Presenters:
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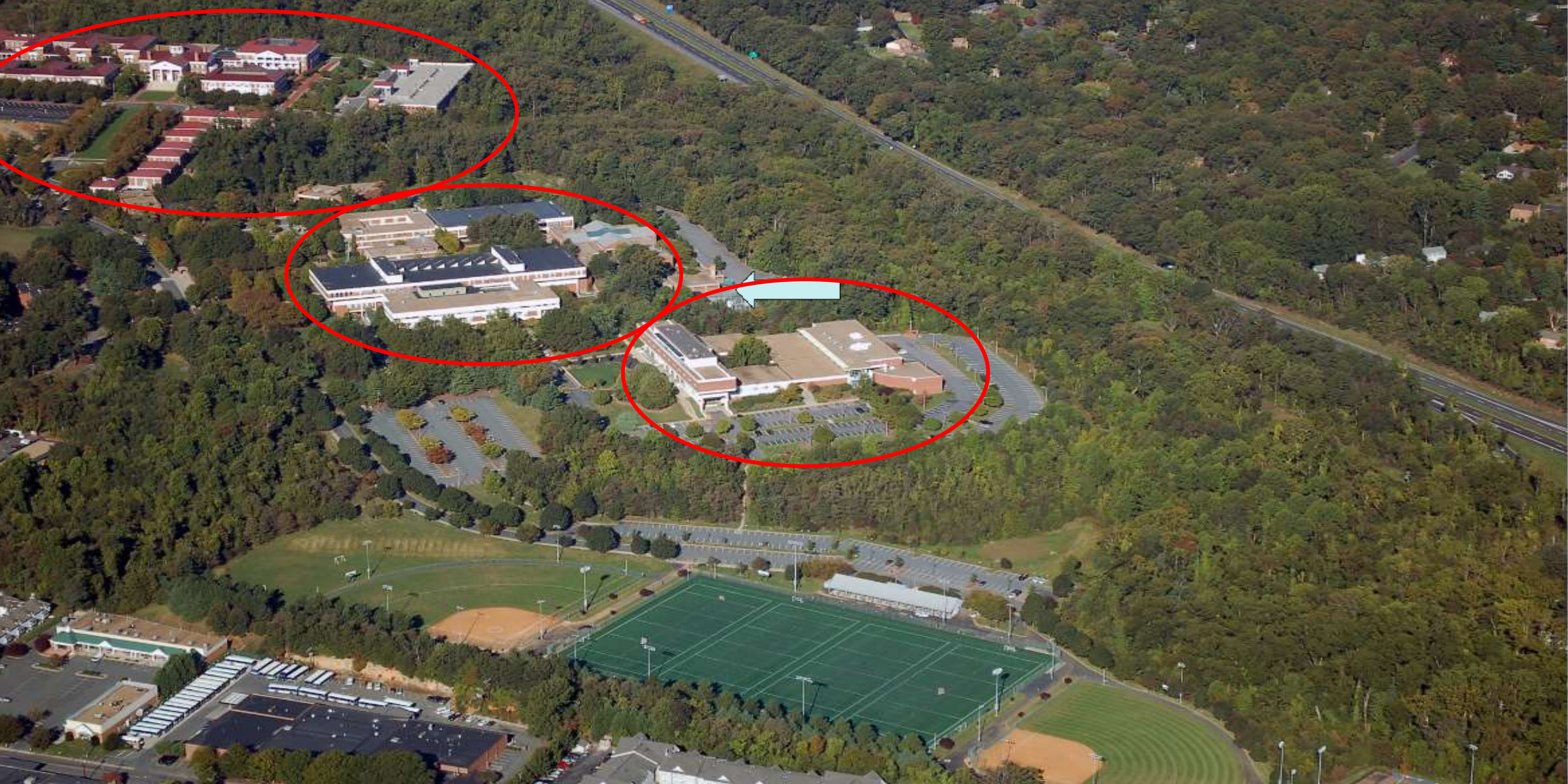
UNIVERSITY of VIRGINIA

North Grounds Boiler and Chiller Plant Replacement

HGA.

Agenda

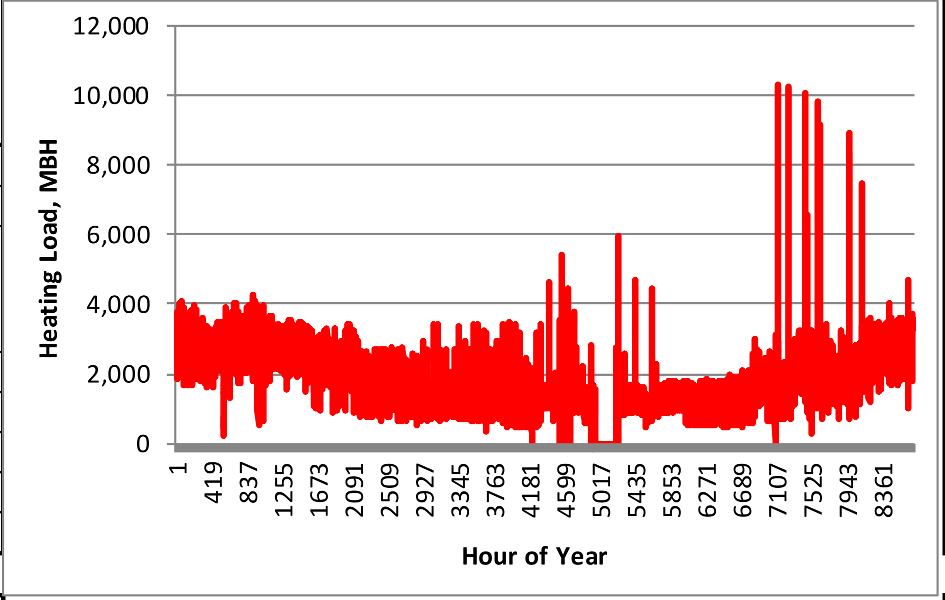
- Project Requirements
- UVA North Grounds
- System Option Evaluation
- Economic Summary
- Challenges



UVA Project Requirements

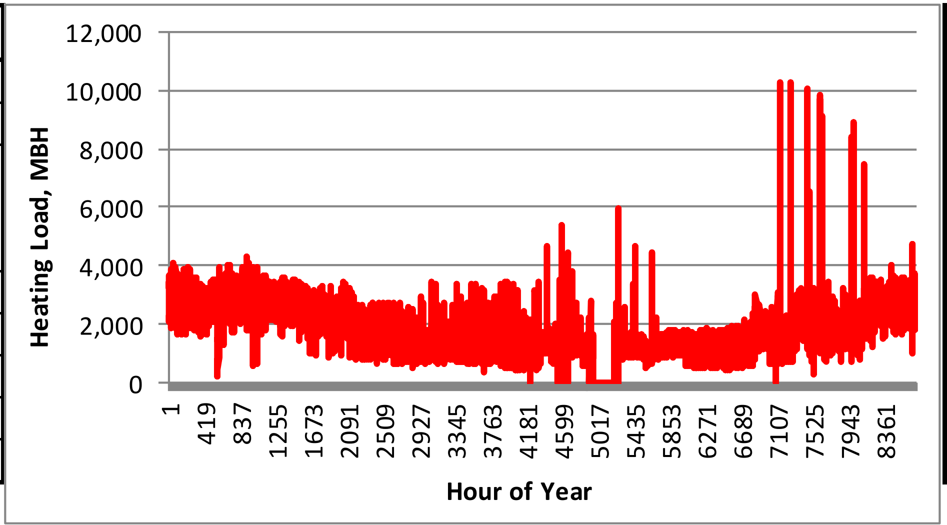
- Replace Aging, Inefficient Plant
- Unmanned plant
- Limited Room for Bldg Growth
- Sustainable
- Energy Use/Cost Reduction
- Handle low loads efficiently
- Reliable
- Redundant
- Adaptable to growth
- Innovative
- Well Thought out controls
- Minimize wasted energy

WB				
Area, Sq Ft	247,471			
Existing NPS	4	Pipe Area	0.0884	ft^3/Ft
	MBH	DT	Flow, GPM	Pipe Velocity, FPS
Existing Peak, MBH	4,949	12	825	20.79
Projected Loads, MBH				
Square Footage Based	4,949	12	825	20.79
Building Meter Data	6,000	12	1,000	**25.20**
Existing HX Output	10,646	49	434	10.94



