Manufacturer’s Roundtable

Industrial Heat Pumps

September 11, 2024

CEDA California Energy Design Assistance

nbi new buildings institute

WHAT IS CEDA?

CEDA

The California Energy Design Assistance (CEDA) is the only statewide utility incentive program for new construction and major renovations.

- Promotes **electrification** and **decarbonization**
- CEDA works in collaboration with project teams to reduce energy demand, consumption, and carbon emissions.
- Serves commercial, public, high-rise multifamily, industrial, and agricultural projects in Pacific Gas & Electric (PG&E), Southern California Edison (SCE), SoCalGas (SCG), and San Diego Gas & Electric (SDG&E) service areas.

WHY PARTICIPATE IN CEDA?

- Receive complimentary **decarbonization** analysis tailored to project goals to identify most effective measures to implement
- Gain analysis of **energy costs and paybacks**
- Receive **financial incentives** to help offset the costs of decarbonization measures
- Demonstrate commitment to high performance building practices and design

INCENTIVES

CEDA

$2,800
+
measure package incentive

- **$2800 Design team incentive** per project as a thank you for participation
- Based on the project measure package the design team chooses for implementation

HIGH PERFORMANCE MEASURES

CEDA aims to exceed California's decarbonization standards by identifying high performance measures and providing educational opportunities to explore use cases and best practices.

This not only advances the market, but also qualifies participants for enhanced incentives through our program.

A current list of eligible high-performance measures can be found on our website here.

HAVE A PROJECT TO DISCUSS?

CEDA

For more information, please contact our program outreach specialists, visit our website, or fill out an interest form

Scan me to enroll a project

CaliforniaEDA.com

Sean M. Williams | Outreach Specialist
swilliams@willdan.com

Tina Hendrix | Program Outreach Specialist
thendrix@willdan.com
760.585.7577

Why Industrial Heat Pumps

In today's roundtable we'll discuss:

Why are a growing number of industries embracing heat pumps?

What is the current landscape of the market for industrial heat pumps?

What are the barriers to the adoption of industrial heat pumps?

What are some of the insights from retrofit projects and real-world adoption?

Today's Panelists

Rajkumar Gnanaraj
Armstrong International

German Robledo
GEA HRT

ARMSTRONG INTERNATIONAL
HEAT PUMP

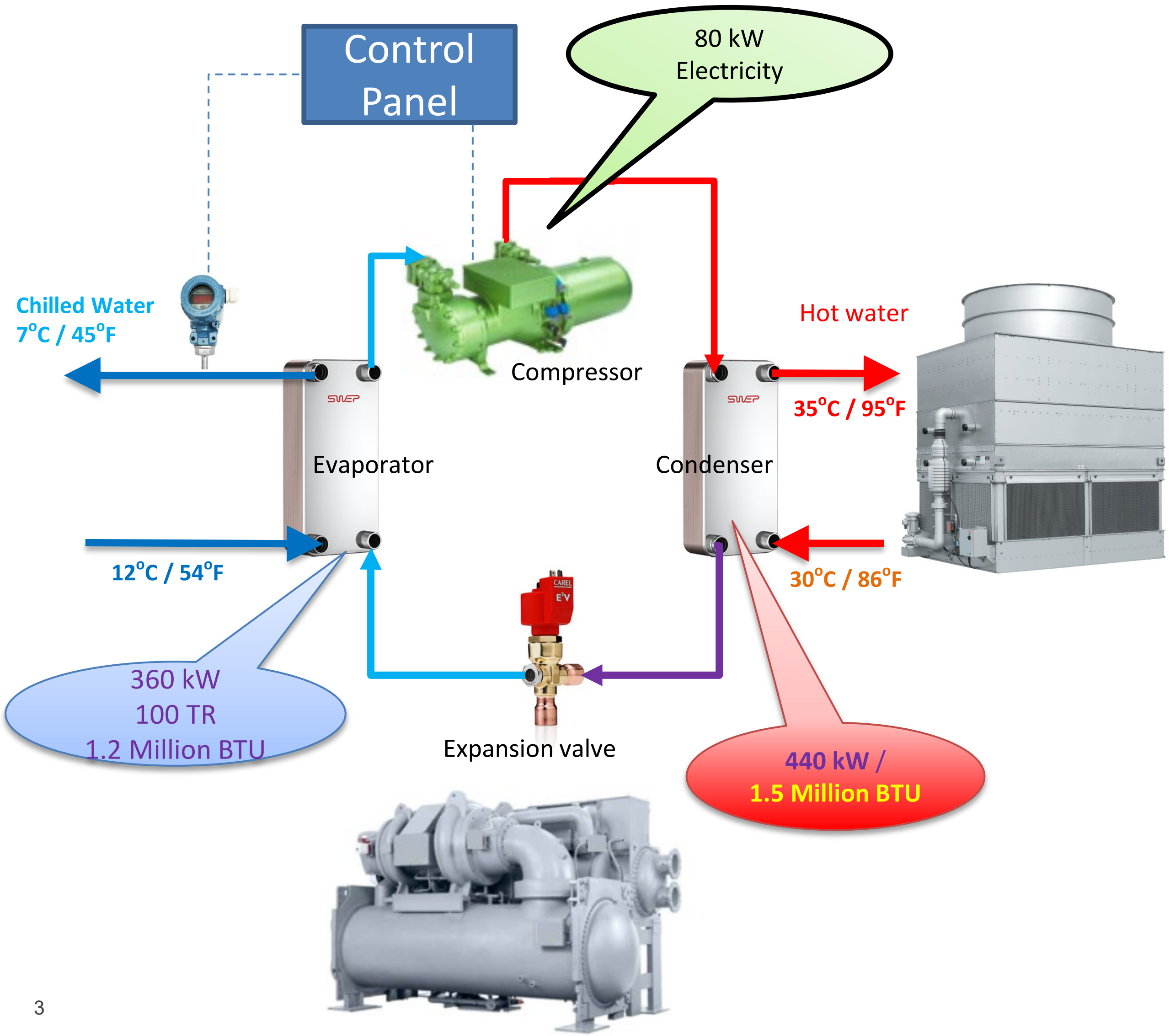
Armstrong Industrial High Temperature Heat Pumps

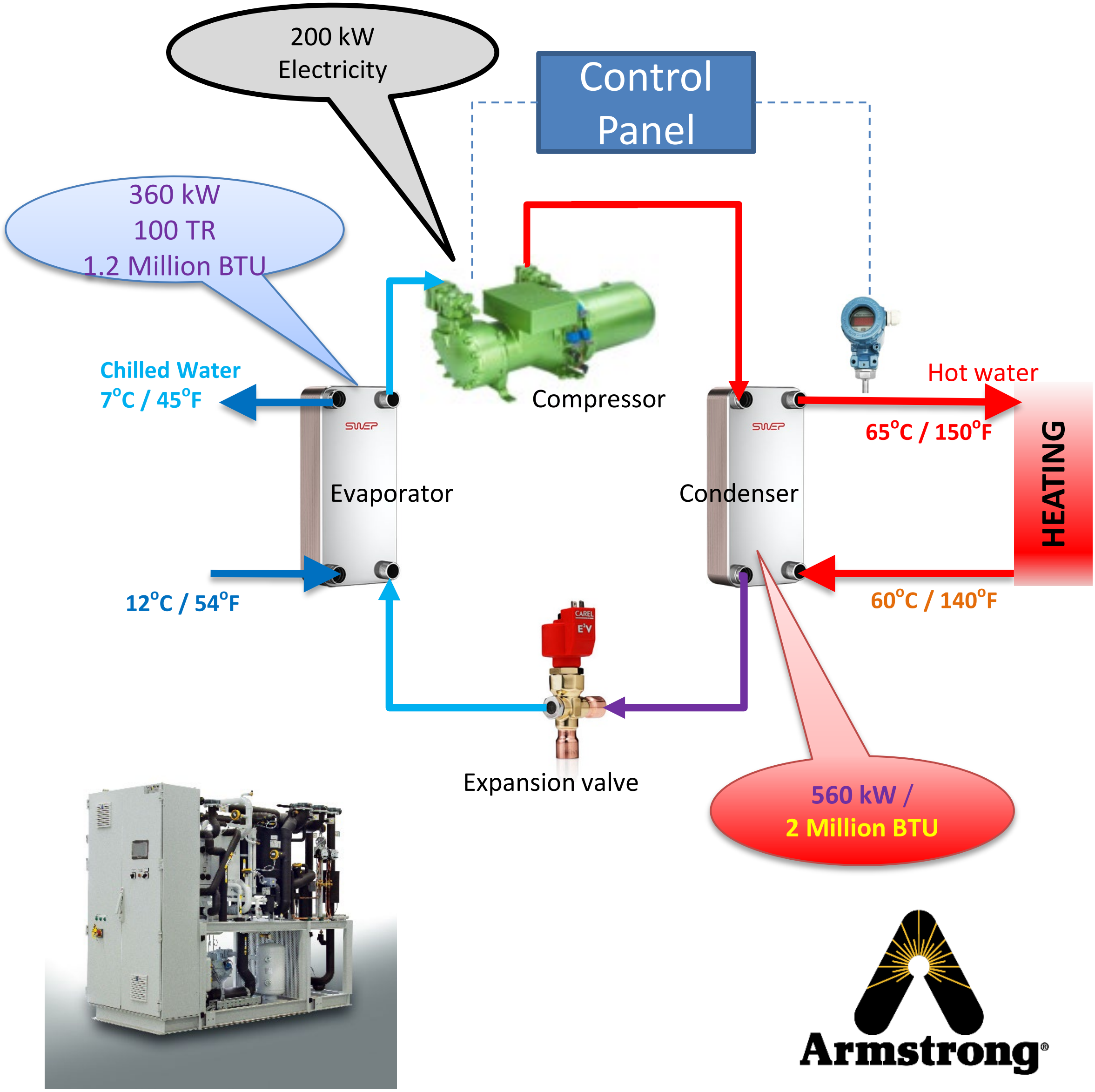
- Up to 248°F Steam or Hot water
- 50 kW – 2000 kW
  (0.15 MMBTU/hr to 7 MMBTU/hr)
- TRL 9
- Received DOE grant for facility creation to produce in the USA
- Customized Heat pump – MADE in NORTH AMERICA

- Founded in 1900
- Family-owned, 5th generation
- 15 manufacturing locations around the globe
- Experts in Thermal Utility optimization and management

Armstrong

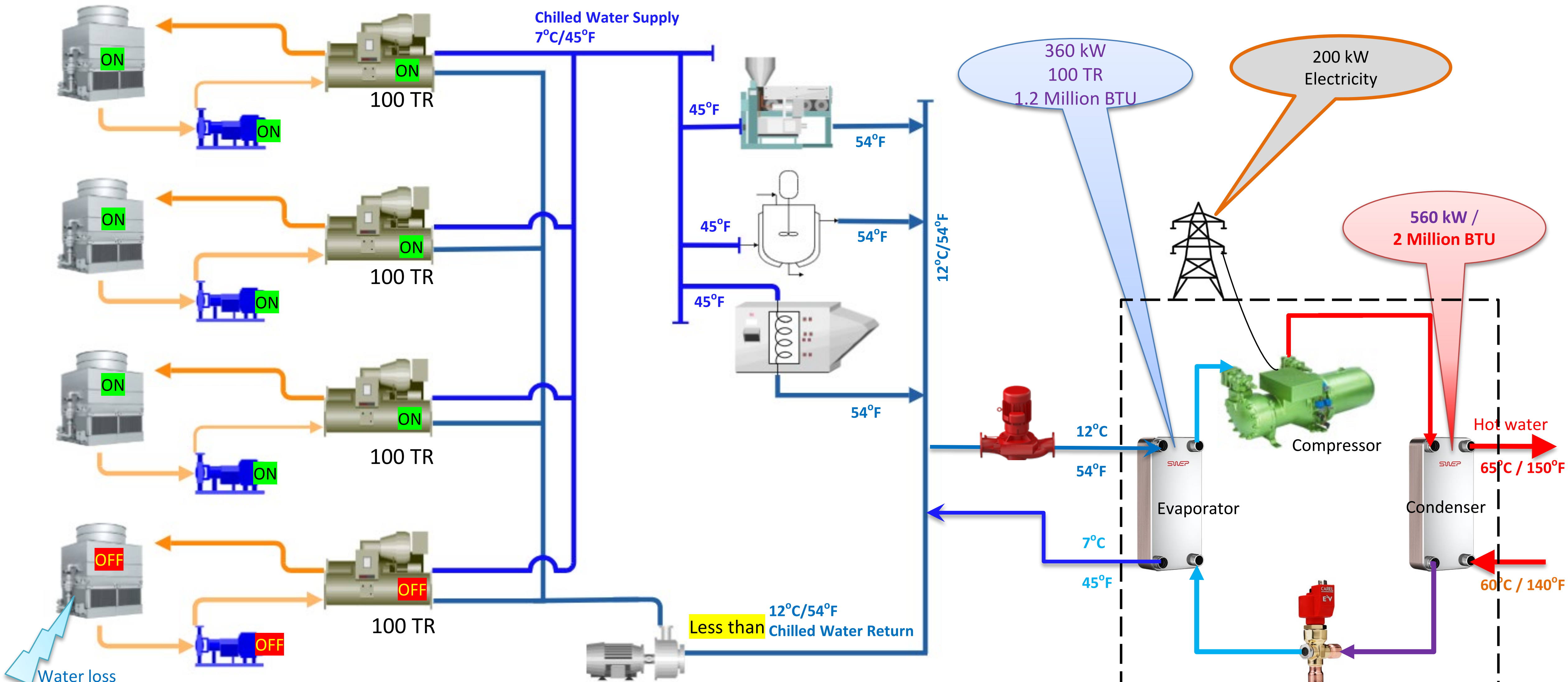
Chiller Vs Heat Pump





Armstrong

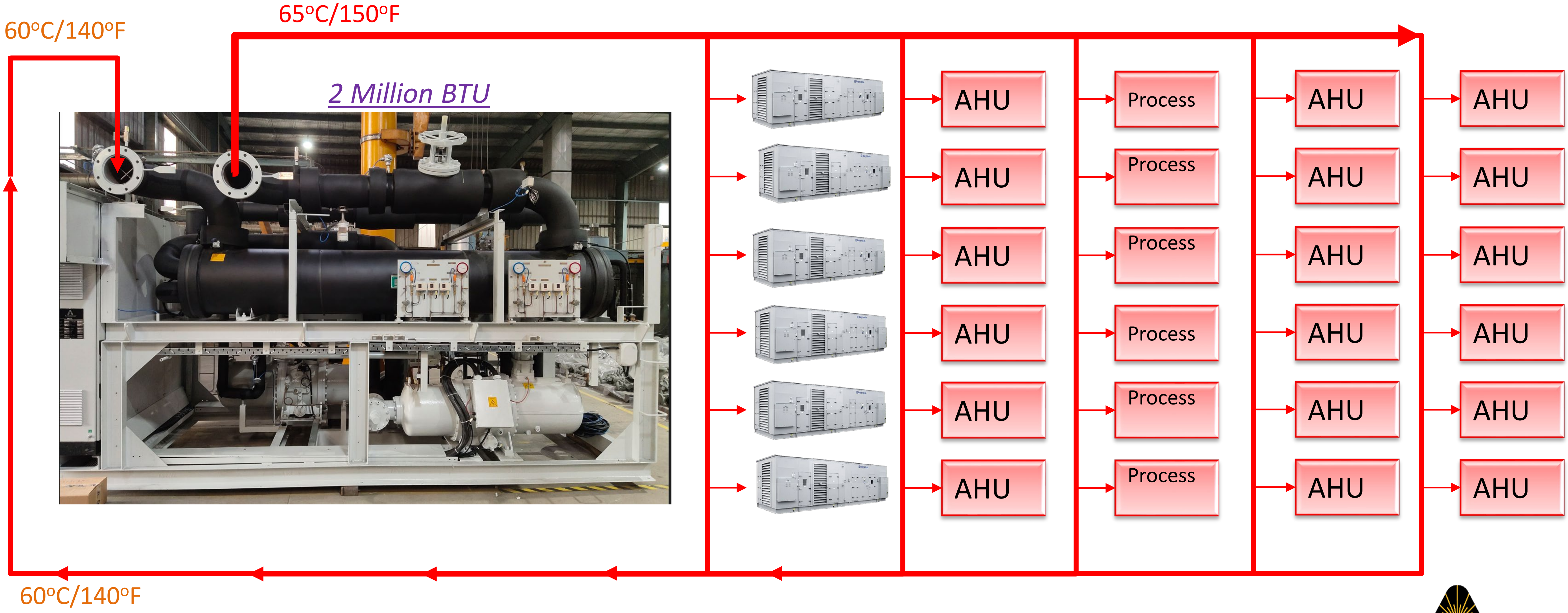
Heat Pump Integration!



- *Evaporation*
- *Drift*
- *Blowdown*

CENTRALISED HOT WATER SYSTEM

PHARMA



Armstrong®

COP – Coefficient Of Performance

560 kW Thermal
(2 Million BTU)

Heating COP = 2.8

Condenser Heating capacity / Electrical power to Compressor

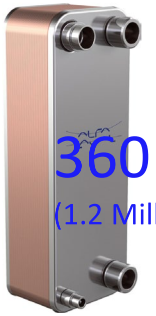
200 kW Electric

$ $ $

560 kW Thermal
(2 Million BTU)

+

$ $



360 kW Thermal
(1.2 Million BTU)

