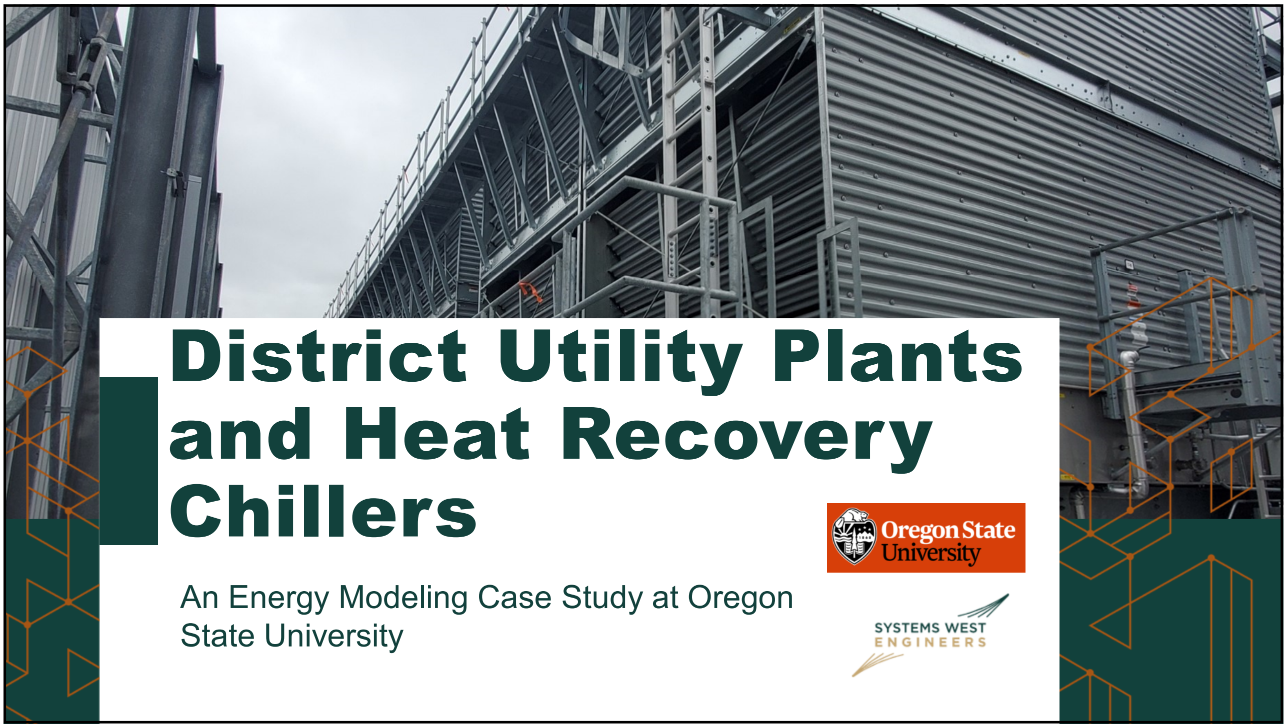
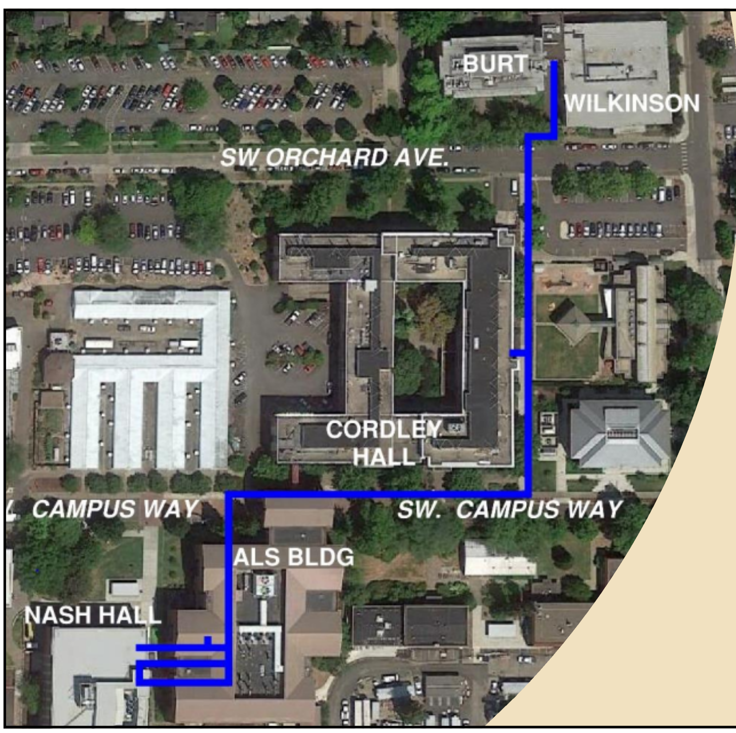


District Utility Plants and Heat Recovery Chillers

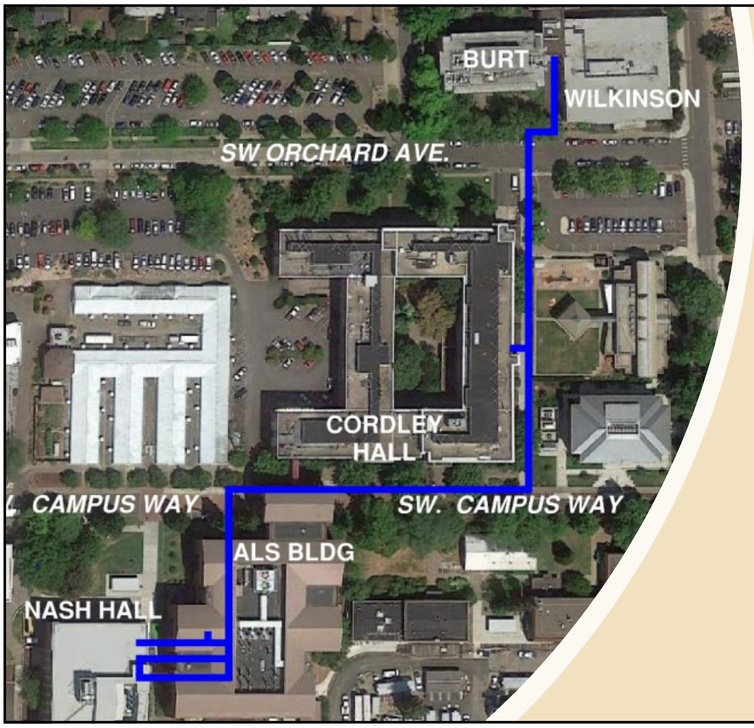
An Energy Modeling Case Study at Oregon State University

1



Project Description

2



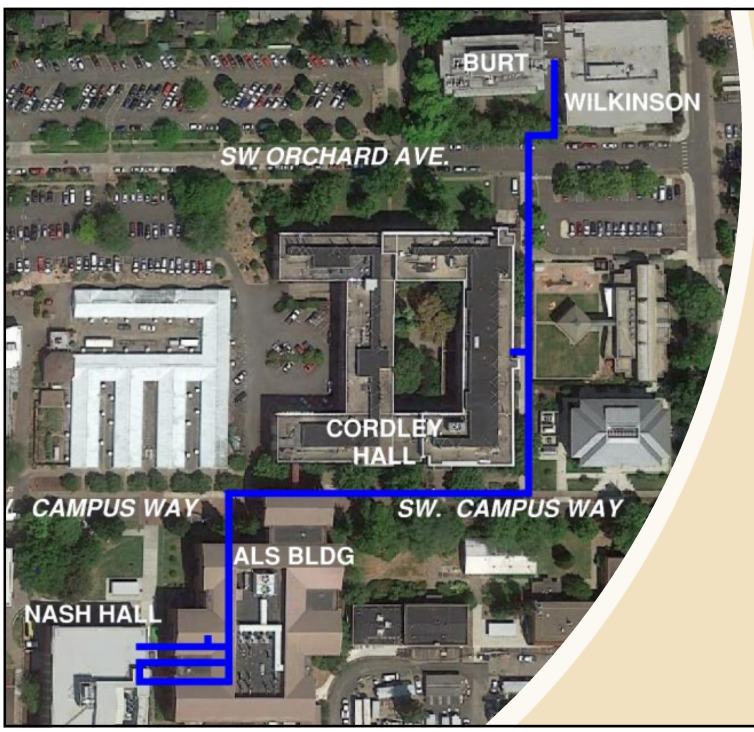
Project Description

Oregon State University

North Campus Chilled Water Loop

Serves primarily Science/Laboratory/Research Buildings

3



Project Description

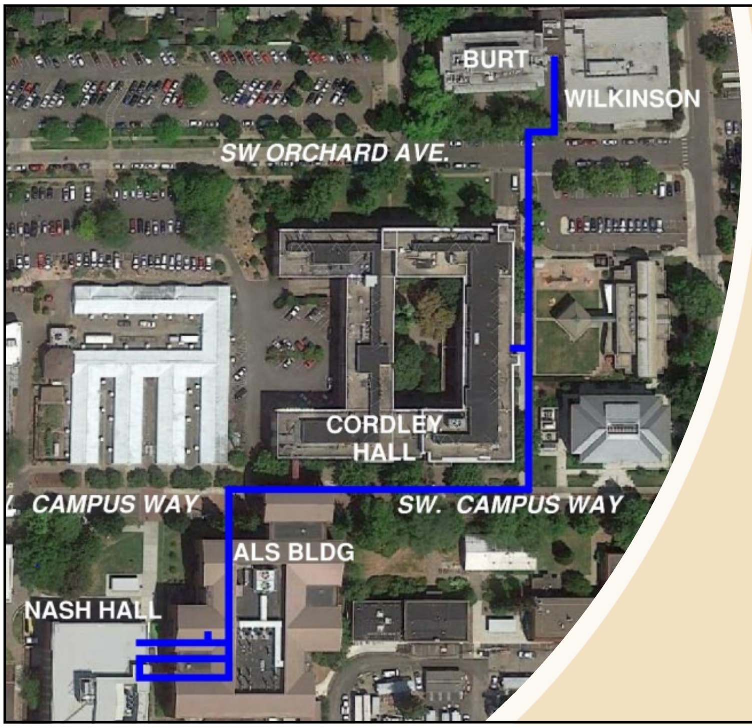
Oregon State University

North Campus Chilled Water Loop

Serves primarily Science/Laboratory/Research Buildings

- Burt/Wilkinson
- Cordley Hall
- Nash Hall
- ALS Bldg

4

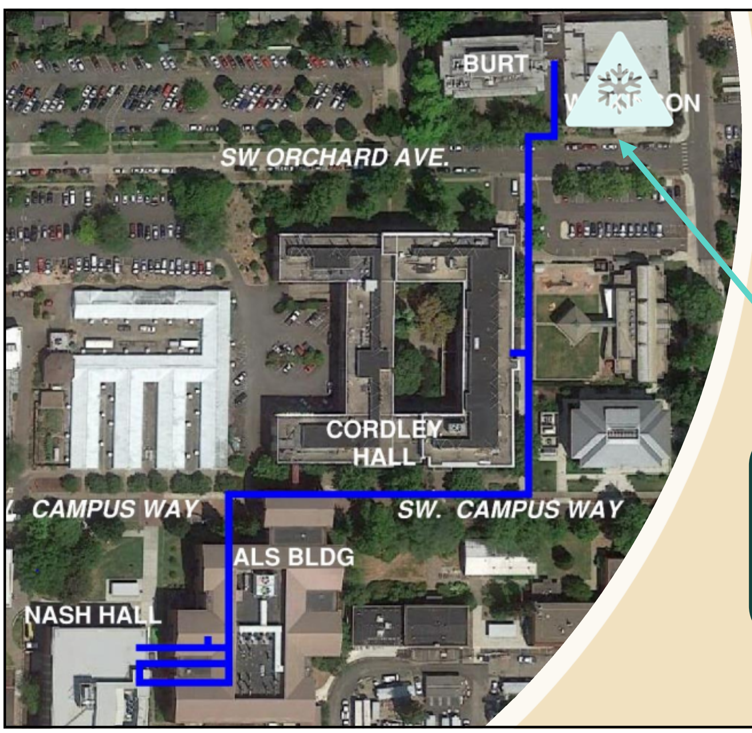


Project Description

Oregon State University

- North Campus Chilled Water Loop
- Serves primarily Science/Laboratory/Research Buildings
- Burt/Wilkinson
- Cordley Hall
- Nash Hall
- ALS Bldg
- Aging Infrastructure
- Sustainability Goals

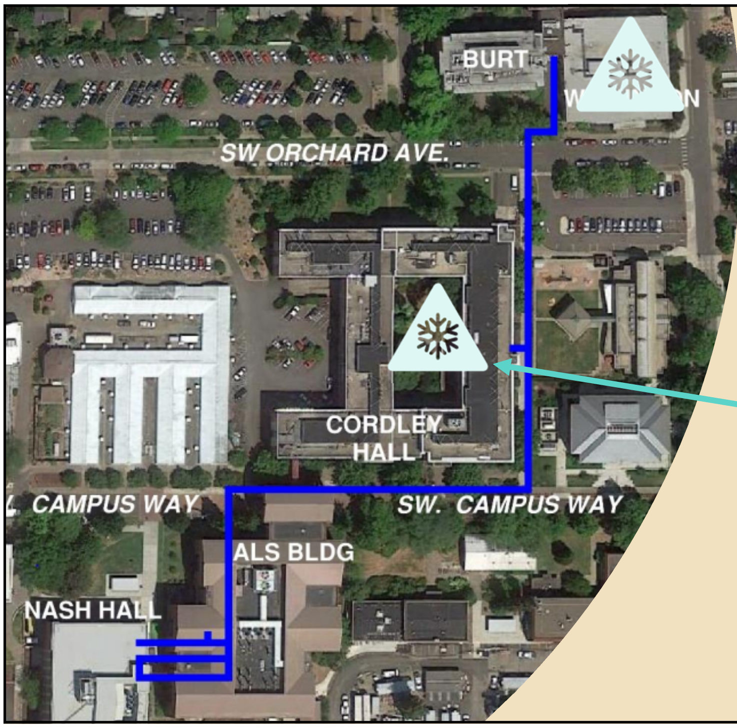
5



Existing Conditions (circa 2019)

- ❑ 50+ year old Absorption Chiller (abandoned in place)
- ❑ 500 Tons

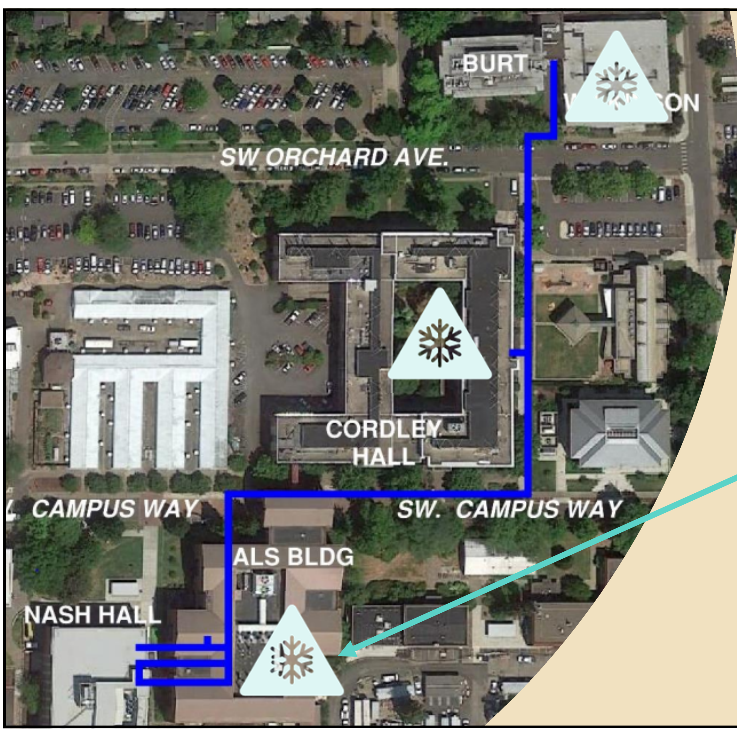
6



Existing Conditions (circa 2019)

- ❑ 28 year old CV Centrifugal Chiller
- ❑ 415 Tons
- ❑ Serves only East Wing

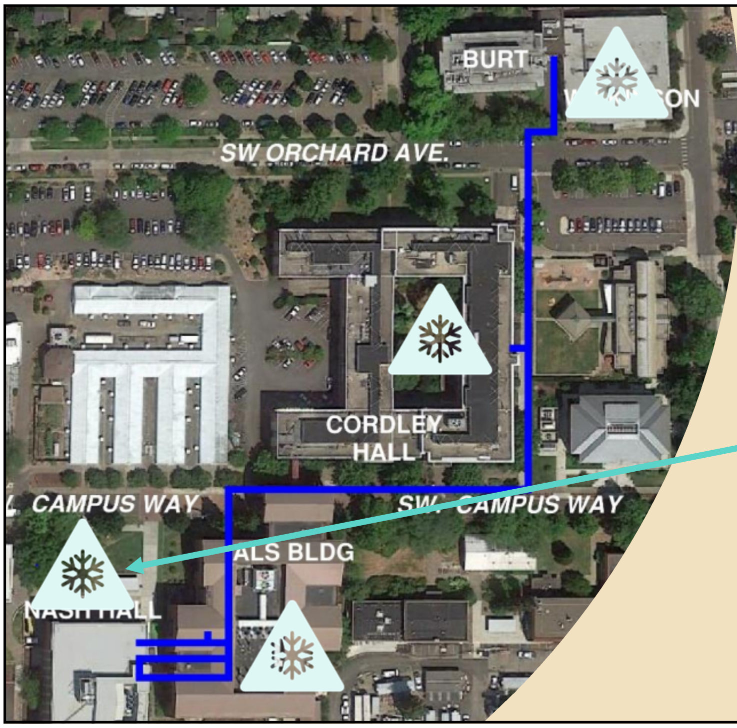
7



Existing Conditions (circa 2019)

