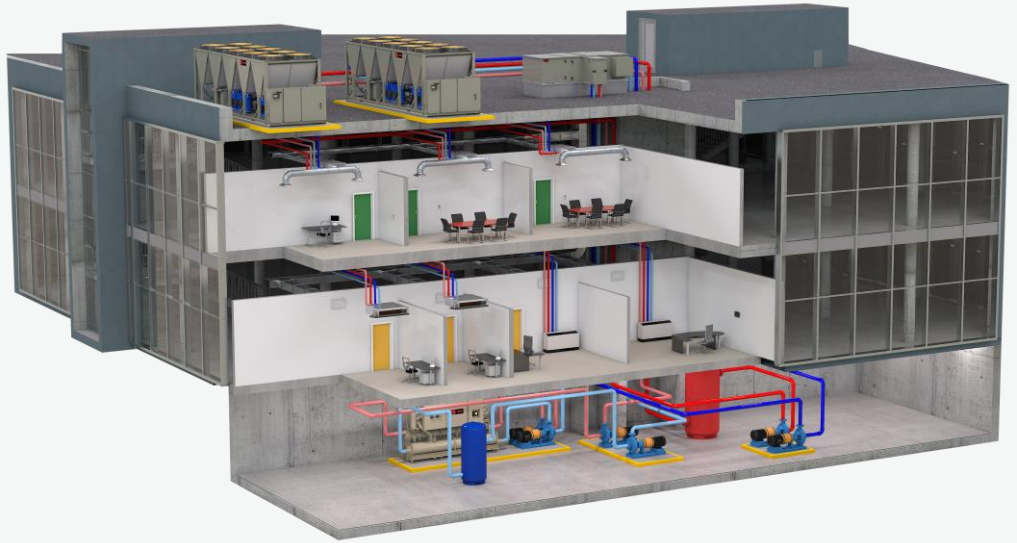
The Hottest HVAC Designs for the Coldest Climates: Decarbonizing through Ultra High Efficiency Electrification

Clean Air Partnership



February 2024

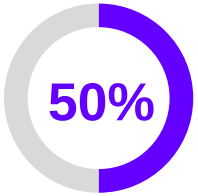
TRANE TECHNOLOGIES

Lukas Glaspell

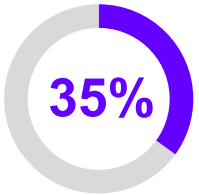
Trane Technologies is positioned to **meet global challenges by addressing**

Carbon Emissions, Food Loss, and Achieving Diversity

In doing so, we have achieved significant **2020 Commitments**



reduction in GHG refrigerant footprint of our product portfolio



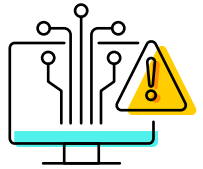
reduction in GHG footprint of our operations

However, we continue to see **opportunities in the world's challenges…**

Sustainability

Climate Change

Urbanization



Technological Disruptions

Demographics

…Leading to our **2030 Commitments**

Gigaton Challenge

Reduce customer carbon footprint by **1 gigaton***

- ✓ Accelerate clean technologies that heat and cool buildings in sustainable ways
- ✓ Increase energy efficiency in buildings, homes and transport
- ✓ Reduce food loss in the global cold chain
- ✓ Transition out of high-Global Warming Potential Refrigerants

Design systems for circularity

Increase access to heating, cooling and fresh food

Leading by Example

Achieve carbon neutral operations

Deliver zero waste to landfills

Become net positive with water use

Reduce absolute energy consumption by 10%†

Opportunity for All

Achieve workforce diversity reflective of our communities

Achieve gender parity in leadership roles

Maintain world-class safety metrics

Provide market-competitive wages, benefits and leading wellness offerings for workforce

Invest $100 million in building sustainable futures for under-represented students

Dedicate 500,000 employee volunteer hours in our communities

*1B metric tons of CO_2e

†Compared to 2019 baseline

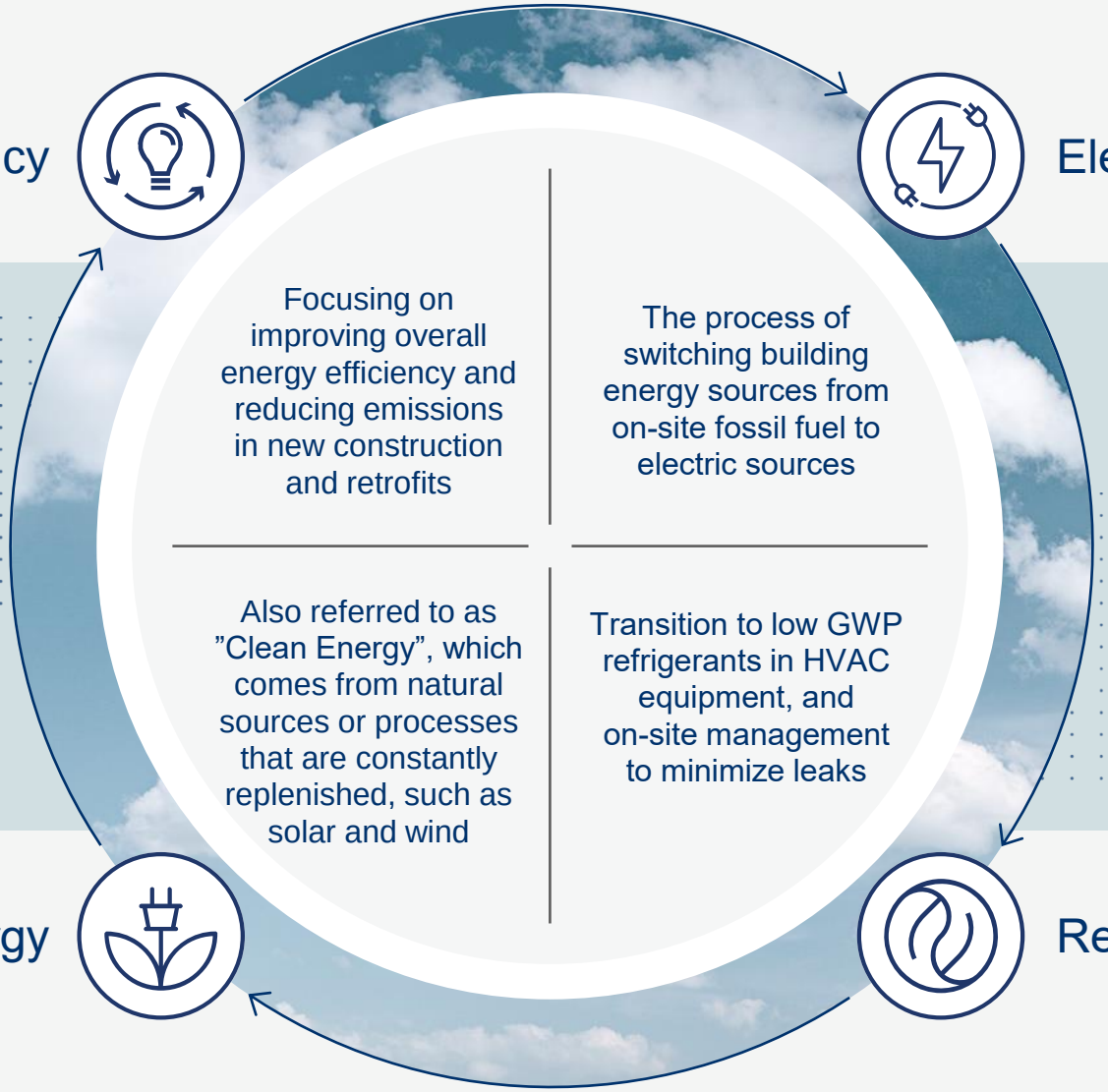
Pillars of Decarbonization

Reducing Indirect Emissions

Indirect GHG emissions (AKA Scope 2) are generally associated with emissions one step removed a customer's direct operations

Reducing Direct Emissions

Direct GHG emissions (AKA Scope 1) are those that occur from sources directly controlled by the customer



Understanding Carbon Emissions

3 Categories of Emissions

GHG Emissions & Scope Components

Scope 1
Direct, on-site emissions (usually due to burning fuels) on-site / by fleet

Scope 2
Emissions associated with energy / utility purchases to operate the business (includes electricity and steam)

Scope 3
Emissions from value chain related to all other company activities (not directly controlled by the company itself)

Carbon Footprint

Solutions

Refrigerant Management

Electrification

+

Energy Efficiency

Renewable Energy

+

Embodied Carbon

=

Decarbonization

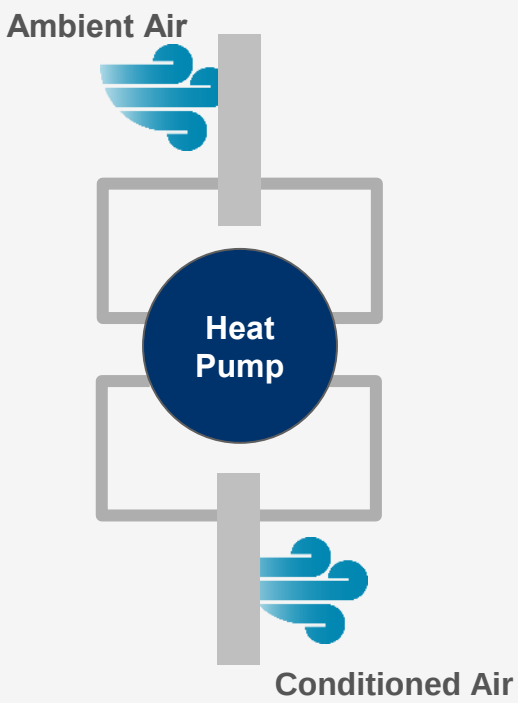
Heat pump

- A heat pump with a reversing valve is a unit which allows the evaporator and condenser to switch roles by reversing the flow of refrigerant within the circuit.
- Heat pumps can come in a wide range of sizes and are available in water source and air source versions.

The future of heat is electric. Heat pumps provide heating or cooling from one reliable unit using a clean and renewable energy source.

Heat Pumps

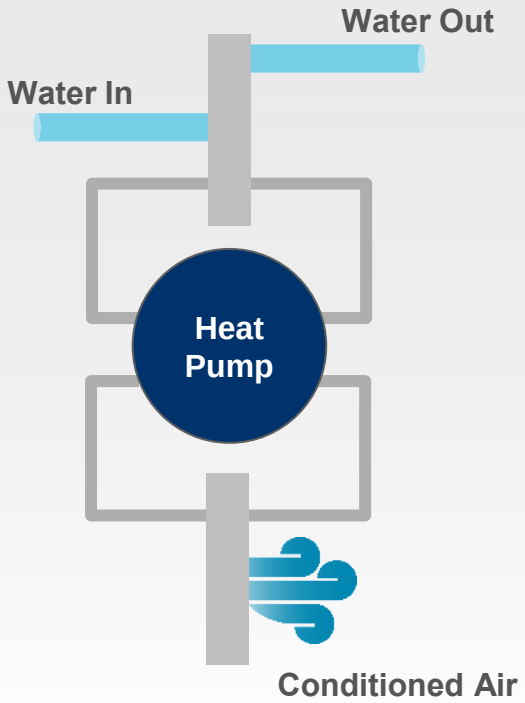
Air to Air



Example:
Rooftop Units
VRF

Reversing

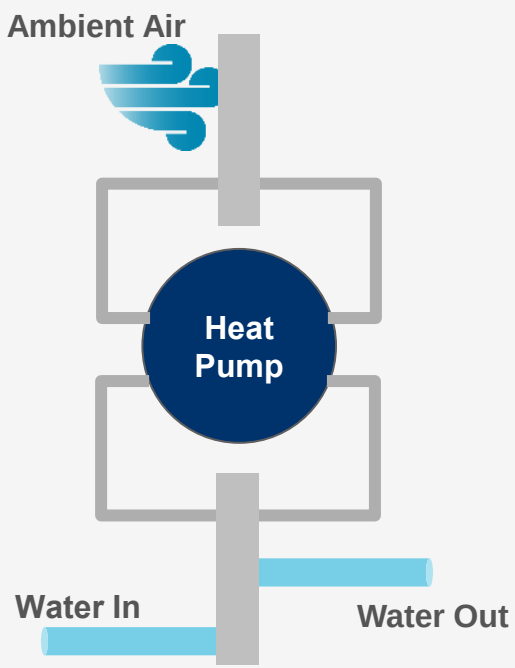
Water to Air



Example:
WSHP

Reversing

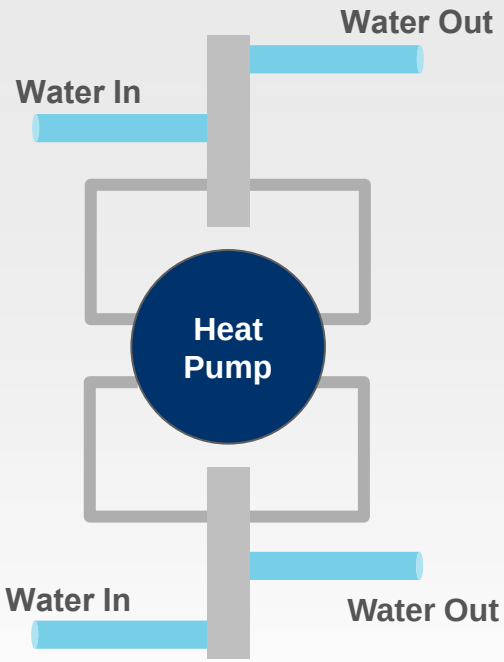
Air to Water



Example:
Air-Source
Heat Pump

Reversing

Water to Water



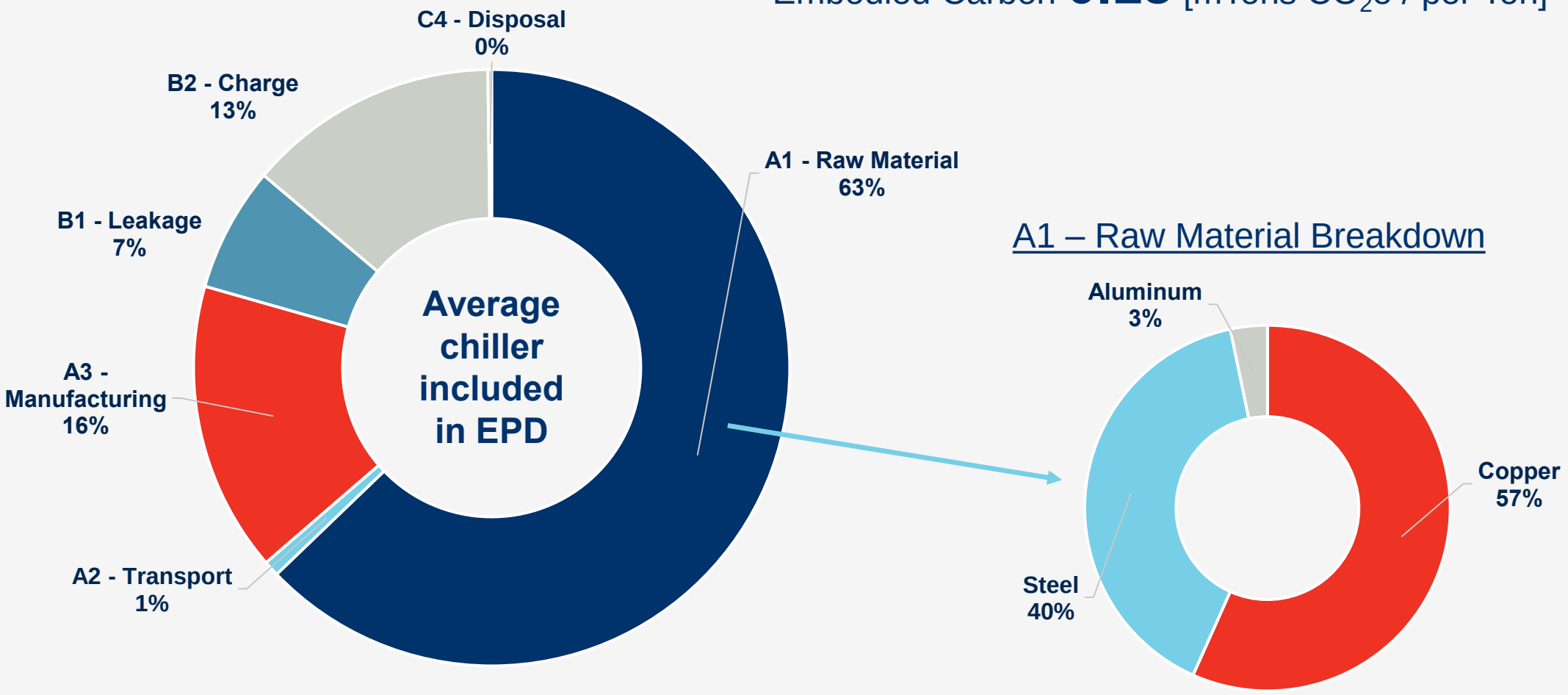
Example:
Chiller/Heater

Reversing / Non-Reversing

What About Embodied Carbon?