Combined COP = 4.6

Condenser + Evaporator capacity / Electrical power to Compressor

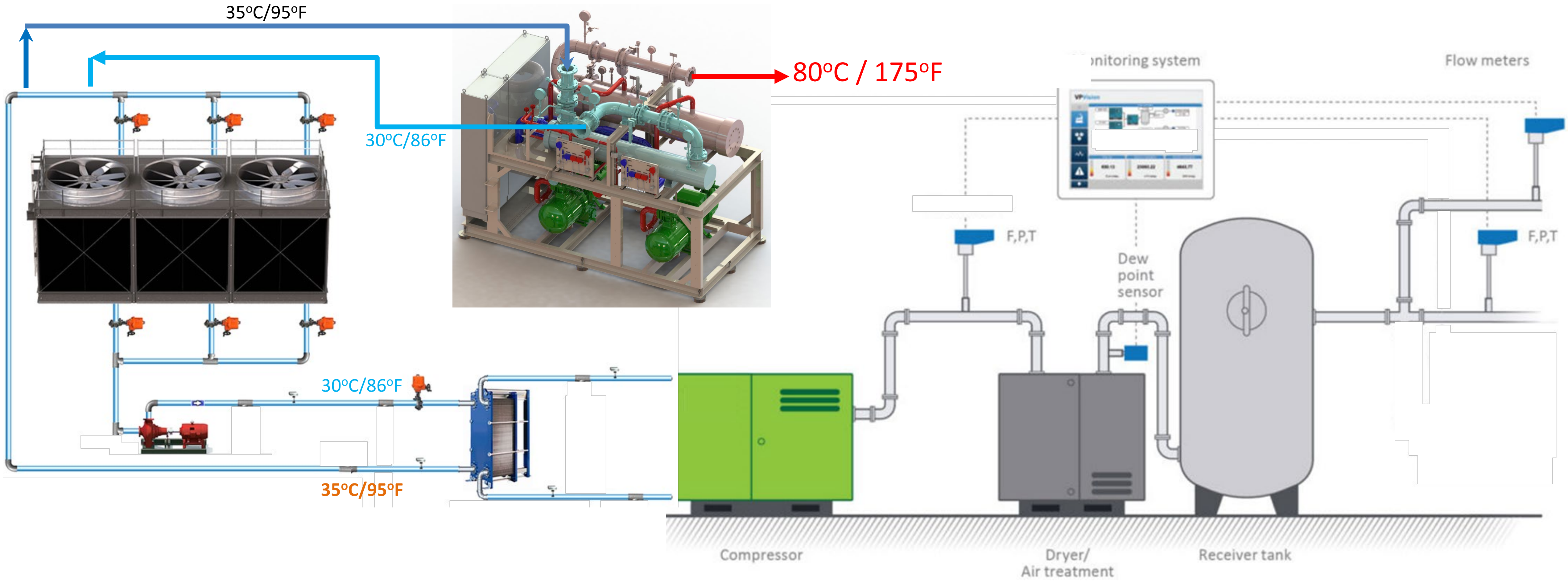
$

200 kW Electric

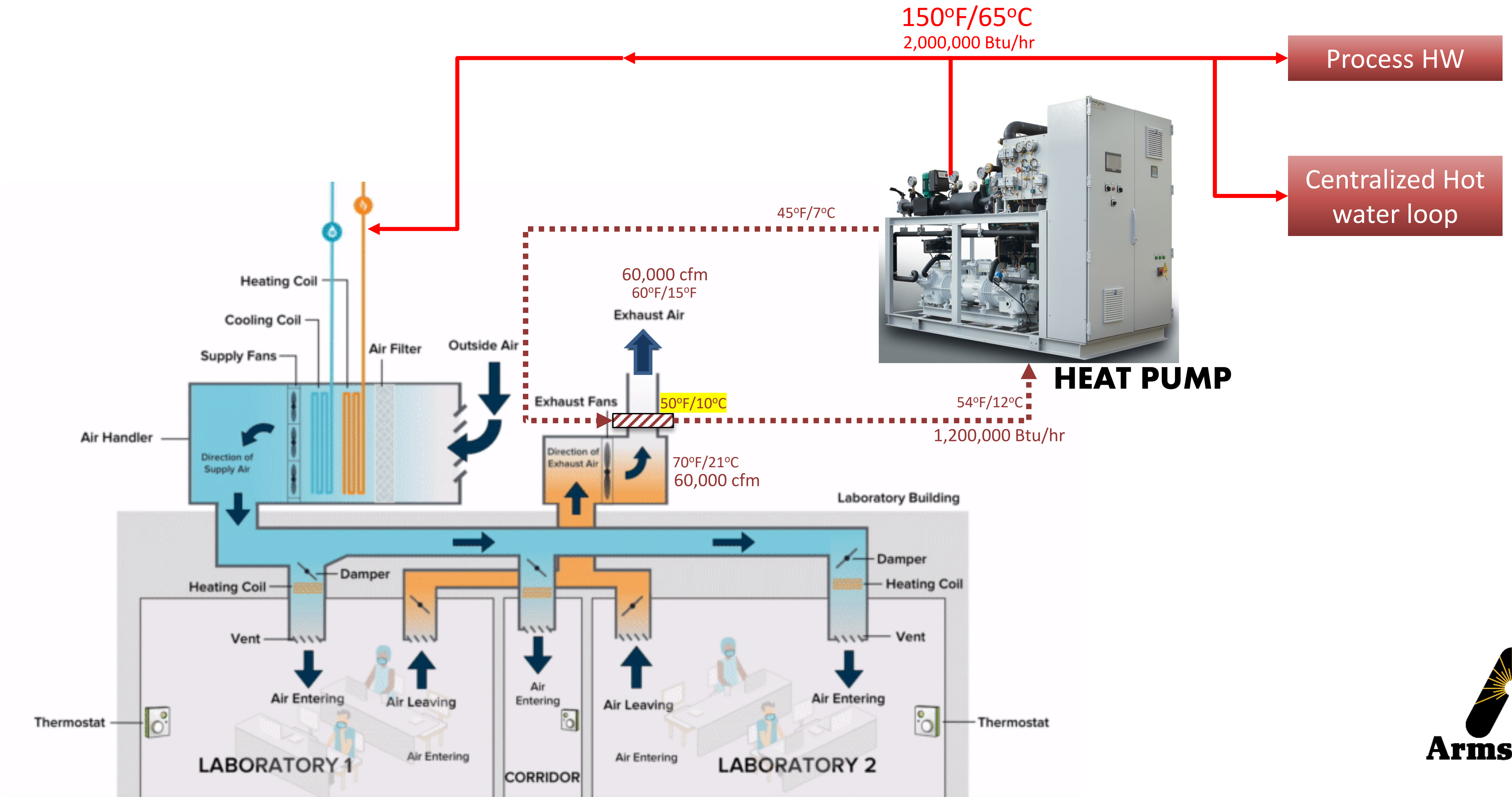
$$\left(\frac{\text{Electricity Cost}}{\text{Fuel Cost}} \times \text{Boiler/Heater Efficiency \%}\right) < \text{COP}$$

Armstrong®

Waste Heat from Air Compressor – Water Cooled!



Exhaust Air Heat Recovery



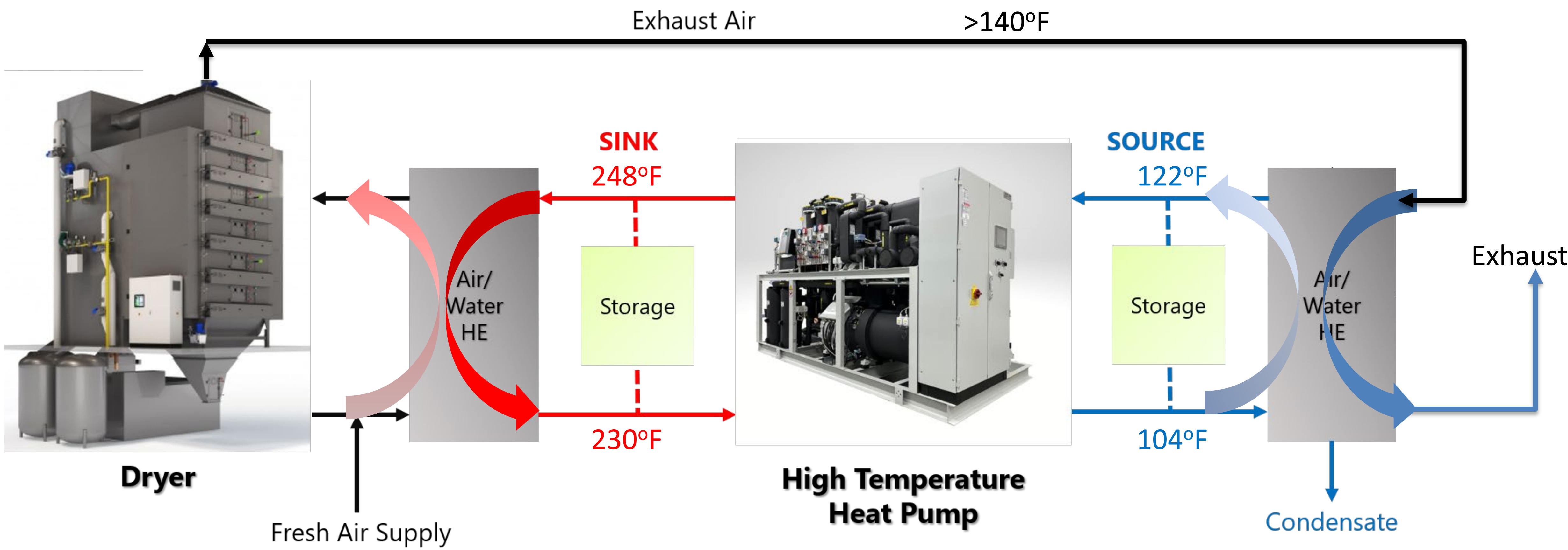
High Temperature Heat Pump - 248°F HW/Steam

2.5 MMBTU/hr Heat pump

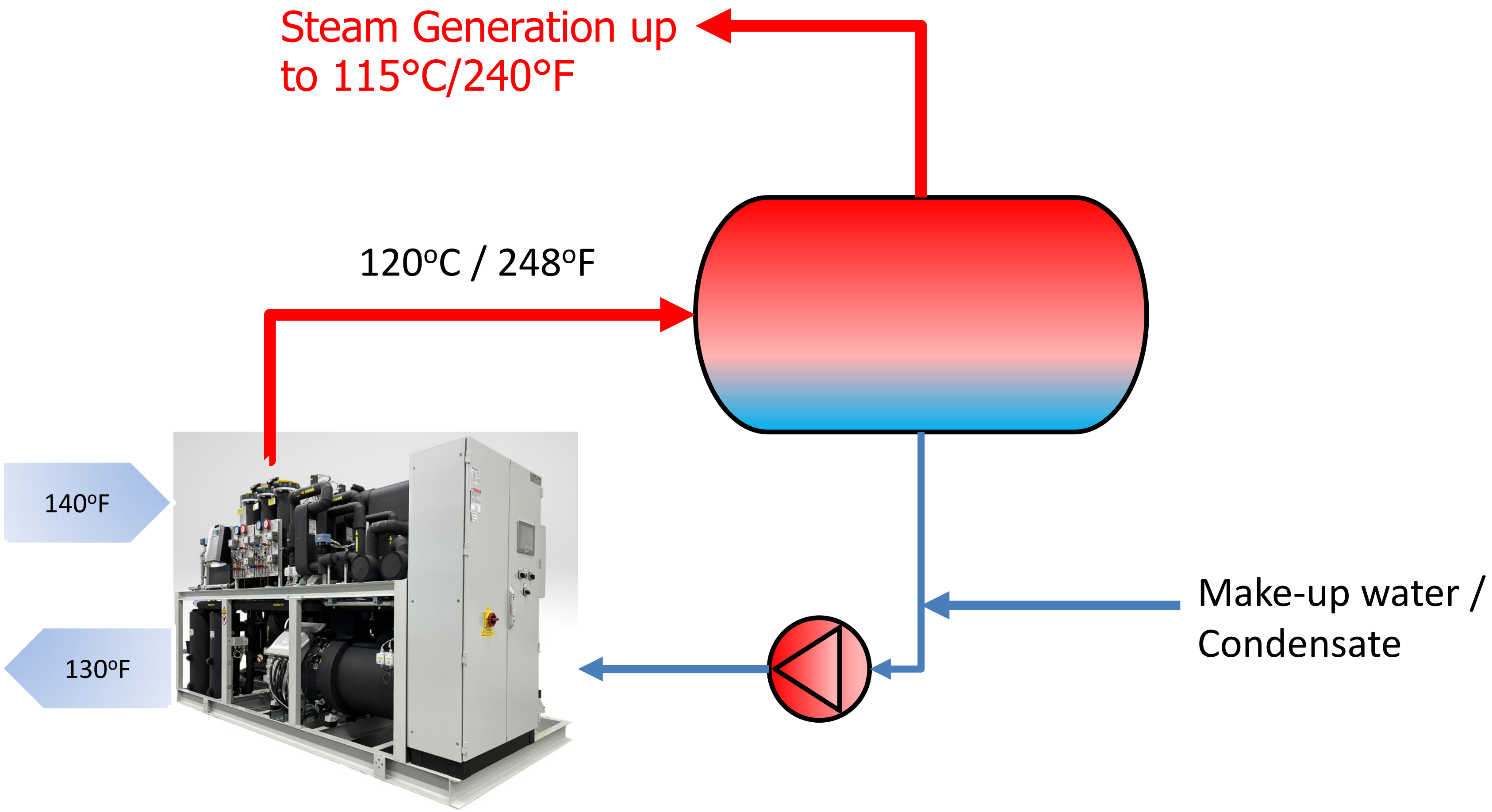
120°C
248°F

Armstrong

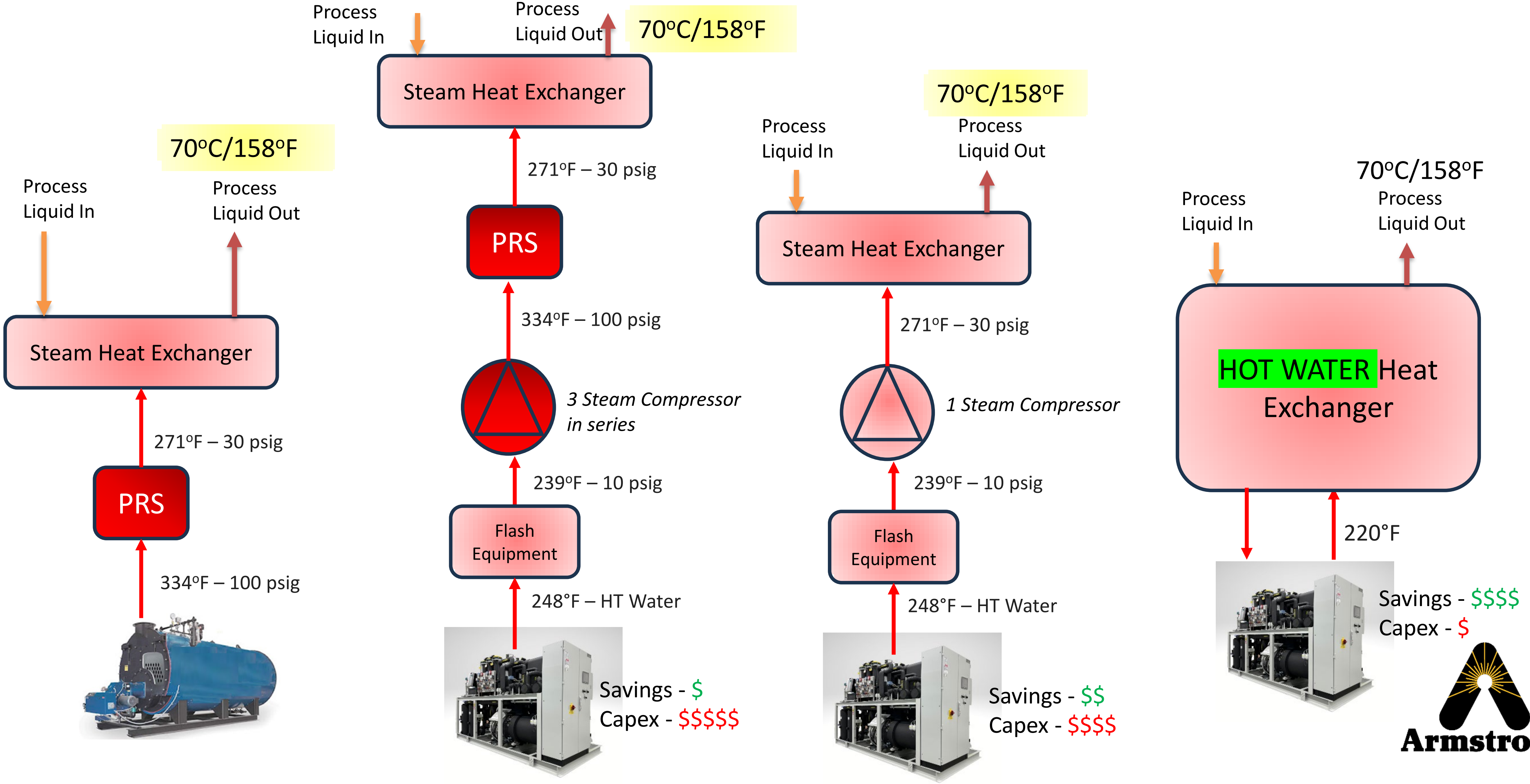
Electrified Dryer



Heat pump generating low pressure steam



Industrial Heat Pump



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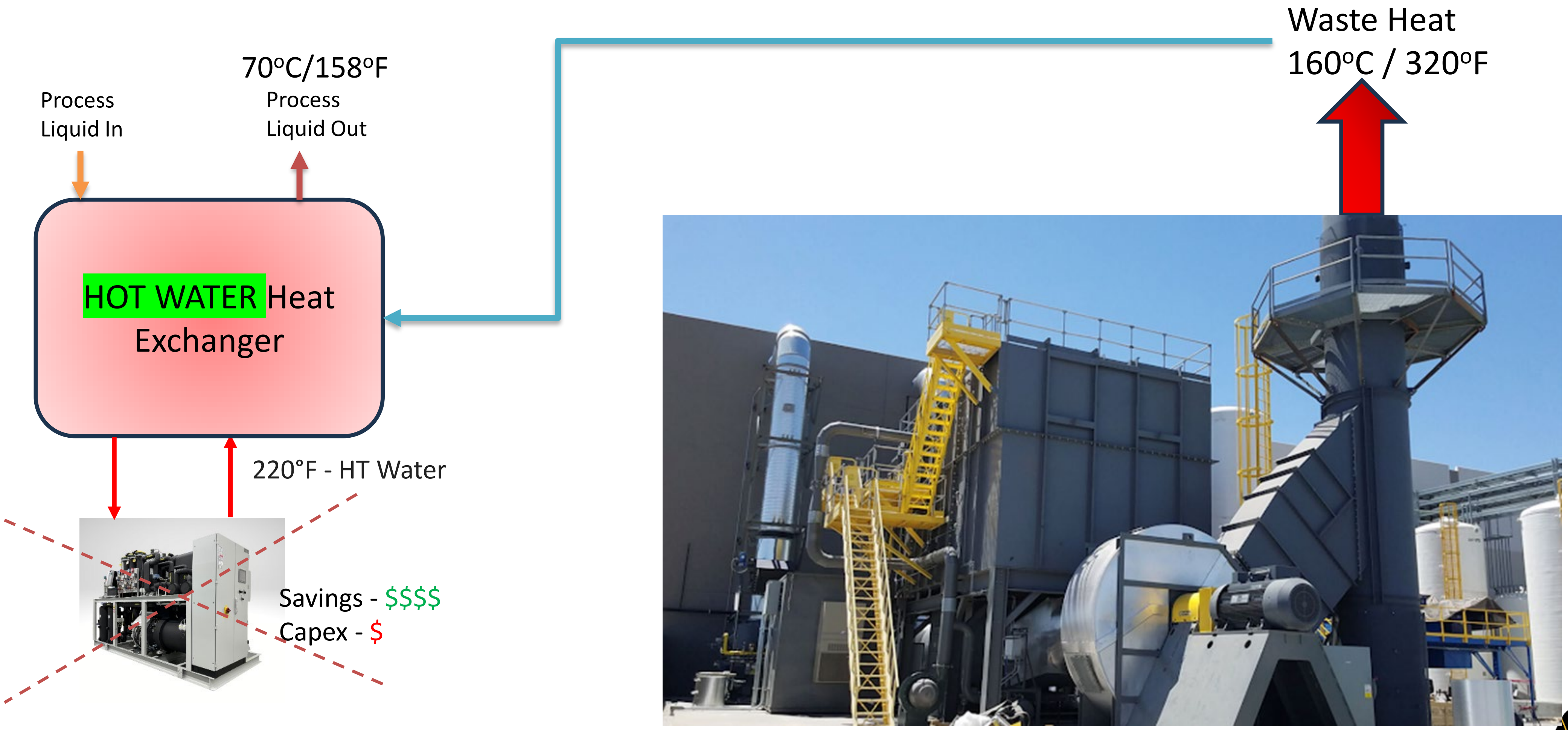
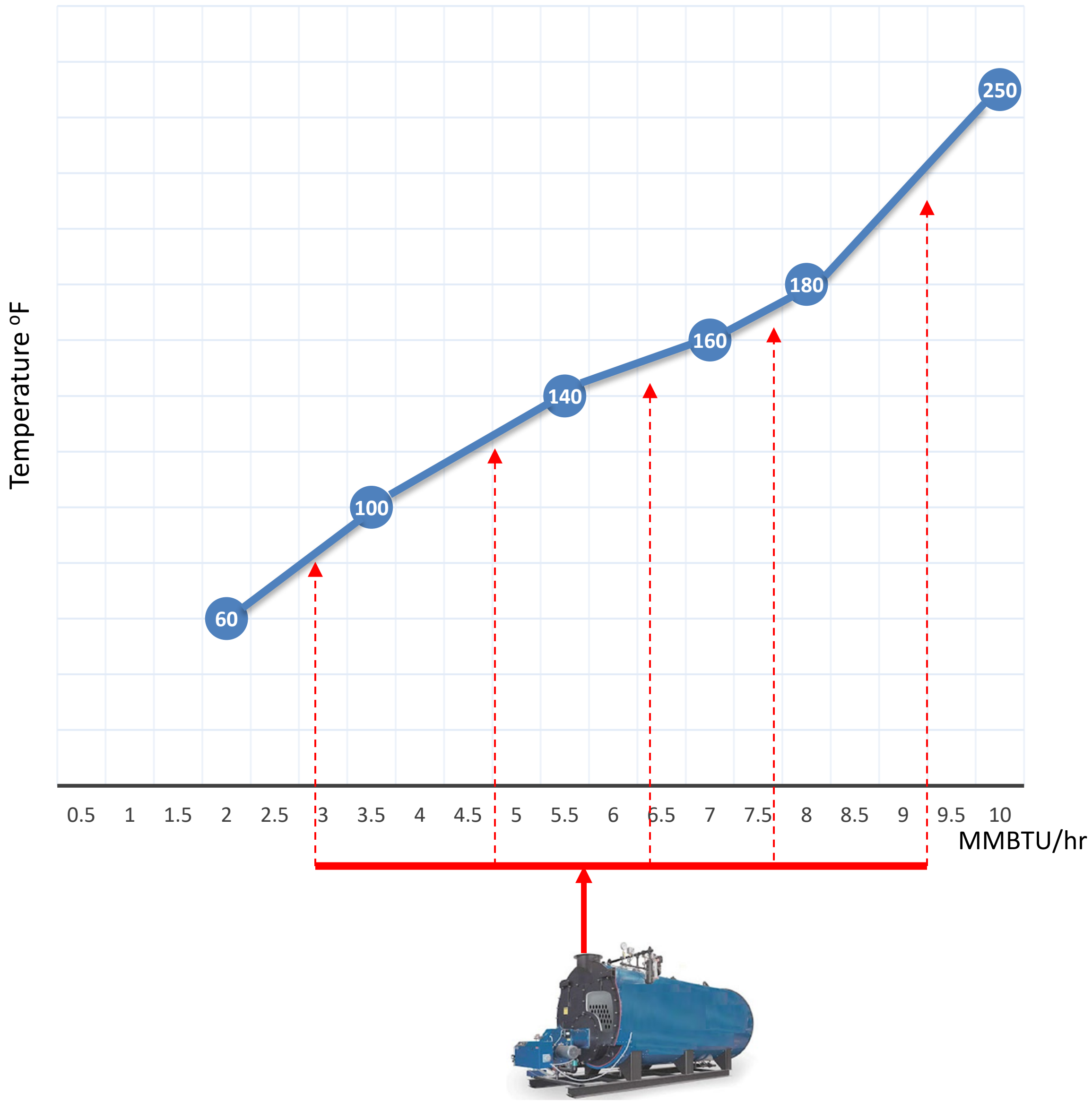
Heat Pump?



