Net Zero HVAC Strategies

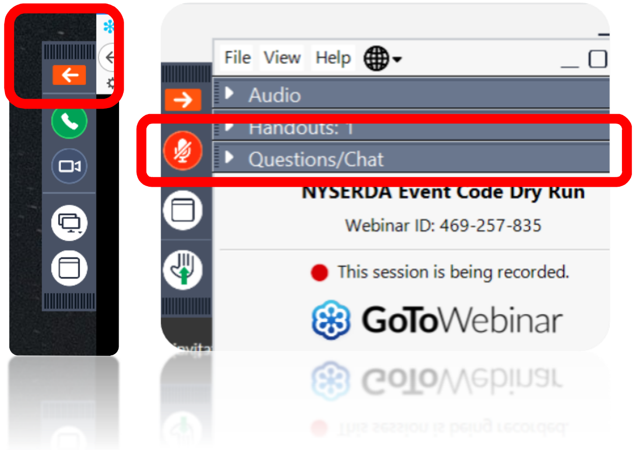
Webinar Overview

All attendees have been placed on mute.

Use the Question Section on the webinar control panel to ask a question at anytime during the presentation.

Q&A will take place at the end of each segment.

Webinar will be recorded and sent.



NYSERDA Event Code Dry Run

Webinar ID: 469-257-835

This session is being recorded.

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Upon Completion of Module

You will receive the following items via email:

- AIA Certificate of completion-can also be used for:
  - PHI Credits
  - NYS PE CEUs
- PDF of final presentation
- Link to the webinar recording

Steven Winter Associates, Inc.
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CONTINUING EDUCATION AIA

CERTIFICATE OF COMPLETION

THIS CERTIFICATE IS TO CERTIFY THAT
Katie Zoppo

PARTICIPATED IN
Module 1: Overview of PH/Net Zero Building Concepts, Techniques and Benefits

COURSE NUMBER
M1OOPHNZBCTAB

ON
February 11th, 2020

LOCATION
New Paltz, NY

EARNING
4 AIA CES Learning Unit/HSW

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Learning Objectives

Name at least two aspects of heat pump performance that are impacted by the type of refrigerant used.

Explain why pump sizing is important for energy savings and why adding a VFD or triple duty valve does not balance out poor sizing.

Explain why hydronic systems need to utilize low temperature heating water to be good electrification candidates.

List at least three barriers that make it hard to electrify domestic hot water usage in a cold climate.

Explain the major steps in sealing and balancing a ventilation system.

Overview of Presentation

1 Reasons For Switching To All-Electric

2 Heat Pumps

10 min break
~9:30 AM

3 Hydronics

4 Campus Central Plant Considerations

10 min break
~10:45 AM

5 DHW

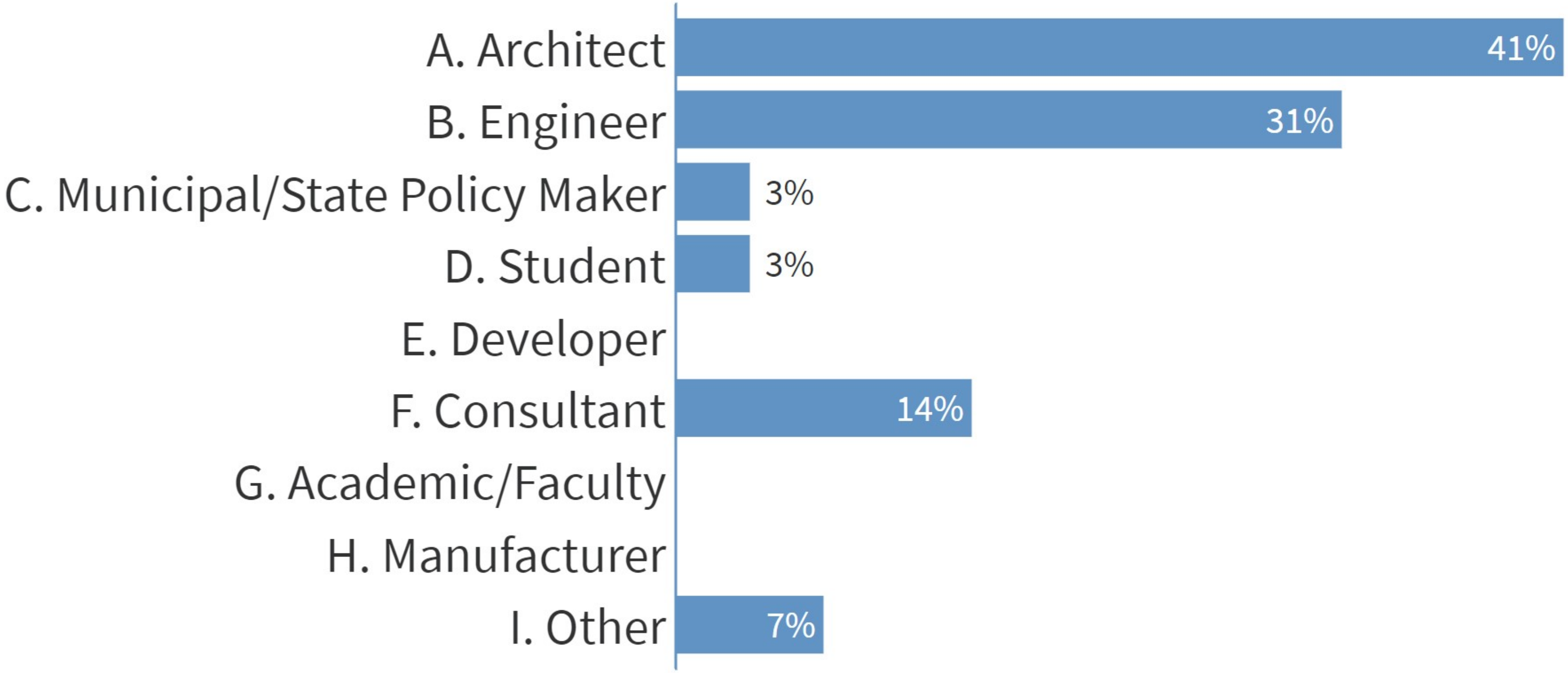
6 Potable Pumps

5 min break
~11:45 AM

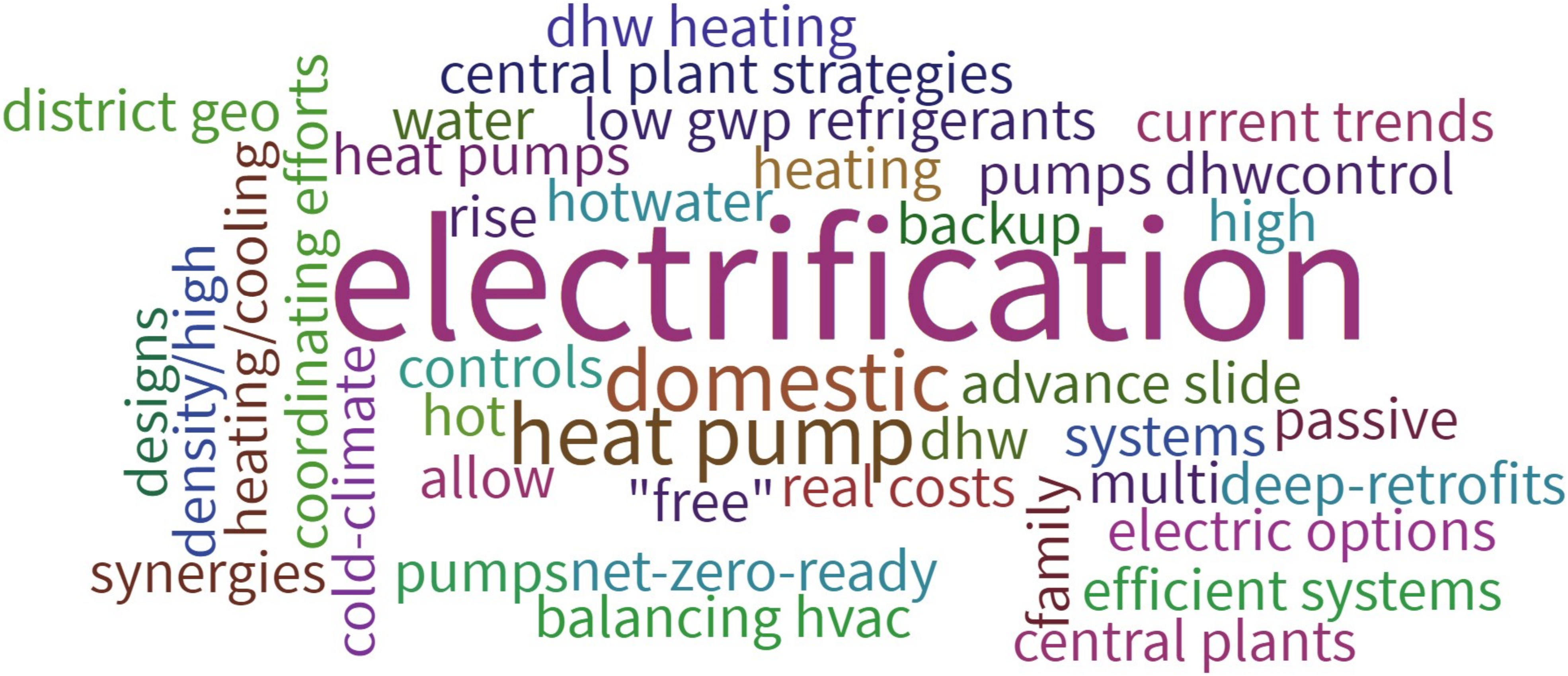
7 Ventilation

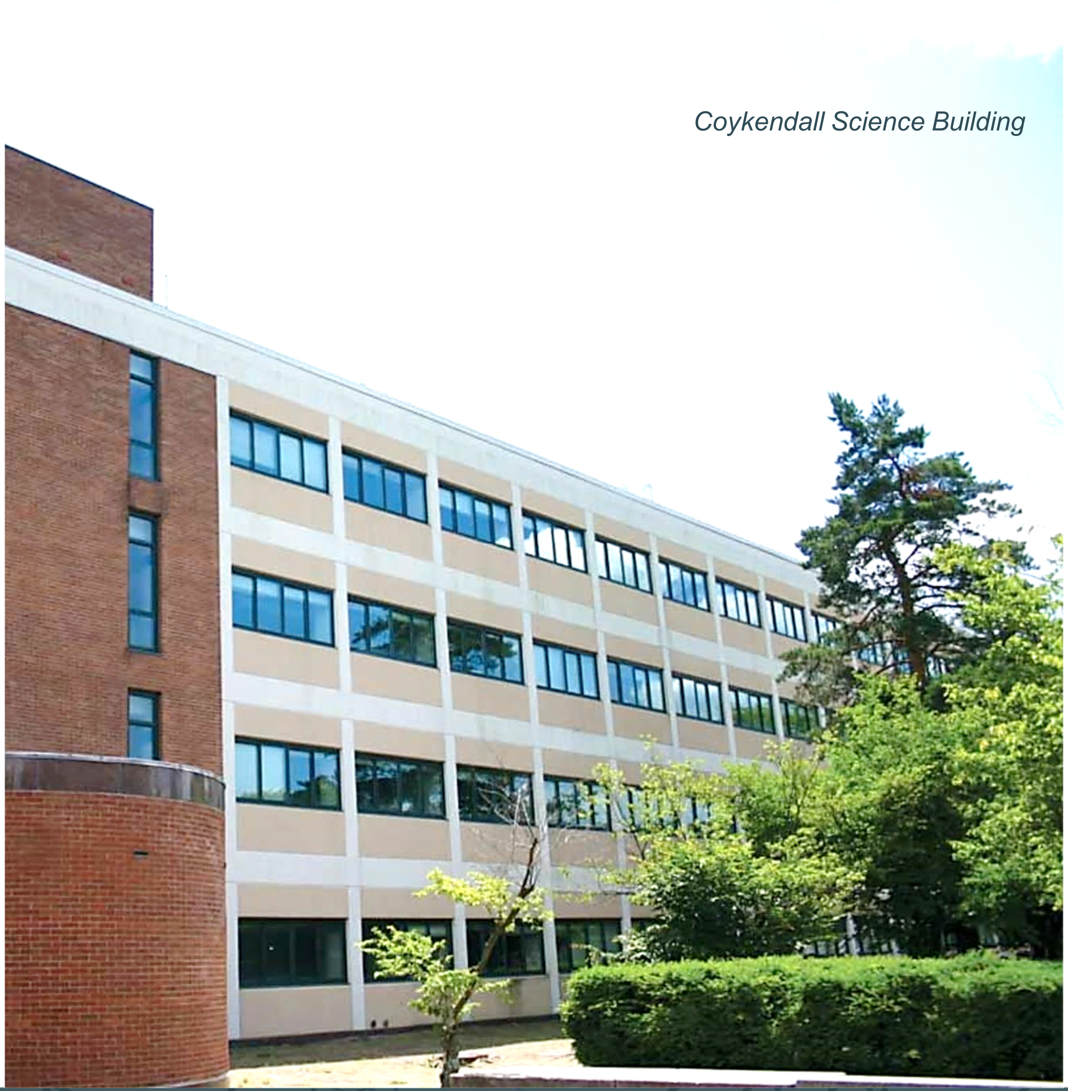
8 Lighting Design & Controls

What is your profession?



What is the one thing you were hoping to learn about today?





Coykendall Science Building

Why we are here:
Directive 1B-2

- 2018 Chancellor calls for all new buildings to be zero-net-carbon & deep energy retrofits for existing buildings
- 2018 SUCF issued Directive 1B-2
  - Purpose: define and identify goals for Net Zero Carbon (NZC) new buildings and Deep Energy Retrofits (DER) of existing buildings.
  - Function: outlines the project target goals and provides direction for project designs.
  - Metrics: Site Energy as the measure of performance and energy consumption.

Why we are here: **Directive 1B-2**

- Design and construct highly energy efficient buildings which significantly reduce energy consumed below an energy code standard for new buildings or energy usage for an existing building.
- In the case of insufficient project funding, the design goal will be to design the building as NZC “capable” where: the design achieves the energy use intensity (EUI) limit using HVAC equipment and systems that can be electrically powered from renewable energy sources.

New Building Performance goals:
Site Energy Use Intensity (EUI) limits

Classroom building	50 kBTU/ft2/year
Office building	50 kBTU/ft2/year
Laboratory building	150 kBTU/ft2/year
Residence Hall	32 kBTU/ft2/year

These **Trainings**

- **Module 1:** Overview of PH and Net Zero
- **Module 2:** Construction Methods and High-Performance Products and Details
- **Module 3:** Air Barrier Development & Implementation
- **Module 4:** Net Zero HVAC Strategies and Controls + DHW
- **Module 5**: Construction Documents and Bidding
- **Module 6**: Deep Energy Retrofits
- **Module 7**: Refrigerant Management in Design, Construction, and Operations
- **Module 8**: Construction Manager/Subcontractor/Tradesperson Training

Net Zero, or, “electrification strategies”

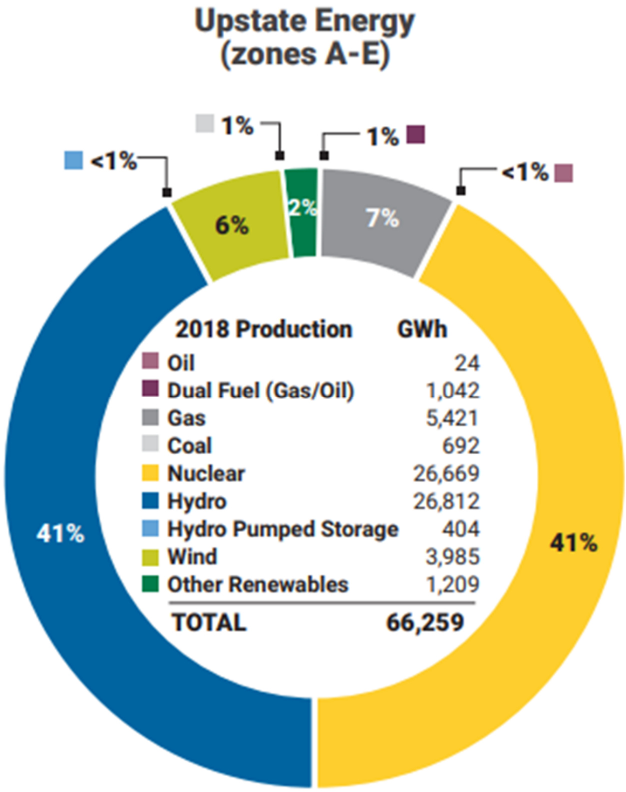
- Burning conventional fuel = emitting CO2
- Using clean electricity = no CO2 emissions
- Net Zero = no emissions (or no energy usage, depending on who you ask)

Reasons for Switching to All-Electric

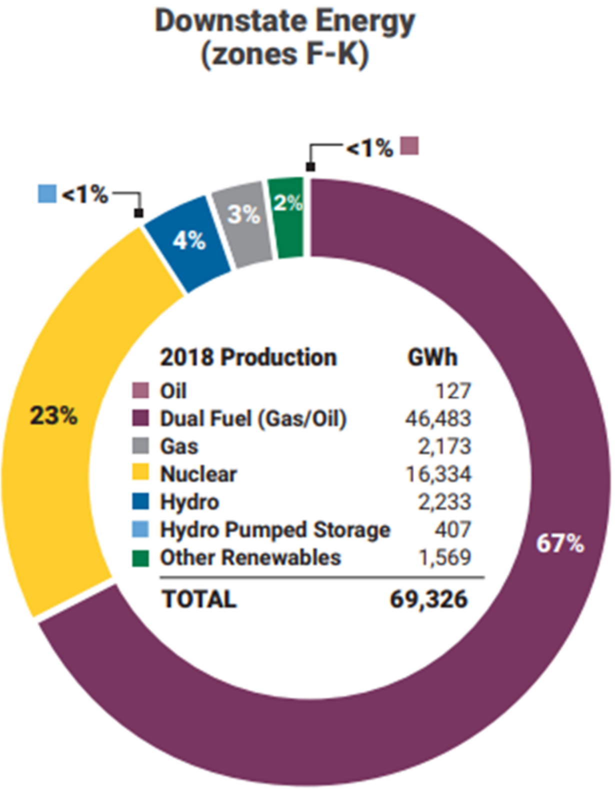
Carbon Neutral NYS Grid by 2040 (CCPA)

- Eliminate 85% NYS grid carbon emissions, offset the additional 15%
  - 6th state to adopt a 100-percent clean electricity target
  - Source 70+% renewable energy by 2030, 100% renewable energy sourcing by 2040
- Currently 60% energy from wind, solar, hydroelectric, and nuclear

Where Does our Electricity Come From?



2018 Production	GWh
Oil	24
Dual Fuel (Gas/Oil)	1,042
Gas	5,421
Coal	692
Nuclear	26,669
Hydro	26,812
Hydro Pumped Storage	404
Wind	3,985
Other Renewables	1,209
TOTAL	**66,259**



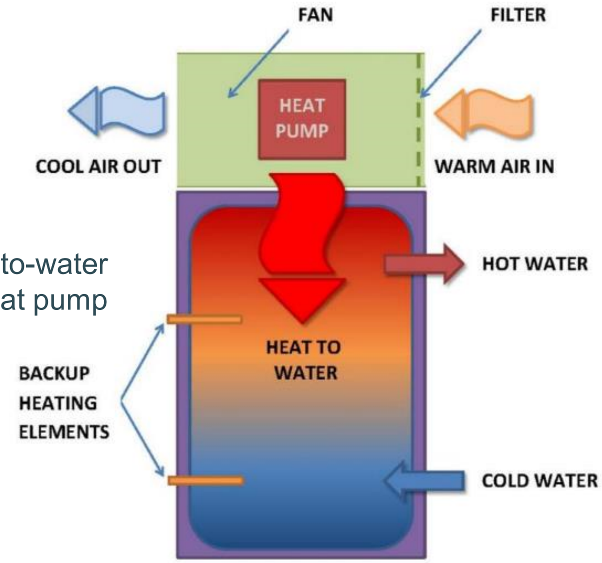
2018 Production	GWh
Oil	127
Dual Fuel (Gas/Oil)	46,483
Gas	2,173
Nuclear	16,334
Hydro	2,233
Hydro Pumped Storage	407
Other Renewables	1,569
TOTAL	**69,326**

Gas Moratoria

- ConEdison moratorium on firm gas in Westchester (15 March 2019)
- National Grid gas moratorium in parts of Brooklyn and Queens (15 May 2019)
  - **Temporarily** ended in late 2019
- Talk of more moratoria to come?

Smart Electrification Options

Smart Electrification: Air Source Heat Pump 101



Example air-to-water heat pump

Example air-to-air heat pump

- Heat is harvested from air or water and pushed into air or water
- Electric compressors and valves move heat-laden refrigerant from one place to another
- Refrigerant is evaporated and condensed to absorb and release heat

Old Heat Pumps

- Used mostly in the South
- Did not work well below ~30°F
- BAD reputation in colder climates

ccASHPs from the past ~10 years can work well up north!

Terminology

Air-Source

Takes heat from air, pushes it into air or water. Commonly moves heat in/out of a building.

Water-Source

Terminal units take heat from (and rejects heat to) a water loop in the building. Moves heat around a building.

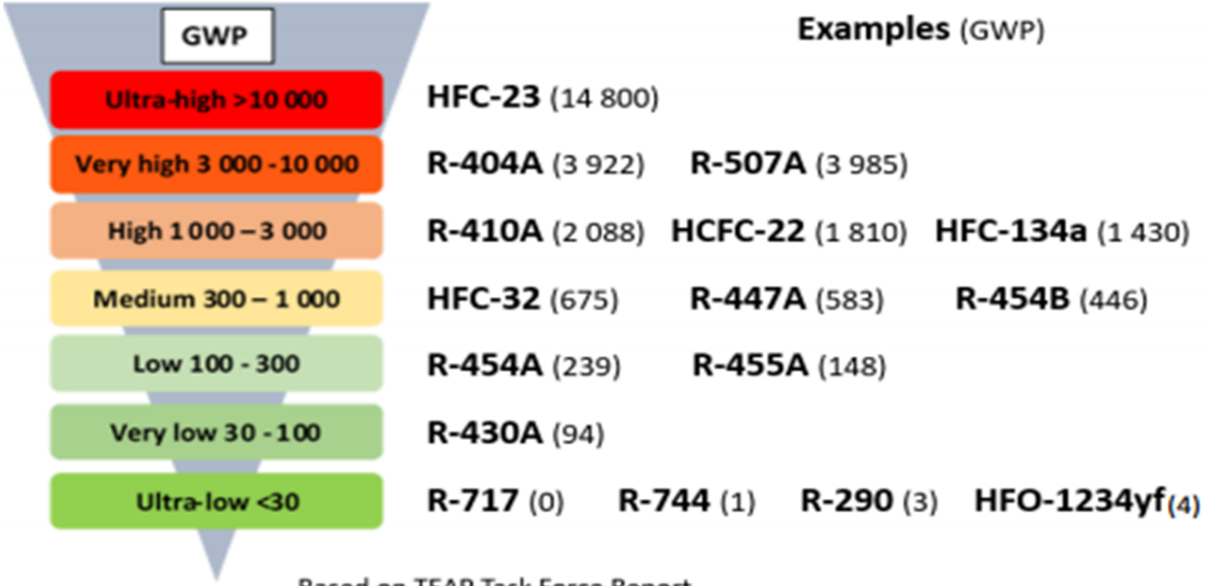
Ground-Source

Takes heat from (and rejects heat to) the ground via a water loop. Moves heat in/out of a building.

Inverter, inverter-driven

Variable-speed compressor.

Refrigerants for Smart Electrification



GWP	Examples (GWP)
Ultra-high >10 000	**HFC-23** (14 800)
Very high 3 000 - 10 000	**R-404A** (3 922) **R-507A** (3 985)
High 1 000 – 3 000	**R-410A** (2 088) **HCFC-22** (1 810) **HFC-134a** (1 430)
Medium 300 – 1 000	**HFC-32** (675) **R-447A** (583) **R-454B** (446)
Low 100 - 300	**R-454A** (239) **R-455A** (148)
Very low 30 - 100	**R-430A** (94)
Ultra-low <30	**R-717** (0) **R-744** (1) **R-290** (3) **HFO-1234yf** (4)

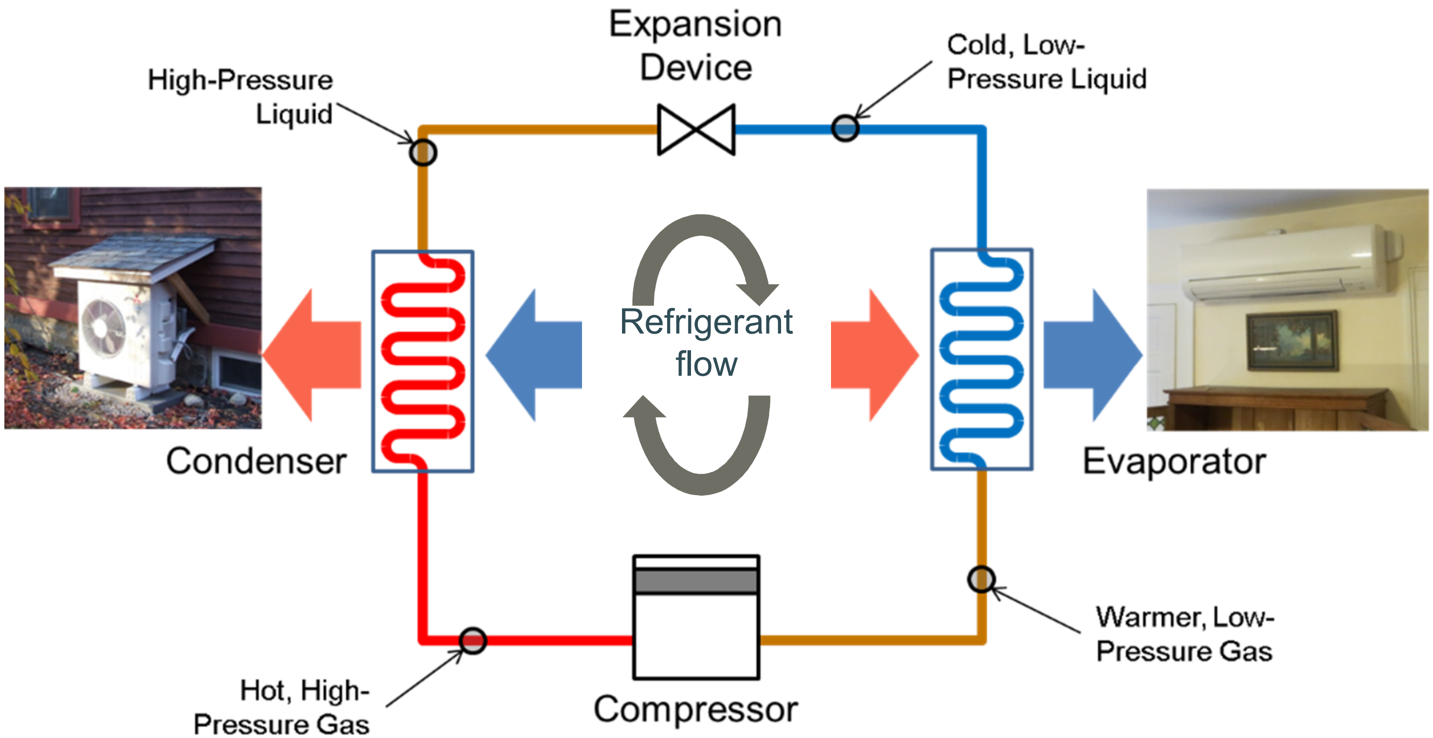
Based on TEAP Task Force Report

- Refrigerants impact:
  - **Operating temperatures (ambient), dT, supply temperature**
- Refrigerants have different greenhouse gas equivalences

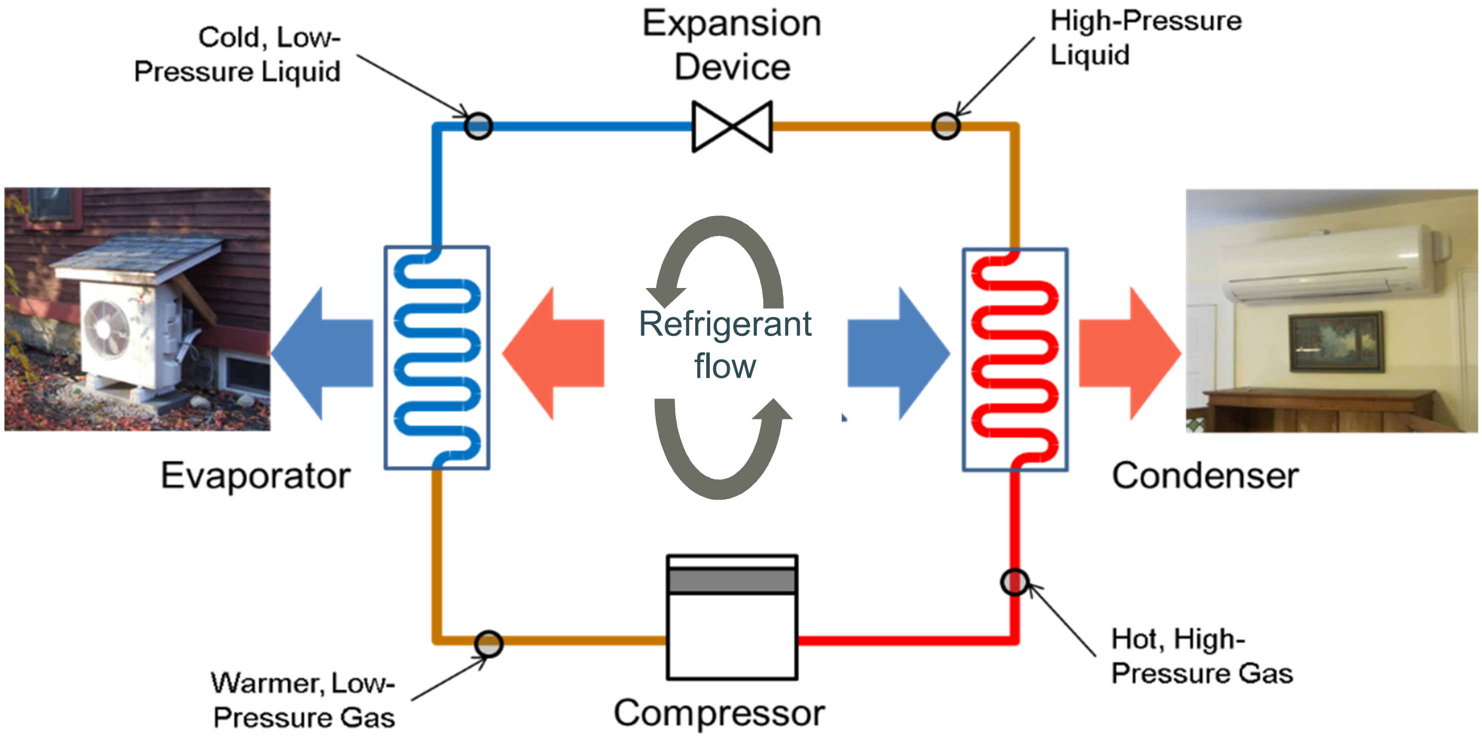
Heating and Cooling

Applying heat pumps

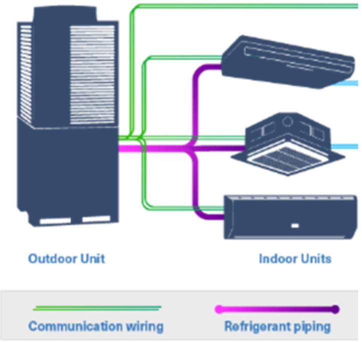
Heat Pump – Cooling Mode (AC)



Heat Pump – Heating Mode

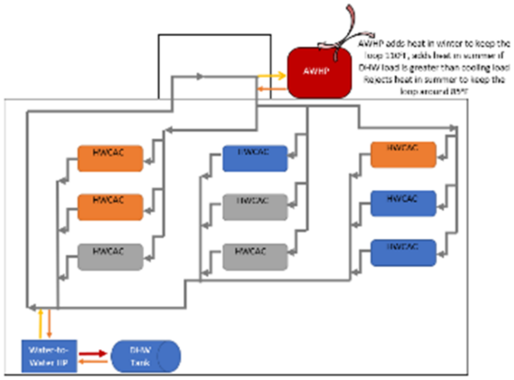


Heating and Cooling Systems Employing Heat Pumps



Source: Cool Automation

Air-Source Heat Pump Mini/Multi-splits, VRF



Source: SWA

Low Temperature Hydronic

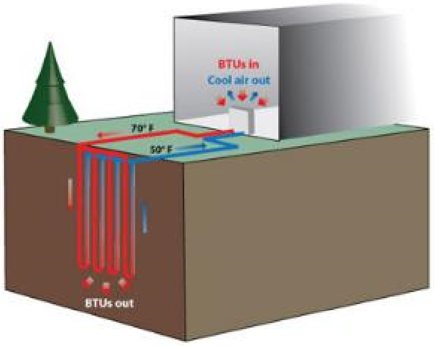


Image: NYSERDA

Water/Geothermal Heat Pump

Questions?

