Electrifying Hospitals

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CANNONDESIGN

SHAPING A BETTER TOMORROW
NOVEMBER 11-12, 2024

Learning Objectives

- Explain the concepts of decarbonization and electrification as they pertain to healthcare facilities
- Design ventilation and process cooling systems using appropriate equipment and technologies to maximize the recovery and use of previously expended energy
- Apply plant and utility systems, equipment, and concepts to amplify the energy recovered at the building level
- Identify control strategies to permit the building and plant level systems to communicate and optimize energy consumption

SHAPING A BETTER TOMORROW
NOVEMBER 11-12, 2024

2024 Midwest Healthcare Engineering
CONFERENCE & TRADE SHOW

Outline/Agenda

1 Background

2 Implementation Approaches

3 Keys to Implementation

4 Building Level

5 Plant Level

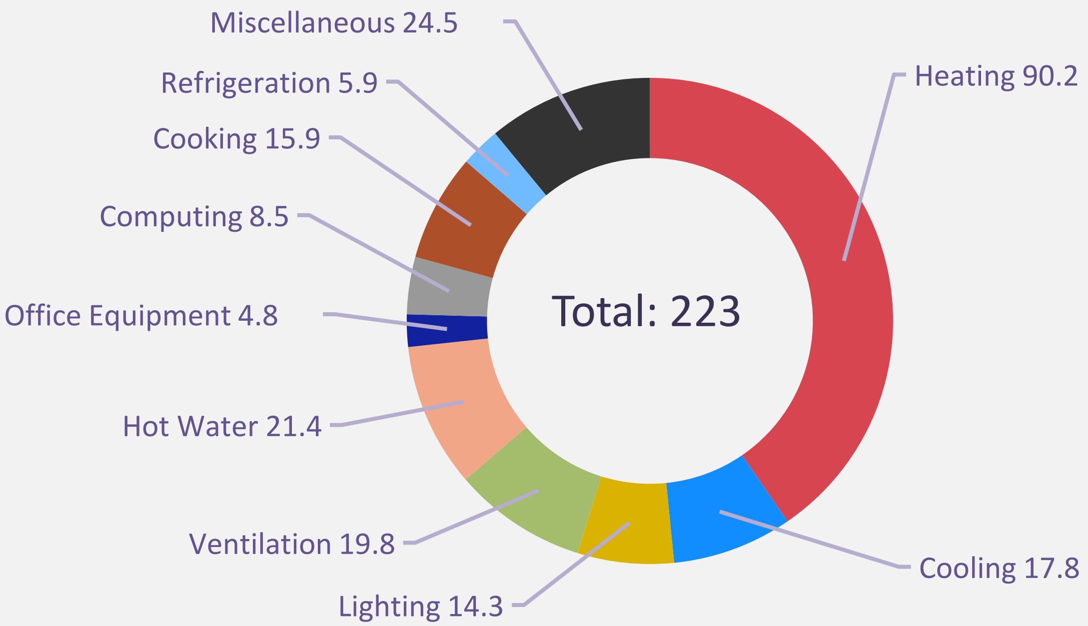
Background

- + Healthcare Energy Use & Emissions
- + Decarbonization & Electrification
- + Power Production
- + Federal Incentives
- + State & Local Governmental Regulations
- + Carbon Emissions

Energy Use in Hospitals

+ Account for 5.5% of commercial building energy use, but only 2% of the floor space
+ Consume 10% of the total energy used in U.S. commercial buildings
+ $8 billion spent annually on energy
+ 8.5% of U.S. greenhouse gas emissions

MEDIAN HOSPITAL END USE ENERGY INTENSITIES (KBTU/SQFT/YR)



Challenges to Emissions Reduction in HC

+ 24/7/365 Mission Critical — Can't go offline
+ High Air Change Rates — Infection Control
+ Patient Satisfaction/Comfort (HCAHPs)
+ Filtration and Air-quality

Energy consumed in hospitals supports more types of services than typical facilities:

+ Laboratories, Living Quarters, Laundry
+ Food Services, Central Sterile Processing
+ Medical Imaging Equipment

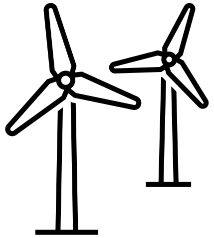
Hospital Decarbonization Pathway

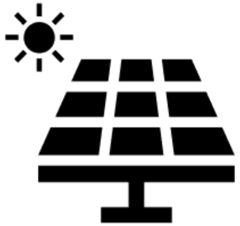
Decarbonization starts with electrification at the building and plant levels

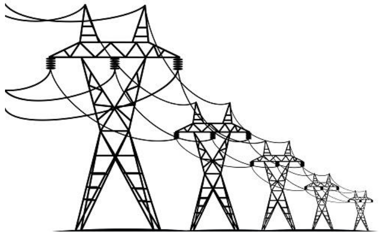
Move from on-site fossil fuel use to 100% electrical power

Ultimately purchase/produce electricity using 100% renewable sources

A **cleaner grid** will **unlock the full potential** of electrification



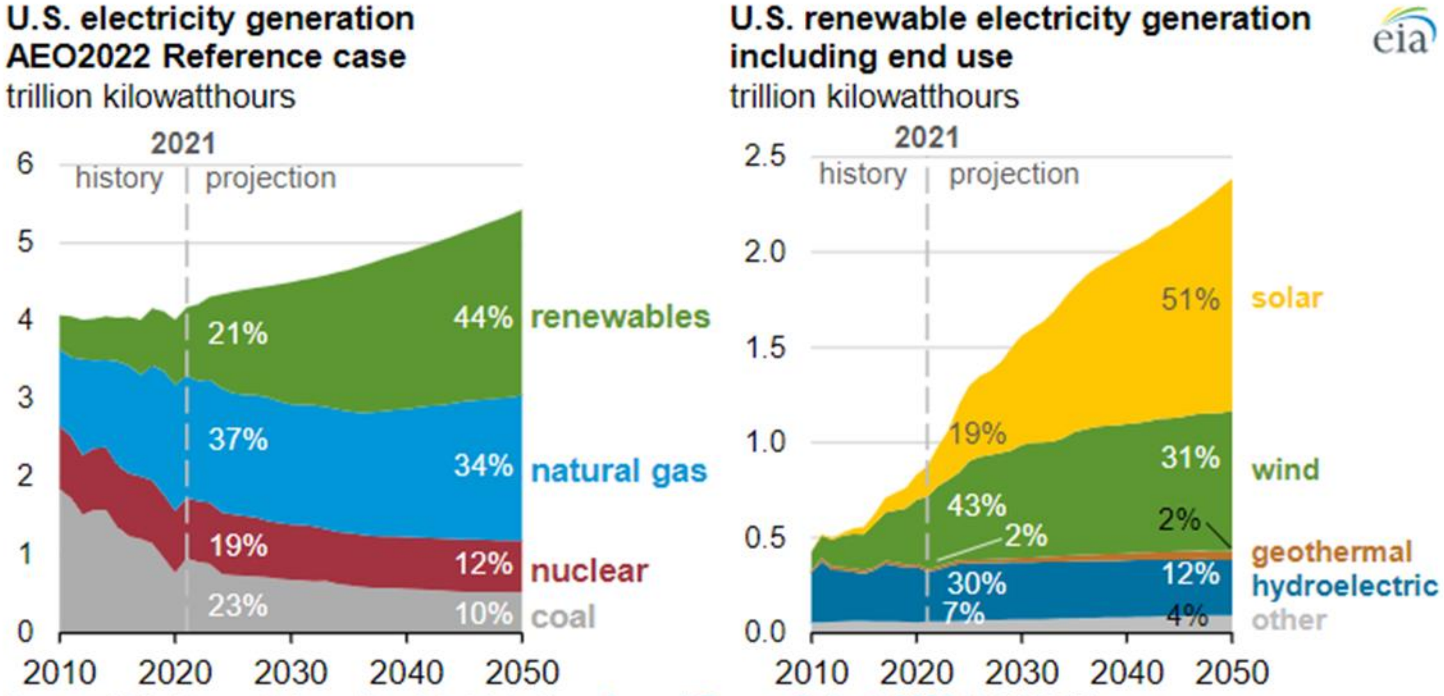




US Energy Production

MARCH 18, 2022

EIA projects that renewable generation will supply 44% of U.S. electricity by 2050

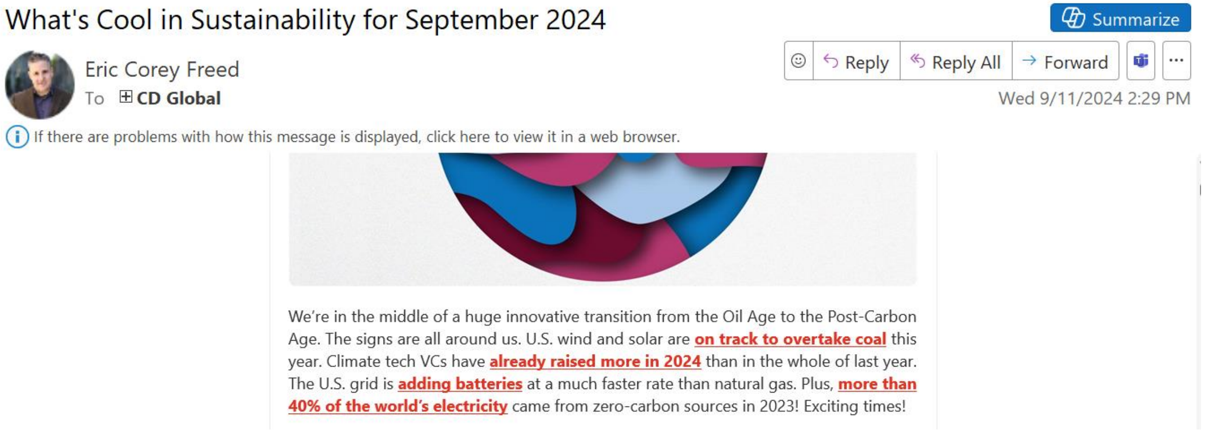


Source: U.S. Energy Information Administration, *Annual Energy Outlook 2022* (AEO2022)
Note: Biofuels are both shown separately and are included in petroleum and other liquids.

Government Incentives

The Production Tax Credit and Investment Tax Credit have driven deployment of wind farms and solar arrays in the U.S.

Majority of all electrical capacity additions in recent years have been



What's Cool in Sustainability for September 2024

Summarize

Eric Corey Freed

To CD Global

Reply Reply All Forward

Wed 9/11/2024 2:29 PM

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We're in the middle of a huge innovative transition from the Oil Age to the Post-Carbon Age. The signs are all around us. U.S. wind and solar are on track to overtake coal this year. Climate tech VCs have already raised more in 2024 than in the whole of last year. The U.S. grid is adding batteries at a much faster rate than natural gas. Plus, more than 40% of the world's electricity came from zero-carbon sources in 2023! Exciting times!

Inflation Reduction Act of 2022

Extends the **Production Tax Credit** and **Investment Tax Credit** until 2025.

Greenhouse Gas Reduction Fund provides the EPA with $27 billion to award for competitive grants for clean energy and climate projects.

The Act provides the Department of Energy with $40 billion in loan authority for innovative energy technologies, including renewable energy systems, carbon capture, nuclear energy and critical minerals processing, manufacturing and recycling.

White House Health Sector Climate Pledge

102 Healthcare organizations representing **837 hospitals** have signed the White House/HHS Health **Sector Climate Pledge.** Goal is to meet bold targets for emissions reduction and climate resiliency.

