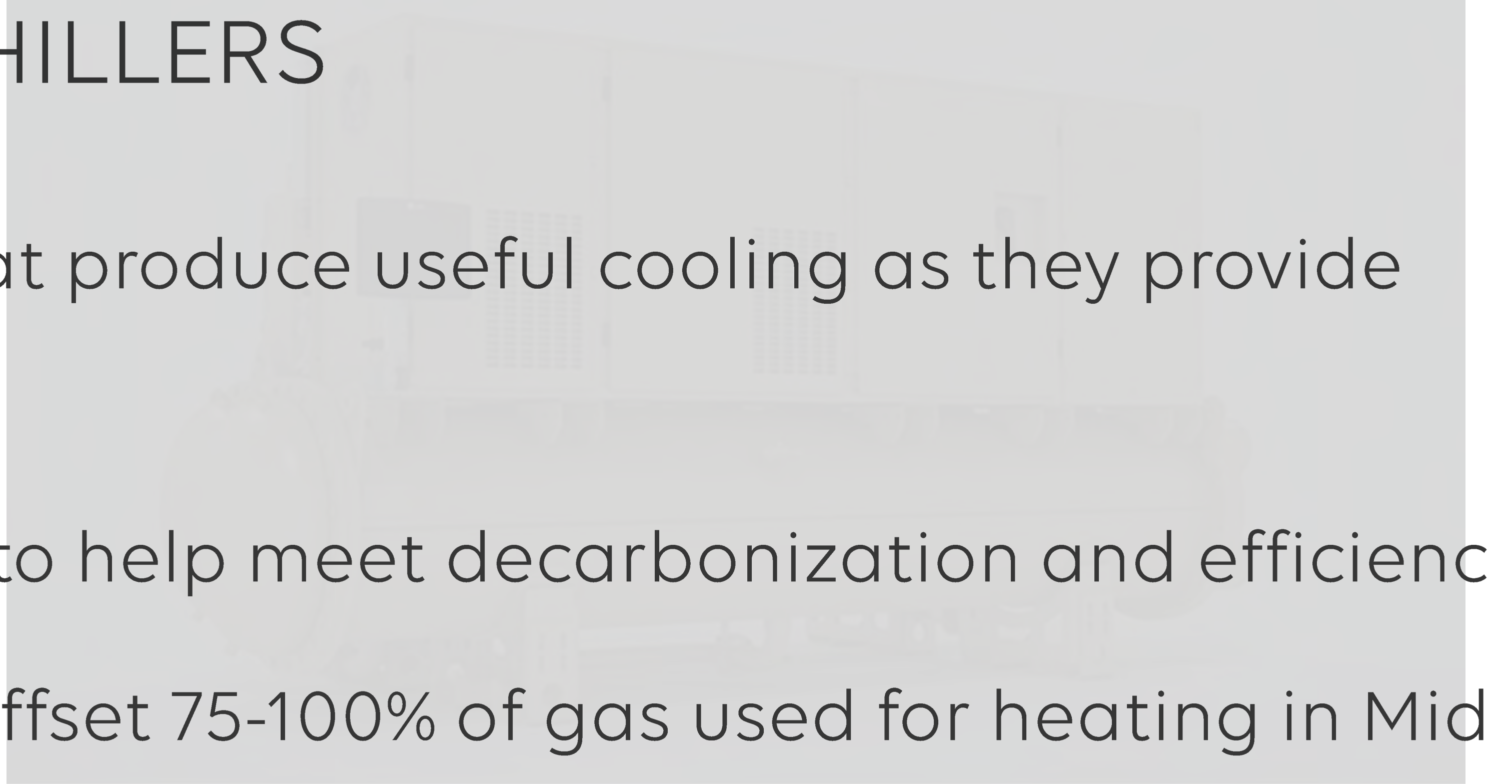
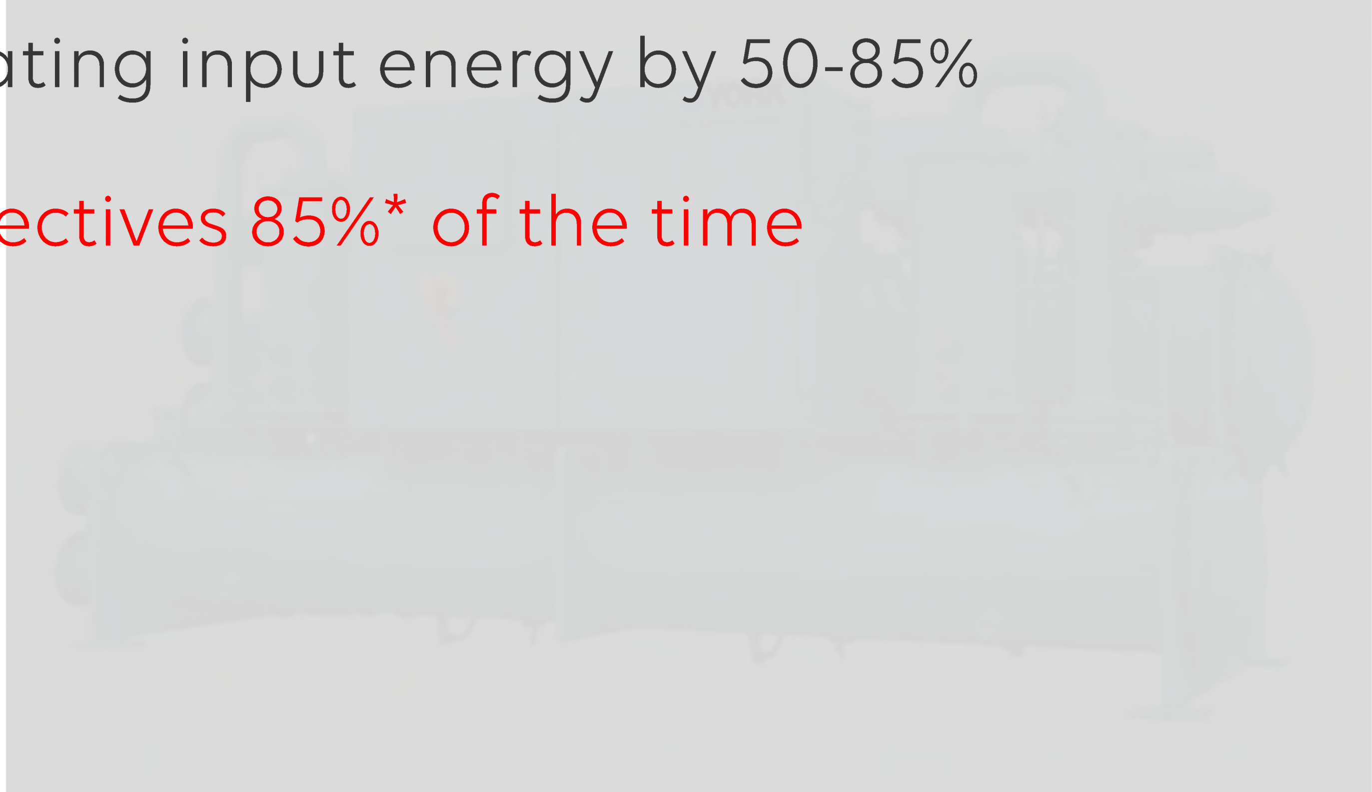
HGA

AVOIDING COMMON PITFALLS WITH HEAT RECOVERY CHILLER APPLICATION

February 13, 2025

HEAT RECOVERY CHILLERS





- Are heating devices that produce useful cooling as they provide heating energy
- Key strategy available to help meet decarbonization and efficiency goals
- Have the potential to offset 75-100% of gas used for heating in Midwest
- In the process reduce heating input energy by 50-85%
- Fail to meet installed objectives 85%* of the time

HEAT RECOVERY CHILLERS

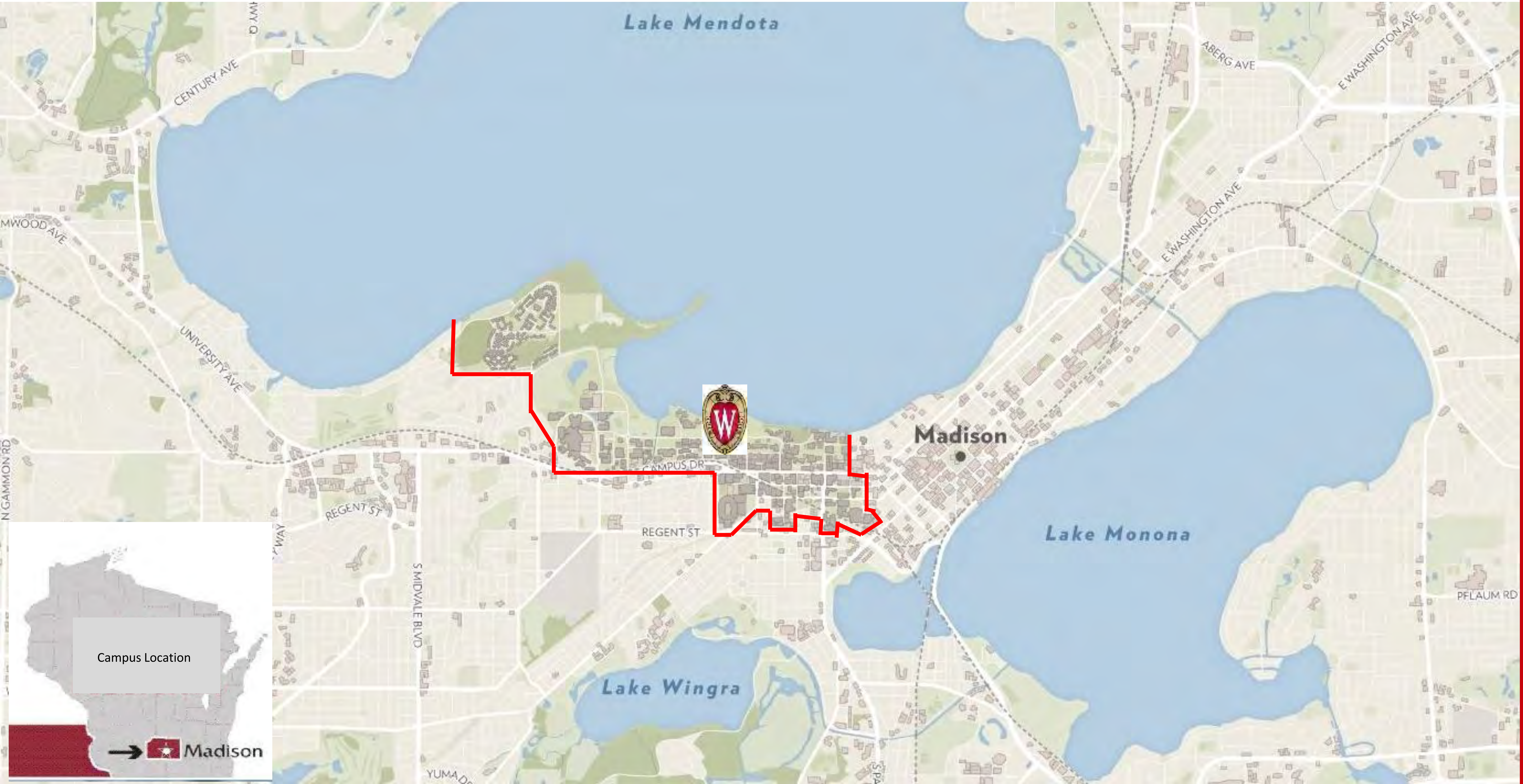
- 2013 – UVA North Grounds Mechanical Plant
- After First year of Operation Recorded savings (Cheryl Gomez Quote 48% reduction in energy use)
  - Cond boilers, Predictively Optimized New Chiller Plant and Heat recovery chillers
  - Success depended on the coincidentality of Native heating and cooling loads
  - Introduced the fundamental concepts of Condenser Ratio, Engageable Load Ratio, Achievable Load ratio and ELR efficiency

- MetroHealth Cleveland Ohio
  - First project where FHRE was designed into the campus from the start
- After First Year of Operation…

HEAT RECOVERY CHILLERS

- At UW 2019-2022
- Used Predictive Optimization Process – No Capital projects
- Reduced Costs by $1,400,000 annual normalized to 2018 loading
  - Not every recommendation was fully implemented
  - Benefitted from Utility cost increases

UNIVERSITY OF WISCONSIN-MADISON LOCATION



UNIVERSITY OF WISCONSIN-MADISON

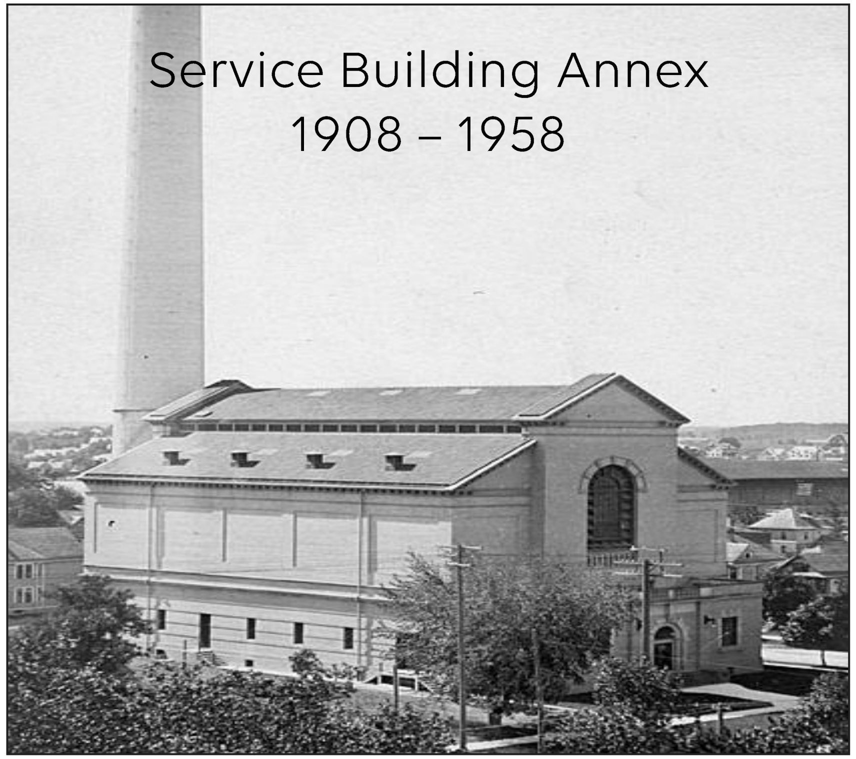
- Founded in 1848 as Wisconsin's land-grant University
- 939-acre main campus (including 300-acre Lakeshore Nature Preserve)
- Largest landowner on Lake Mendota with 4 miles of lakefront
- 9,649 acres statewide including agricultural research stations, experimental farms, arboretum lands and other off-campus properties
- Over 52,097 students, 26,755 faculty & staff (78,852 total), 490,780 living alumni
- $4.0 billion annual operating budget
- Ranked 6th nationally in research funding ($1.7 billion)
- Over 24 million GSF of conditioned space, increased 19.8% from 2005
- State Energy Report - Energy Reduction using 2005 (base year) to 2023 data
    - Campus Energy (BTU/GSF) Reduction of 29.9% (Thermal Reduction=37.1%, Electric Reduction=6.1%)
    - Campus CO2e Emission (lb/GSF) Reduction of 51.7% (Coal → NG Conversion in 2013)