Terminology

Mini-Split

Split and mini (<1.5 tons or so)

Ducted (compact) or Ductless

Usually 1:1

OR

Terminology

Multi-Split (multi-port, multi-zone, <u>not</u> VRF)

- One outdoor unit
- 2+ indoor units
- Ducted, Ductless, or mix
- 1.5 – 4 tons typ.

Images from Mitsubishi

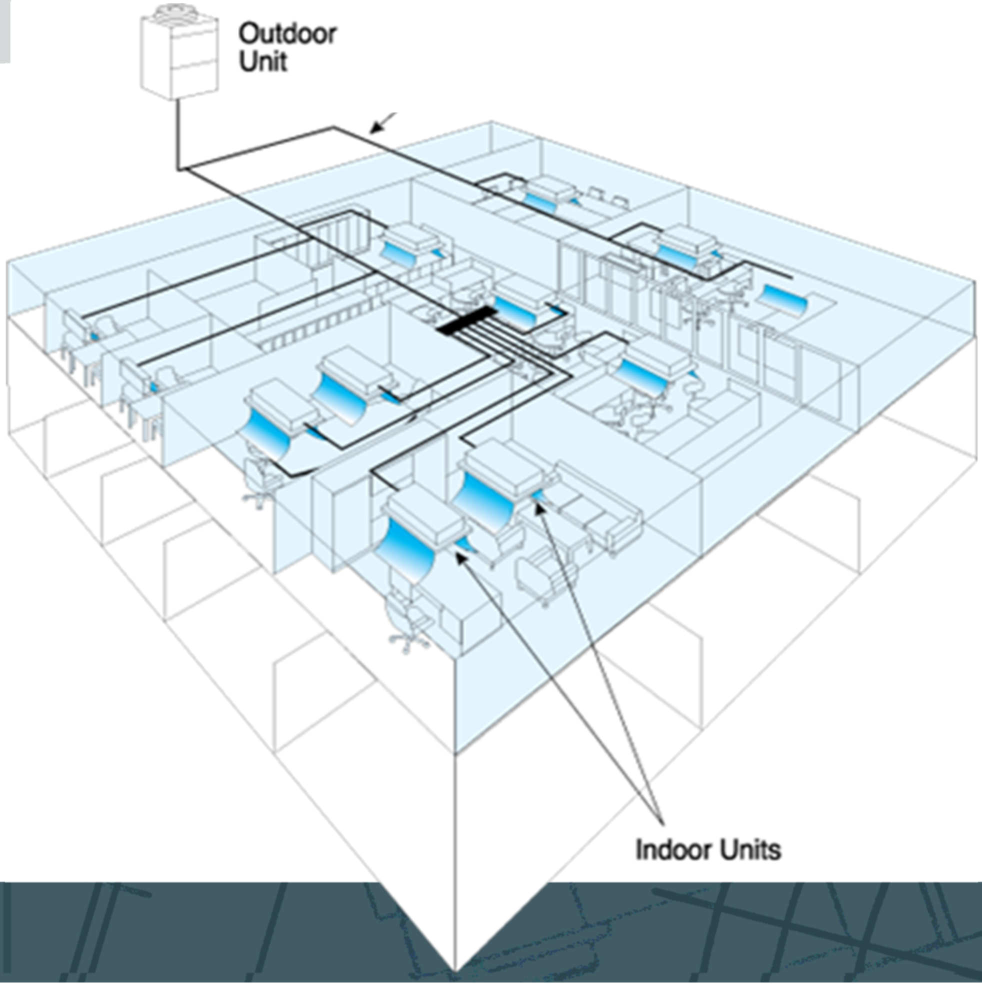
Terminology

VRF (variable refrigerant flow)

- Modular outdoor units, ~6-12 tons typ.
- Many indoor units, many types
- Exp. valves at indoor fan coils

Images from Mitsubishi

VRF



Performance

+ Heat recovery option allows for simultaneous heating and cooling

Design

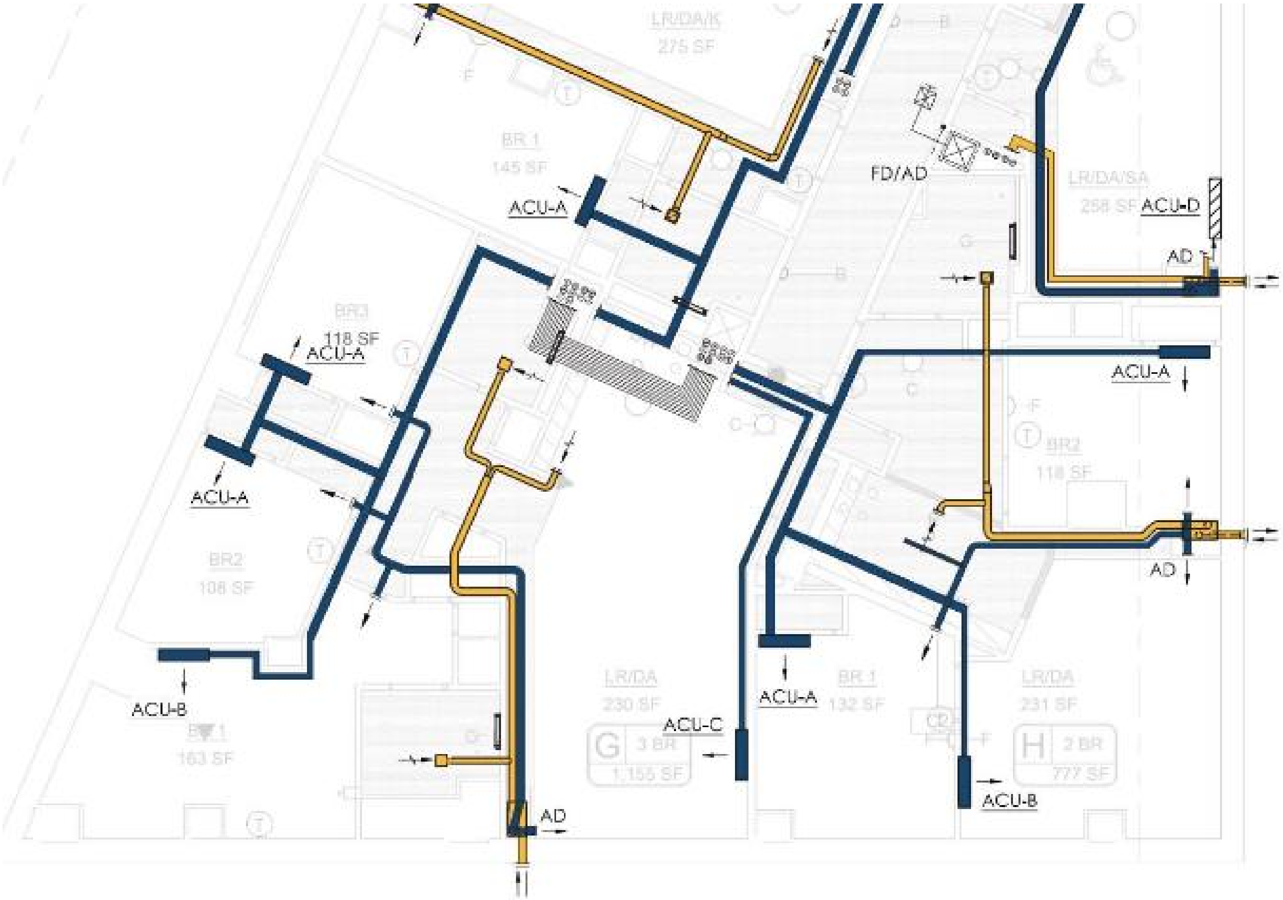
- Extra piping required

<u>Wall Units</u>

+ No additional ceiling space required
- Additional power for individual unit per room one unit per room

<u>Ducted Units</u>

- Requires additional ceiling space
- Required sealing of ducts



Issues

- Higher cost
- Smallest unit 4,500 BTU, could really use a 2,000 BTU unit
- How you have tenants pay for cooling and owner pay for heating?
- Changing filters

Questions?

Comparing Heat Pump Systems

Selecting the right options

Practical Retrofit Considerations

Unitary	Central
• Need to locate outdoor units • More total refrigerant/condensate lines, but smaller systems. Easier to run soft tubing line sets out to a unitary ODU on a balcony. • More installers and servicers available	• Fewer outdoor units needed • Consolidated refrigerant lines, but greater refrigerant volume. Vertical risers with braised or press fit piping, more invasive installation work • Requires more Cx and oversight

Main Considerations

Capacity - How much heat do they provide when it gets really cold?

Capacity – How small are the available terminal units?

Capacity - How much cooling do you get for your glass/south-facing/high internal gain areas?

Efficiency - esp. when it gets cold

How much heating/cooling do you have, and how much energy does it cost to get it?

Hidden Drivers of Performance

Getting the best efficiency
out of air-source heat pumps

Proper Sizing is Important*

- Especially for ductless heat pumps
  - **Oversized systems may stay in “low” fan speed and be less efficient.**

*But may not be possible for high performance and/or low-load spaces

Room Temperature is Stratified

High return air temperatures lead to lower heating efficiencies, so…

Consider floor/low-wall fan coils for heating-dominant settings

Image from Fujitsu

Outdoor Units Drain Water In Winter

Snow is a Design Consideration

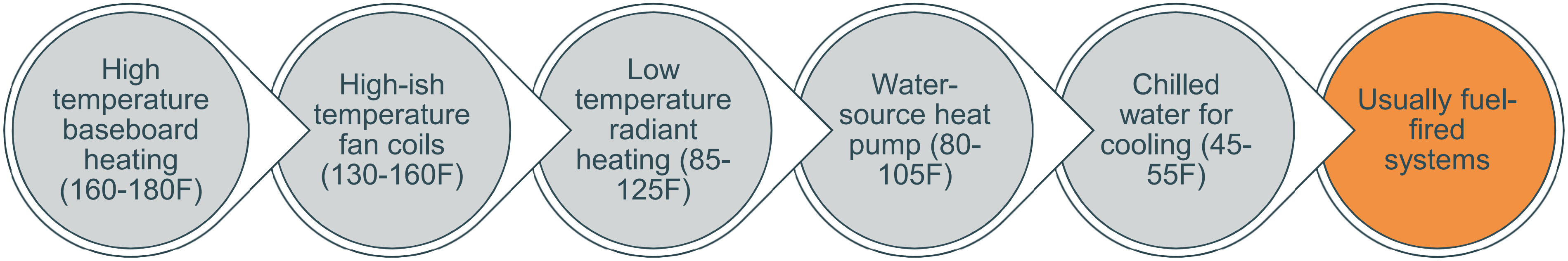
Questions?

10 Minute Break

Hydronics

Heating and cooling with water

Hydronic Systems Vary Widely



High temperature baseboard heating (160-180F)

High-ish temperature fan coils (130-160F)

Low temperature radiant heating (85-125F)

Water-source heat pump (80-105F)

Chilled water for cooling (45-55F)

Usually fuel-fired systems

High Temperature Baseboard Heating

Performance

- \+ Boiler/radiator sizing matched to load
- \- Pumping power for hydronic can be high
- \- Least efficient cooling options*

Design

- \+ Less riser and ceiling space
- \- Need rigorous system to prevent air leakage through window A/C during winter months

* ***But*** local-only cooling can result in BIG savings

Fan Coil Units

- **Performance**

+ Boiler/FCU sizing matched to load
+ Lower temperature heating water = lower distribution losses
+ Can have simultaneous heating and cooling with a 4-pipe system
- Pumping power for hydronic can be high
- Chilled water for cooling = corrosion risk, chiller operator needed

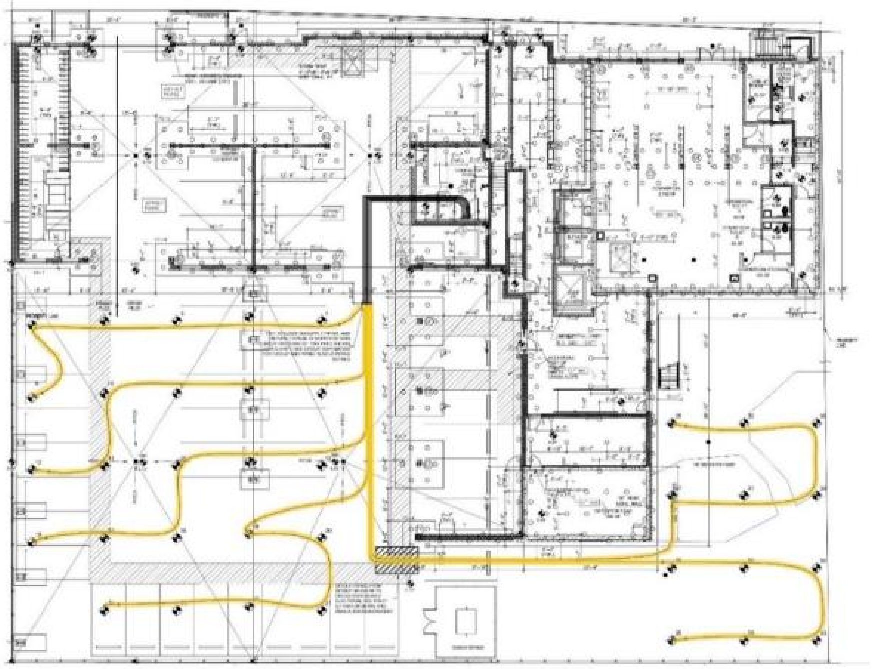
- **Design**

+ Less riser and ceiling space
+ Can provide central cooling

Air Handling Units

- Hydronic, steam, and/or electric heating
- Dx or chilled water cooling
- Same principles as fan coils +
  - ductwork takes up space
  - Chiller maintenance, operator license, or
  - Absorption chillers

Low Temp Hydronic / Water Source Heat Pump



Performance

+ Low temperature heating water = minimal distribution loss, more efficient central plant options
- Pumping energy for water loops

Design

+ Flexibility in terminal units (floor units, ceiling mounted, vertical units in cabinets)
+ No chiller required, cooling tower only
+ Simultaneous heating and cooling

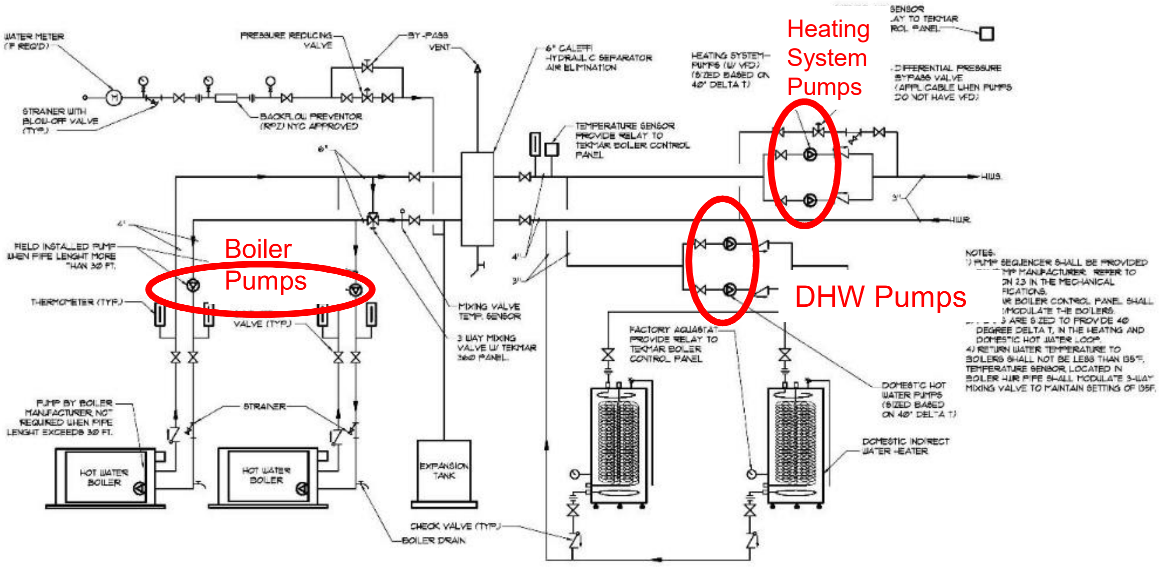
One thing they all have in common...

- Hydronic almost always = heated by fuel
  - Geothermal not common, is often an efficient but costly option
- Hydronic can be cooled by fuel, too (absorption chillers)
- PUMPS

Open versus Closed Loops

- Open: domestic booster pumps, many cooling towers
  - Some hydronic systems
- Closed: hydronic circulators

Pump Schematic

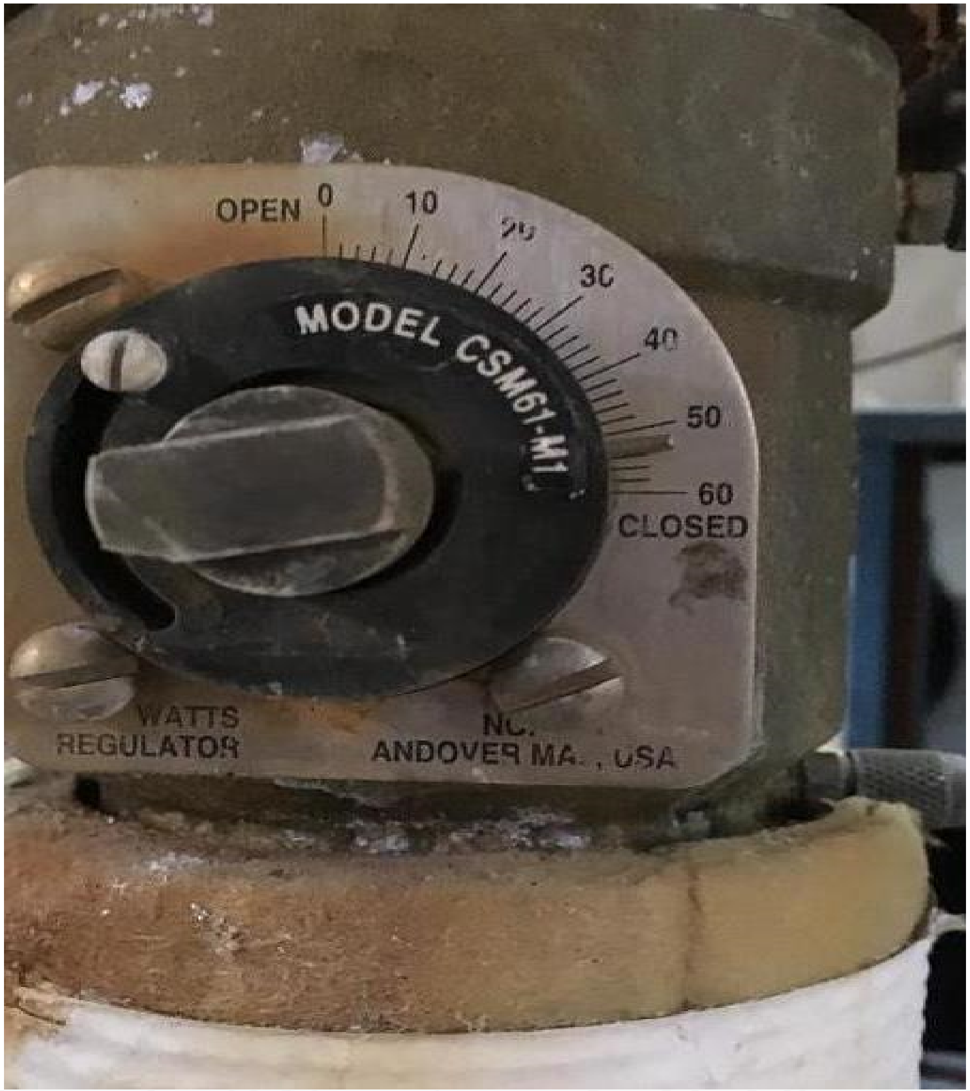

Heating System Pumps

Boiler Pumps

DHW Pumps

COMBINATION HOT WATER BOILER/DOMESTIC WATER HEATER FLOW DIAGRAM

Are engineers always right?



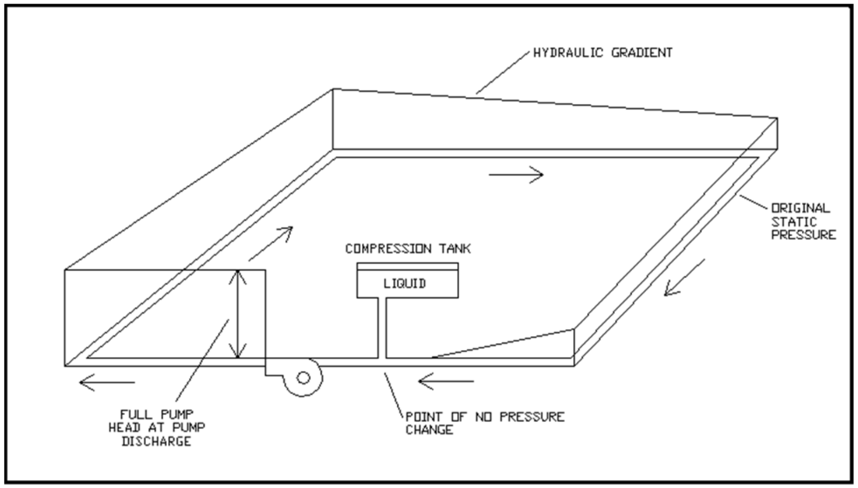
No one sizes pumps

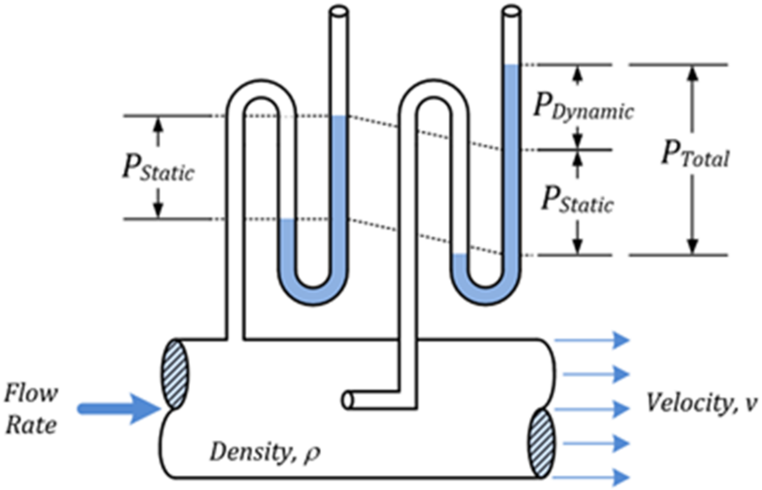
- Closed loops are not open loops
  - Friction losses from piping and fittings are real
  - Friction losses from height are not

Calculating pump selection criteria

- Friction loss
  - Pipe type, roughness, size
  - Fittings (elbows, tees, valves, etc.)
  - Equipment dP
  - Equivalent length
- Flow rate
  - How many terminal units are there? How much flow do they need?
- How much flow where? Friction is a result of flow rate in a given pipe type/size.

Pump Pressure





- Pumps increase pressure
- Pressure causes water to flow through a piping system
- Pressure decreases along the piping path

https://eng-software.com/about-us/press/articles/understanding-the-distinction-between-total-static-and-dynamic-pressure/

Static Pressure in a Closed Loop

Building is ~60 feet tall
Static Pressure = 26 psi
~4.3 psi per story

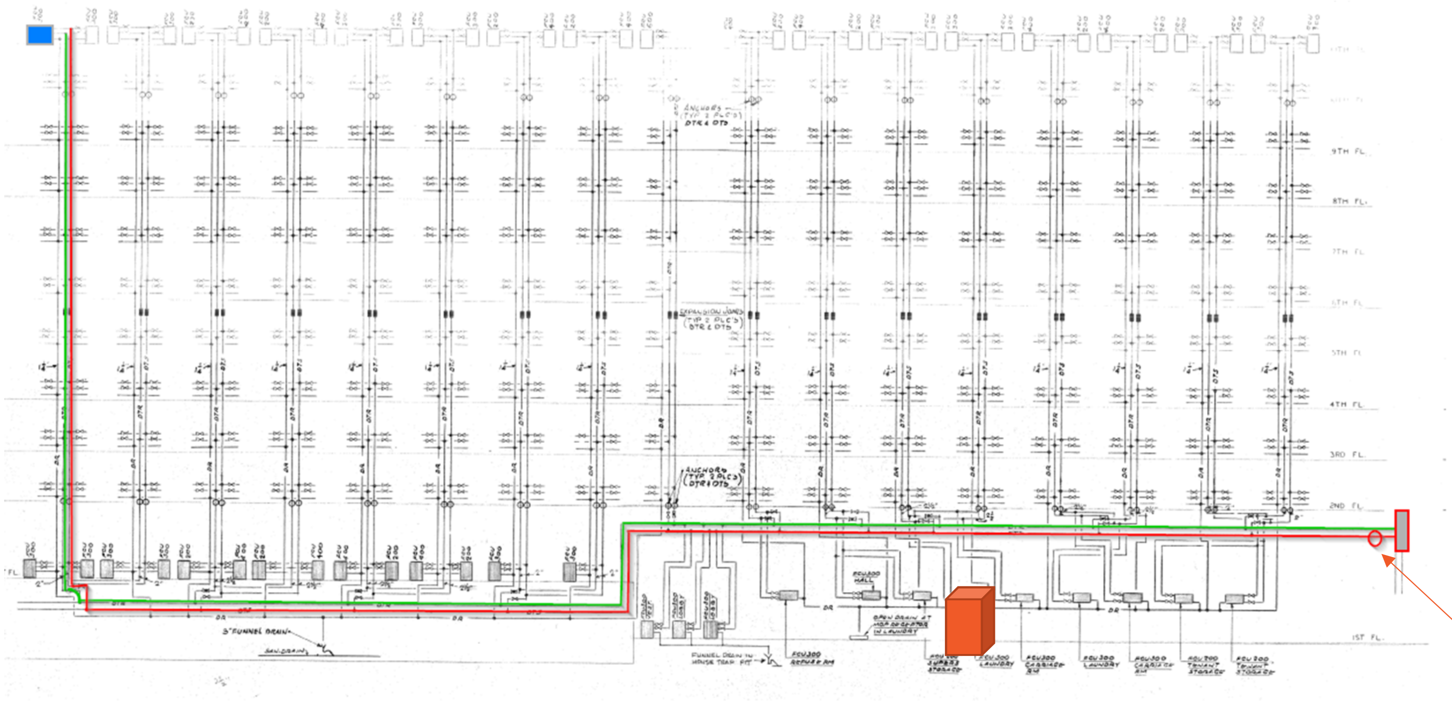
- Static Pressure is the weight of the water filling the pipes
- Pressure when the pumps are off
- Controlled by the PRV on the make-up water line

Dynamic Pressure

Lower Pressure Before the Pump

Higher Pressure After the Pump

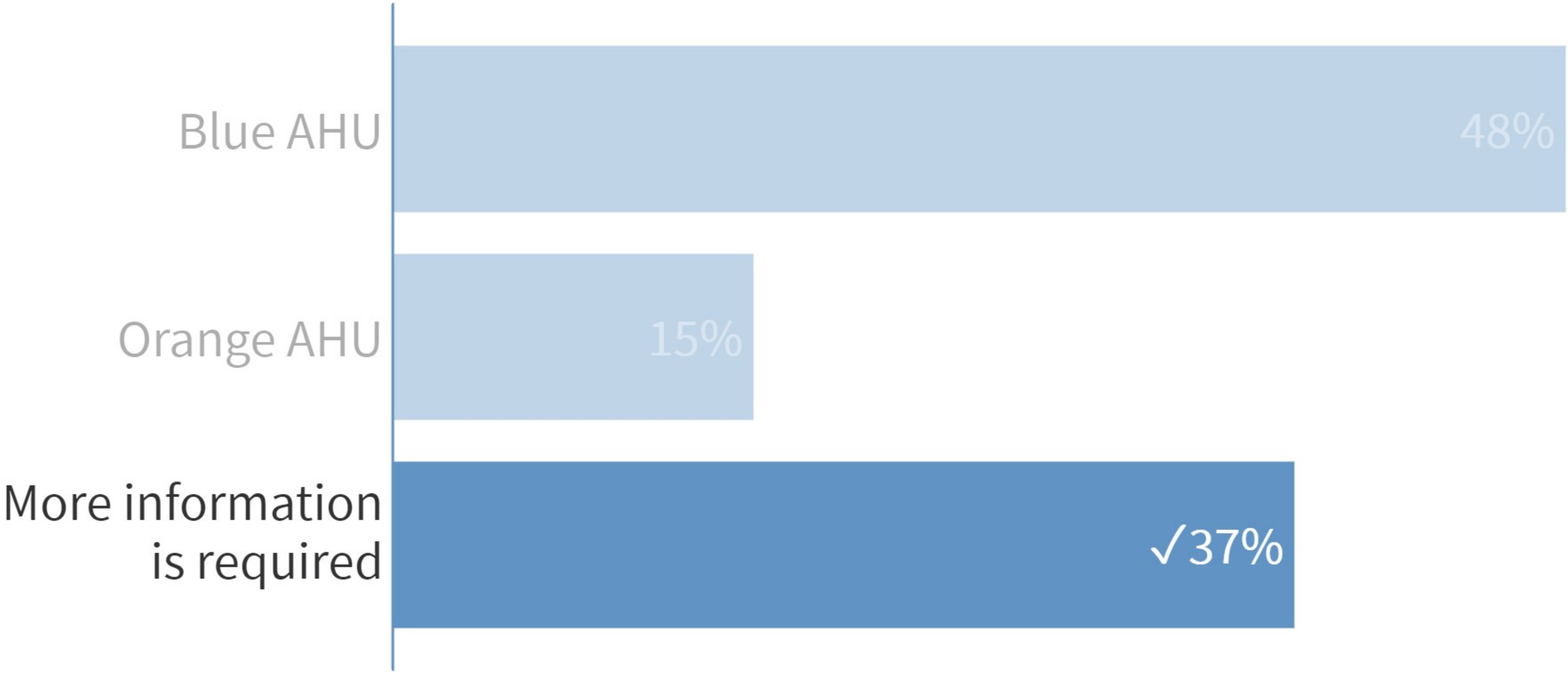
Pump Sizing Example – Which AHU (blue or orange) is the most hydraulically-distant?



Pick your answer for the poll on the next slide

New pump to size

Which unit is the most hydraulically-distant?