Process
Liquid In
70°C/158°F
Process
Liquid Out
Waste Heat
160°C / 320°F
HOT WATER Heat
Exchanger
220°F - HT Water
Savings - $$$$
Capex - $

Heat Sink



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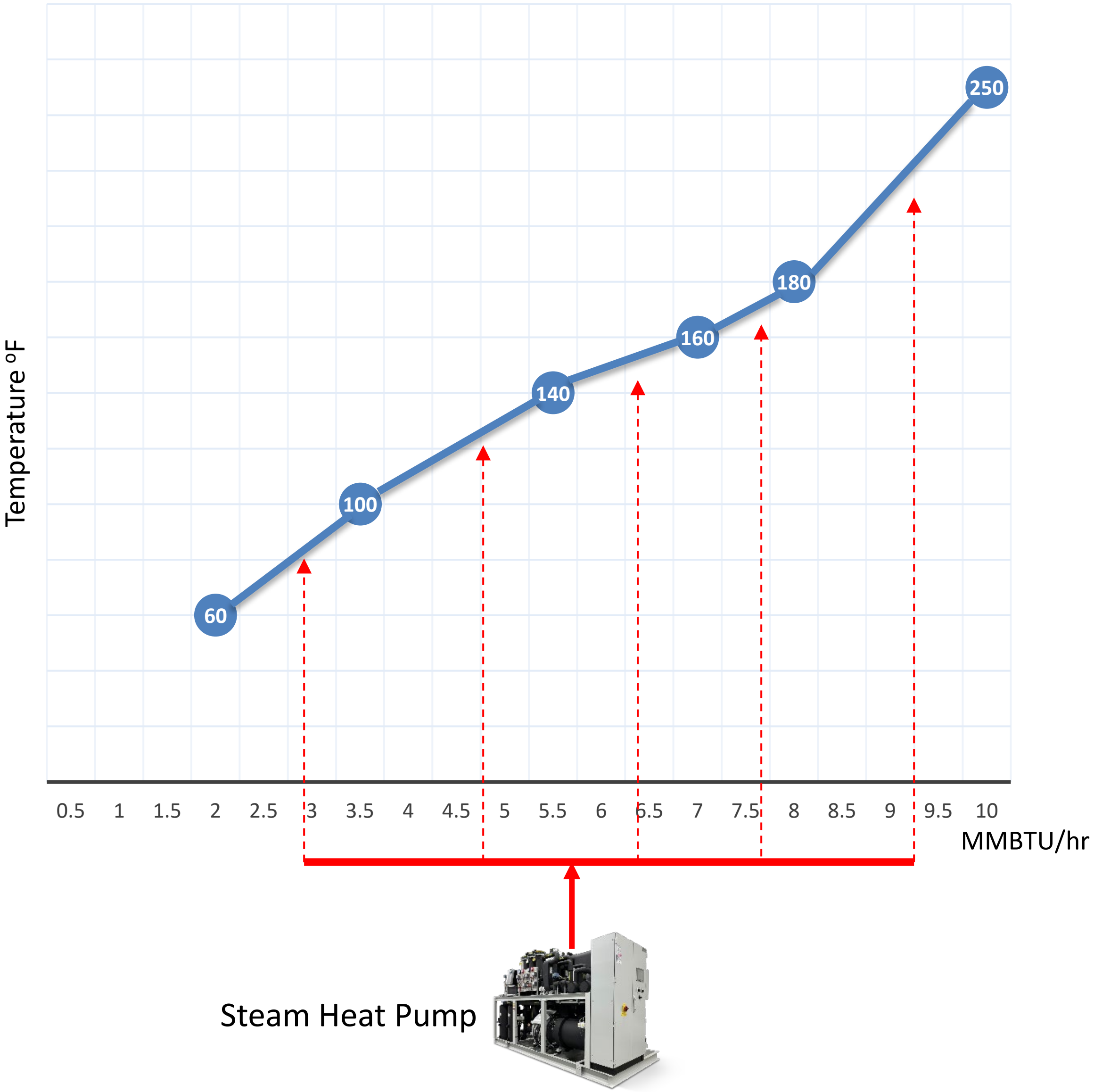
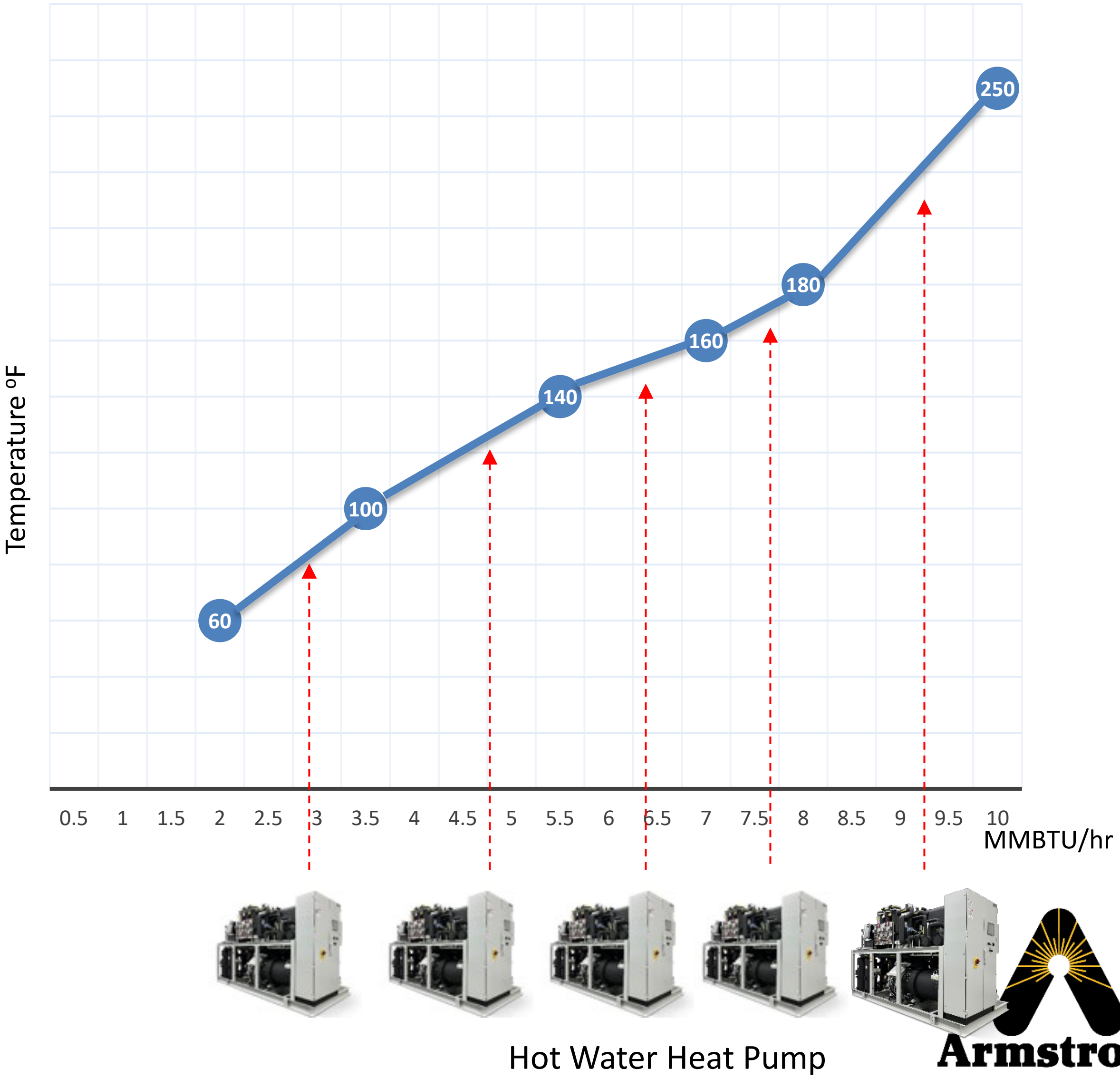
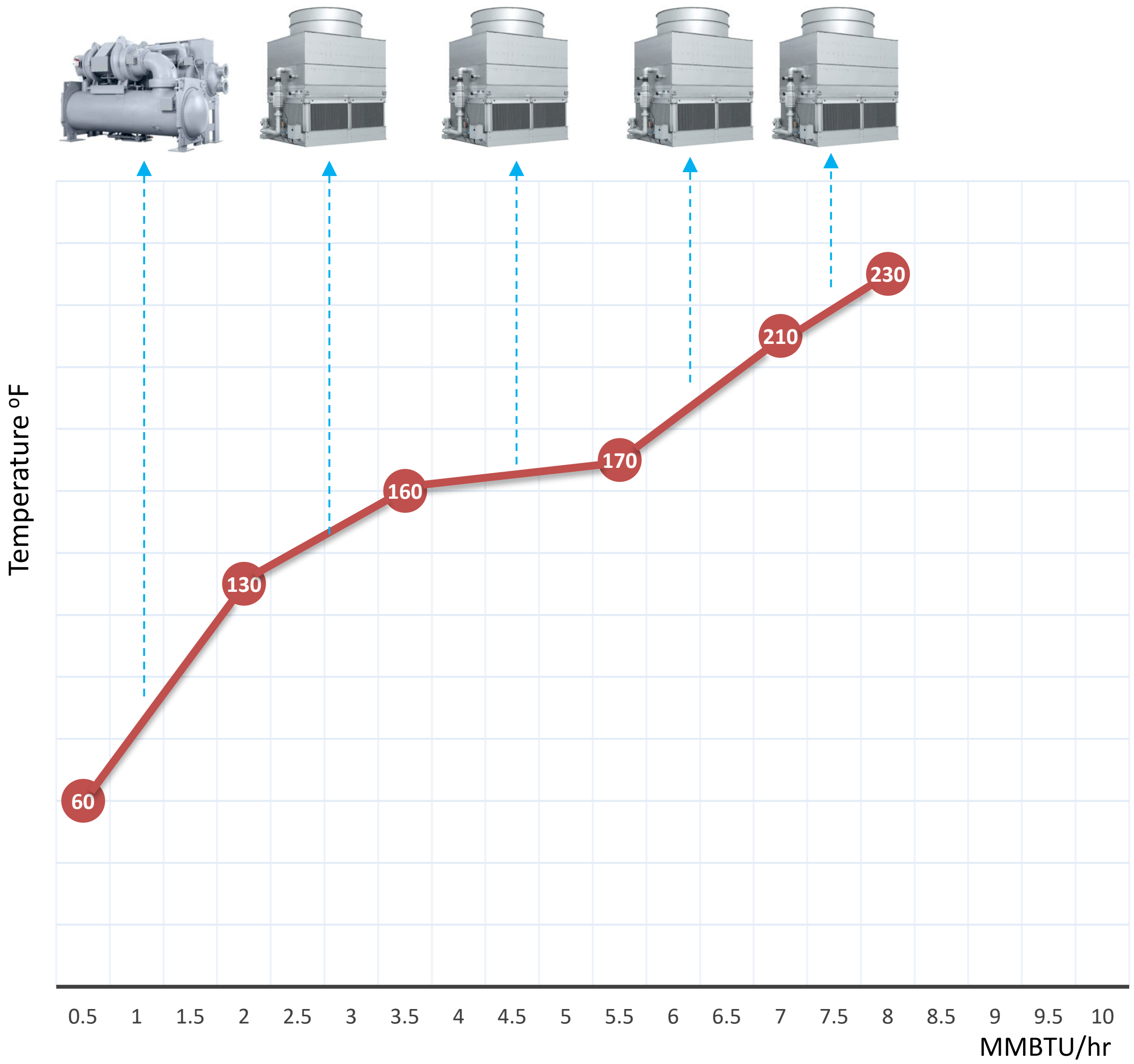
Heat Sink - Decarbonization