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


Radio Hall
1885 – 1908


Ag Bulletin 1899 – 1937


Service Building Annex
1908 – 1958

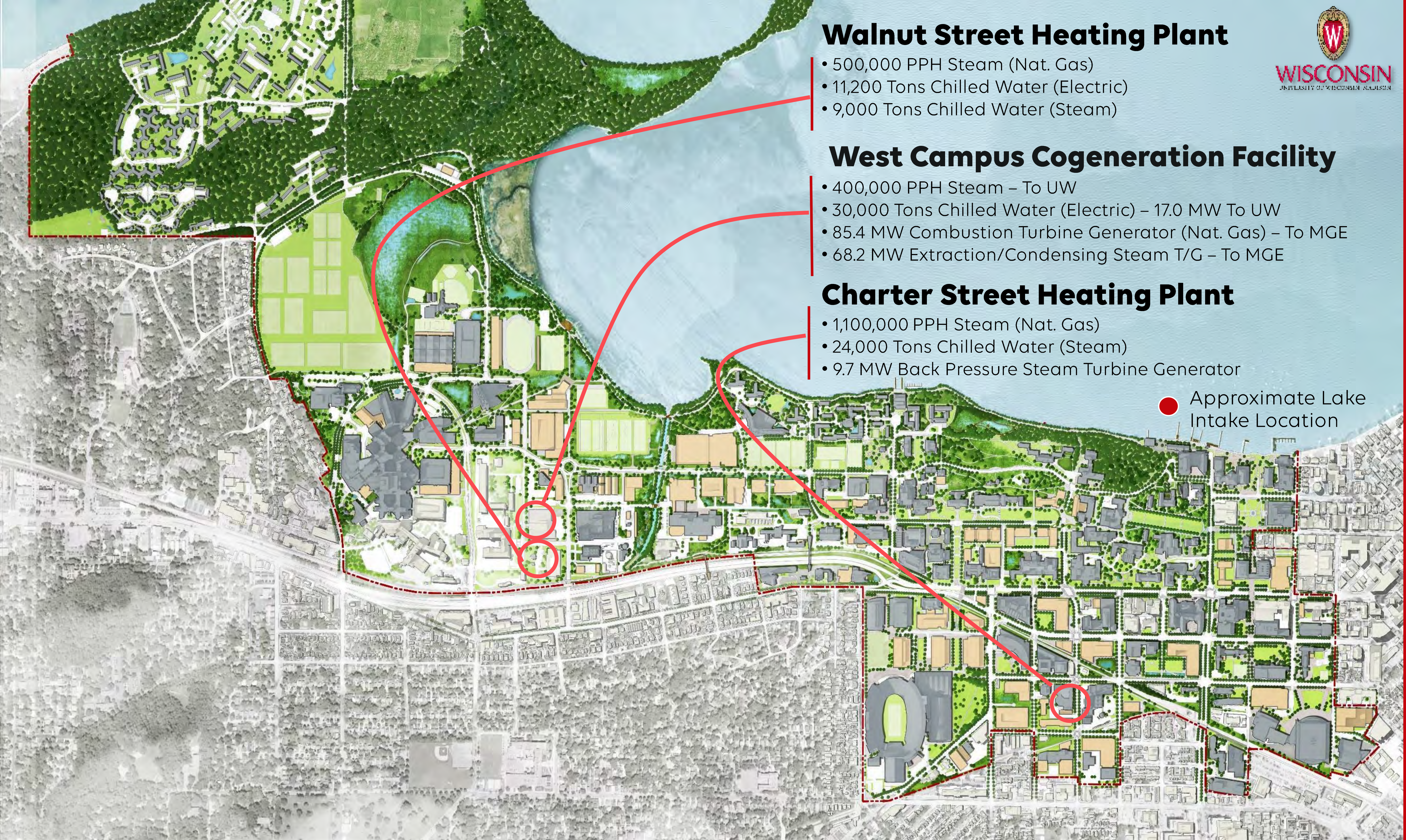
UW-MADISON CAMPUS UTILITY SUMMARY

- Steam
  - 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
  - 74,000 Tons Total (Installed)
  - **66,000 Tons Firm** (Less Largest Unit)
  - 64,000+ Tons Peak (Historical Max)
  - **62,250 Tons Peak** (Aug 2023)
- Electrical
  - **88.7 MW Peak (Aug 2013 Max)**
  - 82.6 MW Peak (Sep 2016)
  - 84.2 MW Peak (Aug 2023)


Charter St
H&C Plant


Walnut St
H&C Plant


West Campus
Cogeneration
Facility



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

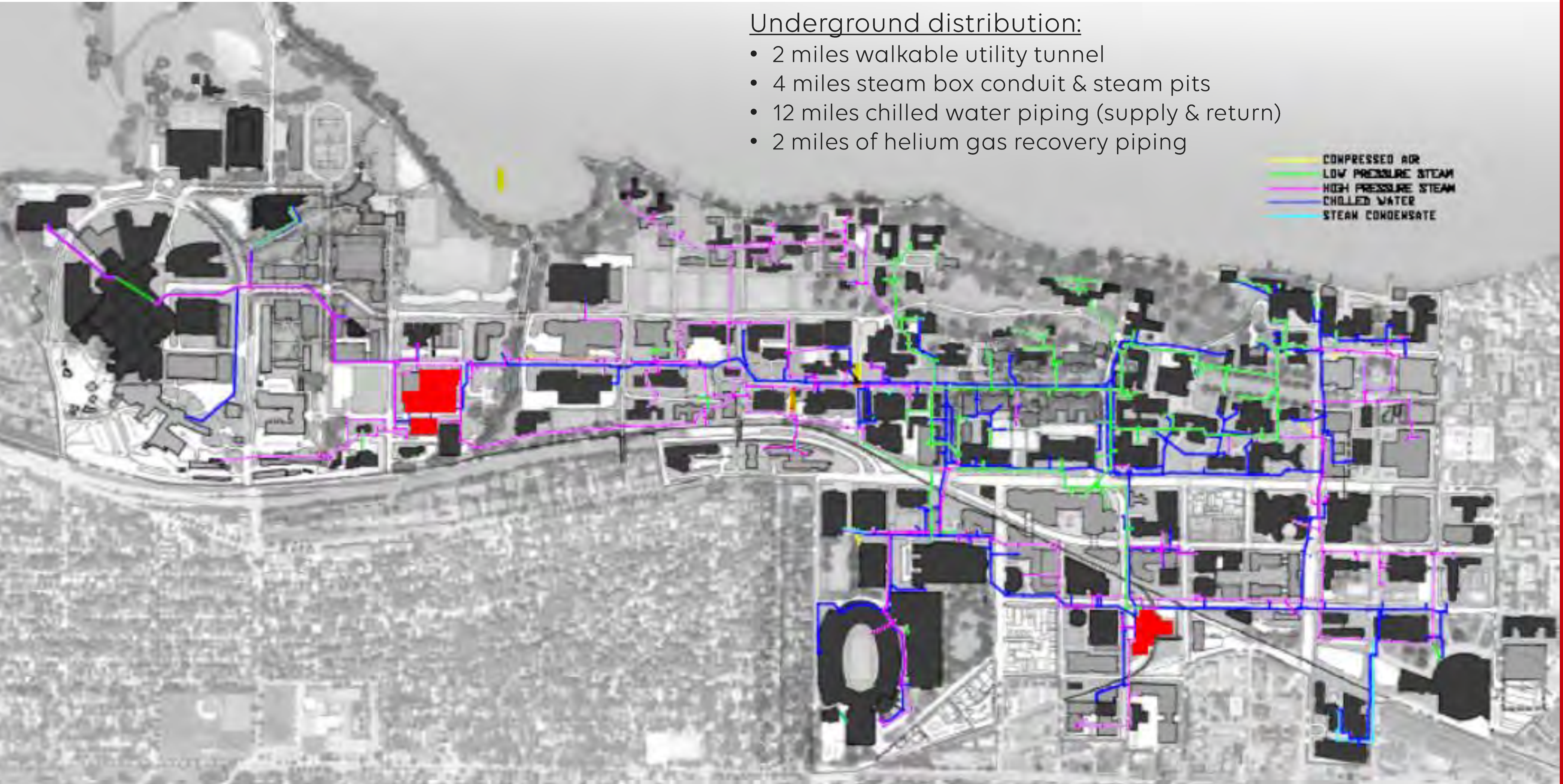
- 400,000 PPH Steam – To UW
- 30,000 Tons Chilled Water (Electric) – 17.0 MW To UW
- 85.4 MW Combustion Turbine Generator (Nat. Gas) – To MGE
- 68.2 MW Extraction/Condensing Steam T/G – To MGE

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

UW-MADISON COMPOSITE UTILITY DISTRIBUTION

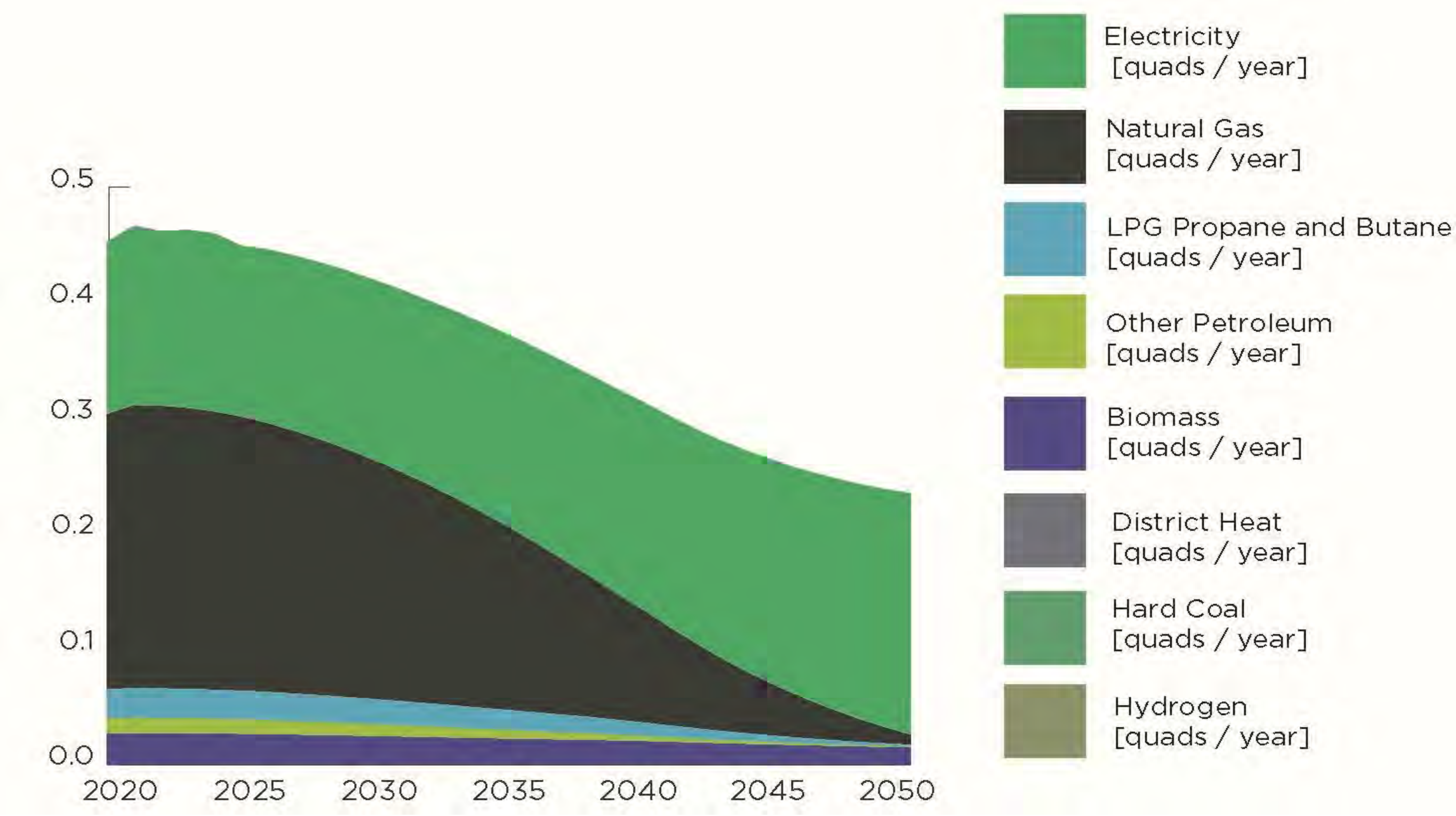


Underground distribution:

- 2 miles walkable utility tunnel
- 4 miles steam box conduit & steam pits
- 12 miles chilled water piping (supply & return)
- 2 miles of helium gas recovery piping

DECARBONIZATION GOALS

State of Wisconsin Energy Plan – Carbon Free by 2050
UW-Madison - Net-zero by 2048 and 100% Renewable Electric by 2030
MGE - 80% Renewable Goal by 2030, 100% Net-zero by 2050



MGE® Madison Gas and Electric
2050 Net-Zero Carbon

CHALLENGES WITH HEAT RECOVERY CHILLERS

1. **UW spent the last 100 years centralizing our steam and chilled water systems to meet Campus Mission Statement of centralized utilities**
2. Campus maximizes the overall system efficiencies as it relates to budget & manpower issues
3. **HRC systems are more complicated to maintenance staff**
4. Limited budgets affect aging building infrastructure and finite amount of maintenance staff
5. **The people making commitments (design stage) do not understand what it takes to execute them (operational stage)**
6. **Maintenance staff is less technical than in past to do the work and maintain systems**
7. Add maintenance equipment, trucks, tools and vehicles for service runs
8. **Proprietary controls for chiller and buildings, who will diagnose during issues**
9. Chillers and pumps bring noise into the buildings
10. **Existing buildings have minimal “extra” space for new equipment**
11. **Building electrical infrastructure may not be able to handle the load**
12. **Continuous running equipment shortens the life of the chiller when operating at machine limits**
13. **We have tried HRCH in the past and each one has been a failure → we have “shut them down”**

CHALLENGES WITH HEAT RECOVERY CHILLERS

15. Infrastructure, Operational and budget issues
16. **Distributed maintenance and costs are system user, if not a whole building HRC. Facilities operates, utilities maintains, user installs and (hopefully) replaces**
17. Replacement cost of chillers
18. **Buildings are designed for steam convertors – 180°F supply water, HRC is 140°F (highest)**
19. Midwest seasons affect run time and operation (controls, increasing ELR efficiency)
20. **Redundancy required for research buildings – no interruptions of utility service expected**
21. Required redundancy has connection to campus thermal piping – when do we switch over?
22. **Control sequences are not consistent between the installed systems**
23. Automation and who is in "control" (building maintenance or campus facilities, local overrides of controls) (operational and controls)
24. **AE firms design the systems with different heat rejection ideas (geothermal, CHW system, air-air)**

CHALLENGES WITH HEAT RECOVERY CHILLERS

26. **Improper tie into CHW system (building and campus)**
27. **Turndown issues (equipment is oversized by AE)**
28. Pumping issues
29. Building heating and cooling loads do not match or align to equipment output
30. Seasons affect duration of heating and cooling requirements
31. Limited mechanical room available area for equipment
32. **Limited equipment use shortens equipment life**
33. **Commercial-grade equipment (scrolls)**
34. Number of compressors
35. **Compressors operate near the critical temperature/pressure**
36. Noise and vibration to building
37. Temperature limitations
38. Vibration failures of screws

CHALLENGES WITH HEAT RECOVERY CHILLERS

These challenges can be broken out into five categories:

1. Organizational and Budget –Universities
2. Maintenance – Universities and Equipment Manufacturers
3. Building Selection – Universities and Engineers
4. Equipment Selection & System Design – Engineers
5. Controls – Engineers, University, Equipment Manufacturers, Installers

ORGANIZATIONAL AND BUDGET

Universities

1. UW spent the last 100 years centralizing our steam and chilled water systems to meet Campus Mission Statement of centralized utilities
2. Campus maximizes the overall system efficiencies as it relates to budget & manpower issues
3. Distributed maintenance and costs are system user, if not a whole building HRC. Facilities operates, utilities maintains, user installs and (hopefully) replaces
4. Replacement cost of chillers
5. Infrastructure, Operational and budget issues
6. Automation and who is in “control” (building maintenance or campus facilities, local overrides of controls)
7. AE firms design the systems with different heat rejection ideas (geothermal, CHW system, air-air)
8. We have tried HRCH in the past and each one has been a failure → we have “shut them down”

MAINTENANCE

Universities & Equipment Manufacturers

9. HRC systems are more complicated to maintenance staff
10. Limited budgets affect aging building infrastructure and finite amount of maintenance staff
11. The people making commitments (design stage) do not understand what it takes to execute them (operational stage)
12. Maintenance staff is less technical than in past to do the work and maintain systems
13. Add maintenance equipment, trucks, tools and vehicles for service runs
14. Proprietary controls for chiller and buildings, who will diagnose during issues

BUILDING SELECTION

Universities and Engineers

15. Chillers and pumps bring noise into the buildings
16. Existing buildings have minimal “extra” space for new equipment
17. Building electrical infrastructure may not be able to handle the load
18. Research buildings require redundancy for resiliency and happy customer
19. Redundancy required for research buildings – no interruptions of utility service expected
20. Building heating and cooling loads do not match or align to equipment output
21. Limited mechanical room available area for equipment
22. Noise and vibration to building
23. Electrical building infrastructure needs

EQUIPMENT SELECTION AND SYSTEM DESIGN

Engineers

24. Continuous running equipment shortens the life of the chiller when operating at machine limits
25. Improper tie into CHW system (building and campus)
26. Turndown issues (equipment is oversized by AE)
27. Pumping issues
28. Seasons affect duration of heating and cooling requirements
29. Limited equipment use shortens equipment life
30. Commercial-grade equipment (scrolls)
31. Number of compressors
32. Compressors operate near the critical temperature/pressure
33. Temperature limitations
34. Vibration failures of screws

CONTROLS

Engineers, University, Equipment Manufacturers, Installers

35. Buildings are designed for steam convertors – 180°F supply water, HRC is 140°F (highest) (selection and controls)
36. Midwest seasons affect run time and operation (controls, increasing ELR efficiency)
37. Control sequences are not consistent between the installed systems
38. Required redundancy has connection to campus thermal piping – when do we switch over?

