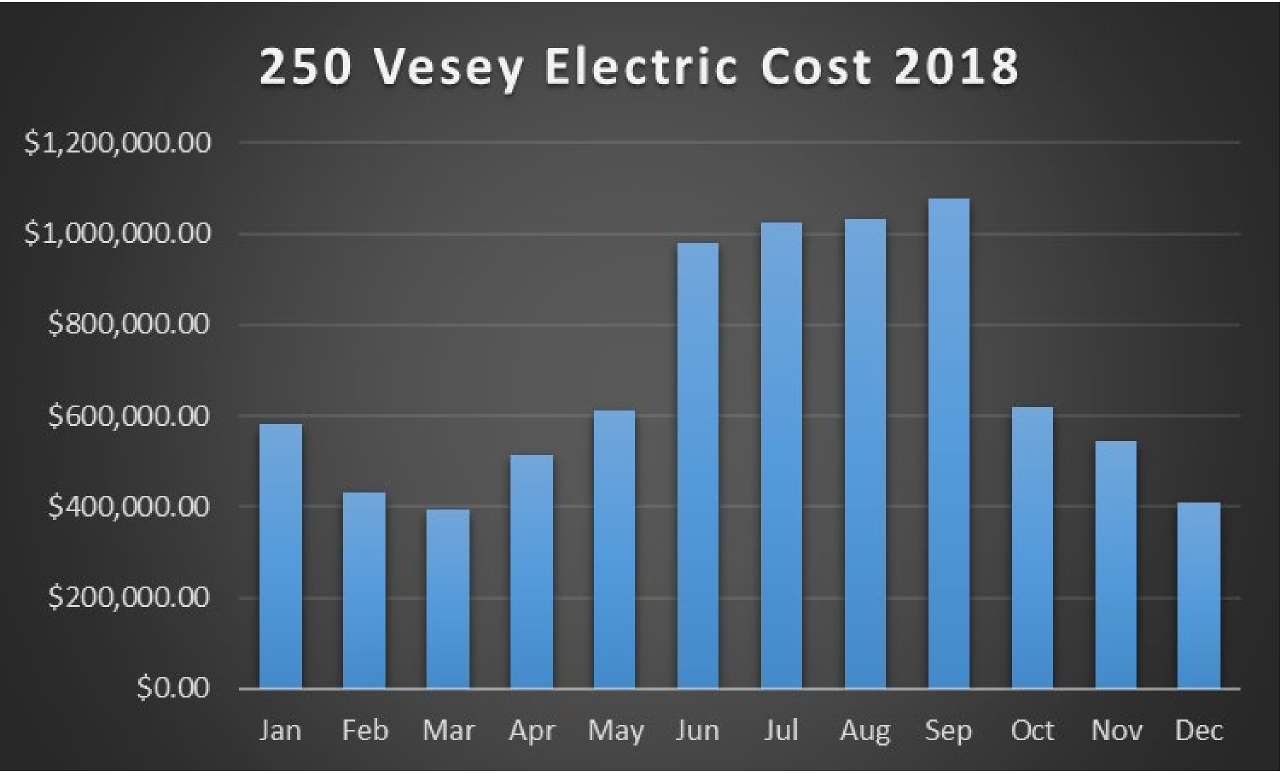
- **The electrical utility use peaks in the summer.**
- **The net MWh for 12 months is 62,160 MWh**

ENERGY – ELECTRIC - DEMAND



- **The electrical utility demand peaks in the summer.**
- **The peak power for 12 months is 16.7MW**

ENERGY – ELECTRIC - COST



Cost

- **The electrical utility cost peaks in the summer.**
- **The net electric cost for 12 months is $8.2MM**

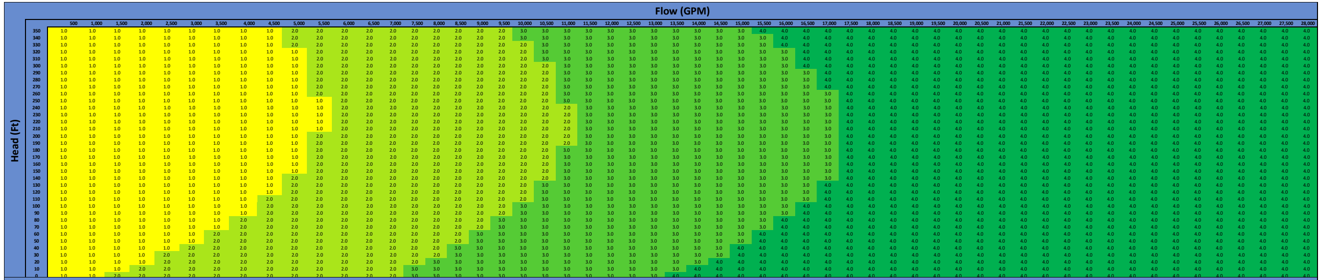
CURRENT RATE STRUCTURE

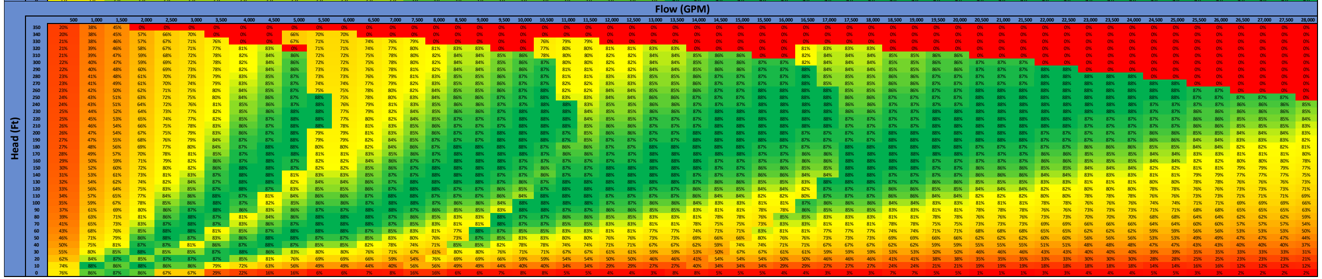
Acc: 49-4011-3020-3003-6			
Rate Structure: EL9 General Large Rate II (ConEd) - 2018			
G&T Demand Rate	By ConEd Summer (June-Sept, Mon-Fri, 8AM to 6PM)	$/kW	$8.23
Primary Demand Rate	By ConEd Summer (June-Sept, Mon-Fri, 8AM to 10PM)	$/kW	$15.39
Demand Delivery Rate	By ConEd Non-Summer (Jan-May and Oct-Dec)	$/kW	$11.35
Reactive Power Demand Rate	By ConEd If P.F is less than 95%	$/kW	$0.00
Energy Delivery Rate	By ConEd All Months	$/kWh	$0.023
Energy Supply Rate: Calpine Energy	By Calpine Energy All Months	$/kWh	$0.069
Blended Demand Rate	**Summer Estimated**	**($/kW)**	**$23.62**
Blended Demand Rate	**Winter Estimated**	**($/kW)**	**$11.35**
Blended Energy Rate	**All Months Estimated**	**($/kWh)**	**$0.093**

