The University of Iowa

PRVN CONSULTANTS, INC

WASTE HEAT CHILLED WATER GENERATION

PRESENTED BY:
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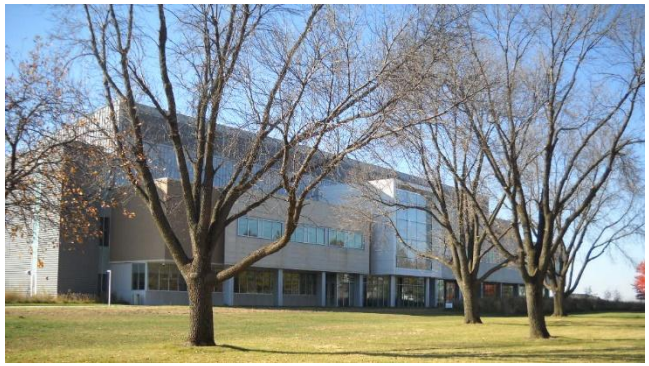
JIM NONNENMANN, PE

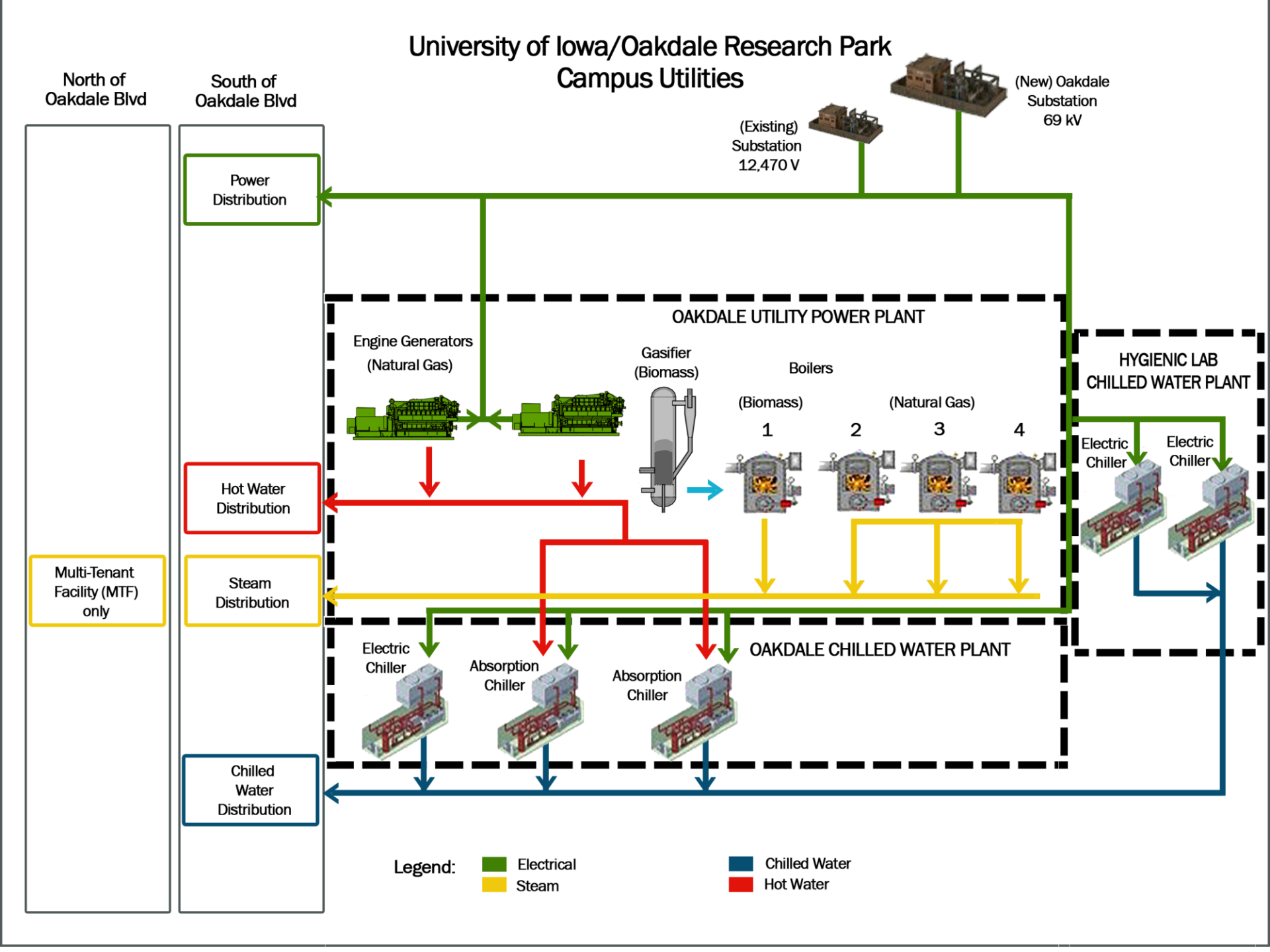
AGENDA

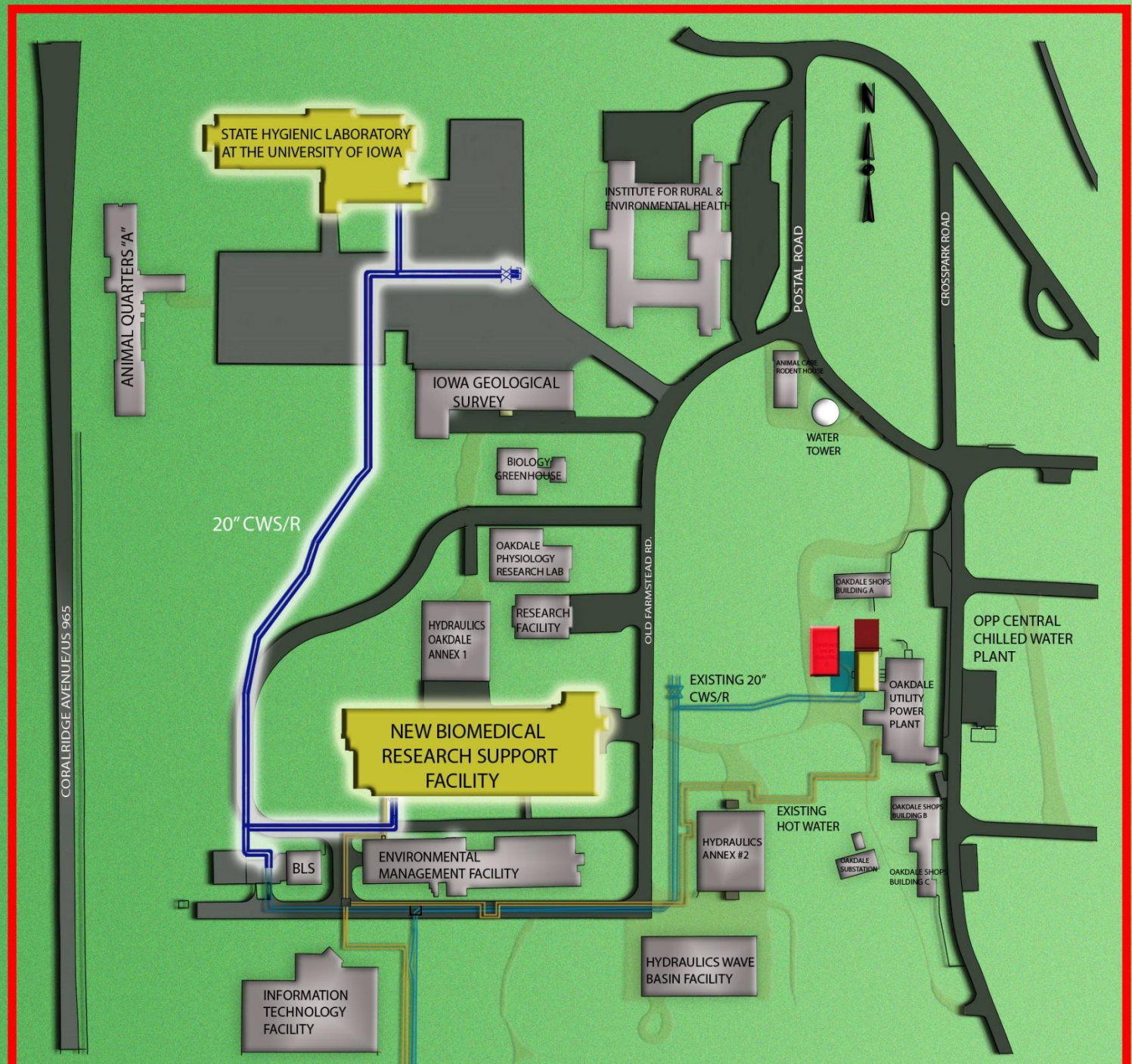
- Research Campus Utilities Overview
- Chilled Water Need and Project Goals
- Project Design and Construction
- Commissioning
- Best Practices and Lessons Learned
- Questions

RESEARCH CAMPUS FACILITIES

- State Hygienic Laboratory
- Information Technology Facility
- Biomedical Research Support Facility
- Environmental Management Facility




University of Iowa/Oakdale Research Park
Campus Utilities
North of Oakdale Blvd
South of Oakdale Blvd
(New) Oakdale Substation 69 kV
(Existing) Substation 12,470 V
Power Distribution
OAKDALE UTILITY POWER PLANT
Engine Generators (Natural Gas)
Gasifier (Biomass)
Boilers
(Biomass)
(Natural Gas)
1
2
3
4
HYGIENIC LAB CHILLED WATER PLANT
Electric Chiller
Electric Chiller
Hot Water Distribution
Multi-Tenant Facility (MTF) only
Steam Distribution
OAKDALE CHILLED WATER PLANT
Electric Chiller
Absorption Chiller
Absorption Chiller
Chilled Water Distribution
Legend:
Electrical
Steam
Chilled Water
Hot Water


STATE HYGIENIC LABORATORY AT THE UNIVERSITY OF IOWA
INSTITUTE FOR RURAL & ENVIRONMENTAL HEALTH
POSTAL ROAD
CROSSPARK ROAD