- ❑ 27 year old CV Centrifugal Chiller
- ❑ 875 Tons
- ❑ R-11

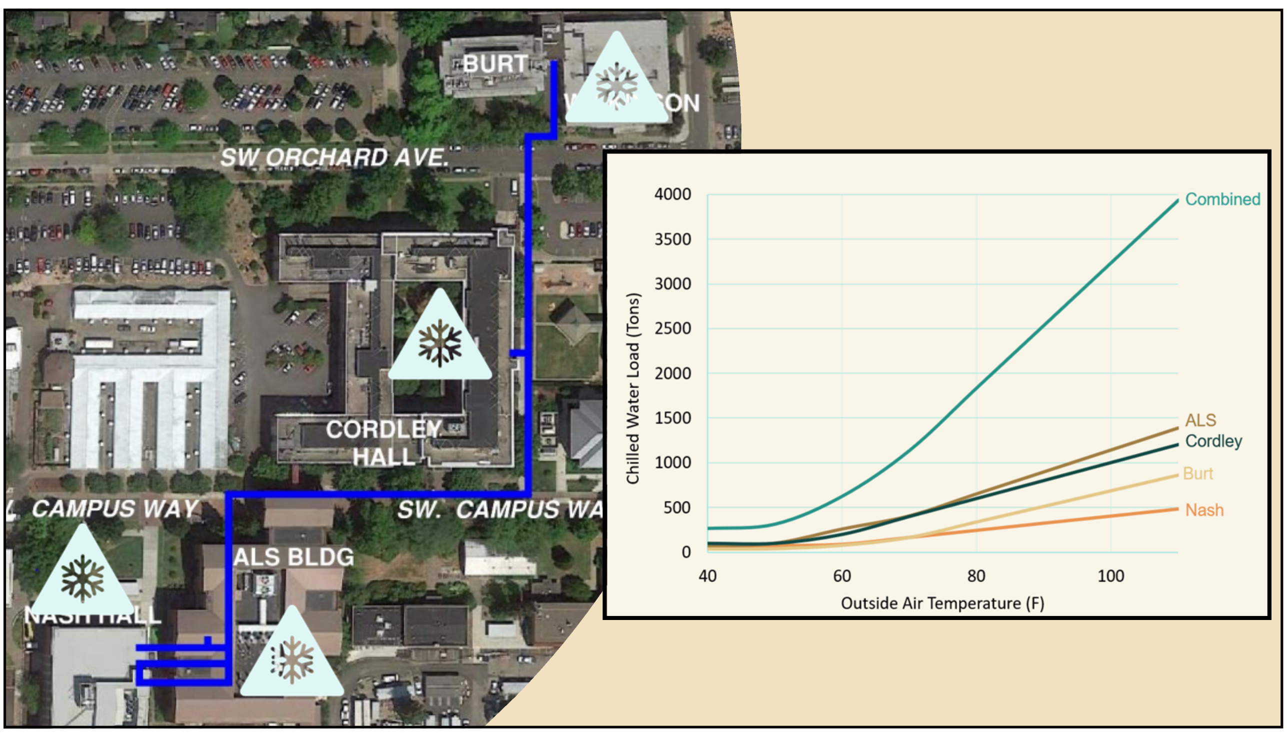
8



Existing Conditions (circa 2019)

- 17 year old VF Centrifugal Chiller
- 600 Tons

9



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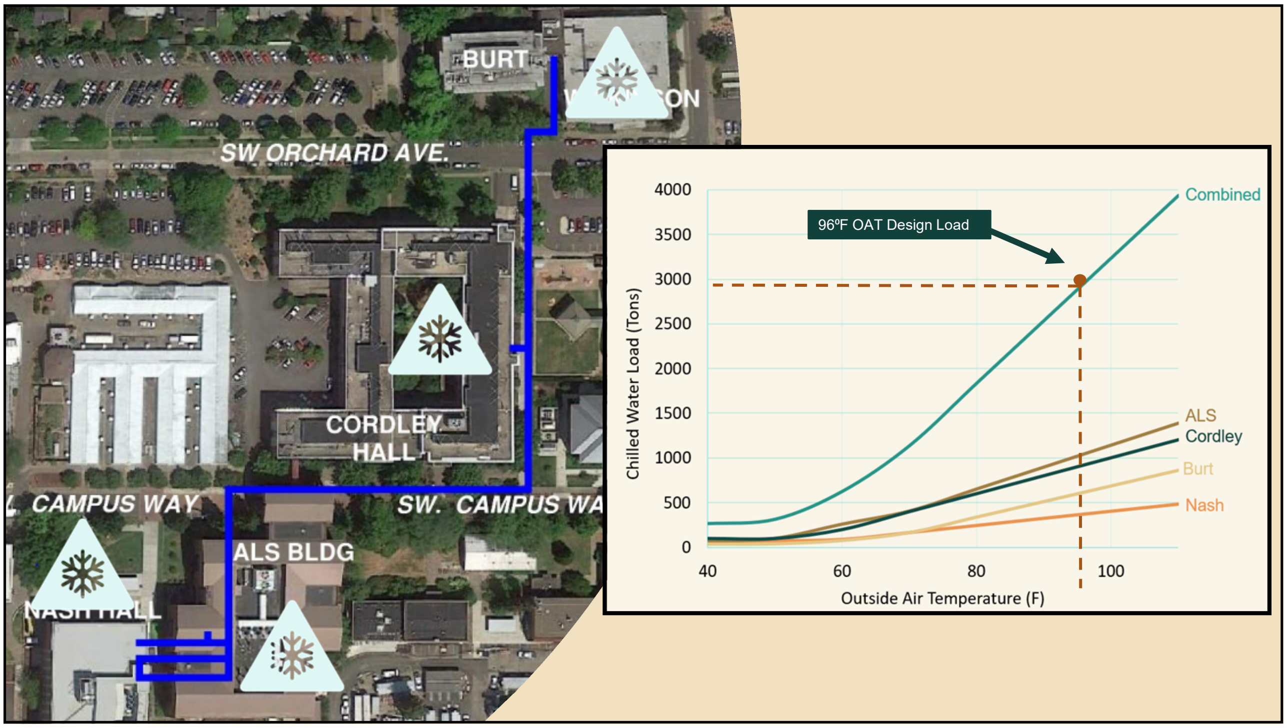
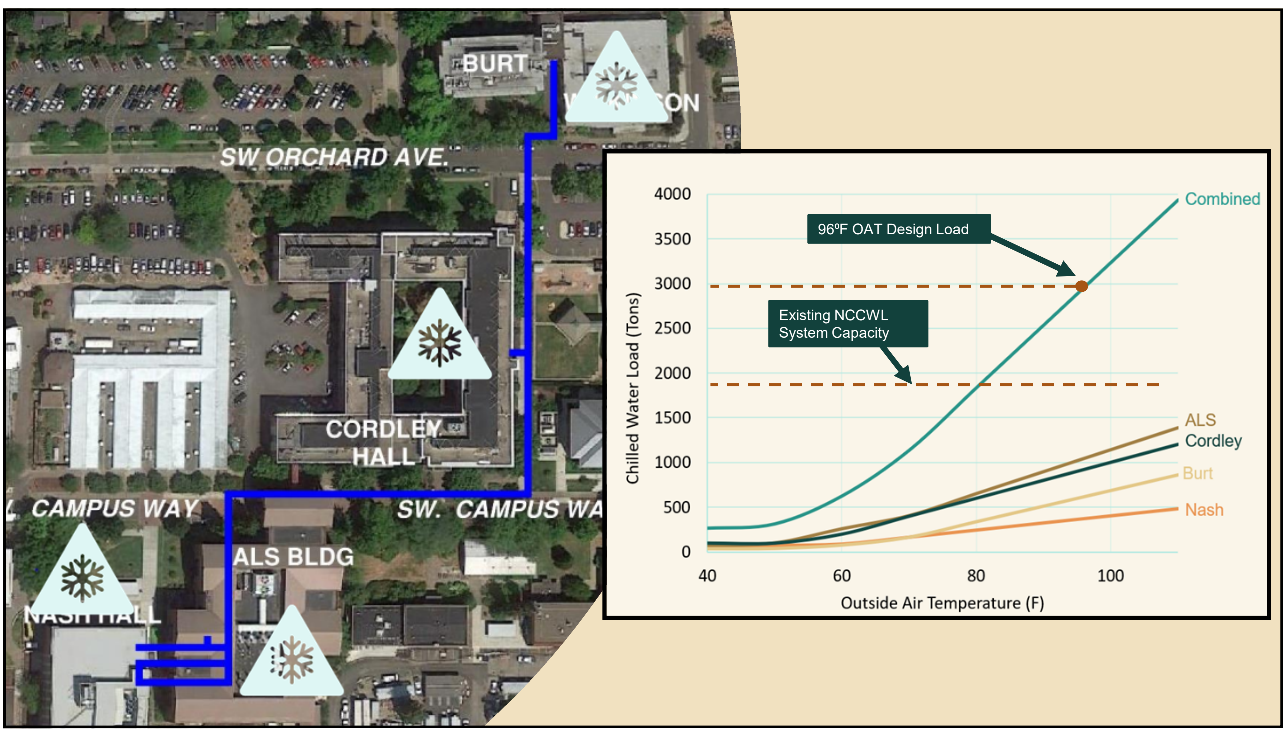
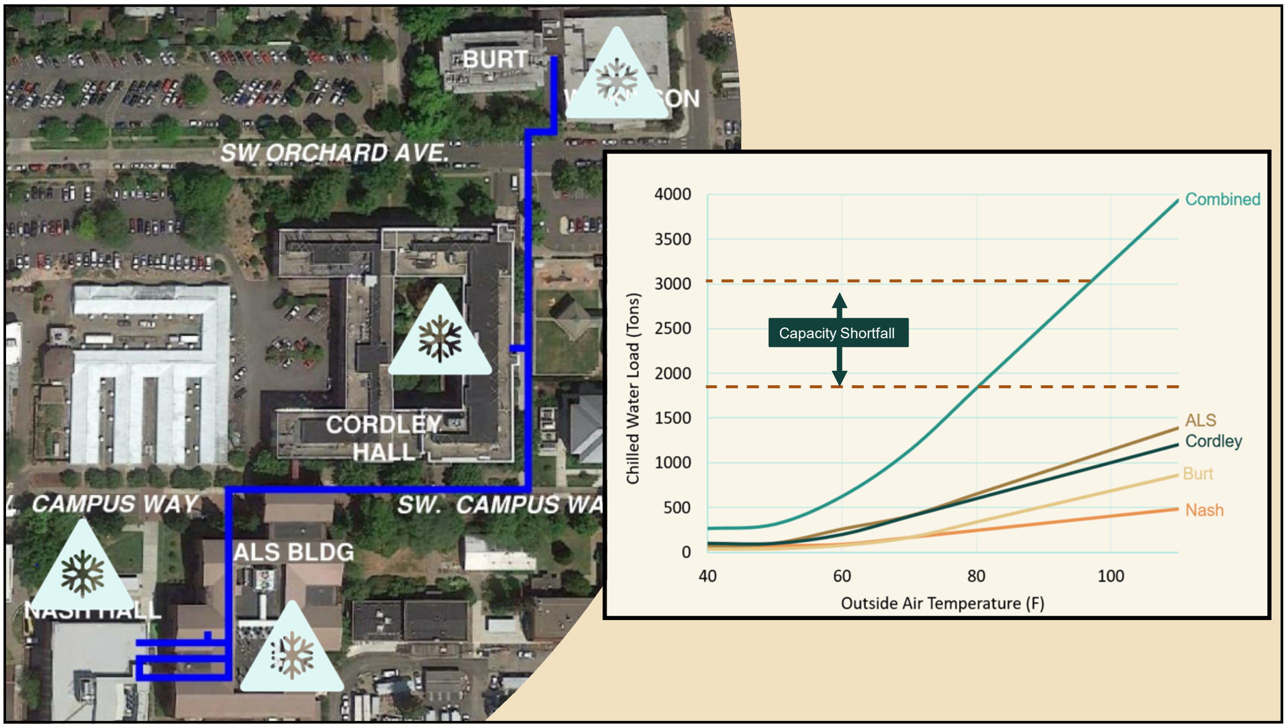

BURT
SW ORCHARD AVE.
CORDLEY HALL
CAMPUS WAY
SW. CAMPUS WA
ALS BLDG
4000
3500
3000
2500
2000
1500
1000
500
0
Chilled Water Load (Tons)
96ºF OAT Design Load
Combined
ALS
Cordley
Burt
Nash
40
60
80
100
Outside Air Temperature (F)

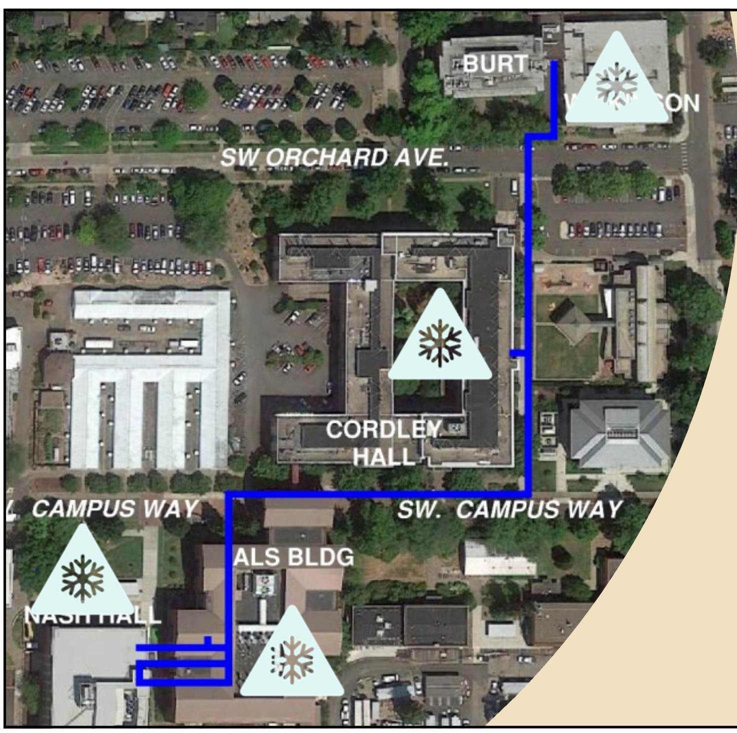
11


BURT
SW ORCHARD AVE.
CORDLEY HALL
CAMPUS WAY
SW. CAMPUS WA
ALS BLDG
4000
3500
3000
2500
2000
1500
1000
500
0
Chilled Water Load (Tons)
96ºF OAT Design Load
Existing NCCWL System Capacity
Combined
ALS
Cordley
Burt
Nash
40
60
80
100
Outside Air Temperature (F)

12



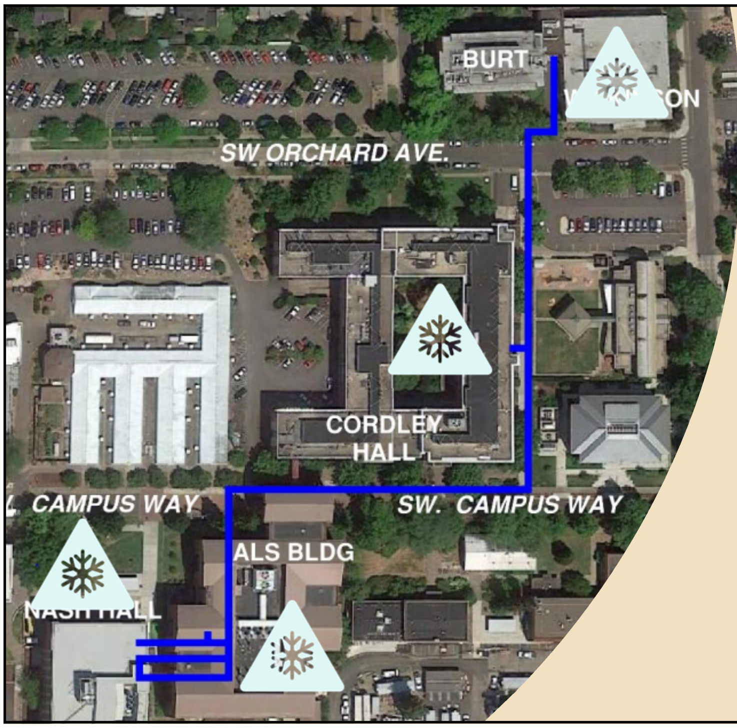
13



Existing Conditions (circa 2019)

Aging Equipment

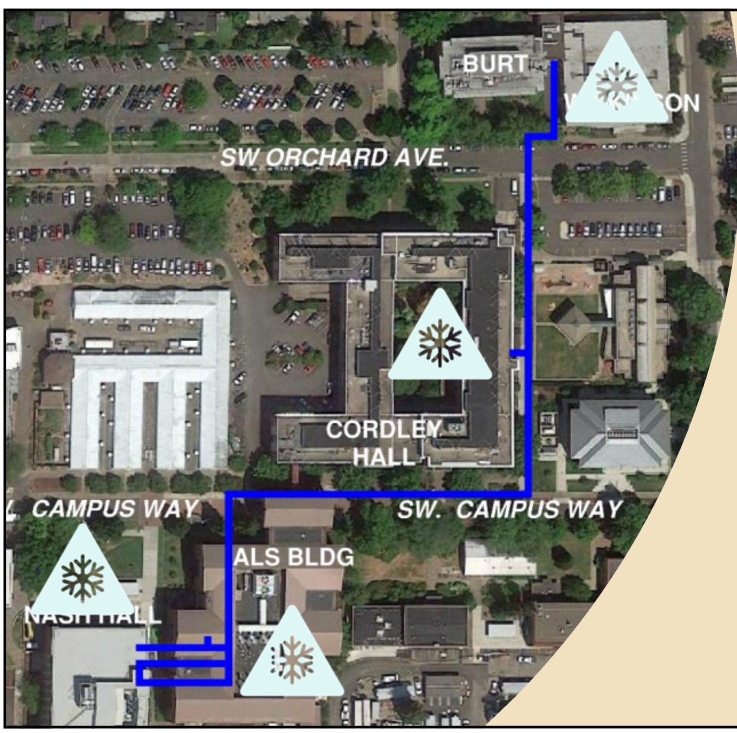
14



Existing Conditions (circa 2019)