CHW PUMP OPTIMIZATION

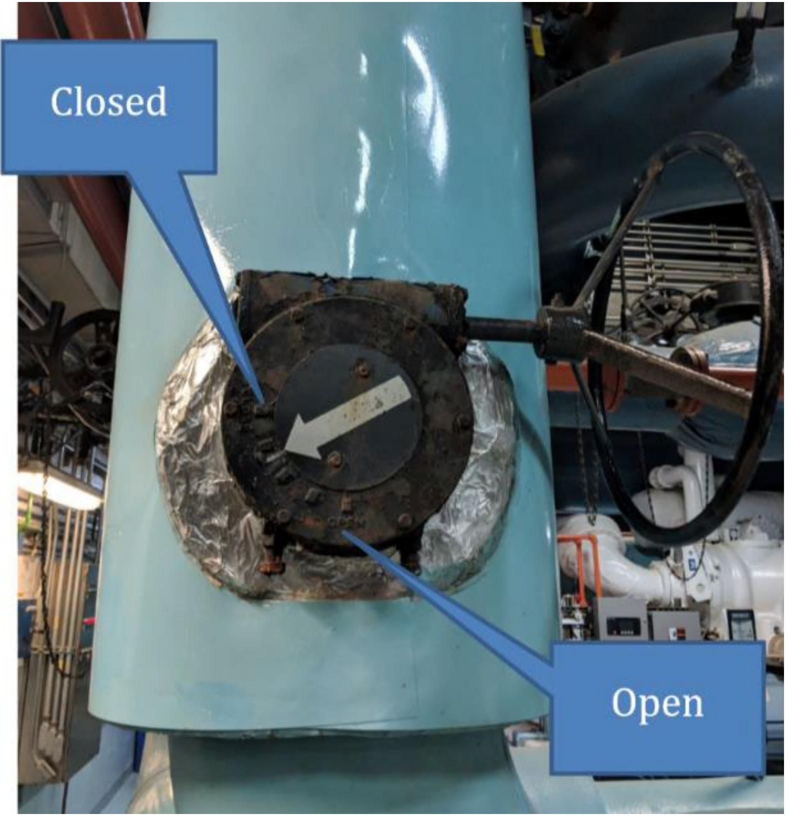
- Stage up at 1.8 and 2.8
  - Dwell timer set-point linear reset
    - X.8 = 2,000 Sec
    - X.99 = 20 Sec
- Stage down at 1.25 and 2.25
  - Dwell timer set-point linear reset
    - X.2 = 2,000 Sec
    - X.01 = 60 Sec
- If pumps speed reaches 90% stage up.

Pumps shall stage on and off based on the following formula.	
Recommended Number of Pumps =A+B*Flow+C*Head+D*Flow^2+E*Head^2+F*Flow*Head	
A	1.23100000000
B	0.00019400000
C	-0.00690000000
D	-0.00000000185
E	0.00001390000
F	0.00000008000

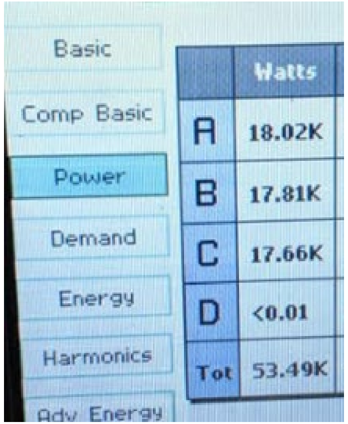




PCHWP - VFDS



Before

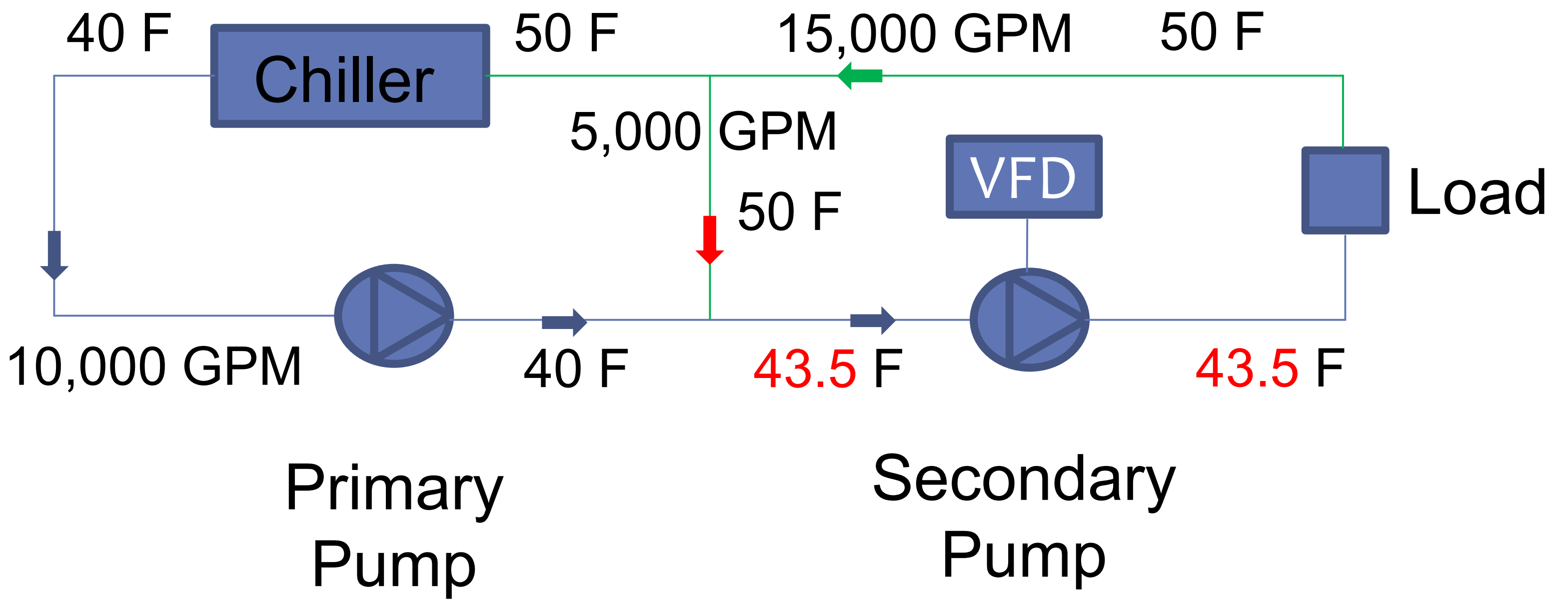


After

- 30kW reduction * 6 Pumps = 180kw
- 180kw = 51 Tons of Heat @ 0.5kW / Ton = an additional 25kW reduction
- Total reduction = 205kW

