University of Wisconsin Campus Chilled Water Optimization- Phase I

IDEA Campus Energy Conference 2020

Denver, CO

Outline

- Background / History
- Project Goals
- Modelling the Systems
- Predictive Optimization
- Dispatch Strategies
- Operator Training
- Projected Performance
- Project Schedule

University of Wisconsin-Madison Location

University of Wisconsin-Madison

- Founded in 1848 as Wisconsin's land-grant university
- Flagship campus of the 26-campus University of Wisconsin System

- 936-acre main campus (including 300-acre Lakeshore Nature Preserve)
- Largest land owner on Lake Mendota with 4 miles of lakefront

- 9,647 acres statewide including agricultural research stations, experimental farms, arboretum lands and other off-campus properties

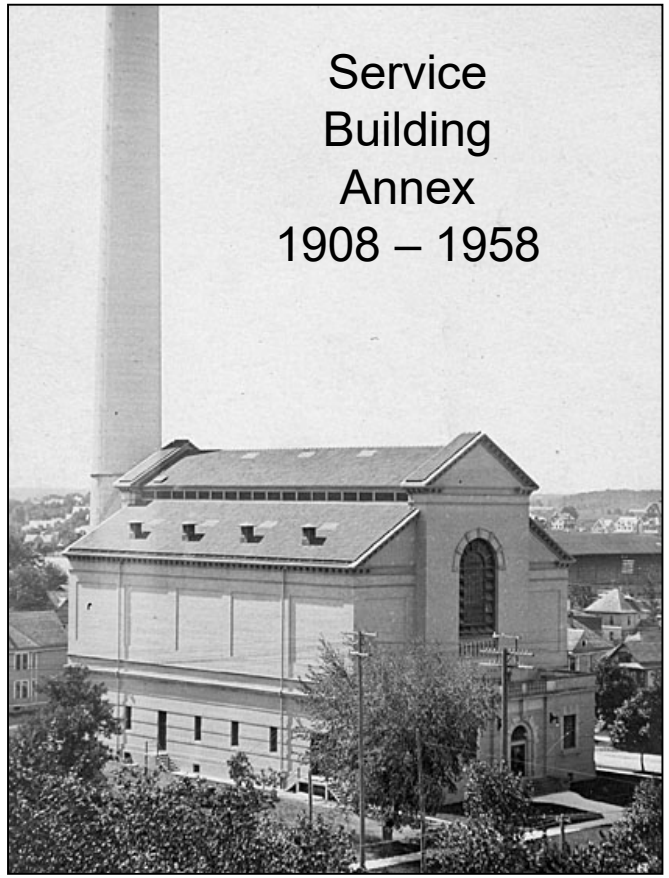
- Over 45,300 students and 22,400 faculty & staff (67,700 total)
- Over 24 million GSF of conditioned space

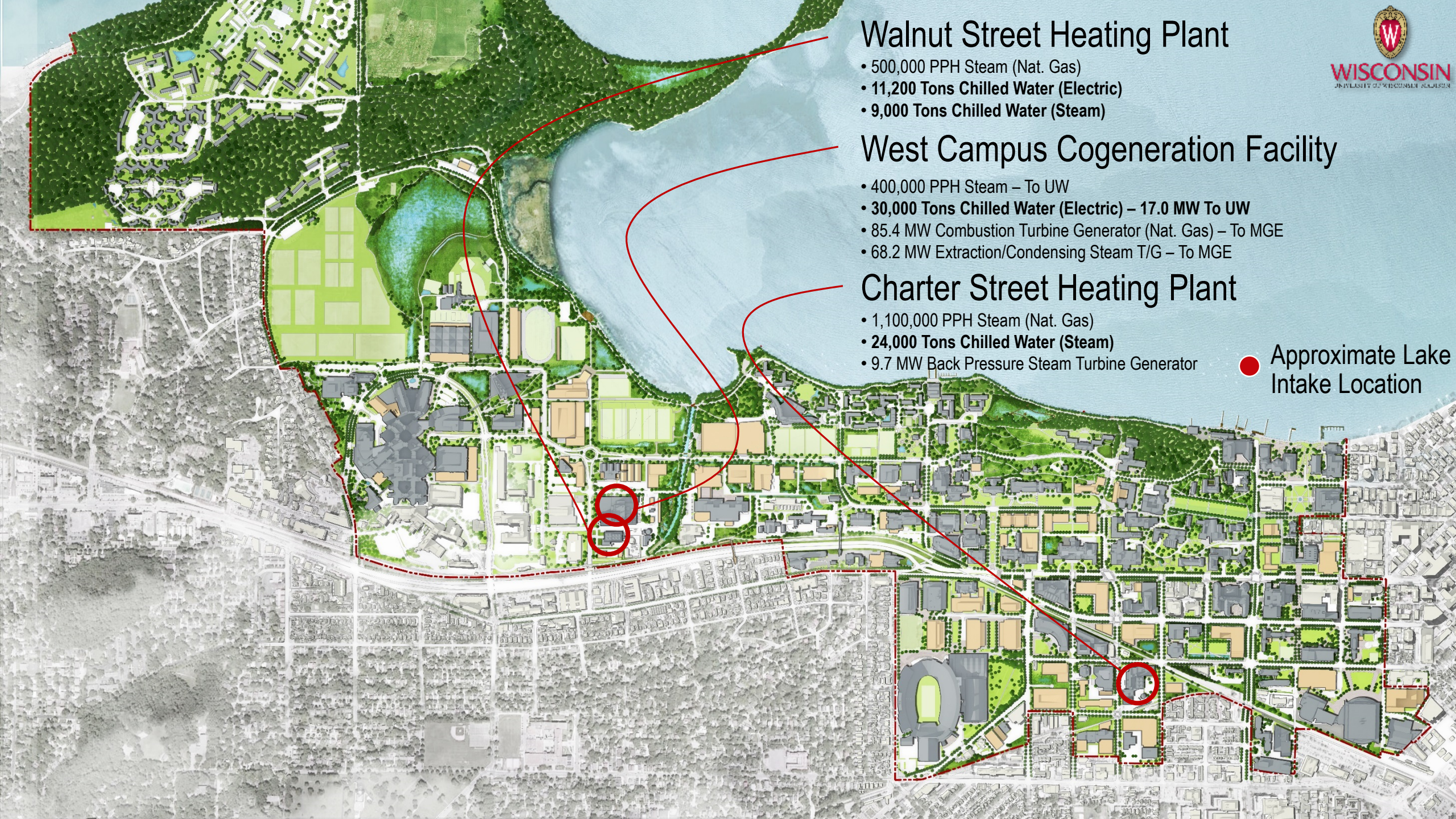
- Over 451,000 living alumni worldwide

- $3.2 billion annual operating budget
- Ranked 6th nationally in research funding

UW-Madison Utility Plant Evolution

• Radio Hall	1885 – 1908
• Ag Bulletin	1899 – 1937
• Service Building Annex	1908 – 1958
• Charter Street H&C Plant **(Cooling - 1966)**	1958 – Present
• Walnut Street H&C Plant	1975 – Present
• West Campus Cogeneration Plant	2005 – Present




Walnut Street Heating Plant
• 500,000 PPH Steam (Nat. Gas)
• 11,200 Tons Chilled Water (Electric)
• 9,000 Tons Chilled Water (Steam)
West Campus Cogeneration Facility
• 400,000 PPH Steam – To UW
• 30,000 Tons Chilled Water (Electric) – 17.0 MW To UW
• 85.4 MW Combustion Turbine Generator (Nat. Gas) – To MGE
• 68.2 MW Extraction/Condensing Steam T/G – To MGE
Charter Street Heating Plant
• 1,100,000 PPH Steam (Nat. Gas)
• 24,000 Tons Chilled Water (Steam)
• 9.7 MW Back Pressure Steam Turbine Generator
Approximate Lake Intake Location
WISCONSIN

UW-Madison Campus Utility Summary

- Steam Summary
  - 2,100,000 PPH Total (Installed)
  - 1,800,000 PPH Firm (Less Largest Unit)
  - 1,316,000 PPH Peak (Historical Max)
  - 879,000 PPH Peak (Jan 2019)
- **Chilled Water Summary**
  - **74,000 Tons Total (Installed)**
  - **66,000 Tons Firm (Less Largest Unit)**
  - **64,000+ Tons Peak (Historical Max)**
  - **56,000 Tons Peak (Jul 2019)**
- Electrical Summary
  - 88.7 MW Peak (Aug 2013 Max)
  - 82.6 MW Peak (Sep 2016)
  - 83.4 MW Peak (Jul 2019)

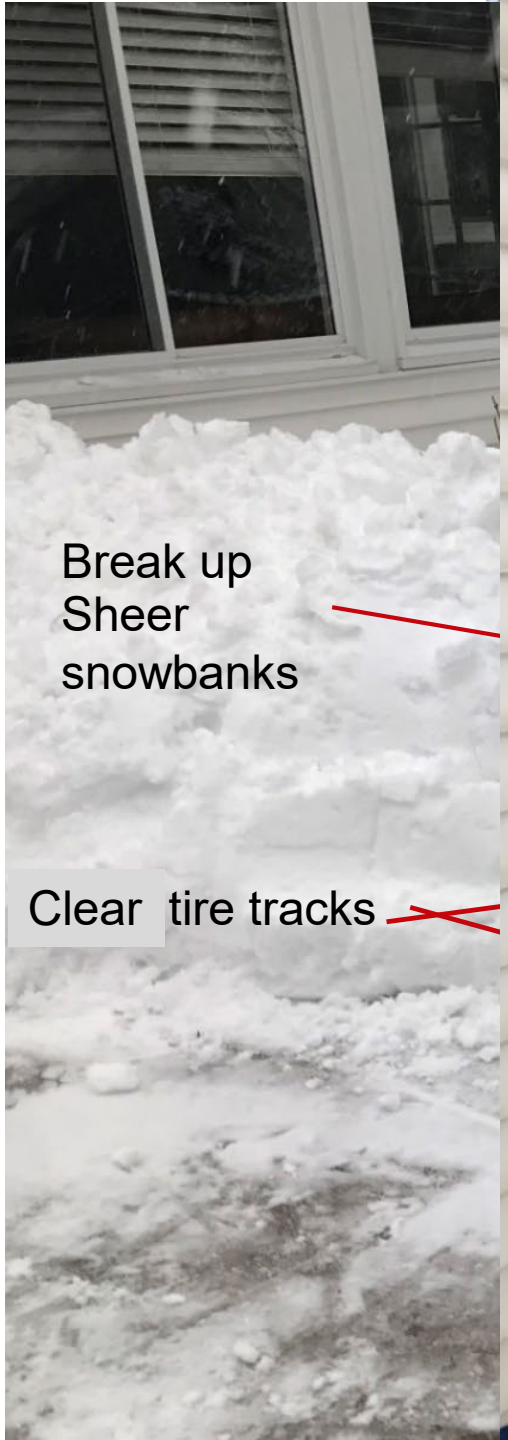
CSHP

WSHP

WCCF

Project Goals

- Reduce operating cost
- Improve efficiency (in that order)
- Make no significant changes to equipment or hardware
- Maintain manual operation of the plants- at least in the short term
- Find potential areas for improvements to be made later


