ASHRAE Northern Nevada Chapter

HEAT RECOVERY CHILLERS:

Opportunities, De-Carbonization, and Other Considerations

Alan Niles

DB

Western Regional Sales Manager
Dunham-Bush USA
Made In America Again

HEAT RECOVERY CHILLERS

Opportunities

- Why Heat Recovery on Condenser Water Systems
- Code Compliance Requirements for Heat Recovery Chillers
- Minimum Expense/Maximum Recovery

De-Carbonization

- Economical Path towards 100% Fossil-Free Heat
  - Water Cooled Chillers with Simultaneous Hot Water
  - Air Cooled Chiller with Simultaneous Hot Water

Other Considerations

- Non-HVAC “free” heat recovery sources often overlooked

Why Heat Recovery on Condenser Water Systems

Heat Recovery Source: AIR to AIR

1. Requires a large amount of conditioned space to run ductwork
2. Fan Power excessive as duct system increases
3. No on-site storage for off-peak use

Why Heat Recovery on Condenser Water Systems

Heat Recovery Source: Refrigerant

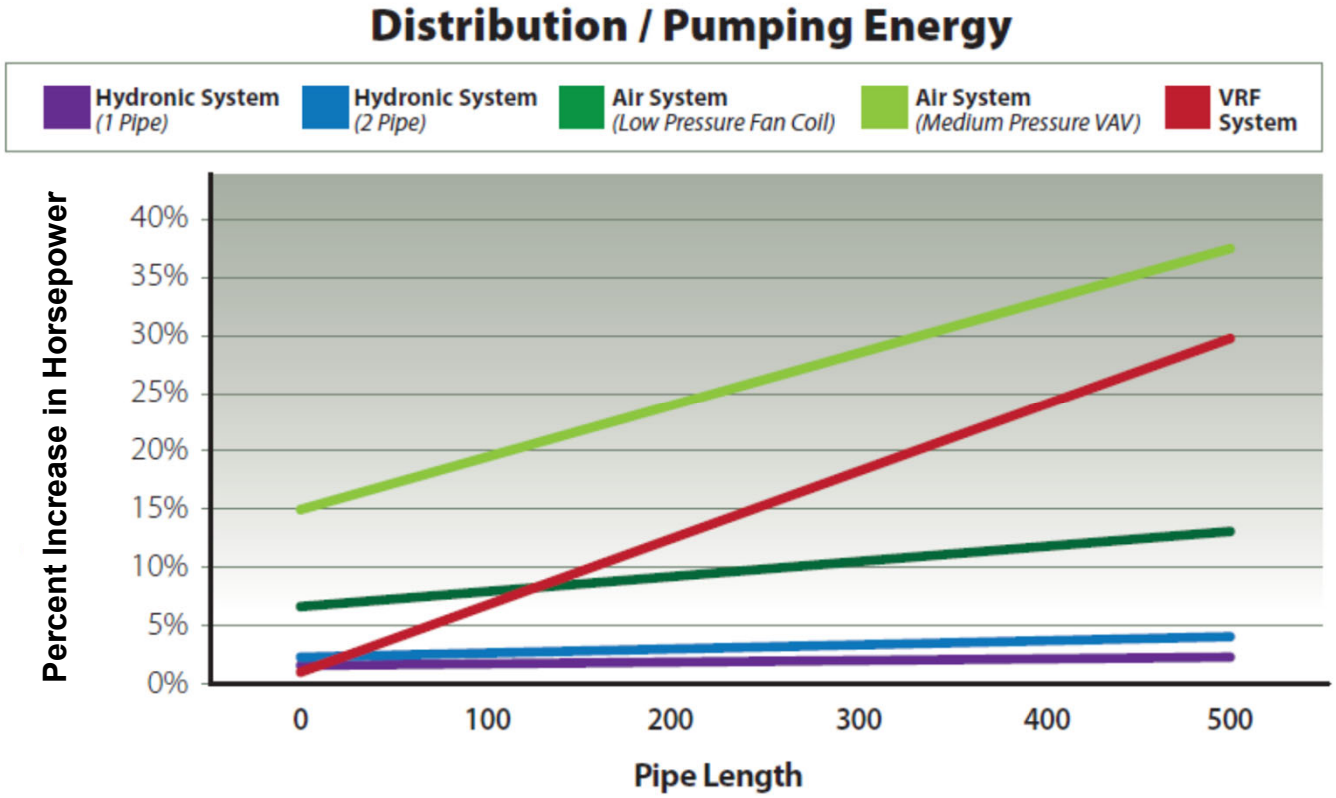
1. Can only share energy within a single circuit
2. Compressor losses limits scalability
   (440 equivalent feet line set = 20% reduction in compressor efficiency)
3. No on-site storage for off-peak use

Why Heat Recovery on Condenser Water Systems

Heat Recovery Source: Water

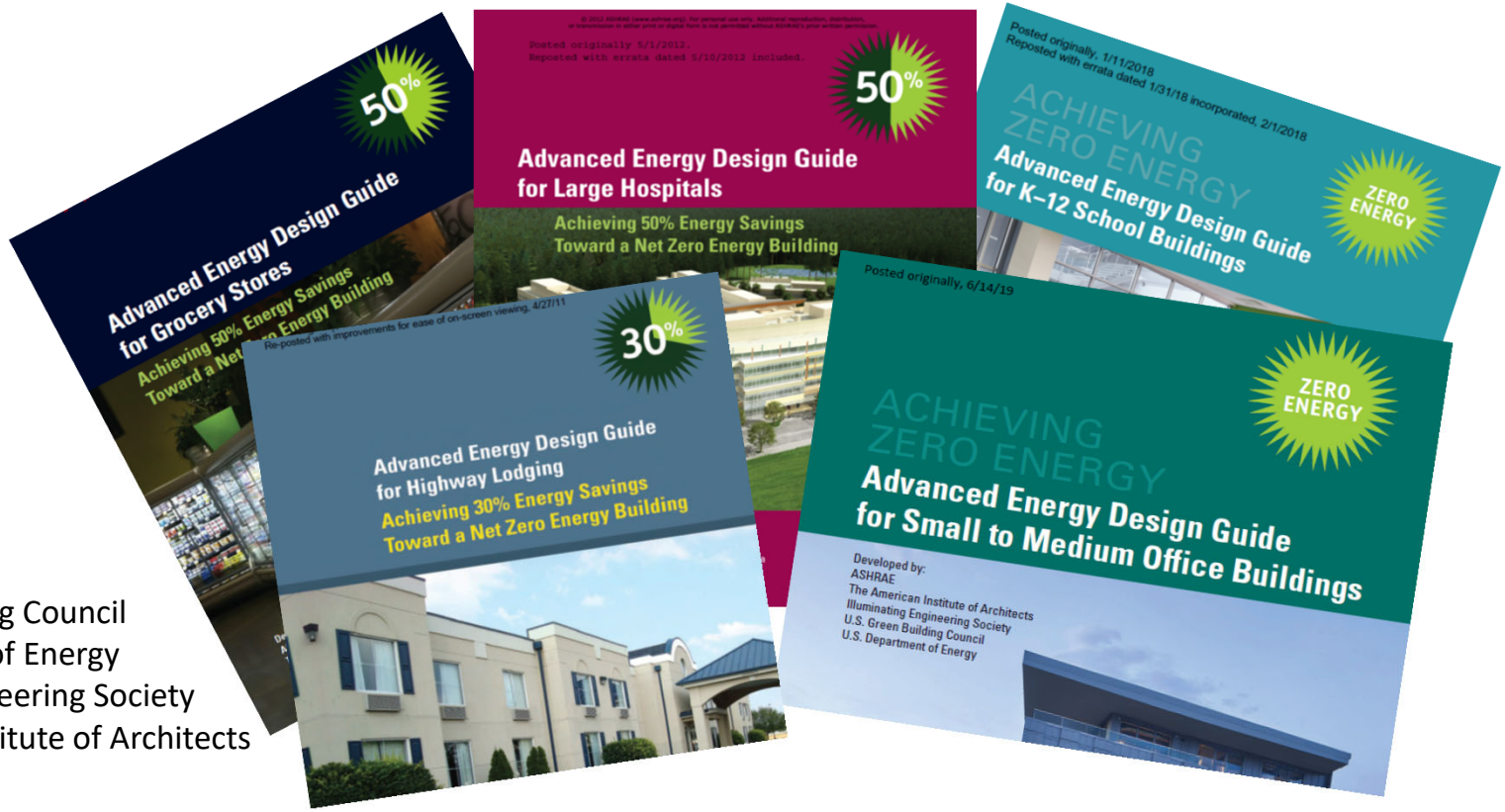
1. Moves energy **10 times more efficiently** than air
2. Small diameter piping moves large amounts of energy
3. Scalable and easy to shut off flow to zones that are satisfied for minimizing operating costs of the transportation system
4. Offers on-site storage opportunities for off-Peak loads
5. Easy to connect to onsite renewables like solar, ground loop, and bio-mass co-generation heat

Why Heat Recovery on Condenser Water Systems



HEAT RECOVERY CHILLERS:

Opportunities, De-Carbonization, and Other Considerations



Developed by:
ASHRAE
U.S. Green Building Council
U.S. Department of Energy
Illuminating Engineering Society
The American Institute of Architects

CODES: HEAT RECOVERY CHILLERS:

ASHRAE 90.1-2019, section 6.5.6.2.1; IECC 2018, section C403.9.5

Heat Recovery for Service Water Heating

Condenser heat recovery systems are mandated on systems of 6,000,000 BTUH (500 tons) of heat of rejection or greater (400 ton CHW), and with service hot water loads exceeding 1,000,000 BTUH (84 tons), and the building operates 24 hours per day.

The required heat recovery system shall have the capacity to provide *(as a minimum)* the smaller of:

a. 60% of the peak heat rejection load at design conditions, or

b. preheat of the peak service hot water draw to 85° F.

CODES: HEAT RECOVERY CHILLERS:

ASHRAE 90.1-2019, section 6.5.6.2.1; IECC 2018, section C403.9.5

Heat Recovery for Service Water Heating

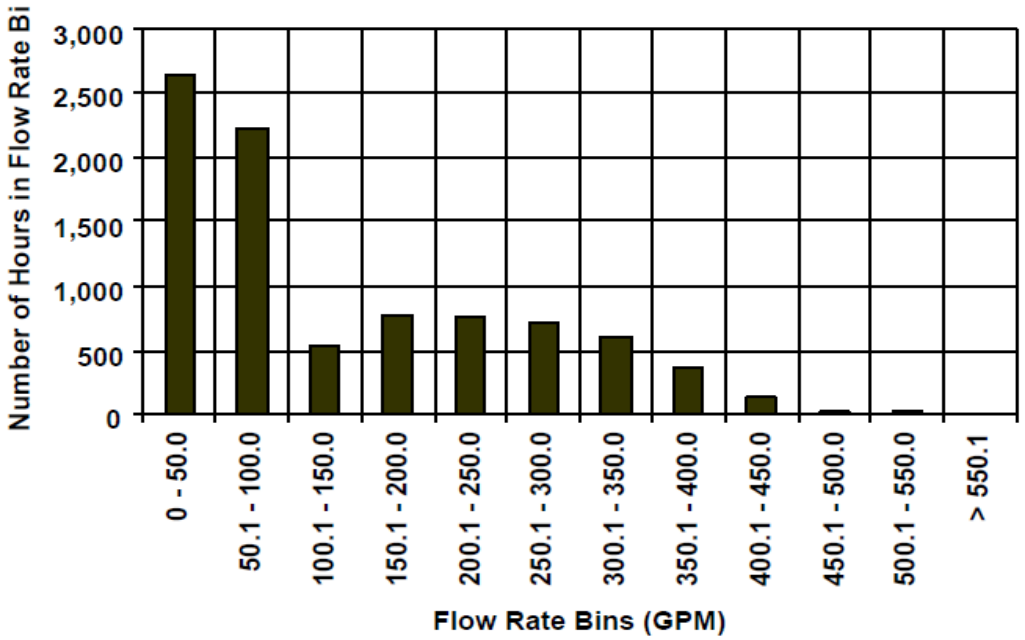
Exception 1:

If the condenser heat recovery system is used to provide space heating and space re-heat exceeding 30% of the designed peak water cooled condenser load

Let’s consider why 30%

CODES: HEAT RECOVERY CHILLERS:

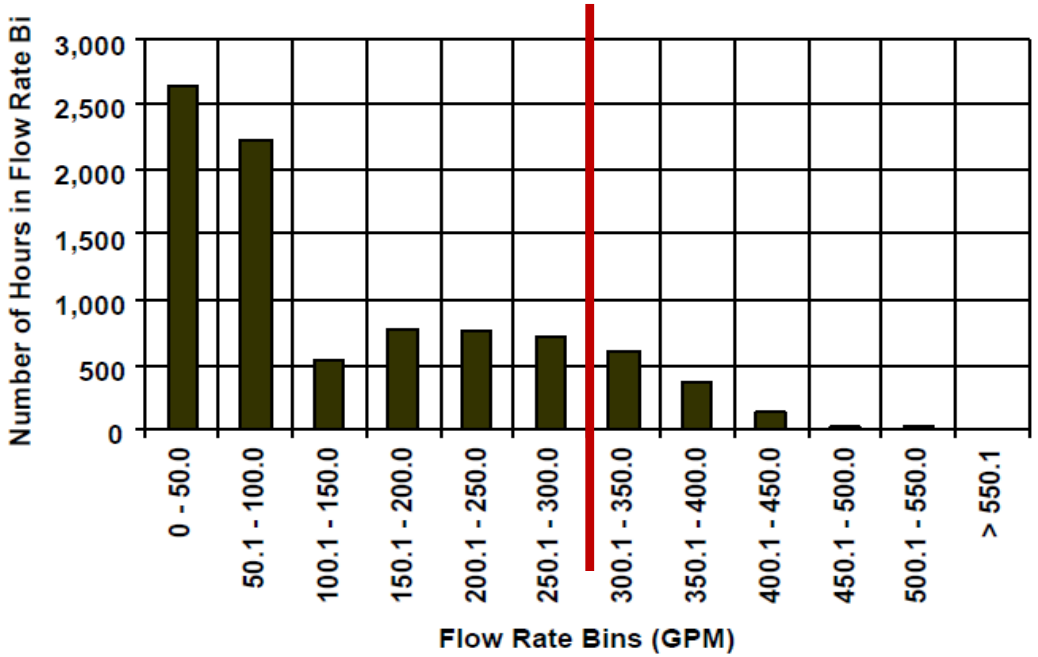
Typical Annual Water Flow Rates: Hours/Year for Bins of measured GPM