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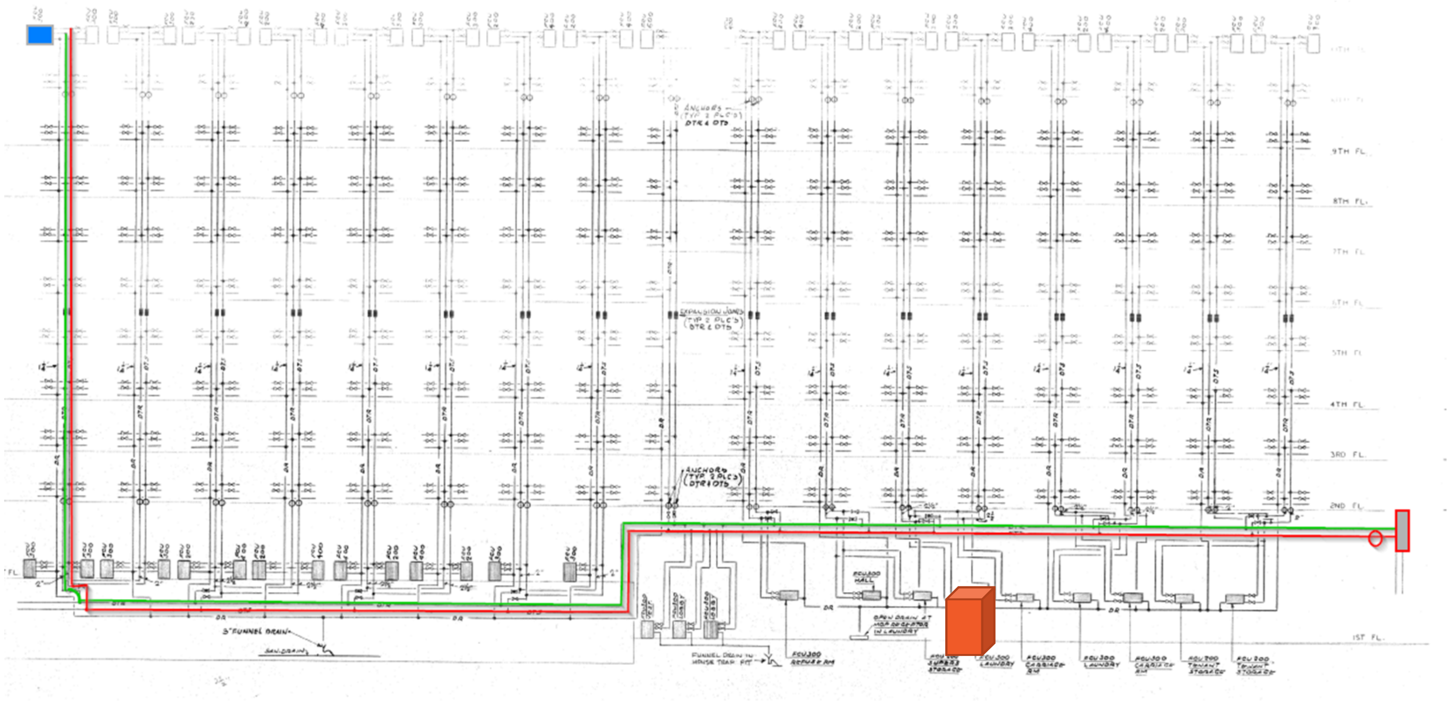
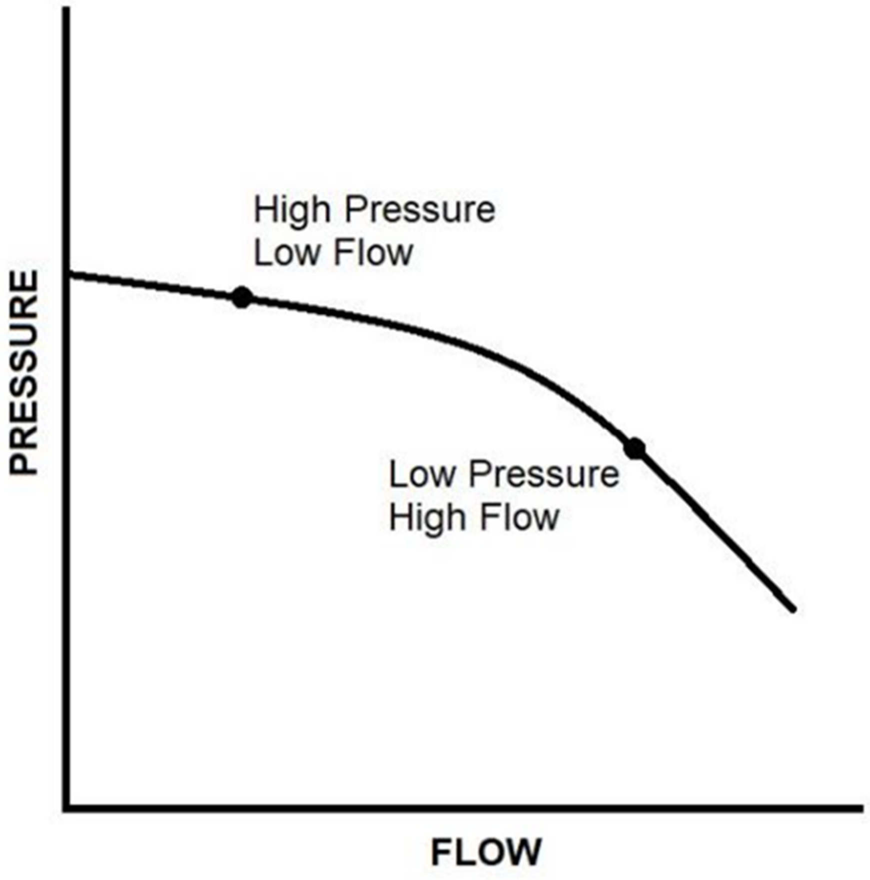


Pump Nameplate

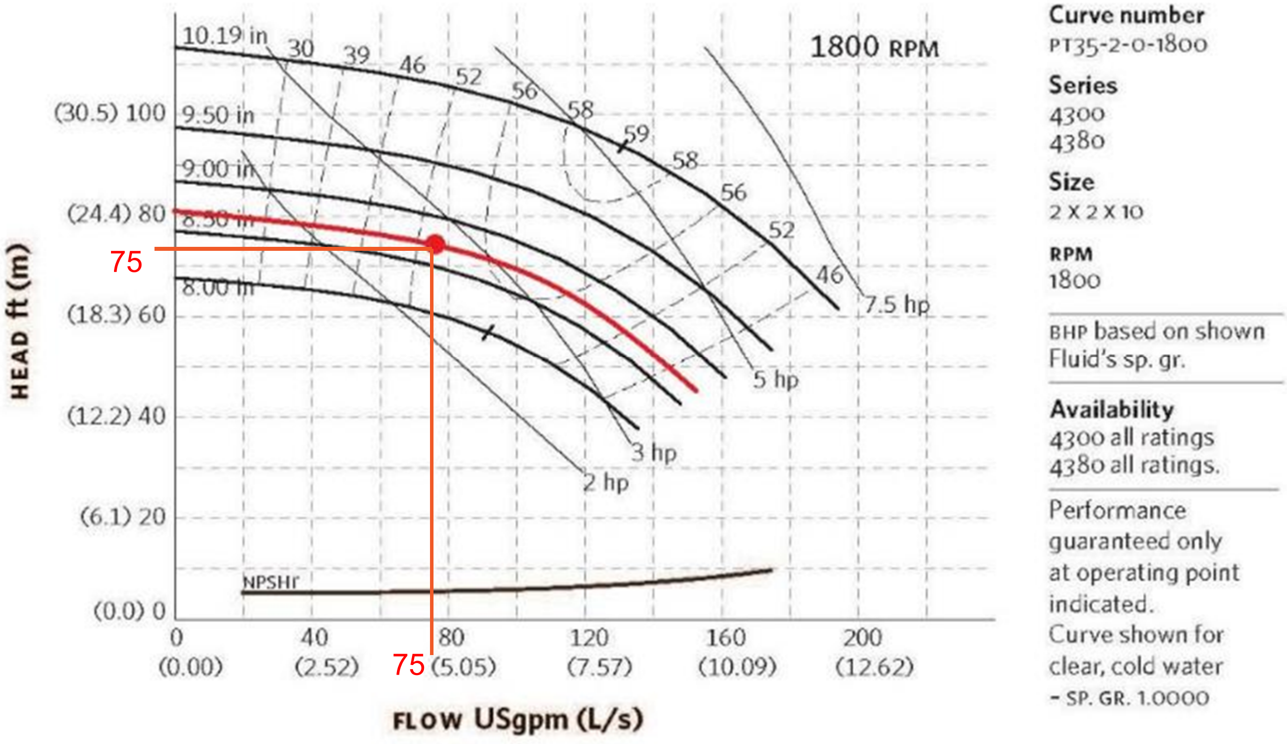
- Each pump has unique curve (relationship between pressure and flow)
- Engineers select a flow rate
- Calculate what the pressure drop will be at that flow rate
- Select a pump to meet that pressure and flow
- This **real** pump supplies 75 gpm at 75 ft of head pressure

Pump Pressure vs. Flow



- Pump curves show the relationship between pressure and flow
- Lower Head pressure = Higher flow
- Higher Head pressure = Lower flow

Determining Flow from Pressure



Curve number
PT35-2-0-1800

Series
4300
4380

Size
2 X 2 X 10

RPM
1800

BHP based on shown Fluid's sp. gr.

Availability
4300 all ratings
4380 all ratings.

Performance guaranteed only at operating point indicated.
Curve shown for clear, cold water - SP. GR. 1.0000

- Here's the design point for our example pump
- The engineer calculated 75 ft of head pressure where the pump supplies 75 gpm

What happened when the pump was installed

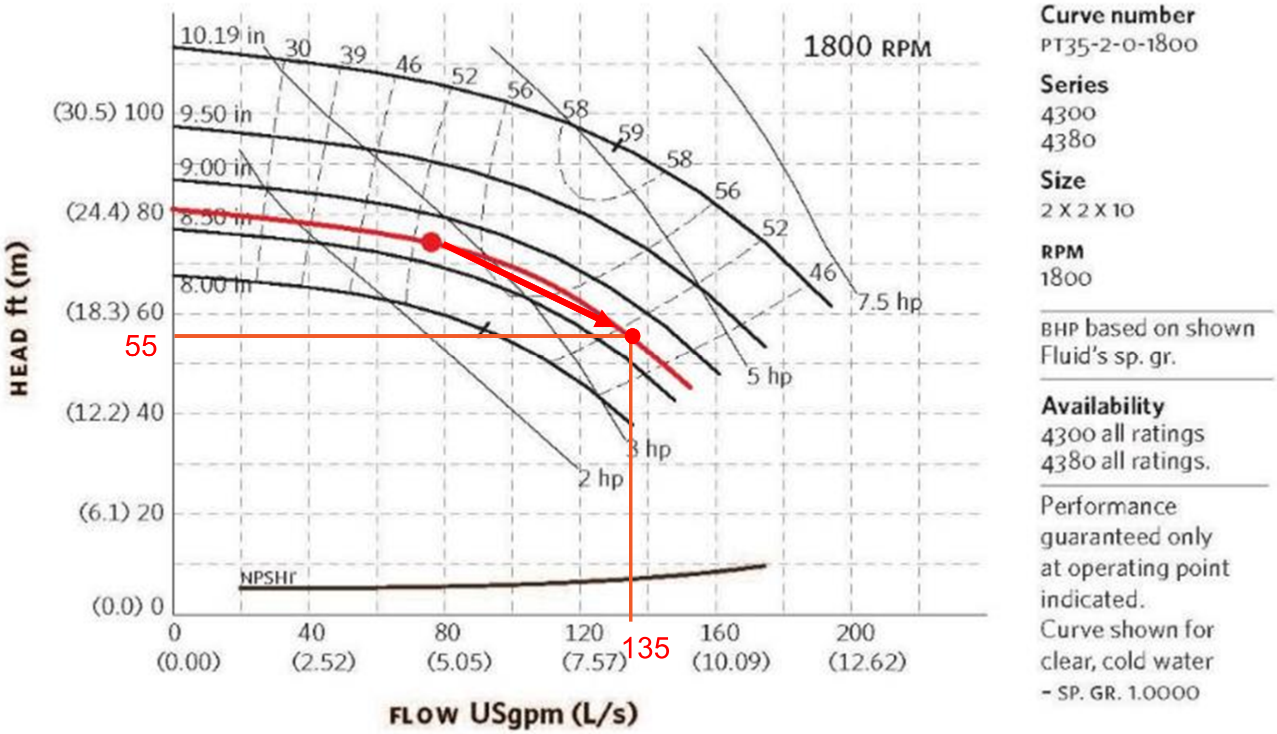
Pressure Before the Pump = 9 psi

Pressure After the Pump = 33 psi

Pump Head Pressure = 33 - 9 = 24 psi

Multiply 24 psi by 2.3 to get 55 ft of Head

Determining Flow from Pressure



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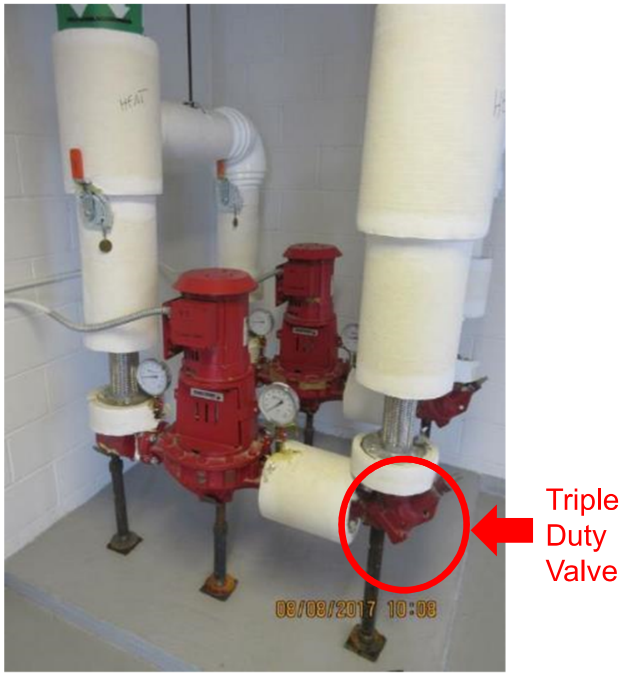
- SP. GR. 1.0000

- 55 ft of head is less than the design of 75 ft of head
- Therefore actual flow rate increases to 135 gpm
- The pump is oversized…

…which is **common**

Engineers are often wrong.

Accounting for Oversized Pumps

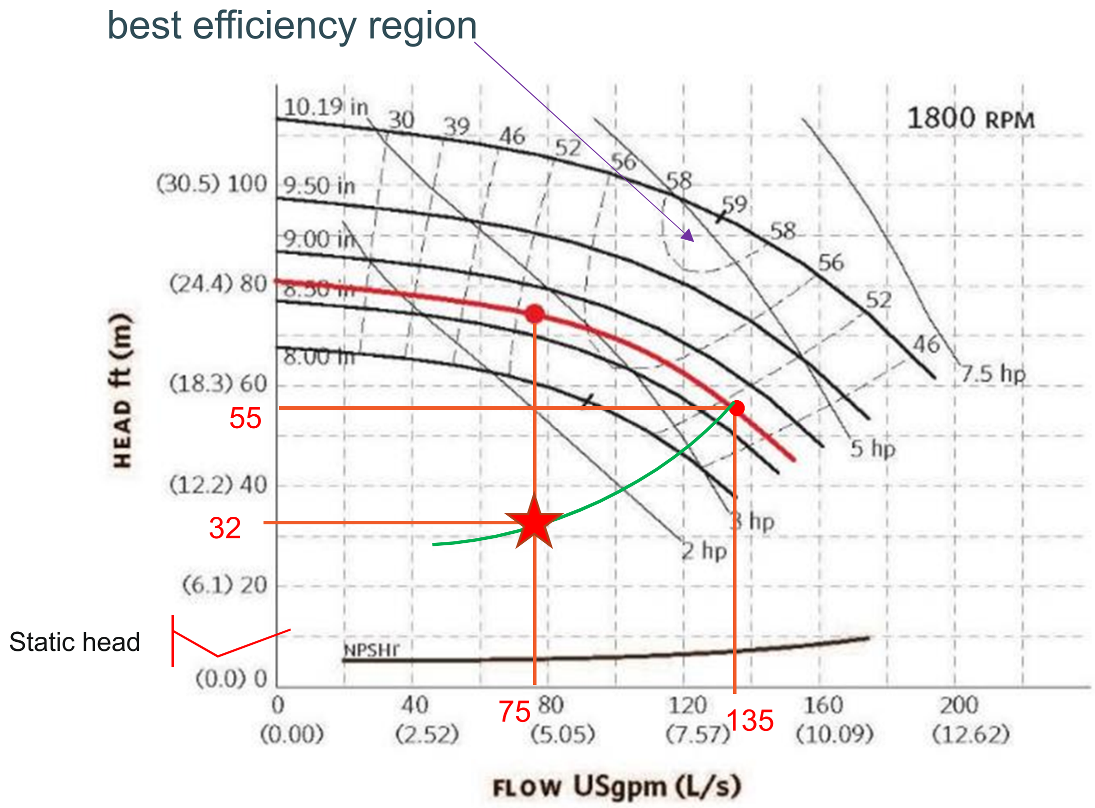


- Triple Duty Valves account for oversized pumps by adjusting the pressure
- Installed on pump discharge
- Tightening the valve adds pressure
  - **And decreases flow back to the design point**

VFDs

- Instead of using triple duty valve, drop speed of pump with VFD
- TDV may still be used for its two other functions at low-cost, but would be opened 100%
- But don’t just slap a VFD in to deal with poor sizing

VFD Impact on Our Oversized Pump


best efficiency region

Static head

- 55 ft of head at 135 gpm means less head at lower gpm (we decrease friction loss)
- VFD lowers speed, pump shifts back along system curve (in green)
- Lower speed = energy savings
  - But, look at efficiency
    - Sizing correctly gives more opportunity for efficiency

All terminal units should have…

- A controlled flow rate
- Balancing valves or Pressure Independent Control Valves (PICVs) add resistance to each heater to ensure they all get flow
- Without, water takes the easier path through the closest heater

2-way vs 3-way valves

- 2-way valves stop flow when closed
- 3-way valves redirect flow when close
- 2-way valves increase pressure when closed…
- 3-way valves do not

What Users Want

The other side of the same coin

- Controllable comfort
- Zoning
- Simultaneous heating/cooling across zones

Advanced Hydronics

Higher performance systems to support electrification

Ground Source Heat Pumps

- Potential source for high efficiency heating and cooling
- Ground is typically consistent temperature
- Can be with electric heat pump or gas (rare)


10/18/2018 13:55

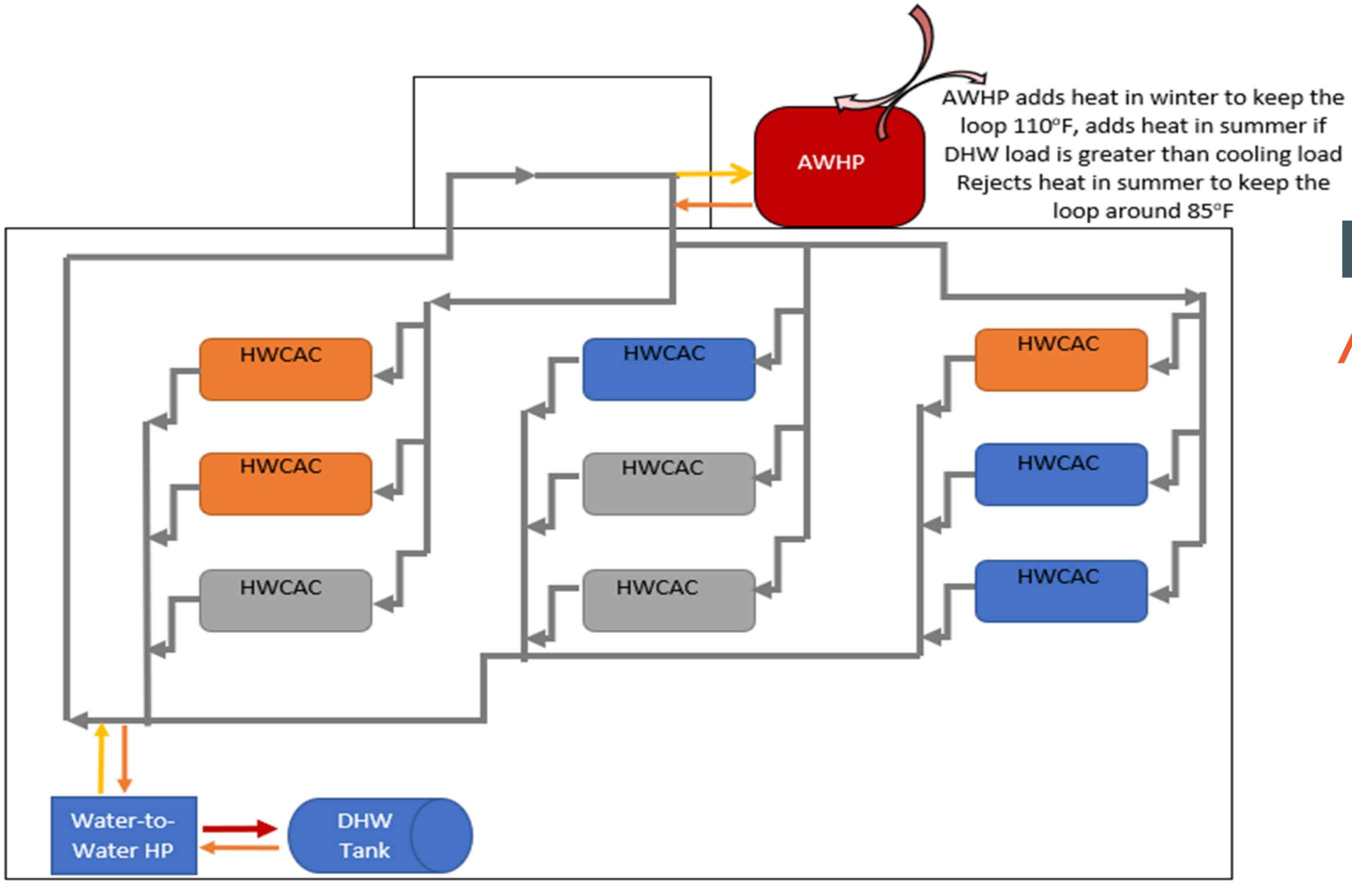
Flexible/Future Electrification

- Incorporate design details that enable low-cost future electrification
- For hydronics: LOW temperature loop

Low Temperature Hydronic Architecture

- *What can and what should be done today for future-proofing*
- Hydronic loop heated by air-to-water heat pumps (AWHPs)
- Terminal units accepting low/moderate temperature ranges (above 70F for cooling, below 110F for heating)
- Heat rejection either accomplished by AWHPs or by cooling tower

Low Temp Architecture



AWHP adds heat in winter to keep the loop 110°F, adds heat in summer if DHW load is greater than cooling load Rejects heat in summer to keep the loop around 85°F

Equipment Featured

HYBRID WATER COOLED AIR CONDITIONER (INDOOR UNIT)

AERMEC NRK AIR TO WATER HEAT PUMP (OUTDOOR UNIT)

WSHP also feasible

Similar products available from Samsung and others

Water-to-water HP

Why low temp?

- Heat pumps have limited operating ranges and efficient ranges
  - Refrigerant is a big limiter
- Assume <110F water produced on the coldest days

AERMEC NRK AIR TO WATER HEAT PUMP (OUTDOOR UNIT)

Interactive thinking

- AWHPs make “low” temp heating water (~110F)
- Low temp terminal units can handle it
- Using low temperature allows for simultaneous heating + cooling and heat recovery between units

HYBRID WATER COOLED AIR CONDITIONER (INDOOR UNIT)

Heat versus Cooling

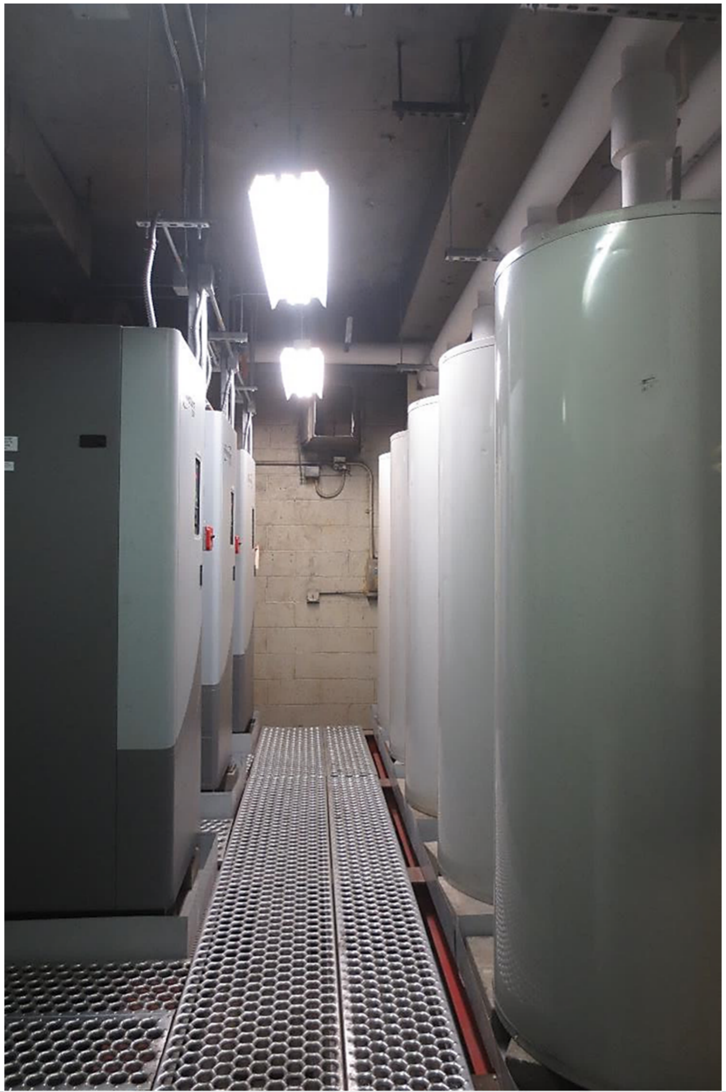
- High efficiency, low load buildings are more likely to blur the lines between heating and cooling season
  - Simultaneous access to heating + cooling is important
- High temp hydronics does not play well with diverse space needs
  - No way to inject and reject heat into “extreme” temp loops

Electrification of Hydronics

Summarizing the future-friendliness of hydronic systems

Future - compatible

- A low temp loop can be heated well by a condensing boiler today
- Selecting low-temp terminal units and leaving futures for AWHP connections makes it “easy” to electrify later
- Roof space
- Plumbing chases
- Futures and valves
- Electrical capacity where possible



Controls

- Control valves are required at every terminal unit to eliminate unneeded flow
- Low temp distribution systems inherently minimize losses
- Low load buildings are sensitive to poor control
- Higher dT on hydronic systems with 2-way control – only flowing where there is a load

Durability Gains

- No chilled water = no condensation
- No condensation = longer lifetime for pipes

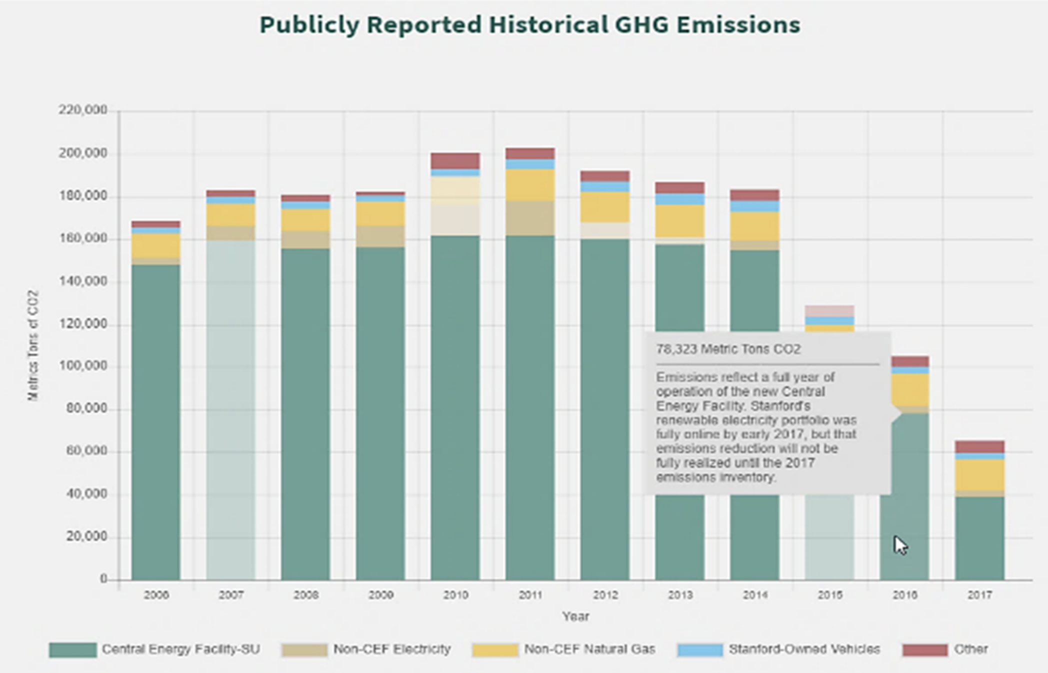
Questions?

Campus Central Plant Considerations

Central Plants in NYS

- There are at least 20 central plants serving district systems in NY, most are at colleges/universities
- Goals: **heat recovery** across multiple building types, electrification
- Typical process: study loads, evaluate remaining lifetime for major equipment, reduce loads, get off steam, move towards lower operating temperatures, improve plant efficiency, bring in renewables

Stanford Success



78,323 Metric Tons CO2

Emissions reflect a full year of operation of the new Central Energy Facility. Stanford's renewable electricity portfolio was fully online by early 2017, but that emissions reduction will not be fully realized until the 2017 emissions inventory.

- Stanford began construction of its central plant conversion in 2012, and emissions dropped 68% from peak levels in the first year the new system has been online (2017).
- Baseline system was a gas-fired cogeneration plant with steam distribution for the campus.

Brown University

Brown University's baseline distribution system is a high temperature high pressure water loop

System redesign to go online in late 2020

Leveraging existing hydronic district infrastructure

A key challenge was determining the heating capacity available in the existing district pipelines and how to meet building loads with the district loop operated at a new temperature setpoint.

SUNY New Paltz

- Develop a long term plan
  - Leverage district loop?
  - Building systems conversions?
  - Addition of geothermal system?
  - Role of renewables and heat recovery?

10 Minute Break

Domestic Hot Water

Water to water hot water heat pumps

Air to water hot water heat pumps

Some Vocab to Start

- Potable – typically we just mean the water people get out of taps, it’s safe and drinkable
- DHW – domestic hot water = potable hot water
- DWH – domestic water heating (the verb form)
- WH/HWH – water heater (or “hot water heater”)
  - Boilers make non-potable water hot
  - WHs make potable water hot
- Fixtures – sinks, showerheads, faucets, etc. things that give you water
- Legionella – the naturally-occurring bacteria that blooms in warm water and causes Legionnaires disease (pneumonia-like) and Pontiac fever (flu-like)

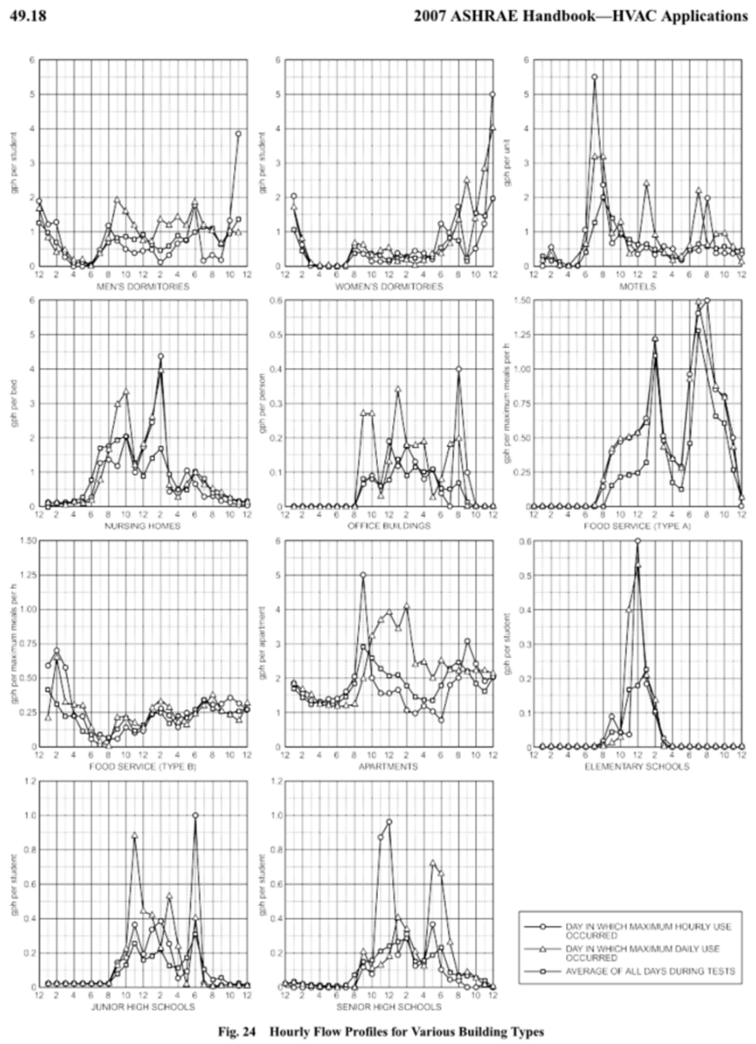
Types of DHW

- **Central**
  - One (or more) big plants that heat water for many units/people

- **Decentralized**
  - Water is heated in many locations, for example in each apartment or dorm, or under each sink (Commercial)

Sizing DHW Loads

- ASHRAE has profiles for many typologies in Applications chapter on Service Water Heating
- MEPs typically oversize
- Measuring actual loads is much cheaper than oversizing

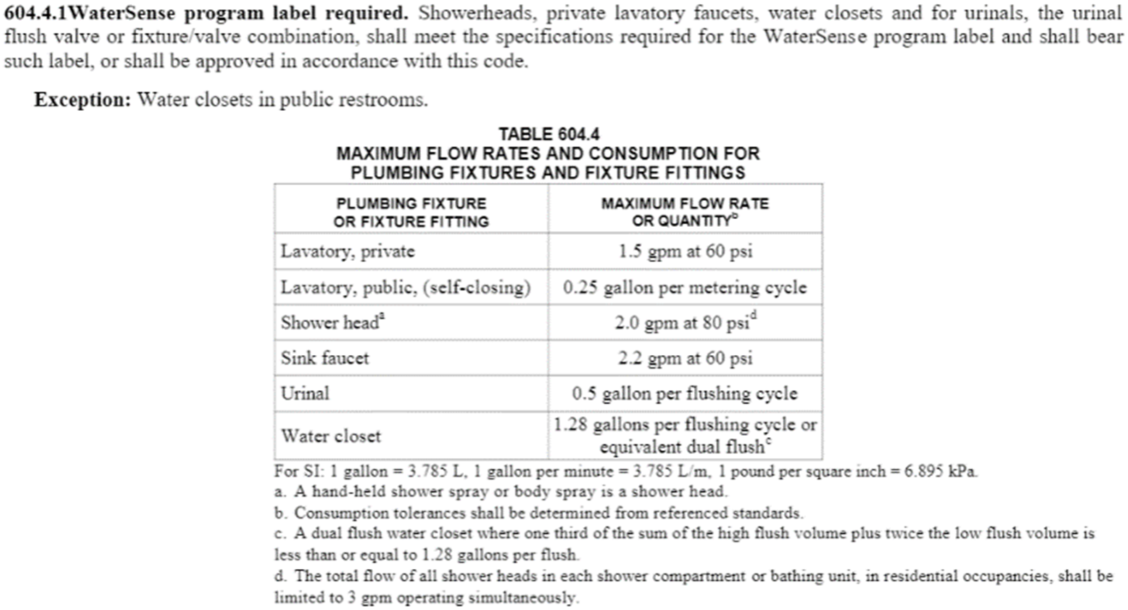


49.18 2007 ASHRAE Handbook—HVAC Applications

Fig. 24 Hourly Flow Profiles for Various Building Types

Flow Rates

- Too-high flow – Home Depot shelves don’t always meet code
- Code flow – NY Plumbing Code
- SWA rec flow – 1.0 gpm bath sink, 1.5 shower and kitchen
- Complaint zone – 0.5 gpm in residences



604.4.1WaterSense program label required. Showerheads, private lavatory faucets, water closets and for urinals, the urinal flush valve or fixture/valve combination, shall meet the specifications required for the WaterSense program label and shall bear such label, or shall be approved in accordance with this code.