DECOUPLER

CONSTANT SPEED PRIMARY PUMPING



DECOUPLER

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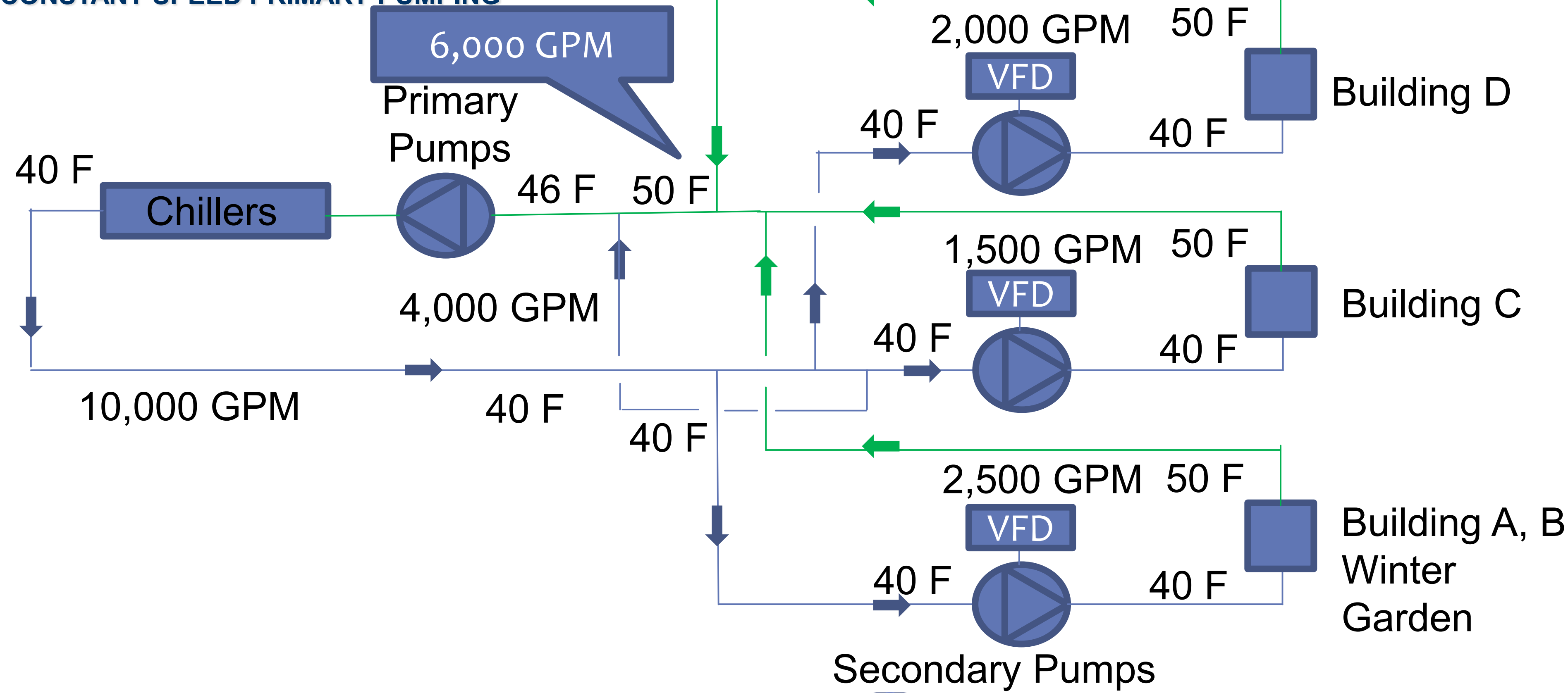
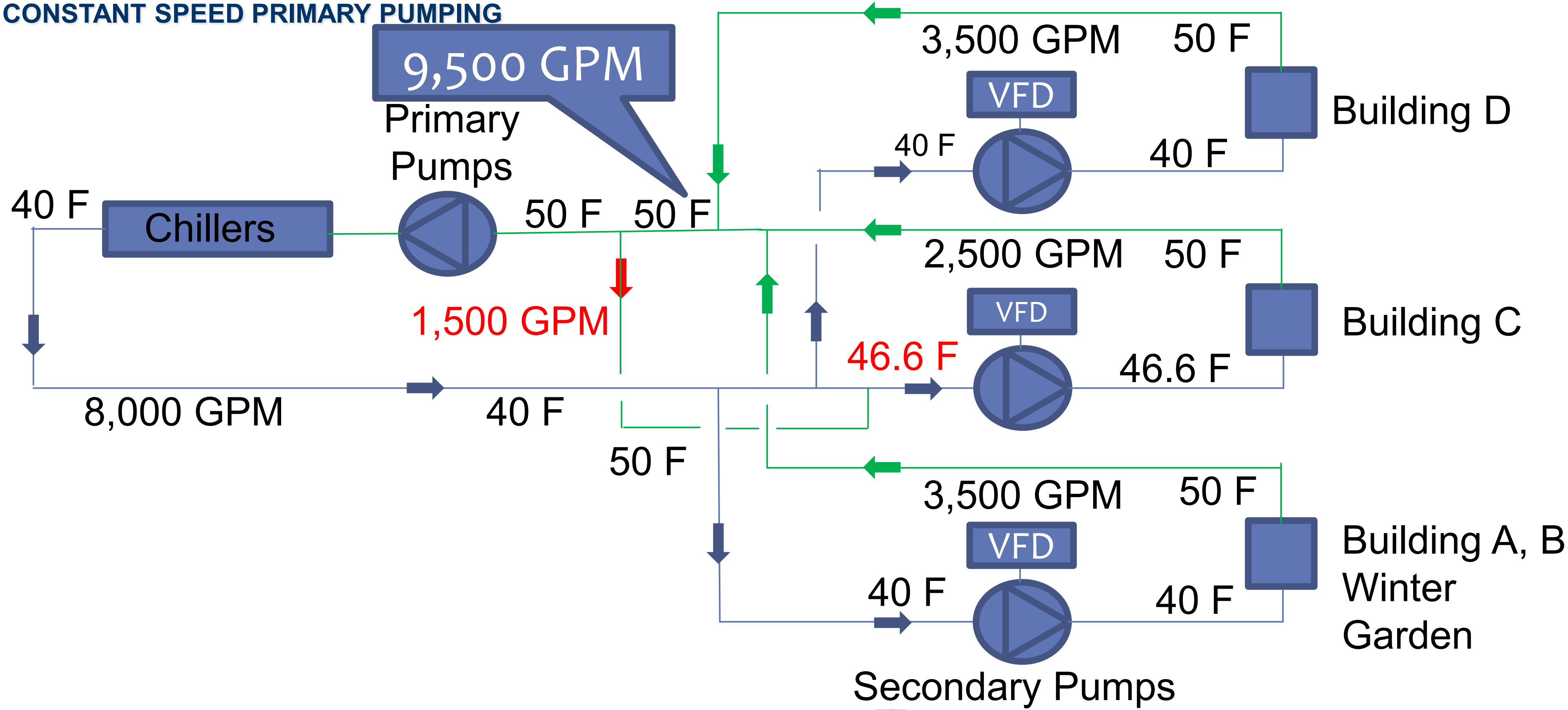