ENGAGEABLE LOAD RATIO

Function of Building & AHU Systems

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

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

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

ACHIEVABLE LOAD RATIO

Function of Equipment

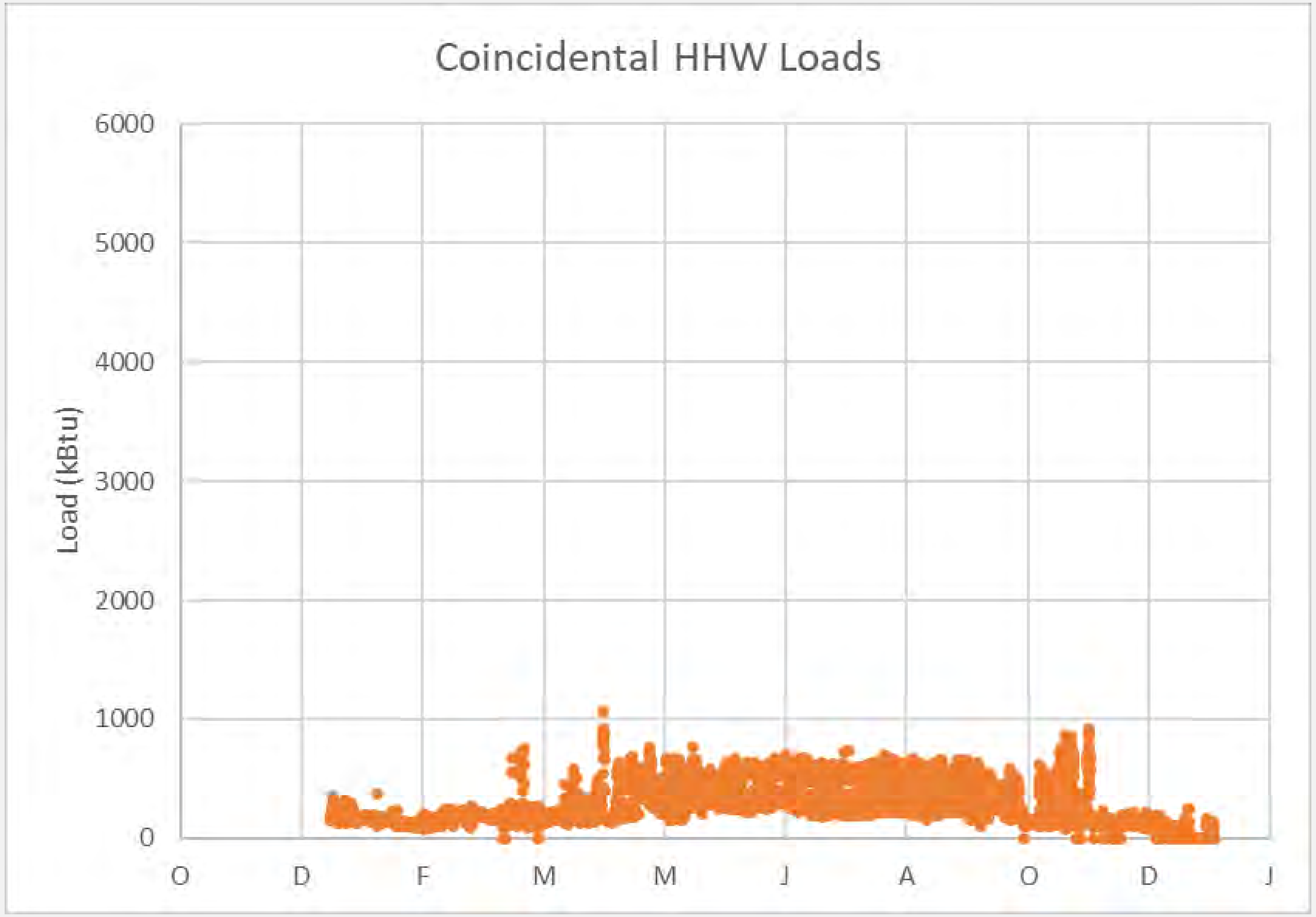
$$\text{Achievable Load Ratio (ALR)} = \frac{\text{Achievable Engaged Thermal Load}}{\text{Total Thermal Load}}$$

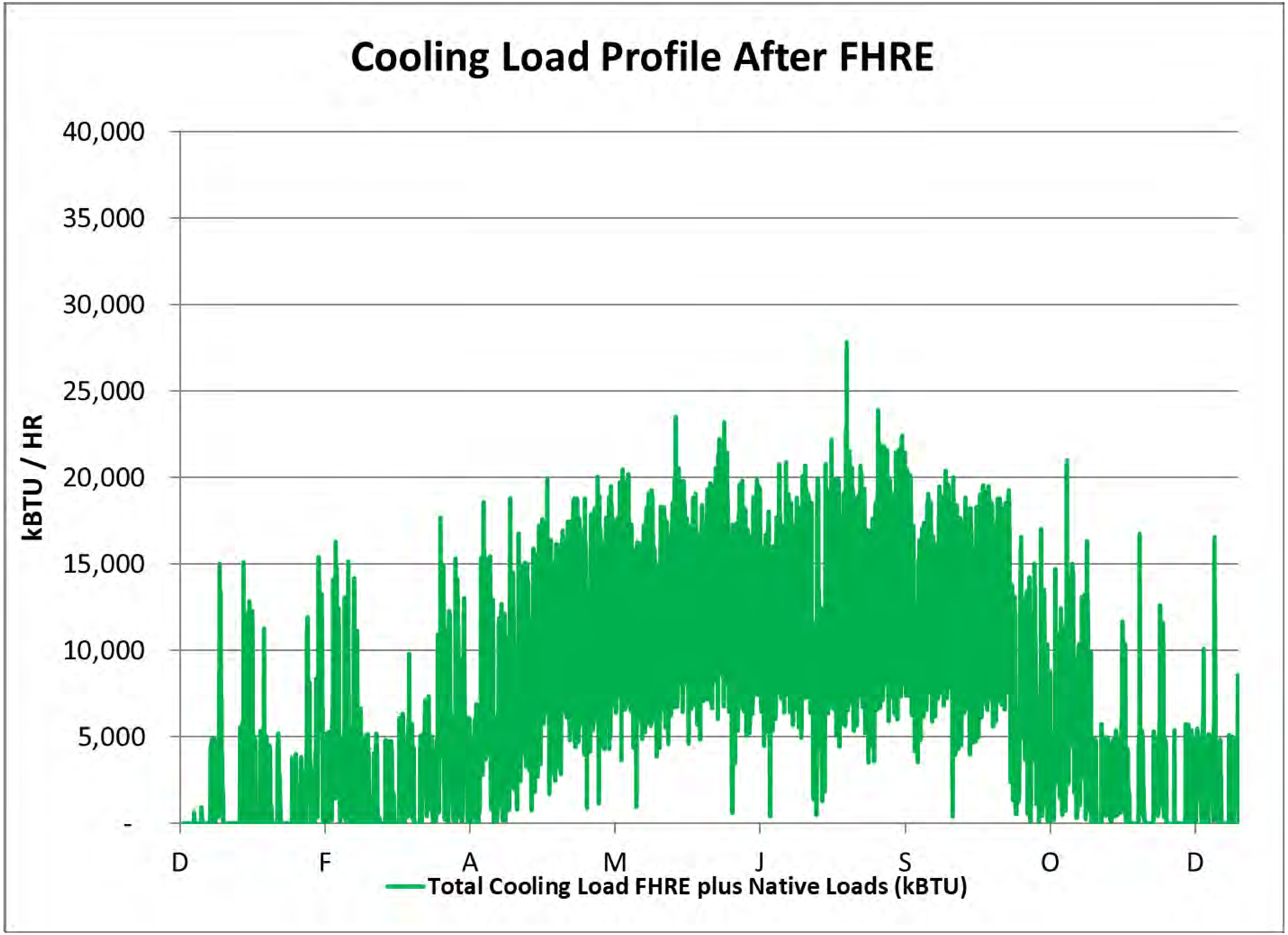
$$\text{Heating Achievable Load Ratio (ALRh)} = \frac{\text{Achievable Engaged Heating Load}}{\text{Total Heating Load}}$$

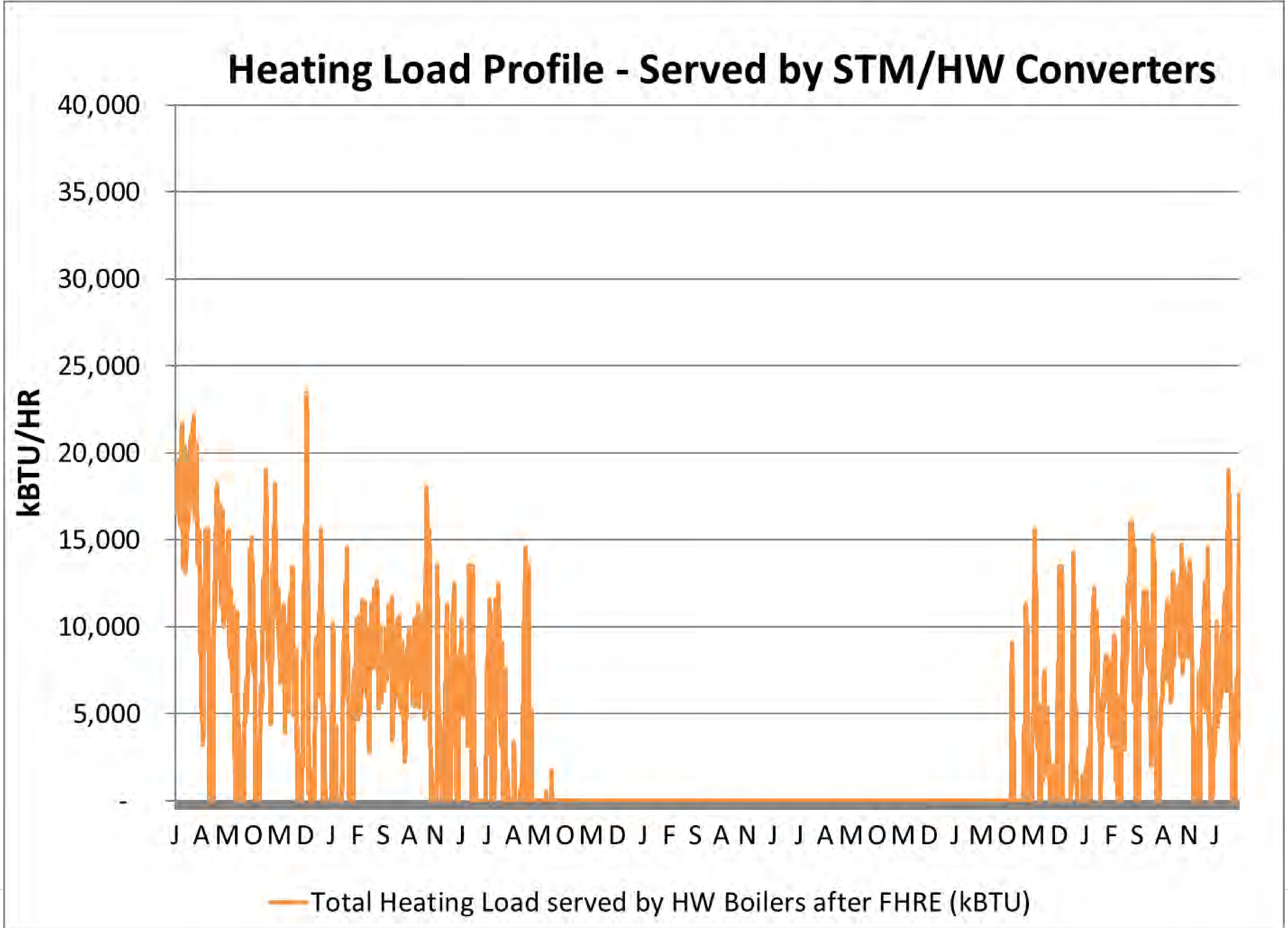
$$\text{Cooling Achievable Load Ratio (ALRc)} = \frac{\text{Achievable Engaged Cooling Load}}{\text{Total Cooling Load}}$$

BUILDING SELECTION

Coincidentality




Cooling Load Profile After FHRE
kBTU / HR
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
D
F
A
M
J
S
O
D
Total Cooling Load FHRE plus Native Loads (kBTU)


Heating Load Profile - Served by STM/HW Converters
kBTU/HR
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
J A M O M D J F S A N J J A M O M D J F S A N J J A M O M D J M O M D J F S A N J
Total Heating Load served by HW Boilers after FHRE (kBTU)

HEAT RECOVERY CHILLERS

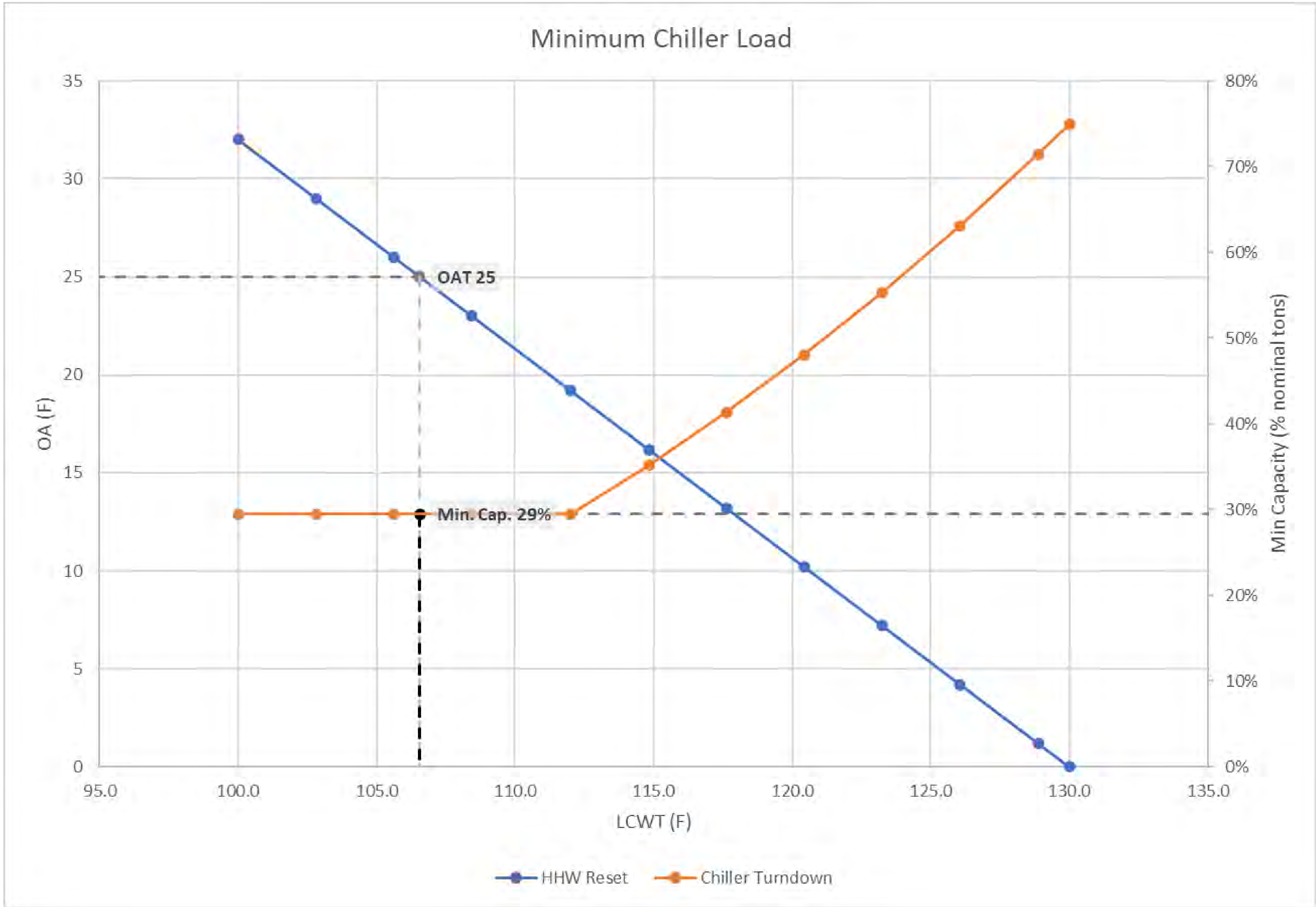
- Modular Scroll
  - Staged turndown
    - o Pro: Can handle low loads
    - o Con: Temperature cycling
  - R-410A / R-454B
    - High Pressure
      - o 140°F = 540psig