Exception: Water closets in public restrooms.

TABLE 604.4
MAXIMUM FLOW RATES AND CONSUMPTION FOR PLUMBING FIXTURES AND FIXTURE FITTINGS

PLUMBING FIXTURE OR FIXTURE FITTING	MAXIMUM FLOW RATE OR QUANTITY[b]
Lavatory, private	1.5 gpm at 60 psi
Lavatory, public, (self-closing)	0.25 gallon per metering cycle
Shower head[a]	2.0 gpm at 80 psi[d]
Sink faucet	2.2 gpm at 60 psi
Urinal	0.5 gallon per flushing cycle
Water closet	1.28 gallons per flushing cycle or equivalent dual flush[c]

For SI: 1 gallon = 3.785 L, 1 gallon per minute = 3.785 L/m, 1 pound per square inch = 6.895 kPa.

a. A hand-held shower spray or body spray is a shower head.

b. Consumption tolerances shall be determined from referenced standards.

c. A dual flush water closet where one third of the sum of the high flush volume plus twice the low flush volume is less than or equal to 1.28 gallons per flush.

d. The total flow of all shower heads in each shower compartment or bathing unit, in residential occupancies, shall be limited to 3 gpm operating simultaneously.

Electrifying DHW

- Efficient electric DHW is analogous to heat pump heating – it is NOT just a replacement of a gas boiler with an electric one.
    - This section touches on many differences

Heat Pumps – Smaller Scale / Indoor Systems

- Many indoor options readily available in US market
- Must get the design right!

Large Scale / Outdoor HPWH

- Commercial grade for modular engineered solutions
- Little to no market penetration in the USA in multifamily
- Widely used in Asia and Europe for DHW
- In USA, used in commercial/industrial applications

Large Scale HPWH

Down to -4F

R-410A

Up to 150F

Down to 40F

R-410A

Up to 150F

Ambient Temp

Refrigerant

Max H_2O Supply

Down to 10F

R-410A

Up to 150F

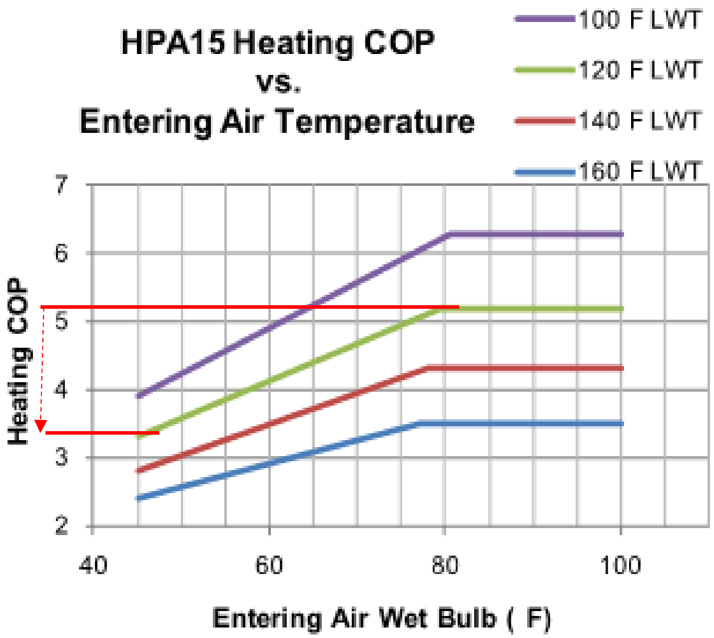
Down to 14F

R-744

Up to 194F

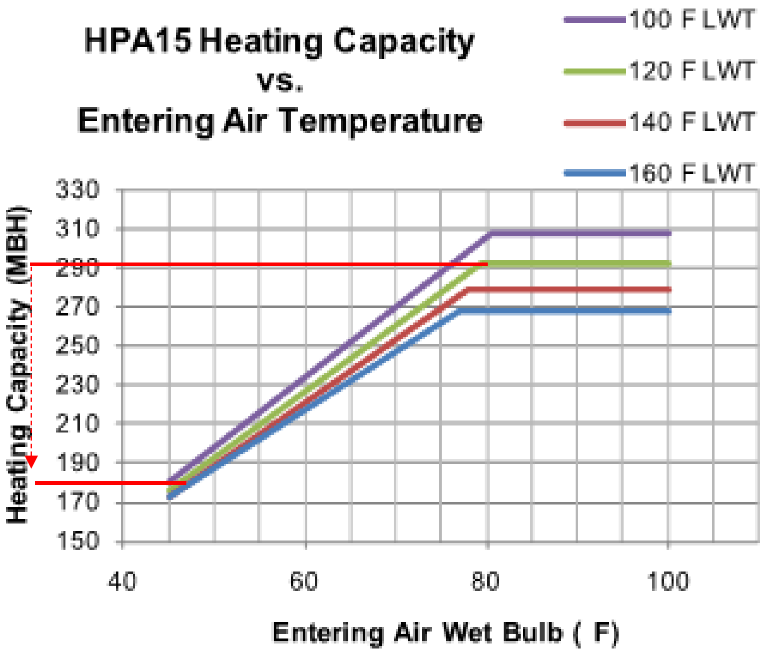
LISTED

Heat Pumps - Designing for Cold Climates



36% efficiency drop in colder temps

Impacts **energy costs and savings**



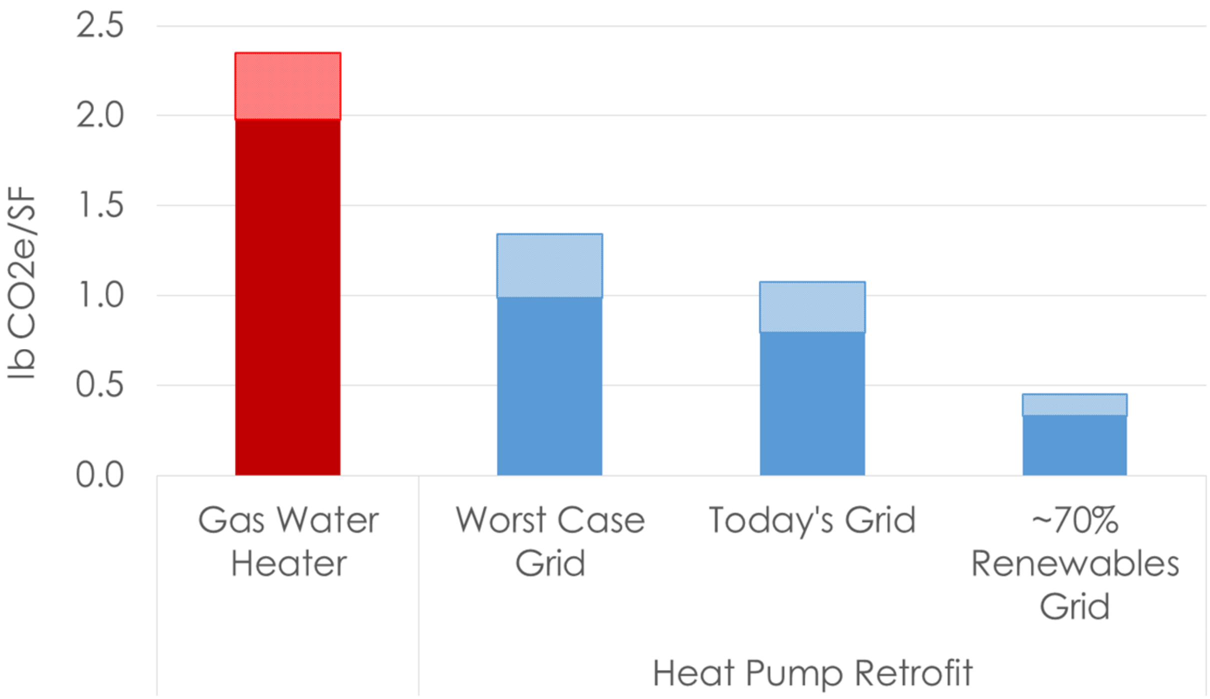
38% capacity drop in colder temps

Impacts **sizing of storage**

Other Challenges

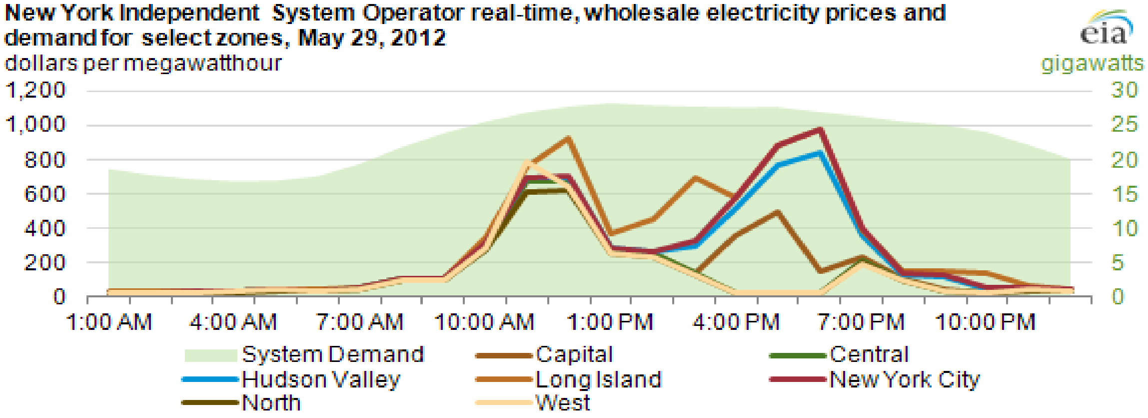
- Finding space outdoors
- Very few outdoor use options in the US market today (Sanden's 15 MBH only CO2)
- Balance of system upgrades required
  - Electrical service to roof, plumbing penetrations/ties ins, pumps
- Potential rooftop installation trouble with larger units – small halls, door openings + large components

Emissions from Traditional DHW vs Heat Pumps in NYC



Gas is the same in up/downstate, but **HP emissions are lower upstate than in NYC**

Reforming the Energy Vision - REV



- Improve system efficiency by balancing peaks and valleys

  1% = $221-330 million/year savings
- Nighttime off-peak storage tank charging
- Daytime solar PV tank charging

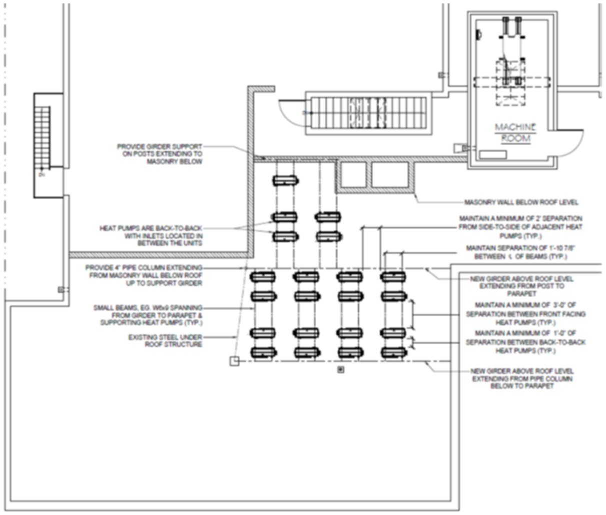
Domestic Hot Water Electrification Summary

- Efficient electrification of DHW is needed
- It gets very cold outside, central plants need high temperature water
- CO2 is a good fit, but very few options on the market in US (many elsewhere)
- R-410a and R-134a options (slightly) more common
- Plant design and sizing requires thought – not 1 for 1 replacement of boilers

Case Studies

Electrifying domestic hot water

Case 1: Aggregation with 100% load coverage



AIR TO WATER
HEAT PUMP

- 14 Sanden units to go on the roof, feeding plant in the basement
- Control system to make DHW with gas or electric intelligently
- ~50 apartment units

Case 2: Summer AC campus concept

- Decentralized DHW and energy storage for campuses – allows for central steam plant to be taken off-line during the summer months.
- HPWHs in basements with ducting to lobbies
- Water heaters provide useful air conditioning in summer

Case 3:

Displacement of District/Campus Steam

- Thermal storage + HPWHs lessen winter steam demand peaks
- HPWHs provide DHW using waste heat from steam piping

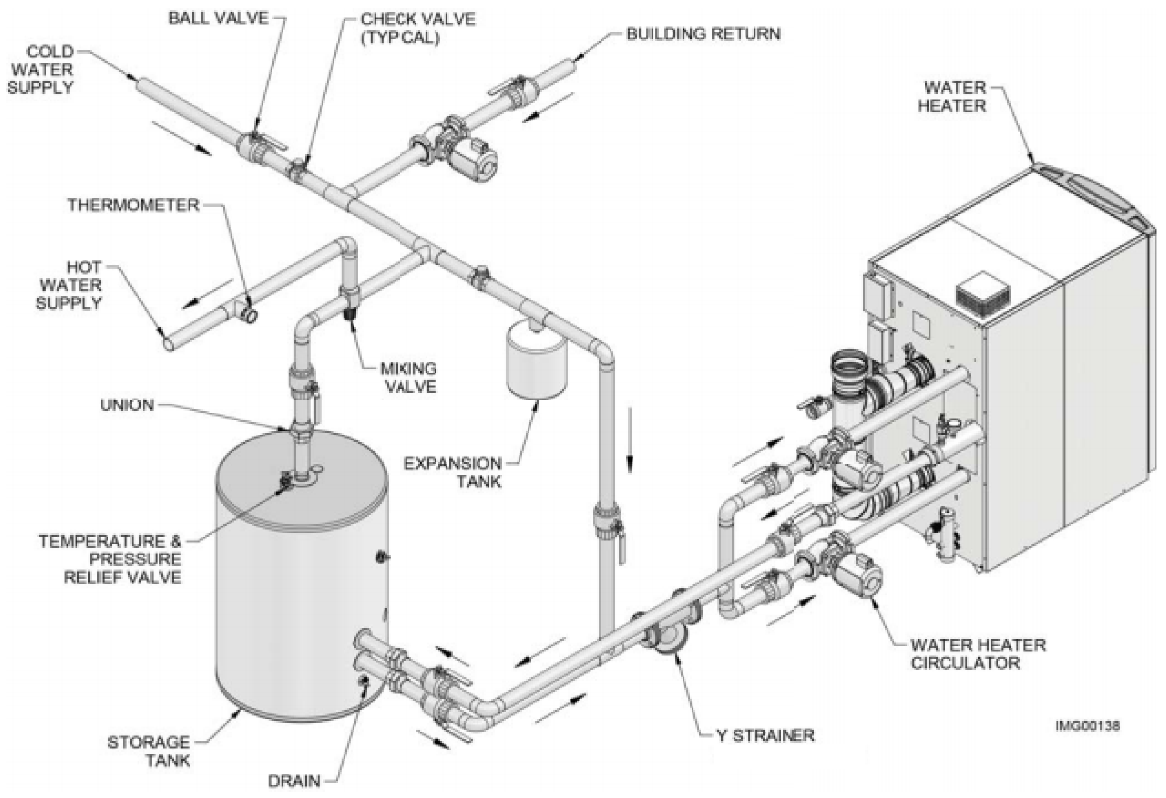
Questions?

What Doesn’t Work

Condensing water heaters are not a silver bullet

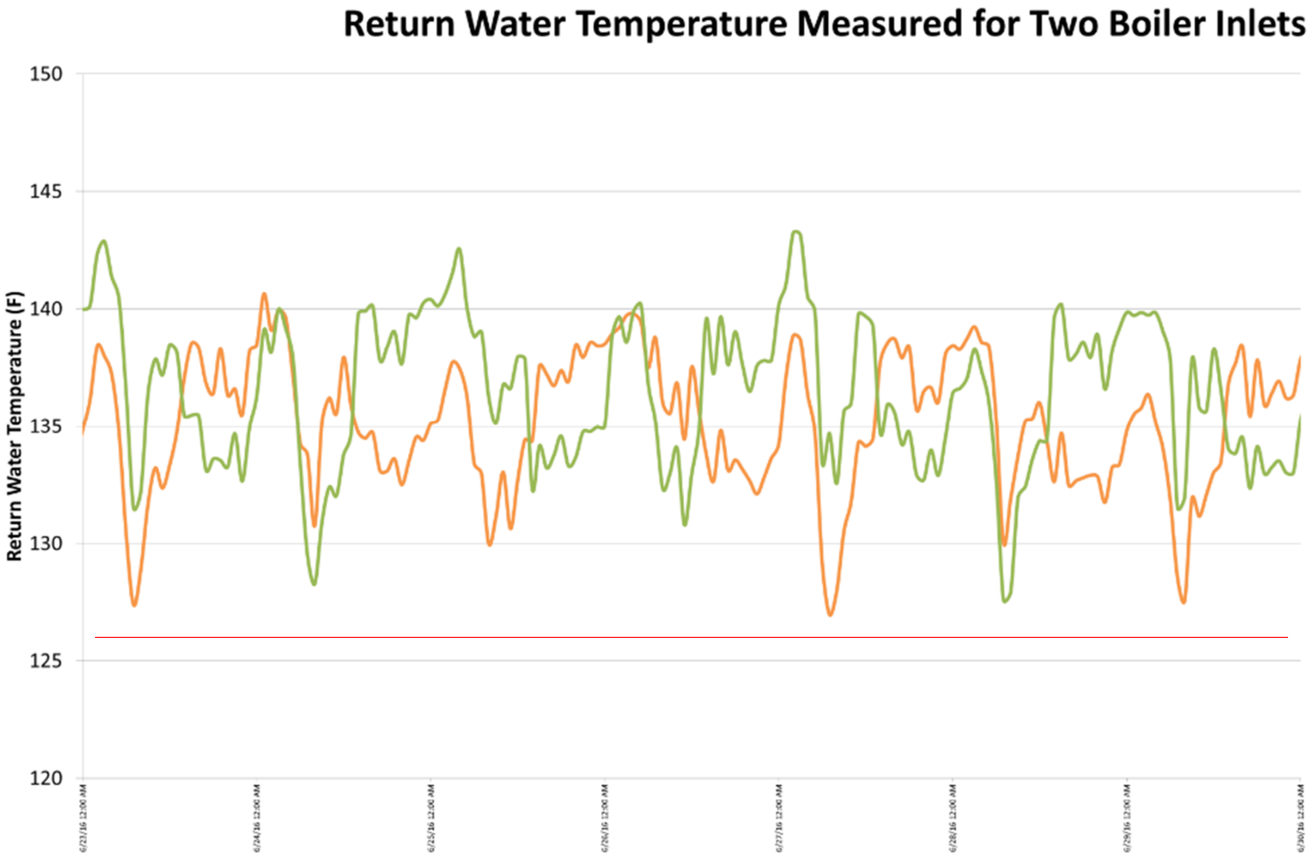
Strategies for Dedicated DHW Production

- Instantaneous DHW
  - High dT (50F to 130F) required
    - Boilers capable of meeting high dT, not HWHs
  - Large boiler plant capacity req’d to meet full peak load without storage
    - **high first cost**



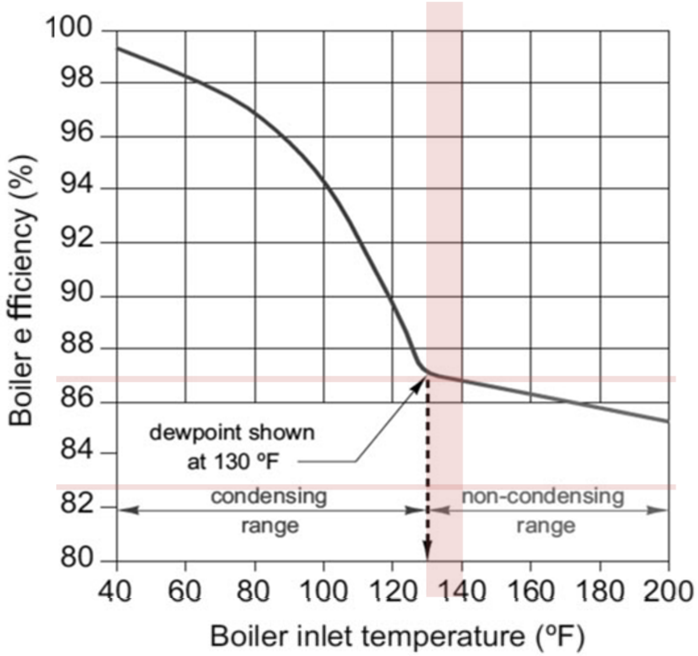
Strategies for Dedicated DHW Production

- Storage (tank) + boiler/heater
  - Common solution – focus of our discussion
  - Lower dT (WH boosts tank only)
  - Hot water heater can meet low dT (boiler not required)
  - Storage tank must be kept >140F due to Legionella, results in too high inlet temp for condensing, **low savings**



Return temp varies with tank and load. High load = more CW blended in, low load = less CW and higher return temp.

[Non] Condensing Boilers



"condensing" boiler
~87%

High mass boiler ~83%
(not atmospheric)

Passing the design buck

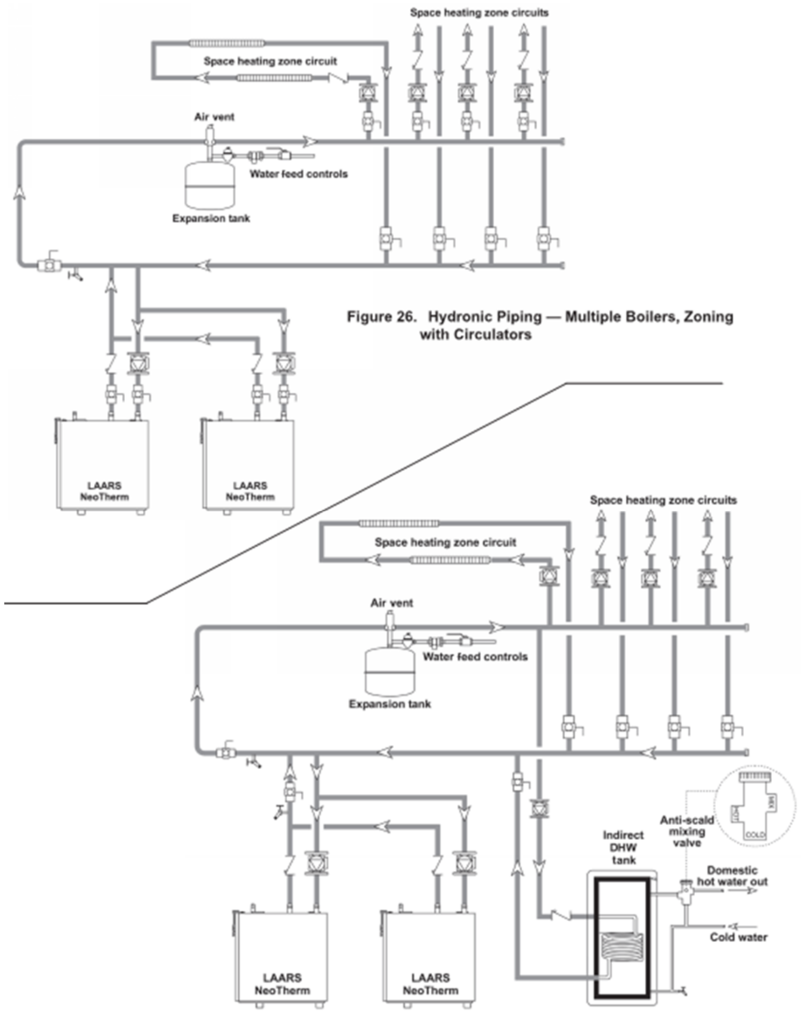


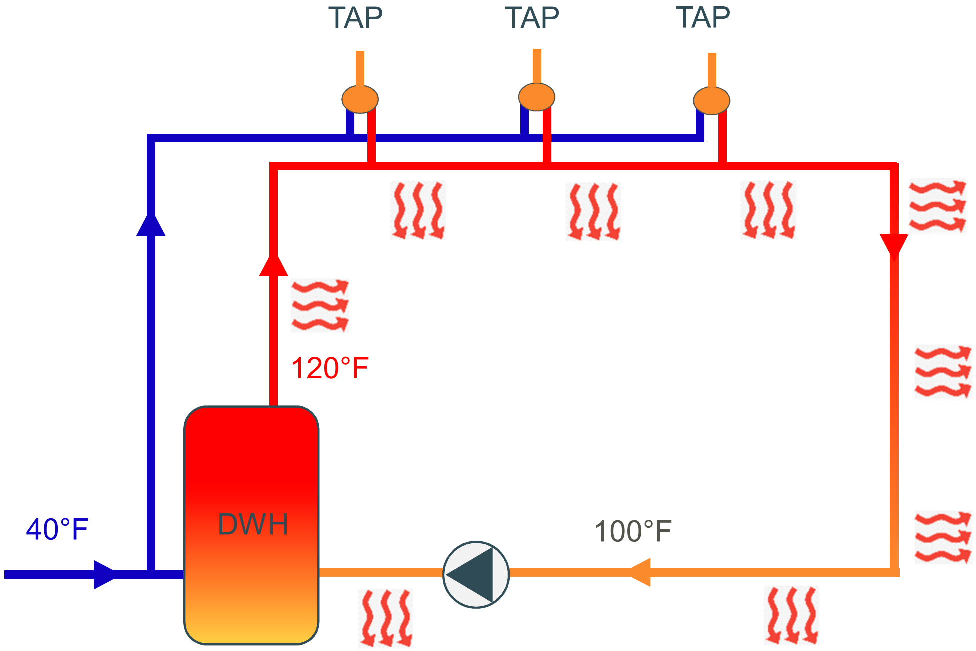
Figure 26. Hydronic Piping — Multiple Boilers, Zoning with Circulators

- Reps and manufacturers effectively design most traditional systems
- MEP budgets don’t support re/invention
- This applies to most HVAC, not just DHW

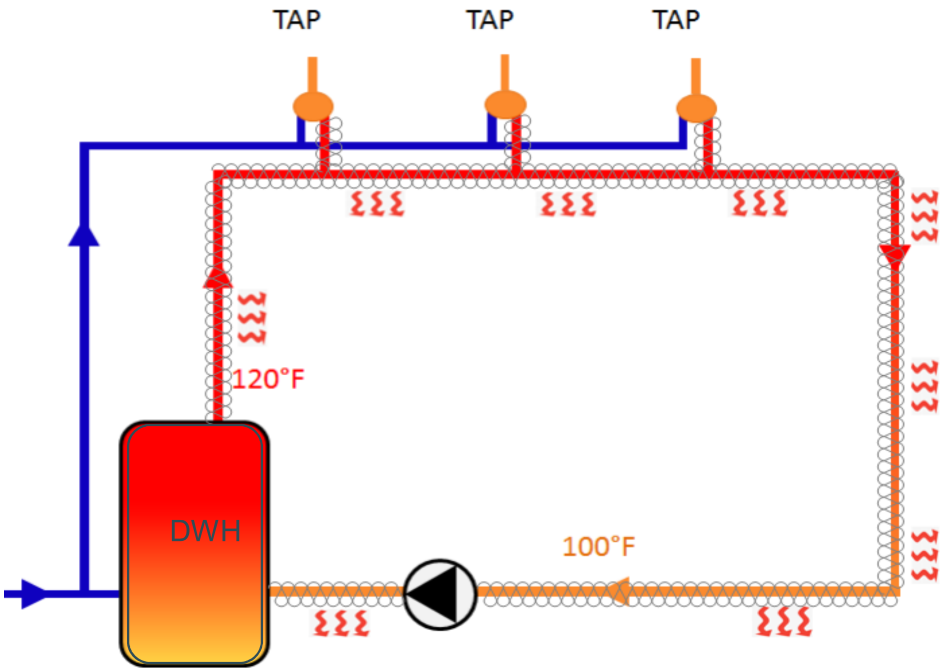
Efficient DHW Delivery

Distribution system losses
are significant

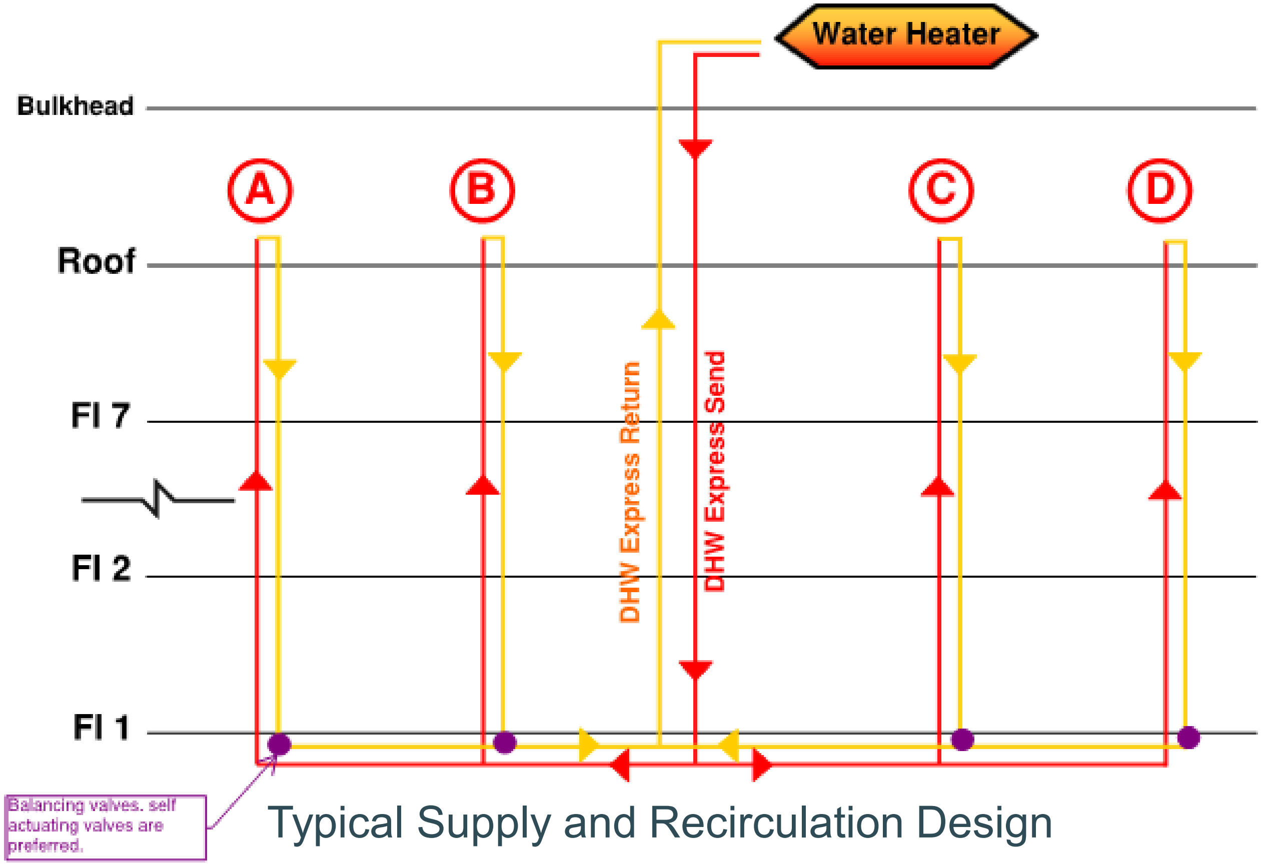
Central Recirculation



Central Recirculation



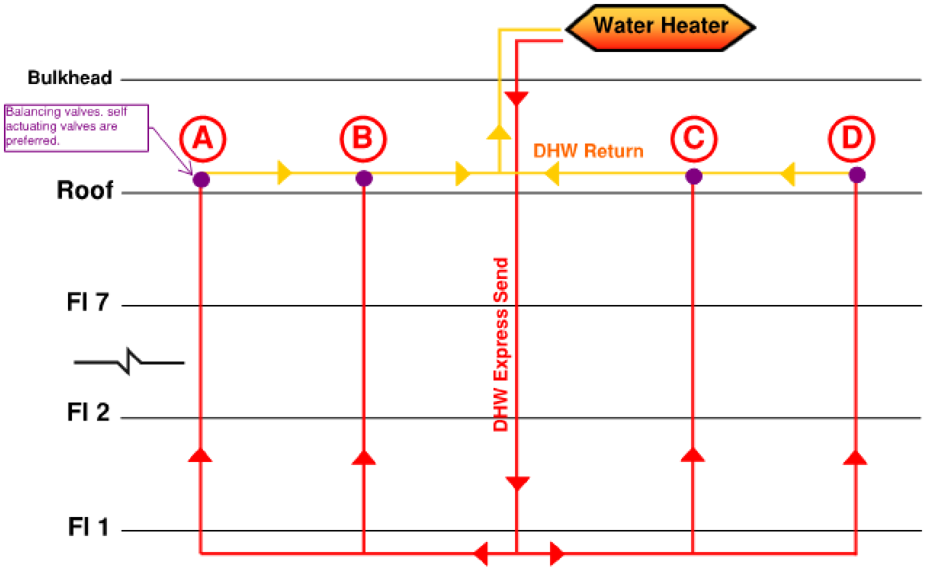
Designing Optimized Recirculation



Balancing valves, self actuating valves are preferred.