ANIMAL QUARTERS "A"
IOWA GEOLOGICAL SURVEY
ANIMAL CARE RODENT HOUSE
WATER TOWER
BIOLOGY GREENHOUSE
20" CWS/R
OAKDALE PHYSIOLOGY RESEARCH LAB
OLD FARMSTEAD RD.
OAKDALE SHOPS BUILDING A
HYDRAULICS OAKDALE ANNEX 1
RESEARCH FACILITY
OPP CENTRAL CHILLED WATER PLANT
CORALRIDGE AVENUE/US 965
EXISTING 20" CWS/R
OAKDALE UTILITY POWER PLANT
NEW BIOMEDICAL RESEARCH SUPPORT FACILITY
EXISTING HOT WATER
OAKDALE SHOPS BUILDING B
HYDRAULICS ANNEX #2
OAKDALE SUBSTATION
BLS
ENVIRONMENTAL MANAGEMENT FACILITY
OAKDALE SHOPS BUILDING C
HYDRAULICS WAVE BASIN FACILITY
INFORMATION TECHNOLOGY FACILITY

CHILLED WATER EXPANSION NEEDS

- Meet the increasing cooling load
- Support mission-critical facilities
- Improve chilled water system reliability
- Continue development of chilled water loop

CHILLED WATER EXPANSION PLAN

- Connect to State Hygienic Laboratory:
  - Extend 20” direct-buried chilled water distribution headers to Hygienic Lab
  - Connect building chillers into distribution network
  - Migrate HLI control to supervisory control from the OCWP, including hardware, software, and communications service
- Oakdale Chilled Water Plant – Install Chillers:
  - Install 440 tons of thermally based chillers
  - Install chiller auxiliary systems

CHILLER TECHNOLOGY

- Renewable energy source:
  - Engine generators
  - Biomass boiler
- Absorption chiller:
  - Hot water
  - Steam
  - Exhaust gas