AdventHealth, Advocate Aurora Health, Advocate Children's Hospital, AltaMed Health Services Corporation, Ascension, Aspirus Health, *Atlantic Health System*, Atrium Health, Baystate Health, Berkshire Health Systems, Beth Israel Deaconess Medical Center, Boston Children's Hospital, Boston Medical Center, Care Alliance Health Center, CentraState Healthcare System, Cherokee Health Systems, Children's National Hospital, Children's Hospital Los Angeles, ChristianaCare, CommonSpirit Health, Dana-Farber Cancer Institute, DaVita, Denver Health and Hospital Authority, Eastern Connecticut Health Network, Englewood Health, Gillette Children's, Greater Lawrence Family Health Center, Gundersen Health System, Hackensack Meridian Health, Hartford HealthCare, HealthPartners, Henry Ford Health, HonorHealth, John Muir Health, Kaiser Permanente, Keck Medicine of USC, Kedren Health, Legacy Health, Mass General Brigham, Memorial Health Services (MemorialCare), Montefiore, Mount Sinai Health System, Nebraska Medicine, Northern Arizona Healthcare, Northern Light Health, Northwell Health, NYC Health + Hospitals, NYU Langone Health, OhioHealth, OLE Health, Oregon Health & Science University, Providence Health, Rochester Regional Health, Rush University System for Health, RWJBarnabas Health, Seattle Children's Hospital, Southcoast Health, SSM Health, Stanford Children's Health, Stanford Health Care, Stanford Health Care Tri-Valley, Steward Health Care System, Stony Brook University Hospital, Sun River Health, Texas Children's, The Valley Health System, Tufts Medicine, University Medical Center of El Paso, University of Arkansas for Medical Sciences, University of California Health, University of Nebraska Medical Center, University of Pittsburgh Medical Center, University of Utah Health, UW Medicine, Valley Children's Healthcare, Waterbury Hospital, WellSpan Health, Western Wisconsin Health

Carbon Emissions – Scope 1, 2, 3

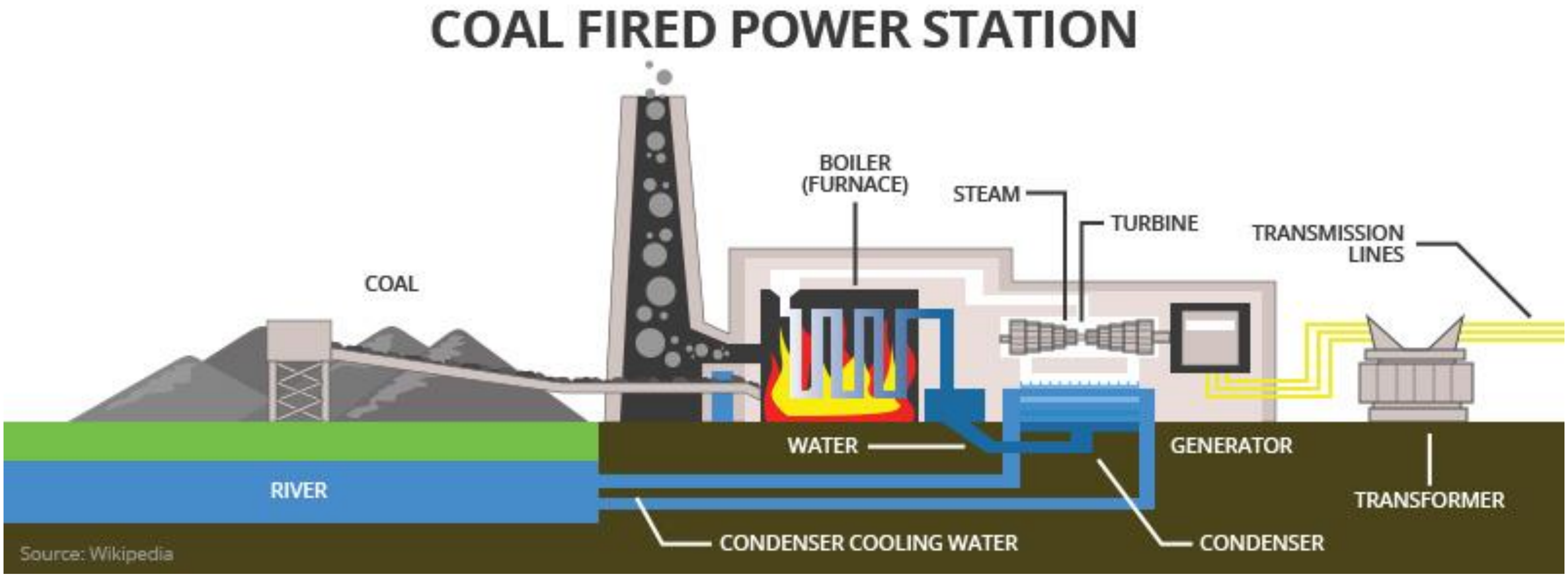
Scope 1 emissions:
Direct emissions from sources that are owned or controlled by the hospital, such as emissions from combustion of fossil fuels in on-site boilers or generators.

Scope 2 emissions:
Indirect emissions from the generation of purchased electricity, heating and cooling consumed by the hospital.

Scope 3 emissions:
All other indirect emissions that occur in the hospital's value chain, including emissions from purchased goods and services, transportation and waste disposal.

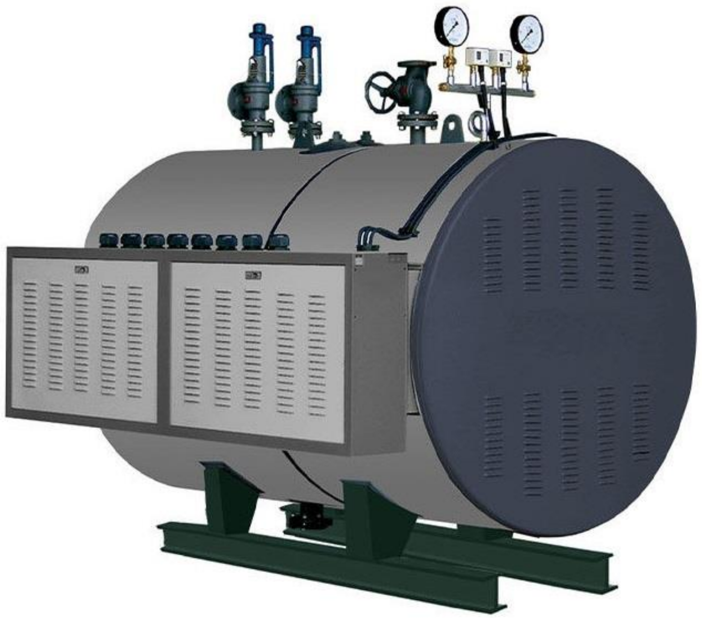
The Greenhouse Gas Protocol

Scope 2 Emissions



Scope 1 Emissions – Paradox?

Electric Boiler = Zero Emissions



Condensing Gas Boiler > Zero Emissions

Implementation Challenges

+ Existing campus thermal utility systems: steam, chilled water
+ Insufficient electrical power: normal and emergency
+ Regional electrical grid may be supported by coal
+ Energy codes

Implementation Approaches

Incremental

Transitional

Full Implementation

Incremental and Transitional Strategies

Energy Conservation

Eliminate/Minimize Steam Usage

Low-temperature Hot Water

Keys to Implementation

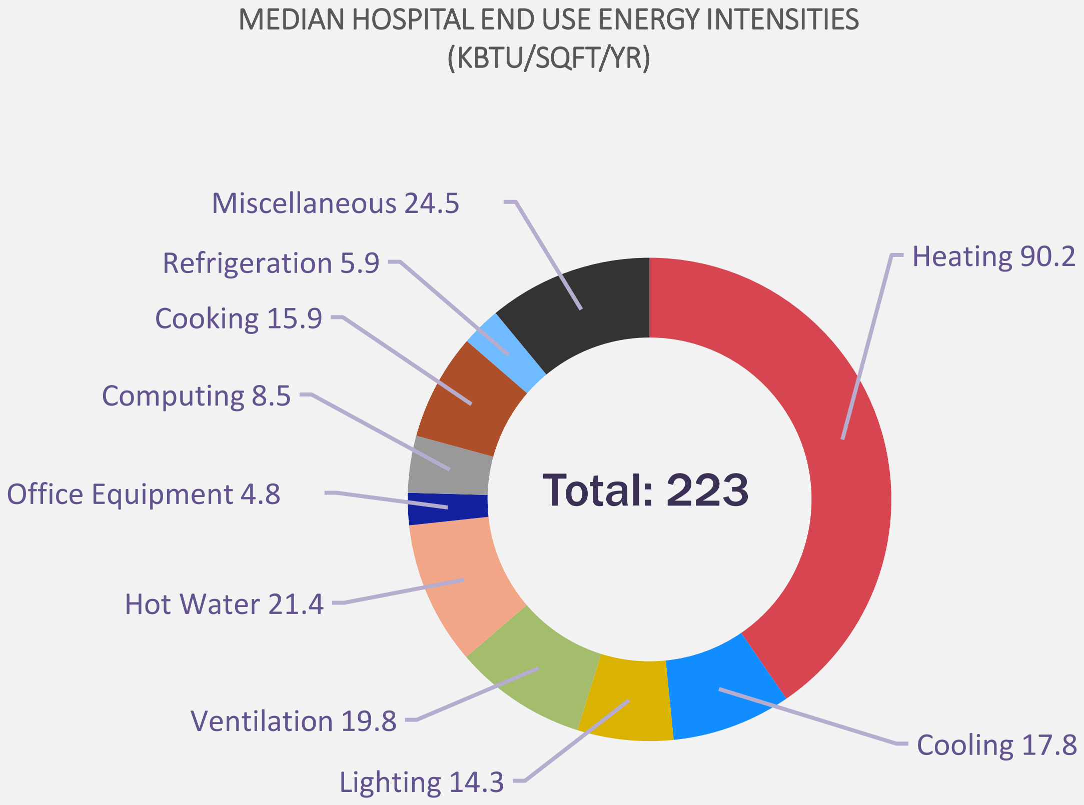
→ Reduce Energy Consumption

→ Reduce or Eliminate Steam Use

→ Recycle Thermal Energy - Heat

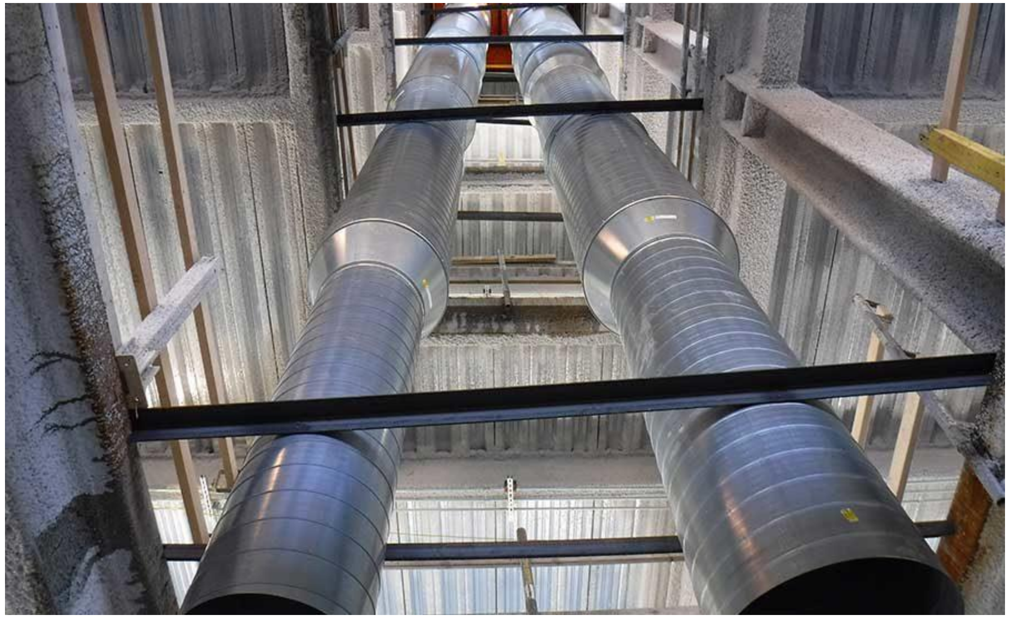
Energy Use in Hospitals

- Heating/reheat the largest end use
  - includes steam/humidification
- Ventilation + cooling
- Internal loads (plug, MRIs, etc.)
- Lighting



