Electrification Trends and the Latest in Heat Pump Technology

Introduction:
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a member of DAIKIN group

MULTISTACK
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Building Decarbonization: What's Next and What Can Engineers Do

From ASHRAE Journal Newsletter, Oct. 26, 2021

Electrification Solutions-Equipment and Incentives

Maximizing Heat Recovery - DON'T throw Energy away
- Get creative, heat sources surround us!
- <u>Look at COPs-heating with lower temperatures</u>

Geothermal
- The largest and greatest energy storage
- We are blessed, and it is the best

Magnetic Bearing Chillers
- Sustainable performance over time
- No oil allows more creative designs

Air/Water Heat Pump Advances
- Simultaneous heating and cooling capabilities
- No geo loop or tower

Inflation Reduction Act- An Overview

- IRA is the largest climate change legislation ever enacted and provides for $369B in tax incentives and grant and loan programs.
- Permits long-term planning with a 10-year timeframe (in contrast to the prior one-to-three-year extensions).
- Expands and increases existing renewable energy tax credits.
- Adds new tax credits for US companies that invest in zero-emissions technologies.
- Credits available to non-profits and governmental units categories that include more than half the nations' hospitals.
- Contains special provisions to benefit low income and energy impacted communities.

Tax Deduction for Energy Efficient Commercial Building Property – IRC Section 179D

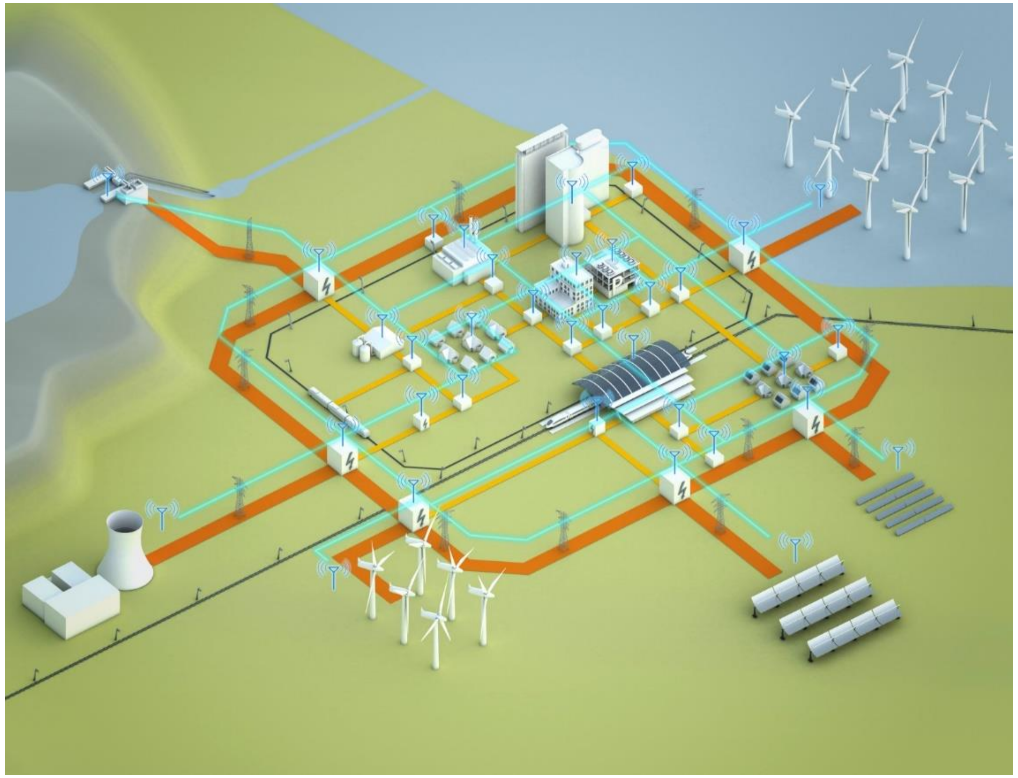
- IRA expanded and increased the deduction for 100% of the cost (subject to a cap) of energy efficient commercial building property (EEP).
  - EEP includes qualifying interior lighting systems, heating, cooling, ventilation, and hot-water systems and the building envelope included in a new energy efficient commercial building or installed in an existing qualified building pursuant to a qualified building retrofit plan.
  - Energy usage needs to be reduced by 25% (previously 50%).
  - The maximum cap is $5.00 per square footage of the building (subject to requirements), if energy usage is reduced 50% (previously $1.88 per square foot).
  - The deduction cap applies on a 3-year basis, rather than forever (i.e., future improvements can be made).
  - Non-profit hospitals and governmental can allocate the deduction to the person who is the primary designer of the EEP.

BENEFITS

- 30% tax credit or direct payment
- 10% bonus tax credit for domestic content
- Up to $5 per square foot tax deduction for energy efficiency improvements (179D)
- Accelerated depreciation benefits

ELIGIBILITY

- Project located in the United States
- Construction begins before January 1, 2035

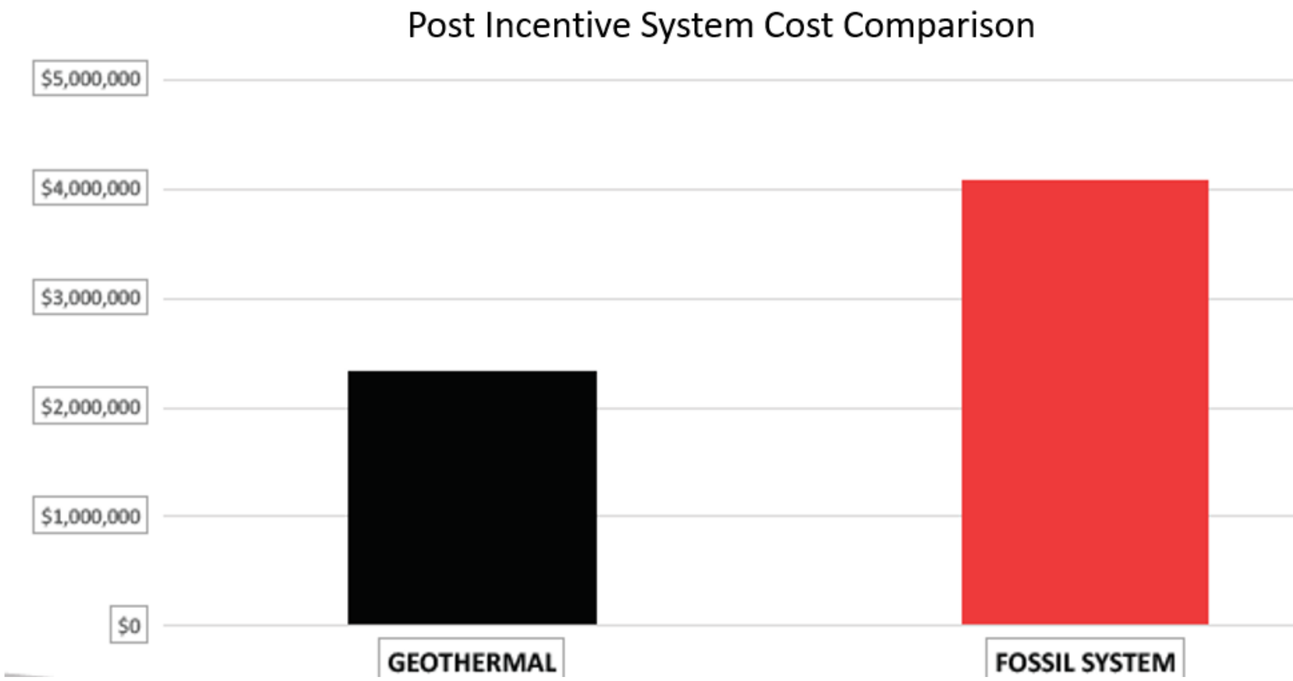


HOW TO CLAIM

Work with your tax professional to capture specific project incentives.

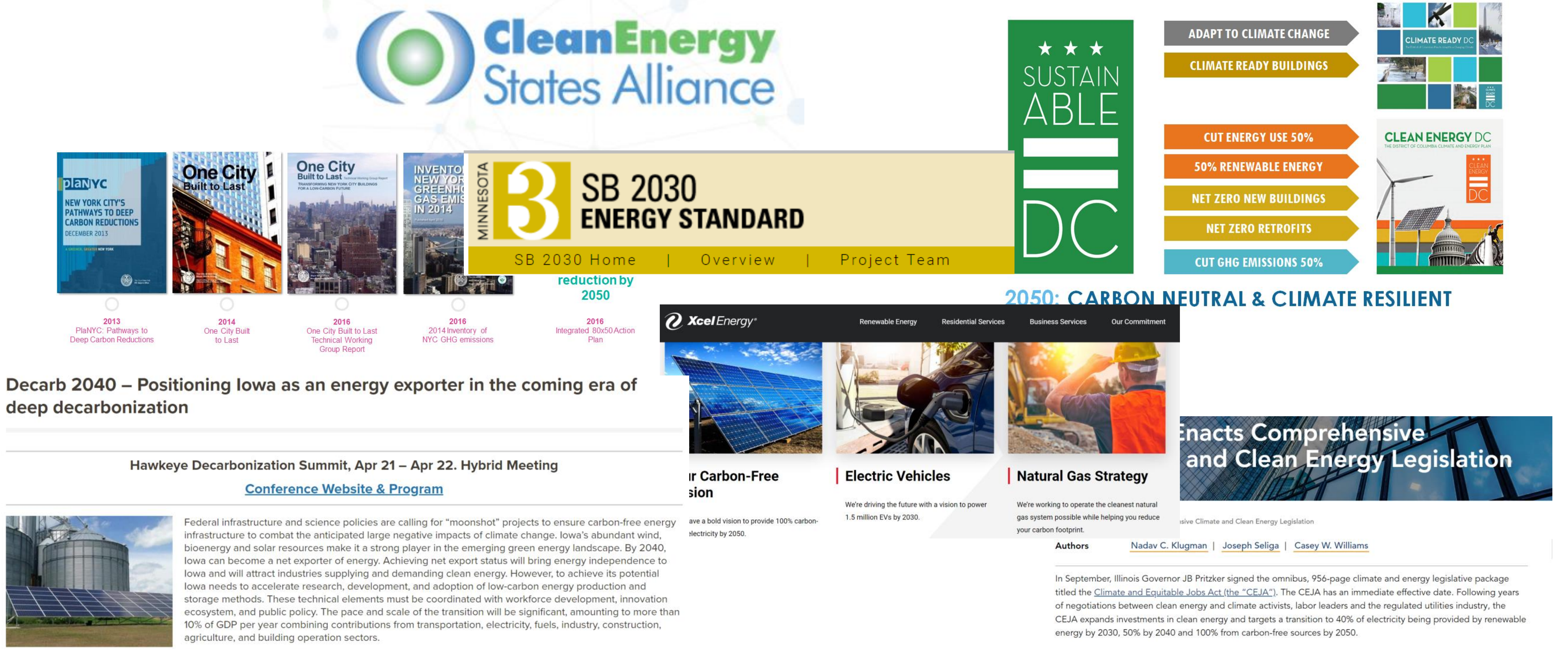
- IRS Form 3468: Claim the Investment Tax Credit
- IRS Form 4562: Claim 5-year accelerated and one- time bonus depreciation
- IRS Form 7205: Deduction for energy efficient commercial building

	GEOTHERMAL	FOSSIL SYSTEM
HVAC Project Cost	$6,400,000	$4,500,000
Geothermal Equipment	$1,600,000	
Distribution Equipment	$4,800,000	
Depreciable Basis	$5,120,000	$4,500,000
Square Feet	215,300	215,300
EUI Improvement	28%	10%
Geothermal Energization	100%	0%
Year Placed in Service	2023	2023
	ITC Value	
Geothermal	$640,000	
Distribution Equipment	$1,920,000	
TOTAL ITC CREDIT	**$2,560,000**	**$0**
	NPV Total Depreciation	NPV Total Depreciation
Depreciation Value	$4,926,798	$1,375,917
Effective Tax Rate	31%	31%
TOTAL DEPRECIATION VALUE	**$1,519,917**	**$424,470**
Total Cost	$6,400,000	$4,500,000
Total Value	$4,079,917	$424,470
NET COST	**$2,320,083**	**$4,075,530**



Electrification Today

Wisconsin 100% Carbon Free by 2050



Decarbonization Momentum Building in the U.S. Sector

The WBA's analysis includes 10 U.S. companies and ranks their performance in the following order (from best to worst): Xcel Energy, AES, Exelon, Dominion, Vistra Energy, American Electric Power, Southern Co., Duke Energy, NextEra Energy, and Pacific Gas and Electric. Xcel leads the list because it differs from other U.S. companies is in its "commitment to a target of 100% emissions reductions by 2050, based on an external report and assessing its plans against a wide range of scenarios," WBA said.

Most Momentum is in the <u>Private Sector</u>

- IKEA (and many other European Companies)
- Public and Private Universities
- Major Manufacturers already committed to Net Zero Emission
  - Toyota
  - GM
  - EPIC (Hospital Networking-Net Zero for 10 years already)
  - Amazon Fleet and Factories
- Aggressive goals set for 2030

Geothermal-Proven Efficiency EPIC-Verona, Wisconsin

- ~25,000 tons of Electric Chillers
  - Magnetic Bearing Chillers - Data Centers
  - Centralized Geo
  - "Old Style" Reversing Valve HPs
  - Quad Scroll-Heating and Cooling
  - Still growing!
- Wind and Solar
  - Net Zero Campus

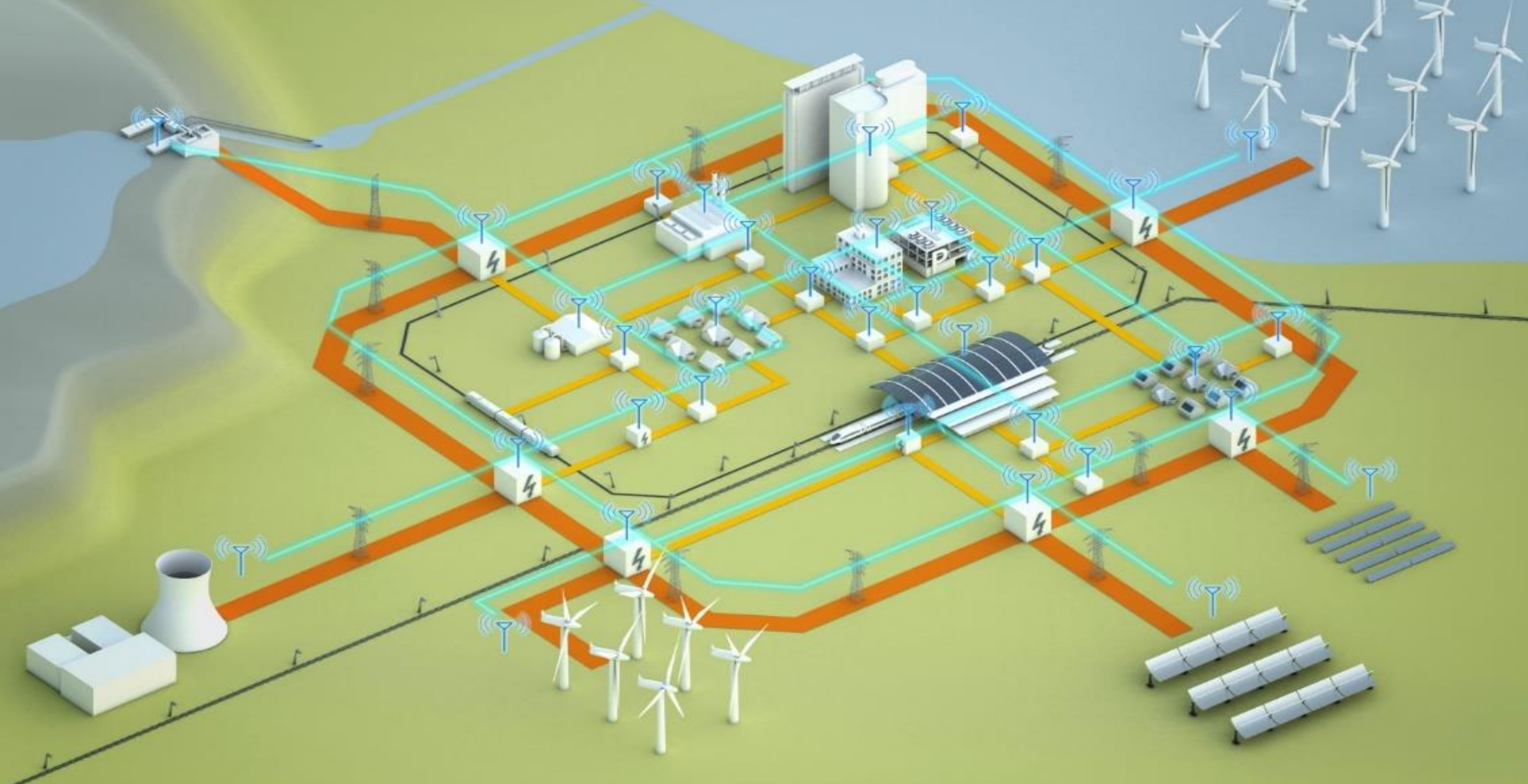
Solving the Large Building All-Electric Heating Problem

BY BRANDON GILL, P.E., MEMBER ASHRAE

The push for building HVAC electrification[1] (i.e., eliminating on-site fossil fuel consumption) poses new challenges for heating large buildings and campuses in a practical and efficient way. Common small- and medium-building all-electric solutions such as air-to-air heat pumps and variable refrigerant flow systems do not scale well for large building applications, and most existing large-building solutions require compromises. One novel solution, time-independent energy recovery (TIER), is an all-electric central plant design that combines thermal energy storage and energy recovery to improve on existing alternatives for large commercial and mixed-use buildings with respect to energy efficiency, cost-effectiveness, equipment spatial requirements and support of grid-interactive efficient building initiatives.