Clay				
Area, Sq Ft	10,440			
Existing NPS	4	Pipe Area	0.0884	ft^3/Ft
	MBH	DT	Flow, GPM	Pipe Velocity, FPS
Existing Peak, MBH	209	12	35	0.88
Projected Loads, MBH				
Square Footage Based	209	12	35	**0.88**
Building Meter Data	NA	12	-	-
Existing HX Output	NA	12	-	-

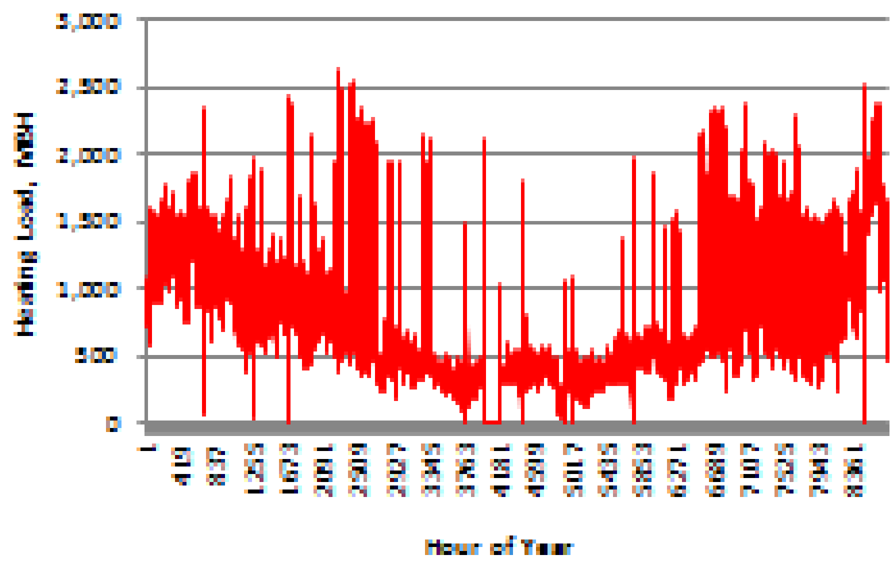
Combined WB- Clay				
Area, Sq Ft	257,911			
Existing NPS	6	Pipe Area	0.2006	ft^3/Ft
	MBH	DT	Flow, GPM	Pipe Velocity, FPS
Existing Peak, MBH	5,158	12	860	9.55
Projected Loads, MBH				
Square Footage Based	5,158	12	860	9.55
Building Meter Data	6,000	12	1,000	11.11
Existing HX Output	10,646	12	1,774	**19.71**



Load Projections

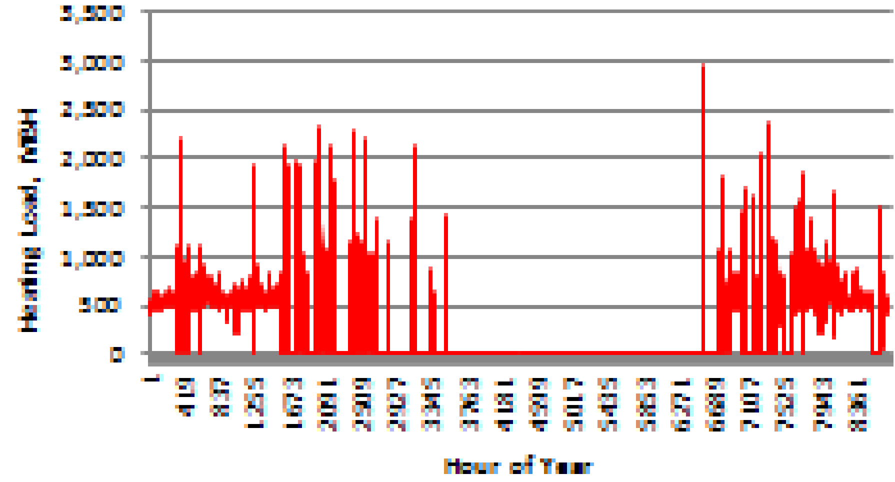
JAG ADDITION

Area, Sq Ft	53,860			
Existing NPS	4	Pipe Are	0.0884	ft^3/Ft
	MBH	DT	Flow, GPM	Pipe Velocity, FPS
Existing Peak, MBH	1,077	12	180	4.52
Projected Loads, MBH				
Square Footage Based	2,277	12	380	9.57
Building Meter Data	2,700	12	450	11.34
Existing HX Output	2,600	20	260	6.55



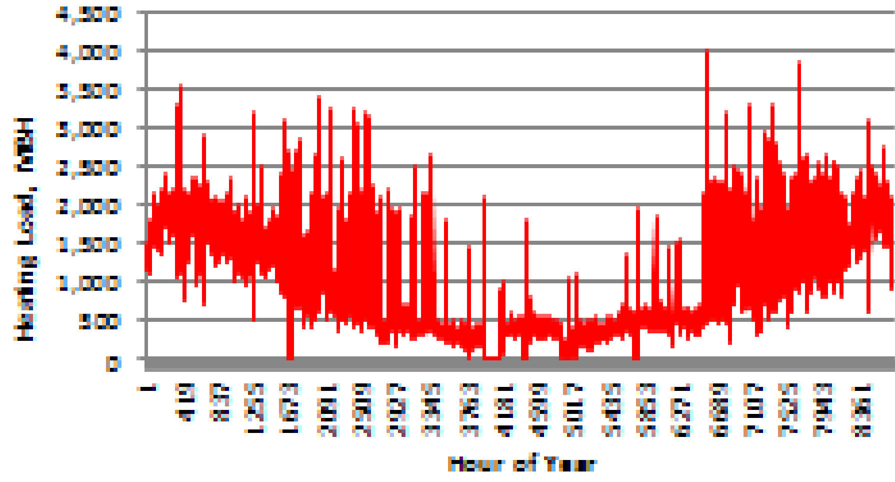
JAG Building

Area, Sq Ft	114,166			
Existing NPS	4	Pipe Are	0.0884	ft^3/Ft
	MBH	DT	Flow, GPM	Pipe Velocity, FPS
Existing Peak, MBH	2,283	12	381	9.59
Projected Loads, MBH				
Square Footage Based	2,283	12	381	9.59
Building Meter Data	2400	12	400	10.08
Existing HX Output	7,106	34	418	10.54