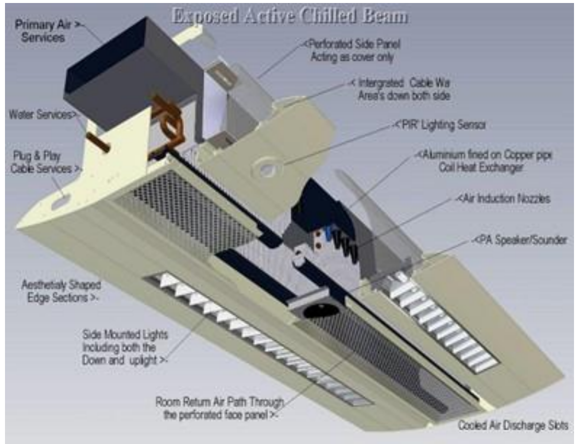
Minimize Fan Energy

Reduce velocities in ductwork and across filters and coils



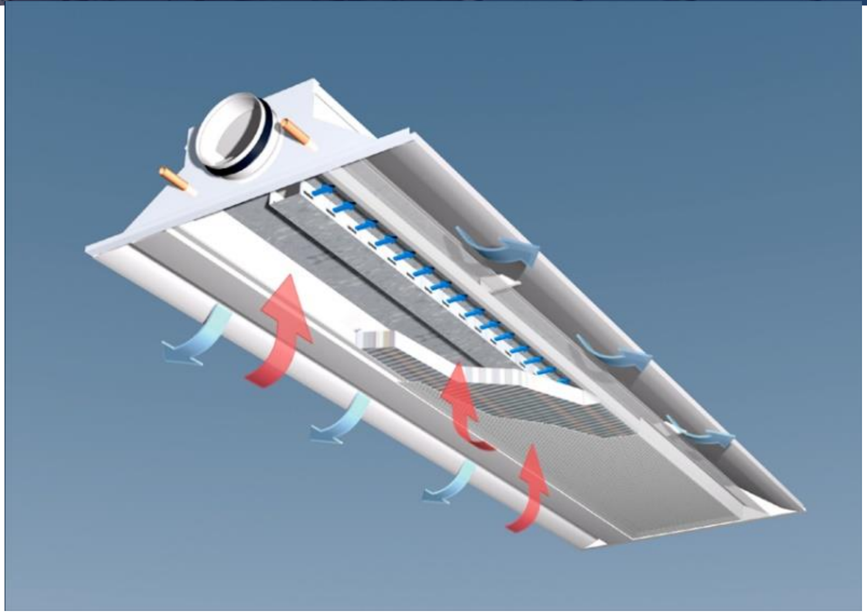
Eliminate Reheat

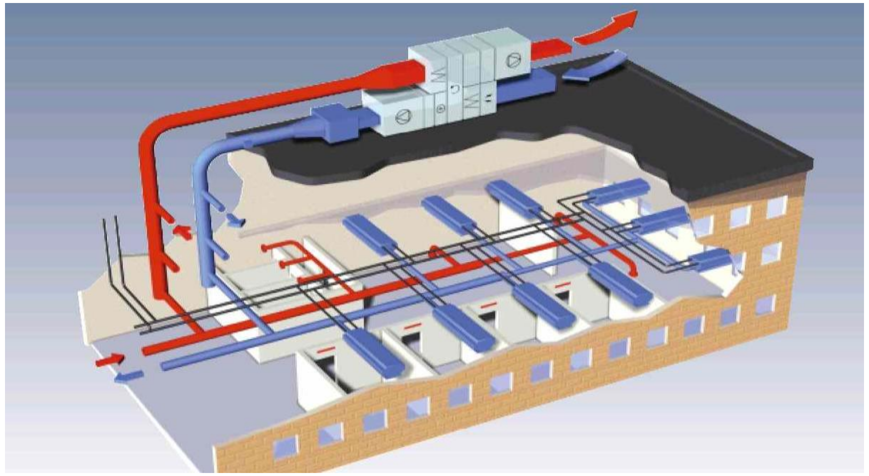
+ Chilled beams in administrative and large circulation spaces
+ Active beams provide fresh air and passive beams supplement
+ Minimizes fan energy and eliminates reheat
+ Perimeter fan coils for administrative spaces



ASHRAE Standard 170 - Ventilation

- Changes to the standard have allowed the use of **active chilled beams** in patient rooms
- Used with **Dedicated Outside Air Systems** (DOAS), chilled beams can save energy - eliminates wasteful reheat
- Delivers the correct amount of outside air, no over ventilation
- Patient rooms can operate with 100% outside air without recirculating air between patient rooms.

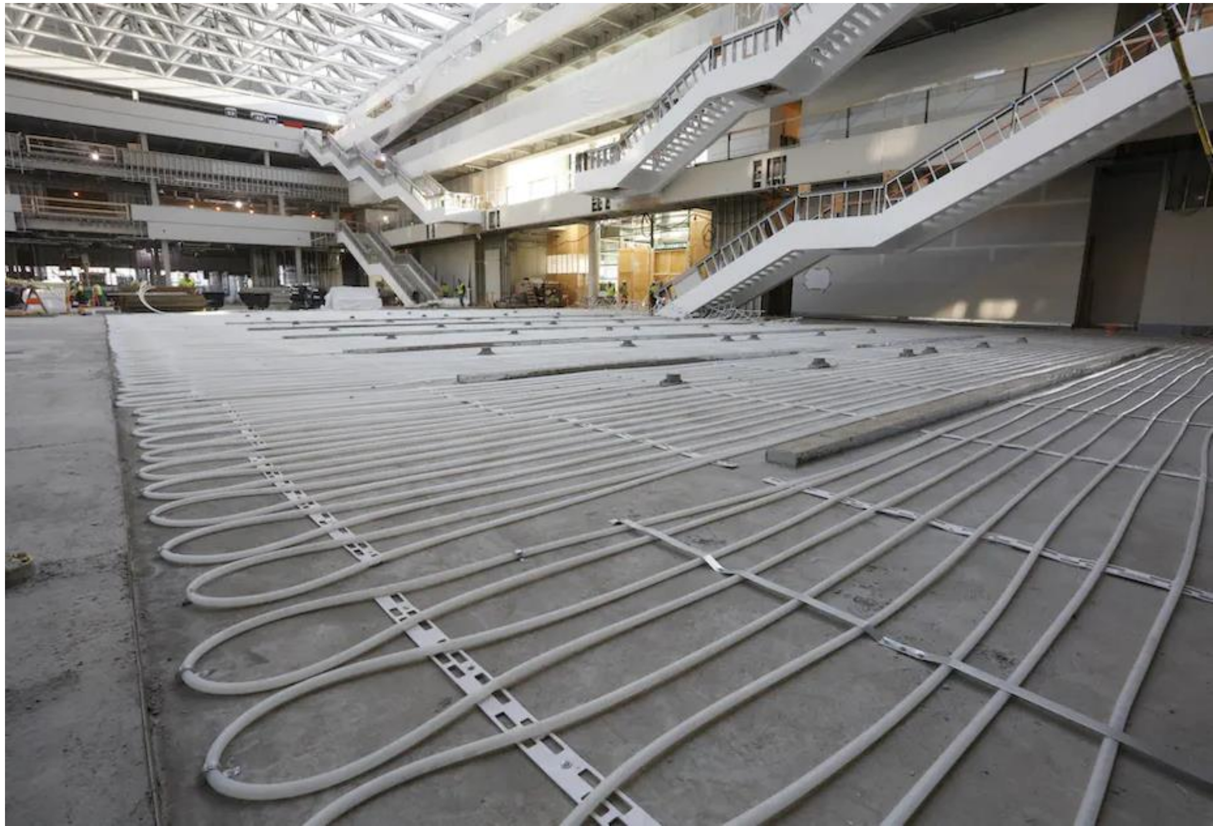




Radiant and Passive Solutions

Atria and lobbies can be treated with radiant floors for heating and cooling

Eliminates reheat and fan energy

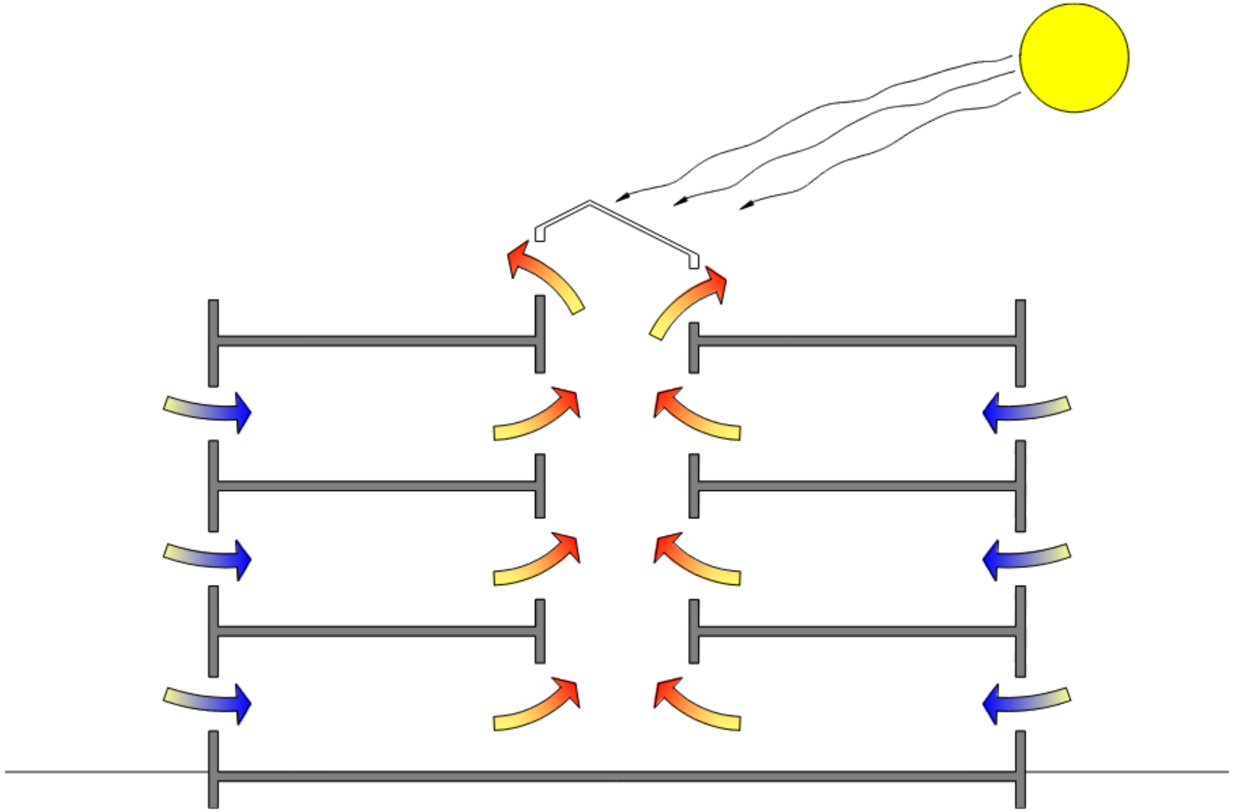


Natural Ventilation

An addendum to ASHRAE Standard 170 regarding filtration of air and minimum outdoor air requirements have paved the way to permit natural ventilation in certain healthcare areas such as:

- General patient rooms
- General exam rooms
- Physical therapy

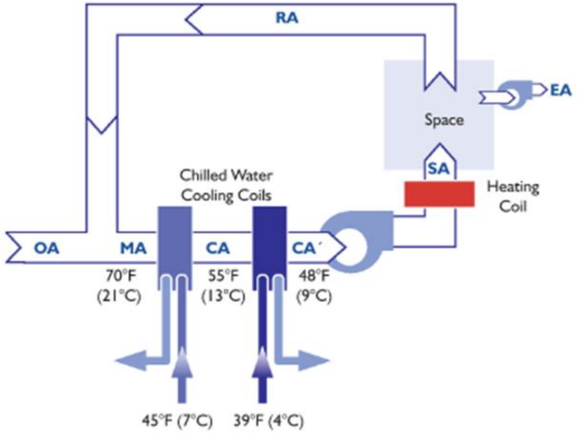
Natural ventilation has been successfully implemented in health care facilities throughout the world.



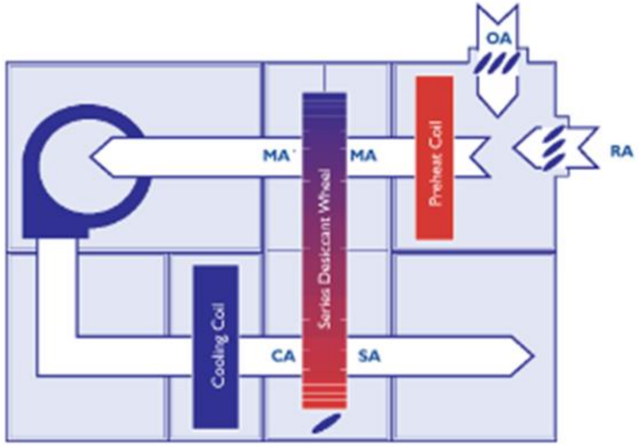
Humidity Control in Operating Rooms (1)

Base Case: Install two cooling coils in series with the first taking the air to 55˙F and the second to 48˙F to achieve 62˙F space temperature and below 60% relative humidity. Requires "surgery" chillers to deliver39F water to second coil.