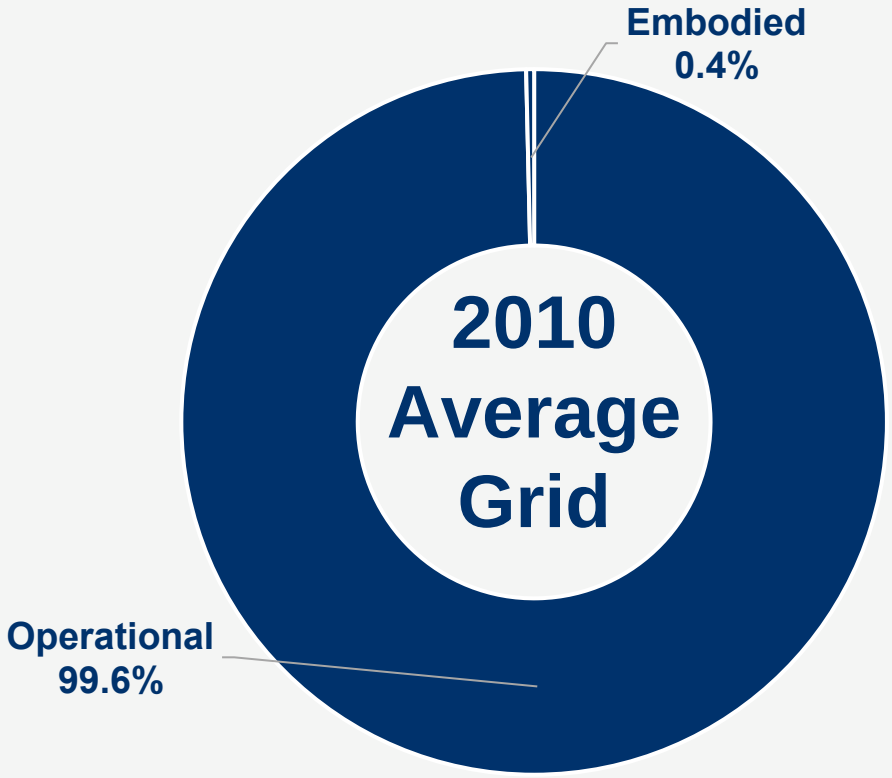
Hydronic Heat Pump Chiller

Embodied Carbon **0.15** [mTons CO_2e / per Ton]

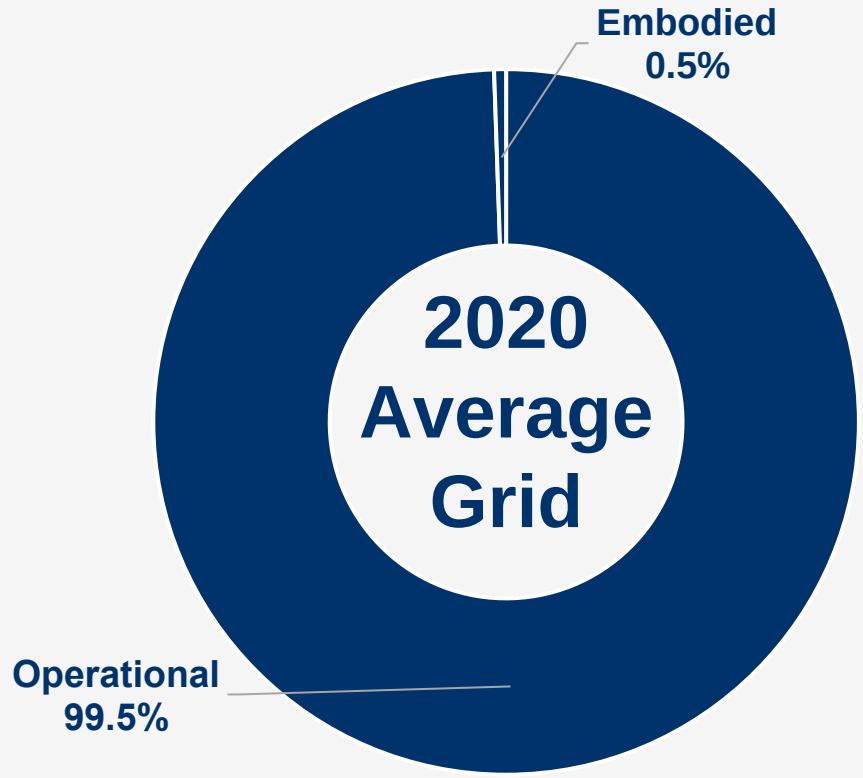


Source: Trane EPD.

Operational Emissions vs Embodied Emissions



	mTons CO_2e
Embodied	0.15
Operational	40.9



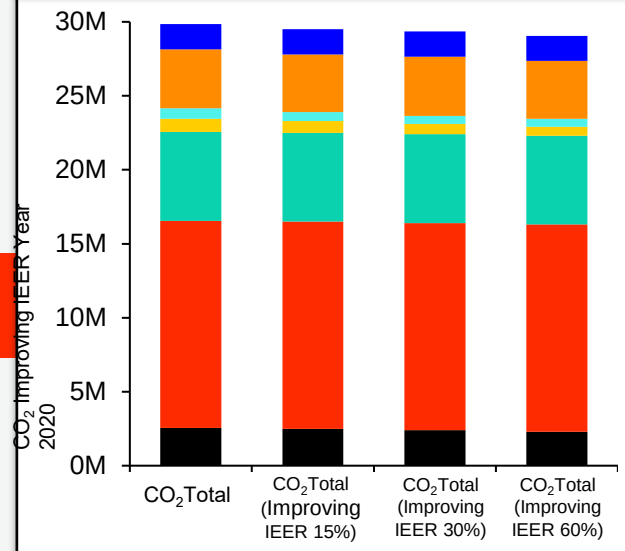
	mTons CO_2e
Embodied	0.15
Operational	27.2

Per Cooling Ton

Source: Trane EPD.

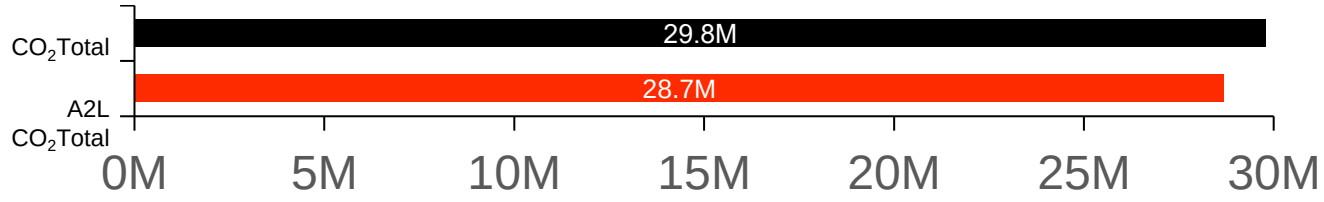
Gas to Heat Pump Conversion Impact to GHG Reduction

EFFICIENCY IMPROVEMENT



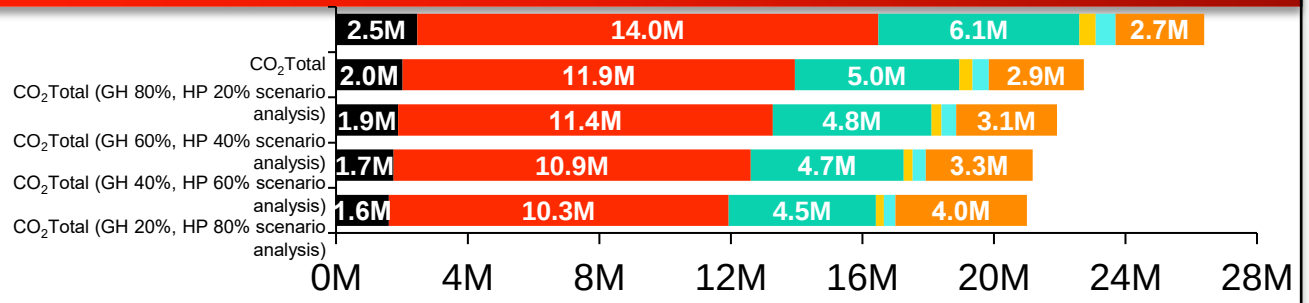
Increasing IEER to eFlex (variable speed) equivalent across all product families reduces CO_2 equivalent by ~3% (1M Tons annually)

REFRIGERANT CHANGE



Converting from R410A to R454B is nearly 80% reduction in GWP yielding a ~3% (1M Tons annually) reduction in CO_2 equivalence

CONVERSION OF GAS HEAT TO HEAT PUMP



Even a 20% conversion on Unitary gas heat to heat pumps would yield ~16% reduction in CO_2 equivalence

Voyager III Voyager II Precedent Intellipak with Symbol Intellipak II Intellipak I

Trane Electrified Heating and Cooling Equipment Portfolio

VRF and Unitary

Heat Pump Heat Recovery

VRF (Variable Refrigerant Flow)

Heat Pump Heat Pump w Dual Fuel

Light RTU

Cooling Only Cooling w Elec Heat

Light RTU & Splits

Cooling Only Cooling w Elec Heat

Large RTU Splits CSC

Heat Pump Heat Recovery Heat Pump w Elec Heat

WSHP

Applied Hydronic

	Chiller	Chiller + Heat Recovery	Heat Pump	Multi-pipe	Thermal Energy Storage
	 Cooling only	 Heating while Cooling	 Heating or Cooling	 Any combination	
Air Cooled Chillers	 All Units	 CGAM AMC/AMT MWC/MWT ACS (2023)	 AXM ACX		
Water-Cooled Chillers	 All units	 CTV/ECTV RTWD/RTHD	 WXM*	 Simultaneous heating & cooling	 Thermal Battery™

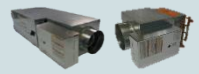
Airside

Custom Air Handlers
- Heat Pump Capable DX Coils – Unitary & VRF Linkage
- Packaged Heat Pump DX
- Standard Electric Heat Option
- Change-over Chilled Water / Hot Water Coils
- Standard Energy Recovery Options

Cataloged & Semi-custom Air Handlers
- Heat Pump Capable DX Coils – Unitary & VRF Linkage
- Standard Electric Heat Option
- Change-over Chilled Water / Hot Water Coils
- Standard Energy Recovery Options

Terminal Products
- Heat Pump Capable DX Coils – Unitary & VRF Linkage
- Standard Electric Heat Option
- Change-over Chilled Water / Hot Water Coils

VAV Products: Standard Electric Heat Option

Single Duct


Single Duct – RIRO

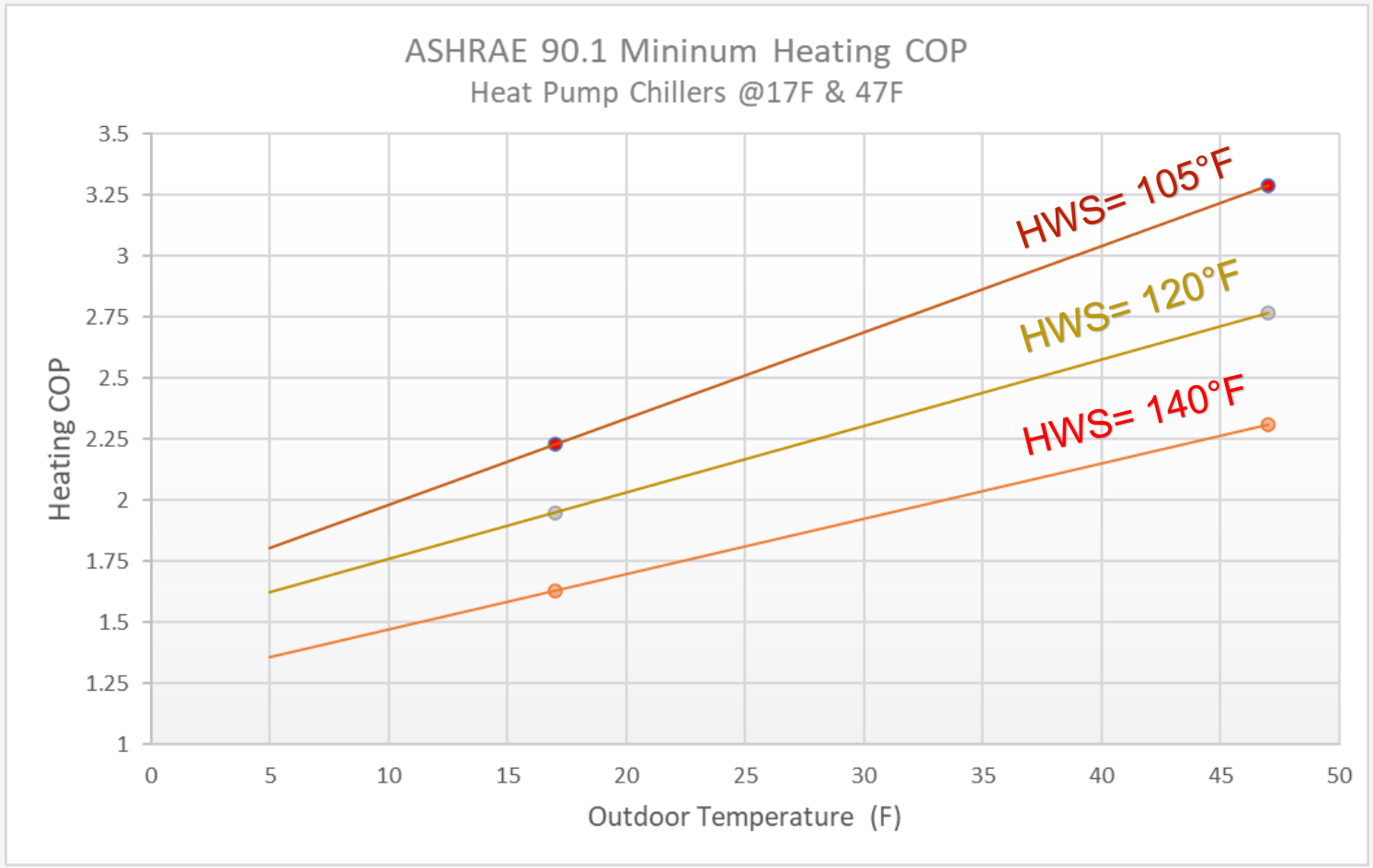

Fan Powered


Dual Duct


Sensible-Cooling (CoolSense) Terminal Unit


* All water-cooled chillers may be referred to as water-to-water heat pumps

Hot Water Supply Temperature, Outdoor Air and COP



1%

1% penalty per
1°F above 105°F

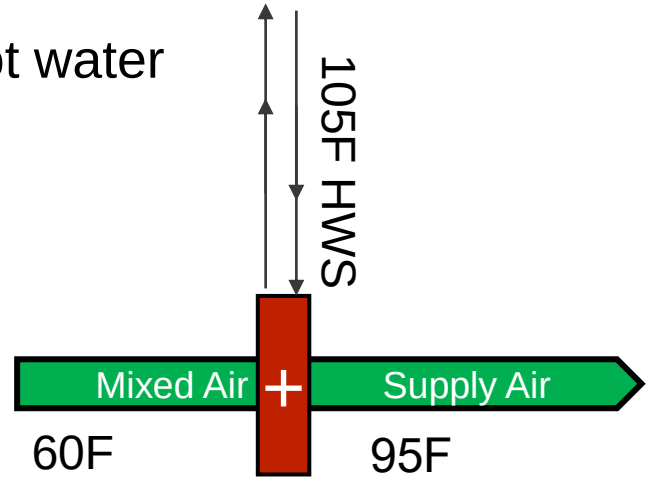
140°F hot water requires 35% more peak power and annual heating energy than 105°F

Hot Water Supply Temperature

What is needed by the zone equipment?