200 Ton Building Load with VFD Pumping

CODES: HEAT RECOVERY CHILLERS:

80 % of the run hours in the year
(Less than 60 % of Peak GPM)

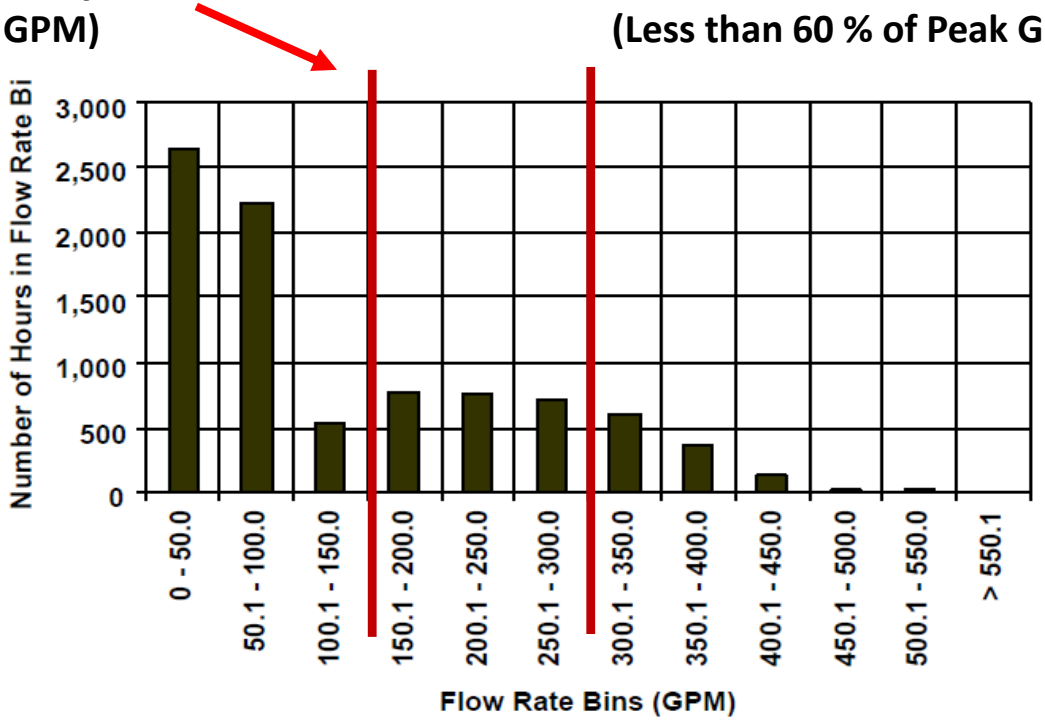


200 Ton Building Load with VFD Pumping

CODES: HEAT RECOVERY CHILLERS:

50 % of the run hours in the year
(Less than 30 % of Peak GPM)

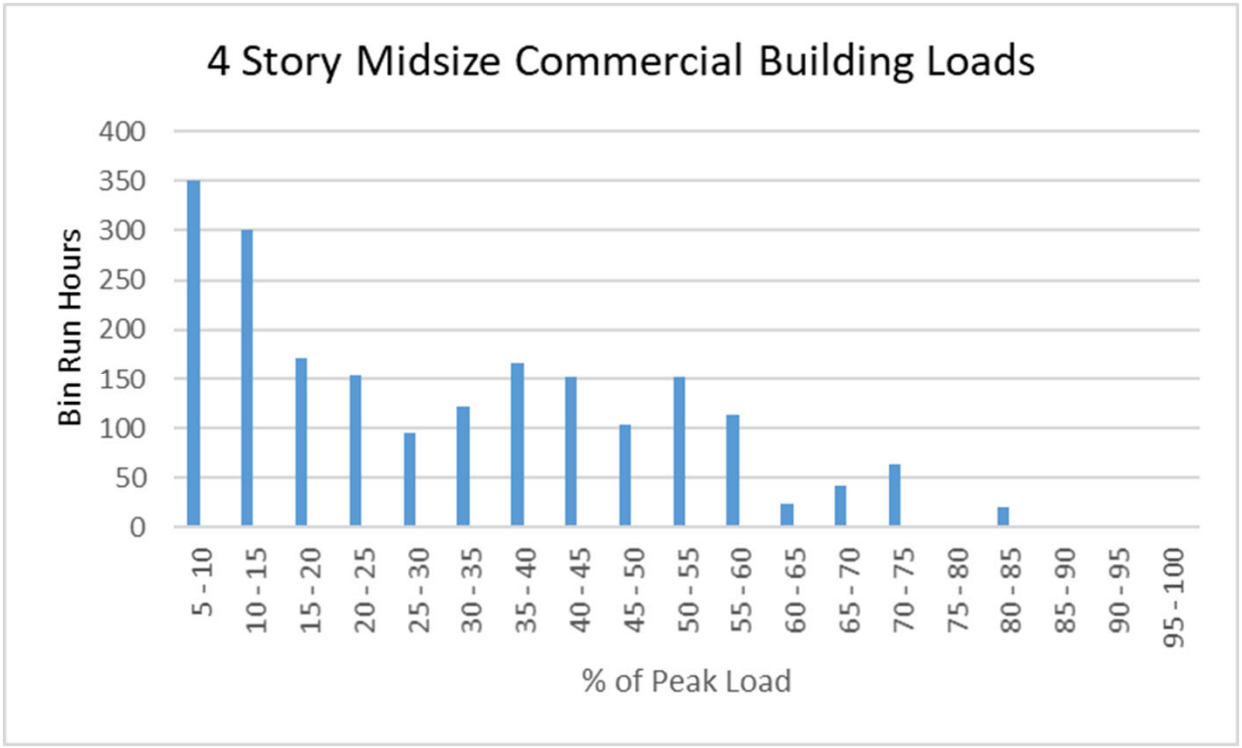
80 % of the run hours in the year
(Less than 60 % of Peak GPM)



200 Ton Building Load with VFD Pumping

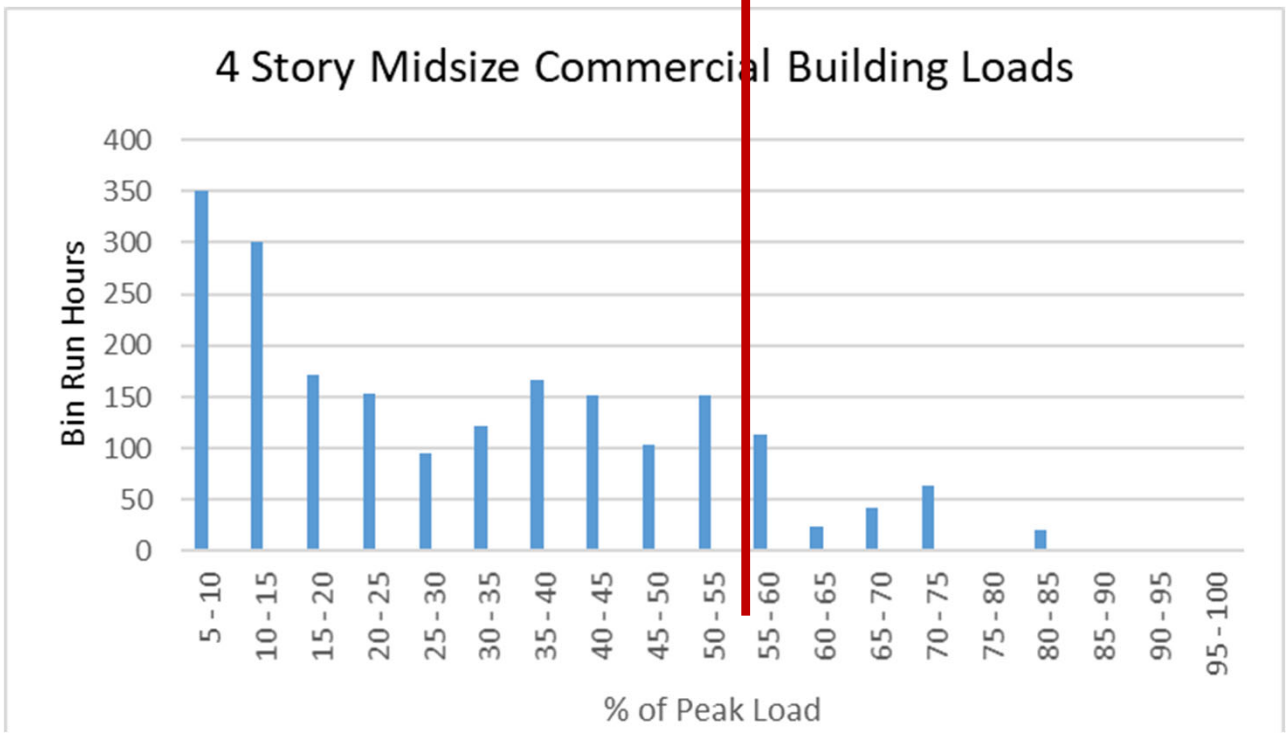
CODES: HEAT RECOVERY CHILLERS:

Typical Annual Chiller Loads: Hours/Year for Bins of measured Chiller Capacity



CODES: HEAT RECOVERY CHILLERS:

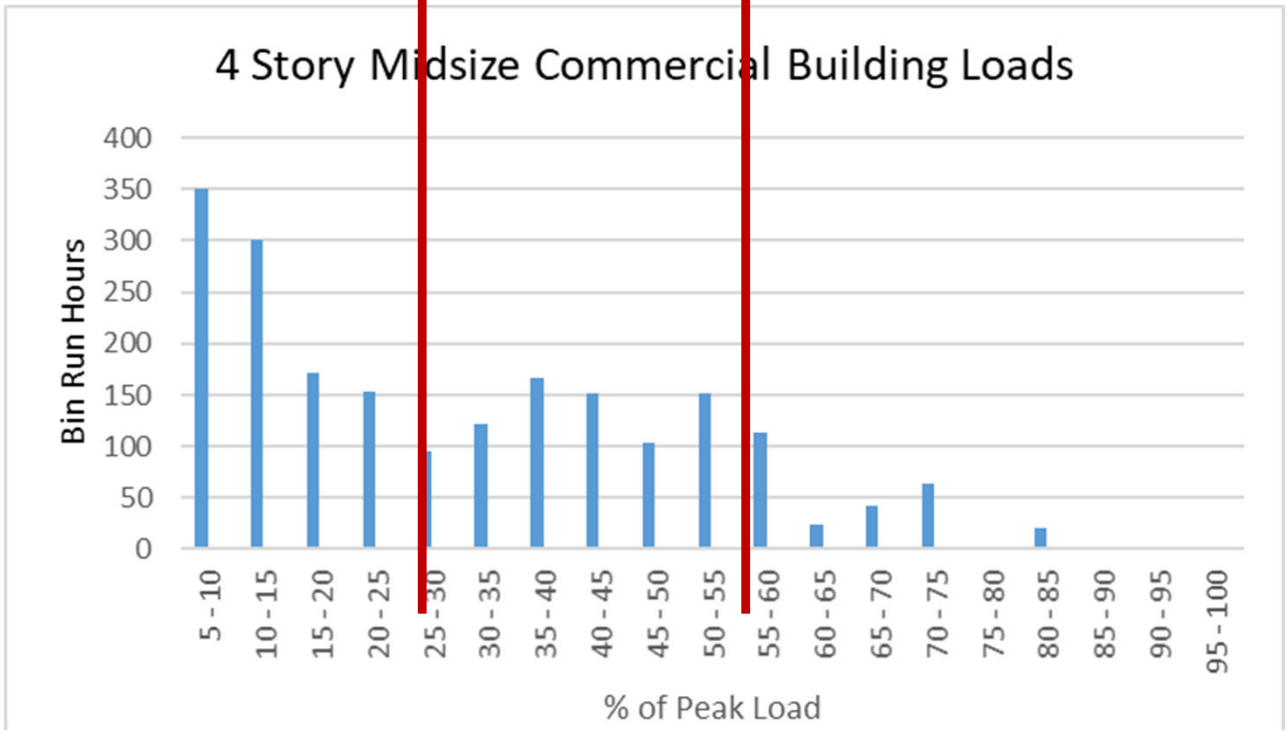
80 % of the run hours in the year
Less than 60 % of Peak Chiller Capacity



CODES: HEAT RECOVERY CHILLERS:

50 % of the run hours in the year
Less than 30 % of Peak

80 % of the run hours in the year
Less than 60 % of Peak Chiller Capacity



CODES: HEAT RECOVERY CHILLERS:

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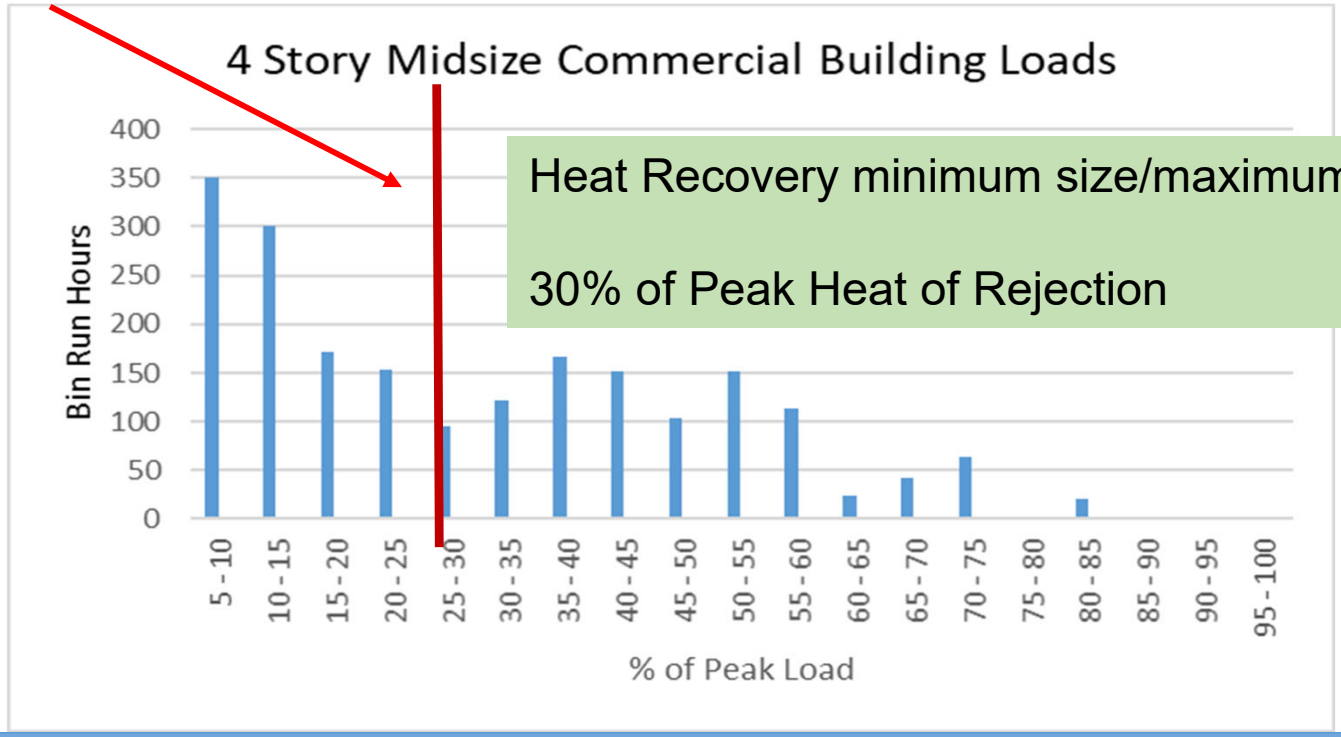
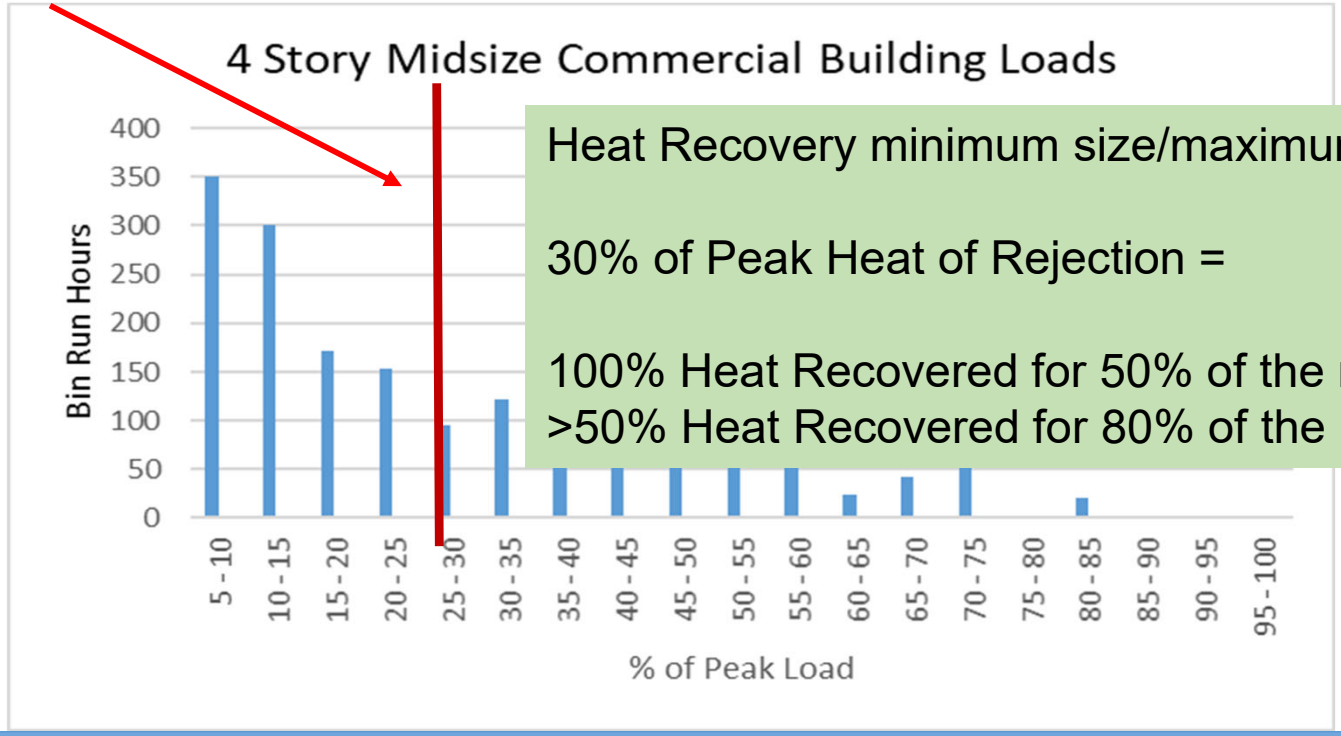


Heat Recovery minimum size/maximum recovery

30% of Peak Heat of Rejection

CODES: HEAT RECOVERY CHILLERS:

50 % of the run hours in the year
(Less than 30 % of Peak)



Heat Recovery minimum size/maximum recovery

30% of Peak Heat of Rejection =

100% Heat Recovered for 50% of the run hours per year
>50% Heat Recovered for 80% of the run hours per year

HEAT RECOVERY CHILLERS

Heat Recovery Application Options:

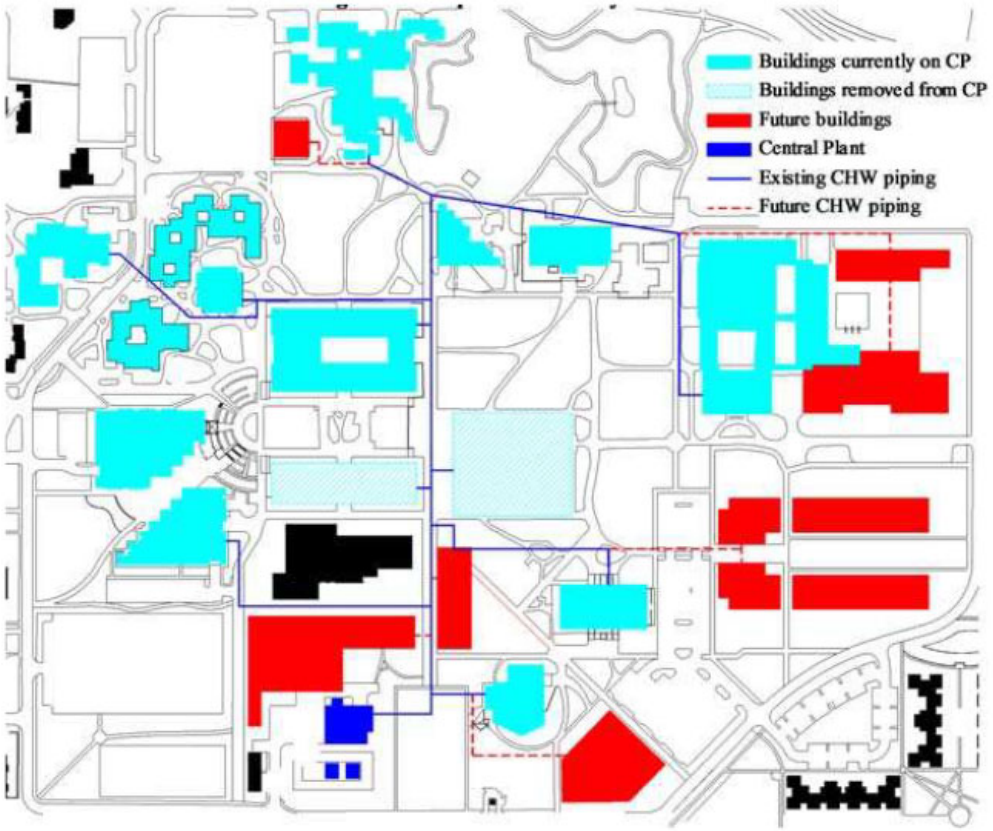
- Dedicated Heat Recovery Chiller
- Primary Chiller with Double Bundle Condenser for Simultaneous CHW & HW
- Primary Air Cooled Chiller with Heat Recovery for Simultaneous CHW & HW

HEAT RECOVERY CHILLERS

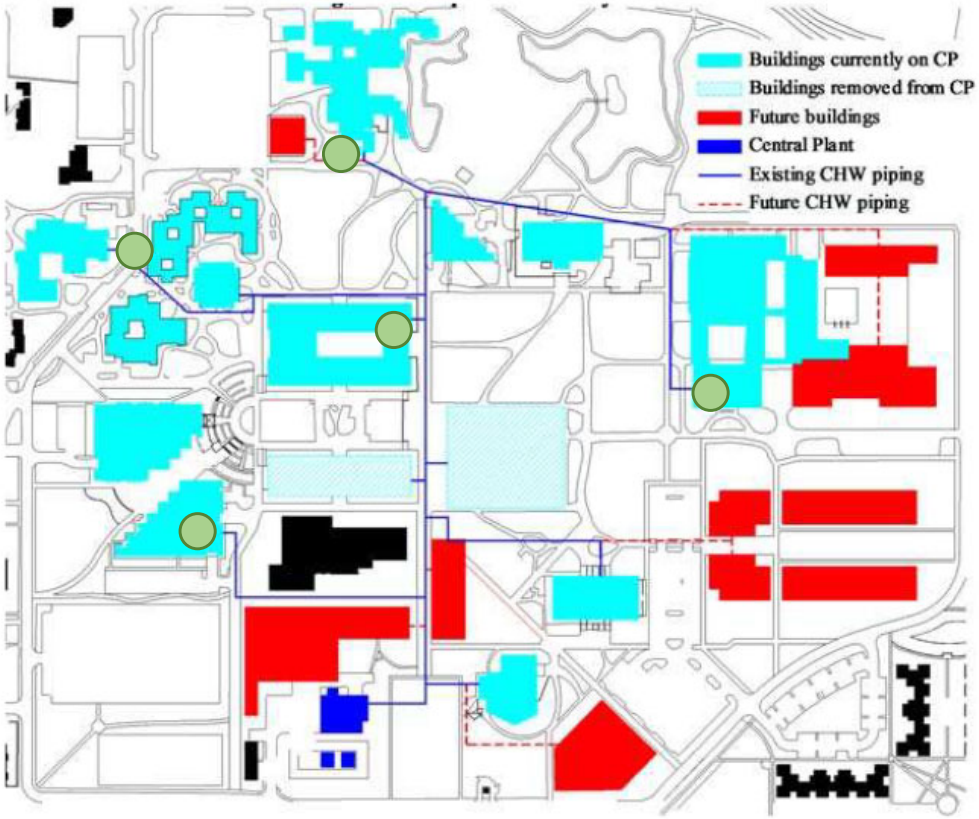
Dedicated Heat Recovery Chiller

- Add-on to existing system
- Installation at convenient point of use for Campus and District Chilled Water

HEAT RECOVERY CHILLERS



HEAT RECOVERY CHILLERS



Dedicated Heat Recovery Chiller

- Add-on to existing system
- Installation at convenient point of use for Campus and District Chilled Water

HEAT RECOVERY CHILLERS

HEAT RECOVERY CHILLERS

Hot Water Capacity

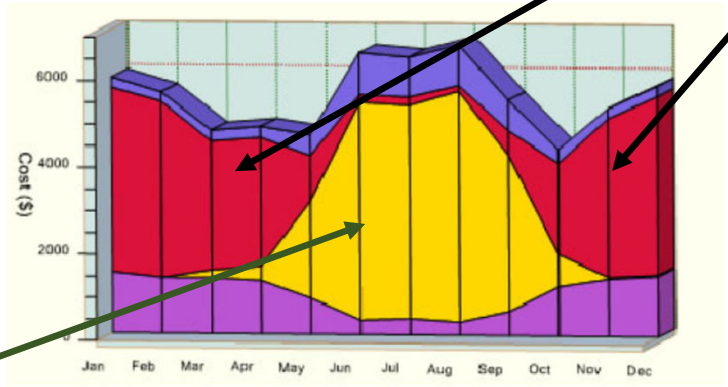
	10S	12S	15S	19S	20S	20T	22T	23S
Heating Capacity (TR)	81.6	100.2	121.3	141.4	177.0	167.0	182.3	213.6
Model	**24T**	**27S**	**27T**	**30S**	**30T**	**36S**	**38T**	**40T**
Heating Capacity (TR)	201.8	251.2	222.9	290.0	250.2	323.3	282.1	349.8
Model	**41S**	**46S**	**46T**	**50T**	**54T**	**57T**	**60T**	**73T**
Heating Capacity (TR)	372.2	430.6	437.4	470.2	509.9	541.4	578.1	651.8
Model	**75T**	**81T**	**87T**	**90T**	**108**	**113**	**118**	**123**
Heating Capacity (TR)	695.0	741.4	799.9	856.7	917.6	956.9	996.1	1037.0