Alternative: Type III desiccant wheel in series to transfer energy between the mixed air and supply air streams. Use 42˙F to 44˙F … oling coil.



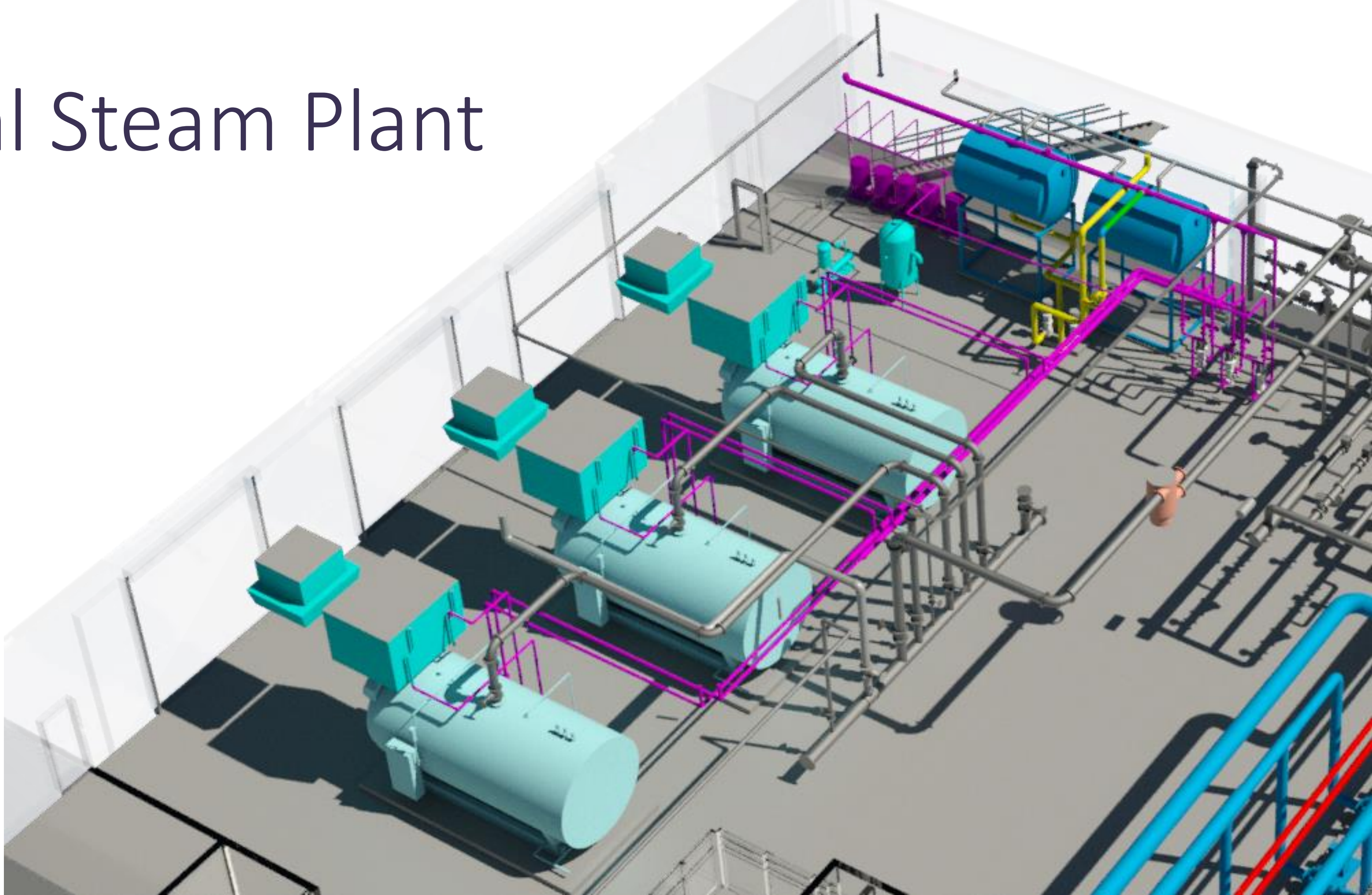
Pros/Cons: Can use warmer chilled water from the central plant. **Significantly reduces cooling required**. **Can eliminate the need for re**



Keys to Implementation

- → Reduce Energy Consumption
- → Reduce or Eliminate Steam Use
- → Recycle Thermal Energy - Heat

Typical Hospital Steam Plant



3 Boilers, Deaerator – **Massive radiation loses**

WINTER

- 2-Operating
- 1- Hot standby

SUMMER

- 1- Operating
- 1- Hot standby
- 1- Lay up

Steam Piping Distribution Losses

+ Radiation, convection, conduction from:

    Piping, Valves, Traps

+ Faulty steam traps

+ Flash steam through vents

+ Blowdown

Trim back the branches of the steam distribution system

Eliminate/Minimize Use of Central Plant Steam

Take these off the central plant:

+ Sterilizers
+ Cart Washers
+ Washer/Disinfectors
+ Laundry
+ Food Service

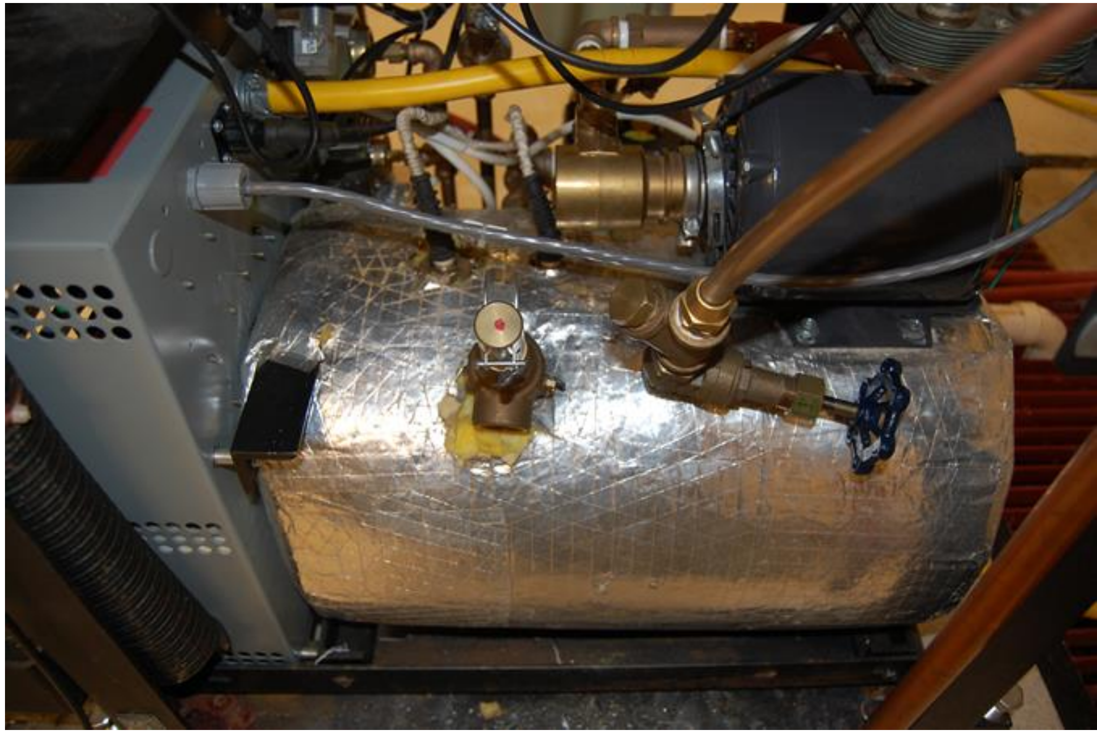
Integrated (Electric) Steam Sterilization

Base Case: Medium pressure steam from boilers or cogeneration plant delivered to sterile processing and flash sterilizers.

Alternative: Medical equipment manufacturers often have an option for integral or stand-alone steam generation through electric power.

Advantage: No standby or distribution losses increasing overall efficiency.

Disadvantage: Increase throughput time and could require need for extra equipment depending on capacity needed.



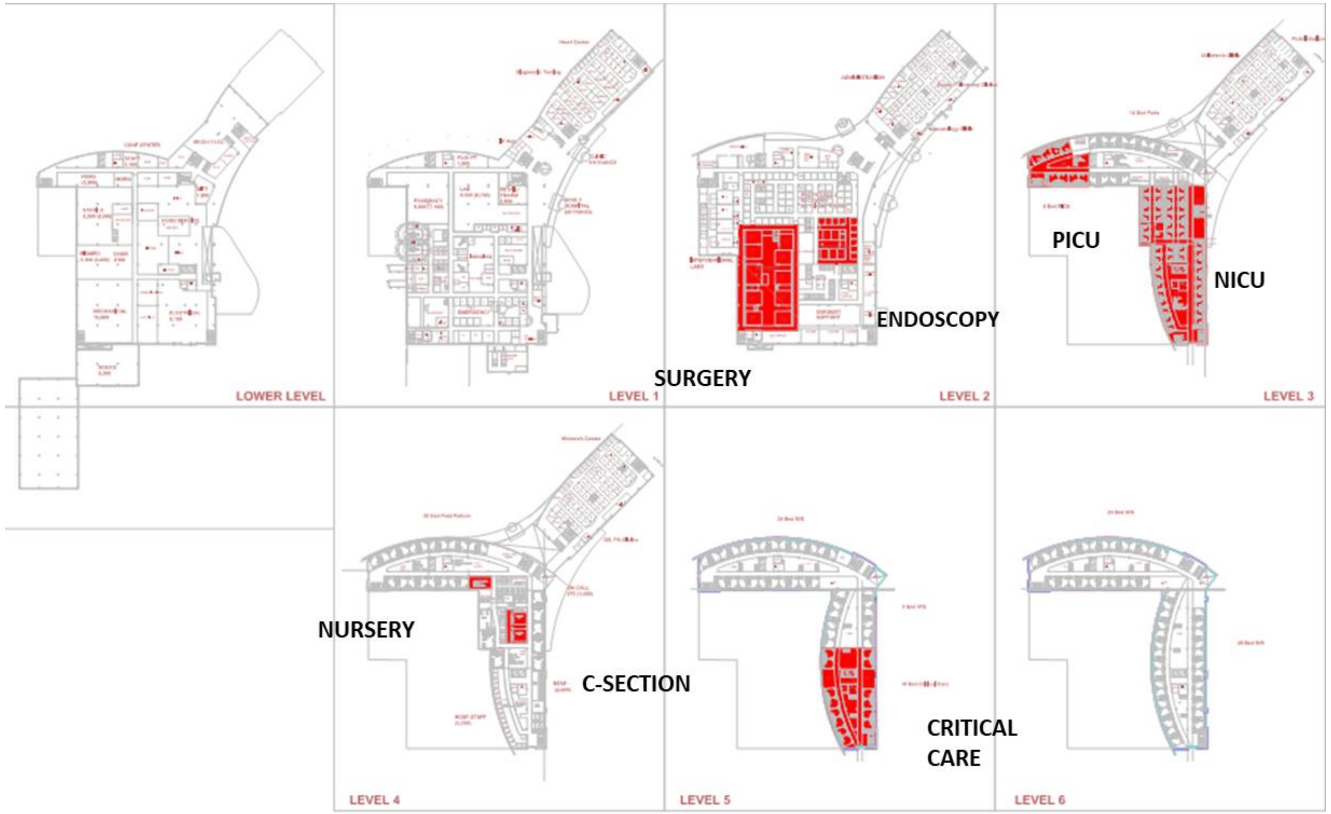
Humidification Levels

Base Case: Prior to 2008 most areas of a hospital were recommended to have a minimum relative humidity of 30% in the winter including patient rooms.