Most equipment can be selected for space heating with 100-110°F Hot water

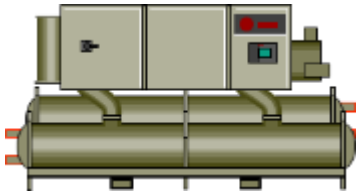
Equipment	Minimum Hot Water Supply Temperature
DOAS Air Handler	>80°F
Central Air Handler/VAV	95-105°F
Single Zone VAV AHU	100-105°F
VAV boxes (4 row)	95-105°F
Fan Coil Units w/ Changeover coil	100-115°F



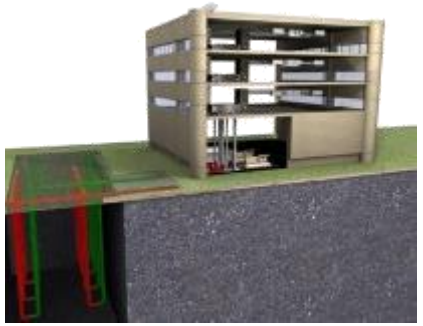
Hydronic Changeover Coil

Electrified Systems – Heat Sources

Ambient Air



Cooling Load
(Heat Recovery)



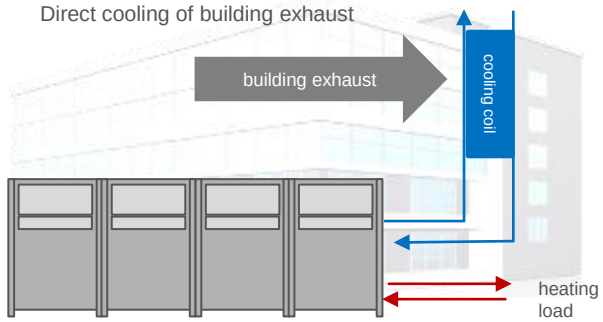
Geothermal
loop

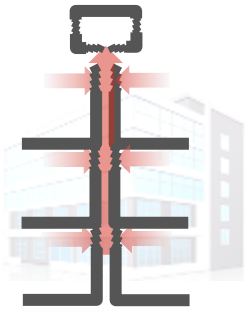
Lake,
river, pond

Storm and
sewer

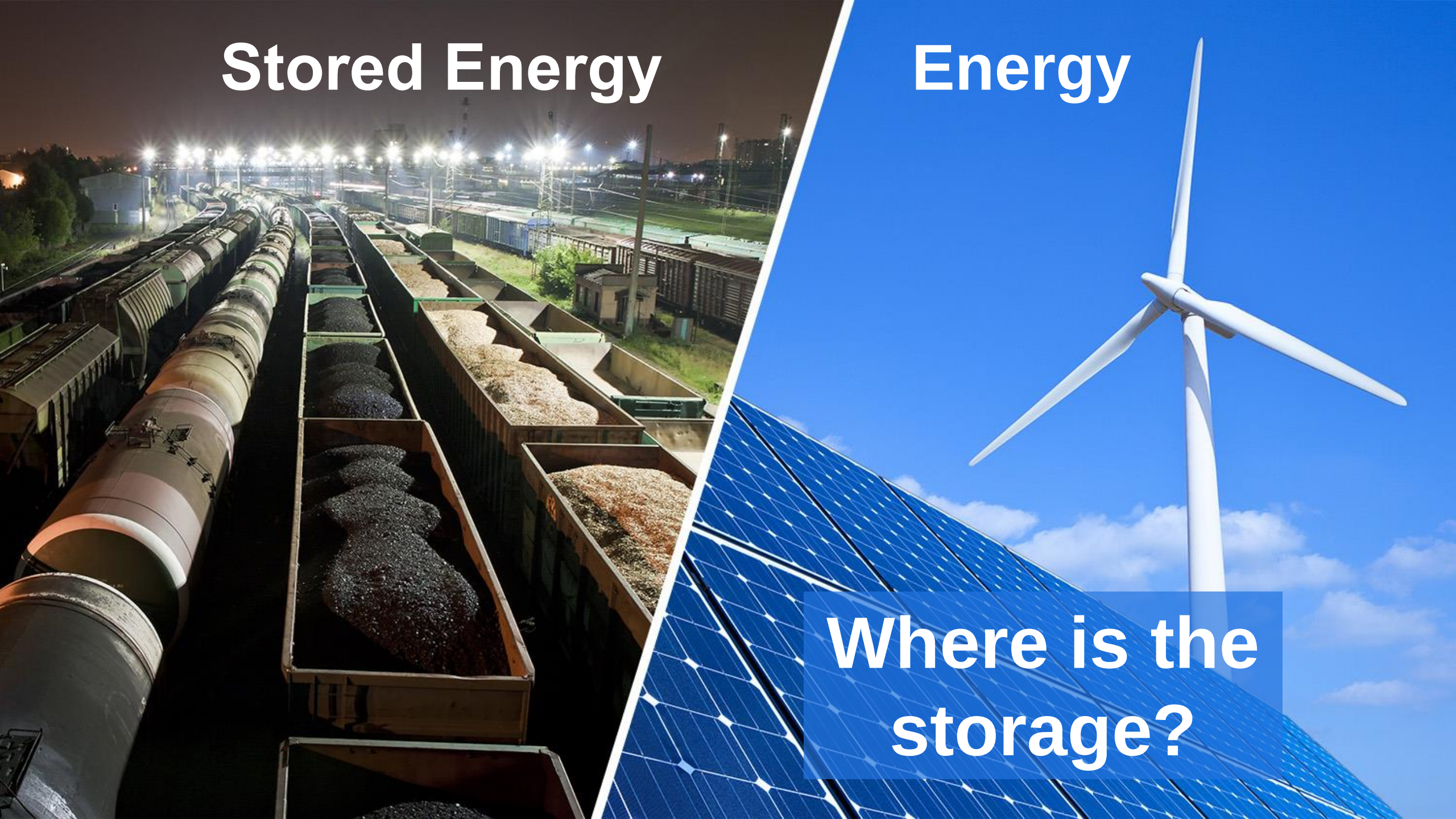
Thermal energy
storage battery

“Storage Source
Heat Pump”



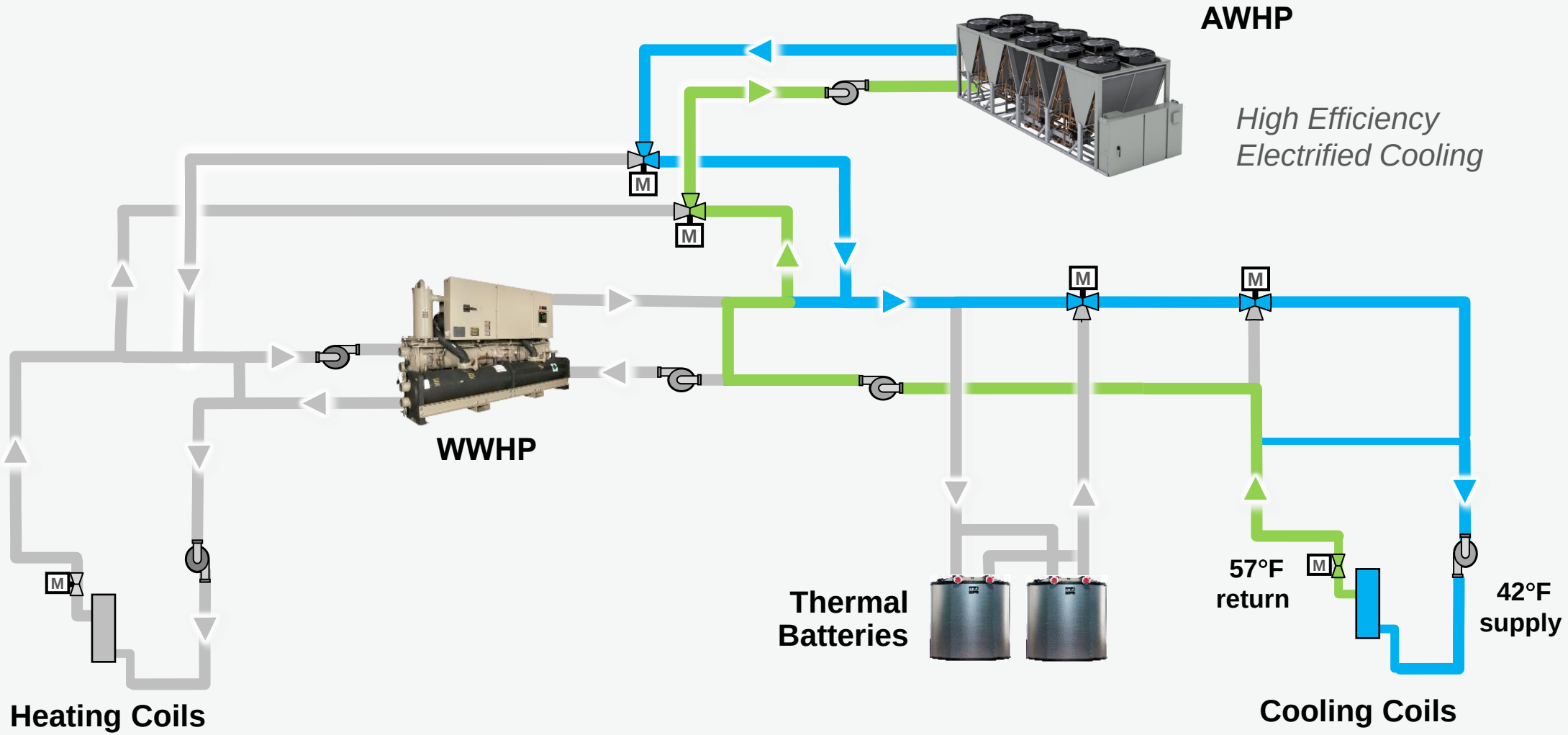


Exhaust
air coil


Stored Energy
Energy
Where is the storage?

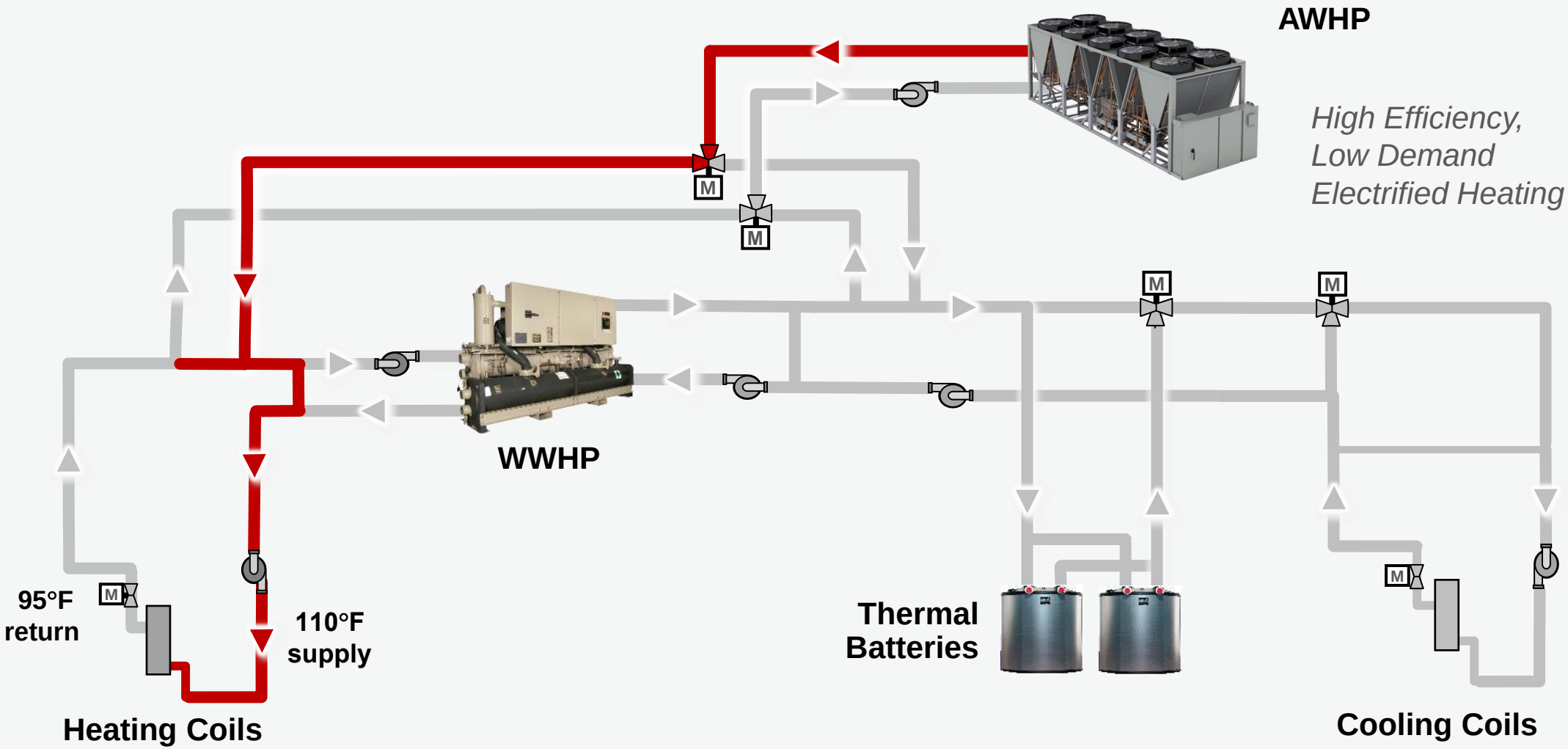
Solving Decarbonization Challenges with Thermal Batteries