DECOUPLER

CONSTANT SPEED PRIMARY PUMPING



DECOUPLER

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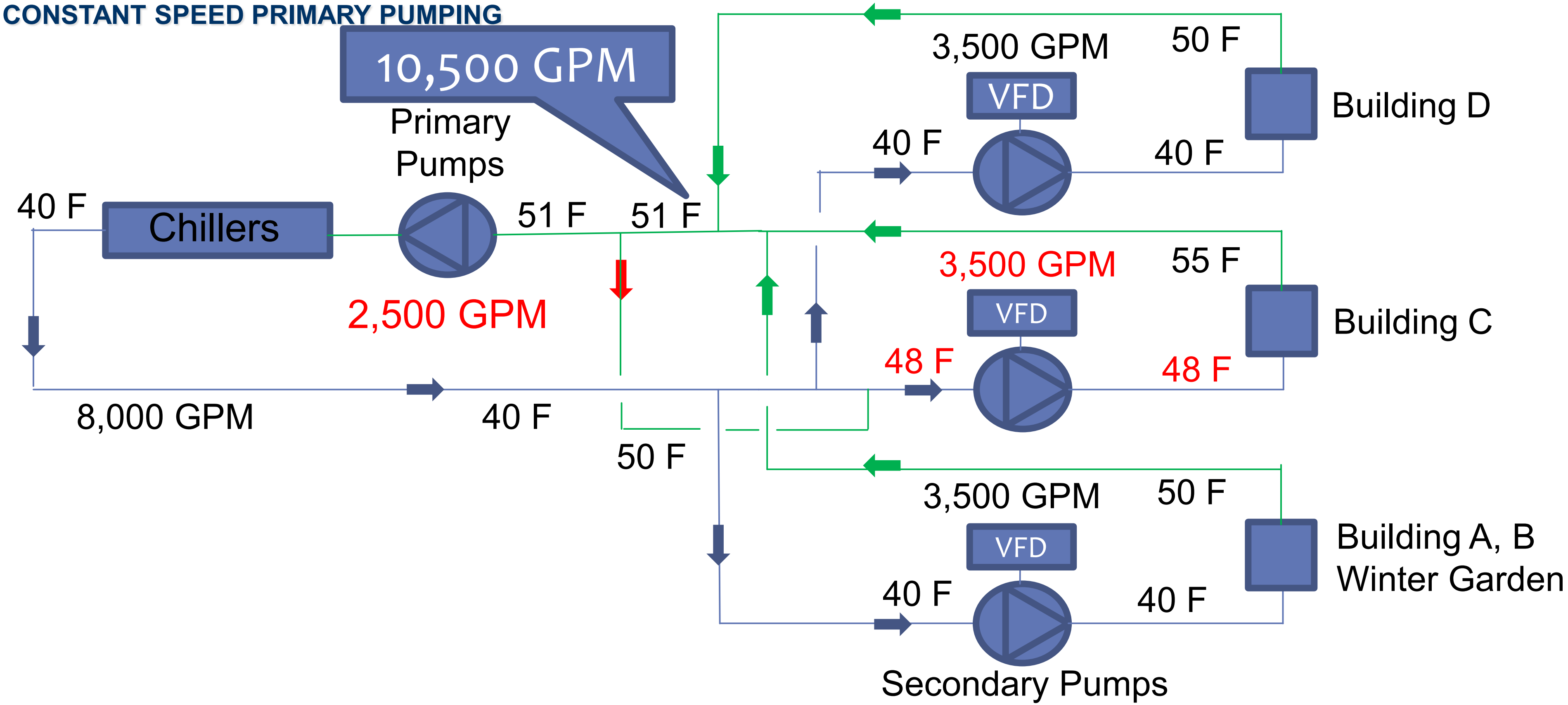
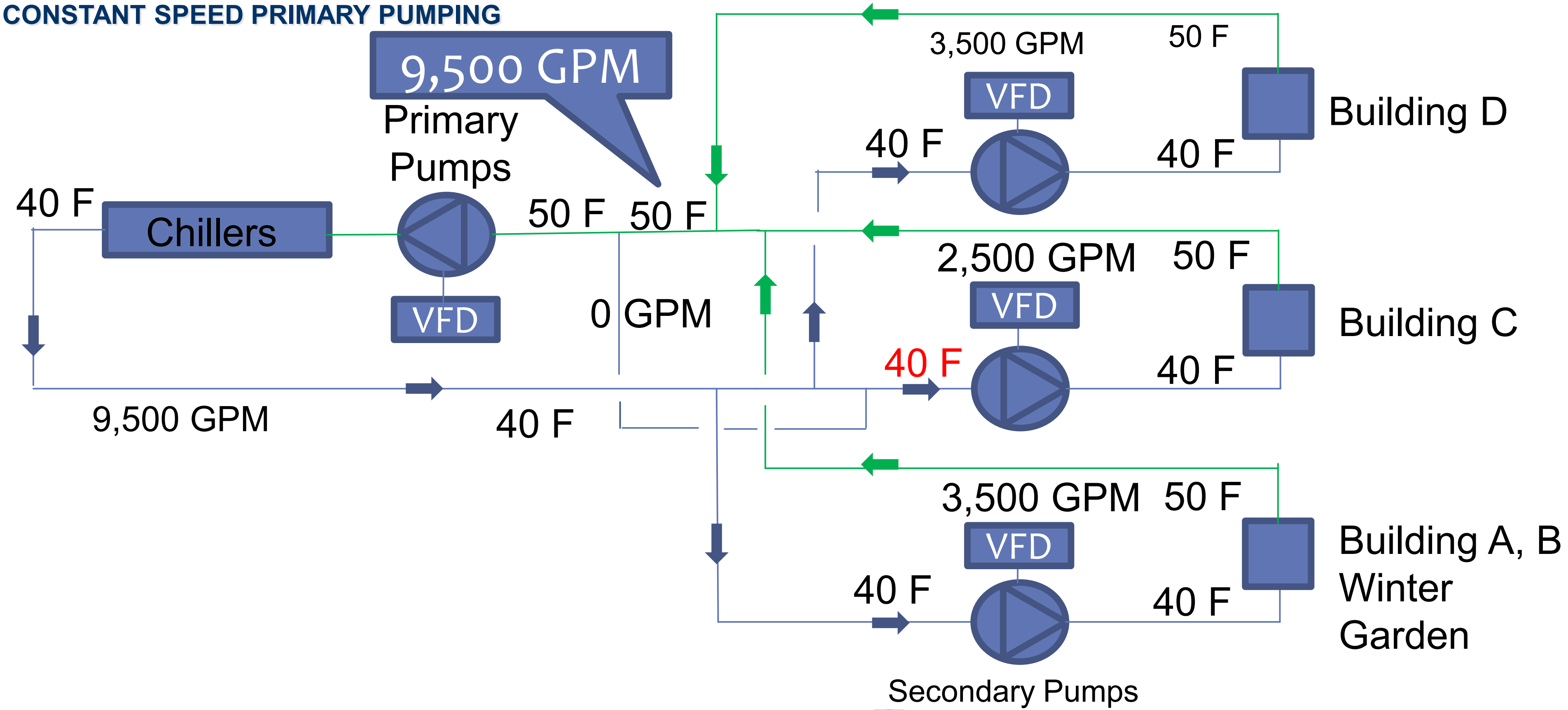
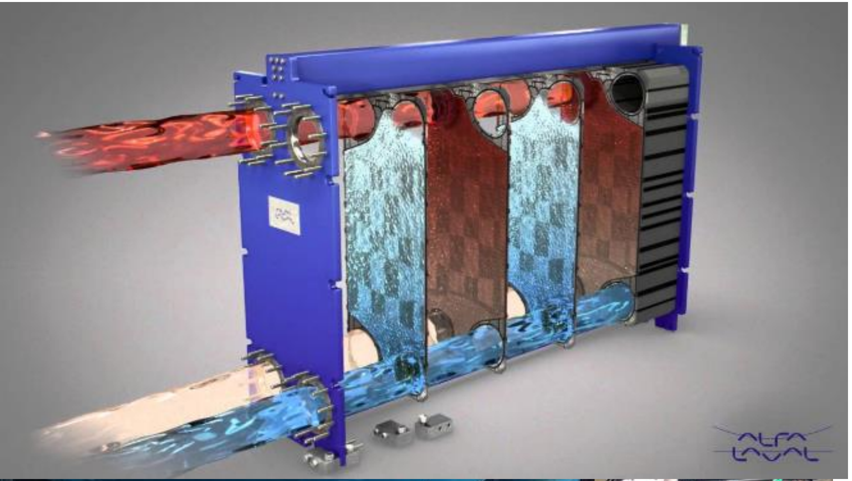


