On Site Energy Summit
Does an on-site energy system work for the economic bottom line and a healthier Maine environment?

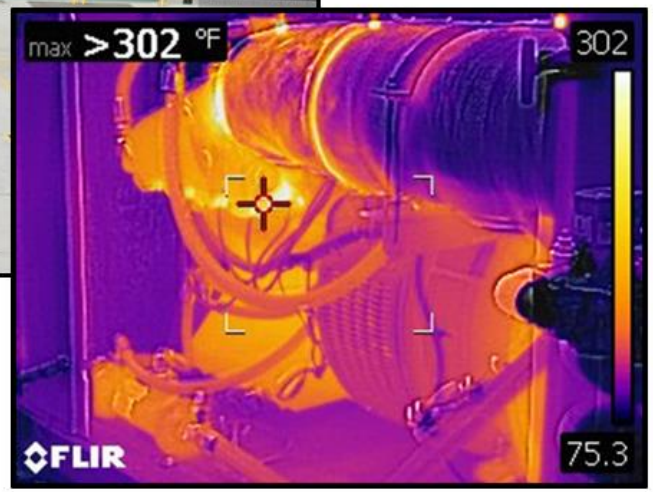
A.J. Ballard, C.E.M
Maine Army National Guard

University of Maine Augusta
April 3,2019

Bayonets, Forward!

Maine Army National Guard “Micro” - 75 KW CHP

Army Aviation Support Facility (AASF)
Building 260 , 123,000 SF
Bangor, Maine



Bayonets, Forward!

MEARNG Strategy for Energy Reduction

- Detail design review starting at feasibility – know what you want!
- New technology that has incremental first cost with reasonable pay backs
- **Combined Heat and Power**, High efficient Boilers, Heat Pumps, etc…
- HVAC controls and analytics
- Building Envelope

MEARNG Energy MMBtu vs. Total Degree Days for 1.6 Million SF

All energy is converted into MMBtu for comparison (1MMBtu =1,000,000 Btu)

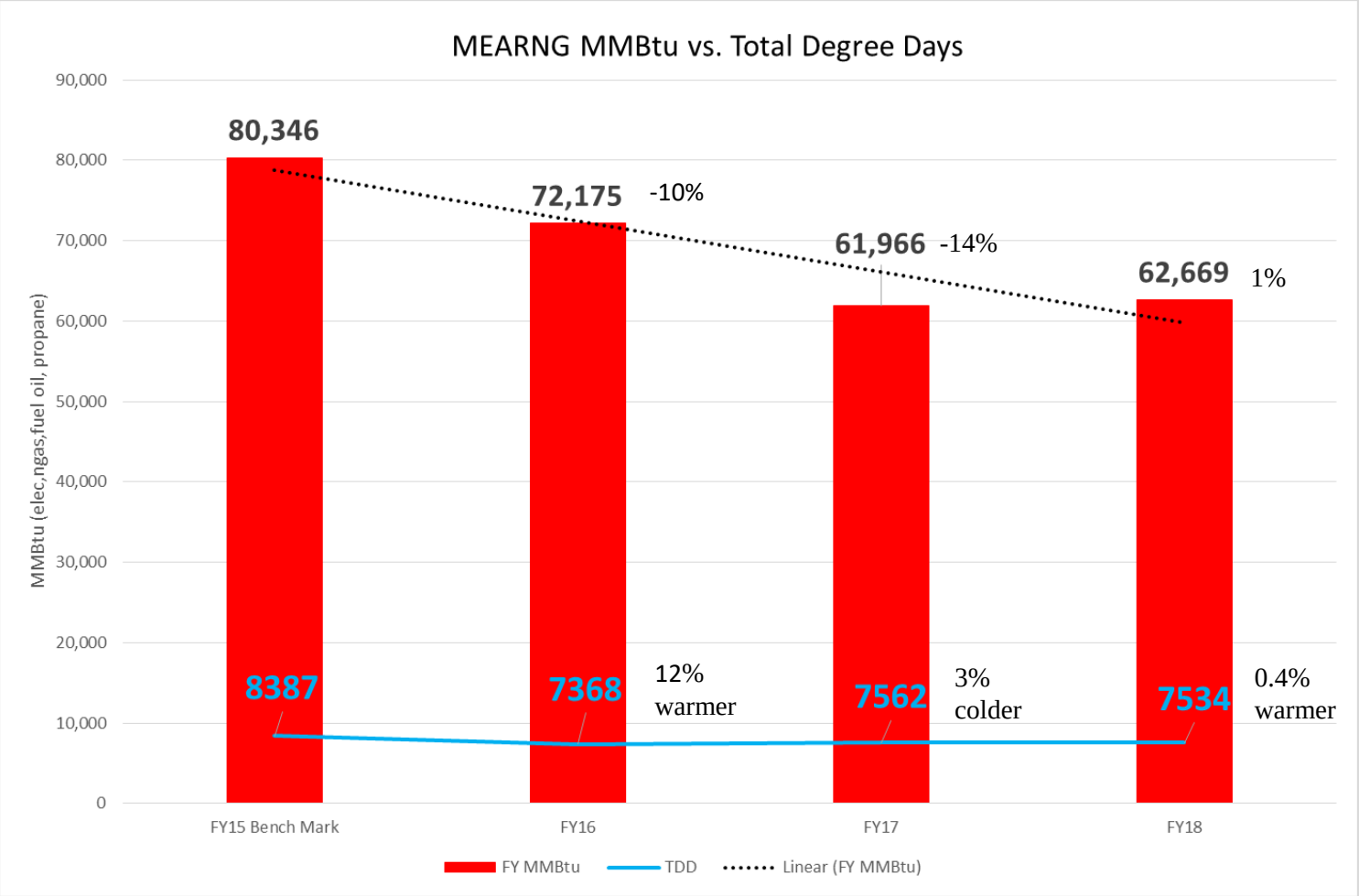
Elec kWh = 3412 Btu / kWh
Oil gal = 138,600 Btu / gallon
Ngas therm = 100,000 Btu / therm
Propane = 91,000 Btu / gallon

Executive Order - Reduce energy consumption 25% by FY 2025

62,669 MMBtu (FY15) / 80,346 MMBtu (FY18)

= 22% reduction to date with 6 years to go.

FY 2016 CHP ~5% Reduction



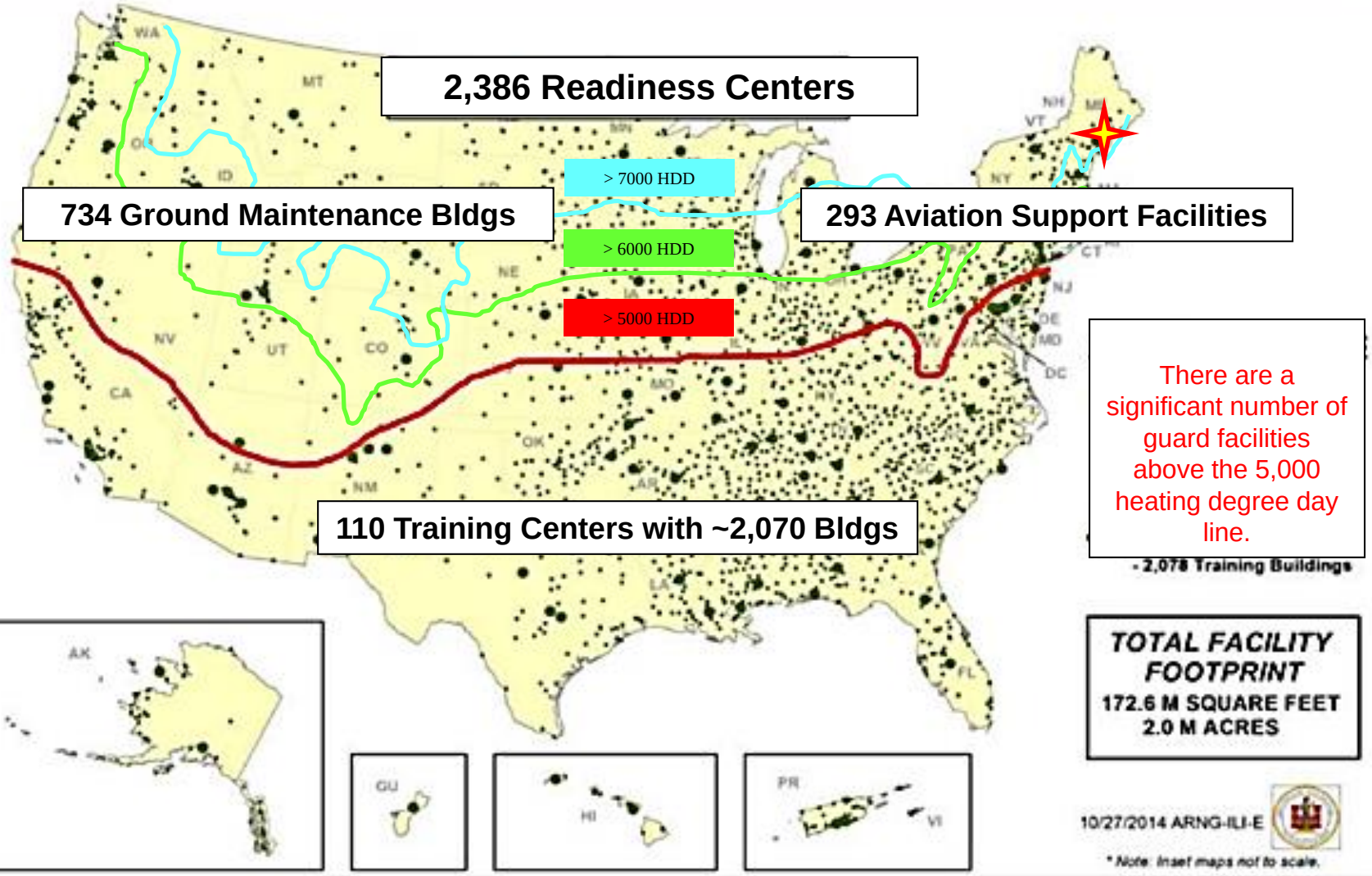
Bayonets, Forward!

Does Micro CHP Work

- Feasibility Study is critical.
- Treat the CHP as a **“boiler”** that is replacing or being added to a heating or process system.
- Key to the design – the viable use of the **“CHP jacket water waste heat”** is critical for the project success.
- Determine the hourly Btu requirement for the load
- Secondary consideration - the CHP generates electricity
- The CHP is typically sized based on the buildings average hourly Btu load and/or the electrical 15 minute demand load.
- Must find an efficient use for **waste heat**!

FOOTPRINT OF THE ARMY NATIONAL GUARD

FY 2015



There are a significant number of guard facilities above the 5,000 heating degree day line.

- 2,078 Training Buildings

TOTAL FACILITY FOOTPRINT
172.6 M SQUARE FEET
2.0 M ACRES

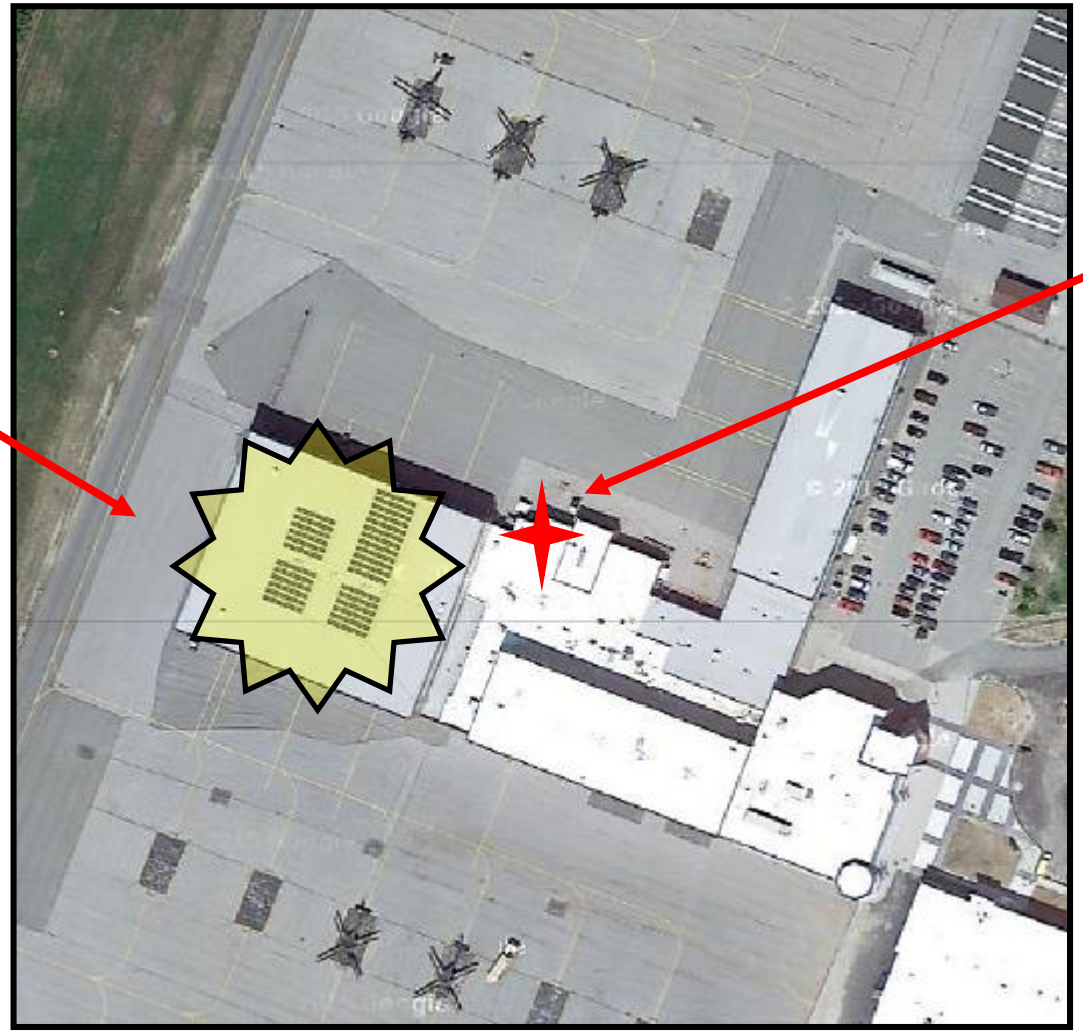
10/27/2014 ARNG-ILI-E

* Note: Inset maps not to scale.