Brandon Gill, P.E., is a principal of Taylor Engineering in Alameda, Calif. He is a voting member of ASHRAE TCs 1.4 and 8.2 and was one of the principal researchers for ASHRAE RP-1711.

Electrification



Creativity can take many forms
Employing new and current technologies

Maximizing Heat Recovery - DON'T throw anything away

- Get creative, heat sources surround us!
- Look at COPs-heating with lower temperatures

Magnetic Bearing HR Chillers-New Chiller Tech

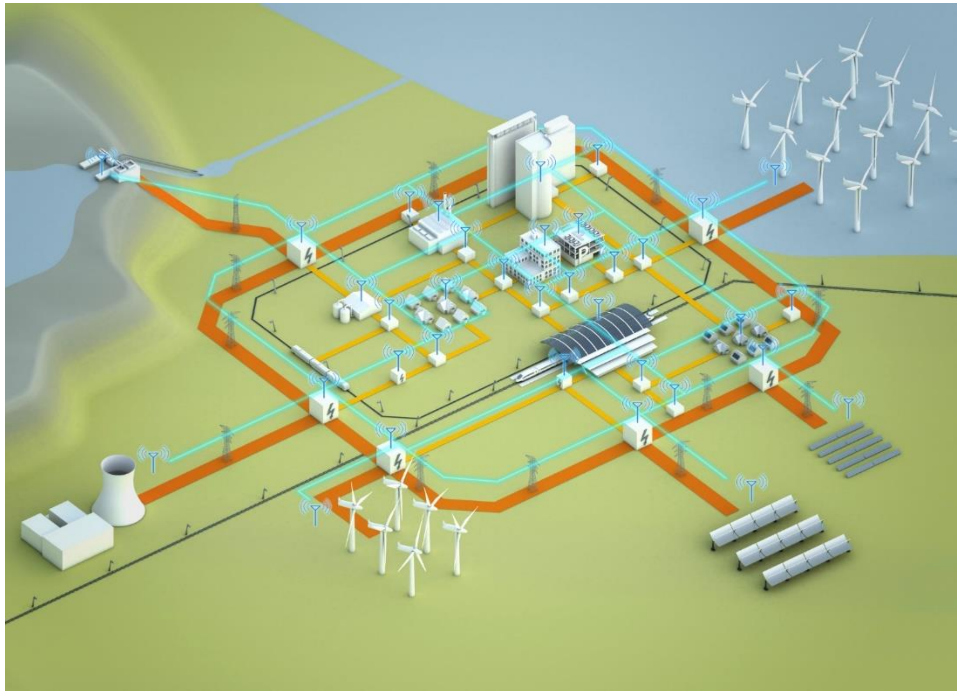
- Sustainable performance over time
- No oil allows more creative designs

Geothermal

- The largest and greatest energy storage
- We are blessed

Air-to-Water Heat Pump Advances

- Simultaneous heating and cooling capabilities
- No geo loop or tower



All-Electric, Combined
Heating and Cooling HVAC Systems

Goals:

- Reduce or eliminate end user carbon emissions
- Use all ‘tools’ available to optimize efficiency and cost
- Understand limitations of equipment, develop creative solutions

Sustainability-Energy Efficiency-Cost Effective

Technologies apply concepts of *Heat Recovery*

Don't throw it away-Use it

Heat of Compression: The increase in temperature that fluid experiences when it is **compressed**

Total Heat of Rejection (THR): Heat rejected by refrigeration system compressors consisting of the design cooling capacity ***plus*** the heat of compression

In essence, Recovering Heat you have taken out of the building. It's free!

Heat Pump:

A unit that produces useful Chilled **OR** Hot-Water.

- **Air-Source [ASHP]:** Ambient Air is used as an energy source (winter) or an energy sink (summer).
- **Water-Source [WSHP]:** Water Loop used as a source/sink.

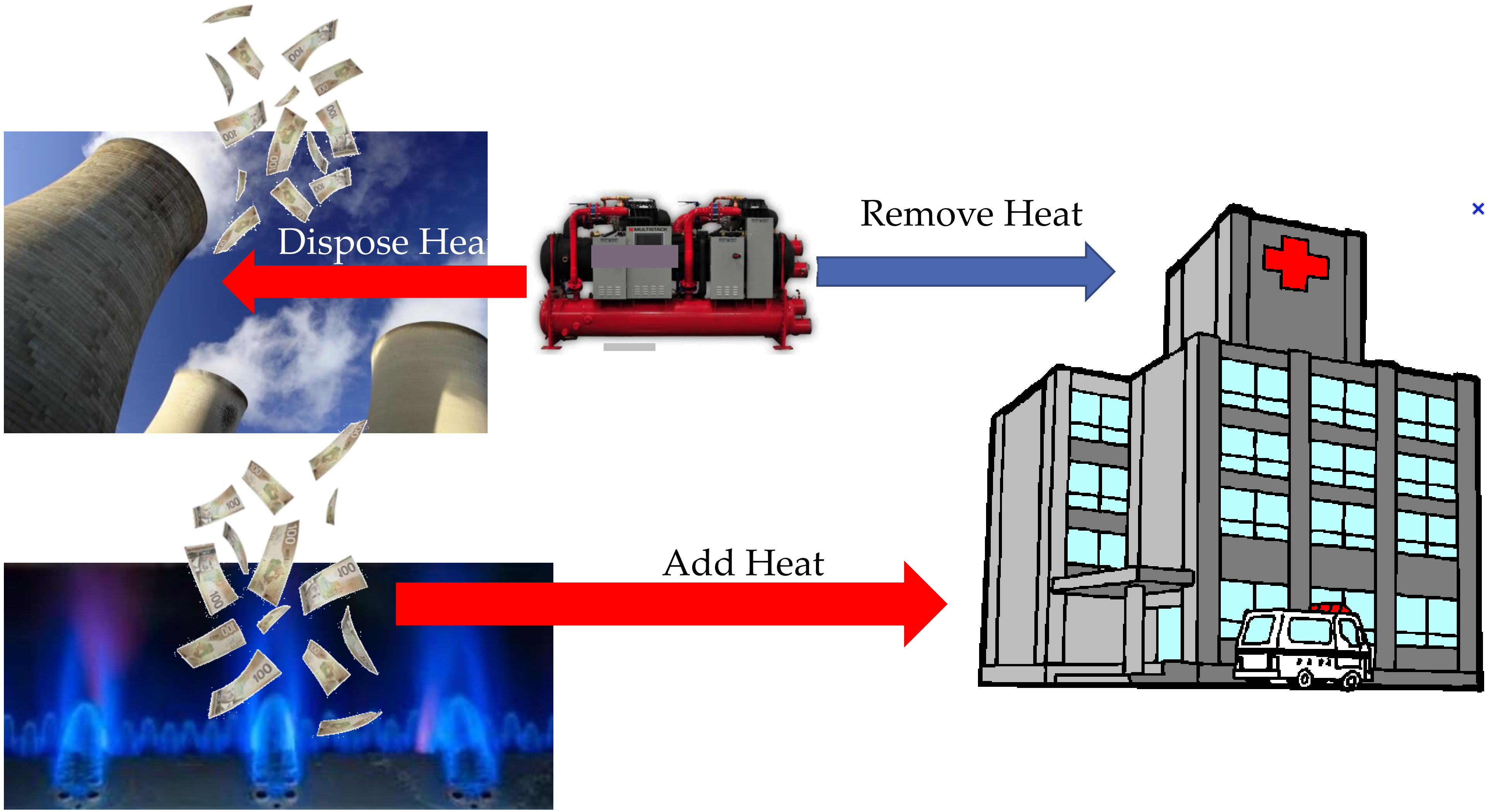
Heat Recovery:

A unit that simultaneously provides useful Chilled **AND** Hot-Water.

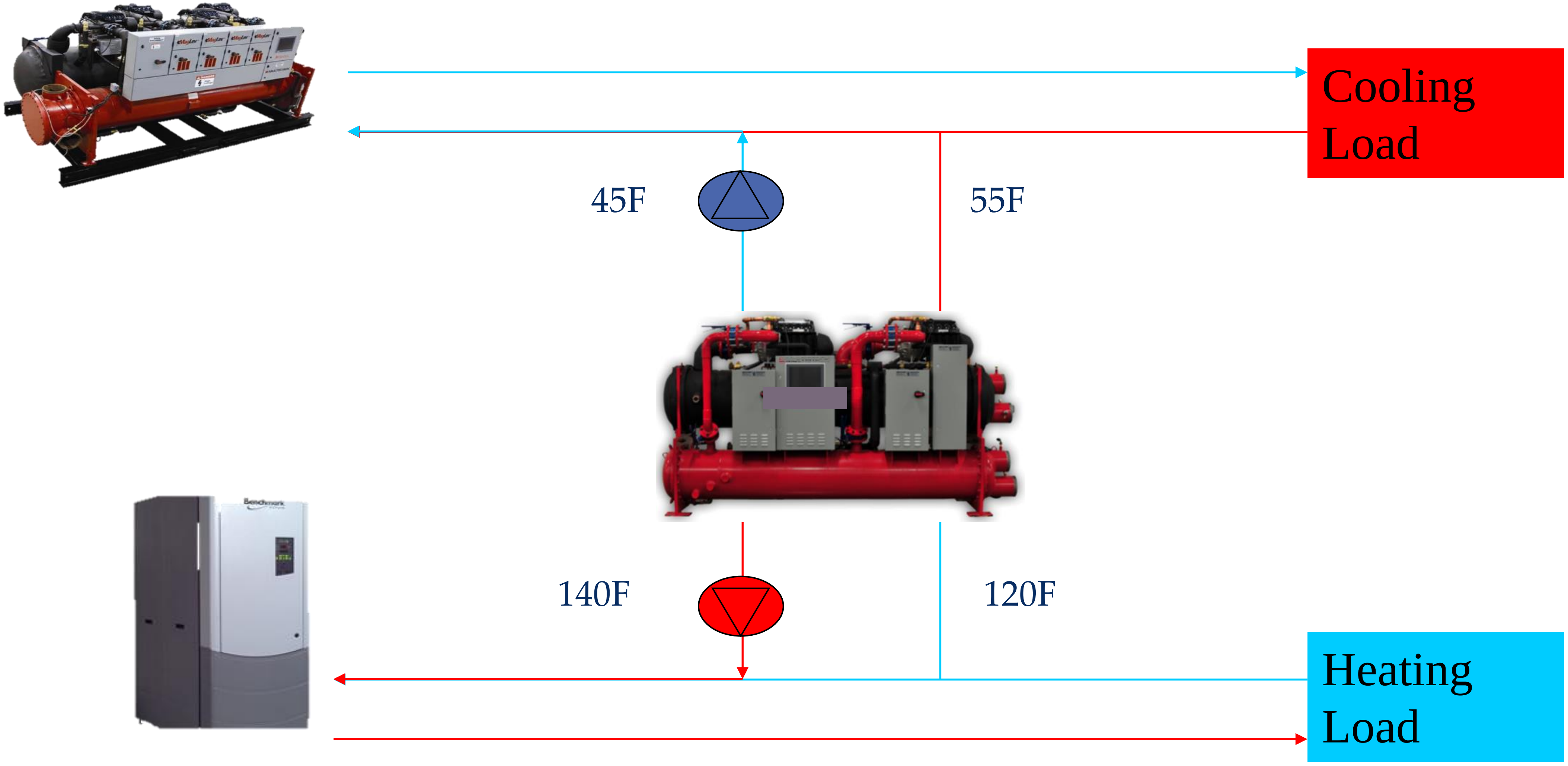
- **Dedicated Heat Recovery Chiller [DHRC]**

Heat Disposal System

Remove heat but then add heat?



DHRC



ASHRAE has recognized that hospitals in particular have a consistent simultaneous load. For this reason, new heat recovery requirements have been added to Standard 90.1 for 7% heat recovery to be utilized.