Break up
Sheer
snowbanks
Clear tire tracks

Controls Strategy

Existing Control Strategy

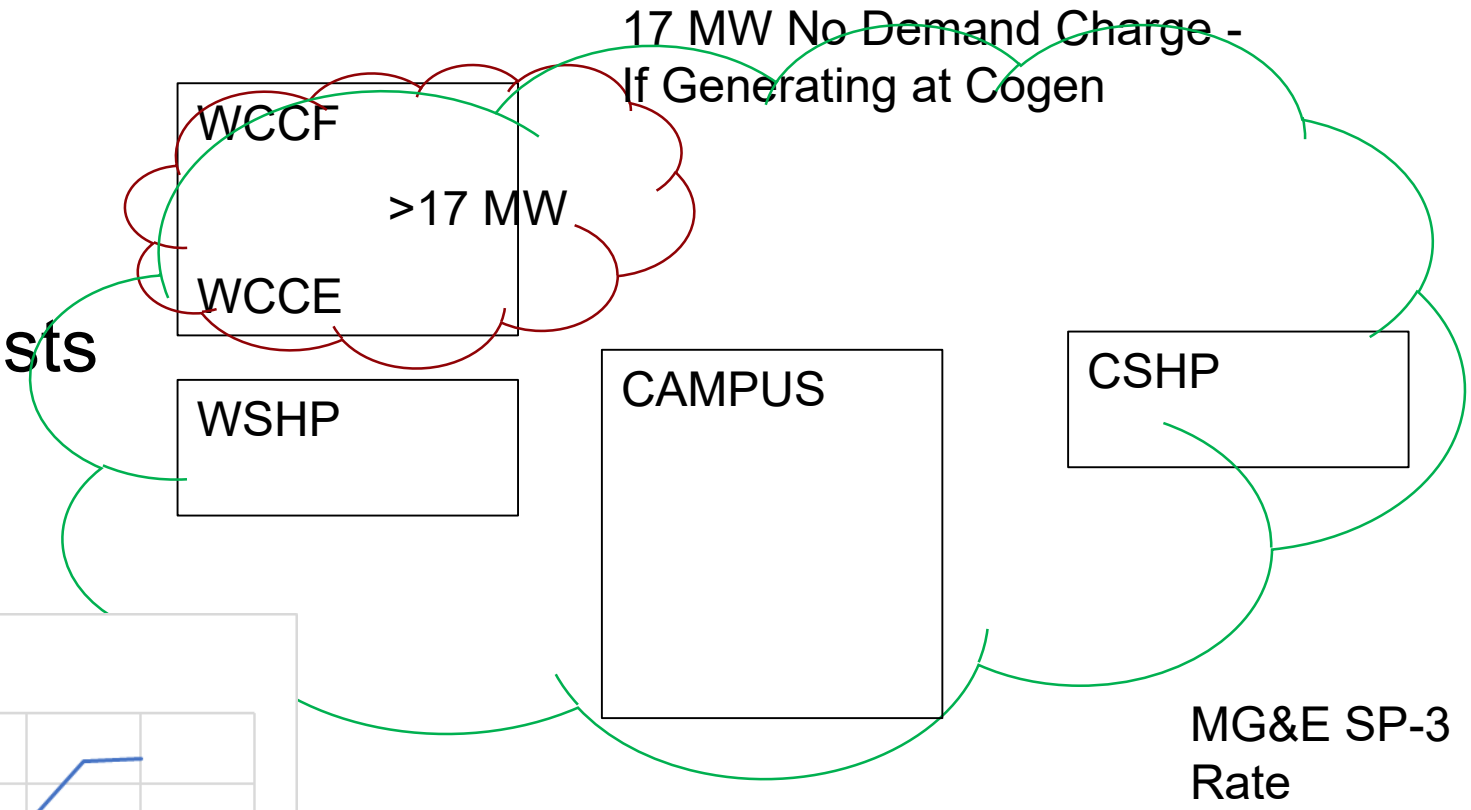
- Delta V
  - Steam Chiller controls
  - Cooling Tower
  - Limited local control loops
- eDNA
  - SCADA
  - Plant Status Board
  - Campus wide data 5 min intervals
- Manual Control
  - Chiller start/stop
  - Dispatch
  - Demand Control

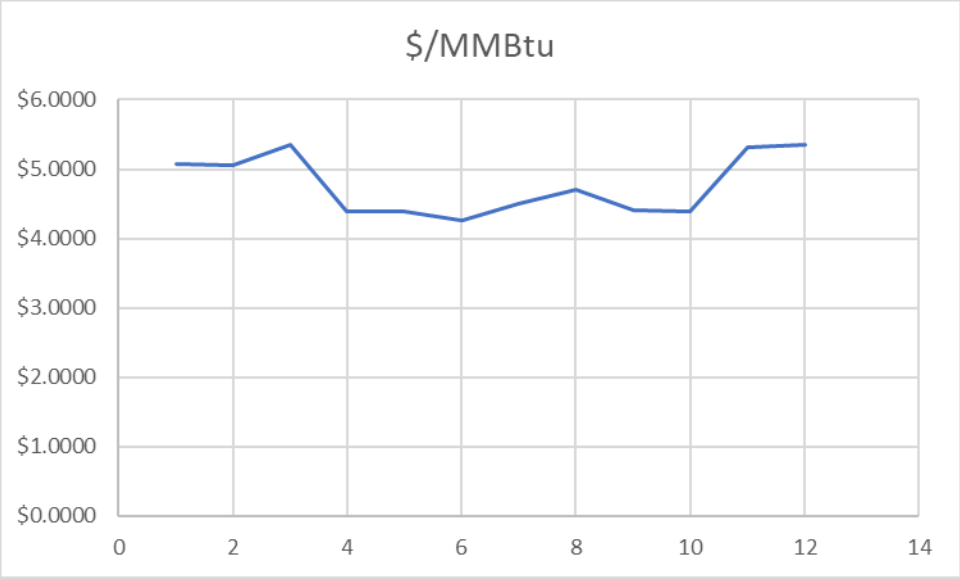
Optimized Strategy

- Delta V
  - Predictive Optimization
  - Recommended Load
  - Plant operating curves
- eDNA (Future Transition to Pi)
  - SCADA – UW added points
  - Update Plant Status Board
  - Campus wide data 5 min intervals
- Manual Using Predictive Tools
  - Hourly/Weekly Load & Demand
  - Equipment Dispatch Model
  - Execution of Dispatch