Bayonets, Forward!

Army Aviation Support Facilty,123,500 sf building

43 KW Solar PV system



75 KW CHP

Bayonets, Forward!

Back

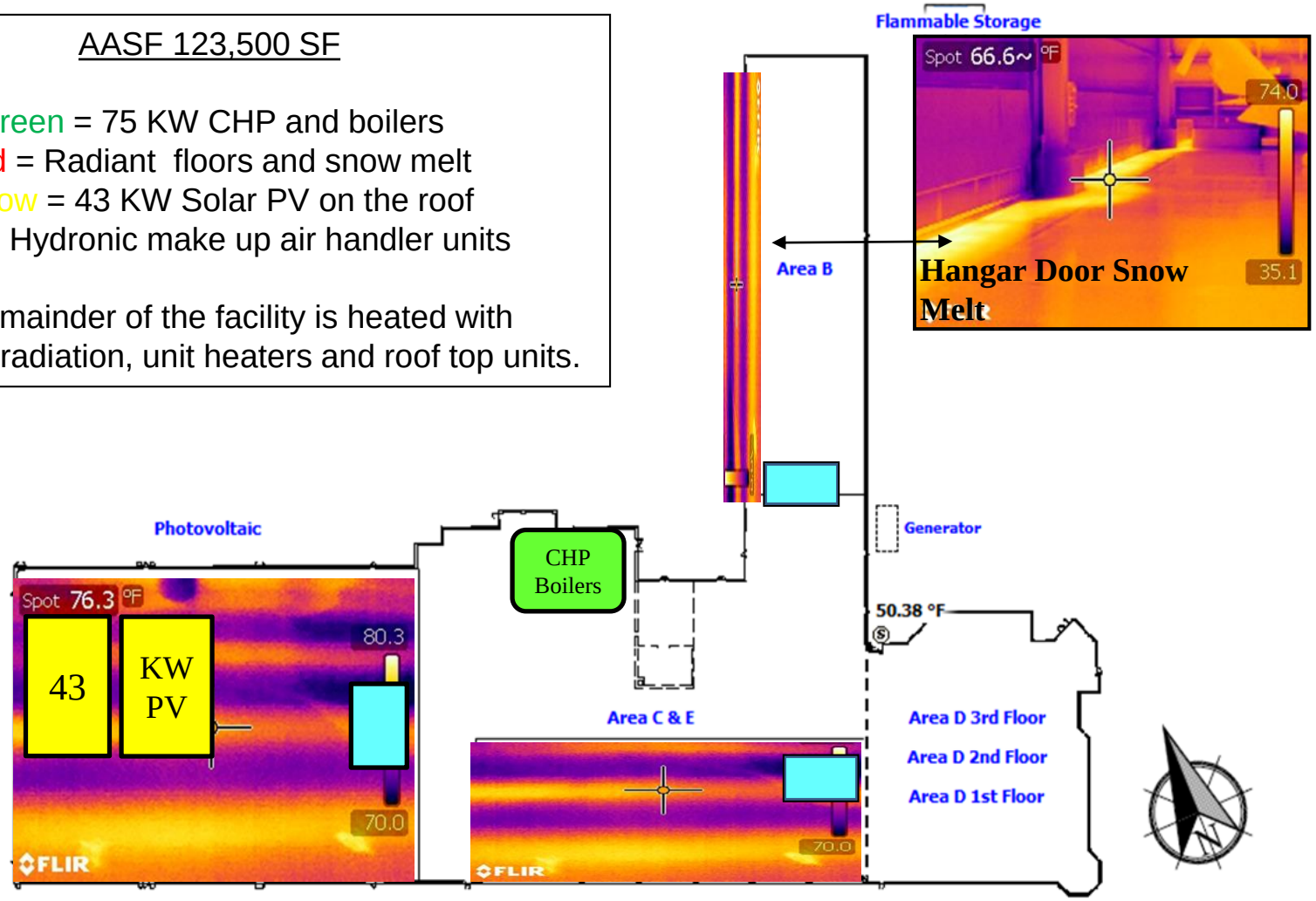
Bangor ~ Building #260 ~ Floor Plan

Outside Air Temp 50.38 °F

AASF 123,500 SF

Green = 75 KW CHP and boilers
Red = Radiant floors and snow melt
Yellow = 43 KW Solar PV on the roof
Blue = Hydronic make up air handler units

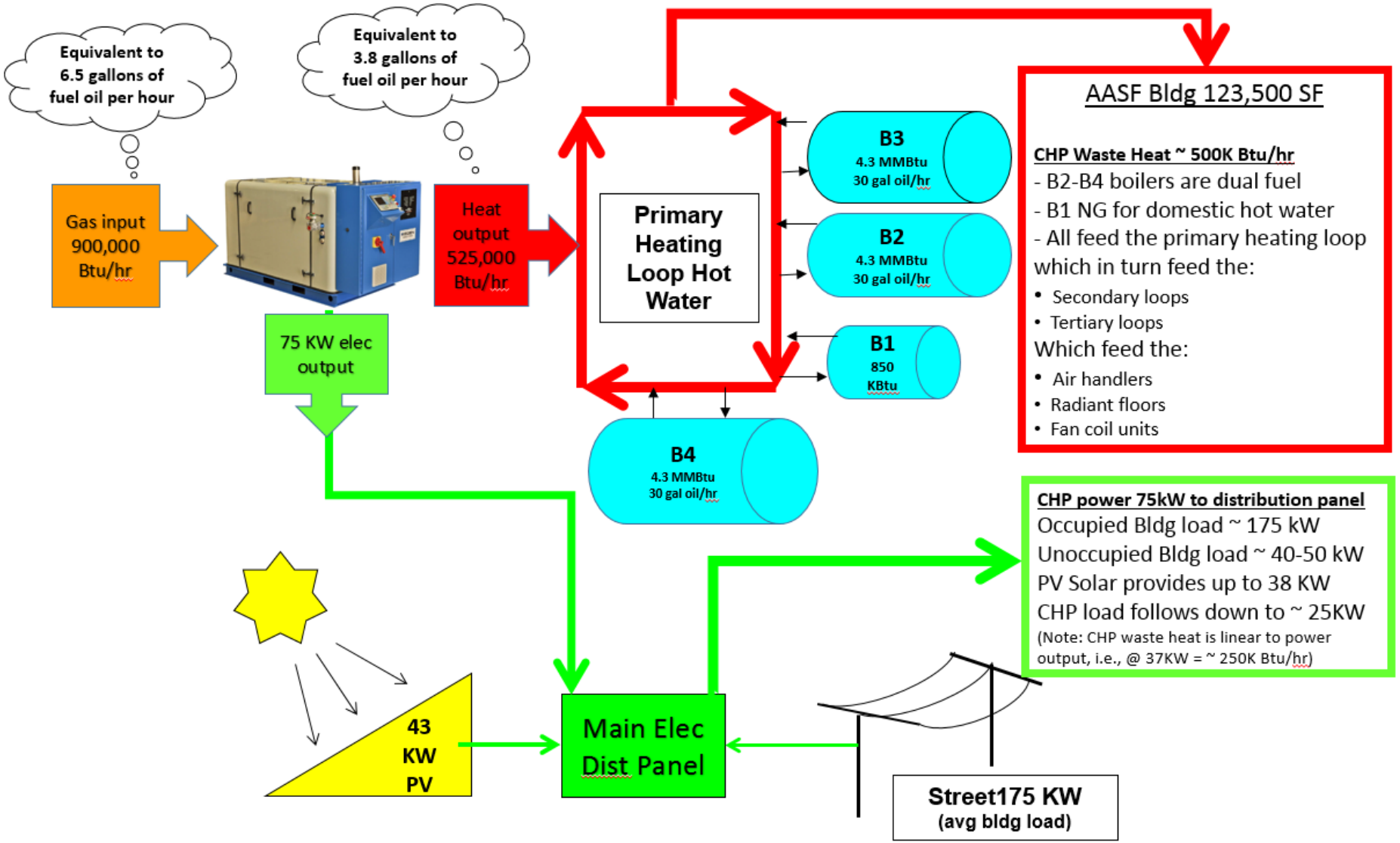
The remainder of the facility is heated with baseboard radiation, unit heaters and roof top units.



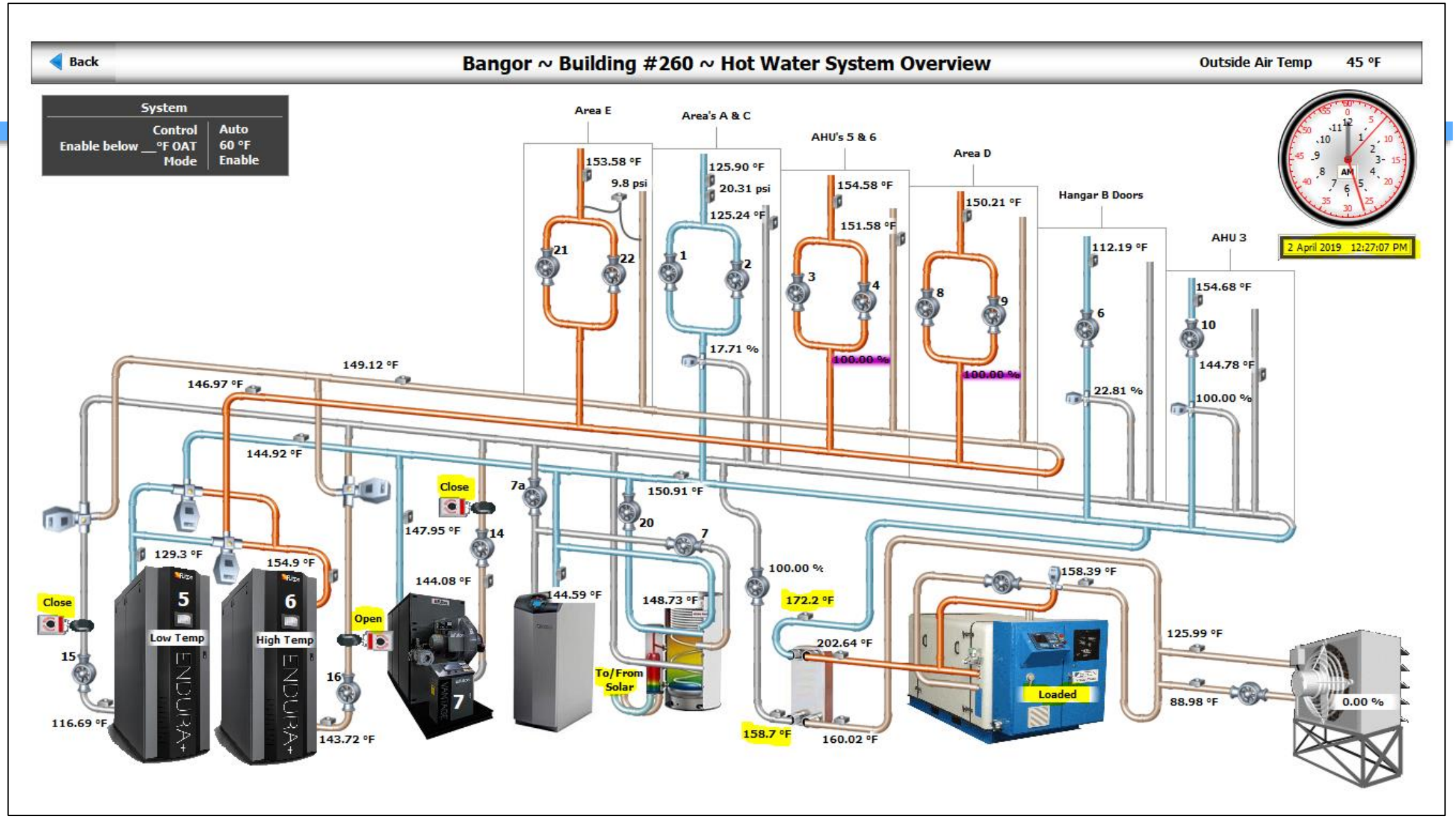
Bayonets, Forward!