Typical Supply and Recirculation Design

Design Optimization – Central Recirculation



Building Section - "Box" Design

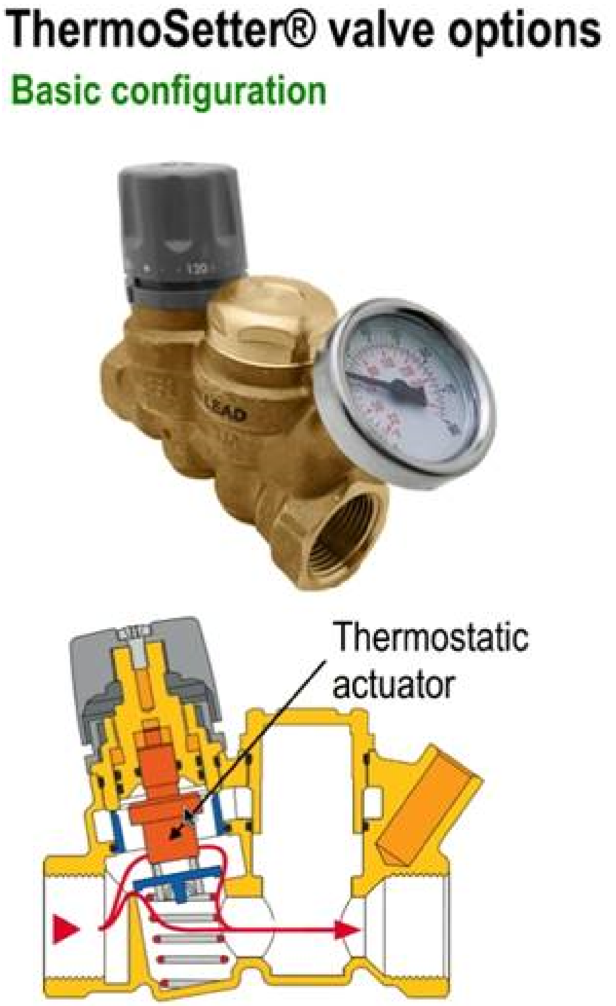
- Will reduce distribution piping by ~40%.
  - Pumping energy ↓
  - Material costs ↓
  - DHW heating costs ↓
- Balancing critical
  - Thermostatic balancing valves help
- May impact floor to floor heights

Central Recirculation Optimization

Case Study

- 37 story residential tower
- Switched from 3-pipe to box design
- Savings
  - 10,000 ft of recirc. piping
  - 18% reduction DHW heating
  - 16% reduction cooling

Hot Water Recirculation Controls



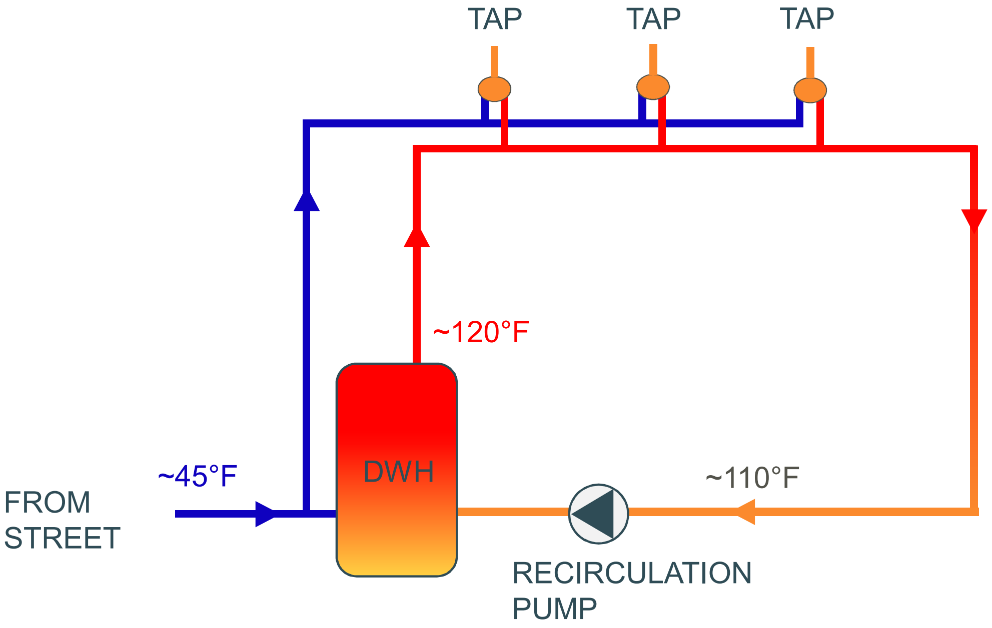
- **Control Options**
  - Timer Control
  - Temperature Control
  - Temperature Modulation Control
  - Demand Recirculation Control
  - Demand + Temperature Modulation Control
- **Balance the returns**
  - Balanced = MUCH lower flow rate needed. Lower flow = energy savings and improved heat pump performance

Potable Water Pumps

Domestic hot and cold pumping

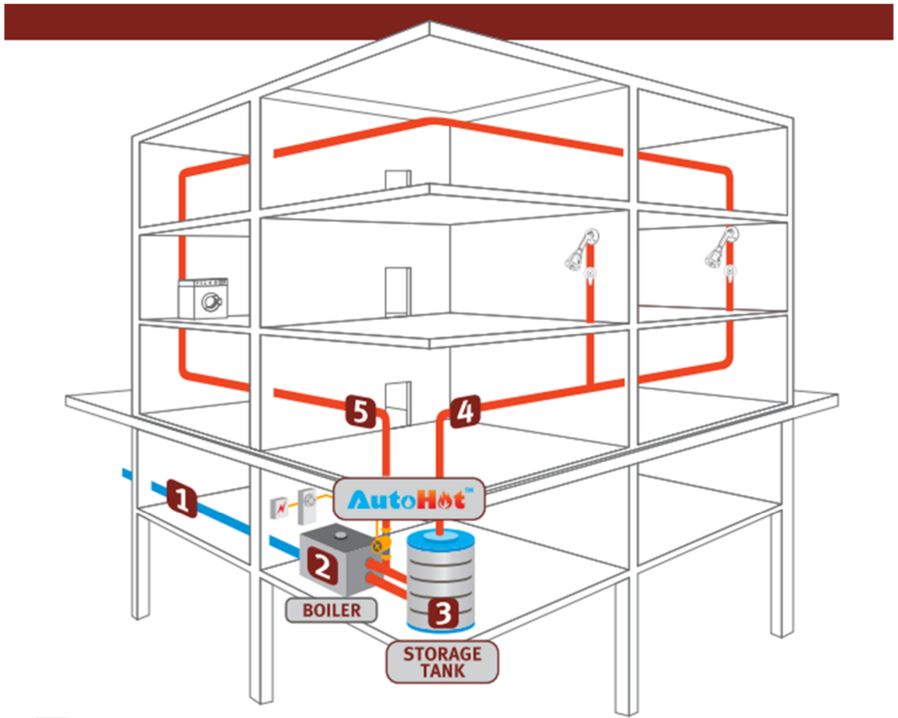
Hot Water Recirculation Pumps

- Used to ensure hot water at taps at all times
- Fractional HP
- Always over"sized"
- Usually constant speed
- Options for controls
  - Limited in larger buildings



Central Plant Sore Spots

- Recirc pumps are always too big
- AutoHot / D’mand systems fight electronic mixing valves
- Mixing valve hunting



1 City Cold Water Supply

2 Is heated to Approximately 140°F

3 Hot water is kept in storage until there is a demand for it

4 Flow sensor is installed on supply line, triggered by user demand

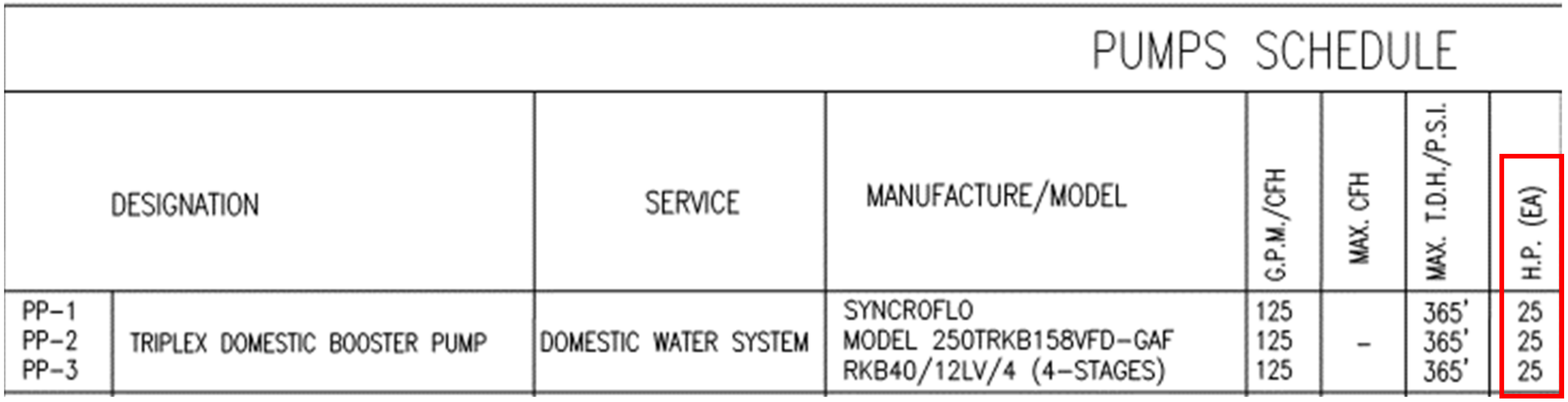
5 **AutoHot™** tracks hot water through a heat sensor on the return line, operating only when demand is combined with below target temperature

Case Study – Recirc Control

- Used demand-based hot water recirculation pump
- Issues
  - **Pump was oversized** – circulating water at >40 gpm. Should be <20 gpm.
  - **Temp sensor** – poor installation
  - **Pump was running during periods of low-demand** (ie. overnight).
  - **Massive temperature swings** in supply hot water temp when pump was not running. Mixing valve was hunting.


BGN DHW Plant- Nov 12
Deg F
160
150
140
130
120
110
100
90
80
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
11 PM
Recirc Pump Status
DHW Supply Temp
DHWR Temp
Tank 2 Temp

Domestic Cold Water Booster Pumps

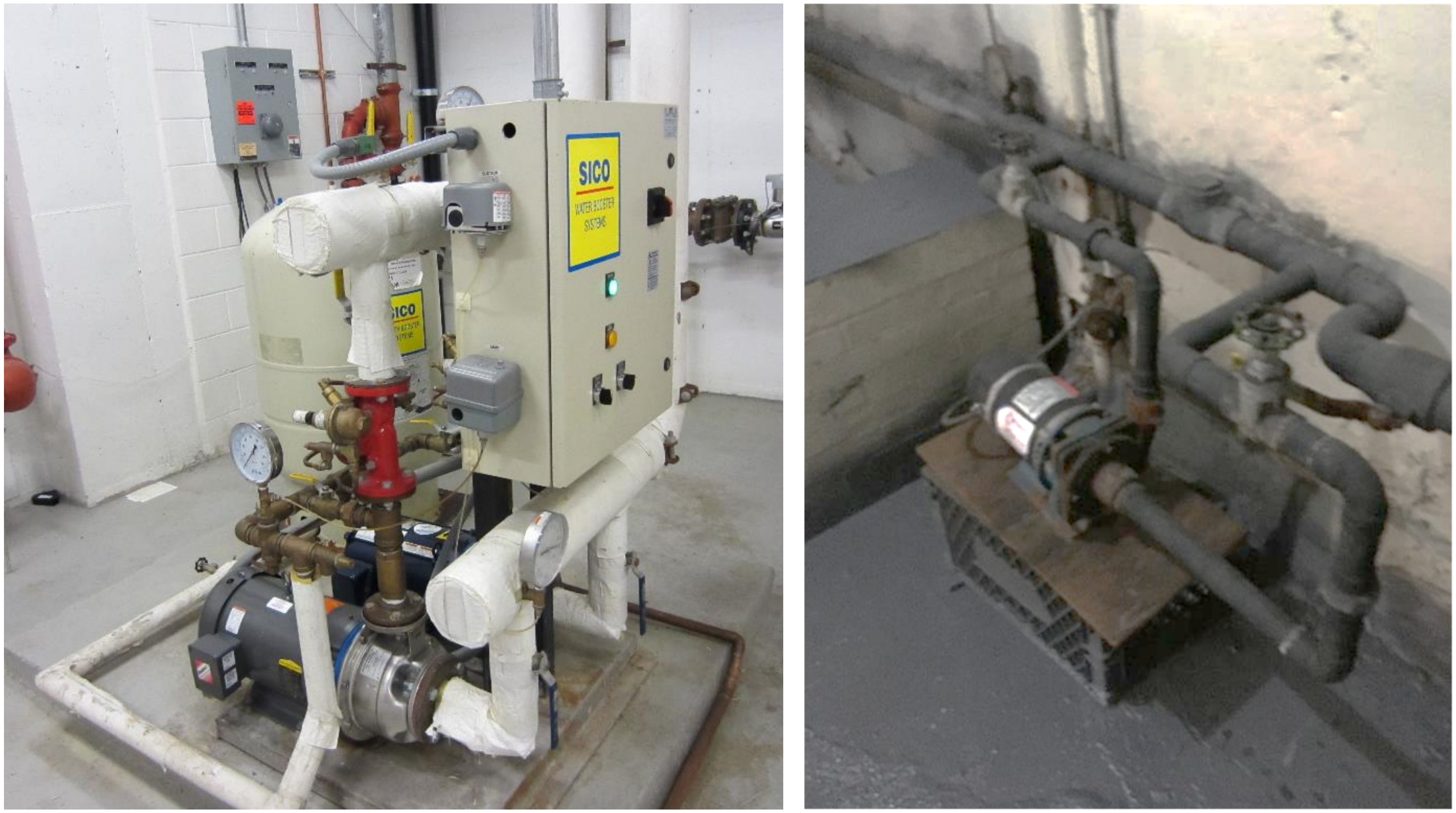


PUMPS SCHEDULE

DESIGNATION		SERVICE	MANUFACTURE/MODEL	G.P.M./CFH	MAX. CFH	MAX. T.D.H./P.S.I.	H.P. (EA)
PP-1	TRIPLEX DOMESTIC BOOSTER PUMP	DOMESTIC WATER SYSTEM	SYNCROFLO MODEL 250TRKB158VFD-GAF RKB40/12LV/4 (4-STAGES)	125	-	365'	25
PP-2				125		365'	25
PP-3				125		365'	25

- Very high horsepower
- Often variable frequency drive (VFD)
- Sized for redundancy

Booster Pumps – Small Buildings

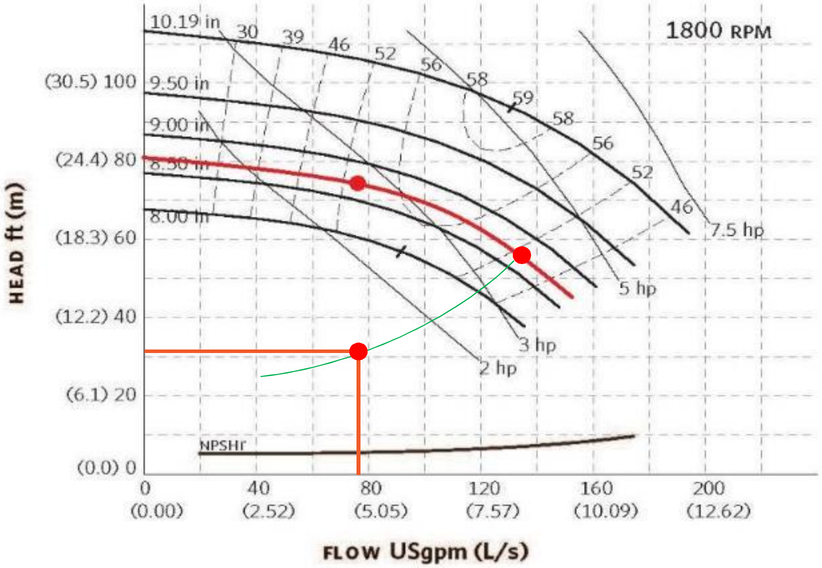


Booster Pumps – Big Buildings

Old meets new

Roof
Tanks

Is a VFD **always** the most efficient option?



Some hints

Questions?

5 Minute Break

Ventilation

Supply, Distribution, Controls, and Performance

Goals

- Meet code minimums
  - Really meet them, not just design to them
- Meet certification program requirements
- Remove contaminants
- Provide comfort
- Mitigate energy penalty of IAQ

Code Requirements

Design, not necessarily performance!

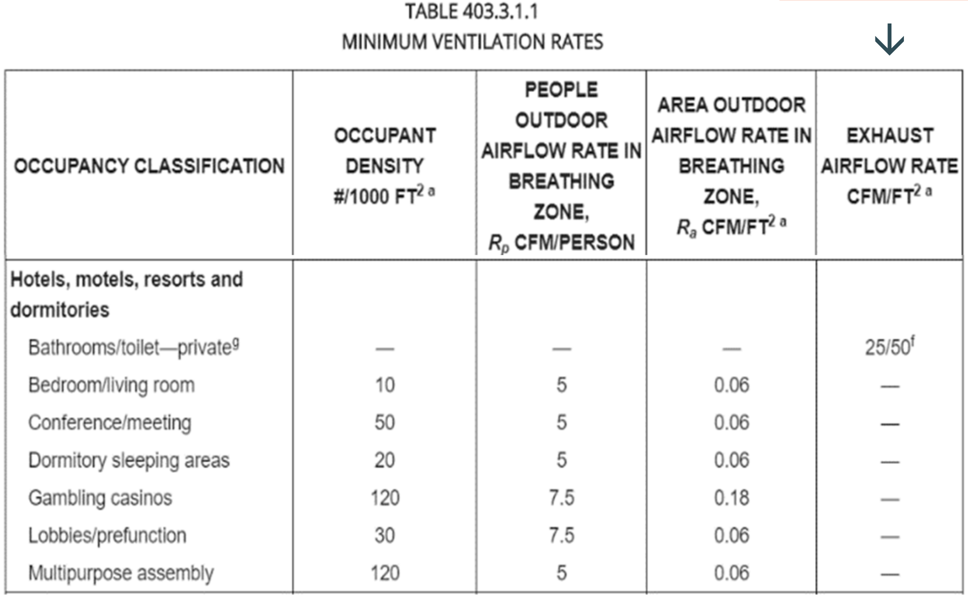


TABLE 403.3.1.1
MINIMUM VENTILATION RATES

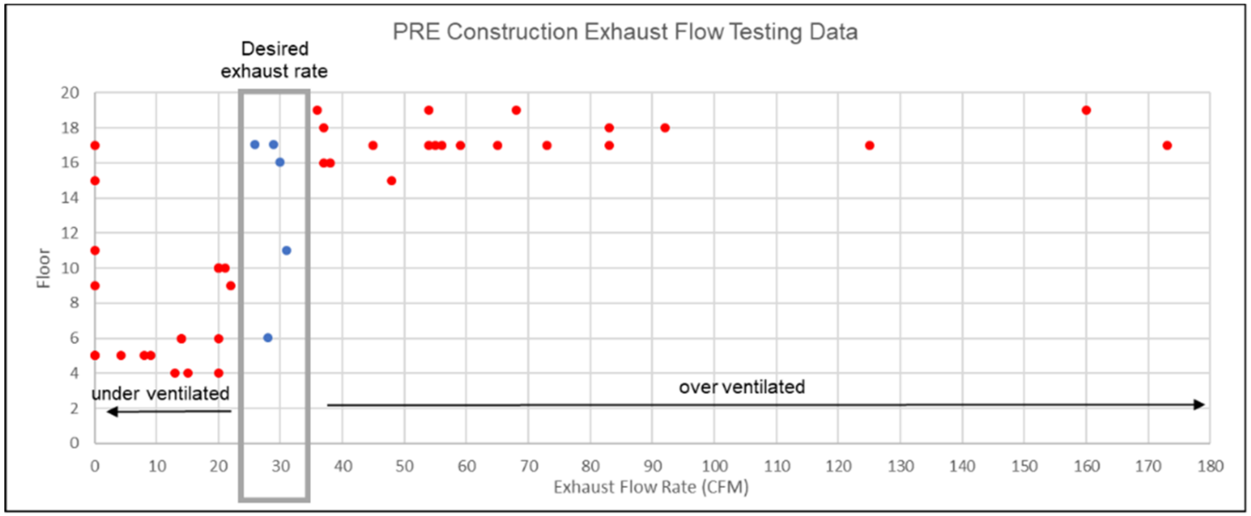
OCCUPANCY CLASSIFICATION	OCCUPANT DENSITY #/1000 FT^2 [a]	PEOPLE OUTDOOR AIRFLOW RATE IN BREATHING ZONE, R_p CFM/PERSON	AREA OUTDOOR AIRFLOW RATE IN BREATHING ZONE, R_a CFM/FT^2 [a]	EXHAUST AIRFLOW RATE CFM/FT^2 [a]
Hotels, motels, resorts and dormitories				
Bathrooms/toilet—private[g]	—	—	—	25/50[f]
Bedroom/living room	10	5	0.06	—
Conference/meeting	50	5	0.06	—
Dormitory sleeping areas	20	5	0.06	—
Gambling casinos	120	7.5	0.18	—
Lobbies/prefunction	30	7.5	0.06	—
Multipurpose assembly	120	5	0.06	—

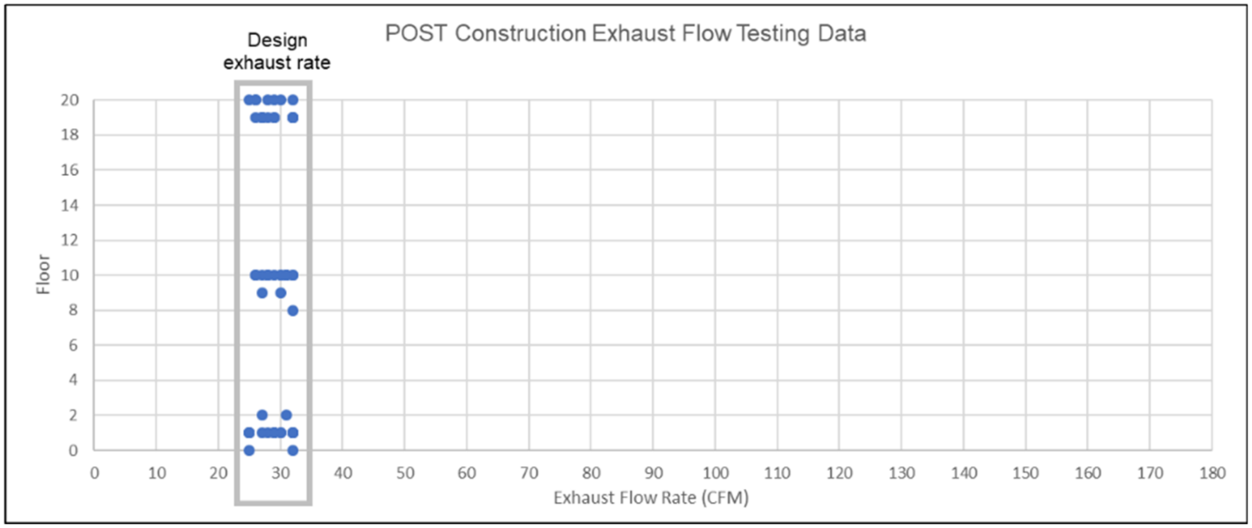
- Exhaust and supply rates required in all spaces
  - Some driven by occupancy (ex. living quarters)
  - Some driven by space (i.e. a space with contaminant loads like a trash room)
- Energy code fan efficiency
- Natural ventilation– is anyone opening a window when it's 10F outside?

Certification Program Requirements

- Passive House, Indoor airPLUS, LEED, etc. have ventilation – related requirements

- Major points in some programs:
  - Heat recovery
  - MEASURED performance (TAB)
  - >code minimum flow rates
  - Minimum system efficiency
  - Duct sealing/testing
  - Kitchen recirculation / charcoal filters





Case Study: 300 Unit Occupied Residence

Retrofit Context – Savings Estimation

- Energy audit measurements of air flow rates at a sampling of grilles and rooftop fans
  - **Measurements at grilles show airflow serving unit**
- Measurement at roof shows total airflow for riser, including leakage

Retrofit Context – Construction Phase

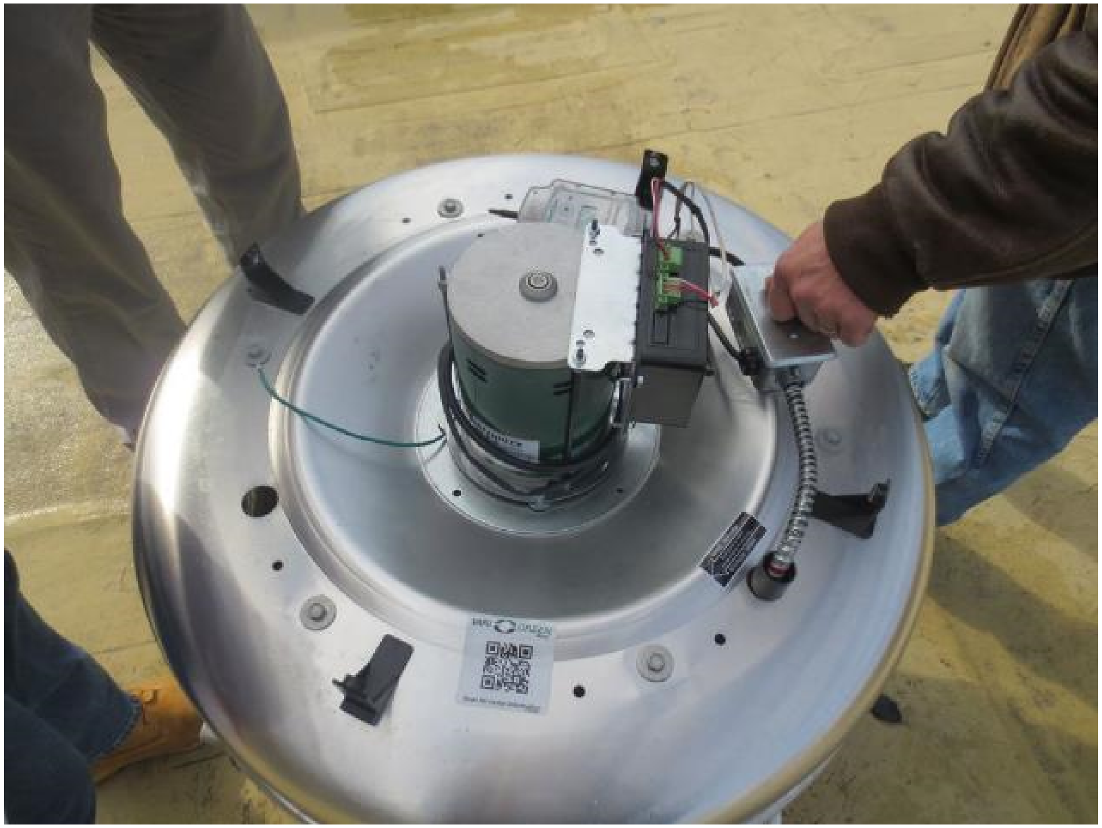
- Scope the existing system, look for holes, blockages, problems
- Clean the ductwork
- Aeroseal, balance
- Replace roof fans with ECM/adjustable

Duct Tightness

- Clean the risers first
- Mastic is not enough in large systems
- Aeroseal gets leakage down
- Duct-to-interior wall transitions must be sealed

Ventilation Balancing

- Tall buildings see stack effect
- All buildings see seasonal pressure changes
- Windy days push/pull
- CAR dampers auto-balance



ECM Exhaust Fans

- ECM = high efficiency
- Potentiometer mounted on motor gives ability to dial in (i.e. reduce) fan speed to match site.
  - Durable savings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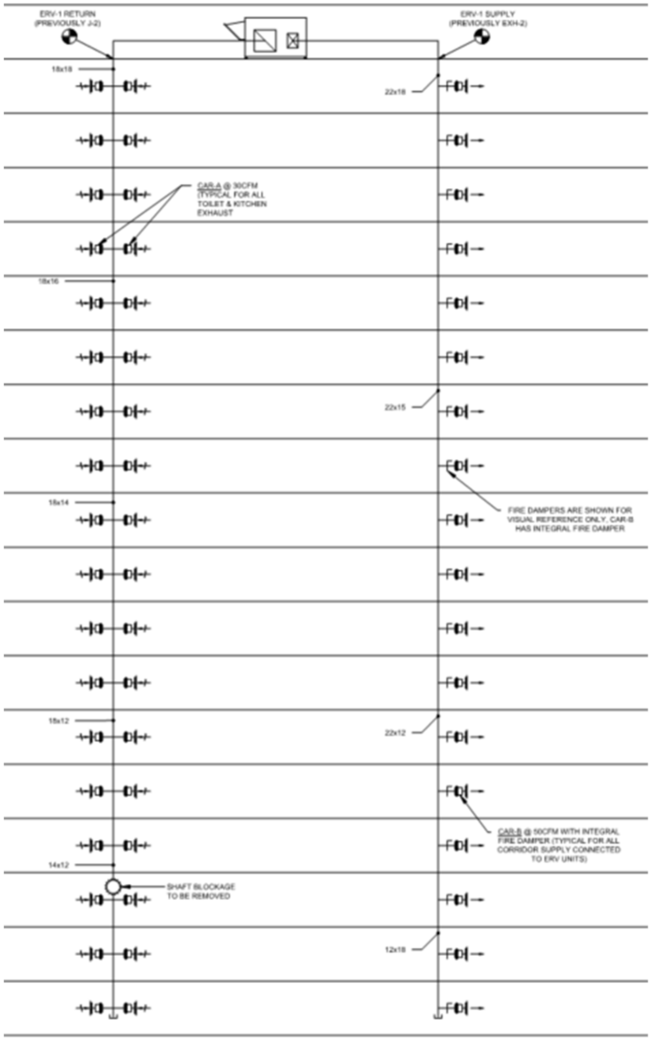
Fan Sizing

- Flow rate (+ leakage) & duct pressure drop
- Flow rate based on code/programs
- Leakage is lowest with Aeroseal
- Pressure drop can be lowered by:
  - Smart damper selections
  - Fewer offsets
  - Lower flow rate

Supply Side Considerations



- Again, flow rate (+ leakage) & pressure drop matter
- Balance supply and exhaust, use energy recovery

DOAS

- Aim to supply air for ventilation only
- Keep air same temperature as the space – not heating or cooling it
- Air flow is controlled based on ventilation needs, space temp dealt with by terminal units
- Allows for smaller duct work, lower air flow and fan usage

Balancing Supply and Exhaust

- **ERVs perform best when air flows are well balanced**
- Careful look space-by-space
  - What has to be exhaust?
  - What has to be supply?
  - What can be either?
  - Toxic, abrasive, or fire hazard loads kept separate

Energy Recovery Solutions

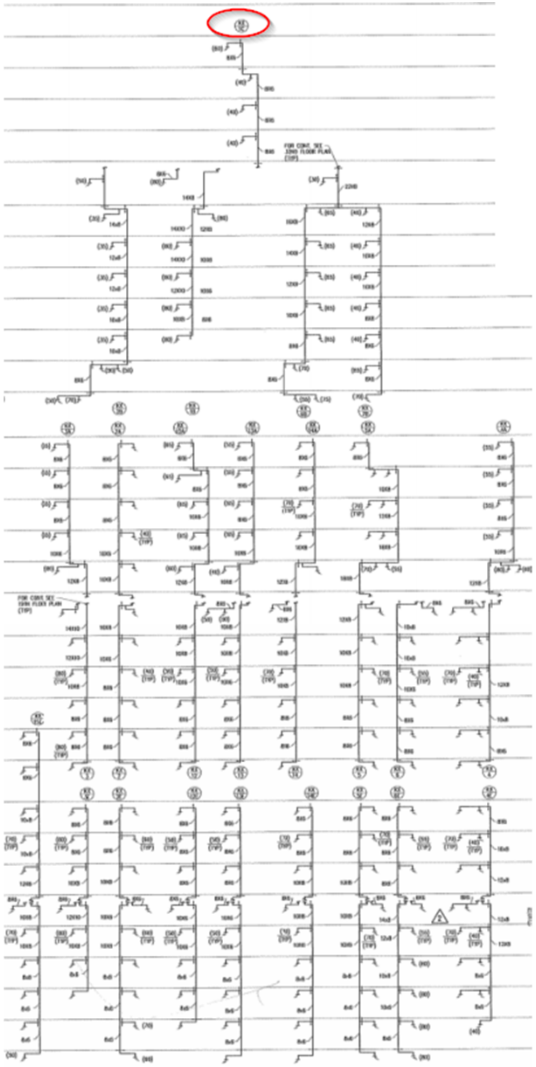
- Typically core or wheel
- Passive House standard is >75% heat recovery, ≤ 0.765 W/CFM
- Not often easy to break down for roof access
- Available as preconditioners or w/heating and cooling sections

Central/Decentralized Options

- ERVs can serve one unit/cluster/floor/wing/building
- Maintenance, duct size/run considerations
- Hybrid approach: large central system plus smaller units for smelly spaces like trash rooms

Imbalance

One fan (exhaust in the ERV, for example) cannot serve all of these lines well!