DECOUPLER

CONSTANT SPEED PRIMARY PUMPING



TES HX - PLATE ADDITION



$$Q = U * A * LMTD$$

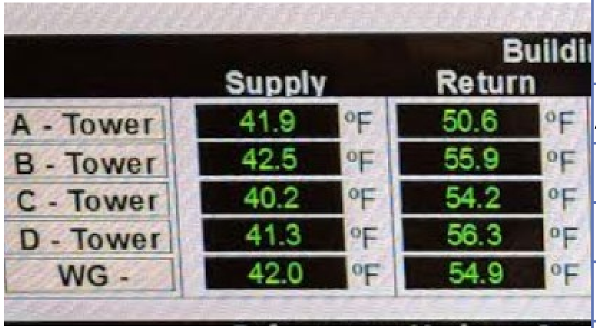
$$5{,}404kbtu = 1{,}103 * 2{,}442 * 2.01$$

$$Q = U * \uparrow 33\%\, A * \downarrow 33\% LMTD$$

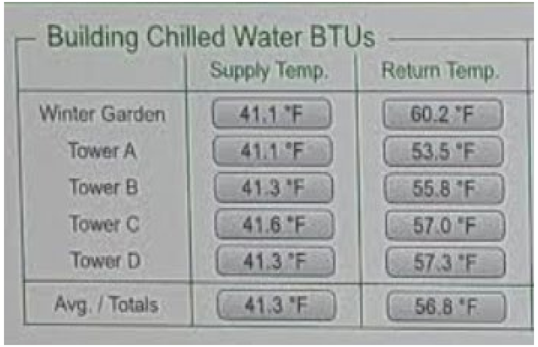
TES TANK - IMPROVED DT

- *Roughly 30,000 Ton-hrs*
- ***Every degree of DT is about 2,000 Ton-Hrs of additional storage with the existing system***
    - *Increased by*
        - *Storing colder*
        - *Warmer CHWR*
        - *Increased storage volume*

Before

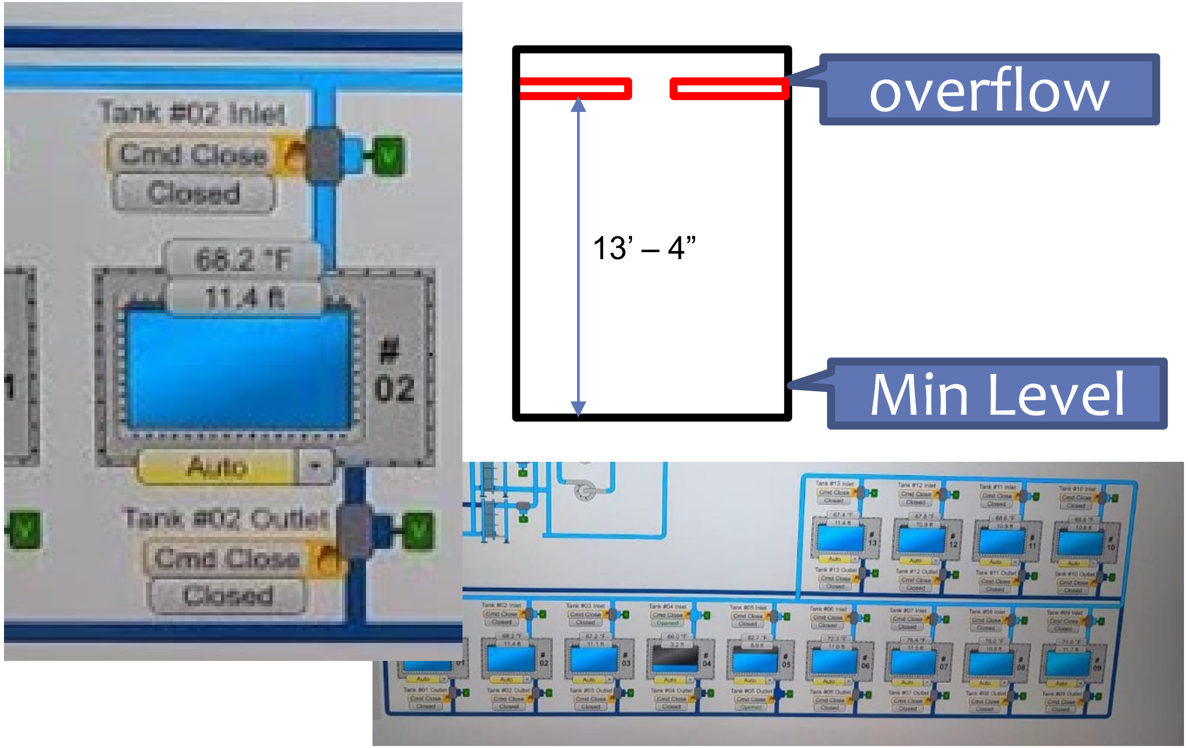


After



	Before (F)	After (F)	Increase %	Increase F
A	8.7	12.4	43%	3.7
B	13.4	14.7	10%	1.3
C	14	15.4	10%	1.4
D	15	16.2	8%	1.2
WG	12.9	19.1	48%	6.2

TES TANKS - LEVEL SENSORS

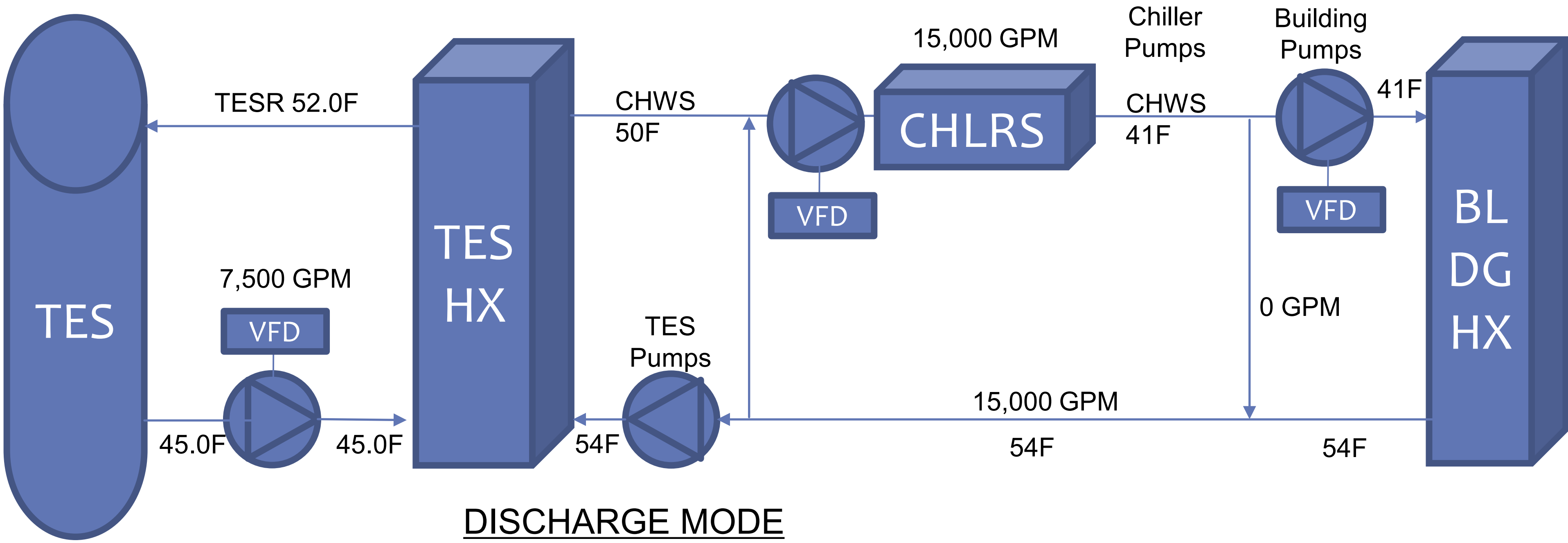


- New Level Sensors allow:
  - Higher Tank Fill
  - Lower Tank Draw
- Allows for an additional 1-2 feet
- Previous was roughly 9' draw down
- 10% - 20% more total capacity