Cooling with Air-to-Water Heat Pump



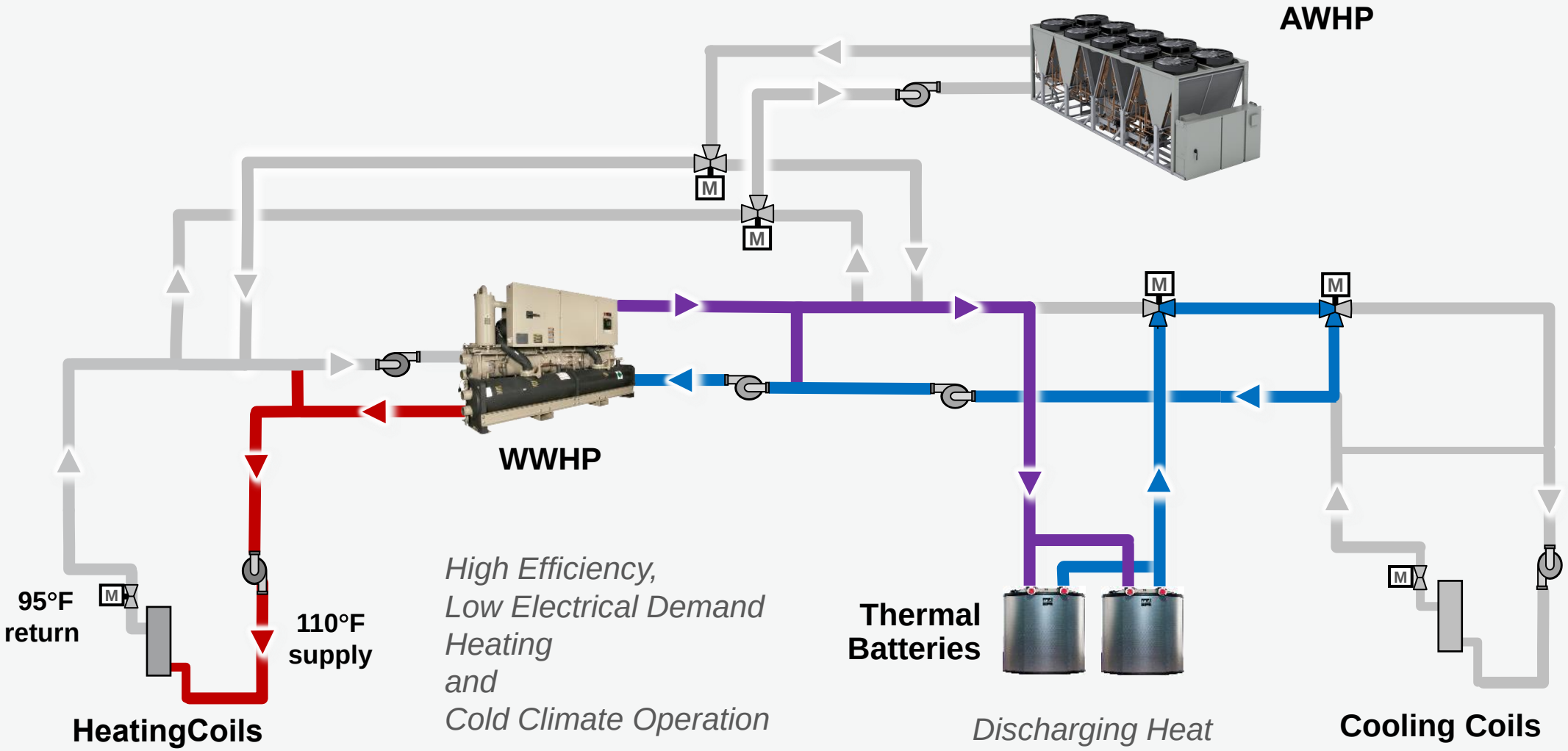
Solving Decarbonization Challenges with Thermal Batteries

Heating with Air-to-Water Heat Pump



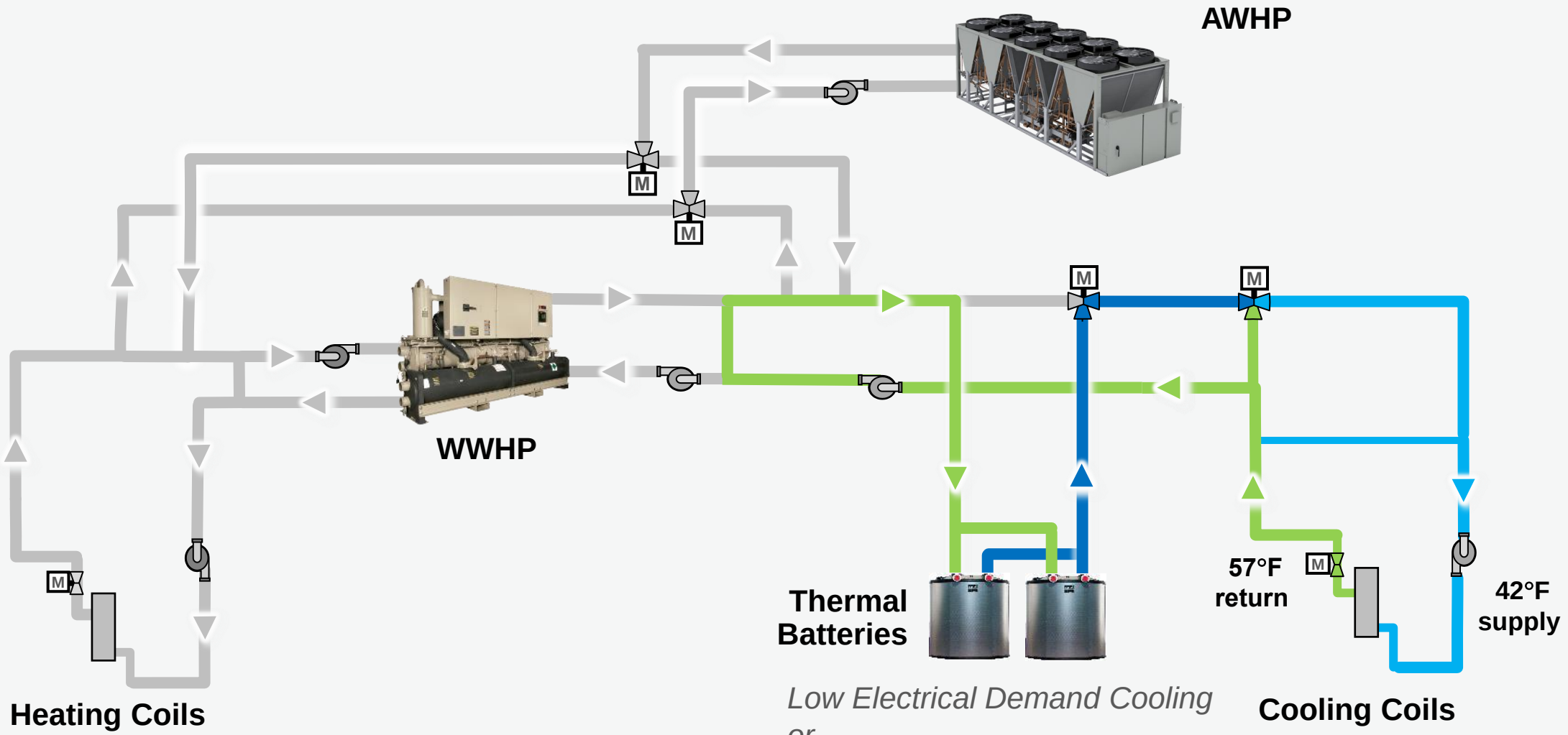
Solving Decarbonization Challenges with Thermal Batteries

Storage Source Heating - Thermal Batteries & Chiller-Heater



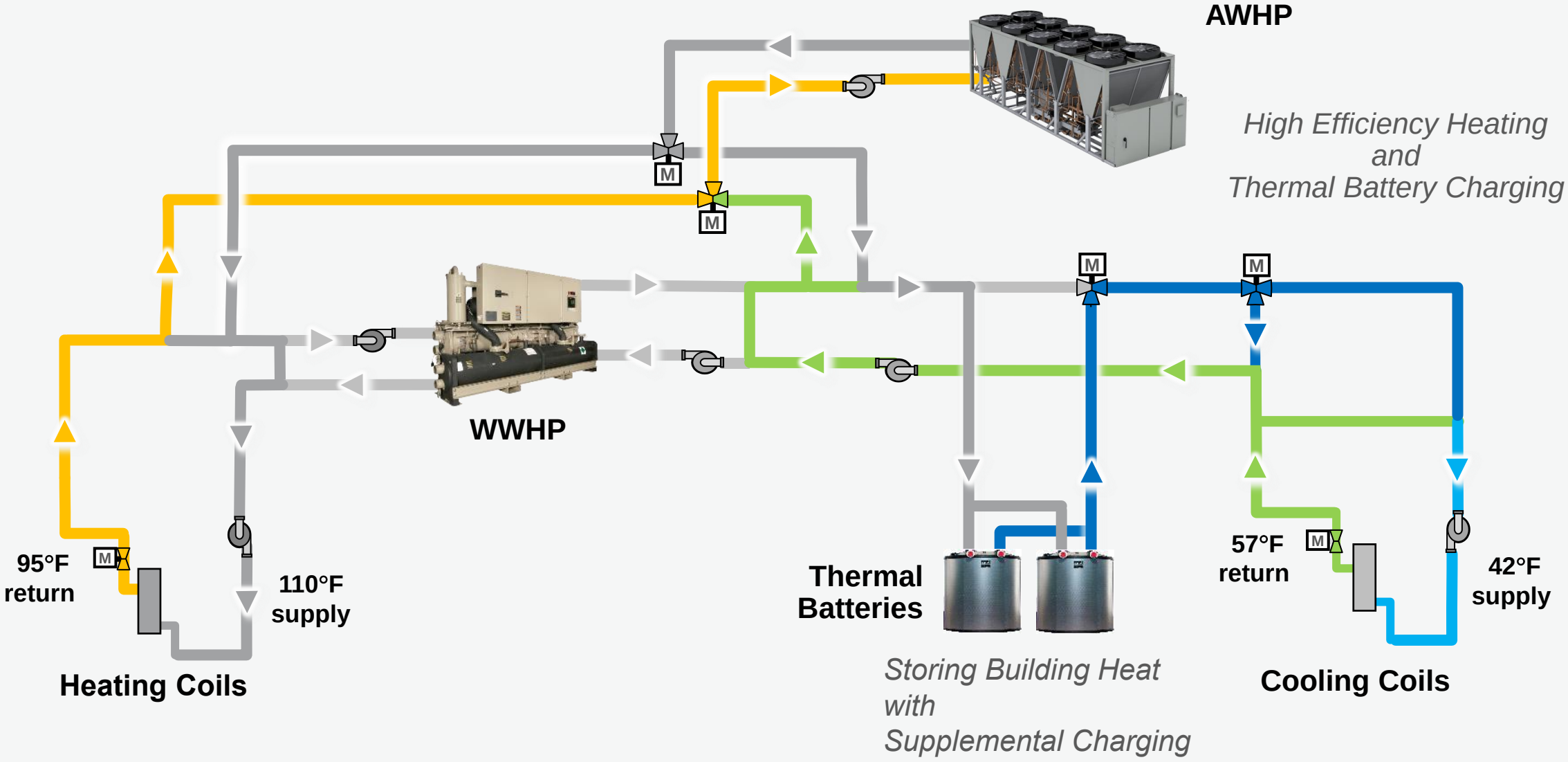
Solving Decarbonization Challenges with Thermal Batteries

Cooling with Thermal Batteries



Solving Decarbonization Challenges with Thermal Batteries

Heating and Cooling with Supplemental Energy – when Ample Green Power!



Heat Pump RTUs

ASCEND® Air-to-Water Heat Pump

Model ACX(140 to 230 tons cooling, 1500 to 2500 MBh heating)

R454B

A perfect fit to meet your sustainability and efficiency targets

FEATURES

Built on Trane's Ascend chiller platform and Trane controls knowledge and expertise to provide consistent quality and reliability.

- **Support of electrification of heat**
- **Ease of installation**
- **Simplified service**

- **Options:** Integrated pump packages & sound-reduction packages, Drain pan

Operating Limitations		
Chilled Water	40 to 65F	0 to 125F Ambient
Hot Water	68 to 140F	0 to 95F Ambient
Max leaving at min ambient – 90F at 0F		

Thermafit™ Modular Air-to-Water Heat Pump

Model AXM (30 tons cooling, 390 MBh heating)

R410A

Modular flexibility

FEATURES

Each module produces 30 tons cooling, 390 MBh heating. (300T bank) Expandable up to 10 modules. Provides all electric heating and cooling

- **True redundancy**
- **Cold weather comfort (Vapor injection technology)**
- **Easy expandability**
- **Simplified service**
- **Small footprint**
- **Options:** coated coils, compressor wraps, BMS Integration, Single frame / beam assembly

Operating Limitations		
Chilled Water	30 to 65F	0 to 115F Ambient
Hot Water	68 to 140F	0 to 95F Ambient
Max leaving at min ambient – 130F at 0F		

Next Gen Future ASHP

Thermafit™ Multipipe Unit

Model MWS (30 to 60 tons cooling, 1275 to 2690 MBh)

FEATURES

Thermafit multi-pipe units enable electric heating and cooling to get you one step closer to making net-zero goals happen and meet changing building codes and regulations for electrification.

- **Ultra Efficient**
- **Simultaneous Heating and Cooling**
- **Single System to meet Varying Heating and Cooling Demands**
- **Electric Heating**
- **Fluids from Different Loops do not mix**
- **Options:** Low sound

Operating Limitations		
Cooling only	Chilled water 54-44F	Source 85-95F
Heating only	Hot water 100-120F	Source 54-44F
Simultaneous	Chilled water 54-44F	Hot water 100-120F

Cascade Chiller Heater

20,000 to 35,000 heating MBh

R514A
R1233zd

District heating application

FEATURES

CVHH Booster product that is designed to deliver 180°F hot water for high-capacity district heating application.

- **Available as Engineered-to-Order**
- **Lift capability: 145F**
- **Turndown: 25%**
- **High Temp CVHH can provide additional cooling in summer**
- **High Temp CVHH can be sold individually as boost**
- **Factory-installed Optional Features:** 6 pipe heat recovery, Belzona coating, sacrificial anodes, CuNi tubes

Operating Limitations	
Hot Water	Up to 180F
Chilled Water	38 to 65F

High Temperature Hot water Booster

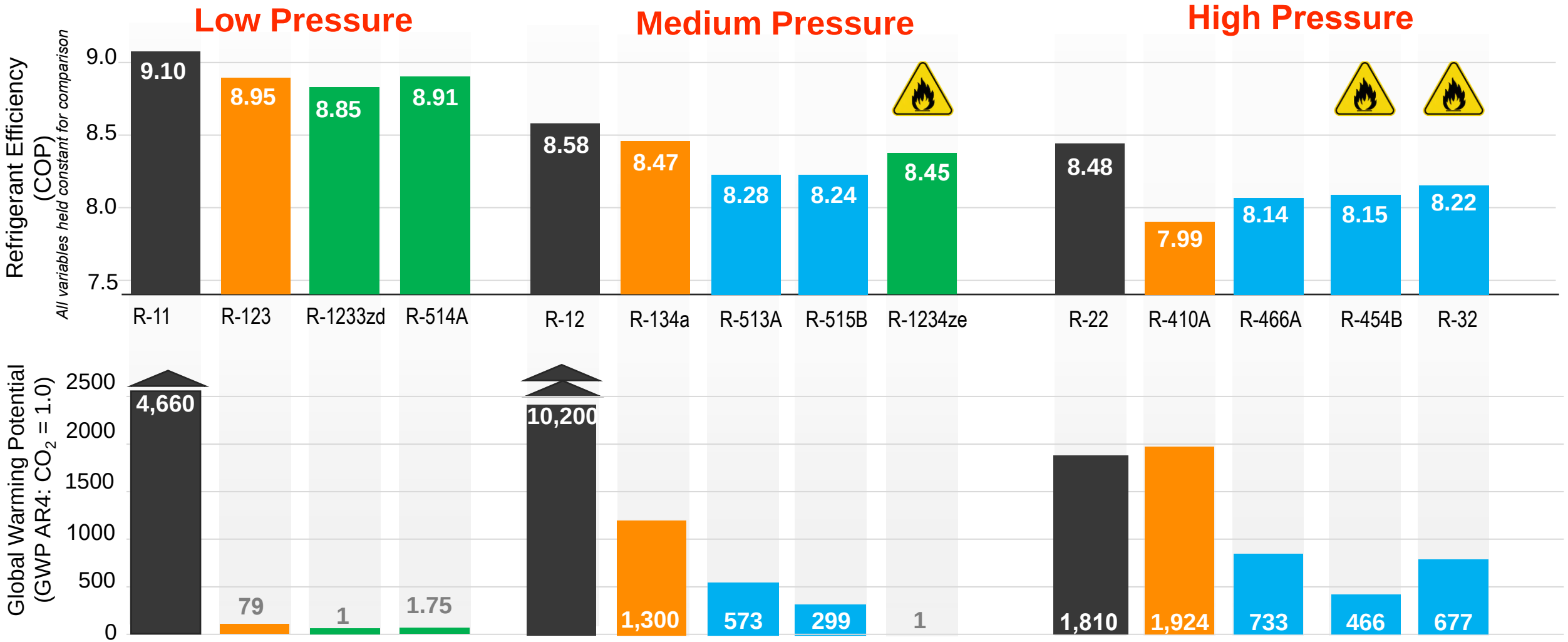
- Maximum condenser temperature of **+120°C (248°F)**
- Minimum Heat Source temperature of **-20°C (-4°F)**
- Refrigerants at and near 1 GWP