Hot Water: 120/140 F @ CHW: 54/44 F @ as high as 3.75 COP

HEAT RECOVERY CHILLERS

Dedicated Heat Recovery Chiller Operating Economics

Gas Boiler – 100%
(red-heating)



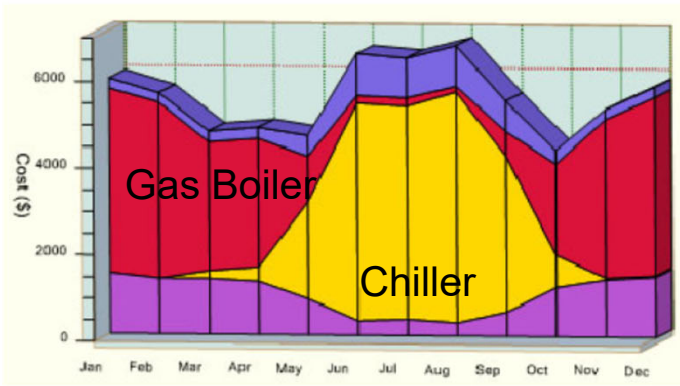
Chiller – 100%
(yellow-cooling)

4 Story Building, 60,000 Sq. Ft, Denver, CO

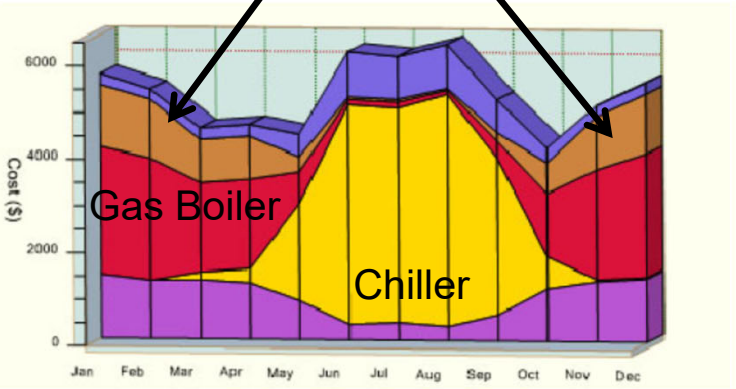
HEAT RECOVERY CHILLERS

Dedicated Heat Recovery Chiller Operating Economics

100% Chiller & 100% Gas Boiler



Chiller with 70% Gas Boiler and **30%** Heat Recovery Chiller

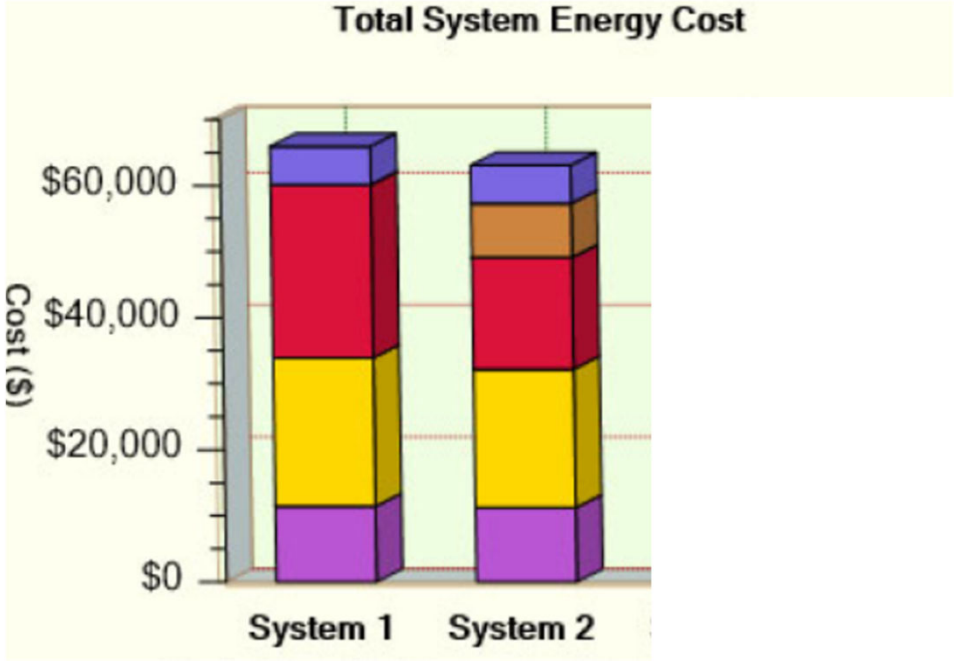


4 Story Building, 60,000 Sq. Ft, Denver, CO

HEAT RECOVERY CHILLERS

System1
100% Chiller & 100% Gas Boiler

System 2
100% Chiller
70% Gas Boiler
30% Heat Recovery Chiller



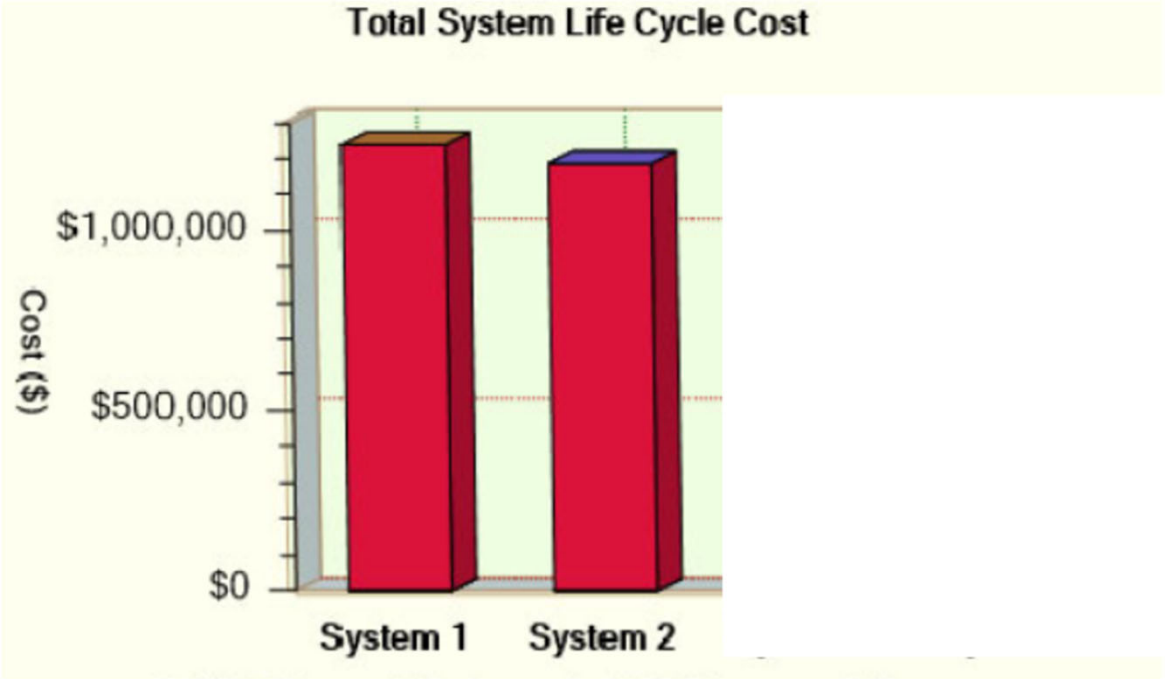
Brown - Heat Recovery
Red - Gas Heat
Yellow - Chiller

4 Story Building, 60,000 Sq. Ft, Denver, CO

HEAT RECOVERY CHILLERS

System1
Chiller/100% Gas Boiler

System 2
Chiller/70% Gas Boiler
30% Recovery Chiller



4 Story Building, 60,000 Sq. Ft, Denver, CO

Simultaneous Chilled Water & Hot Water Chillers

De-Carbonization:

Economical Path towards 100% Fossil-Free Heat

Lower First Cost than adding a 30% Heat Recovery Chiller

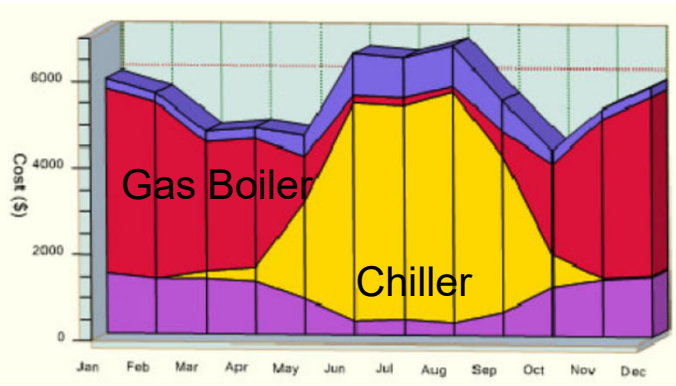
Simultaneous Chilled Water & Hot Water Chillers

Water Cooled Chillers & the Double Bundle Condenser

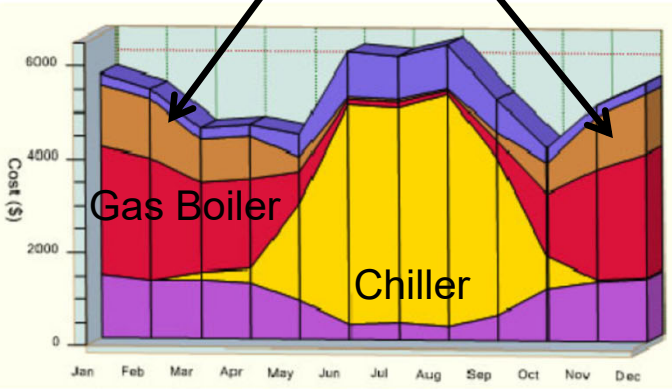
Simultaneous Chilled Water & Hot Water Chillers

Dedicated Heat Recovery Chiller Operating Economics

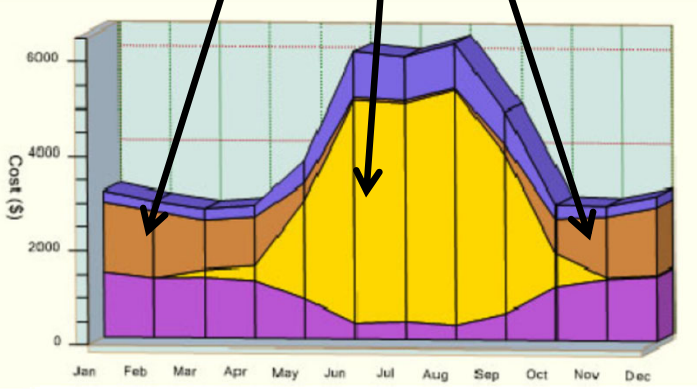
100% Chiller & 100% Gas Boiler



Chiller with 70% Gas Boiler and **30%** Heat Recovery Chiller



100% Heat Recovery with Double Bundle Chiller



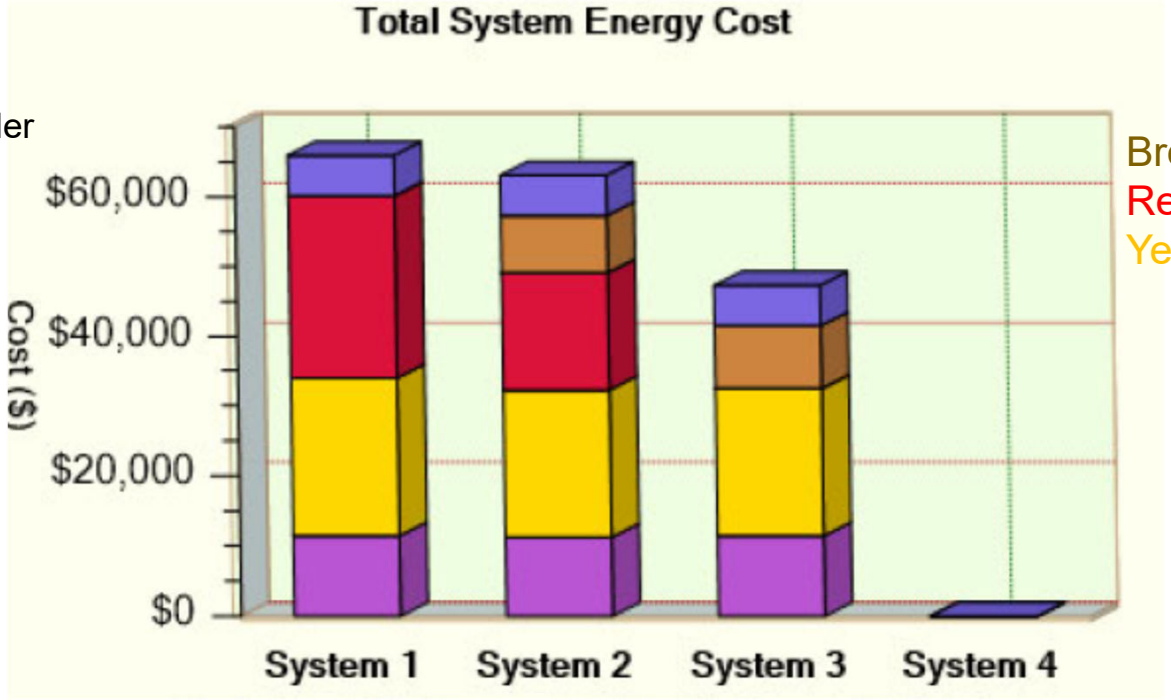
4 Story Building, 60,000 Sq. Ft, Denver, CO