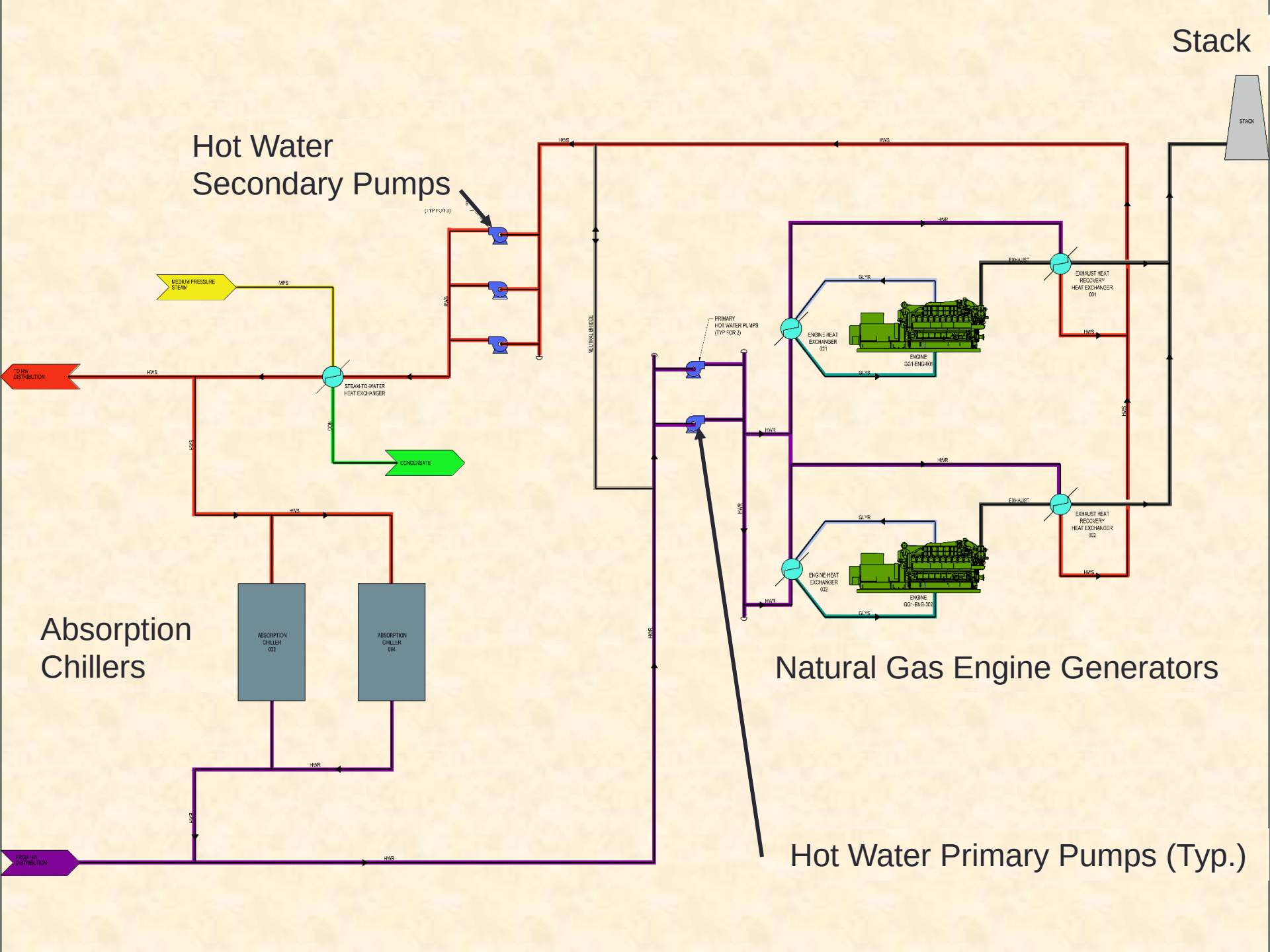
2020 Vision: The University of Iowa's Sustainability Targets

Broad Absorption Chiller (Right)

Thermax Absorption Chillers

AVAILABLE RENEWABLE ENERGY

- Waste heat from (2) 1,400 kW natural-gas-fired reciprocating engines
- Renewable steam from 20,000 lb/hr biomass boiler and heat exchanger (backup)


Stack
Hot Water
Secondary Pumps
Absorption
Chillers
Natural Gas Engine Generators
Hot Water Primary Pumps (Typ.)
STACK
MEDIUM PRESSURE STEAM
MPS
TO HW DISTRIBUTION
HWS
STEAM-TO-WATER HEAT EXCHANGER
CONDENSATE
COND
NEUTRAL BRIDGE
PRIMARY HOT WATER PUMPS (TYP FOR 2)
ENGINE HEAT EXCHANGER 001
ENGINE GG1-ENG-001
EXHAUST HEAT RECOVERY HEAT EXCHANGER 001
ENGINE HEAT EXCHANGER 002
ENGINE GG1-ENG-002
EXHAUST HEAT RECOVERY HEAT EXCHANGER 002
GLYR
EXHAUST
HWR
ABSORPTION CHILLER 003
ABSORPTION CHILLER 004
FROM HW DISTRIBUTION

LIFE-CYCLE COST ANALYSIS

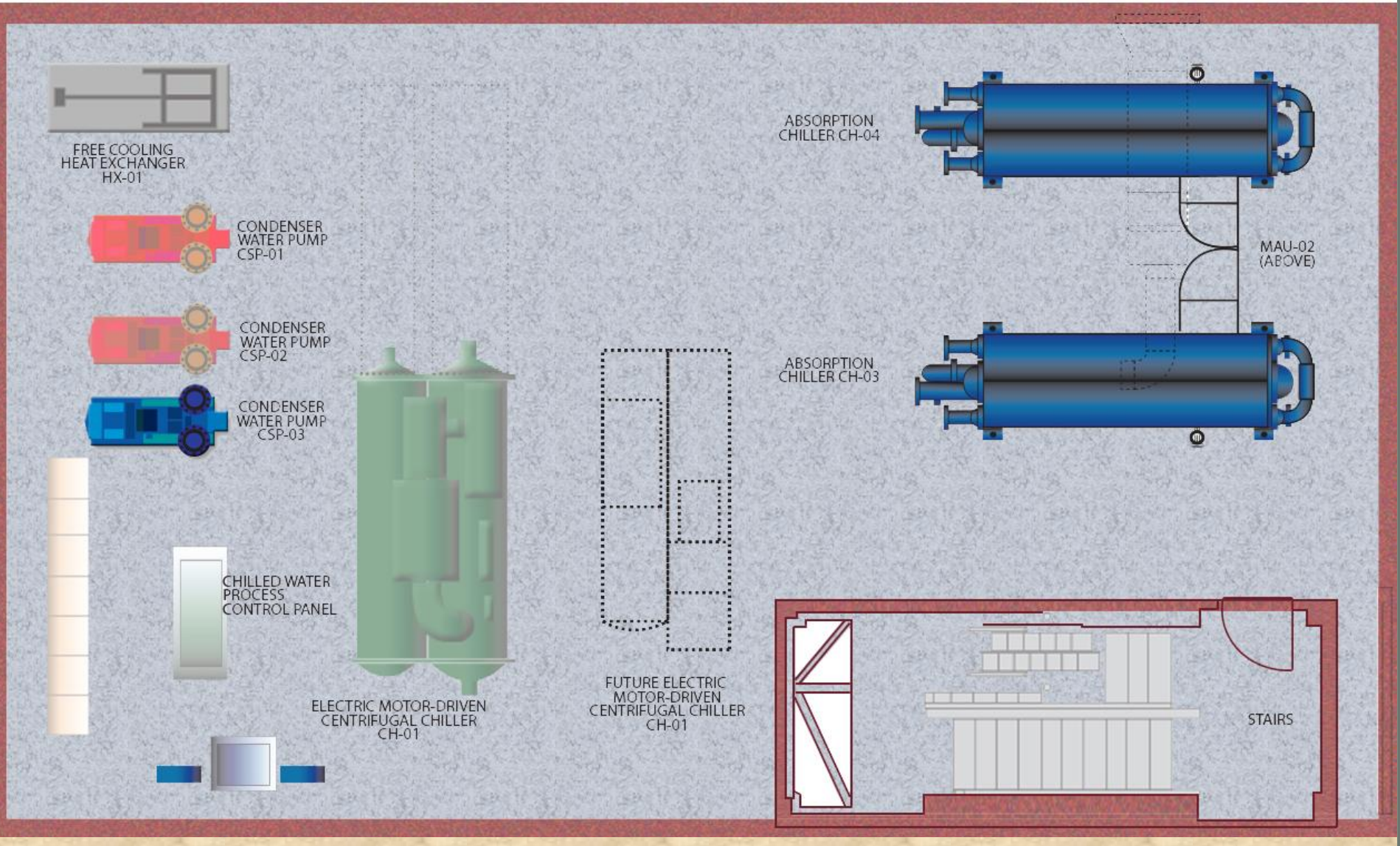
- Analysis compared installation of the following:
  - Steam absorption
  - Hot water absorption
  - Electric centrifugal
- Calculated a 25-year net present value
  - Single engine and chiller base loaded
  - Avoided purchased electricity for both operation of engines and use of thermal chiller
  - Cost of natural gas
  - Cost of electricity for auxiliaries
- Waste heat hot water absorption chiller had lowest net present value of the options

