

Houston Area Association of Hospital Engineers, January 8, 2015

Heat Pumps and Heat Recovery for Healthcare

Bill Chalmers P.E., CPD, CEM, CDT



Learning Objectives

Ensure healthcare facility people are aware of benefits and application issues associated with heat pumps and heat recovery used for heating, reheat and domestic hot water heating.

Ensure you are the smartest person in the room

Reheat and space heating review

Basic domestic hot water heating system and COP

Financial benefits

Refrigeration review

Heat pump basics

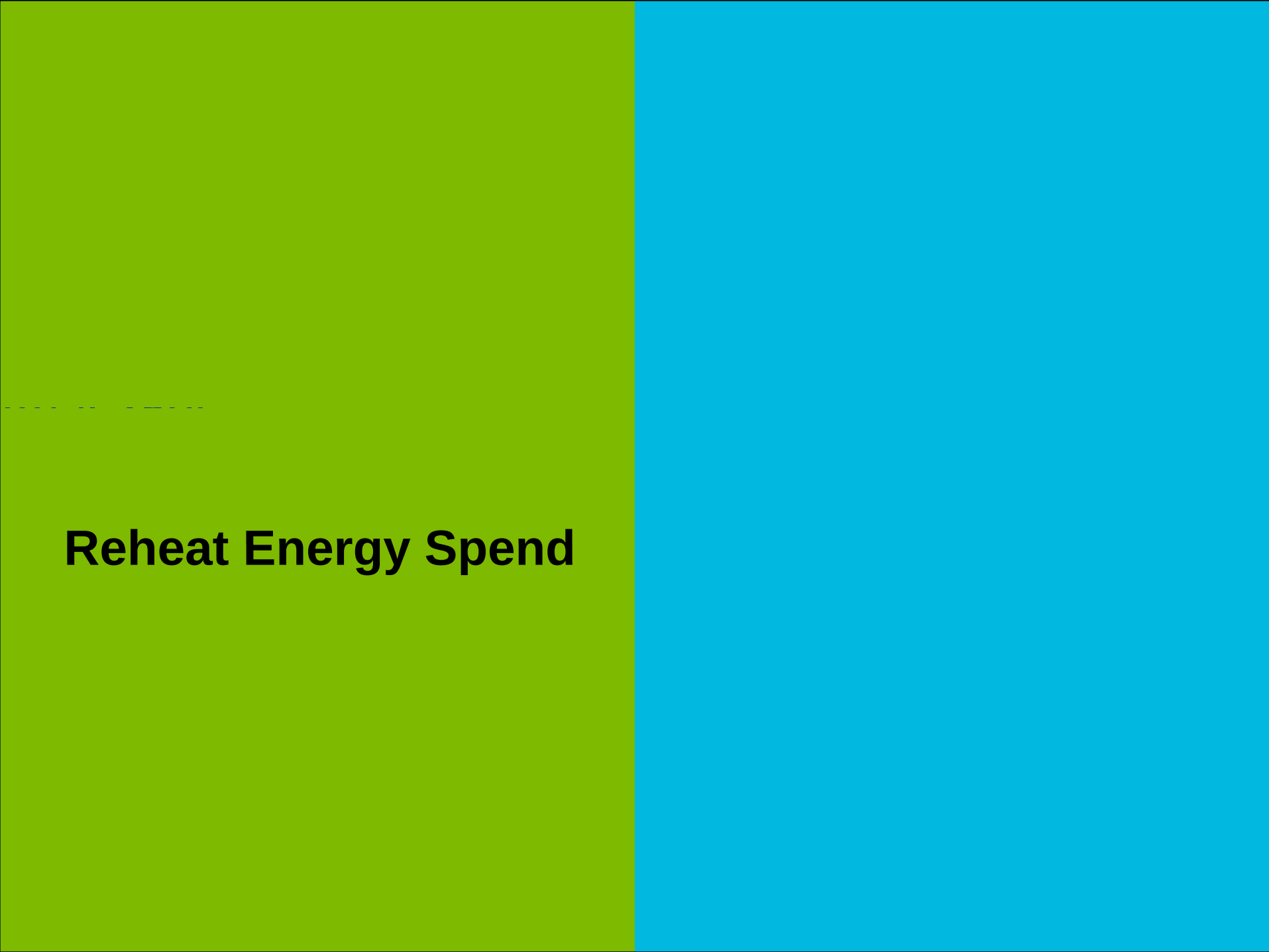
Water to water heat pumps

Heat recovery systems

Desuperheaters

Air to water heat pumps

Application Issues

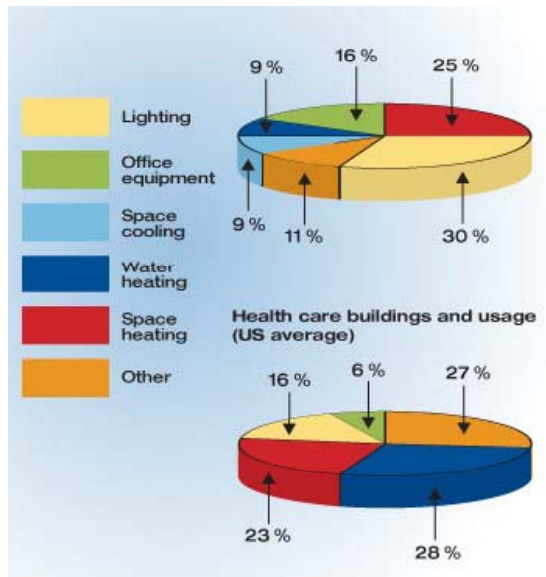


Reheat Energy Spend

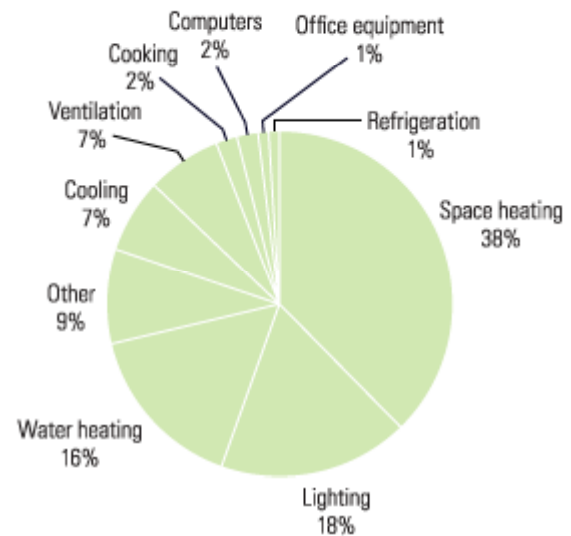
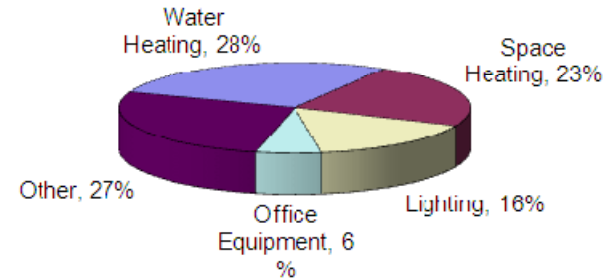
Reheat Energy Spend

November 2014 HAAHE Meeting

- UT M.D. Anderson Cancer Center spends 37% of their energy on reheat
- Numerous other studies indicate that reheat and domestic hot water heating are the largest energy spends in healthcare.



Health Care Buildings end usage (U.S. Average)



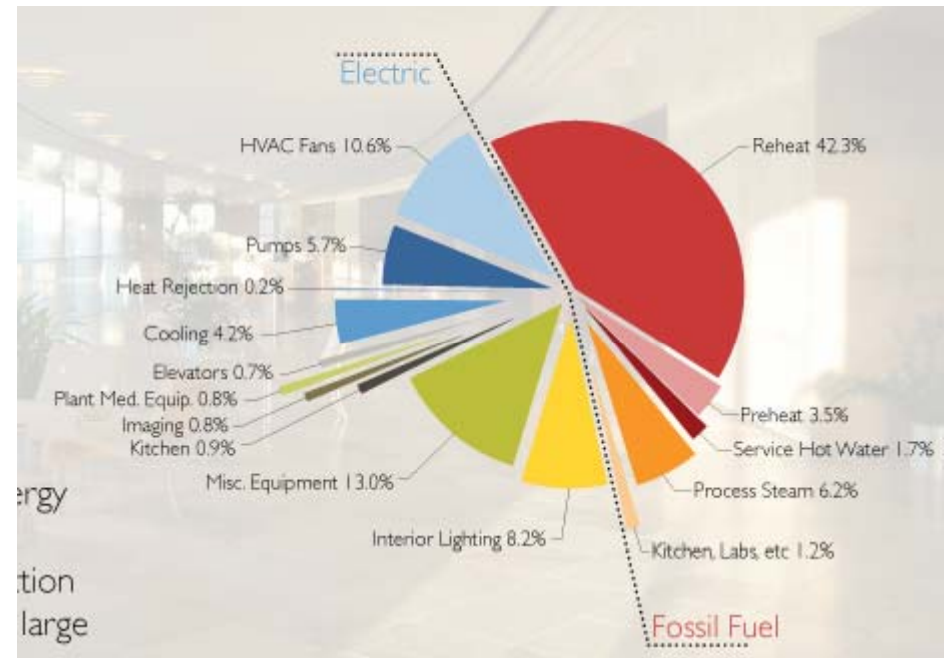
Note: Percentages may not add up to 100% due to rounding.

© E SOURCE; data from the U.S. Energy Information Administration (2003)

Reheat Energy Spend

Organizations are devoted to studying hospital energy use

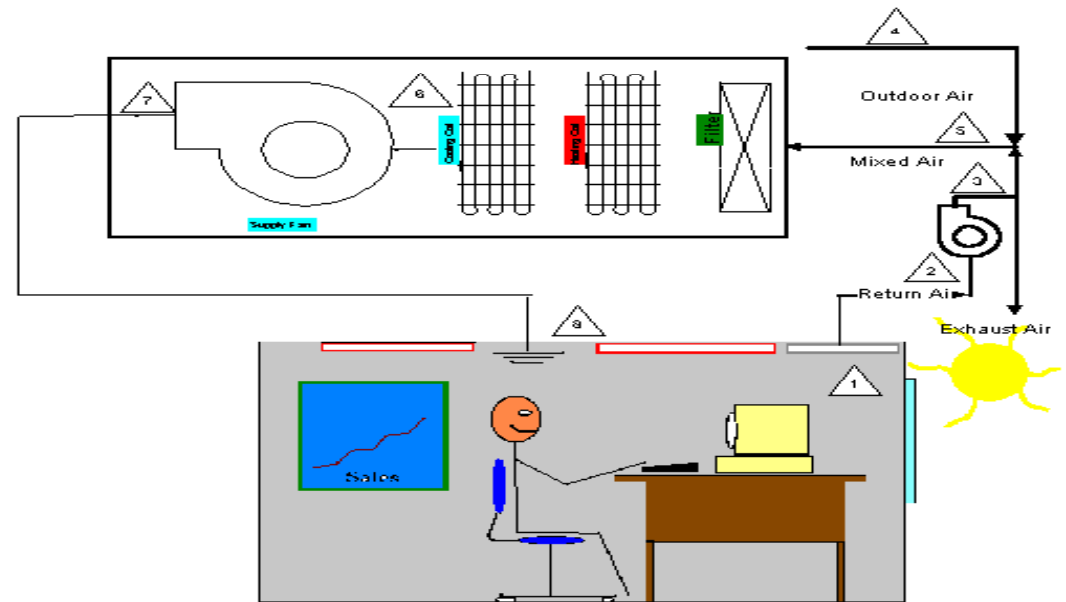
- Targeting 100!



Reheat Energy Spend

Space Conditioning Basics

- Calculate the heat gain in the space Q
- Calculate the required airflow (cfm) using the formula:
 - $Q = 1.085 \times \text{cfm} \times (T_s - T_{sa})$
 - T_s is the space temperature 75°F
 - T_{sa} is the supply air temperature 55°F
- As heat gain decreases, typically vary the airflow (cfm) to match the load



Understanding Reheat Energy

Texas Department of State Health Services (TDSHS)

- Prescribes minimum airflow rates
- 15 air changes per hour is 2 cfm/sq. ft. for a room with an 8 foot ceiling.



Department of State Health Services

Title 25 Texas Administrative Code
Chapter 133
Hospital Licensing Rules
Effective June 21, 2007

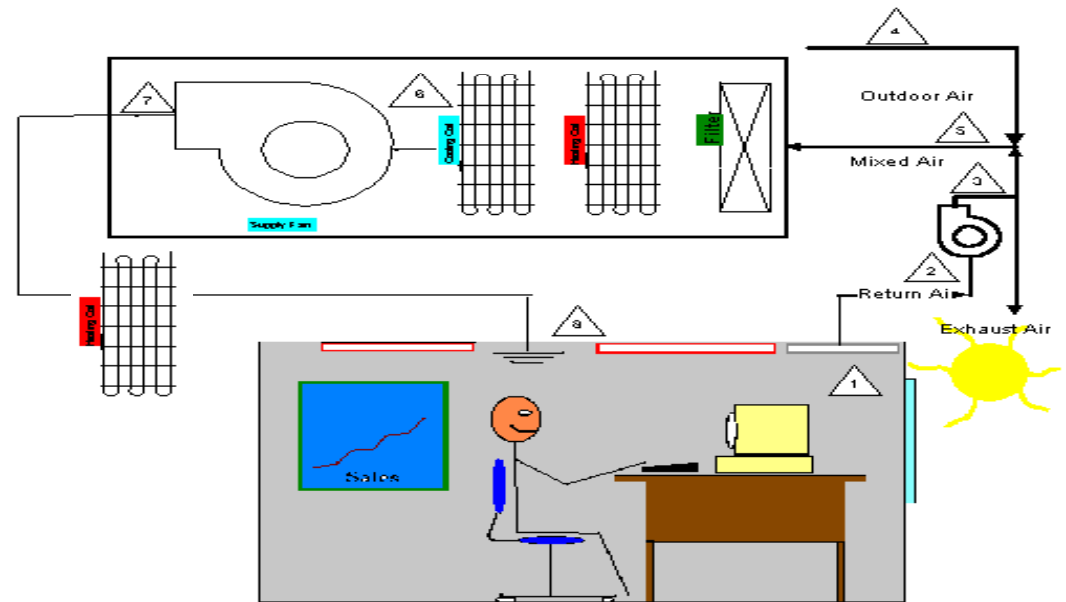
TABLE 3
VENTILATION REQUIREMENTS FOR HOSPITALS AND OUTPATIENT FACILITIES ¹

Area Designation	Air movement relationship to adjacent areas ^{2,16}	Minimum air changes of outdoor air per hour ⁴	Minimum total air changes per hour ⁴	All air exhausted directly to outdoors ⁵	Recirculated by means of room units ⁶	Relative humidity ⁷ (%)	Design temperature ⁸ (degrees F)
SURGERY AND CRITICAL CARE							
Operating/Surgical, cystoscopic rooms ^{9,16}	Out	4	20	----	No	30-60	68-73 ¹⁷
Airborne infection isolation surgical rooms	In	4	15	Yes	No	30-60	68-73
Isolation anteroom (surgery)	In/Out ²⁰	----	10	Yes	No	----	----
Delivery room ⁹	Out	3	15	----	No	30-60	68-73
Recovery room ⁹	----	2	6	----	No	30-60	70-75
Critical and intensive care	----	2	6	----	No	30-60	70-75