Simultaneous Chilled Water & Hot Water Chillers

System1
100% Chiller & 100% Gas Boiler

System 2
100% Chiller
70% Gas Boiler
30% Heat Recovery Chiller

System 3
100% Recovery Double Bundel Chiller



Brown - Heat Recovery
Red - Gas Heat
Yellow - Chiller

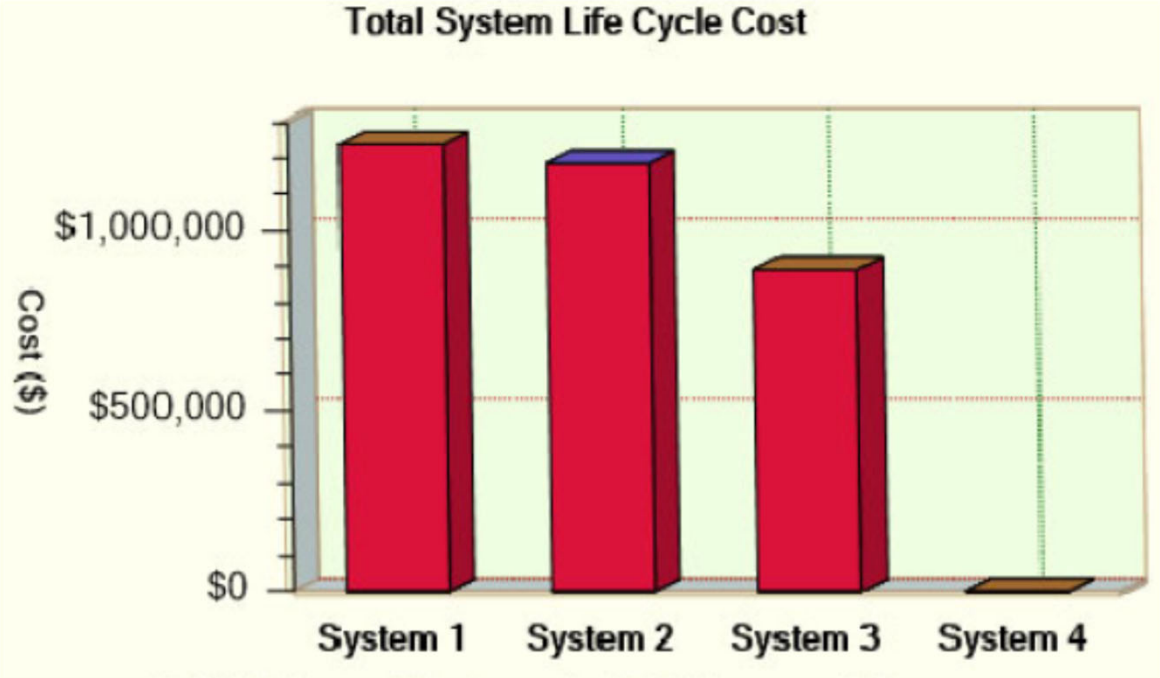
4 Story Building, 60,000 Sq. Ft, Denver, CO

Simultaneous Chilled Water & Hot Water Chillers

System1
Chiller/100% Gas Boiler

System 2
Chiller/70% Gas Boiler
30% Recovery Chiller

System 3
100% Recovery Double Bundle Chiller



4 Story Building, 60,000 Sq. Ft, Denver, CO

Water Cooled Chillers & the Double Bundle Condenser

Simultaneous Chilled Water & Hot Water Chillers

Primary Chiller with Double Bundle Condenser

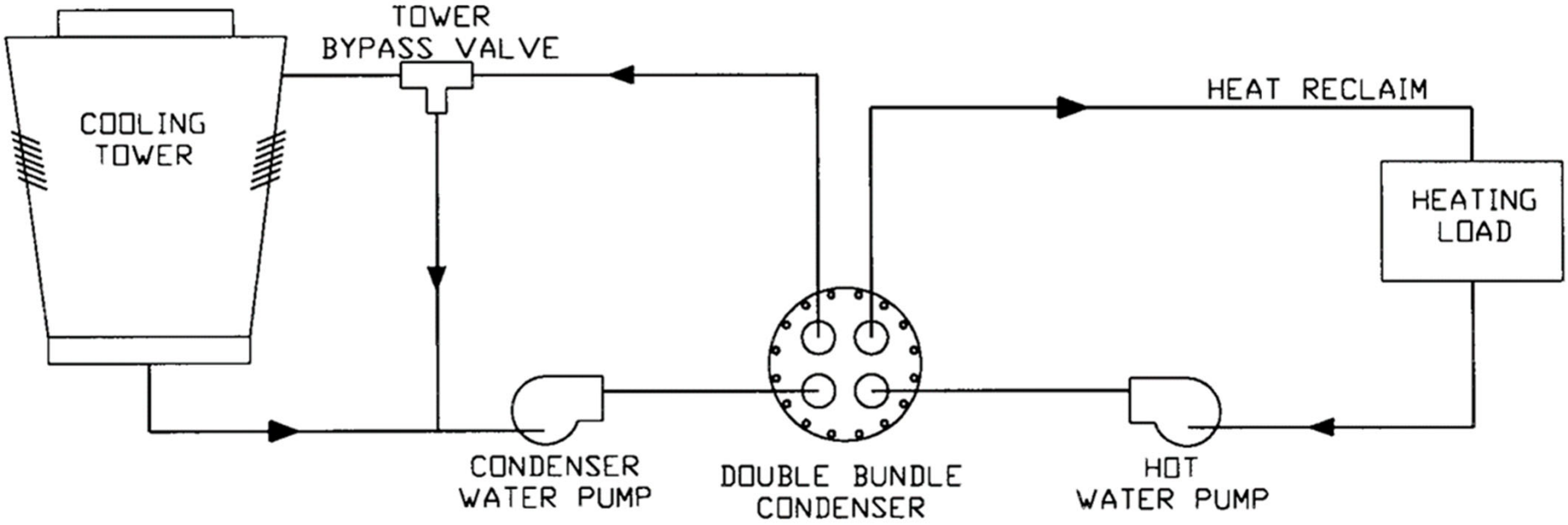
Simultaneous Chilled Water & Hot Water Chillers

Water Cooled Screw Liquid Chillers

Cooling Capacity: 60 to 1000 TR (211 to 3517 kW)

Simultaneous Chilled Water & Hot Water Chillers

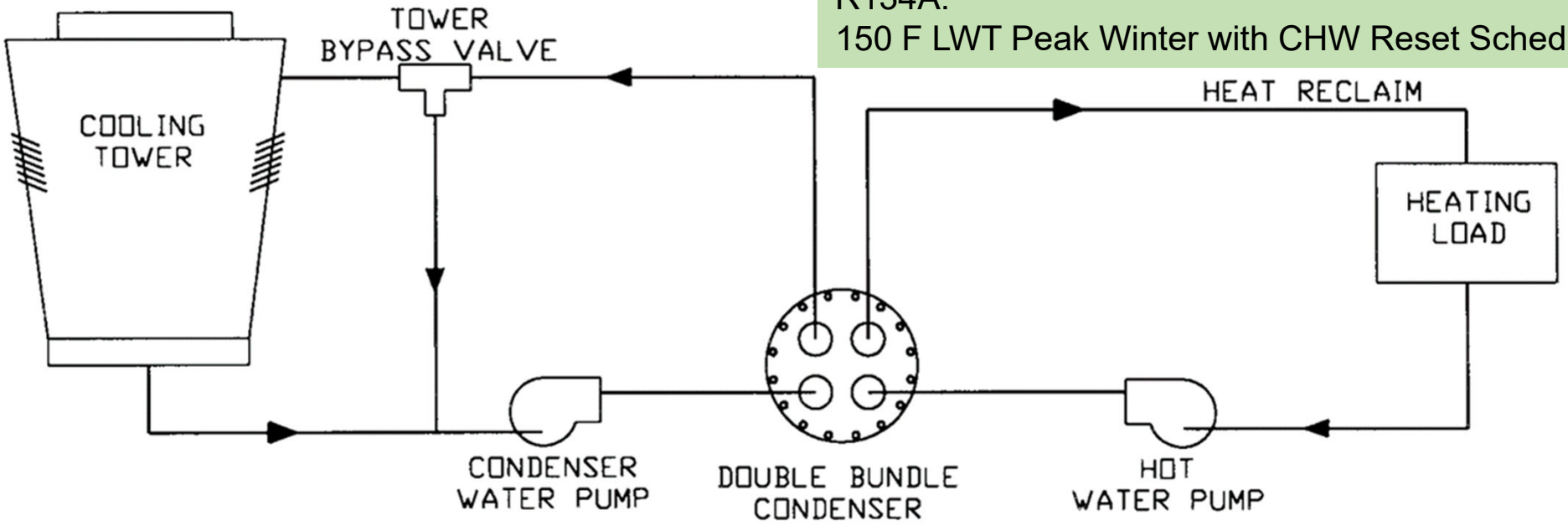
Primary Chiller with Double Bundle Condenser



Simultaneous Chilled Water & Hot Water CHILLERS

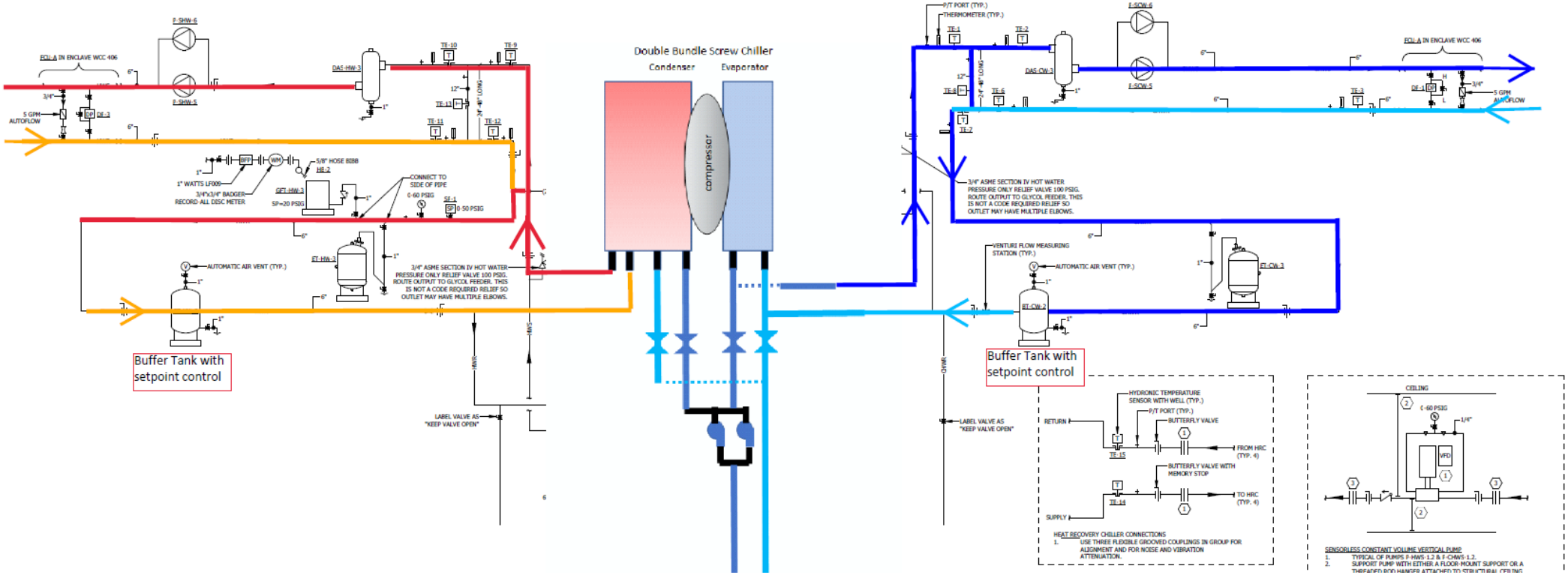
Primary Chiller with Double Bundle Condenser

R134A:
150 F LWT Peak Winter with CHW Reset Schedule



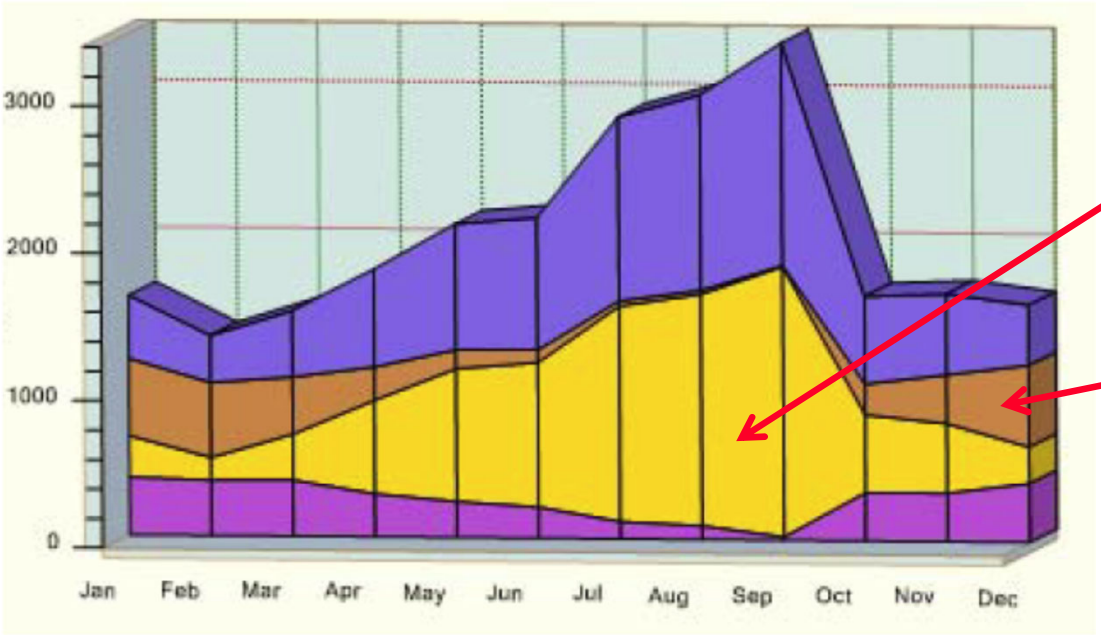
Simultaneous Chilled Water & Hot Water Chillers