PROJECT GOALS

- Add chilled water capacity for Research Campus
- Utilize available waste heat source year round
- Diversify energy source for chilled water generation
- Reduce summertime, on peak, purchased electricity
- Better utilization of existing electrical generation assets
- Integrate new equipment into existing utility control system

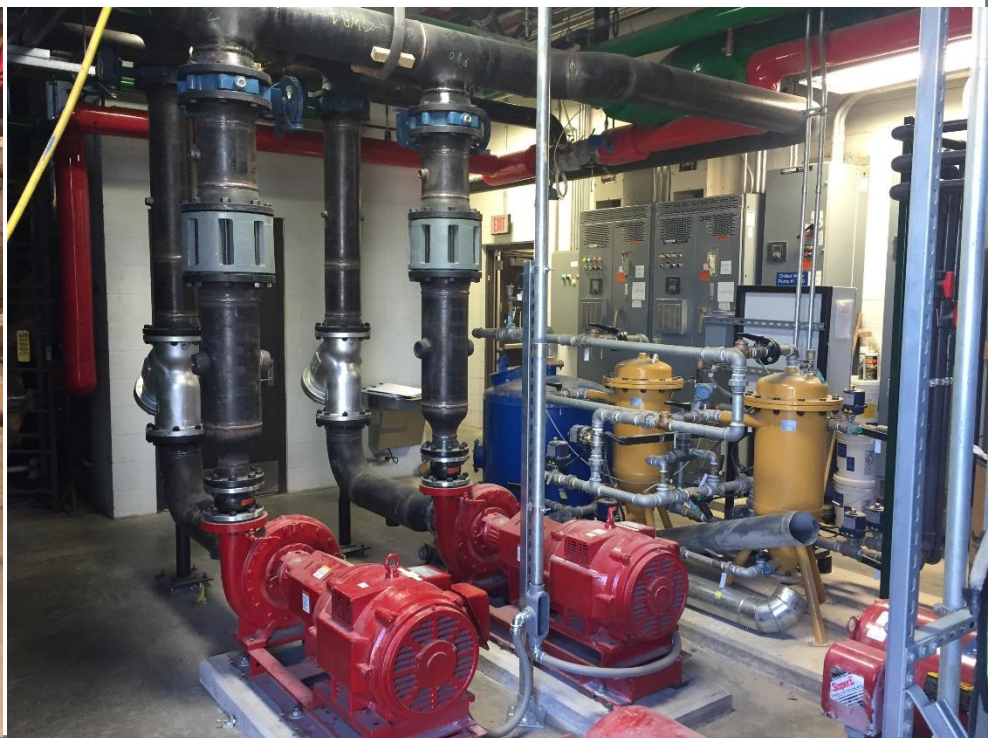
PROJECT DESIGN AND CONSTRUCTION

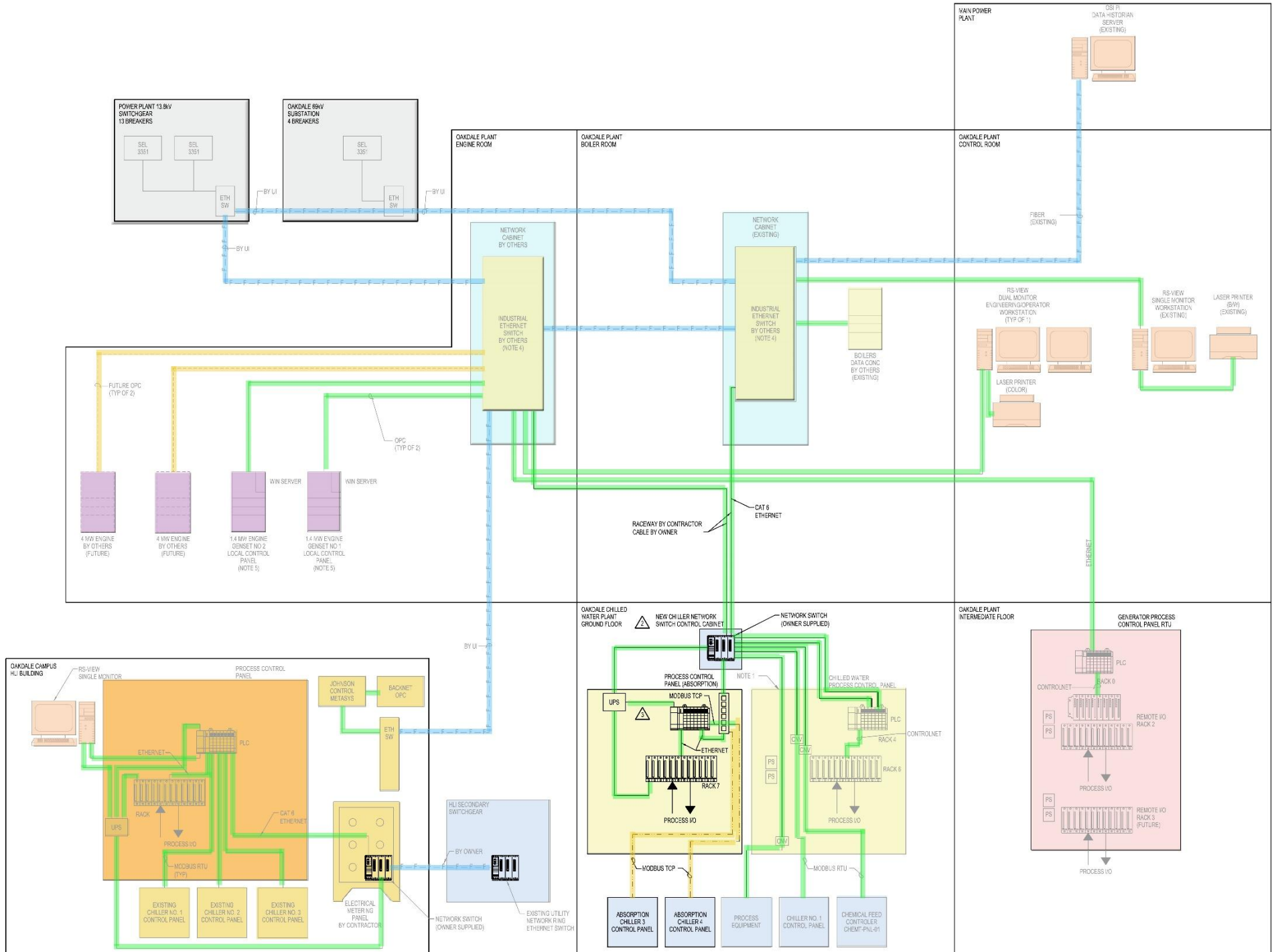
- Renovate Oakdale Chilled Water Plant to add absorption chillers and auxiliaries
- 440 tons of chilled water capacity
- Two 220-ton Trane/Thermax hot water absorption chillers
- Variable-primary chilled water pumping
- Minimize impact to plant operations during construction
- Minimize impact to Information Technology Facility during construction