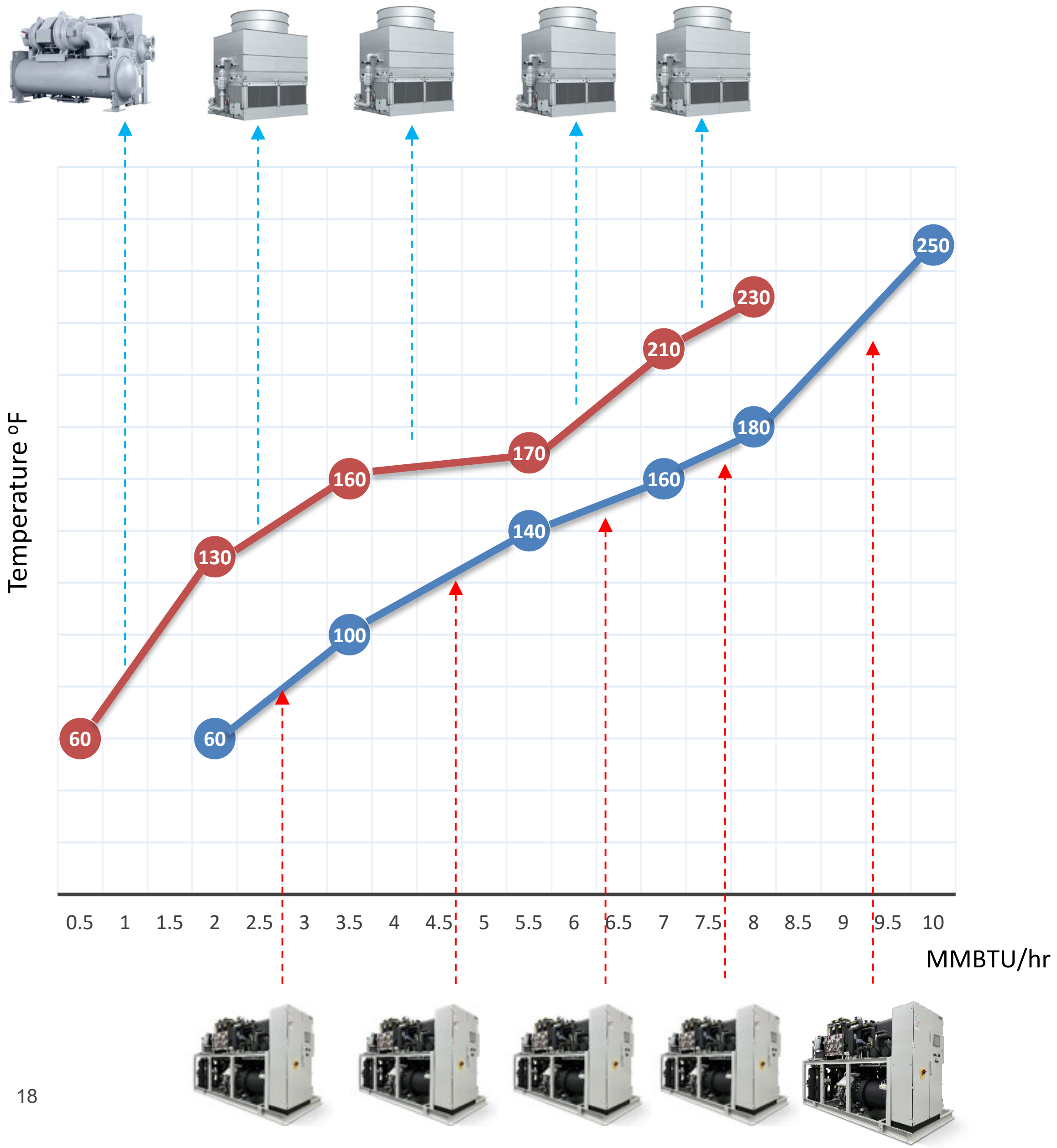


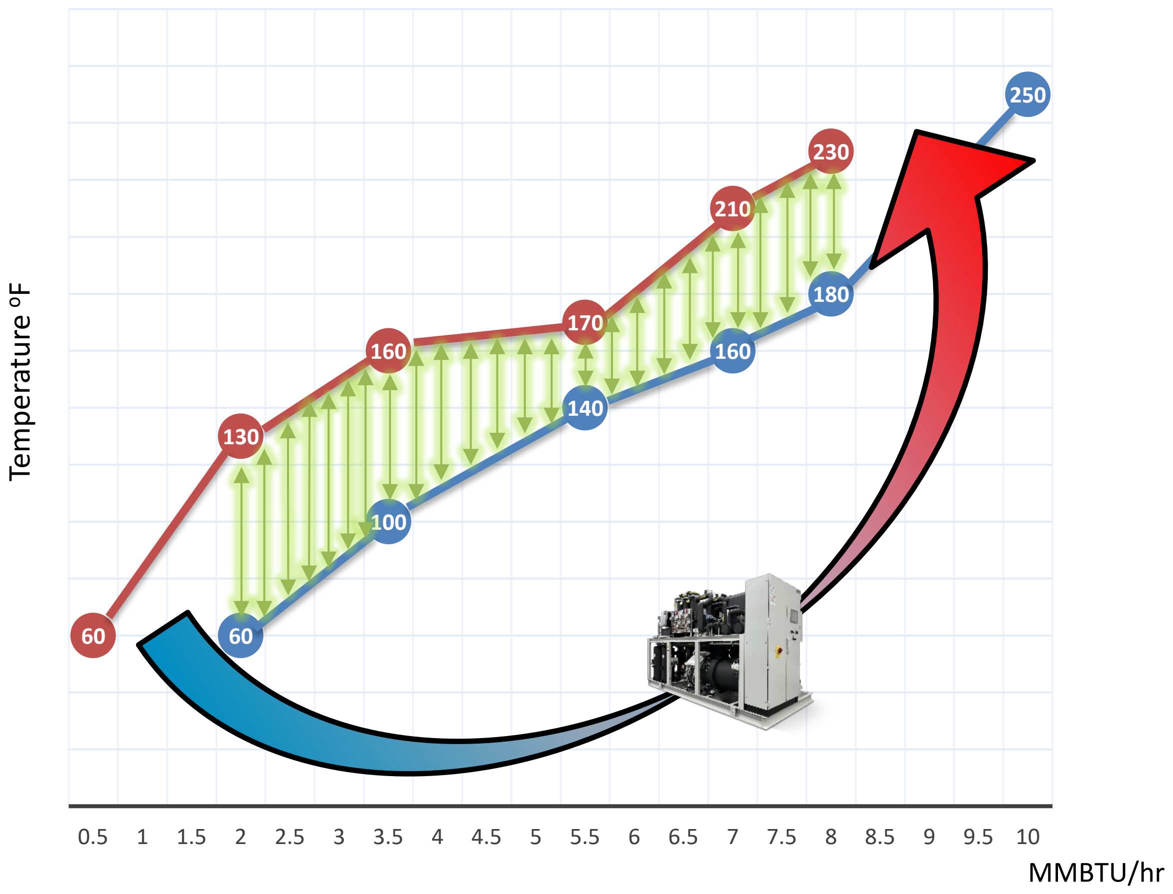


Waste Heat Source



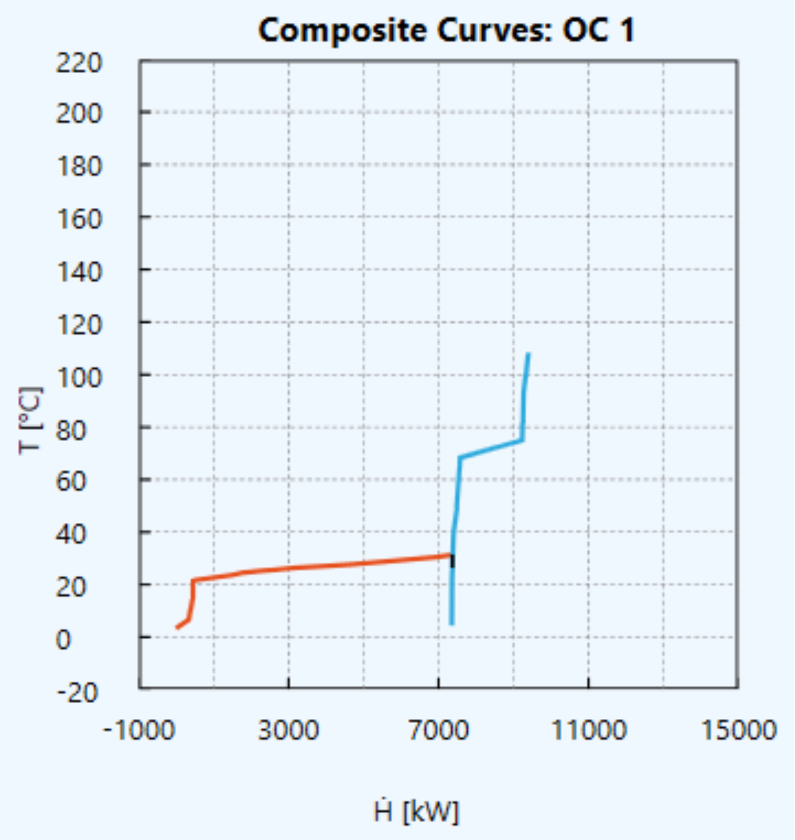
Pinch Methodology
Unlocking the full potential of heat recovery





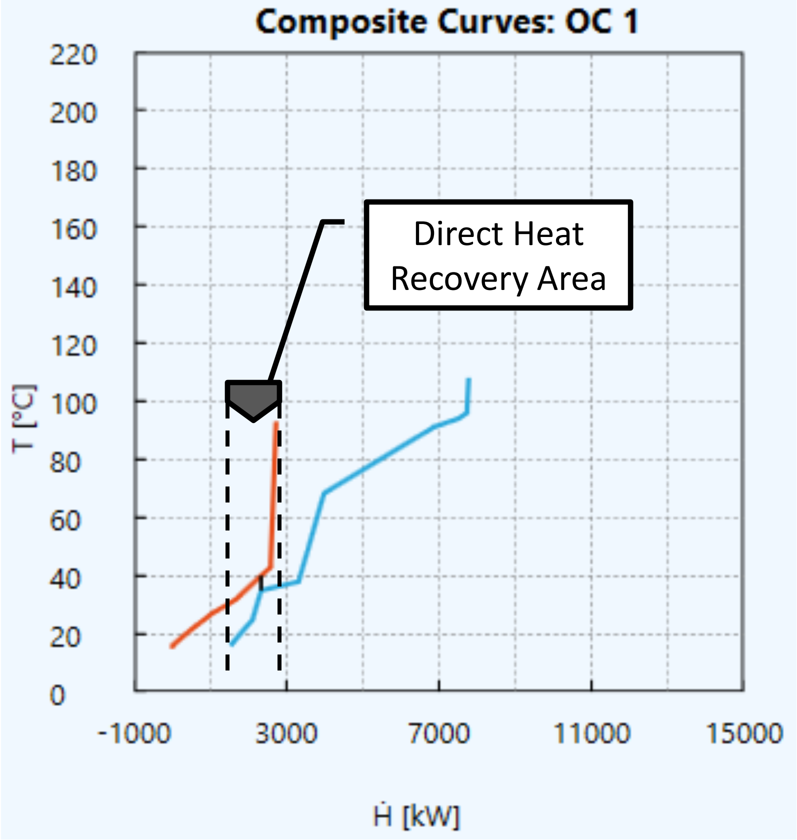
Pinch Composite Curve Analysis

Quebec Winter Base Case



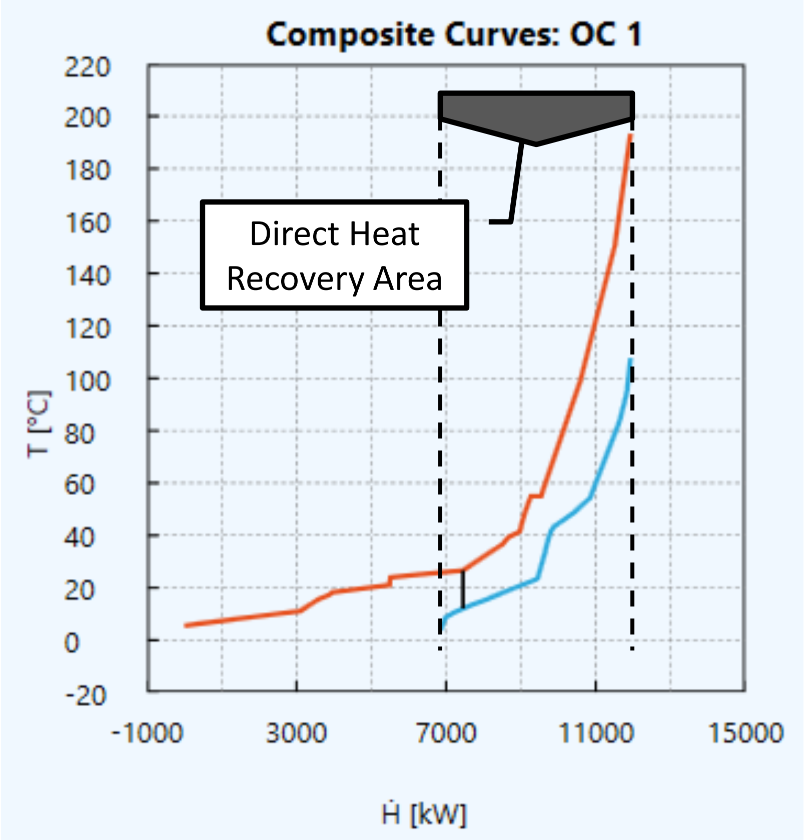
ΔTmin K	Pinch T °C	Heat Recovery [kW]	Hot Util [kW]	Cold Util [kW]
5.00	28.9	15.7	2'029.3	7'352.9
		-	-	-

Iowa Winter Base Case



ΔTmin K	Pinch T °C	Heat Recovery [kW]	Hot Util [kW]	Cold Util [kW]
5.00	37.5	1'200.9	5'049.0	1'528.1
		-	-	-

Louisiana Winter Base Case



ΔTmin K	Pinch T °C	Heat Recovery [kW]	Hot Util [kW]	Cold Util [kW]
14.54	19.4	5'075.0	0.0	6'853.2
		-	-	-

Armstrong®

Armstrong provides intelligent system solutions that improve utility performance, lower energy consumption, and reduce environmental emissions while providing an enjoyable experience.

ARMSTRONGINTERNATIONAL.COM

GEA Engineering for a better world.

German Robledo

Heat To Cool

Industrial Heat Pumps Roundtable

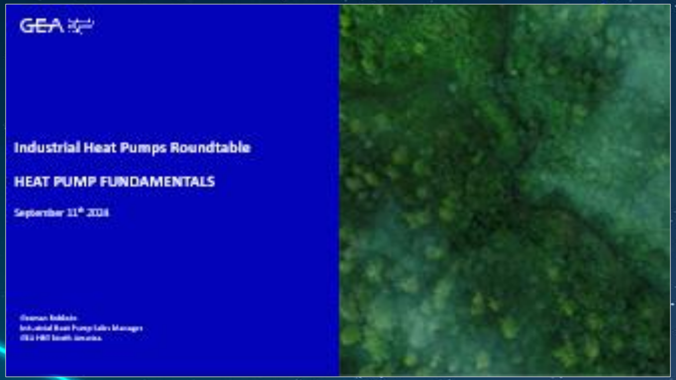
September 11th 2024

Using GEA heat pumps to cool our warming planet

GERMAN ROBLEDO
Heat Pump Sales Manager
GEA HRT North America

gea.com/heat-to-cool

Industrial Heat Pumps Roundtable



Industrial Heat Pumps Roundtable

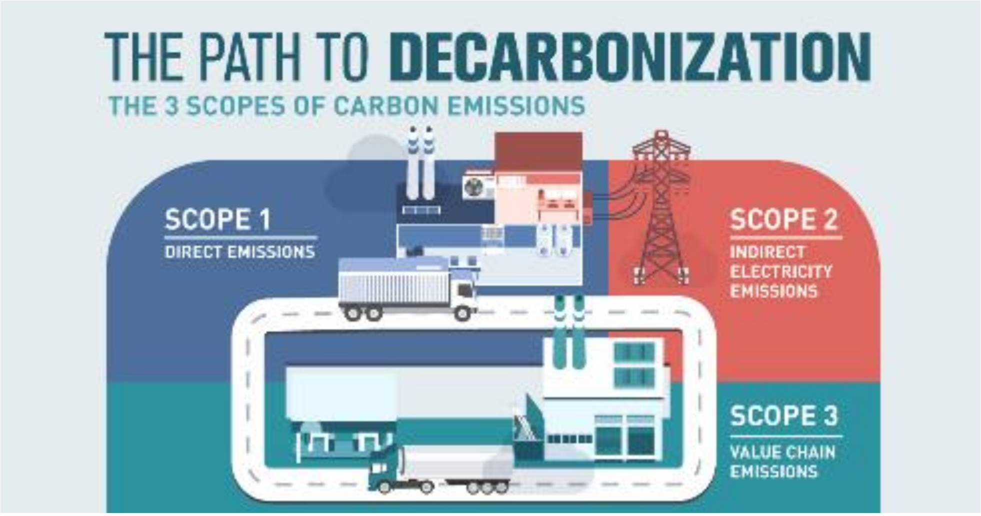
ELECTRIFICATION - DECARBONIZATION

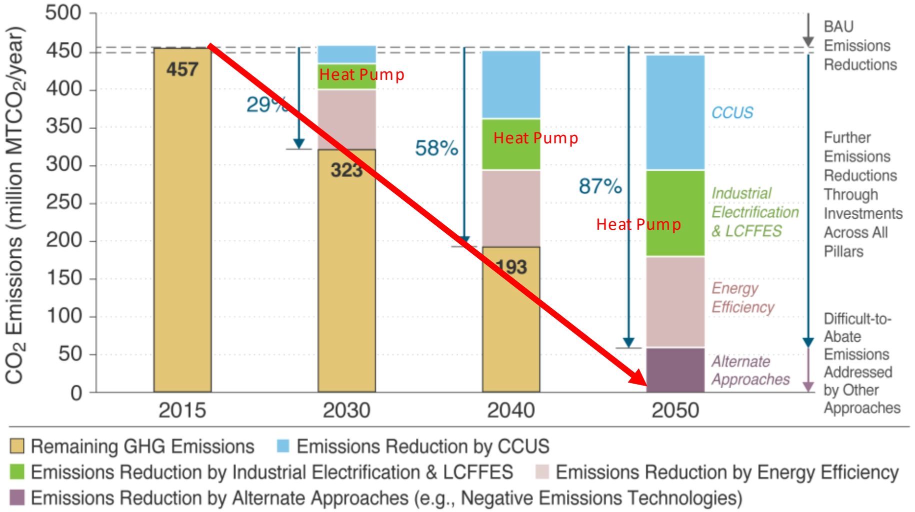
September 11th 2024

German Robledo
Industrial Heat Pump Sales Manager
GEA HRT North America

Four PILLARS for DECARBONIZATION

Why a Customer would get into a Heat Pump ??





Department of Energy | September 2022

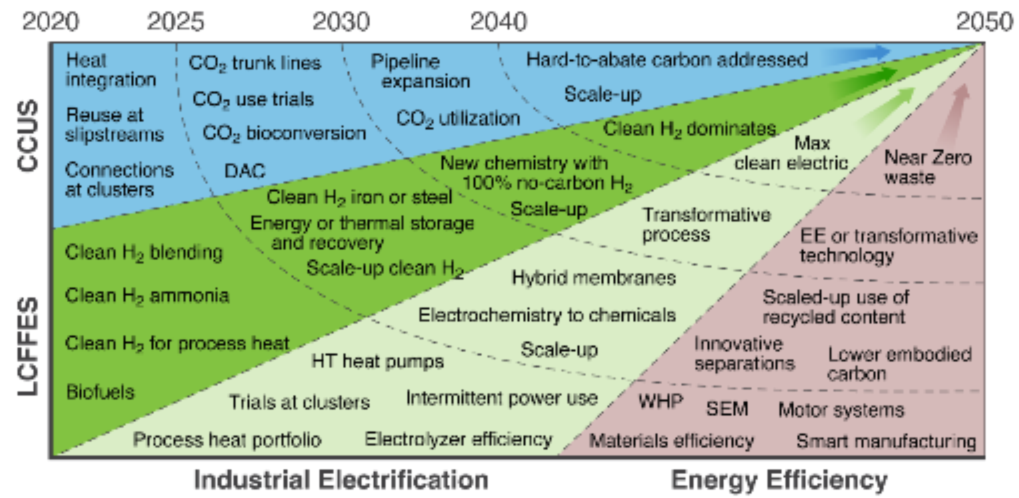
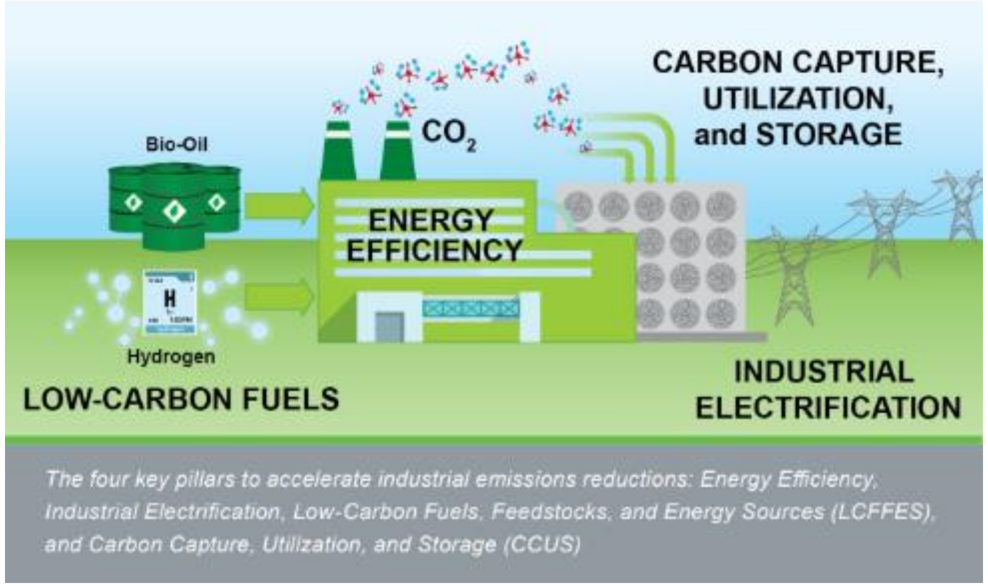
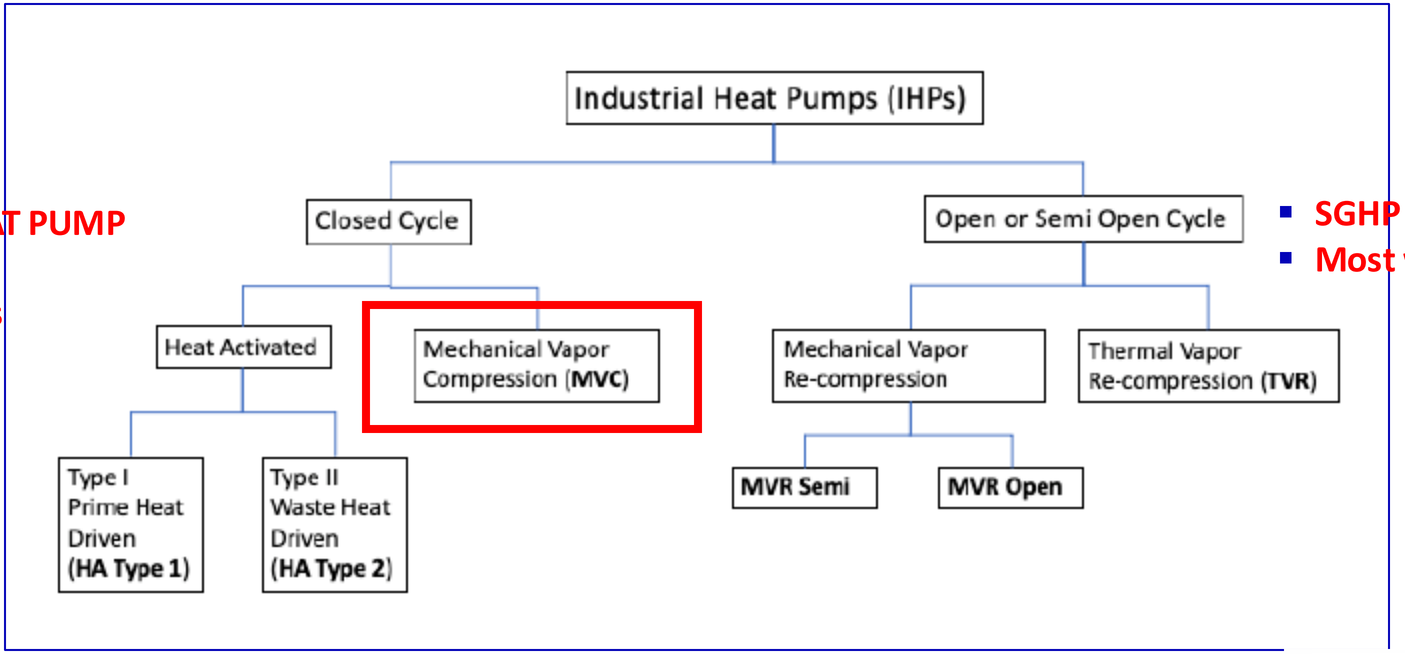


Figure 10. Landscape of major RD&D investment opportunities for industrial decarbonization across all subsectors by decade and decarbonization pillar.