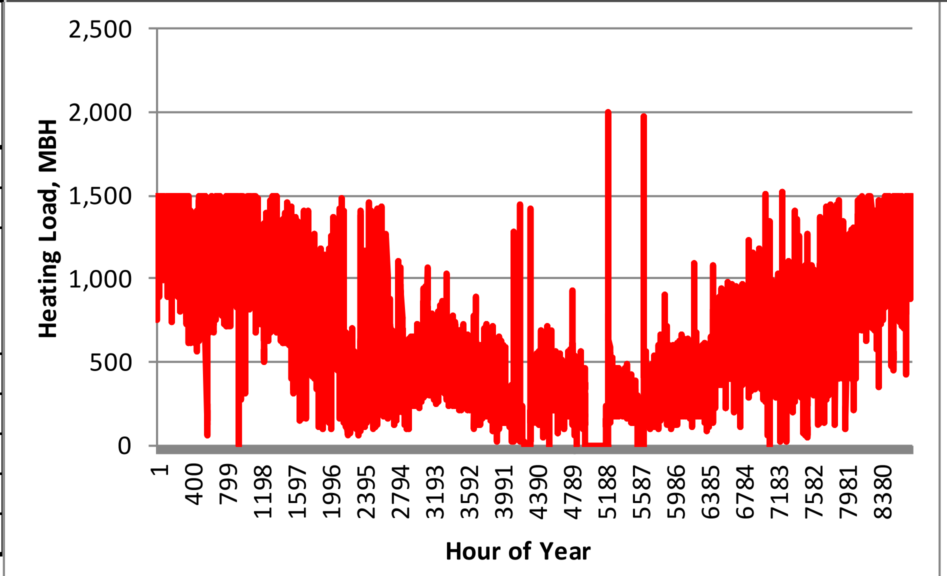


Combined JAG

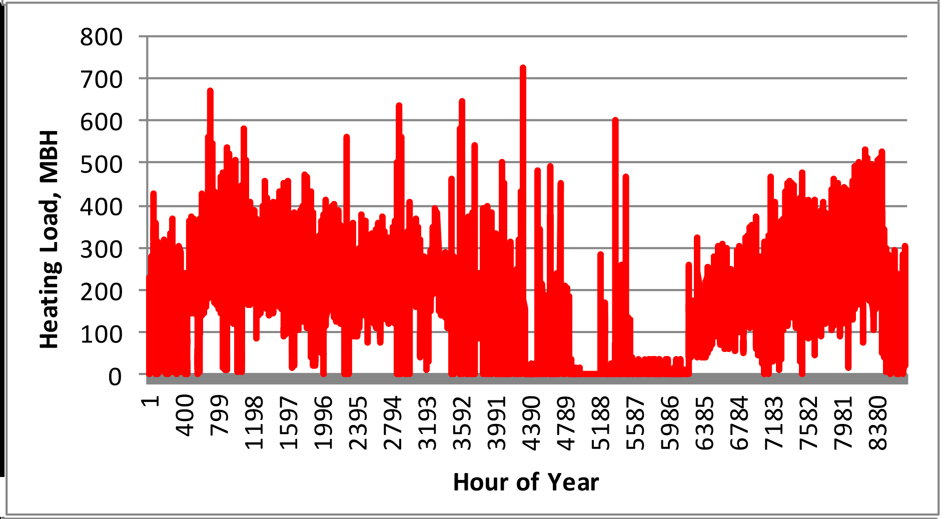
Area, Sq Ft	168,026			
Existing NPS	6	Pipe Are	0.2006	ft^3/Ft
	MBH	DT	Flow, GPM	Pipe Velocity, FPS
Existing Peak, MBH	3,361	12	560	6.22
Projected Loads, MBH				
Square Footage Based	4,561	12	760	8.44
Building Meter Data	5100	12	850	9.44
Existing HX Output	9,706	28.4	683.52	7.59



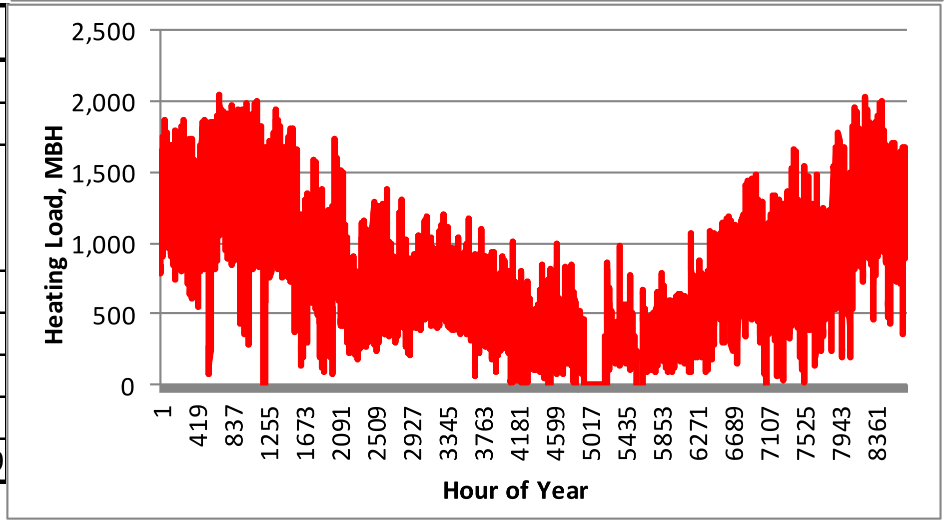
Slaughter				
Area, Sq Ft	101,300			
Existing NPS	4	Pipe Area	0.0884	ft^3/Ft
	MBH	DT	Flow, GPM	Pipe Velocity, FPS
Existing Peak, MBH	2,026	20	203	5.11
Projected Loads, MBH				
Square Footage Based	2,026	20	203	5.11
Building Meter Data	1,500	20	150	3.78
Existing HX Output	4,848	48	202	5.09



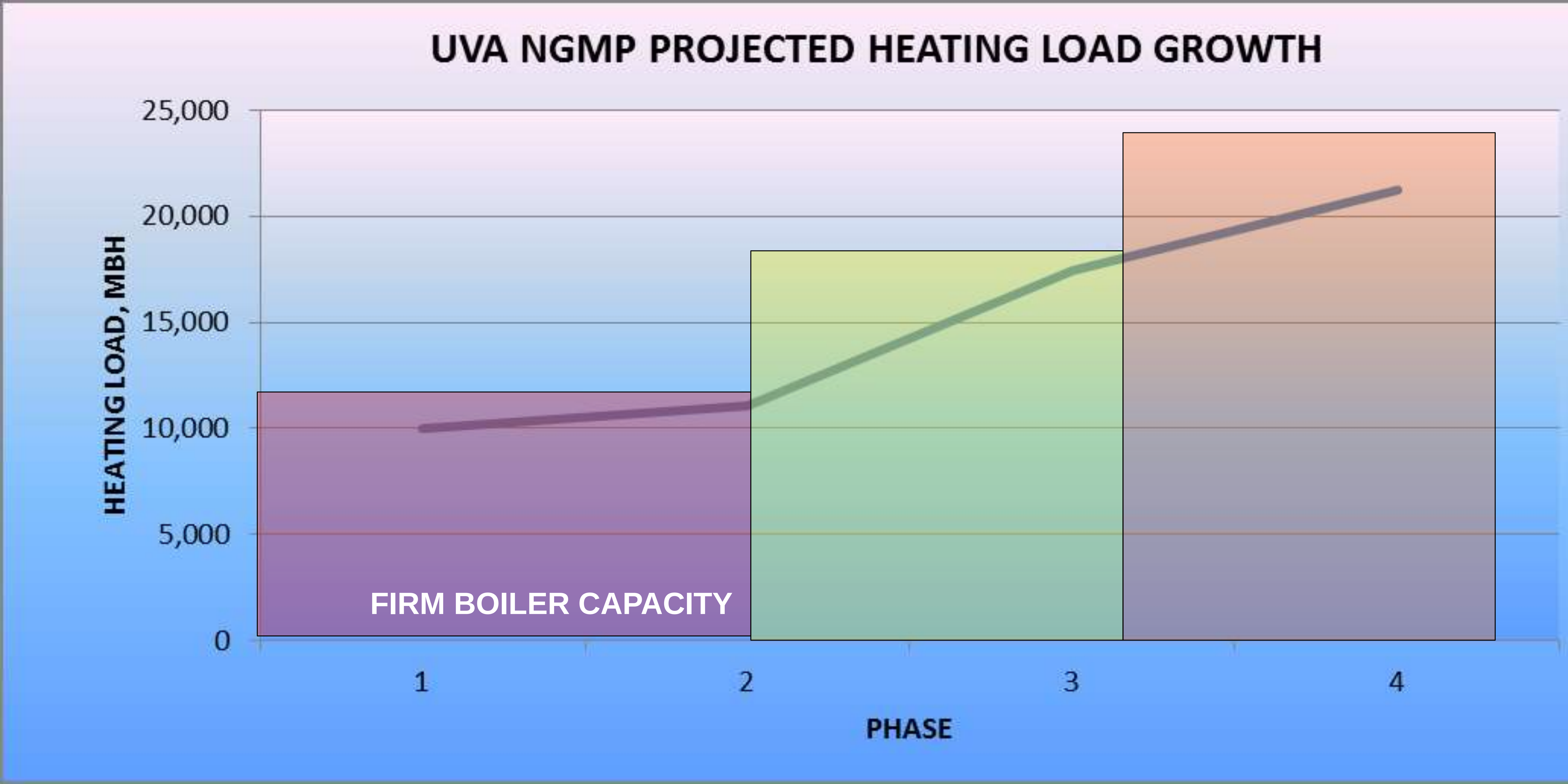
Student Faculty				
Area, Sq Ft	26,317			
Existing NPS	2	Pipe Area	0.0233	ft^3/Ft
	MBH	DT	Flow, GPM	Pipe Velocity, FPS
Existing Peak, MBH	526	15	70	6.71
Projected Loads, MBH				
Square Footage Based	526	15	70	6.71
Building Meter Data	650	15	87	8.29
Existing HX Output	1,850	19.6	189	18.05