FREE COOLING
HEAT EXCHANGER
HX-01
CONDENSER
WATER PUMP
CSP-01
CONDENSER
WATER PUMP
CSP-02
CONDENSER
WATER PUMP
CSP-03
CHILLED WATER
PROCESS
CONTROL PANEL
ELECTRIC MOTOR-DRIVEN
CENTRIFUGAL CHILLER
CH-01
FUTURE ELECTRIC
MOTOR-DRIVEN
CENTRIFUGAL CHILLER
CH-01
ABSORPTION
CHILLER CH-04
MAU-02
(ABOVE)
ABSORPTION
CHILLER CH-03
STAIRS


5G 3M C/18
WT 10.4 TONS
MADE IN INDIA


SPX
Marley

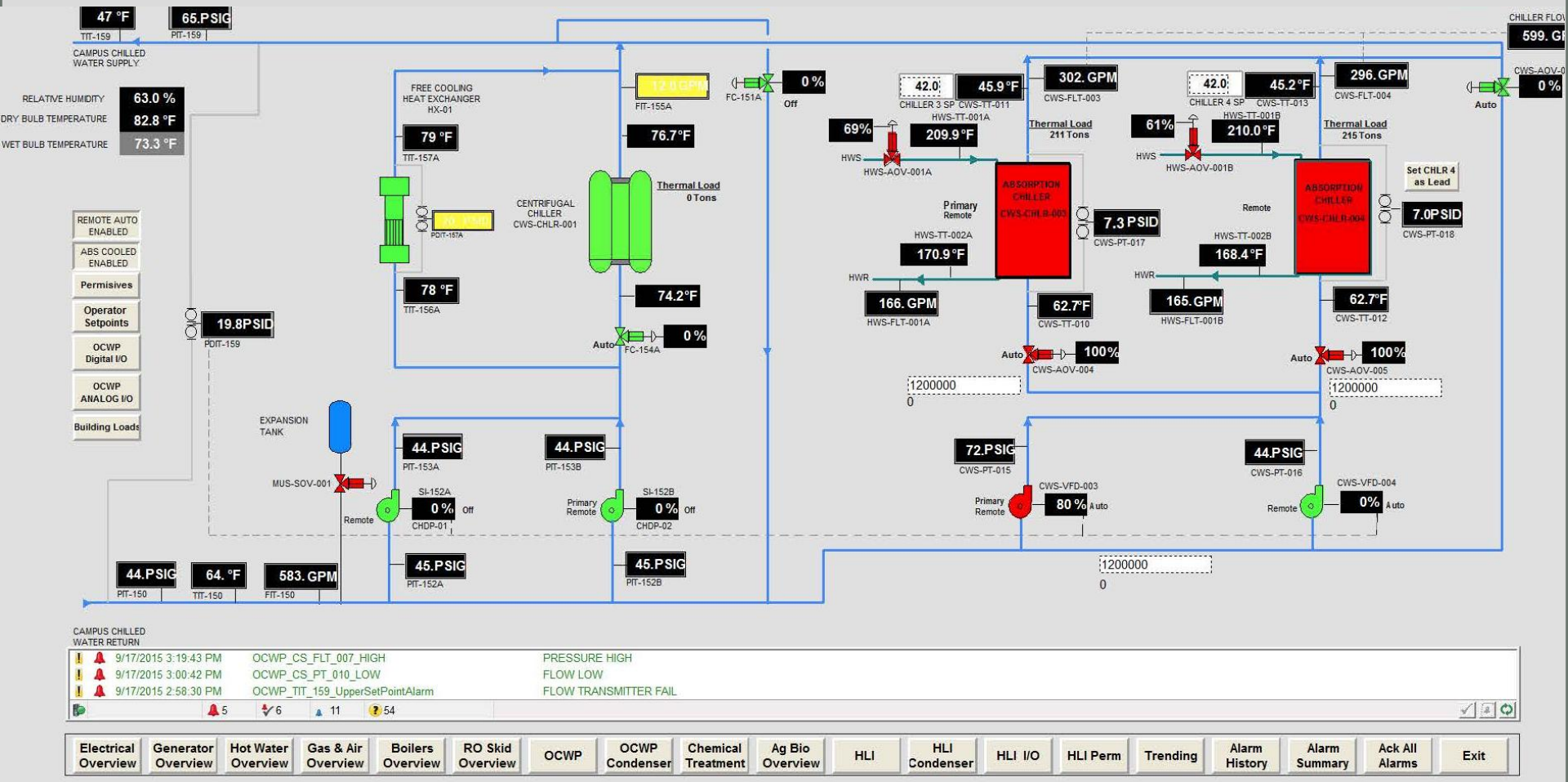



MAIN POWER PLANT
OSI PI DATA HISTORIAN SERVER (EXISTING)
POWER PLANT 13.8kV SWITCHGEAR 13 BREAKERS
SEL 3351
SEL 3351
ETH SW
OAKDALE 69kV SUBSTATION 4 BREAKERS
SEL 3351
ETH SW
BY UI
BY UI
BY UI
OAKDALE PLANT ENGINE ROOM
OAKDALE PLANT BOILER ROOM
OAKDALE PLANT CONTROL ROOM
NETWORK CABINET BY OTHERS
INDUSTRIAL ETHERNET SWITCH BY OTHERS (NOTE 4)
NETWORK CABINET (EXISTING)
INDUSTRIAL ETHERNET SWITCH BY OTHERS (NOTE 4)
FIBER (EXISTING)
BOILERS DATA CONC BY OTHERS (EXISTING)
RS-VIEW DUAL MONITOR ENGINEERING/OPERATOR WORKSTATION (TYP OF 1)
LASER PRINTER (COLOR)
RS-VIEW SINGLE MONITOR WORKSTATION (EXISTING)
LASER PRINTER (B/W) (EXISTING)
FUTURE OPC (TYP OF 2)
OPC (TYP OF 2)
WIN SERVER
WIN SERVER
4 MW ENGINE BY OTHERS (FUTURE)
4 MW ENGINE BY OTHERS (FUTURE)
1.4 MW ENGINE GENSET NO 2 LOCAL CONTROL PANEL (NOTE 5)
1.4 MW ENGINE GENSET NO 1 LOCAL CONTROL PANEL (NOTE 5)
RACEWAY BY CONTRACTOR CABLE BY OWNER
CAT 6 ETHERNET
ETHERNET
OAKDALE CHILLED WATER PLANT GROUND FLOOR
NEW CHILLER NETWORK SWITCH CONTROL CABINET
NETWORK SWITCH (OWNER SUPPLIED)
OAKDALE PLANT INTERMEDIATE FLOOR
GENERATOR PROCESS CONTROL PANEL RTU
PLC
CONTROLNET
RACK 0
REMOTE I/O RACK 2
PROCESS I/O
REMOTE I/O RACK 3 (FUTURE)
PROCESS I/O