Reheat Energy

Space Conditioning Basics

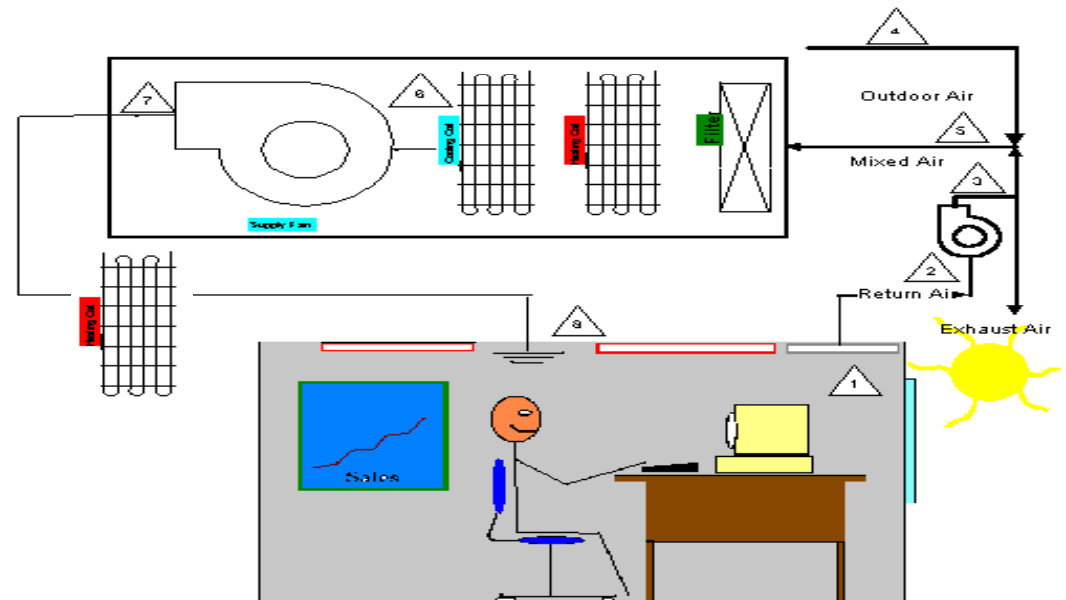
- Calculate the heat gain in the space Q
- Calculate the required airflow (cfm) using the formula:
 - $Q = 1.085 \times \text{cfm} \times (T_s - T_{sa})$
 - T_s is the space temperature 75°F
 - T_{sa} is the supply air temperature 55°F
- But TDSHS sets the cfm!
- Because airflow (cfm) and supply air temperature are fixed, space gets cold as load (Q) decreases
- Reheat is required to maintain space temperature (T_s)
- 110°F hot water can make 75°F air

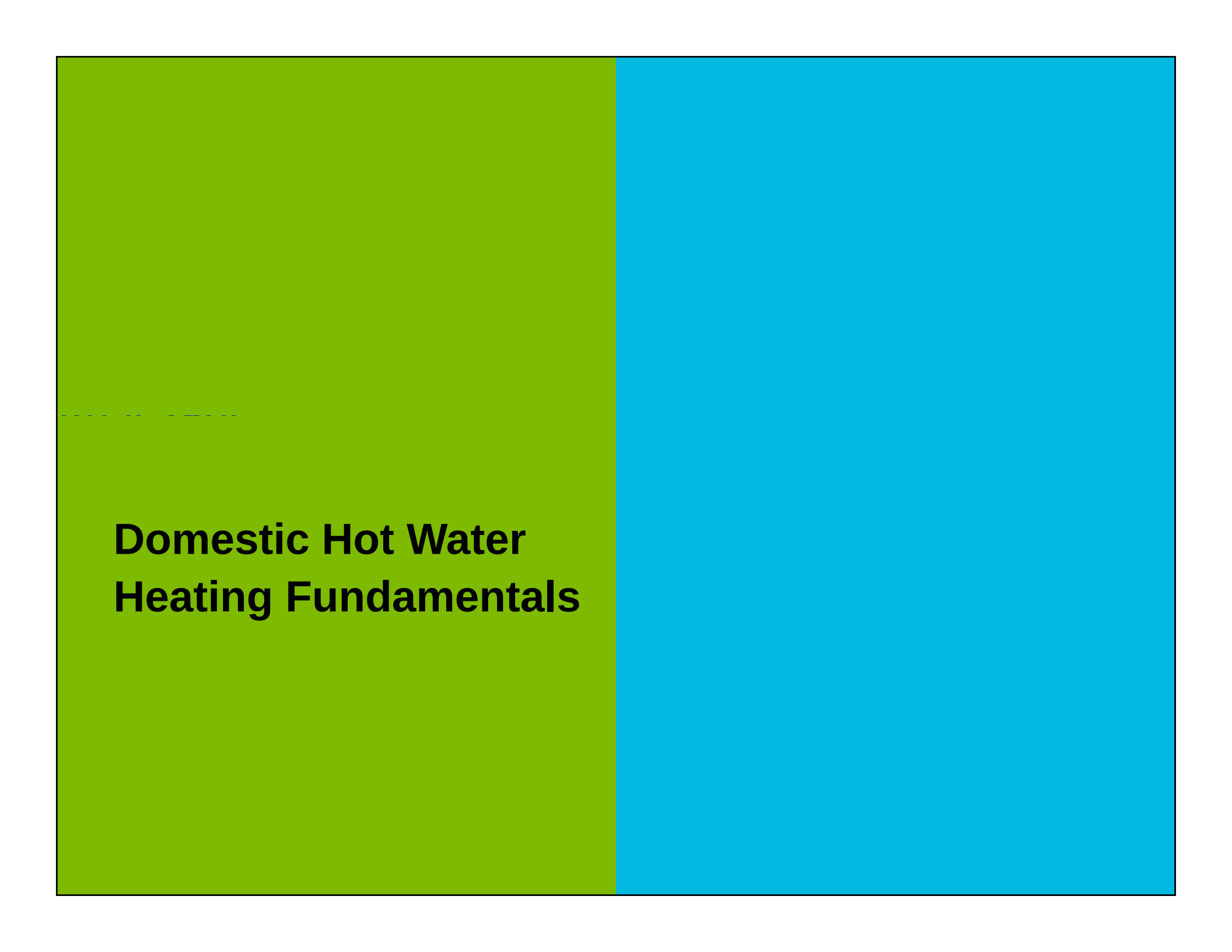


Reheat Energy

Space Conditioning Basics

- Calculate the heat loss in the space Q_h
- Calculate the required airflow (cfm) using the formula:
 - $Q_h = 1.085 \times \text{cfm} \times (T_s - T_{sa})$
 - T_s is the space temperature 75°F
 - $T_{sa} = T_s - Q_h / (1.085 \times \text{cfm})$
 - T_{sa} usually $< 85^\circ\text{F}$
- 110°F hot water can make 85°F air which is adequate for space heating



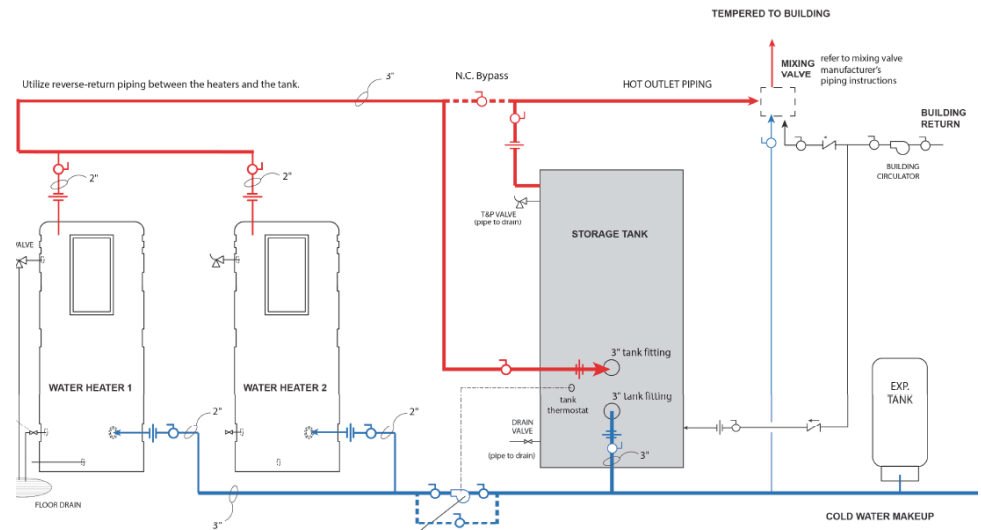


Domestic Hot Water Heating Fundamentals

Domestic Hot Water Heating

ASPE Handbook says:

- Calculate hot water demand based upon fixture units
- Determine available heat source – natural gas, propane, electric, steam
- Required hot water temperatures
 - 110 °F for lavatories and showers
 - 140 °F for dishwashers and laundry
- Select preferred system
 - Instantaneous
 - Copper tube boiler with storage tank
 - Bent tube boiler with storage tank
- Size boilers and tanks based upon load



Domestic Hot Water Heating

Good engineering practice

- 140 °F design
 - Minimizes tank size
 - Eliminates legionella
 - Ensures boilers do not condense
- Potable water must be kept safe
 - Primary heating fluid must be separated from the secondary fluid
- DHW loads vary greatly (0% to 100%)
- Potable water temperature varies (40°F to 72°F)



Domestic Hot Water Heating

Most Important

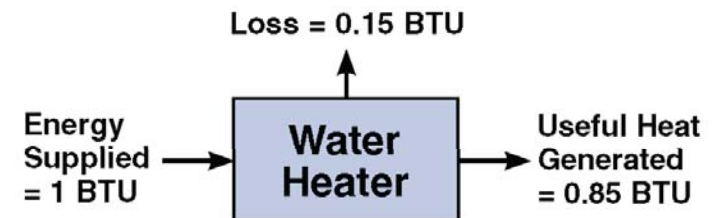
- Failure is not an option!
- People will suffer loss of air conditioning but will not tolerate lack of hot water!



Domestic Hot Water Heating

Heating Efficiency

- Coefficient of Performance (COP) is the heat output divided by the heat input
- Gas heat COP < 1
- Electric heat COP = 1



$$\begin{aligned}\text{COP} &= \frac{\text{Useful Heat Generated}}{\text{Energy Supplied}} \\ &= \frac{0.85 \text{ BTU Heat Generated}}{1.00 \text{ BTU Energy Supplied}} = 0.85\end{aligned}$$

Figure 1: COP of water heater.

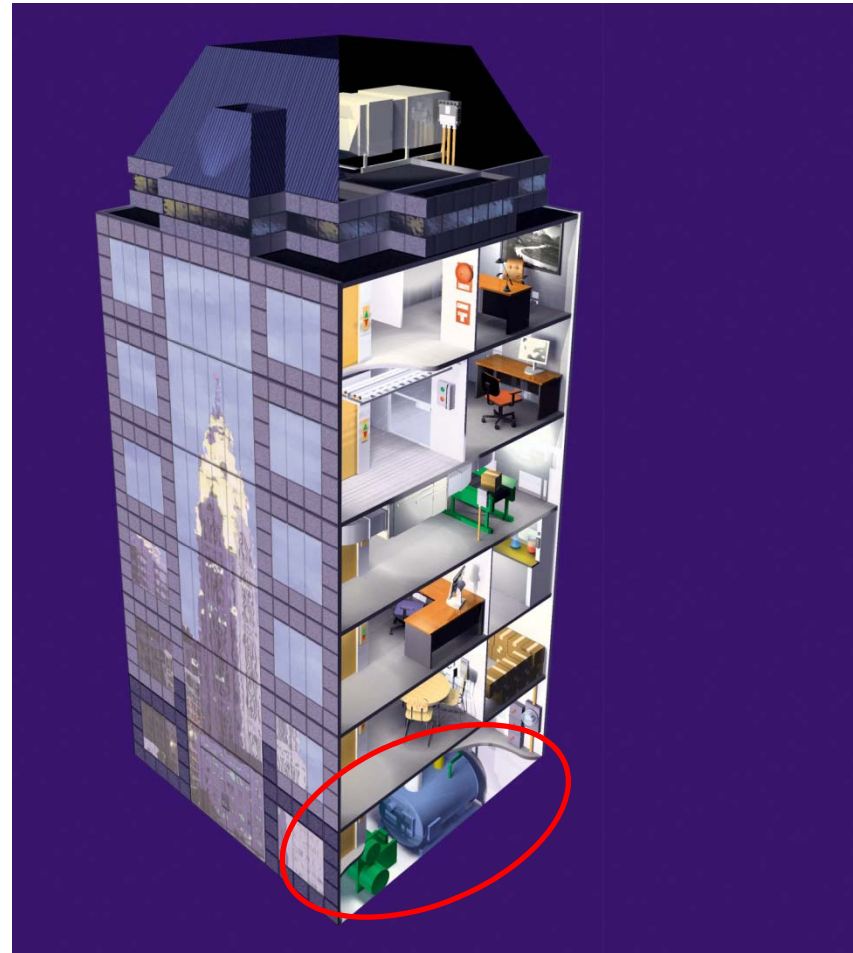


What's the Point???

The Elephant in the Room – Using Heat Rejected from the Chiller Plant for Reheat, Space Heating and DHW Heating

Boilers and Chillers Operate Simultaneously Throughout the Year in Houston

- Billions of BTUs are rejected to atmosphere, at the same time:
- Billions of cubic feet of natural gas are combusted
- Billions of kW are used for electric heat
- How do we use the heat rejected from the building for reheat, space heating and domestic hot water heating?