- Aging Equipment
- Control Sequence is Complex

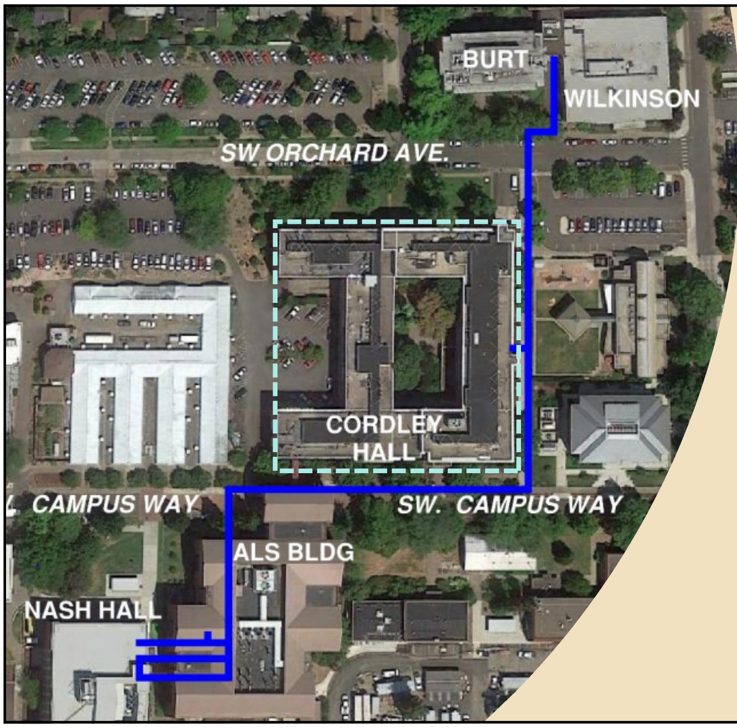
15



Existing Conditions (circa 2019)

- Aging Equipment
- Control Sequence is Complex
- Cooling Capacity cannot meet load when OAT > 82°F

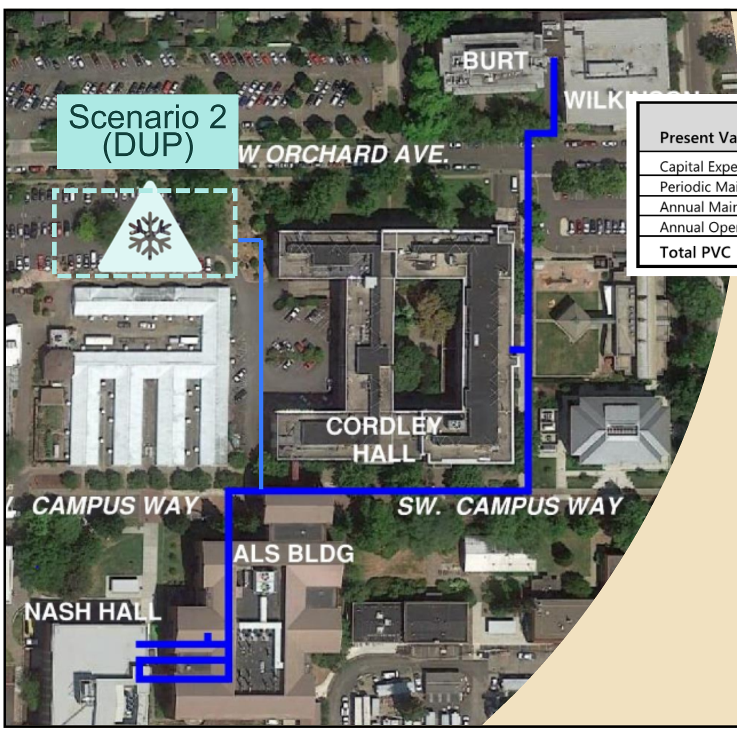
16



Existing Conditions (circa 2019)

- Aging Equipment
- Control Sequence is Complex
- Cooling Capacity cannot meet load when OAT > 82°F
- Planned Cordley Load ++

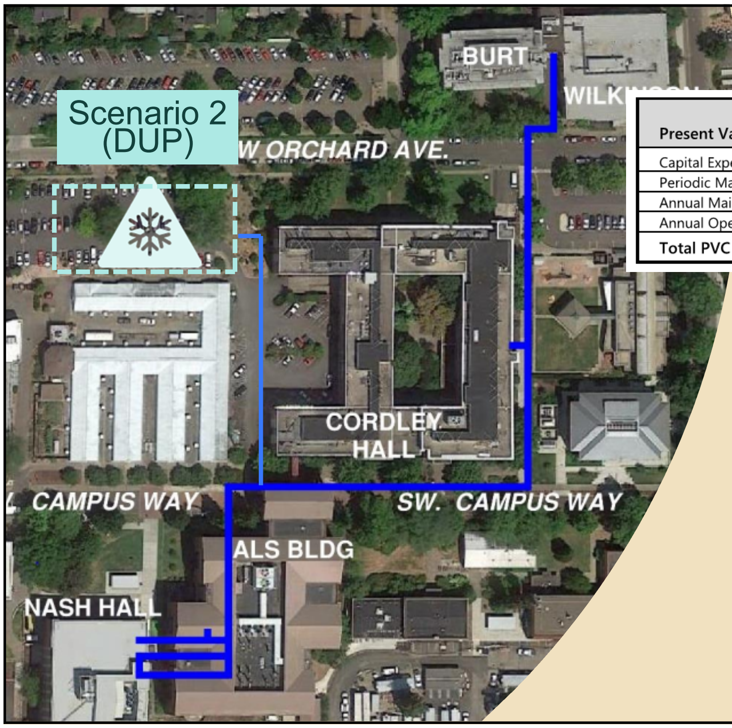
17



Present Value of Cost	Scenario 1 Local Plants	Scenario 2 District Plant
Capital Expenditures	$17,052,000	$17,547,000
Periodic Maintenance	1,597,000	224,000
Annual Maintenance	1,364,000	1,038,000
Annual Operation	5,891,000	4,034,000
Total PVC	**$25,904,000**	**$22,843,000**

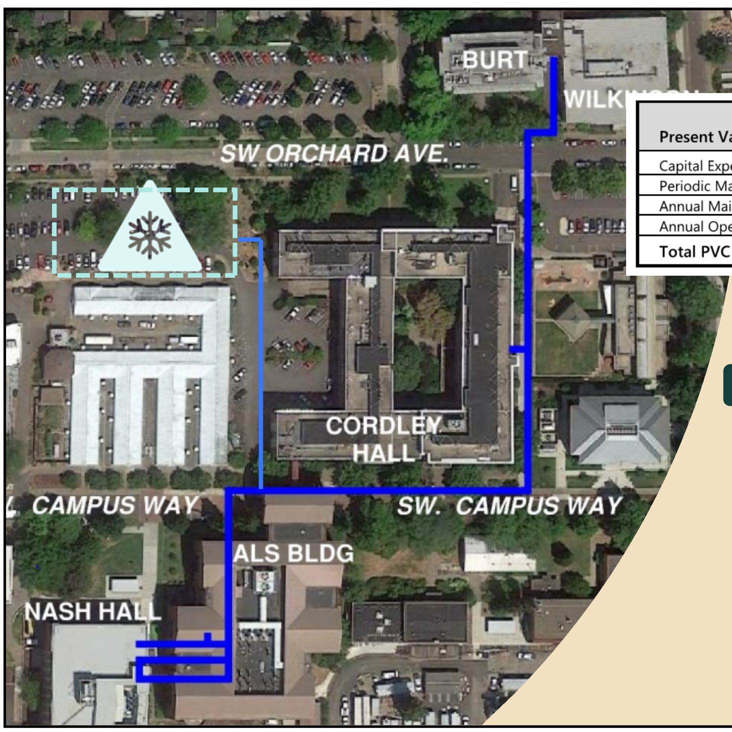
18

Scenario 2 (DUP)



Present Value of Cost	Scenario 1 Local Plants	Scenario 2 District Plant
Capital Expenditures	$17,052,000	$17,547,000
Periodic Maintenance	1,597,000	224,000
Annual Maintenance	1,364,000	1,038,000
Annual Operation	5,891,000	4,034,000
Total PVC	**$25,904,000**	**$22,843,000**

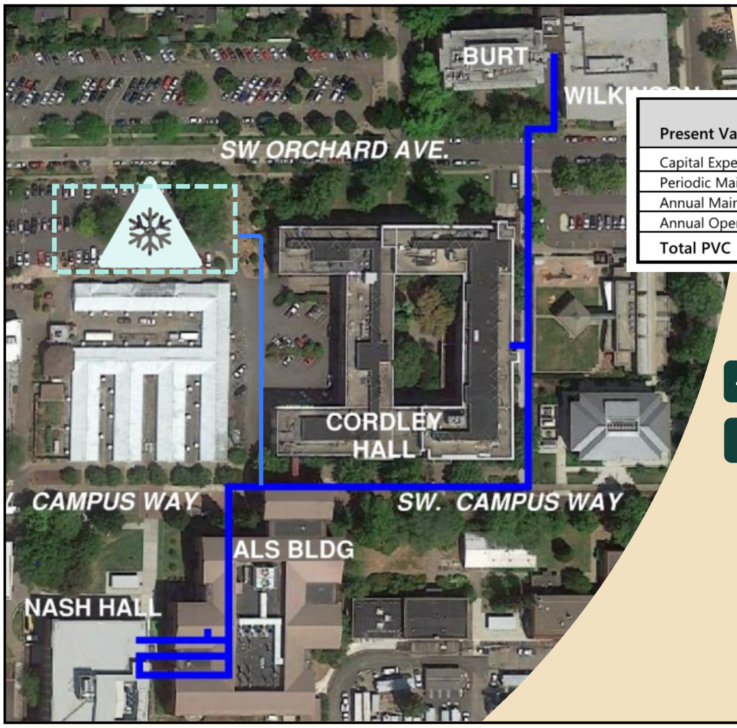
19



Present Value of Cost	Scenario 1 Local Plants	Scenario 2 District Plant
Capital Expenditures	$17,052,000	$17,547,000
Periodic Maintenance	1,597,000	224,000
Annual Maintenance	1,364,000	1,038,000
Annual Operation	5,891,000	4,034,000
Total PVC	**$25,904,000**	**$22,843,000**

4,500 Ton Primary-Only Central Plant

20

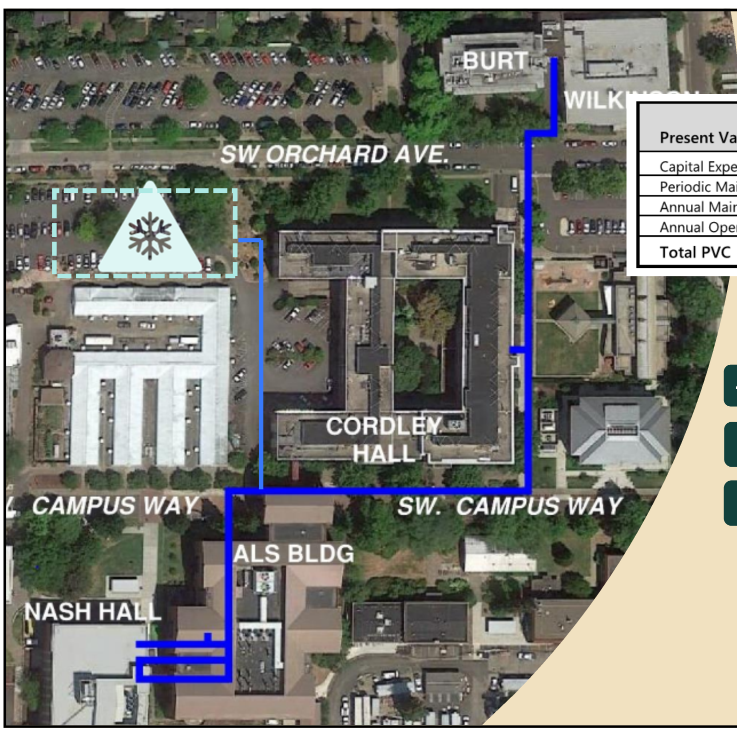


Present Value of Cost	Scenario 1 Local Plants	Scenario 2 District Plant
Capital Expenditures	$17,052,000	$17,547,000
Periodic Maintenance	1,597,000	224,000
Annual Maintenance	1,364,000	1,038,000
Annual Operation	5,891,000	4,034,000
Total PVC	**$25,904,000**	**$22,843,000**

4,500 Ton Primary-Only Central Plant

Magnetic Levitation Chillers

21



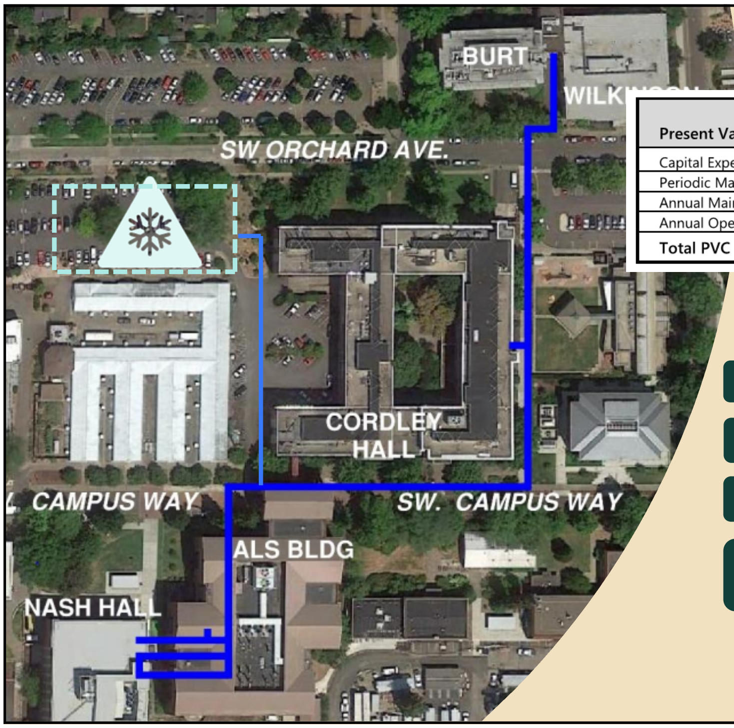
Present Value of Cost	Scenario 1 Local Plants	Scenario 2 District Plant
Capital Expenditures	$17,052,000	$17,547,000
Periodic Maintenance	1,597,000	224,000
Annual Maintenance	1,364,000	1,038,000
Annual Operation	5,891,000	4,034,000
Total PVC	**$25,904,000**	**$22,843,000**

4,500 Ton Primary-Only Central Plant

Magnetic Levitation Chillers

Plant Range of down to 150 Tons

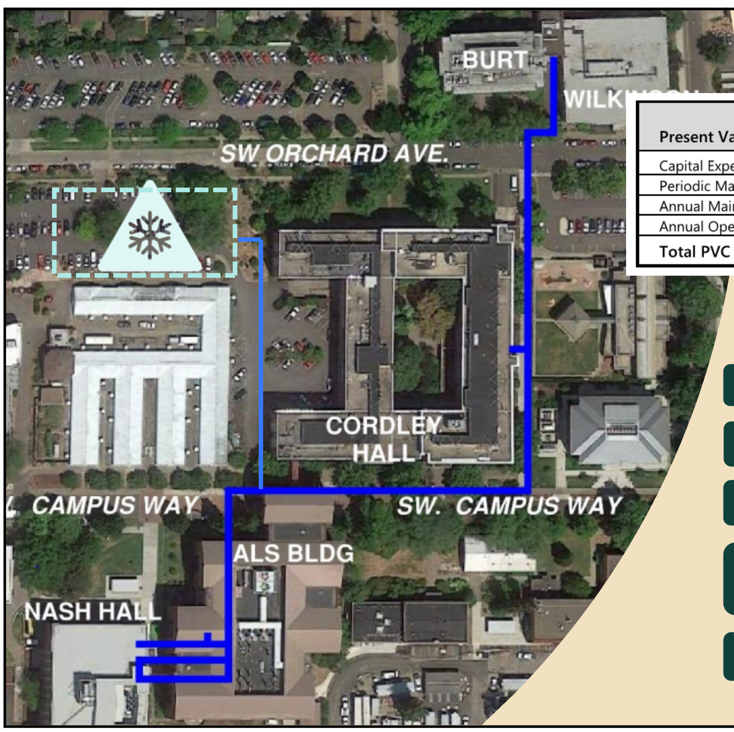
22



Present Value of Cost	Scenario 1 Local Plants	Scenario 2 District Plant
Capital Expenditures	$17,052,000	$17,547,000
Periodic Maintenance	1,597,000	224,000
Annual Maintenance	1,364,000	1,038,000
Annual Operation	5,891,000	4,034,000
Total PVC	**$25,904,000**	**$22,843,000**

- 4,500 Ton Primary-Only Central Plant
- Magnetic Levitation Chillers
- Plant Range of down to 150 Tons
- Condenser Water Operation down to 45°F