Simultaneous Cooling and Heating



Simultaneous Chilled Water & Hot Water Chillers

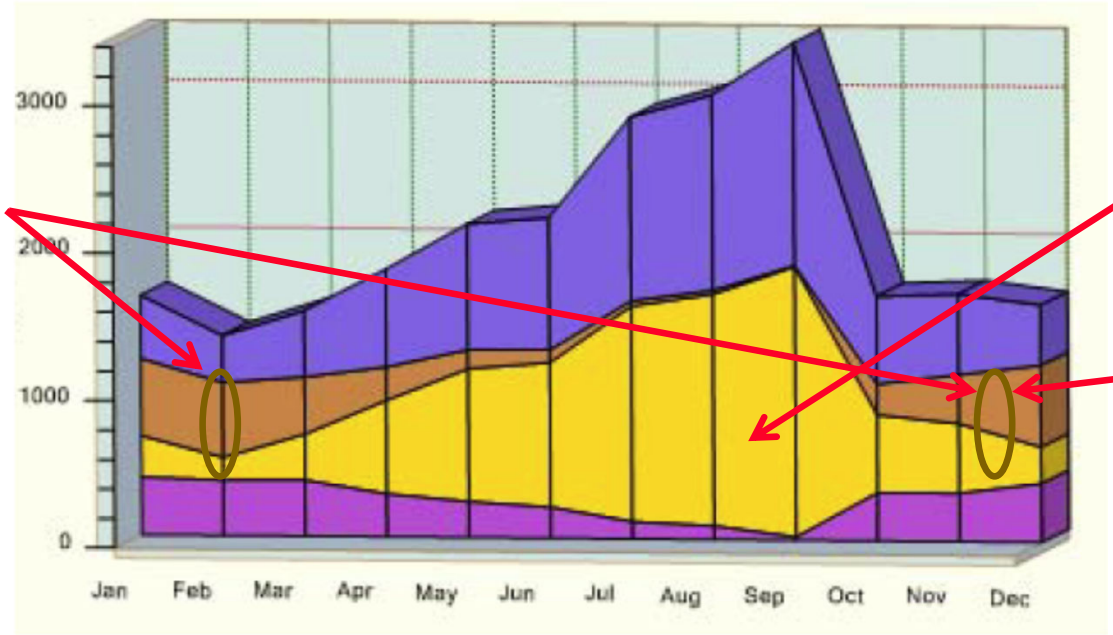
Simultaneous Chilled Water & Hot Water Central Plant



Simultaneous Chilled Water & Hot Water Chillers

Simultaneous Chilled Water & Hot Water Central Plant

Peak Simultaneous Loads



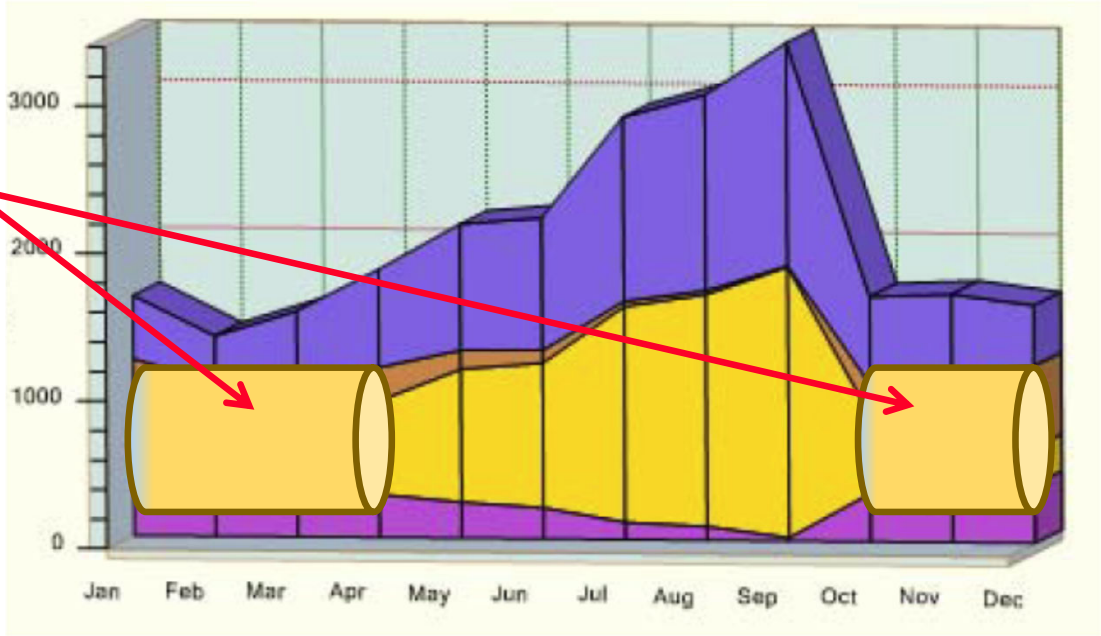
Chilled Water Central Plant Loads

Hot Water Central Plant Loads

Simultaneous Chilled Water & Hot Water Chillers

Simultaneous Chilled Water & Hot Water Central Plant

Simultaneous Loads
Runtime
@ 27 EER or 8 COP

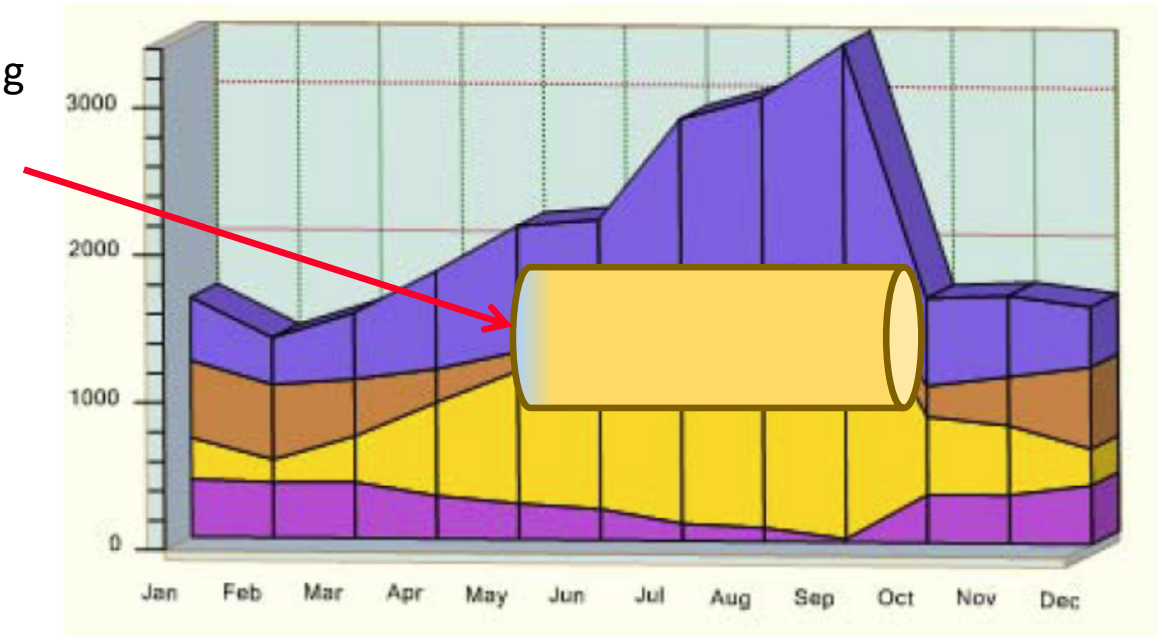


Month

Simultaneous Chilled Water & Hot Water Chillers

Simultaneous Chilled Water & Hot Water Central Plant

Storage Tank Sizing for minimum runtime requirements



Month

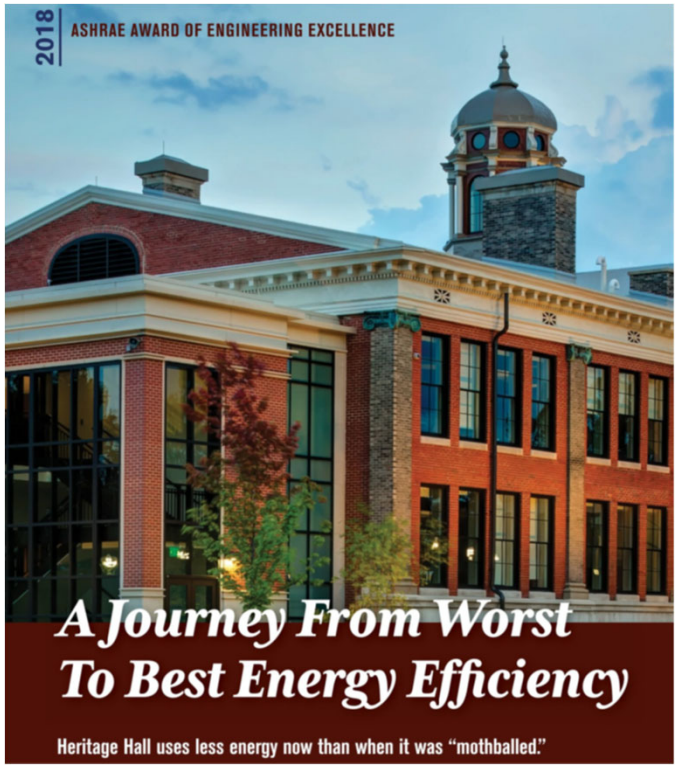
HEAT RECOVERY CHILLERS:

Opportunities, **De-Carbonization**, and Other Considerations

March 2018 ASHRAE Journal Vol 60, No 3

Case Study

- Whole Building Variable Capacity System replaces
- Chilled Water and Steam Heat from Campus Central Plant



HEAT RECOVERY CHILLERS:

Opportunities, **De-Carbonization**, and Other Considerations

March 2018 ASHRAE Journal Vol 60, No 3

Building's Central Plant:

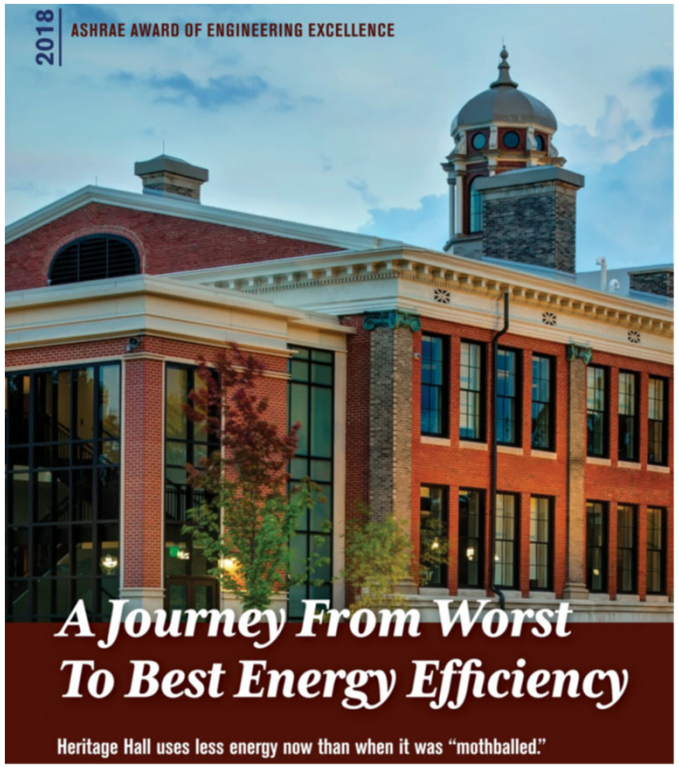
- Simultaneous Chilled Water/Hot Water Piping
- Heat Source: Ground-Coupled Condenser Loop
- Variable/Primary Pumping

- 130 F Hot Water/44 F Chilled Water Setpoints

- 2 F increment OAT Reset Schedule:

  Chilled Water 44 F – 60 F

  Hot Water 130 F – 90 F



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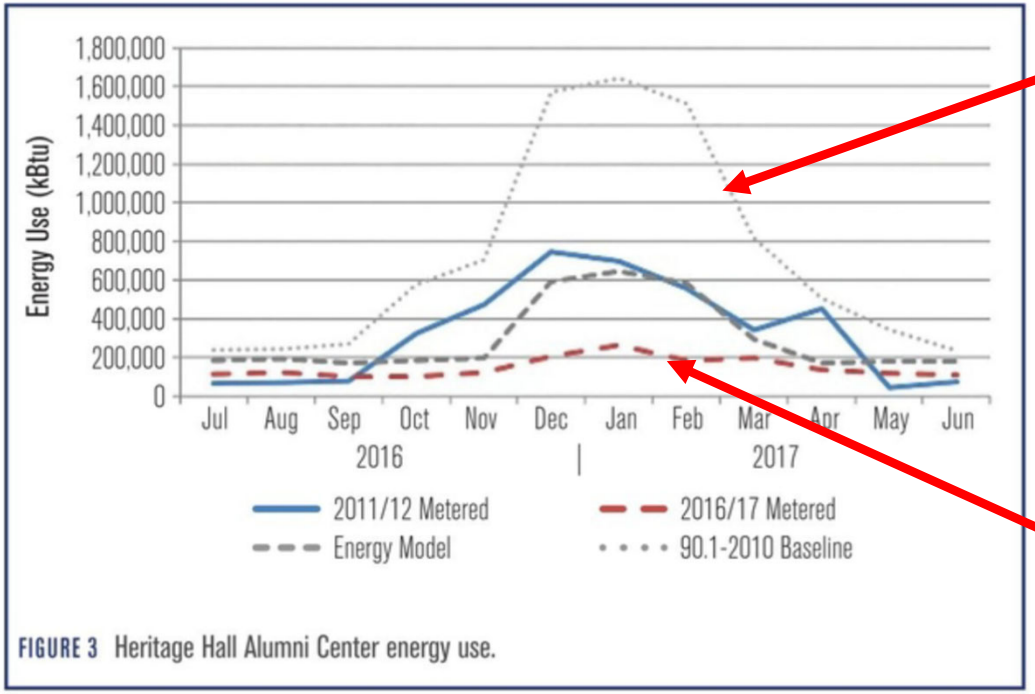

FIGURE 3 Heritage Hall Alumni Center energy use.