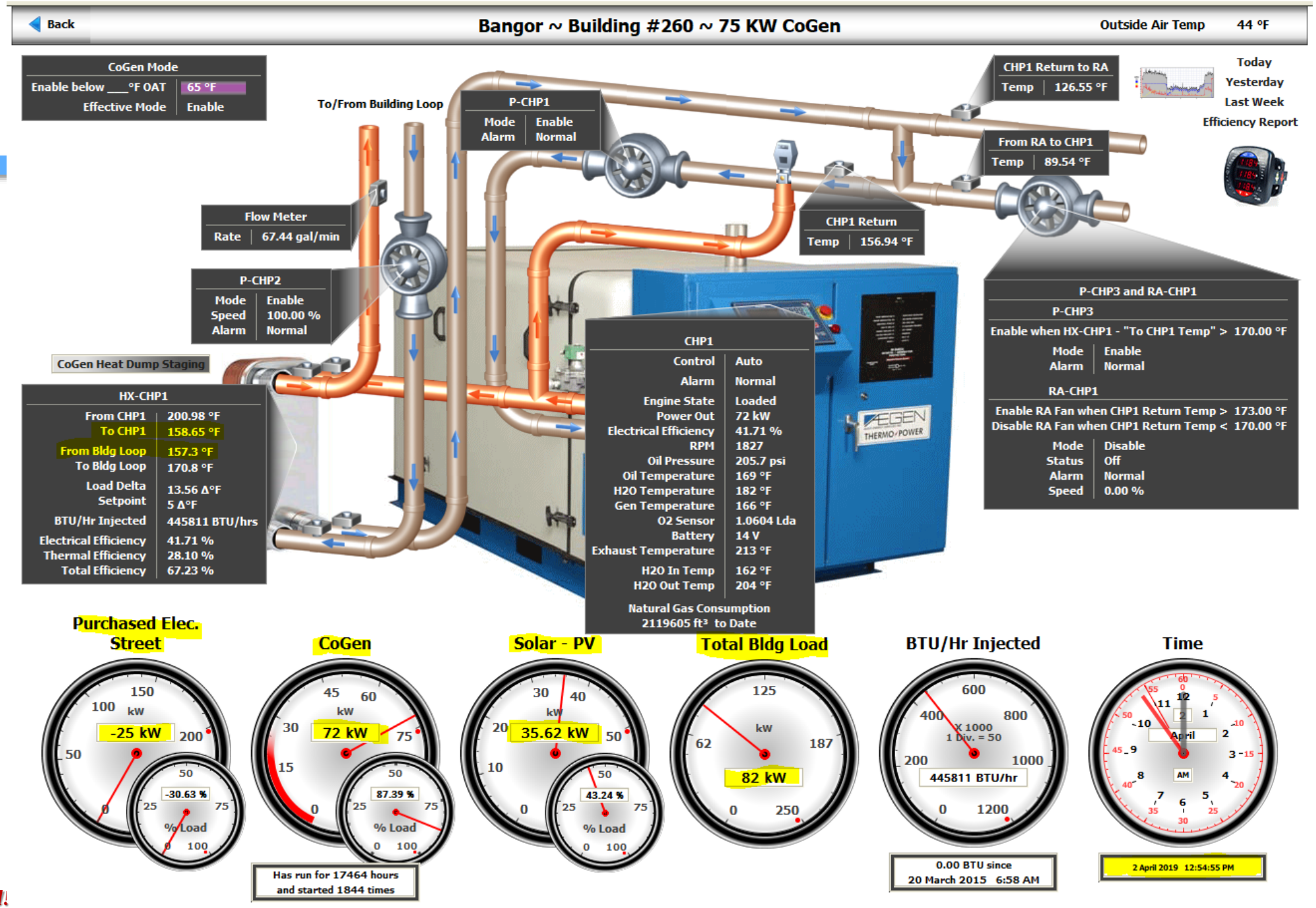
40,000 SF of Low Temperature (< 120 F) Radiant Floors = Good Match for CHP

Hot Water and Electric Distribution

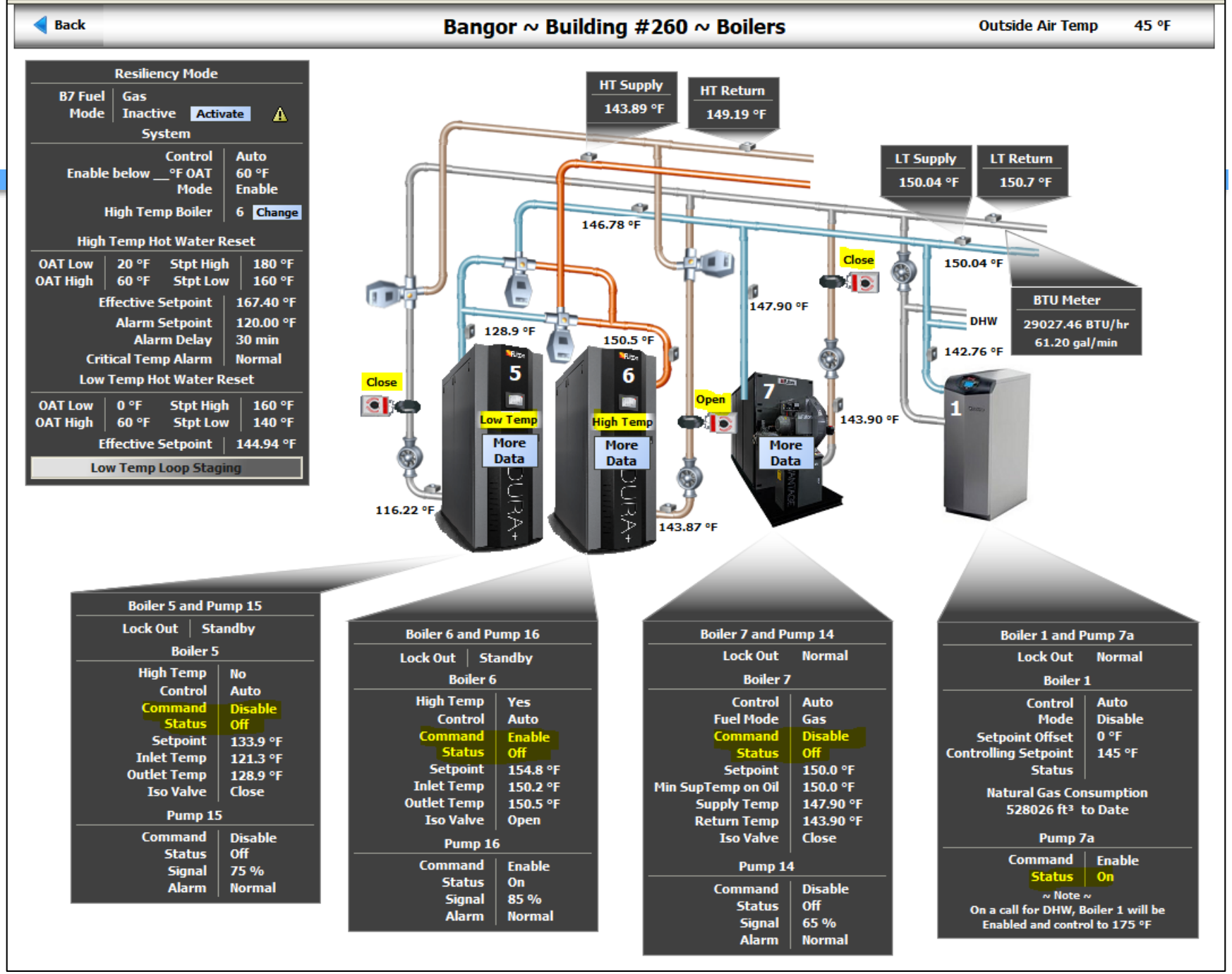


Bayonets, Forward!


Back
Bangor ~ Building #260 ~ Hot Water System Overview
Outside Air Temp 45 °F
System
Control Auto
Enable below __°F OAT 60 °F
Mode Enable
Area E
Area's A & C
AHU's 5 & 6
Area D
Hangar B Doors
AHU 3
2 April 2019 12:27:07 PM
153.58 °F
9.8 psi
125.90 °F
20.31 psi
125.24 °F
154.58 °F
151.58 °F
150.21 °F
112.19 °F
154.68 °F
144.78 °F
100.00 %
22.81 %
17.71 %
149.12 °F
146.97 °F
144.92 °F
150.91 °F
147.95 °F
144.08 °F
144.59 °F
148.73 °F
100.00 %
172.2 °F
202.64 °F
158.39 °F
125.99 °F
88.98 °F
0.00 %
158.7 °F
160.02 °F
143.72 °F
116.69 °F
129.3 °F
154.9 °F
Close
Open
Low Temp
High Temp
To/From Solar
Loaded



Bayonets, Forward!



Bayonets, Forward!

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Bangor ~ Building #260 ~ 75 KW CoGen ~ Heat Dump Config

Outside Air Temp 45 °F

2 April 2019 12:52:08 PM

CHP Dump Staging Call

HX Src Lvg Temp	159.56 °F
CHP RWTemp	157.89 °F
Stage 1	154 °F
Stage 2	156 °F
Stage 3	158 °F
Stage 4	160 °F
Stage 5	162 °F
Stage 6	164 °F
Stage 7	166 °F
Stage 8	168 °F
Calling for ___ Stgs	3

CHP Dump Staging Priority/Available/Call/Active

Stages Available	8			
	Prio	Avail	Called	Active
Domestic Hot Water	1	Yes	On	Yes
Hangar B Doors	2	Yes	On	Yes
Hangar B AHU-3	3	Yes	On	Yes
Hangar A Floor	4	Yes	Off	No
Hangar A AHU-1	5	Yes	Off	No
Hangar A AHU-2	6	Yes	Off	No
Hangar C Floor	7	Yes	Off	No
Hangar C AHU-4	8	Yes	Off	No
Are 8 Stages Accounted For?	Yes			

Final Effort

"To CHP1 Temp" Sensor	159.56 °F
CHP1 Return Temp	157.89 °F

P-CHP3

Enable when HX-CHP1 when "To CHP1 Temp" > 170.00 °F

Mode	Enable
Alarm	Normal

RA-CHP1

Enable RA Fan when CHP1 Return Temp > 173.00 °F

Disable RA Fan when CHP1 Return Temp < 170.00 °F

Mode	Disable
Status	Off
Alarm	Normal
Speed	0.00 %

Domestic Hot Water

Upper Sensor (US)	148.91 °F
Available for Dump if US < ___°F	185 °F
Is Available?	Yes
CHP Call	On
Is Active?	Yes

Hangar B Door Track Ice Melt

HWS Sensor (HWST)	108.46 °F
Available for Dump if HWST < ___°F	115 °F
Is Available?	Yes
CHP Call	On
Is Active?	Yes

Hangar B Air Handling Unit #3

Space Sensor (SpcT)	69.70 °F
Available for Dump if (SpcT) < ___°F	75 °F
Is Available?	Yes
CHP Call	On
Is Active?	Yes
Fan Speed when Active = Yes	50 %
Fan Speed	50.00 %
Fan Status	On
Discharge Air Setpoint when Active = Yes	104 °F
Discharge Air Sensor	103.82 °F
Outside Air Damper when Active = Yes	50 %
Damper Command	50.00 %
Mixed Air Sensor	69.53 °F

Hot Water Pumps 1 & 2 ~ Common to Hangars A & C

Hot Water Supply Sensor (HWST)	148.91 °F
HWST Setpoint when any of the 5 Hangar A or C stages are called	185 °F

Hangar A Radiant Floor

Floor Sensor (SlbT)	72.82 °F
Space Sensor (SpcT)	72.51 °F
Available for Dump if SlbT < ___°F	85 °F
and SpcT < ___°F	75 °F
Is Available?	Yes
CHP Call	Off
Is Active?	No
Slab HWST Setpoint when Active = Yes	115 °F
HWS Sensor (HWST)	78.97 °F

Hangar A Air Handling Unit #1

Space Sensor (SpcT)	72.51 °F
Available for Dump if (SpcT) < ___°F	75 °F
Is Available?	Yes
CHP Call	Off
Is Active?	No
Fan Speed when Active = Yes	50 %
Fan Speed	0.00 %
Fan Status	Off
Discharge Air Setpoint when Active = Yes	104 °F
Discharge Air Sensor	78.67 °F
Outside Air Damper when Active = Yes	50 %
Damper Command	0.00 %
Mixed Air Sensor	73.96 °F

Hangar A Air Handling Unit #2

Space Sensor (SpcT)	72.51 °F
Available for Dump if (SpcT) < ___°F	75 °F
Is Available?	Yes
CHP Call	Off
Is Active?	No
Fan Speed when Active = Yes	50 %
Fan Speed	0.00 %
Fan Status	Off