- Exergy heat pumps provide significant results for a wide variety of applications:

- Heating in residential or commercial buildings
- District heating
- Heating industrial processes
- Domestic hot water delivery

Efficiency and GWP Comparison

Past | Transitional | Lower GWP | Ultra-Low GWP



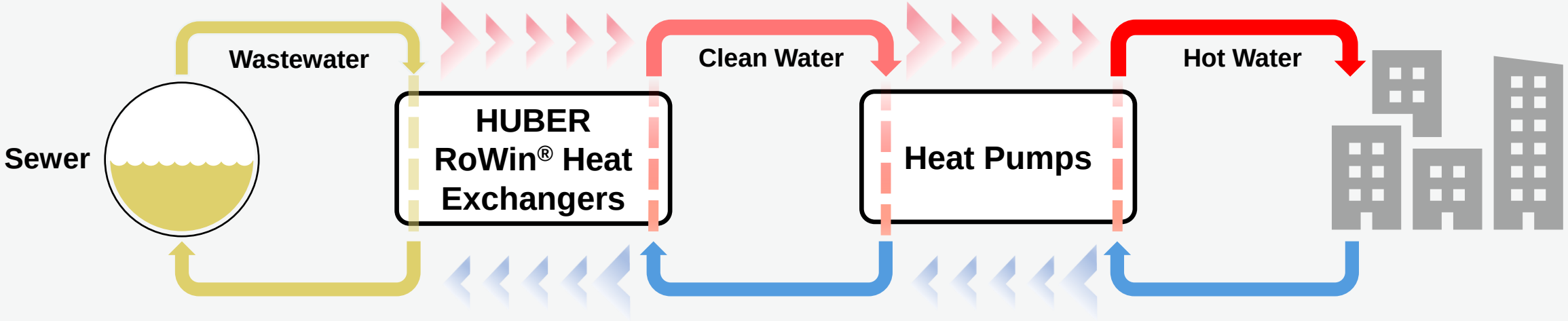
TRANE

Industry choices offer options & trade-offs; New options evolving

WET™ System Operations (Heating Mode)

Thermal energy extracted from **wastewater**

Heat pumps increase **temperature** to desired set point



Noventa™
INNOVATING TO DECARBONIZE OUR FUTURE™

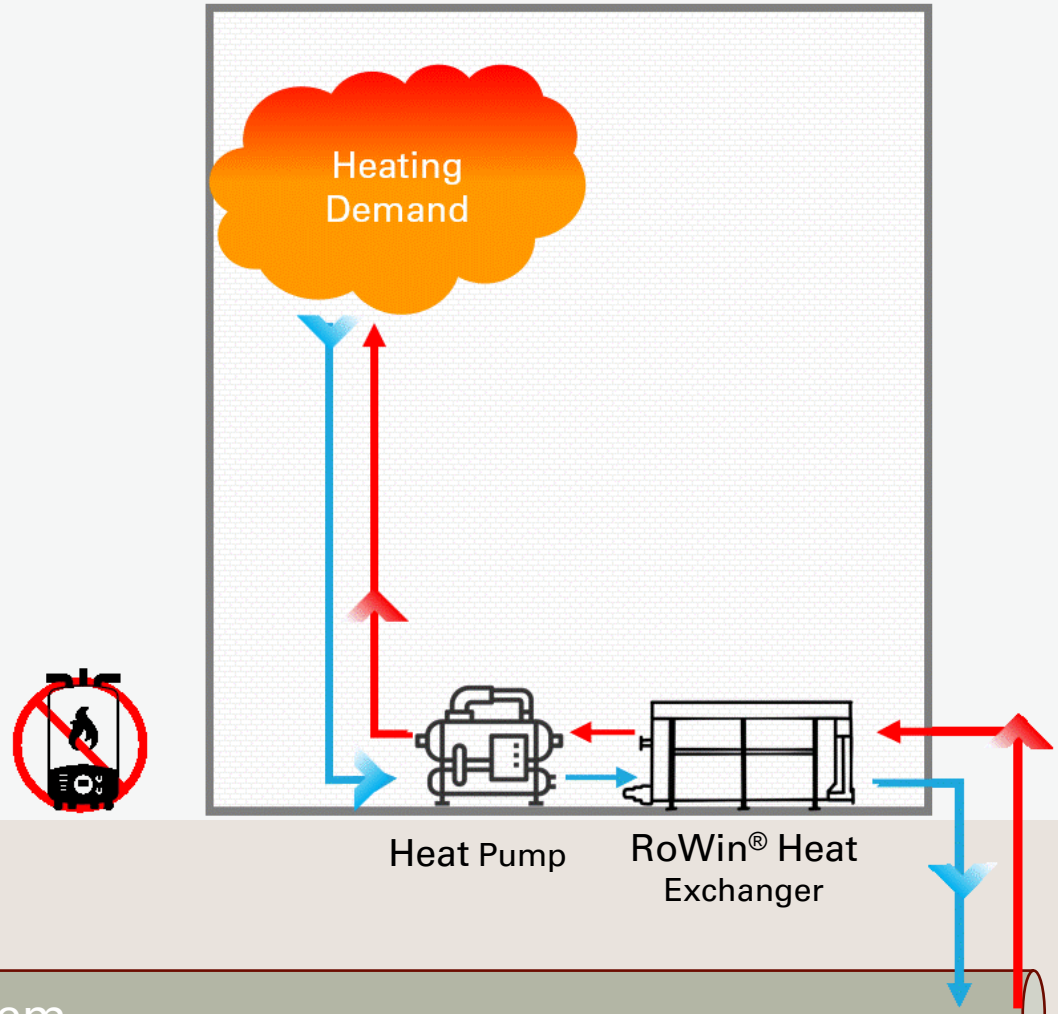
Noventa WET™ System - Heating

Carbon Free Heating Solution

Heat is extracted from **wastewater** via the HUBER ThermWin® system to heat the building.

Significant reduction in **natural gas consumption from decreased** or eliminated boiler plant use.

Overall ***COP of 4.5 (or higher)*** as a result of less natural gas usage



Toronto Western Hospital (TWH)

Toronto, Canada

- Major hospital - 1,500,000 sq.ft.
- Over 120,000 MBH of boiler capacity
- Over 6,800 tons of chiller capacity

- Integrate low-temperature hot water loop while maintaining existing steam infrastructure
- Provide **>90%** of annual space heating and cooling demand
- Over **10MW** of heating and **9MW** of cooling from wastewater

- Approximately $685,000/year in energy savings
- Over 8,400 tonnes/year GHG reduction
- Over 11.8 million gallons of water saved per year

TRANE®

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647.991.9570
Lukas.Glaspell@trane.com

TRANE TECHNOLOGIES™

Thermafit™ Heater/Heat Recovery

Model MWC and MWT (15 to 80 tons cooling, 216 to 1140 MBh)

The perfect package

R410A

FEATURES

Heat recovery reduces overall facility heating. Simply recover heat from the chiller, rather than reject it during the normal cooling process.

- **Easy expandability**
- **Extreme flexibility**
- **Simplified service**
- **Small footprint**
- **Precise temperature control**
- **Options:** VSD, Free Cooling, Low sound, Pump/Tank package

Operating Limitations	
Chilled Water	38 to 65F
Hot Water	60 to 165F
R410A, 42 F minimum LWT and 140 F maximum LWT	
R134a, ~ 70 F minimum LWT to get 175 F maximum LWT; at 42 F LWT, maximum 160 F LWT	

Series R® Heater/Heat Recovery

Model RTWD (80 to 250 tons)

FEATURES

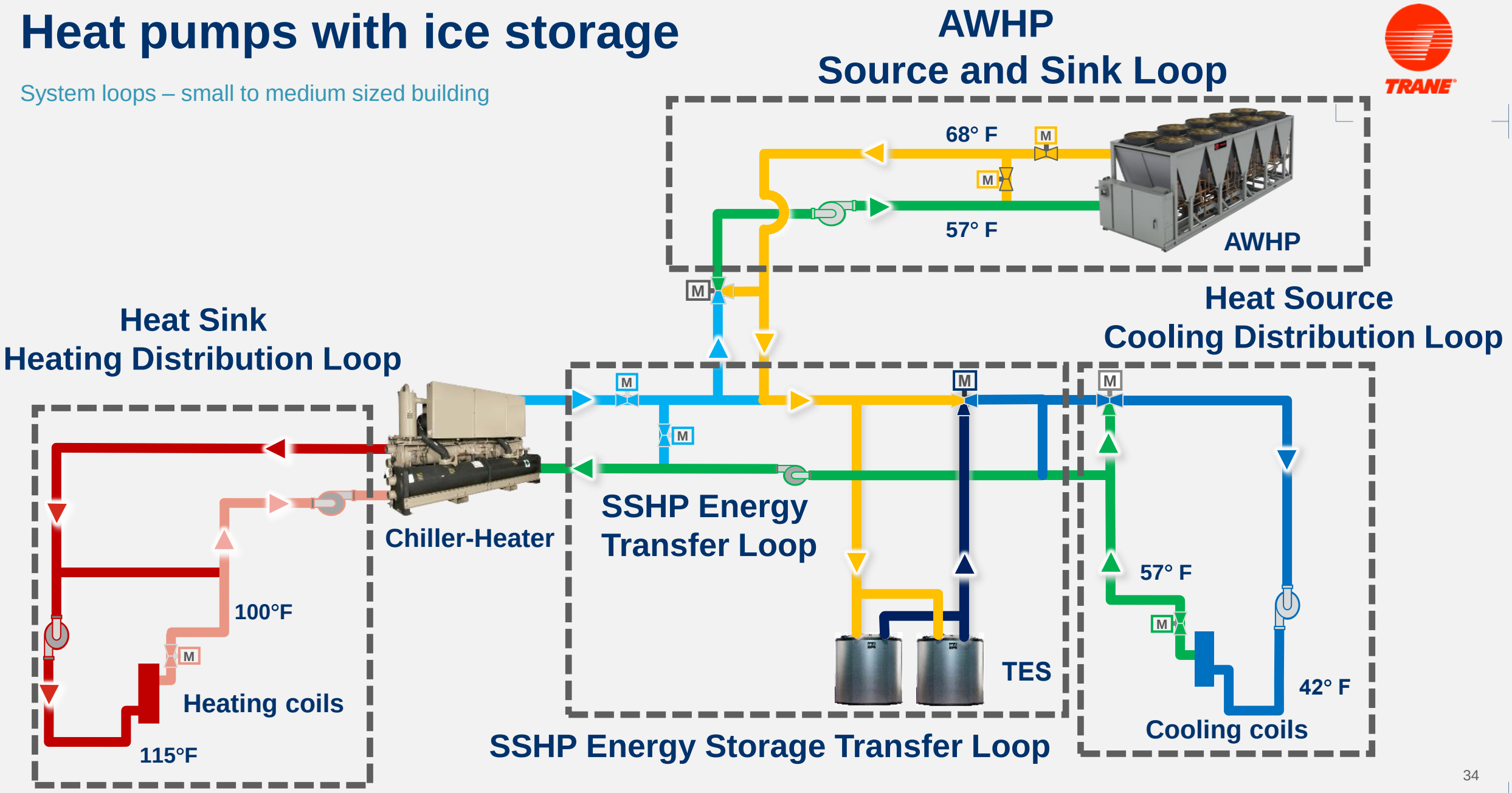
Heat recovery offers an extremely energy efficient solution and a first step to electrifying heating.

- **Reliability**
- **High Lift Versatility**
- **Precision Temperature Control**
- **Options:** sound-reduction package

Operating Limitations	
Chilled Water	10F (-12C) to 65F
Hot Water	60 to 167F (75C)
Max lift 100F	

