



NORTH GROUNDS PLANT EXPANSION

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An aerial photograph of a university campus. The campus is surrounded by dense green trees. In the top left, there are several large, multi-story buildings with red roofs, identified as the Darden School. To the right, a multi-lane highway runs diagonally across the frame. In the center, there is a large complex of buildings with dark roofs, identified as the Law School. To the right of the Law School, a smaller building is circled in white and labeled 'Plant'. At the bottom center, there is a large building complex with a flat roof, identified as JAG. Several parking lots are visible throughout the campus.

Darden

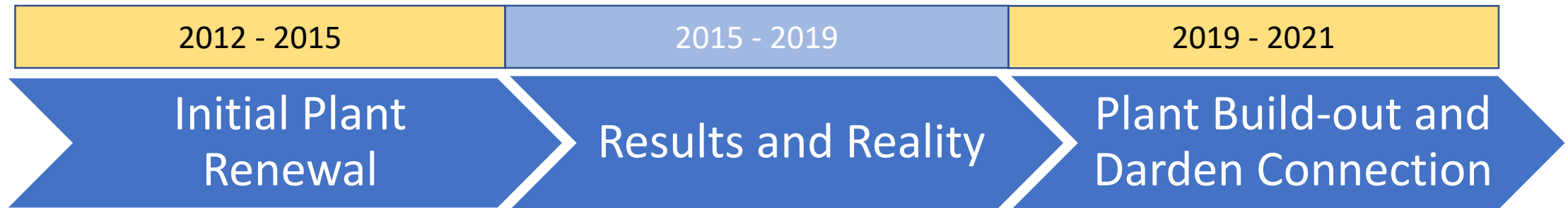
Law

Plant

JAG

Context and Timeline

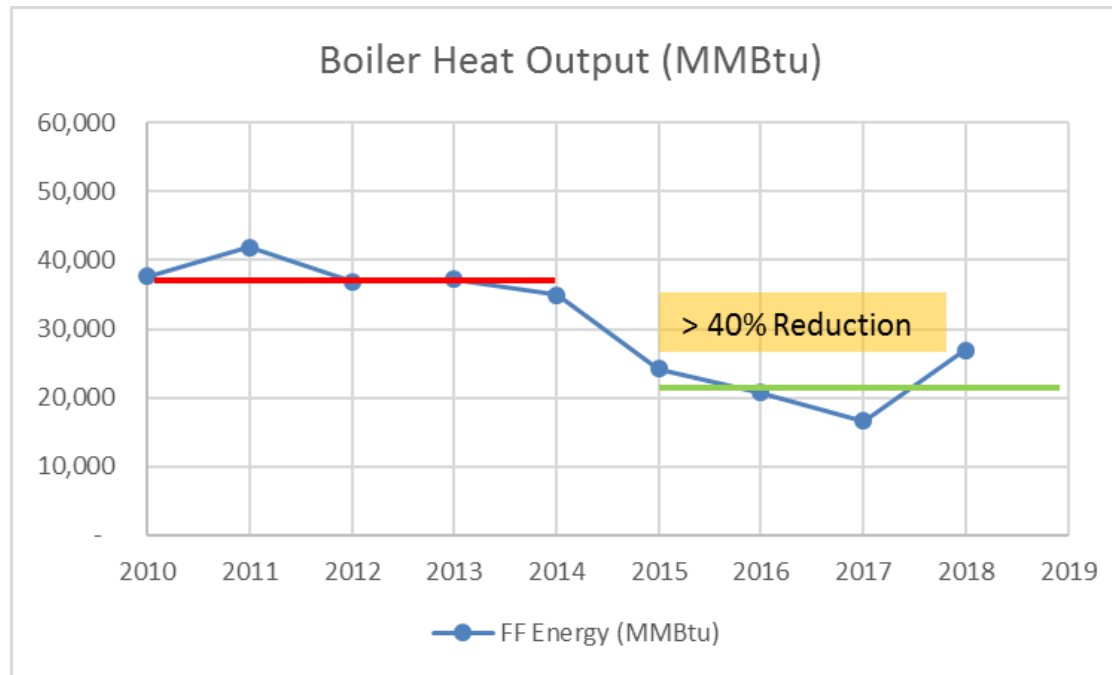
- 554K GSF of existing buildings (Law and JAG)
- 250F to 140F Hot Water
- Renew equipment in an existing plant
- Add heat recovery chillers
- 351K GSF of new buildings (Darden)
- Build out plant capacity and add new distribution
- Add boilers/chillers
- Replace heat recovery chillers



Results and Reality

- Success!

- Transitioned to LTHW
- Efficient Plant



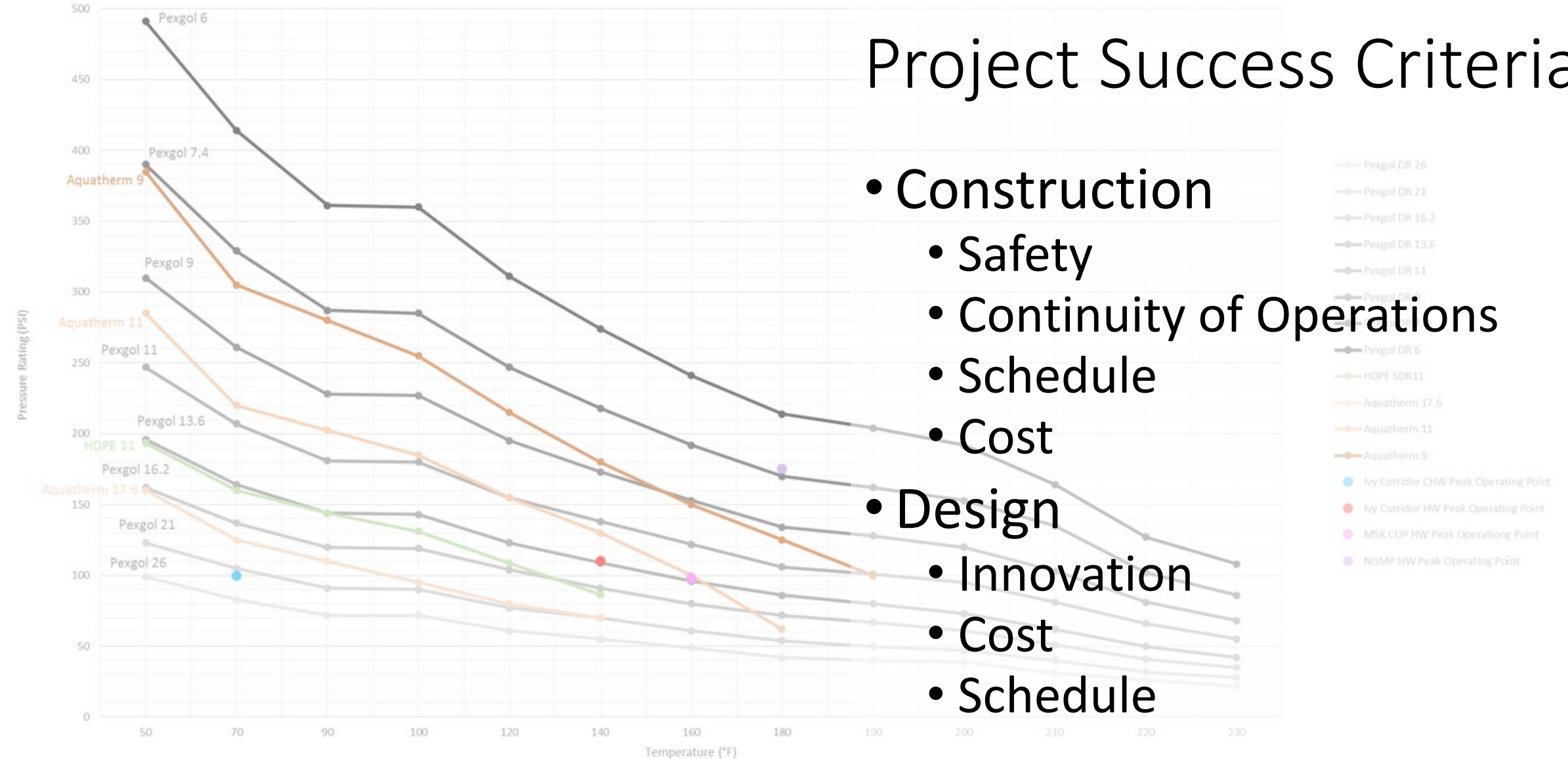
- Opportunity 😊

- HRC performance
- DHW issues



Project Success Criteria

- Construction
 - Safety
 - Continuity of Operations
 - Schedule
 - Cost
- Design
 - Innovation
 - Cost
 - Schedule