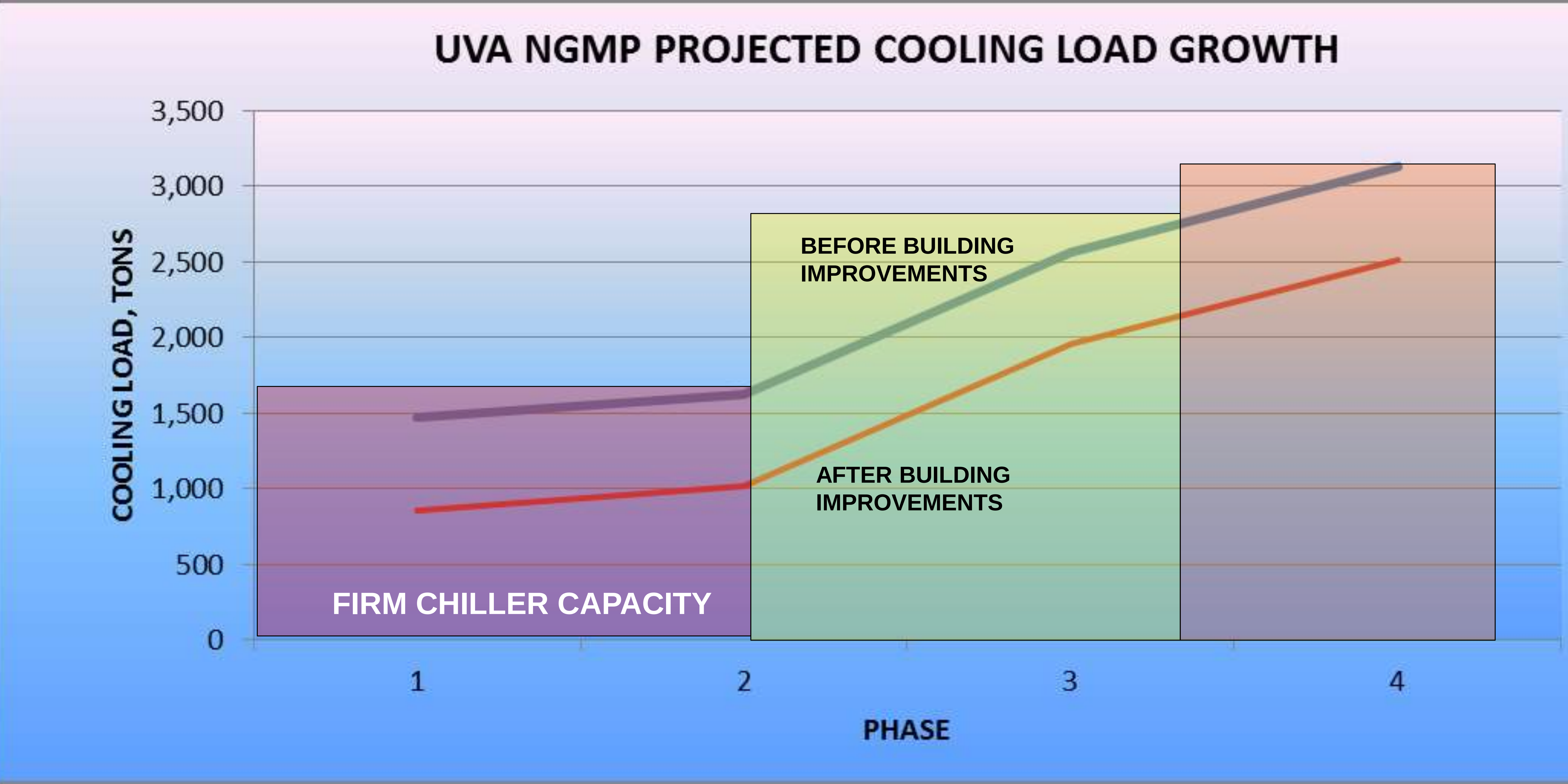


West Loop Piping				
Area, Sq Ft	385,528			
Existing NPS	6	Pipe Area	0.2006	ft^3/Ft
	MBH	DT	Flow, GPM	Pipe Velocity, FPS
Existing Peak, MBH	7,711	13.6	1,132	12.58
Projected Loads, MBH				
Square Footage Based	7,711	13.6	1,132	12.58
Building Meter Data	8,150	13.2	1,237	13.73
Existing HX Output	17,344	40.2	864	9.59



Projected System Growth	Area (sq ft)
Future JAG Addition	60,000
Saunders Central Plant Loads	***354,920***
Darden Classroom	79,949
Darden Library	36,450
Darden Faculty	45,138
Saunders	45,240
Abbott Center	64,743
Sponsors West	79,900
Sponsors Gatehouse	3,500
Buildings Not on a Central Plant	***213,975***
Future Darden Expansion	50,000
Sponsors Dining Hall	20,400
Sponsors East	33,600
Sponsors Addition Future	60,000
Slaughter Recreation Center	49,975
Future Area Served	**628,895**
Existing Area	558,198
Total Projected Area	**1,187,093**


UVA NGMP PROJECTED HEATING LOAD GROWTH
25,000
20,000
15,000
10,000
5,000
0
HEATING LOAD, MBH
FIRM BOILER CAPACITY
1
2
3
4
PHASE

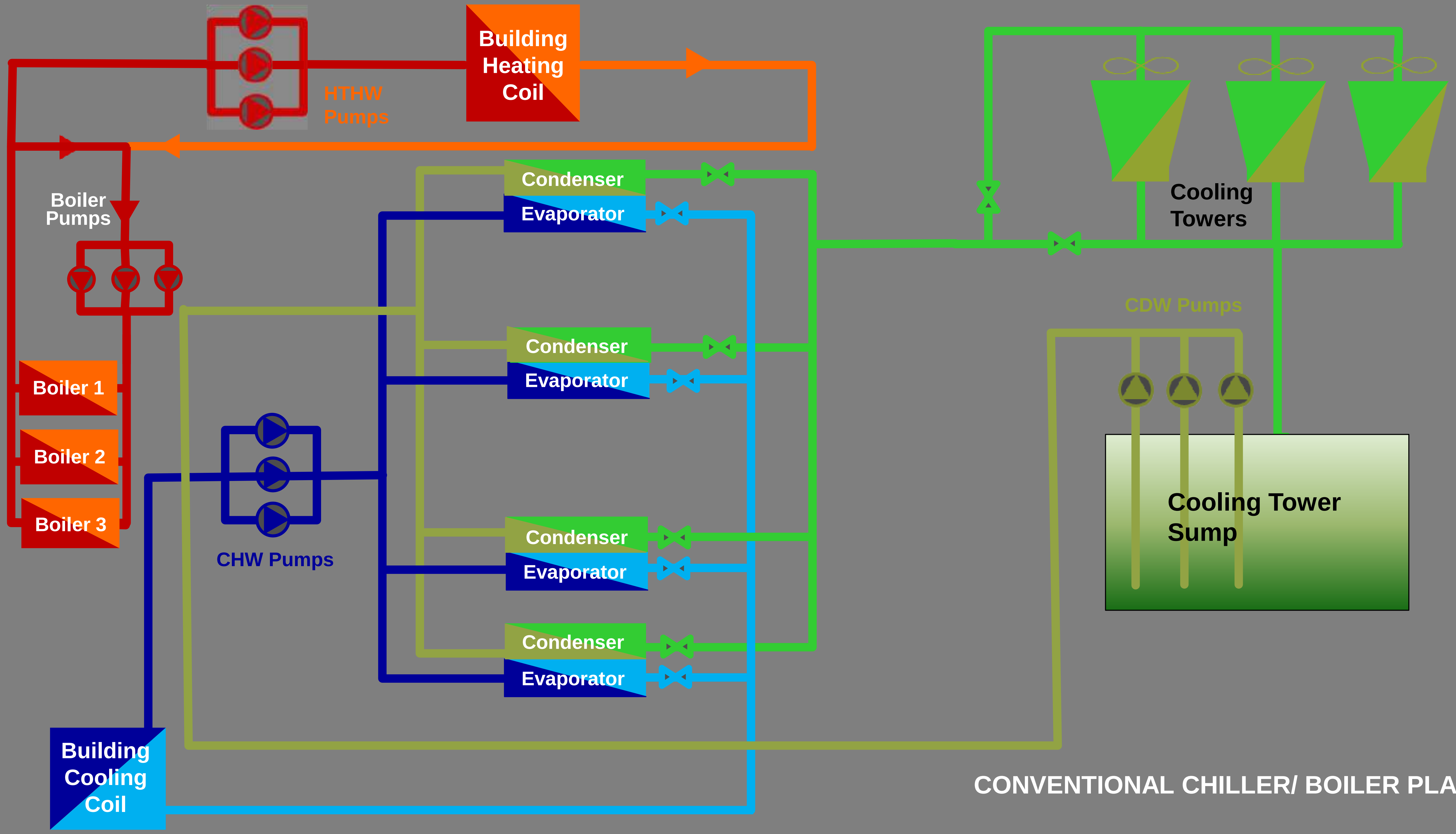


UVA NGMP PROJECTED COOLING LOAD GROWTH
COOLING LOAD, TONS
3,500
3,000
2,500
2,000
1,500
1,000
500
0
BEFORE BUILDING IMPROVEMENTS
AFTER BUILDING IMPROVEMENTS
FIRM CHILLER CAPACITY
1
2
3
4
PHASE