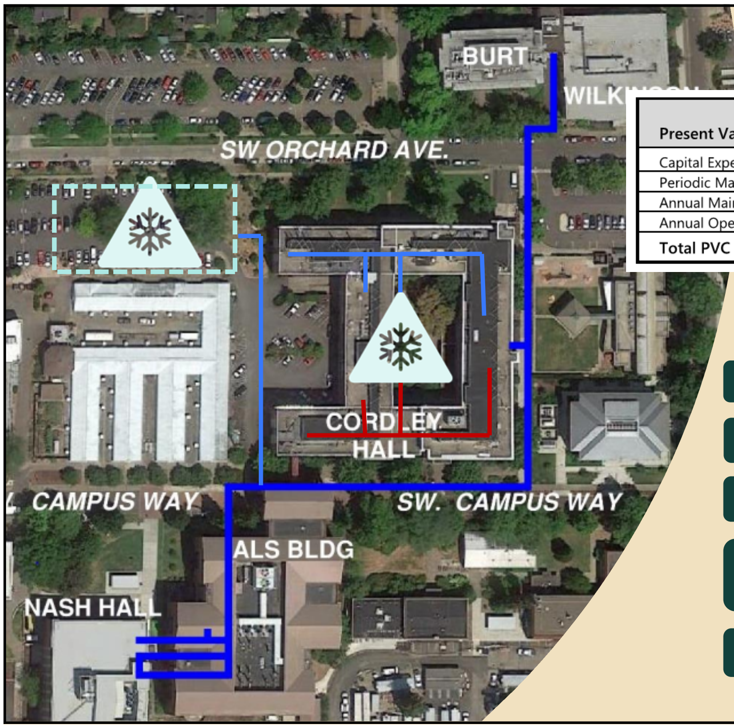
23



Present Value of Cost	Scenario 1 Local Plants	Scenario 2 District Plant
Capital Expenditures	$17,052,000	$17,547,000
Periodic Maintenance	1,597,000	224,000
Annual Maintenance	1,364,000	1,038,000
Annual Operation	5,891,000	4,034,000
Total PVC	**$25,904,000**	**$22,843,000**

- 4,500 Ton Primary-Only Central Plant
- Magnetic Levitation Chillers
- Plant Range of down to 150 Tons
- Condenser Water Operation down to 45°F
- Simultaneous Operation of 6 CT cells

24



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Capital Expenditures	$17,052,000	$17,547,000
Periodic Maintenance	1,597,000	224,000
Annual Maintenance	1,364,000	1,038,000
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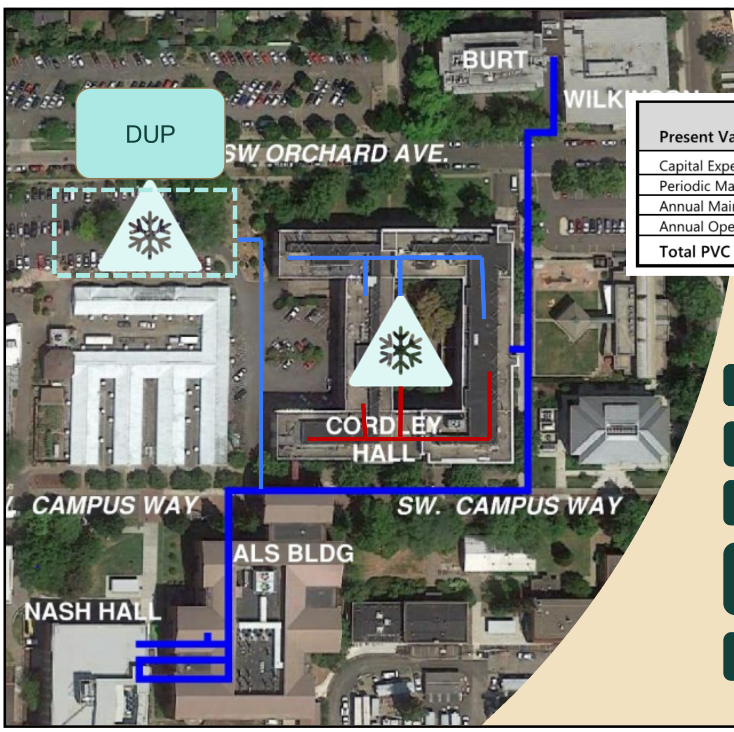
Total PVC	**$25,904,000**	**$22,843,000**

- 4,500 Ton Primary-Only Central Plant
- Magnetic Levitation Chillers
- Plant Range of down to 150 Tons
- Condenser Water Operation down to 45°F
- Simultaneous Operation of 6 CT cells

25



Present Value of Cost	Scenario 1 Local Plants	Scenario 2 District Plant
Capital Expenditures	$17,052,000	$17,547,000
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Annual Operation	5,891,000	4,034,000
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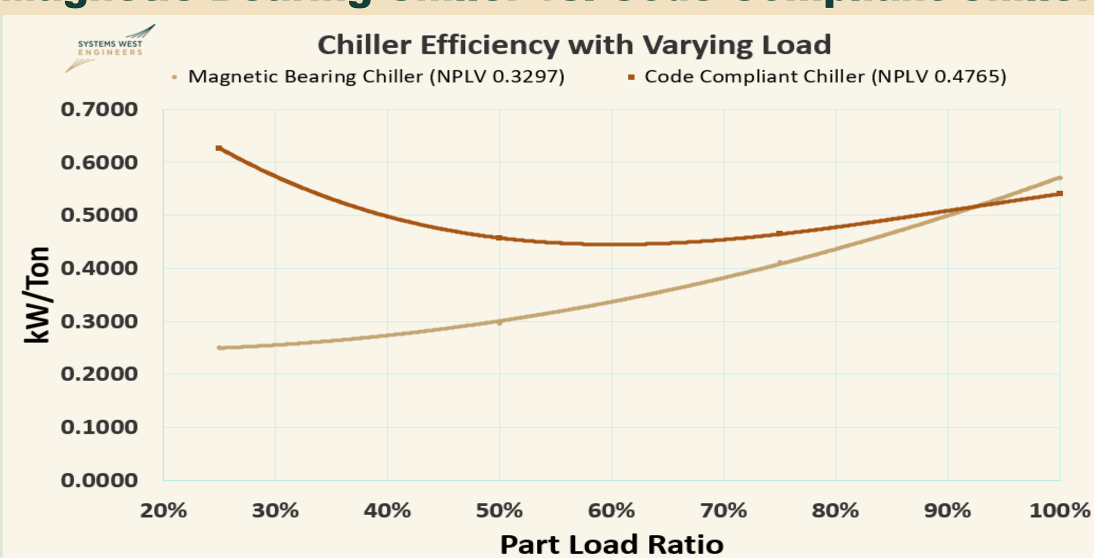
- 4,500 Ton Primary-Only Central Plant
- Magnetic Levitation Chillers
- Plant Range of down to 150 Tons
- Condenser Water Operation down to 45°F
- Simultaneous Operation of 6 CT cells

26

Cordley Hall District Utility Plant

27

DUP Efficiencies:
Magnetic Bearing Chiller vs. Code Compliant Chiller

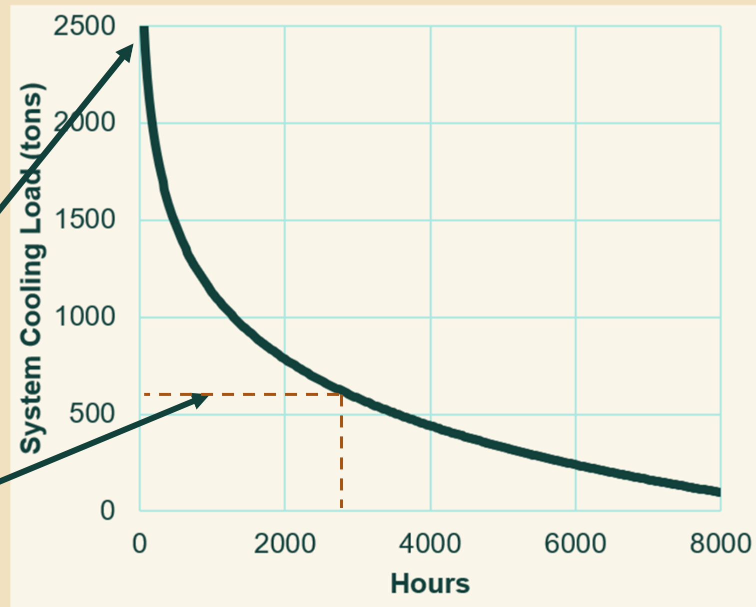


28

Load Duration Curve

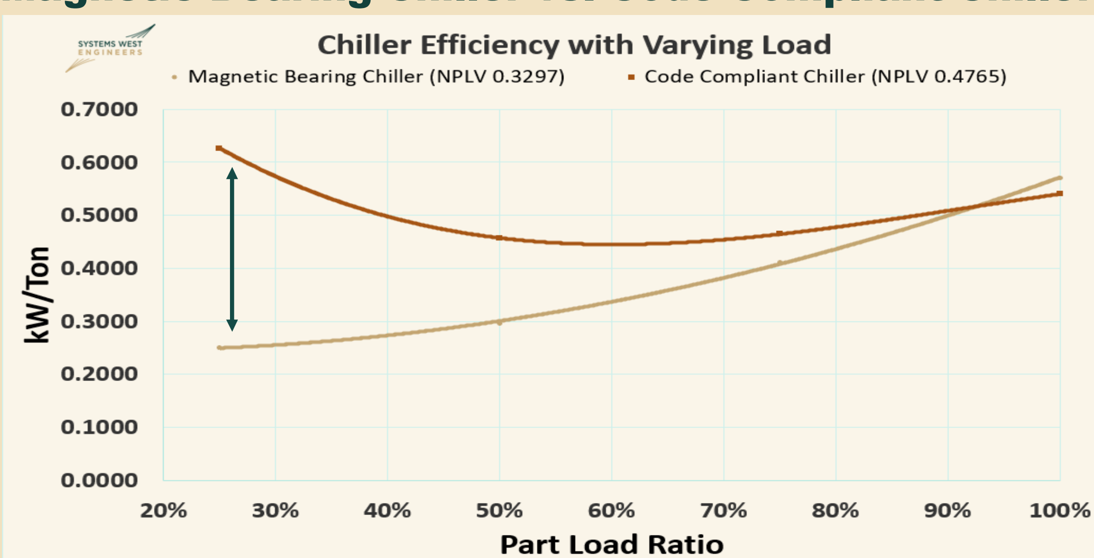
Full Load
<10hrs

25% Load
~2,700 hours



29

DUP Efficiencies (Custom Curves): Magnetic Bearing Chiller vs. Code Compliant Chiller



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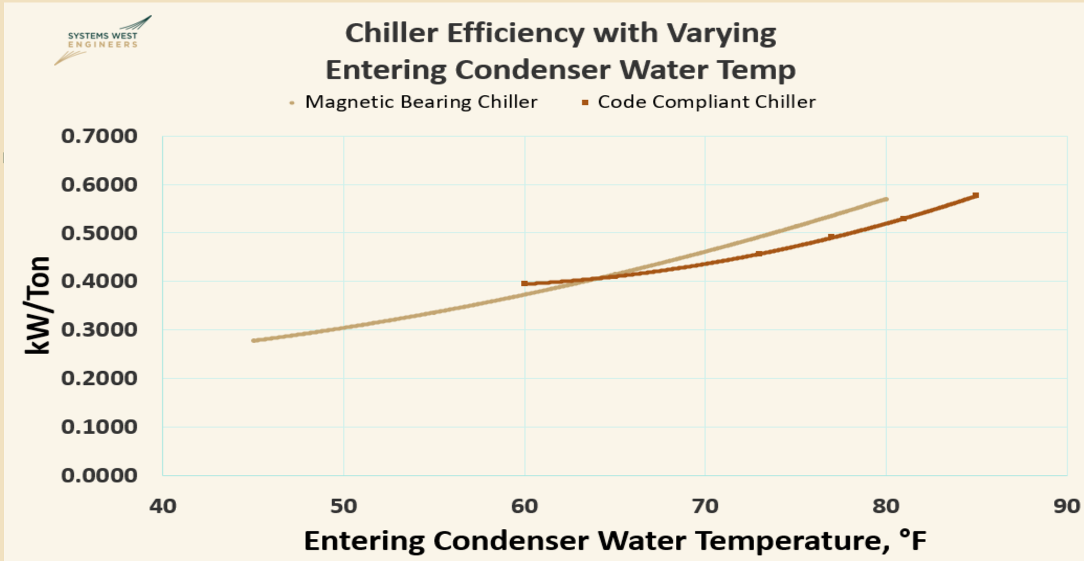
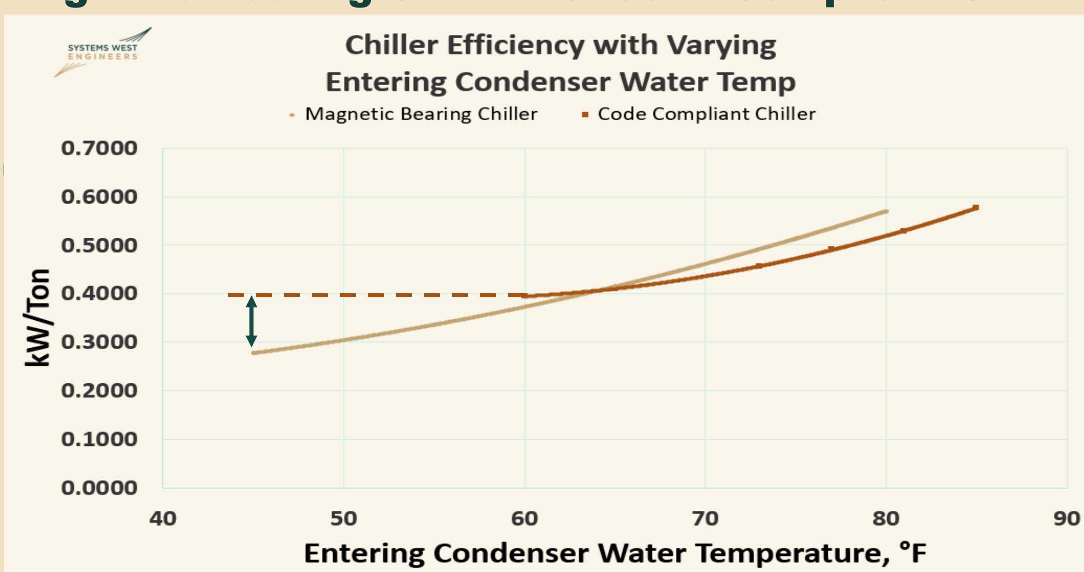
DUP Efficiencies (Custom Curves): Magnetic Bearing Chiller vs. Code Compliant Chiller



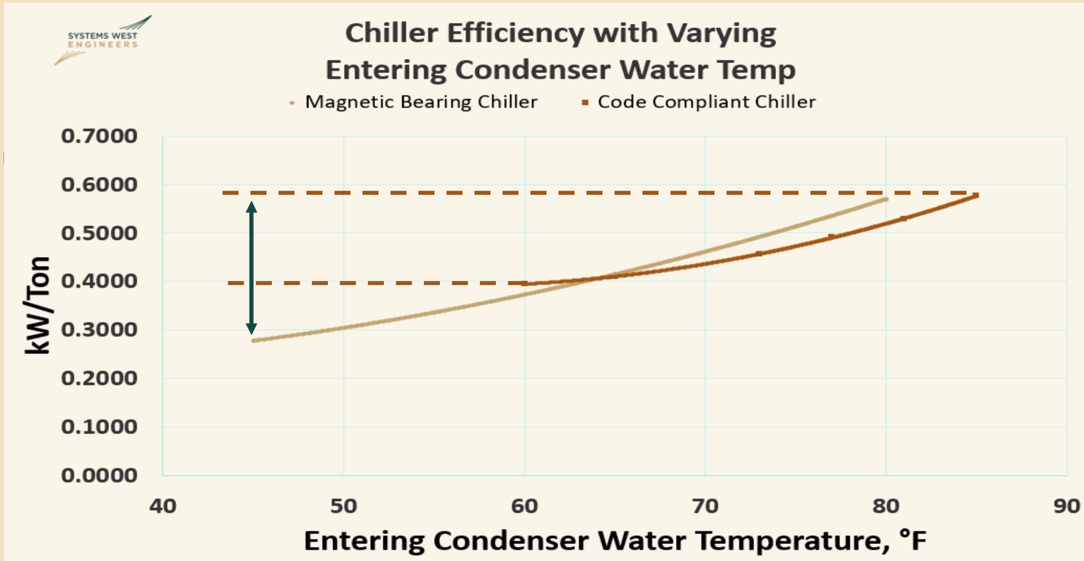
31

DUP Efficiencies (Custom Curves): Magnetic Bearing Chiller vs. Code Compliant Chiller



32

DUP Efficiencies (Custom Curves): Magnetic Bearing Chiller vs. Code Compliant Chiller



33

DUP Efficiencies: Custom Performance Curves Vs. Standard AHRI Conditions

Custom performance curves allow for closer approximation of chiller efficiencies at various conditions

Part Load Ratio	AHRI Condition: IPLV & NPLV kW/Ton Based on Percent @ PLR	AHRI Condition: IPLV kW/Ton Calculated with Following Cond. Water Temp	AHRI Condition: Entering/Leaving Evaporator Temperature	Custom Performance Curve Conditions kW/Ton Based on Operating Conditions
100%	1% of the time	85°F	55°F / 44°F	• Evap EWT/LWT = Actual, 42-45°F • OSA Conditions = Based on TMY3 data • Condenser Water – temperature based on actual OSA and cooling tower performance and Chiller limitations • Number of hours at part load based on actual calculated conditions • More accurate kW/Ton possible with varying conditions
75%	42% of the time	75°F	55°F / 44°F	
50%	45% of the time	65°F	55°F / 44°F	
25%	12% of the time	65°F	55°F / 44°F	

34

DUP Efficiencies: Custom Performance Curves Vs. Standard AHRI Conditions

Custom performance curves allow for closer approximation of chiller efficiencies at various conditions

Part Load Ratio	AHRI Condition: IPLV & NPLV kW/Ton Based on Percent @ PLR	AHRI Condition: IPLV kW/Ton Calculated with Following Cond. Water Temp	AHRI Condition: Entering/Leaving Evaporator Temperature	Custom Performance Curve Conditions kW/Ton Based on Operating Conditions
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50%	45% of the time	65°F	55°F / 44°F	
25%	12% of the time	65°F	55°F / 44°F	

