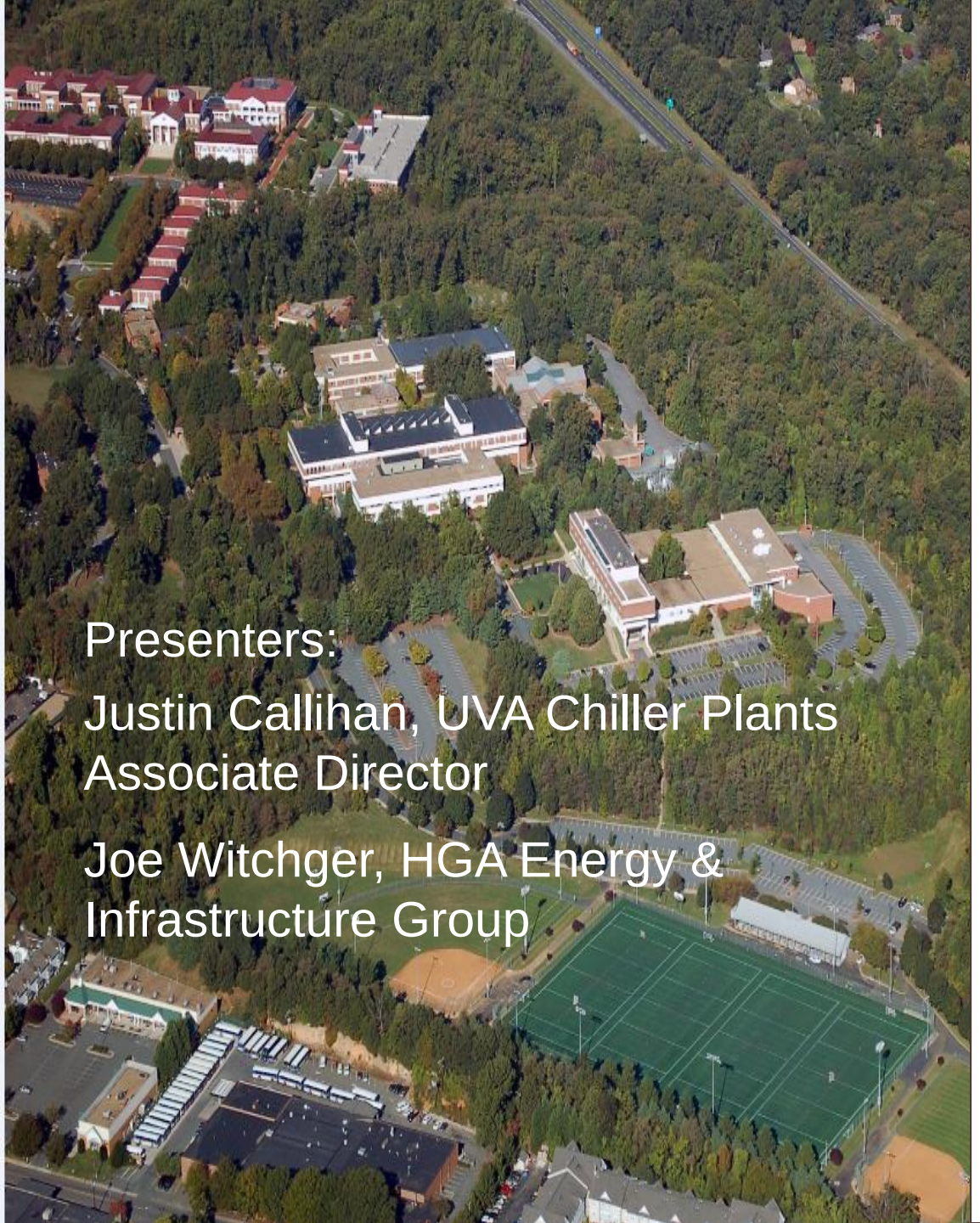

Presenters:

Justin Callihan, UVA Chiller Plants Associate Director

Joe Witchger, HGA Energy & Infrastructure Group

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North Grounds Boiler and Chiller Plant Replacement

HGA

- 558,200 SF Served
- 628,900 SF Potential Future Load
- 1,187,000 SF Total

Final Configuration- HR/Centrifugal Plant

- (2+1) 1000 Ton High Efficiency Centrifugal Chillers
  - Redundant Variable Primary CHW Pumping
- (4+3) 160 Ton HR Chillers- 140°F /42°F
- (3+1) 1025 Ton Cooling Towers
- (3+2) 6000 MBH High Efficiency Condensing Boilers
  - Redundant Primary/ Secondary HHW Pumping
- 2400 sq. ft. Added to house additional equipment
- CHWP @ 125 HP each (170 ft. to accommodate future)
- CDWPs @ 150 HP each