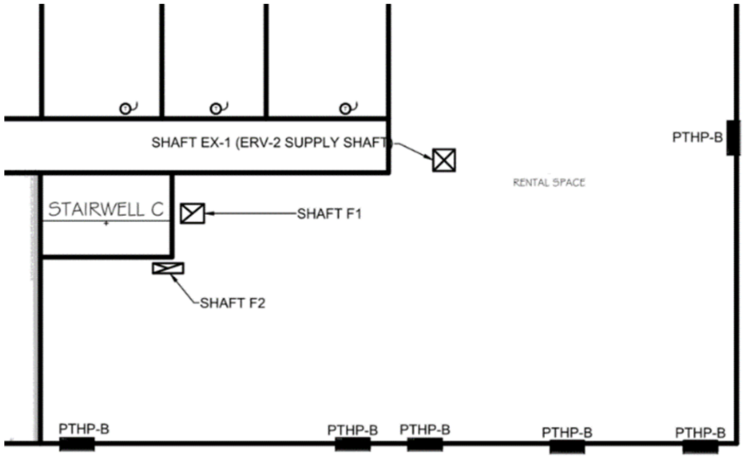


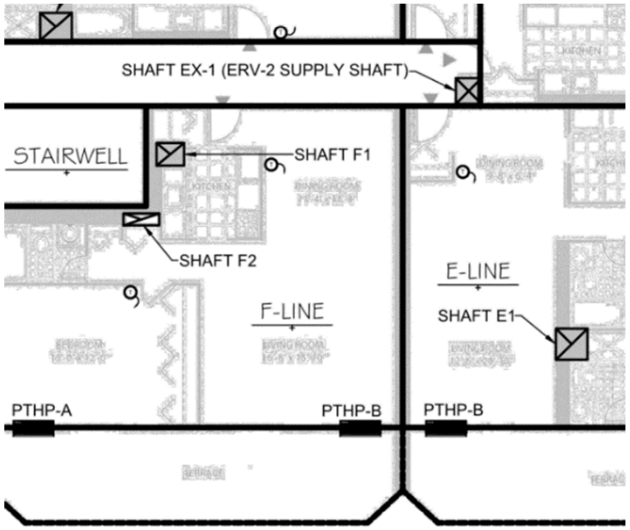
Exterior Ducts

- Costly
- Require insulation and jacketing
- Minimize runs, do not have one ERV serving too many risers across the roof (always results in imbalance)

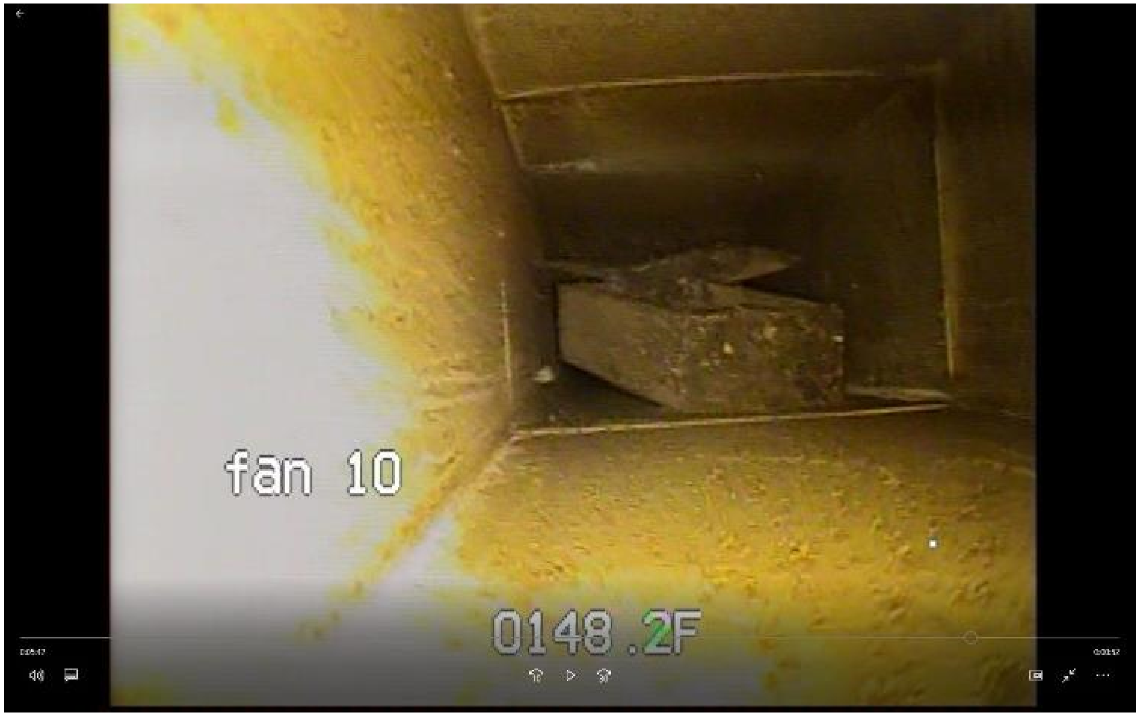
Controls

- Demand controlled ventilation allowable in many settings
- ERVs may serve spaces with varying and non-varying loads
  - Cannot turn down a central piece of equipment without ensuring ALL spaces it serves are OK





Performance-Based Specs



- Code does not ensure performance – especially true for ventilation
- Leakage (testable) and balance (testable) must be called out in spec

Laundry Challenges

- Balancing dryer exhaust is HARD in high performance buildings
- Dedicated MAU but no heat recovery
- Unvented heat pump commercial dryers would be the best answer (but not on market in US)

1000s of CFM of exhaust in this room

Questions?

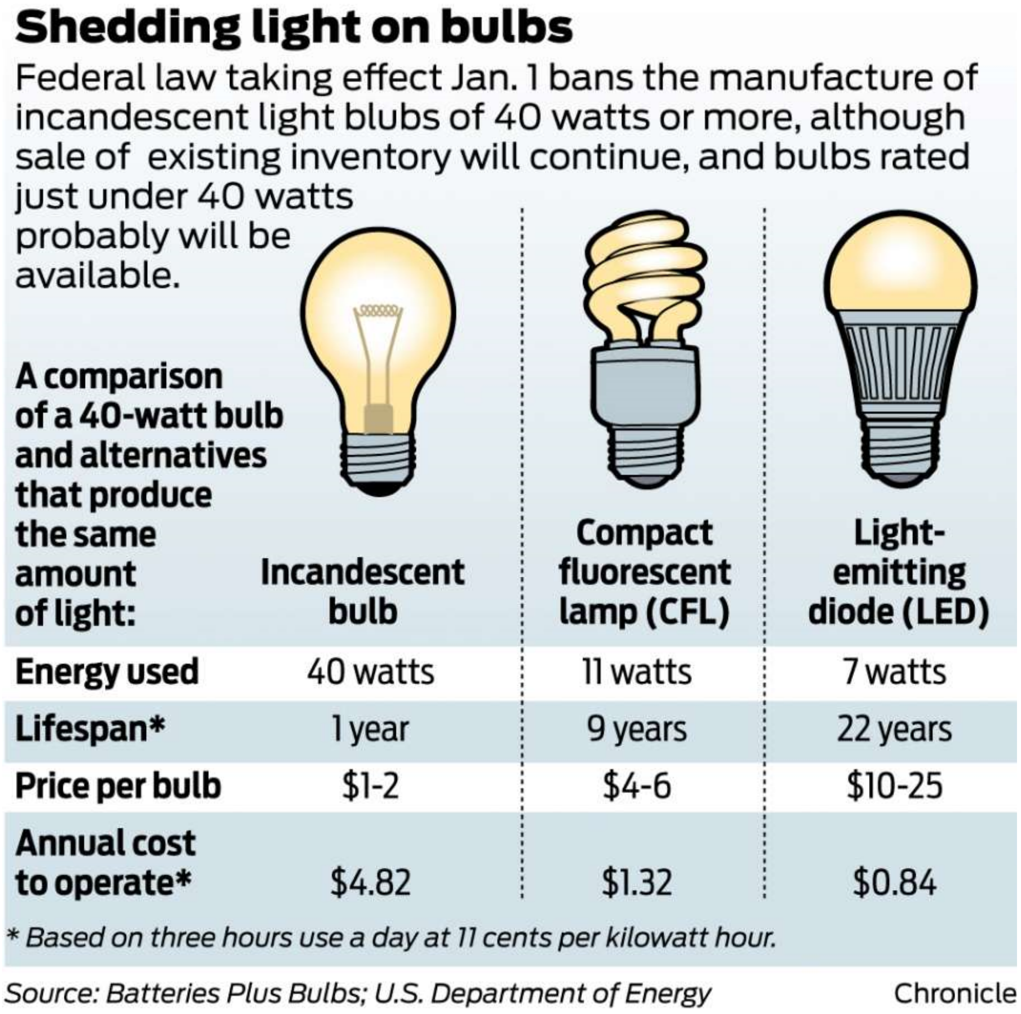
Lighting Design and Controls

Lighting System Goals


- **Efficiently** and **sufficiently** illuminate interior spaces.
- Use the **most efficient equipment** to produce and deliver light and meet Energy Code req's
  - Lumens / Watt
- **Provide the proper environment** for the intended task
  - Color
  - Brightness
- **Control the light** to reduce run-time:
  - If you don't need it at full power, turn it
  - down.
  - If you don't need it at all, turn it off.
- **Maintain the light** to ensure efficient operation and long life

Typical Lamp Technologies

- Fluorescents
- LEDs
- Others
  - Metal halide, induction, halogen, incandescent
- Emergency fixtures



Shedding light on bulbs

Federal law taking effect Jan. 1 bans the manufacture of incandescent light blubs of 40 watts or more, although sale of existing inventory will continue, and bulbs rated just under 40 watts probably will be available.

A comparison of a 40-watt bulb and alternatives that produce the same amount of light:	**Incandescent bulb**	**Compact fluorescent lamp (CFL)**	**Light-emitting diode (LED)**
Energy used	40 watts	11 watts	7 watts
Lifespan*	1 year	9 years	22 years
Price per bulb	$1-2	$4-6	$10-25
Annual cost to operate*	$4.82	$1.32	$0.84

** Based on three hours use a day at 11 cents per kilowatt hour.*

Source: Batteries Plus Bulbs; U.S. Department of Energy

Chronicle

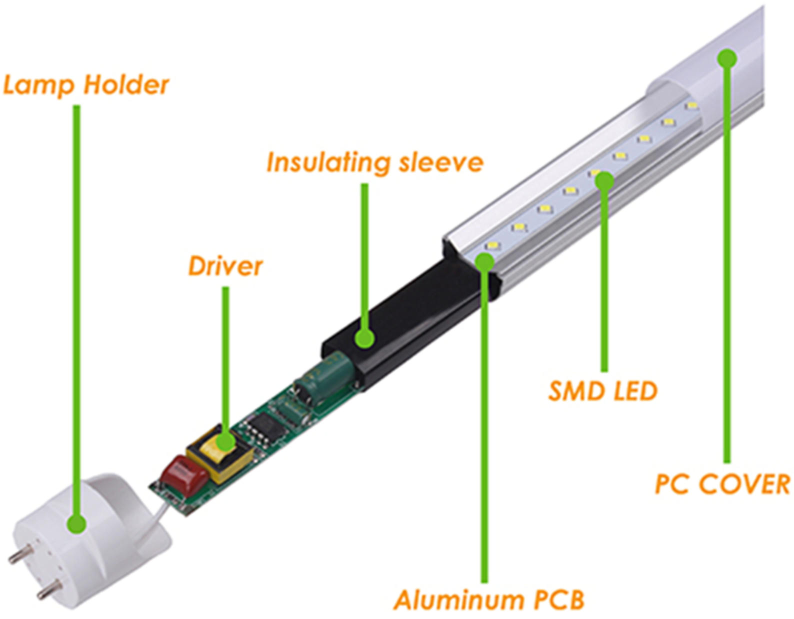
Light Emitting Diodes (LEDs)

- Often lighting has already been upgraded to LED
- LED retrofits handled in two ways:
  - Plug and Play
  - New fixtures

LED Lamps/Fixtures

- **Linear LED lamps or LED tubes are replacements for traditional T8 lamps.**

- **They come in three variations:**
  - **UL Type A** - Direct replacement: which can be installed into an existing fixture without any modification.
  - **UL Type B** - Ballast bypass: which require the ballast to removed (electrically) from the fixture and line voltage wired to the lamp holder.
  - **UL Type C** – Remote driver: which require a driver to be installed in place of the ballast.



LED Tubes: Direct Replacement vs. Ballast Bypass vs. Remote Driver

Direct Replacement

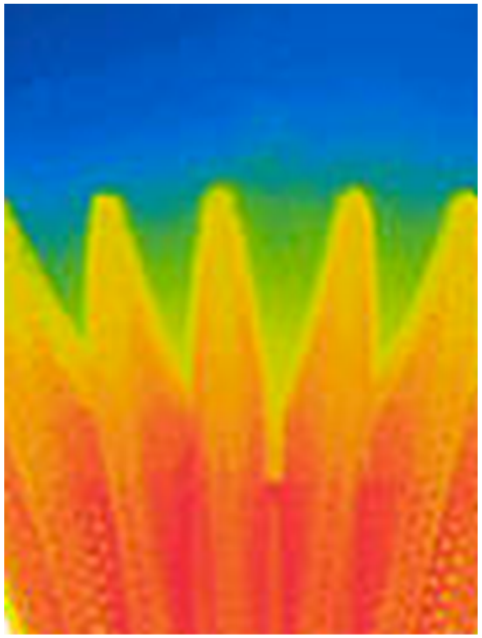
- Pros
  - Easy installation
  - Low cost
- Cons
  - Not as efficient due to ballast energy consumption.
  - Shorter life spans and increased maintenance, because you are limited by the life span of the ballast.
  - Compatibility issues with some types of ballasts: magnetic, program start, dimming.

Ballast Bypass

- Pros
  - More efficient and requires less maintenance, because the ballast is bypassed.
- Cons
  - Installation is more complicated, and comes with a higher cost.
  - Safety issue because line voltage is present at lamp holders. Fixture must be labeled.

Remote Driver

- Pros
  - Most efficient option and requires less maintenance, because the ballast is bypassed.
  - Safer approach than ballast bypass.
  - No ballast compatibility issues
- Cons
  - Installation is more complicated, and comes with a higher material and labor cost.



LED Overheating

- When replacing lamps in enclosed fixtures ensure that the LED lamp is approved for use in an enclosed fixture.
  - LED lamps are very sensitive to heat, when they are installed in an enclosed fixture the temperature of the lamp will increase and could cause damage/premature failure.

Typical Existing Exterior Lighting

High Intensity Discharge (HID)

- Metal Halide (white light) and High Pressure Sodium (yellowish light)
- For intense lighting applications
  - Building exteriors
  - Parking lots
- Less efficient than modern LEDs
- Requires proper disposal

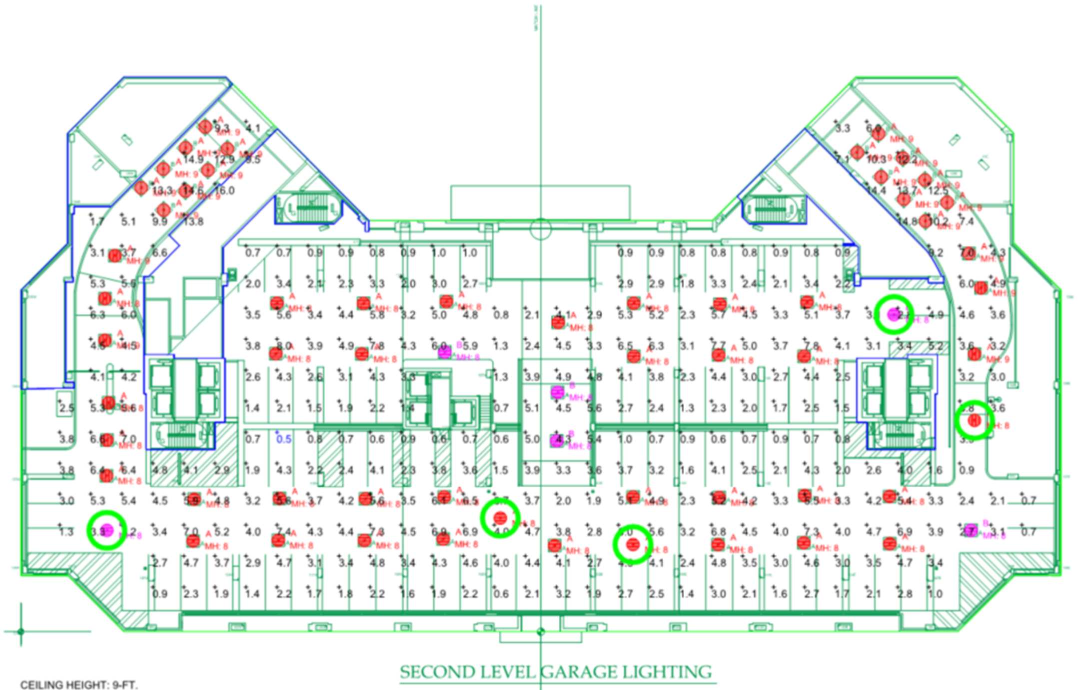
Where the light goes is important, too!

LEDs for Exterior Lighting

- **LED Corn Cob lamps can be used to replace existing HID lamps**
- **These lamps come in two variations:**
  - **Direct replacement:** which can be installed into an existing fixture without any modification.
  - **Ballast bypass:** which require the ballast to removed (electrically) from the fixture and line voltage wired to the lamp socket.

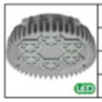
Evaluating New Lighting Options

Photometric plans can show uneven lighting and where to step up or down



SECOND LEVEL GARAGE LIGHTING

CEILING HEIGHT: 9-FT.
FIXTURE MOUNTING HEIGHT: SURFACE OR AS INDICATED
REFLECTANCE'S: 35/35/20

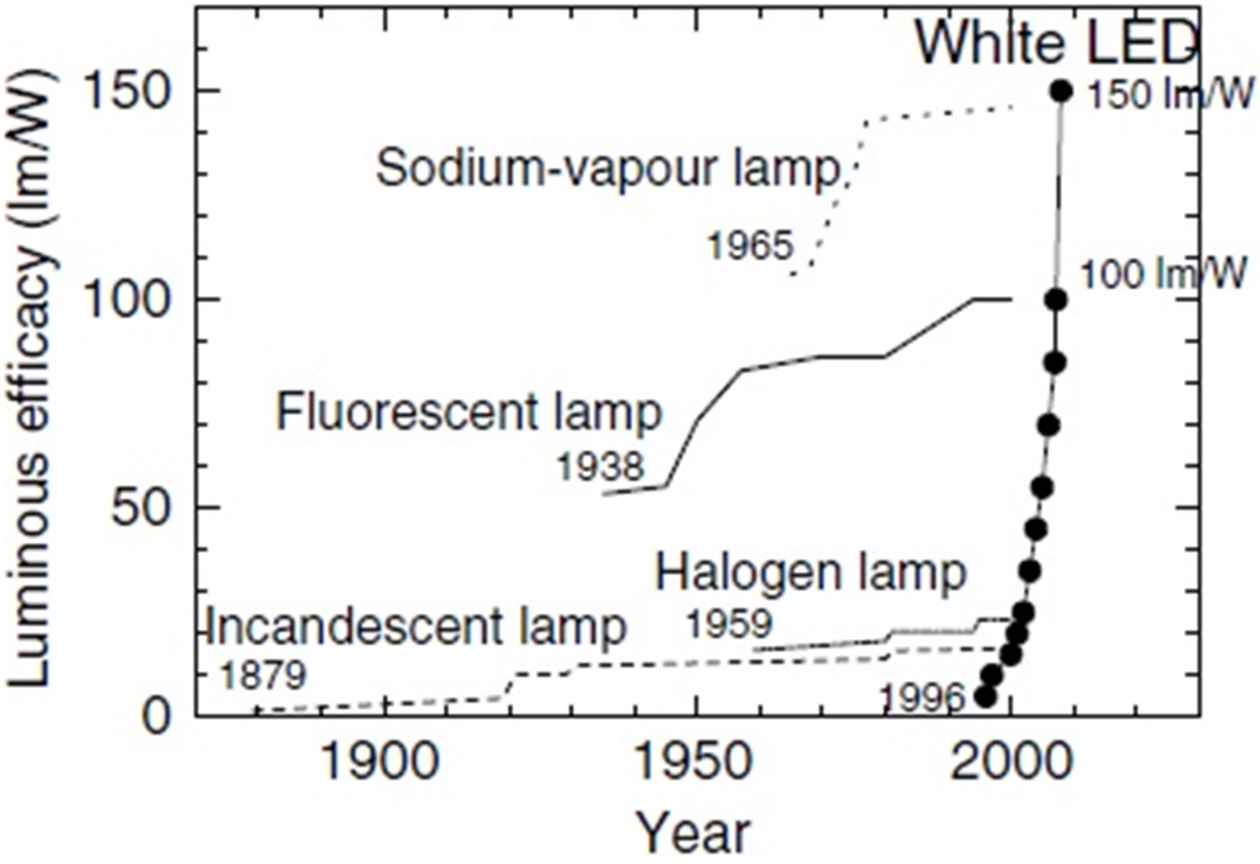
	Luminaire Schedule													
	Symbol	Label	Qty	Description	Lum. Lumens	Filename	[TEST]	Lum. Watts	Total Watts	LLD	LDD	BF	UDF	LLF
	🔴	A	120	SCP-18LU-5K-5R-XX	3781	SCP-18LU-5K-5R-XX.IES	6044	36.7	4404	0.950	0.900	1.000	0.750	0.641
	🟣	B	22	SCP-18LU-5K-5M-XX	3689	SCP-18LU-5K-5M-XX.IES	6045	37.2	818.4	0.950	0.900	1.000	0.750	0.641

Calculation Summary							
Label	Avg	Max	Min	Avg/Min	Max/Min	PtSpcLr	PtSpcTb
Eighth Level_Floor	3.00	7.9	0.6	5.00	13.17	10	10
Second Level_Floor	3.90	16.0	0.5	7.80	32.00	10	10
Typical Levels 3 Thru 7_Floor	3.03	7.7	0.4	7.58	19.25	10	10

UDF REPRESENTS DEPRECIATION FACTOR FOR LENS.

Efficacy

The more lumens per watt a light source produces, the more efficacious, or energy-efficient, the light source is



Color Rendering Index (CRI)

- CRI is a measure of a light source's ability to show objects "naturally" as compared to a standard reference light source.

(worst) **0** → **100** *(best)*

Color Temperature

Identify savings opportunities

Can any adjustments provide adequate lighting & energy savings?

- Eliminate fixture quantity or reduce wattage
  - especially wall sconces, wall art lighting, or chandelier fixtures

Original	Improved
10 fixtures	7 fixtures
@ 13W each	@ 13W each
= **130W**	= **91W**

Identify savings opportunities

Can any adjustments provide adequate lighting & energy savings?

- Select higher efficacy fixtures

Original	Improved
28W	28W
@ 50 LPW	@ 80 LPW
1,400 lumens	**2,240 lumens**

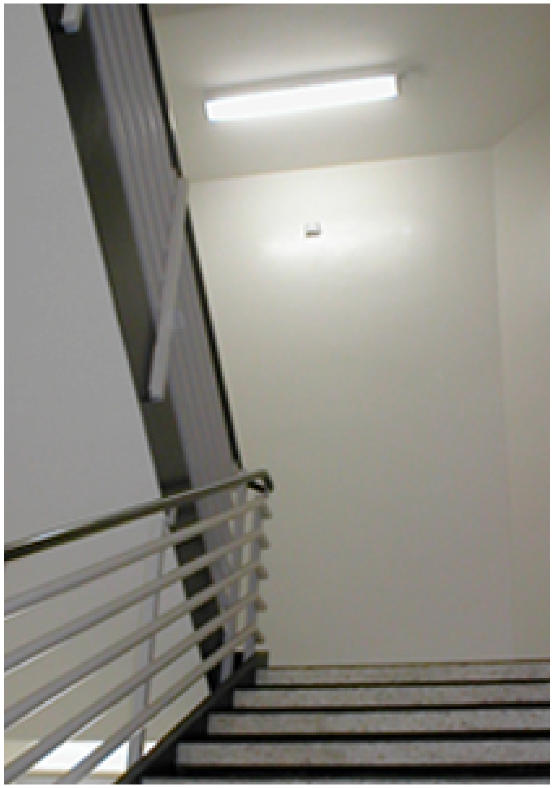
Typical Controls Technologies

- Task lighting
- Manual switches
- Vacancy sensors
- Bi-levels
- Daylighting
- Photocells
- Timers

Occupancy Sensors

- Three technology types
  - Infrared
  - Ultrasonic
  - Dual technology
- Occupancy Sensor (auto on – auto off)
- Vacancy Sensor (manual on -auto off)
- Work well with proper selection and positioning
- Make sure they are rated for the connected wattage of fixtures (“load capacity”)
- Make sure to use programmed start ballasts

Bilevel Lighting



- Operates at lower light output under normal conditions
- Occupancy sensor triggers full light level
- Allows for code minimum lighting in rarely-occupied spaces, with safer lighting when in use

Daylighting/Photosensors/Timers

Spaces with adequate natural light do not need electrical light

Thinking Outside the Box

Summarizing these thoughts on high performance systems

The biggest question is

What are we saving?

Carbon

Future Proofing

- Design for the products you wish you had, not what's on the truck
- Electrify if you can, and if not, plan for it later

What do we scale first?

What can every building do that will have a LASTING and positive impact?

- Technology uptake
- Mindset shifting
- Creating long-term campus-wide plan

Future Conditions

Heat waves and hotter temperatures mean cooling becomes an equity and safety issue, not a luxury

Winter performance must meet cold snap design day conditions, but spend even more time at part load and erratic conditions

Efficient low-carbon technologies must perform in all climates and weather conditions

Thank You

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212-564-5800

www.swinter.com

Join Us for More Trainings!

- **Module 5**: Contracting for Passive House: Construction Documents and Bidding
- **Module 6**: Deep Energy Retrofits: Strategies for Gut Rehab or Full Occupancy Retrofits
- **Module 7**: Beyond Hydrofluorocarbons (HFCs): Refrigerant Management in Design, Construction, and Operations
- **Module 8**: Construction Manager/Subcontractor/Tradesperson Training: Classroom and Field Training

Register here: https://www.newpaltz.edu/sustainability/view-programs-and-progress/zero-net-carbon-training/workshop-schedule-registration--details/

Take our survey:

PollEv.com/swa335

Resources

- www.gov.uk/government/publications/impacts-of-leakage-from-refrigerants-in-heat-pumps
- https://wbdg.org/FFC/DOD/UFC/ufc_3_410_01_2013_c4.pdf
- https://www.epa.gov/ghgemissions/overview-greenhouse-gases#carbon-dioxide
- https://science.sciencemag.org/content/361/6398/186
- https://www.nps.gov/nr/travel/nevada/sea.htmm
- https://sustainability-year-in-review.stanford.edu/2018/
- Pg 26-27 of “The Energy to Lead: 2015 NYS Energy Plan”
- https://www.youtube.com/watch?v=e6HTC_rOQOA

Electrification Will Not Happen Overnight

- Assume a 20-25 year lifespan for fuel-burning equipment
- No new fuel-fired equipment after ~2025 if 80x50 is to be reached without ripping out live equipment

Mini/Multi-Splits

Smaller and decentralized air-source heat pump systems

VRFs

Central/commercial air-source heat pump systems

Rough Efficiency Estimates

Unitary

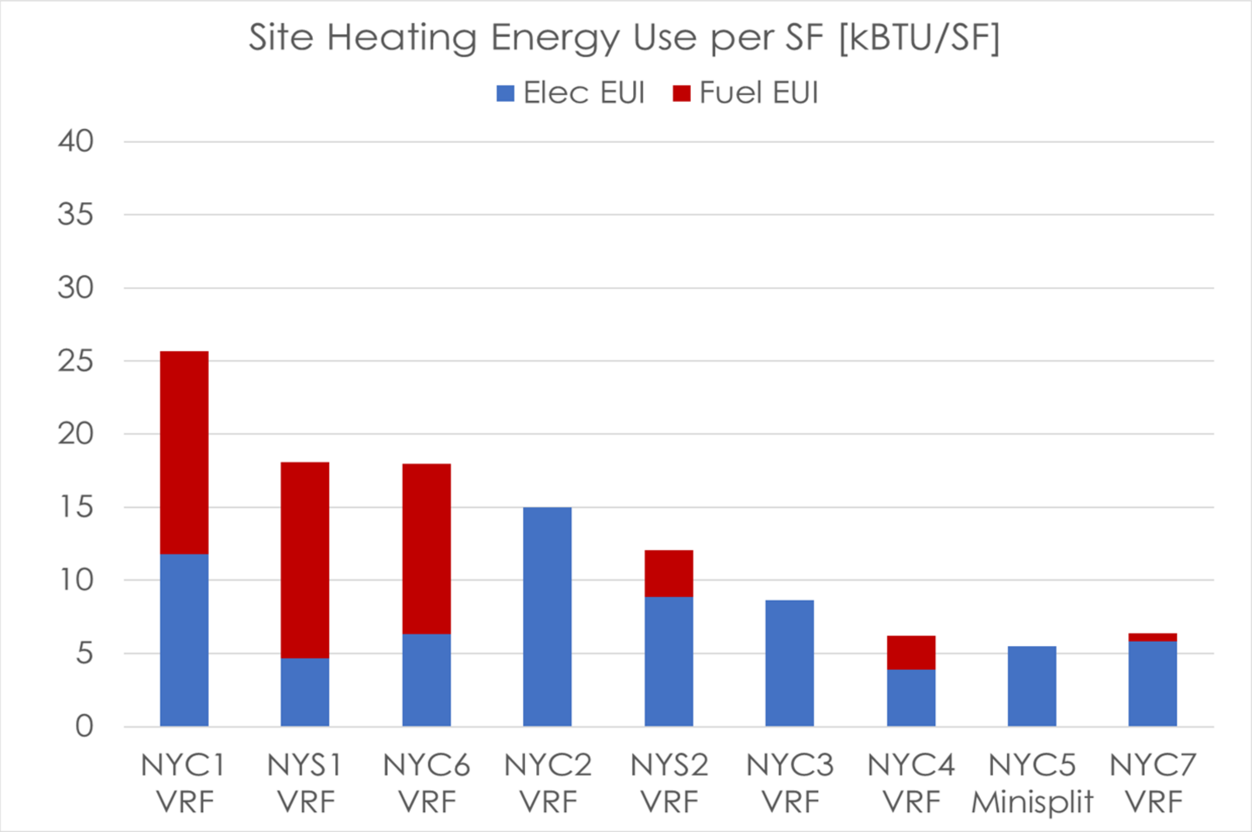
- Expected efficiency is better for smaller systems. You may be able to achieve actual seasonal average COPs of 2.5 to 3 with very good installation and Cx.