35

DUP Efficiencies: Custom Performance Curves Vs. Standard AHRI Conditions

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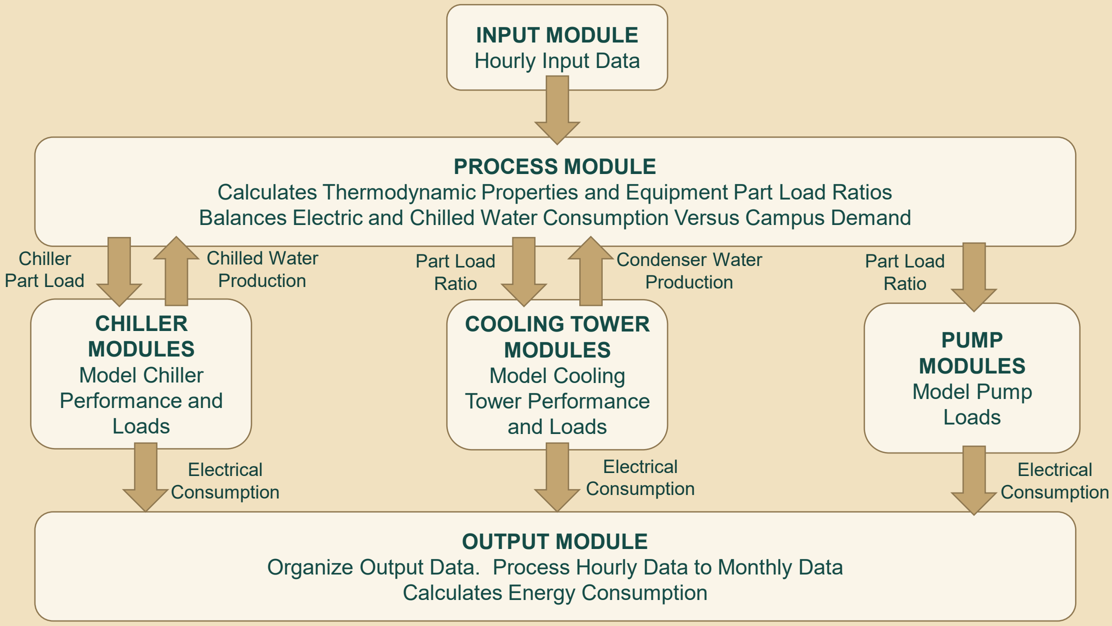
50%	45% of the time	65°F	55°F / 44°F	
25%	12% of the time	65°F	55°F / 44°F	

36

DUP – Custom Spreadsheet Model Flow Diagram:



37

DUP – Modeling Control Sequences:

Baseline Model Sample Parameters

CHILLER WATER SYSTEM INPUT PARAMETERS		
CWS Setpoint (high)	42.0	°F
CWS Setpoint (low)	45.0	°F
OSA Setpoint (high)	65.0	°F
OSA Setpoint (low)	45.0	°F
Chiller Plant Minimum Capacity	10	Tons
Sytems Secondary Design DT	16.0	°F
Primary Evap. Pump Speed Control	VFD	
Plant Configuration	Primary/Secondary	
CHILLER STAGING PARAMETERS		
Chiller Plant Min OSA Enable Temp	0.1	°F
Chiller Staging Load Percent	98%	

NASH CONDENSER WATER SYSTEM INPUT PARAMETERS		
CDS Setpoint (high)	85.0	°F
CDS Setpoint (low)	85.0	°F
OSA Setpoint (high)	95.0	°F
OSA Setpoint (low)	55.0	°F
Primary Cond. Pump Speed Control	VFD	

DUP CONDENSER WATER SYSTEM INPUT PARAMETERS		
CDS Setpoint (high)	85.0	°F
CDS Setpoint (low)	70.0	°F
OSA Setpoint (high)	75.0	°F
OSA Setpoint (low)	60.0	°F
Primary Cond. Pump Speed Control	VFD	

Proposed Model Sample Parameters

CHILLER WATER SYSTEM INPUT PARAMETERS		
CWS Setpoint (high)	42.0	°F
CWS Setpoint (low)	45.0	°F
OSA Setpoint (high)	65.0	°F
OSA Setpoint (low)	45.0	°F
Chiller Plant Minimum Capacity	10	Tons
Sytems Secondary Design DT	16.0	°F
Primary Evap. Pump Speed Control	VFD	
Plant Configuration	Primary/Secondary	

Chiller Staging Differential Flow	400.0	
CHWP Stage 1	2000.0	gpm
CHWP Stage 2	2500.0	gpm
CHWP Stage 3	3000.0	gpm
CHWP Staging Differential flow	400.0	gpm

CONDENSER WATER SYSTEM INPUT PARAMETERS		
CDS Setpoint (high)	80.0	°F
CDS Setpoint (low)	47.0	°F
OSA Setpoint (high)	95.0	°F
OSA Setpoint (low)	42.0	°F
Primary Cond. Pump Speed Control	VFD	
CWP Stage 1	2500.0	gpm
CWP Stage 2	3000.0	gpm
CWP Stage 3	3500.0	gpm
CWP Staging Differential Flow	400.0	gpm
CWP High Setpoint Flow	3000.0	
CWP Low Setpoint Flow	2100.0	
CWP High Chiller FLA	0.9	
CWP Low Chiller FLA	0.4	

COOLING TOWER FAN SPEED PARAMETERS		
CT Fan Speed Setpoint (High)	60.0	Hz
CT Fan Speed Setpoint (Low)	20.0	Hz
CT Chiller Cum % FLA (High)	23%	
CT Chiller Cum % FLA (Low)	6%	

Parameters are written to develop staging setpoints and Sequence of Operations to model enabling and disabling equipment operation

38

DUP – Modeling Control Sequences:

Baseline Model Sample Parameters

CHILLER WATER SYSTEM INPUT PARAMETERS		
CWS Setpoint (high)	42.0	°F
CWS Setpoint (low)	45.0	°F
OSA Setpoint (high)	65.0	°F
OSA Setpoint (low)	45.0	°F
Chiller Plant Minimum Capacity	10	Tons
Sytems Secondary Design DT	16.0	°F
Primary Evap. Pump Speed Control	VFD	
Plant Configuration	Primary/Secondary	
CHILLER STAGING PARAMETERS		
Chiller Plant Min OSA Enable Temp	0.1	°F
Chiller Staging Load Percent	98%	

NASH CONDENSER WATER SYSTEM INPUT PARAMETERS		
CDS Setpoint (high)	85.0	°F
CDS Setpoint (low)	85.0	°F
OSA Setpoint (high)	95.0	°F
OSA Setpoint (low)	55.0	°F
Primary Cond. Pump Speed Control	VFD	

DUP CONDENSER WATER SYSTEM INPUT PARAMETERS		
CDS Setpoint (high)	85.0	°F
CDS Setpoint (low)	70.0	°F
OSA Setpoint (high)	75.0	°F
OSA Setpoint (low)	60.0	°F
Primary Cond. Pump Speed Control	VFD	

Proposed Model Sample Parameters

CHILLER WATER SYSTEM INPUT PARAMETERS		
CWS Setpoint (high)	42.0	°F
CWS Setpoint (low)	45.0	°F
OSA Setpoint (high)	65.0	°F
OSA Setpoint (low)	45.0	°F
Chiller Plant Minimum Capacity	10	Tons
Sytems Secondary Design DT	16.0	°F
Primary Evap. Pump Speed Control	VFD	
Plant Configuration	Primary/Secondary	
Chiller Staging Differential Flow	400.0	
CHWP Stage 1	2000.0	gpm
CHWP Stage 2	2500.0	gpm
CHWP Stage 3	3000.0	gpm
CHWP Staging Differential flow	400.0	gpm

CONDENSER WATER SYSTEM INPUT PARAMETERS		
CDS Setpoint (high)	80.0	°F
CDS Setpoint (low)	47.0	°F
OSA Setpoint (high)	95.0	°F
OSA Setpoint (low)	42.0	°F
Primary Cond. Pump Speed Control	VFD	
CWP Stage 1	2500.0	gpm
CWP Stage 2	3000.0	gpm
CWP Stage 3	3500.0	gpm
CWP Staging Differential Flow	400.0	gpm
CWP High Setpoint Flow	3000.0	
CWP Low Setpoint Flow	2100.0	
CWP High Chiller FLA	0.9	
CWP Low Chiller FLA	0.4	

COOLING TOWER FAN SPEED PARAMETERS		
CT Fan Speed Setpoint (High)	60.0	Hz
CT Fan Speed Setpoint (Low)	20.0	Hz
CT Chiller Cum % FLA (High)	23%	
CT Chiller Cum % FLA (Low)	6%	

Parameters are written to develop staging setpoints and Sequence of Operations to model enabling and disabling equipment operation

DUP – Modeling Control Sequences:

Proposed Model

MODE STATE MATRIX

Mode Control Parameters		Current Time / Date	OSA Temp (F)	Cooling Load (tons)	OSA Temp Plant Lockout	Chilled Water Flow (gpm)	Cond. Water Flow (gpm)
		8/9/11 15:00	93.4	2592.1	1.0	5040.8	6695.4

Operating Modes

State Description	State Value (1=On, 0=Off)	Chiller Stages	Cooling Twr Stages	Pump Stages
Chiller #1	1	1		
Chiller #2	1	1		
Chiller #3	1	1		
~~Chiller #4~~	0	0		
~~Chiller #5~~	0	0		
CT #1	1		1	
CT #2	1		1	
CT #3	1		1	
CT #4	1		1	
CT #5	1		1	
CT #6	1		1	

Baseline Model

MODE STATE MATRIX

Mode Control Parameters		Current Time / Date	OSA Temp (F)	Cooling Load (tons)	OSA Temp Plant Lockout	Chilled Water Flow (gpm)
		Aug-09 15:00	93.4	2592.1	1.0	5040.8

Operating Modes

State Description	State Value (1=On, 0=Off)	Chiller Stages	Cooling Twr Stages	Pump Stages
Chiller #1 (Nash)	1	1		
Chiller #2	1	1		
Chiller #3	1	1		
Chiller #4	0	0		
~~Chiller #5~~	0	0		
CT #1 (Nash)	1		1	
CT #2	1		1	
CT #3	1		1	
CT #4	1		1	
CT #5	1		1	
CT #6	1		1	
CT #7	1		1	

Pumps for Baseline are tracked inside Chiller and CT Modules

Summer temperatures and high cooling load condition

Enabled equipment identified with a "1"

DUP – Modeling Control Sequences:

Proposed Model

MODE STATE MATRIX

Mode Control Parameters	Current Time / Date	OSA Temp (F)	Cooling Load (tons)	OSA Temp Plant Lockout	Chilled Water Flow (gpm)	Cond. Water Flow (gpm)
	4/16/11 14:00	61.7	710.9	1.0	2277.8	4200.0

Operating Modes

State Description	State Value (1=On, 0=Off)	Chiller Stages	Cooling Twr Stages	Pump Stages
Chiller #1	1	1		
Chiller #2	1	1		
Chiller #3	0	0		
~~Chiller #4~~	~~0~~	~~0~~		
~~Chiller #5~~	~~0~~	~~0~~		
CT #1	1		1	
CT #2	1		1	
CT #3	1		1	
CT #4	1		1	
CT #5	1		1	
CT #6	1		1	

Baseline Model

MODE STATE MATRIX

Mode Control Parameters	Current Time / Date	OSA Temp (F)	Cooling Load (tons)	OSA Temp Plant Lockout	Chilled Water Flow (gpm)
	Apr-16 14:00	61.7	710.9	1.0	2277.8

Operating Modes

State Description	State Value (1=On, 0=Off)	Chiller Stages	Cooling Twr Stages	Pump Stages
Chiller #1	1	1		
Chiller #2	1	1		
Chiller #3	0	0		
Chiller #4	0	0		
~~Chiller #5~~	~~0~~	~~0~~		
CT #1	1		1	
CT #2	1		1	
CT #3	1		1	
CT #4	1		1	
CT #5	0		0	
CT #6	0		0	
CT #7	0		0	

Pumps for Baseline are tracked inside Chiller and CT Modules

Moderate temperatures and moderate cooling load condition

Enabled equipment identified with a "1"

DUP – Modeling Control Sequences:

Proposed Model

MODE STATE MATRIX

Mode Control Parameters	Current Time / Date	OSA Temp (F)	Cooling Load (tons)	OSA Temp Plant Lockout	Chilled Water Flow (gpm)	Cond. Water Flow (gpm)
	12/15/11 8:00	35.6	110.0	1.0	773.2	2100.0

Operating Modes

State Description	State Value (1=On, 0=Off)	Chiller Stages	Cooling Twr Stages	Pump Stages
Chiller #1	1	1		
Chiller #2	0	0		
Chiller #3	0	0		
~~Chiller #4~~	~~0~~	~~0~~		
~~Chiller #5~~	~~0~~	~~0~~		
CT #1	1		1	
CT #2	1		1	
CT #3	1		1	
CT #4	1		1	
CT #5	1		1	
CT #6	1		1	

Baseline Model

MODE STATE MATRIX

Mode Control Parameters	Current Time / Date	OSA Temp (F)	Cooling Load (tons)	OSA Temp Plant Lockout	Chilled Water Flow (gpm)
	Dec-15 8:00	35.6	110.0	1.0	773.2

Operating Modes

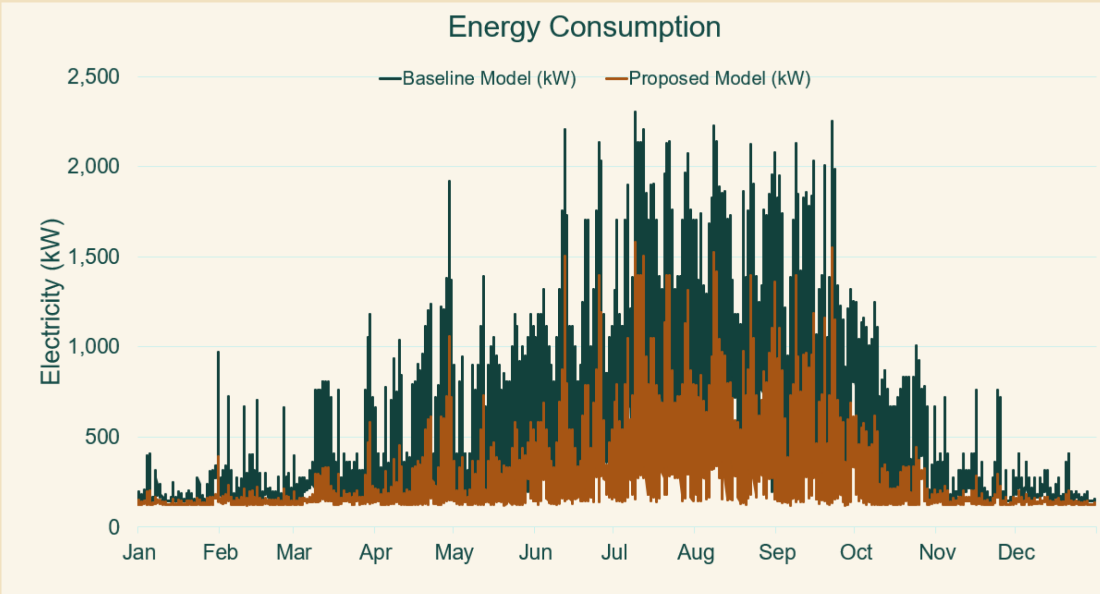
State Description	State Value (1=On, 0=Off)	Chiller Stages	Cooling Twr Stages	Pump Stages
Chiller #1	1	1		
Chiller #2	0	0		
Chiller #3	0	0		
Chiller #4	0	0		
~~Chiller #5~~	~~0~~	~~0~~		
CT #1	1		1	
CT #2	0		0	
CT #3	0		0	
CT #4	0		0	
CT #5	0		0	
CT #6	0		0	
CT #7	0		0	

Pumps for Baseline are tracked inside Chiller and CT

Winter temperatures and low cooling load condition

Enabled equipment identified with a "1"

DUP – Proposed Vs. Baseline



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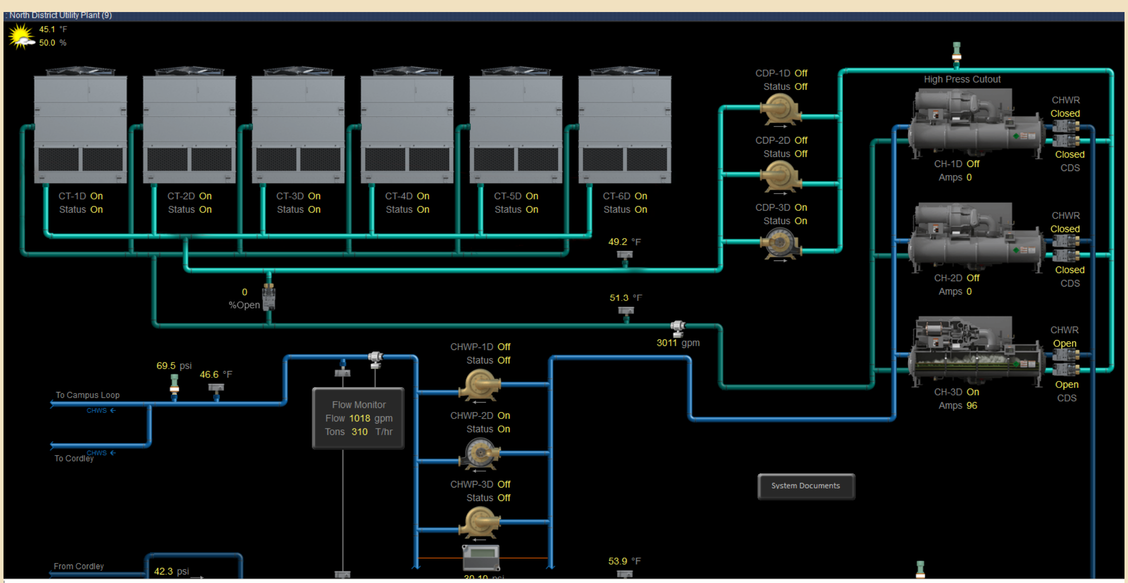
DUP – BAS Interface