Summary of Projected Performance

System Option	Gas Use (MMBTU)	Purchased Electricity (kWh)	Total Site Input Energy, MMBTU	Total Source Input Energy, MMBTU	Annual Greenhouse Gas Emissions (MT CO2e)	NGP Greenhouse Gas Emissions Reduction (MT CO2e)	Estimated First Year Operating Cost
Existing Plant	58,400	4,142,000	72,500	108,900	5,230		$857,000
Heat Recovery Chiller	19,700	4,239,000	34,200	71,400	3,230	38%	$508,000
Savings	38,700	-97,000	38,300	37,500	2,000		$349,000

Summary of Projected Economics

System Option	Gas Cost	Electric Cost	Water Cost	First Year Operating Cost	Capital Cost	Life Cycle Cost incl. Incremental Maintenance	Incremental Simple Payback Period
Existing Plant	$488,000	$313,000	$56,000	$857,000			
Basic Replacement	$414,000	$241,000	$51,300	$706,000	$8,500,000	$72,300,000	
Heat Recovery Chiller	$164,600	$319,000	$23,900	$508,000	$8,580,000	$67,300,000	0.4

Innovative Features

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

Conversion MTHW to LTHW

Old System

- Thhws: 240°F @ 90°F dT @30-40°F dT

New System

- Thhws: 140°F
- Eliminate Recirc Paths – Install 2-way valves
- Operate at 140°F until Systems require elevated Thhws
- Min. Thhws 140°F – DHW loads
- Clean up buildings in future to increase performance.

Interface of Open and Closed Systems

- Use open towers
- Dedicate service of HR chillers to HR or baseload
  - Service mode change over time
- Flush heat exchangers as part of transition
- Two valves for redundant isolation
- Automated process

Control for System Efficiency

- Most Efficient Combination desired in all load conditions
  - Packaged control strategies not efficient for overall system
  - Modular Equipment chosen
    - Less Robust Controls
    - Limited Flexibility
  - HR Chillers
    - Not efficient in Cooling Mode
- HGA's Control Sequences

Key Performance Indicators

- Overall Plant Efficiency
- Chiller Plant Efficiency
- HR Chiller Efficiency
- Heating Plant Efficiency
- Cooling Delivered Efficiency

UVA Criteria: $\frac{\text{Total Energy Delivered by Plant}}{\text{Input Energy to Plant}}$

Key Performance Indicators

	Toa=83			Toa=85			Toa=	86.1	39.60%	Toa=	81
CHW KPI	11:00			12:00			3:10				
	kW	kW/ton		kW	kW/ton		kW	kW/ton		kW	kW/ton
CH1	455	0.495		410	0.499		351.7	0.428		364.6	0.444
CH2		0.000			0.000			0.000			0.000
CT1		0.000			0.000			0.000			0.000
CT2	13	0.014		9	0.011		12	0.015		16	0.019
CT3	14	0.015		9	0.011			0.000			0.000
CHWP1	50	0.054		46	0.056		44	0.054		45	0.055
CHWP2		0.000			0.000			0.000			0.000
CHWP3		0.000			0.000			0.000			0.000
CDWP1	19	0.021		25	0.030		25	0.030		29	0.035
CDWP2		0.000			0.000			0.000			0.000
CDWP3		0.000			0.000			0.000			0.000
TOTAL kW	551			499			432.7			454.6	
Tons	920			821			859			785	
mbh	11,040			9,852			10,308			9,420	
kW	3,236			2,887			3,021			2,761	
kW/ton		0.599			0.608			0.527			0.579
COP		5.87			5.78			6.67			6.07

Chilled Water Generation KPIs

Key Performance Indicators

Heating System Performance	kW		kW	% Demand	kW		kW	
HRCHWP1	5		5		5		5	
HRCHWP2	6		5		5		6	
HRHWP1	6		6		6		6	
HRCH1-HR	74.8	0.4	59.8	0.32	59.8	0.32	97.2	0.52
HRCH1-HR	71.1	0.38	71.1	0.38	71.1	0.38	87.9	0.47
HHWP1	19		18		18		19	
Electric kW In Total	181.8		164.9		164.9		221.1	
Metered including pumphouse and AHU)								
GAS USE	**kW**	**SCFM**	**kW**	**SCFM**	**kW**	**SCFM**	**kW**	**SCFM**
B1 Gas (KW/ SCFM)	0	0	0	0	0	0	0	0
B2 Gas (KW/ SCFM)	0	0	0	0	0	0	0	0
B3 Gas (KW/ SCFM)	0	0	0	0	0	0	0	0
Total kW IN	181.8		164.9		164.9		221.1	
Htg MBH Out	1911		2071		2071		2666	
Htg kW Out	560.1		607.0		607.0		781.4	
Cooling Tons	106.2		115.1		115.1		148.1	
Cooling MBH - CR	1274.0		1380.7		1380.7		1777.3	
Cooling kW thermal	373.4		404.7		404.7		520.9	
Heating Efficiency -Net COP	308%		368%		368%		353%	