Model Billing structure

- Electrical
- Steam vs Gas
- Burdened steam costs



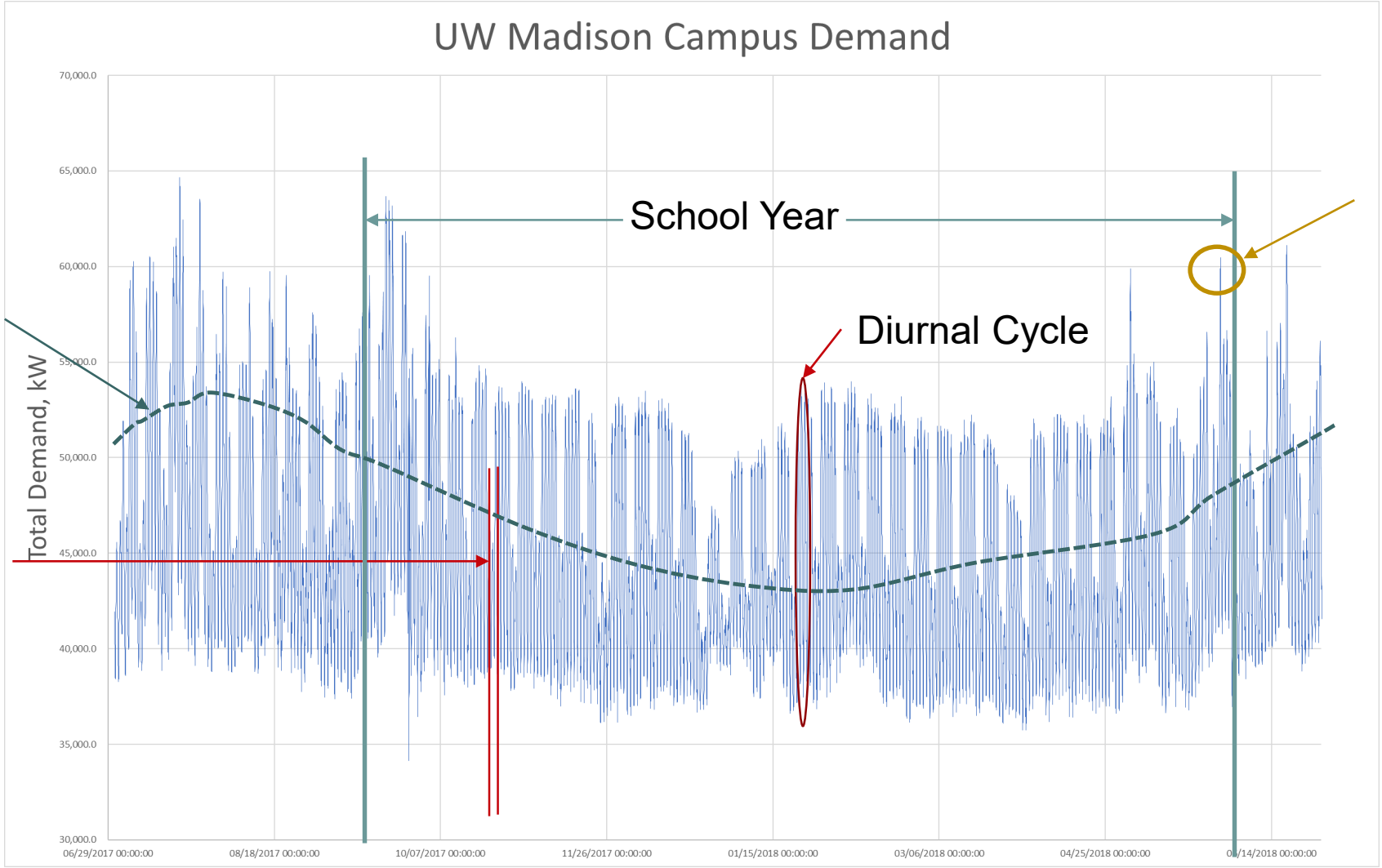


Model Campus Electricity Use

Make Axes Values larger

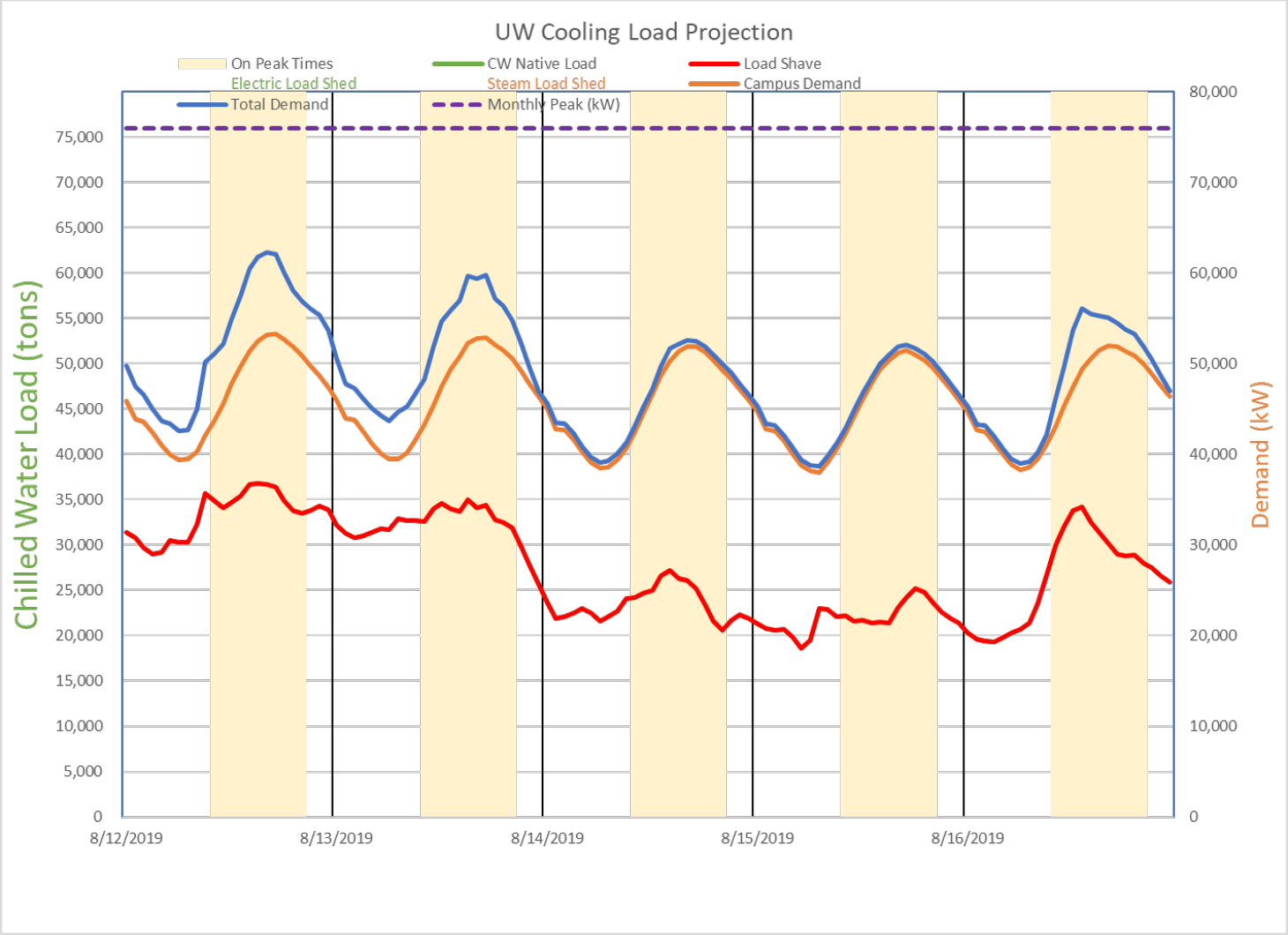
Weather Influence

Weekends



Graduation

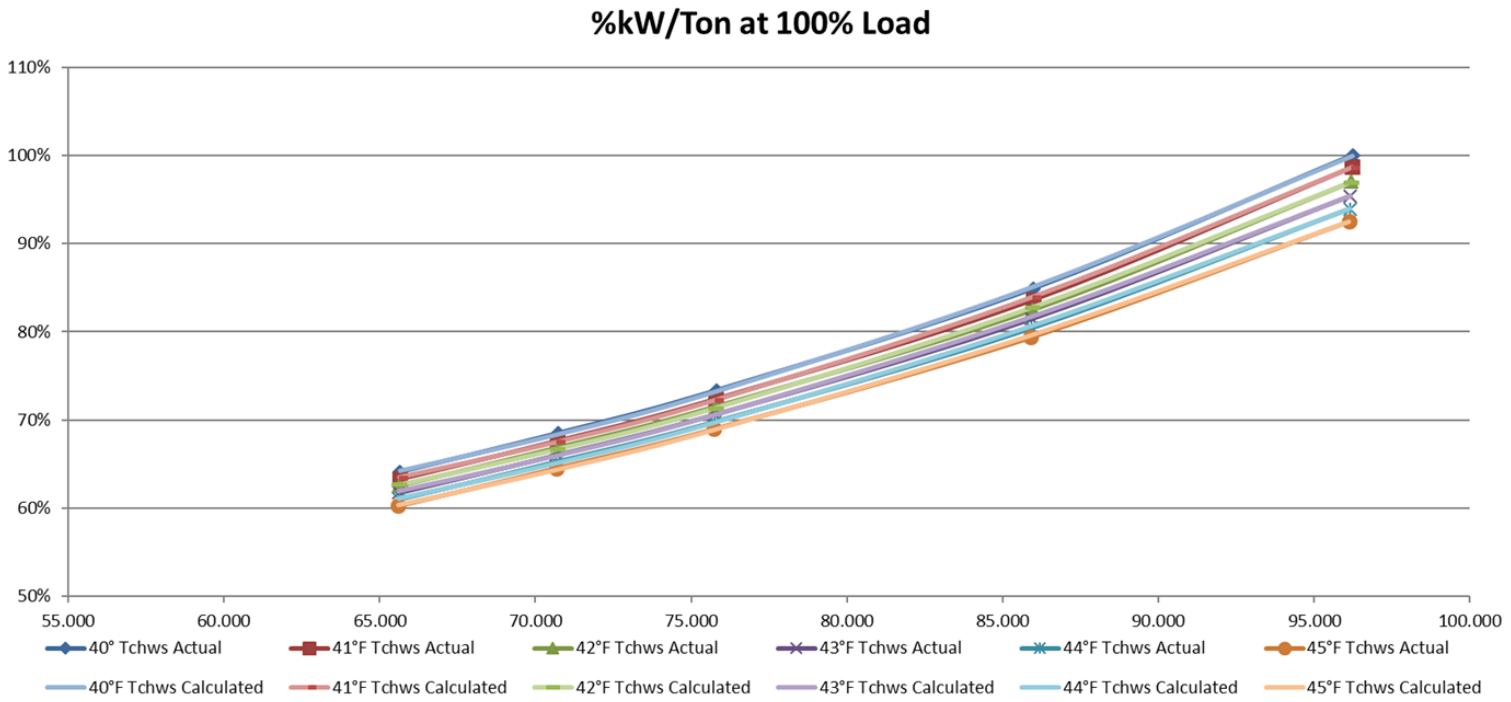
Model Chilled Water Use

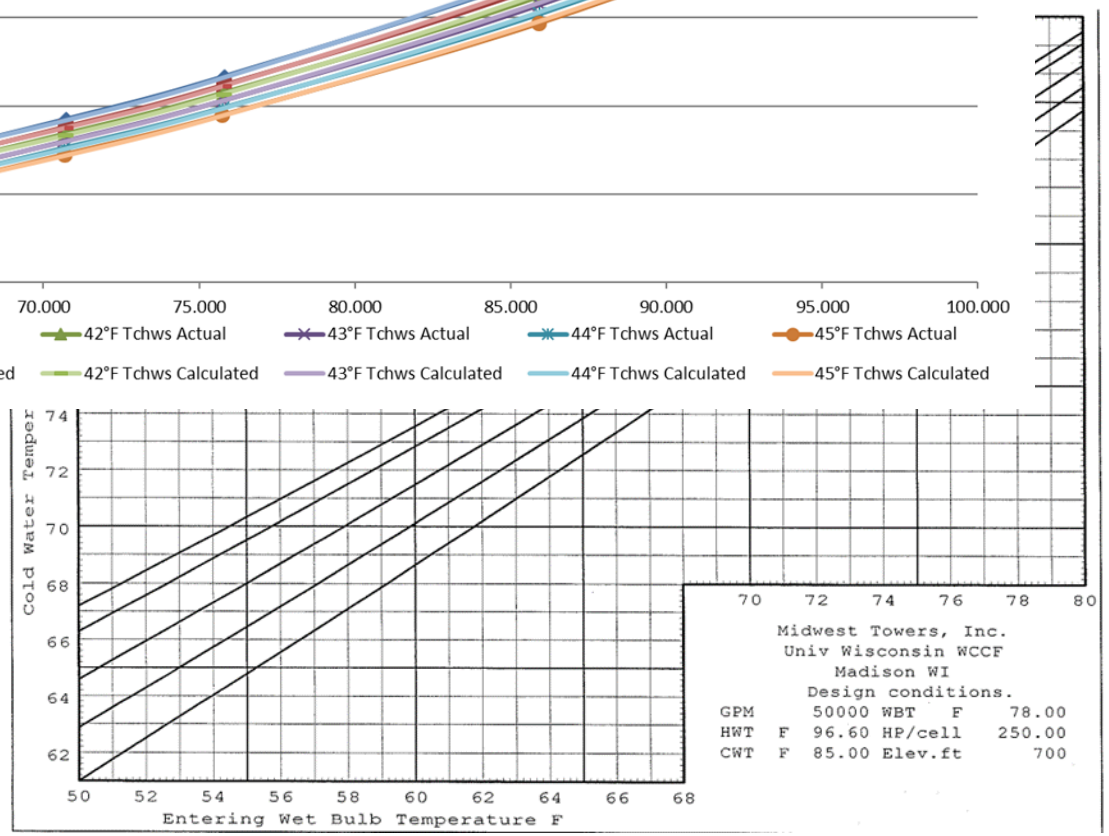


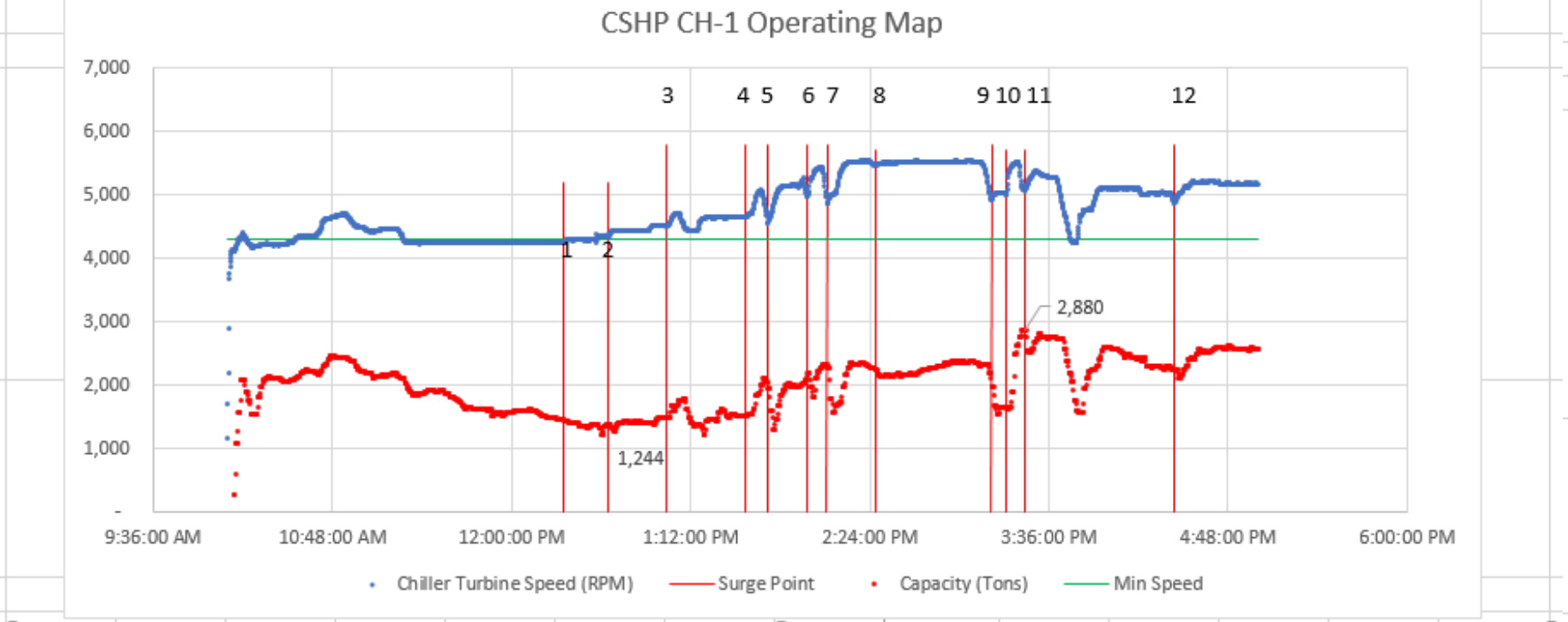
August

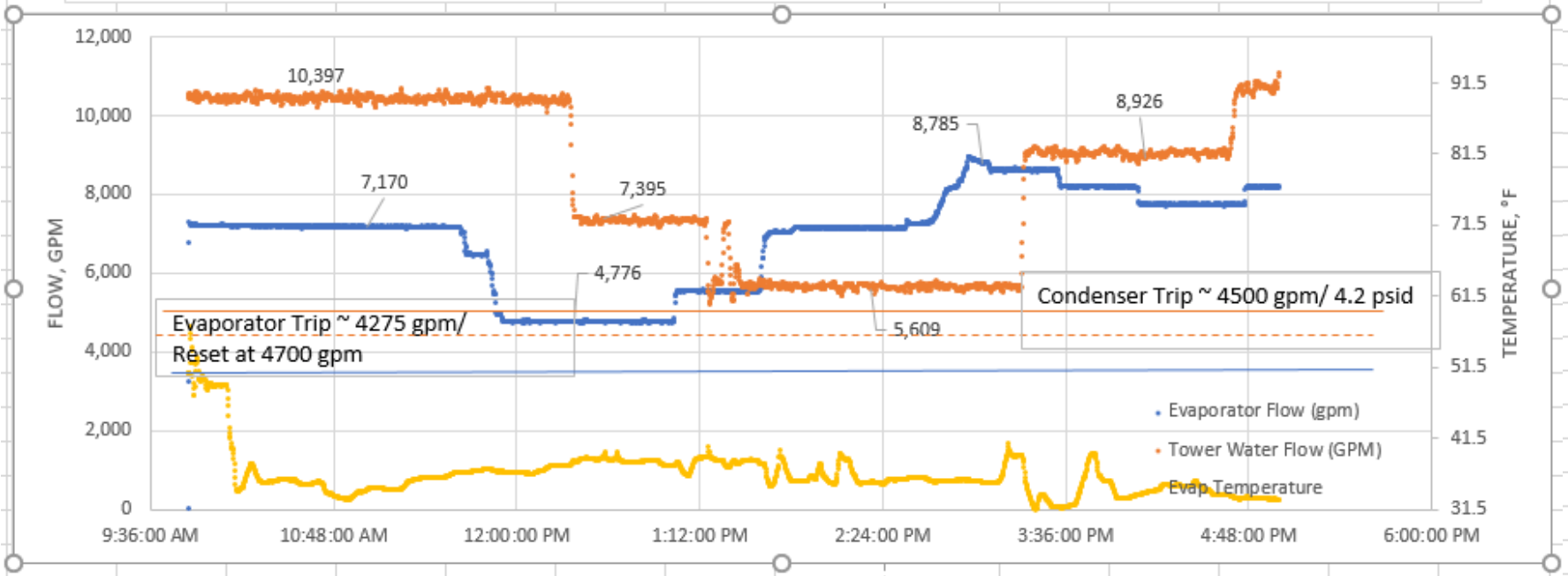
Model Plants

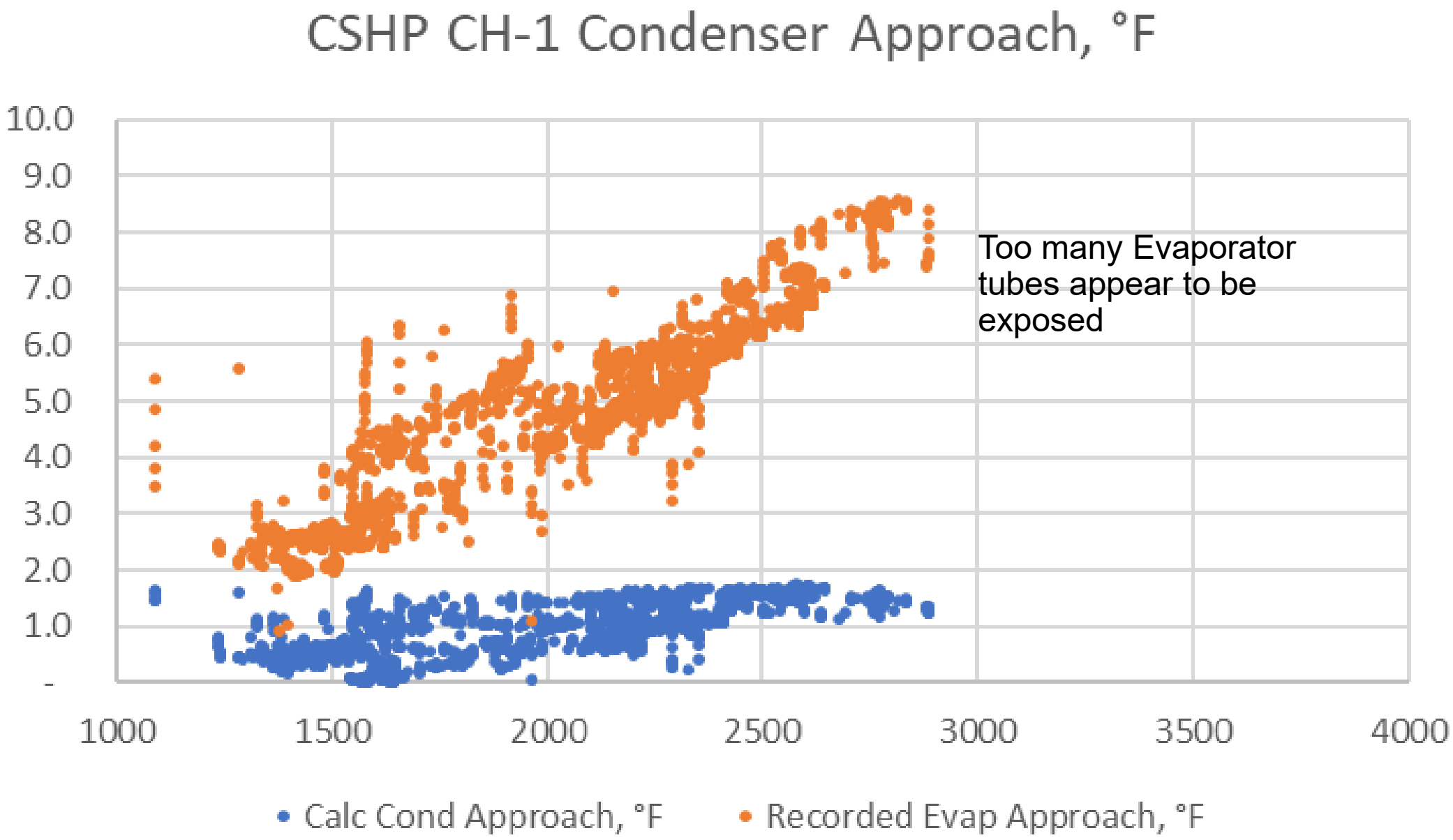
- WCCF
- WCCE
- Combined operation
- Charter Street






CSHP CH-1 Operating Map