Central

- Efficiency depends on whether heat recovery is installed.
- Rated efficiency in manufacturer literature requires major adjustment (lineset lengths not accounted for, can drop efficiency by 25%, defrost can be another ~15%).
- Rated COP of 3.2 to 3.7 at 47F OAT, EER of 10.5-13.5

Selected NYS New Construction Heat Pump Projects

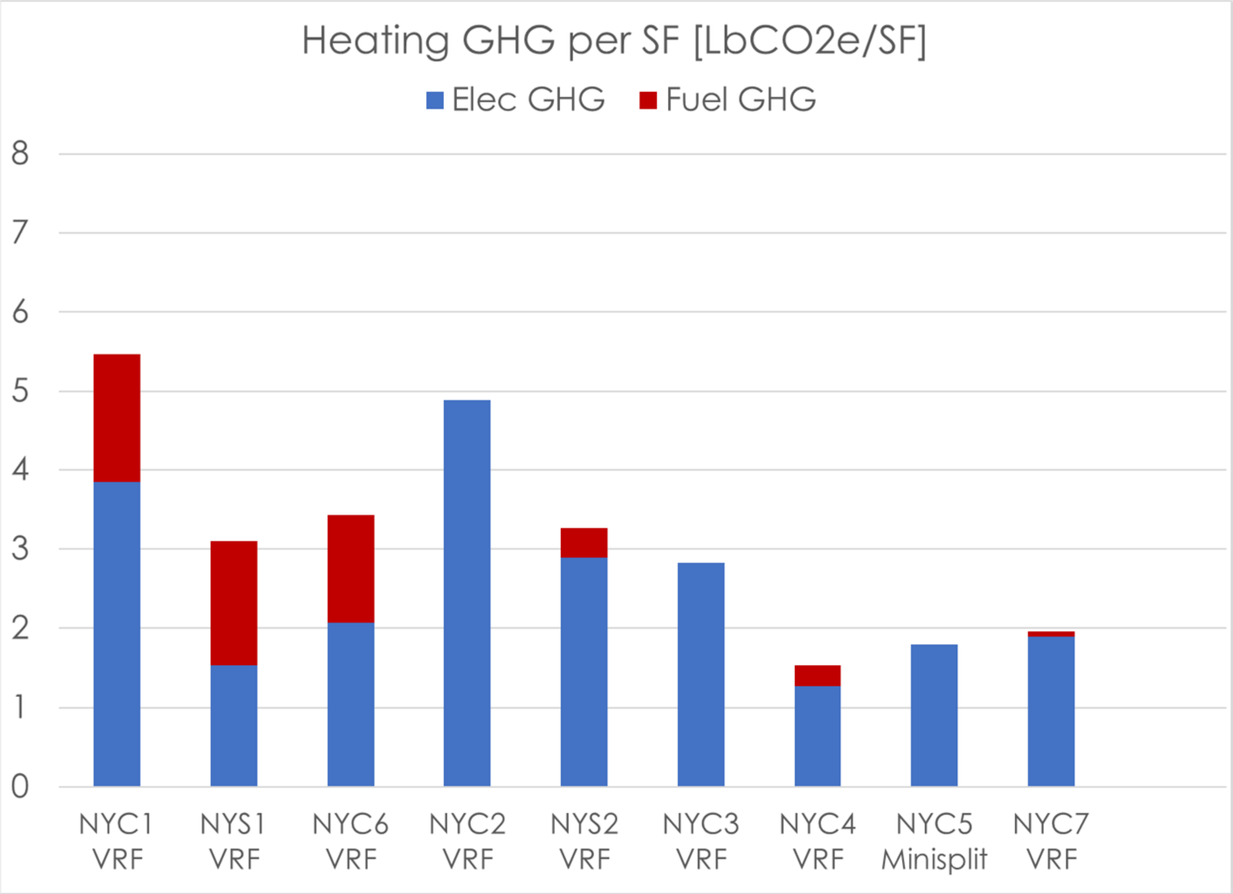
Real World Energy Performance



Climate/Carbon Impacts

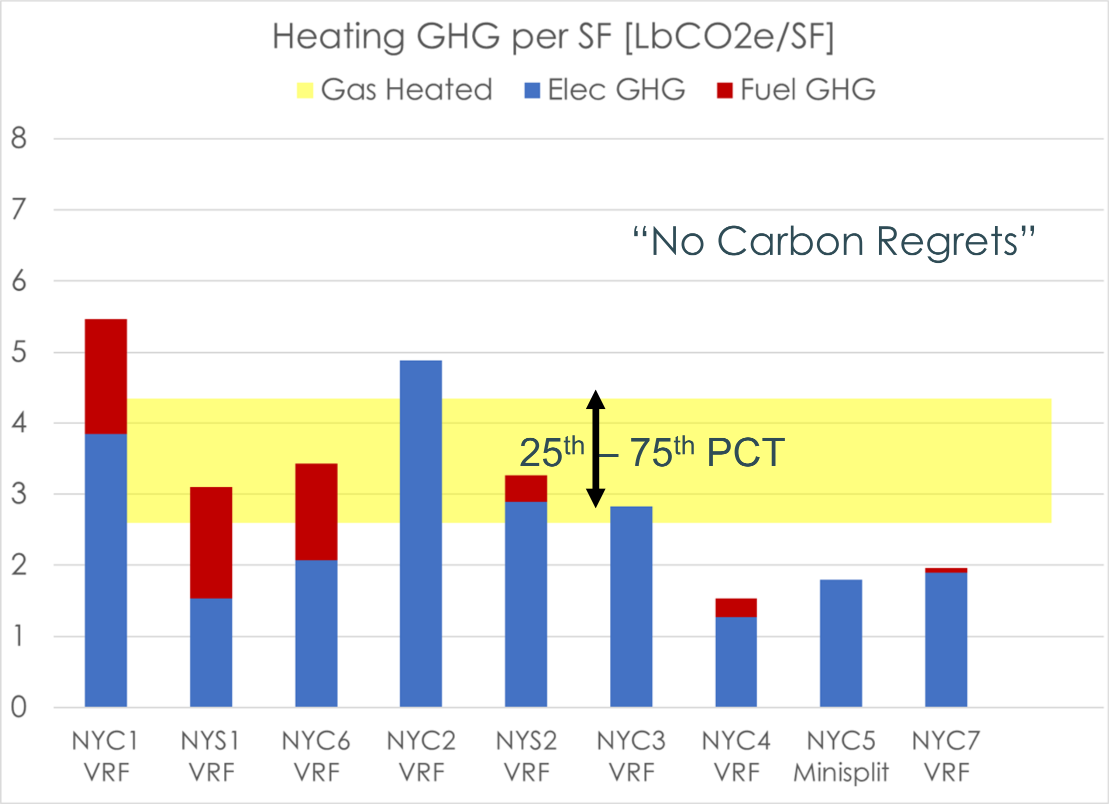
How do heat pumps
impact carbon footprint?

Real World Carbon Performance



LbCO2e/kBTU
Gas: 0.1173
Elec: 0.3260
(non-baseload)

Real World Carbon Performance



LbCO2e/kBTU
Gas: 0.1173
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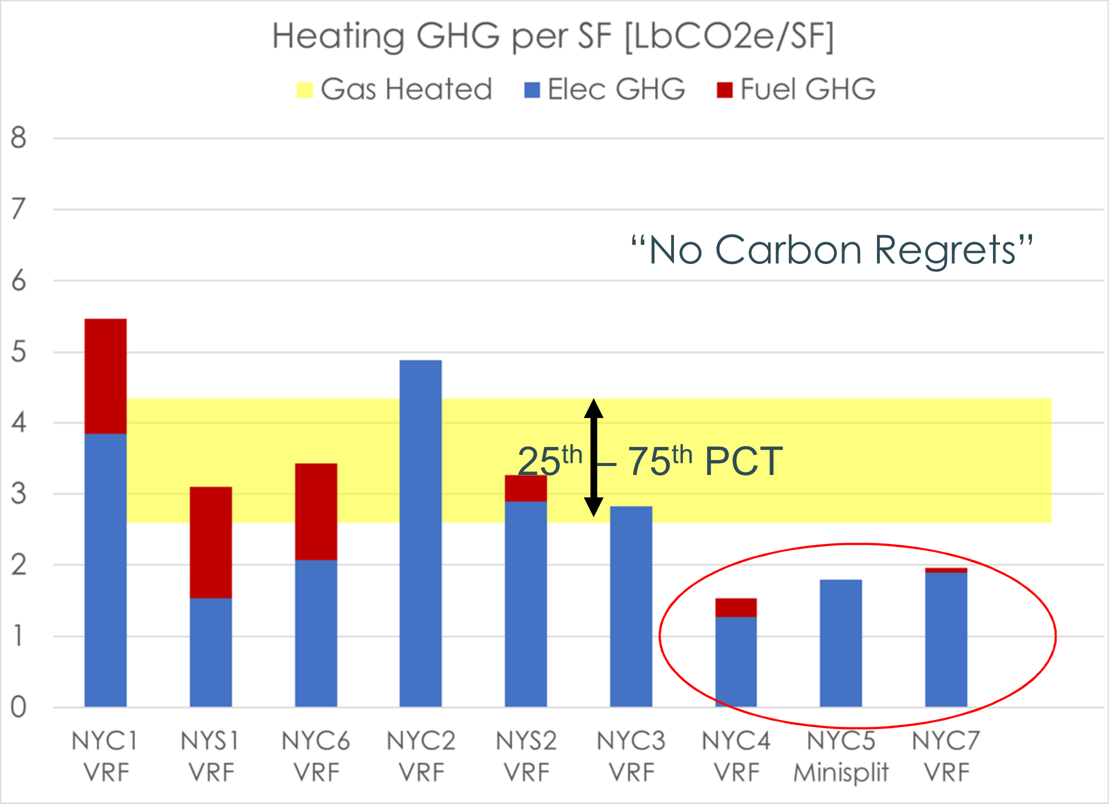
(non-baseload)

Real World Carbon Performance



LbCO2e/kBTU
Gas: 0.1173
Elec: 0.3260
(non-baseload)

Refrigerant Leakage – Government Perspectives

Empirical Study: Impacts of Leakage from Refrigerants in Heat Pumps

www.gov.uk/government/publications/impacts-of-leakage-from-refrigerants-in-heat-pumps

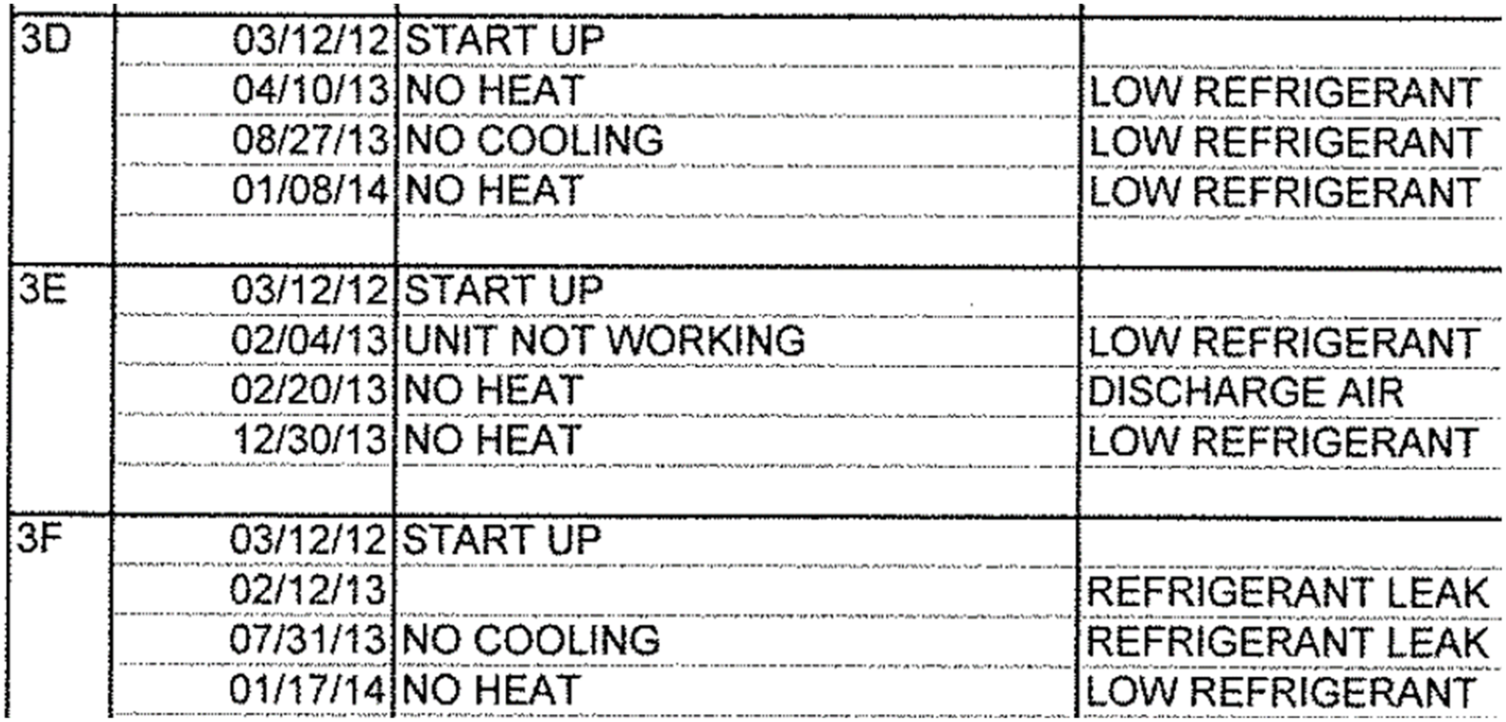
- Mostly Air to Water Heat Pumps and Ground Source Heat Pumps **(which tends to be more packaged type equipment than VRF)**
- **3.5% of refrigerant is leaking, but** that's accounted for by 8-10% of systems leaking 40-50% of refrigerant, with half of those as **"catastrophic" leaks**, where the system stops functioning and may be fully evacuated. These account for 75-90% of total leaked refrigerant.
- "The analysis suggests that trying to reduce the level of leakage in the short-term whilst incentivizing low GWP refrigerants in the longer term would be the most appropriate course of action to maximize the CO2e benefits associated with heat pumps"

Refrigerant Leakage – Government Perspectives

Department of Defense – Unified Facilities Criteria:
https://wbdg.org/FFC/DOD/UFC/ufc_3_410_01_2013_c4.pdf

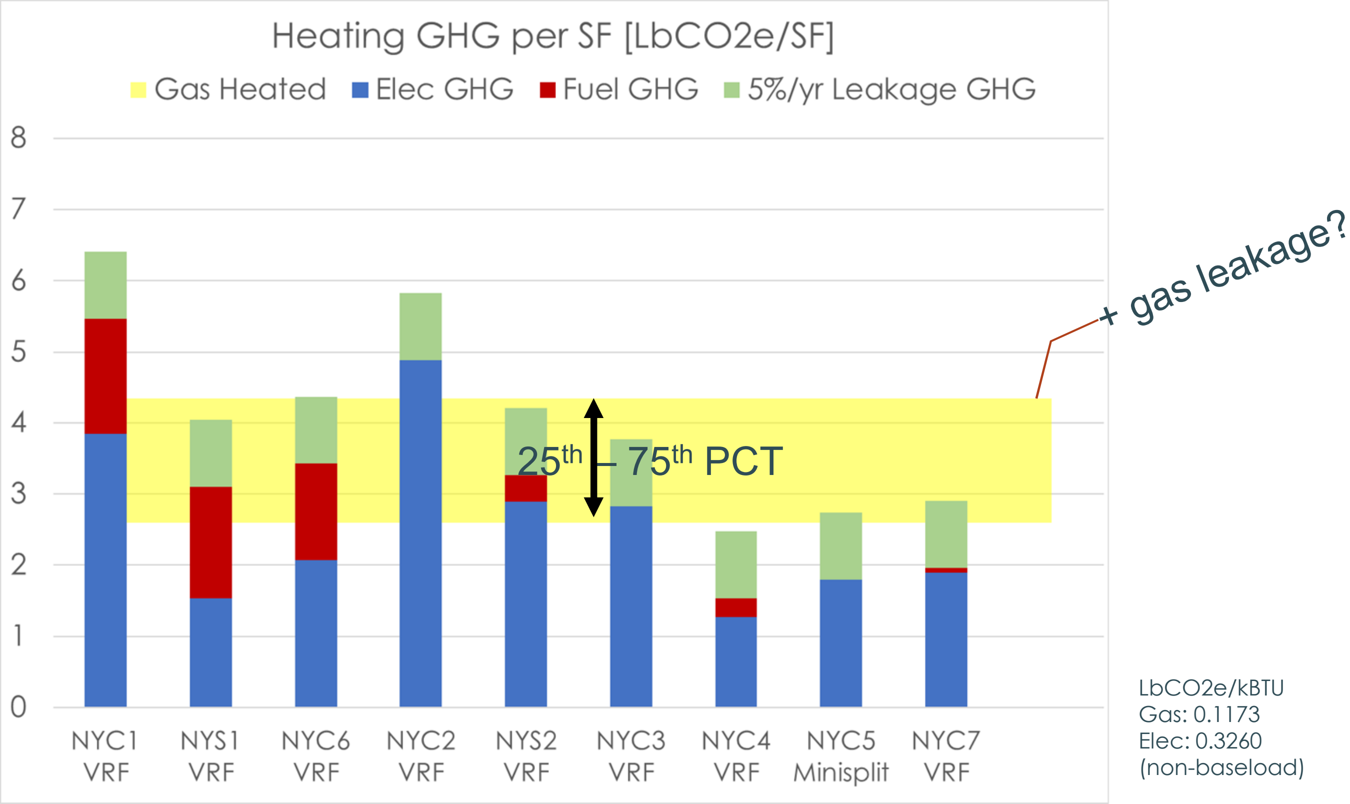
- **“(The Services estimate a current annual refrigerant leak rate of 25%.)”**
- “Tracing and repairing a leak on a VRF system is many times more difficult with an additional access requirement of maintenance crews to the workspace environment.”

One Anecdotal Case
NYC VRF Building Service Record



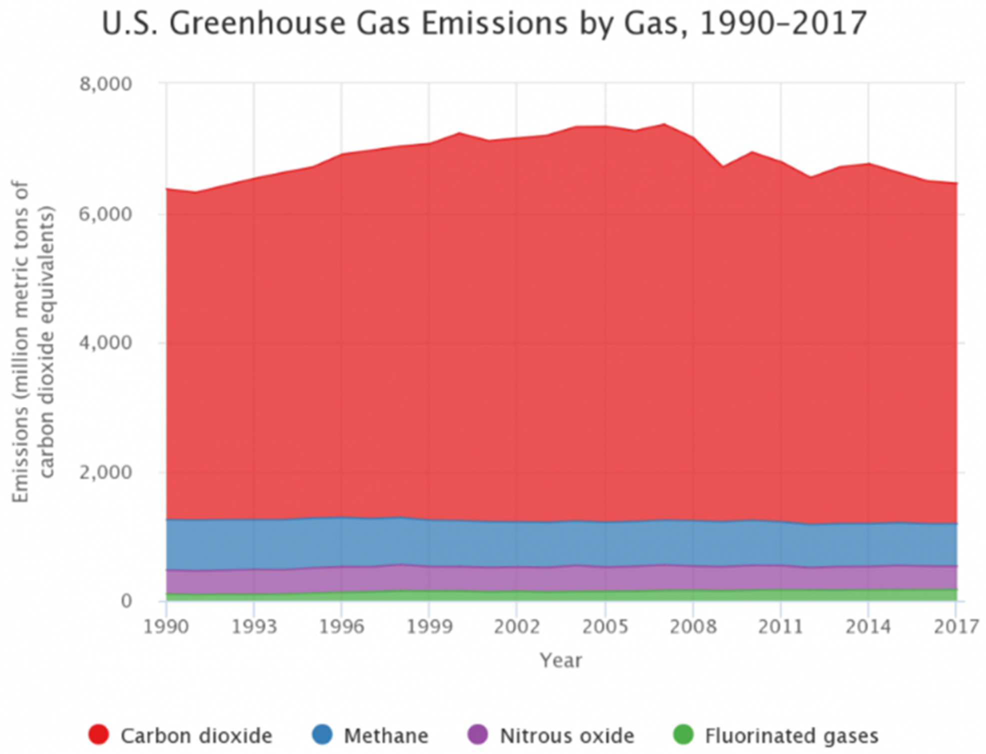
3D	03/12/12	START UP	
	04/10/13	NO HEAT	LOW REFRIGERANT
	08/27/13	NO COOLING	LOW REFRIGERANT
	01/08/14	NO HEAT	LOW REFRIGERANT
3E	03/12/12	START UP	
	02/04/13	UNIT NOT WORKING	LOW REFRIGERANT
	02/20/13	NO HEAT	DISCHARGE AIR
	12/30/13	NO HEAT	LOW REFRIGERANT
3F	03/12/12	START UP	
	02/12/13		REFRIGERANT LEAK
	07/31/13	NO COOLING	REFRIGERANT LEAK
	01/17/14	NO HEAT	LOW REFRIGERANT

Real World Carbon Performance



LbCO2e/kBTU
Gas: 0.1173
Elec: 0.3260
(non-baseload)

Gas Leakage

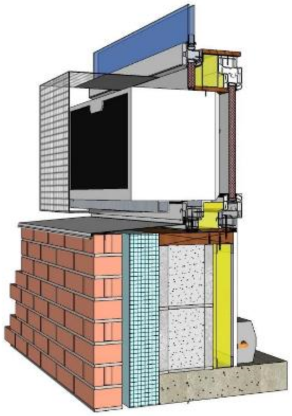


Source: U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017.
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

AND

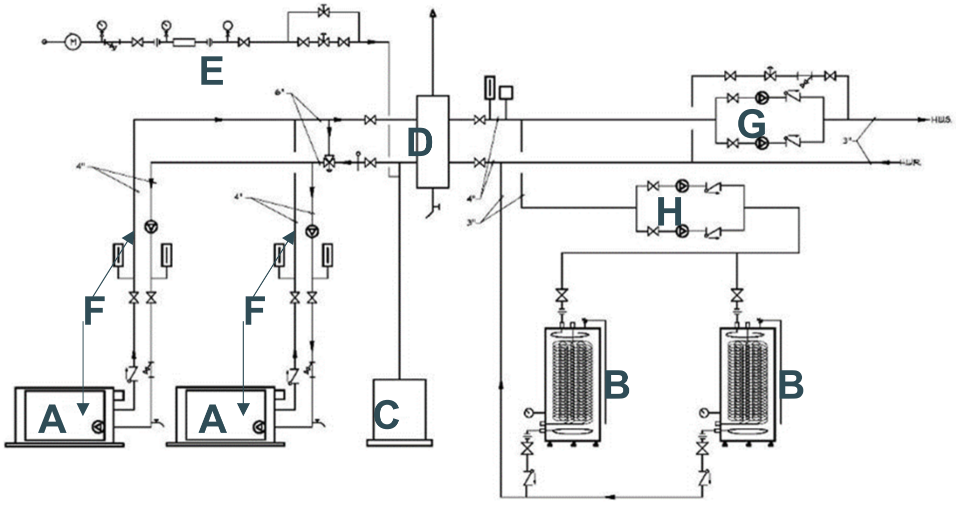
- Recent study shows 60% higher methane loss than EPA measured

Window AC Airsealing in Development



Currently being installed in two NYC multifamily buildings

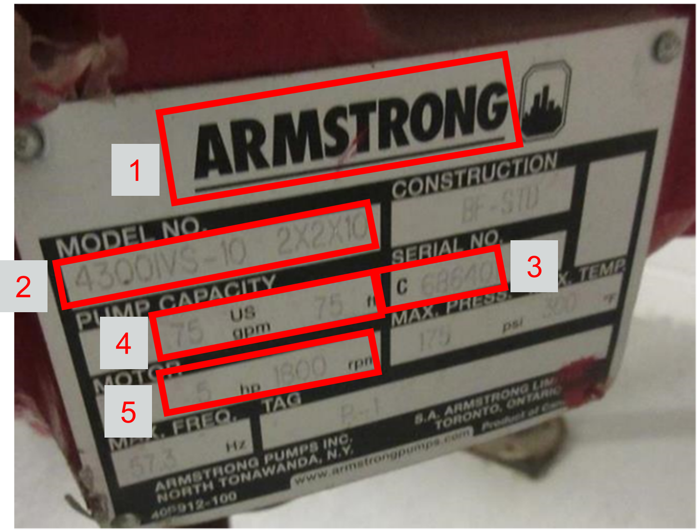
Boiler Plant Schematic
What can you identify?

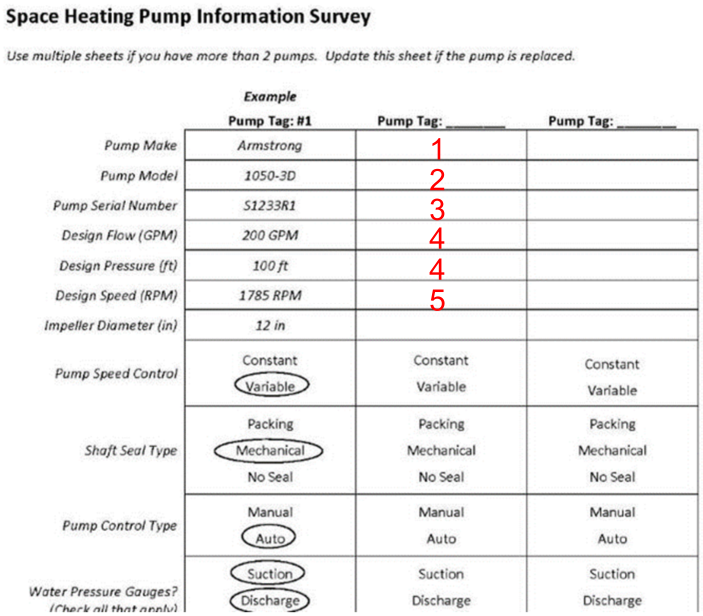


COMBINATION HOT WATER BOILER/DOMESTIC WATER HEATER FLOW DIAGRAM

A. Boilers
B. DHW Heaters
C. Expansion Tank
D. Hydraulic Separator
E. Make-up Water
F. Boiler Pumps
G. Heating Pumps
H. DHW Pumps

Pump Nameplate



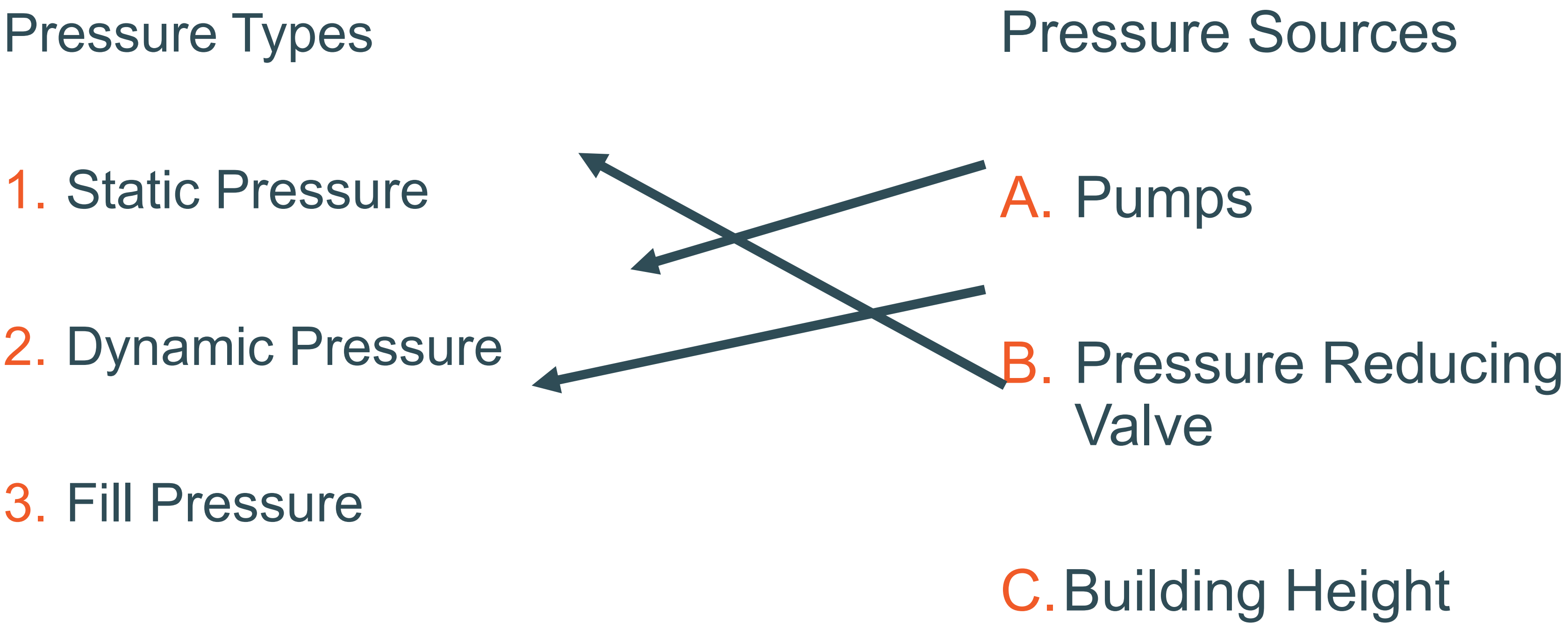


Space Heating Pump Information Survey

Use multiple sheets if you have more than 2 pumps. Update this sheet if the pump is replaced.

	Example		
	Pump Tag: #1	**Pump Tag: ________**	**Pump Tag: ________**
Pump Make	*Armstrong*	1	
Pump Model	*1050-3D*	2	
Pump Serial Number	*51233R1*	3	
Design Flow (GPM)	*200 GPM*	4	
Design Pressure (ft)	*100 ft*	4	
Design Speed (RPM)	*1785 RPM*	5	
Impeller Diameter (in)	*12 in*		
Pump Speed Control	Constant [✓ Variable]	Constant Variable	Constant Variable
Shaft Seal Type	Packing [✓ Mechanical] No Seal	Packing Mechanical No Seal	Packing Mechanical No Seal
Pump Control Type	Manual [✓ Auto]	Manual Auto	Manual Auto
Water Pressure Gauges? (Check all that apply)	[✓ Suction] [✓ Discharge]	Suction Discharge	Suction Discharge

Can you connect pressure types with sources?