Heating System KPIs

Key Performance Indicators

Centrifugal Chiller Plant kW/ton								
COP								
kW/Ton	0.599		0.608		0.527		0.579	
COP	5.87		5.78		6.67		6.07	
NET COOLING KPI								
Total Cooling Energy Delivery	922.5	Tons	960.5	Tons	915.7	Tons	1076.7	Tons
Total CHW Plant Energy Input	509	kW	442.7	Kw	465.6	Kw	545.5	Kw
Effective kW/Ton	0.552	kW/Ton	0.461	kW/Ton	0.508	kW/Ton	0.507	kW/Ton
Heating Efficiency - Net COP	368%		368%		353%		349%	
Heat Efficiency - Net COP w/ AHU and Pump House								
Overall Plant COP								
Total Energy Delivered	3,850		3,985		4,262		4,078	
Total Energy In	664		598		654		693	
Overall Plant COP	5.8		6.67		6.52		5.89	

UVA Plant KPIs

First Year Challenges

Challenges During Construction

- Project initiation delayed
- Cooling in Cooling Season
- Heating In Heating Season

First Year's Challenges

- System is less forgiving and problems throughout building are exposed:
  - Existing conditions
  - Control or piping issues
  - Different approach

First Year Challenges (continued)

- Reliability of HR Chillers
- Learning Curve
- Equipment Issues
  - HR Chiller Reliability
  - Controls set points and sequencing-boilers, HR Chillers
- Conventional equipment reliable
- DHW at JAG
- Contract issues for building work
- Manufacturer – Rep engagement relationship