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-
1
2
3
4 5
6 7
8
9 10 11
12
2,880
1,244
9:36:00 AM
10:48:00 AM
12:00:00 PM
1:12:00 PM
2:24:00 PM
3:36:00 PM
4:48:00 PM
6:00:00 PM
Chiller Turbine Speed (RPM)
Surge Point
Capacity (Tons)
Min Speed

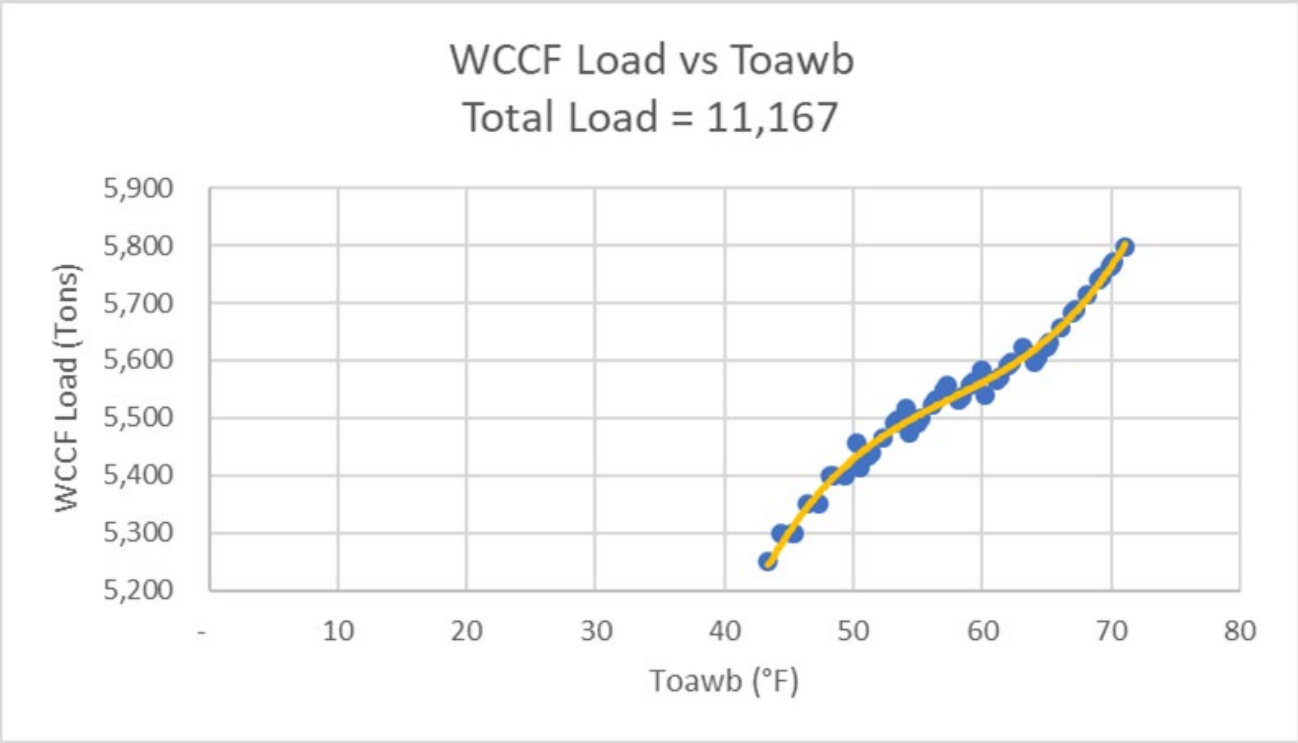

FLOW, GPM
TEMPERATURE, °F
12,000
10,000
8,000
6,000
4,000
2,000
0
91.5
81.5
71.5
61.5
51.5
41.5
31.5
10,397
7,170
7,395
4,776
8,785
8,926
5,609
Evaporator Trip ~ 4275 gpm/
Reset at 4700 gpm
Condenser Trip ~ 4500 gpm/ 4.2 psid
Evaporator Flow (gpm)
Tower Water Flow (GPM)
Evap Temperature
9:36:00 AM
10:48:00 AM
12:00:00 PM
1:12:00 PM
2:24:00 PM
3:36:00 PM