TES OPERATION - EXISTING

EXISTING WITH 449 PLATE PER HX (4 HEAT EXCHANGERS)

- Tank Capacity = ((52.0F - 45.0F) * 3,000,000 Gallons * 1 BTU/LB-F * 8.34 LB/Gallon / 12,000 BTUH/Ton)) = 14,595 Ton-Hrs
- Much lower than the design capacity of 30k ton-hours

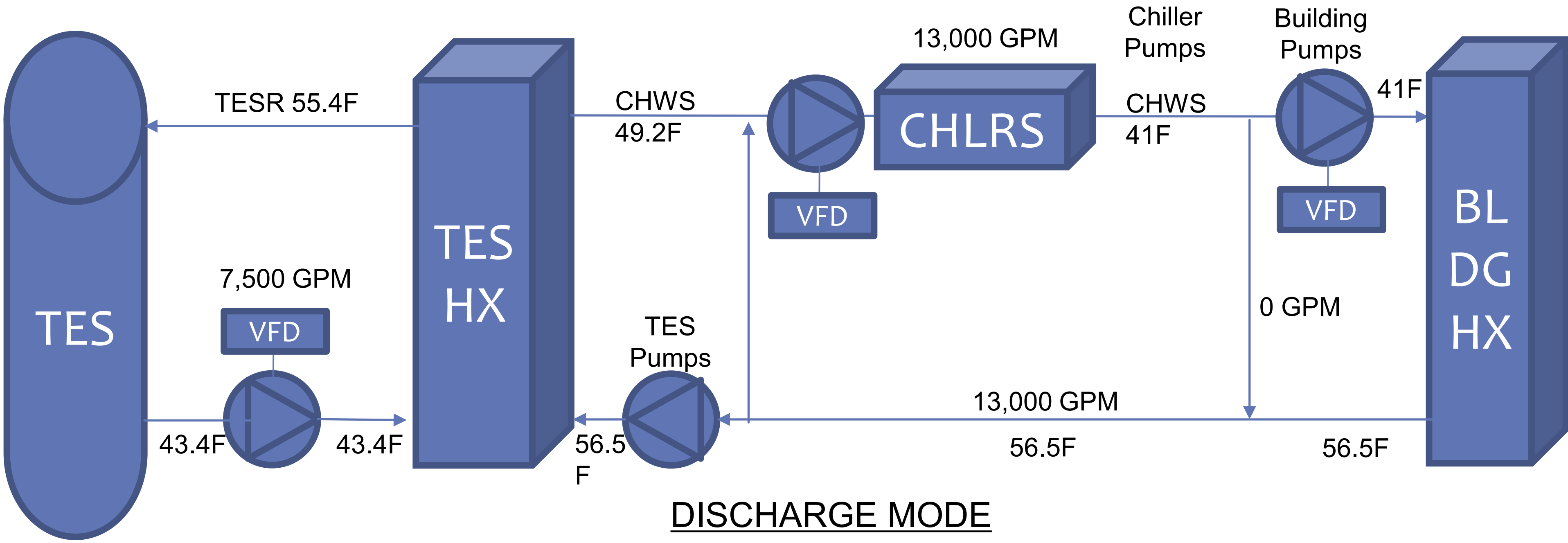


DISCHARGE MODE

TES OPERATION - NEW

EXISTING WITH 600 PLATE PER HX (4 HEAT EXCHANGERS)

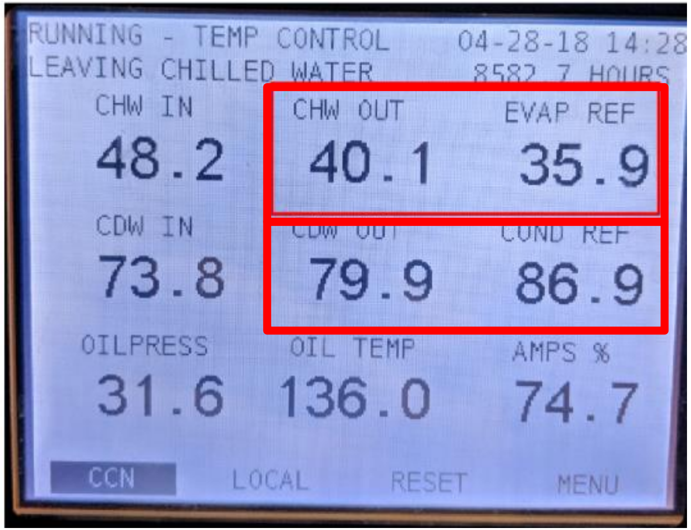
- Tank Capacity = ((55.4F - 42.0F) * 3,300,000 Gallons * 1 BTU/LB-F * 8.34 LB/Gallon / 12,000 BTUH/Ton)) = 27,522 Ton-Hrs
- Much closer to the design capacity of 30k ton-hours



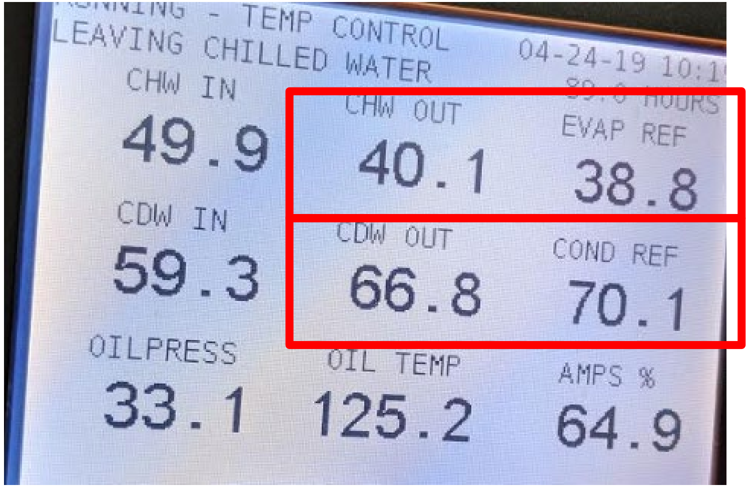
DISCHARGE MODE

CHILLER UPGRADE - RETUBE

Before



After

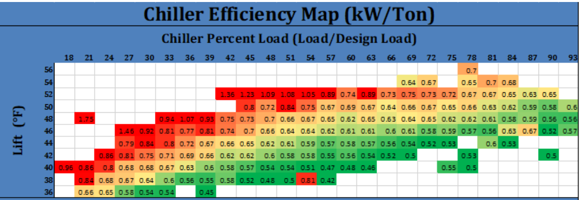


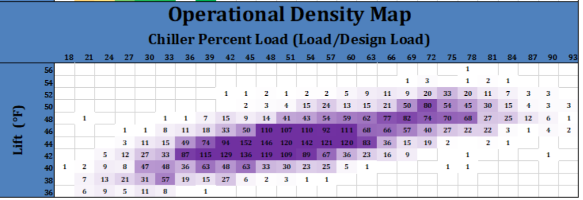
This approach improvement results in a 12% to 40% lift and power reduction.