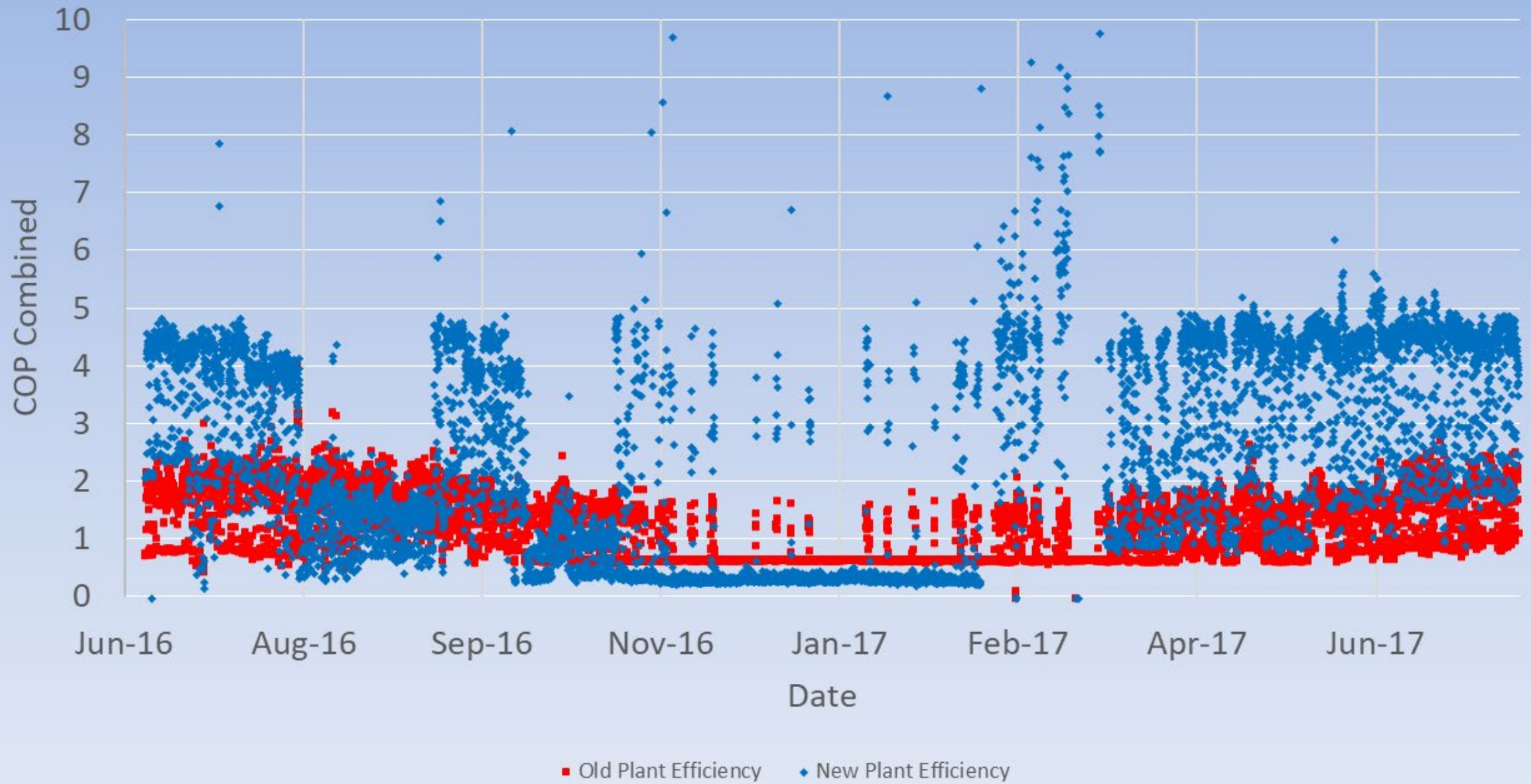




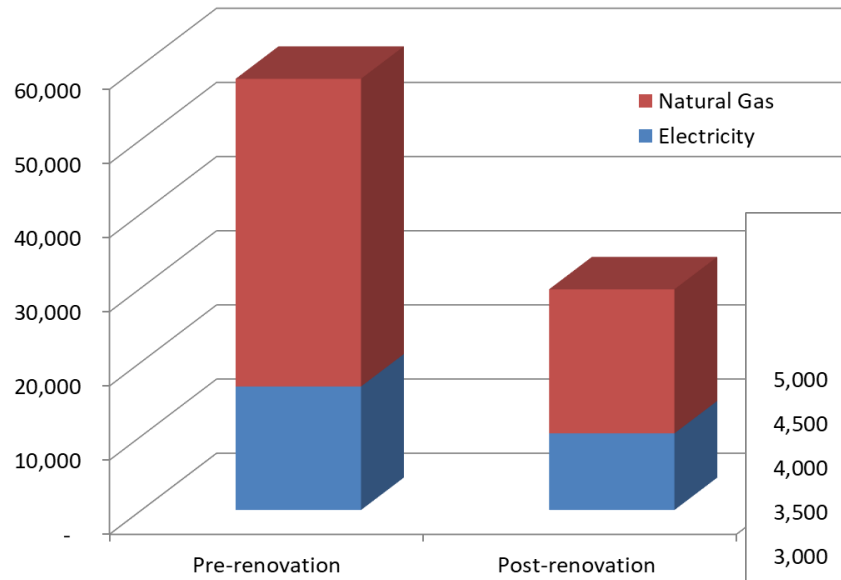
Innovations at NGMP

- Conversion of MTHW to LTHW with minimal building modifications
- Integrating Commercial and Industrial Equipment
- Interface of Open and Closed Systems
- Control for System Efficiency