4:48:00 PM
6:00:00 PM


CSHP CH-1 Condenser Approach, °F
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
-
1000
1500
2000
2500
3000
3500
4000
Too many Evaporator tubes appear to be exposed
Calc Cond Approach, °F
Recorded Evap Approach, °F

© 2019 HGA

Predictive Optimization

- Equipment Models
- Plant Limitations
- Loads and Weather
- Optimize Overall Plant Energy Efficiency
- Set up control algorithms



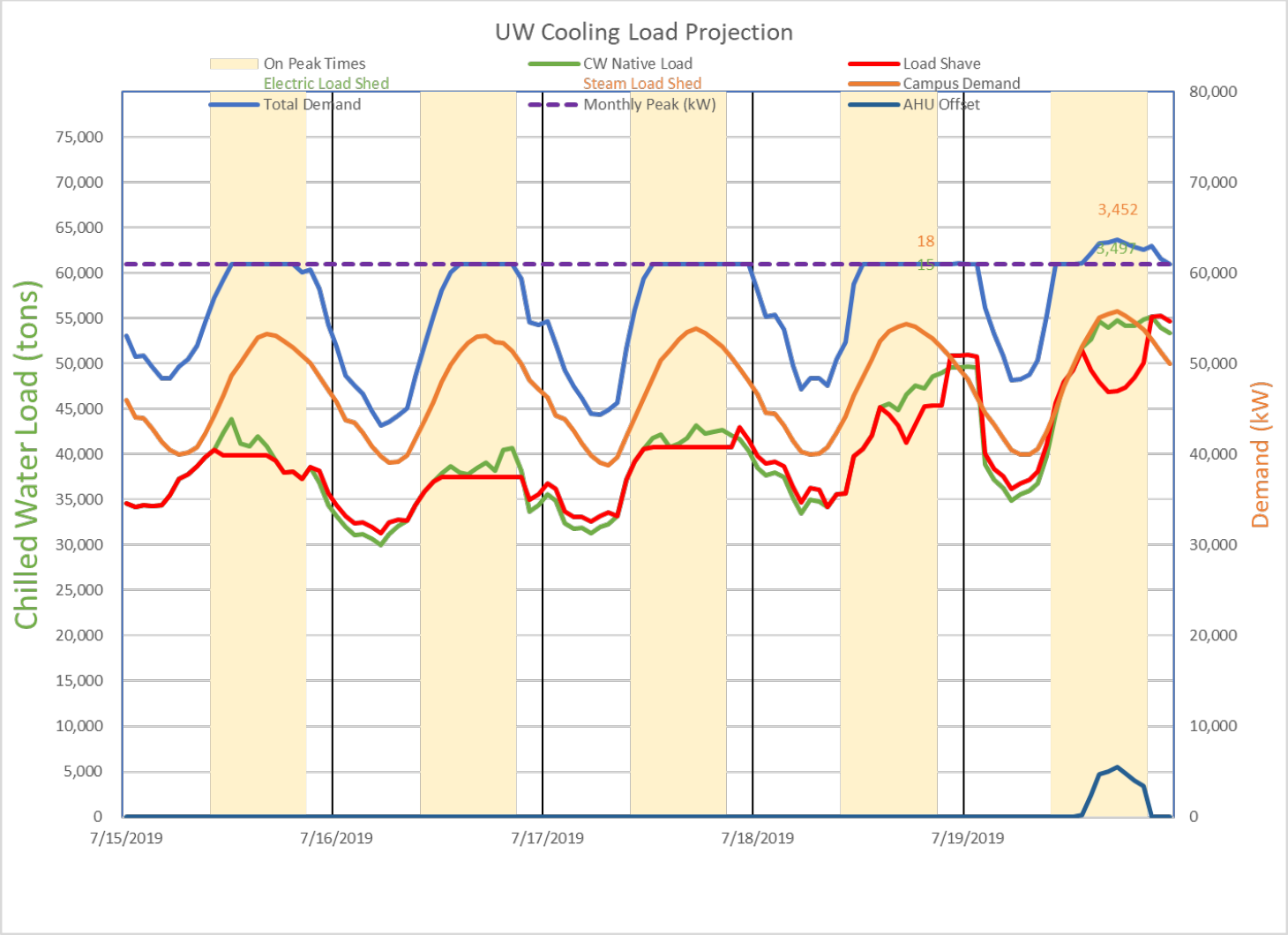
Model System

- Demand Control Options
  - Steam Driven Chillers
  - Loop based TES-
    - 4,500,000 Gallons x 4 °F dT ~ 12,500 ton-hrs
  - Building TES (~5,500 tons)