HIGH TEMPERATURE - HEAT PUMP - TECHNOLOGIES

- **HTHP - HIGH TEMPERATURE HEAT PUMP**
- **Most will be Compression Cycles**

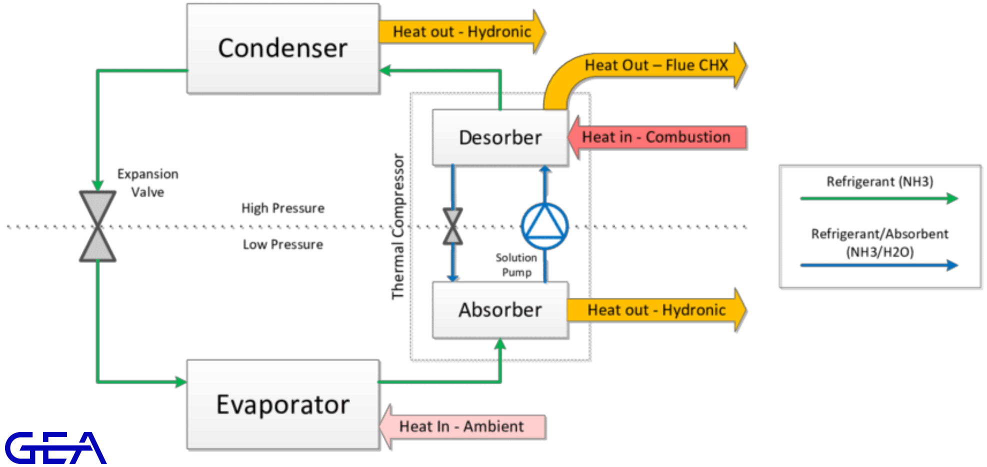


- **SGHP - STEAM GENERATING HEAT PUMP**
- **Most will be recompression of Steam**

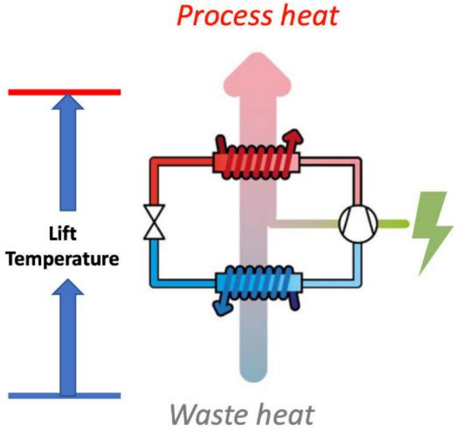
Can be driven by:

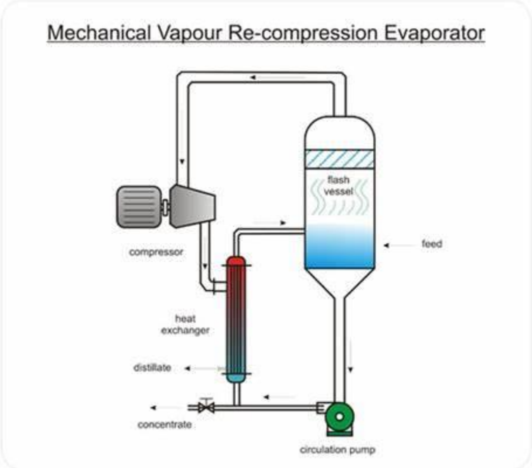
- Electricity (motor-driven)
- Steam (steam ejector)
- Heat-activated(sorption)

- **Absorption Cycles**

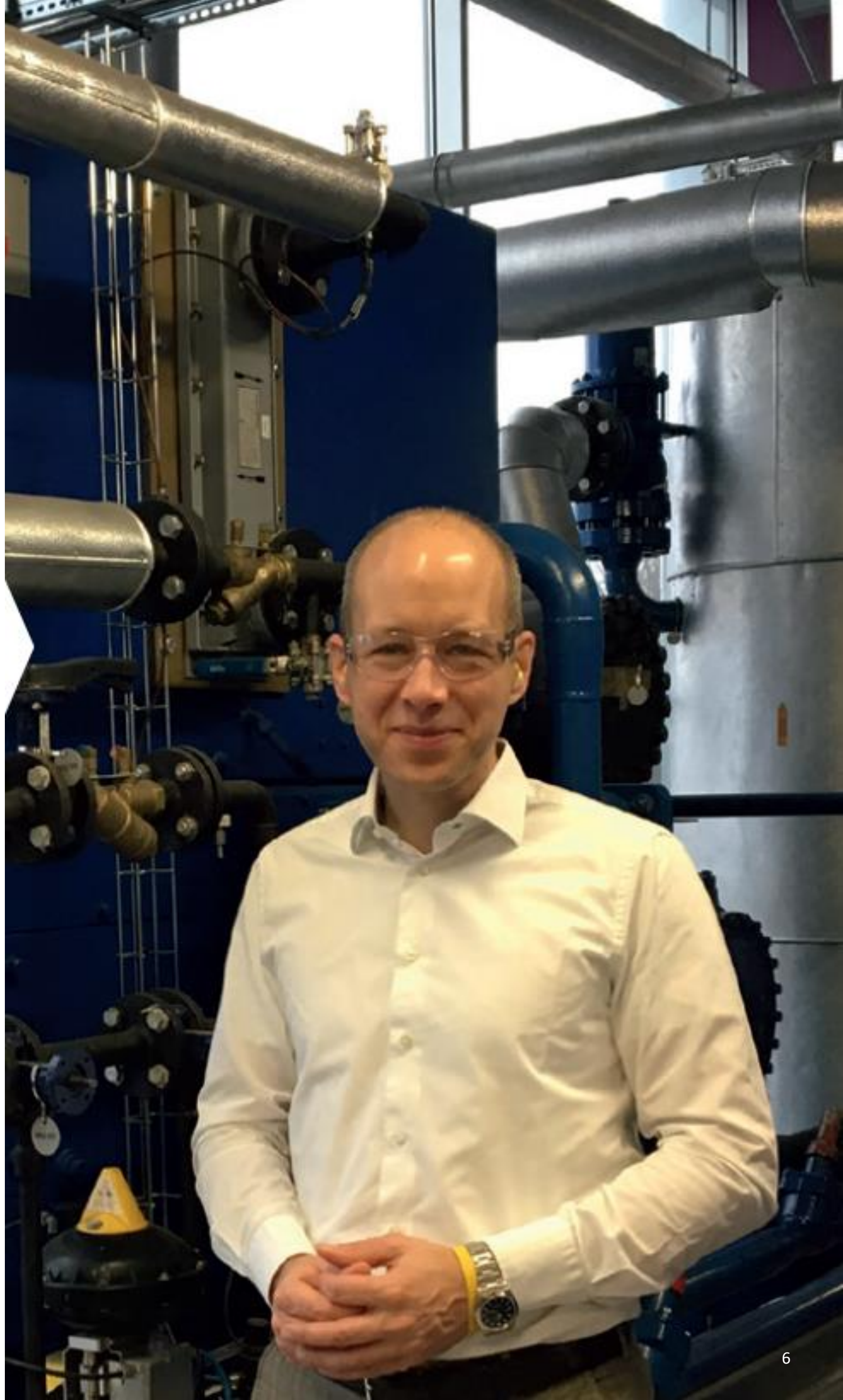


- **Compression Cycles**





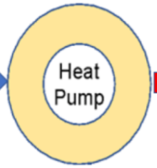
When it comes to heat decarbonization, heat pump is the game changer



Heat pumps

understanding your thermal needs!

Sector	Process	Typical Range
Brewing	Hot water, process cooling	5-60° C
Dairy	Hot water, process cooling	5-60° C
Paper	Waste water	30-100° C
Brick	Exhaust air, waste heat	50-90° C
Starch	Exhaust air	50-90° C
Chemical	Waste heat, process cooling	60-120° C
Sugar	Waste heat	60-120° C



Sector	Process	Typical Range
Brewing	Hot water or saturated streams	60-120° C
Dairy	Hot water or saturated streams	80-150° C
Paper	Preheating	80-160° C
Brick	Hot air	100-140° C
Starch	Hot air	140-160° C
Chemical	Hot water or saturated streams	80-159° C
Sugar	Hot water or saturated streams	80-160° C

- **HEATING**
- **COOLING**

	Product Intake		Defeathering / Pasteurisation / Blanching		Chilling / Freezing		Final Product	
POULTRY		+38 °C / 100.4°F	Defeathering 	+52 °C /125.6°F	Chilling 	+2 °C /35.6°F		+2 °C / 35.6°F
DAIRY BEVERAGE		+2 °C / 35.6°F	Pasteurisation 	+74 °C / 165.2°F	Chilling 	+2 °C / 35.6°F		+2 °C / 35.6°F
VEGETABLES		+20 °C / 68°F	Blanching 	+80 °C / 176°F	Freezing 	-18 °C / -0.4°F		-22 °C / -7.6°F

Heat/energy **in**

Heat/energy **OUT**

..The same Heat,
just the wrong
temperature!

GEA

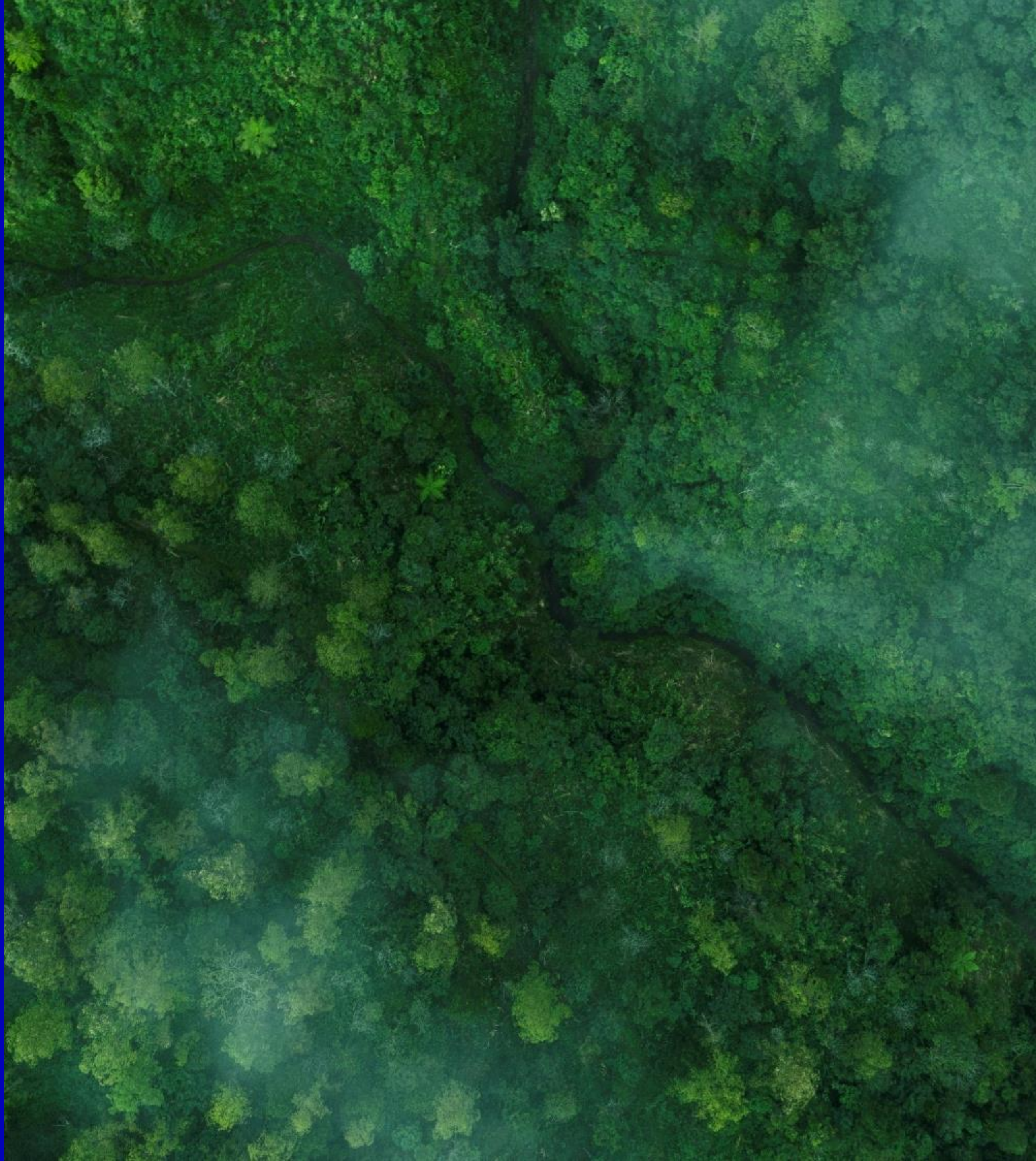
Engineering for a better world.

Industrial Heat Pumps Roundtable

HEAT PUMP FUNDAMENTALS

September 11th 2024

German Robledo
Industrial Heat Pump Sales Manager
GEA HRT North America



INDUSTRIAL HEAT PUMP - Fundamentals

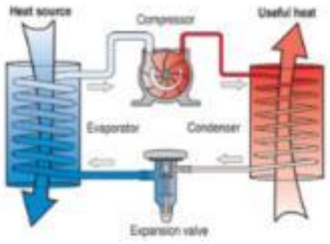
1. Industrial heat pumps are recovering excess heat from the same process as they are supplying to.

2. Both the heating demand and the cooling demand of a process can be covered, and performances get very high.

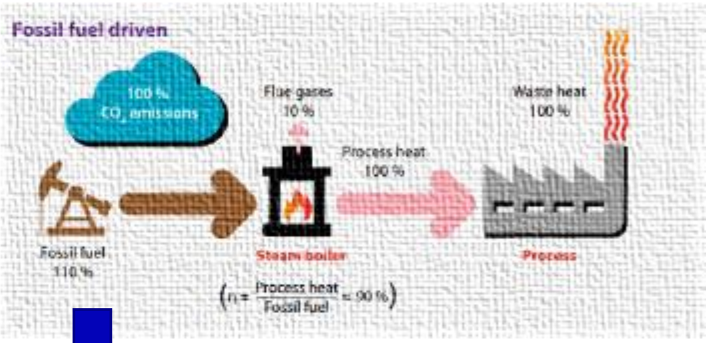
3. A Mechanical Vapor Compression Cycle, when used in Refrigeration it provides Cooling Benefit.

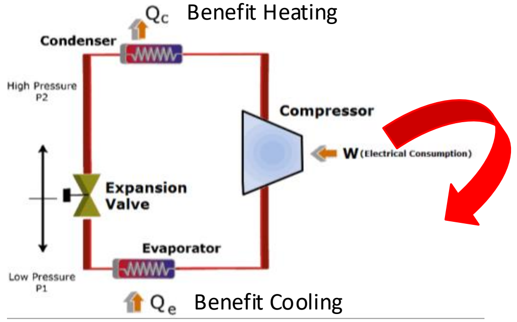
4. When used in Heat Pump, it provides Heating Benefit

5. Therefore, Heat Pump represents opportunities to provide Cooling and Heating at the same time with the same system.

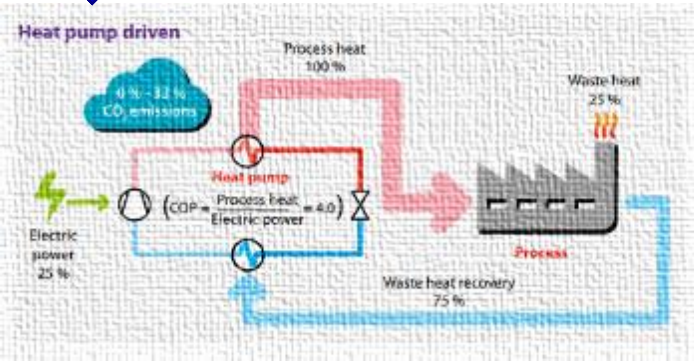


COMBUSTION ENERGY





ELECTRIC ENERGY



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Source: https://industrialheatpumps.nl/english/operating_principle/cop_heat_pump/ & Strengthening Industrial Heat Pump Innovation Decarbonizing Industrial Heat

HEAT SOURCE / HEAT PUMP CYCLE / HEAT SINK

1. **Air Source**
2. **Water Source**
3. **Ground Source**
4. **Industrial Waste Heat**
5. **Others**

Heat Source Loop

Heat Pump Package

Heat Pump Compressor

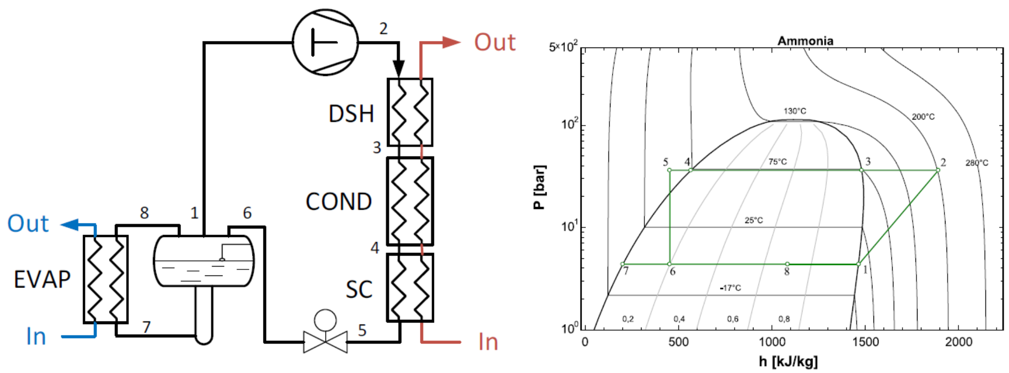


Figure 1: To the left: A scheme of a simple one-stage HP cycle. This configuration serves as reference case. To the right: A log(p)-h-diagram of the HP cycle under the given design conditions. The numbers indicates the state points, as given in the scheme.