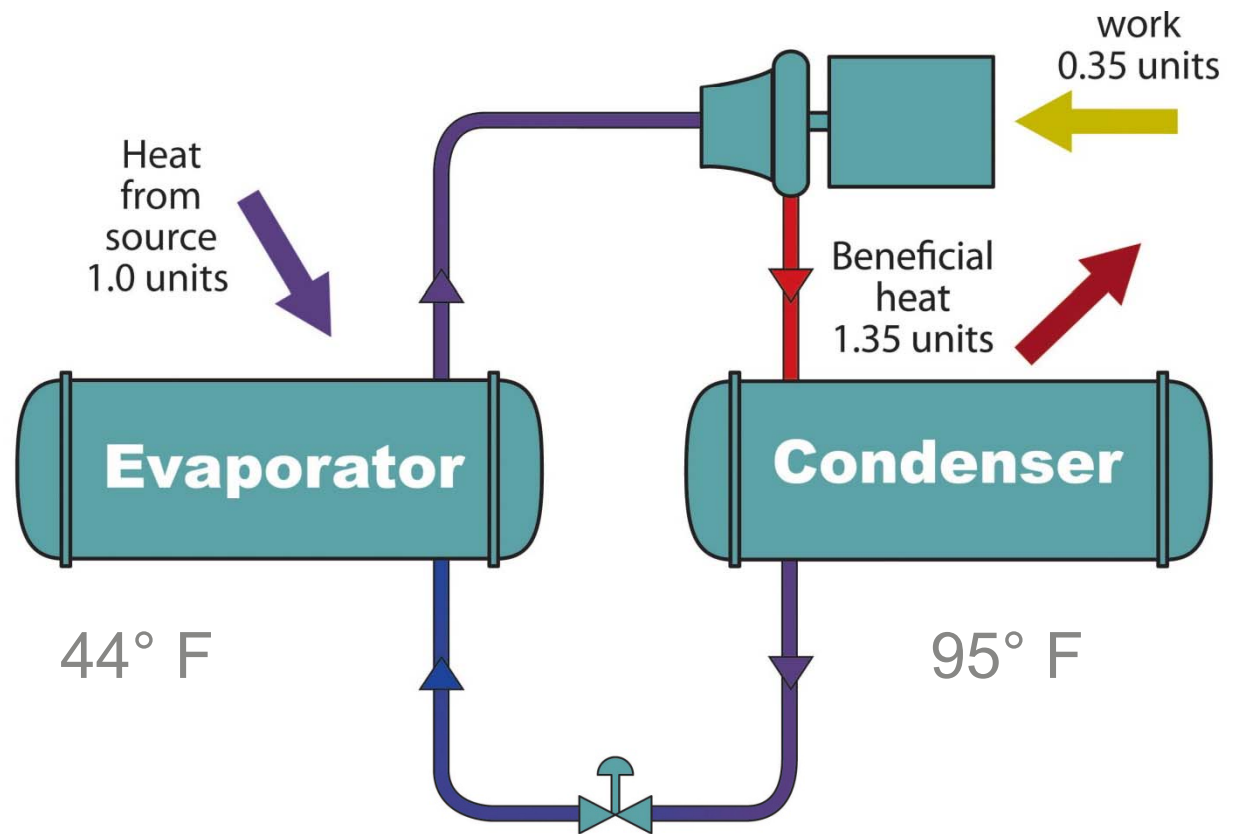


Refrigeration Review

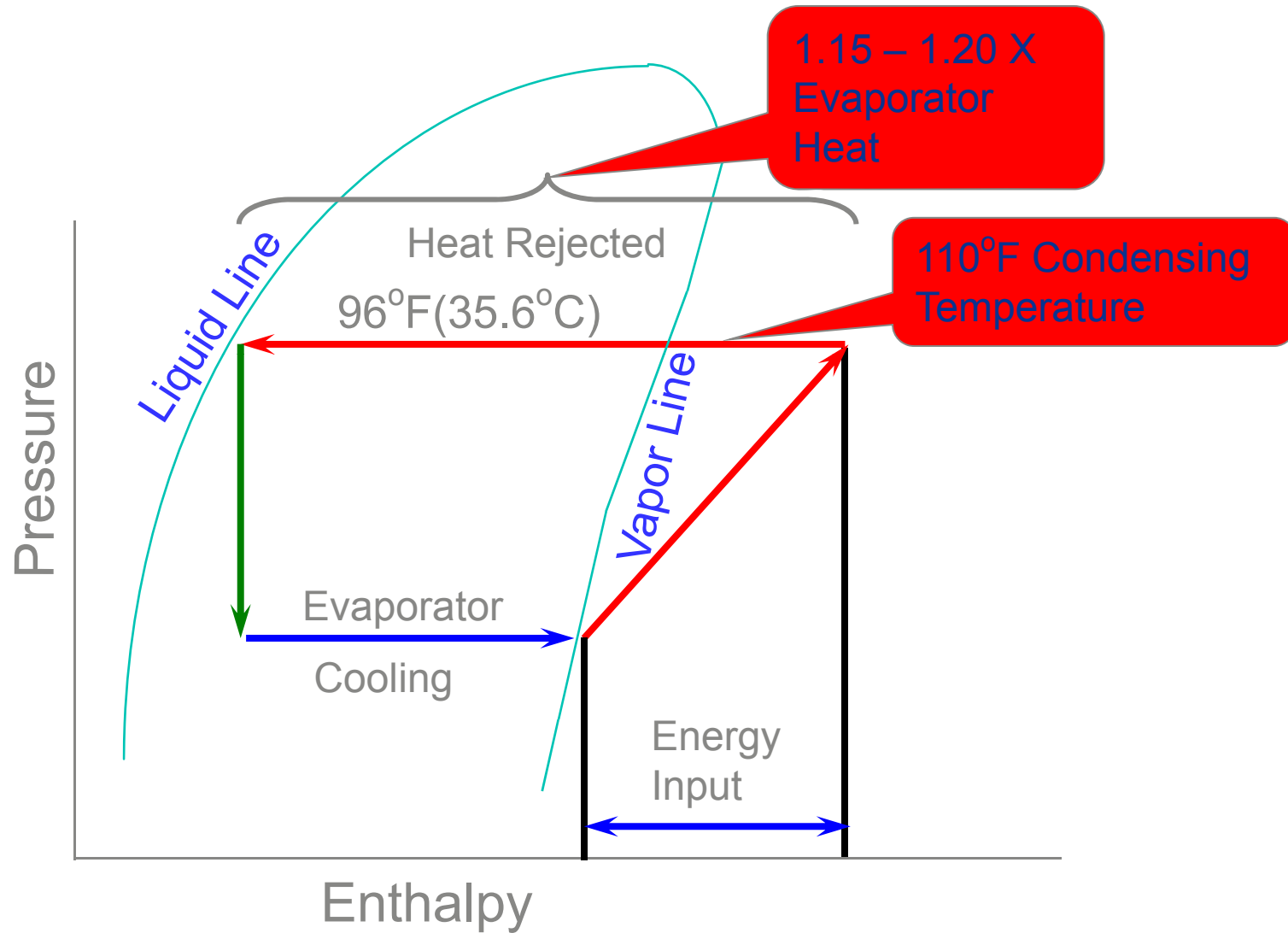
Refrigeration Review

Basic Cycle

- Heat is rejected to:
 - Cooling tower
 - Air cooled condenser
 - Ground loop
- Temperature is too low for domestic hot water heat



Typical Chiller P-H Diagram - R134a

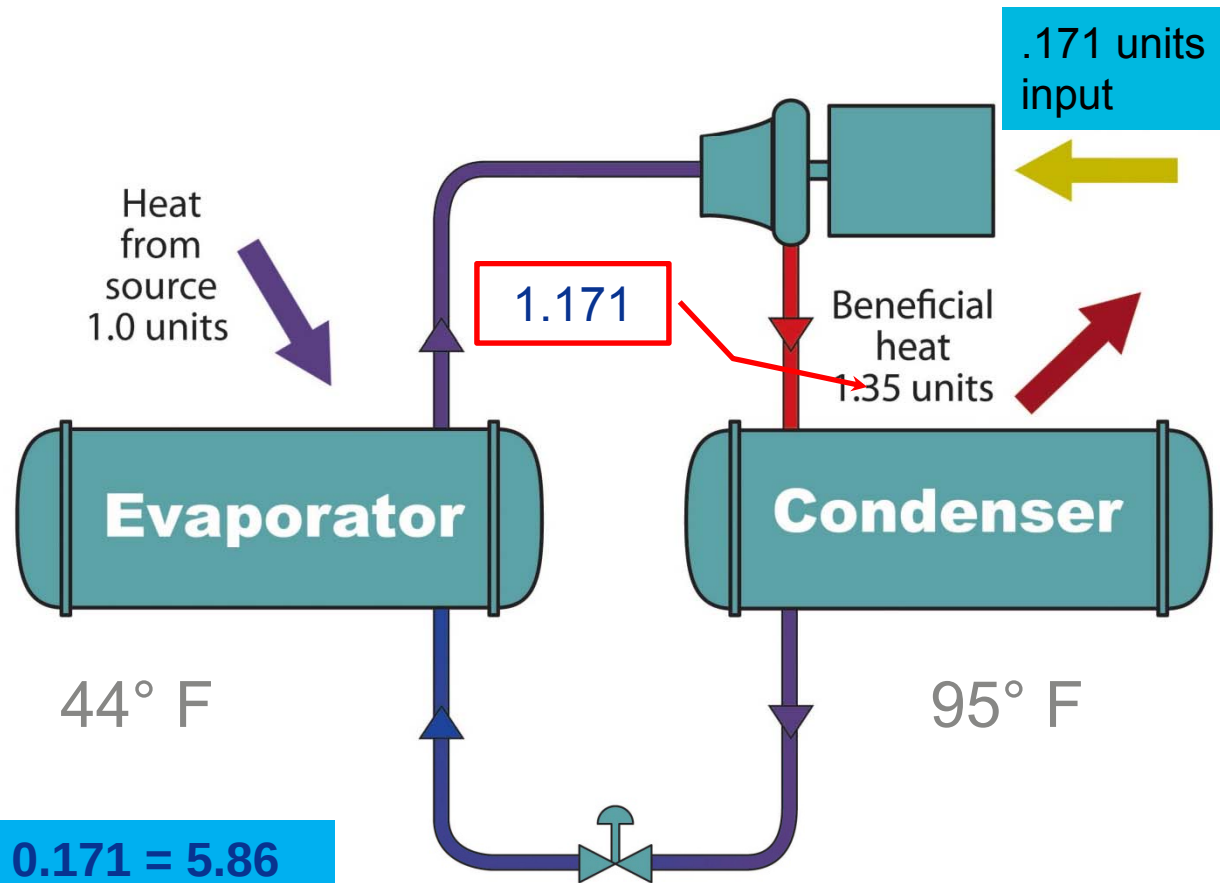


Chiller Coefficient of Performance (COP)

Typical Cooling Chiller COP

- ASHRAE 90.1 requires minimum .6 kW/ton
- Input is .171
- Cooling output is 1.0
- Every .171 unit of input energy makes 1.0 units of cooling

$$\text{Cooling COP} = 1.00 / 0.171 = 5.86$$



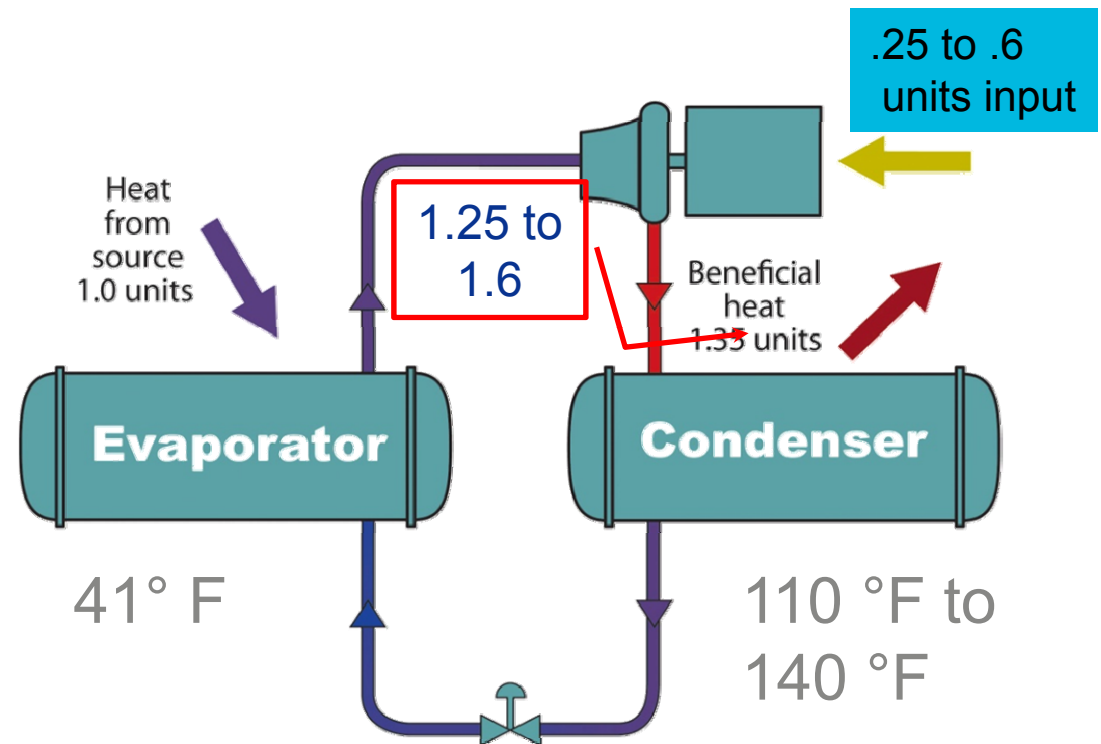
Heat Pump Review

Heat pump is the refrigeration cycle used to produce heat

Heat Pump Review

Heat Rejection

- Temperature suitable for heating
 - Domestic water
 - Heating hot water
 - Outdoor air

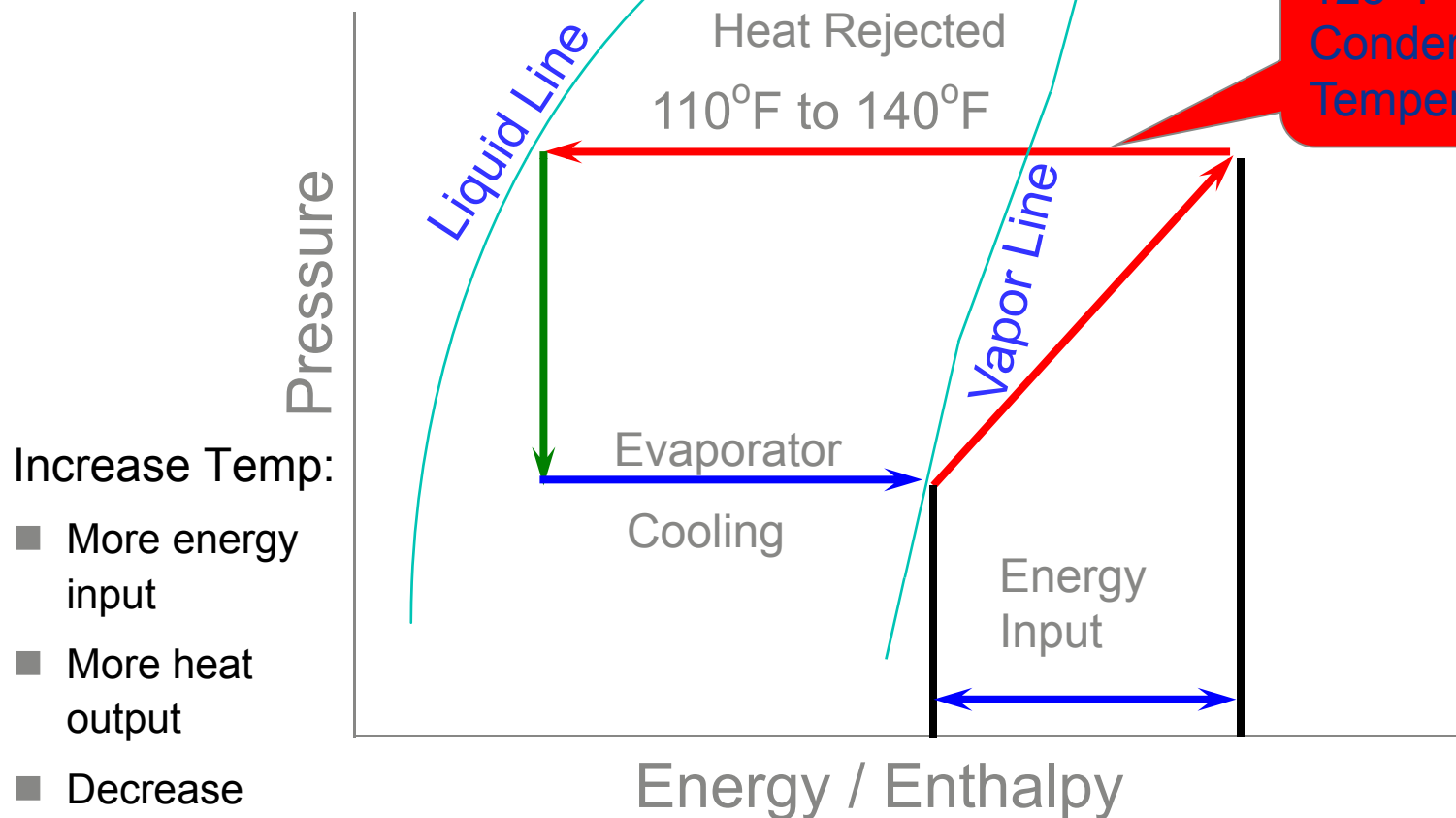


Heat Pump P-H Diagram – R134a

Heat Rejection Factor (HRF)

Heat Pump 1.25 to
1.6 X Evaporator
Heat

125 °F to 144 °F
Condensing
Temperature



Increase Temp:

- More energy input
- More heat output
- Decrease efficiency

Heat Pump Review

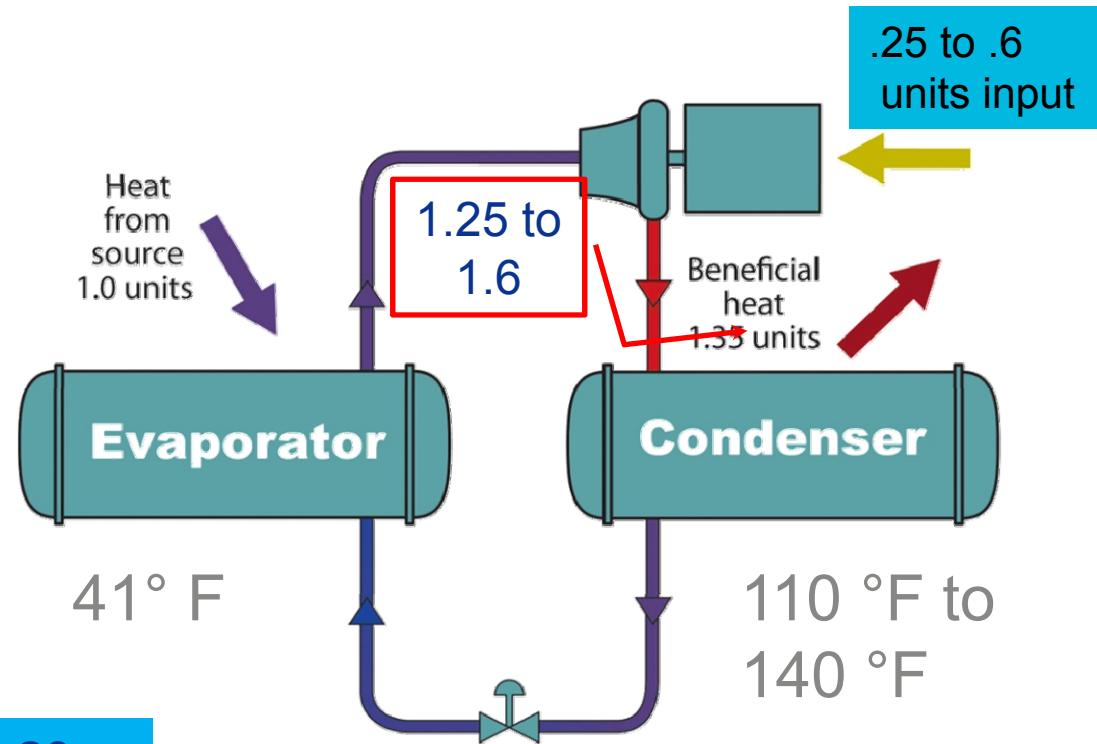
Heat Pump COP

- COP depends upon the application
 - Dedicated Cooling
 - Dedicated Heat Pump
 - Combination Cooling and Heat Pump
- Notice the COP is much lower than ASHRAE minimum (5.86 COP)

$$\text{Cooling COP} = 1.00 / 0.35 = 2.86$$

$$\text{Heating COP} = 1.35 / 0.35 = 3.86$$

$$\text{Combined COP} = 2.35 / 0.35 = 6.71$$



$$\text{COP} = \frac{\text{Useful Work}}{\text{Input Power}}$$

**Heat Recovery and
Heat Pumps for
Healthcare – Show Me
the Money!**

Domestic Hot Water Heating Heat Pump Example

Using Waste Heat for Energy Savings – ASHRAE Journal April 2006

- Cost of natural gas for DHW heat: \$2,294,000
- Cost of electricity used by heat pump: \$814,000
- Annual energy savings: \$1,480,000
- Capital cost for heat pump: \$408,000