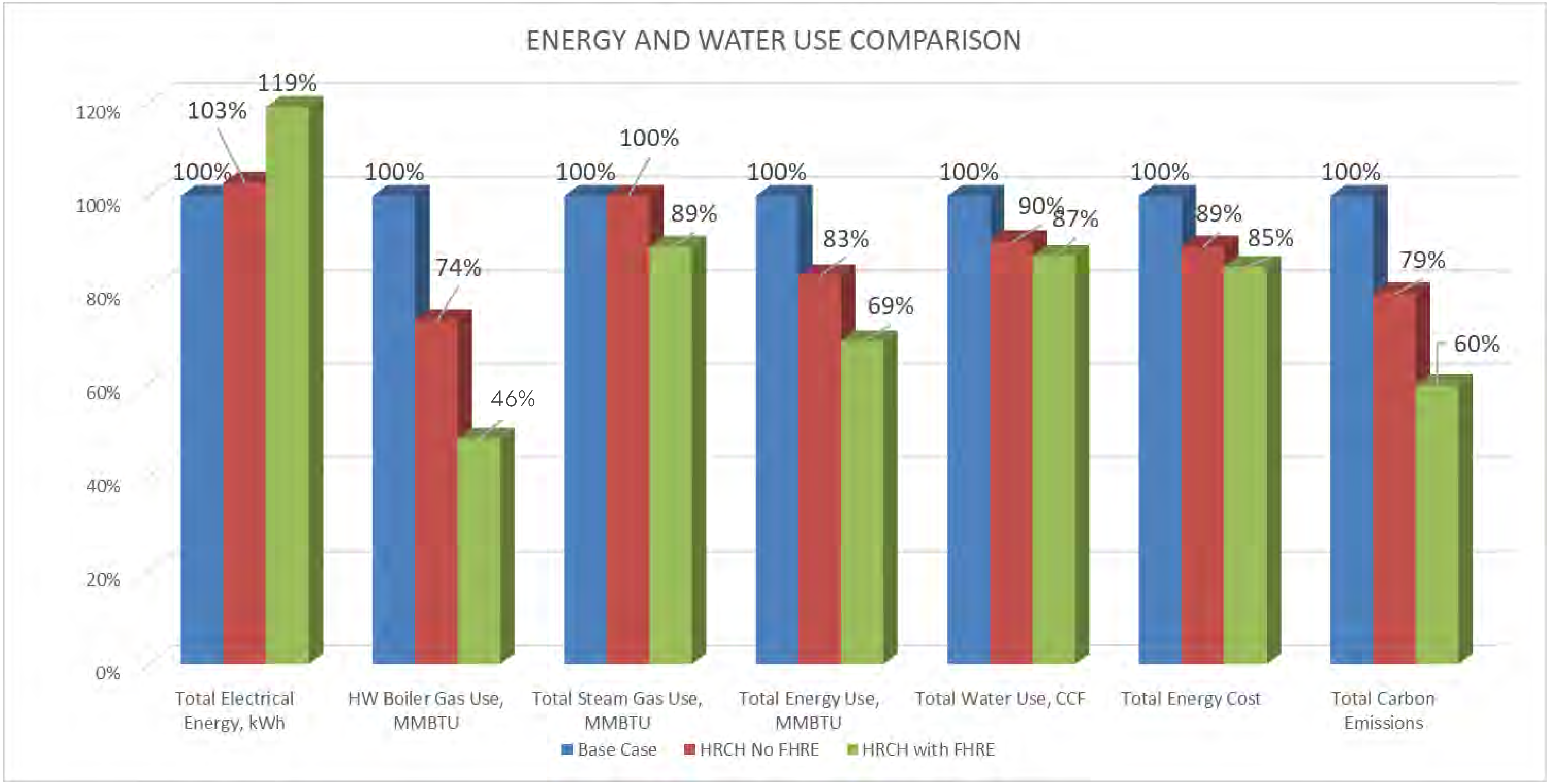
HEAT RECOVERY CHILLERS

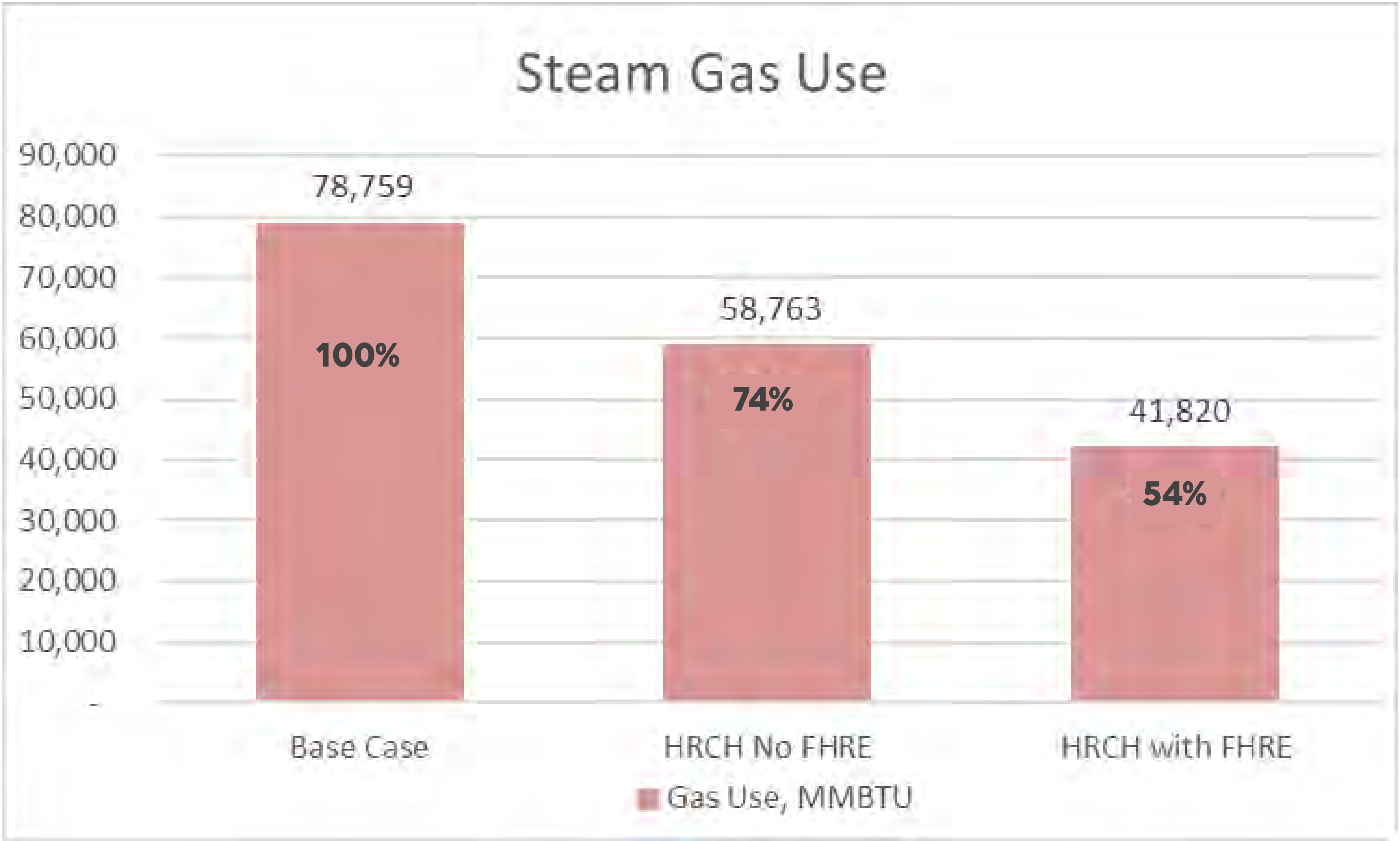
- Screw
  - Temperature capabilities from 145°F up to 170°F
  - Turndown to ~50%
  - Vibration
    - Noise
    - Component Failure
  - R-134a / R-513a

HEAT RECOVERY CHILLERS

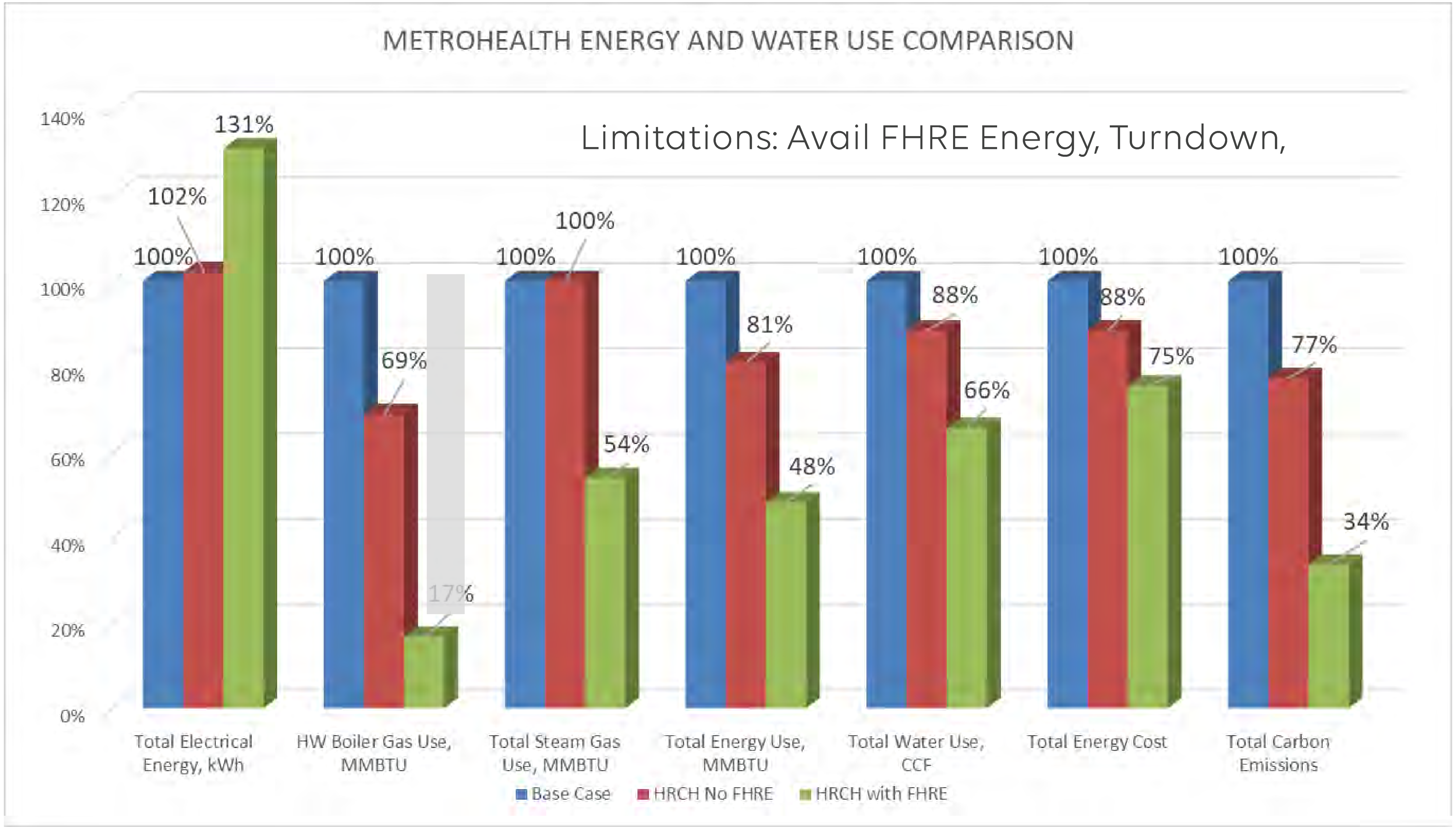
- Centrifugal
  - Low Lift (Max Temp ~120°F)
    - Can be installed/sold in series
  - Quieter & efficient operation
  - Poor turndown – example below
  - R-123 / R-1233zd


Minimum Chiller Load
OA (F)
Min Capacity (% nominal tons)
LCWT (F)
35
30
25
20
15
10
5
0
80%
70%
60%
50%
40%
30%
20%
10%
0%
95.0
100.0
105.0
110.0
115.0
120.0
125.0
130.0
135.0
OAT 25
Min. Cap. 29%
HHW Reset
Chiller Turndown


ENERGY AND WATER USE COMPARISON
120%
100%
80%
60%
40%
20%
0%
100%
103%
119%
100%
74%
46%
100%
100%
89%
100%
83%
69%
100%
90%
87%
100%
89%
85%
100%
79%
60%
Total Electrical Energy, kWh
HW Boiler Gas Use, MMBTU
Total Steam Gas Use, MMBTU
Total Energy Use, MMBTU
Total Water Use, CCF
Total Energy Cost
Total Carbon Emissions
Base Case
HRCH No FHRE
HRCH with FHRE

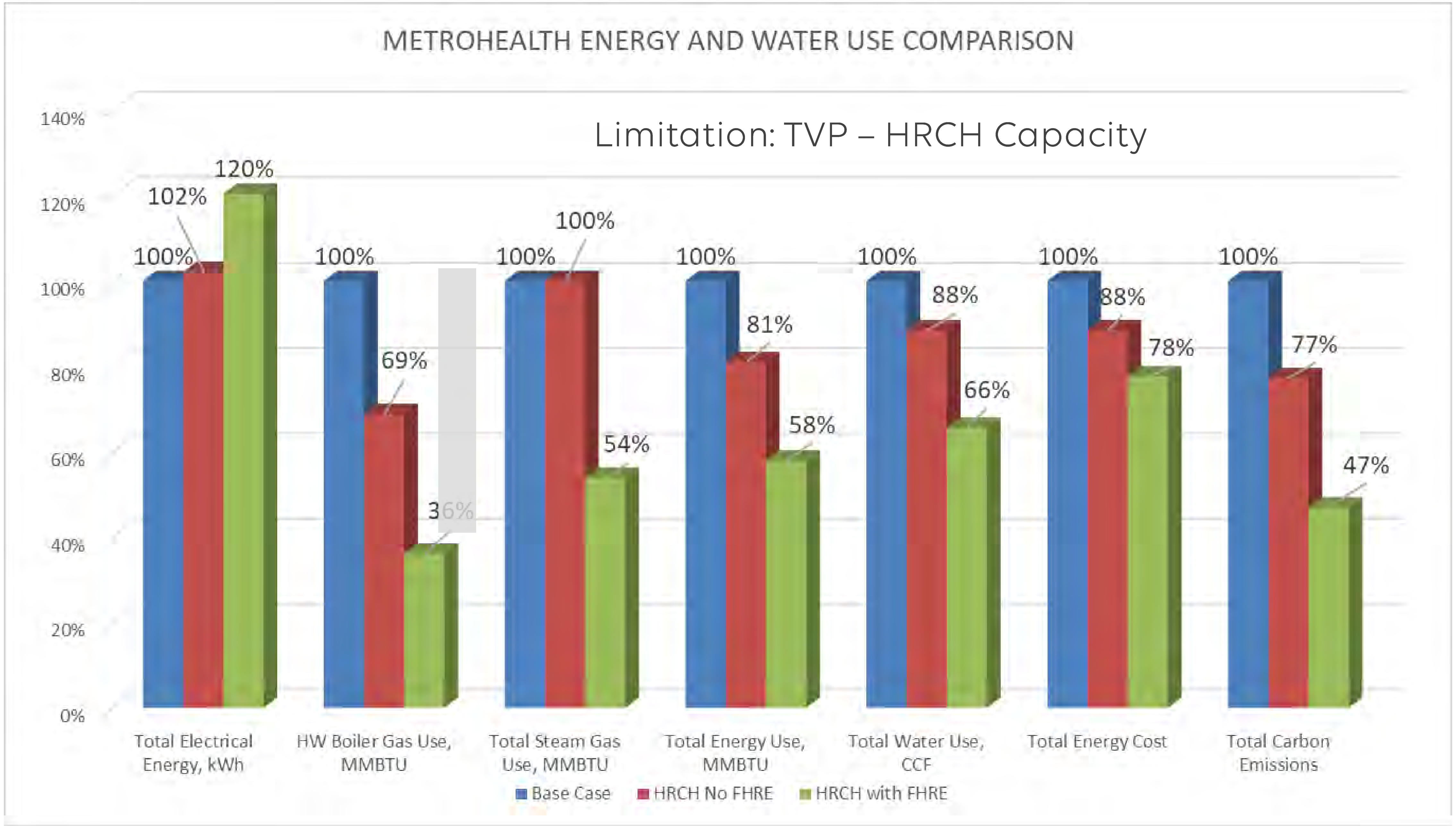

Steam Gas Use
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
78,759
100%
58,763
74%
41,820
54%
Base Case
HRCH No FHRE
HRCH with FHRE
Gas Use, MMBTU