Dispatch Model

	Date:	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12	8/12
	Hour:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
WCCF EX	**Available**	11,586	11,609	11,647	11,669	11,665	11,620	11,631	11,634	11,567	11,399	11,441	11,485	11,454	11,418	11,340	11,334	11,346	11,362	11,444	11,502	11,510	11,496	11,472	11,493
C-5	Yes	5,793	5,804	5,823	5,834	5,832	5,810	5,815	5,817	5,784	5,700	5,720	5,742	5,727	5,709	5,670	5,667	5,673	5,681	5,722	5,751	5,755	5,748	5,736	5,747
C-6	Yes	5,793	5,804	5,823	5,834	5,832	5,810	5,815	5,817	5,784	5,700	5,720	5,742	5,727	5,709	5,670	5,667	5,673	5,681	5,722	5,751	5,755	5,748	5,736	5,747
WCCF	**Available**	3,693	3,702	3,719	3,729	3,727	3,707	3,712	3,713	3,686	3,628	3,641	3,656	3,646	3,634	3,611	3,609	3,612	3,617	3,642	3,662	3,665	3,660	3,651	3,659
C-A	No																								
C-B	Yes	3,693	3,702	3,719	3,729	3,727	3,707	3,712	3,713	3,686	3,628	3,641	3,656	3,646	3,634	3,611	3,609	3,612	3,617	3,642	3,662	3,665	3,660	3,651	3,659
C-C	No																								
C-D	Yes																								
CSHP	**Available**	2,083	2,083	2,083	2,083	2,083	2,083	2,083	2,083	2,083	2,756	2,083	2,083	2,083	2,083	2,083	2,153	3,691	3,745	2,083	2,083	2,083	2,083	2,384	2,083
C-1	Yes	2,083	2,083	2,083	2,083	2,083	2,083	2,083	2,083	2,083	2,756	2,083	2,083	2,083	2,083	2,083	2,153	1,845	1,872	2,083	2,083	2,083	2,083	2,384	2,083
C-2	Yes																	1,845	1,872						
C-3	Yes																								
C-4	Yes																								
WSHP	**Available**	6,658	5,994	4,834	4,088	4,243	5,682	5,400	5,468	7,559	10,625	10,454	9,546	9,776	9,845	9,994	9,936	8,376	8,293	9,794	9,214	8,947	9,260	10,625	10,464
C-1	Yes	3,388	3,050	4,834	4,088	4,243	2,892	2,748	2,783	3,847	5,407	5,321	4,858	4,975	5,010	5,086	5,057	4,263	4,220	4,985	4,689	4,553	4,713	5,407	5,326
C-2	Yes																								
C-3	Yes																								
C-4	Yes	3,269	2,943				2,790	2,652	2,685	3,712	5,218	5,134	4,688	4,801	4,835	4,908	4,880	4,113	4,072	4,810	4,525	4,393	4,548	5,218	5,139

Set up plant dispatch strategies



Operator training

- Change the focus to different KPIs
- Get used to the models and tools
- Thermal Storage

http://ednaweb.fpm.wisc.edu/ednaview.aspx?File=UWEDNA.APP:PLANT COMMON\STM_CW_OVERVIEW2.rtv

eDNA View Display

WALNUT ST HEATING PLANT

BOILER # 1	BOILER # 2	BOILER # 3
0.0 KPPH	0.0 KPPH	0.0 KPPH

CSC EAST 173.3 PSI
CSC WEST 166.7 PSI
AFCH 169.9 PSI

0 KPPH

175 PSI HEADER 175 PSI

WCCF

GEN

0 KPPH

171 PSI

CHARTER ST HEATING PLANT

BOILER # 5	BOILER # 6	BOILER # 7	BOILER # 8	BOILER # 9
0.0 KPPH	80.0 KPPH	0.0 KPPH	80.6 KPPH	81.1 KPPH

600# Steam Flow
245 KPPH

3 PSI

STG Steam Flow
3 KPPH

PRV #1	PRV #2	PRV #3	PRV #5	STG BYPASS
0.0 %	0.0 %	50.0 %	20.7 %	0.0 %

GEN

-0.00 MW

132 KPPH

175 PSI

Outside Dry Bulb Temp	65 °F
Outside Wet Bulb Temp	60 °F
Outside Dew Point Temp	58 °F
Outside Humidity	79 % RH

MEM UNION	167.8 PSI
CHAZEN	167.2 PSI

Charter Daily Gas Burn	120 MCF
Walnut Daily Gas Burn	0 MCF
Plants Steam Production	244 KPPH
Plants 175# Steam Export	130 KPPH
CSHP 13.5# Steam Export	-25 KPPH

Charter St Heating Plant

Chiller 1: 55.3 °F → 58.0 °F; 0GPM; 0.0 PPH/ton; 0 /4000 tons

Chiller 2: 48.2 °F → 48.2 °F; 0GPM; 8.5 PPH/ton; 0 /4000 tons

Chiller 3 On: 48.2 °F → 39.6 °F; 14337GPM; 7.0 PPH/ton; 5144 /8000 tons

Chiller 4: 54.9 °F → 54.9 °F; 122GPM; 0.0 PPH/ton; 0 /8000 tons

Plant DP SP 15.0 psid
Plant DP 15.0 psid
SEC FLOW 17103 GPM

RTN 51.6 °F; SPLY 42.0 °F

Walnut St Heating Plant

Chiller 1: 80.8 °F → 82.0 °F; 1 GPM; 0 /8000 tons

Chiller 2: 63.8 °F → 63.7 °F; 0 GPM; 0 /3500 tons

Chiller 3: 76.6 °F → 76.2 °F; 0 GPM; 0 /5500 tons

Chiller 4: 80.3 °F → 77.0 °F; 0 GPM; 0 /5500 tons

Plant DP SP 0.0 PSID
Plant DP 19.4 PSID

RTN 50.9 °F; SPLY 41.8 °F

WCCF

RTN 51.3 °F; SPLY 40.3 °F

Plant DP	19.1 psid
BYP FLOW	0.0 GPM
PRIM FLOW	17961 GPM
SEC FLOW	21445 GPM
TWR-TEMP	70 °F

Chiller 5: Comp A On, Comp B On; 51.8 °F → 39.7 °F; 9065 GPM; 0.539 kW/ton; 4565tons

Chiller 6: Comp A On, Comp B On; 51.6 °F → 39.7 °F; 8919 GPM; 0.556 kW/ton; 4422tons

Chiller A: 73.0 °F → 74.0 °F; 129 GPM; 0.000 kW/ton; 1tons

Chiller B On: 49.0 °F → 40.0 °F; 9028 GPM; 0.515 kW/ton; 3637 tons

Chiller C On: 50.0 °F → 39.0 °F; 9022 GPM; 0.470 kW/ton; 3821tons

Chiller D On: 50.0 °F → 39.0 °F; 9053 GPM; 0.525 kW/ton; 4084 tons

Plant DP	19.7 psid
PRIM FLOW	27418 GPM
SEC FLOW	23965 GPM
TWR-TEMP	69 °F

RTN 51.0 °F; SPLY 40.2 °F

EAST CAMPUS

10.5 PSI

54.1 °F	11.2 PSI	40.3 °F	RTN P2 MEM LIB/UNION SPLY
57.2 °F	13.1 PSI	40.9 °F	RTN EDUCATION SPLY
50.3 °F		40.0 °F	RTN CHAZEN SPLY

WEST CAMPUS

53.5 °F	17.8 PSI	40.5 °F	RTN AFCH SPLY
51.3 °F P1		40.5 °F	
52.1 °F	16.9 PSI	40.5 °F	RTN CSC SPLY
50.2 °F	16.8 PSI	40.2 °F	RTN WAISMAN SPLY

CSHP CHW MAKE UP	0 Gal
WSHP CHW MAKE UP	0 Gal
WCCF A-D CHW MAKE UP	0 Gal
WCCF 5-6 CHW MAKE UP	607 Gal
TOTAL CHW MAKE UP	597 Gal

CSHP	5034 tons
WSHP	0 tons
WCCF	11647 tons
WCCF - EXP	9009 tons
TOTAL CAMPUS	25690 tons
ESTIMATED	23684 tons