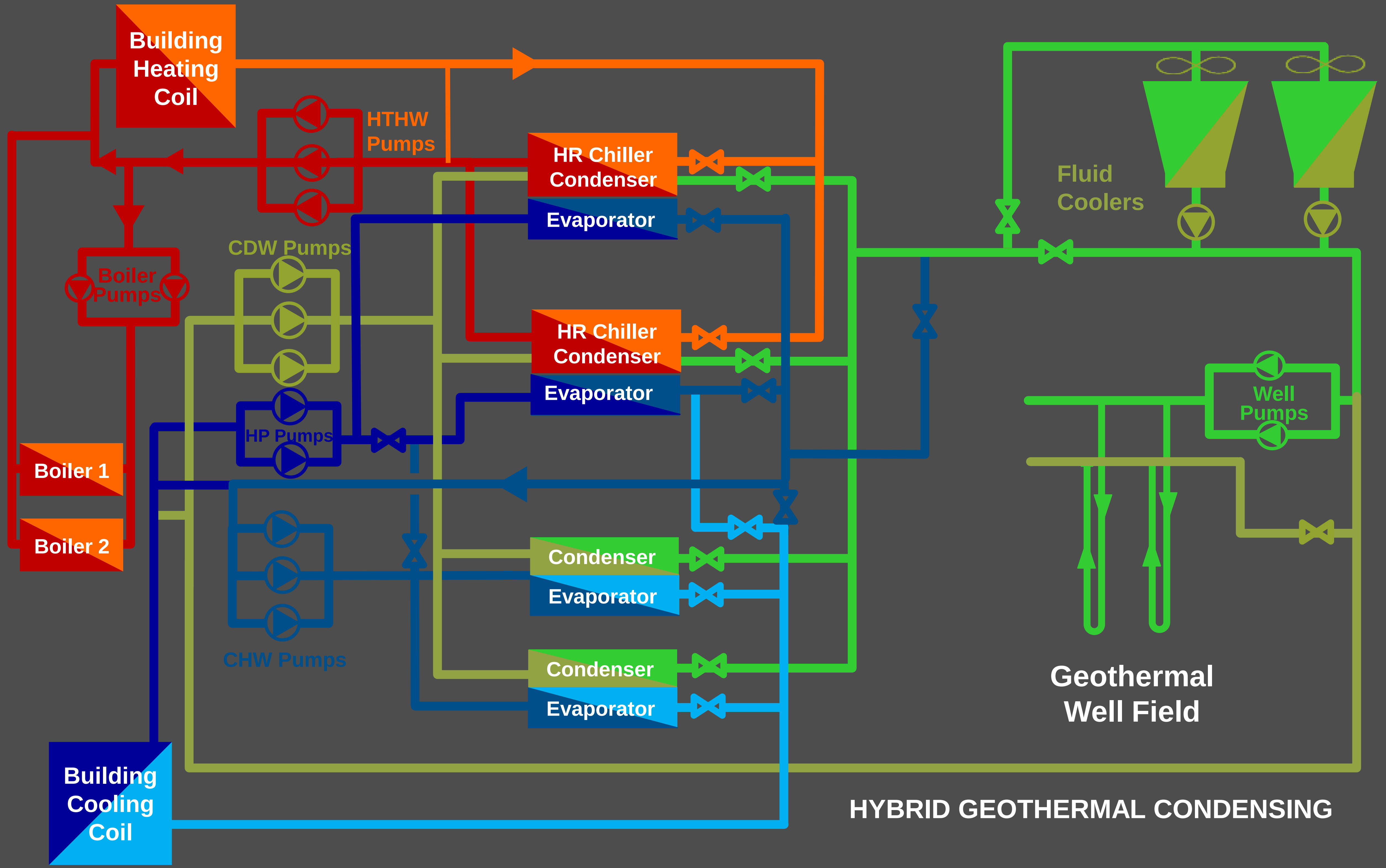
UVA Project Monitoring

- Trend Logs from existing plant perform the basis for monitoring performance / Improvement of new Plant.
- Key Metric:

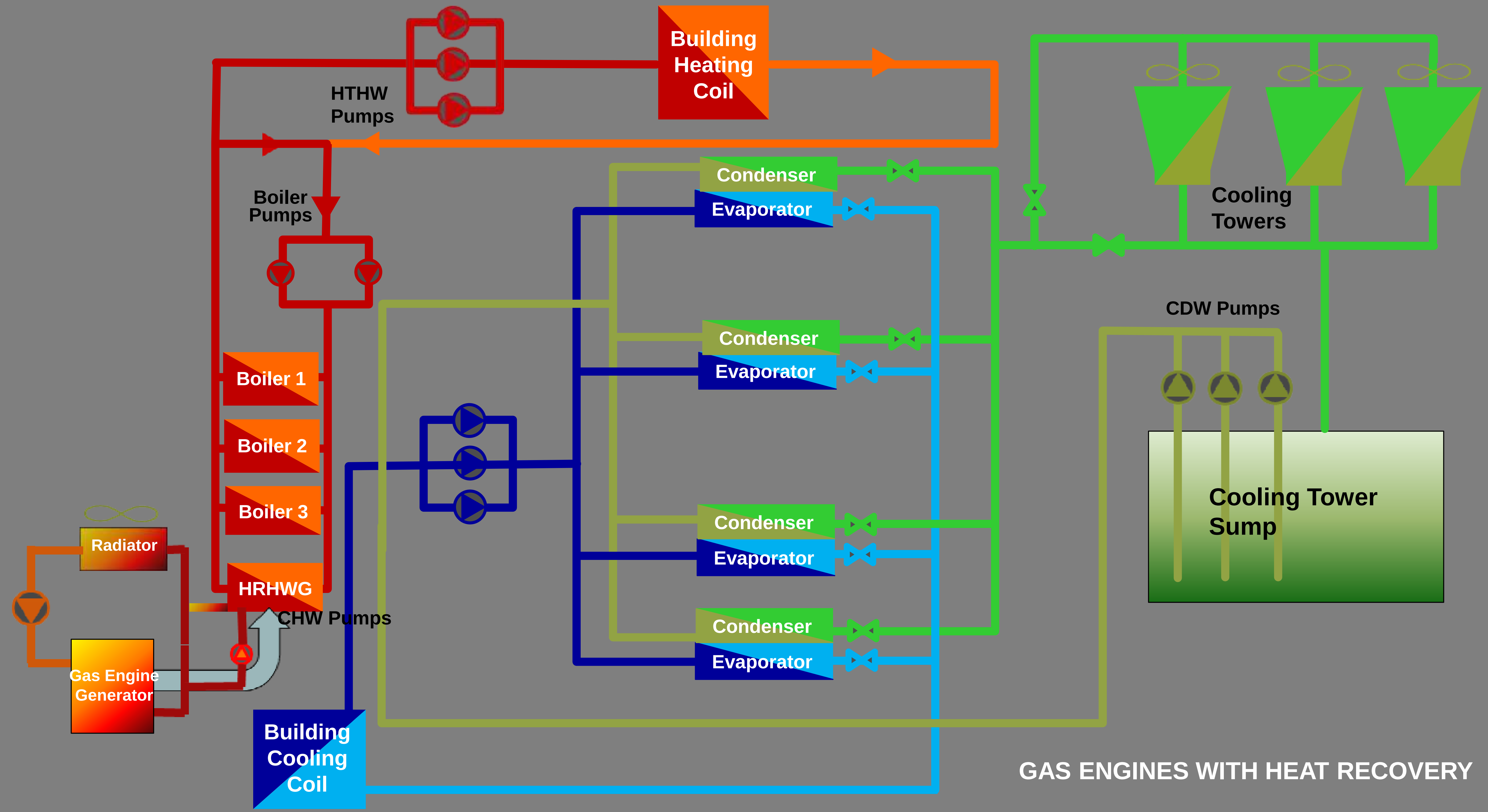
$$\frac{\text{Total Energy Delivered by Plant}}{\text{Input Energy to Plant}}$$