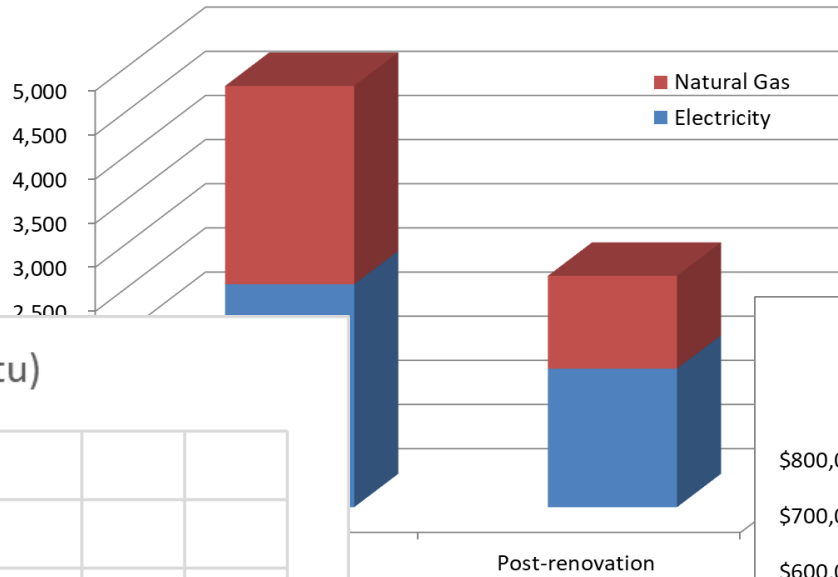
Combined Plant COP



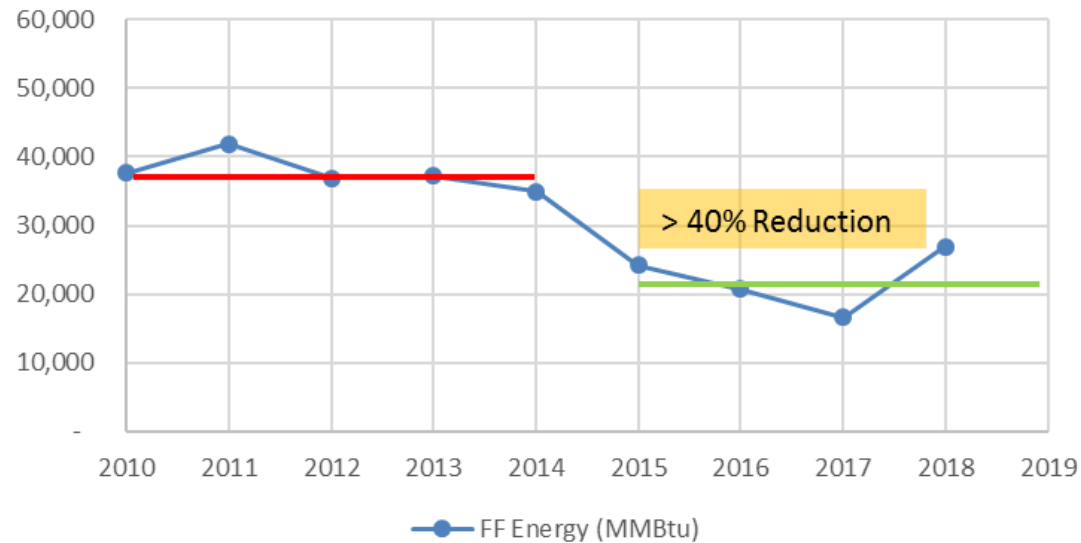
Energy Purchased (MMBTU)



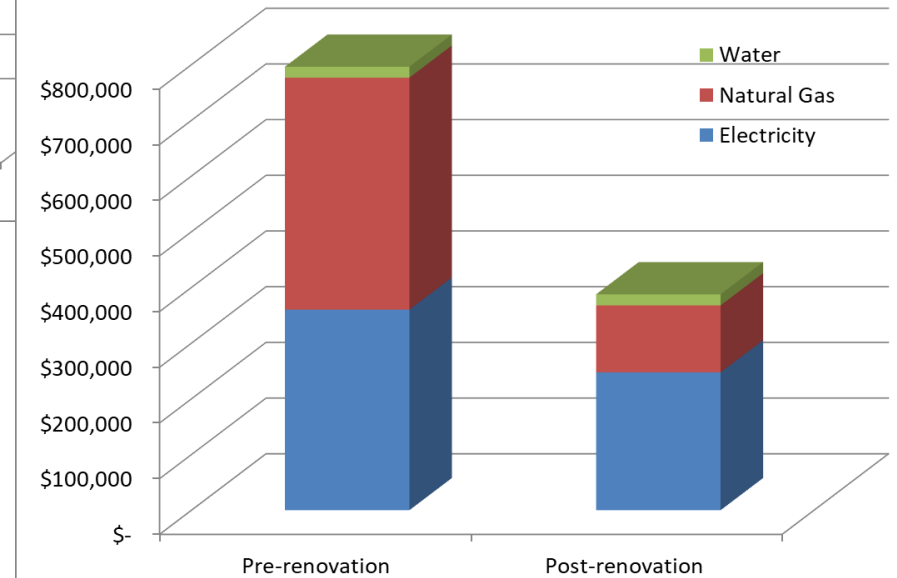
Total CO2 Emission (MTe)



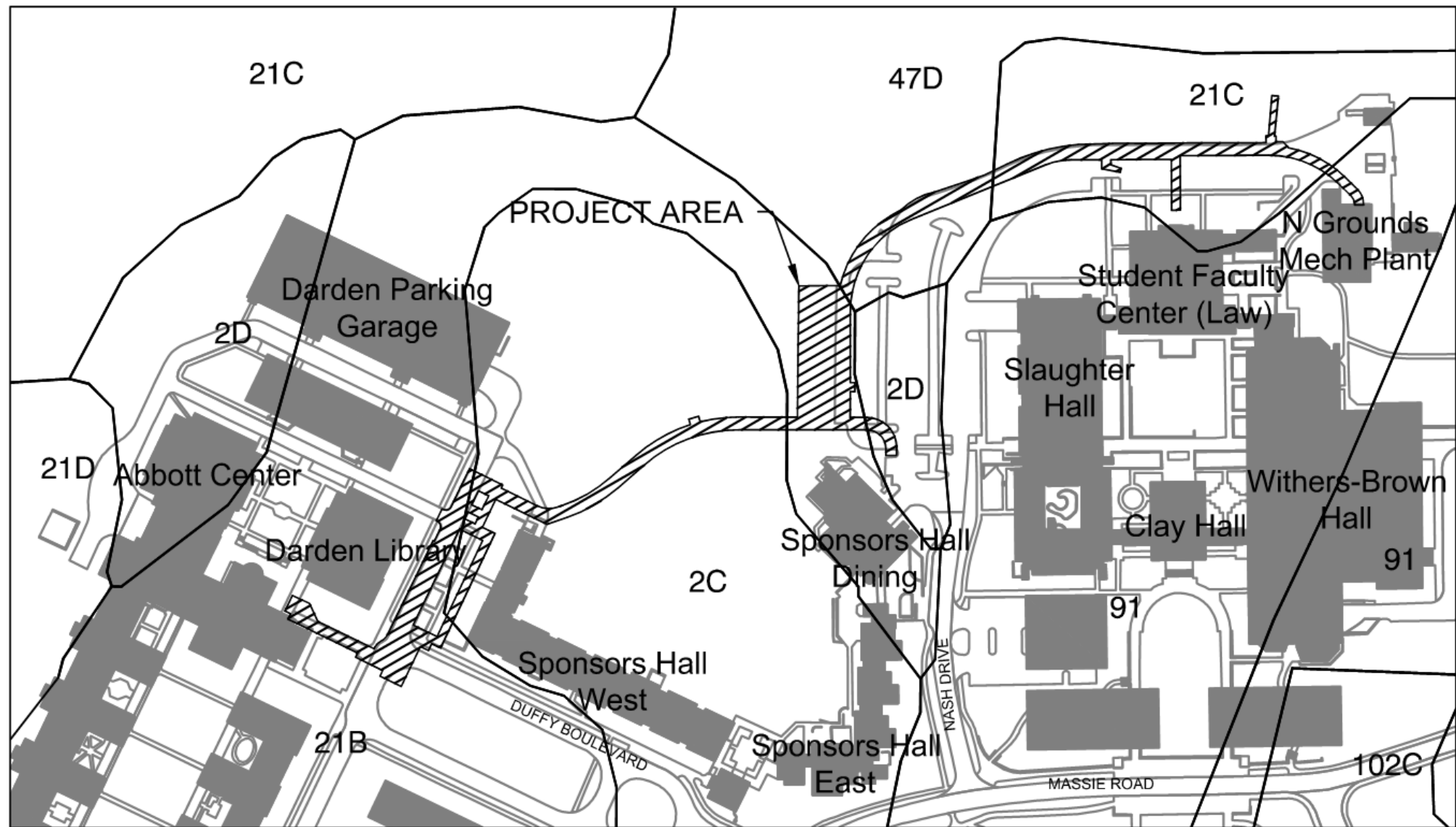
Boiler Heat Output (MMBtu)