Alternative: Current guidelines have eliminated humidification for many areas and have lowered the minimums to from 30% to 20% in many areas such as operating rooms, procedure rooms, and recovery rooms.

Pros: going with the new guidelines will reduce first costs as well as energy and O&M costs.

Cons: Studies indicate that a minimum of 30% is beneficial to health. Some equipment and supply manufacturers list 30% minimum relative humidity in their O&Ms and packaging.

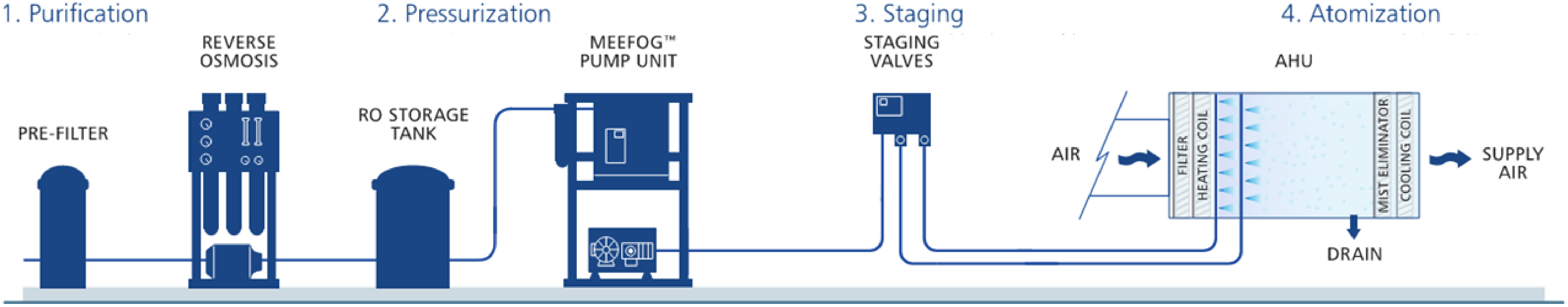


Humidification Methods

Base Case: Fossil fuel sources steam from boiler or cogeneration plant.

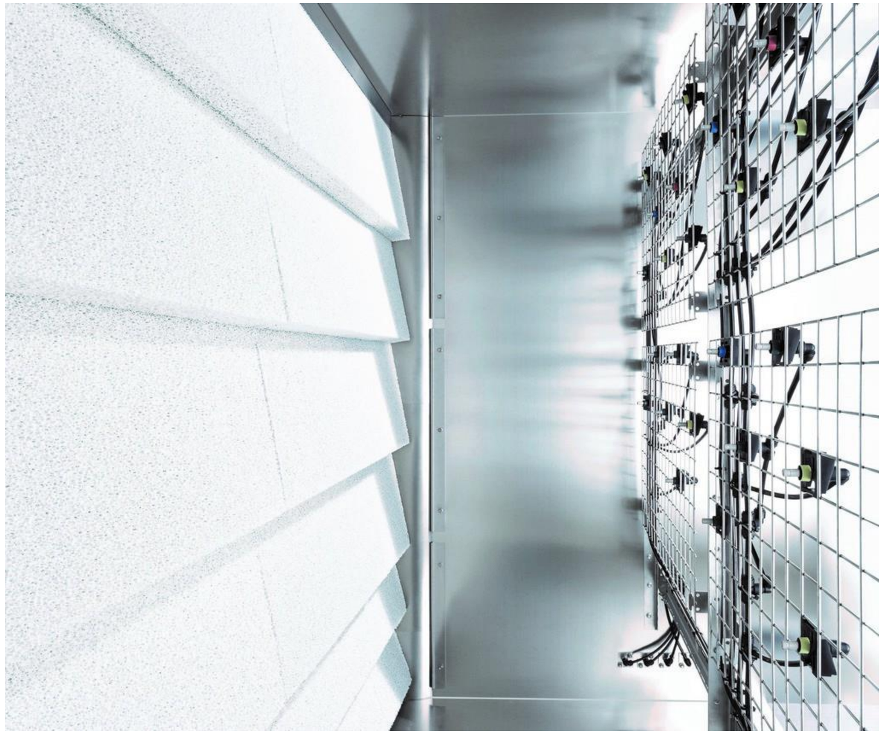
Alternative: Recent changes to the guidelines permit adiabatic humidification if the feedwater is RO and is treated with UV lights and submicron filter.

Pros/Cons: Adiabatic lowers the leaving dry bulb temperature, which a good strategy to couple with eliminating airside economizer.



ASHRAE Std 170 Humidification Requirements

- Adiabatic humidifiers are now acceptable
- Systems require
  - Reverse osmosis (RO) water
  - UV sterilization
  - Filtration
  - Moisture eliminators
  - Continuous circulation
  - Testing ports



Migrating to Hot Water

Easier to design a new facility this way

Existing facilities need overhaul

+ Replace steam and hot water coils in AHUs
+ Go to 2-row reheat coils in VAVs
+ Space for new boiler plant
+ Kitchen / laundry / sterilization
+ Humidification

Condensing Boilers – Transitional Approach

+ Condensing boilers can extract more energy out of the flue gases causing condensation to occur
+ Operate at higher system efficiencies
+ Boilers are smaller and don’t need to be kept in hot standby
+ Reduced radiation losses

Low Temperature Hot Water

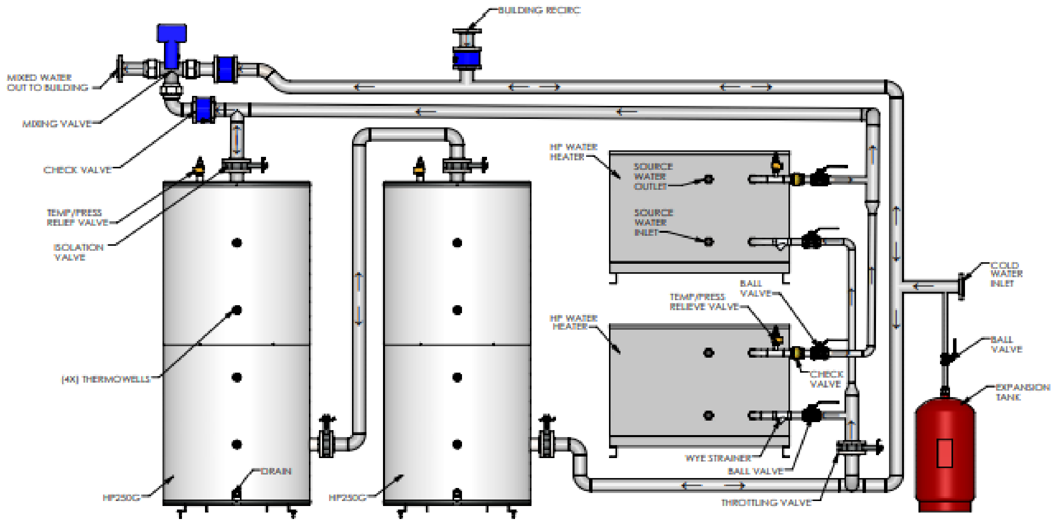
Low temperature hot water allows for better thermal efficiencies **now**

AND

Sets the stage for **future electrification**

Domestic Water Heating

+ Not a huge ANNUAL consumer, but…
+ Peak demands drive size of the steam plant
+ Need for hot water 24/7 requires dual fuel
+ Few manufacturers of dual fuel water heaters
+ Look at a hybrid with electric primary and steam a
+ Heat pump water heaters with electric resistance



Implementation Approaches

Incremental

Transitional

Full Implementation

Full Implementation of decarbonization requires **changing** how we **design** and **think** about building HVAC systems

Keys to Implementation

→ Reduce Energy Consumption

→ Reduce or Eliminate Steam Use

→ Recycle Thermal Energy - Heat

Conservation of Energy

Energy cannot be created or destroyed – Law of the Conservation of Energy. It can only be transferred or transformed from one form to another. Let's use this to our benefit.

Fortunately for consumers energy is cheap (ignoring externalities) considering what it does for us. This is bad for conservationists as good energy is often let go and not recycled as it is cheaper to consume more energy that recycle.

When a watt or btu is delivered to or generated in a building through occupants, lighting, daylighting, equipment, process… let's keep it, trap it.

Simultaneous Heating and Cooling

Energy Recovery and the Energy Code

+ Energy recovery is required for **extracting energy** from the exhaust air with some exceptions.
+ Arrange exhaust and relief air streams at air handlers to allow for effective heat recovery either through enthalpy wheels.
+ Will require additional space for heat recovery equipment. Additional first cost and maintenance costs.

HEAT RECOVERY WHEEL

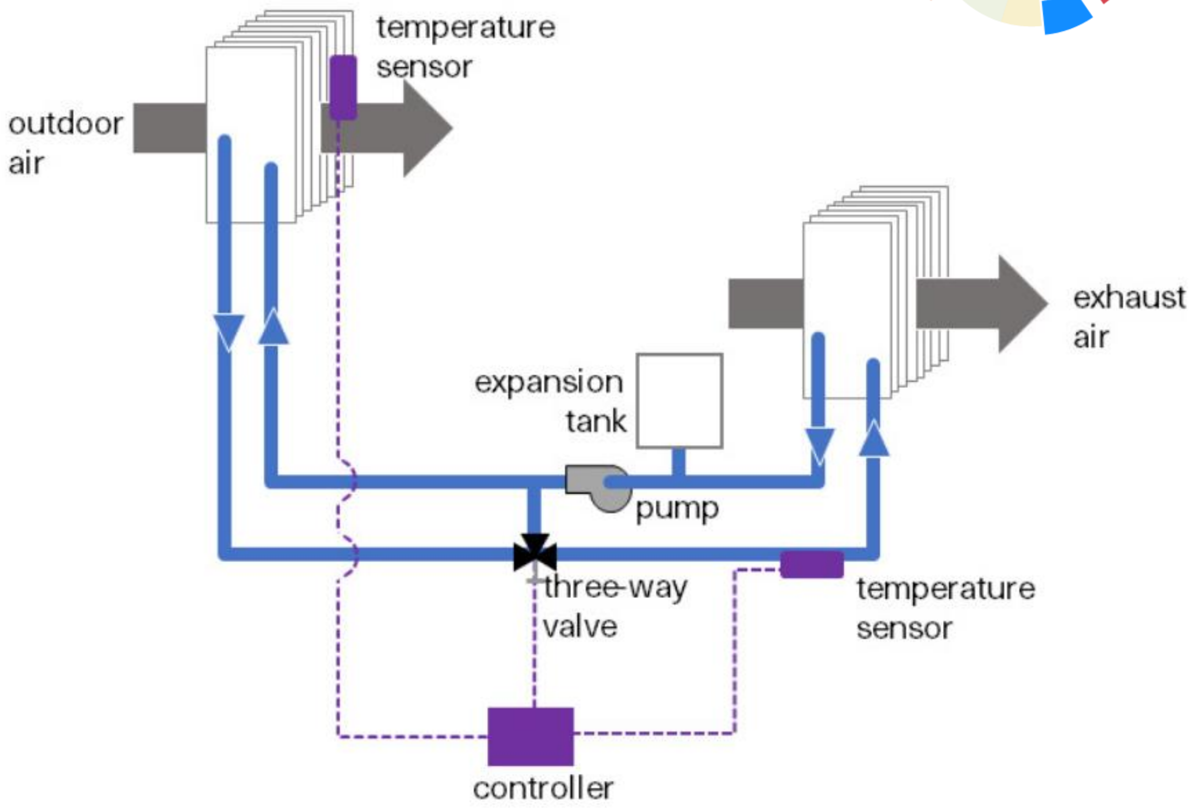
Energy Recovery and Standard 170

+ If recovery system has leakage potential, it is limited to 5%.

- ED waiting rooms
- Triage
- ED decontamination
- Radiology waiting rooms
- Darkroom
- Bronchoscopy sputum collection
- Laboratory fume hood
- Waste anesthesia gas disposal
- Autopsy
- Non-refrigerated body holding
- Endoscopy cleaning
- Soiled linen
- SPD decontamination room
- Laundry general
- Hazardous material storage
- Dialyzer reprocessing room
- Nuclear medicine hot lab
- Nuclear med treatment room

Deeper Energy Recovery

+ **Networked Coil Loops**
+ Use on relief air takes up little space
+ Air paths can be far away from each other
+ Ease of retrofit
+ Avoids cross leakage of exhaust. Use on
  + Isolation room exhaust
  + Decontamination room exhaust
  + Laboratory exhaust



Airside Economizer and the Energy Code

Economizers not required in healthcare where more than 75% of the supply is to spaces required to be humidified above a dewpoint of 35˙F to comply with

Most portions of a hospital do not currently require humidification by Standard 170. Additionally, some spaces have been lowered to 20% Rh, which is below 35F dewpoint.