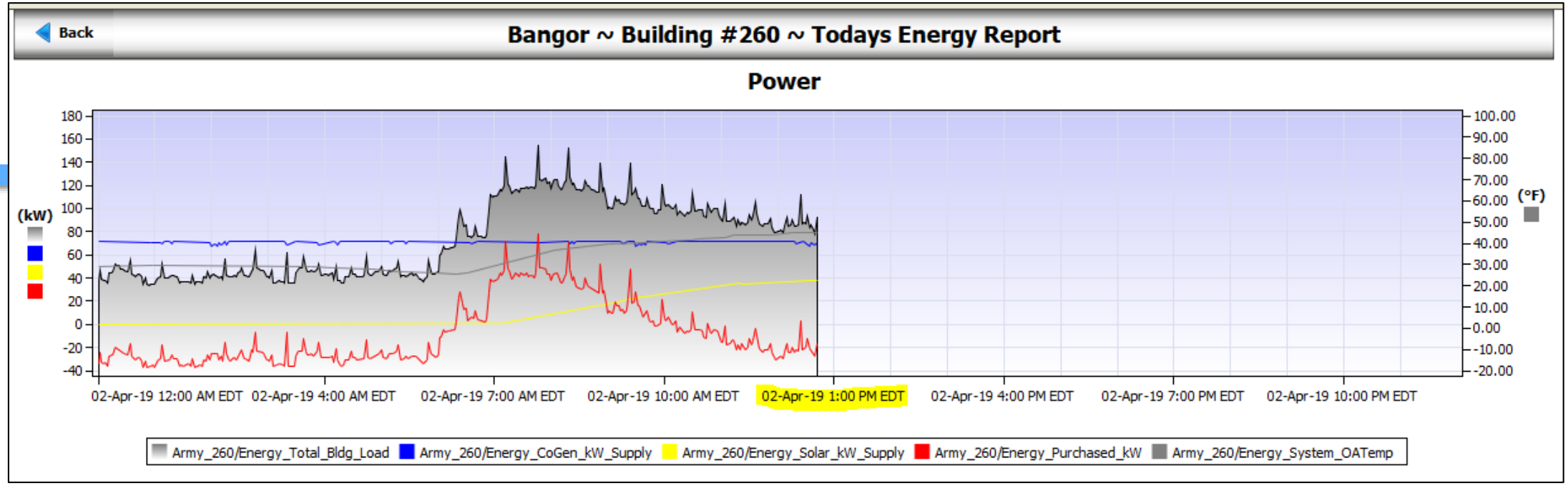
Hangar C Radiant Floor

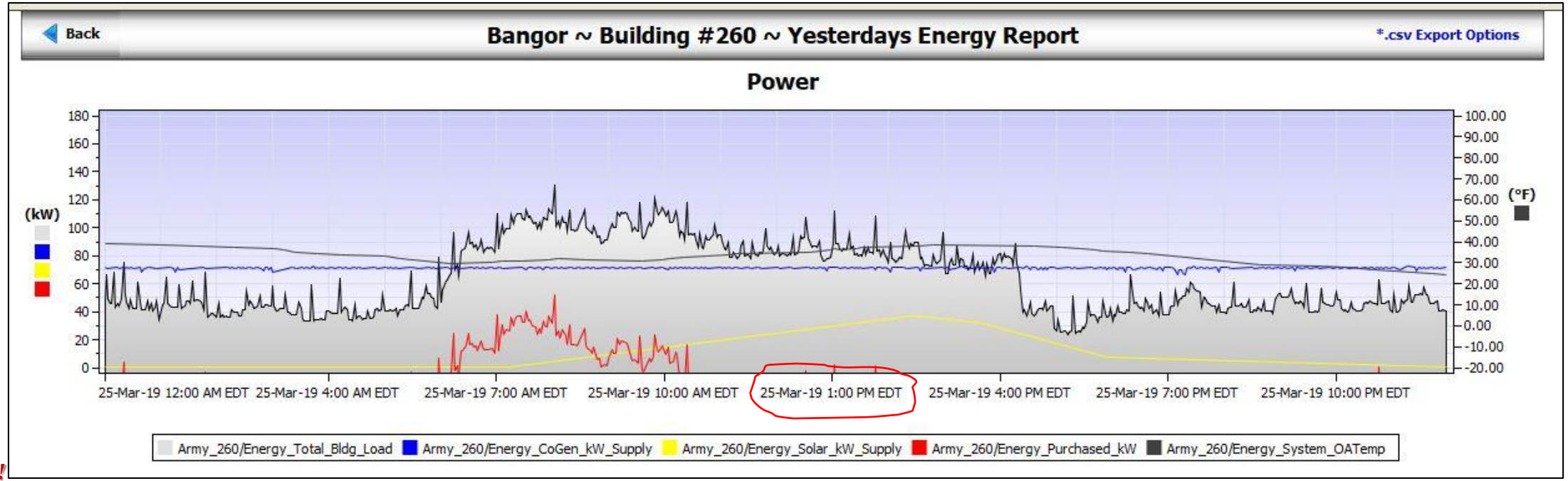
Floor Sensor (SlbT)	70.50 °F
Space Sensor (SpcT)	72.80 °F
Available for Dump if SlbT < ___°F	85 °F
and SpcT < ___°F	75 °F
Is Available?	Yes
CHP Call	Off
Is Active?	No
Slab HWST Setpoint when Active = Yes	115 °F
HWS Sensor (HWST)	75.52 °F

Hangar C Air Handling Unit #4

Space Sensor (SpcT)	72.80 °F
Available for Dump if (SpcT) < ___°F	75 °F
Is Available?	Yes
CHP Call	Off
Is Active?	No
Fan Speed when Active = Yes	50 %
Fan Speed	0.00 %
Fan Status	Off
Discharge Air Setpoint when Active = Yes	104 °F
Discharge Air Sensor	103.71 °F
Outside Air Damper when Active = Yes	50 %
Damper Command	0.00 %
Mixed Air Sensor	77.30 °F

Bayonets, Forward!





Bayonets, Forward!

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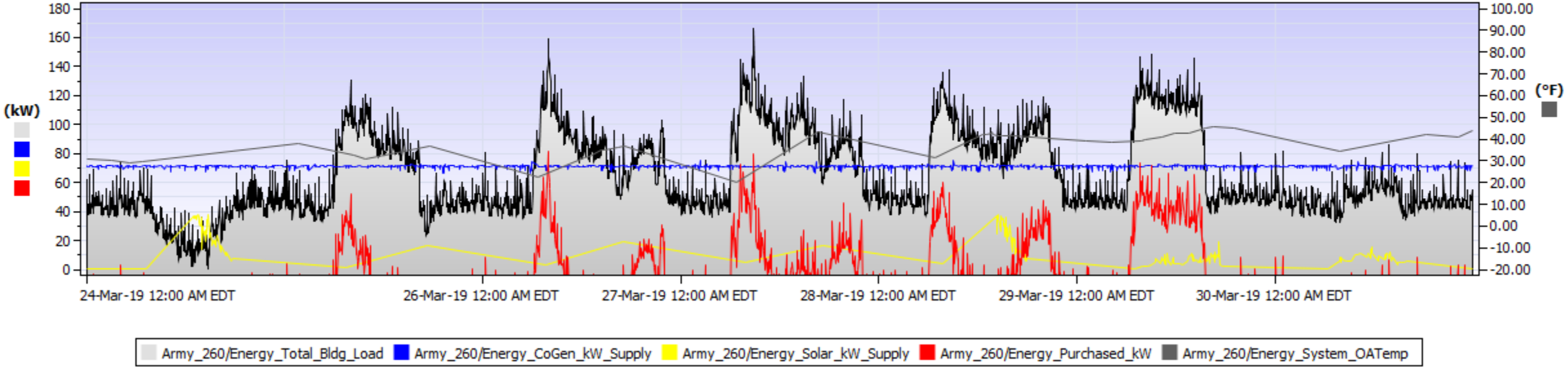
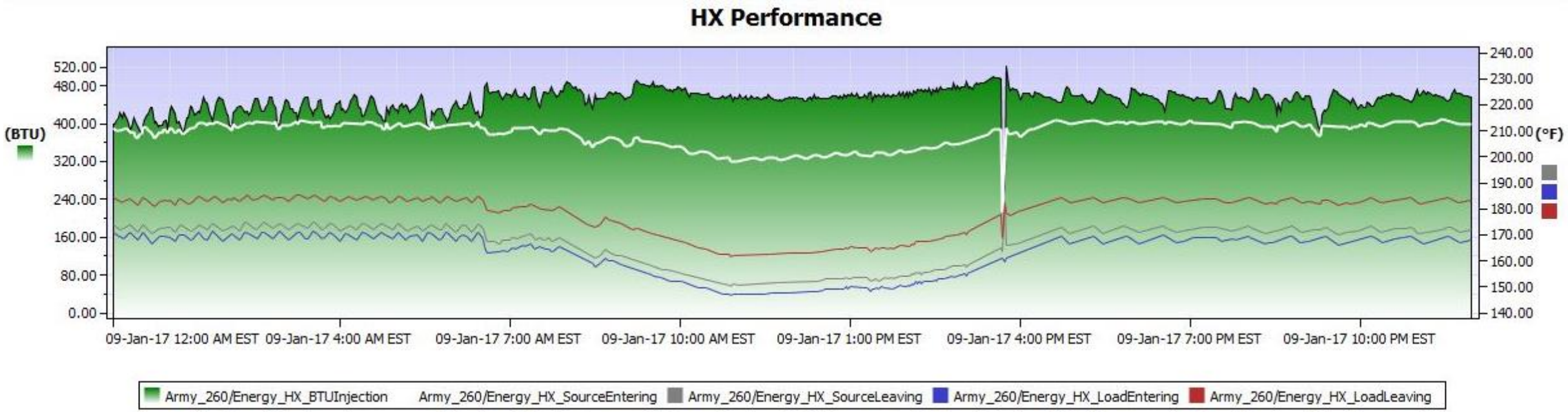
Bangor ~ Building #260 ~ Last Weeks Energy Report

*.csv Export Options

Power



Btu Injection and Heat Exchanger Daily Report



Does Micro CHP work operating from mid October to mid May?

123,000 SF AASF Average Annual Electric and Fuel bill ~$210,000

The 75 KW CHP generated the following over the last three years:

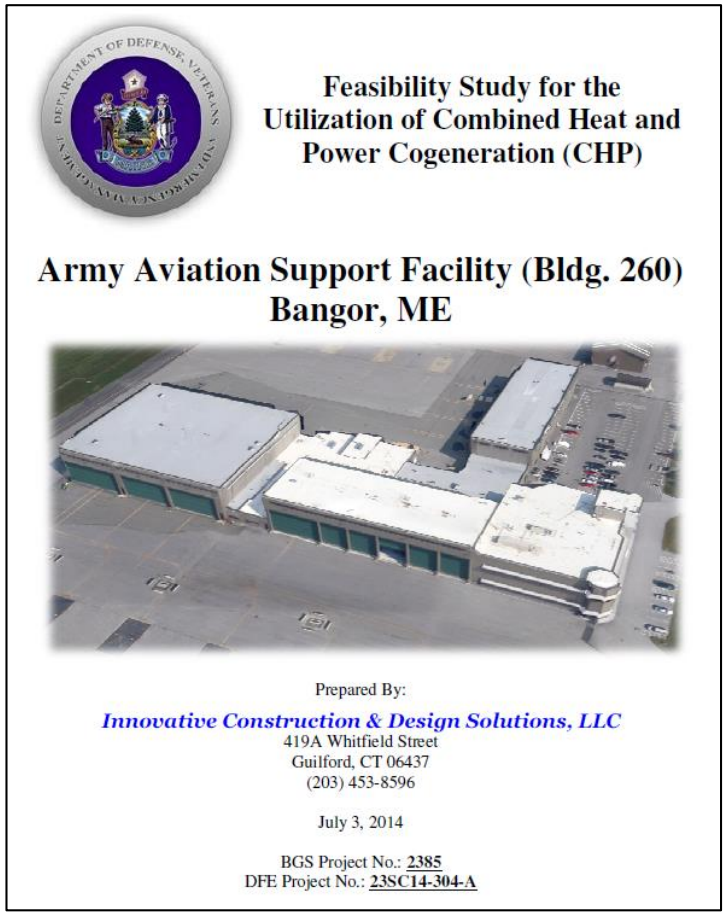
- ~$28,500 in average electrical savings
- ~$26,500 in average fuel savings (normalized for fuel prices and HDD)
- **~$55,000 in annual energy savings**
- ~ 26% reduction in building energy consumption
- ~ 5% reduction of the MEARNG total energy bill

Bayonets, Forward!

Engineering

- $15,000 Type A (Feasibility Study)
- $27,000 Type B (Design)
- $25,000 Type C (Construction)
- $67,000 A/E cost

- $67,000/75KW = $893 per KW



Feasibility Study for the Utilization of Combined Heat and Power Cogeneration (CHP)

Army Aviation Support Facility (Bldg. 260)
Bangor, ME

Prepared By:

Innovative Construction & Design Solutions, LLC
419A Whitfield Street
Guilford, CT 06437
(203) 453-8596

July 3, 2014

BGS Project No.: 2385
DFE Project No.: 23SC14-304-A

MEARNG CHP Economics

- $67,000 A/E cost
- $350,000 project cost (total project cost $489,000)
- $ 9,285 maintenance cost ($1.85 x 4,882 hours)
- $426,285

- $55,000 savings (average annual utility cost ~$210,000)

- 7.7 years simple pay back

- Does not include demand savings estimated at ~$5-9,000 a year and additional electrical and heating savings.