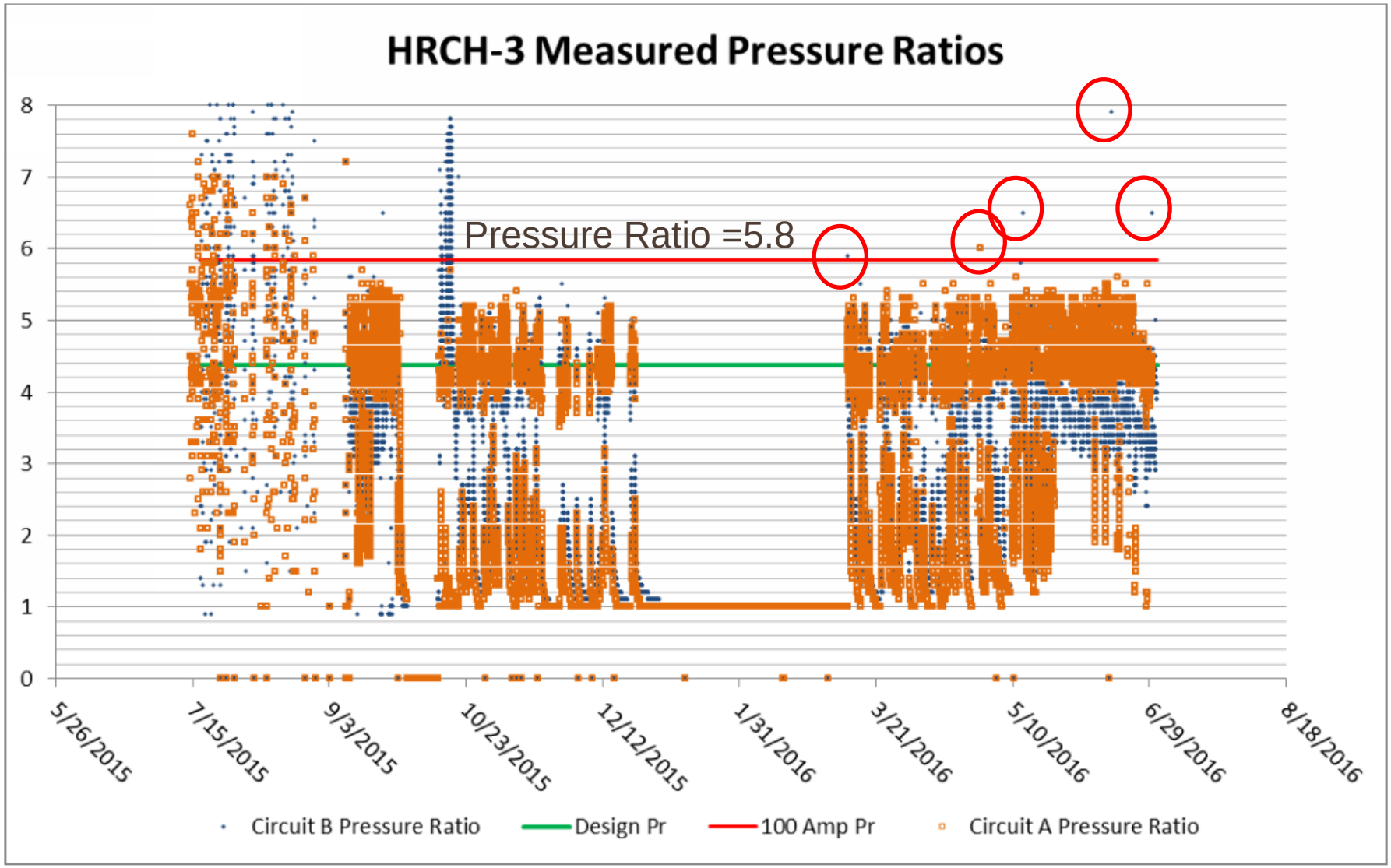
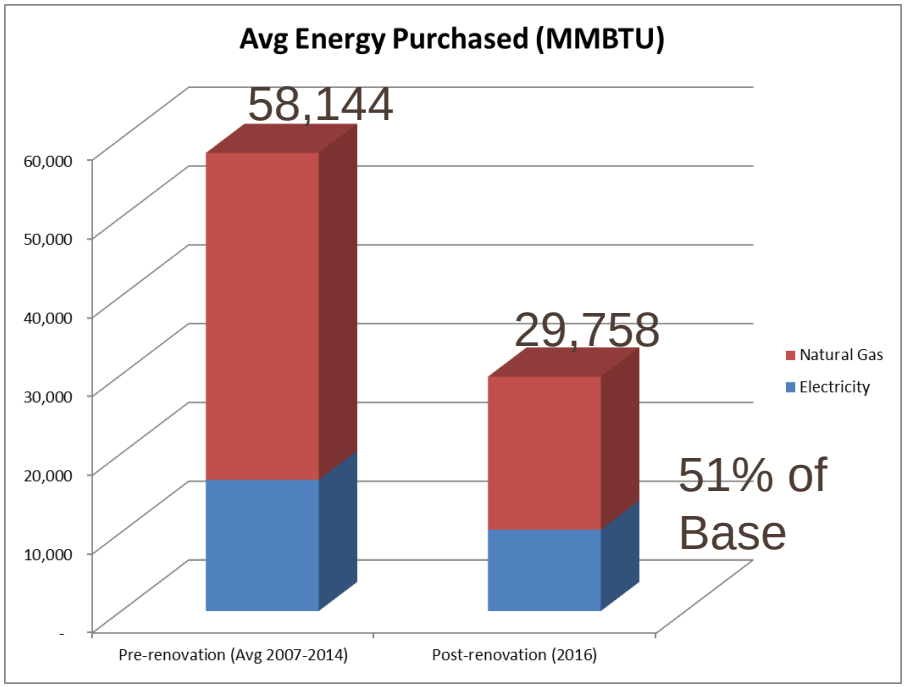


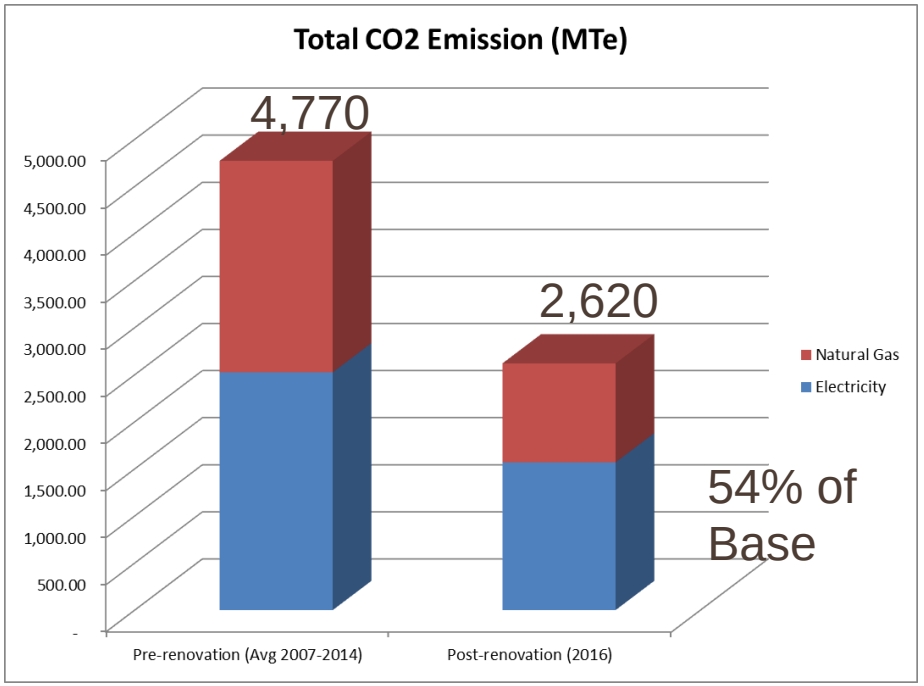
Figure E-15 HRCH-3 Pressure Ratios during First Operating Year