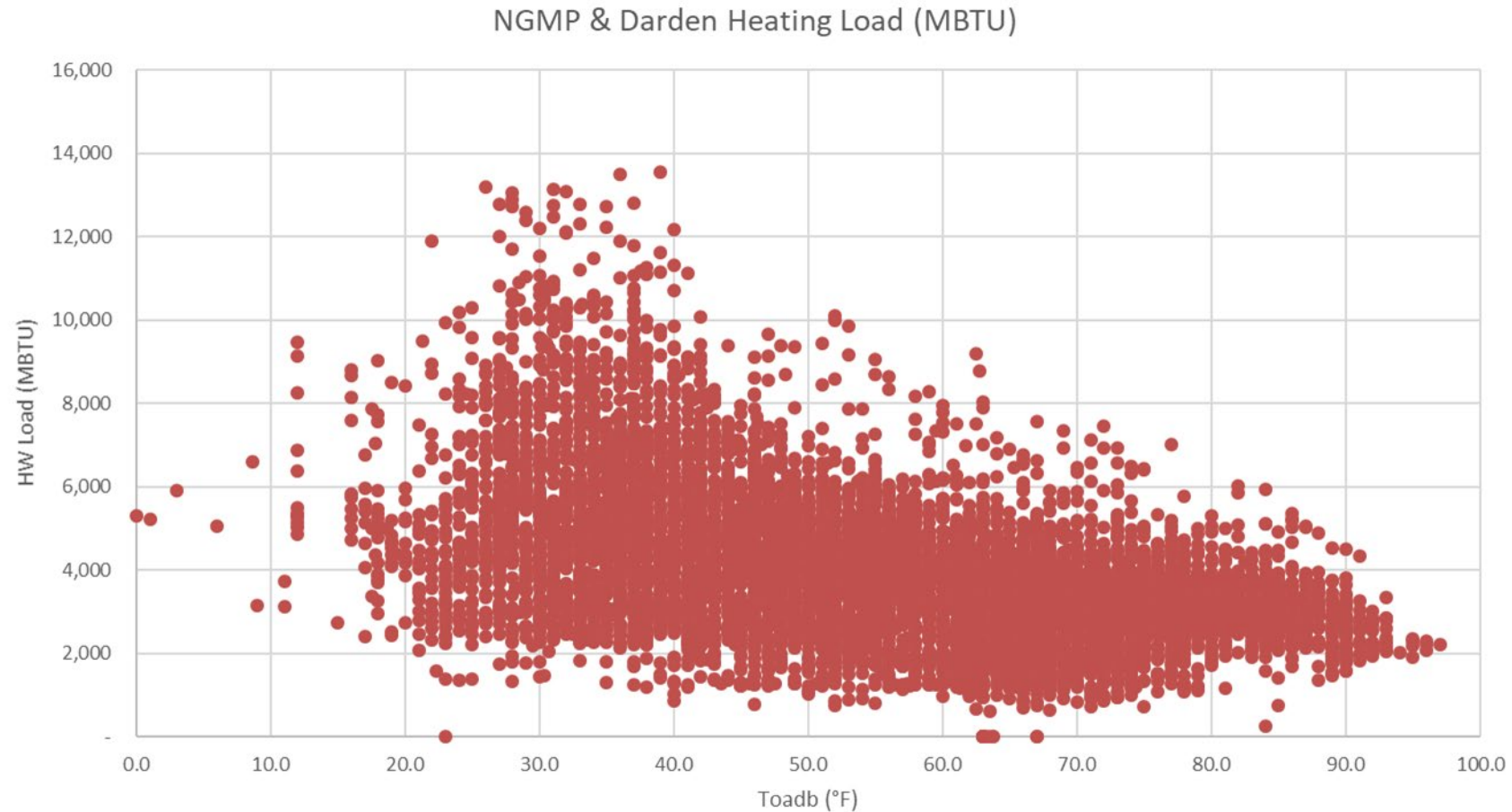
Energy and Water Cost



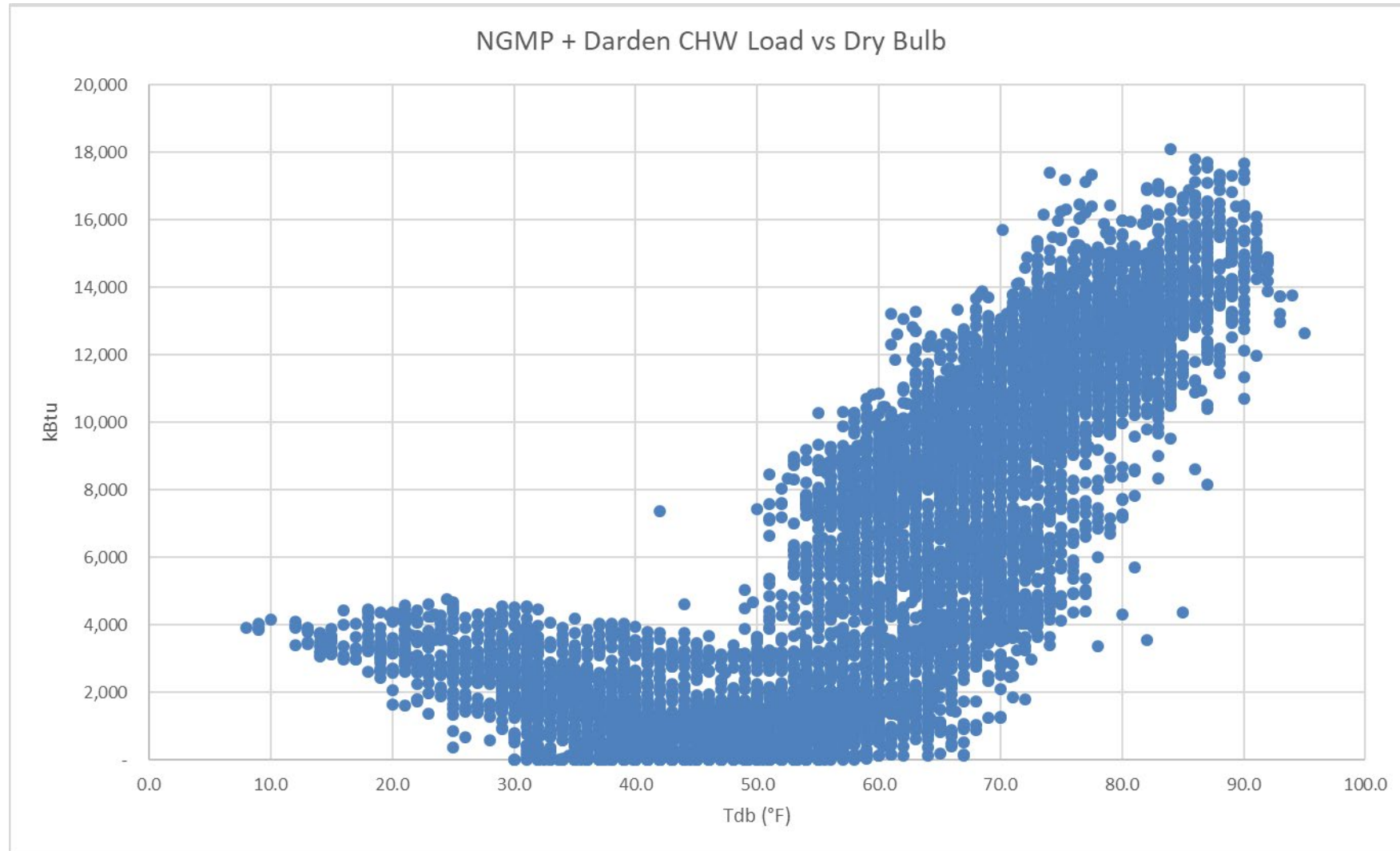




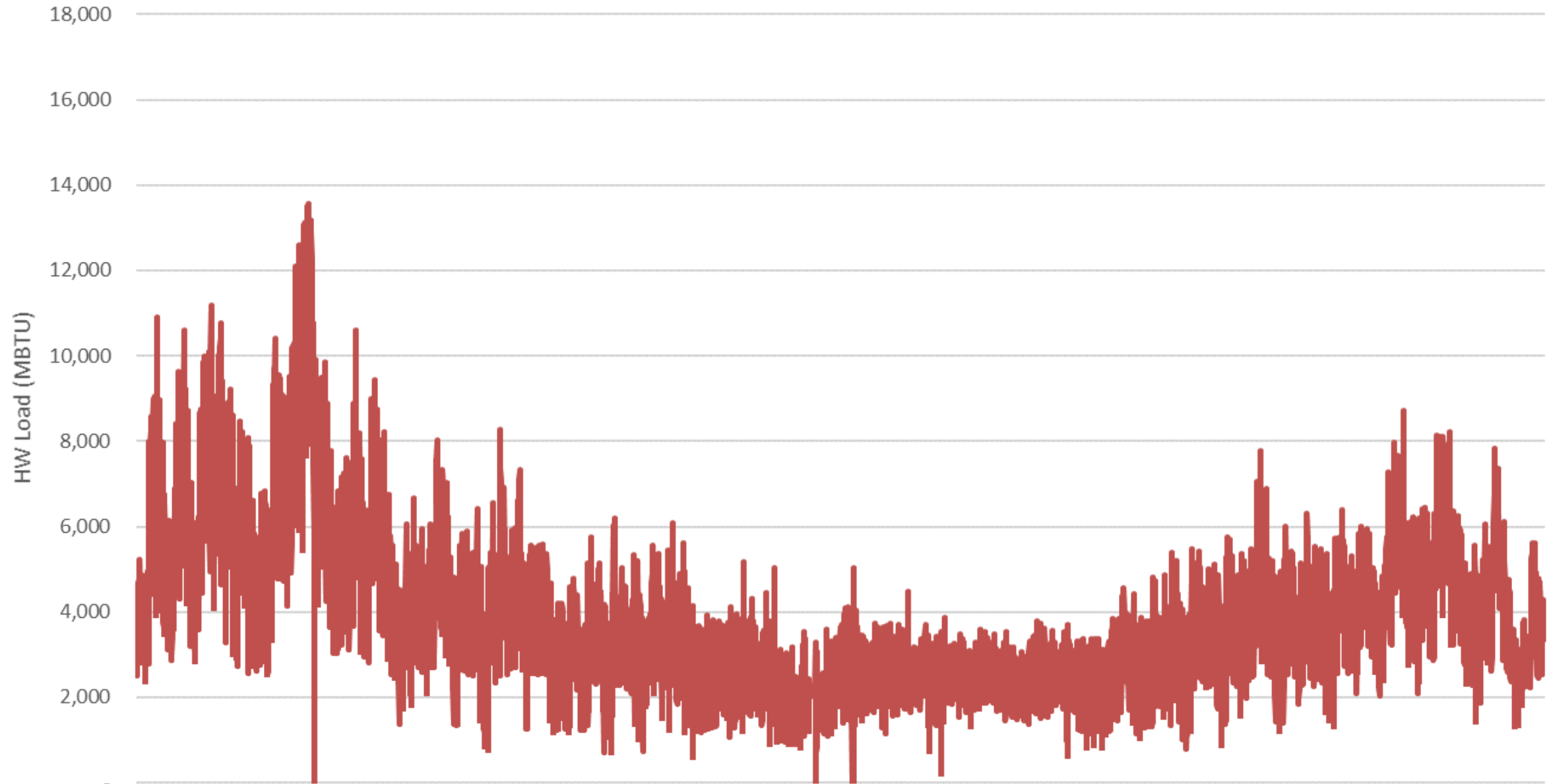
Load Comparison



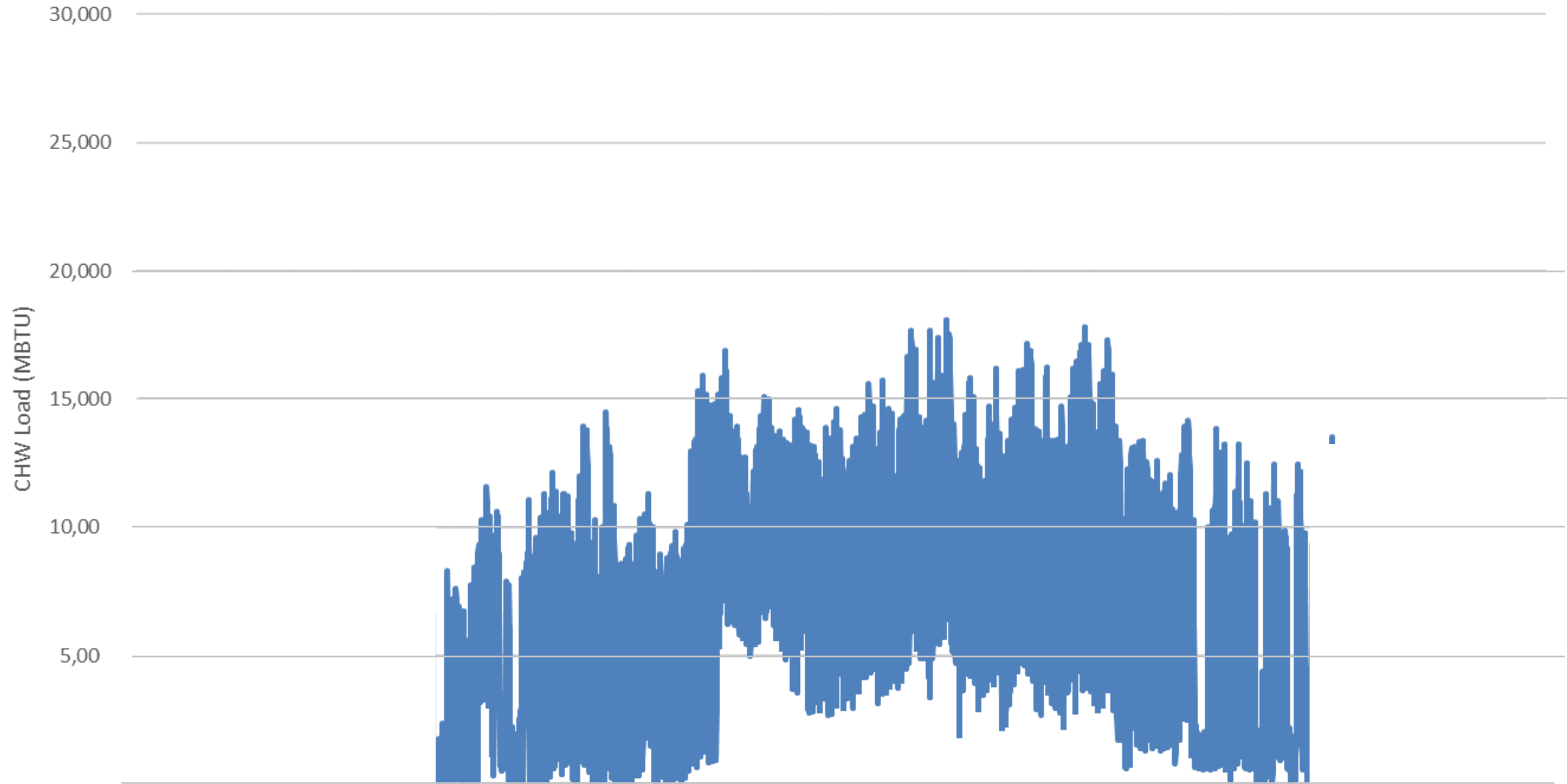
Load Comparison



2016-16 NG & Darden HW Load

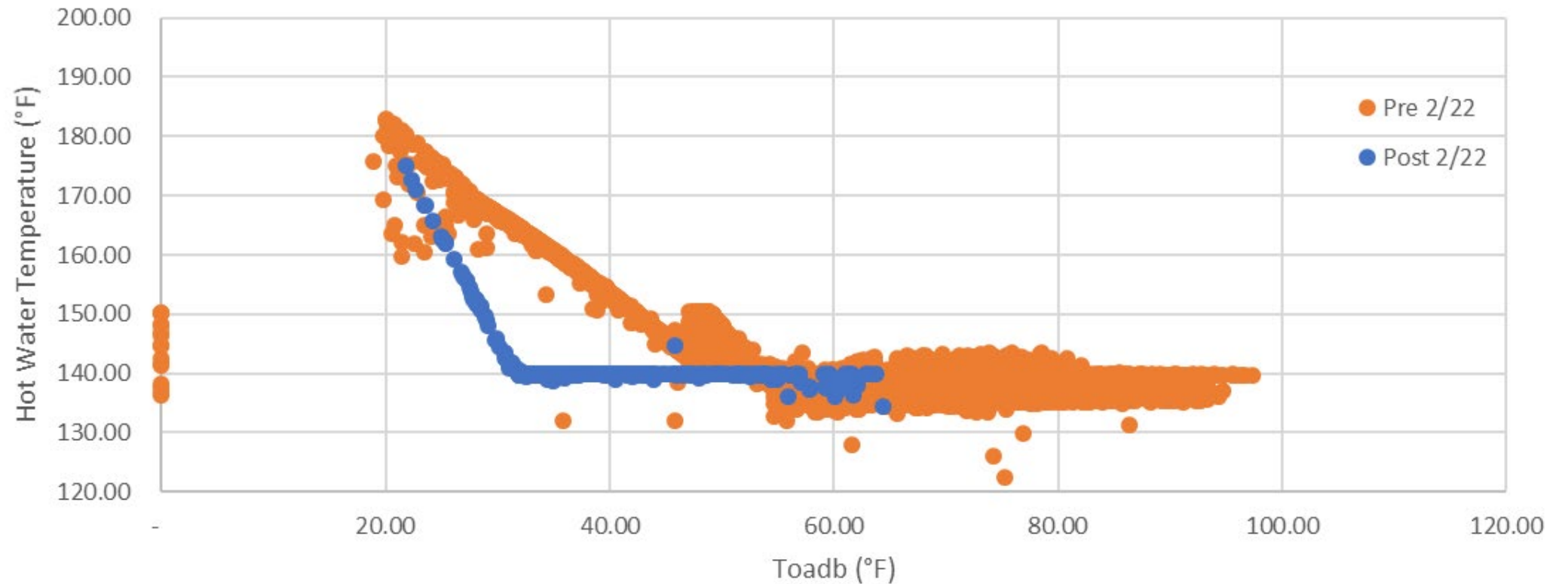


2016-16 NG & Darden CHW Load



Heating Hot Water Reset History

Heating Hot Water Reset Schedule



Engageable Load Ratio- Function of Building

- Engaged Load Ratio (ELR) =
$$\frac{\text{Engaged Thermal Load}}{\text{Total Thermal Load}}$$

$$\text{Heating Engaged Load Ratio} = \frac{\text{Engaged Heating Load}}{\text{Total Heating Load}}$$