- $4,950 per KW

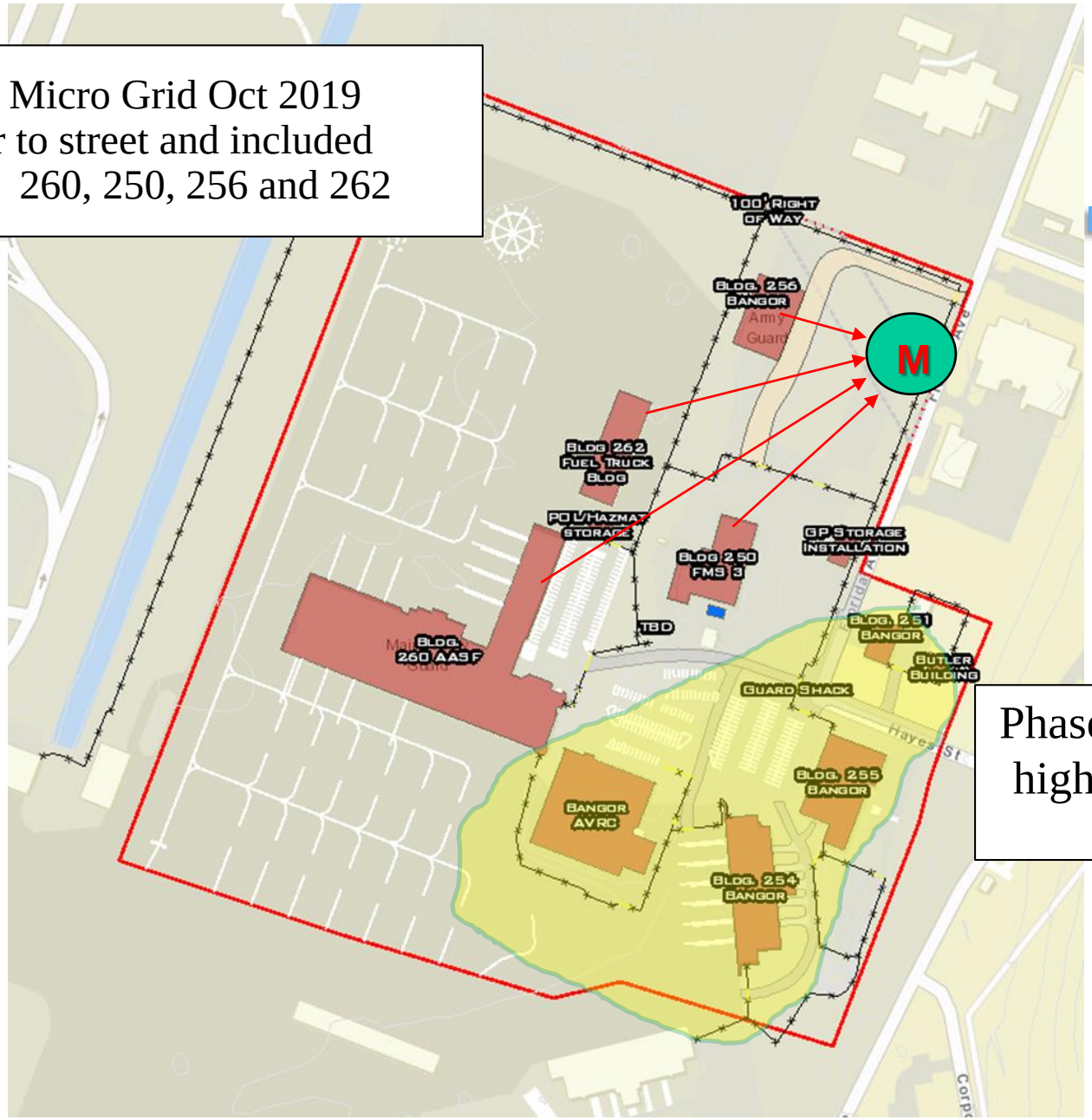
MEARNG FY 2018 CHP Optimization

- Established net metering agreement with utility
- Switch from “electrical” to “thermal” load following
- CHP will no longer “throttle down” due to reduced electrical demand during the unoccupied periods (nights and weekends)
- CHP to run at design RPM 24/7 = 75 KW / 525,000 Btu/hour
- ~ $7-10,000 in additional electrical and thermal savings
- ~ $7,000 annually estimated demand savings

  ($20/KW * 75 KW = $1,500 * 6 months = $9,000)

Bayonets, Forward!

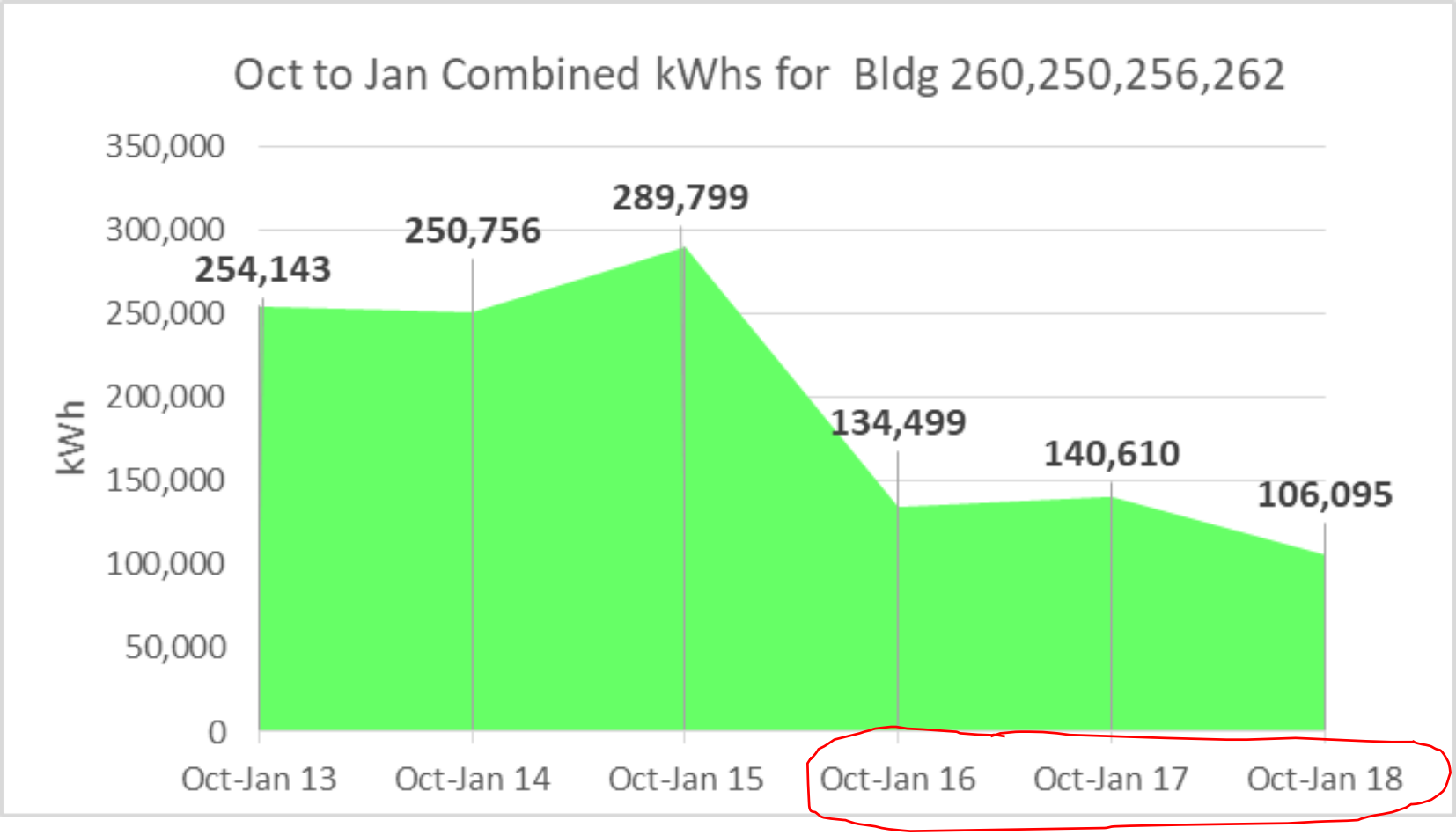
Bangor East Micro Grid Oct 2019
Moved meter to street and included
four buildings 260, 250, 256 and 262



Phase 2 add the (4) buildings highlighted in yellow to the Micro grid

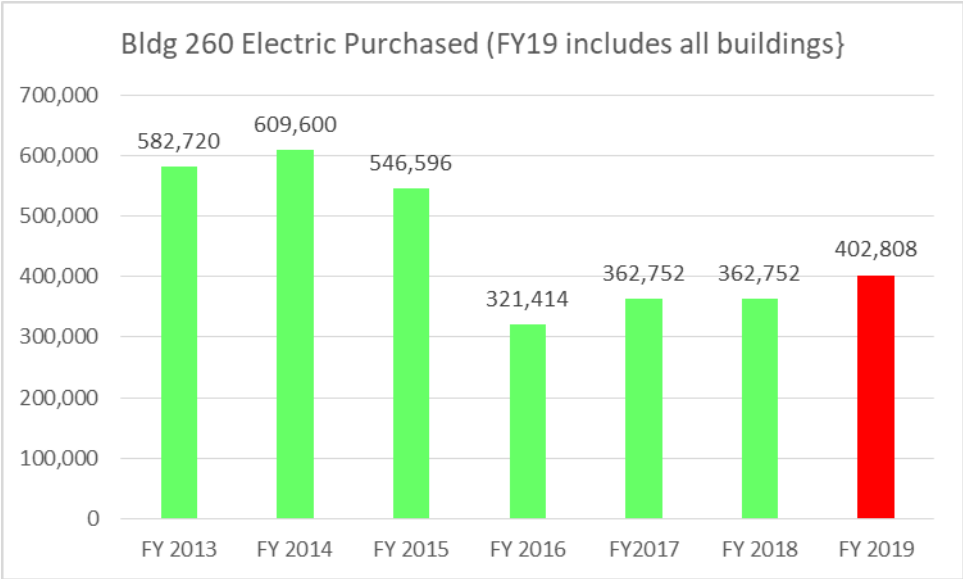
Bayonets, Forward!

Single Meter Started in October 2018
CHP on line ~Oct 15, 2016, 2017, 2018

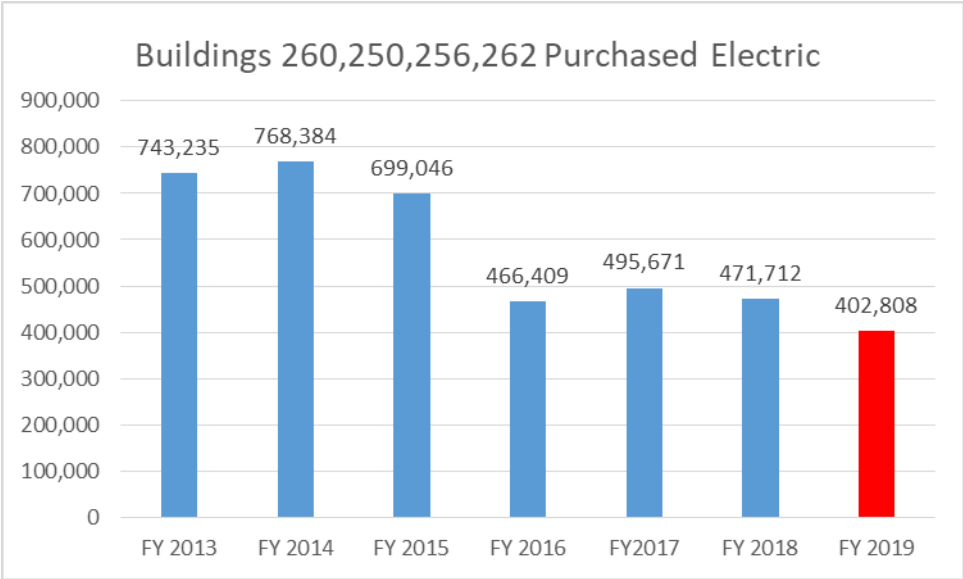


Bayonets, Forward!

Bldg 260 CHP on line FY 2016 “electrically” load following



CHP “thermally” load following FY 2019 all buildings



Micro Grid Energy Used Bldgs 260,250, 256, 262 Bill period 12/30/2018 - 1/30/2019	
Bldg 250 energy used, Shark meter	20,837
Bldg 260 energy used smart meter (MDMS)	53,070
Bldg 256, Estimated prior bills	1,000
Bldg 262, Estimated prior bills	1,000
Micro grid energy used Bldg 260, 250, 256, 262	75,907
Bldg 260 CHP energy produced, BACS point	-51,884
Bldg 260 PV Solar delivered kWh, Emon meter	-2,195
Total Electric from street, Emera meter	21,828
Actual Emera Bill 12/30-1/30/2019	22,080
Emera Exported kWh for period (Credit)	-3,360
Emera Billed kWh	18,720

72 KW x 24 hours x 30 days

Bayonets, Forward!