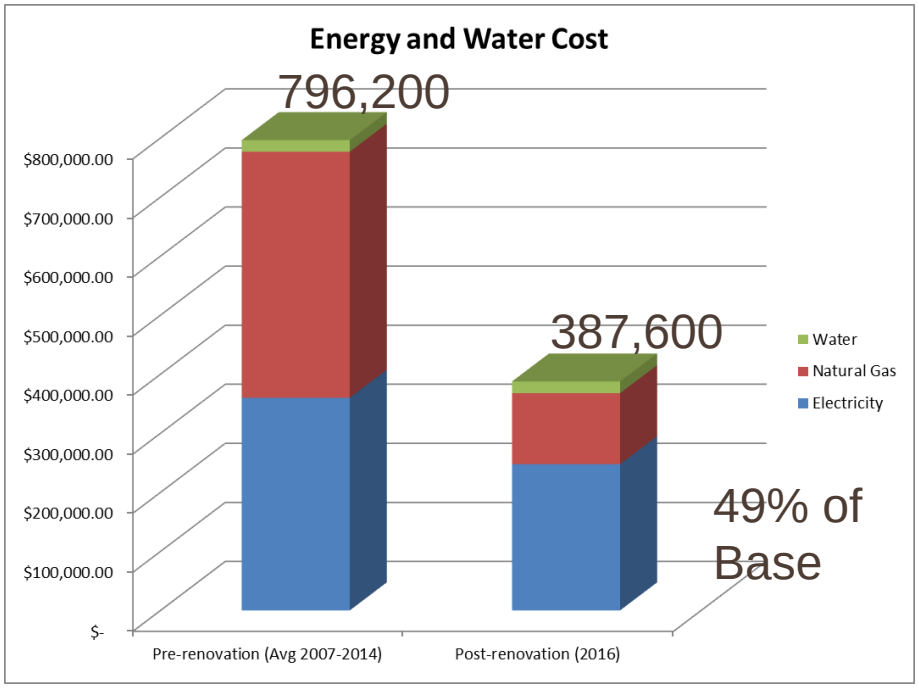
UVA Project Monitoring

- Trend Logs from existing plant perform the basis for monitoring performance/ improvement of new Plant.
- Key Metric:
- Total Energy Delivered by Plant