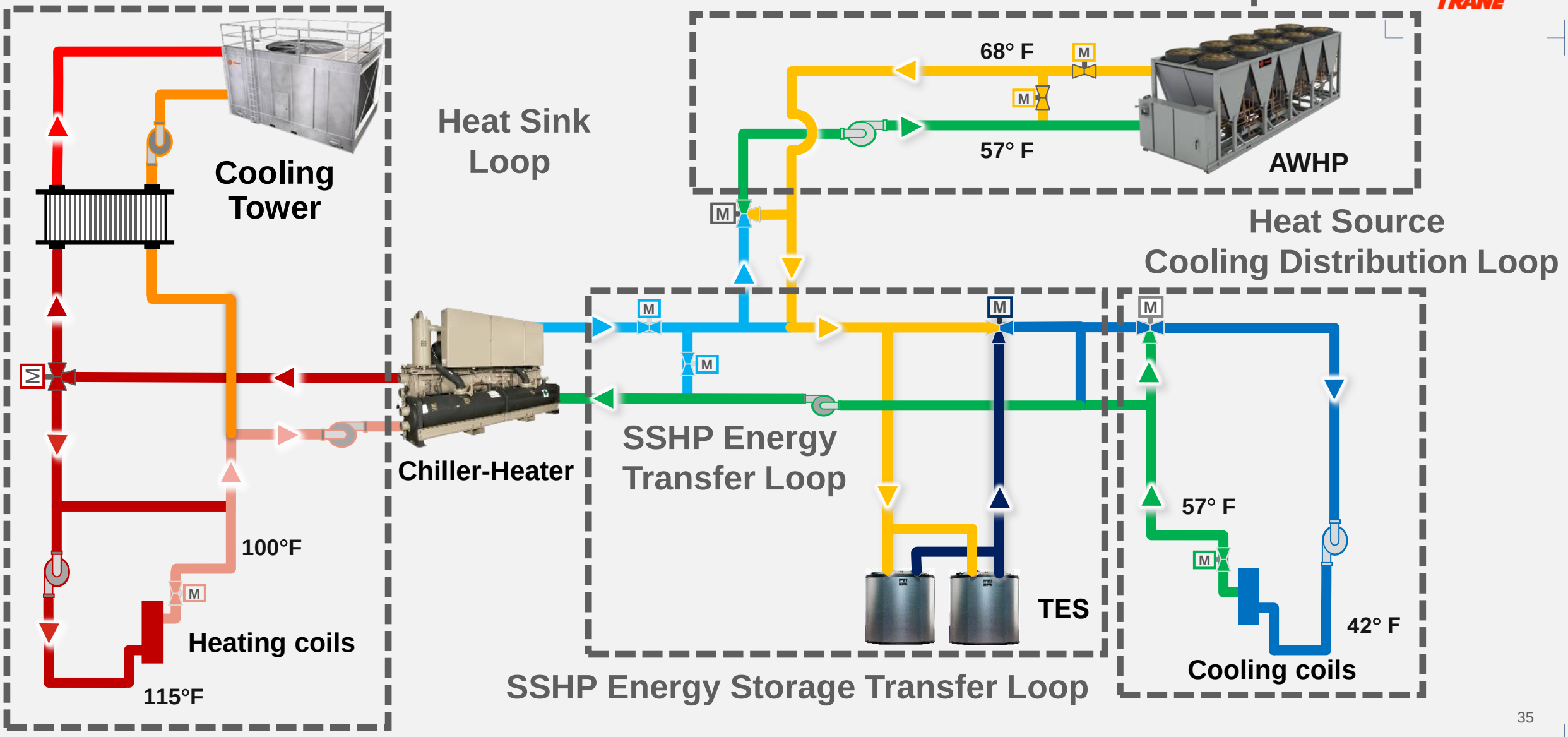
Heat pumps with ice storage

System loops – small to medium sized building



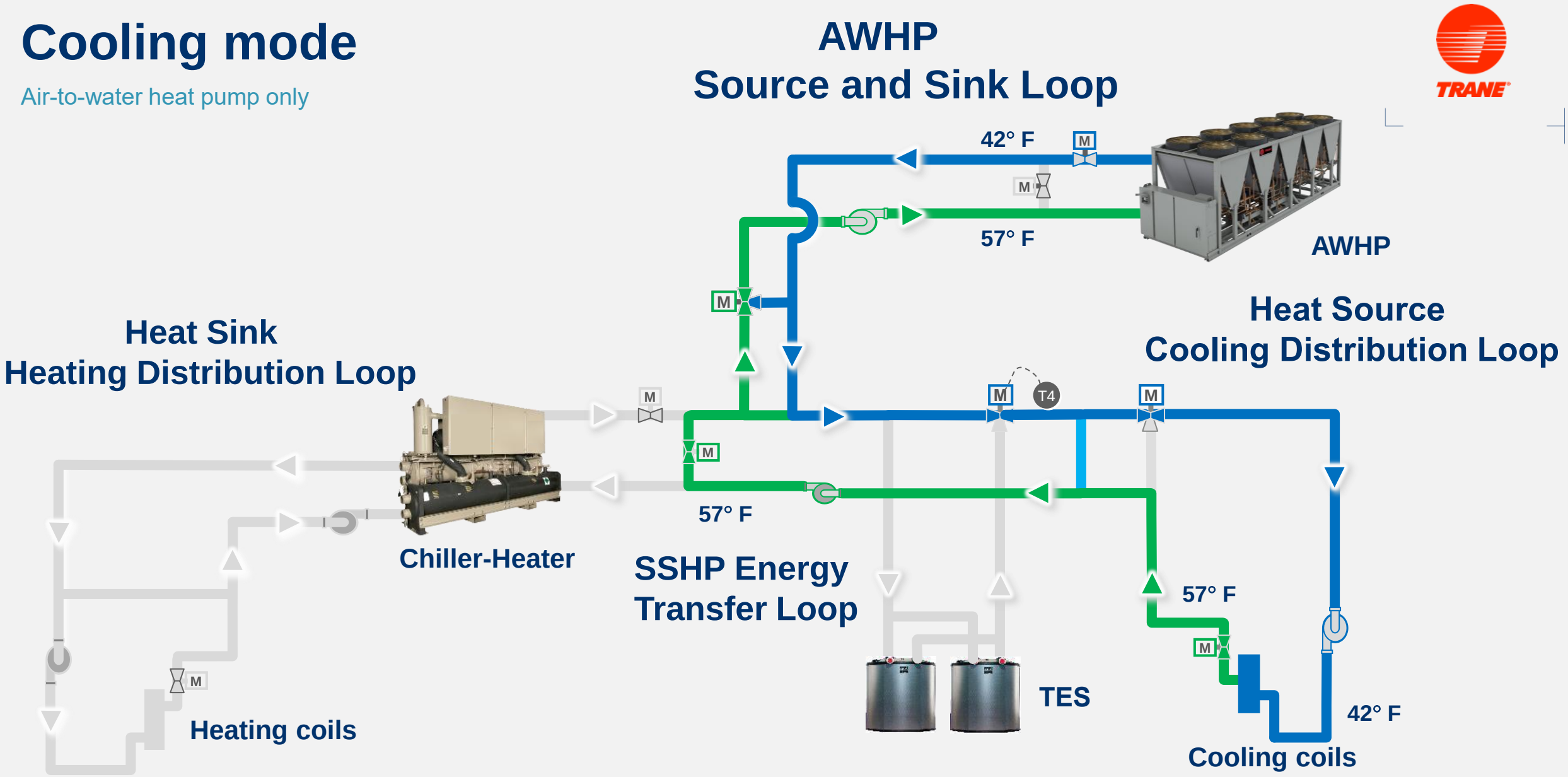
Heat pumps with ice storage

System loops – large building



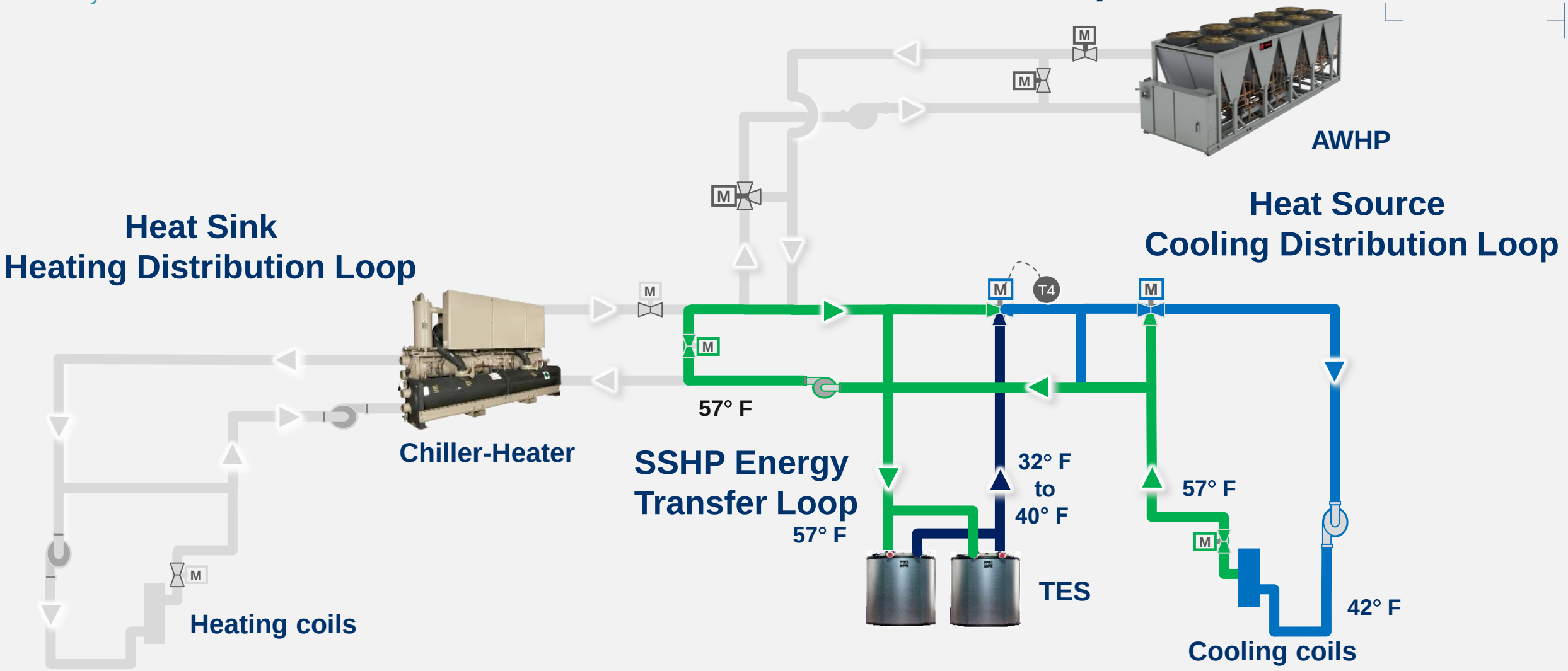
Cooling mode

Air-to-water heat pump only



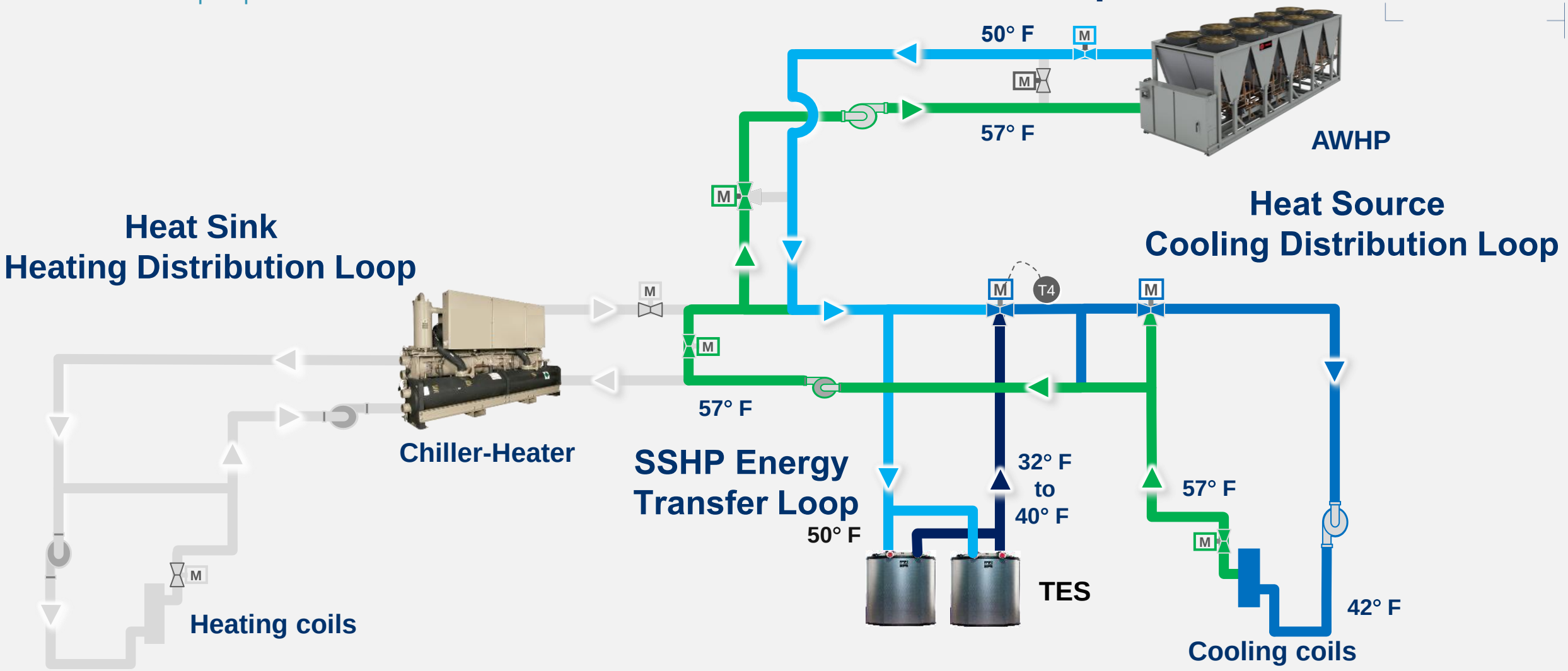
Cooling mode

Ice only



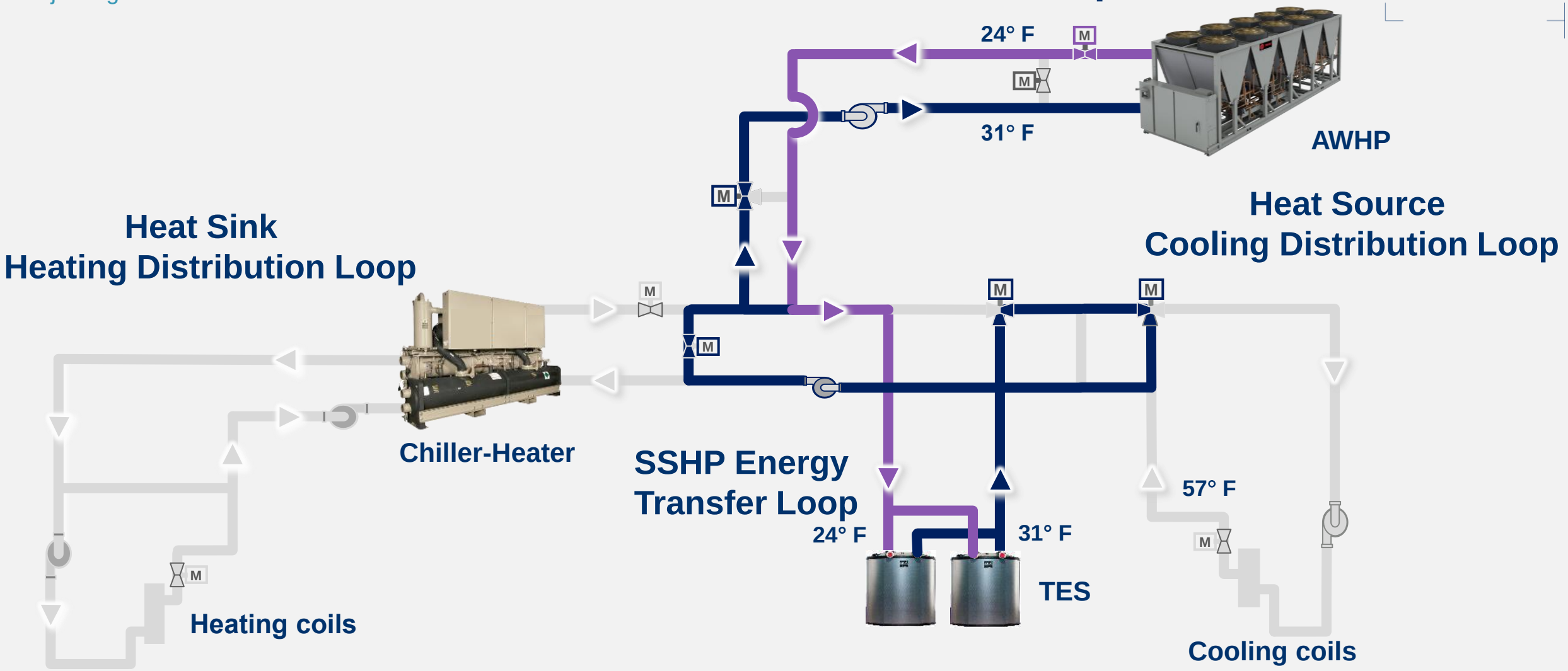
Cooling mode

air-to-water heat pump and ice



Summer ice making at night

Rejecting heat to ambient

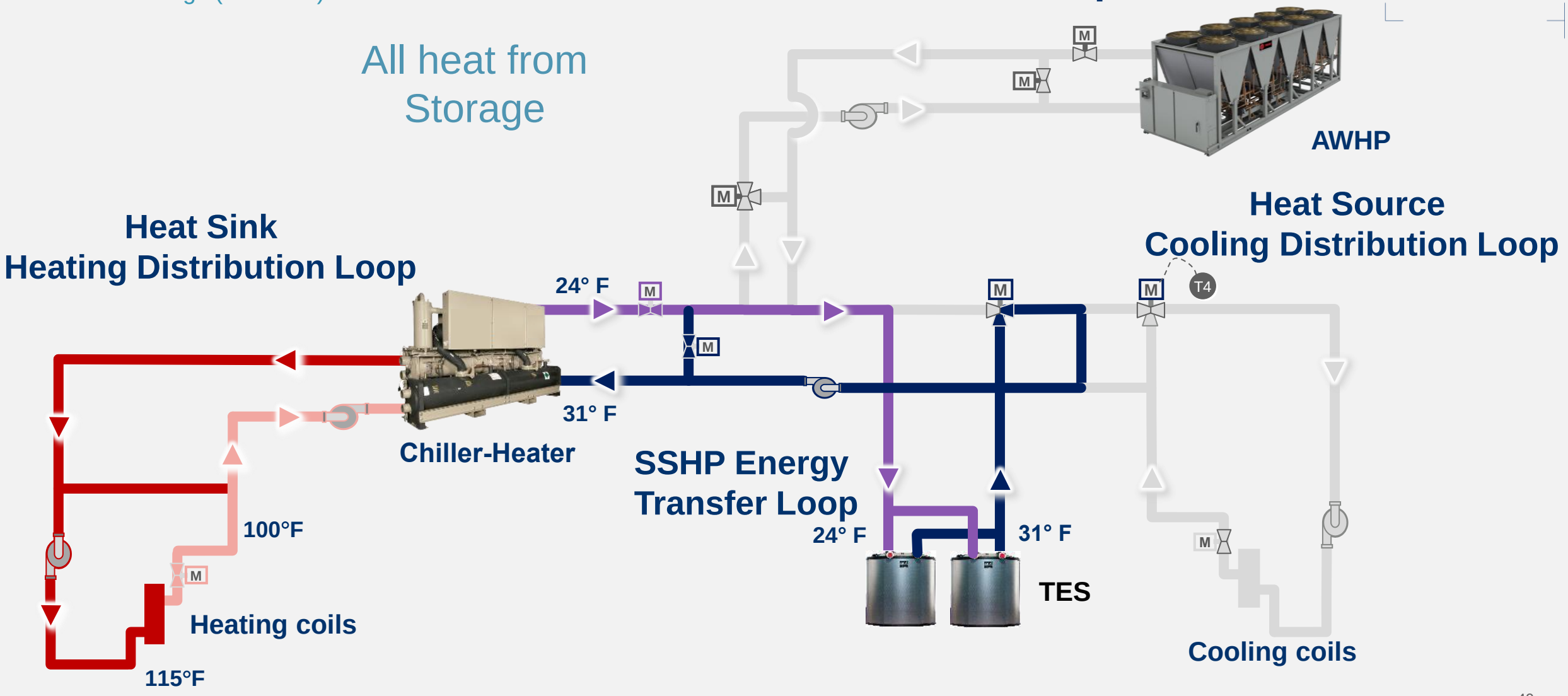


Heating mode

Heat from storage (water/ice)