6.5.6.3 Heat Recovery for Space Conditioning

Where heating water is used for space heating, a condenser heat recovery *system* shall be installed, provided all of the following are true:

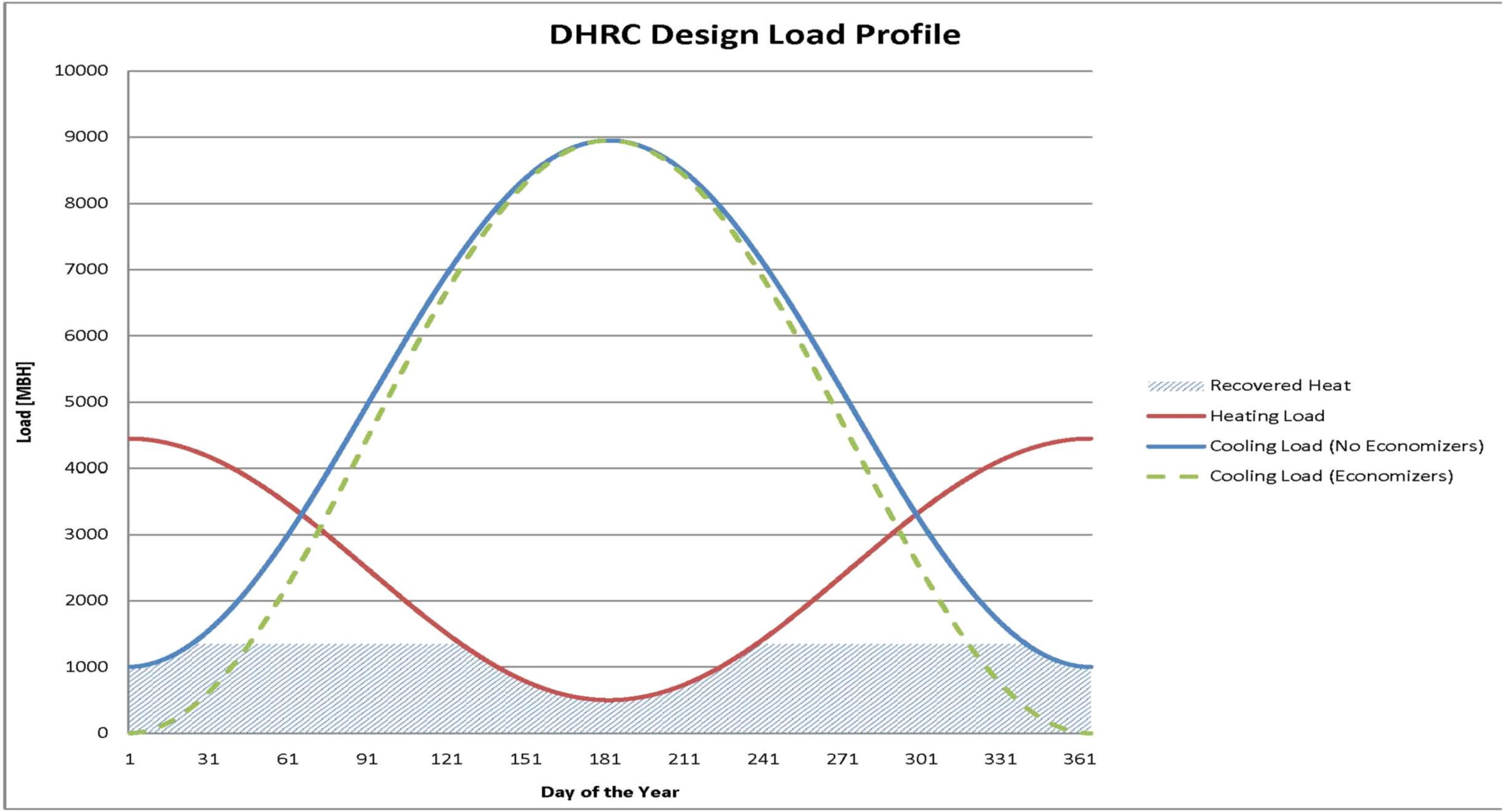
a. The building is an acute inpatient hospital, where the building or portion of a building is used on a 24-hour basis for the inpatient medical, obstetric, or surgical care for patients.

b. The total design chilled-water capacity for the acute inpatient hospital, either air cooled or water cooled, required at cooling *design conditions* exceeds 3,600,000 Btu/h of cooling.

c. Simultaneous heating and cooling occurs above 60°F *outdoor air temperature.*

The required heat recovery *system* shall have a cooling capacity that is at least 7% of the total design chilled-water capacity of the acute inpatient hospital at peak *design conditions*.

Design Consideration: DHRC Sizing



Design Consideration: Maximizing COP

10,000 CFM Coil
862 MBH
20.3 Sq ft Face

EWT [F]	Rows	FPI	Airside PD	Waterside PD	Baseline
200	1	13	0.233	5.97	-$674
180	**2**	**8**	**0.371**	**7.95**	**$0**
160	2	10	0.419	8.00	$75
140	2	12	0.478	8.06	$150
120	3	10	0.665	10.24	$700
100	4	11	0.757	12.58	$1,463

Design Consideration: Maximizing COP

Scroll HR Unit Compressor Example:

	Condenser LWT	Cooling Tons	Heating MBH	Heating COP	Combined COP
	100	50.16	739	5.39	9.79
410a	120	44.38	695	4.28	7.56
	140	38.85	657	3.44	5.88
	140	25.84	440	3.39	5.78
134a	150	24.37	435	3.05	5.1
	170	18.34	320	2.07	3.14

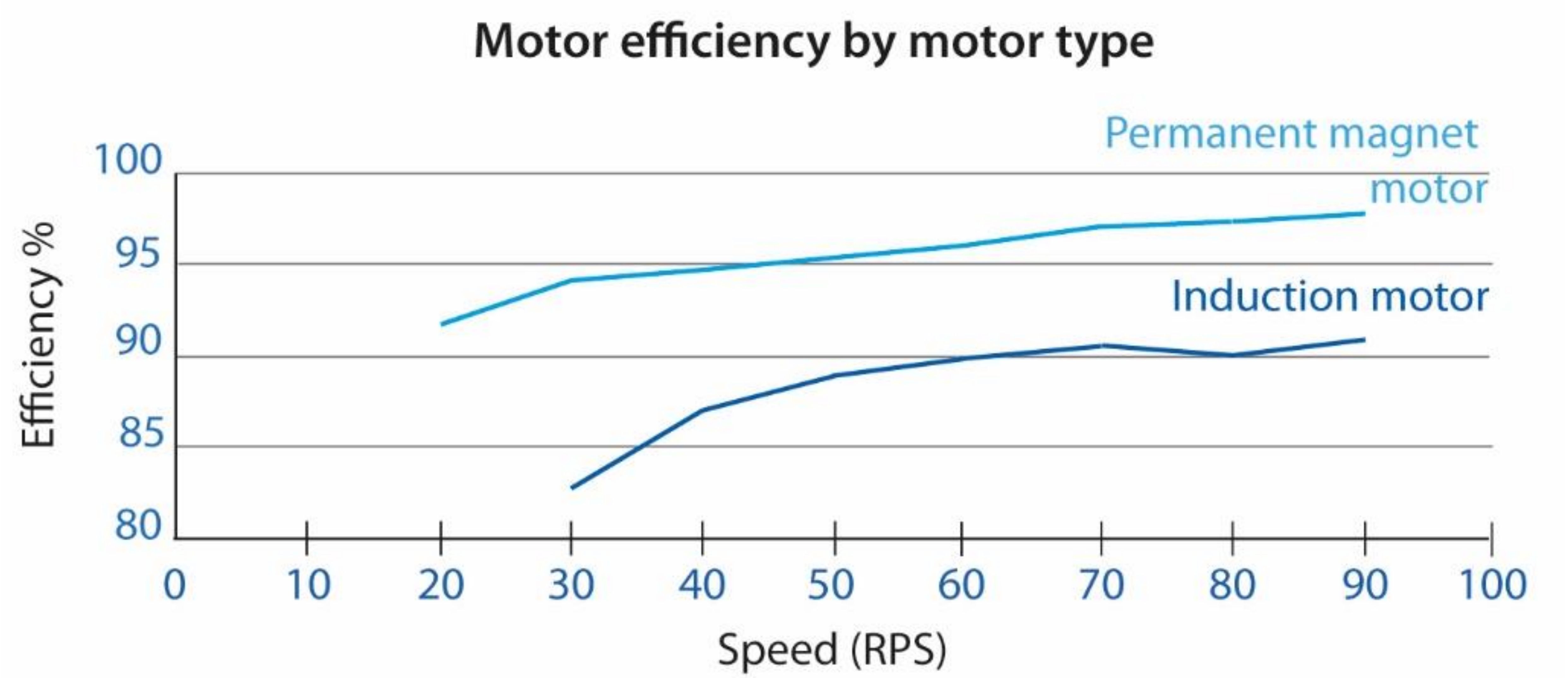
Tonnage/Capacity Suffers at higher hot-water LWT

COP Suffers at higher hot-water LWT

True Variable Speed Scroll Permanent Magnet Motor (PM)

- Manufacturer matched VFD and Compressor
  - Unloading to about 20% Water Cooled
  - Unloading to about 30% Heat Recovery
    - Can be overdriven
  - Higher cost
  - External Drive
  - Demands higher engineering
  - Limited sizes (~25 tons)
  - More complex controls
    - Single or tandem

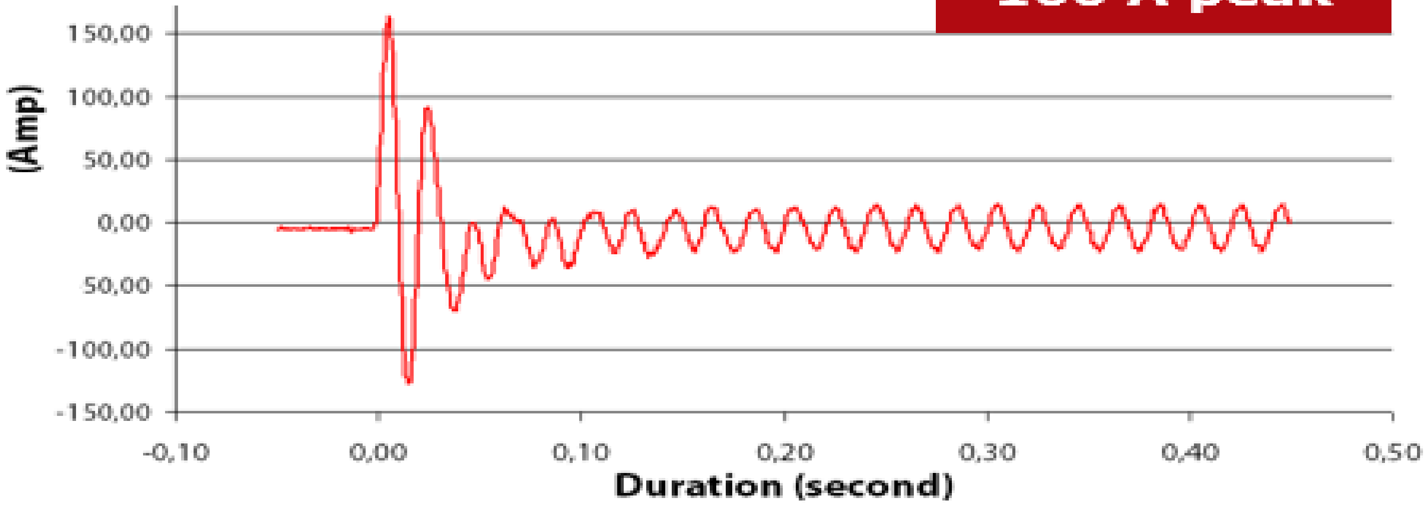
True Variable Speed Scrolls



True Variable Speed Scrolls vs On/Off Inrush

Starting Current 10TR Fixed Speed Compressor

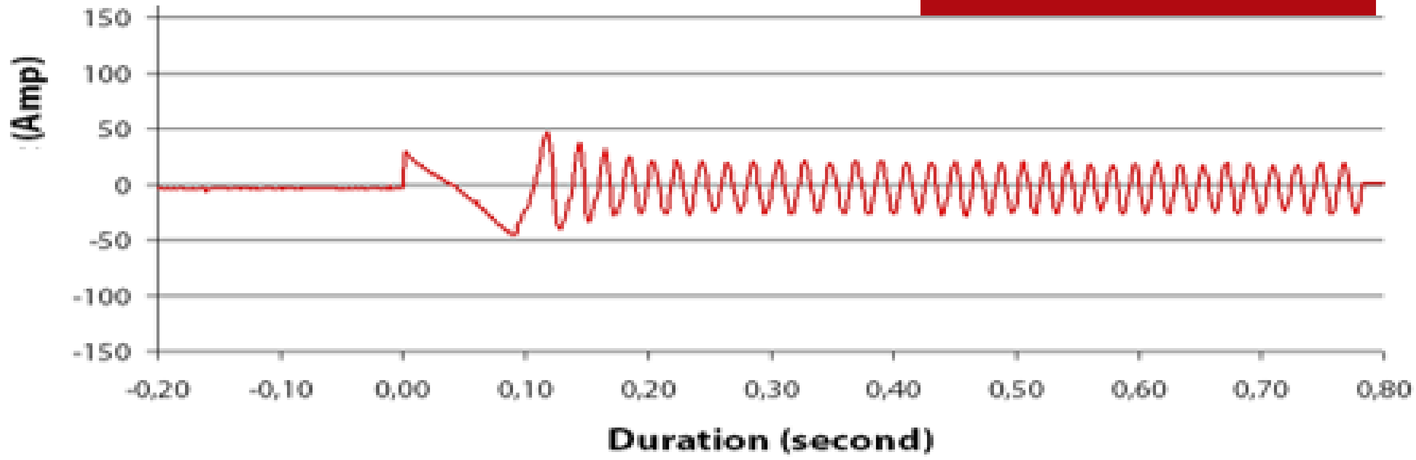
160 A peak



70% reduction

Starting Current 12TR Variable Speed Compressor

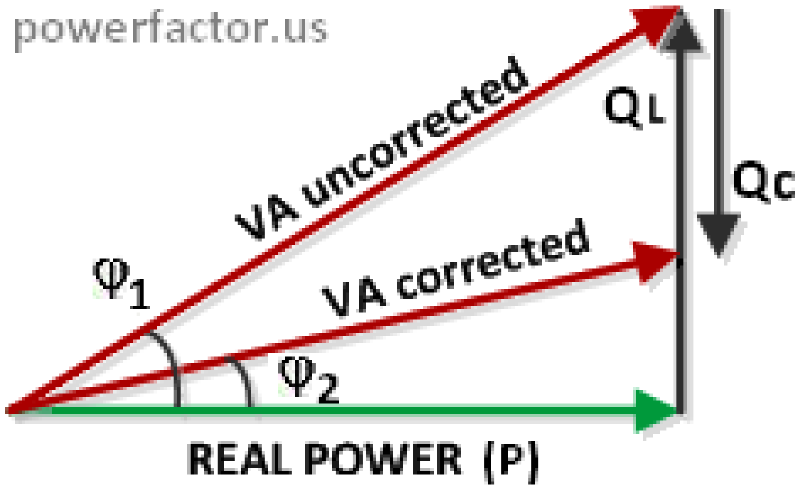
48 A peak



True Variable Speed Scrolls

- Integrated Power Factor Correction
  - Avoids costly penalties with some utilities (and external suppression and PF equipment)

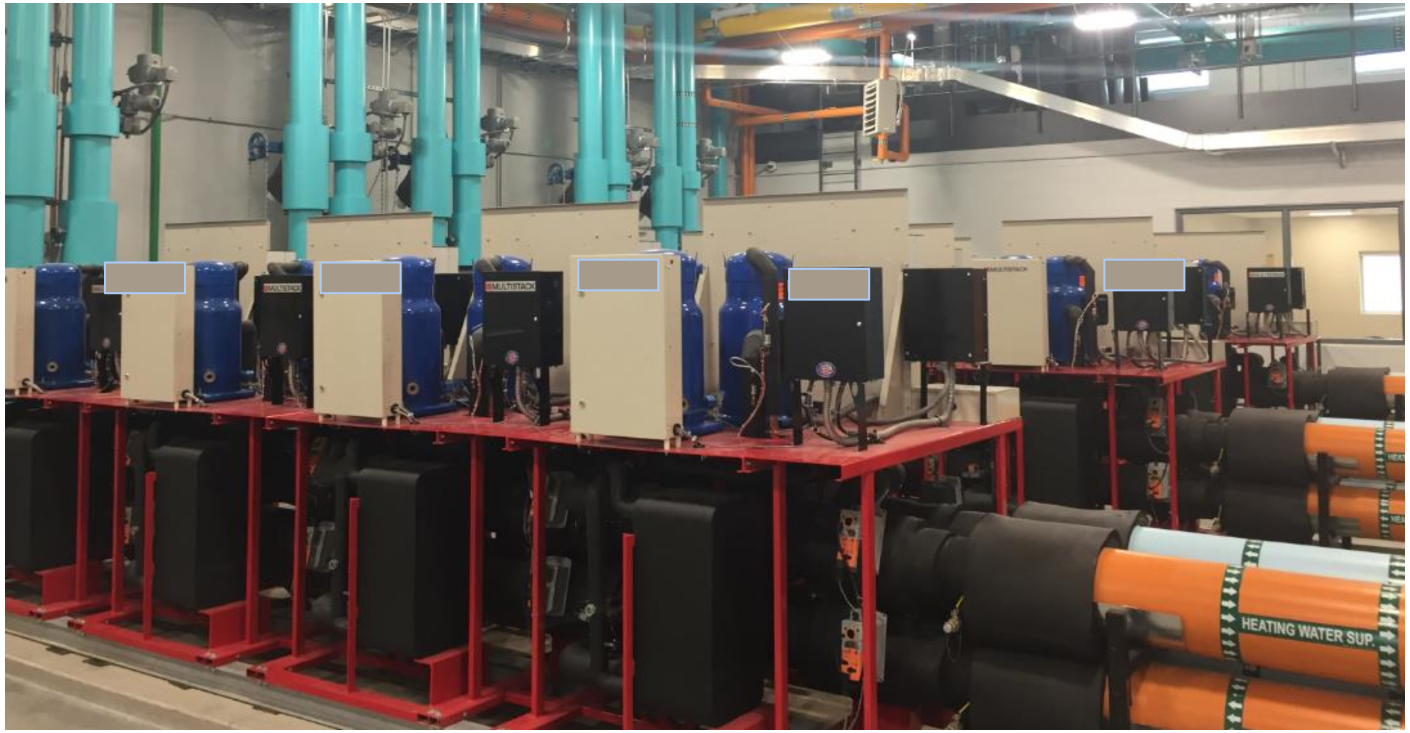
- Harmonic Suppression
  - Avoids interference with mains and other sensitive equipment



Who might want all these benefits?