Exemption for systems that include a condenser heat recovery system with a minimum capacity of 6,000,000 btuh of heat rejection. (500 tons cooling or 625 tons including heat of compression).

Reduce or Eliminate Airside Economizer

Eliminating airside economizer deepens and expands the simultaneous heating and cooling potential

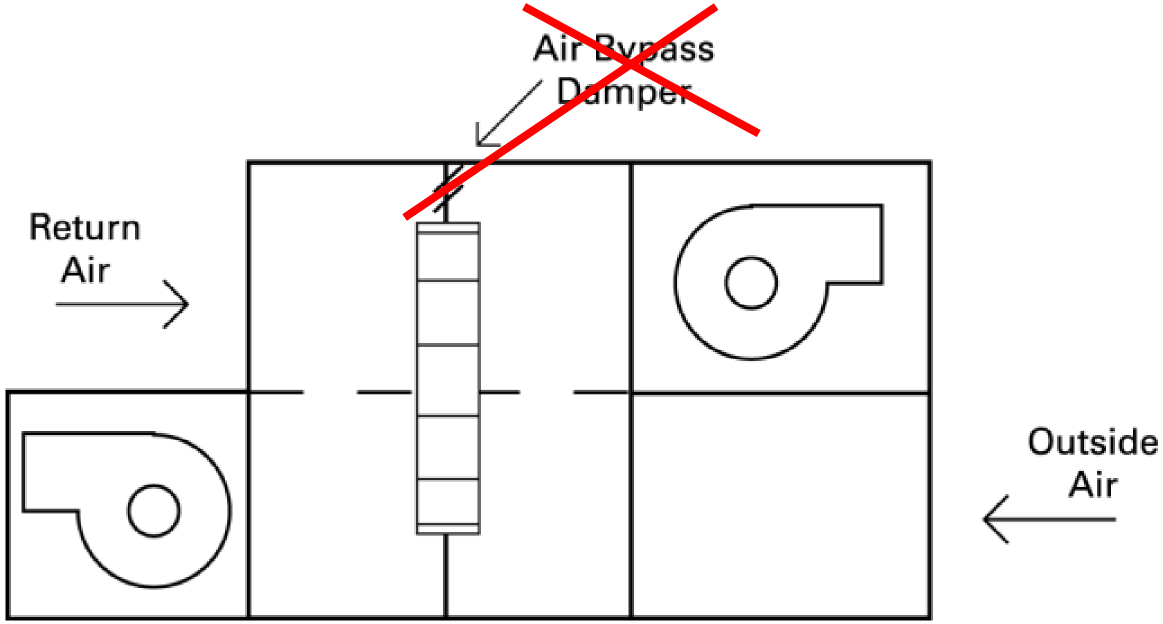
D. Koenigshofer and J. Roberts made a case against the airside economizer for hospitals in their climate (SE US) based on the marginal energy savings, increased first cost and poor reliability of sensors and control components. (2)

D. Schurk in a letter to the editor of ASHRAE went on to make a point that eliminating the economizer opens up the opportunity for heat recovery chillers with increased simultaneous heating and cooling. (3)

Don’t Bypass Energy Recovery

+ Extract the energy put into the building through the lighting, plug loads and occupants and recycle it.

+ Use the chilled water coil and send the energy back to the central plant.



IT and Electrical Rooms

+ Use fan and blower coils year round
+ Extract heat from IT rooms and from transformers
+ Recover the heat and send it back to the plant
+ Don’t use air from the patient care air handlers

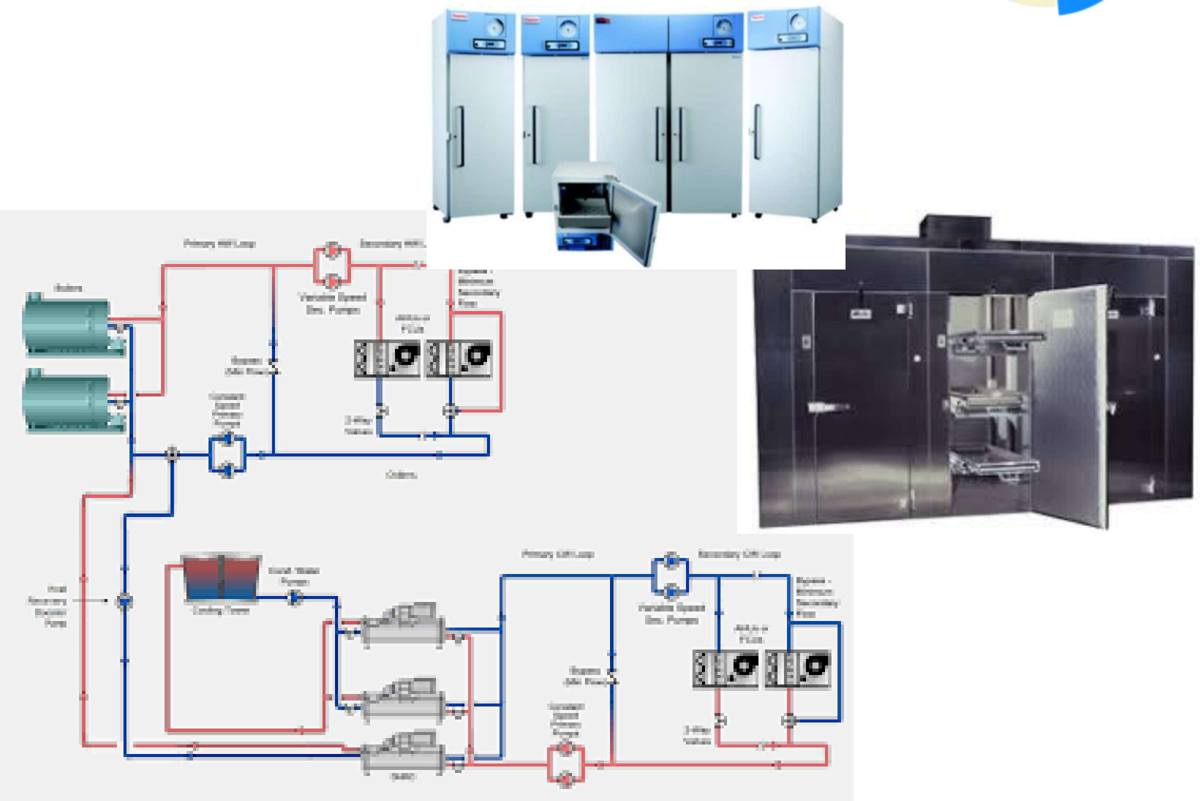
Water-Cooled Refrigeration Equipment

Specify Water-Cooled:

+ Lab refrigerators/freezers
+ Kitchen coolers/freezers
+ Morgue cooler
+ Ice machines

IT rooms/data center on same loop

Use rejected heat for building heating needs with **heat recovery chiller**. Can save nearly **10%** of annual energy consumed in a hospital.



Heat Pump vs Heat Recovery Chillers

Heat Pump Chiller:
Transfers heat from a low-temperature source such as the ambient air, ground heat exchanger or a water source to a higher temperature, which is then used to provide cooling to the hospital. It can also provide heating in the winter by reversing the cycle.

Heat Recovery Chiller:
Recovers heat from a hospital's cooling system and use it to heat domestic water, process use or space heating. It does not use external waste heat like a heat pump chiller but recovers heat that would otherwise be wasted to the environment.

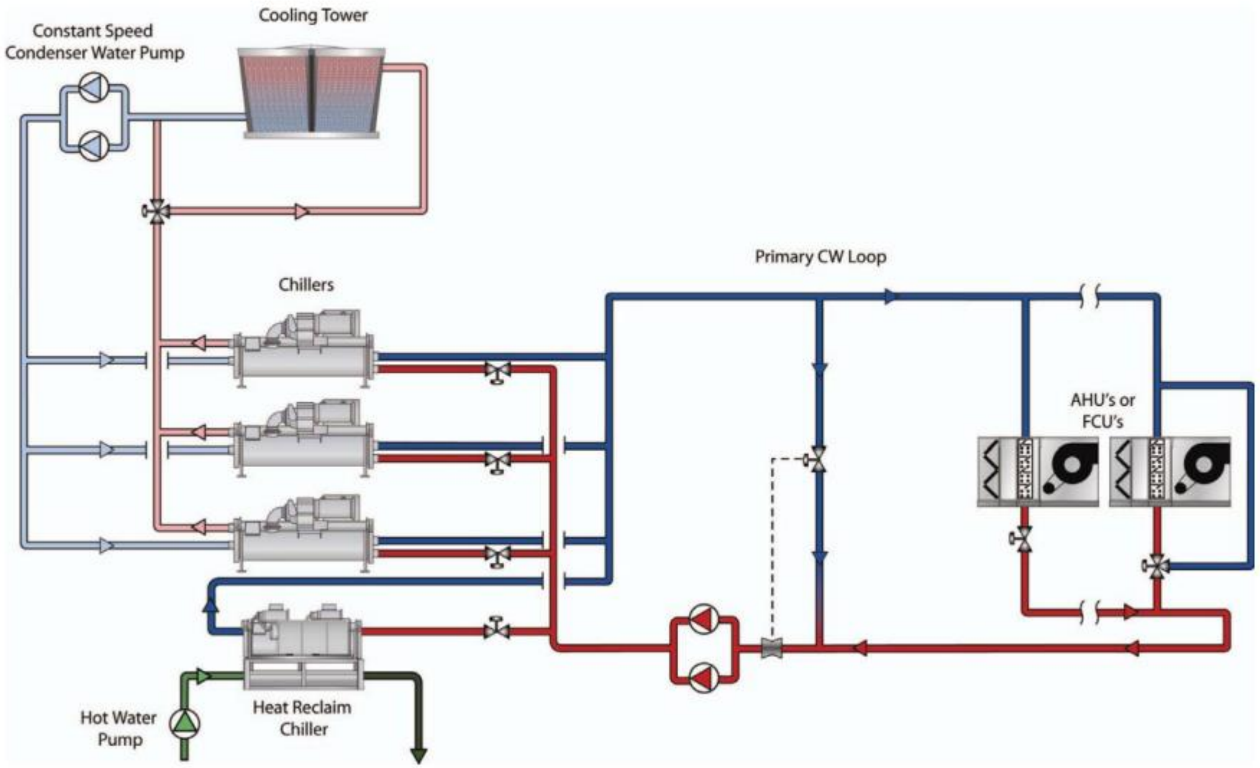
Heat Recovery Chillers

+ Traditional health care settings can require much reheat making a heat recovery chiller an economical solution.
+ The chiller can simultaneously generate chilled water for cooling internal spaces such as electrical and data rooms while producing hot water for reheating.
+ These can be located at the building level or remotely.