Emera Maine

Emera Maine Customer Service Center
207-973-2000
1-855-Emera11(1-855-363-7211)
Email: custserv@emeramaine.com
Pay Online at www.emeramaine.com

Account Information

Account Number:	0000000010042482-1
Service Address:	STATE OF MAINE - MILITARY BUREAU BLDG 260 (CO-GEN) UNIT HANGAR BANGOR
Read Cycle:	24
Next Planned Meter Read:	Mar-29-2019

Customer Account Summary

Previous Statement Balance	Payments (-) Thank You	Adjustments (+/-)	Balance Before New Charges	New Charges	Current Account Balance	Total Now Due
$5,909.84	$5,909.84	$0.00	$0.00	$3,709.59	$3,709.59	$3,709.59

Energy Comparison

	This Month	Last Month	One Year Ago
kWh			
Service Days			
kWh Per Day			
Cost Per Day			

Meter Information (Service 1)

Meter Number	Units	For Service From	For Service To	Days	Meter Reading Current	Meter Reading Previous	Constant	kWh
007701682	1	01/30/2019	02/27/2019	28	9160	9128	480	15360

Carryover	New Credits	Allocated	Remaining	Time Period
0	4800	4800	0	

Message from Emera Maine

190 KW is average demand
Saved 70 KW for month
70 KW X $21.40 = $1,498

Copy not paid. not

Emera Maine (Service 1 Rate Code M-1)

Distribution	129.12 kW@8.0500	$1,039.42
Transmission	129.12 kW@12.5200	$1,616.58
Stranded Costs	10560 kWh@0.00352	$37.17
Stranded Costs	129.12 kW@0.8300	$107.17
Conservation Charge	10560 kWh@0.00243	$25.66
Customer Charge		$39.85
Balance Forward		**$0.00**
Total Emera Maine Delivery Charges Due		**$2,865.85**

ASFF 75 KW CHP vs. 43 KW Solar PV Comparison

75 KW CHP
~$425,000

43 KW PV
~$200,000

75 KW CHP vs. 86 KW Solar PV Comparison

(43 KW PV x 2 = 86 KW produces ~74 KW)

Bldg 260 75 KW CHP vs. 86 KW Solar PV				
	Unit	75 KW CHP	86 KW PV	% Difference
Capital Cost	$	$350,000	$400,000	14%
Max KW Production	KW	75	74	1%
Annual Capacity Factor	KW	75	23	69%
Annual Electricity Production*	kWh	360,810	100,000	72%
Annual Electricity savings ($.13 kWh)	kWh	$46,905	$13,000	72%
Annual Useful Heat savings	Therms	12,500	0	100%
Annual Useful Heat savings ($1.05 therm)	$	$13,125	$0	100%
Annual Maintenance cost **	$ average	$9,000	$750	-92%
Annual Total Energy savings	$	$51,030	$12,250	76%
Simple pay back	years	6.9	32.7	376%
Estimated Life Cycle (new eng @ 35,000 hrs)	years	21	25	-19%
Annual CO2 Savings	Tons	90	4	96%
Cost per KW to install	$	$4,667	$5,405	16%
Cost per Watt to install	$	$4.67	$5.41	16%
Electrical Savings per KW installed	$	$680.40	$284.88	58%
Potential Demand Savings ($15/KW)	$	$6,750	$0	100%
Footprint Required sf	Square feet	150	9,000	5900%

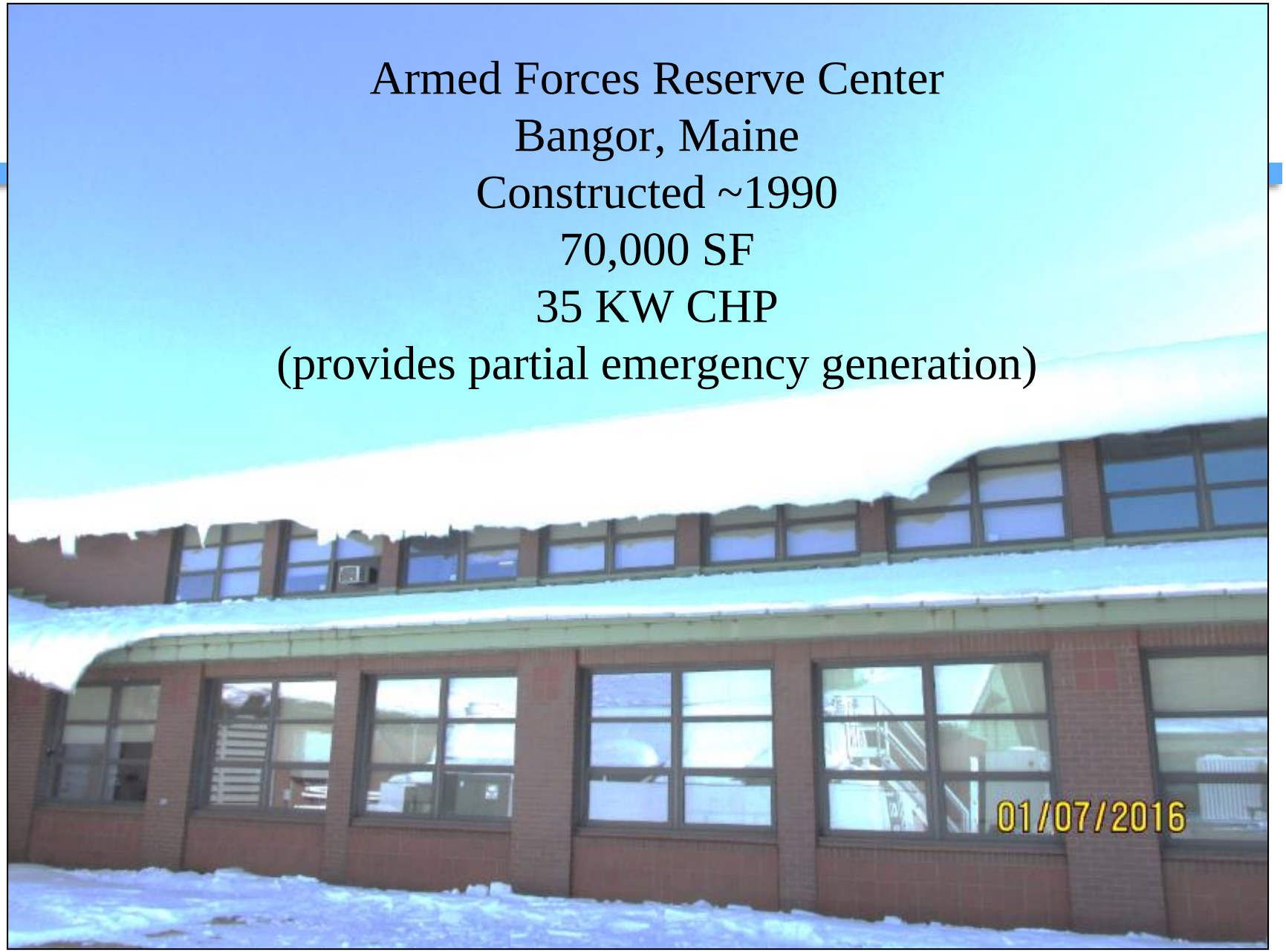
Bayonets, Forward!

Additional CHP Projects

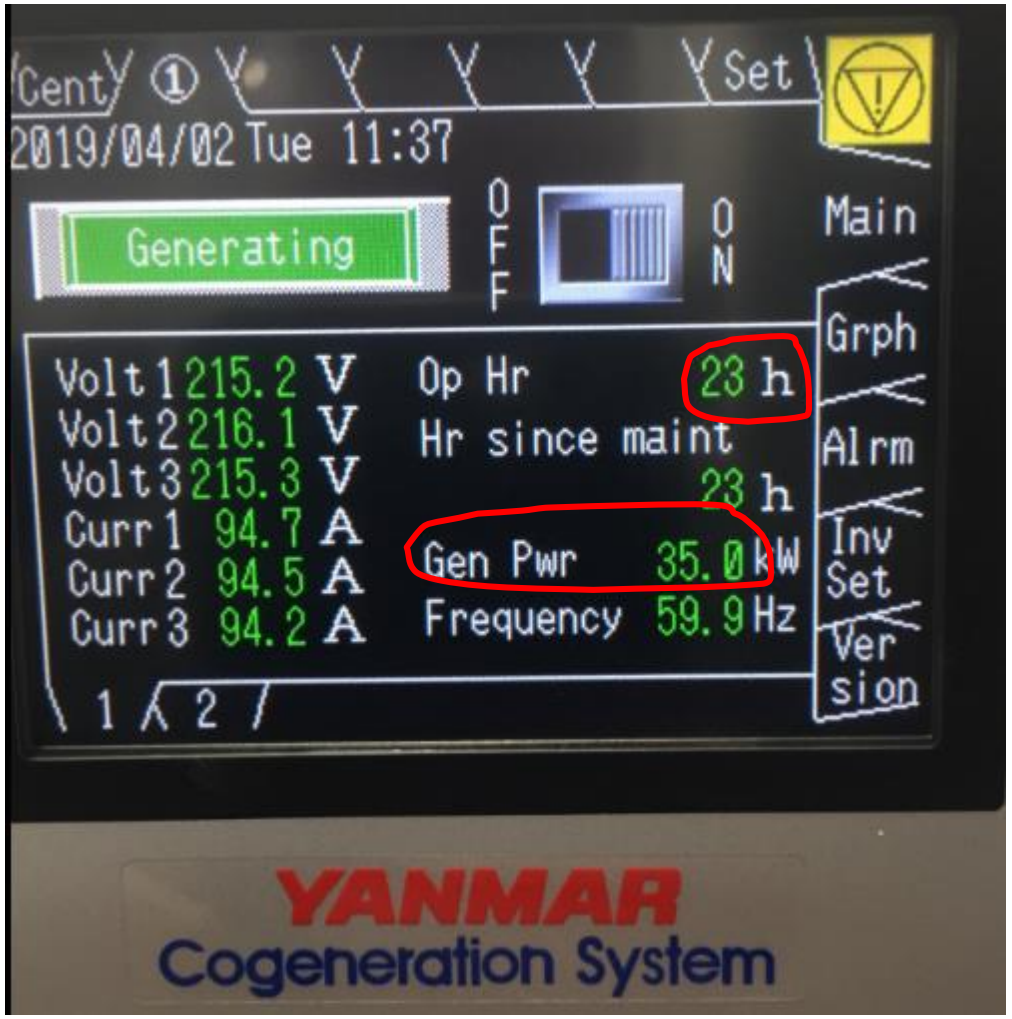
- AFRC, Bangor, Maine, 70,000 SF HVAC upgrade project (SRM)
  - Perimeter baseboard radiation, brick façade on CMU walls built ~1990
  - Remove existing two large mass 2.7 MMBtu boilers
  - 2 gas condensing boilers
  - 35 KW CHP
  - Awarded Oct 2017

- Northern Maine Readiness Center (New Construction - MILCON)
  - 45,000 SF, ~$16M
  - AHU, low temperature radiant floors and ice melt walkways
  - 2 - 10KW CHP's and variable refrigerant flow heat pump system
  - Award Late spring 2018

Armed Forces Reserve Center
Bangor, Maine
Constructed ~1990
70,000 SF
35 KW CHP
(provides partial emergency generation)



35 KW Yanmar CHP On Line April 1, 2019



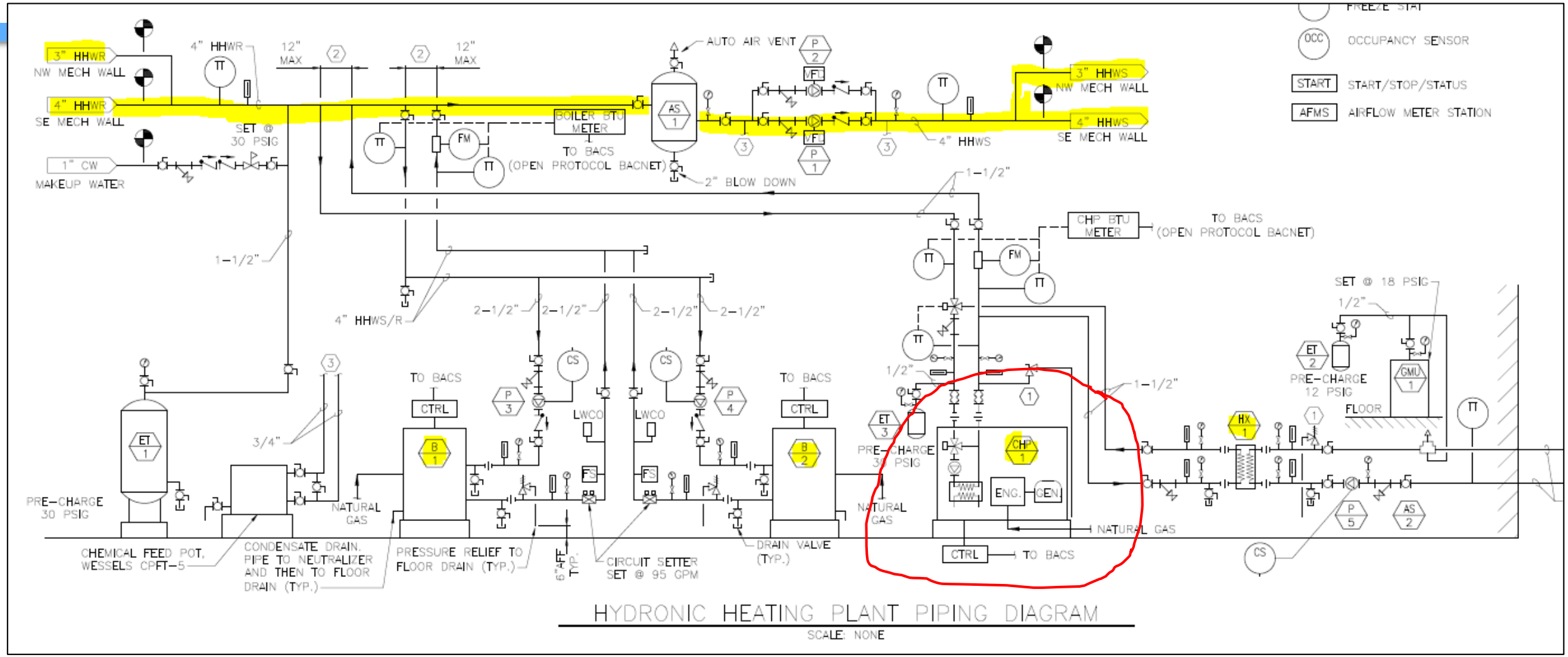
Bayonets, Forward!