	Before	After	Reduction
Evap Approach (F)	4.2	1.3	2.9
Cond Approach (F)	7	3.3	3.7
Total Approach (F)	11.2	4.6	6.6

CHILLER UPGRADE – NEW VFD COMPRESSOR

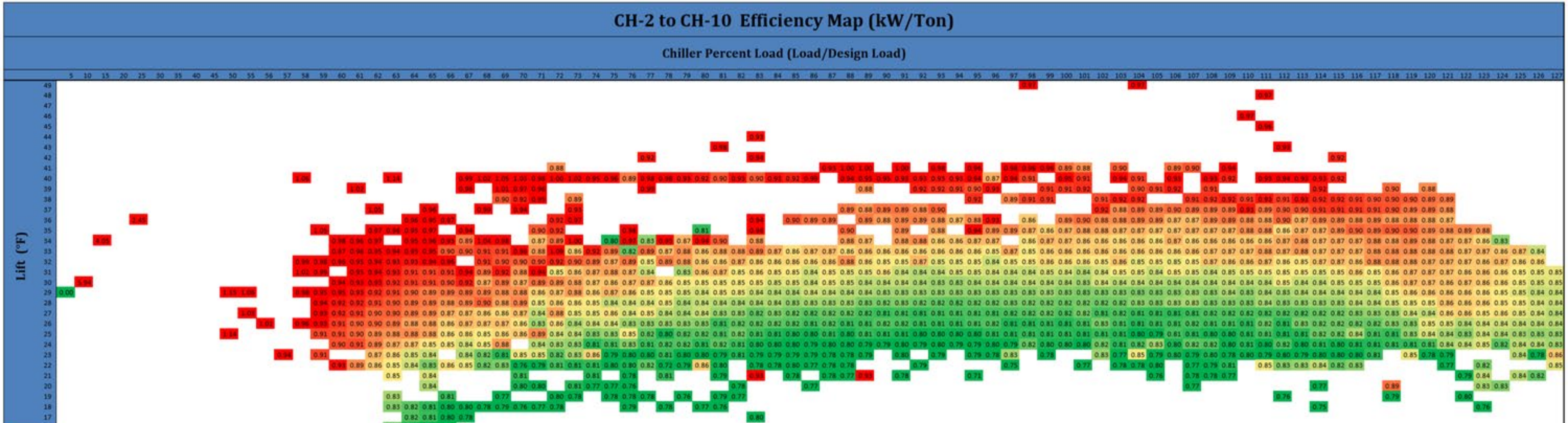
Carrier 19XRV Chiller



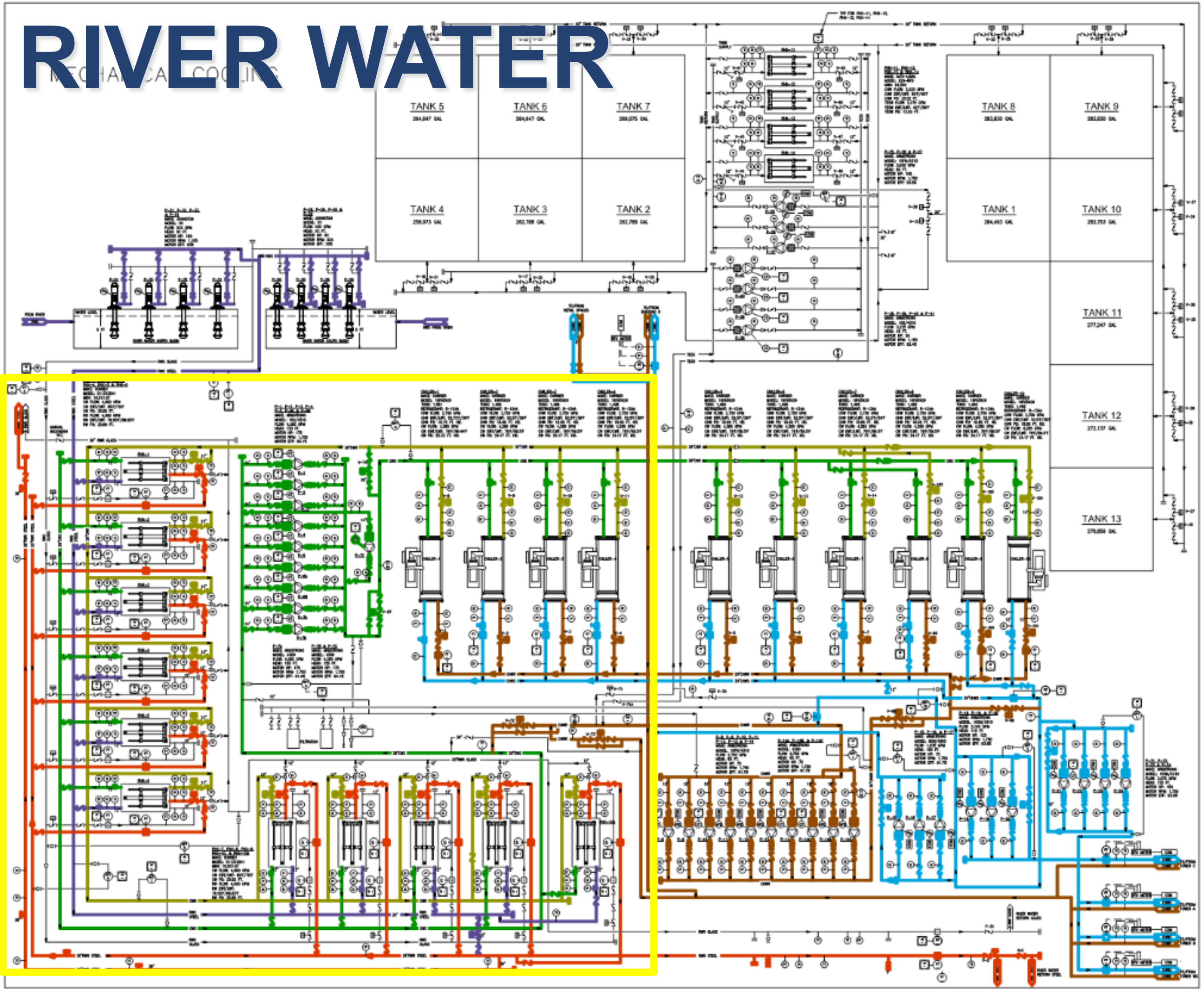


ASHRAE 90.1 Compliant Rebuild

	Existing	New	Reduction
Chiller kW/Ton	0.75	0.525	0.225
Tons	10,000	10,000	
kW	7500	5250	2,250