- Load matching
- Low inrush current
- 98% power factor
- Accurate temperature control +/- 0.5 °F
- Low refrigerant charge
- ASHRAE 15 compliant

Electric
Cooperative, Inc.
Your Touchstone Energy® Cooperative



Geothermal

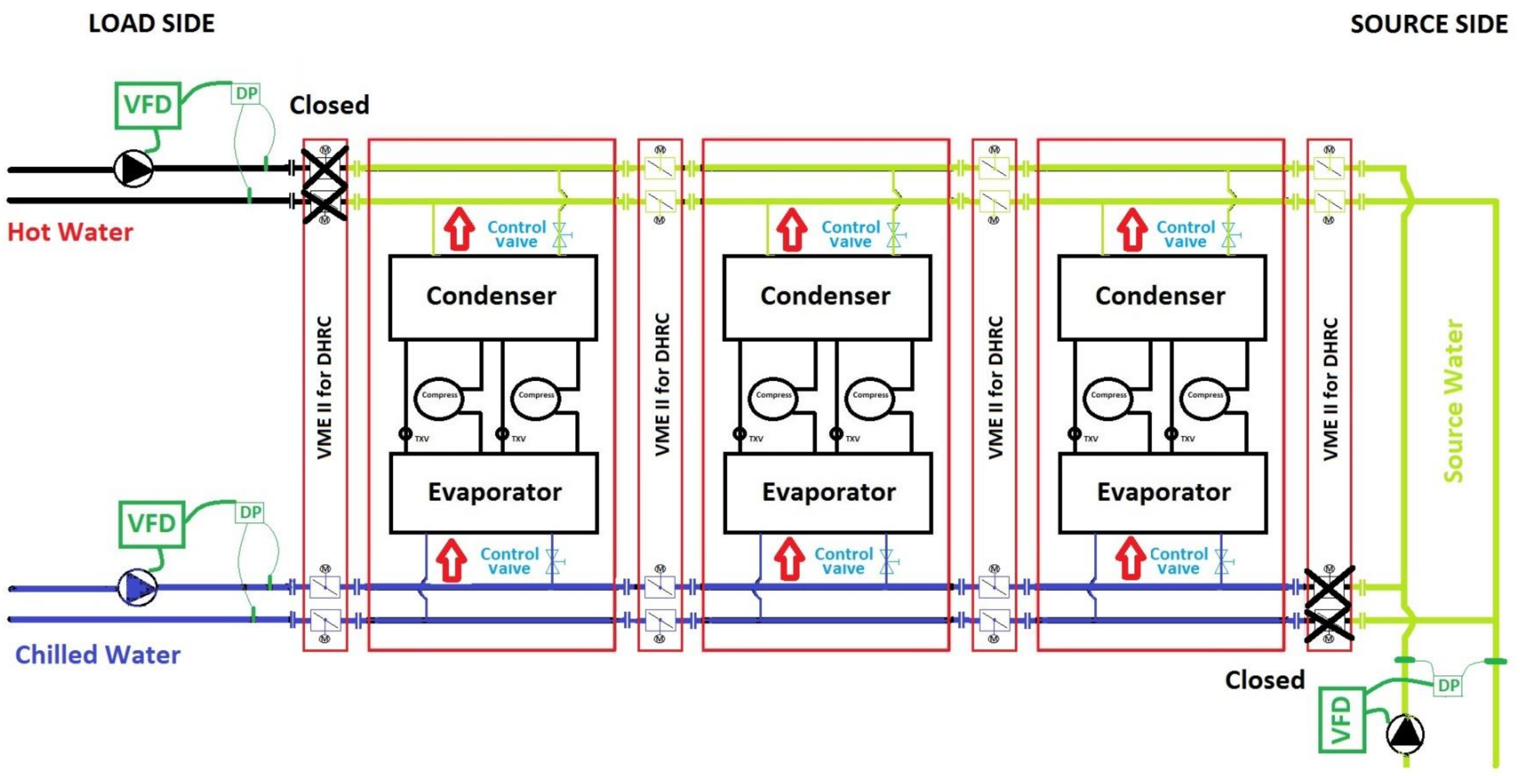
- The largest energy storage device

- Easily adaptable to simultaneous heating and cooling modular systems

Central Geo & Simultaneous Heat/Cool

Modular Simultaneous H/C with Integrated Heat Recovery (Geo or Earth-Coupled)

3 Cooling
0 Heating
3 Source rejecting
0 Simultaneous load



Modular Simultaneous H/C with Integrated Heat Recovery (Geo or Earth-Coupled)

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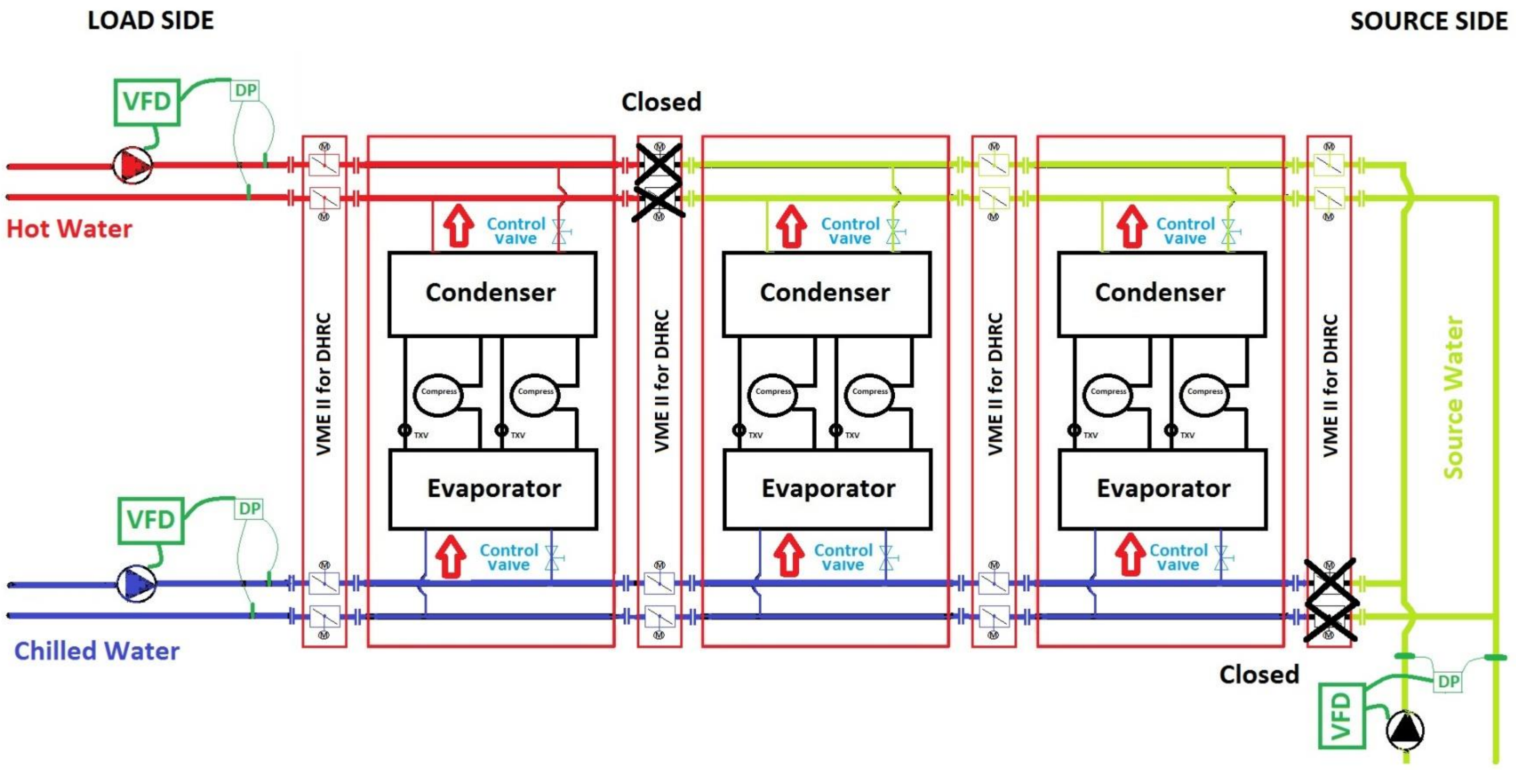

Modular Simultaneous H/C with Integrated Heat Recovery (Geo or Earth-Coupled)

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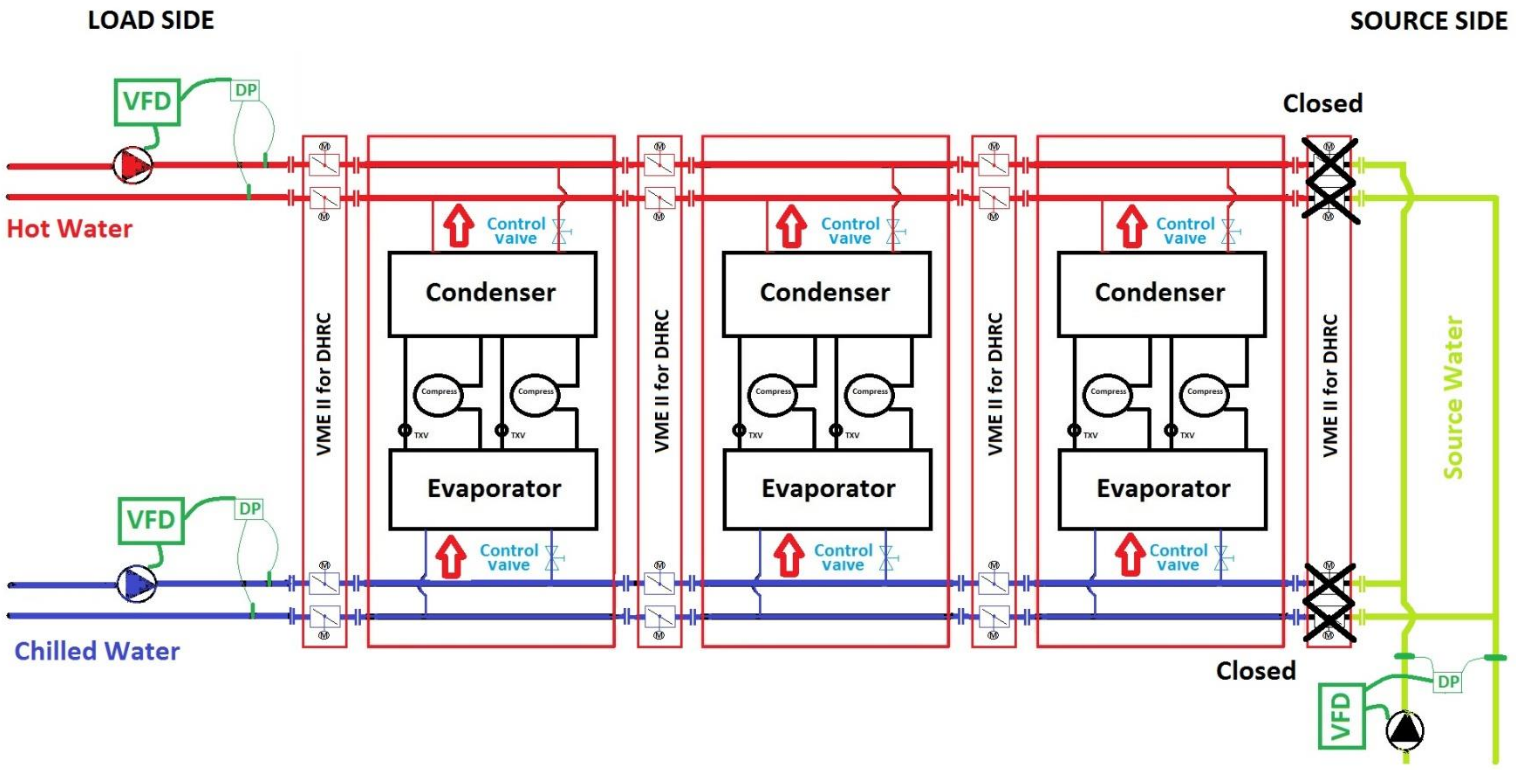


Centralized Geothermal Heater/Chiller

- No reversing valve-not really a Heat Pump
- Able to do simultaneous Cooling and Heating in the same module
- Comfort and control, reheat capabilities
- Redundancy-lose a circuit, you still have others
- Can work on the machine and still have capacity in the rest
- Small mechanical room footprint

There is a big difference

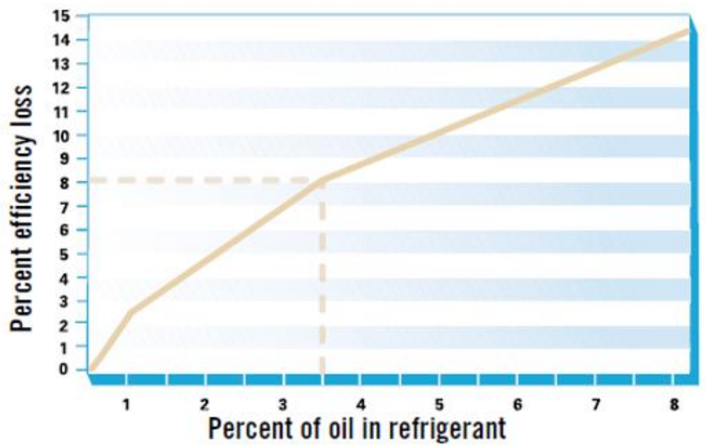
Distributed Heat Pump System

- Reversing Valve losses and maintenance
- Only one mode-Heating OR Cooling
- No reheat capabilities
- Lose a Heat Pump-Lose the Room
- Small mechanical room footprint

Oil Free Magnetic Bearing Flexibility
Go for High Efficiency and Sustainability

- NO Parasitic Loads and failure points attributed to oil
- Oil degradation and Performance-it is real!
- Low Inrush-Impact
- Elimination of Oil lends well to creative designs