INTENDED ACHIEVABLE HEATING LOAD RATIO:83%
ηELR= 92%



Limitations: Avail FHRE Energy, Turndown,

ACTUAL ACHIEVABLE HEATING LOAD RATIO: 64%
ηELR =71.1%



COMMON PITFALLS

- The number of HRCH systems abandoned or underperforming is a very significant percentage of the Systems involved. Designs reveal not well understood by designers or engineers - Several reasons for this:
- Running equipment outside its previous design range.
- High lift application limits turndown on all equipment – Smaller eq, can get better turndown at the expense of reliability and temperature capability and temperature control
- Competing approaches:
    1. Focusing on building- making equipment meet Building needs or shut it down, OR
    2. Design system to meet limitations of Equipment (CYA)

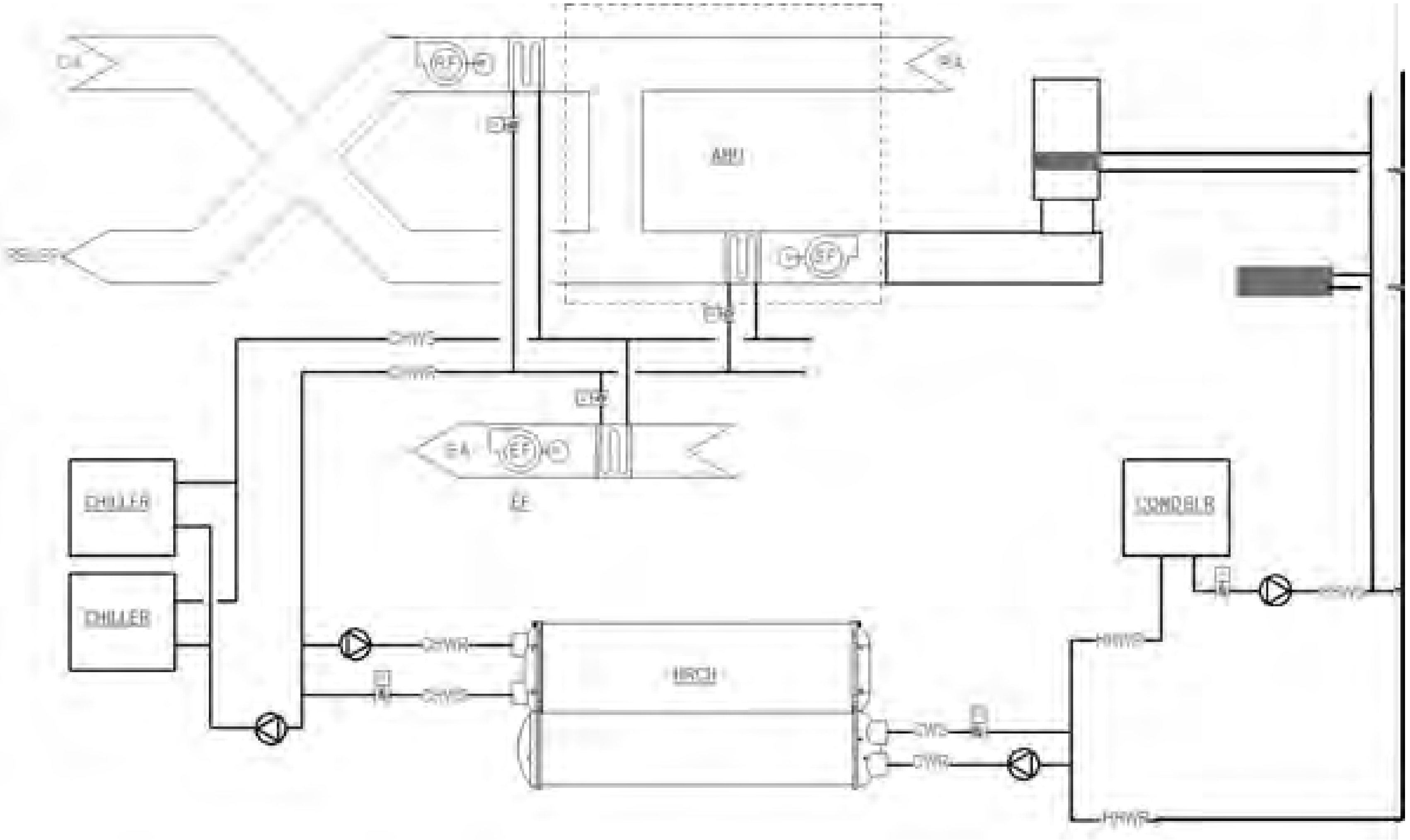
COMMON PITFALLS

- OR System is designed to try to make HRCH work
- Two stage compressors restrict the operating map, result in operating a system to make the chiller run well- a backwards, but sometimes necessary approach
- Resistance by owners, operators considering HRCH as cooling devices
- Good Design of HRCH systems requires understanding of the Equipment limitations- This is why we developed the idea of ALR and ELR efficiency
- HRCH must run proportionately loaded on Condenser and Evap. side (Condenser Ratio)
- The CR changes as function of temperatures and flows
- Machine is limited by lowest load presented (Cooling or Heating and Eq Capacity)
- Failure to respect these limits will cycle off, trip out or damage machine
- This results in stopping and starting, inefficient operation

FULL HEAT RECOVERY ENGAGEMENT (FHRE)

Integrate control of buildings and plant

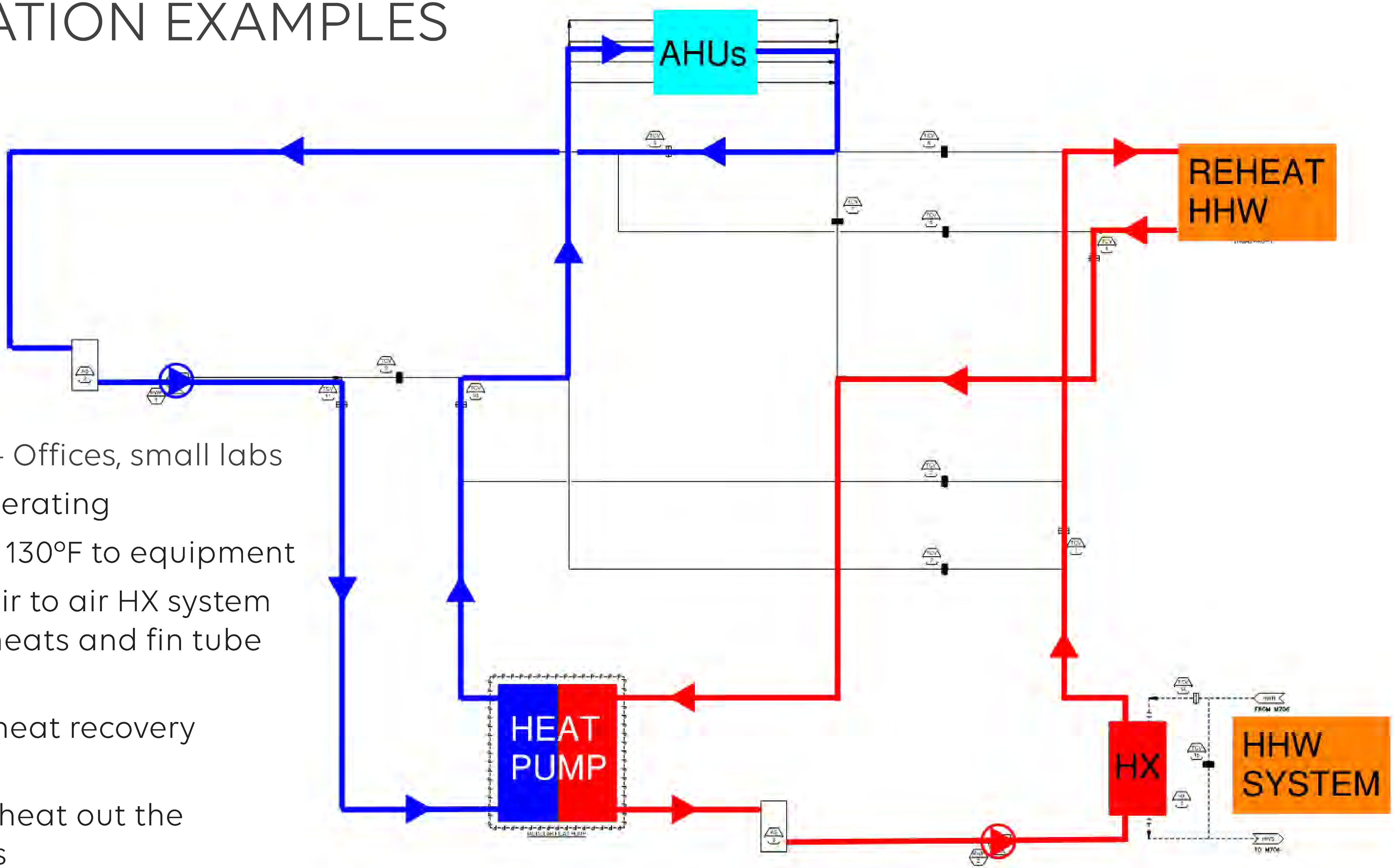
- Two-way communication between plant and AHUs
- Coordinated control of plant and buildings



CHALLENGES OF APPLYING HRCH

1. Running equipment outside its previous design range.
2. High lift application limits turndown on all equipment
3. Competing approaches: Designing to equipment vs buildings
4. Resistance by owners, operators considering HRCH as cooling devices
5. Good Design of HRCH systems requires understanding of the Equipment limitations- This is why we developed the idea of ALR and ELR efficiency

HRCH APPLICATION EXAMPLES



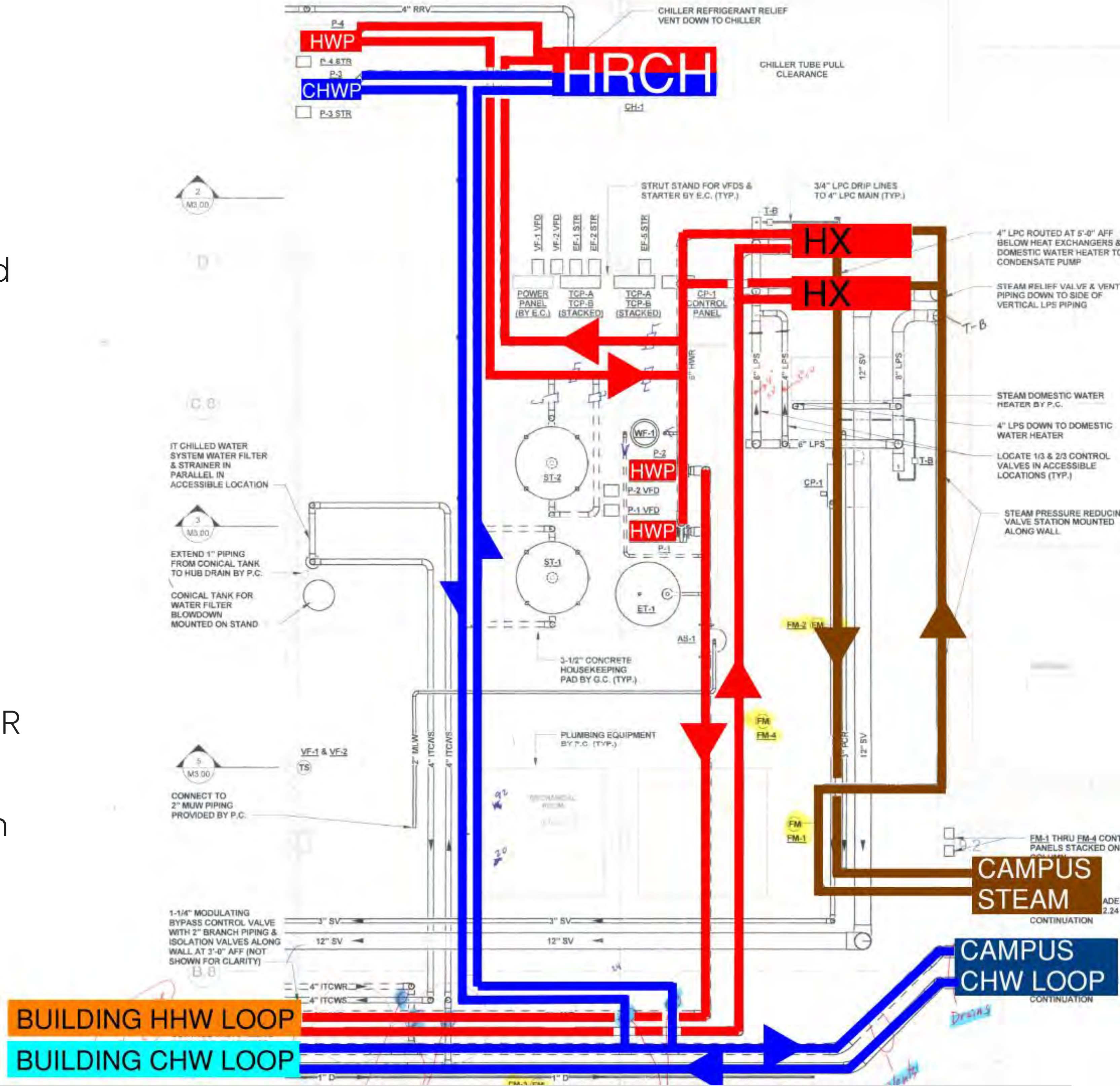
Wisconsin Energy Institute – Offices, small labs

- Installed 2014, still operating
- Building designed at 130°F to equipment
- Adds heat to glycol air to air HX system for reheats, AHU preheats and fin tube systems
- Supplemental to air heat recovery (run-around loops)
- Cooling mode sends heat out the building exhaust fans
- No longer operating