Flooded Chiller

Hot Water Loop

Paper	Drying
	Boiling
	Bleaching
	De-inking
Food & Beverages	Drying
	Evaporation
	Pasteurization
	Sterilization
	Boiling
	Distillation
	Blanching
	Scalding
	Concentration
	Tempering
	Smoking
Chemical	Destillation
	Compression
	Thermoforming
	Concentration
	Boiling
	Bioreactions
Automotive	Resin Molding
Metal	Drying
	Pickling
	Degreasing
	Electroplating
	Phosphating
	Chromating
	Purging
Plastic	Injection Molding
	Pellets Drying
	Preheating
Mechanical Engineering	Surface Treatment
	Cleaning
Textiles	Coloring
	Drying
	Washing
	Bleaching
Wood	Glueing
	Pressing
	Drying
	Steaming
	Cocking
	Staining
	Pickling
Several Sectors	Hot Water
	Preheating
	Washing /Cleaning
	Space Heating

HEAT PUMP APPLICATIONS

Possible Industries Applications & Commercial Technology Available

Technology Readiness Level (TRL)

- conventional HP < 80°C / 176°F, established in the Industry
- commercial availbale HP 80-100° C / 176-212°F key technology
- prototype stauts, technology development, High Temperature Heat Pump HTHP 100-140°C/ 212-284°F
- laboratory research, functional models, proof of concept Very High Temperatura Heat Pump VHTHP >140°C / 284°F

Proven and Commercially Available Technology
up to 203°F / (95°C)
WATER

TEMPERATURES: 20 / 68, 40 / 104, 60 / 140, 80 / 176, 100 / 212, 120 / 248, 140 / 284, 160 / 320, 180 / 356, 200 / 392 (°C / °F)

Commercially Available — Proven Technology — AMMONIA R717 NH3 Up to 95°C (203°F)

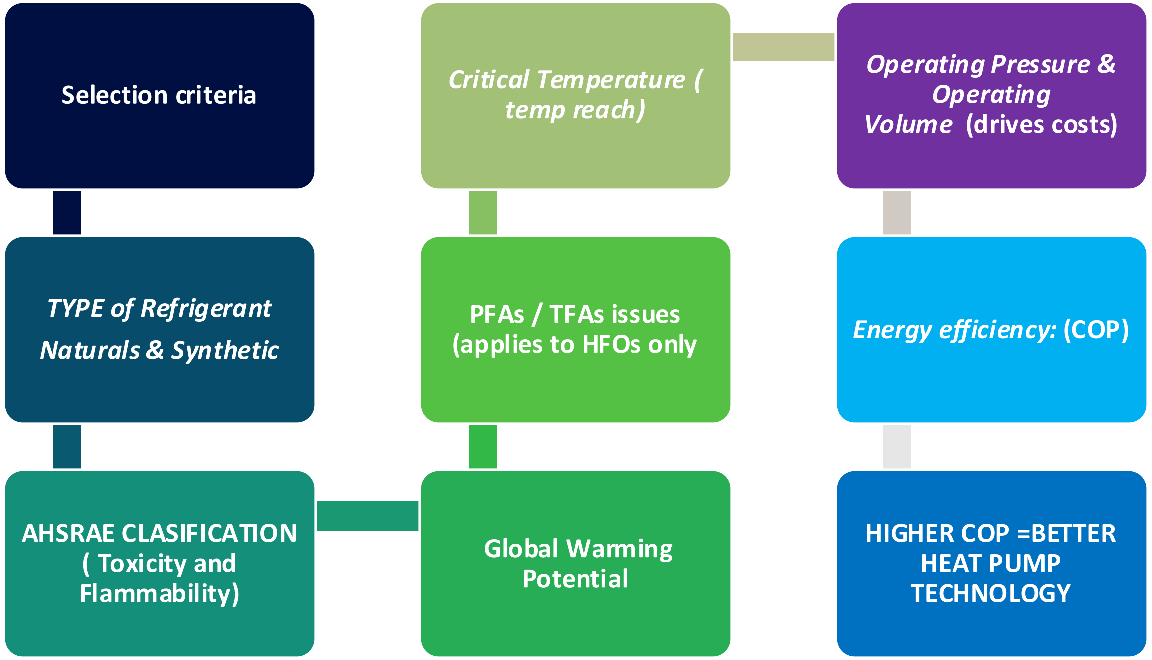
Prototype

LAB RESEARCH

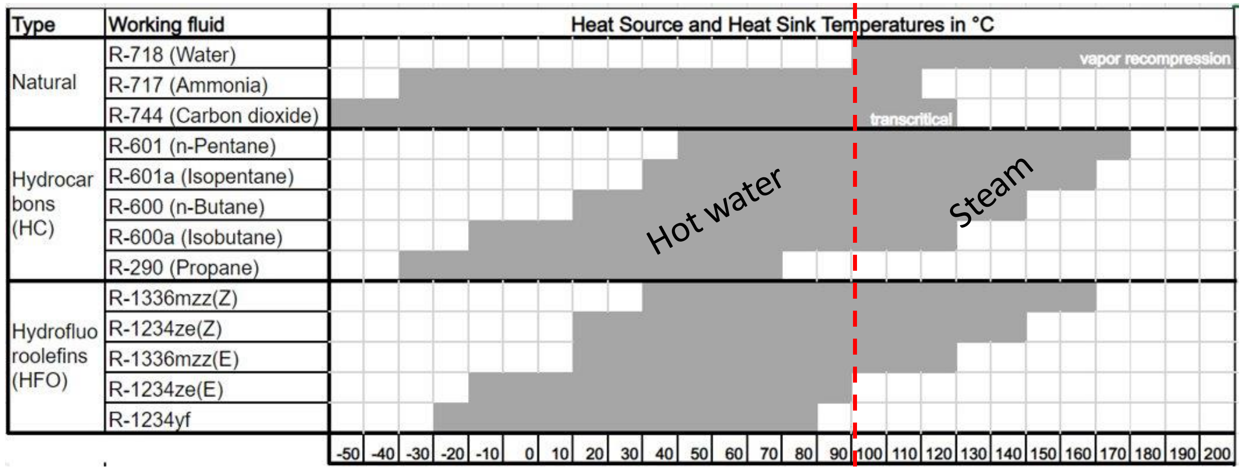
SECTOR	PROCESS	TEMP RANGE (°C)	TEMP RANGE (°F)
Paper	Drying	90-240°C	194-464°F
	Boiling	110-180°C	230-356°F
	Bleaching	40-150°C	104-302°F
	De-inking	50-70°C	122-158°F
Food &Beverages	Drying	40-250°C	104-482°F
	Evaporation	40-170°C	104-338°F
	Pasteurization	60-150°C	140-302°F
	Sterilization	110-140°C	230-284°F
	Boiling	70-120°C	158-248°F
	Distillation	40-100°C	104-212°F
	Blanching	60-90°C	140-194°F
	Scalding	50-90°C	122-194°F
	Concentration	60-80°C	140-176°F
	Tempering	40-80°C	104-176°F
	Smoking	20-80°C	68-176°F
Chemical	Destillation	100-300°C	212-572°F
	Compression	110-170°C	230-338°F
	Thermoforming	130-160°C	266-320°F
	Concentration	120-140°C	248-284°F
	Boiling	80-110°C	176-230°F
	Bioreactions	20-60°C	68-140°F
Automotive	Resin Molding	70-130°C	158-266°F
Metal	Drying	60-200°C	140-392°F
	Pickling	20-100°C	68-212°F
	Degreasing	20-100°C	68-212°F
	Electroplating	30-90°C	86-194°F
	Phosphating	30-90°C	86-194°F
	Chromating	20-80°C	68-176°F
	Purging	40-70°C	104-158°F
Plastic	Injection Molding	90-300°C	194-572°F
	Pellets Drying	40-150°C	104-302°F
	Preheating	50-70°C	122-158°F
Mechanical Engineering	Surface Treatment	20-120°C	68-248°F
	Cleaning	40-90°C	104-194°F
Textiles	Coloring	40-160°C	104-320°F
	Drying	60-130°C	140-266°F
	Washing	40-110°C	104-230°F
	Bleaching	40-110°C	104-230°F
Wood	Glueing	120-180°C	248-356°F
	Pressing	120-170°C	248-338°F
	Drying	40-150°C	104-302°F
	Steaming	70-100°C	158212°F
	Cocking	80-90°C	176-194°F
	Staining	50-80°C	122-176°F
	Pickling	40-70°C	104-158°F
Several Sectors	Hot Water	20-110°C	68-230°F
	Preheating	20-100°C	68-230°F
	Washing /Cleaning	30-90°C	86-194°F
	Space Heating	20-80°C	68-176°F

GEA

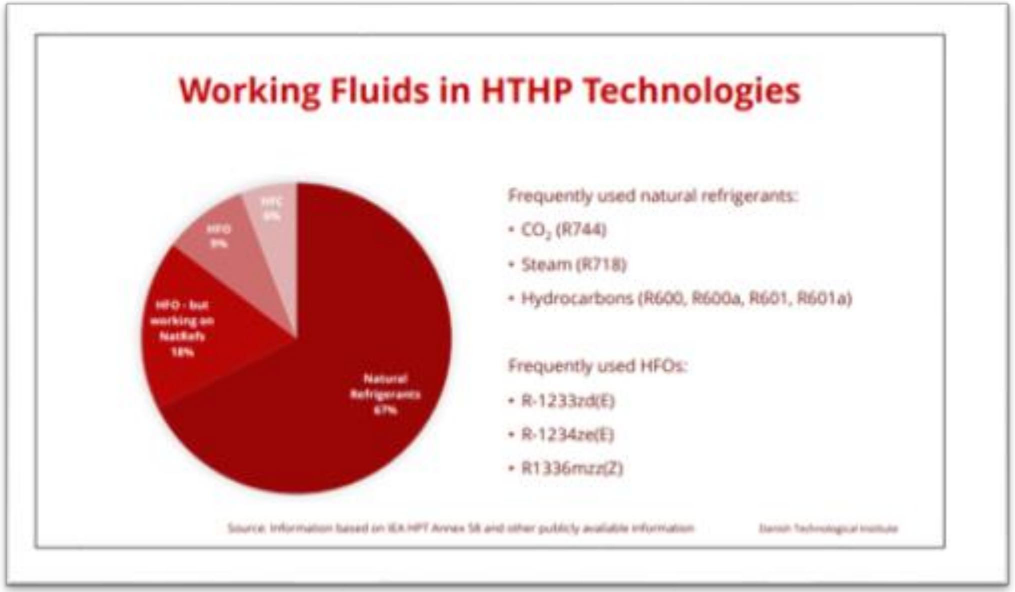
Type of Refrigerant to be used on Heat Pumps



- **HTHP - HIGH TEMPERATURE HEAT PUMP**



- **SGHP - STEAM GENERATING HEAT PUMP**

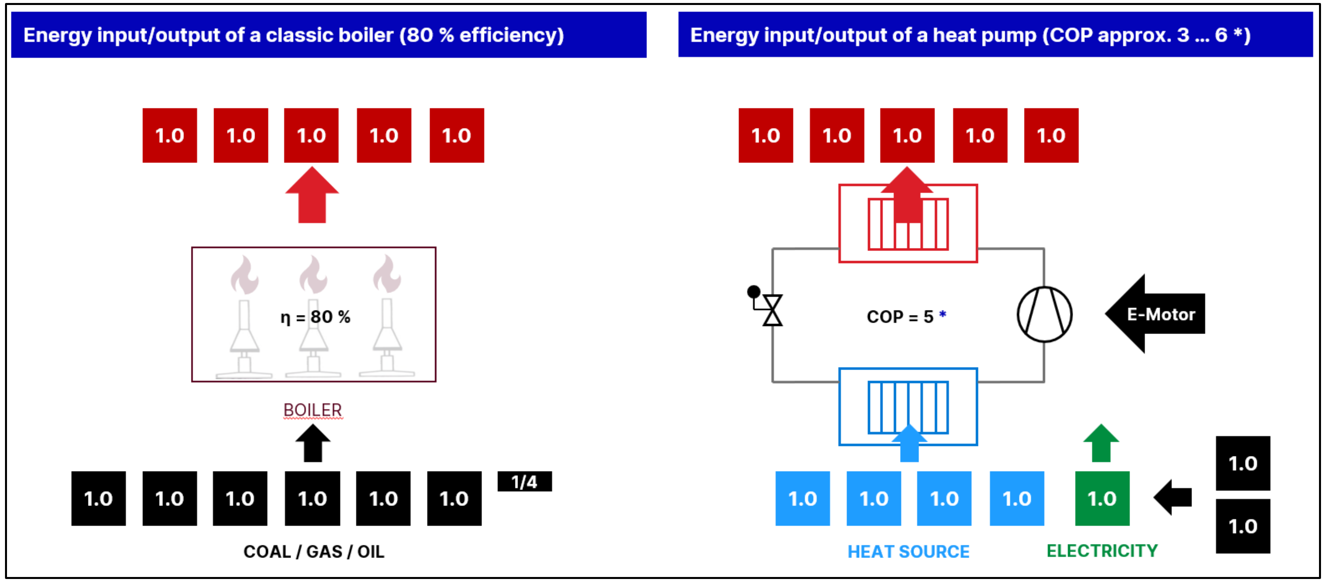


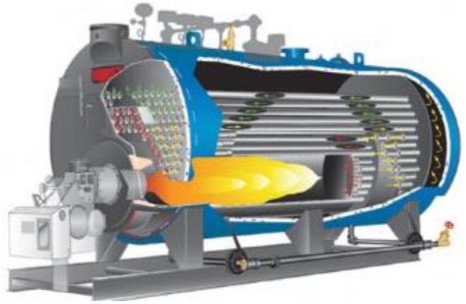
	COP	Heating rating (kW) [1]	Heating Rating MBTU	Volumetric heating (kW/[m³/h])	Volumetric Heating MBTU / [CFM]	GWP
R-717	3,43	5125	17,486.5	1,75	3.51	0
R134a	2,71	2578	8,796.14	0,88	1.76	1430
R152	2,95	3014	10,283.7	1,03	2.06	124
R1234yf	2,37	2510	8,564.12	[illegible]	1.72	4
R1234ze	2,59	2201	7,509.81	0,75	1.51	7
R1336mzzZ	3,00	518	1,746.94	0,18	0.37	7
R600a	3,03	1720	5,868.64	0,59	1.18	3
R515B	2,39	1996	6,810.35	0,68	1.36	293

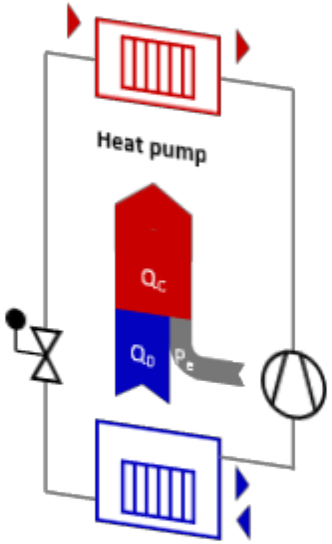
- PFAs and TFAs related

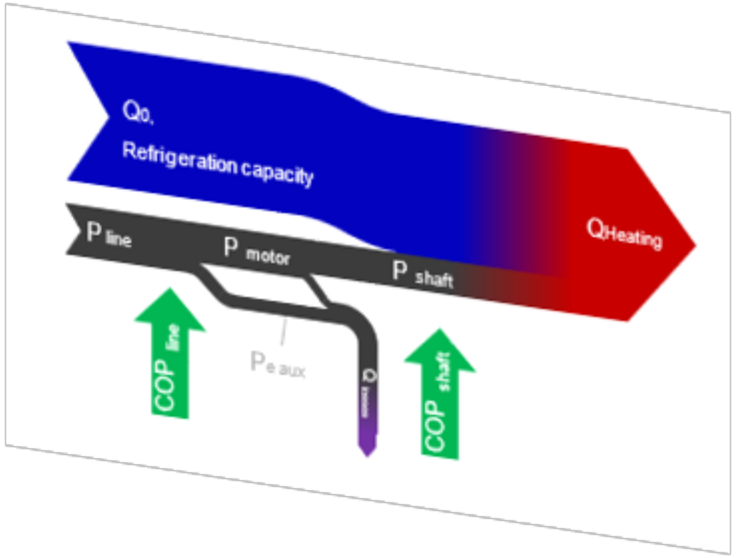
Heat Pump Efficiency (COP)

BOILER EFFICIENCY vs HEAT PUMP EFF









- EFFICIENCY is related to TEMPERATURE LIFT
  - Low temp lifts, HIGH Eff
  - High temp lifts, LOW Eff
- COP line means or considers motor eff, VFD eff, any other electric component eff
- COP shaft is on the compressor, not to be used since does not consider all other eff of whole heat pump, this will be higher than line.
- Some manufacturers just provide SHAFT rather than LINE.

COST ENERGY COMPARISONS and IHP COP (COP of 3 & 4)

Boiler Calculations				
Heat Capacity REQUIRED	kW	1500	5,115 MBH	
Boiler Efficiency	%	80%	COP = 0.8	
Running hours	h / y	5,400	18 hours/day * 6 days * 50 weeks / year	
Energy Consumed	BOILER	1,875	**HEAT PUMP**	500 kW
Naturals Gas Burned	kWh/y	10,125,000	Electricity Used kW / y	**2,700,000**

HEAT PUMP COP 3.0

Assuming $800 / kW (800*1500)
Capital Cost of Heat Pump = $1,200,000
does not include other associated costs

$$Spark\ Gap = \frac{Electric\ Price\ \left(\frac{\$}{kW}\right)}{Gas\ Price\ \left(\frac{\$}{kW\ h\ eq}\right)}$$

$$Spark\ Gap = \frac{Electric\ Price\ \left(\frac{\$0.10}{kW}\right)}{Gas\ Price\ \frac{\$10}{MMBtu} * \left(\frac{1\ MMBtu}{293\ kW\ h}\right)} = 2.9$$

Cost / kw/h	Electricity kW/h	Natural Gas Price $/MMBtu	Natural Gas kW/h	Spark Gap (Ratio)	Boiler OPEX / y	Heat Pump OPEX / y	OPEX Diff / y	Return Of Investment (ROI) years
Lubbock, TX	$ 0.0481	$ 6.33	$0.0216	2.2	$218,700	$ 129,870	$ 88,830	14
Nevada	$ 0.1047	$ 10.84	$0.0370	2.8	$374,625	$ 282,690	$ 91,935	13
Trulock, CA	$ 0.1129	$ 13.60	$0.0464	2.4	$469,800	$ 304,830	$ 164,970	7
Fort Morgen, CO	$ 0.0432	$ 8.44	$0.0288	1.5	$291,600	$ 116,640	$ 174,960	7
Jerome, ID	$ 0.0543	$ 5.74	$0.0196	2.8	$198,450	$ 146,610	$ 51,840	23

*ROI does not include other savings that may help reduce ROI, like water savings and others

	MW/ h	MW /h
Lubbock, TX	$ 48.10	$ 21.60
Nevada	$ 104.70	$ 37.00
Trulock, CA	$ 112.90	$ 46.40
Fort Morgen, CO	$ 43.20	$ 28.80
Jerome, ID	$ 54.30	$ 19.60

$$Savings\ on\ Energy\ Costs = \frac{Gas\ Price - \left(\frac{kw\ Price}{IHP\ COP}\right)}{Gas\ Price}$$

Savings on Energy Costs	
≈	26%
≈	6%
≈	19%
≈	50%
≈	8%

COP Increase:

- Improves Heat Pump OPEX
- Improves Energy Savings
- Reduces the Payback time
- SPARK GAP has to be lower than COP for HEAT PUMP Effectiveness

- Scoping Test:

IHP COP	**3.0**	**4.0**
Gas Boiler Efficiency	80%	80%
Efficiency Ratio (IHP COP/ Boiler eff)	3.75	5.0

- If Spark Gap < 3.75 or 5.0 will save utility cost
- If Spark Gap = 3.75 or 5.0 will break even on utility costs
- If Spark Gap > 3.75 or 5.0 will spend more on utilities

Boiler Calculations				
Heat Capacity REQUIRED	kW	1500	5,115 MBH	
Boiler Efficiency	%	80%	COP = 0.8	
Running hours	h / y	5,400	18 hours/day * 6 days * 50 weeks / year	
Energy Consumed	BOILER	1,875	**HEAT PUMP**	375 kW
Naturals Gas Burned	kWh/y	10,125,000	Electricity Used kW / y	**2,025,000**

HEAT PUMP COP 4.0

Assuming $800 / kW (800*1500)
Capital Cost of Heat Pump = $1,200,000
does not include other associated costs

$$Spark\ Gap = \frac{Electric\ Price\ \left(\frac{\$}{kW}\right)}{Gas\ Price\ \left(\frac{\$}{kW\ h\ eq}\right)}$$

$$Spark\ Gap = \frac{Electric\ Price\ \left(\frac{\$0.10}{kW}\right)}{Gas\ Price\ \frac{\$10}{MMBtu} * \left(\frac{1\ MMBtu}{293\ kW\ h}\right)} = 2.9$$