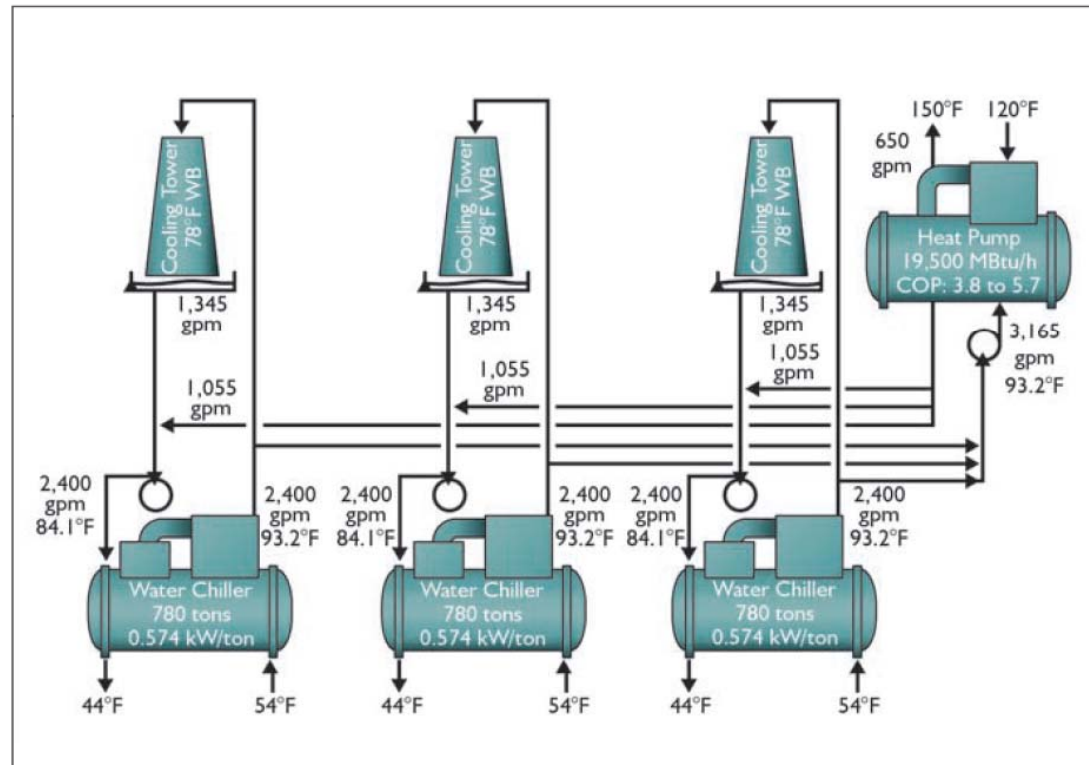
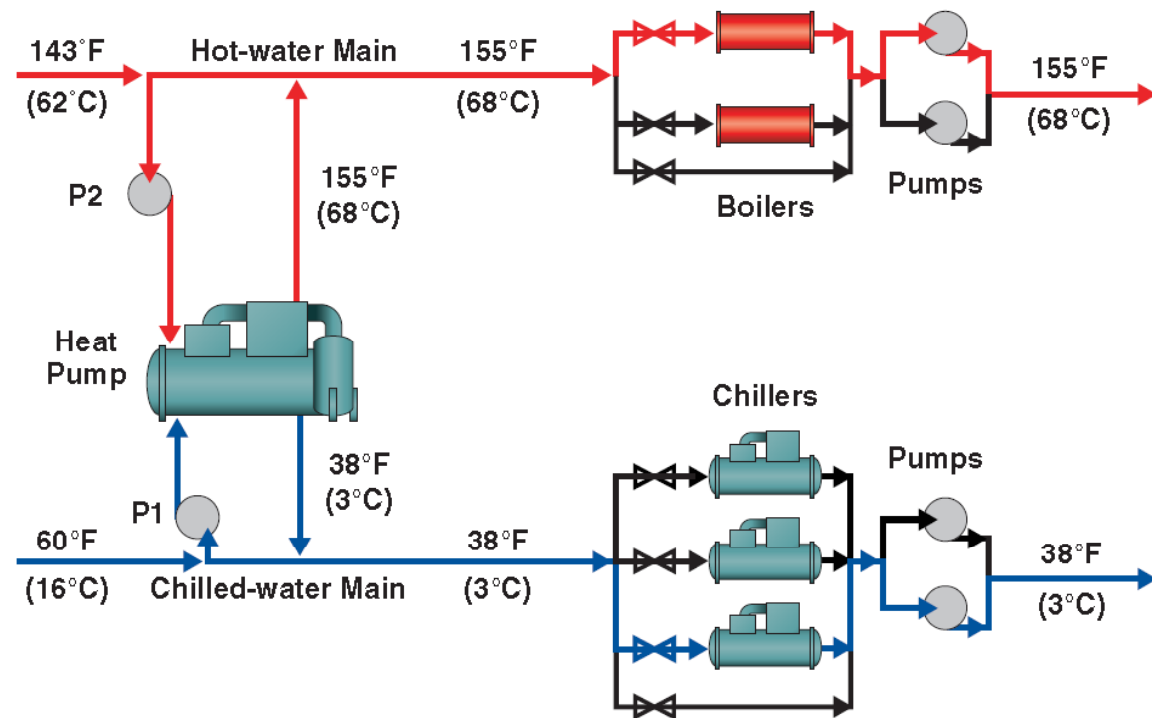


Figure 4: Schematic of WTWHP system for a hospital in Texas.

Heating Hot Water Heating Heat Pump Example

Arkansas University

- Heat pump heat is 20% of the cost of a natural gas fired steam boiler
- Produces all the heat required in the summer
- \$1,000,000 annual savings
- Savings were almost instantaneous



Heating Hot Water and Domestic Hot Water Heating Heat Pump Example Wisconsin Medical Center, ASHRAE Journal June, 2013

Aurora Medical Center

- 107 patient rooms, 18 ORs, Imaging, 4 Cath Labs, Atrium
- 207 kBTU/ft²/yr

Component	Initial Cost	Yearly Savings	Payback Period
Low Flow Plumbing Fixtures (33% reduction)	\$28,000	\$8,000	3.5 Years
AHUs and Ductwork Sized to Exceed Standard 90.1-2004 Fan Horsepower Requirements	\$500,000	\$100,000	5 Years
Chilled Water Cooling	\$50,000	\$14,000	3.5 Years
Energy Efficient Boilers	\$240,000	\$60,000	4 Years
Energy Recovery Chillers	\$360,000	\$120,000	3 Years

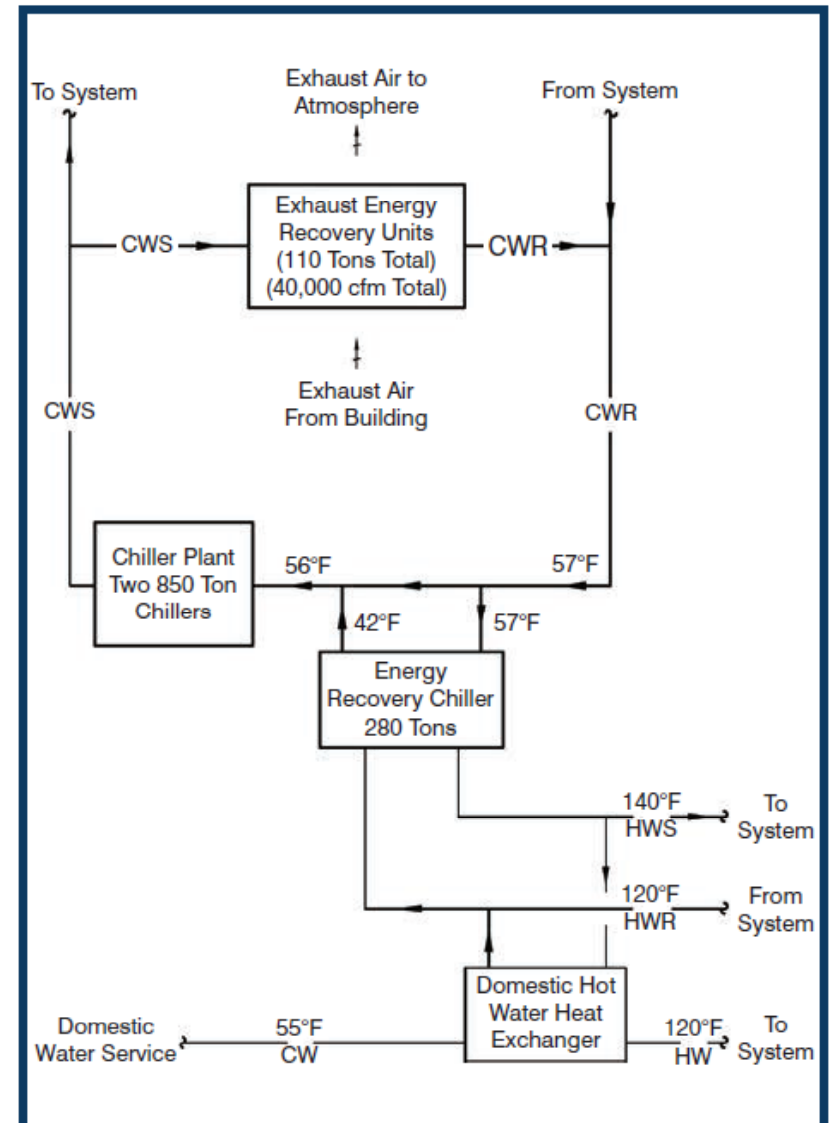
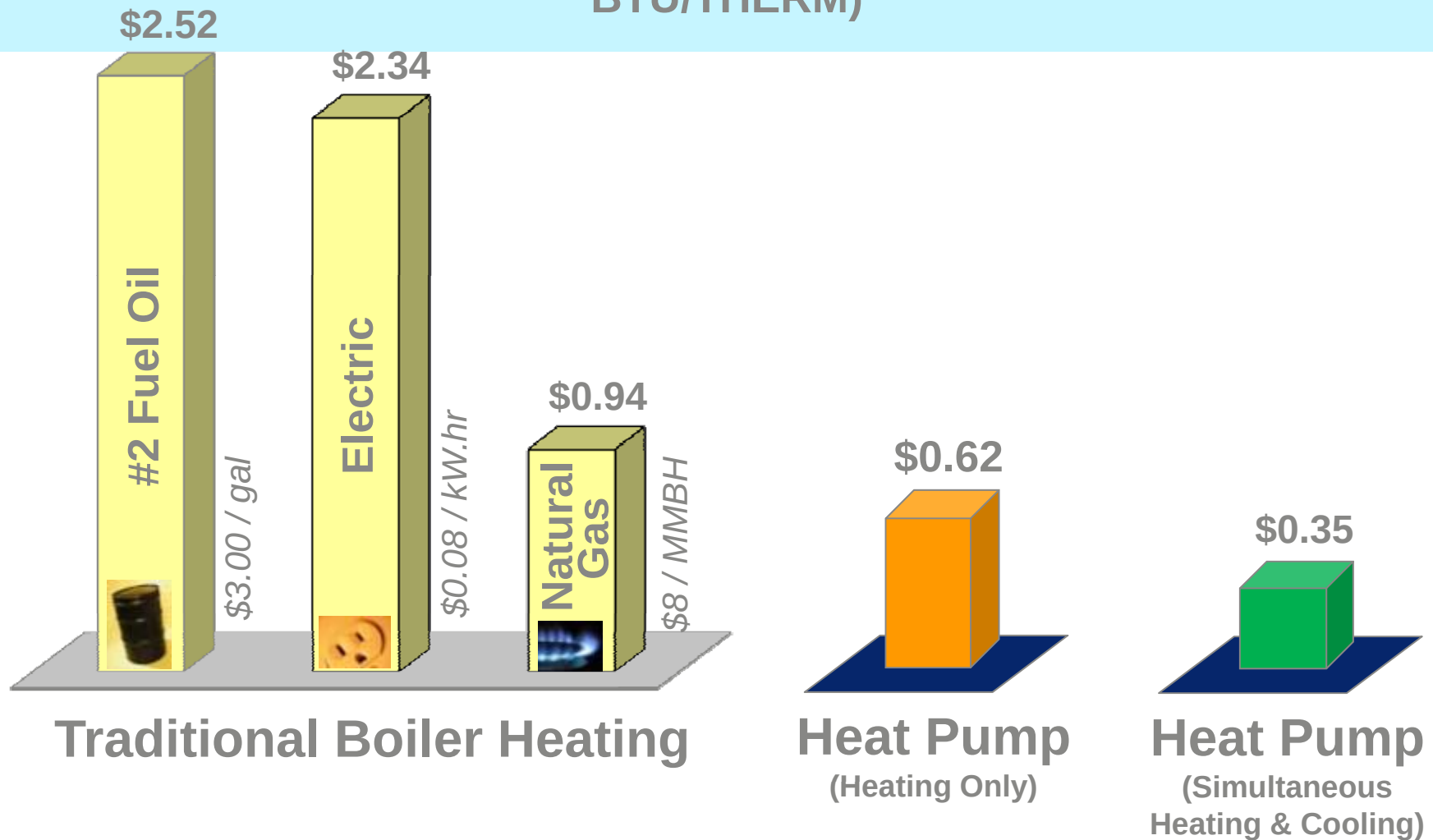


Figure 3: Exhaust energy recovery unit and energy recovery chiller optimization.