35 KW CHP delivers ~200,000 Btu/hr
CHP runs from mid October to mid May

Load	
	Btu/hr
AHUs and Fan coil units.	800,000
Unit Heaters	32,000
Base board radiation	800,000
	1,632,000
Supply	
Gas condensing boilers (2)	2,000,000
CHP	200,000
	2,200,000

Avg hourly heat loss

- Sep ~75,000 Btu/hr
- Oct ~200,000 Btu/hr
- Nov ~260,000 Btu/hr
- Dec ~360,000 Btu/hr
- Jan ~430,000 Btu/hr
- Feb ~395,000 Btu/hr
- Mar ~310,000 Btu/hr
- Apr ~210,000 Btu/hr
- May ~115,000 Btu/hr



Bayonets, Forward!

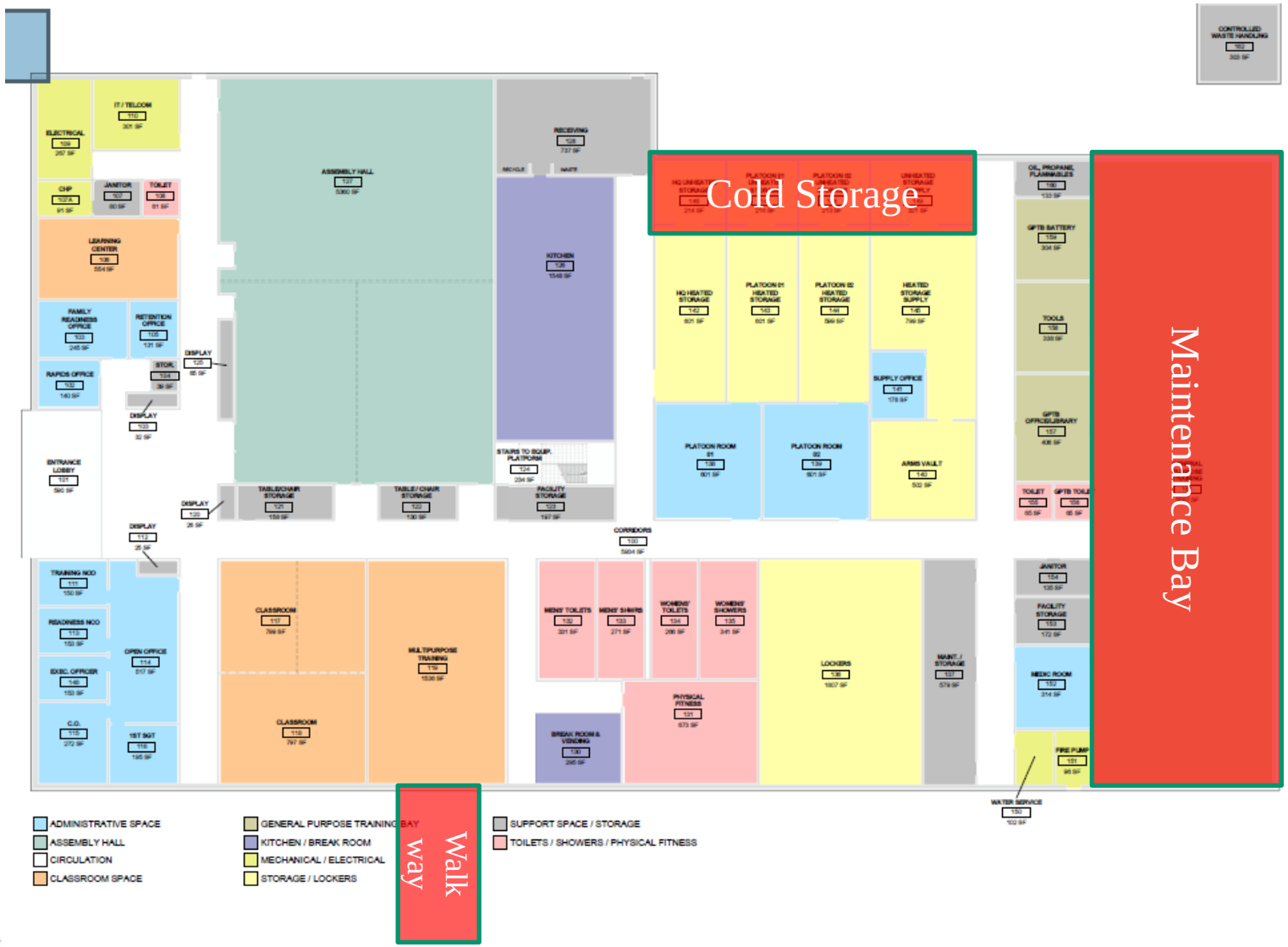
Northern Maine Readiness Center
Presque Isle ~ 45,000 SF

Bayonets, Forward!

February 2019

Bayonets, Forward!

NMRC layout (~45,000SF) primary heating will be by CHP low temperature (~110F) radiant slab through out the building.



Red areas = dump zones

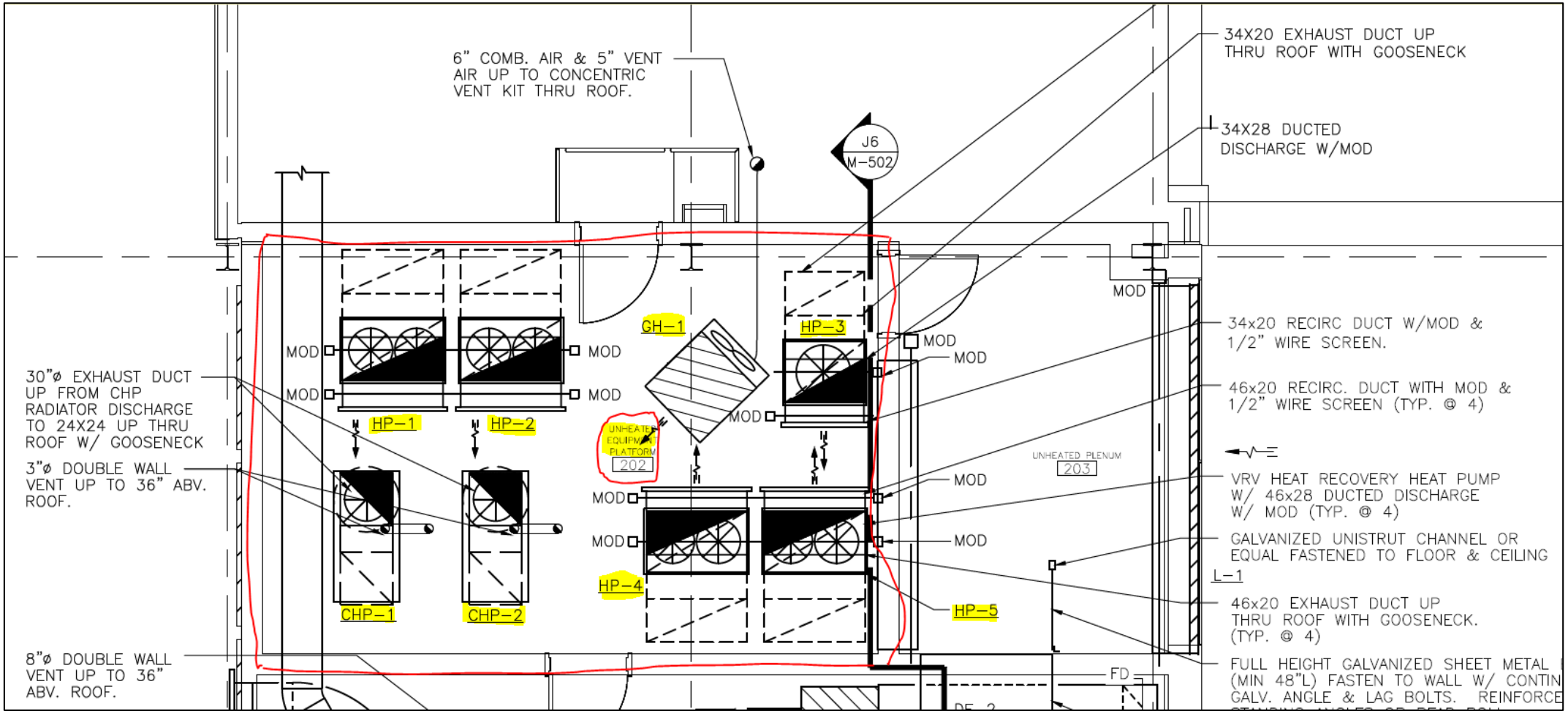
Bayonets, Forward!