	Standard Centrifugal	Magnetic Bearing Centrifugal
Oil	YES	NO
+ Oil Heater	YES	NO
+ Oil Cooler	YES	NO
+ Oil Pump/Starter	YES	NO
+ Oil Reservoir	YES	NO
+ Oil Filter	YES	NO
+ Oil Piping/Valving	YES	NO
+ Oil Sensors/Controls	YES	NO

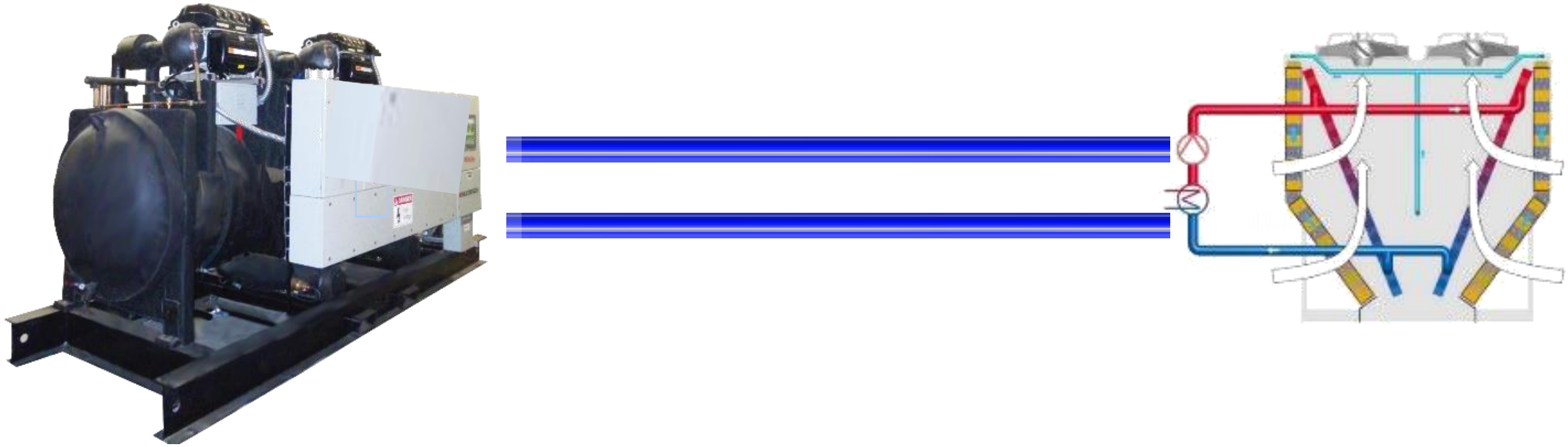


RSES Journal-November 2002
ASHRAE 604-TRP

Oil Contamination

Oil In Evaporator	Performance Loss
1-2%	2-4%
3-4%	5-8%
5-6%	9-11%
7-8%	13-15%

Oil Free Magnetic Bearing (MagLev) Flexibility…
Adiabatic Condenser

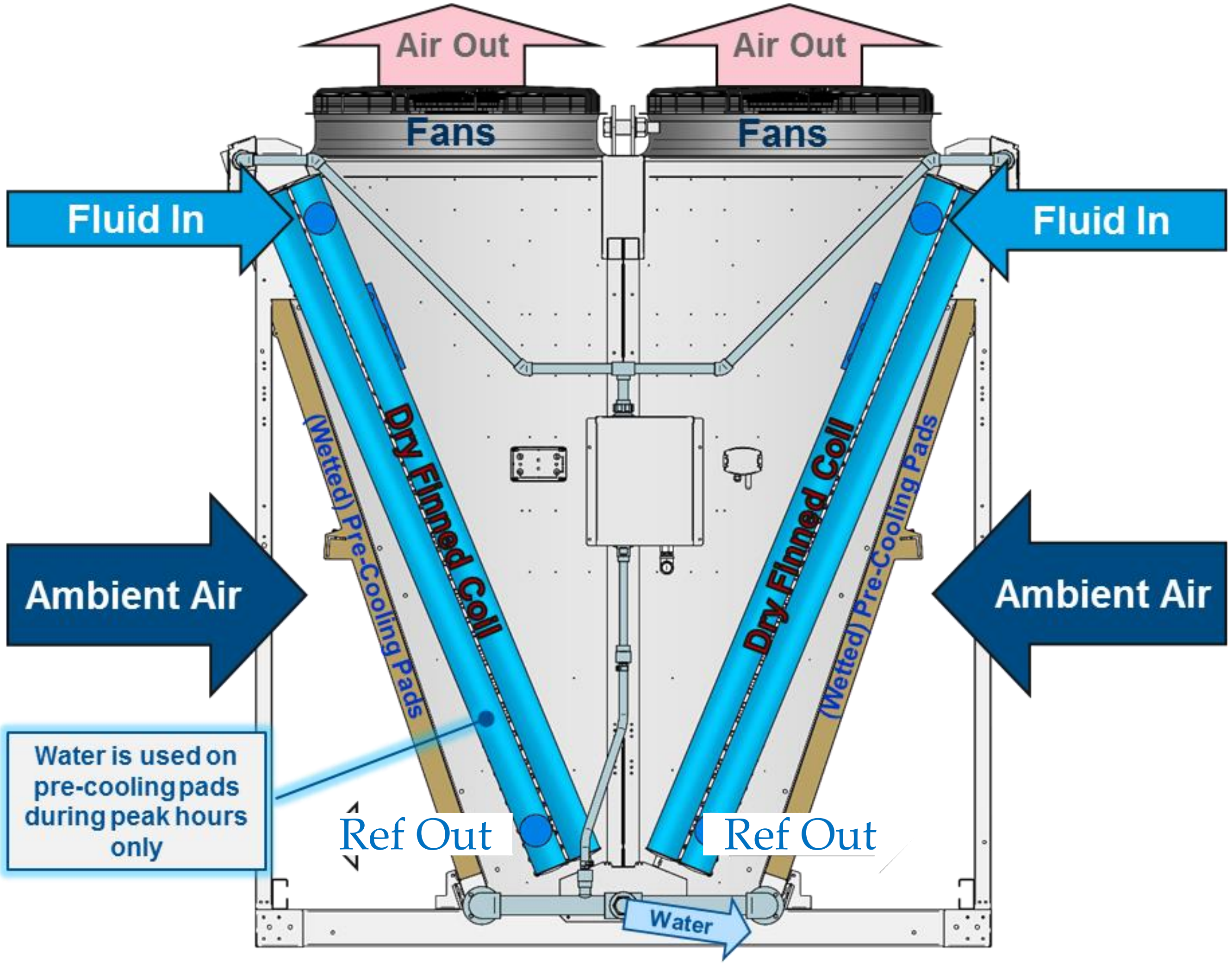


- Decrease Equipment Room Footprint
- Increase Efficiency
- LOWER First Cost
- No Condenser Pump, Tower Bypass or control

Adiabatic Condenser

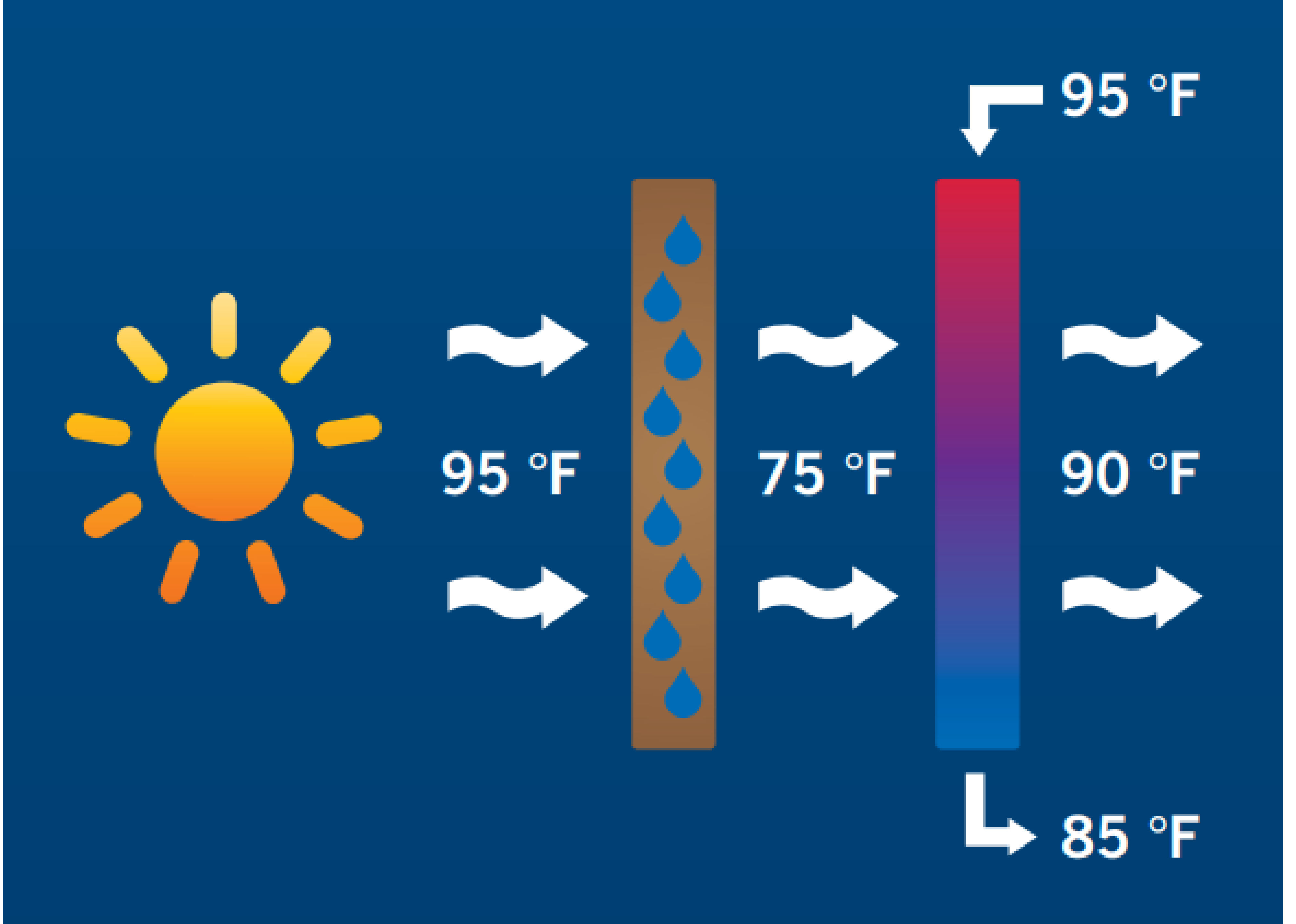
COMPONENTS & SCHEMATIC

- City Water-Untreated
- **No Legionella** risk (too cold)
- Easy change of adiabatic media
- Standard EC Fans-Quiet



Lowers your High Ambient to a mixed Wet Bulb and Ambient condition when air it hits the coil.

Lower lift = Greater efficiency



Cooling Tower Vs Adiabatic Maintenance

Cooling Tower

- Maintenance for air movement system
  - Speed reducer (belts and sheaves)
  - Bearing maintenance
- Capital cost of water treatment delivery system
  - Reoccurring cost of water treatment
  - Reoccurring cost of basin cleaning
  - Energy cost of sump sweeper pump
  - Legionella concerns
- Winterization
  - Energy of basin heaters

Adiabatic

- No maintenance required for air movement system
  - Direct drive motors
  - Maintenance free motors
- No water treatment system required
  - City/well temps too cold for Legionella
- Winterization concerns eliminated
  - No unsightly plume or ice build up as no water is utilized in colder months
- Pad replacement
  - 3 to 5 years-easy/low cost

Mag Bearing Chiller-Split

Magnetic Bearing Split System Air Cooled Chiller w/ Evaporative Media (15.2 EER Full Load / 26.0 EER IPLV)

Unheard of AC Chiller Efficiency!

% Load	Capacity (Tons)	Comp. kW	Chiller kW / Ton	THR (MBH)	Fan kW	Chiller and Condenser kW/Ton	SCT°F	Evap. Flow (GPM)	Evap. Entering°F	Evap. DeltaP (PSI)	Ambient Dry Bulb °F	Ambient Wet Bulb°F	Condenser Mode of Operation	Water Required for ACS (GPM)
100	250	170.5	0.682	3582	27.4	0.792	105	600	54	5.51	95	76	Wet	6.6
75	187.5	99.64	0.531	2590	9.96	0.585	92.5	600	49	5.51	80	68	Wet	3.1
50	125	51.5	0.412	1676	2.64	0.433	80	600	46.5	5.51	65	59	Wet	1.1
50	125	51.5	0.412	1676	6.96	0.468	80	600	46.5	5.51	65	59	Dry	NA
25	62.5	15.37	0.246	802	0.48	0.254	65	600	47	5.51	55	49.5	Wet	0.9
25	62.5	15.37	0.246	802	1.68	0.273	65	600	47	5.51	55	49.5	Dry	NA

What rebate would this chiller achieve?

Next Generation of Heat Recovery
High Lift Magnetic Bearing Compressors

- Zero performance degradation and no mechanical wear over the life of the compressor
- Outstanding energy efficiency at part load
- Compact, lightweight and simple system design reduce installation and maintenance costs
- Soft start reduces in-rush current at startup
- Exceptionally quiet operation - 70 dB(A), up to 8 dB(A) quieter vs comparable size screw compressor