Heat Recovery Chillers

+ Preferentially load to take warmest water from the load side

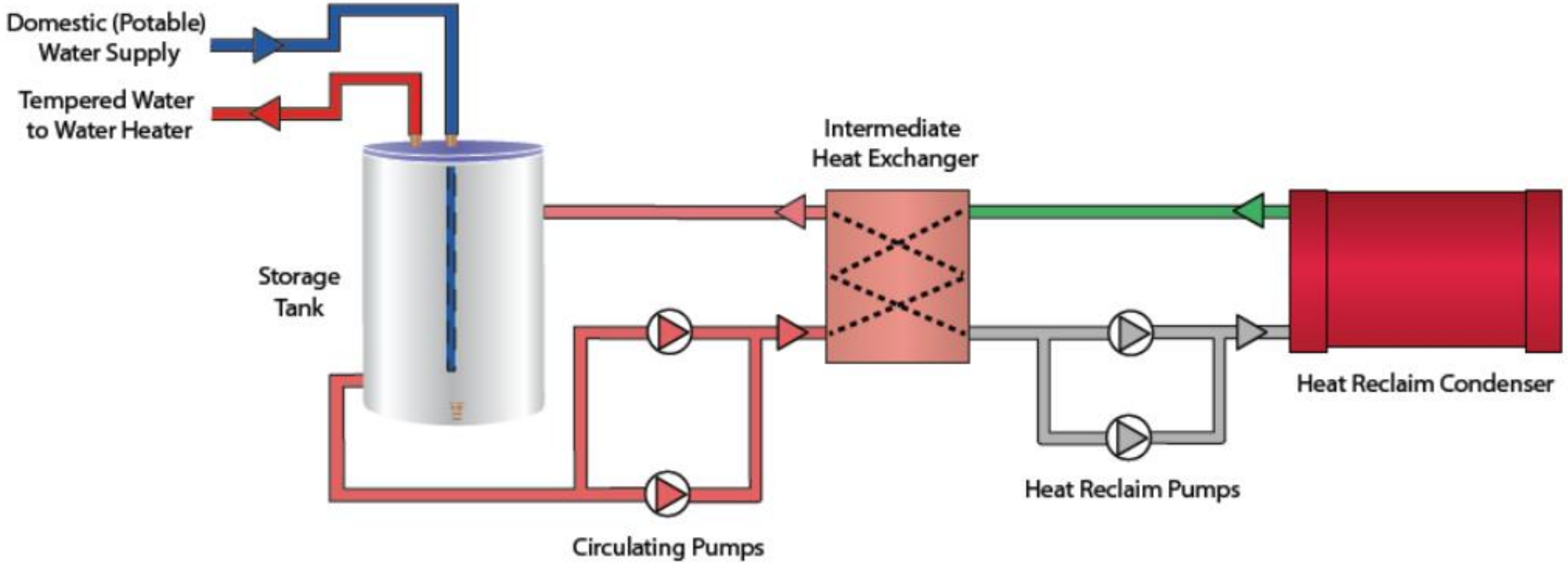
+ Provide hot and chilled water simultaneously



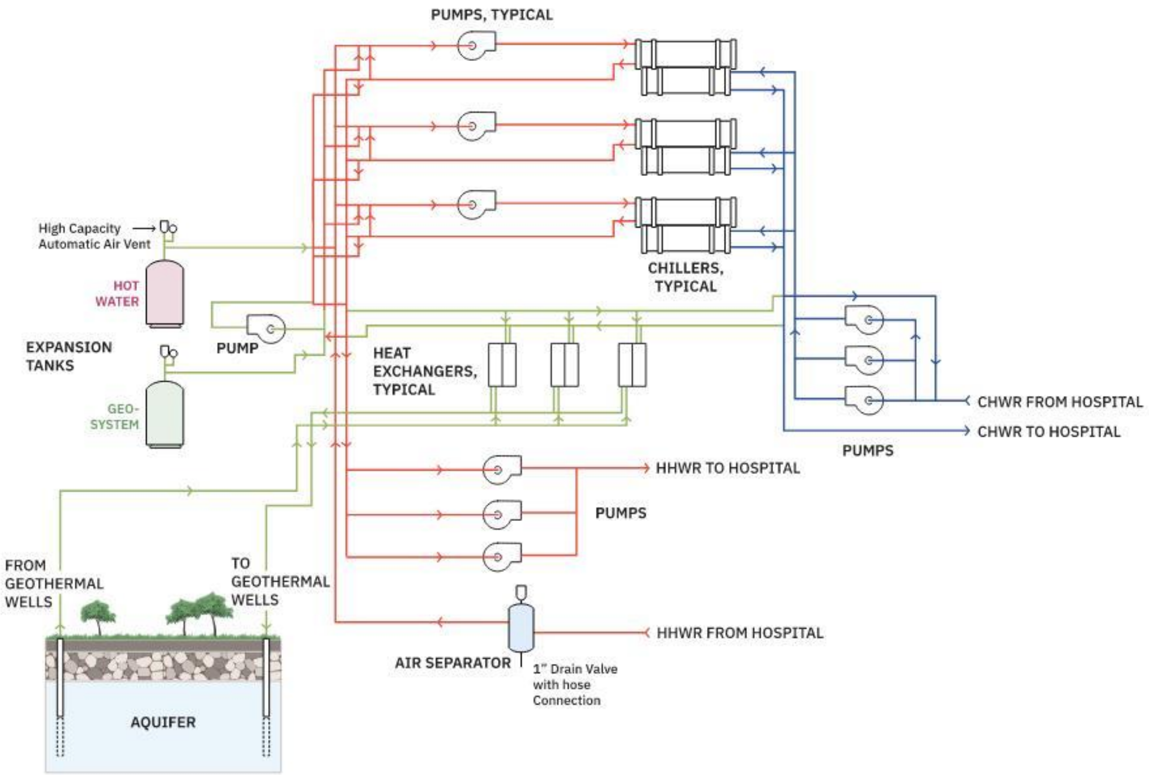
Domestic Water Heating

Common application for heat recovery on a chiller is for domestic water heating.

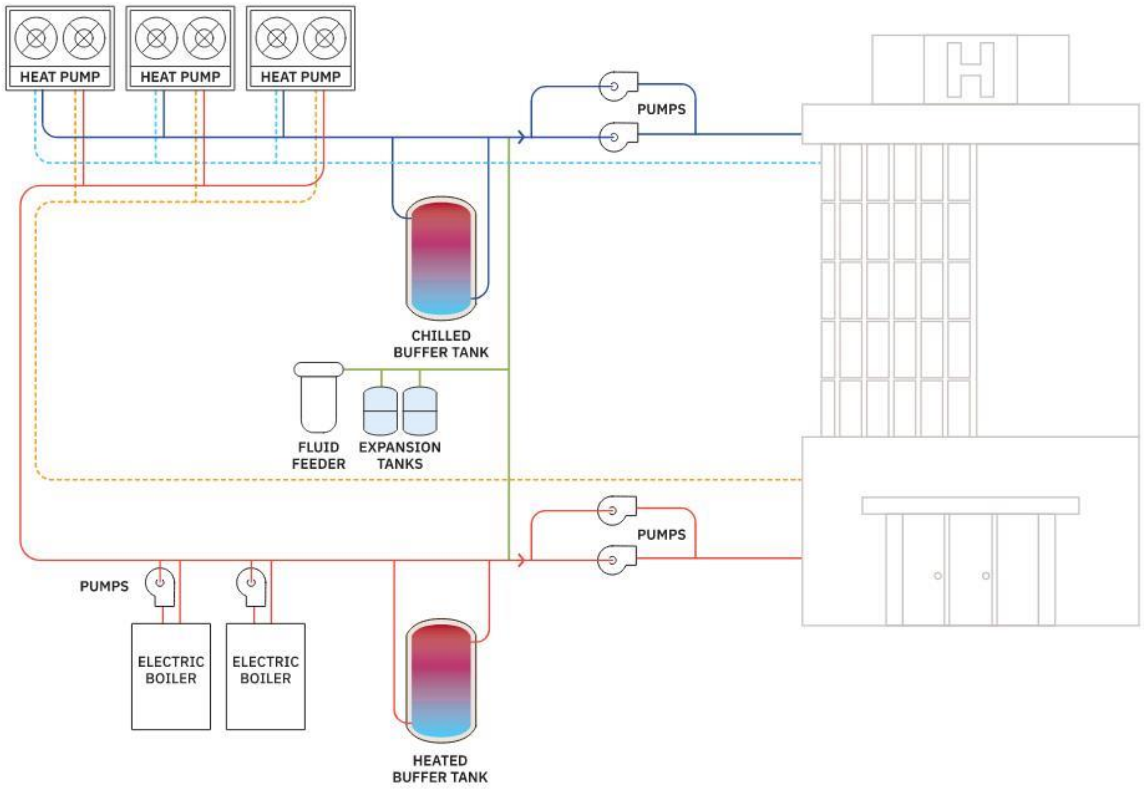
Code requirement that applies in many healthcare applications



Centralized Heat Pumps - Ground Source



Centralized Heat Pumps – Air Source



Electric Resistance and Electrode Boilers (4)

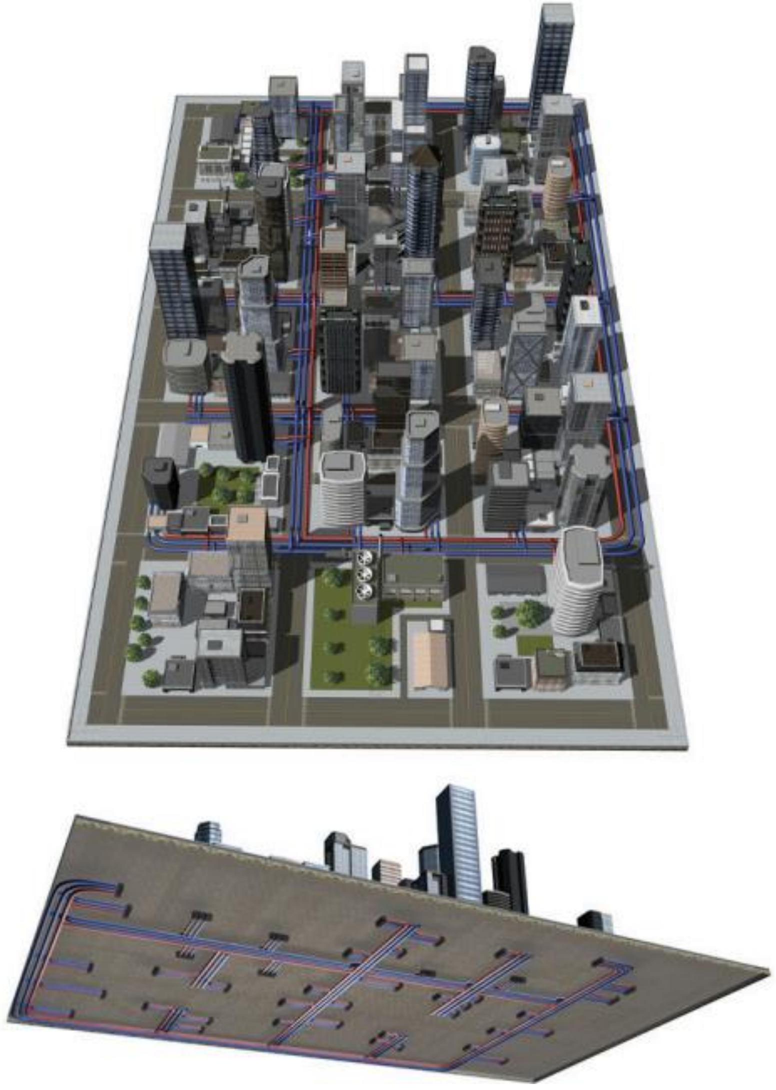
Typical Electric Resistance Boiler Offering

+ 480V, 3PH, Nickel-Iron-Chromium alloy resistance heating elements
+ Available up to 300 BHP for steam and 9,000 MBH for hot water
+ Up to 99% efficient

Typical Electrode Steam Boiler Offering

+ 4,160V to 13,200V
+ Uses the fluid itself as the electric heating medium
+ Capacities up to 5,000 BHP
+ Quick start-up (5 to 20 min), 100:1 turn down
+ Requires good water quality

Thermal Energy Networks



+ Ambient temperature loop system which connects buildings by using variation of ground-source heat pumps, geothermal infrastructure, waste heat energy and load balancing systems.
+ Buildings varying HVAC loads are linked to share thermal resources. Proximity to land with space for boreholes, ground coupling; water pipes or sewer mains; waste heat from laundry, sterile processing, data center; surface water: rivers, lakes, ponds

Wastewater Heat Recovery

Consistent Flow: Constantly being produced, making it a consistent source of energy. Reliable year-round and in all weather conditions.

Consistent Temperature: Relatively constant temperature facilitating the design as a recoverable source of energy.