HRCH APPLICATION DEFICIENCIES

School of Nursing – Classroom, small labs dedicated heat recovery

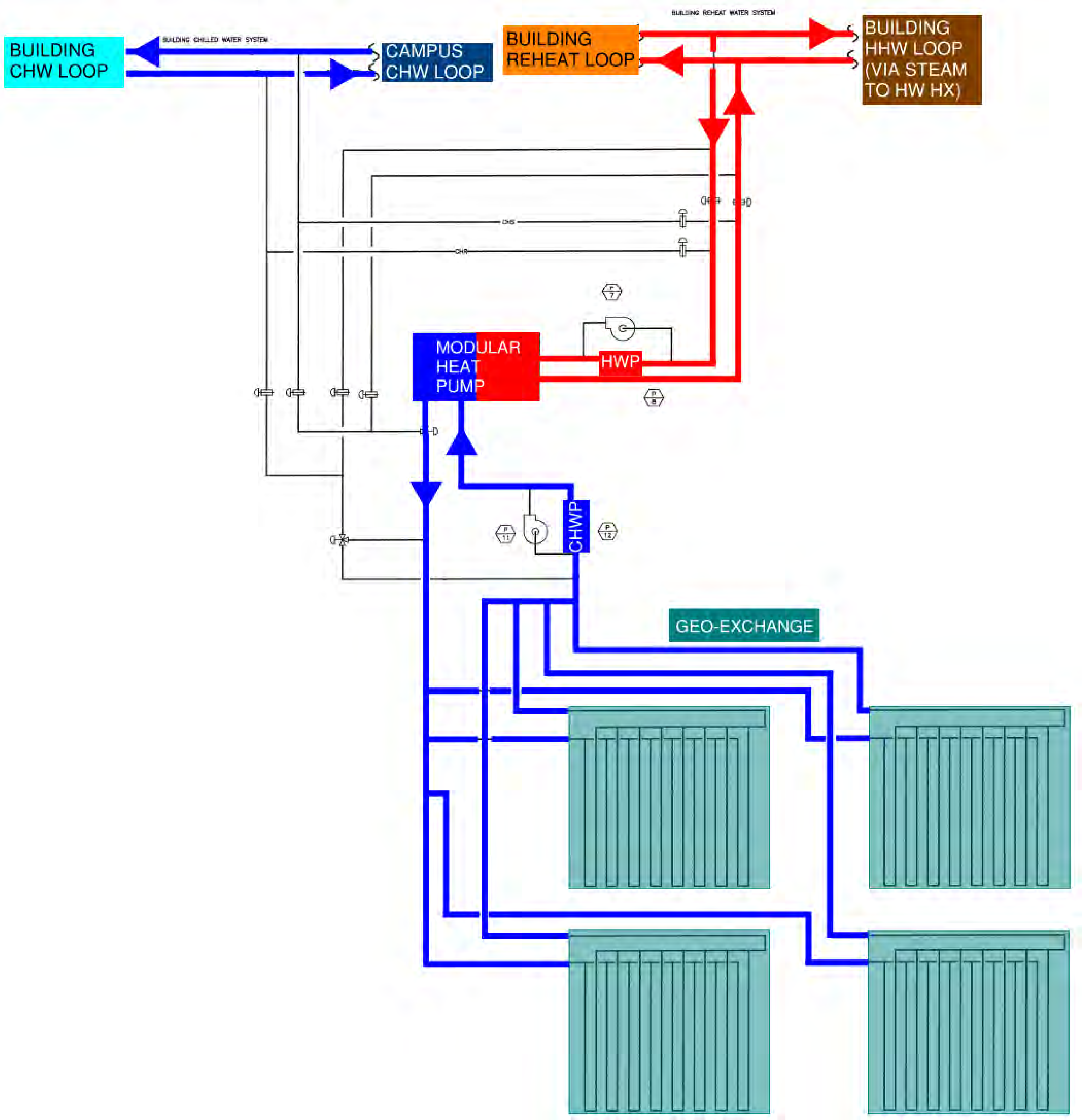
- Installed fall 2014, taken out of service in spring 2016
- Building designed at 140°F for the reheats, AHU preheats and fin tube systems
- 58 ton Chiller LWT of 140°F , JCI/York 410A scroll chiller
- Served portion of the building heating load, evaporator connection is to/from campus CHR system only
- High number of start/stops due to changes in the load profile



HRCH APPLICATION DEFICIENCIES

Wisconsin Institute of Discovery – Labs and classroom

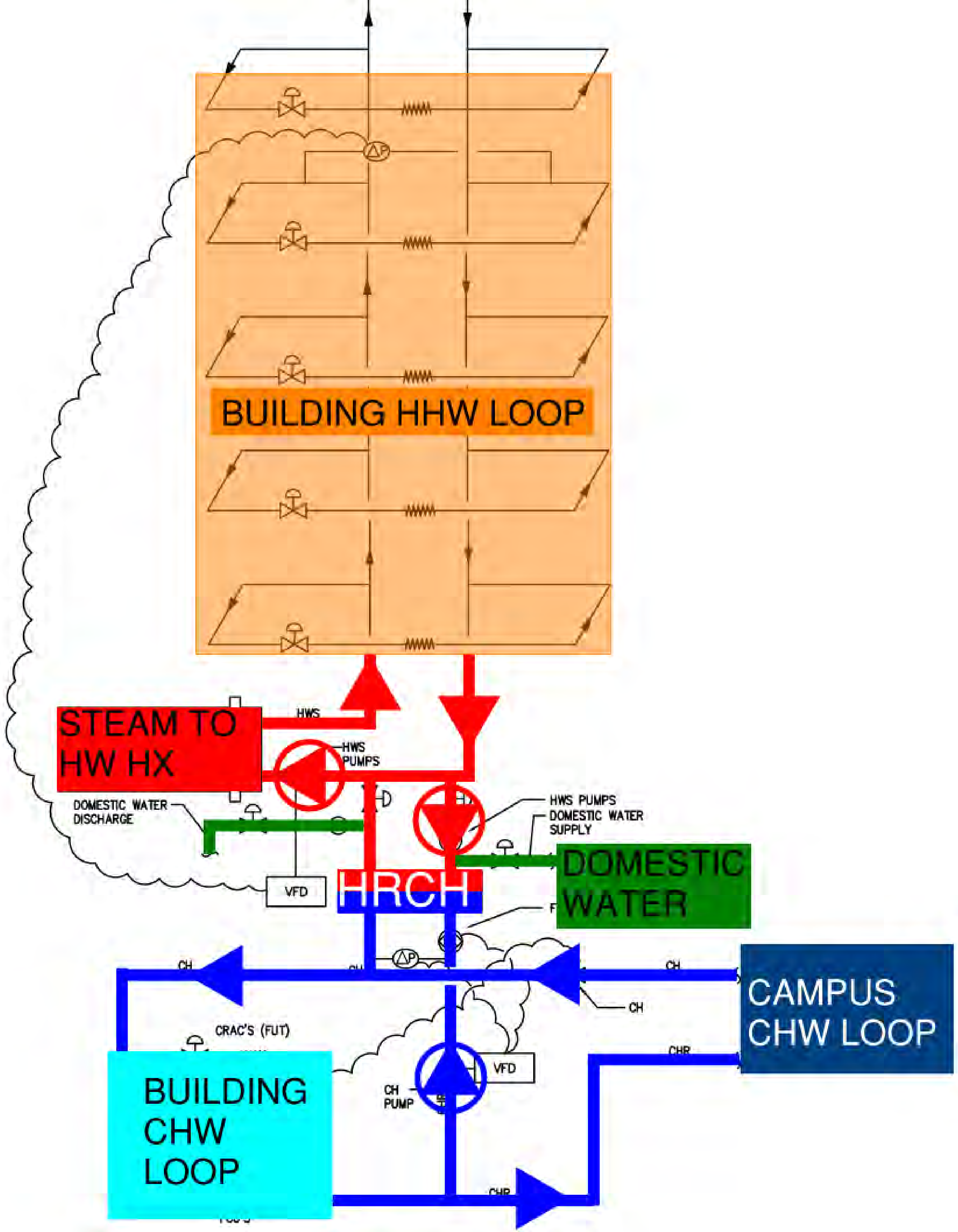
- Installed in 2010, taken out of service in 2014
- Uses Geothermal Wells for Heat input/output
- Not used with simultaneous heating and cooling loads, used as geothermal for a singl mode – heated wells & ground only
- Design and Value Engineering issues with pipe size, different elevations of equipment, geothermal well leakage, etc
- Unbalanced well design
- 16% for a week of full-out for a few hours
- System completely shut down



HRCH APPLICATION DEFICIENCIES

MFCB – Office Building

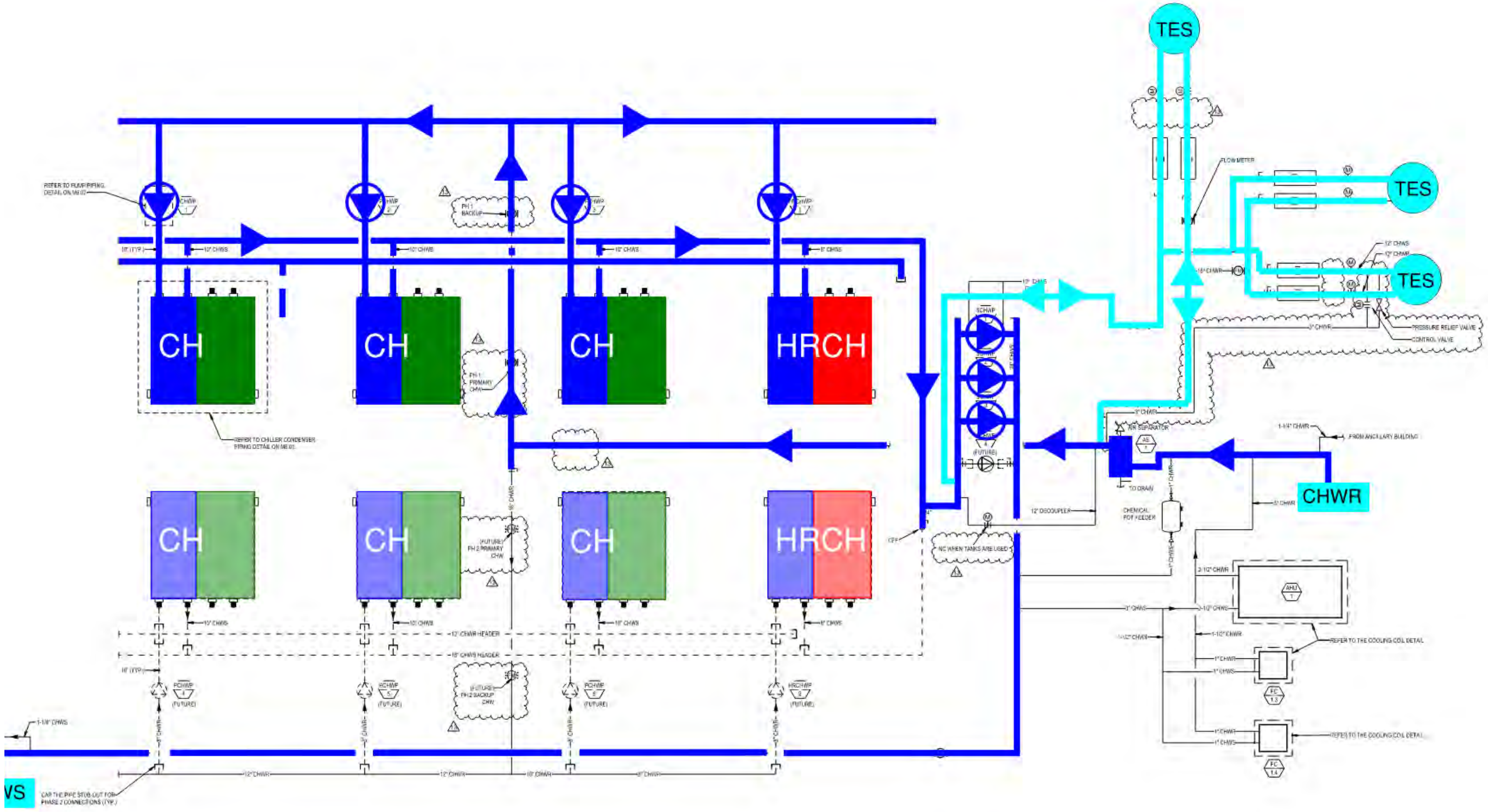
- Originally installed in 2010, taken out of full service in 2013
- 136k GSF Office Building – Building designed at 140°F for the reheats, AHU preheats and fin tube systems
- 93 tons – 4 Multistack scroll compressors
- At 140°F condenser LWT from chiller
- Added City water to condenser side for cooling only unit for IT room. Steady need for CHW due to IT server space
- Currently, HRC used as a backup, if campus CHW system is down
- Evaporator connected to building CHW
- Double deadband (system and equipment); throws off load matching and may trip out equipment, leading to full load going back to steam
- Equipment capacities/steps can lead to frequent loading and unloading

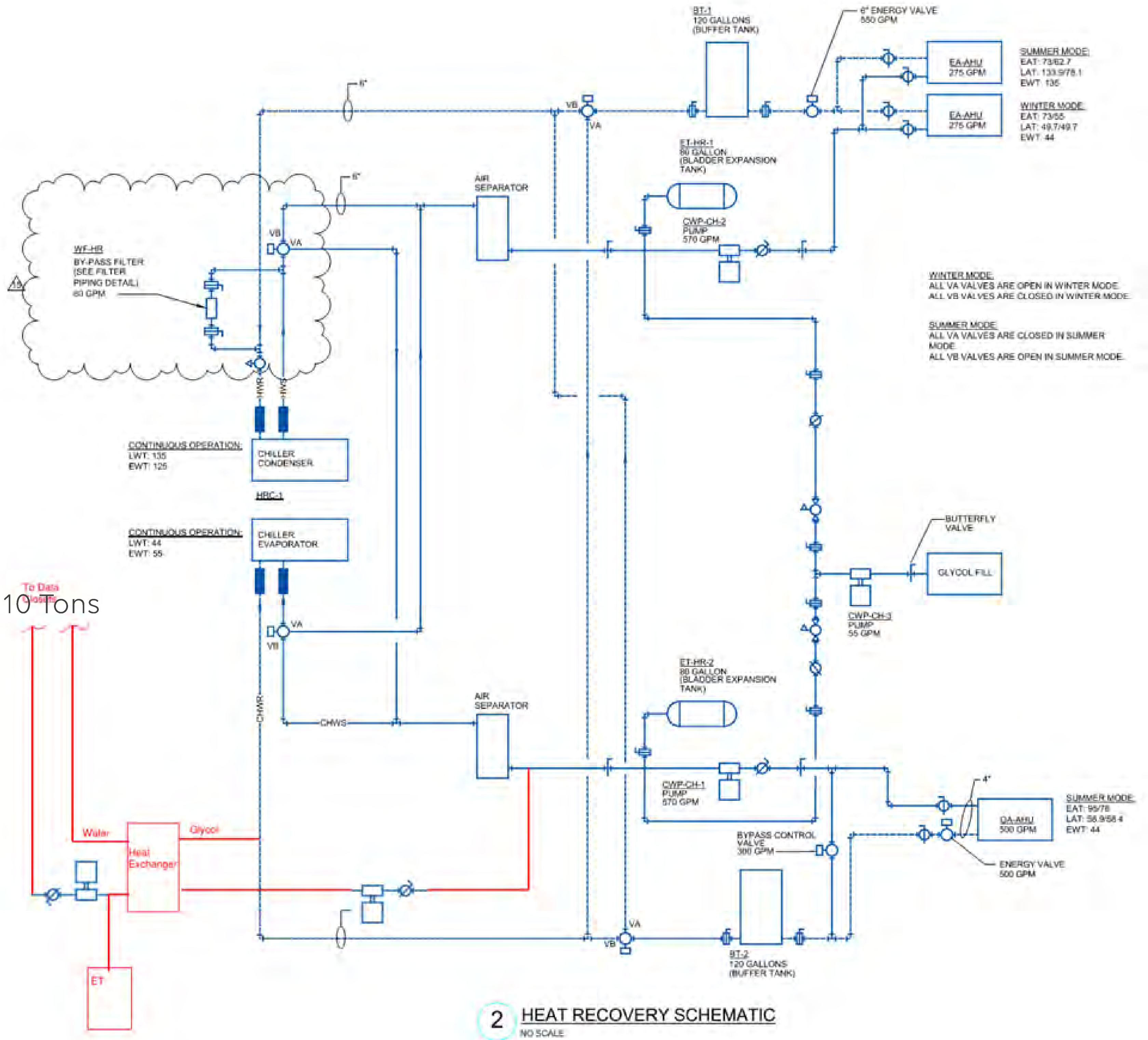


HRCH APPLICATION DEFICIENCIES

Confidential Project

- Designed for 20 °F dT, fully loaded system
- Pumping heads and equipment flows minimized to save energy
- Piped HRCH in parallel with Centrifugal chillers- forcing always to operate at Tchws set.
- No means to turn down HRCH- no means to meet minimum loads on chillers
- Blending in primary secondary system to get load turndown (can't meet lift)
- Relying on HHW and CHW TES to provide loads for HRCH





10 Tons

WINTER MODE:
ALL VA VALVES ARE OPEN IN WINTER MODE.
ALL VB VALVES ARE CLOSED IN WINTER MODE.

SUMMER MODE:
ALL VA VALVES ARE CLOSED IN SUMMER MODE.
ALL VB VALVES ARE OPEN IN SUMMER MODE.