CONVENTIONAL CHILLER/ BOILER PLANT



HYBRID GEOTHERMAL CONDENSING


Building Heating Coil
HTHW Pumps
Boiler Pumps
Boiler 1
Boiler 2
Boiler 3
HRHWG
Radiator
Gas Engine Generator
CHW Pumps
Building Cooling Coil
Condenser
Evaporator
Condenser
Evaporator
Condenser
Evaporator
Condenser
Evaporator
Cooling Towers
CDW Pumps
Cooling Tower Sump
GAS ENGINES WITH HEAT RECOVERY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Economic Parameters At Time of Study

4.75 % Cost of Capital
2.4 % Average Inflation Rate
2.35% Discount Rate
25 Year Life Cycle Cost Analysis, Operations Start 2014
Gas Cost FY 2012 Average of $8.46 / MMBTU
VA Electric & Power Co 6VA Rate with All Riders
EIA Projected Inflation Rates for Gas, Electric, Carbon
$15/ MTECD Nominal Carbon Value 2014

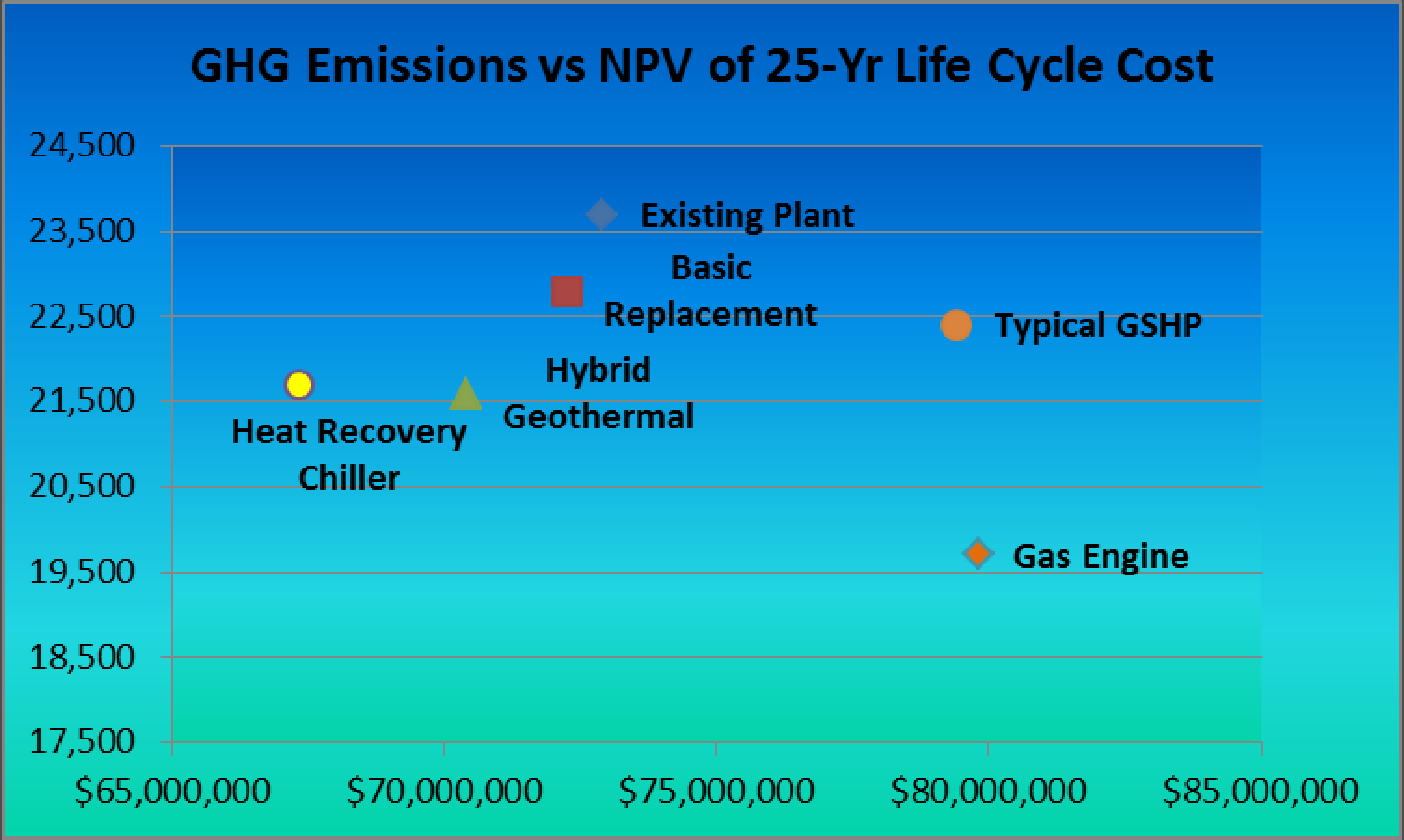
Summary of Performance

System Option	Gas Use, MMBTU	Purchased Electricity, kWh	Total Site Input Energy, MMBTU	Total Source Input Energy, MMBTU	Annual Greenhouse Gas Emissions (MT CO2e)
Existing Plant	58,400	39,944,000	195,000	545,000	23,700
Basic Replacement	49,600	39,075,000	183,000	526,000	22,800
Hybrid Heat Pump	19,700	39,971,000	156,000	507,000	21,600
Heat Recovery Chiller	19,700	40,041,000	156,000	508,000	21,700
Gas Engine	158,000	22,045,000	233,000	427,000	19,700

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 Annual 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
Basic Replacement	49,600	3,273,000	60,800	89,500	4,310	18%	$713,000
Hybrid Heat Pump	19,700	4,168,000	33,900	70,500	3,190	39%	$496,000
Heat Recovery Chiller	19,700	4,239,000	34,200	71,400	3,230	38%	$508,000

Summary of Economics

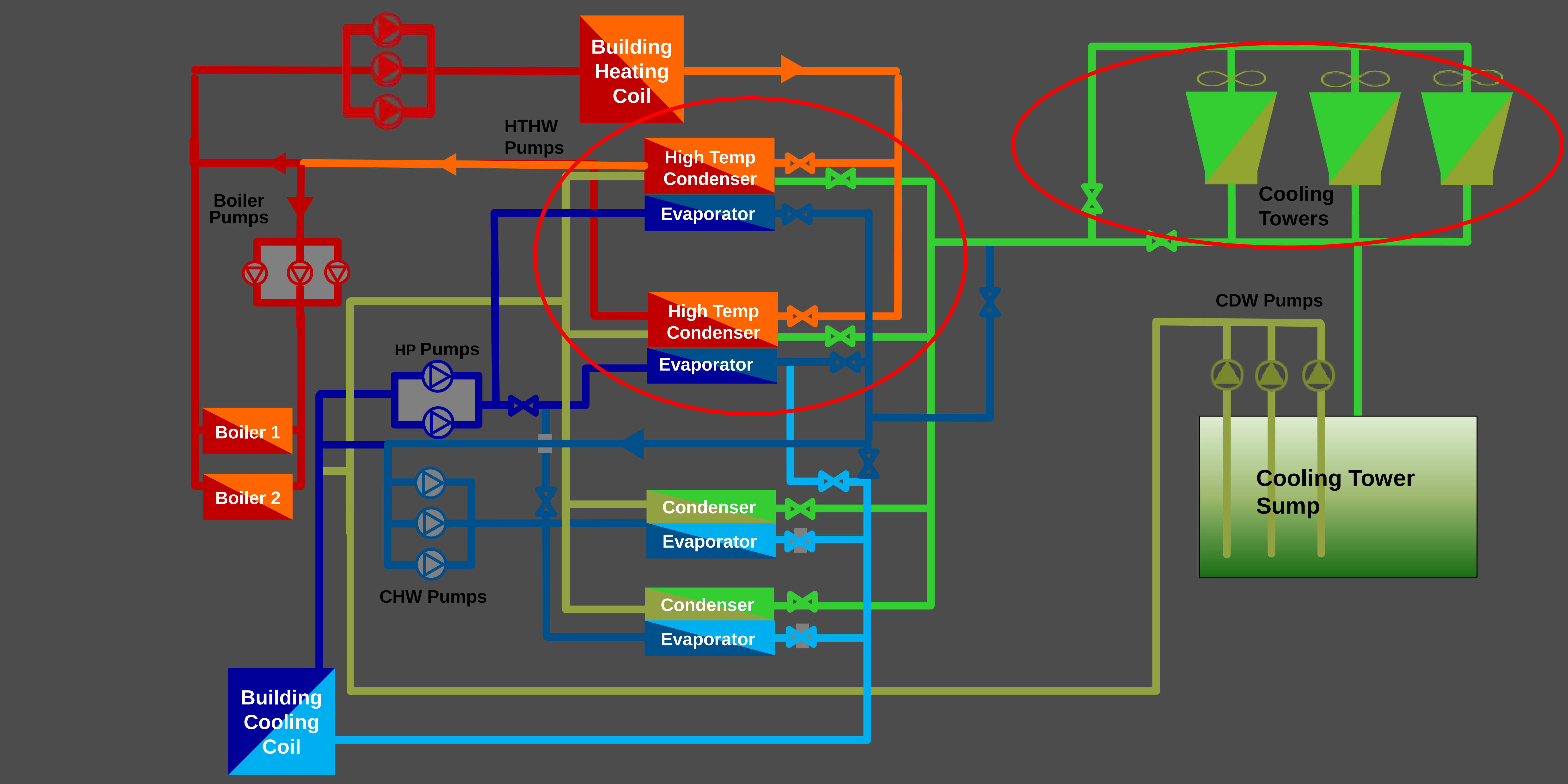
System Option	Gas Cost	Electric Cost	Water Cost	First Year Operating Cost	Capital Cost	Life Cycle Cost incl. Incremental Maintenance	Incremental Simple Payback Period
Existing Plant	$488,000	$3,021,000	$56,000	$3,560,000			
Basic Replacement	$414,000	$2,949,000	$51,300	$3,400,000	$8,500,000	$72,300,000	
Hybrid Heat Pump	$163,000	$3,006,000	$17,900	$3,190,000	$11,900,000	$70,400,000	16.2
Heat Recovery Chiller	$163,000	$3,011,000	$23,900	$3,200,000	$8,580,000	$67,300,000	0.4
Gas Engine	$1,340,000	$1,965,000	$36,400	$3,520,000	$9,980,000	$79,800,000	-12.3