OAKDALE CAMPUS HLI BUILDING
RS-VIEW SINGLE MONITOR
PROCESS CONTROL PANEL
JOHNSON CONTROL METASYS
BACKNET OPC
ETH SW
ETHERNET
PLC
RACK
UPS
PROCESS I/O
MODBUS RTU (TYP)
CAT 6 ETHERNET
EXISTING CHILLER NO. 1 CONTROL PANEL
EXISTING CHILLER NO. 2 CONTROL PANEL
EXISTING CHILLER NO. 3 CONTROL PANEL
ELECTRICAL METERING PANEL BY CONTRACTOR
HLI SECONDARY SWITCHGEAR
BY OWNER
NETWORK SWITCH (OWNER SUPPLIED)
EXISTING UTILITY NETWORK RING ETHERNET SWITCH
PROCESS CONTROL PANEL (ABSORPTION)
UPS
MODBUS TCP
ETHERNET
RACK 7
PROCESS I/O
NOTE 1
CHILLED WATER PROCESS CONTRO. PANEL
PLC
CONTROLNET
RACK 4
RACK 5
PROCESS I/O
MODBUS TCP
MODBUS RTU
ABSORPTION CHILLER 3 CONTROL PANEL
ABSORPTION CHILLER 4 CONTROL PANEL
PROCESS EQUIPMENT
CHILLER NO. 1 CONTROL PANEL
CHEMICAL FEED CONTROLER CHEMT-PNL-01

COMMISSIONING

- Get CX Agent involved early and develop checklists early
- Project wiring diagrams
- Operating/control system description with equipment vendor-supplied data and review
- Control system FAT with Control Service Technician and equipment vendor in attendance
- Loop checkout utilizing vendor representatives
- Set up historian (PI, etc.) prior to startup
- Startup and testing procedures prior to startup efforts

FUNCTIONAL PERFORMANCE TESTING



OPERATIONAL SAVINGS

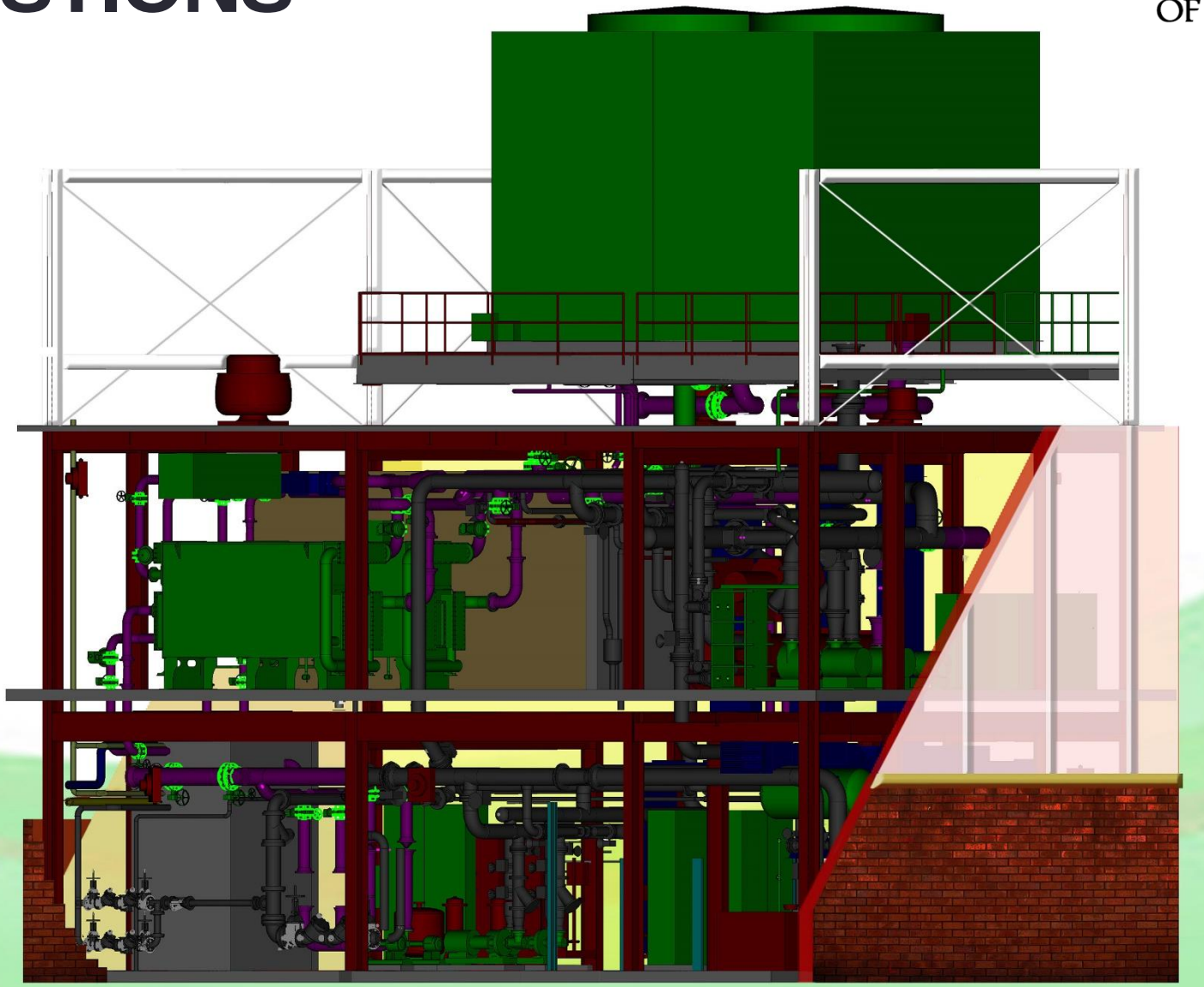
- Case parameters:
  - Natural gas cost: $3.50 per MMBtu
  - One engine producing 1,300 kW
  - Two absorption chillers producing 400 tons chilled water
- Save approximately $84.50 per hour for engine generator operation
- Save additional $28 per hour with absorption chiller operation
- Reduces peak electrical load, avoiding higher demand charges