2 HEAT RECOVERY SCHEMATIC

NO SCALE

Detailed Performance Summary For CHR-1

Project: Childrens NW Tower
Prepared By:

10/08/2024
02:11PM

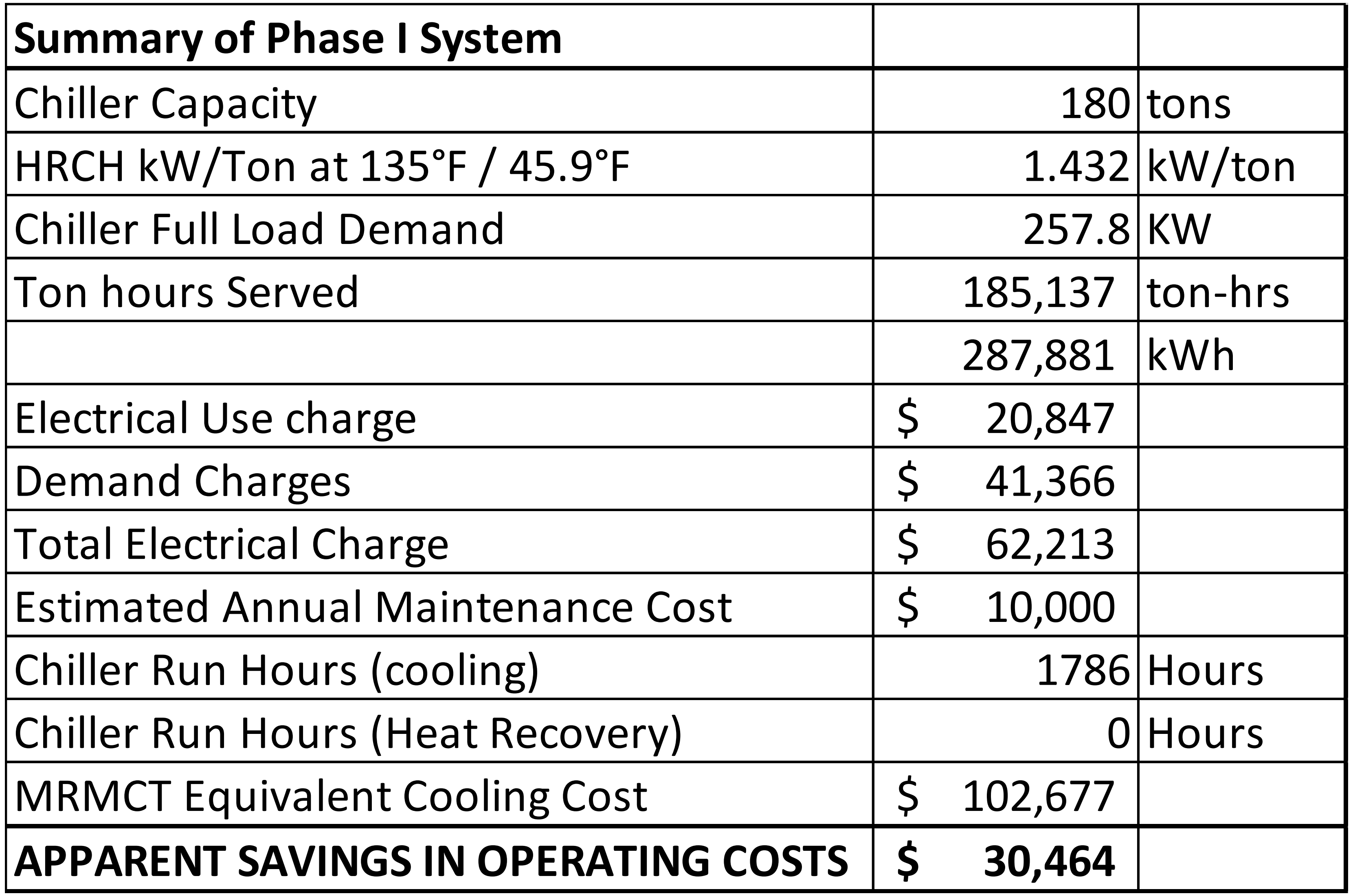
Load Line

Unit Performance										(1)
Percent Full Load Heating Capacity, %	100.00	90.00	80.00	70.00	60.00	50.00	40.00	30.00	20.00	10.00
Percent of Full Load Power, %	100.00	89.73	79.46	70.06	61.41	53.08	48.35	46.60	24.33	14.83
Unloading Sequence	Default	Default	Default	Default	Default	Default	Default	Default	Default	Default
Cooling Capacity, Tons	180.6	162.7	144.8	126.4	107.4	88.22	66.64	45.06	35.37	17.69
Heating Capacity, Tons	247.5	222.7	198.0	173.2	148.5	123.7	98.98	74.24	49.49	24.75
Total Unit Power, kW	258.6	232.0	205.5	181.1	158.8	137.2	125.0	120.5	62.90	38.35
Cooling Efficiency (EER), BTU/Wh	8.380	8.414	8.458	8.370	8.116	7.713	6.397	4.487	6.749	5.535
Cooling Efficiency, kW/Ton	1.432	1.426	1.419	1.434	1.479	1.556	1.876	2.674	1.778	2.168
Heating Efficiency (COPH), kW/kW	3.366	3.376	3.389	3.363	3.289	3.171	2.785	2.167	2.767	2.270
Evaporator Data										
Fluid Entering Temperature, °F	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00
Fluid Leaving Temperature, °F	45.93	46.83	47.73	48.65	49.60	50.57	51.65	52.74	50.51	50.51
Fluid Flow Rate, gpm	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
Fouling Factor, (hr-sqft-F)/BTU	0.000100	0.000100	0.000100	0.000100	0.000100	0.000100	0.000100	0.000100	0.000100	0.000100
Condenser Data										
Fluid Entering Temperature, °F	120.00	121.53	123.03	124.52	126.02	127.52	129.01	130.51	127.43	127.43
Fluid Leaving Temperature, °F	135.00	135.00	135.00	135.00	135.00	135.00	135.00	135.00	135.00	135.00
Fluid Flow Rate, gpm	416.5	416.5	416.5	416.5	416.5	416.5	416.5	416.5	416.5	416.5
Fouling Factor, (hr-sqft-F)/BTU	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250

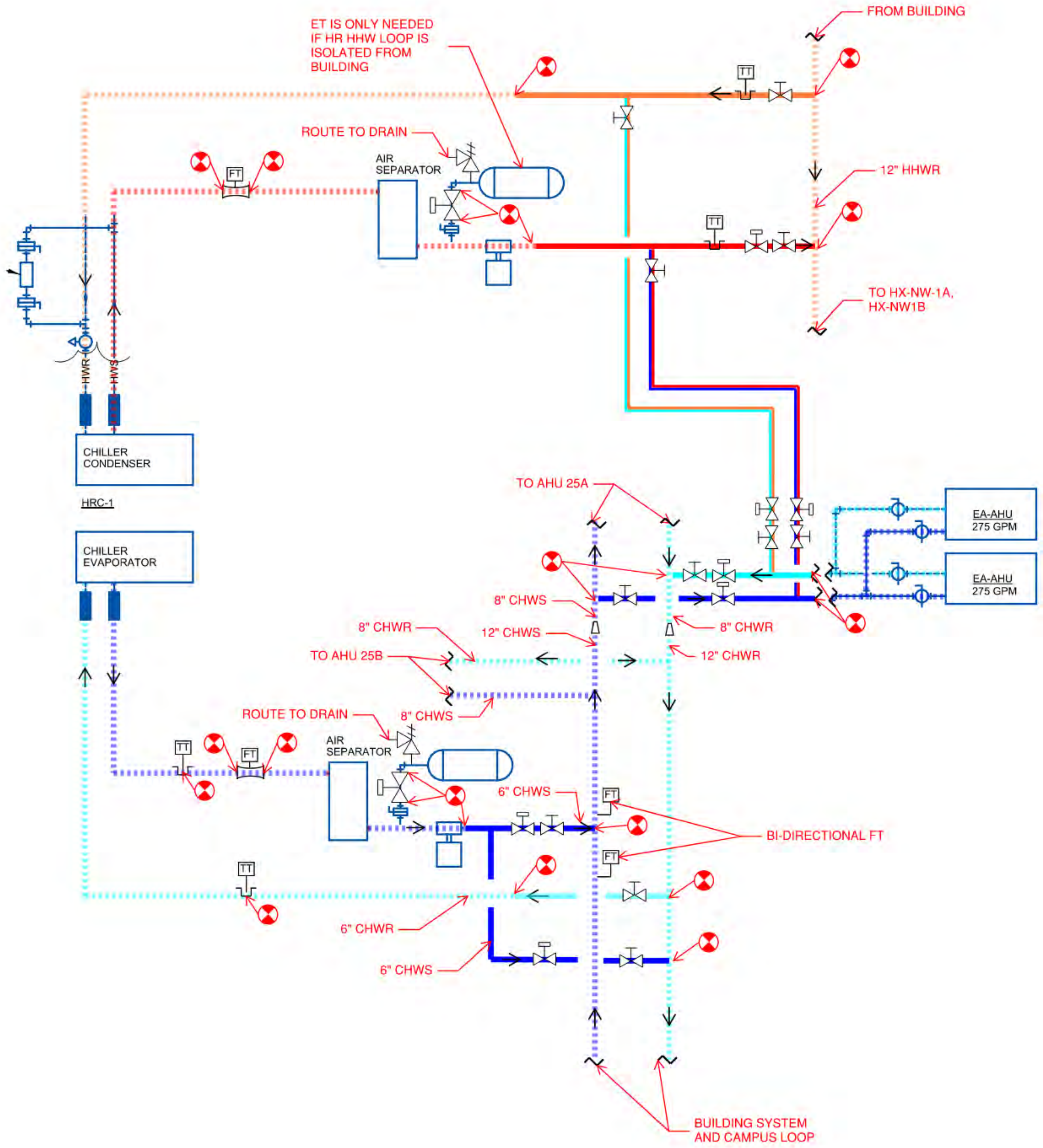
(1) Minimum load control is required. Performance is an approximation.

Note: Performance is at nominal voltage. Chiller may unload if job site voltage is lower than 380 volts.
Sound pressure level data used to develop this program was determined in accordance with AHRI Standard 575-2008 for water chillers in a free field.
Outside the scope of AHRI Water-Cooled Water-Chilling and Heat Pump Water-Heating Packages Certification Program, but is rated in accordance with AHRI Standard 550/590 (I-P) and AHRI Standard 551/591 (SI).

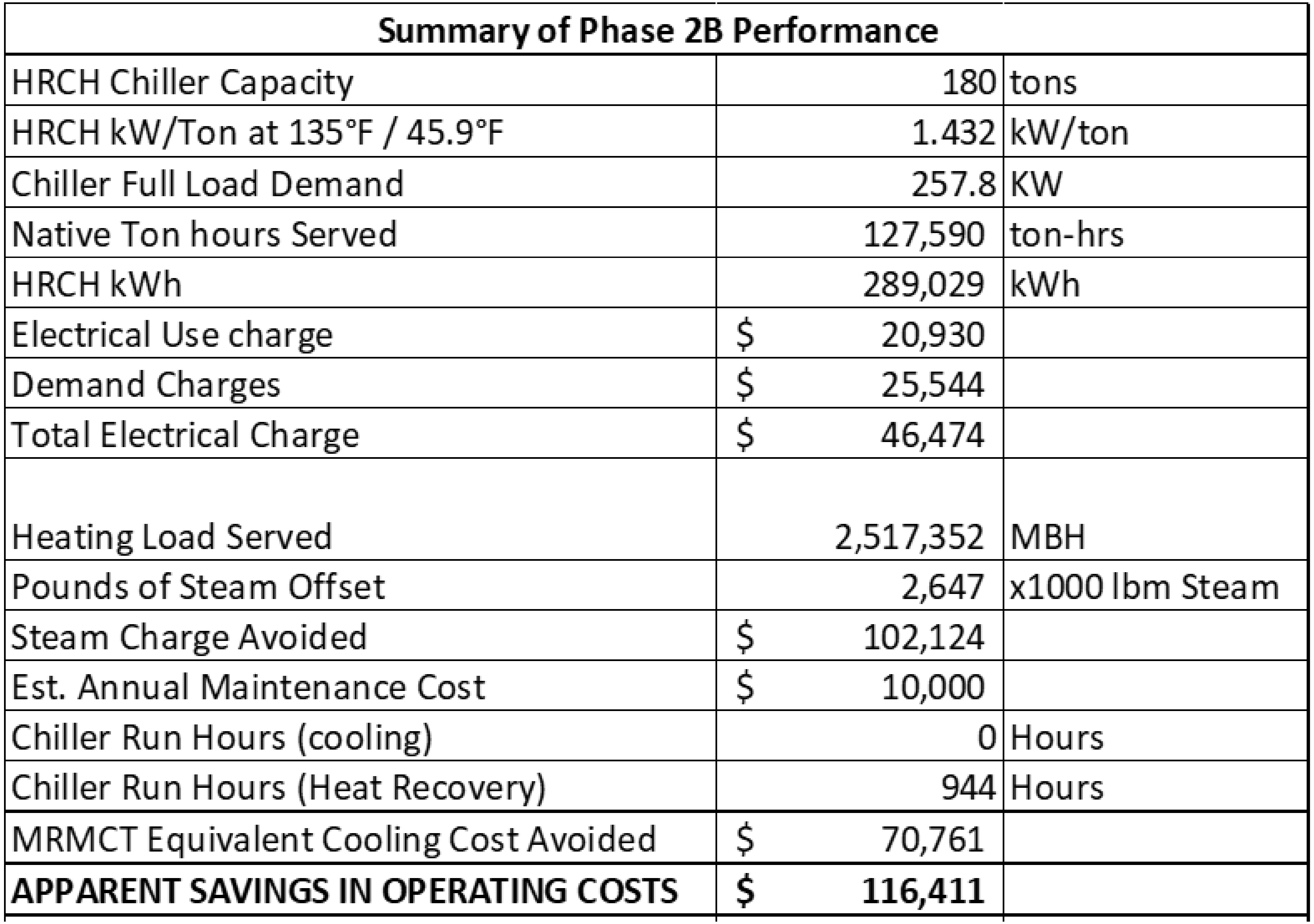
HOSPITAL EXAMPLE - ORIGINAL DESIGN



Summary of Phase I System		
Chiller Capacity	180	tons
HRCH kW/Ton at 135°F / 45.9°F	1.432	kW/ton
Chiller Full Load Demand	257.8	KW
Ton hours Served	185,137	ton-hrs
	287,881	kWh
Electrical Use charge	$ 20,847	
Demand Charges	$ 41,366	
Total Electrical Charge	$ 62,213	
Estimated Annual Maintenance Cost	$ 10,000	
Chiller Run Hours (cooling)	1786	Hours
Chiller Run Hours (Heat Recovery)	0	Hours
MRMCT Equivalent Cooling Cost	$ 102,677	
APPARENT SAVINGS IN OPERATING COSTS	**$ 30,464**	


FROM BUILDING
ET IS ONLY NEEDED IF HR HHW LOOP IS ISOLATED FROM BUILDING
TT
ROUTE TO DRAIN
AIR SEPARATOR
FT
12" HHWR
TT
TO HX-NW-1A, HX-NW1B
HWR
HWS
CHILLER CONDENSER
HRC-1
CHILLER EVAPORATOR
TO AHU 25A
EA-AHU 275 GPM
EA-AHU 275 GPM
8" CHWS
8" CHWR
12" CHWS
8" CHWR
TO AHU 25B
12" CHWR
8" CHWS
ROUTE TO DRAIN
AIR SEPARATOR
TT
FT
6" CHWS
FT
BI-DIRECTIONAL FT
FT
TT
6" CHWR
6" CHWS
BUILDING SYSTEM AND CAMPUS LOOP