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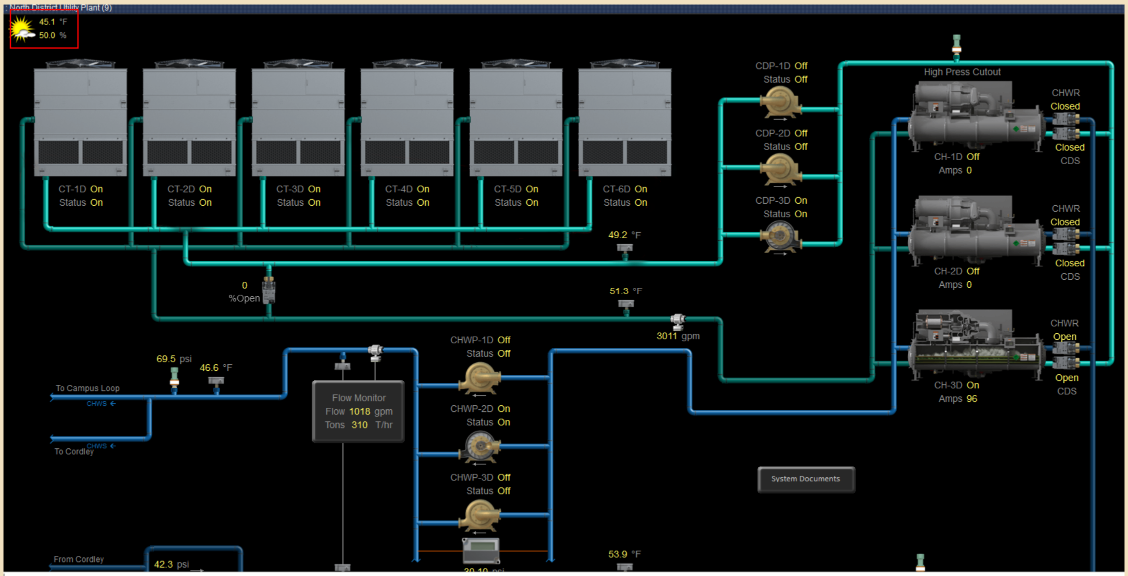
DUP – BAS Interface



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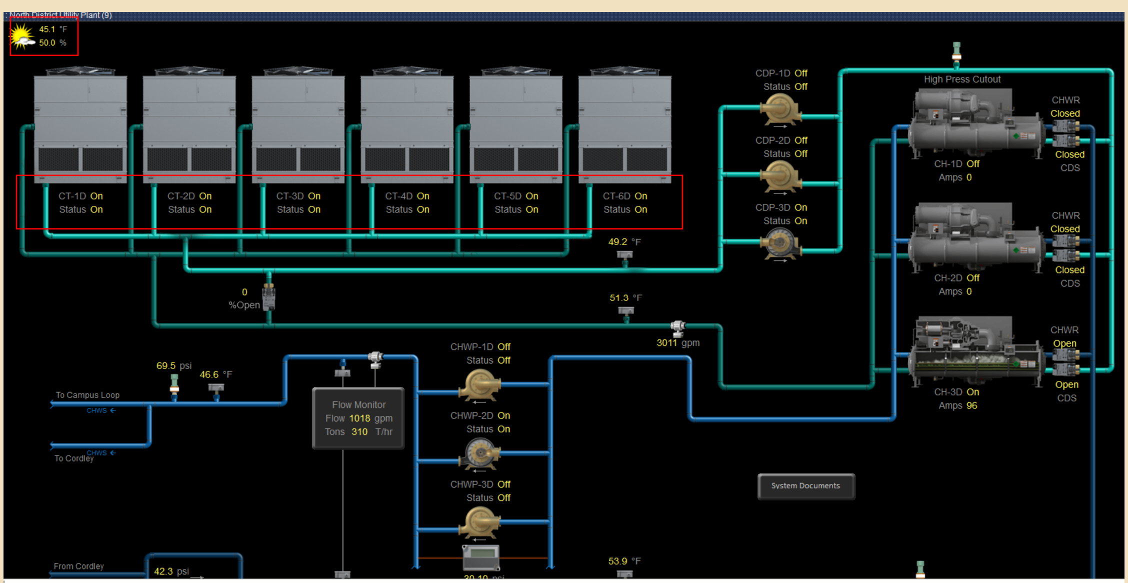
DUP – BAS Interface



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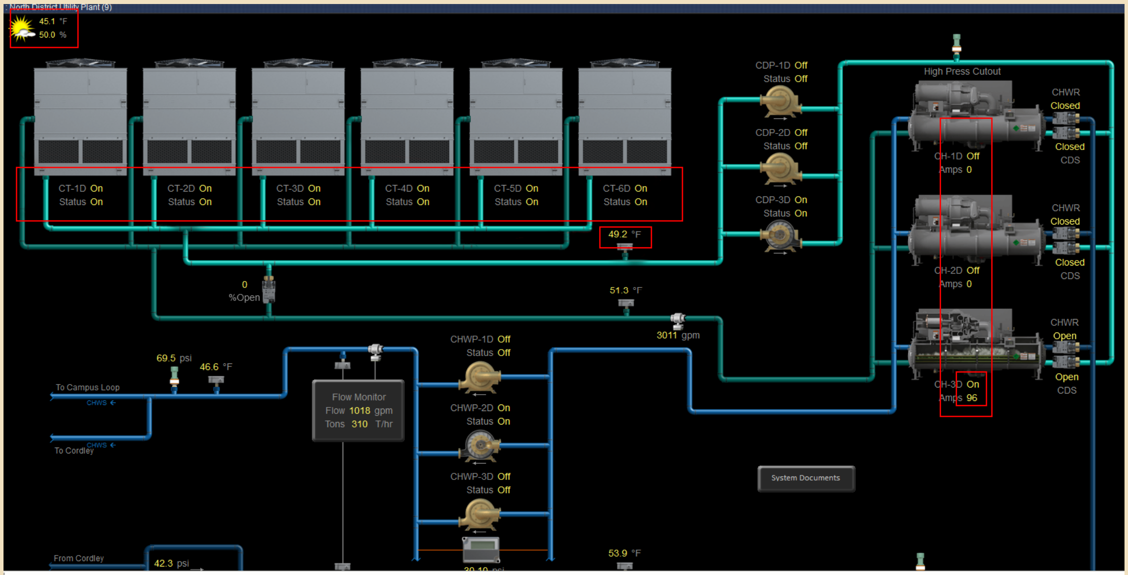
DUP – BAS Interface



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DUP – Operating Performance

Chilled Water Current Data

Supply Water Temp 46.6 °F
Return Water Temp 53.9 °F
Tonnage 303 tons
Flow 995 gpm

Chilled Water Plant

Totals 082 Kw
000 Kw / ton

Current Equipment Demands

Plant Chillers	Chilled Water Plant CW Pumps	Chilled Water Plant CD Pumps
CH - 1D 000 Kw	CWP - 1D 000 Kw	CDP - 1D 000 Kw
CH - 2D 000 Kw	CWP - 2D 020 Kw	CDP - 2D 000 Kw
CH - 3D 006 Kw	CWP - 3D 000 Kw	CDP - 3D 045 Kw
CH Totals 006 Kw	CWP Totals 020 Kw	CDP Totals 045 Kw
000 Kw / ton	000 Kw / ton	000 Kw / ton
	995 gpm	3018 gpm
	020 watt / gpm	015 watt / gpm

Chilled Water Plant Cooling Towers

CT - 1D 002 Kw	CT - 3D 002 Kw	CT - 5D 002 Kw
CT - 2D 002 Kw	CT - 4D 002 Kw	CT - 6D 002 Kw
CT Totals 011 Kw		
000 Kw / ton		

0.02 kw/Ton

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DUP – Expected Performance

Performance Matrix

Standard Performance Rated with Variable Primary Flow [Evaporator] (VPF[E])

Capacity ton	% of Design Load	Evaporator Flow gpm	Evaporator Fluid Leaving Temperature °F	Condenser Flow gpm	59.00	58.00	57.00	56.00	55.00	54.00	53.00	52.00	51.00	50.00	49.00	48.00	47.00	46.00	45.00
					Cooling Efficiency kW/ton (Condenser Fluid Entering Temperature °F)														
1,500.0	100.0	2,570.00	44.00	3,000.00	0.3646	0.3571	0.3497	0.3426	0.3353	0.3282	0.3214	0.3150	0.3088	0.3028	0.2968	0.2916	0.2867	0.2821	0.2778
1,350.0	90.0	2,313.00	44.00	3,000.00	0.3295	0.3218	0.3144	0.3072	0.3003	0.2936	0.2871	0.2809	0.2748	0.2683	0.2622	0.2565	0.2512	0.2463	0.2416
1,200.0	80.0	2,056.00	44.00	3,000.00	0.2988	0.2905	0.2826	0.2751	0.2679	0.2608	0.2541	0.2475	0.2413	0.2353	0.2293	0.2234	0.2179	0.2128	0.2081
1,050.0	70.0	1,799.00	44.00	3,000.00	0.2718	0.2636	0.2557	0.2478	0.2399	0.2325	0.2253	0.2184	0.2117	0.2053	0.1992	0.1932	0.1873	0.1818	0.1768
900.0	60.0	1,542.00	44.00	3,000.00	0.2511	0.2424	0.2338	0.2255	0.2175	0.2094	0.2016	0.1942	0.1870	0.1801	0.1734	0.1671	0.1610	0.1553	0.1500
750.0	50.0	1,285.00	44.00	3,000.00	0.2376	0.2281	0.2189	0.2099	0.2012	0.1927	0.1845	0.1764	0.1687	0.1612	0.1540	0.1470	0.1404	0.1341	0.1282
600.0	40.0	1,028.00	44.00	3,000.00	0.2326	0.2222	0.2121	0.2021	0.1925	0.1830	0.1738	0.1649	0.1562	0.1478	0.1398	0.1321	0.1248	0.1181	0.1117
450.0	30.0	799.69	44.00	3,000.00	0.2108	0.2030	0.1956	0.1885	0.1816	0.1749	0.1686	0.1625	0.1530	0.1430	0.1334	0.1240	0.1148	0.1064	0.0967
300.0	20.0	799.69	44.00	3,000.00	0.2021	0.1923	0.1827	0.1734	0.1644	0.1557	0.1473	0.1392	0.1316	0.1244	0.1178	0.1110	0.1050	0.0968	0.0886
150.0	10.0	799.69	44.00	3,000.00	0.2671	0.2517	0.2361	0.2208	0.2058	0.1912	0.1768	0.1628	0.1492	0.1364	0.1234	0.1129	0.1045	0.0976	0.0916

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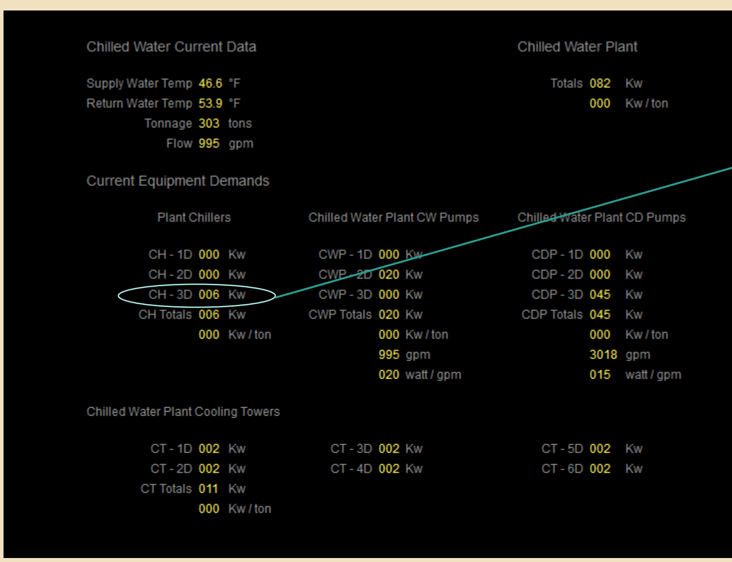
DUP – Importance of Proper Cx



Programmed to pull % RLA, not kW!

Actual kW = 37 (0.121 kW/ton)

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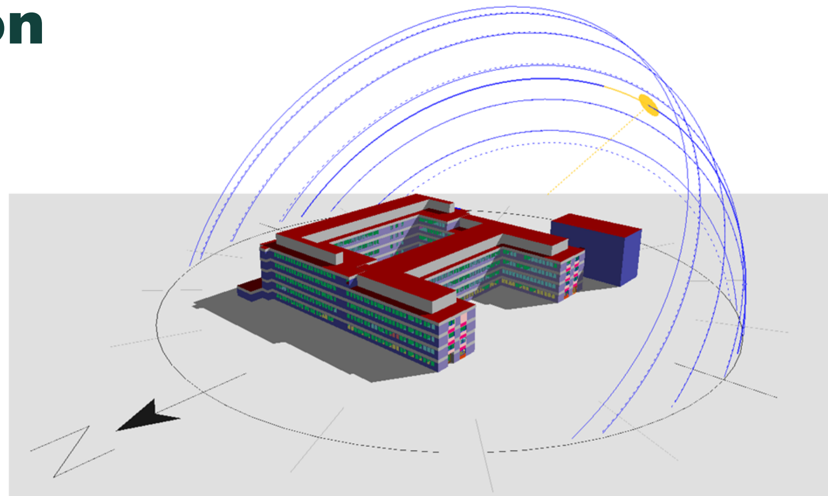
Cordley Hall Renovation

- 220,000 Square Feet
- Registered Historical
- 6-8 ACH in Labs
- Modeled with EDSL Tas



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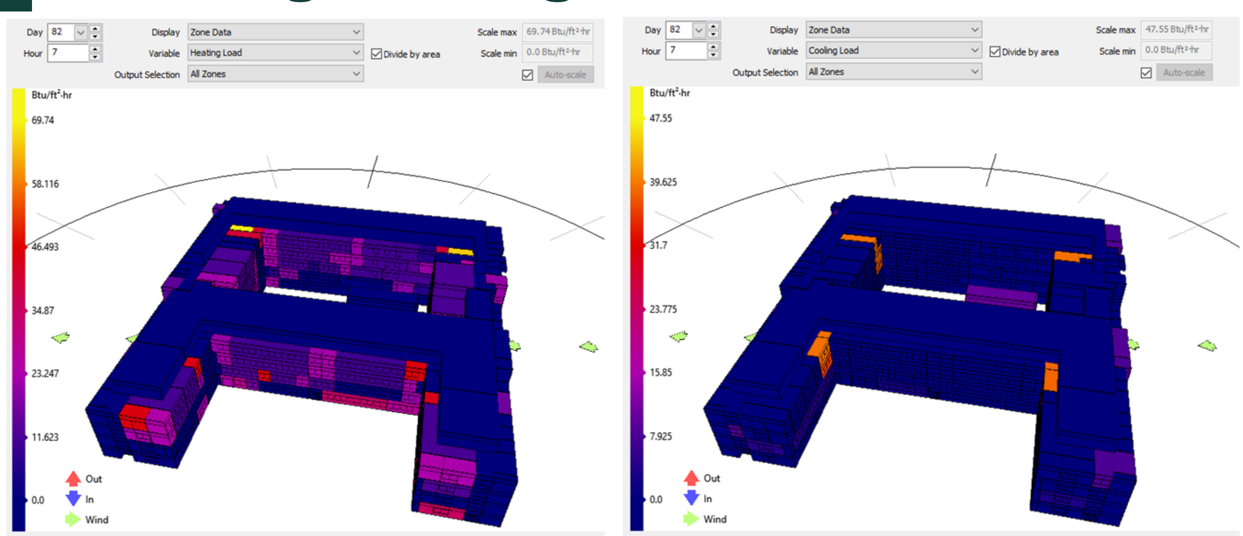
Tas 3D Model – Simultaneous Heating/Cooling



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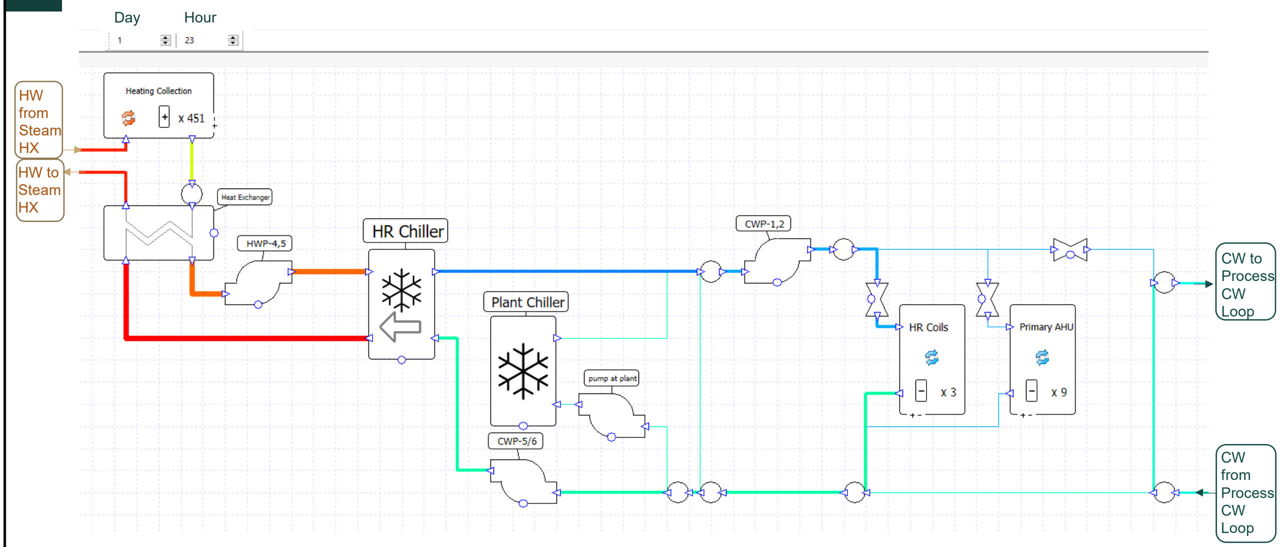
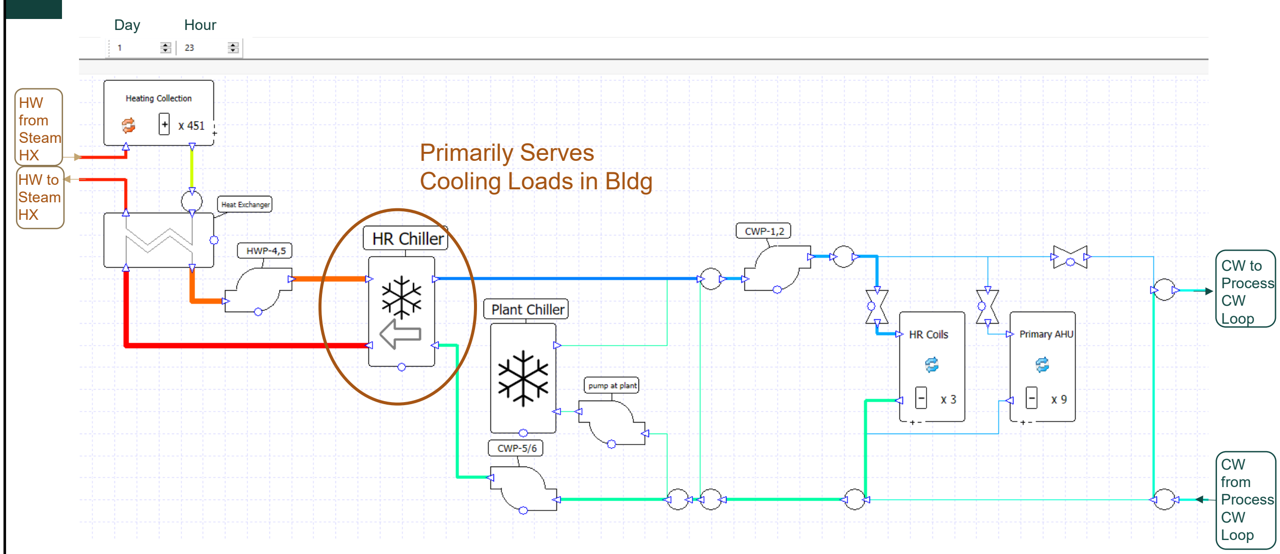
HR Chiller Modeled in Tas