WCCF ELEC DEMAND	14320 kW
CAMPUS ELEC DEMAND	52320 kW
TOTAL ELEC DEMAND	52320 kW
PEAK ELEC DEMAND	62420 kW

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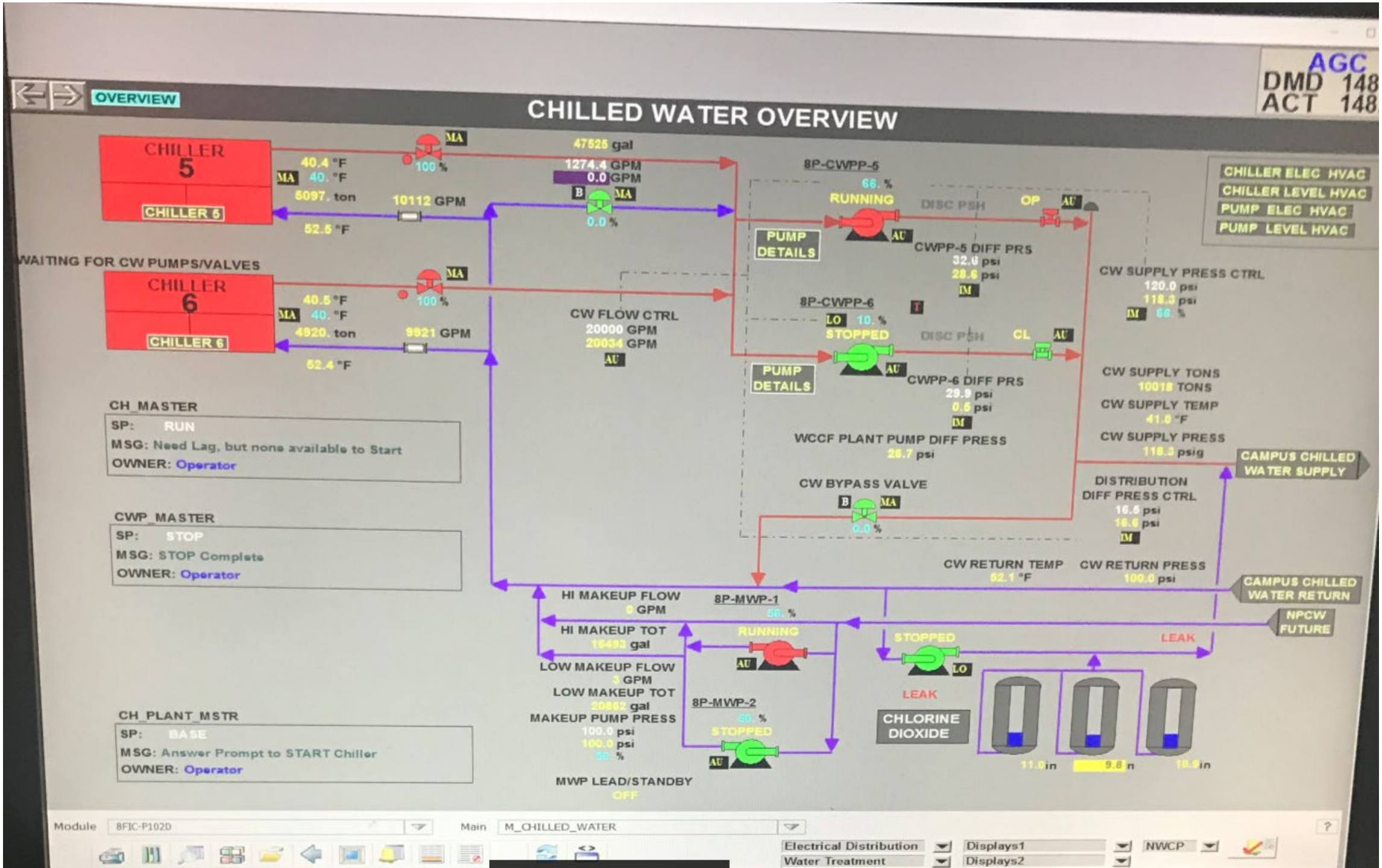
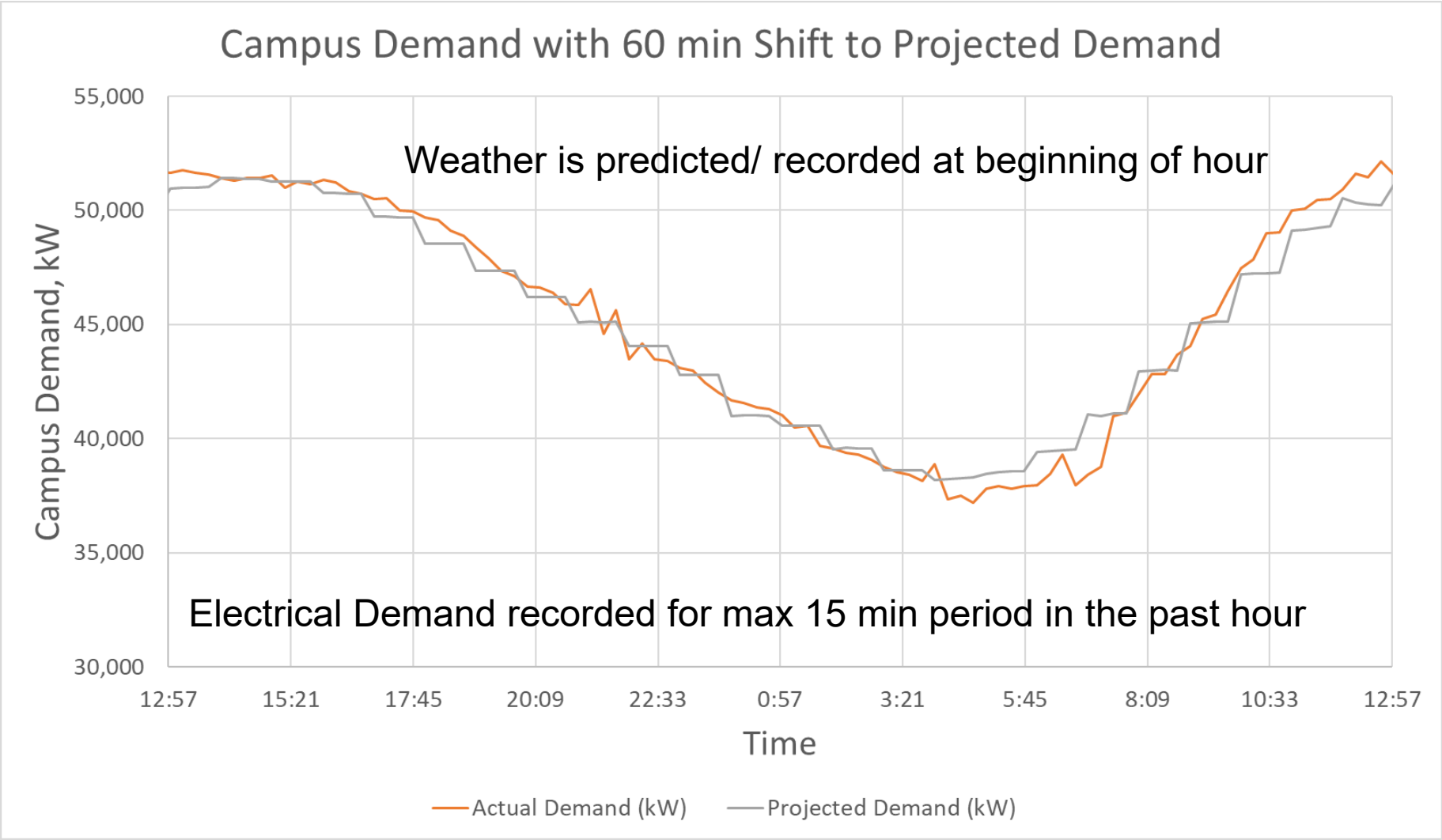
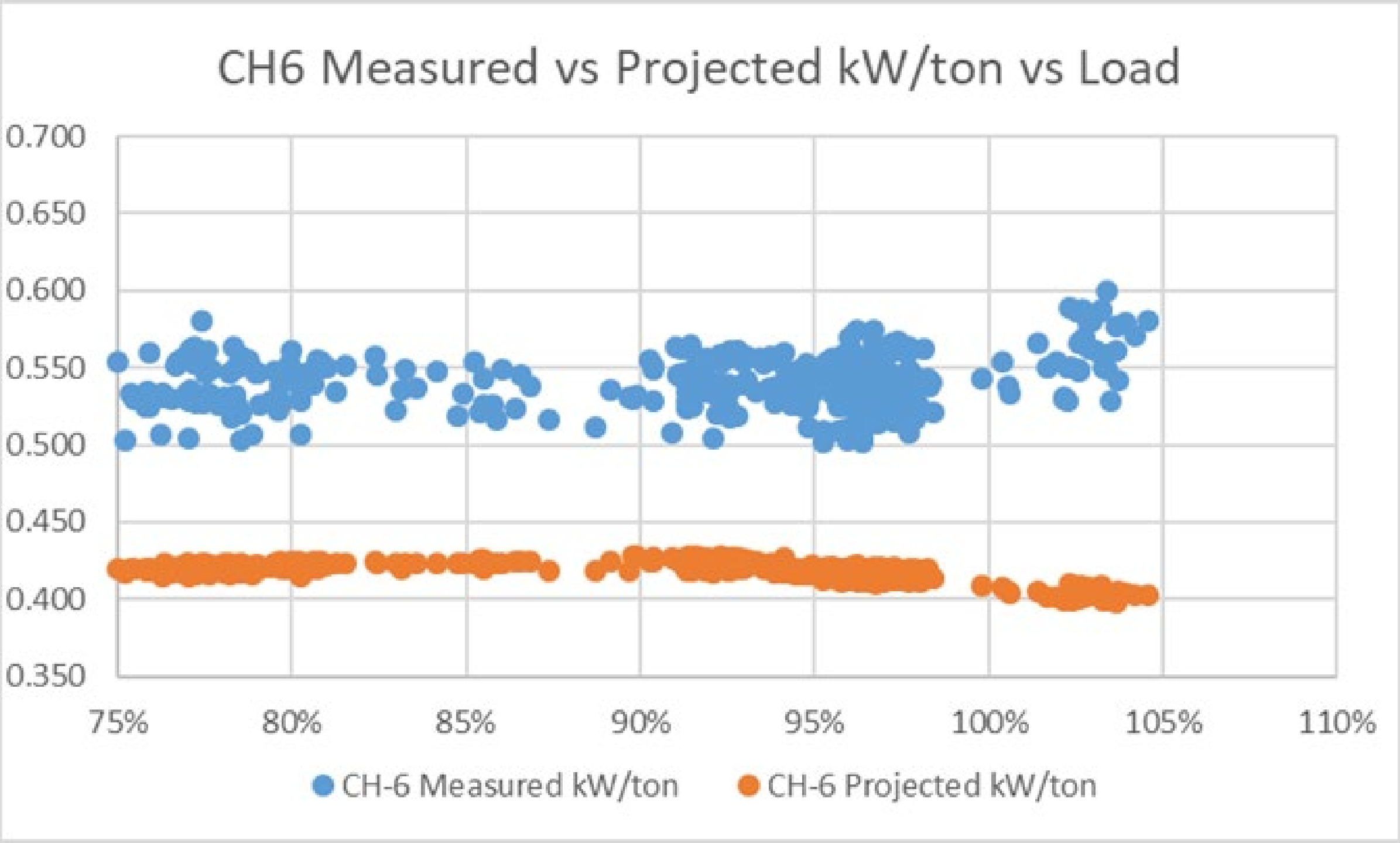
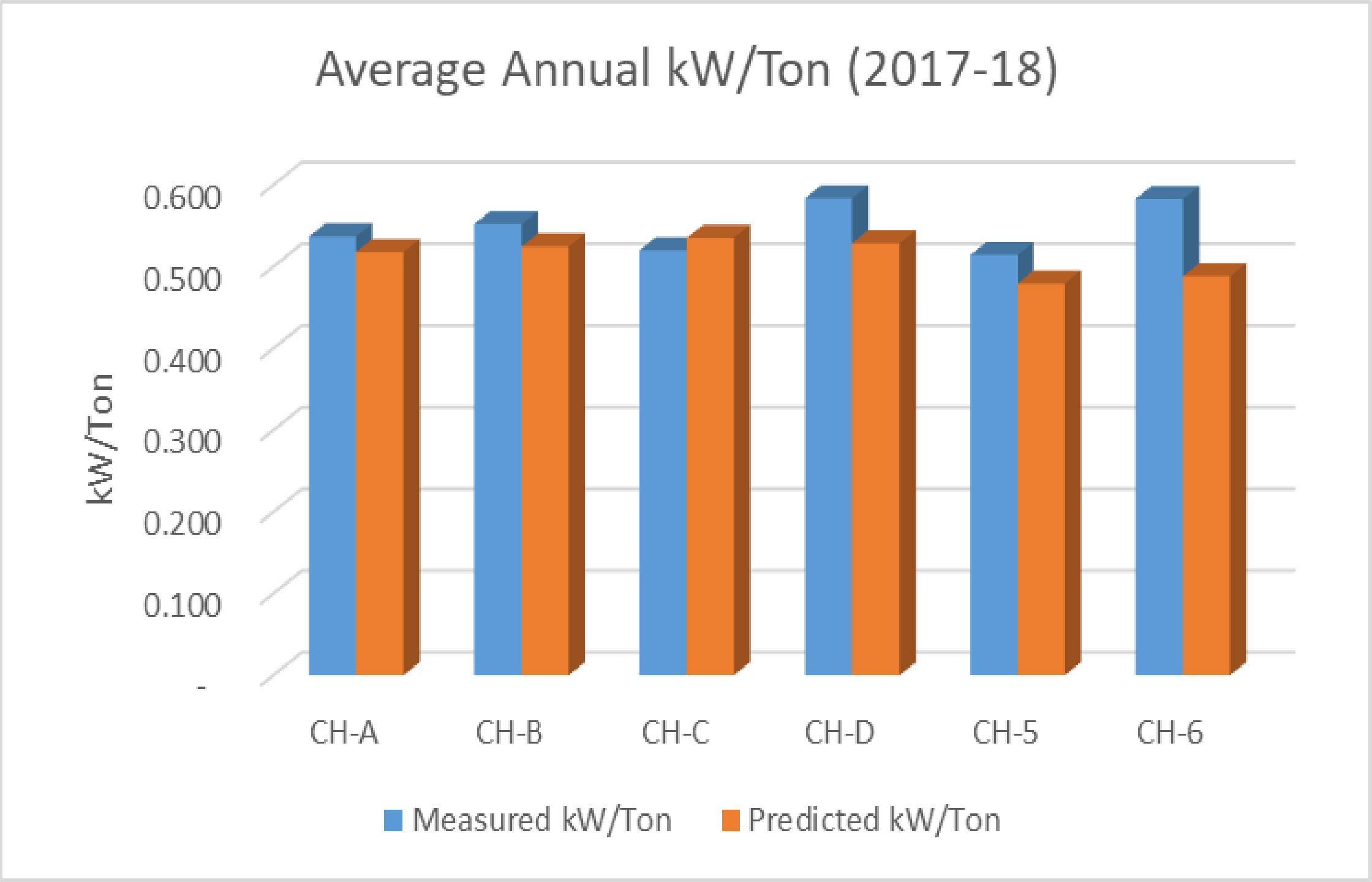
9/13/2019