  Input Energy to Plant







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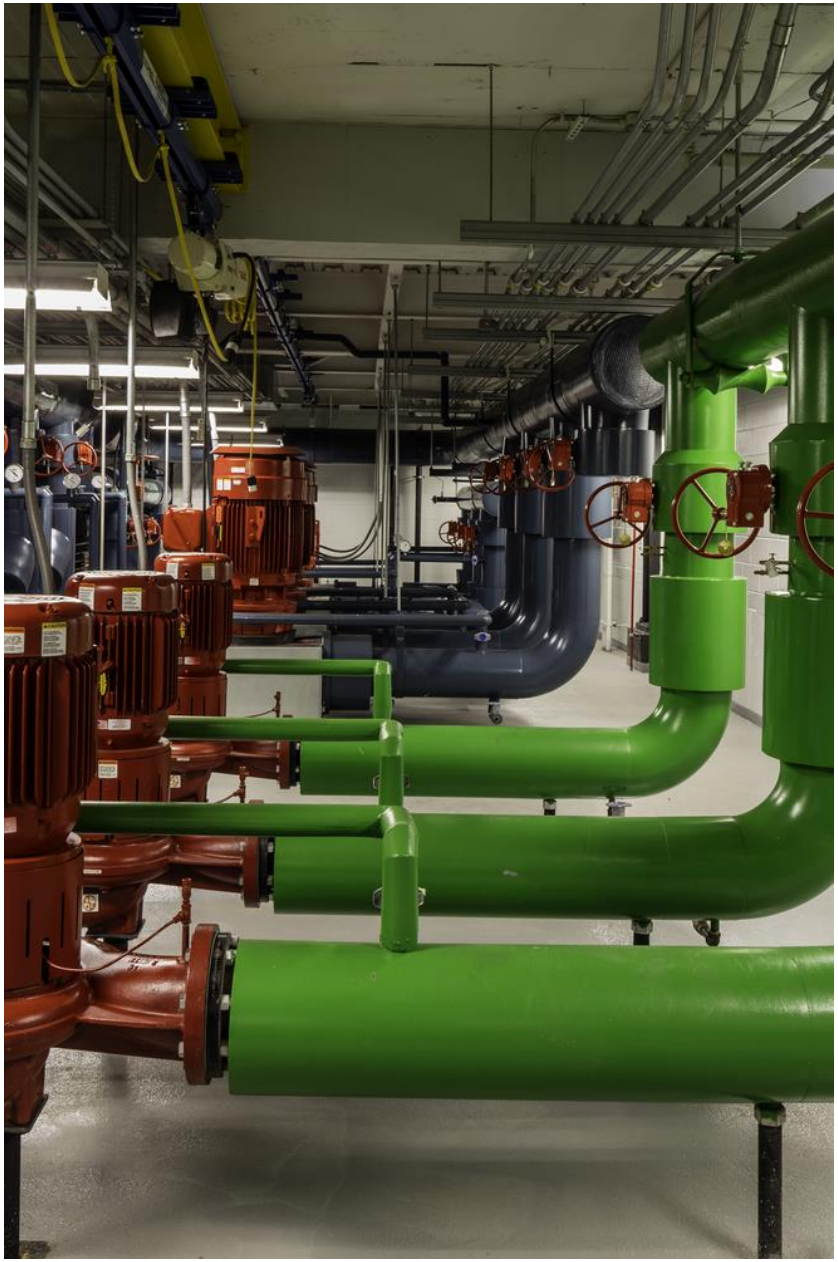
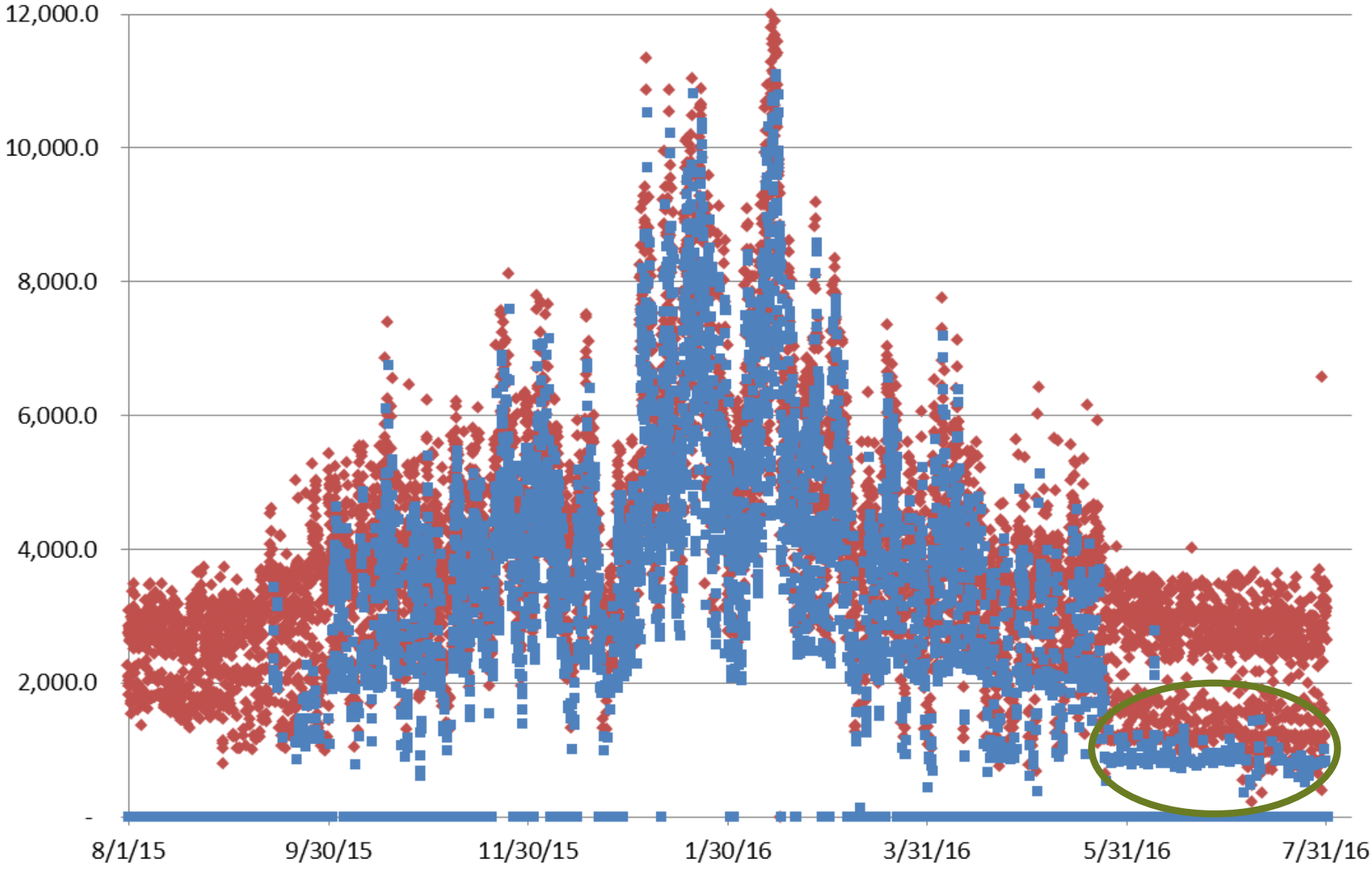
First Year Performance