RIVER WATER



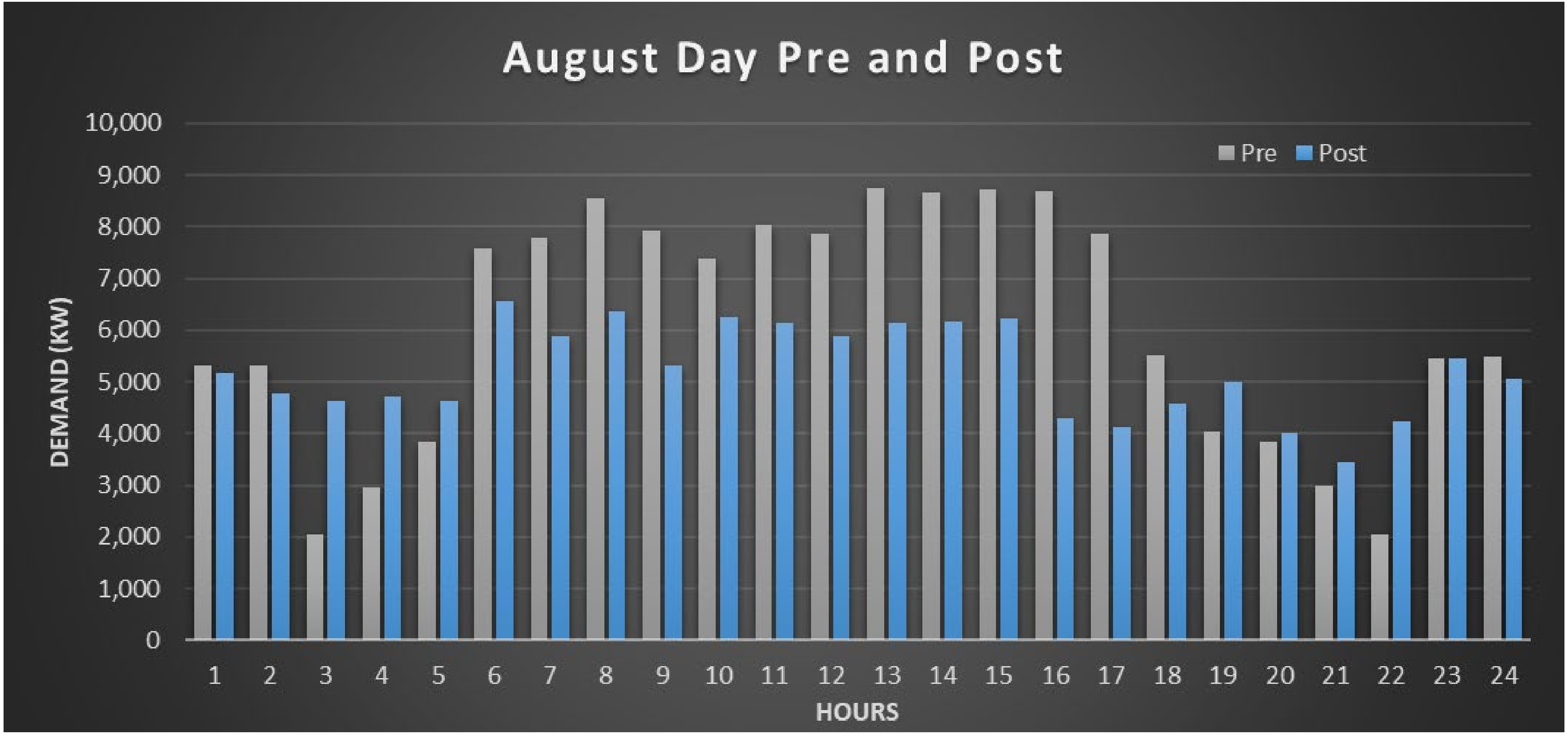
Use more plates per chiller to reduce CWS to chiller, reducing lift and reducing compressor power

Connected Services Screens

CHILLER SCREEN

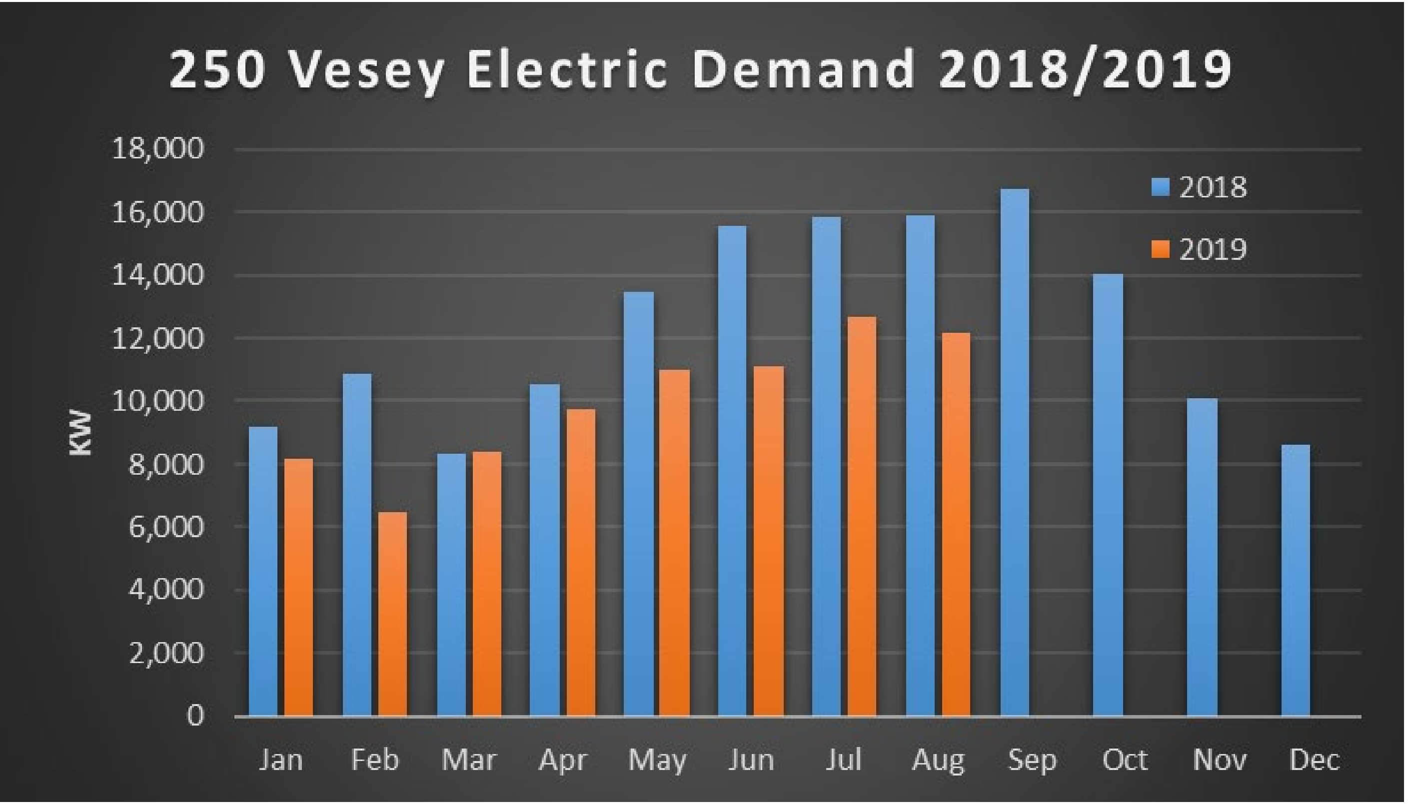
Conclusions

RESULTS



August Day Pre and Post
Pre
Post
DEMAND (KW)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
HOURS

RESULTS



- The peak power for 2018 was 16.7 MW
- The peak power for 2019 was 12.2 MW
- **4.5 MW Reduction!**

PROJECT RESULTS

	Estimated	Actual
Option	Optimization and Chiller Rebuild	Optimization and Chiller Rebuild
Energy Savings (kWh)	5,975,274	9,309,800
Demand Window Power Reductions (kW)	3,377	5,162*
First Cost ($)	($11,489,000.00)	($11,381,414.01)
Rebate ($)	$3,377,094.21	$4,090,180.64
Net CapEX ($)	($8,111,905.79)	($7,291,233.37)
Annual Energy Savings ($)	$1,220,254	$1,760,935
Simple Payback (Years)	6.86	4.14

* During Demand Management Program Window.

Month	Cost ($)			Demand (kW)			Project Status
	2018	2019	Reduction	2018	2019	Reduction	
Jun	$ 1,165,581	$ 941,356	$ 224,225	13,584	11,136	2,448	40% Complete
Jul	$ 1,481,759	$ 1,189,061	$ 292,698	15,840	12,720	3,120	60% Complete
Aug	$ 1,521,453	$ 1,121,589	$ 399,864	15,936	12,144	3,792	90% Complete