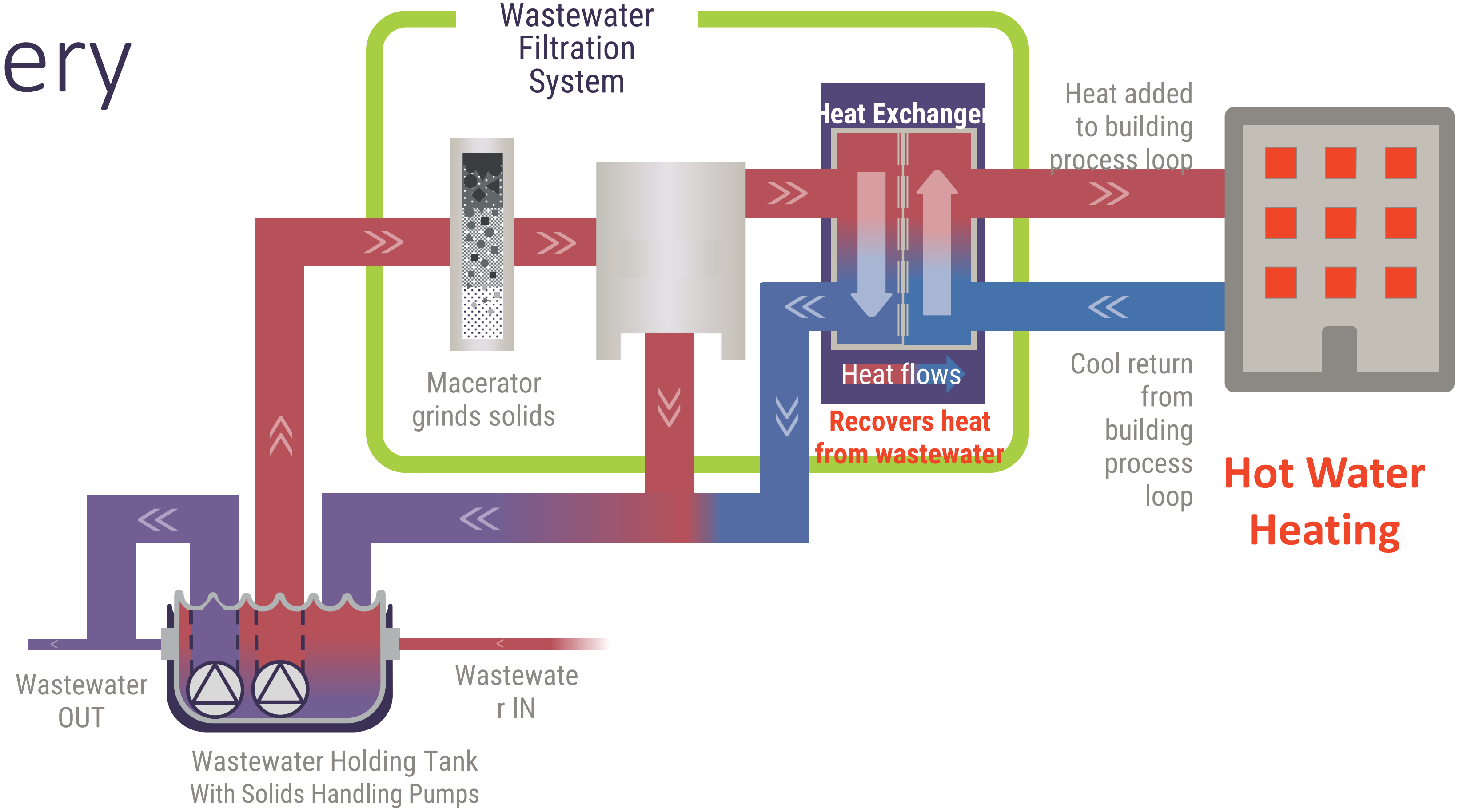
Accessibility: ubiquitous resource found at every hospital.

Uses: Domestic water preheating, heat sink for heat pump system.

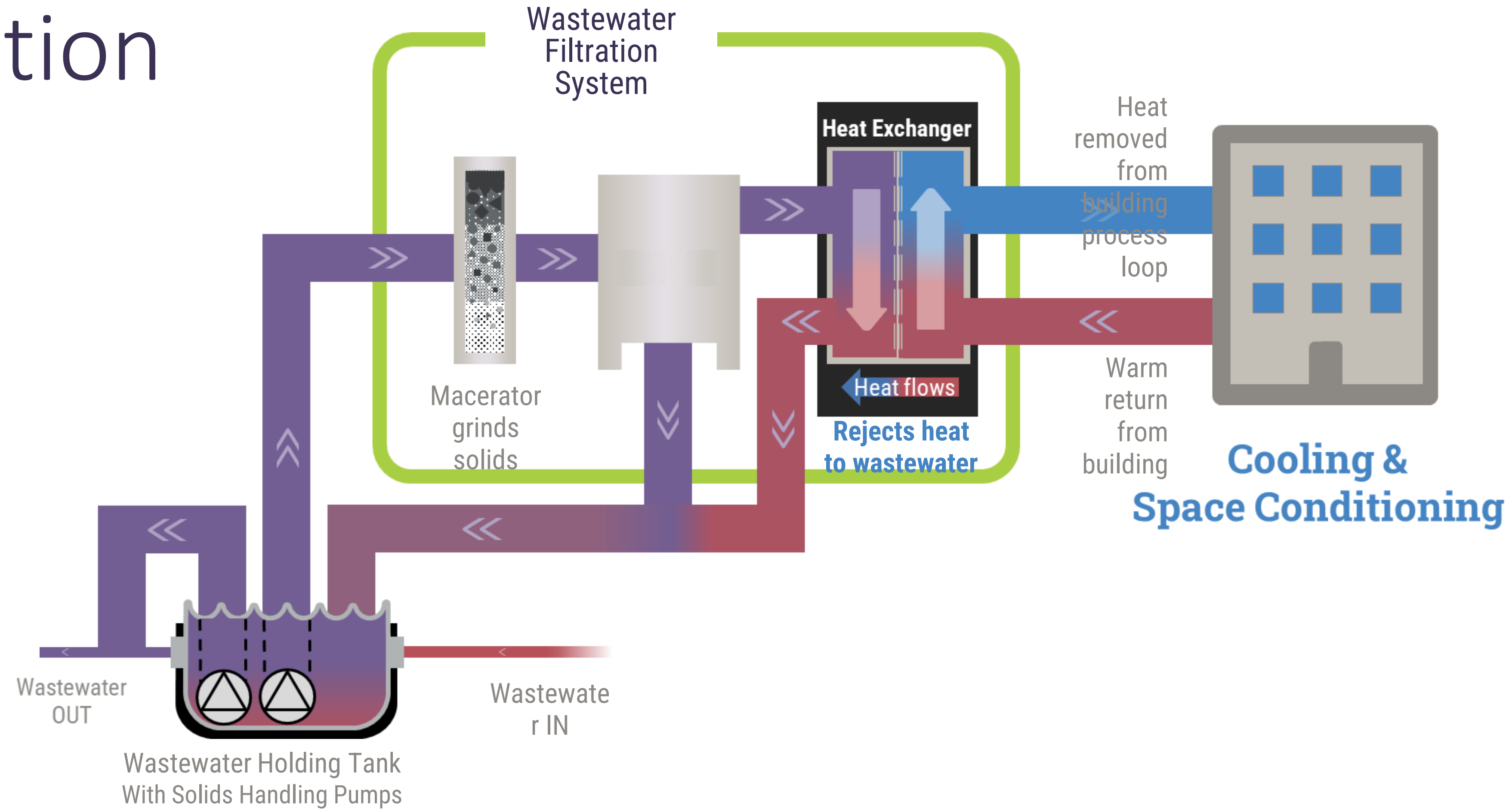
Same Heat Pump System, Different Source/Sink

Boiler/Tower	Ground-Coupled	WWHR + WSHP
+ Cooling Tower Rejects Heat	+ GHEX Rejects and Injects Heat	+ WWHR Rejects and Injects Heat
+ Gas Boilers Inject Heat	+ High First Costs; Borefield	+ Slight First Cost Premium
+ Lowest First Installed Cost	+ Low Utility Costs	+ Lowest Utility Costs
+ High Utility Costs	+ Low Maintenance Costs	+ Low Maintenance Costs
+ High Maintenance Costs	+ No Water Consumption	+ No Water Consumption
+ High Water Consumption	+ Rooftop Space Preserved	+ Rooftop Space Preserved
+ Lose Rooftop Space		

Wastewater Energy Recovery

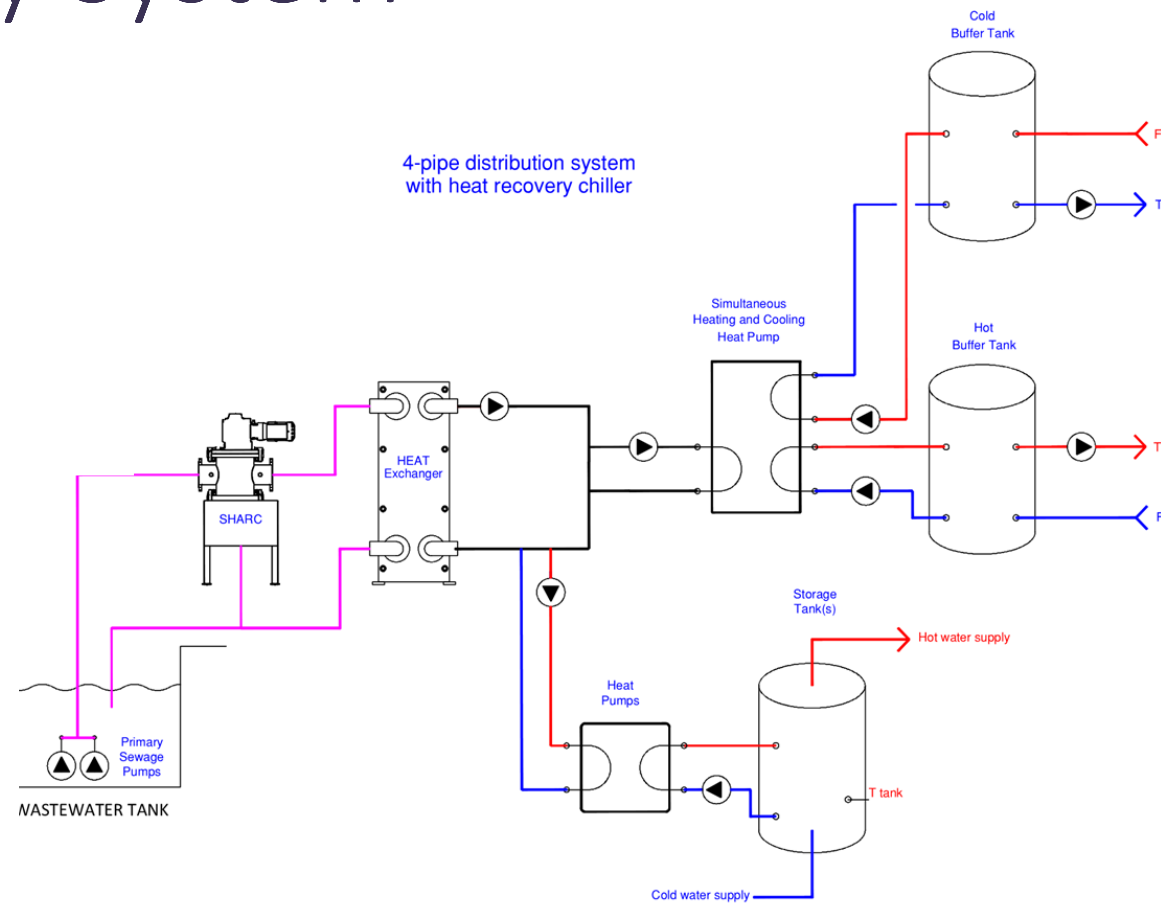


Wastewater Energy Rejection



Wastewater Heat Recovery System

+ Wastewater filtration unit
+ Heat exchanger
+ Heat pump HVAC system
+ 100% of heating/cooling loads
+ Reduces boilers and cooling tower operation
+ No chemical water treatment



Other Heat Sources & Sinks to Consider

+ Send chilled water to a solar thermal system
+ Send heating hot water to above system at night for radiant cooling
+ Pass chilled water through exhaust air stream run-around coil
+ Direct evaporative medium upstream of a heating hot water coil for heat rejection

Conclusions

Industry and governments are driving the process of decarbonization.

This concept needs to be embraced by the HVAC design community.

+ Large impacts on electrical infrastructure require rethinking HVAC design
  + Reduce energy consumption
  + Move away from steam
  + Capture and recycle heat
  + Air side energy recovery, avoid economizer operation
  + Wastewater heat recovery
  + Heat recovery and heat pump chiller use
  + Thermal energy sharing among buildings

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Q&A

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