Max Temp ~145

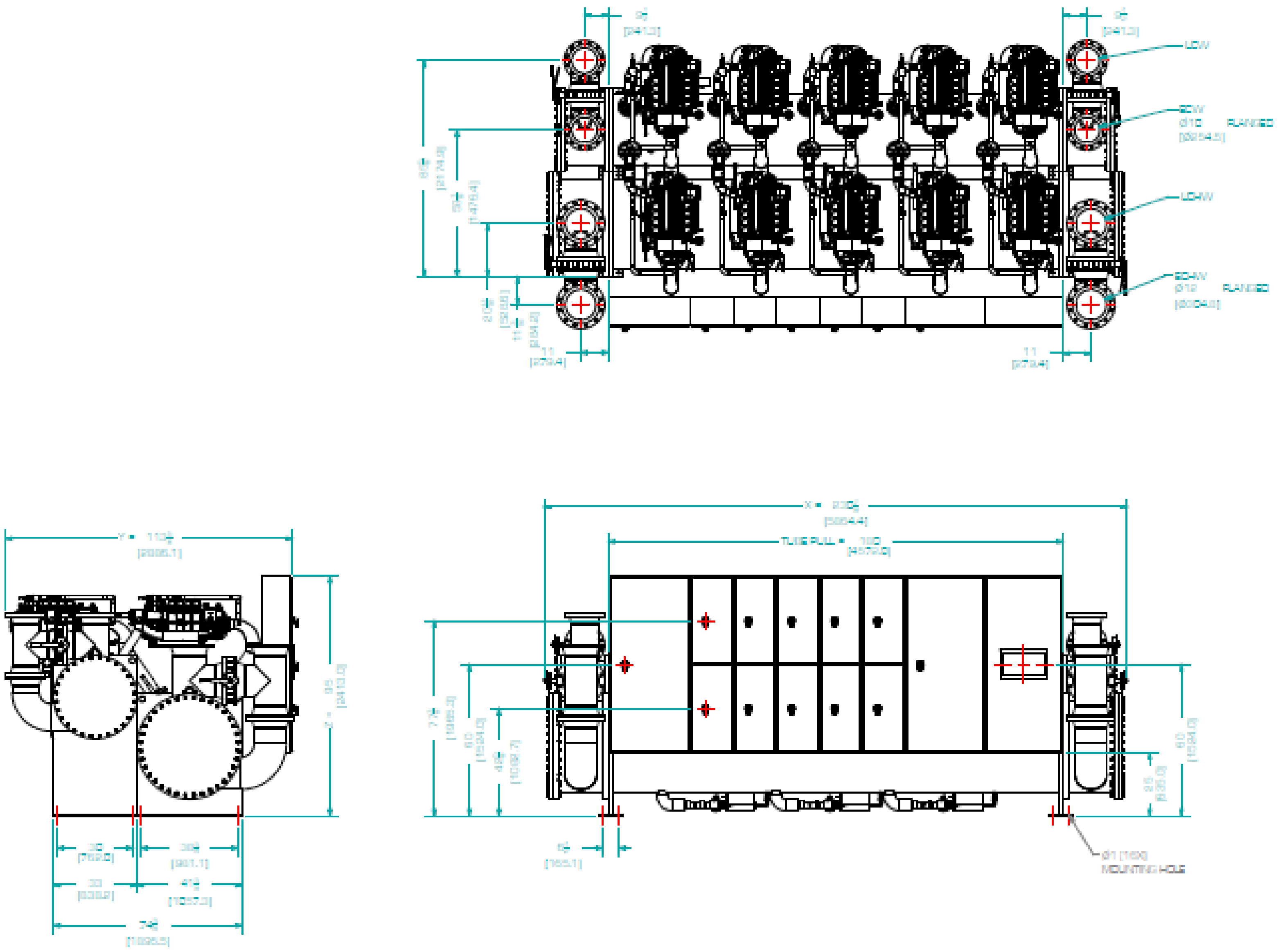
Magnetic Bearing High Lift Compressors

With

Refrigerant Choices

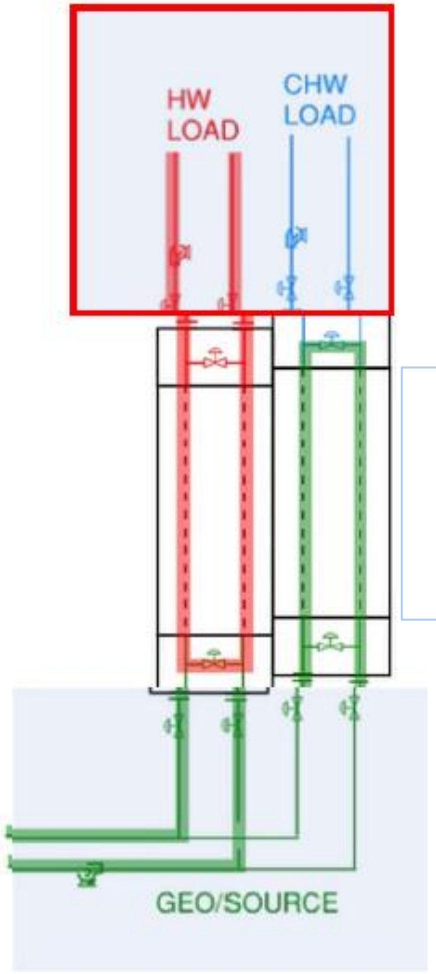
134a 513a 514a 1234ze

10 Compressor Mag Bearing Heat Recovery



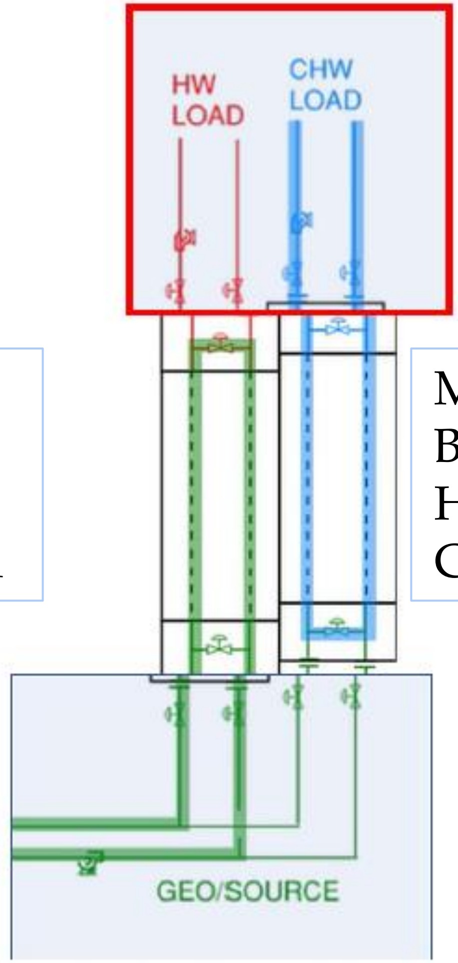
OR 8 Pipe Geothermal

8 Pipe Geothermal
Up to 145 F HW



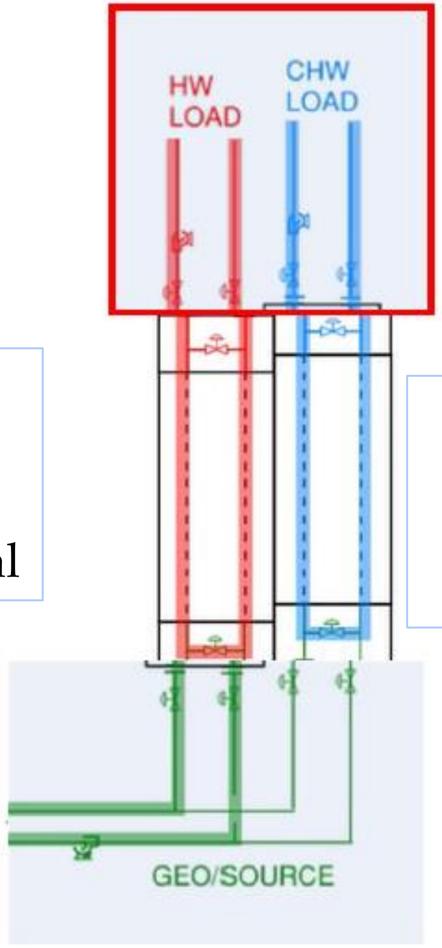
Magnetic Bearing High Lift Centrifugal

HEATING DOMINANT



Magnetic Bearing High Lift Centrifugal

COOLING DOMINANT

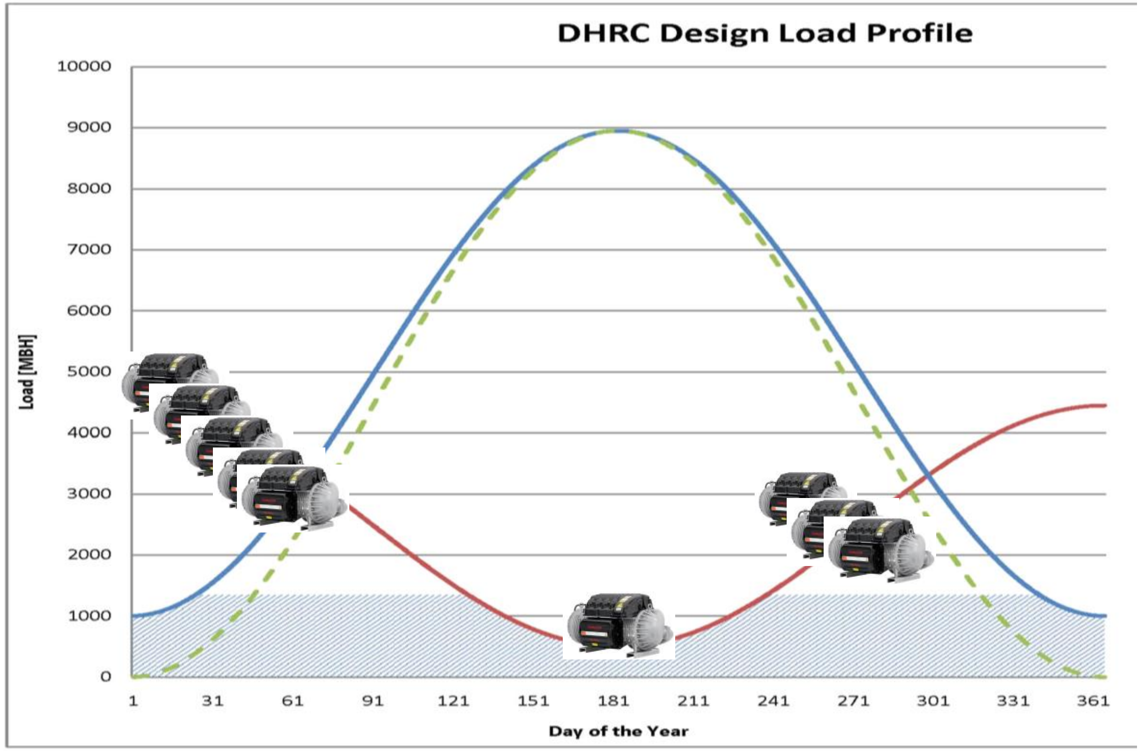


Magnetic Bearing High Lift Centrifugal

SIMULTANEOUS H/C

Load Modulation Summary

- Centrifugal Compressors are extremely energy efficient and great for Heat Recovery at high tonnage ranges.
- However, great care must be taken to ensure our design can modulate
- Use Multiple Compressors to build a robust compressor map.
- Check ALL partial-load points on the map.
- Multiple compressors good for COP consistency.



VFD SCREW

54/44 120/140

Load %	Tons	kW	kW/ton
100	190.3	285.4	1.500
90	171.4	256.3	1.495
80	151.8	229.9	1.514
70	129.4	213	1.646
60	108.5	191	1.760
50	87.57	169.3	1.933
40	66.53	147.8	2.222

4 x50t VFD Scroll

NO MORE

54/44 120/140

Load %	Tons	kW	kW/ton
100	168	243.5	1.450
90	151.2	219.4	1.451
80	134.4	196.3	1.461
70	117.6	170.5	1.449
60	100.8	147.0	1.458
50	84	120.5	1.435
40	67.2	97.1	1.445
30	50.4	73.1	1.449
20	33.6	48.9	1.455
10	16.8	25.6	1.524

Can go down to 5%

44/54 120/14

Magnetic Bearing Compressor

% Load	Capacity/ Tons	Capacity MBH	Input kW	kW/ton
100	200	3095	204.1	1.021
90	180	2749	173.2	0.962
80	160	2426	148.8	0.930
70	140	2121	130	0.929
60	120	1834	116.1	0.968
50	100	1540	100.2	1.002
40	80	1208	73.15	0.914
30	60	915	57.62	0.960
20	40	6445	48.83	1.221

VFD Scrolls can unload VERY low

Note kW/ton DOES NOT change very much while on screws it gets worse as it unloads

kW/ton is not the measure of efficiency as this is an electric chiller that acts like a boiler