Heat Pump Benefits – Economic Advantages

RELATIVE COST TO PROVIDE ONE THERM OF HEAT (100,000 BTU/THERM)



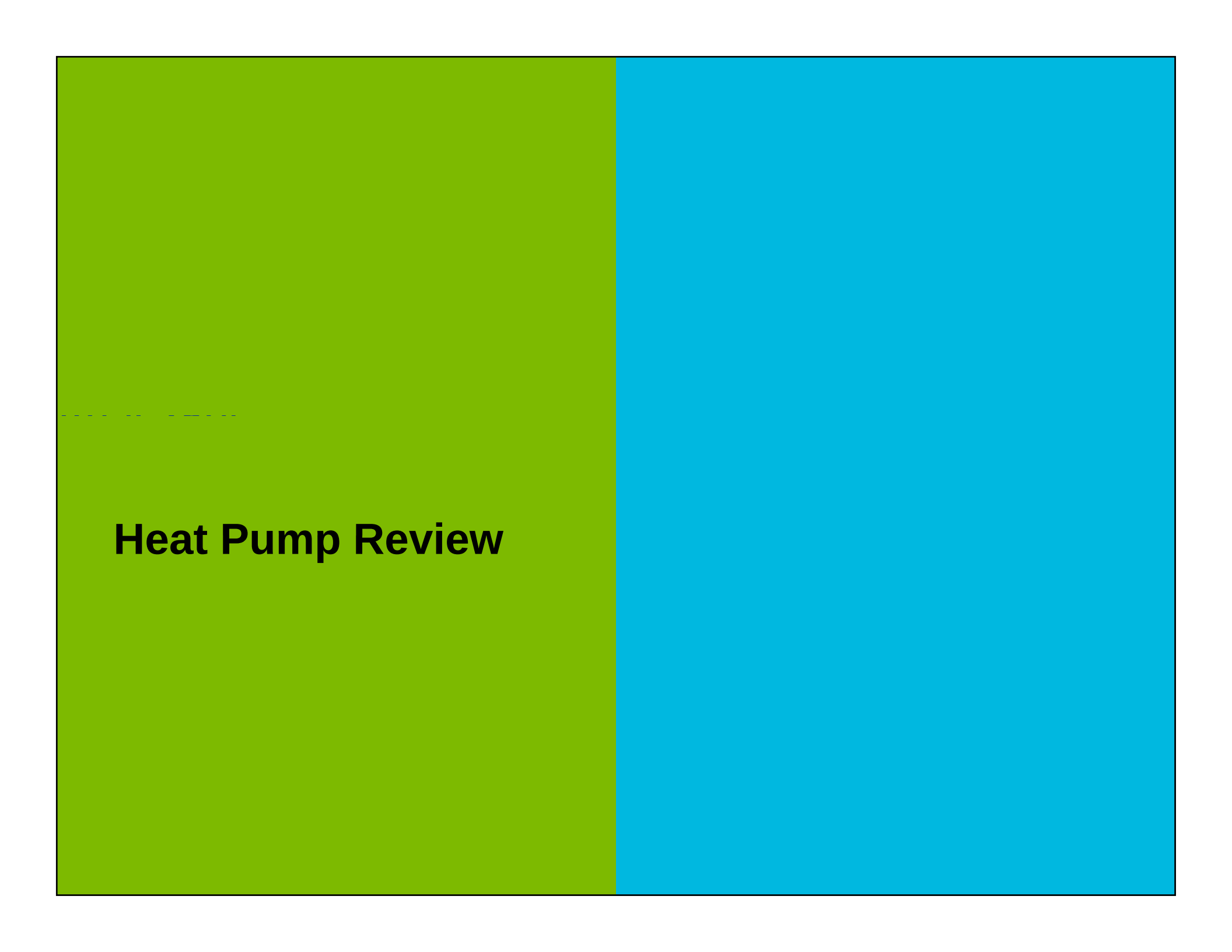
Heat Pumps and Heat Recovery for Healthcare Operations

Be the smartest person in the room when the topic of using waste heat for hot water heating and domestic hot water heating arises

- Know system types:
 - Water to Water Heat Pump
 - Heat recovery
 - Desuperheaters
 - Air to Water Heat Pumps
- Know application issues



Typical Design Team Members



Heat Pump Review

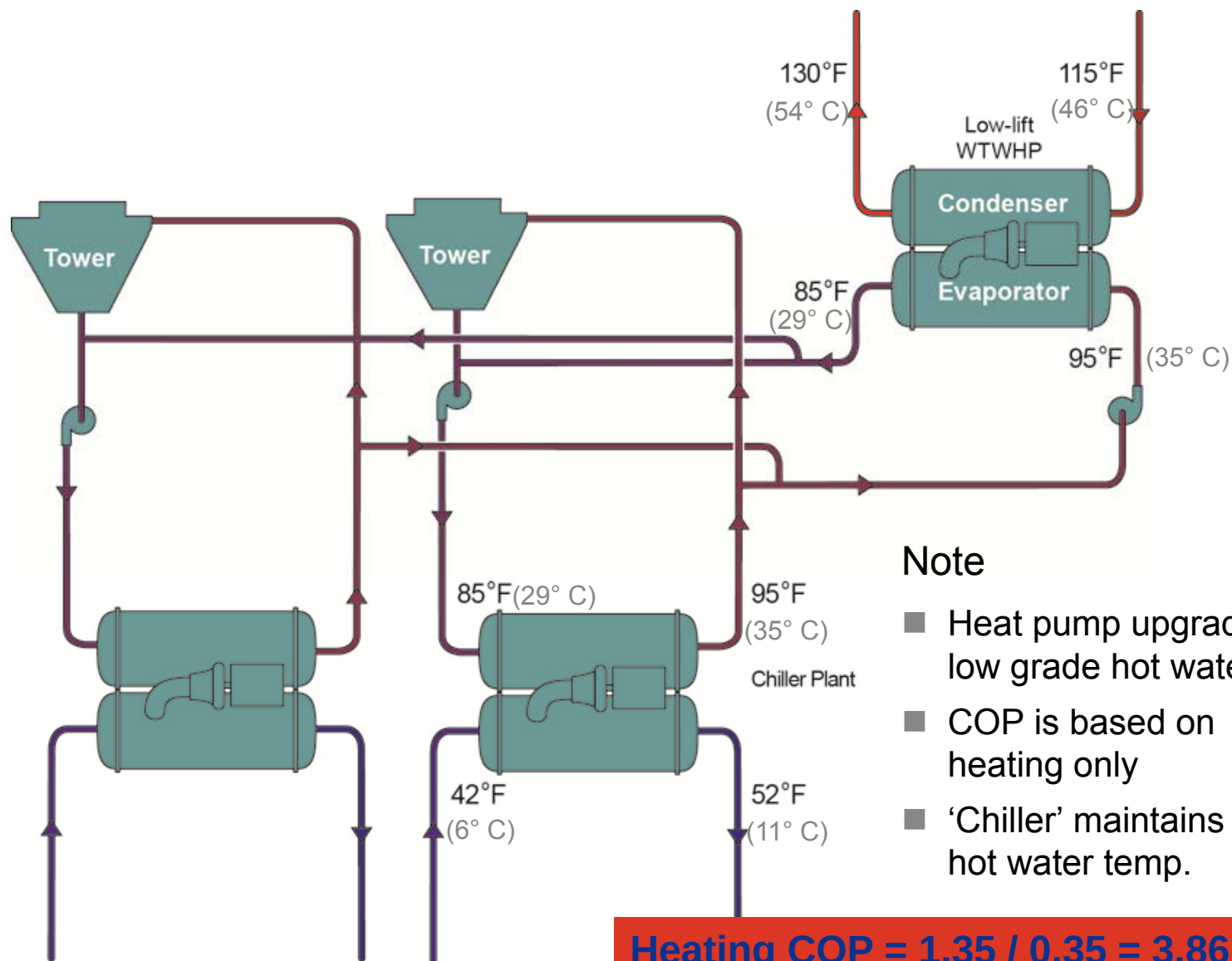
Building Air Conditioning Review

Chilled water system:

- Collects heat from the building
- Chiller removes heat from the chilled water loop
- Chiller rejects heat into the cooling tower water
- Cooling tower rejects heat into the atmosphere by water evaporation

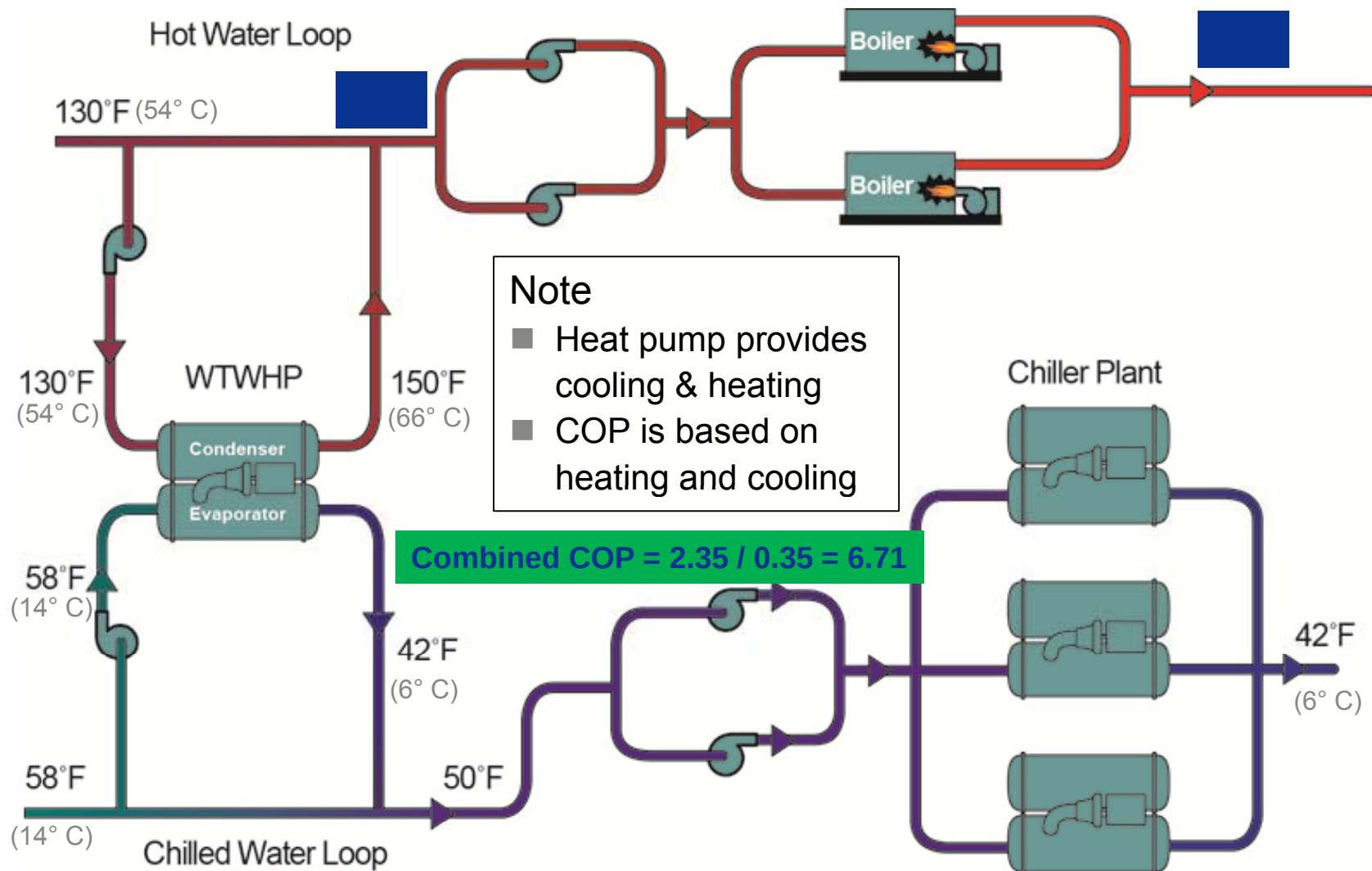


Water-Side Cascade Arrangement



Heating COP = $1.35 / 0.35 = 3.86$

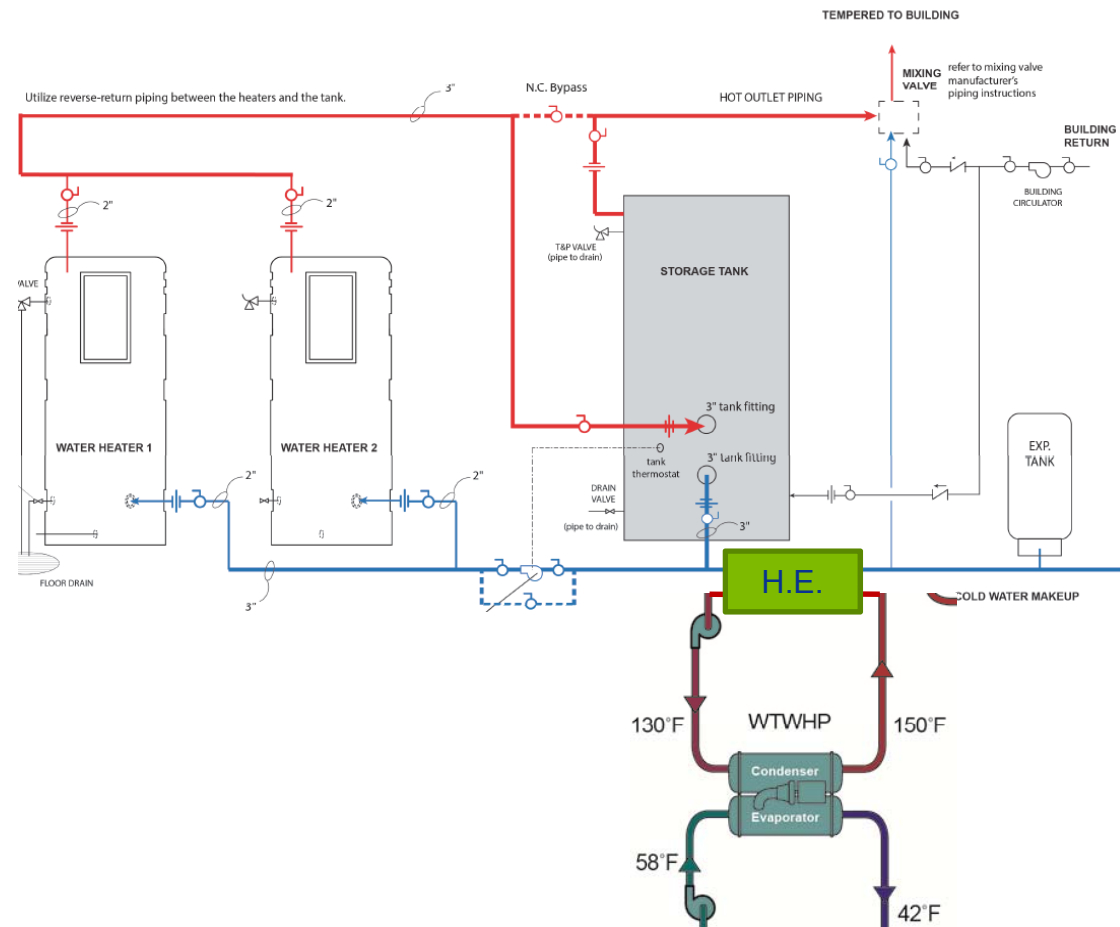
Simple “Side Car” Piping Arrangement - Simultaneous Heating & Cooling



Domestic Hot Water Heating Heat Pump Application

Bill's Recommendation

- Heat exchanger tempers the incoming domestic cold water.
- The heat exchanger pump runs continuously.
- The heat pump produces 150 degree heating hot water
- 'Chiller' load depends upon the DHW demand
- Side-car or cascade configuration
- Do not reduce chiller or cooling tower capacity unless DHW load is constant!



Heat Pump Benefits – Social / Environmental



How much water would a 10 MMBH Heat Pump (at 65% utilization) save, by not sending the heat to the cooling tower?

Assumptions:

- 600 ton design cooling load with 3 gpm/ton (0.054 L/s) condenser water flow
- Cooling tower evaporation rate of 1% & blow-down of 0.3% (4 cycles of concentration)

22,500 gallons (85,000 L) per DAY!