BEST PRACTICES & LESSONS LEARNED

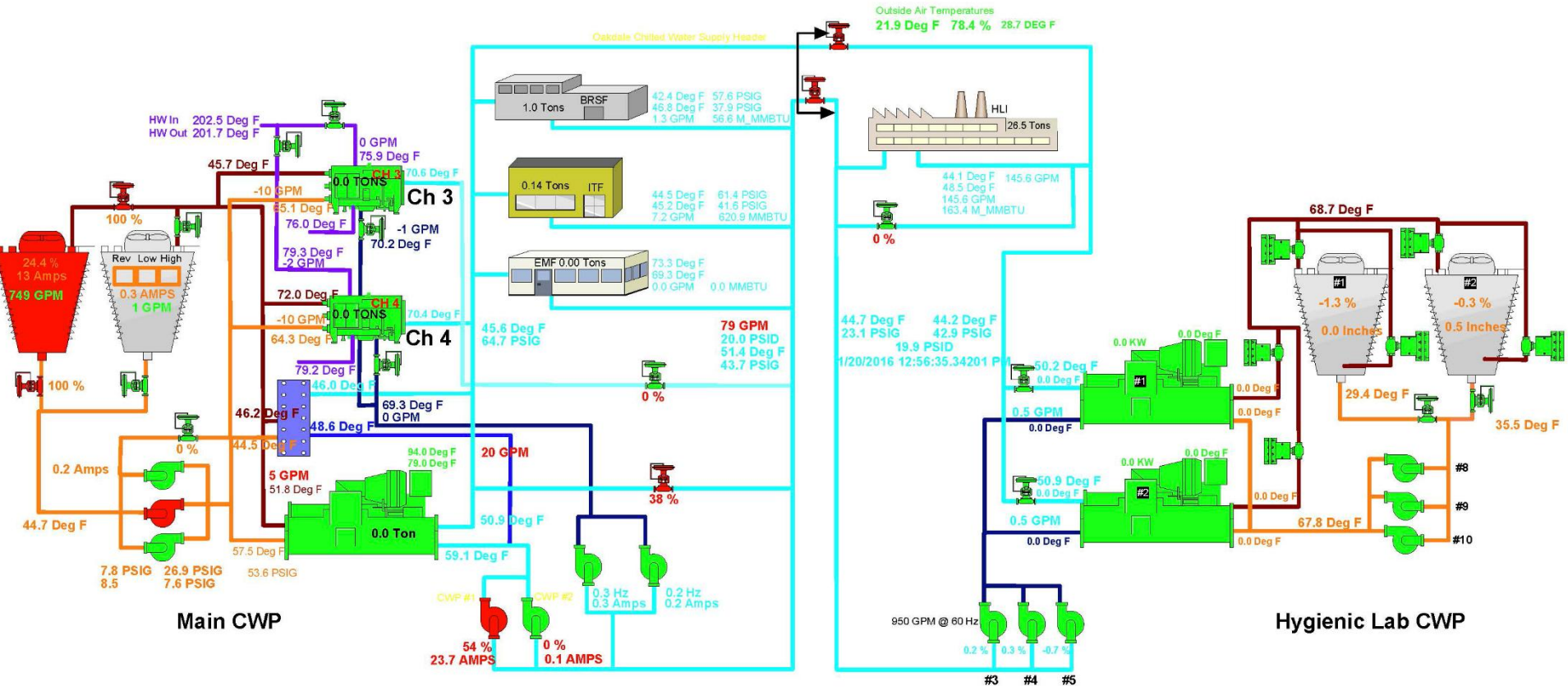
- Outage sequencing and plant risk management:
  - Oakdale Utility Power Plant
  - Information Technology Facility
- Absorption chiller sensitivity
- Commissioning is king
- 100 + page document guided the team
- Good control system integrator is critical
- Startups are startups – expect issues
- Pump performance issues

QUESTIONS

THE UNIVERSITY OF IOWA



PRVN
The Proven Solution!


Outside Air Temperatures
21.9 Deg F 78.4 % 28.7 DEG F
Oakdale Chilled Water Supply Header
1.0 Tons BRSF
42.4 Deg F 57.6 PSIG
46.8 Deg F 37.9 PSIG
1.3 GPM 56.6 M_MMBTU
HLI
26.5 Tons
0.14 Tons ITF
44.5 Deg F 61.4 PSIG
45.2 Deg F 41.6 PSIG
7.2 GPM 620.9 MMBTU
EMF 0.00 Tons
73.3 Deg F
69.3 Deg F
0.0 GPM 0.0 MMBTU
44.1 Deg F 145.6 GPM
48.5 Deg F
145.6 GPM
163.4 M_MMBTU
HW In 202.5 Deg F
HW Out 201.7 Deg F
0 GPM
75.9 Deg F
45.7 Deg F
CH 3
0.0 TONS
Ch 3
70.6 Deg F
-10 GPM
85.1 Deg F
76.0 Deg F
-1 GPM
70.2 Deg F
79.3 Deg F
-2 GPM
100 %
24.4 %
13 Amps
749 GPM
Rev Low High
0.3 AMPS
1 GPM
72.0 Deg F
CH 4
0.0 TONS
Ch 4
70.4 Deg F
-10 GPM
64.3 Deg F
79.2 Deg F
46.0 Deg F
100 %
46.2 Deg F
48.6 Deg F
69.3 Deg F
0 GPM
45.6 Deg F
64.7 PSIG
79 GPM
20.0 PSID
51.4 Deg F
43.7 PSIG
0 %
0 %
0.2 Amps
44.5 Deg F
94.0 Deg F
79.0 Deg F
20 GPM
5 GPM
51.8 Deg F
0.0 Ton
38 %
44.7 Deg F
50.9 Deg F
59.1 Deg F
57.5 Deg F
7.8 PSIG 26.9 PSIG
8.5 7.6 PSIG
53.6 PSIG
CWP #1
CWP #2
0.3 Hz
0.3 Amps
0.2 Hz
0.2 Amps
54 %
23.7 AMPS
0 %
0.1 AMPS
Main CWP
44.7 Deg F 44.2 Deg F
23.1 PSIG 42.9 PSIG
19.9 PSID
1/20/2016 12:56:35.34201 P
0 %
950 GPM @ 60 Hz
0.2 % 0.3 % -0.7 %
#3 #4 #5
0.0 KW
0.0 Deg F
50.2 Deg F
#1
0.5 GPM
0.0 Deg F
50.9 Deg F
#2
0.5 GPM
0.0 Deg F
68.7 Deg F
#1
-1.3 %
0.0 Inches
#2
-0.3 %
0.5 Inches
29.4 Deg F
35.5 Deg F
67.8 Deg F
#8
#9
#10
Hygienic Lab CWP