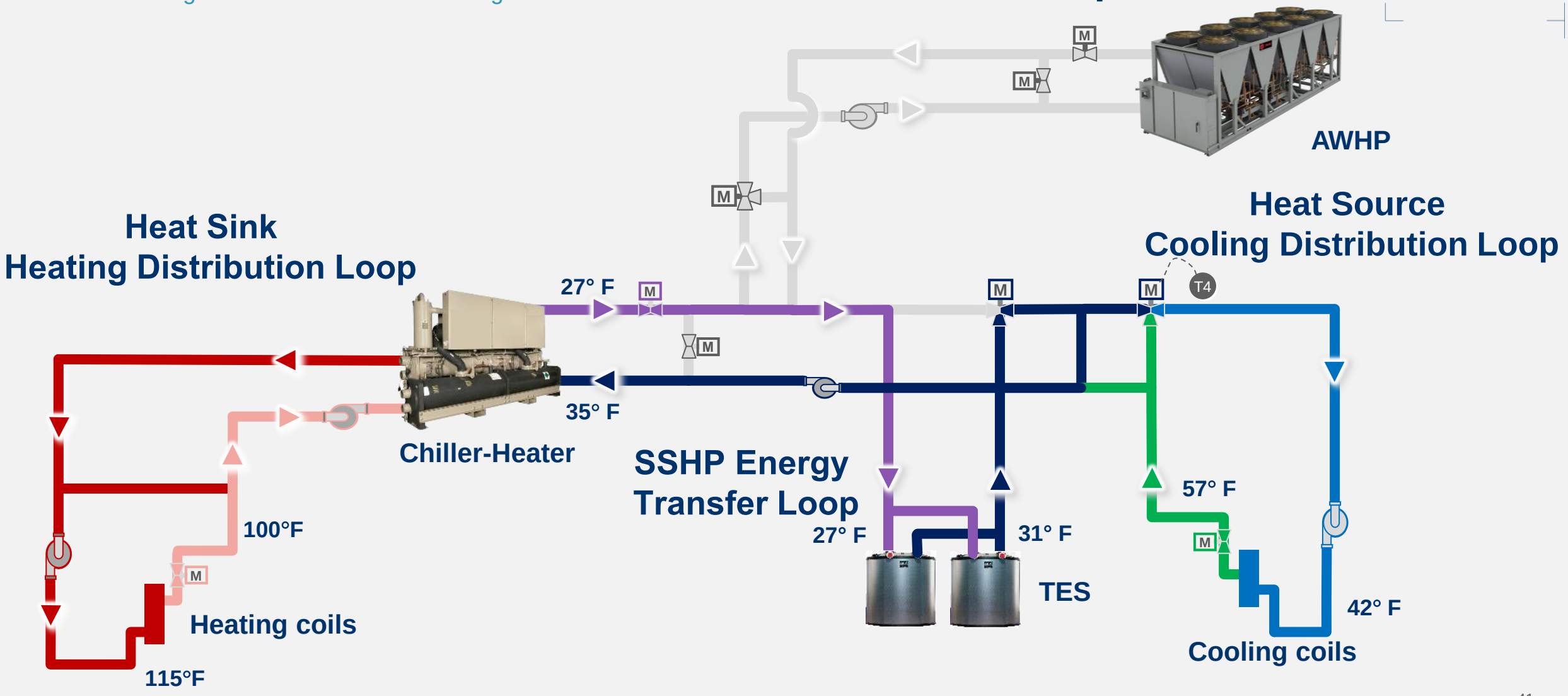
AWHP
Source and Sink Loop

All heat from Storage



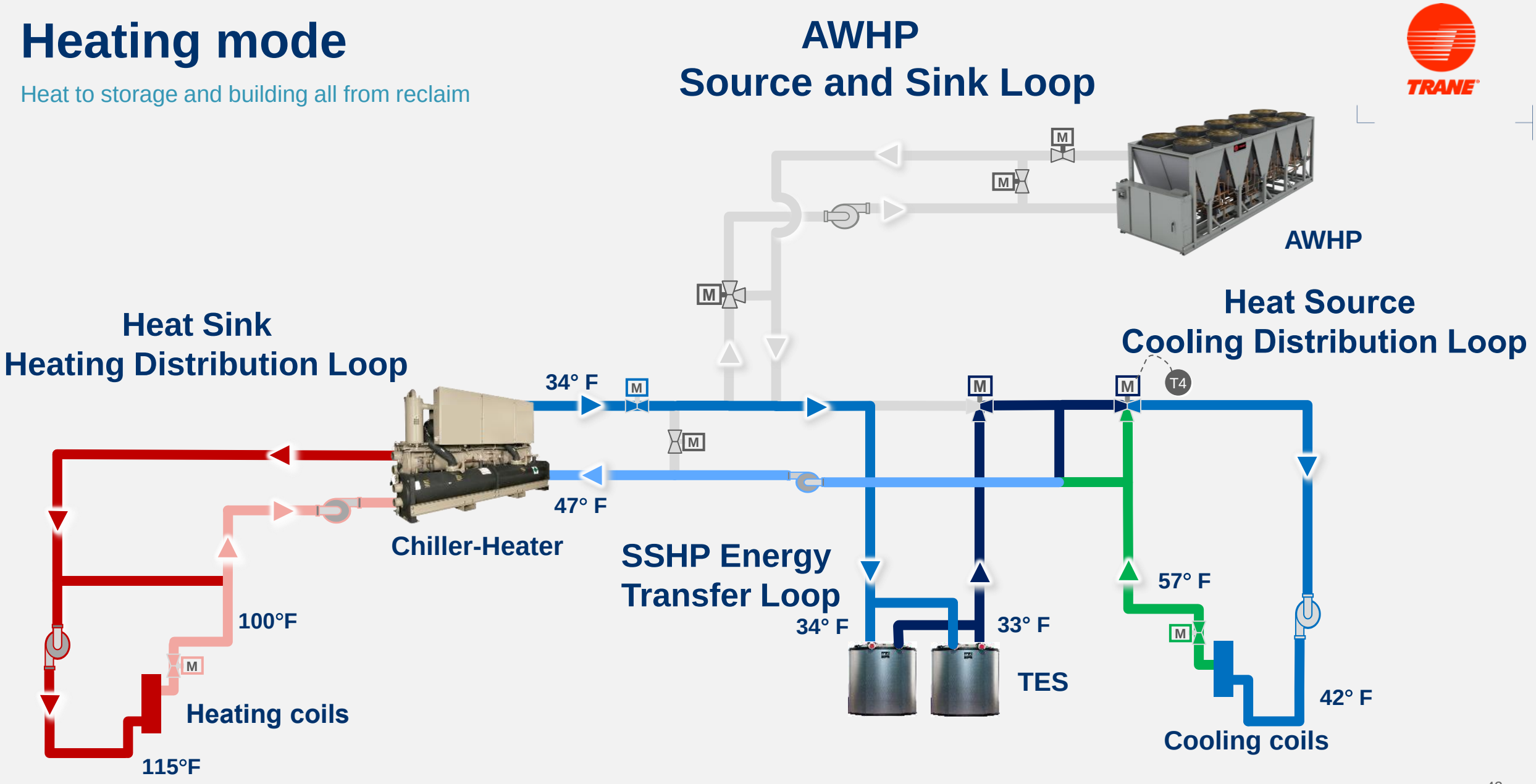
Heating mode

Heat from storage and reclaimed from building



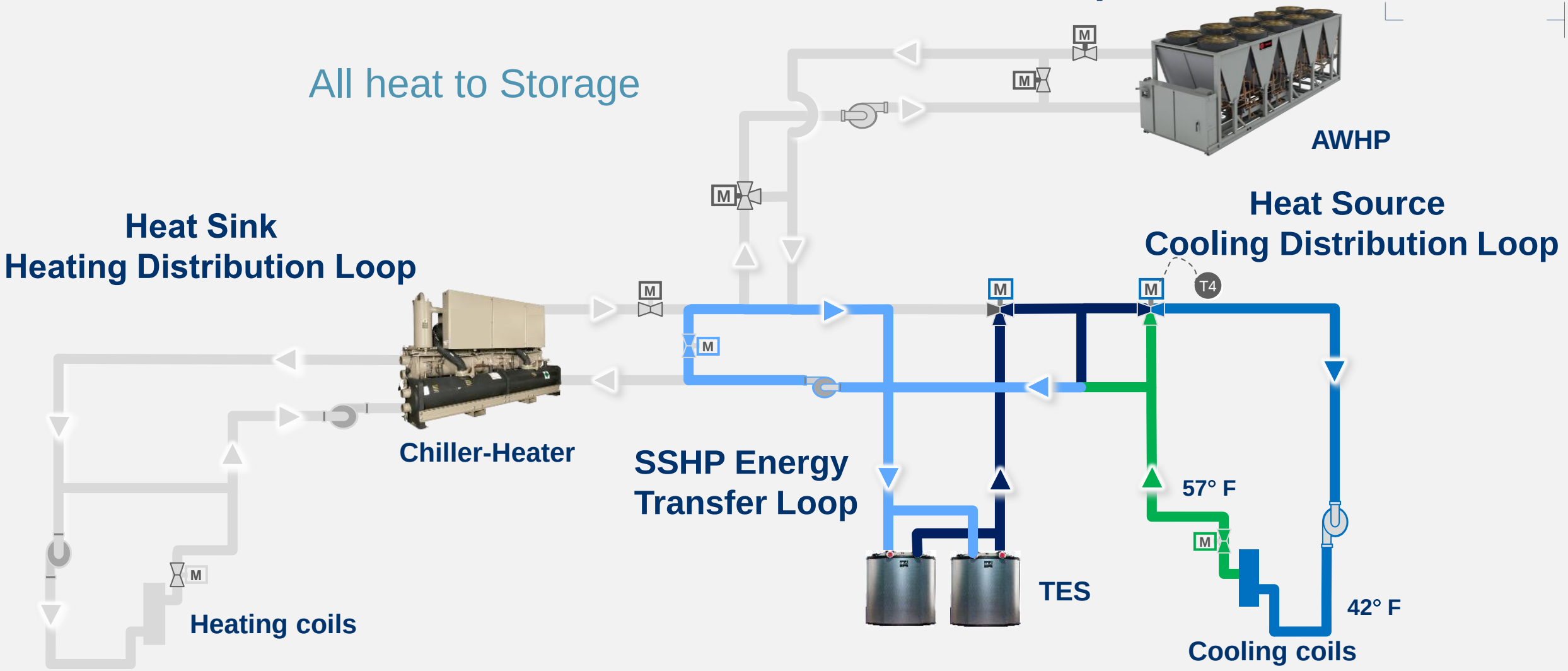
Heating mode

Heat to storage and building all from reclaim



“Free Cooling” with storage

Melt ice to store reclaimed heat



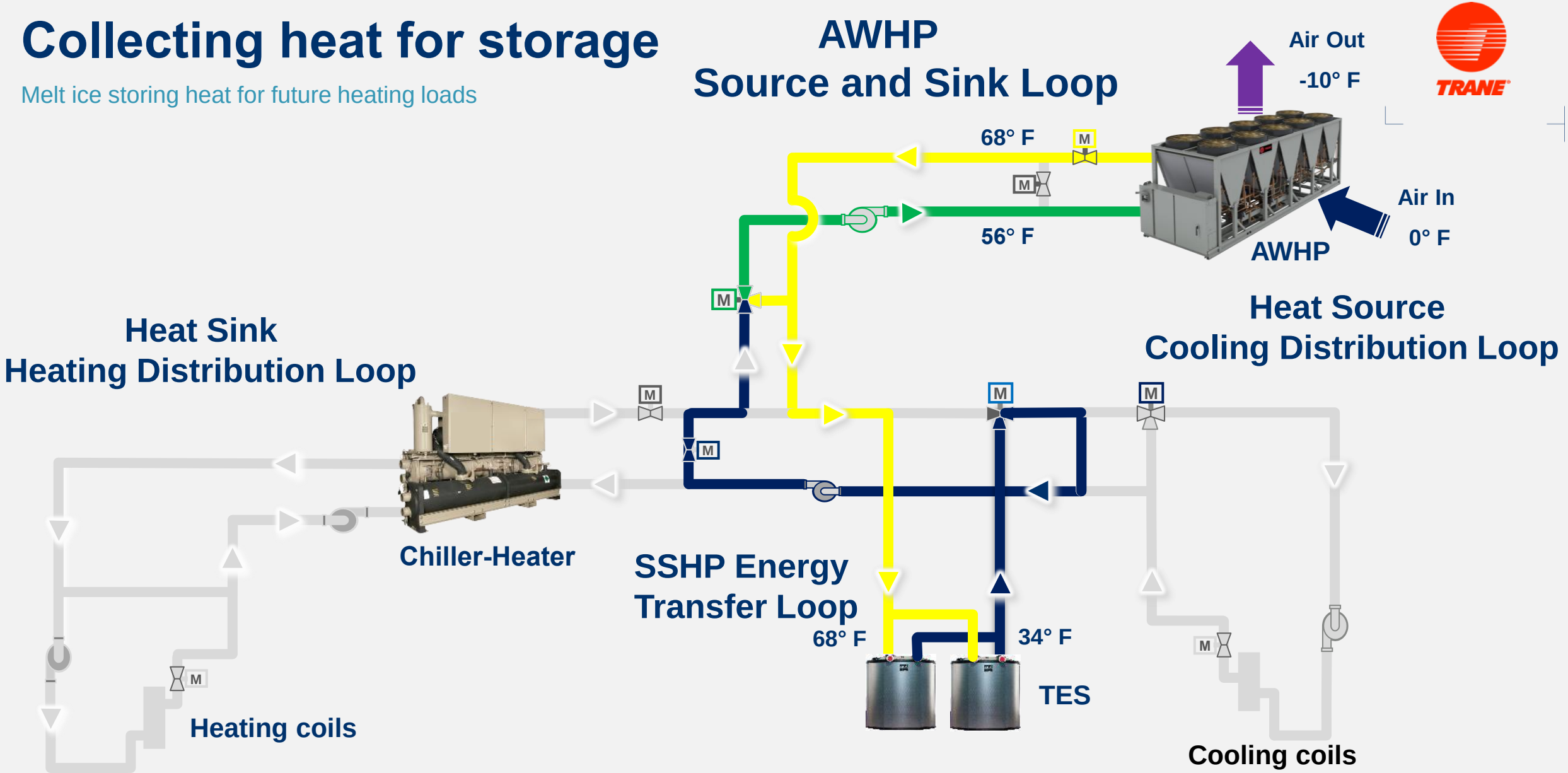
What if there is not enough reclaimable heat?

If the 24-hour design day heat load is more than the reclaimed heat, heat must be added to the system.

- Electric resistance will work but energy costs are high.
- Air-to-Water Heat Pumps have lower energy costs than electric resistance but more expensive upfront costs.