OVERVIEW
CHILLED WATER OVERVIEW
AGC
DMD 148
ACT 148
CHILLER 5
CHILLER 5
40.4 °F
40. °F
5097. ton
52.5 °F
100 %
10112 GPM
47525 gal
1274.4 GPM
0.0 GPM
0.0 %
WAITING FOR CW PUMPS/VALVES
CHILLER 6
CHILLER 6
40.5 °F
40. °F
4920. ton
52.4 °F
100 %
9921 GPM
CW FLOW CTRL
20000 GPM
20034 GPM
8P-CWPP-5
66. %
RUNNING
DISC PSH
OP
PUMP DETAILS
CWPP-5 DIFF PRS
32.0 psi
28.6 psi
8P-CWPP-6
10. %
STOPPED
DISC PSH
CL
PUMP DETAILS
CWPP-6 DIFF PRS
29.9 psi
0.6 psi
WCCF PLANT PUMP DIFF PRESS
26.7 psi
CW BYPASS VALVE
0.0 %
CHILLER ELEC HVAC
CHILLER LEVEL HVAC
PUMP ELEC HVAC
PUMP LEVEL HVAC
CW SUPPLY PRESS CTRL
120.0 psi
118.3 psi
66 %
CW SUPPLY TONS
10018 TONS
CW SUPPLY TEMP
41.0 °F
CW SUPPLY PRESS
118.3 psig
CAMPUS CHILLED WATER SUPPLY
DISTRIBUTION DIFF PRESS CTRL
16.6 psi
16.6 psi
CW RETURN TEMP
52.1 °F
CW RETURN PRESS
100.0 psi
CAMPUS CHILLED WATER RETURN
NPCW FUTURE
CH_MASTER
SP: RUN
MSG: Need Lag, but none available to Start
OWNER: Operator
CWP_MASTER
SP: STOP
MSG: STOP Complete
OWNER: Operator
CH_PLANT_MSTR
SP: BASE
MSG: Answer Prompt to START Chiller
OWNER: Operator
HI MAKEUP FLOW
0 GPM
HI MAKEUP TOT
15493 gal
LOW MAKEUP FLOW
3 GPM
LOW MAKEUP TOT
20862 gal
MAKEUP PUMP PRESS
100.0 psi
100.0 psi
50. %
MWP LEAD/STANDBY
OFF
8P-MWP-1
50. %
RUNNING
8P-MWP-2
50. %
STOPPED
STOPPED
LEAK
LEAK
CHLORINE DIOXIDE
11.0 in
9.8 in
10.9 in
Module
8FIC-P102D
Main
M_CHILLED_WATER
Electrical Distribution
Water Treatment
Displays1
Displays2
NWCP

Adjusting the model




CH6 Measured vs Projected kW/ton vs Load
0.700
0.650
0.600
0.550
0.500
0.450
0.400
0.350
75%
80%
85%
90%
95%
100%
105%
110%
CH-6 Measured kW/ton
CH-6 Projected kW/ton


Average Annual kW/Ton (2017-18)
kW/Ton
0.600
0.500
0.400
0.300
0.200
0.100
-
CH-A
CH-B
CH-C
CH-D
CH-5
CH-6
Measured kW/Ton
Predicted kW/Ton

Projected Savings

	2018 Historical	Optimized Plant Load Sharing	% Change
Demand Costs			
Customer Maximum Demand	$450,715	$541,996	20%
Maximum On-Peak Demand	$655,378	$732,424	12%
WCCF Demand Adder	$292,842	$0	-100%
Energy Costs			
On Peak Energy	$146,853	$131,357	-11%
On Peak Energy	$158,589	$115,703	-27%
WCCF Energy	$1,791,861	$1,921,075	7%
Total Annual Electric Utility Bill	**$3,496,239**	**$3,442,555**	-2%
CW System Steam Utility Cost	**$1,351,239**	**$1,053,026**	-22%
	$4,847,478	$4,495,581	-7%
	Potential Savings:	$351,897	

Strategy	**Savings % on Baseline**	**Utility Cost Avoidance**
WCCFE Savings	14% Electric	$143,000
WCCFOM Savings	8% Electric	$144,000
CSHP Savings	8% on Steam 4% on Electric	$201,000
Demand Shifting Savings	9% On-Peak Demand	$270,000
Dispatch Strategy Savings	13% on Bills	$352,000
All Combined (with interactions)	**18% on Bills**	**$890,000**

Timeline

	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20	20
Model Utility Rates (Elec & CHW)																		
Confirm limitations and Curves																		
Implement Load projection Model																		
Test alternate plant configurations																		
Ongoing Training																		
Update Status Screens																		
Optimize WCCF																		
Optimize WCCE																		
Create Operating Curves for CSHP Chillers																		
Optimize CSHP																		
Implement Cost Tool																		
Monitor and Make Adjustments																		
Physical Plant Changes																		

THANK YOU!

Questions?

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