Cost / kw/h	Electricity kW/h	Natural Gas Price $/MMBtu	Natural Gas kW/h	Spark Gap (Ratio)	Boiler OPEX / y	Heat Pump OPEX / y	OPEX Diff / y	Return Of Investment (ROI) years
Lubbock, TX	$ 0.0481	$ 6.33	$0.0216	2.2	$218,700	$ 97,403	$ 121,298	10
Nevada	$ 0.1047	$ 10.84	$0.0370	2.8	$374,625	$ 212,018	$ 162,608	7
Trulock, CA	$ 0.1129	$ 13.60	$0.0464	2.4	$469,800	$ 228,623	$ 241,178	5
Fort Morgen, CO	$ 0.0432	$ 8.44	$0.0288	1.5	$291,600	$ 87,480	$ 204,120	6
Jerome, ID	$ 0.0543	$ 5.74	$0.0196	2.8	$198,450	$ 109,958	$ 88,493	14

*ROI does not include other savings that may help reduce ROI, like water savings and others

	MW/ h	MW /h
Lubbock, TX	$ 48.10	$ 21.60
Nevada	$ 104.70	$ 37.00
Trulock, CA	$ 112.90	$ 46.40
Fort Morgen, CO	$ 43.20	$ 28.80
Jerome, ID	$ 54.30	$ 19.60

$$Savings\ on\ Energy\ Costs = \frac{Gas\ Price - \left(\frac{kw\ Price}{IHP\ COP}\right)}{Gas\ Price}$$

Savings on Energy Costs	
≈	44%
≈	29%
≈	39%
≈	63%
≈	31%

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COST ENERGY COMPARISONS and IHP COP (COP of 5 & 6)

Boiler Calculations					
Heat Capacity REQUIRED	kW	1500	5,115 MBH		
Boiler Efficiency	%	80%	COP = 0.8		
Running hours	h / y	5,400	18 hours/day * 6 days * 50 weeks / year		
Energy Consumed	BOILER	1,875	HEAT PUMP	300	kW
Naturals Gas Burned	kWh/y	10,125,000	Electricity Used kW / y	1,620,000	

HEAT PUMP COP 5.0

Assuming $800 / kW (800*1500)
Capital Cost of Heat Pump = $1,200,000
does not include other associated costs

$$Spark\ Gap = \frac{Electric\ Price\ \left(\frac{\$}{kW}\right)}{Gas\ Price\ \left(\frac{\$}{kW\ h\ eq}\right)}$$

$$Spark\ Gap = \frac{Electric\ Price\ \left(\frac{\$0.10}{kW}\right)}{Gas\ Price\ \frac{\$10}{MMBtu} * \left(\frac{1\ MMBtu}{293\ kW\ h}\right)} = 2.9$$

Cost / kw/h	Electricity kW/h	Natural Gas Price $/MMBtu	Natural Gas kW/h	Spark Gap (Ratio)	Boiler OPEX / y	Heat Pump OPEX / y	OPEX Diff / y	Return Of Investment (ROI) years
Lubbock, TX	$ 0.0481	$ 6.33	$0.0216	2.2	$218,700	$ 77,922	$ 140,778	9
Nevada	$ 0.1047	$ 10.84	$0.0370	2.8	$374,625	$ 169,614	$ 205,011	6
Trulock, CA	$ 0.1129	$ 13.60	$0.0464	2.4	$469,800	$ 182,898	$ 286,902	4
Fort Morgen, CO	$ 0.0432	$ 8.44	$0.0288	1.5	$291,600	$ 69,984	$ 221,616	5
Jerome, ID	$ 0.0543	$ 5.74	$0.0196	2.8	$198,450	$ 87,966	$ 110,484	11

*ROI does not include other savings that may help reduce ROI, like water savings and others

	MW/ h	MW /h
Lubbock, TX	$ 48.10	$ 21.60
Nevada	$ 104.70	$ 37.00
Trulock, CA	$ 112.90	$ 46.40
Fort Morgen, CO	$ 43.20	$ 28.80
Jerome, ID	$ 54.30	$ 19.60

$$\text{Savings on Energy Costs} = \frac{Gas\ Price - \left(\frac{kw\ Price}{IHP\ COP}\right)}{\text{Gas Price}}$$

Savings on Energy Costs	
≈	55%
≈	43%
≈	51%
≈	70%
≈	45%

COP Increase:

- Improves Heat Pump OPEX
- Improves Energy Savings
- Reduces the Payback time
- SPARK GAP has to be lower than COP for HEAT PUMP Effectiveness

- Scoping Test:

IHP COP	5.0	6.0
Gas Boiler Efficiency	80%	80%
Efficiency Ratio (IHP COP/ Boiler eff)	6.25	7.5

- If Spark Gap < 6.25 or 7.5,will save utility cost
- If Spark Gap = 6.25 or 7.5 will break even on utility costs
- If Spark Gap > 6.25 or 7.5 will spend more on utilities

Boiler Calculations					
Heat Capacity REQUIRED	kW	1500	5,115 MBH		
Boiler Efficiency	%	80%	COP = 0.8		
Running hours	h / y	5,400	18 hours/day * 6 days * 50 weeks / year		
Energy Consumed	BOILER	1,875	HEAT PUMP	250	kW
Naturals Gas Burned	kWh/y	10,125,000	Electricity Used kW / y	1,350,000	

HEAT PUMP COP 6.0

Assuming $800 / kW (800*1500)
Capital Cost of Heat Pump = $1,200,000
does not include other associated costs

$$Spark\ Gap = \frac{Electric\ Price\ \left(\frac{\$}{kW}\right)}{Gas\ Price\ \left(\frac{\$}{kW\ h\ eq}\right)}$$

$$Spark\ Gap = \frac{Electric\ Price\ \left(\frac{\$0.10}{kW}\right)}{Gas\ Price\ \frac{\$10}{MMBtu} * \left(\frac{1\ MMBtu}{293\ kW\ h}\right)} = 2.9$$

Cost / kw/h	Electricity kW/h	Natural Gas Price $/MMBtu	Natural Gas kW/h	Spark Gap (Ratio)	Boiler OPEX / y	Heat Pump OPEX / y	OPEX Diff / y	Return Of Investment (ROI) years
Lubbock, TX	$ 0.0481	$ 6.33	$0.0216	2.2	$218,700	$ 64,935	$ 153,765	8
Nevada	$ 0.1047	$ 10.84	$0.0370	2.8	$374,625	$ 141,345	$ 233,280	5
Trulock, CA	$ 0.1129	$ 13.60	$0.0464	2.4	$469,800	$ 152,415	$ 317,385	4
Fort Morgen, CO	$ 0.0432	$ 8.44	$0.0288	1.5	$291,600	$ 58,320	$ 233,280	5
Jerome, ID	$ 0.0543	$ 5.74	$0.0196	2.8	$198,450	$ 73,305	$ 125,145	10

*ROI does not include other savings that may help reduce ROI, like water savings and others

	MW/ h	MW /h
Lubbock, TX	$ 48.10	$ 21.60
Nevada	$ 104.70	$ 37.00
Trulock, CA	$ 112.90	$ 46.40
Fort Morgen, CO	$ 43.20	$ 28.80
Jerome, ID	$ 54.30	$ 19.60

$$\text{Savings on Energy Costs} = \frac{Gas\ Price - \left(\frac{kw\ Price}{IHP\ COP}\right)}{\text{Gas Price}}$$

Savings on Energy Costs	
≈	63%
≈	53%
≈	59%
≈	75%
≈	54%

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Engineering for a better world.

Industrial Heat Pumps Roundtable

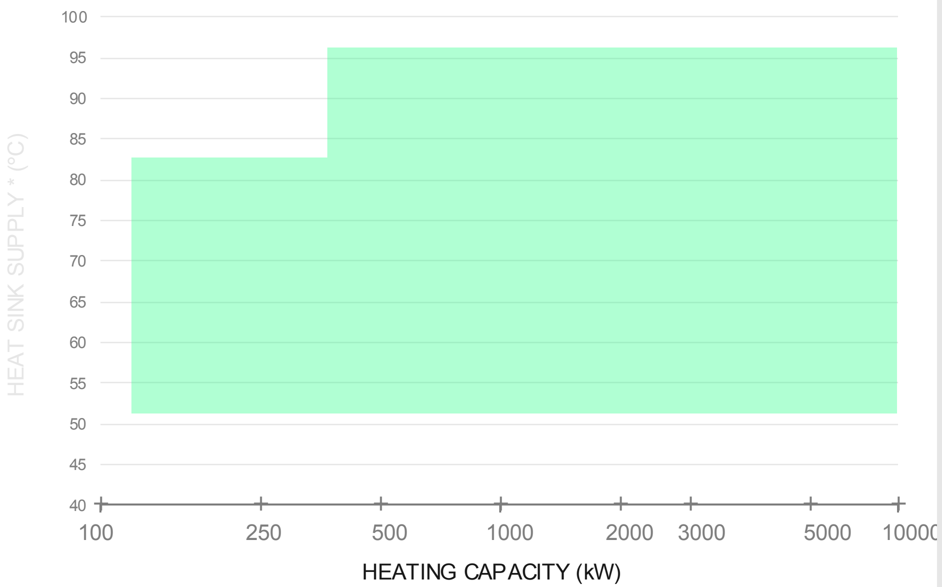
PRODUCT AND TECHNOLOGIES TO MARKET

September 11th 2024

German Robledo
Industrial Heat Pump Sales Manager
GEA HRT North America

Ammonia Heat Pump Portfolio

Temperature – Capacity Application Diagram



The highlighted area shows the range of supply temperatures for the heating demand and the heating capacity at ambient heat source level.

RedGenium

Standard reciprocating compressor heat pump

- 11 types
- up to +95 °C / 203°F
- 150 – 3,500 kW
- 511 – 11,945 MBH

Highlights:

- highest supply temperatures
- best-in-class efficiency
- lowest energy consumption
- lowest total costs

RedAstrum

Standard screw compressor heat pump

- 7 types
- up to +85 °C / 185°F
- 500 – 3,000 Kw
- 1706 – 10,238 MBH

Highlights:

- low footprint
- high differential pressures
- large heat source to heat sink tempe-rature lifts

Blu-Red Fusion

Standard chiller plus heat pump combination

- multiple types
- up to +95 °C /203°F
- 500 – 3,500 kW
- 1706 – 11,945 MBH

Highlights:

- combined cooling and heating
- highest efficiency
- unique flexibility: full cooling and heating, reduced heating and chiller-only modes possible

Custom unit

Customized recip. and screw heat pumps

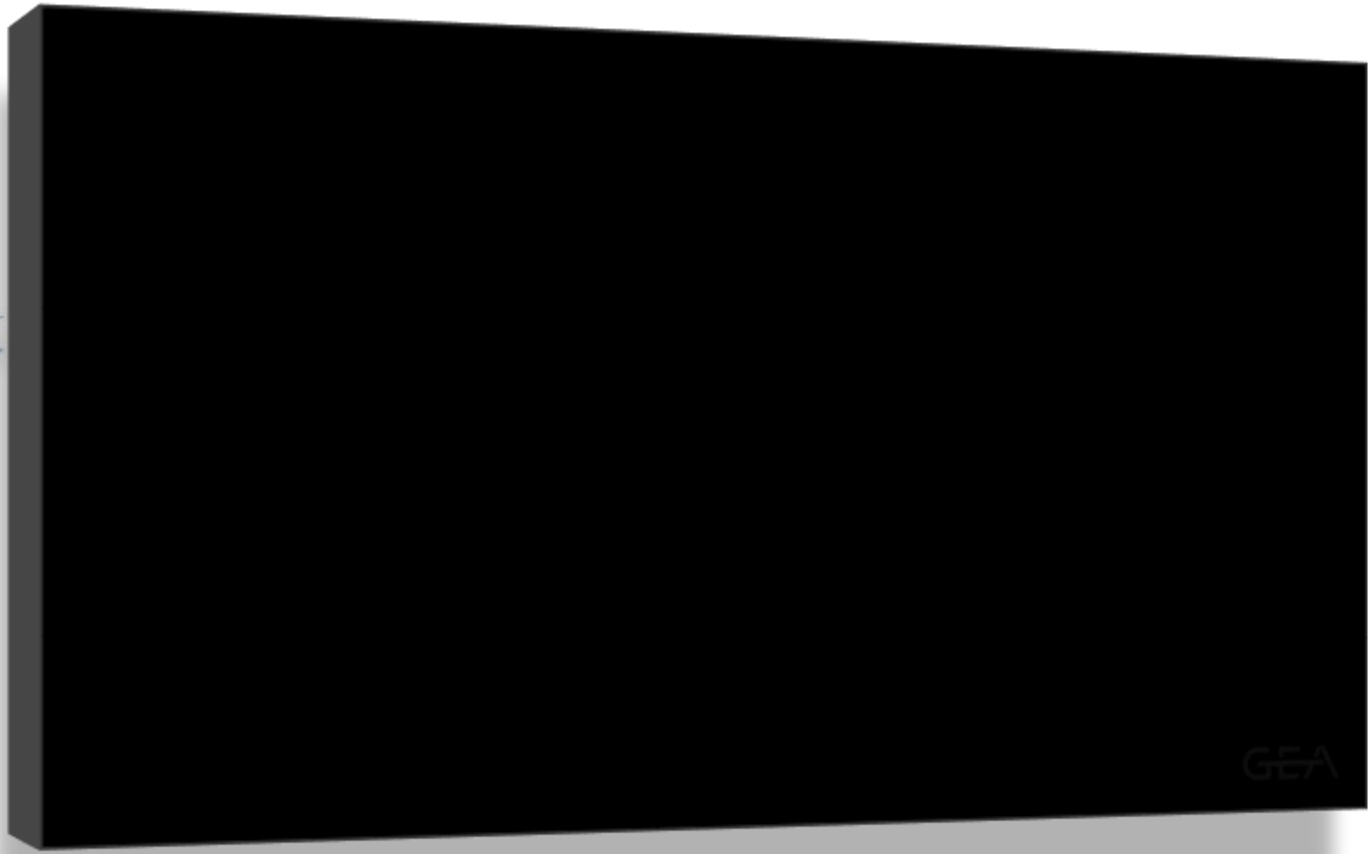
- all compressors
- up to +95 °C / 203°F
- 250 – 10,000 Kw
- 853 – 34,129 MBH

Highlights:

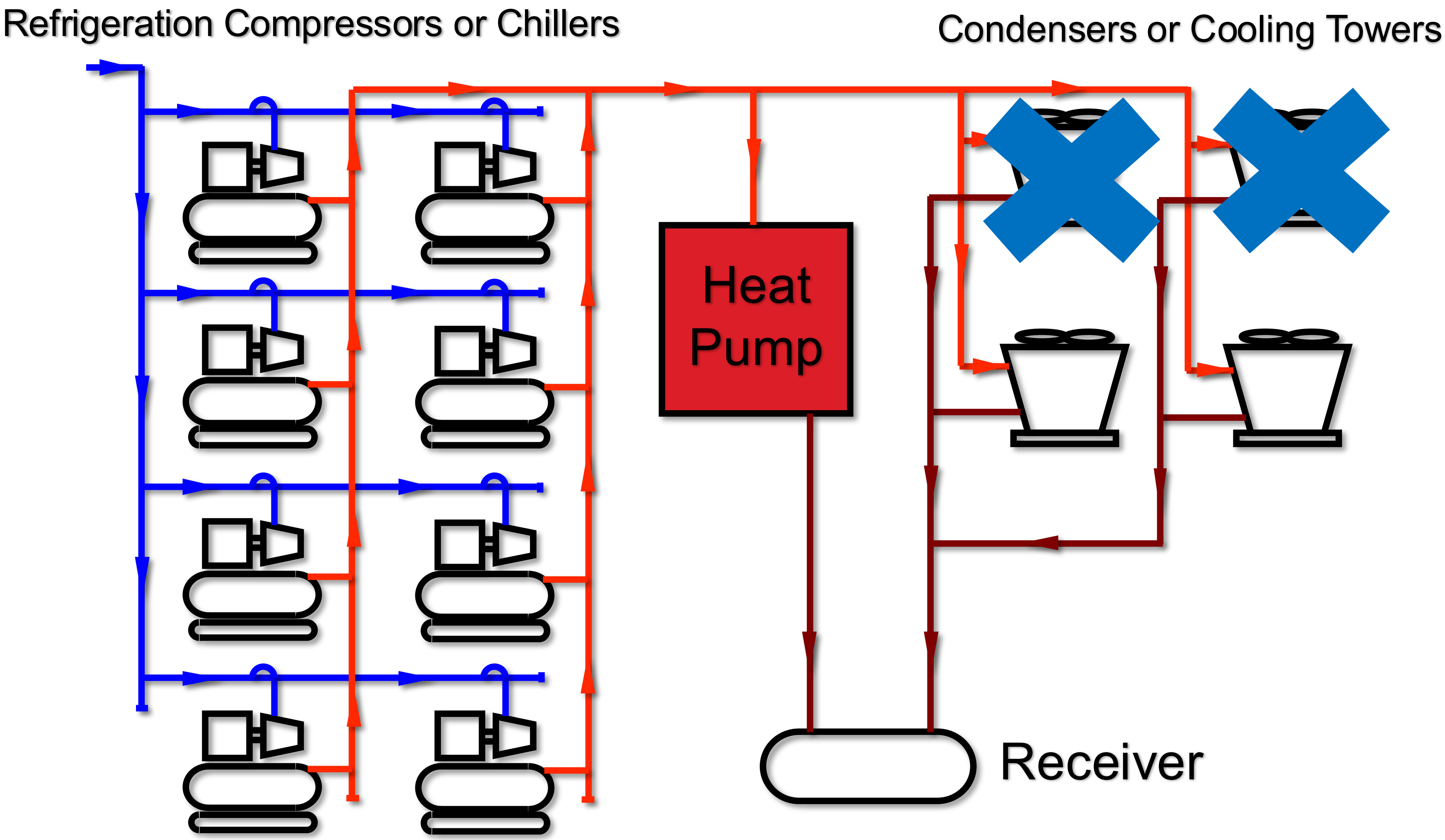
- widest application range
- up to highest capa-cities
- many flexible de-sign and configu-ration options

Ammonia heat pump example GEA RedGenium

Design of the standard reciprocating compressor heat pump:



Waste heat (heat rejection)



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DECARBONIZE STEAM

Heat pump

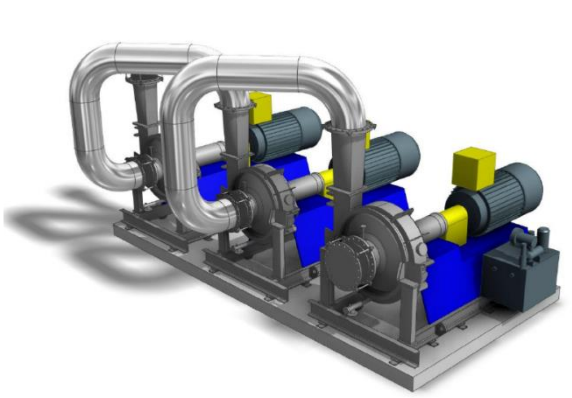
MVR (Mechanical Vapor Recompression)