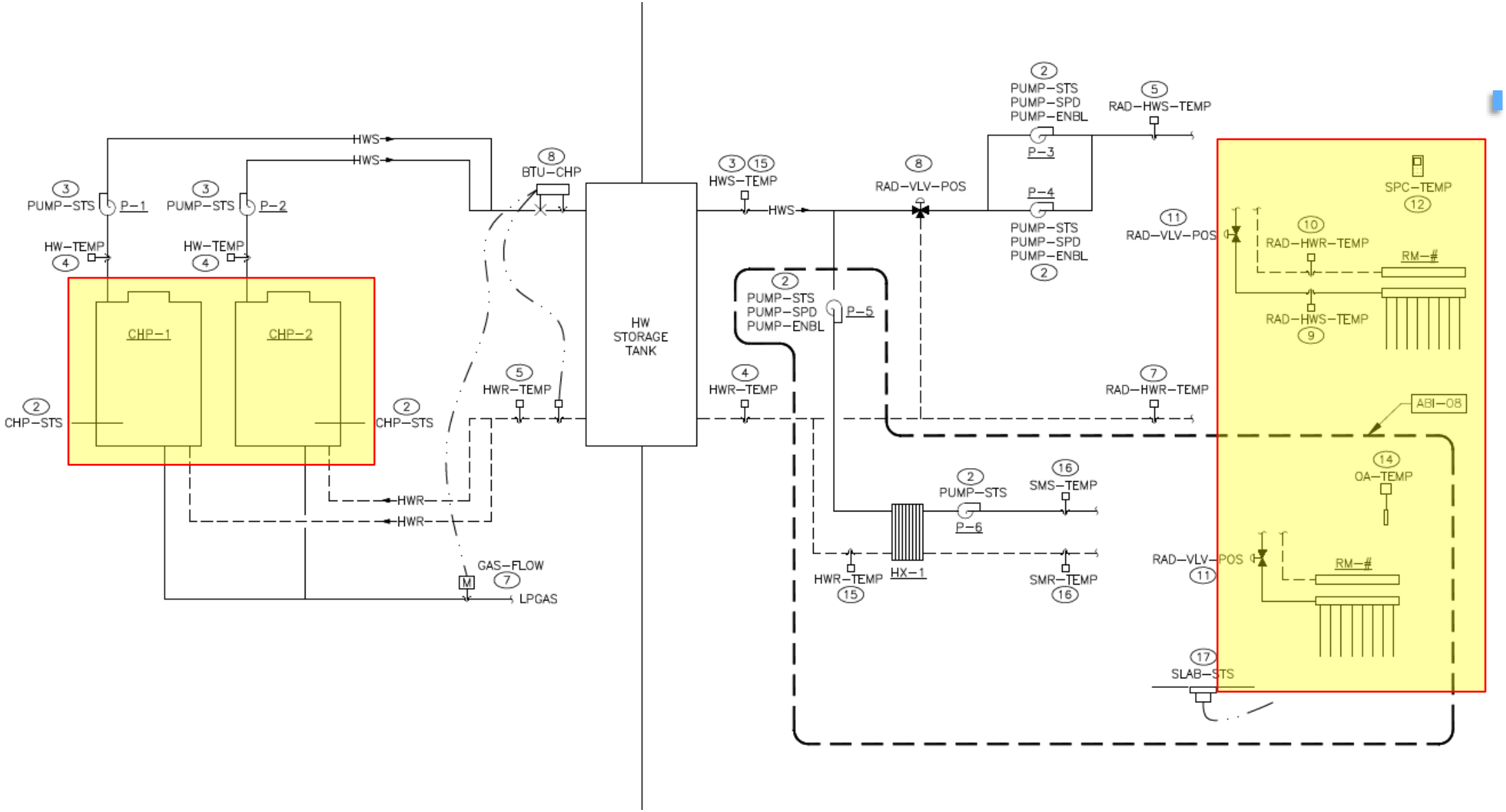
CP10WN

Model			CP10WN	
			CP10WN-SN (B)	CP10WN-SPB
Power	Output	Rated Output	10 kW	
		Voltage	240/120 V, 60Hz (208V, 277V)	
		Phases/Wires	Single phase, 3 wire	
		Modulation	0.3 to 10 kW with optional CT/Transducer kit (*1)	
Fuel	Gas type		Natural gas	Propane gas
	Pressure	Standard	8 in WC (2kPa)	11 in WC (2.8kPa)
		Range	4 ~ 10 in WC (1 ~ 2.5kPa)	8 ~ 13 in WC (2 ~ 3.3kPa)
	Consumption (LHV)		107,500 BTU (31.5kW)	112,800 BTU (33.1kW)
			1.08 therms/hr	1.34 Gallon (*3)
	Consumption (HHV) (*3, *4)		119,100 BTU (34.9 kW)	122,800 BTU (36.0 kW)
			1.19 therms/hr	1.34 Gallon (*3)
Heat output	Rated recovered heat		57,300 BTU/h	65,200 BTU/h
	Rated hot water temp.	Inlet	149 F (65 C)	
		Outlet	158 F (70 C)	
	Rated Hot water flow rate		12.7 GPM (48.2 L/min)	
	Maximum hot water temp. (Outlet)		172 F (78 C)	
Input power	Voltage, Frequency		240V, 60Hz	
	Starting current		21.7 A	
	Power consumption	Radiator fan stop	0.39 kW	
		Radiator fan run	0.71 kW	
Gross Efficiency (LHV)	Overall efficiency		85%	88%
	Electrical generation efficiency		31.5%	30%
	Exhaust heat recovery ratio		53.5%	58%
Sound level	Radiator fan stopped		54 dB (A)	
	Radiator fan operating		56 dB (A)	
Dimensions	Width		57.9 in (1,470 mm)	
	Depth		31.5 in (800 mm)	
	Height		70.5 in (1,790 mm)	
	Net weight		1,653 lb (750 kg)	1,664 lb (755 kg)
Maintenance Interval			10,000 hrs	
Standard Warranty			2 Years; Unlimited Hours	
YES Product Protection	10 Years / 30,000 hrs		Optional	
	10 Years / 60,000 hrs		Optional	
	15 Years / 90,000 hrs		Optional	
Emissions & Certifications			EPA Certified UL2200 Certified CSAC22.2 No 14 Certified CSAC22.2 No 100 Certified UL1741/IEEE1547 Certified (*2)	

Bayonets, Forward!

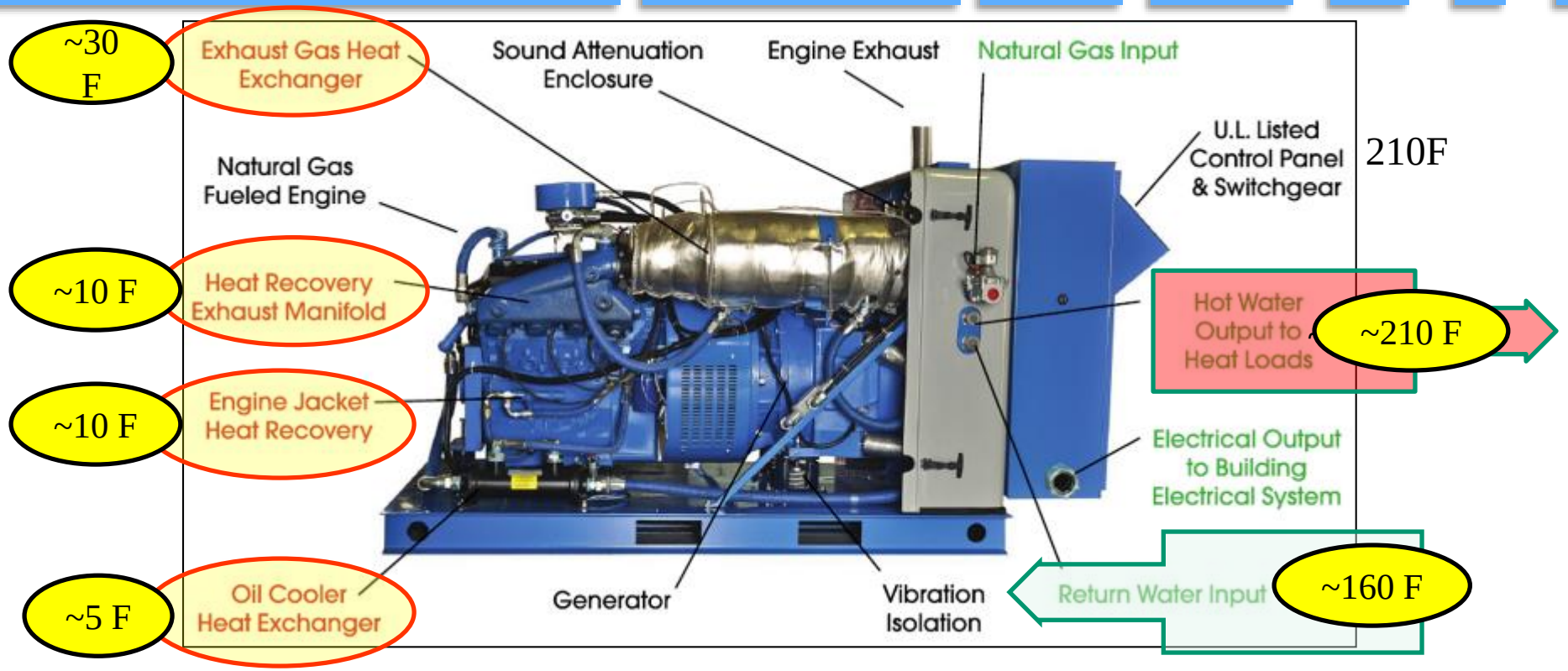
Two 10 KW CHP
Mid October to Mid May




HWS
HWS
3
PUMP–STS
P–1
3
PUMP–STS
P–2
HW–TEMP
4
HW–TEMP
4
CHP–1
CHP–2
2
CHP–STS
2
CHP–STS
HWR
HWR
GAS–FLOW
7
M
LPGAS
8
BTU–CHP
5
HWR–TEMP
HW
STORAGE
TANK
3
15
HWS–TEMP
HWS
4
HWR–TEMP
8
RAD–VLV–POS
2
PUMP–STS
PUMP–SPD
PUMP–ENBL
P–5
2
PUMP–STS
PUMP–SPD
PUMP–ENBL
P–3
P–4
PUMP–STS
PUMP–SPD
PUMP–ENBL
2
5
RAD–HWS–TEMP
11
RAD–VLV–POS
7
RAD–HWR–TEMP
2
PUMP–STS
P–6
16
SMS–TEMP
HWR–TEMP
15
HX–1
SMR–TEMP
16
SPC–TEMP
12
10
RAD–HWR–TEMP
RM–#
RAD–HWS–TEMP
9
ABI–08
14
OA–TEMP
RAD–VLV–POS
11
RM–#
17
SLAB–STS

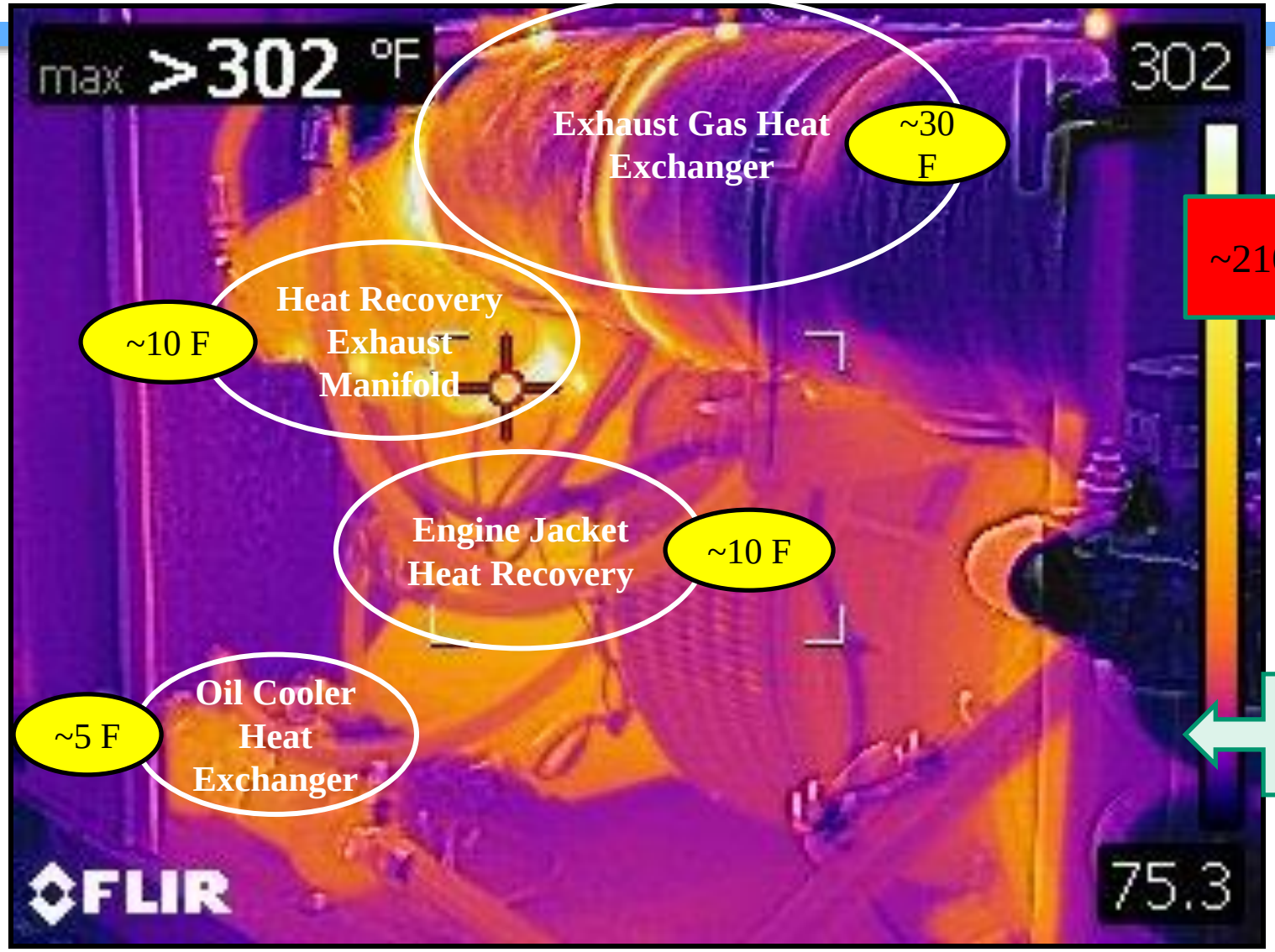
Aegis 75 KW CHP Compact Design
Fit Through the Mechanical Room Double Doors

75 KW Combined Heat and Power (CHP)



- 7.4 liter (454 ci) V8 internal combustion engine (since 1970)
- Input 9.3 therms/ hr natural gas (~6.8 gals fuel oil/ hr eq.)
- Output 5.2 therms/ hr, 525,000 Btu/ hr (~3.8 gals fuel oil/ hr eq.)
- Generates 75 kWh per hour

75 KW CHP Waste Heat Recovery



~210F

~160 F

Bayonets, Forward!

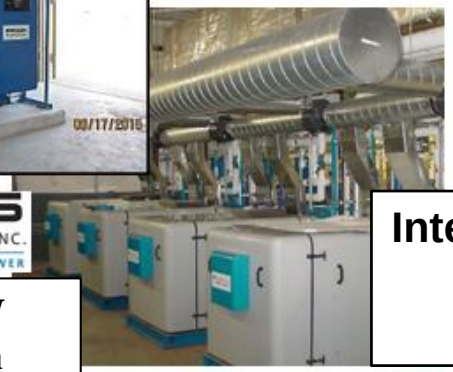
Micro CHP's: 5 - 400 KW, 35,000 – 2 MMBtu / hr

75 KW

65 KW

~300 KW

AEGIS ENERGY SERVICES, INC. COMBINED HEAT & POWER



300 KW Tandem

Internal Combustion Engines & Micro turbines

400 KW

YANMAR

5 KW 10 KW 35 KW

micro Combined Heat & Power (mCHP)

35 KW

Bayonets, Forward!

Any questions please contact:

A.J. Ballard, C.E.M

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Maine Army National Guard

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207-522-7927

Bayonets, Forward!