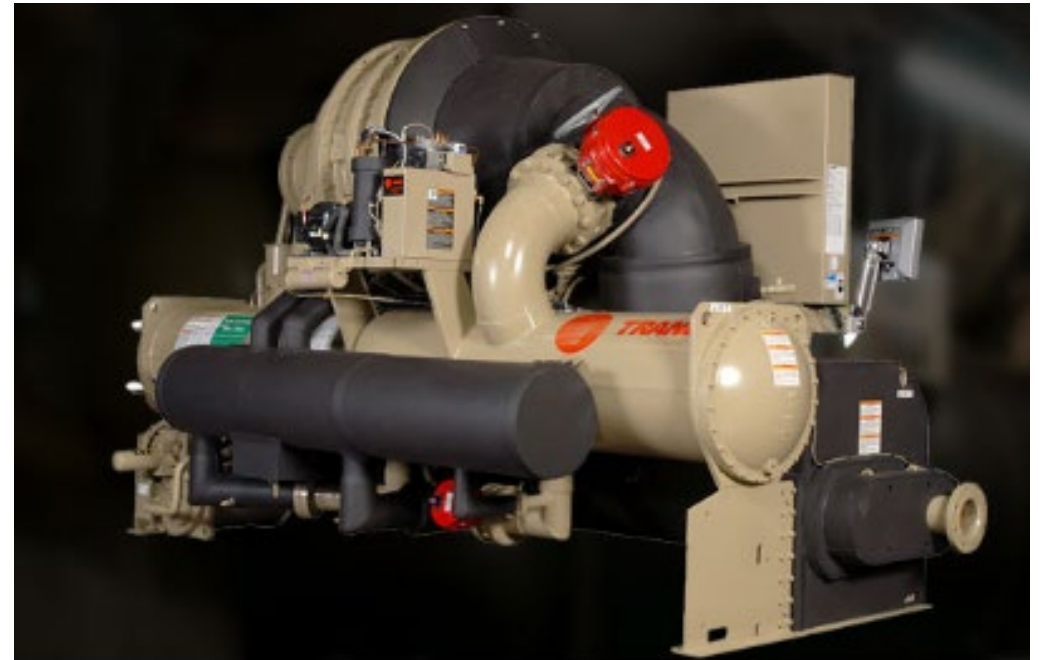
$$\text{Cooling Engaged Load Ratio} = \frac{\text{Engaged Cooling Load}}{\text{Total Cooling Load}}$$

Evaluation Tools

		Theoretical Maximum	
	Total Load (MBTU)	Engageable Load (MBTU)	Engageable Load Ratio (ELR)
NGMP Cooling	31,644,665	11,530,201	36%
NGMP Heating	26,484,106	11,541,731	44%
Darden Cooling	18,656,502	6,509,167	35%
Darden Heating	7,857,116	6,515,676	83%
Combined Cooling	50,301,167	20,446,235	41%
Combined Heating	34,341,223	20,466,681	60%

Centrifugal Chillers

- R1233zd:
 - Full Load: 0.5825 kW/ton
 - NPLV: 0.3777 kW/ton
- R514
 - Full Load: 0.5454 kW/ton
 - NPLV: 0.3597 kW/ton
- Free Cooling: 430 Tons at 40°F ECWT



Heat Recovery Chillers – Centrifugal

- Up to 170°F HW
- Turndown concerns
- Takes space of CH-3



Heat Recovery Chillers – Ammonia

- Up to 195°F HW
- 200T cooling at 175°F
- 368T cooling at 140°F
- 8' x 18'
- Long lead time
- >\$1million per unit



Heat Recovery Chillers – Screw

- R-134a
- Up to 149°F HW
- 300T Peak Cooling
- ~200T cooling at 149°F
- Smaller unit with max temp of 140°F
 - (4) 160T units



Heat Recovery Chillers – Scroll

- R-134a
- Up to 160°F HW
- 4 Units fit in space
 - 312 Tons at 160°F
 - 6,500 MBH at 160°F