Pressure Types

1. Static Pressure
2. Dynamic Pressure
3. Fill Pressure

Pressure Sources

A. Pumps
B. Pressure Reducing Valve
C. Building Height

Triple Duty Valves

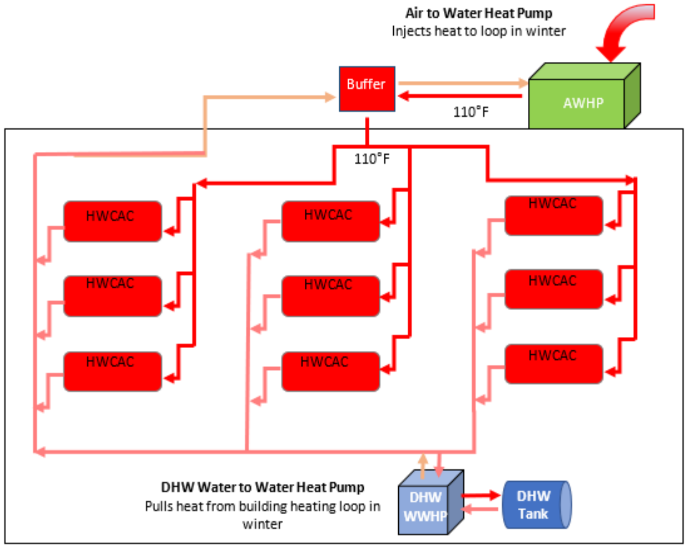
Triple Duty Valve

Triple Duty Valves also:

- Serve as a Check Valve
  - **Prevents backwards flow through an off pump**
- Serve as a Shut-off Valve
  - **Allows pump to be removed for maintenance**

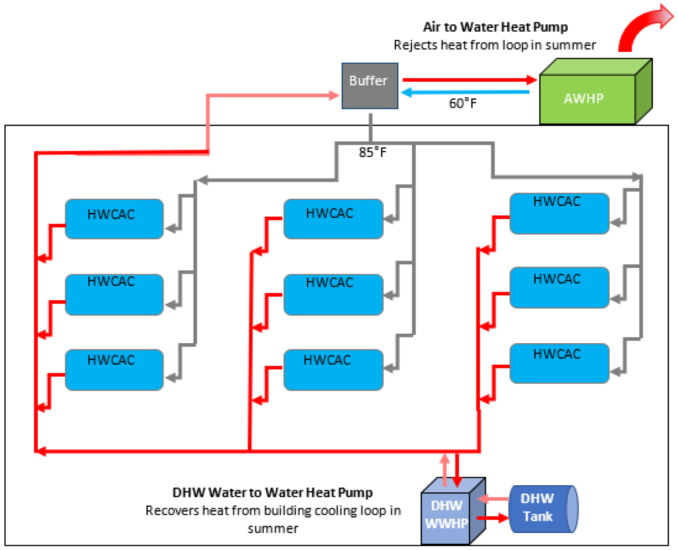
Low Temp Architecture

HEATING


Air to Water Heat Pump
Injects heat to loop in winter

DHW Water to Water Heat Pump
Pulls heat from building heating loop in winter

COOLING

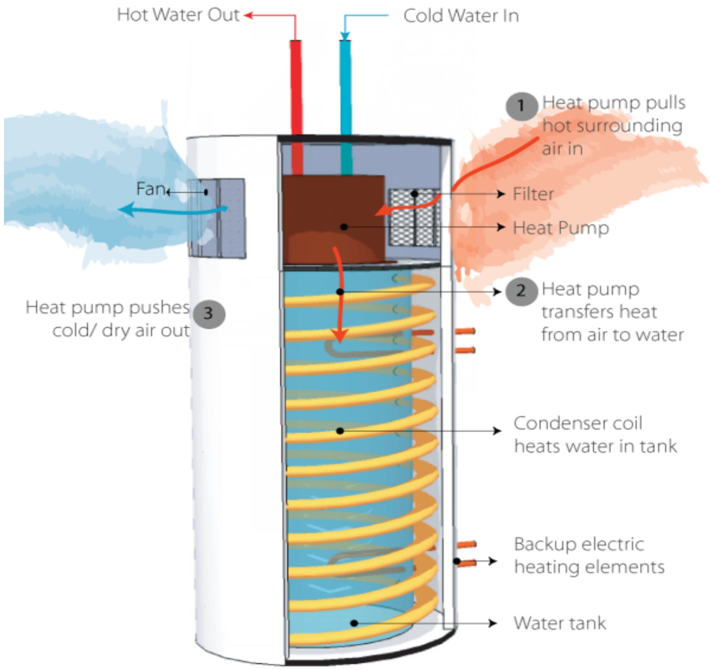

Air to Water Heat Pump
Rejects heat from loop in summer

DHW Water to Water Heat Pump
Recovers heat from building cooling loop in summer

Interactivity

- AWHP temperatures and HWCAC performance
- WWHPs and cooling efficiency of HWCACs
- WWHPs and heating load on the AWHPs
- WWHPs and the cooling load on the AWHPs
- Neighbors in heating and cooling modes simultaneously

Heat Pump Water Heaters



Domestic Hot Water – Individual

Benefits

- On tenant meter
- If unit is down, only one apartment is affected
- Minimized piping losses

Challenges

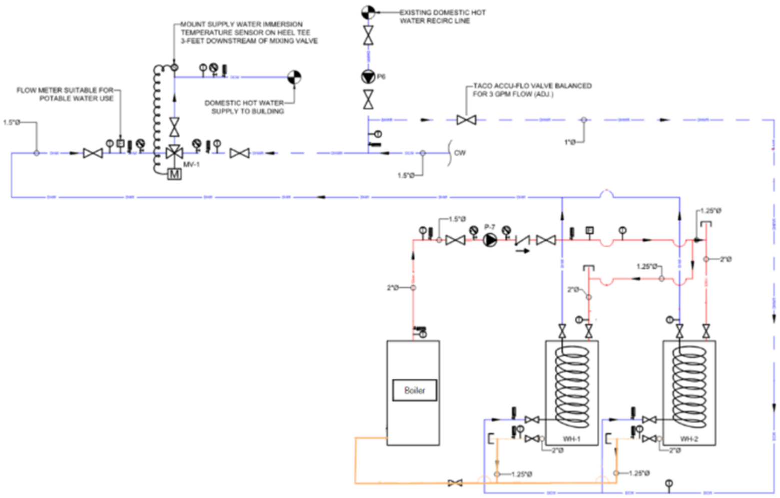
- **Very** difficult to pull this off in a multi-unit or dense environment
- Loss of floor space
- Maintenance
- Heat pump water heaters require large volume of air for proper operation
- Heat is pulled from surroundings

Heat Pumps – Smaller Scale Systems

- Volume of air (~1,000 ft^3)
- Warm air, above ~50°F
- **BIGGER** is better
- **HOTTER** is better (with tempering valve)
- Drain condensate
- Locate where noise and cool air won’t cause discomfort
- Doesn’t “steal” much space heat
  - Don’t heat space with electric resistance!

If all this is done right, they can use 50-70% less energy than electric resistance.

Heat Pumps – Larger Scale Systems

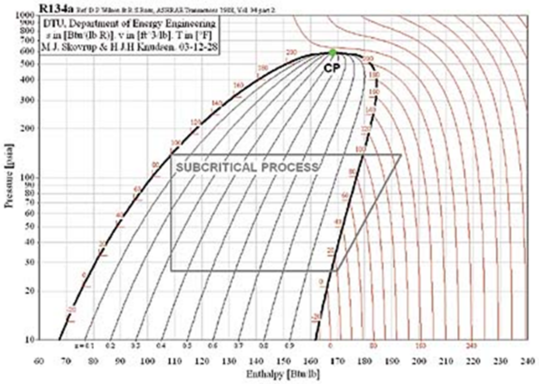


- WH
- Mixing valve
- Distribution
- Risers
- Returns
- Recirc pump
- Return balancing

CO_2 Systems

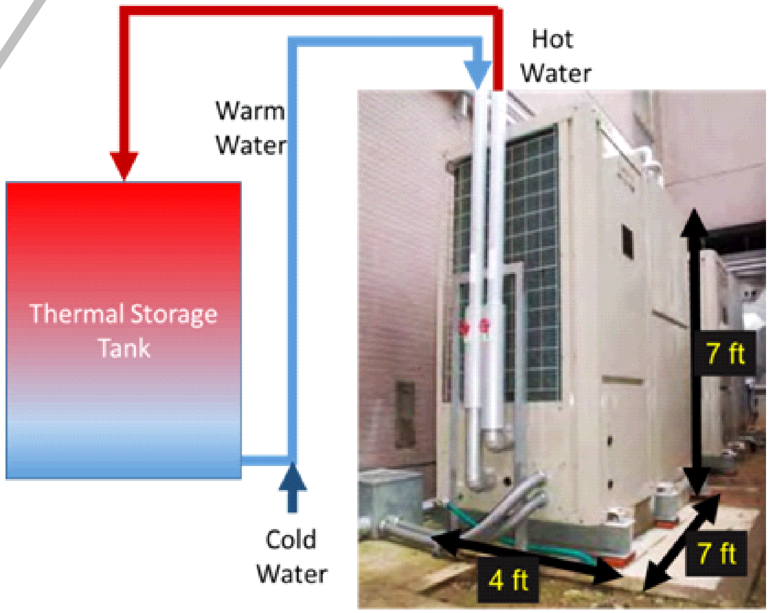
- High pressure and low critical point temperature = more complex equipment systems
- Not many service technicians with experience
- CO_2 cannot be added into existing heat pumps (high pressure needed)

R134a

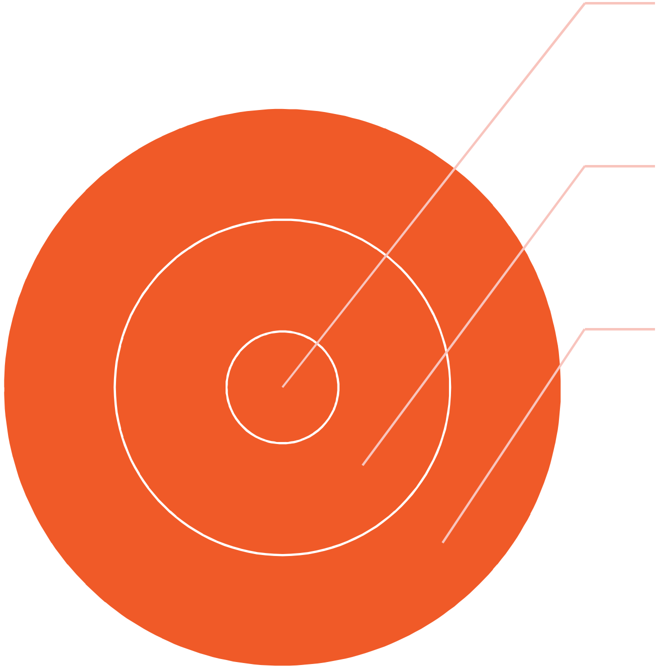


CO2

Goldilocks Product Offerings



Econ 101

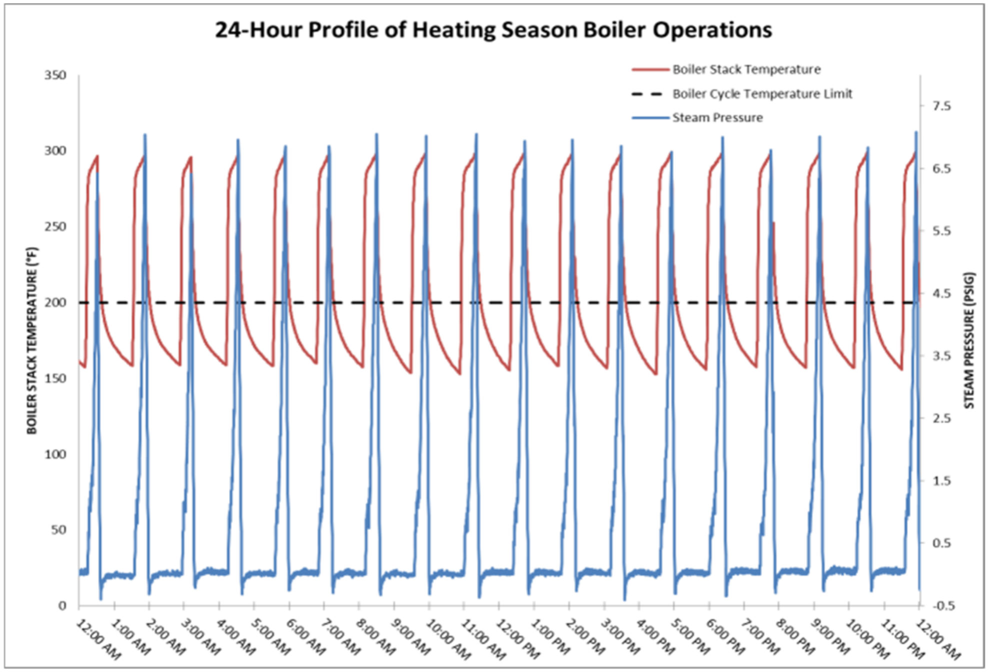


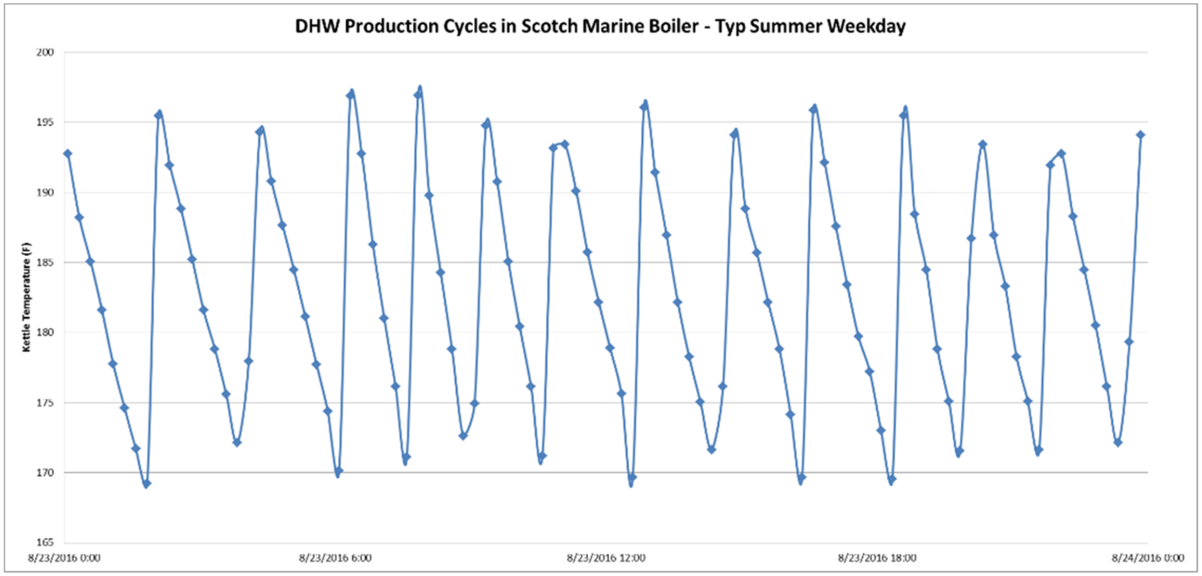
Not enough (any) installations, so no real pricing yet

Payback is dependent on fuel type – gas is cheap

Low-cost electricity helps a lot

Heat Timer Example




DHW Production Cycles in Scotch Marine Boiler - Typ Summer Weekday
Kettle Temperature (F)
200
195
190
185
180
175
170
165
8/23/2016 0:00
8/23/2016 6:00
8/23/2016 12:00
8/23/2016 18:00
8/24/2016 0:00

The Verdict (individual bldgs)

- We would expect to see some savings
  - Replace scotch marine @ 81% efficiency with HWH + storage tank @ 86% efficiency
  - 5% efficiency boost for 33% of the year
  - winter boiler does not fire for DHW, losses not attributed to DHW, reduces efficiency gain to ~3% for 67% of year

but not enough savings opportunity to justify high cost

Does Dedicated DHW Work? - Campuses

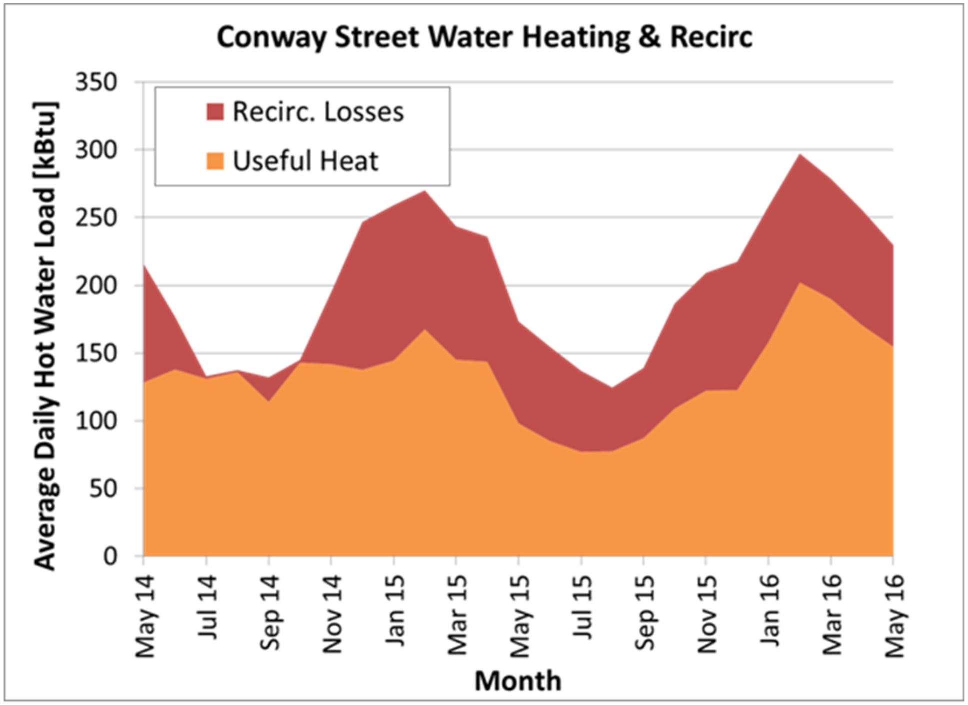
- We would expect to see better savings in campus scenarios:
  - Summer performance of ~30% efficiency (major steam distribution losses/leaks)
  - Winter performance ~63% (most losses attributable to heating load
  - Replace with HWH + storage tank @ 86% efficiency
- Installation cost tends to be higher, though

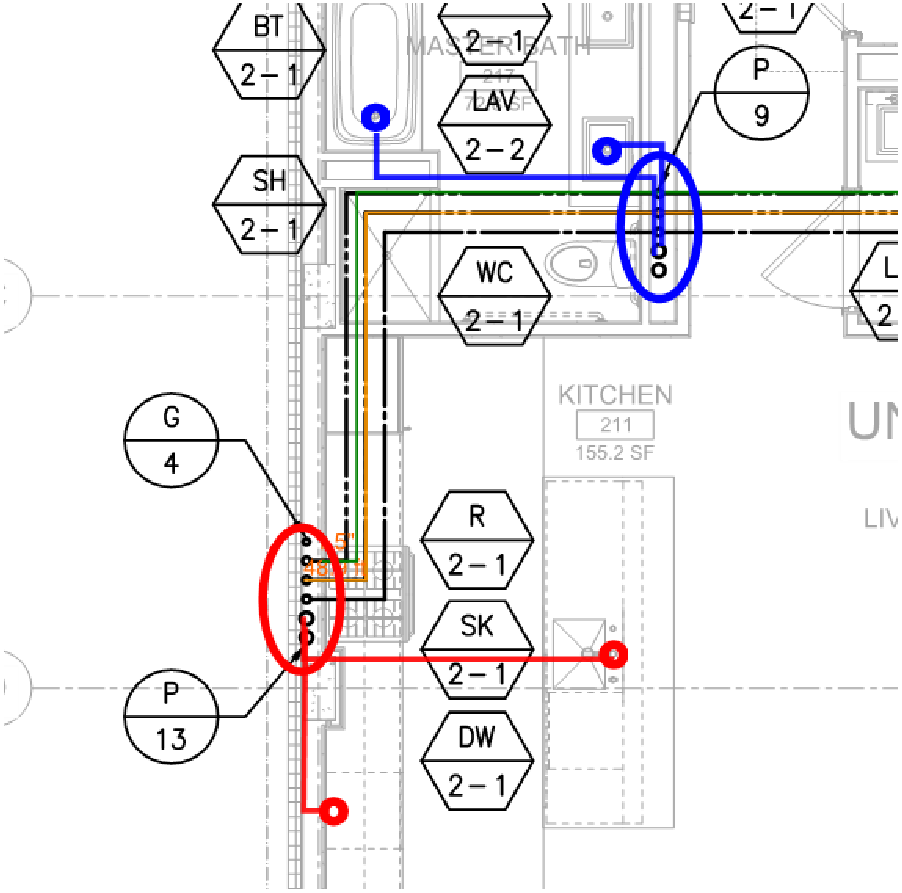
And We Frequently See Costs Underestimated

- Boiler unit cost is “easy” to ballpark, but
    - Flues are expensive
    - New gas service/meter/piping/accessories are expensive
    - Cost of redundancy can sneak in and inflate price
    - Plus ASHRAE and industry sizing tends high

Hot Water Recirculation Pump Controls

Hot Water Recirculation Pump Controls





Design Optimization – Central Recirculation

- Distribution losses ~ **30% of DHW heating demand**
- Reduce risers
  - Cluster plumbing locations when feasible
  - Optimize HWR loop location – reduce runouts from riser to fixtures
- Insulation
  - Code required (NYS Energy Code 1” to 1.5”)

Domestic Cold Water Booster Pumps

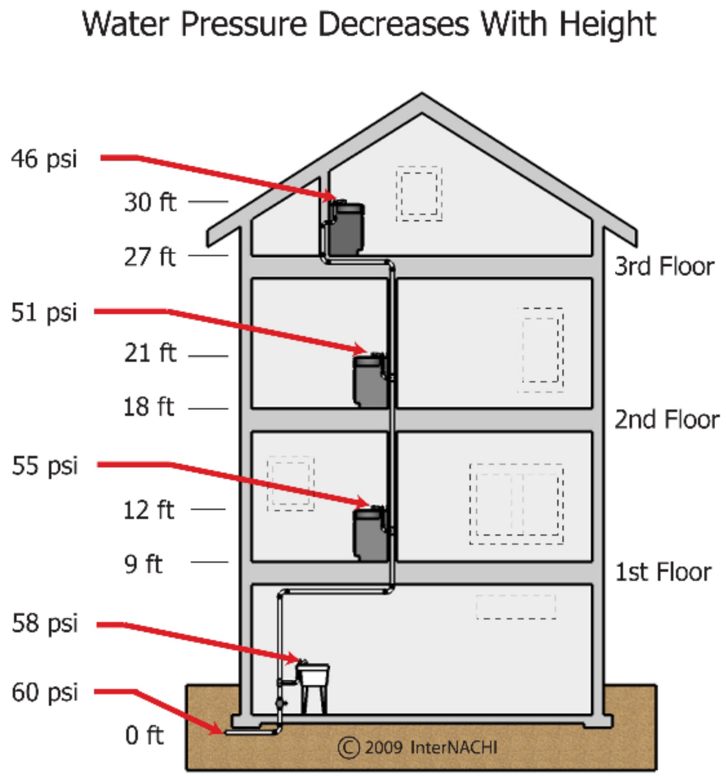
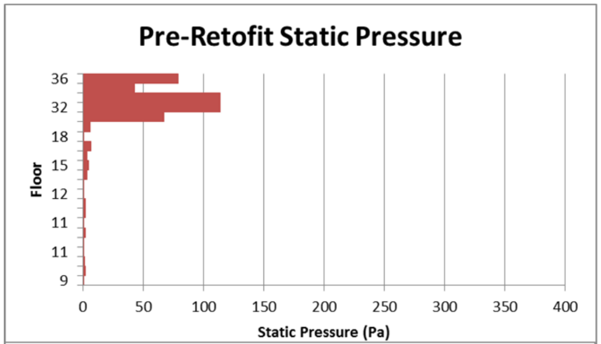


TABLE 604.3
WATER DISTRIBUTION SYSTEM DESIGN CRITERIA REQUIRED CAPACITY AT FIXTURE SUPPLY PIPE OUTLETS

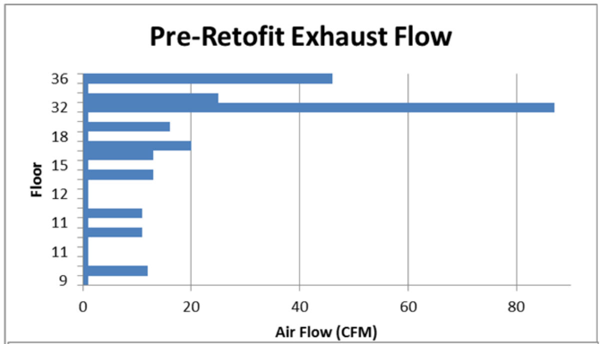
FIXTURE SUPPLY OUTLET SERVING	FLOW RATE[a] (gpm)	FLOW PRESSURE (psi)
Bathtub, balanced-pressure, thermostatic or combination balanced-pressure/thermostatic mixing valve	4	20
Bidet, thermostatic mixing valve	2	20
Combination fixture	4	8
Dishwasher, residential	2.75	8
Drinking fountain	0.75	8
Laundry tray	4	8
Lavatory, private	0.8	8
Lavatory, private, mixing valve	0.8	8
Lavatory, public	0.4	8
Shower	2.5	8
Shower, balanced-pressure, thermostatic or combination balanced-pressure/thermostatic mixing valve	2.5[b]	20
Sillcock, hose bibb	5	8
Sink, residential	1.75	8
Sink, service	3	8
Urinal, valve	12	25
Water closet, blow out, flushometer valve	25	45
Water closet, flushometer tank	1.6	20
Water closet, siphonic, flushometer valve	25	35
Water closet, tank, close coupled	3	20
Water closet, tank, one piece	6	20

How does this match with reality?

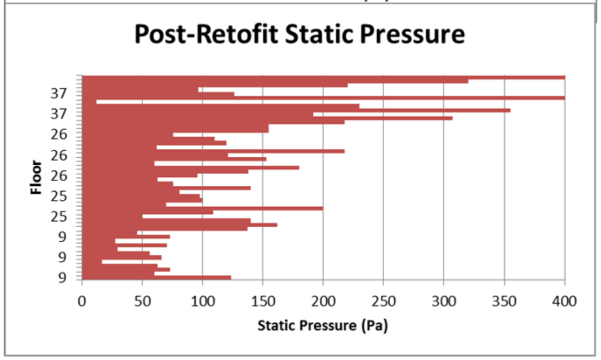
SWA Exhaust Retrofit Case Study - 650 Unit Occupied Residence



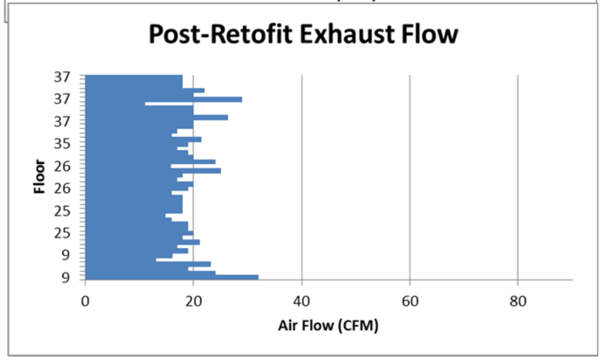
Pre-Retofit Static Pressure



Pre-Retofit Exhaust Flow



Post-Retofit Static Pressure



Post-Retofit Exhaust Flow

Glossary

- **Lamp vs bulb vs fixture**
  - Industry calls each light bulb a "lamp"
  - Use "fixture" term to eliminate confusion of lamp vs fixture
- **Lumens** = light output unit
- **Efficacy** = lumens / Watt
  - The higher the efficacy, the more efficient the fixture
- **LPD** (Lighting Power Density) = Watts/square foot
  - Lower number saves energy but may not provide sufficient illumination
- **1 Footcandle** (fc) = 1 lumen/square foot
  - Varies based on space type
  - Ex: Proposed corridor design = 10.5 fc; IESNA requires 10 fc min. This space is compliant per IESNA.
- **IESNA** = Illuminating Engineering Society of North America
  - sets lighting standards

Fluorescents - Magnetic Ballast

- Simplest ballast
- T12 technology
- Less efficient
- Magnetic Ballast May
  - Modulate electrical current at lower cycle rate = noticeable flicker
  - May vibrate at a low frequency = audible humming
- When replacing a magnetic ballast with an electronic ballast, make sure you address proper disposal in accordance with hazardous waste laws due to PCB's (Polychlorinated biphenyl).

Efficacy

The more lumens per watt a light source produces, the more efficacious, or energy-efficient, the light source is

$$Lamp\ Efficacy = \frac{Total\ luminous\ flux\ (lumens)}{Total\ lamp\ power\ input\ (w)} \qquad Systm\ Efficacy = \frac{Rated\ lamp\ lumens\ x\ BF}{Total\ input\ watts}$$

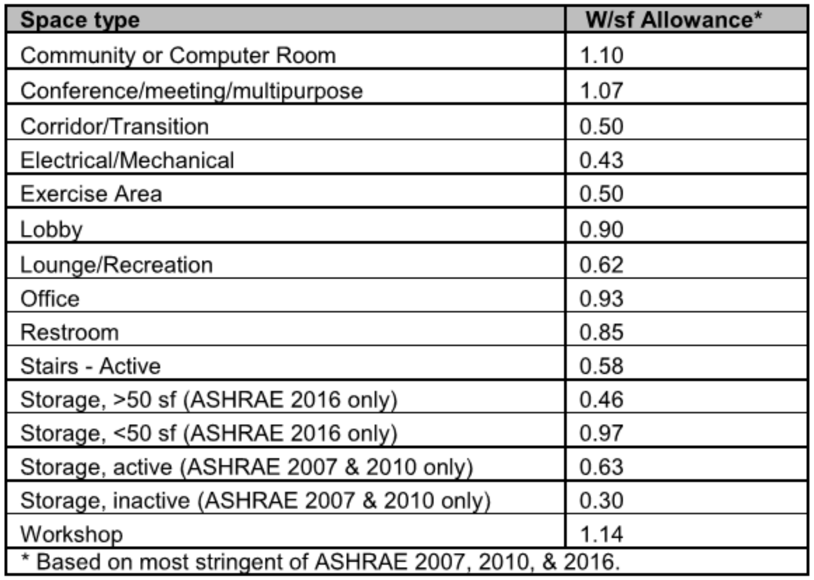
For example, it takes a CFL 20 Watts to create 1000 lumens

Lamp Efficacy = 1000 lumens / 20 Watts

Lamp Efficacy = 50 lm/W

Plan for Success

- Table indicates **target W/SF allowance by space type**, according to the most stringent version of ASHRAE 2007, 2010, & 2016.



Space type	W/sf Allowance*
Community or Computer Room	1.10
Conference/meeting/multipurpose	1.07
Corridor/Transition	0.50
Electrical/Mechanical	0.43
Exercise Area	0.50
Lobby	0.90
Lounge/Recreation	0.62
Office	0.93
Restroom	0.85
Stairs - Active	0.58
Storage, >50 sf (ASHRAE 2016 only)	0.46
Storage, <50 sf (ASHRAE 2016 only)	0.97
Storage, active (ASHRAE 2007 & 2010 only)	0.63
Storage, inactive (ASHRAE 2007 & 2010 only)	0.30
Workshop	1.14

* Based on most stringent of ASHRAE 2007, 2010, & 2016.

DOE Lighting Facts Label

Light Output/Lumens
Measures light output. The higher the number, the more light is emitted.

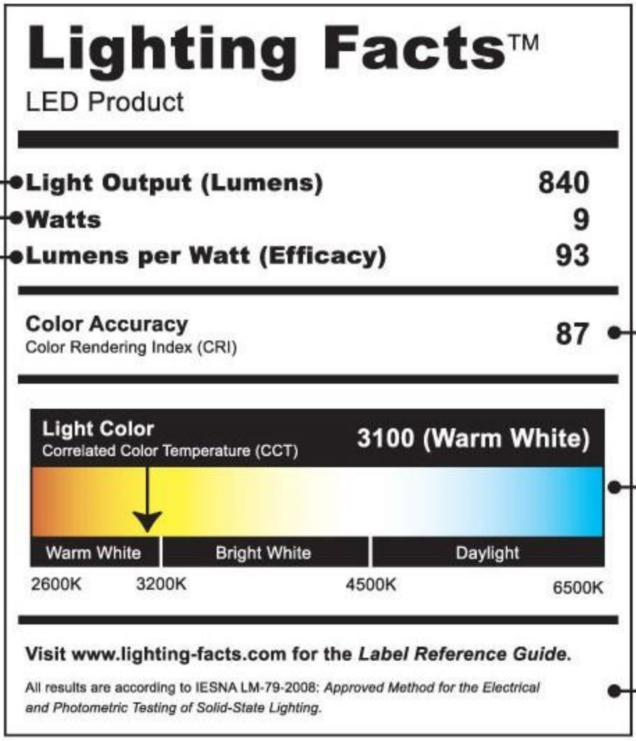
Reported as "Total Integrated Flux (Lumens)" on LM-79 test report.

Watts
Measures energy required to light the product. The lower the wattage, the less energy used.

Reported as "Input Power (Watts)" on LM-79 report.

Lumens per Watt/Efficacy
Measures efficiency. The higher the number, the more efficient the product.

Reported as "Efficacy" on LM-79 test report.



Lighting Facts™
LED Product

Light Output (Lumens)	840
Watts	9
Lumens per Watt (Efficacy)	93
Color Accuracy Color Rendering Index (CRI)	87
Light Color Correlated Color Temperature (CCT)	3100 (Warm White)

Visit www.lighting-facts.com for the *Label Reference Guide.*

All results are according to IESNA LM-79-2008: *Approved Method for the Electrical and Photometric Testing of Solid-State Lighting.*

Color Rendering Index (CRI)
Measures color accuracy.

Color rendition is the effect of the lamp's light spectrum on the color appearance of objects.

Correlated Color Temperature (CCT)
Measures light color.

"Cool" colors have higher Kelvin temperatures (3600–5500 K); "warm" colors have lower color temperatures (2700–3500 K).

IESNA LM-79-2008
Industry standardized test procedure that measures performance qualities of LED luminaires and integral lamps. It allows for a true comparison of luminaires regardless of the light source.