(plus water treatment & sewer savings)

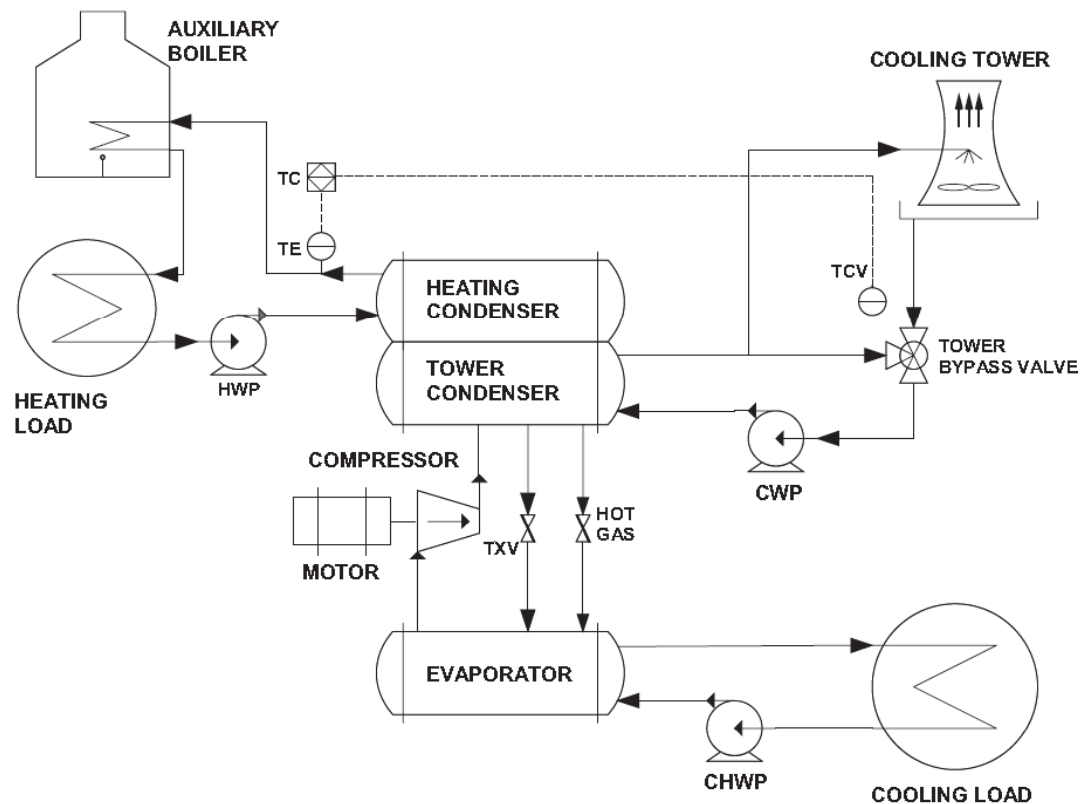


Heat Recovery

Heat Recovery

Heat Recovery is a standard chilled water system with an extra condenser

- Refrigerant goes to the coldest spot
- Bypassing the tower forces heat to the DHW heat exchanger
- Maximum temperature is 110 °F



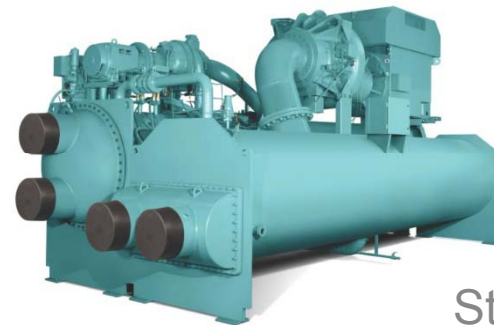
Heat Recovery

Advantage

- Cost is the extra condenser vs. a dedicated chiller
- Simplicity

Disadvantage

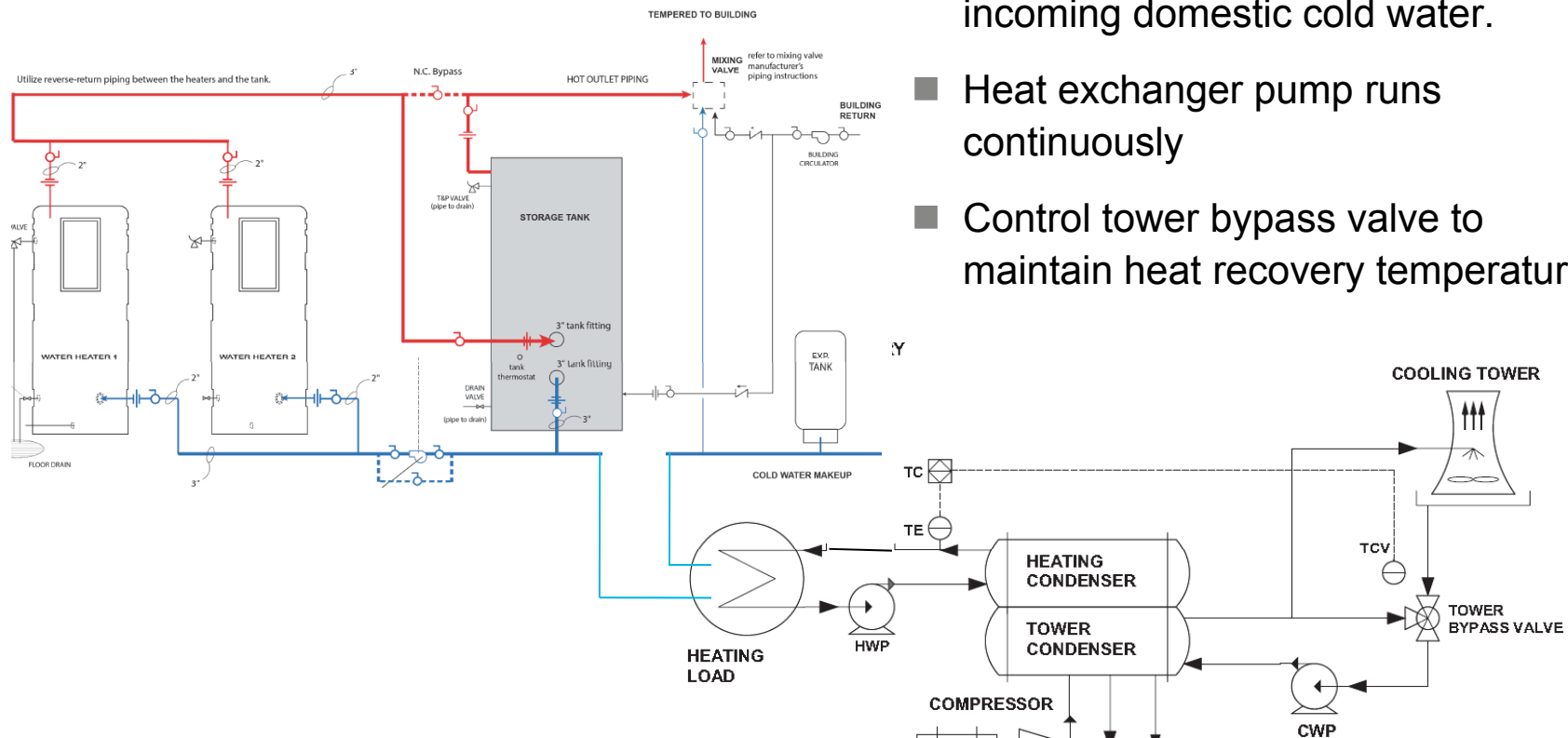
- Maximum 110°F hot water
- Tower bypass valve and associate controls

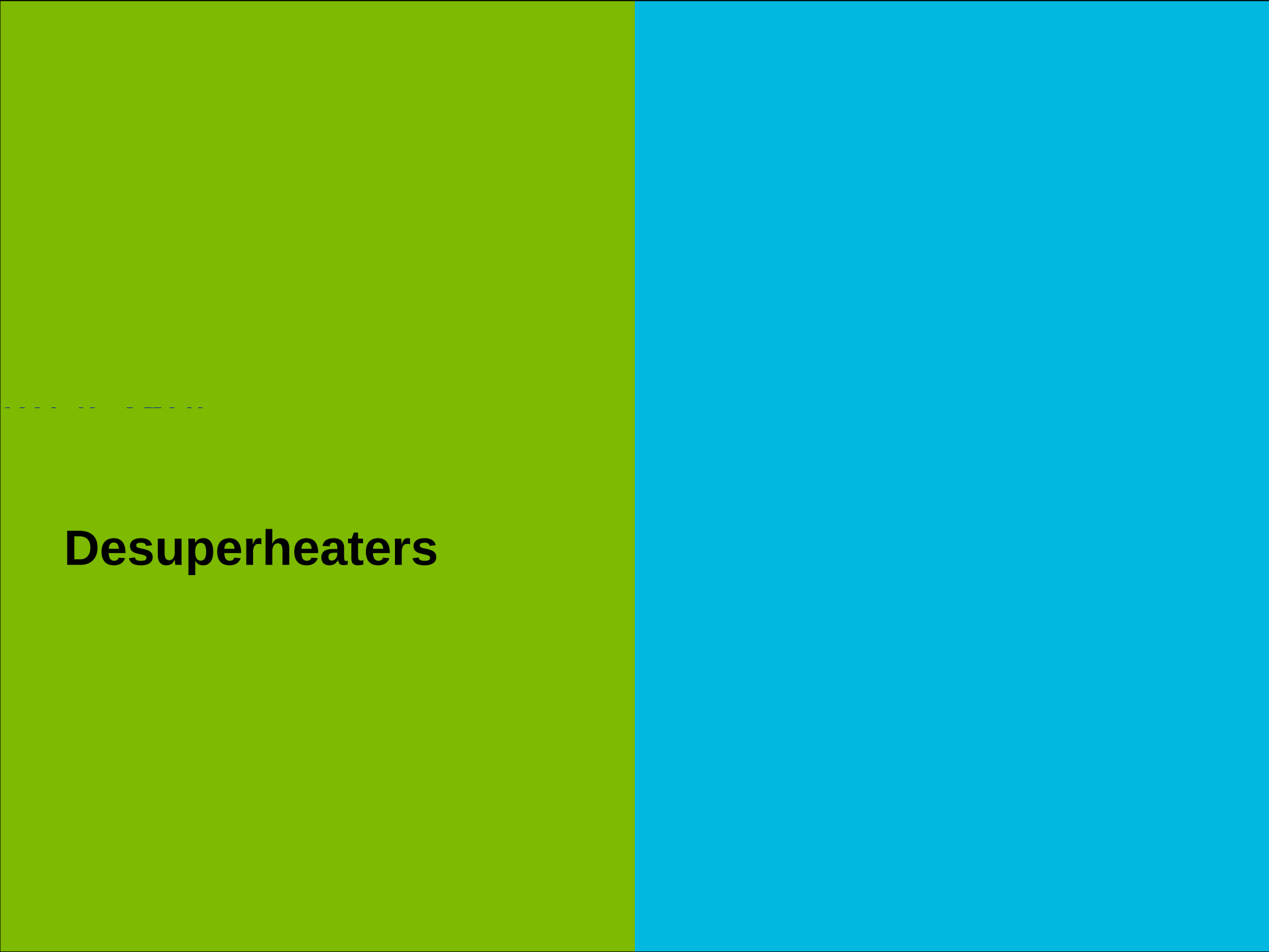


Domestic Hot Water Heat Recovery Application

Bill's Recommendation

- Heat exchanger tempers the incoming domestic cold water.
- Heat exchanger pump runs continuously
- Control tower bypass valve to maintain heat recovery temperature





Desuperheaters

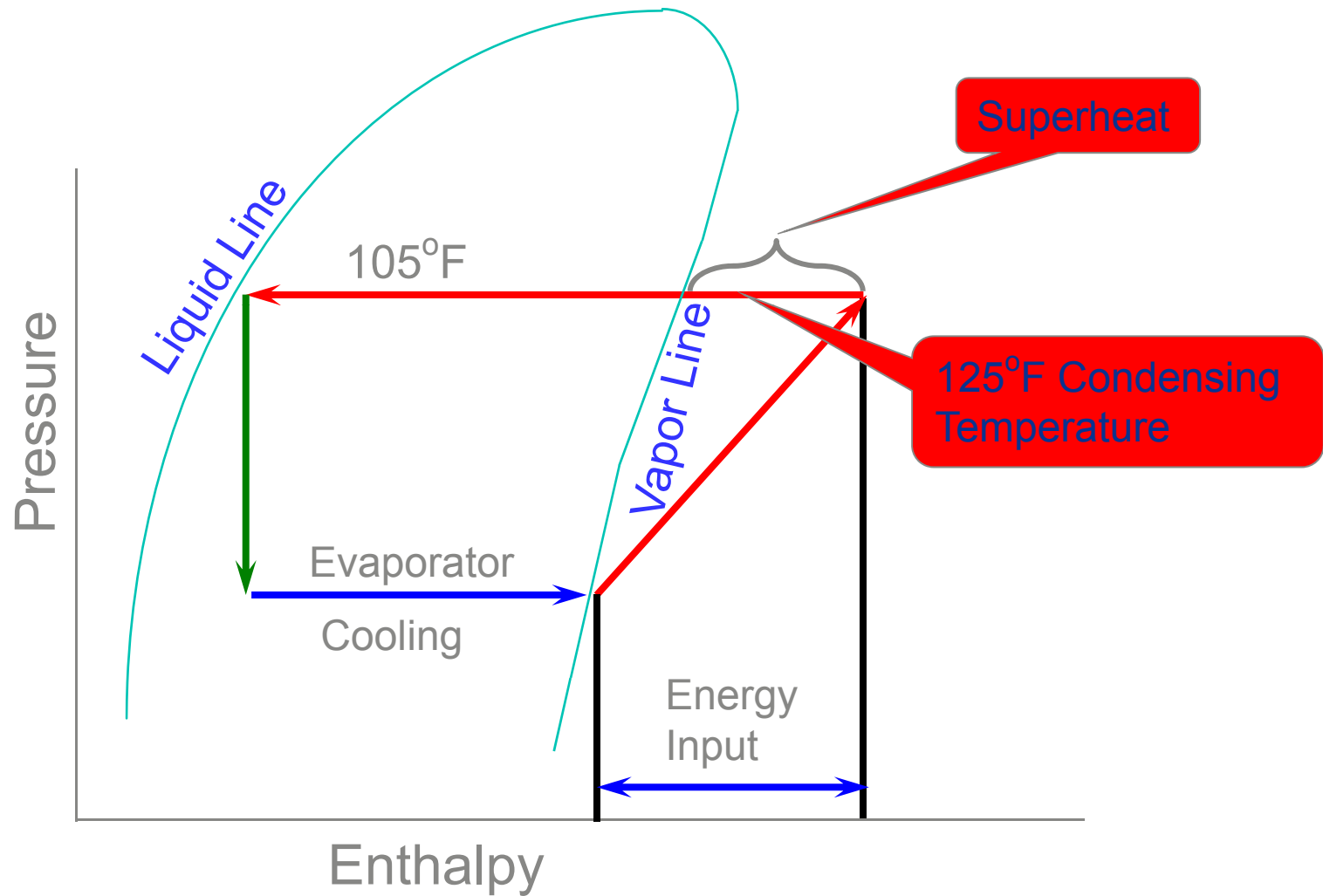
Desuperheaters

You are probably asking yourself:

- My building is being designed with air cooled chillers. How can the waste heat be used for domestic hot water heating?
- Use compressor superheat!