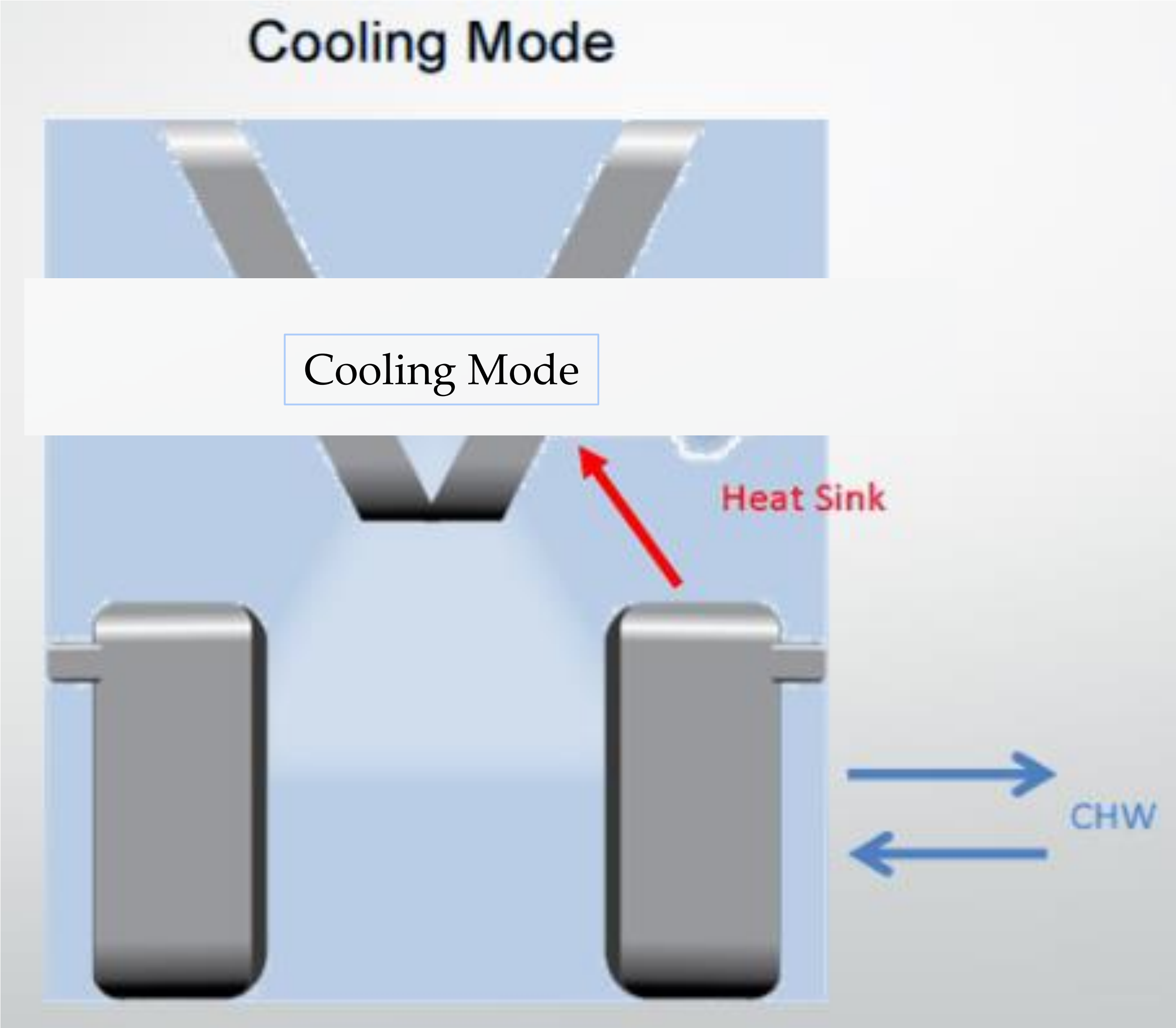
Air Source Heat Pumps

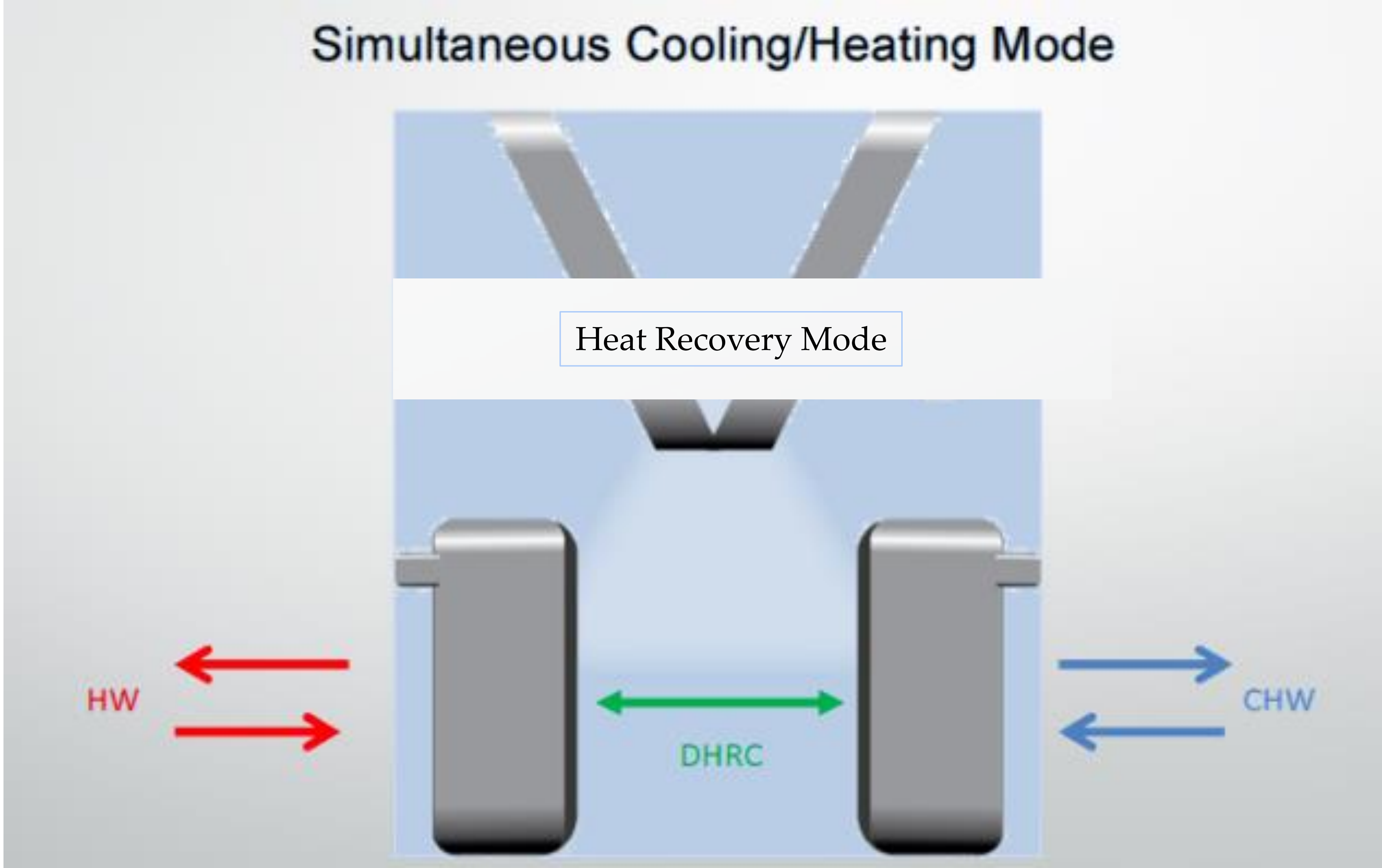
- 2 Pipe Systems
- Past Compressor Technology-Limited Heating
  - <40F Ambient-Difficult to Heat
- Heating OR Cooling

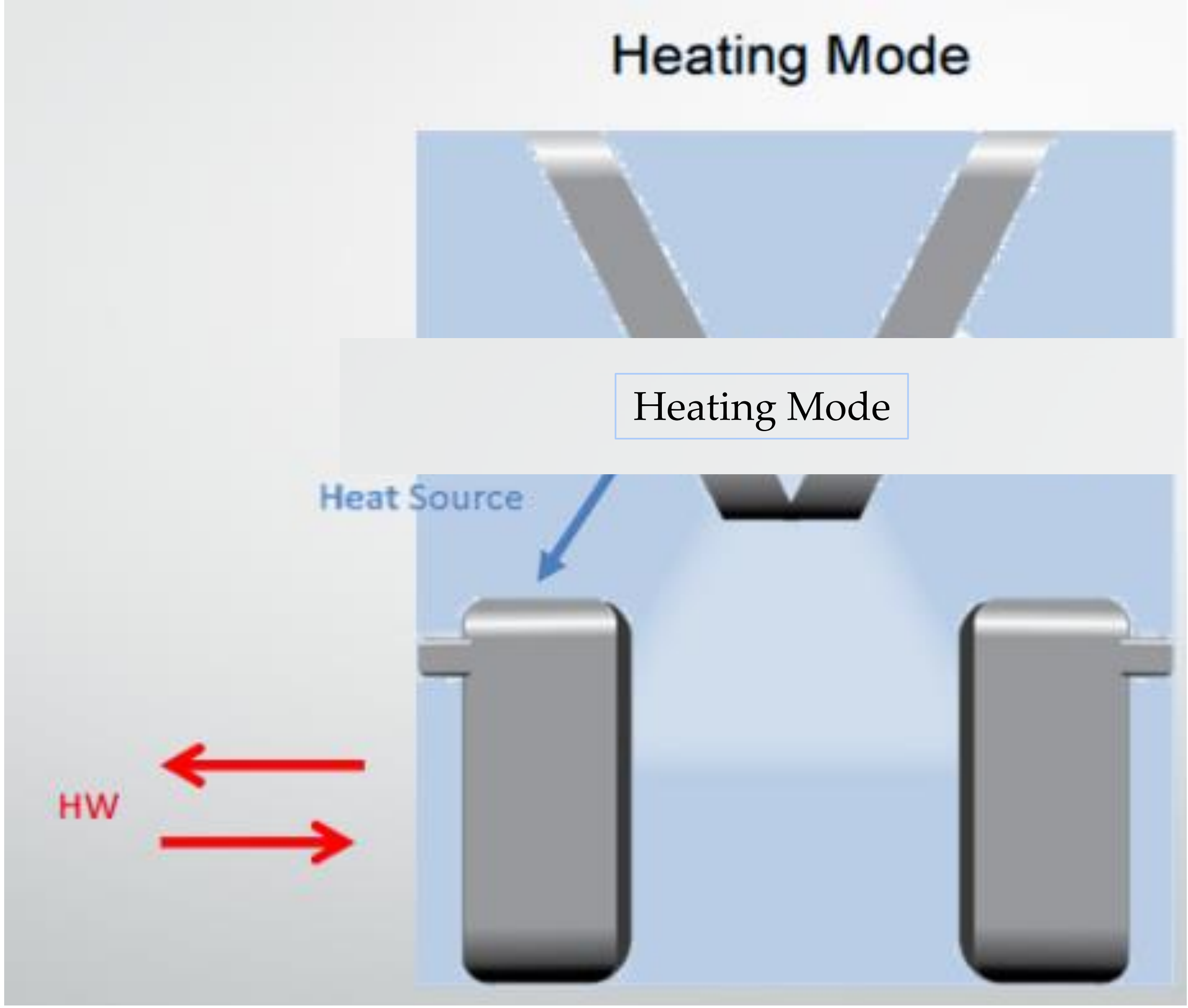
NEW Technology

- 4 Pipe Systems
  - Heating Down to 0F
- Heating or Cooling <u>and</u> Simultaneous

Air to Water Heat Pumps with DHRC Capability




Simultaneous Cooling/Heating Mode
Heat Recovery Mode
HW
DHRC
CHW



Heating Mode

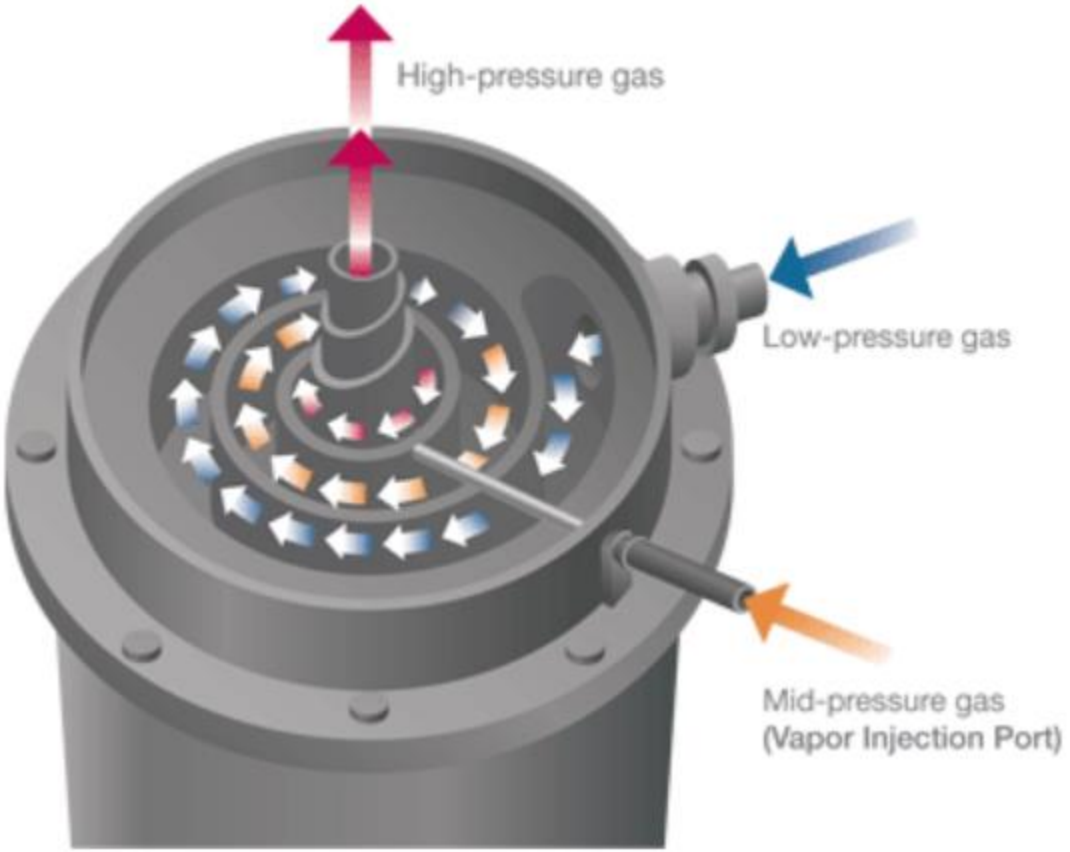
New Technology-Extended Range Refrigerant Injection Scrolls

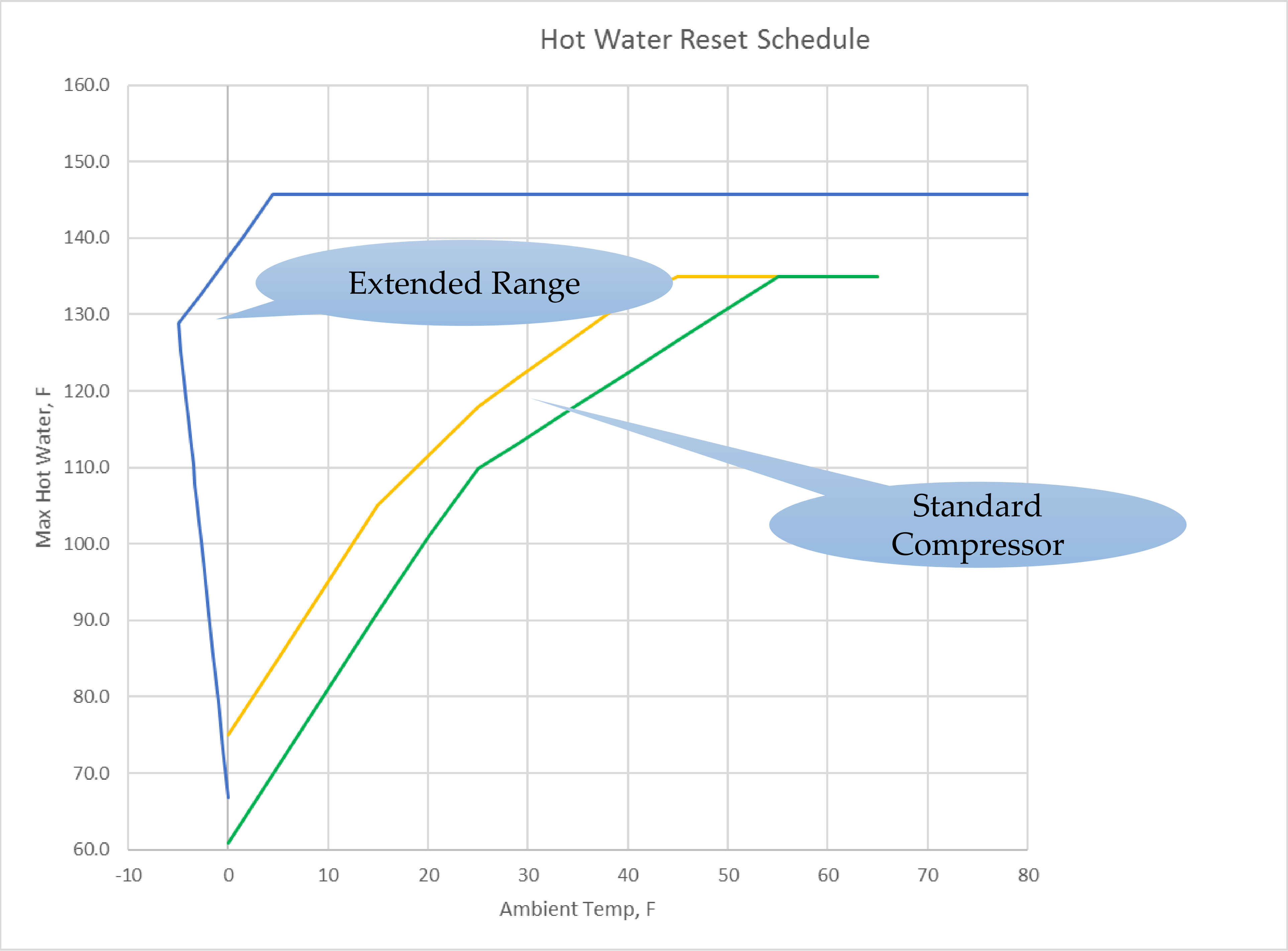
- Expands the Operational Envelope
  - Heating Down to ~0F
  - Higher Temperatures (~140f)
  - 15 Ton Compressor for now (30 Ton Modules)
  - No Alternative Refrigerants in development ‘yet’

  - Requires Glycol
  - Lower Temps may require an Ambient/Temp Reset schedule
  - Defrost Cycle
  - Modular Design helps build in redundancy

15T Compressors Only For Now

- Refrigerant Injection similar to interstage economizer
- Refrigeration flow is increased by ~20%
- Operational range is extended in colder climates