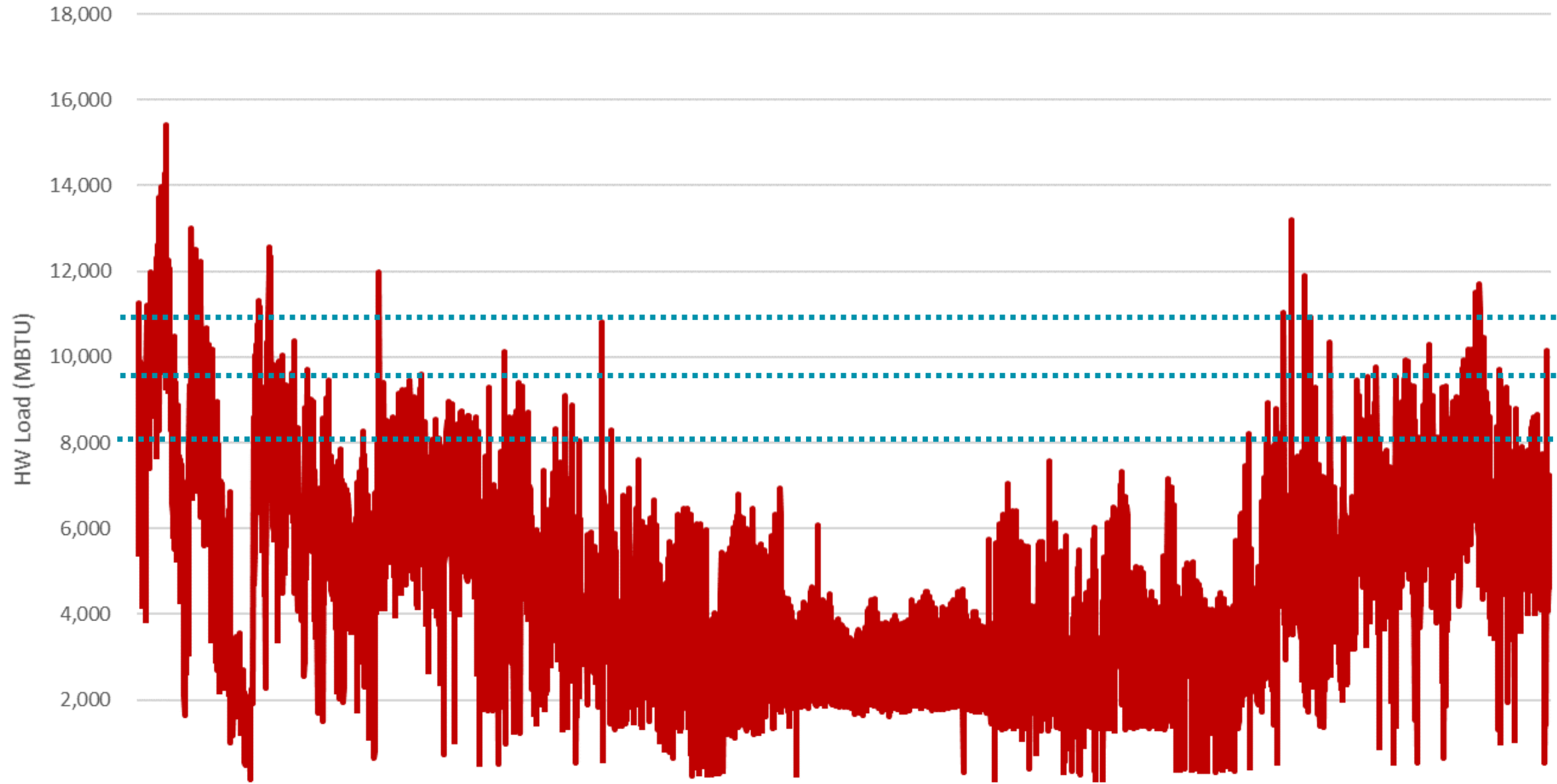


Heat Recovery Chillers – Modular Scrolls

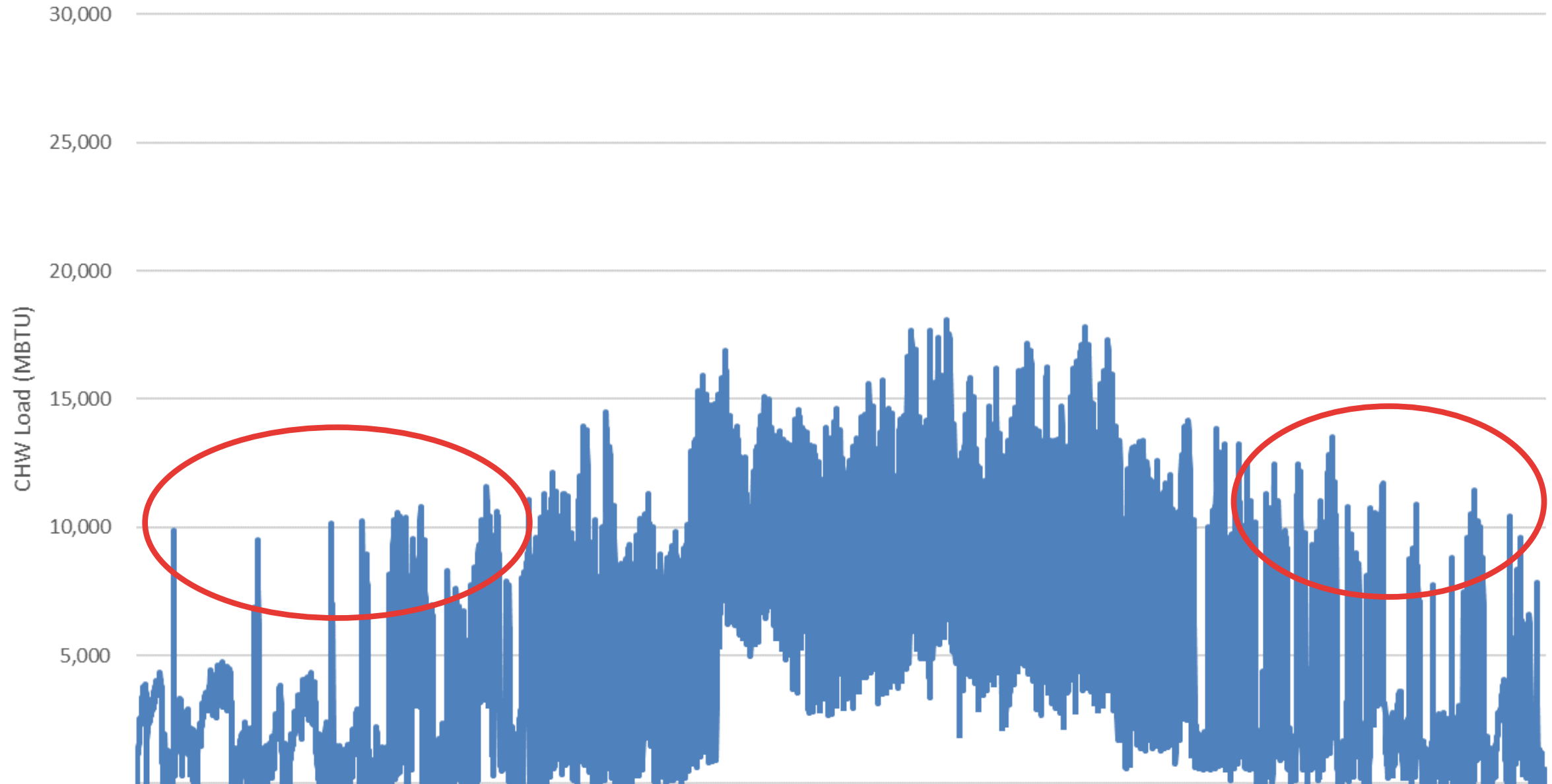
- R-134a
- Up to 165°F HW
- 12-20 units fit in space
 - 25 Tons/unit at 165°F
 - 510 MBH/unit at 165°F



2018 NG & Darden HW Load Profile



2016-16 NG & Darden CHW Load



Achievable Load Ratios

- Machine Capacity
- Machine Efficiency – (Condenser Ratio)
- Turndown Capabilities
- Temperature Limits
- Building Required Reset Schedules

Achievable Load Ratio- Function of Equipment

- Achievable Load Ratio (ALR) =
$$\frac{\text{Achievable Engaged Thermal Load}}{\text{Total Thermal Load}}$$

$$\text{Heating Achievable Load Ratio (ALRh)} = \frac{\text{Achievable Engaged Heating Load}}{\text{Total Heating Load}}$$

$$\text{Cooling Achievable Load Ratio (ALRc)} = \frac{\text{Achievable Engaged Cooling Load}}{\text{Total Cooling Load}}$$

Achievable Load Ratios

- Machine Capacity
- Machine Efficiency –
 - (Condenser Ratio)
- Turndown Capabilities
- Temperature Limits
- Reset Schedules

		Existing Thw's Reset and Scroll HRCH	
	Total Load (MBTU)	Achievable Load (MBTU)	Achievable Load Ratio (ALR)
NGMP Cooling	31,644,665	7,268,115	23%
NGMP Heating	26,484,106	10,175,361	38%
Darden Cooling	18,656,502	1,423,782	8%
Darden Heating	7,857,116	1,993,295	25%
Combined Cooling	50,301,167	10,868,930	22%
Combined Heating	34,341,223	15,216,502	44%

ELR Efficiency- How Equipment Performs in Bldg

- The ratio of Achievable Load Engagement to ELR - A Machine dependent measure of how effective the selected equipment will be in capturing the potential for thermal energy recovery for a given building.