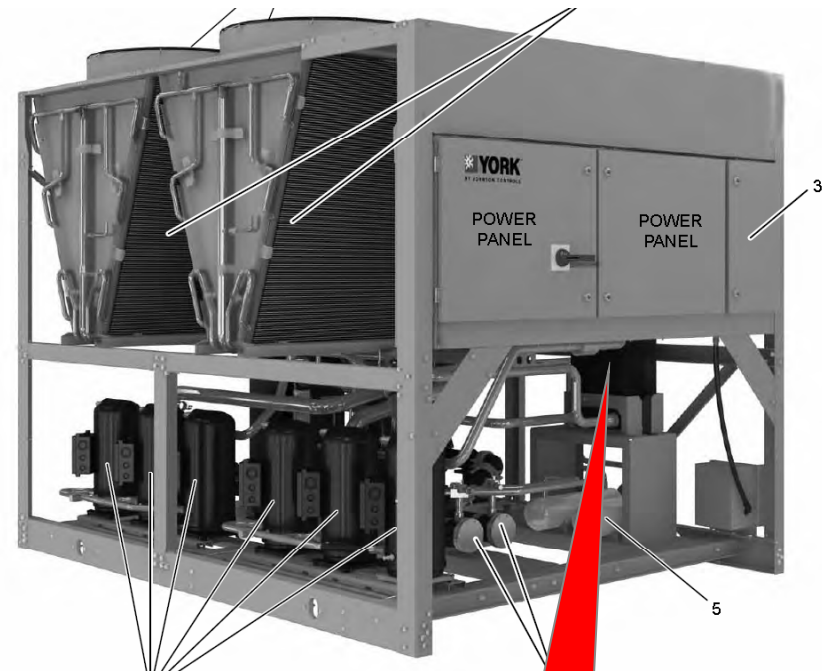
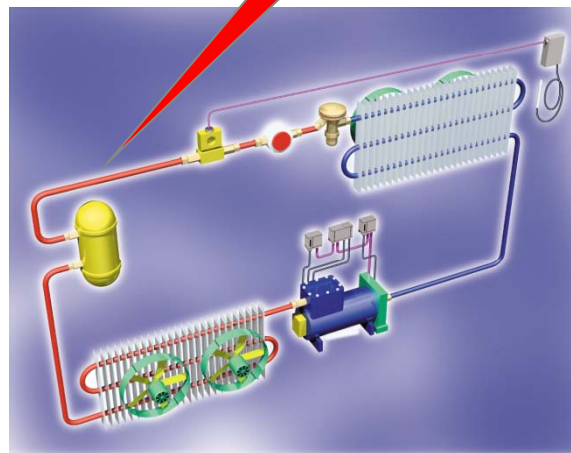
Typical Chiller P-H Diagram - R134a



Desuperheater

Refrigerant to water heat exchanger

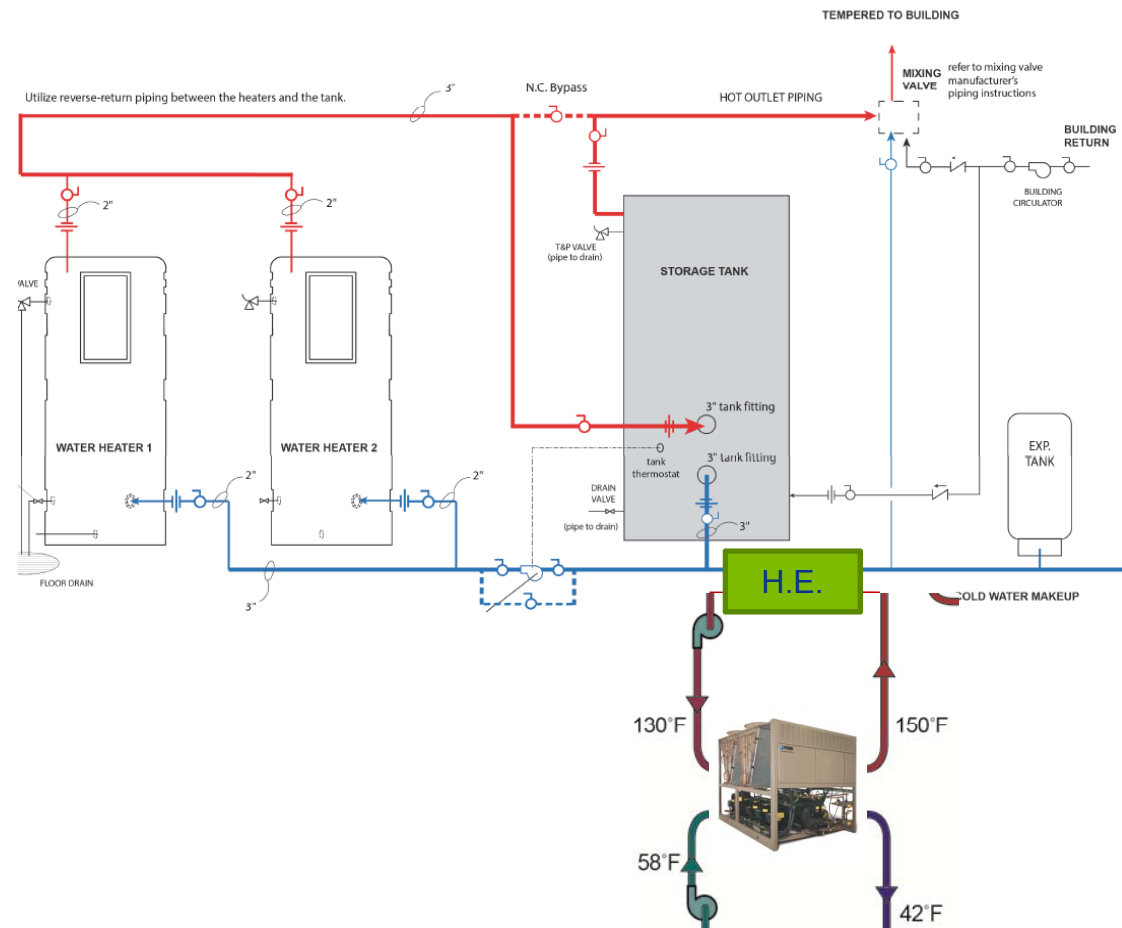
- Produces 140°F water
- Factory standard option
- Inexpensive
- Simple



Desuperheater for Domestic Hot Water Heating

Bill's Recommendation

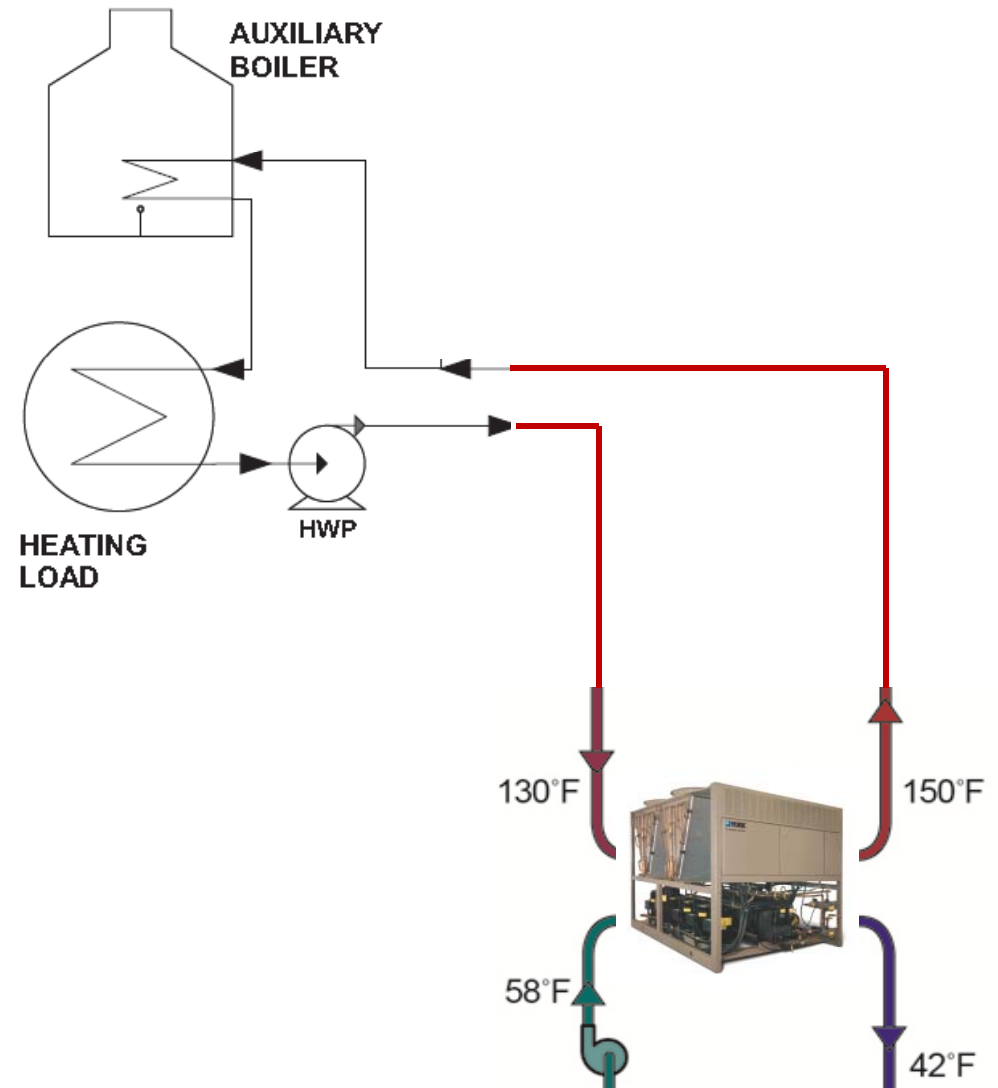
- Heat exchanger tempers the incoming domestic cold water.
- The desuperheater pump runs continuously.
- No temperature control is required because the desuperheater water is not warm enough to overheat the DHW.
- The desuperheater produces whatever hot water temperature is available
- Remaining heat rejected in the air cooled condenser.



Desuperheater for Hot Water Heating

Heat Recovery is a standard air cooled chiller option

- Desuperheater adds whatever heat is available.
- Boiler adds additional heat
- Boiler is able to satisfy the entire heating load.

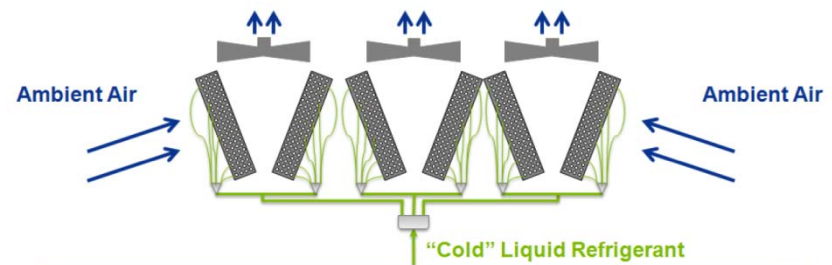
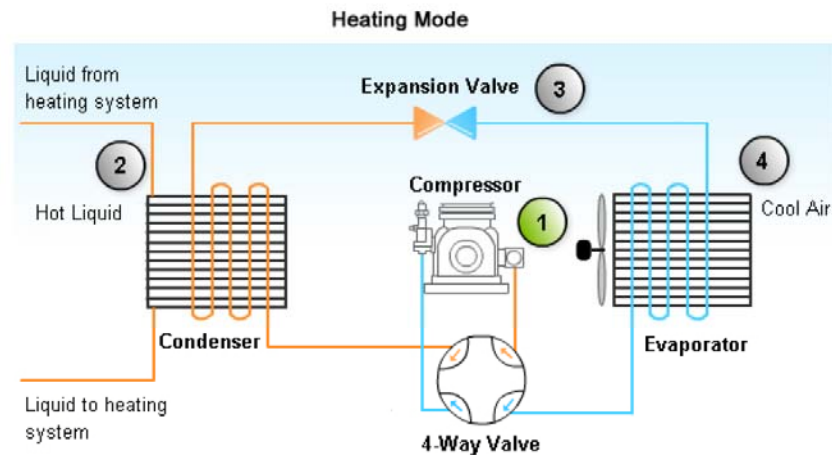


**Air to Water Heat
Pumps**

Air to Water Heat Pump

A 'chiller' that makes hot water

- Ambient air is cooled
- Heat is rejected into the water loop
- Produces 130°F water at 32°F ambient



Efficiency

Turn off your boiler. Turn on energy savings.

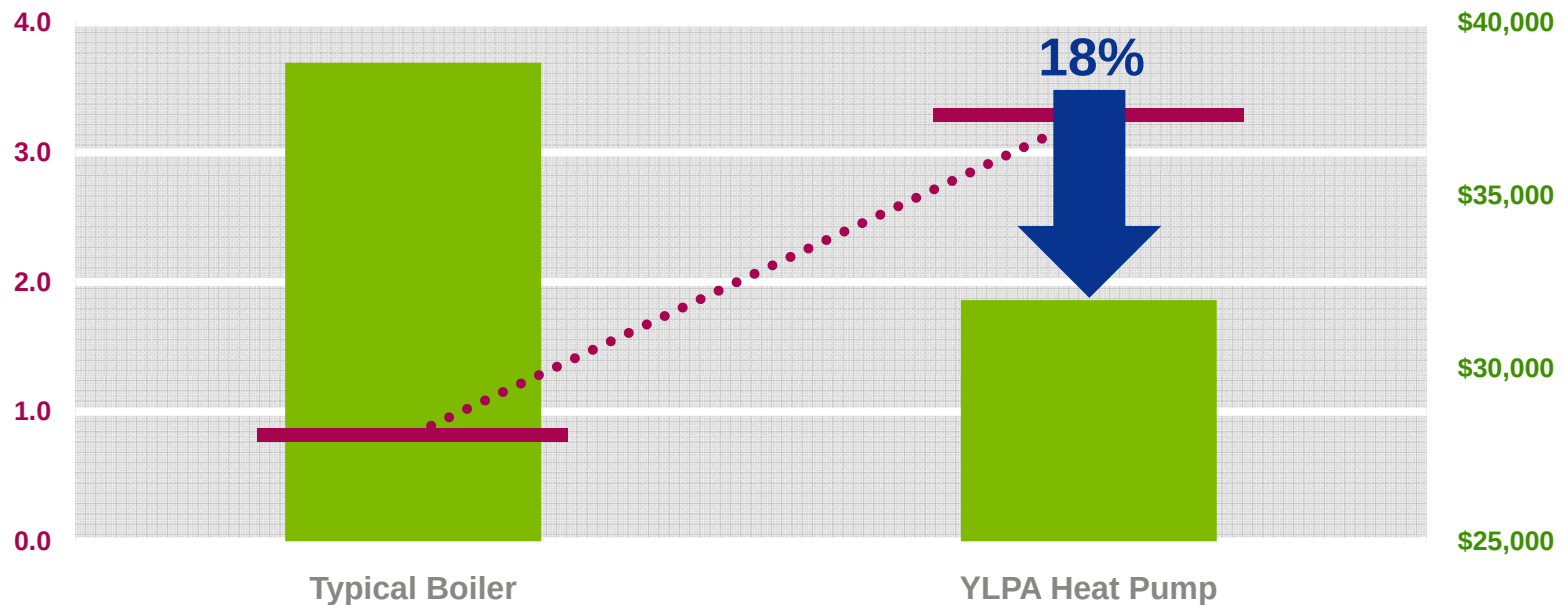
The most efficient way to heat liquids

- Three times higher COP than a typical boiler
- Produce hot water up to 130° F at 32° F
- Capable of producing hot water above 116° F at 14° F.

Maximize heat pump
operating hours to
maximize system
efficiency and
savings

Efficiency (COP)

Annual Energy Cost



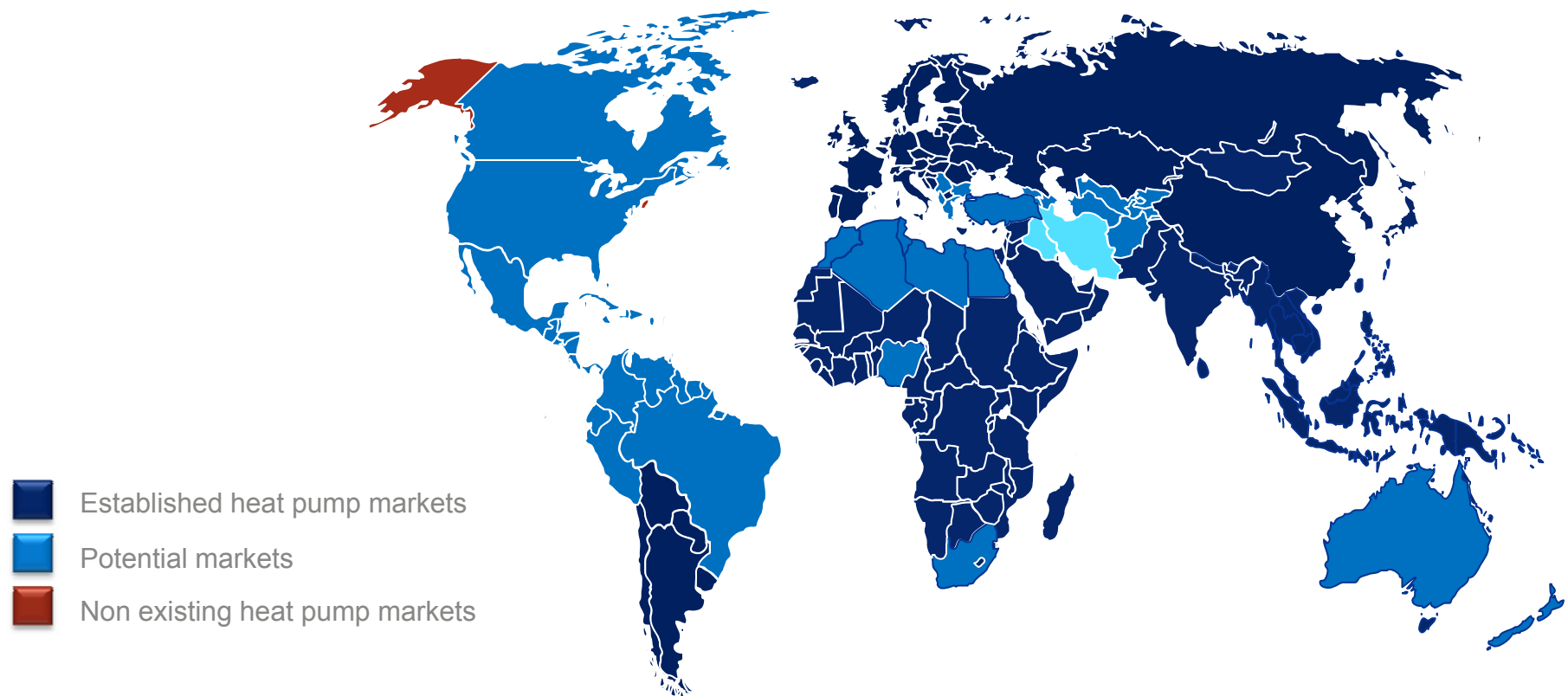
Energy Rate: Electricity 0.1 \$/kWh; Gas 9.17 \$/MMBTU

Why are you telling me about heat pumps?