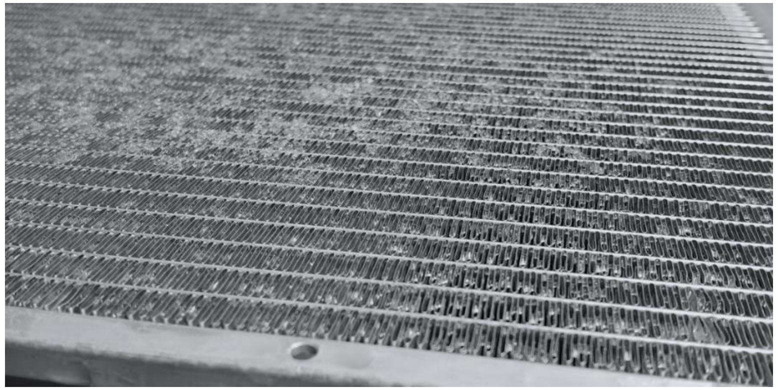


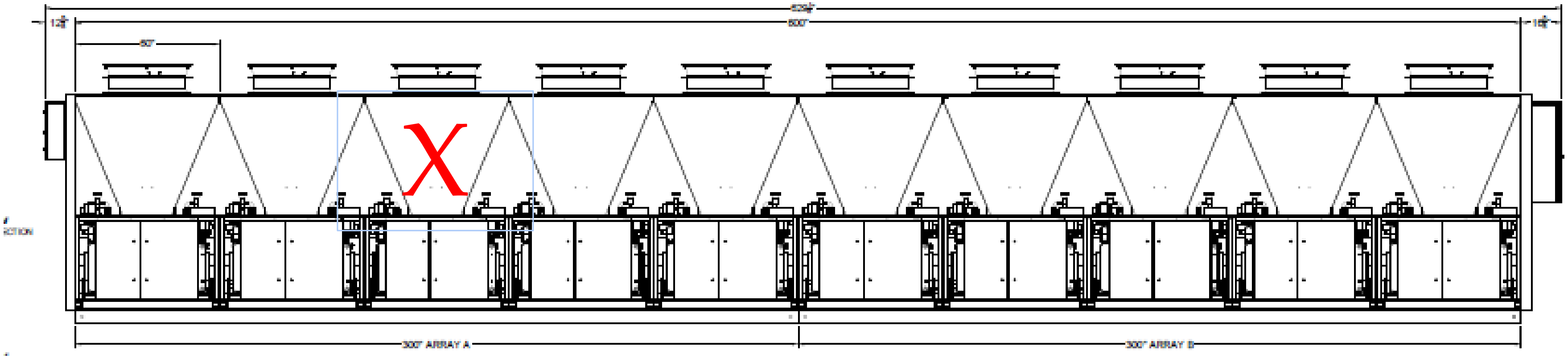


Hot Water Reset Schedule
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
Max Hot Water, F
-10
0
10
20
30
40
50
60
70
80
Ambient Temp, F
Extended Range
Standard Compressor

Design Consideration: Defrost

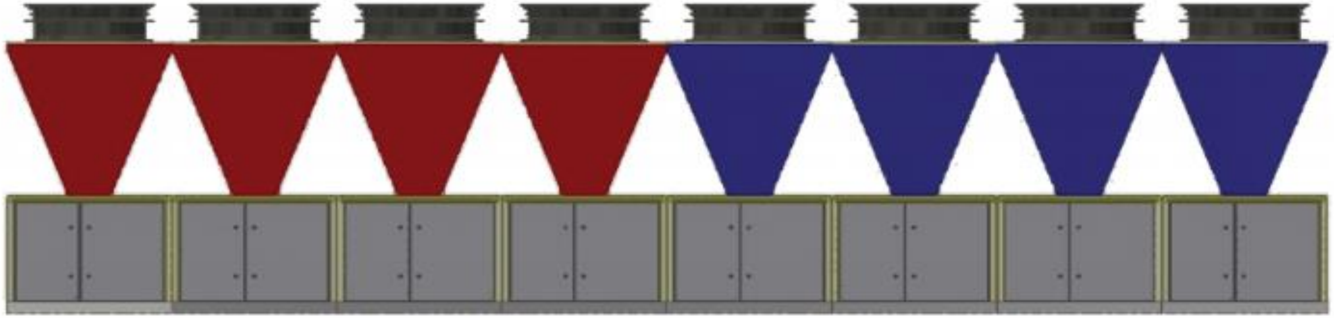
- Outdoor evaporator coils often will have surface temperatures below dew-point, causing water to condense.
- During the winter, this condensation can freeze directly on the coils.
- One module at a time (versus packaged chiller taken out of operation)





Packaged

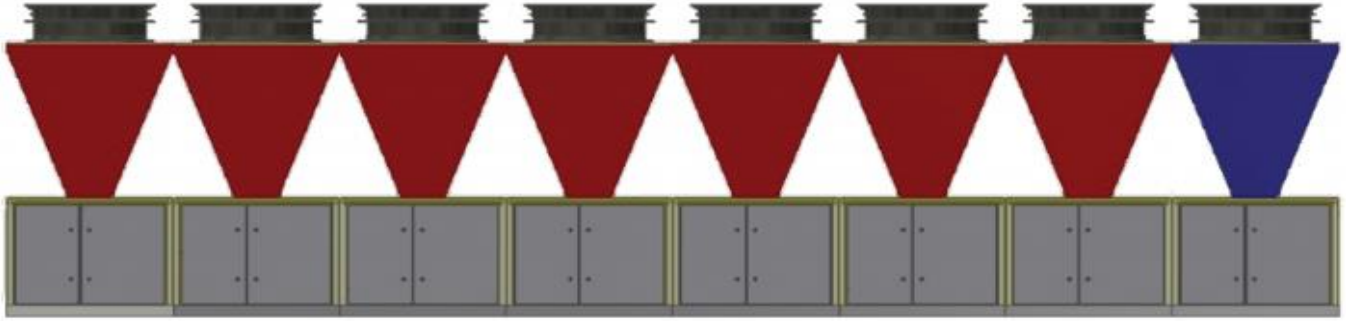
- 1 Circuit in Heating
- 1 Circuit in Defrost
- Supply Water Temperature <= Return Water Temperature



Modular

- 7 Modules in Heating
- 1 Module in Defrost
- Supply Water Temperature always greater than return

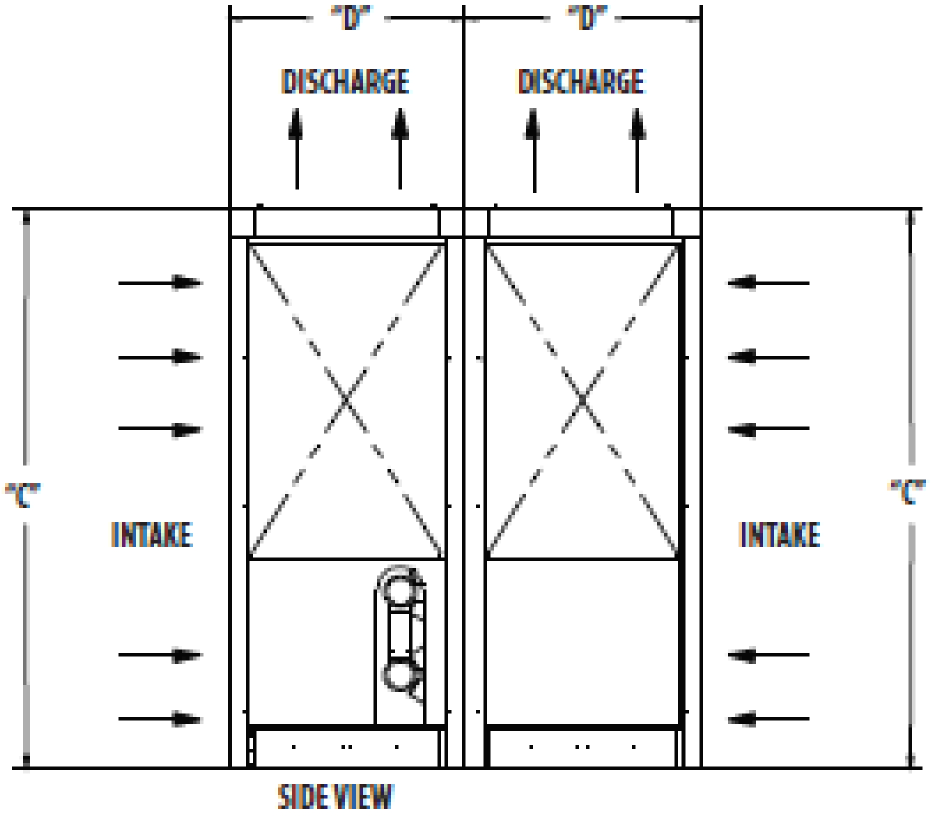
Intelligent Defrost Programming



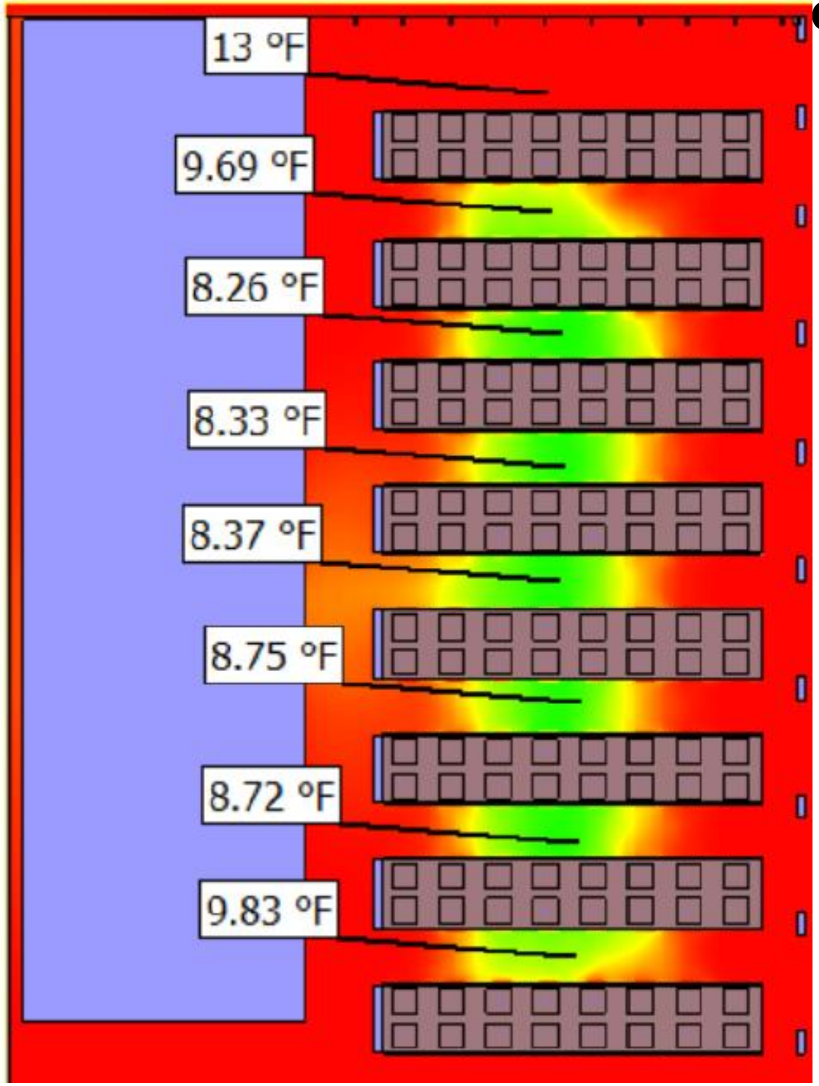
<u>Redundancy</u> Recommended for Defrost Derate!

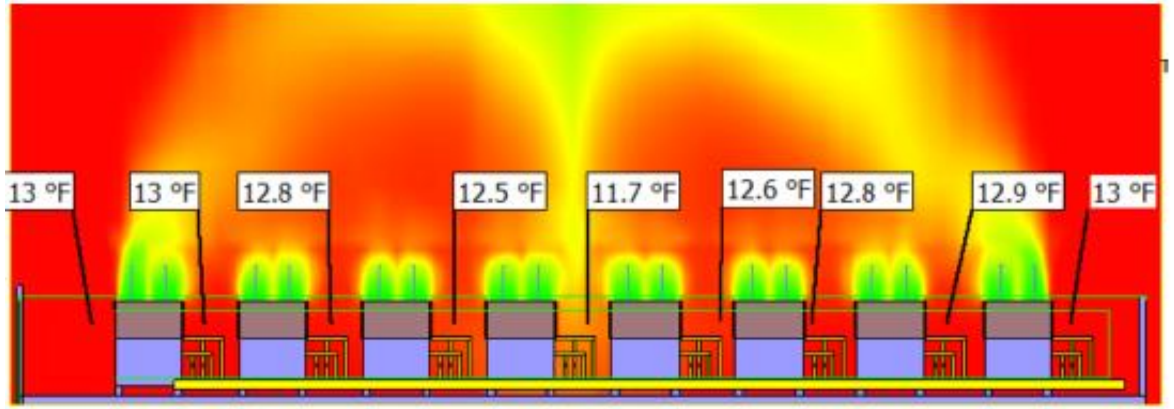
Design Consideration: Airflow Requirements

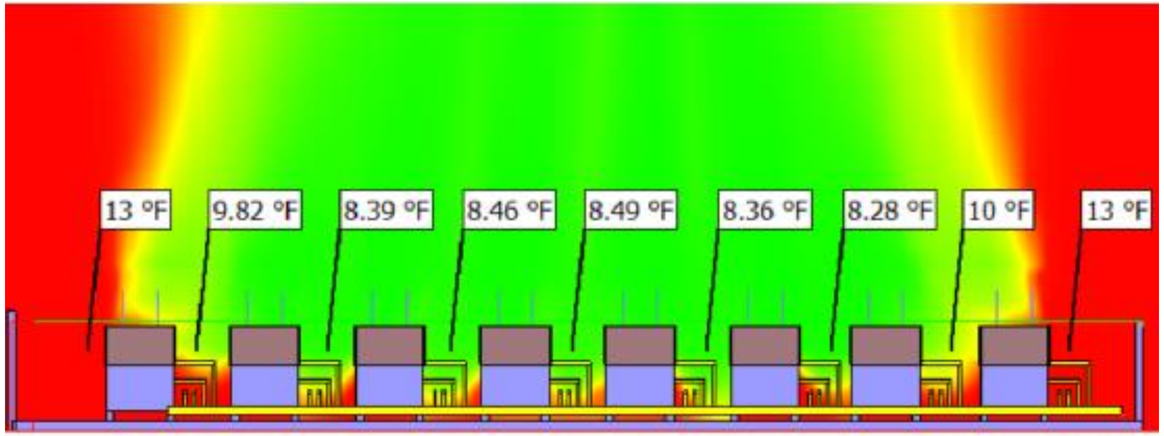
- Standard Practice for ensuring sufficient airflow includes
  - Minimum Free Area or “Clearance” around the unit
  - Minimize air velocity for entering or “make-up” air
  - Discharge air is at or above any enclosure structure/wall
- Enhanced analysis with CFD Model



Design Consideration: Airflow Requirements







Avoid Short Cycling!

Design Consideration: Low Ambient Derate

- Unit capacity will decrease at lower ambient temperatures because more lift is required.
- COP is also reduced at lower ambient (MORE LIFT, LESS COP)

HEATING PERFORMANCE DATA								
Load	Heating (MBH)	kW	Heating COP	Fan kW	Cond Flow (GPM)	Entering Temp. °F	Leaving Temp. °F	Ambient °F
100%	1501	239.8	1.830	20.80	315.0	110.0	120.0	0.00
100%	1683	244.7	2.010	20.80	352.8	110.0	120.0	10.00
100%	1871	249.3	2.200	20.80	392.3	110.0	120.0	20.00
100%	2112	254.1	2.440	20.80	443.5	110.0	120.0	30.00
100%	2365	258.7	2.680	20.80	496.4	110.0	120.0	40.00
100%	2628	263.2	2.930	20.80	551.9	110.0	120.0	50.00
100%	2966	268.3	3.240	20.80	622.4	110.0	120.0	60.00

Electrification is the HERE and NOW
Creative use of technologies is key

- Find creative ways to apply heat recovery, even on small opportunities

- Look for Geothermal opportunities employing Heat Recovery concepts

- Apply Mag Bearing technology with Heat Recovery and different methods in water cooled environments that improve its already stellar, sustainable performance

- Air to Water Heap Pumps and new compressor technology

Creativity can take many forms
Employing new and current technologies

A/W Heat Pumps:
New Refrigerant Designs for Scrolls are expected to change the operational envelope and opportunity for hotter water at lower ambient winter designs. Testing is underway at an OEM level but will proceed to the manufacturers over the next year to bring to market.

All of this technology is being expedited to meet the goals of Electrification and reduction of carbon emissions.

Expect innovations to continue at a very fast speed!