GHG Emissions vs NPV of 25-Yr Life Cycle Cost
24,500
23,500
22,500
21,500
20,500
19,500
18,500
17,500
$65,000,000
$70,000,000
$75,000,000
$80,000,000
$85,000,000
Existing Plant
Basic Replacement
Typical GSHP
Hybrid Geothermal
Heat Recovery Chiller
Gas Engine

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



Building Heating Coil
HTHW Pumps
High Temp Condenser
Evaporator
High Temp Condenser
Evaporator
Boiler Pumps
HP Pumps
Boiler 1
Boiler 2
CHW Pumps
Condenser
Evaporator
Condenser
Evaporator
Building Cooling Coil
Cooling Towers
CDW Pumps
Cooling Tower Sump

Conversion MTHW to LTHW

Observations

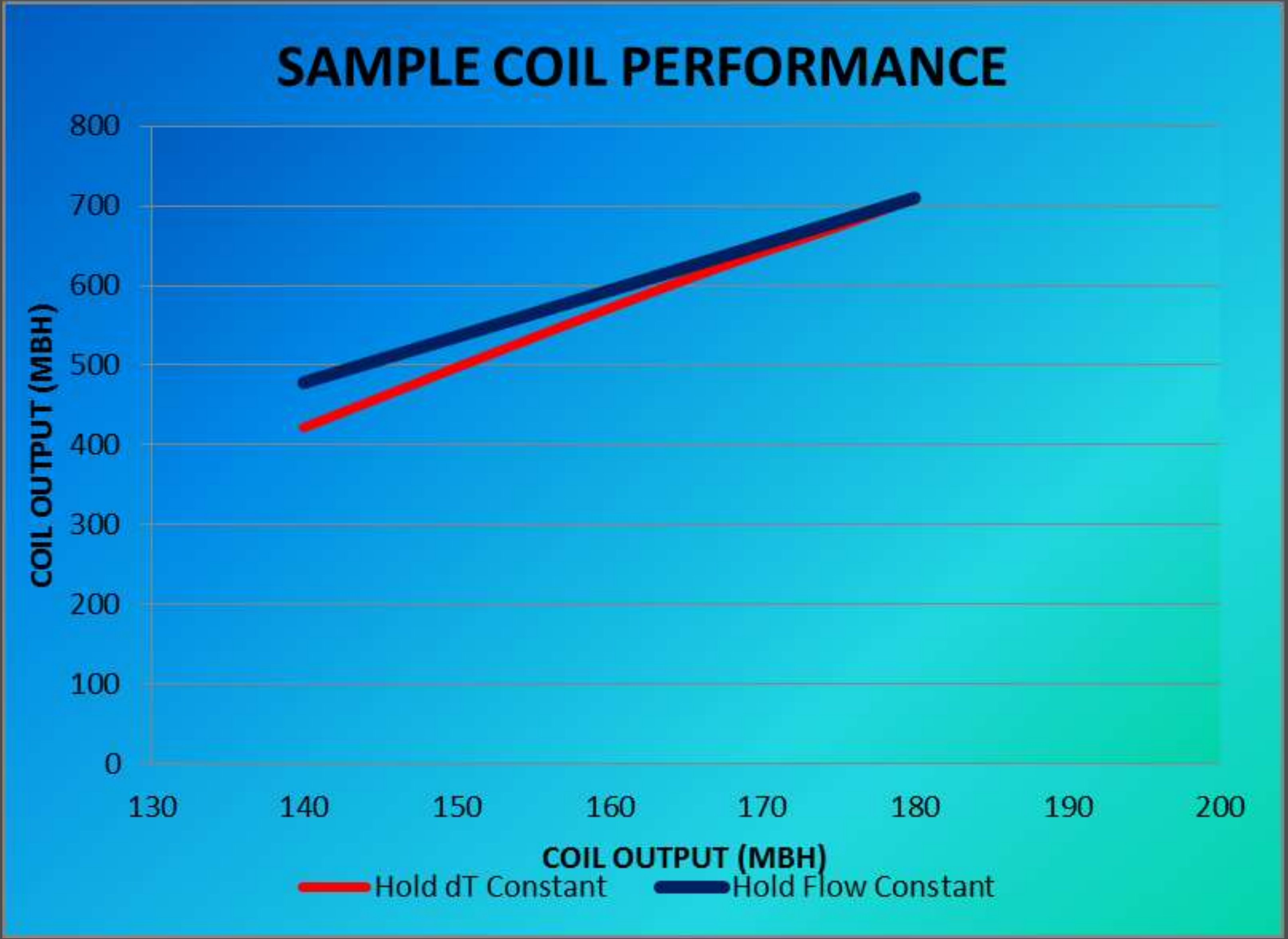
- Thhws 240°F@ 90°F dT
- Heat Generation Equipment less Efficient
- No Opportunity for Heat Recovery
- Building Thhws: 200-154°F @ 30-40°F dT