York's fastest growing market

Proven by experience

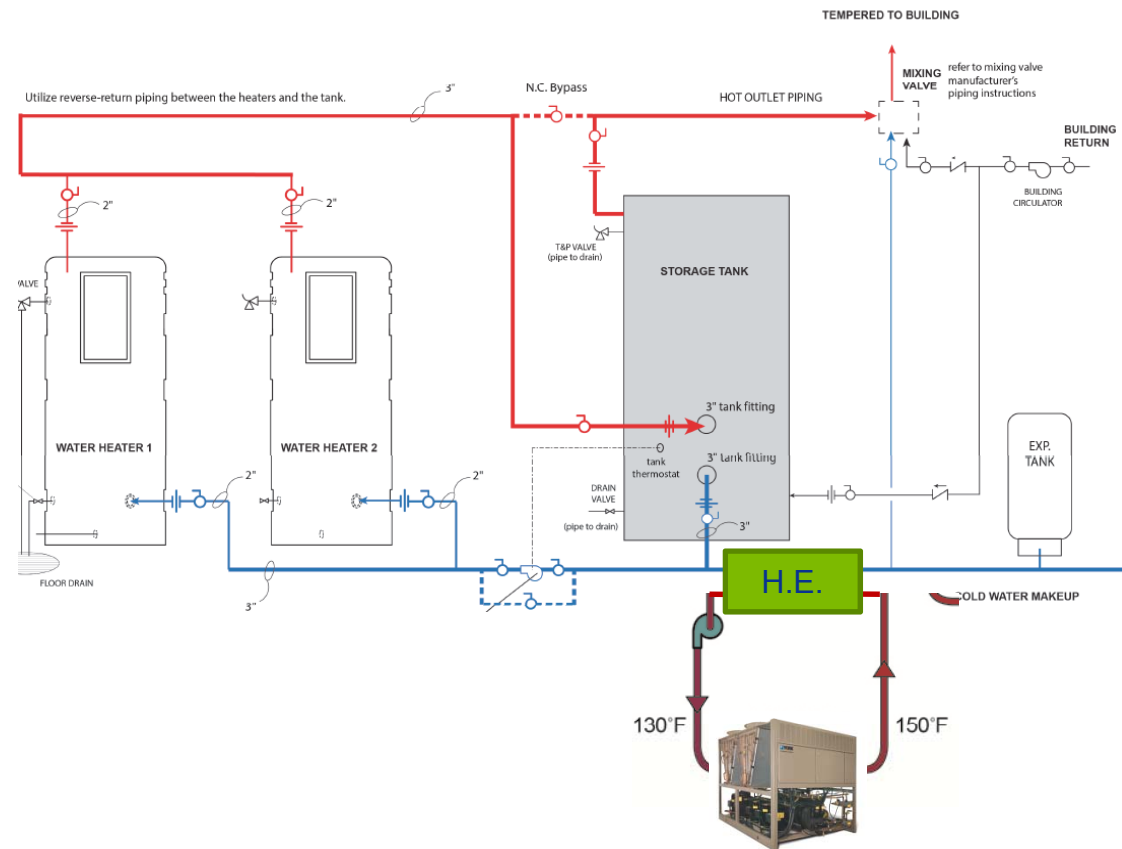
- More than 30 years experience in nearly all Heat Pump markets globally
- Selling YLPA since 2010 in Asia and Europe



Air to Water Heat Pumps for Domestic Hot Water Heating

Bill's Recommendation

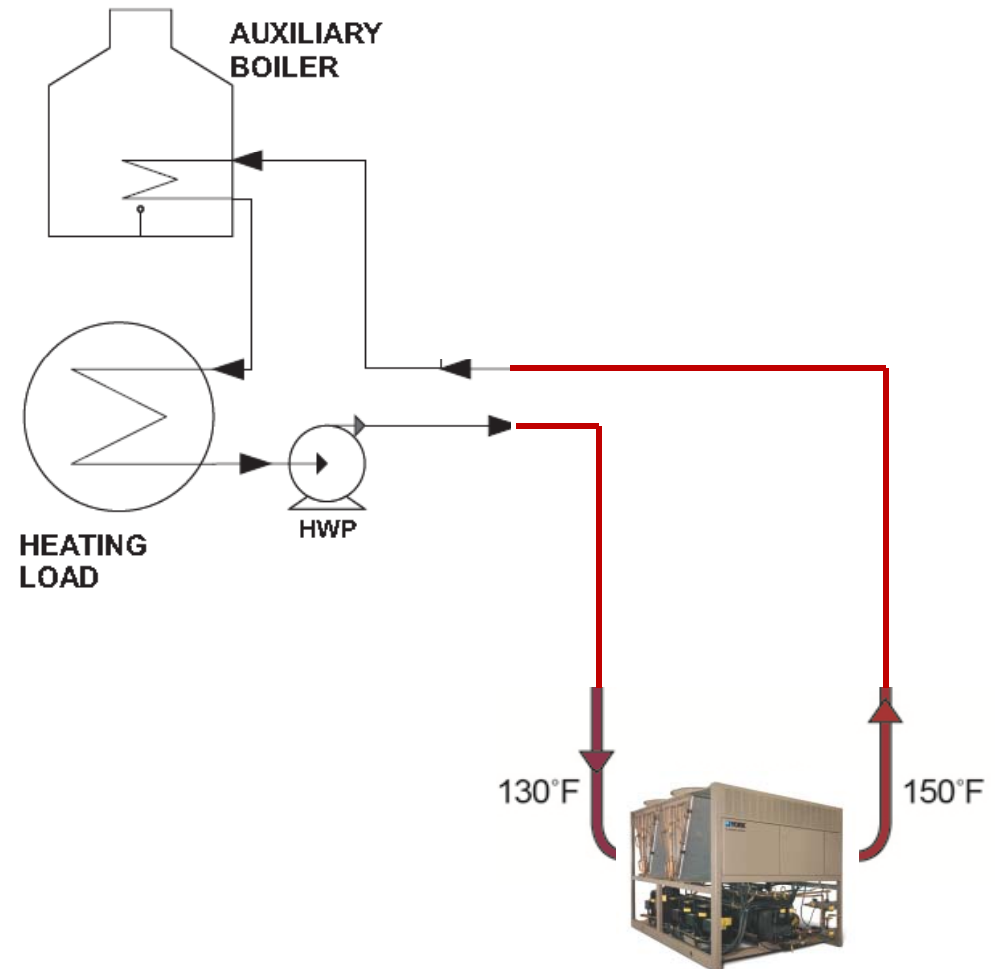
- Heat exchanger tempers the incoming domestic cold water.
- The heat pump pump runs continuously.
- Heat pump controls maintain the leaving hot water temperature



Air to Water Heat Pumps for Hot Water Heating

Air to water heat pump is a cataloged product

- Base load the heat pump.
- Boiler adds additional heat
- Boiler is able to satisfy the entire heating load.



**Be the smartest
person in the room**



Compressor types

Two types of compressors are available

- **Positive Displacement**

- Scroll 50 to 200 tons
- Screw 100 to 435 tons

- Scrolls and screws lose capacity at high temperatures and pressures, but keep working

- **Non – positive displacement**

- Centrifugal 250 to 5500 tons
- Centrifugals surge at high pressure and low loads. Remind the mechanical engineer that domestic hot water loads vary widely.



Scroll



Screw

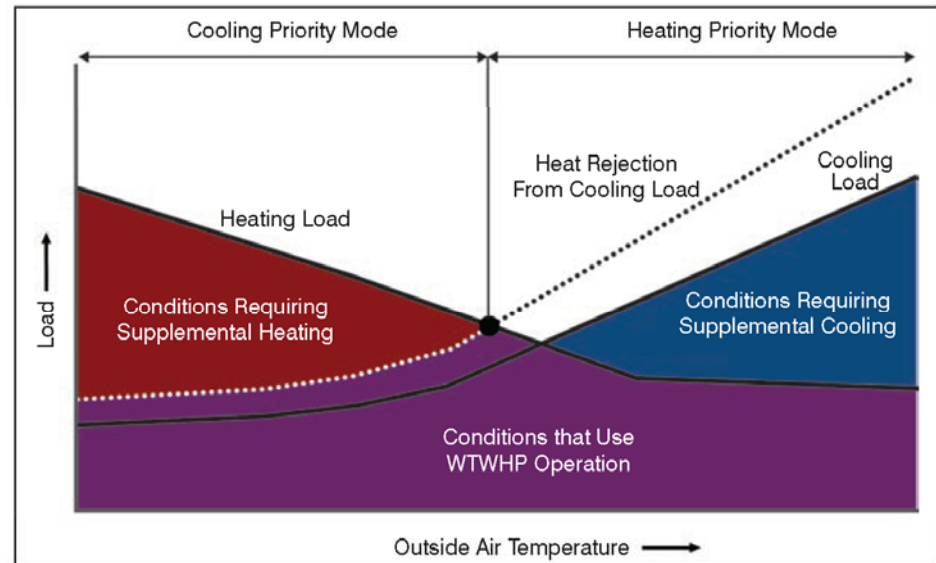


Centrifugal

Cooling Load Required to make Hot Water

Heat pumps and heat recovery use the building as a heat source

- Cooling loads vary
 - Time of day
 - Day of the week
 - Time of year
- Failure is not an option!
 - Always require a boiler sized for 100% of the load
 - Consider heat pump or heat recovery as an unreliable heat source



Chillers are not Boilers

Chillers vs Boilers

- Chillers are expensive vs. boilers
- Chillers are complex refrigeration devices vs. a gas water heater
- Chillers have minimum capacity of about 10% vs. boilers with low turndown
- Chillers can surge or trip on safeties at low load conditions vs. boilers that are designed to fire at low loads
- Chillers require a heat exchanger and pump vs. boilers that take domestic water directly.



≠

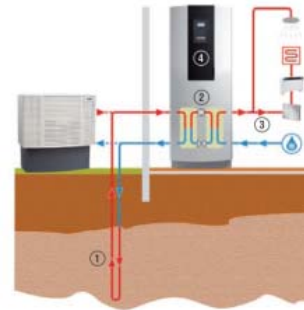


Be Aware of the Deeply Weird

Heat Pump and Heat Recovery Technology

- Coupled to the ground loop
- Heat available for a water source loop
- Multiple stage centrifugal compressors for high temperatures (150 to 180°F)
- Custom equipment

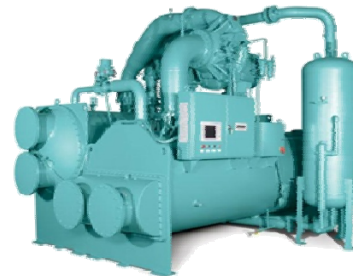
Ground-Source



Water-Source



Multiple Stages



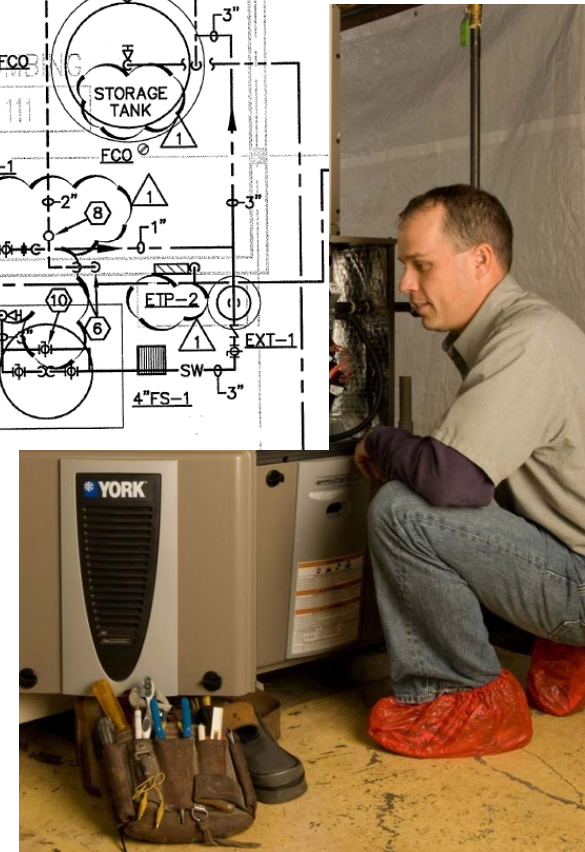
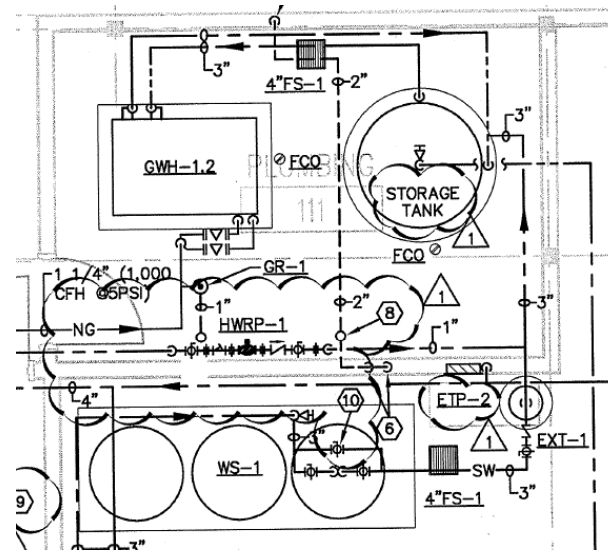
Custom Equipment



Hot Water Systems Should be Simple

Do not sacrifice simplicity for energy savings

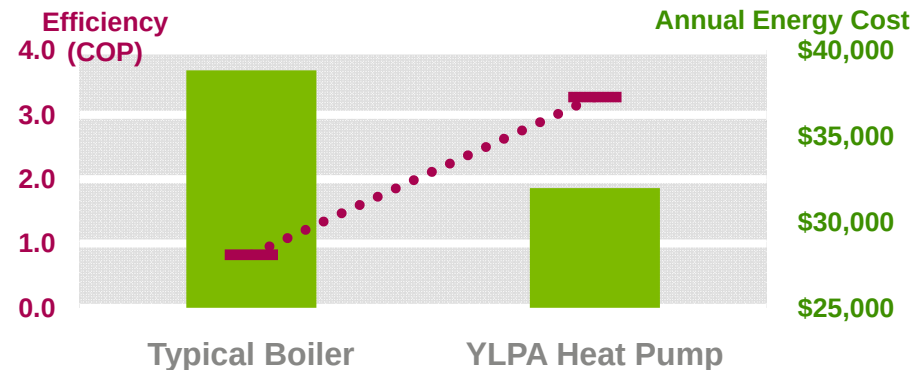
- Improve on standard designs
- Add heat exchangers to temper incoming water
- Avoid complicated controls
- Failure is not an option!
 - Plumbers must understand the system and fix it quickly



Advocate Heat Pump and Heat Recovery Technology

Proven, reliable technology

- Energy savings are true
- Least expensive option is most attractive
 - Desuperheater
 - Heat recovery
- Dedicated heat pumps are more expensive but should be investigated for large heating loads
 - Hospitals
 - Student housing
 - Hotels
 - Residential
 - Natatoriums



Summary

- Heating systems must be simple and reliable
- Conventional boilers COP is .85 or less
- Heating only refrigeration equipment has a COP > 3
- Heating and cooling refrigeration equipment has a COP > 6
- Available technology:
 - Water to water heat pump
 - Water to water heat recovery
 - Desuperheater
 - Air to water heat pump
- Systems payback is often less than a year
- Promote the use of waste heat for domestic hot water heat,
- Be the smartest person in the room

Using Waste Heat for Domestic Hot Water Heating Questions?

Bill Chalmers P.E., CPD

Thanks for being interested.



Bill Chalmers P.E., CPD

Thanks for being interested!
Questions?