53

HR Chiller Modeled in Tas



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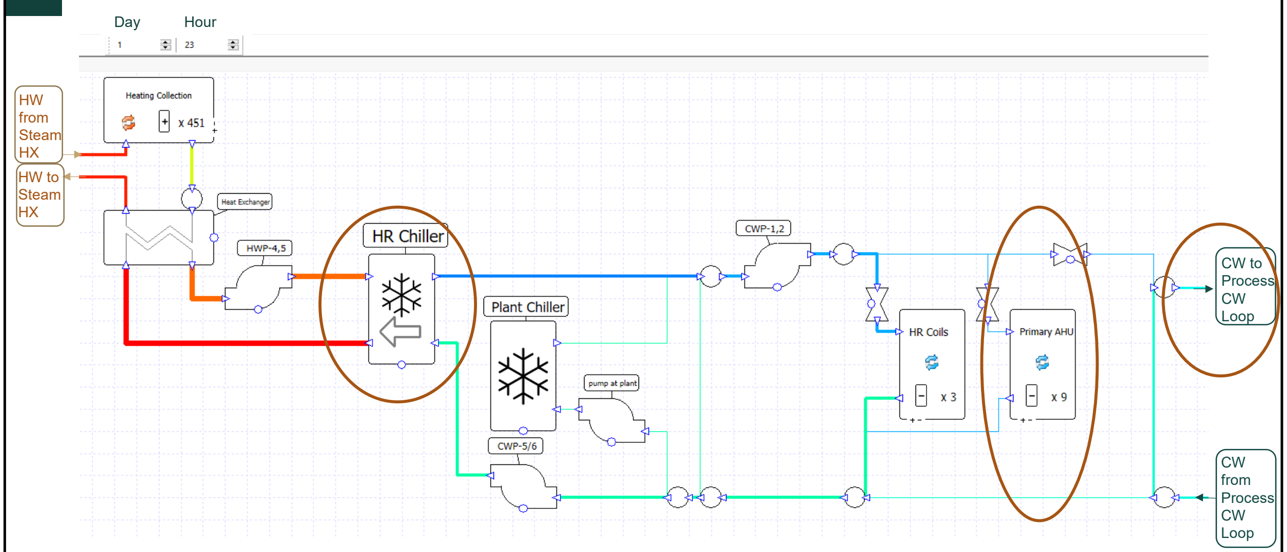
HR Chiller Modeled in Tas



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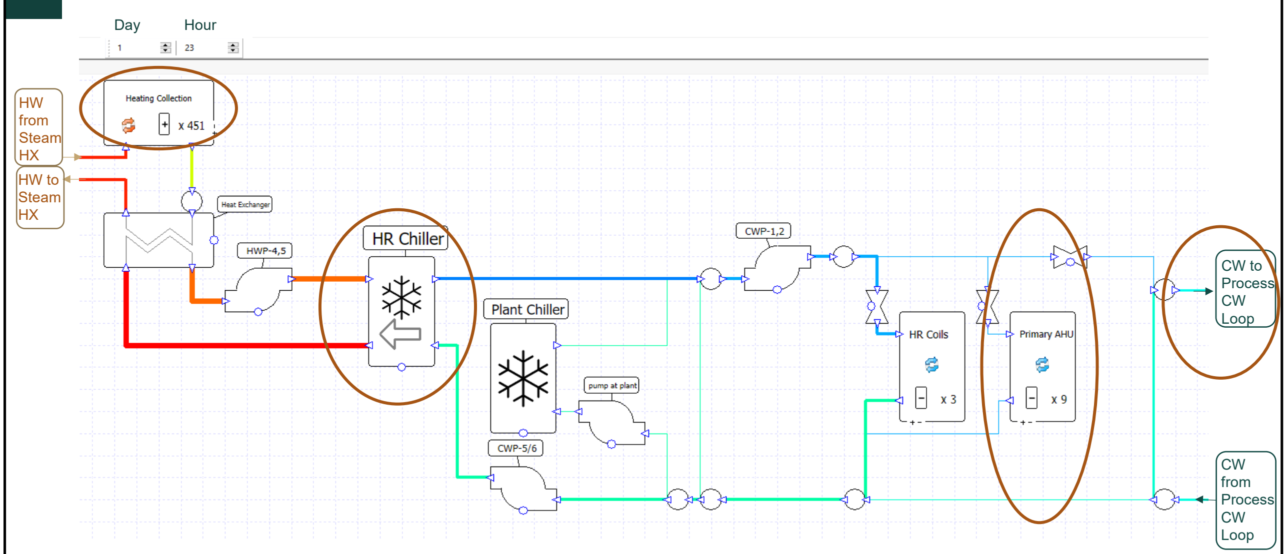
HR Chiller Modeled in Tas



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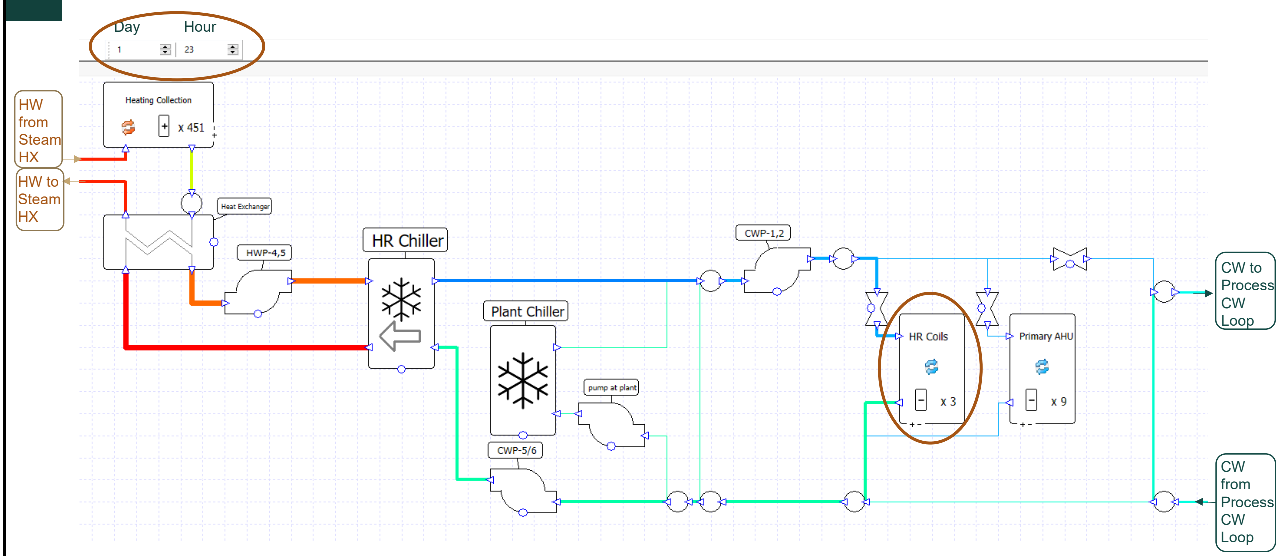
HR Chiller Modeled in Tas



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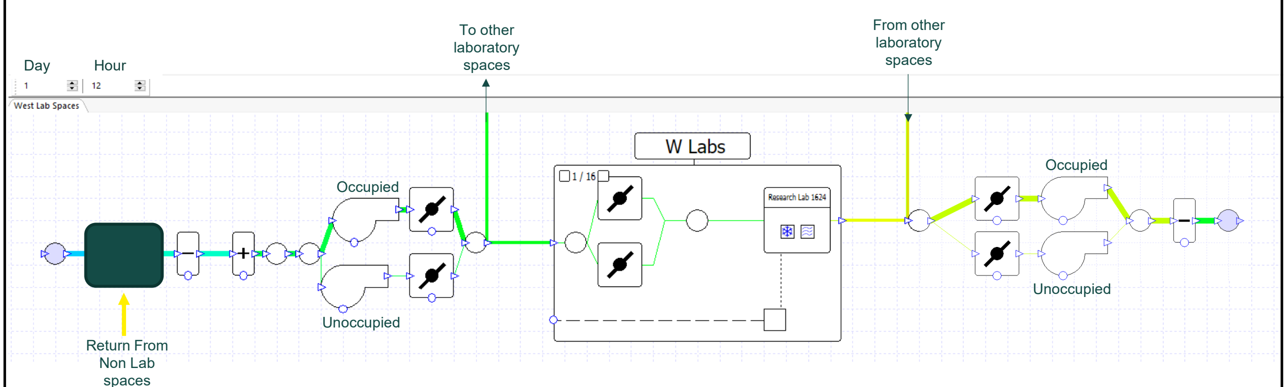
HR Cooling Coils Modeled in Tas



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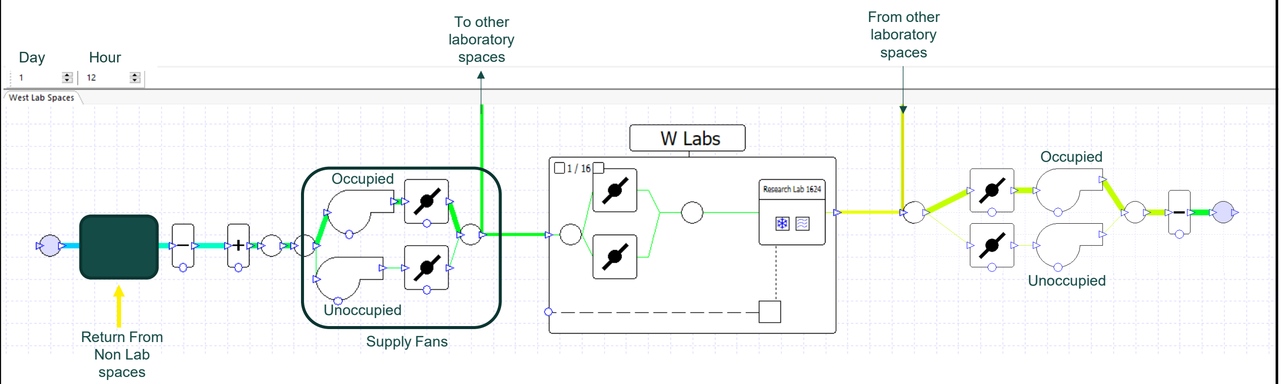
HR Cooling Coils Modeled in Tas



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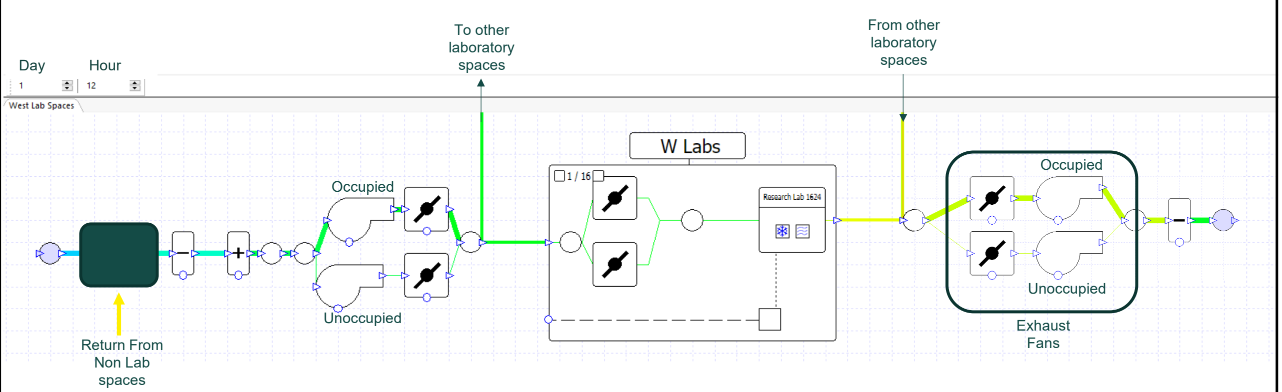
HR Cooling Coils Modeled in Tas



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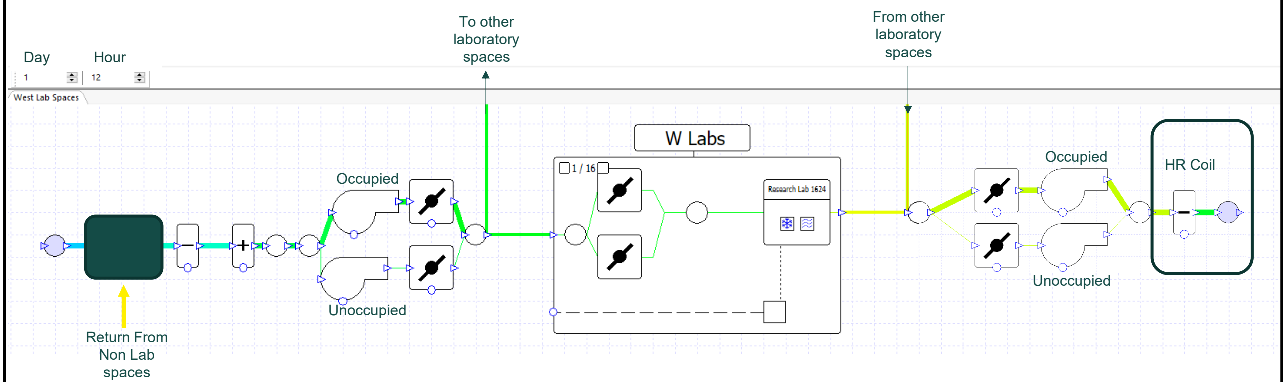
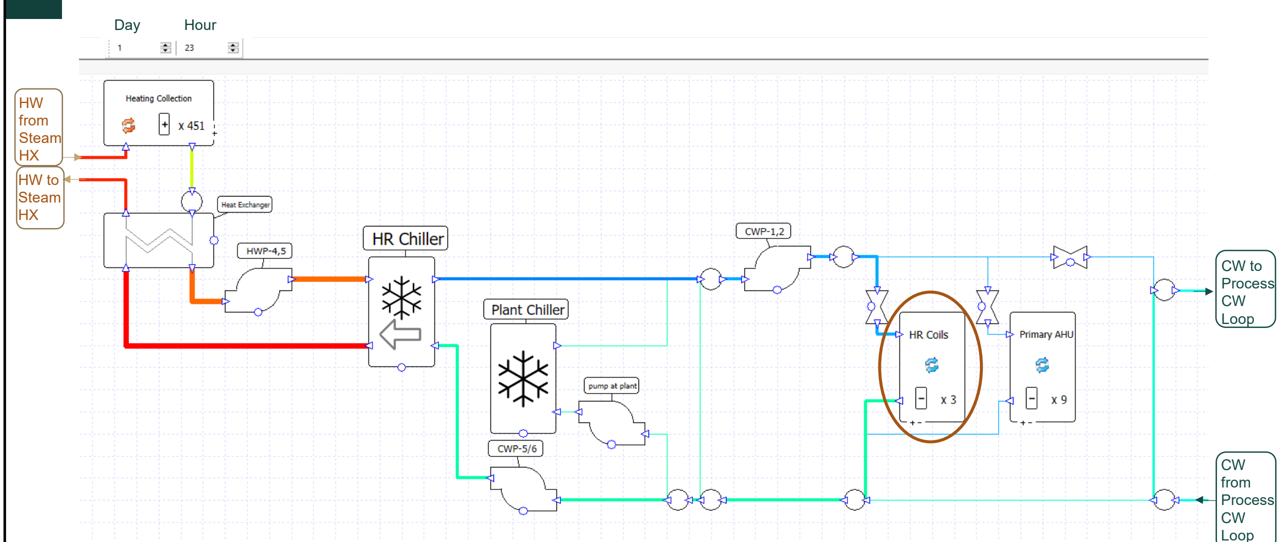
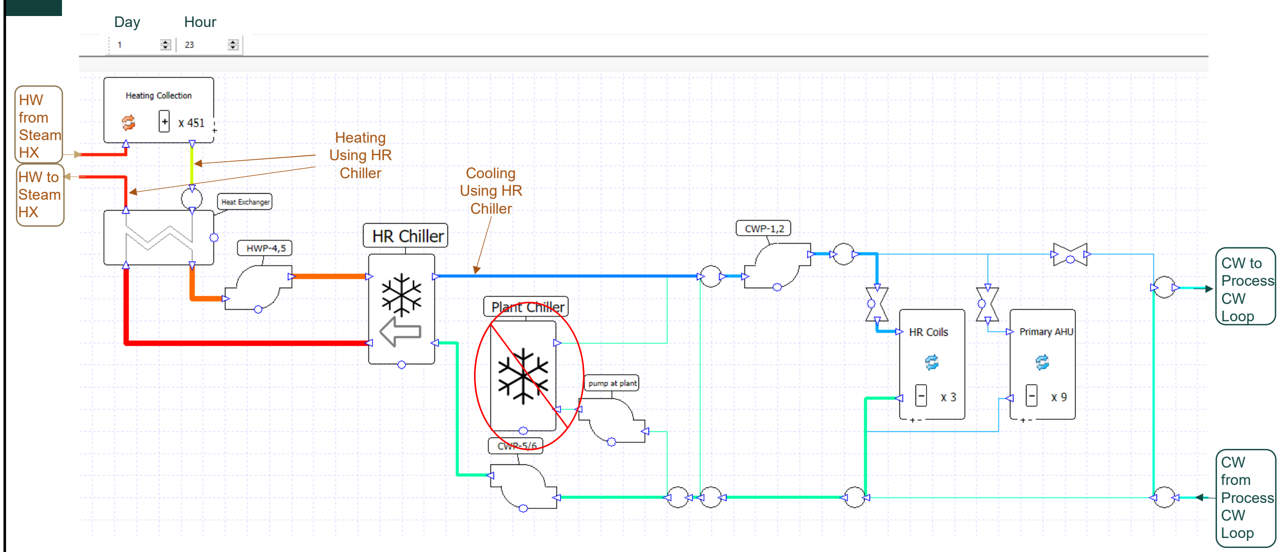
HR Cooling Coils Modeled in Tas