Collecting heat for storage

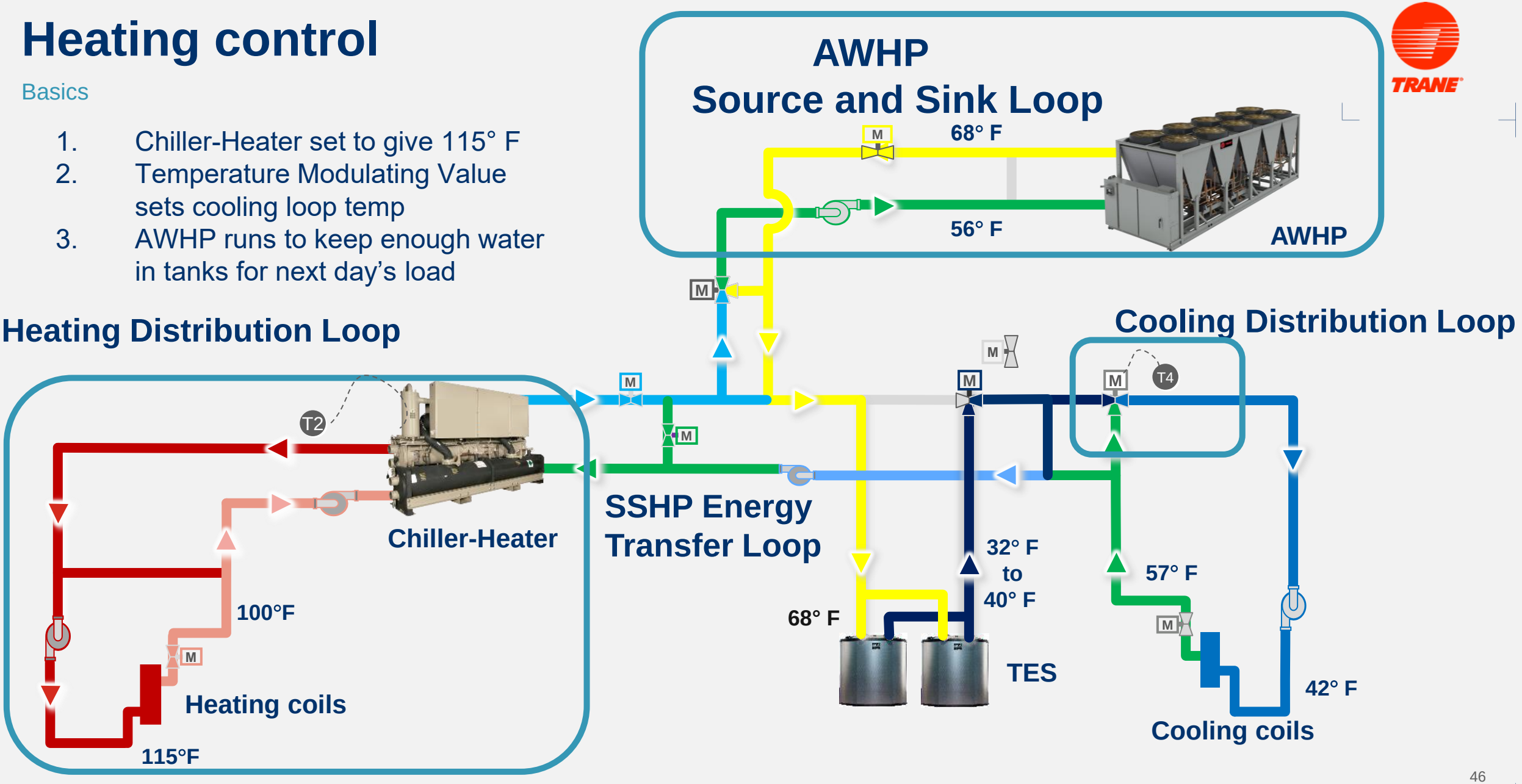
Melt ice storing heat for future heating loads



Heating control

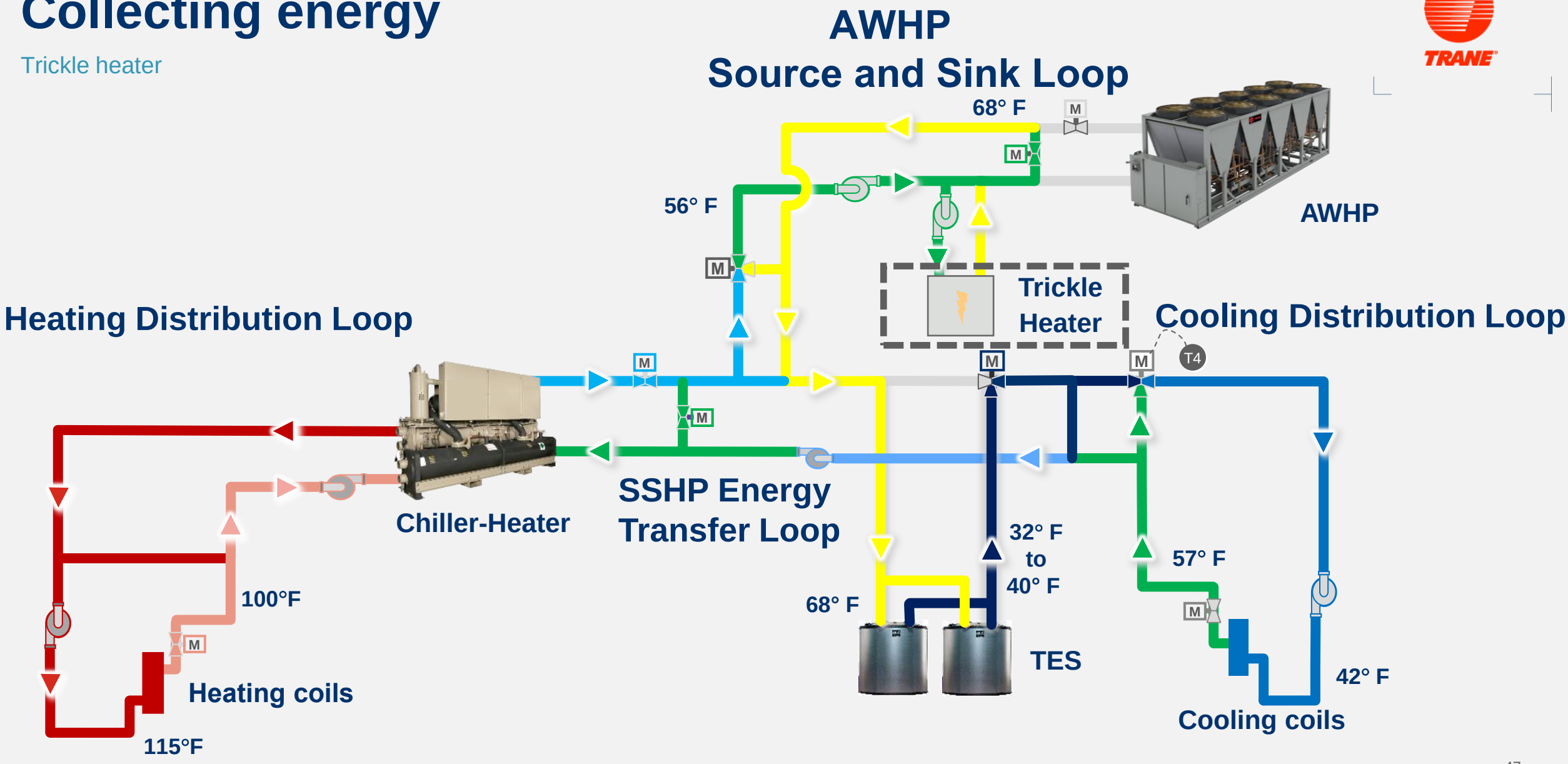
Basics

1. Chiller-Heater set to give 115° F
2. Temperature Modulating Value sets cooling loop temp
3. AWHP runs to keep enough water in tanks for next day's load



Collecting energy

Trickle heater



SSHP System* addresses these challenges, and more!

1. *Thermal Balancing*
2. *Space for heat pumps outdoors*
3. *Efficient use of heat pumps in colder climate*
4. *Peak electrical demand and energy cost reductions*
5. *Affordable, reliable solution for electrification*

Sustainability

- Enables elimination of fossil fuels for heating to reduce carbon
- Makes electrified heat pump heating possible in cold, dense urban environments where there is limited roof space
- Optimizes carbon emission reductions based on when renewable energy is available
- Adds Load Flexibility for Grid-Interactive Efficient Buildings (GEB)
- Avoids wasting water required to reject heat through a cooling tower

Efficiency

- Reclaims excess energy (heat) from the building, stores and uses it to heat the building at other times
- Captures other sources of thermal energy, above 32°F, to be stored for later use (domestic wastewater, exhaust air, etc.)
- Collects ambient energy when temperatures are warm and when it is beneficial to customer
- Ice making COP during heating is much better than AWHP at very cold ambient temperatures

Reliability

- Uses stored heating until more favorable conditions are available for AWHP operation such as extreme cold/defrost cycle
- Backs up AWHP with stored energy for 12-24 hours depending on system and economic parameters
- Downsizes back up heating and power sources such as electric boilers and generators
- Adds “Storage” to be used as a Grid Resource

Trane Thermal Battery™ Storage Source Heat Pump System

*Source: Electrification, HP’s and TES-ASHRAE Journal July 2020

American Geophysical Union (AGU)

Washington D.C.

Operational since May 2018

- 7-storey structure and 62,000 ft² of refurbished office space
- Certified net-zero building by the U.S. Green Building Council

- RoK4-700 fine screen pumping station inserted in a shaft beside the sewer next to building
- Sewer flow rate of 6,400 GPM
- 1 RoWin® BG 8 heat exchanger installed

- The system provides 480kW of heating & 840kW of cooling
- Coefficient of Performance (COP) > 6

Residential Apartment Complex

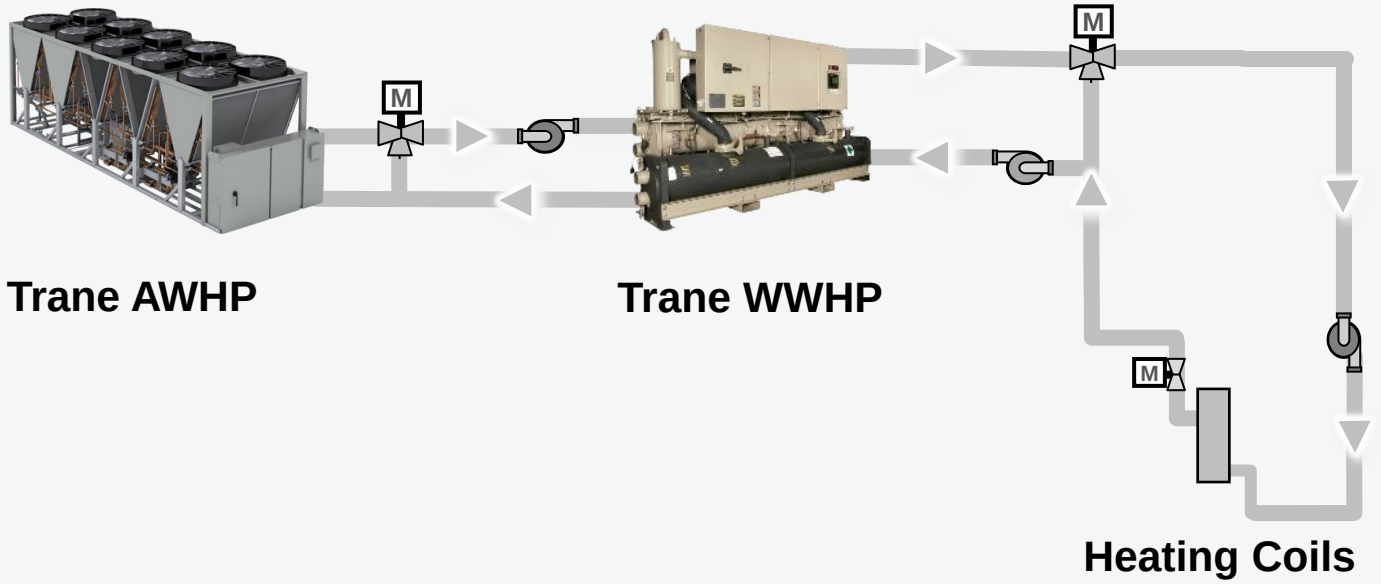
Straubing, Germany

Operational since 2010

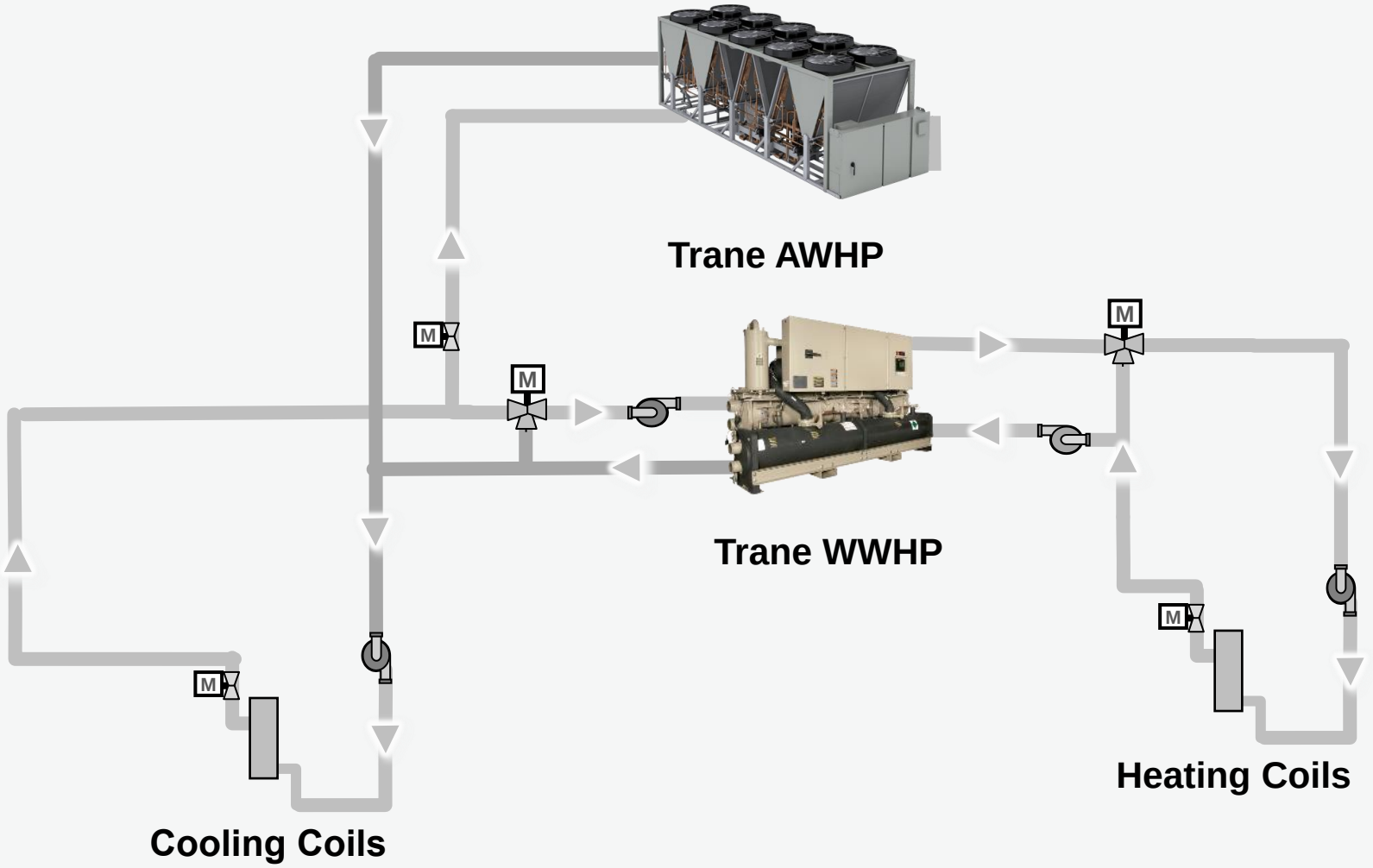
- Low-rise apartment complex, 11 buildings
- Total units: 102

- Partial flow of wastewater (20 L/s) taken from main sewer running outside apartment buildings
- 2x HUBER RoWin® Heat Exchanger extract up to 210 kW thermal energy from the wastewater

- Energy savings of ~386,000 kWh/year
- Heat output of approx. 260 kW with heat pump
- Coefficient of Performance (COP) > 6



*Buffer tanks on the intermediate and hot water loops minimize unit cycling



*Buffer tanks on the intermediate and hot water loops minimize unit cycling