CHILLER DESIGN CONDITIONS

Design Criteria	
Guaranteed Capacity (Tons)	220
Chilled Water Flow Rate (GPM)	300
Chilled Water Supply Temperature (°F)	42.0
Chilled Water Return Temperature (°F)	60.0
Condenser Water Flow Rate (GPM)	970
Condenser Water Supply Temperature (°F)	85.0
Condenser Water Supply Temperature (°F)	97.5
Hot Water Flow Rate (GPM)	160
Hot Water Supply Temperature (°F)	210.0
Hot Water Return Temperature (°F)	165.0

LIFE-CYCLE COST PARAMETERS

- Electrical Rate Structure

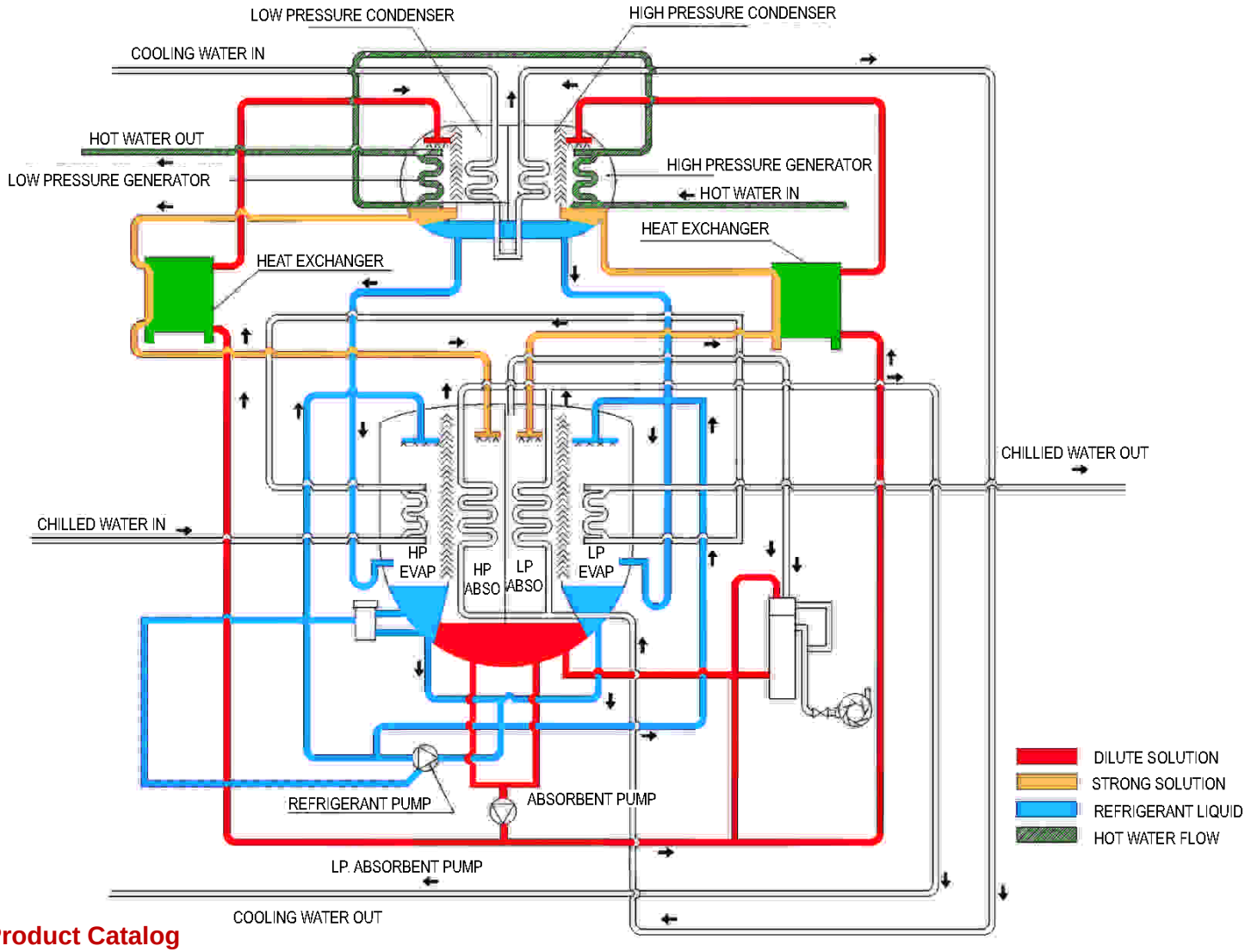
Energy Charges	Summer On Peak (Per kWh)	Summer Off Peak (Per kWh)	Winter On Peak (Per kWh)	Winter Off Peak (Per kWh)
Energy Charge	$0.027	$0.018	$0.018	$0.009
Energy Cost Adjustment	$0.026		$0.026	

Demand Charges	First 200 kW	Next 800 kW	Next 9,000 kW	Next 20,000 kW	Next 30,000 kW
Summer	$15.61	$15.48	$15.27	$15.18	$12.29
Winter	$8.21	$7.49	$6.86	$6.68	$4.98

LIFE-CYCLE COST PARAMETERS

- Natural Gas: $4.57 per MMBtu
- Water Cost: $4.45 per 1,000 gallons
- Sewer Cost: $3.70 per 1,000 gallons
- Electric Chiller Maintenance Costs: $40 per ton annually
- Absorption Chiller Maintenance Costs: $50 per ton annually

ABSORPTION CHILLER CYCLE



Source: Thermax Product Catalog

HYGIENIC LAB CHILLED WATER PLANT