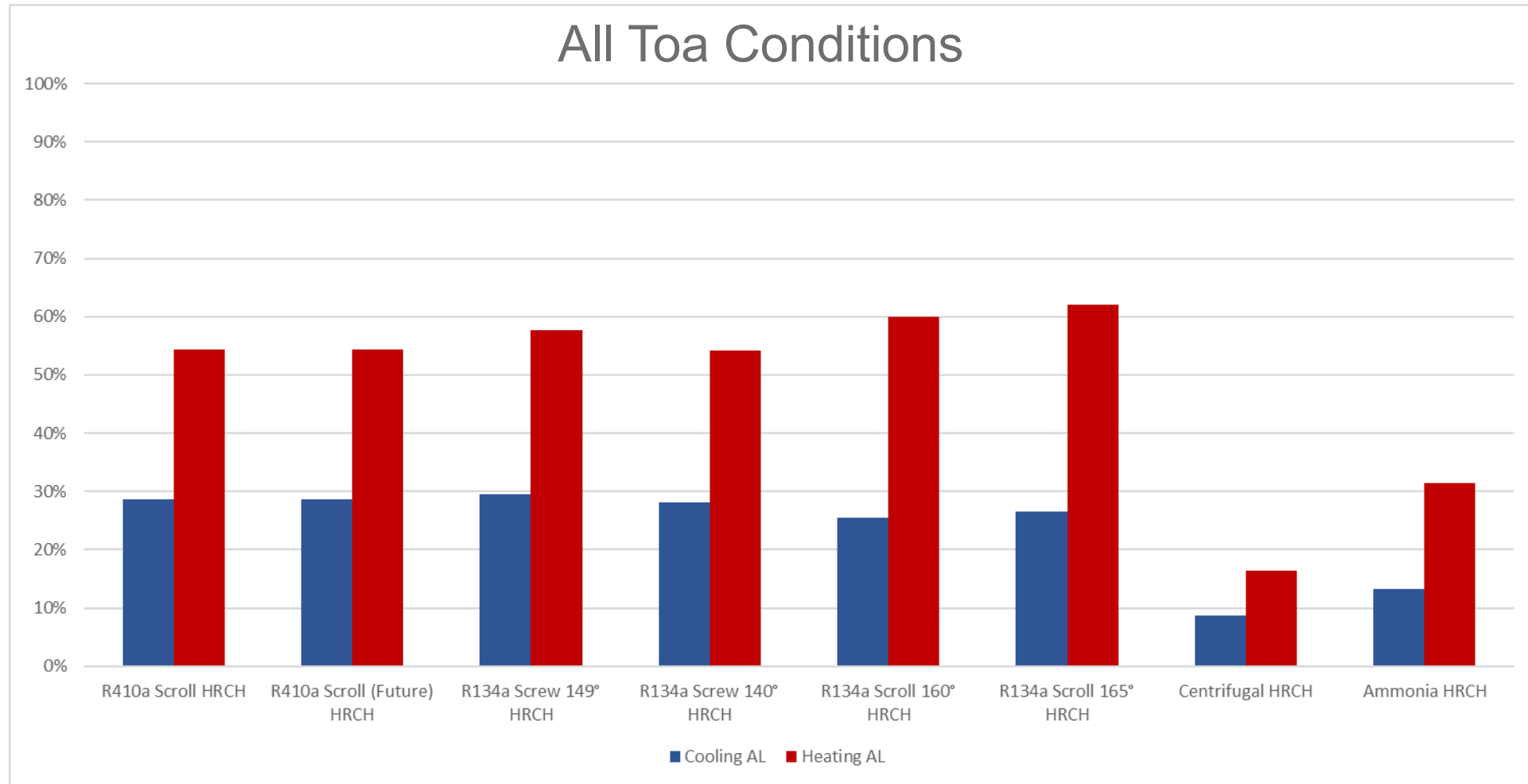
$$\eta_{\text{ELR}} = \text{ALR} / \text{ELR}$$

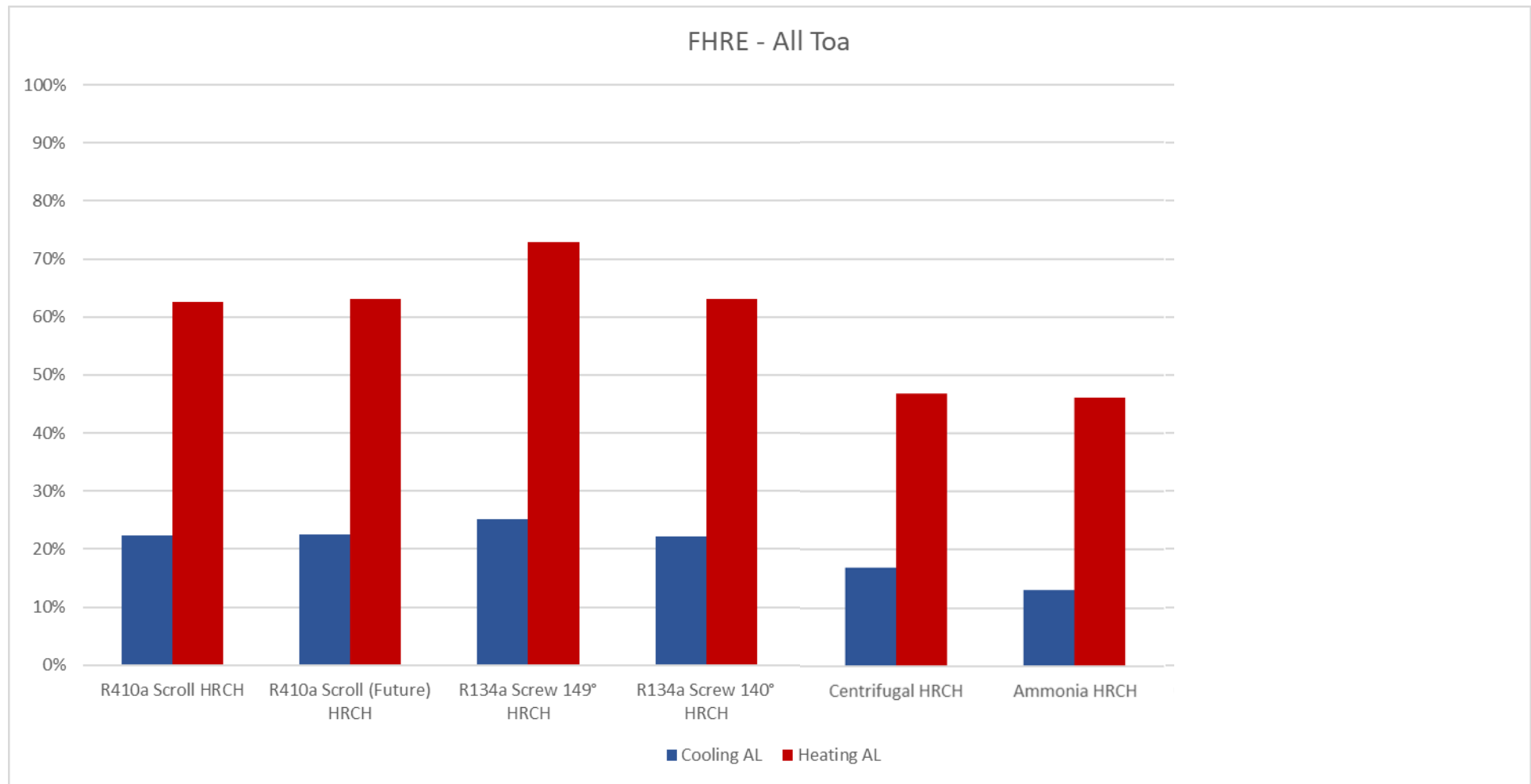


ELR Efficiency

		Existing Thw's Reset and Scroll HRCH		
	Total Load (MBTU)	Achievable Load (MBTU)	Achievable Load Ratio (ALR)	η_{ELR}
NGMP Cooling	31,644,665	7,268,115	23%	76%
NGMP Heating	26,484,106	10,175,361	38%	
Darden Cooling	18,656,502	1,423,782	8%	26%
Darden Heating	7,857,116	1,993,295	25%	
Combined Cooling	50,301,167	10,868,930	22%	64%
Combined Heating	34,341,223	15,216,502	44%	

Performance of Available Equipment Options





Fully Engaged Heat Recovery (FHRE)

Option	FHRE Savings (\$/Yr)	Energy Reduction (MMBtu/Yr)	EUI Reduction (kBtu/SF/Yr)	Gas Savings (%)	Carbon Reduction (MteCD)
Base Case FHRE	\$137,629	12,465	17.43	24.8%	648
Base + Exh	\$155,228	16,762	23.44	38.2%	999
Base + Exh + ReA	\$157,125	20,324	28.42	51.1%	1,345
Base + Exh + ReA + 3 HRCH	\$170,107	23,929	33.46	62.6%	1,647
Base + Exh + ReA + 4 HRCH	\$174,728	25,600	35.80	68.1%	1,793

Thank You

- Questions?

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