The renovated Building saves nearly 80% over a Standard 90.1-2010 baseline

2016/17 Academic Year

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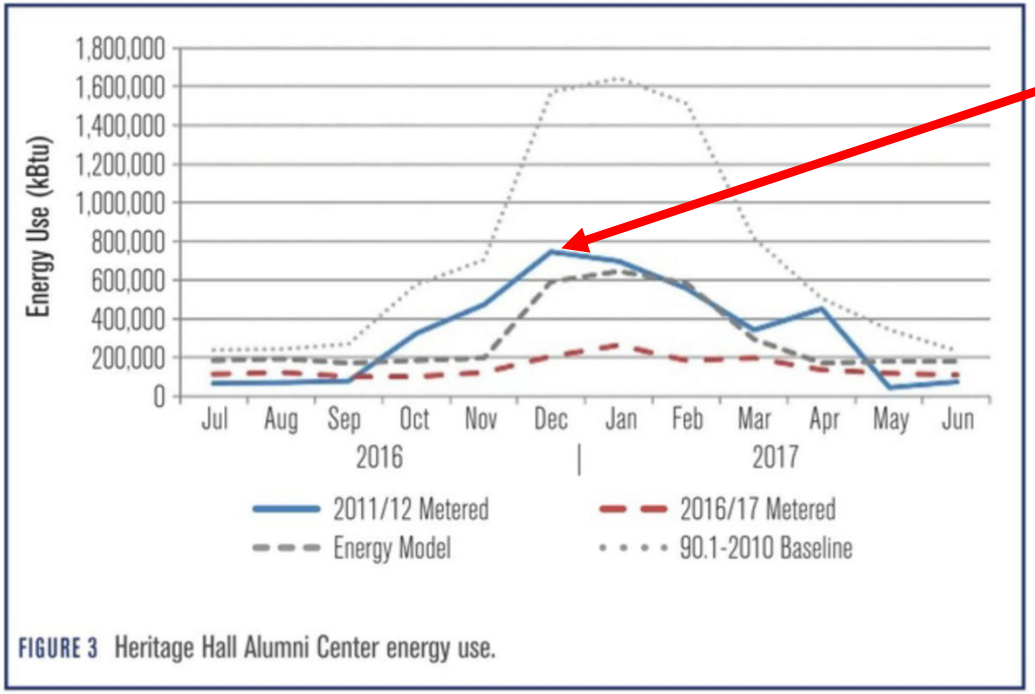

FIGURE 3 Heritage Hall Alumni Center energy use.

The renovated Building **saves** over "**moth balled**" 2011/12 academic year!

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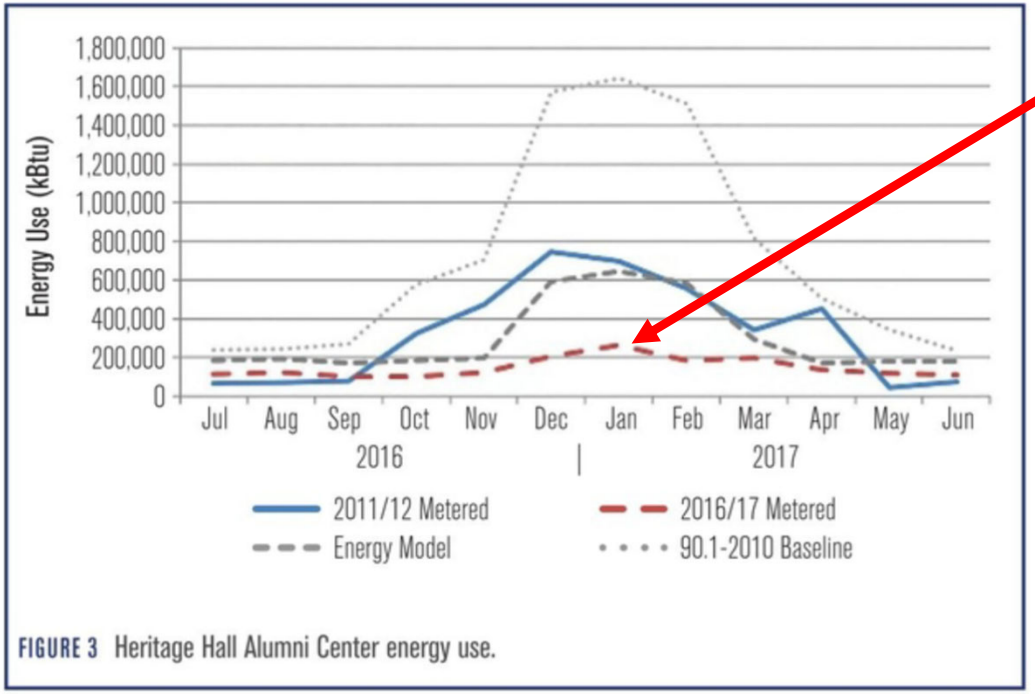

FIGURE 3 Heritage Hall Alumni Center energy use.

The Ground-Coupled Condenser Loop allows chiller to provide 100% heating at Peak Heat Load

HEAT RECOVERY CHILLERS:

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Cold Climate Load Profile

Simultaneous Loads Runtime @ 27 EER or 8 COP

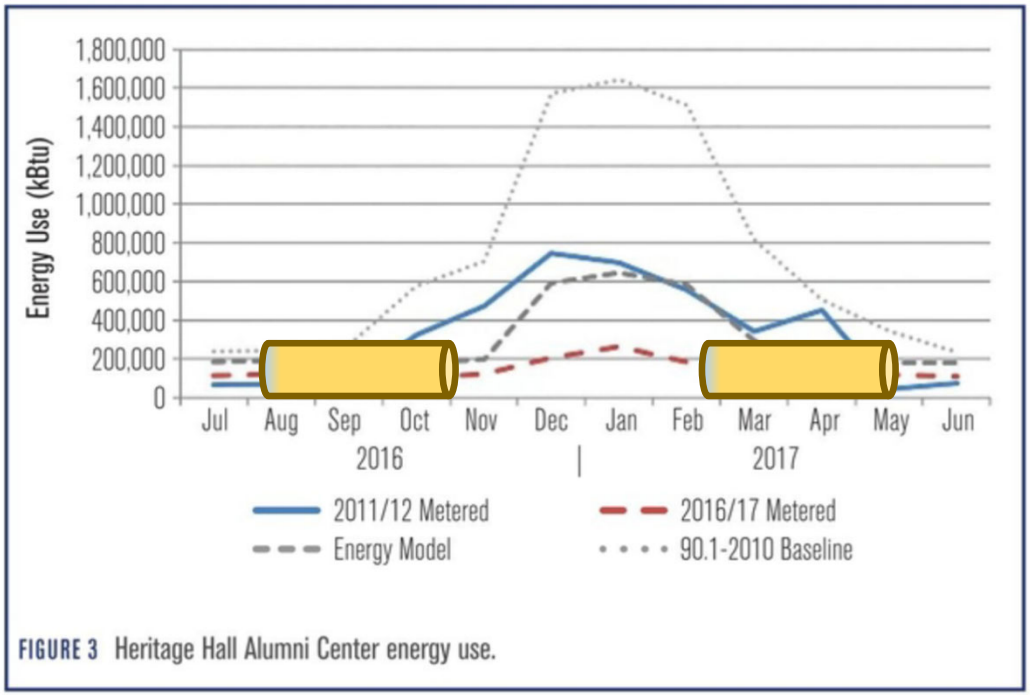


FIGURE 3 Heritage Hall Alumni Center energy use.

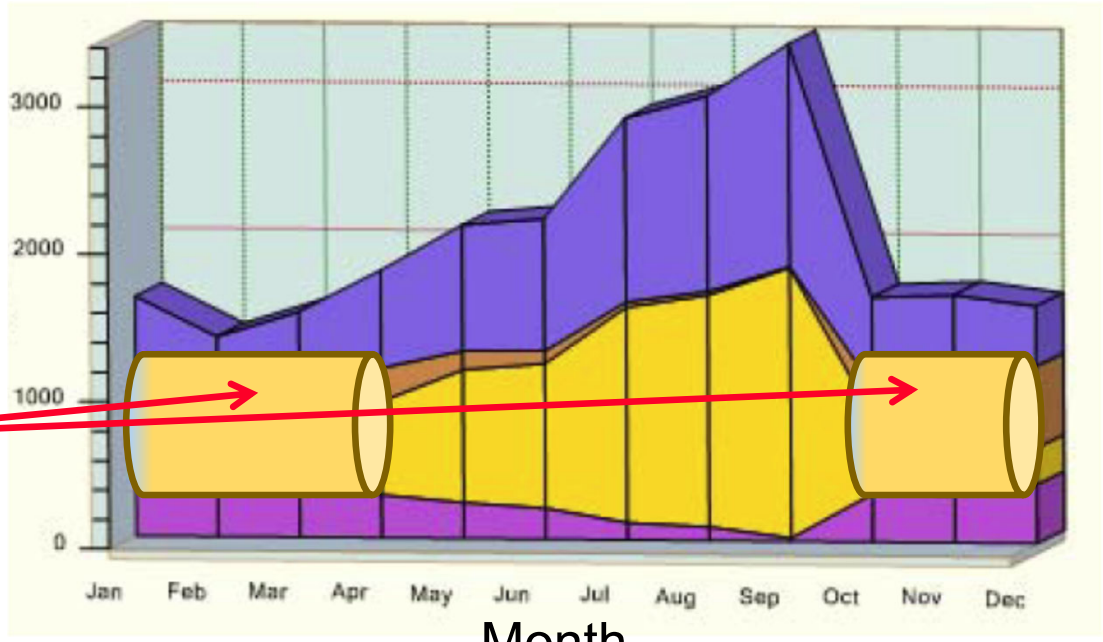
HEAT RECOVERY CHILLERS:

Opportunities, **De-Carbonization**, and Other Considerations

Simultaneous Chilled Water & Hot Water Central Plant

Warm Climate Load Profile

Simultaneous Loads Runtime
@ 27 EER or 8 COP

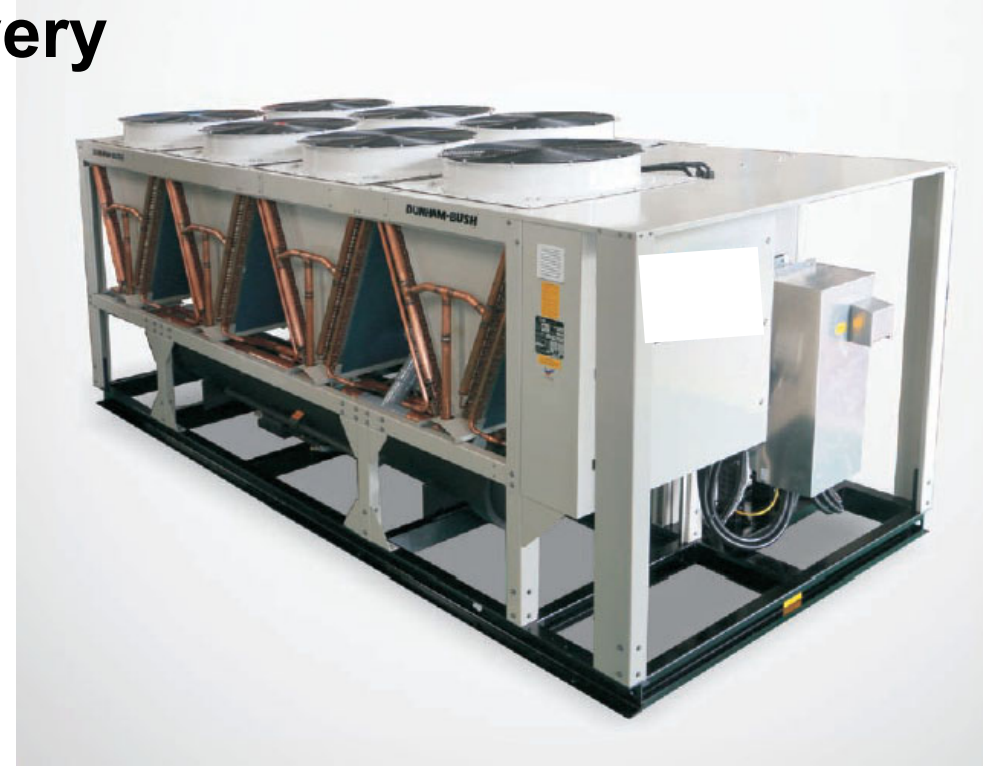


Simultaneous Chilled Water & Hot Water Chillers

Air Cooled Chiller Heat Recovery

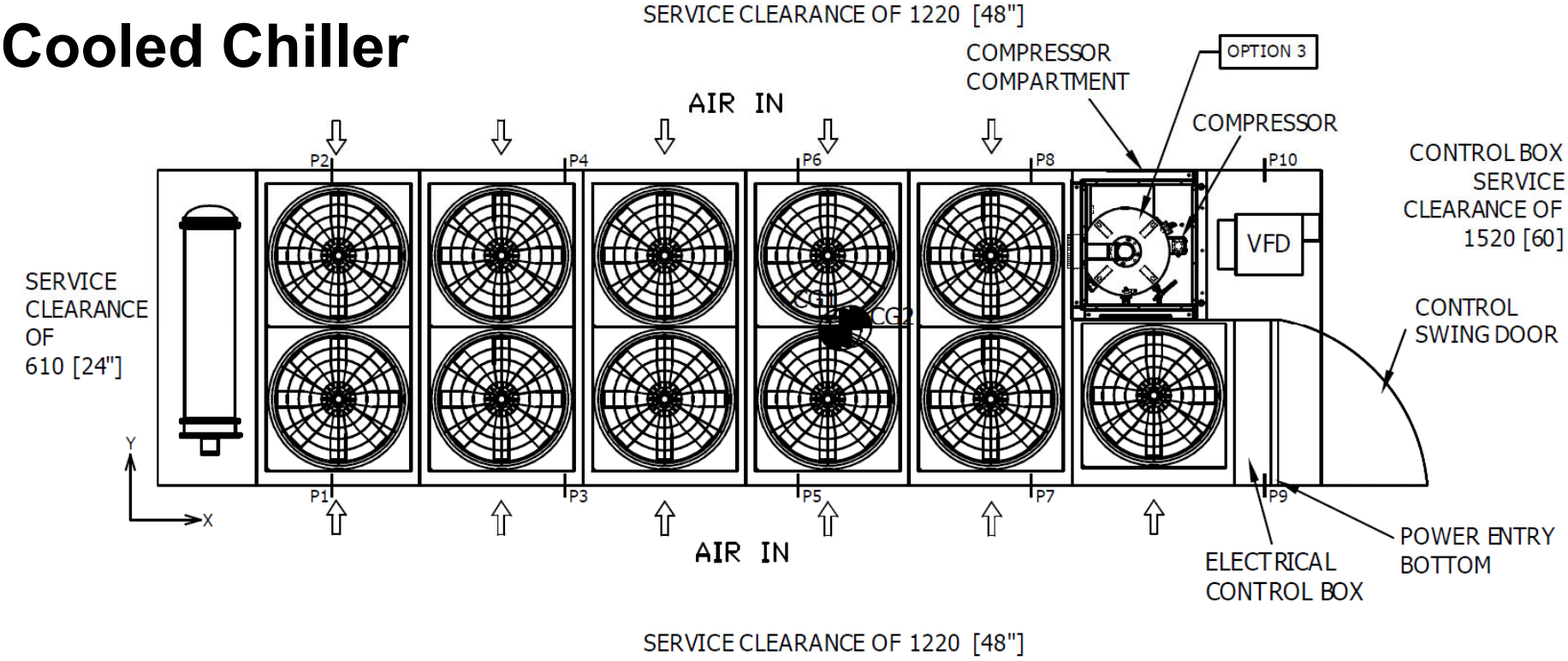
Variable Speed Air Cooled Screw Chillers

Cooling Capacity: 115 to 470 TR (406 to 1656 kW)



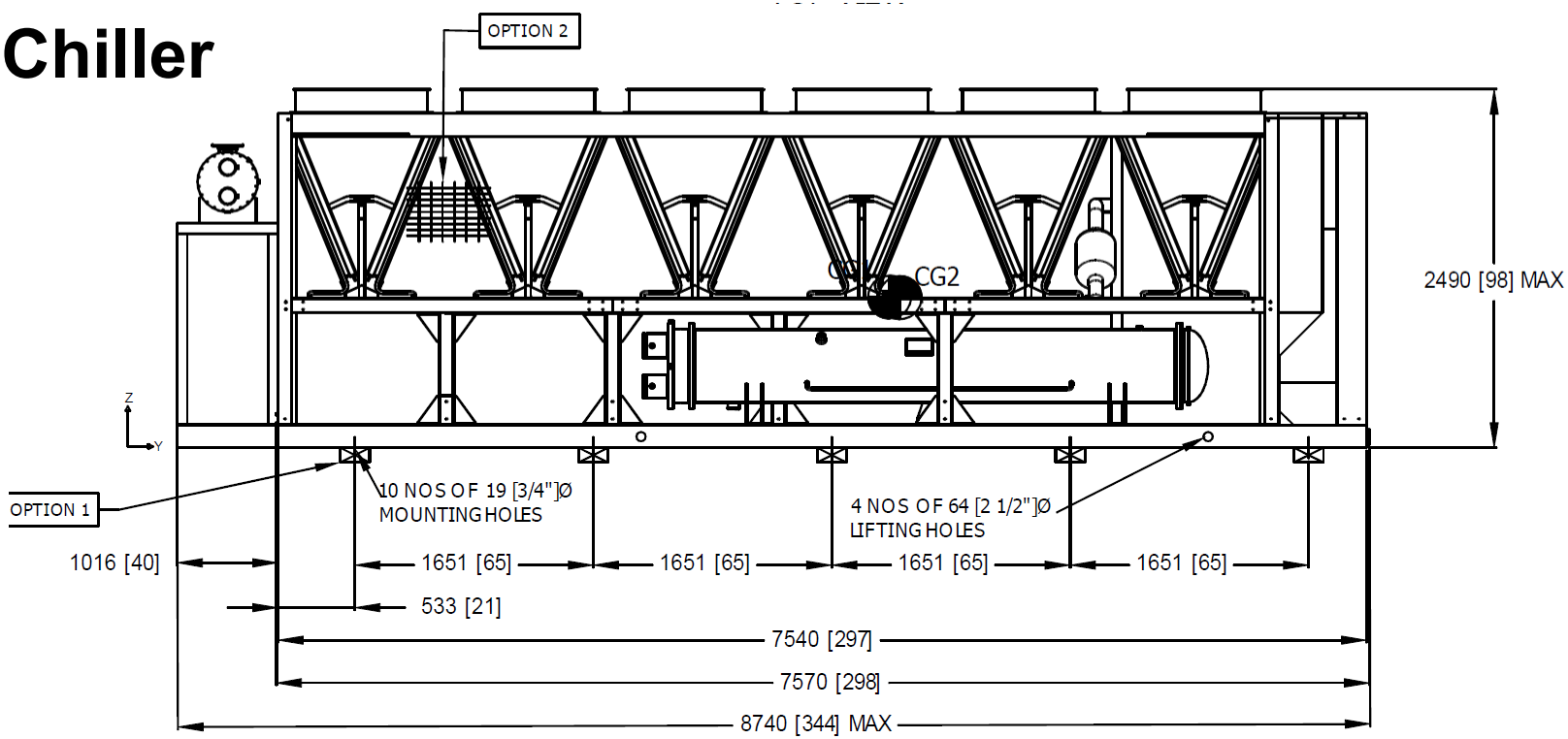
Simultaneous Chilled Water & Hot Water Chillers

Air Cooled Chiller



Simultaneous Chilled Water & Hot Water Chillers

Air Cooled Chiller



Simultaneous Chilled Water & Hot Water Chillers

Conditions of service (Heat Recovery Condenser Mode)			
Percent of full load	100%	Compressor power (kW)	212.28
Capacity (Tons)	161.81	Total Fan Power (kW)	4.07
Unit power (kW)	216.35	Unit Efficiency (COP, kW/TR)	1.337

Evaporator			
Model (Qty)	SHELL AND TUBE (1)	Entering fluid temp. (°F)	45.00
Number of passes	2	Leaving fluid temp. (°F)	35.00
Fluid	25% PG	Fouling factor (hr.ft.°F/Btu)	0.0001
Fluid flow rate (USgpm)	405.76	Pressure drop (psi)	9.36

Condensing coil				
Design Ambient (°F)	95.00	Altitude (ft)		0.00
		Fan Motor Power (kW) (Qty)	0.37 Kwi	(11)

Additional accessories			
Heat Recovery Condenser			
Model #	Shell & Tube (1)	Fouling factor (hr.ft.°F/Btu)	0.00025
Heating capacity (TR)	128.00	Flow rate (usgpm)	323.20
Hot water in/out (°F)	115 / 125	Pressure drop (psi)	1.70

HEAT RECOVERY CHILLERS:

Opportunities, De-Carbonization, and **Other Considerations**

Other Considerations:

- Non-HVAC "**FREE**" heat recovery sources often overlooked

HEAT RECOVERY CHILLERS:

Opportunities, De-Carbonization, and **Other Considerations**

ASHRAE 90.1-2019, section 6.5.6.2.1

IECC 2018, section C403.9.5 Heat Recovery for Service Water Heating

Exception 2:

- Facilities that provide 60 percent of their service water heating from site solar or site recovered energy or from other sources.

HEAT RECOVERY CHILLERS:

Opportunities, De-Carbonization, and **Other Considerations**

Non-HVAC “free” heat recovery sources often overlooked

Integrate non-HVAC systems and equipment:

Cafeteria Equipment/Mini-Marts/Coffee Concessions

- Walk-in Refrigeration Rooms
- Walk-in Freezer Rooms
- Ice making machines
- Freezer cases
- Refrigeration cases

HEAT RECOVERY CHILLERS:

Opportunities, De-Carbonization, and **Other Considerations**

Non-HVAC “free” heat recovery sources often overlooked

Integrate non-HVAC systems and equipment:

Cafeteria Equipment/Mini-Marts/Coffee Concessions

Walk-in Refrigeration Rooms	AHRI 1251
Walk-in Freezer Rooms	AHRI 1251
Ice making machines	AHRI 810
Freezer cases	AHRI 820/821
Refrigeration cases	AHRI 1200

HEAT RECOVERY CHILLERS:

Opportunities, De-Carbonization, and **Other Considerations**

Non-HVAC “free” heat recovery sources often overlooked

Integrate non-HVAC systems and equipment:

Energy Reduction of Water Cooled vs Air Cooled

Walk-in Refrigeration Rooms	18%
Walk-in Freezer Rooms	24%
Ice making machines	22%
Freezer cases	24%
Refrigeration cases	18%

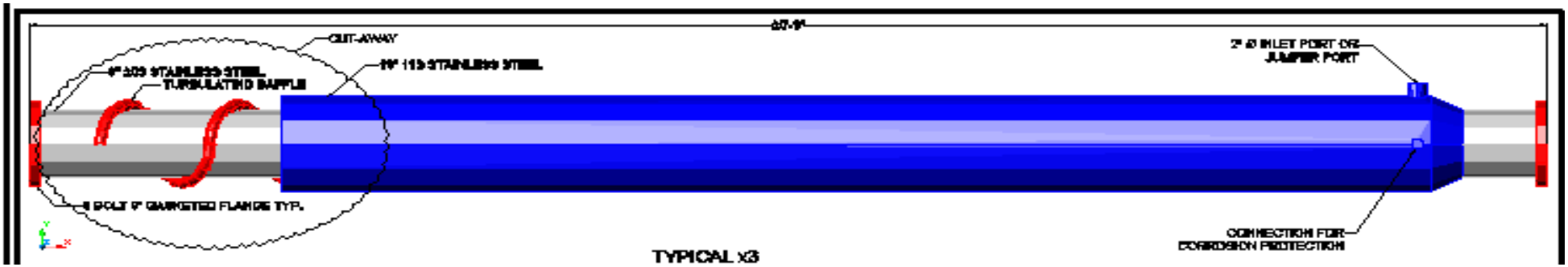
HEAT RECOVERY CHILLERS:

Opportunities, De-Carbonization, and **Other Considerations**

Non-HVAC "FREE" heat recovery sources often overlooked

Integrate non-HVAC systems and equipment:

- Black Water/Grey Water Heat Exchanger



HEAT RECOVERY CHILLERS:

Opportunities, De-Carbonization, and **Other Considerations**

Black Water/Grey Water Heat Exchanger

a)

b)

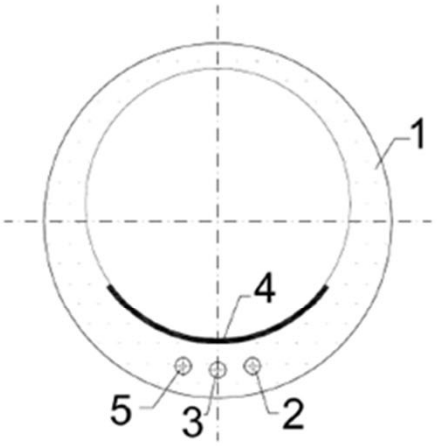


Fig. 3. Heat exchanger integrated in concrete sewage pipe: a) heat exchanger before instalation, b) cross-section of heat exchanger; 1 - concrete pipe, 2 - cold water supply to the heat exchanger, 3 - bypass, 4 - heat exchanger, 5 - output of the heated water from the heat exchanger [5]

HEAT RECOVERY CHILLERS:

Opportunities, De-Carbonization, and **Other Considerations**

Integrate as much system efficiency as your budget allows

Add Renewable Energy:

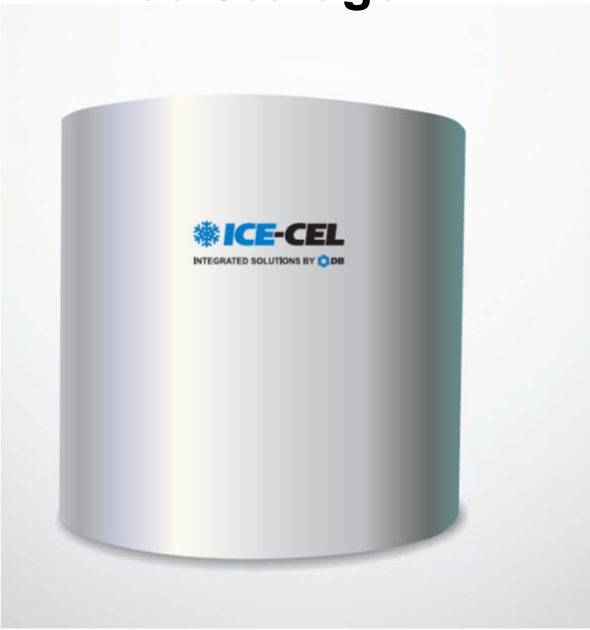
- Solar Hot Water Panels
- Solar PV Panels
- Co-Generation Bio-Mass
- Hybrid Ground Loop System

HEAT RECOVERY CHILLERS:

Opportunities, De-Carbonization, and **Other Considerations**

Add On-Site Storage of Energy

Ice Storage



Hot Water Storage

Hybrid & Ground Loop System

Vertical Closed Loop
Horizontal Closed Loop
Hybrid (Geo and Tower/Boiler)
Lake Closed Loop
Closed to the Aquifer (Open Loop)

Questions?

Presented by:

Alan Niles