HR Chiller Modeled in Tas



HR Chiller Modeled in Tas



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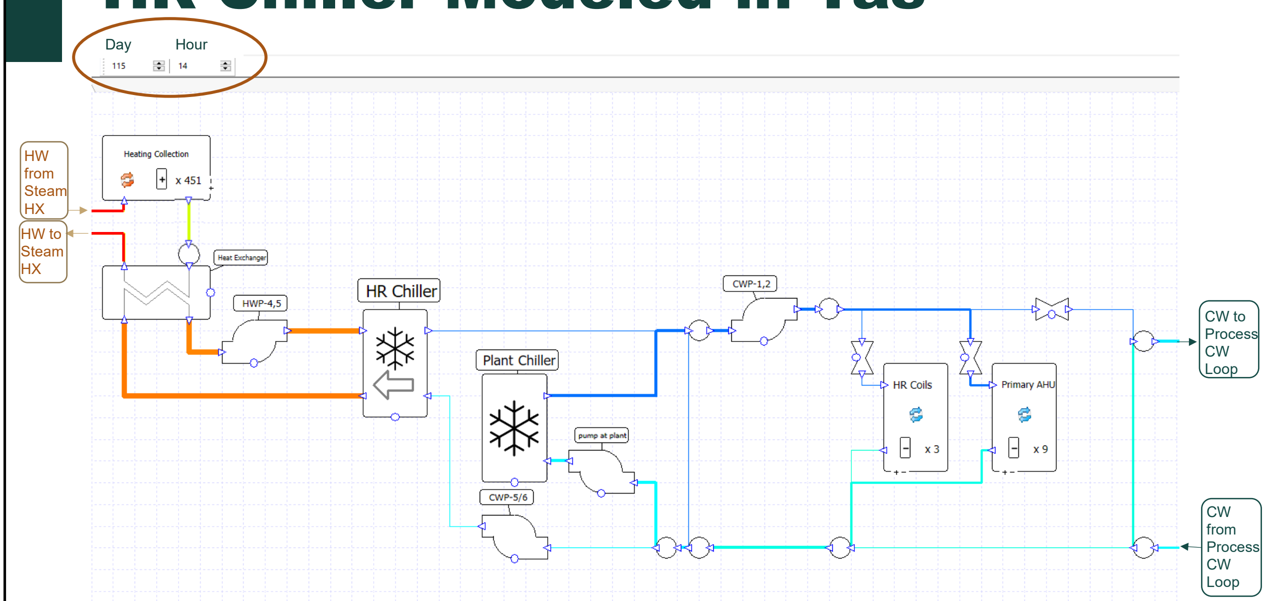
HR Chiller Modeled in Tas



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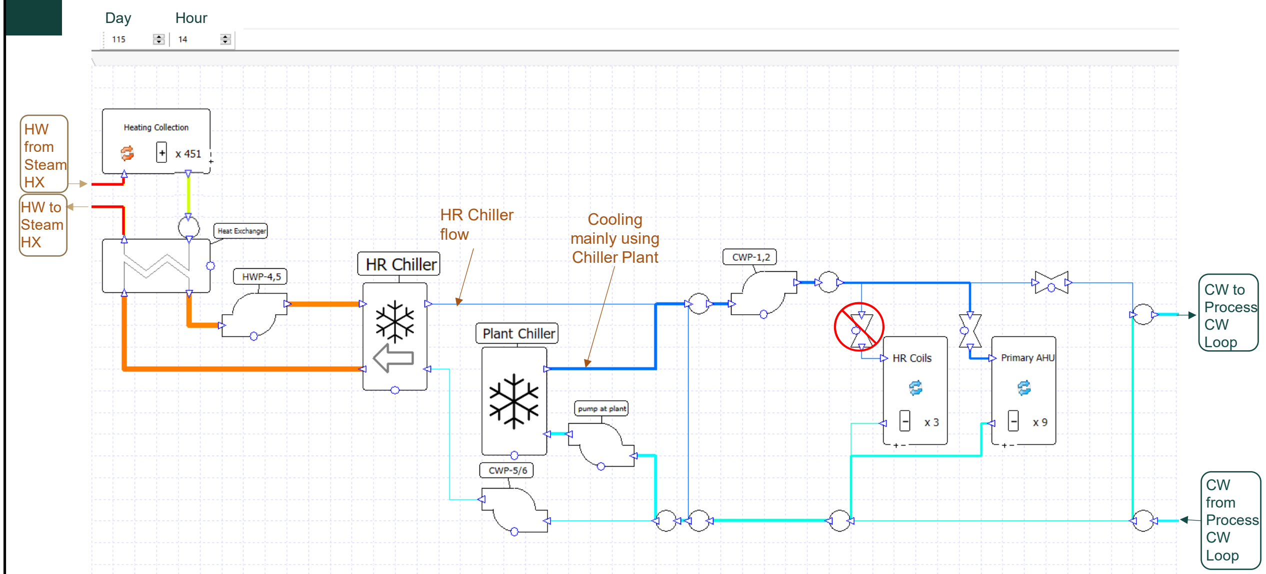
HR Chiller Modeled in Tas



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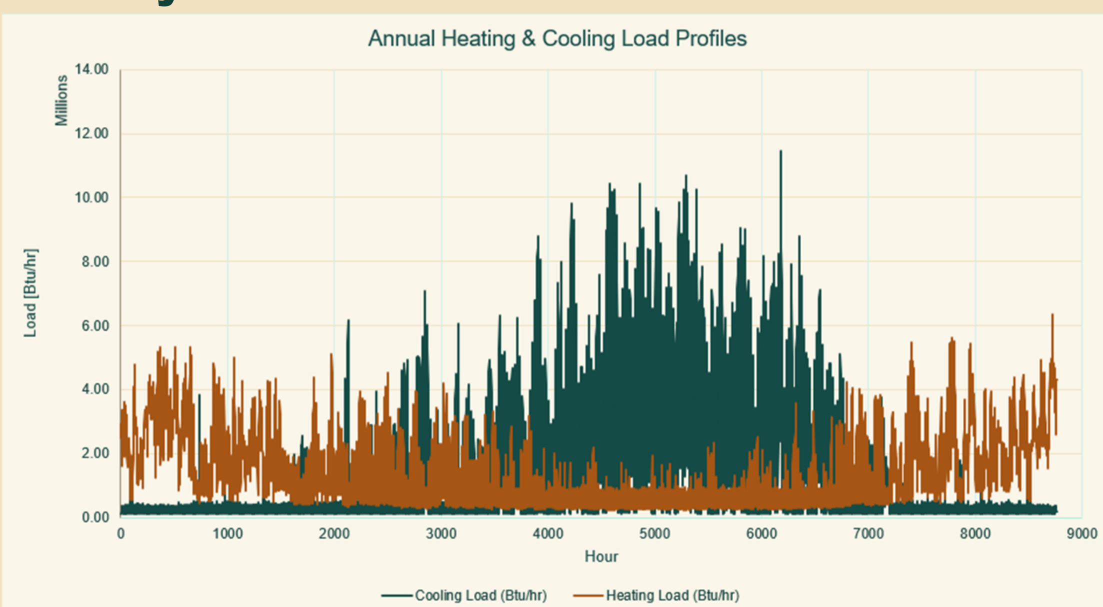
Cordley Load Profiles



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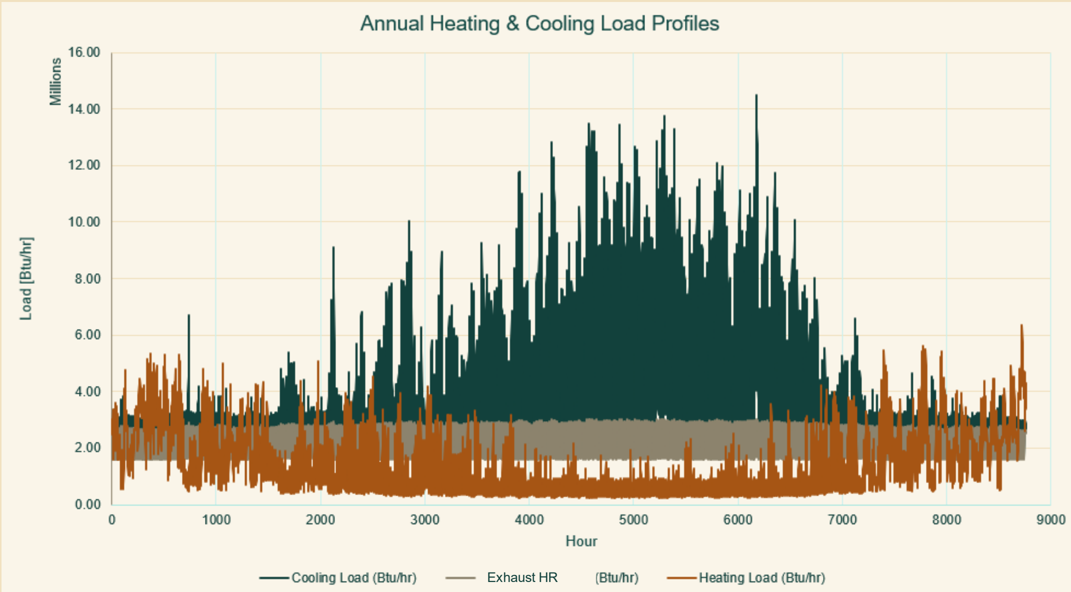
Cordley Load Profiles



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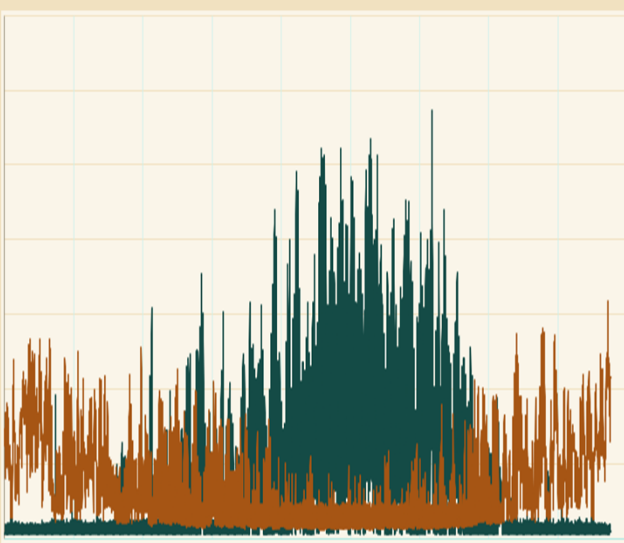
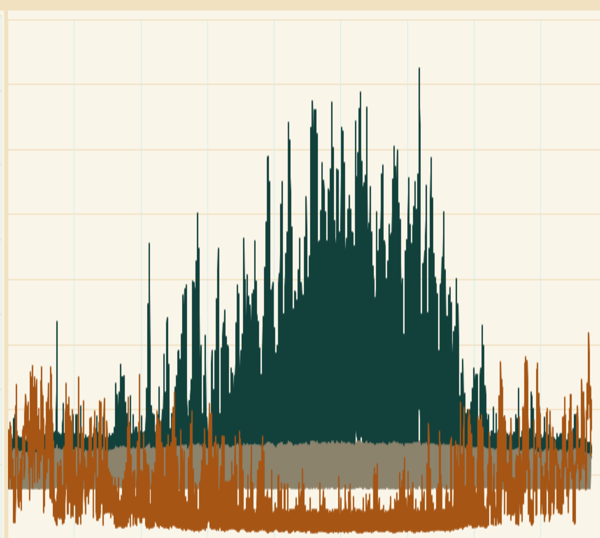
Cordley Load Profiles





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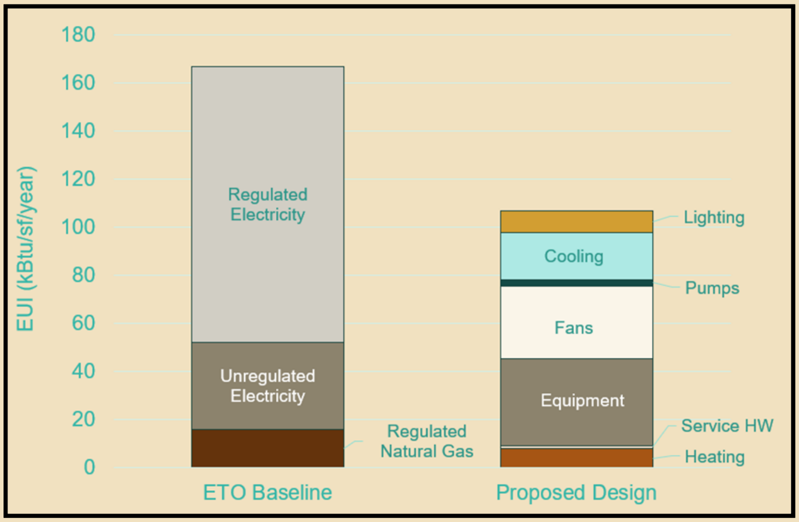
Cordley Renovation Summary

- ASHRAE 90.1 2016 Baseline
- ETO Baseline Modified
- HR Chiller inflates Cooling
- HR Chiller reduces Steam



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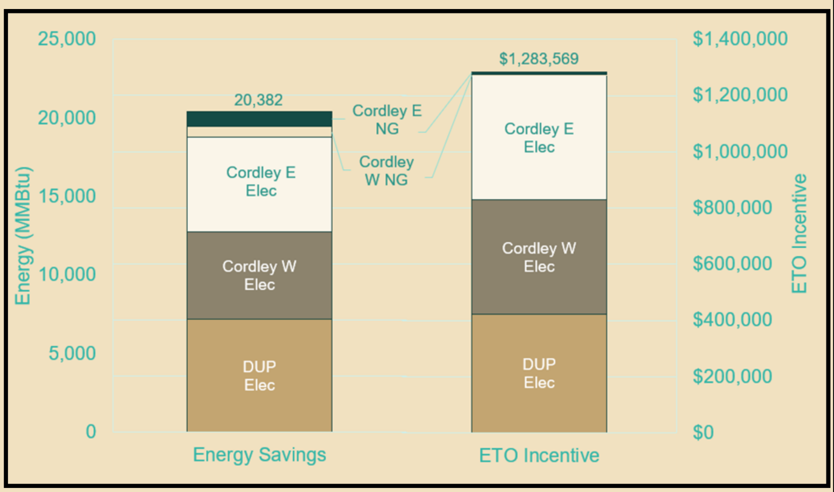
DUP and Cordley Renovation Summary

	kWH	Therm
DUP	2,110,000	0
Cordley West	1,627,469	6,573
Cordley East	1,767,651	9,415

2,000 tons of CO_2



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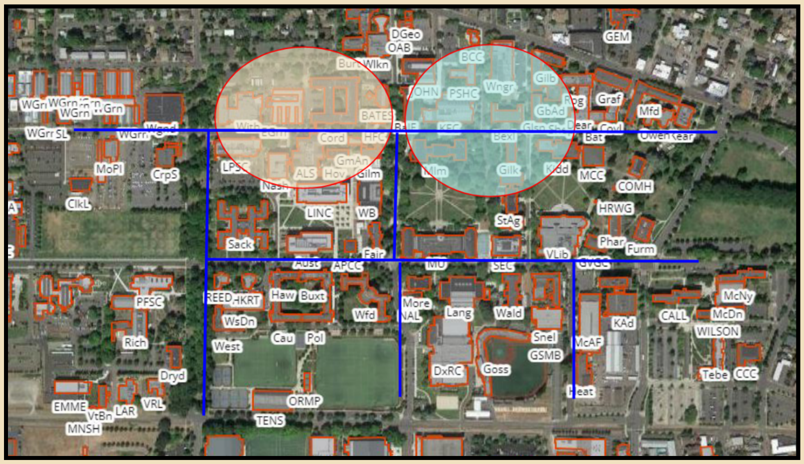
Future Campus-Wide Concept

- District Chilled Water Plants
- Strategic Placement of HRCs
- Reimagine CHW Distribution
- Heat Recycling



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Thank you!

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