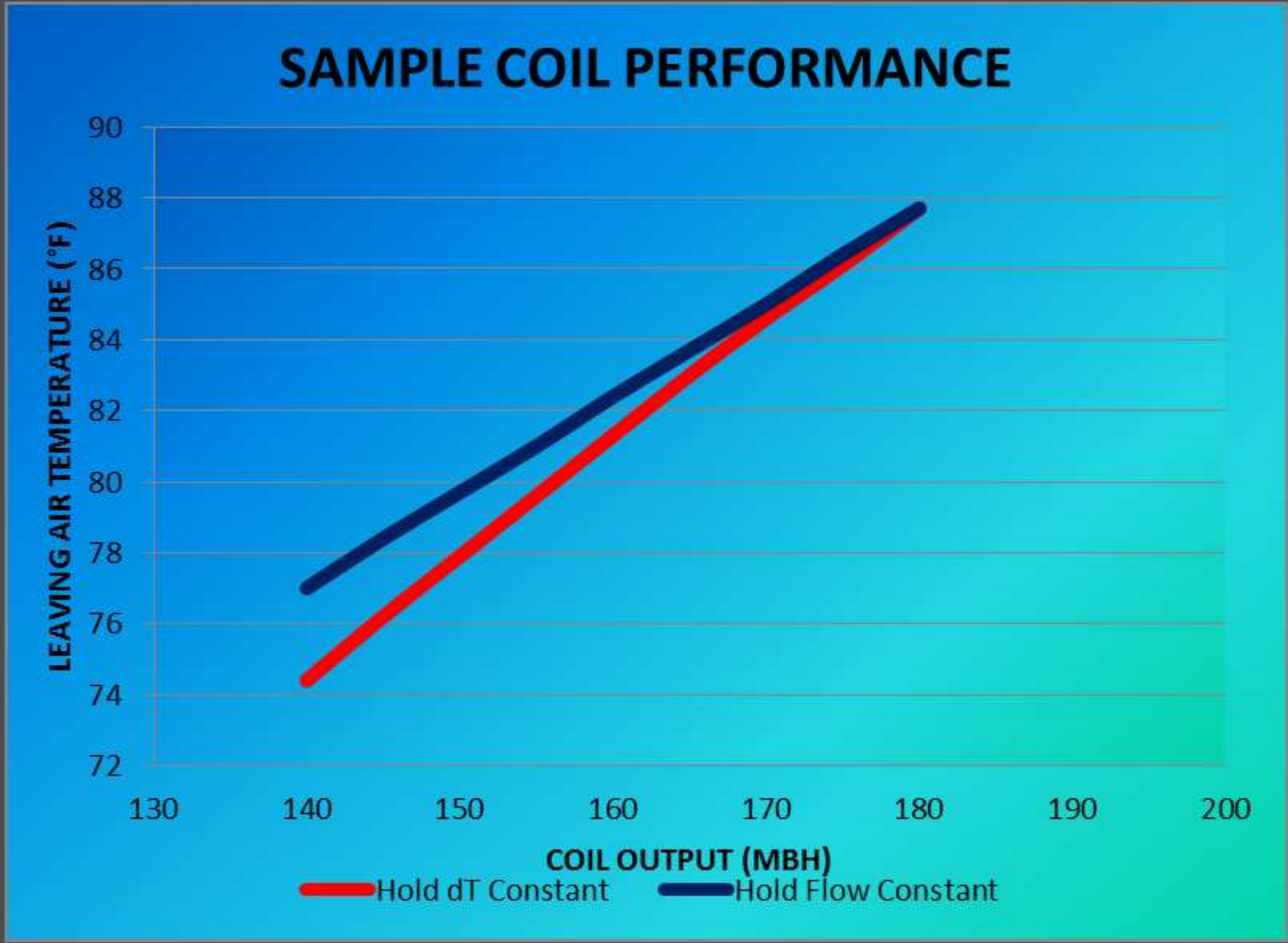
Limitations

- Solution has to work with existing AHU Systems
- System has to be adaptable to future changes
- No Budget to repipe entire system

Conversion MTHW to LTHW

- **Typical Coil Performance**





Conversion MTHW to LTHW

Strategy-

- Target Thhws: 140°F
- Eliminate HXR- Direct Connection
- 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.
- Requires education of operators

Load Profile Considerations

Observations

- High Turndown required
- Significant Coincident Heating and Cooling
- Ability to serve additional HR load
- Ability to serve reduced HR load as buildings improve

Limitations

- Simultaneous 140 deg F Thhws with 42 deg F Tchws
- Turndown to 25 Tons desired
- N+1 Redundancy required
- Space constraints- Limit Size of redundant capacity

Load Profile Considerations

Strategy

- Modular HR Chillers for simultaneous Htg and Clg loads
- Centrifugal Chillers for High Efficiency and Reliability
- Reduce load with HR
- Remaining Loads served with High Efficiency Equipment

Interface of Open and Closed Systems

Observations:

With HR Chillers

- Condenser side open to HHW and Condensing Loop
  - Conventional approach: Closed Loop Fluid Coolers / HXR
- Goal is to avoid getting dirty Tower Water in HHW/ CHW
- Plant load profile such that HR Chiller capacity needed-generally stable

Limitations:

- Space constraints
- Centrifugal Chillers on Open Towers
- All VS Centr. chiller more efficient beyond capacity of 1 HR chiller
- Fourth HR unit becomes redundant/ Swing chiller

Interface of Open and Closed Systems

- Strategy
  - Use open Towers
  - Dedicate service of HR chillers to HR or baseload
    - Service mode can change over time
  - Flush Heat exchangers as part of Transition
  - Two Valves for redundant isolation
  - Automated process

Controls Opportunities

Observations:

- Equipment Controls Geared to Equipment performance
- Most Efficient Combination desired in all load conditions
- Packaged control strategies not be efficient

Limitations:

Modular Equipment chosen

- Less Robust Controls
- Limited Flexibility

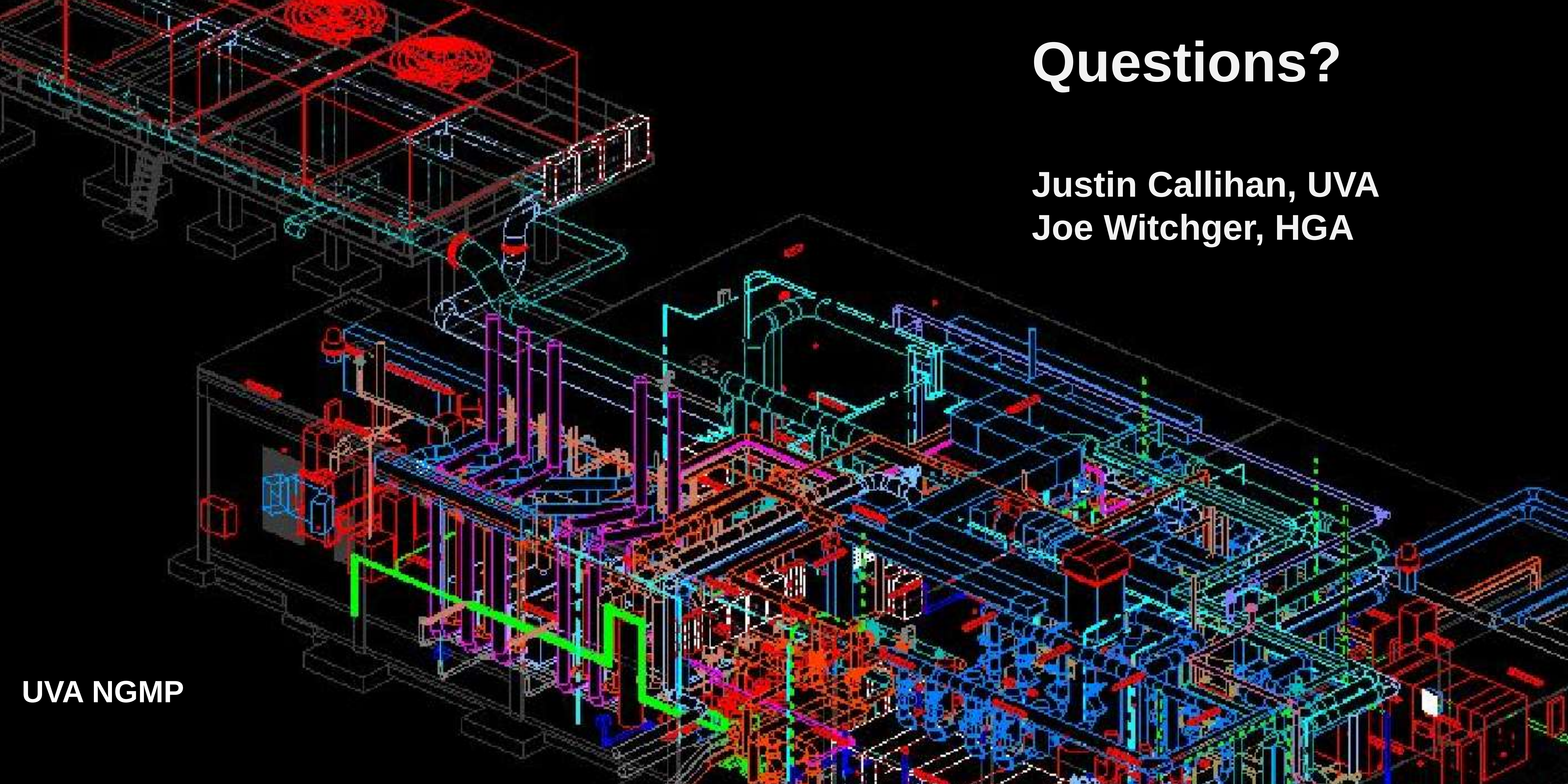
- HR Chillers
  - Not efficient in Cooling Mode
  - Share CDW with HR chillers in Cooling Mode

Controls Opportunities

- Strategy
  - Baseload HR chiller on limiting load
  - Dispatch equipment to serve remainder of load
    - Use All Variable Speed Plant
    - Condensing boilers Efficiently serve remainder of load

Questions?

Justin Callihan, UVA
Joe Witchger, HGA



UVA NGMP