1. Manufacturer responsive
2. Always be able to deliver hot water and cold water under
3. Reduce energy cost by 50%
4. GHG savings and water conservation predicted



Gas Comparison



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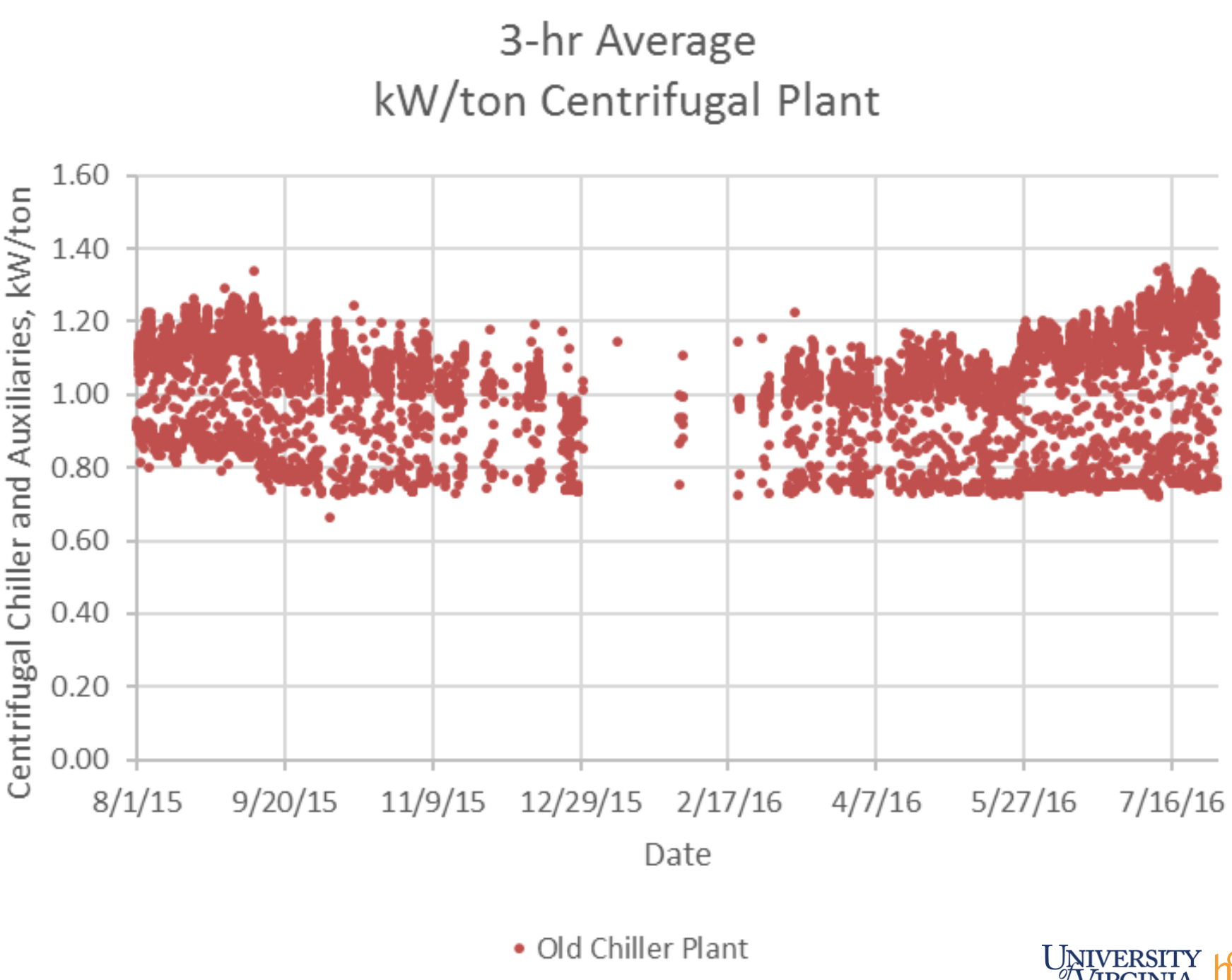
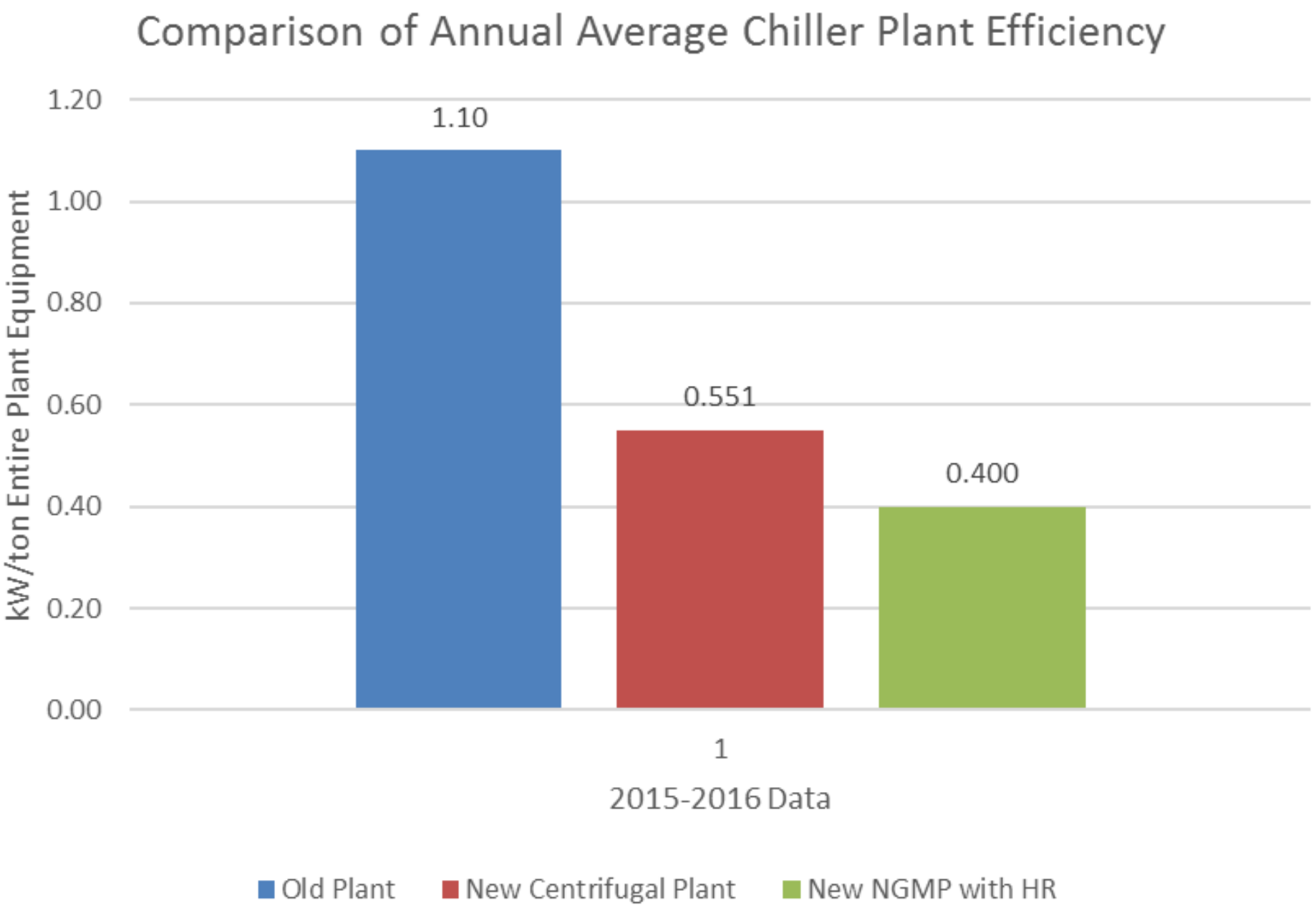

3-hr Average
kW/ton Centrifugal Plant
Centrifugal Chiller and Auxiliaries, kW/ton
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
8/1/15
9/20/15
11/9/15
12/29/15
2/17/16
4/7/16
5/27/16
7/16/16
Date
Old Chiller Plant


Comparison of Annual Average Chiller Plant Efficiency
1.20
1.00
0.80
0.60
0.40
0.20
0.00
KW/ton Entire Plant Equipment
1.10
0.551
0.400
1
2015-2016 Data
Old Plant
New Centrifugal Plant
New NGMP with HR

Questions?

Thank You

Justin Callihan, UVA Chiller Plants Associate Director

Joe Witchger, HGA Energy & Infrastructure Group