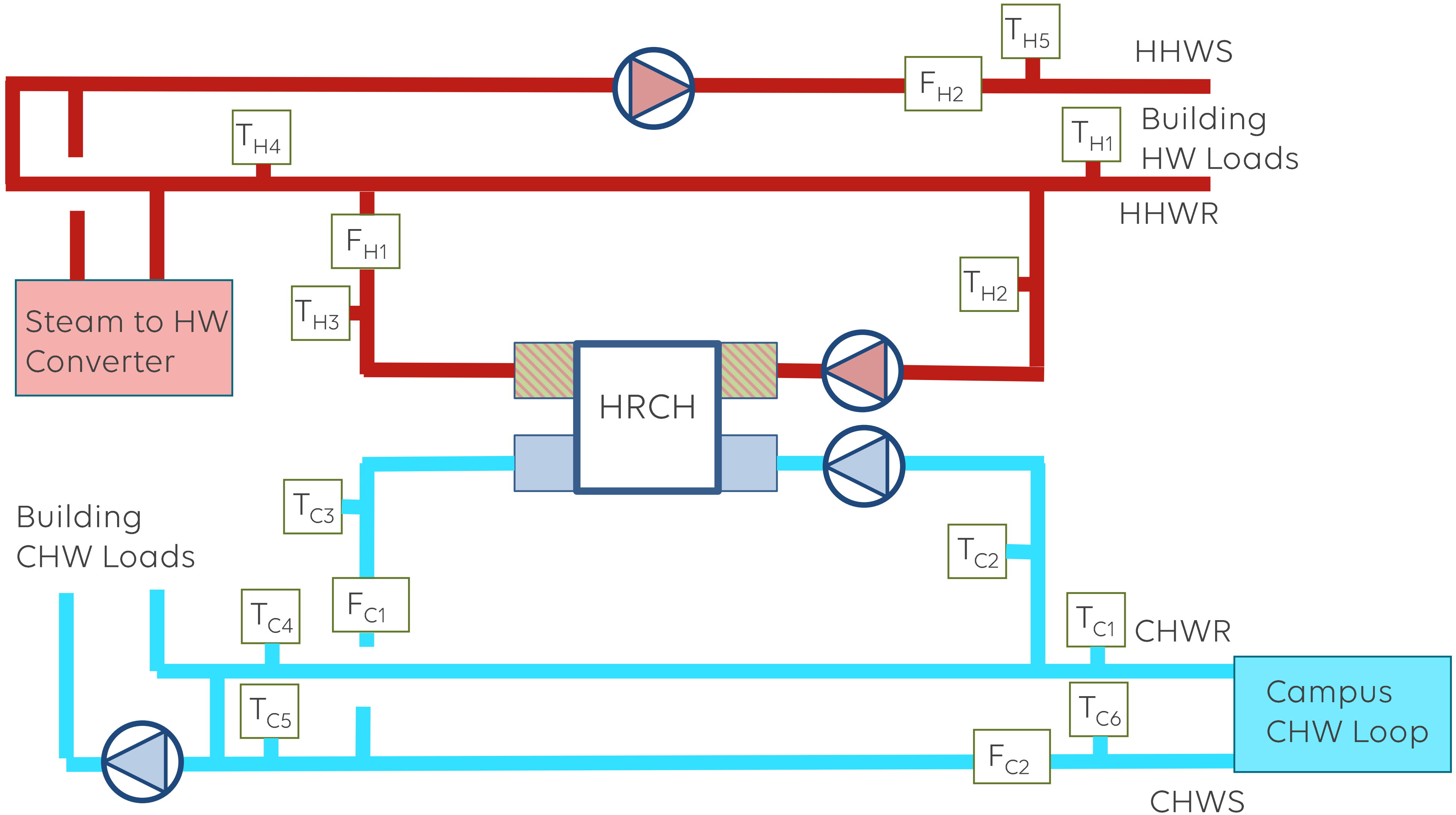
HOSPITAL EXAMPLE - MODIFIED DESIGN



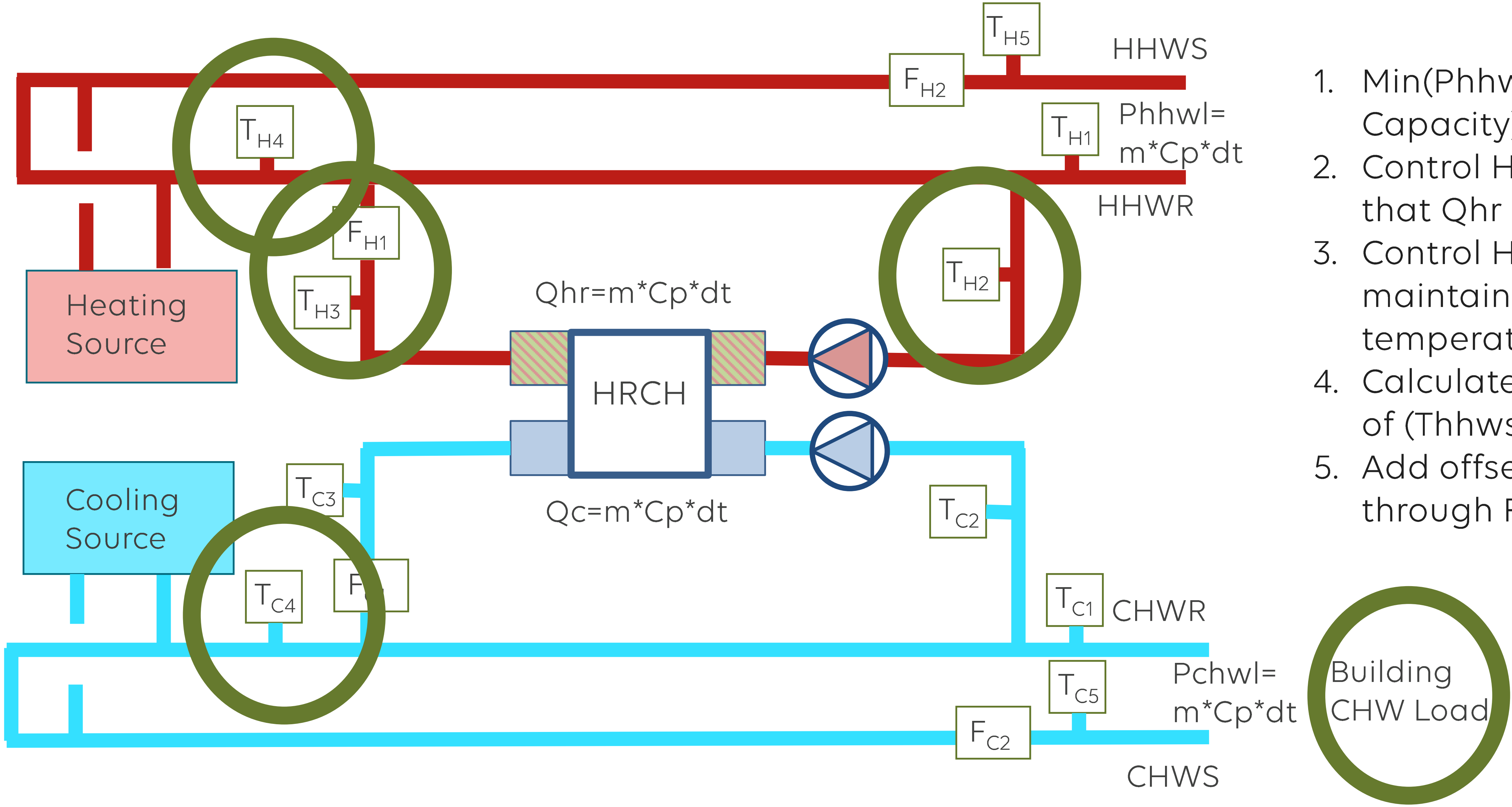
Summary of Phase 2B Performance		
HRCH Chiller Capacity	180	tons
HRCH kW/Ton at 135°F / 45.9°F	1.432	kW/ton
Chiller Full Load Demand	257.8	KW
Native Ton hours Served	127,590	ton-hrs
HRCH kWh	289,029	kWh
Electrical Use charge	$ 20,930	
Demand Charges	$ 25,544	
Total Electrical Charge	$ 46,474	
Heating Load Served	2,517,352	MBH
Pounds of Steam Offset	2,647	x1000 lbm Steam
Steam Charge Avoided	$ 102,124	
Est. Annual Maintenance Cost	$ 10,000	
Chiller Run Hours (cooling)	0	Hours
Chiller Run Hours (Heat Recovery)	944	Hours
MRMCT Equivalent Cooling Cost Avoided	$ 70,761	
APPARENT SAVINGS IN OPERATING COSTS	**$ 116,411**	

CONTROLS FOR A DISTRICT STEAM & CHW SYSTEM

- Campus CHW Loop is an "infinite" heat source
- HRCH is controlled to match building heating load



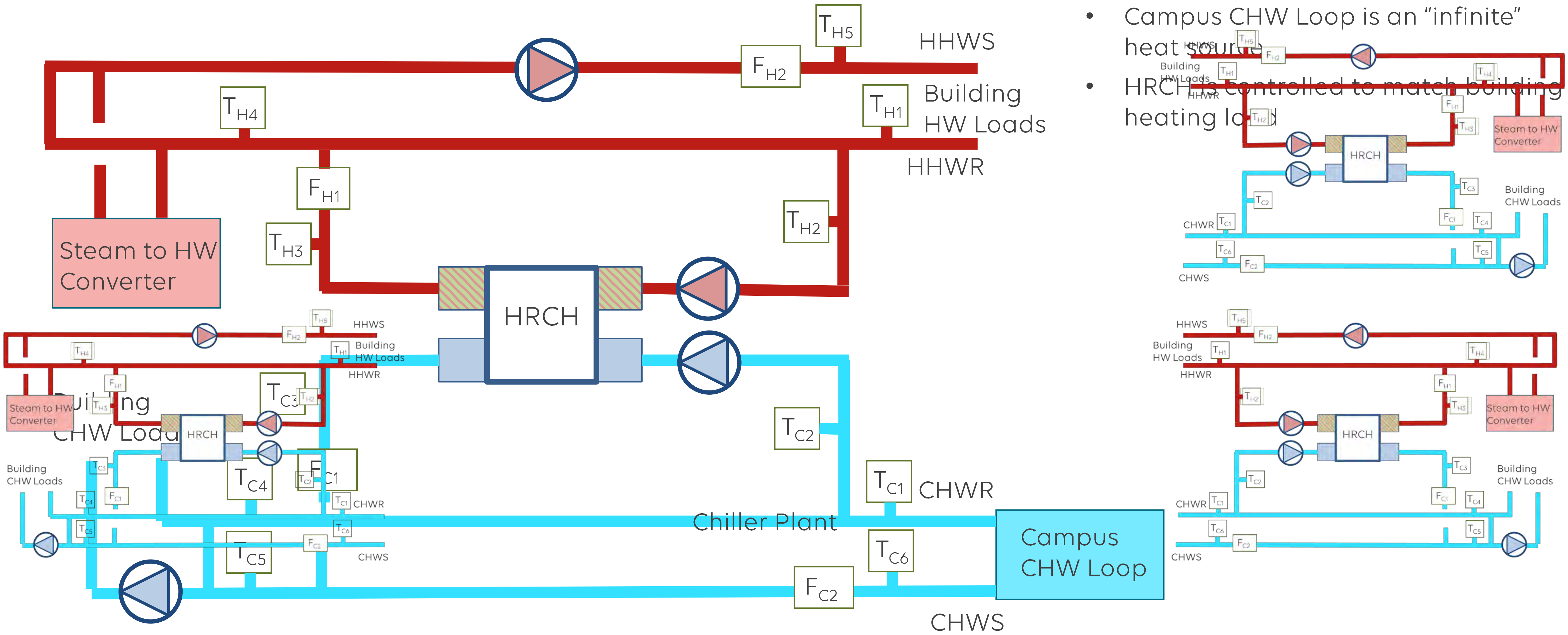
CONTROLS FOR A SINGLE BUILDING



1. Min(Phhwl, Pchwl*CR, HRCH Capacity)
2. Control HRCH condenser flow so that Qhr = Phhwl
3. Control HRCH evaporator flow to maintain evaporator leaving temperature at setpoint
4. Calculate offset load as a function of (Thhwset – TH4)
5. Add offset load to CHW system through FHRE

CONTROLS FOR A DISTRICT STEAM & CHW SYSTEM

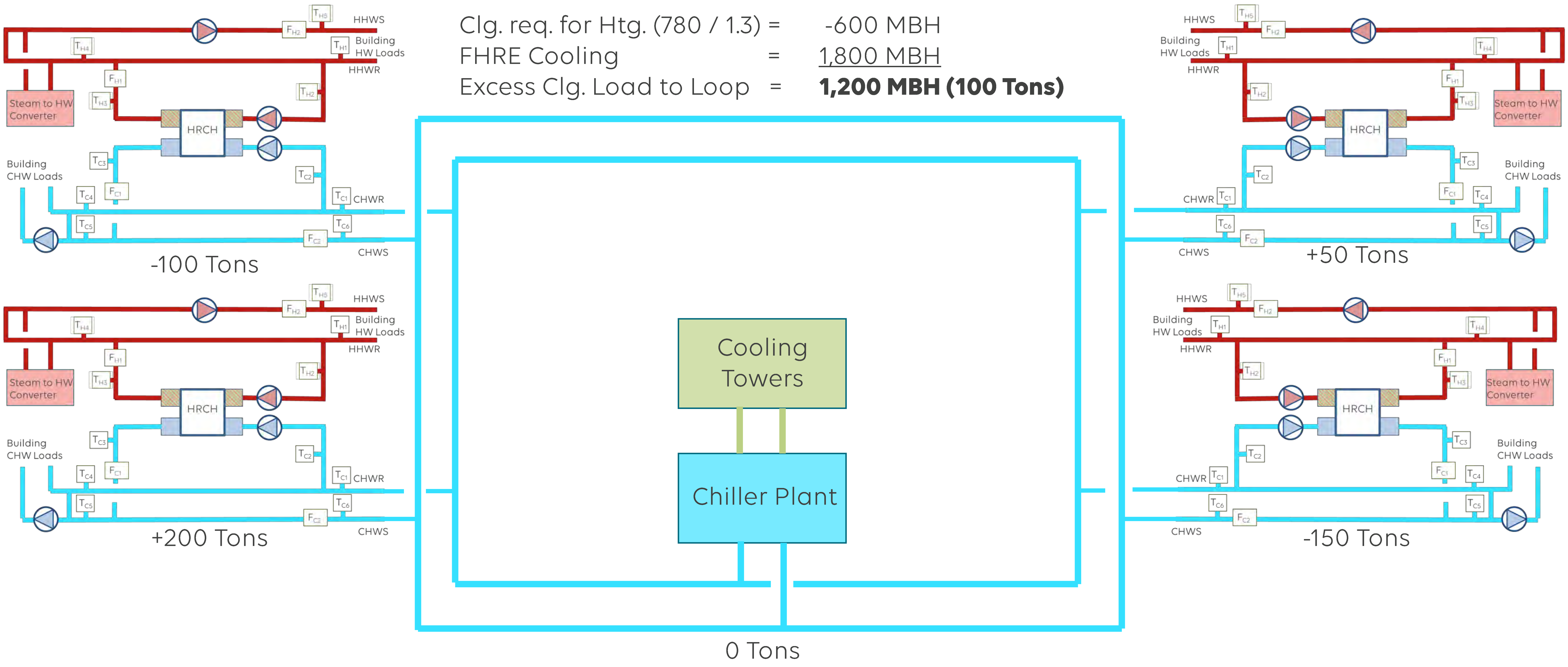
- Campus CHW Loop is an "infinite" heat source
- HRCH is controlled to match building heating load



FHRE LOAD SHARING

Heating Load: 780 MBH

Clg. req. for Htg. (780 / 1.3) = -600 MBH
FHRE Cooling = 1,800 MBH
Excess Clg. Load to Loop = **1,200 MBH (100 Tons)**



SUMMARY OF DESIGN PARAMETERS	**UPMC**	**MH**	**MH Actual**
Building Area, SF	875,960	723,000	
Major AHUs CFM	1,067,000	745,000	
AHUs with A/A ER. CFM	0	505,000	
HRU Exhau	30,000	80,000	
Centrifugal	4,000	7,000	
HRCH Capa			
HRCH Capa			
HHW Syste			
Total Coolir	00	7,634,000	7,354,000
Total MMBT	417	68,299	64,206
ELR-H		90%	
ALR-H	54%	64%	79.5%
η-ELR-H	81%	71%	88.3%
Total Energy Savings, MMBTU	38,981	60,442	71,589
Projected Savings	$442,000	$ 434,500	$ 483,000
Emissions Reduction, MTECD	1,995	3,562	4,200
Emissions Reduction, %	42%	64%	

Savings ~ $400,000

42 - 64% Emissions Reductions

Shift 50 – 75% gas to electricity

Cost Savings 15 - 25%

WITH FHRE ~ SPP =2.0 -3.5

HGA