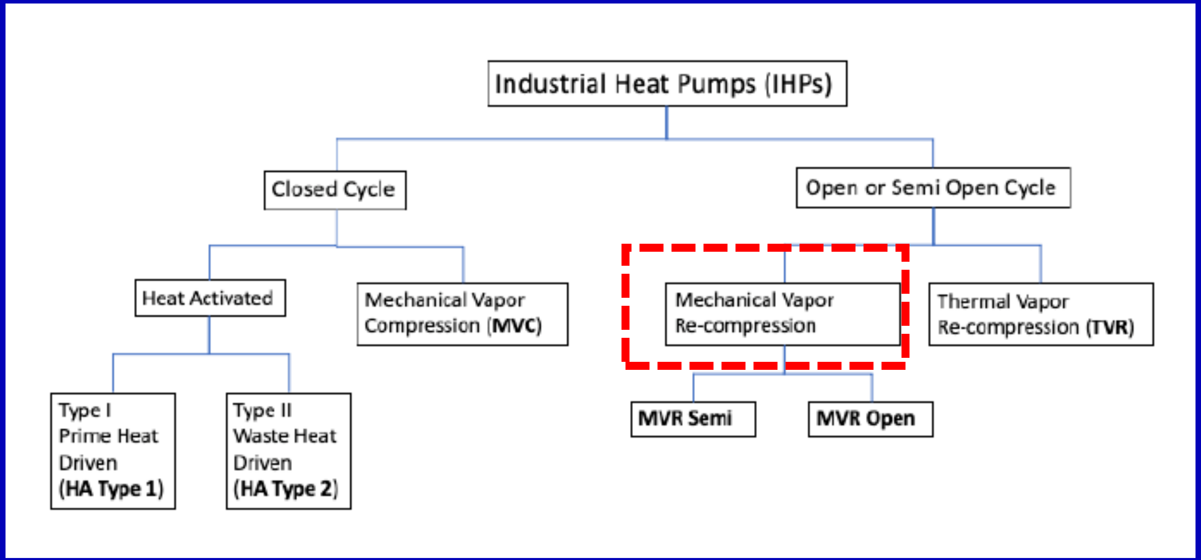
Heat Pump

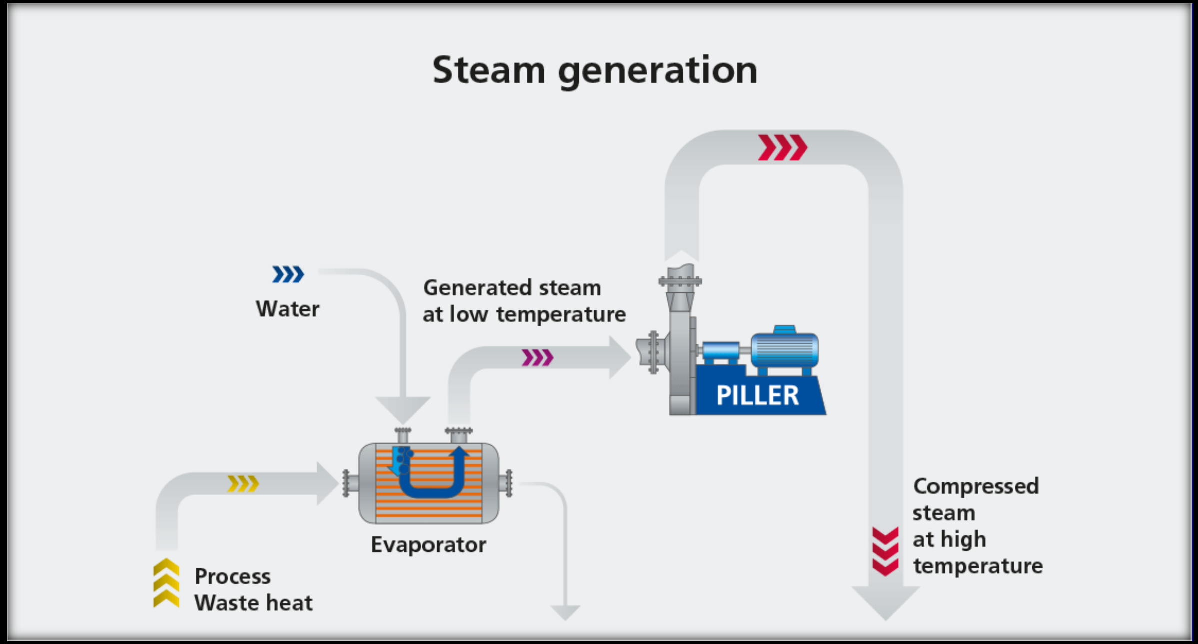
How does a Steam Generating Heat Pump work? How does an MRV works ??

Steam Compression Heat Pumps (MVR)

- Vacuum pressure steam generated from conventional heat pumps can be compressed using mechanical vapor compression (MVR).
- These system can generate header pressure steam (<275 psig) at the same quality as existing boiler by sourcing feedwater from the deaerator.
- Typical Hot water feeds to MVR are
  - 120° F or 48.8° C
  - 140° F or 60° C
  - 170° F or 76° C
  - or higher.
- The higher the inlet hot water the better COP for MVR.

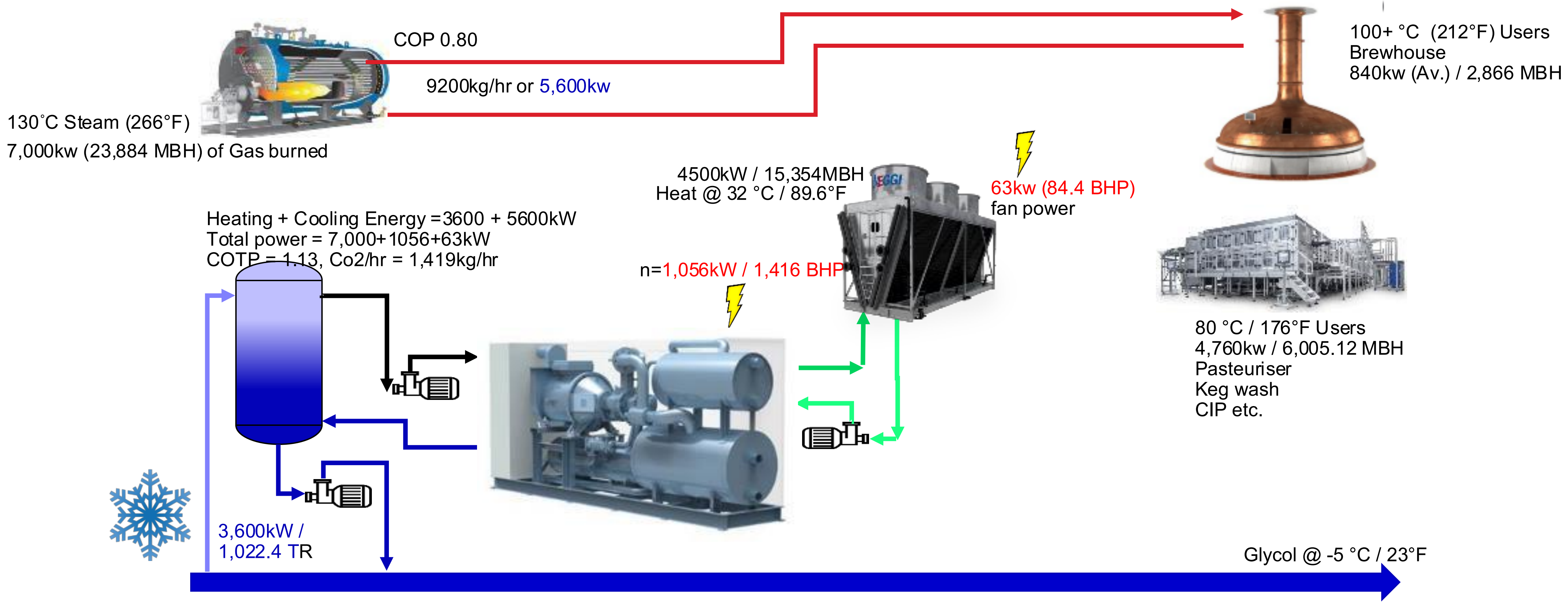






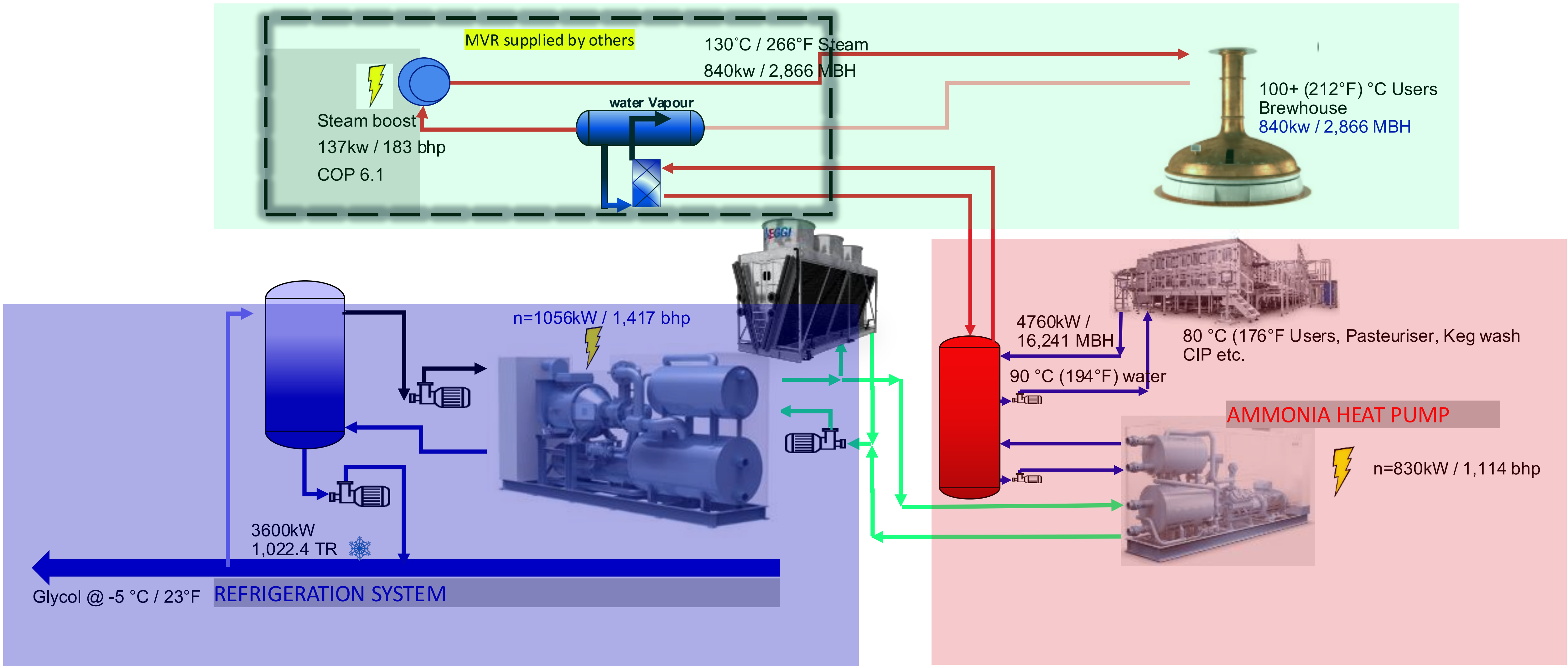
“The Norm in brewing” HOT WATER & STEAM use

Boiler = Heating, Refrigeration = Cooling



SHGP STEAM GENERATING HEAT PUMP

Heating + Cooling Energy =3600 + 5600kW
Total power = 137+1056+830kw
COTP = 4.5, Co2/hr = 158kg/hr



Industrial Heat Pumps Roundtable

HEAT PUMP BARRIERS

September 11th 2024

German Robledo
Industrial Heat Pump Sales Manager
GEA HRT North America

DECARBONIZATION

Why still so hard in the USA to get into a Heat pump ??

What makes the USA different from Europe:

→ Spark Gap or Spark Spread (gas prices & kw prices) are much higher in EU which helps justify the energy savings and pay back

→ USA does not have yet a CO2 Emission Tax where in EU this factor justify many Heat pumps rather that Spark Gap ratio and Energy Savings.

→ Many times EU decides an HP over the money saved on this CARBON TAX over Energy Savings

→ There are more District Heating networks in EU compared to USA which makes a large installation of Heat Pumps over the USA

→ Europe has learned to switch from Steam to Hot Water to make heating process more efficient

→ EU has more Gov Funding than US.

→ **WHAT ARE THE DOE or FEDERAL GOVERNMENT TARGETS for DECARBONIZATION:**

→ That by 2050 we can be at Pre-Historic Levels of CO2 before Industrialization came to the world.

DECARBONIZATION

Why still so hard in the USA to get into a Heat pump ??

Despite the great ecological potential, there are still some market barriers to the wider spread of industrial HTHPs:

1. **Lack in the understanding of the HTHP technology** (low level of awareness of the technical possibilities among users, consultants, investors, plant designers, producers, and installers).
2. **Lack of knowledge about the integration of HTHPs** in industrial processes.
3. **Cost-intensive integration into existing processes** due to tailor-made designs (leads to payback periods larger than for gas or oil-fired boilers).
4. **Lack of suitable and approved** compressors and refrigerants.
5. **Competing heat-producing technologies** generating high temperature using fossil fuels.
6. **Low fossil energy prices** (low gas to electricity price ratio)
7. **Lack of pilot and demonstration** systems.
8. **Lack of training and events** additionally supporting the spread of HTHP knowledge
9. **Domestic Manufacturing:** Not enough Manufacturers in the US and long lead delivery times (40 -50 weeks) (Who holds the line are Heat Exchanger Manufacturers, they are in the 25-30 weeks lead time).
10. **Utility Pricing Structures** Currently utility demand tariffs are structured in such a way that drawing load during peak hours contributes to making electricity a non-competitive input fuel, compared to natural gas.
11. **Insufficient Grid Infrastructure** Infrastructure to support the requisite load of electrifying process heat is typically inadequate, including both distribution infrastructure and customer substation and internal wiring.

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INVESMENT ON Heat Pumps

- <u>CURRENT BARRIERS</u>
- <u>COST</u>
- **Heat pumps are still over $900k or $1MM at minimum.**
- **Lower prices are probably LOW COP and LOW CAPACITIES. (Better buy an Electric Boiler).**
- **Installation Costs may be a ratio of 1:1 or 4:1 of heat pump cost, all depending what is needed.**
- **This may turn a whole job from $2MM to $4MM for a 1 MW heat pump.**
- **Depending on Spark Gap Ratio and other factors, PayBack may go into 3 years and 10 years.**
- **AVERAGE PAYBACK 7 – 10 YEARS**

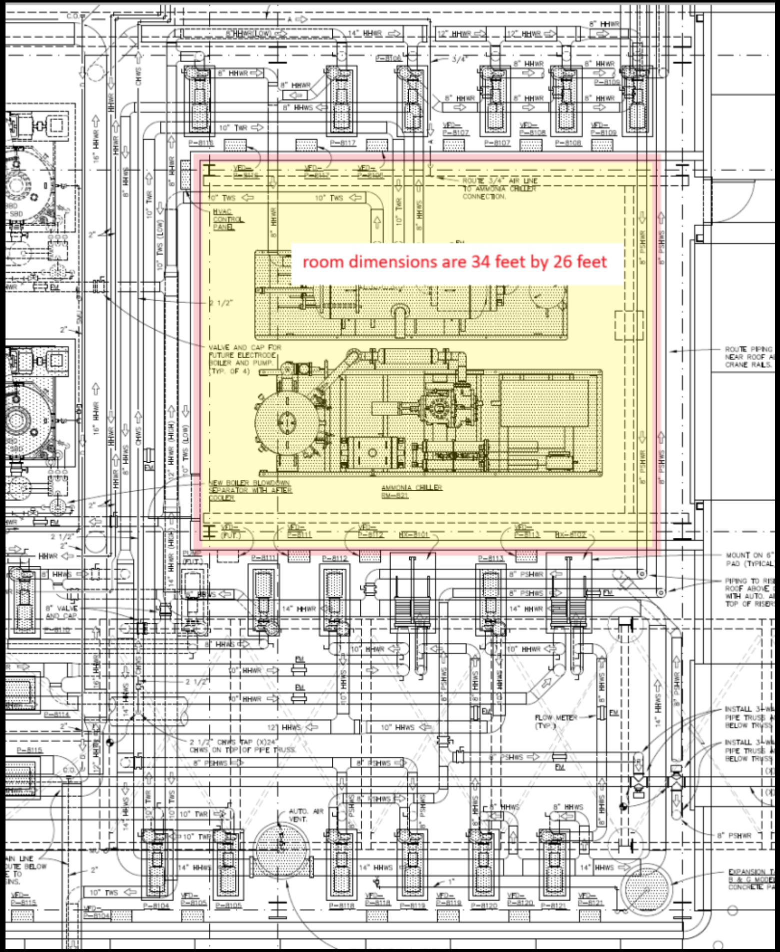
SPACE for HEAT PUMPS

Many Brownfields – Retrofits do not have space for IHP

- <u>CURRENT BARRIERS</u>
- <u>SPACE on BROWN FIELDS - RETROFITS</u>
- Heat Pumps required to be INDOORS.
- Many companies do not have space in their current Engine Room or Plant.

- <u>OUTDOORS</u>
- This will force a market for ENCLOSURES and probably long piping hot water distribution.

- ENCLOSURES becomes Engine room so now it needs to follow all
- Refrigerant Codes
- Fire Codes
- Any building code related.



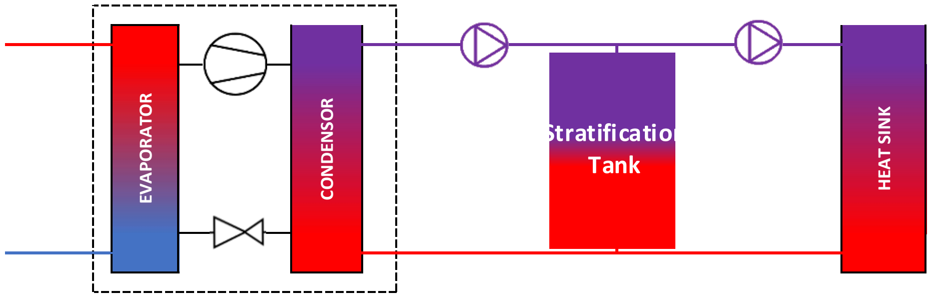
USE OF TES (Thermal Energy Storage)

Water Tank either at HEAT SOURCE or HEAT SINK

▪TES

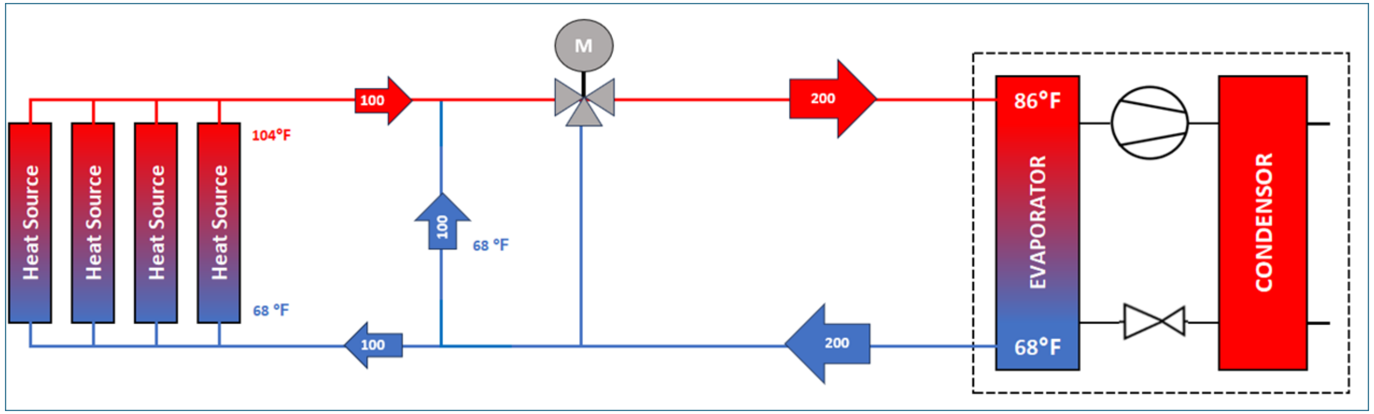
- Provides Great Benefits for:
  - Partial Load
  - Spikes
  - Sudden Changes
  - Multiple Temperature Differences
  - Provides a more steady / stable operation
  - Helps or protects Heat Pumps from operational issues
  - Relative this adder may increase the CAPEX or investment

Heat pump can only operate 30 … 100%



BUT **Heat sink required to operate 0…100 %**

Heat Source may have different temperatures or high temperature Differences



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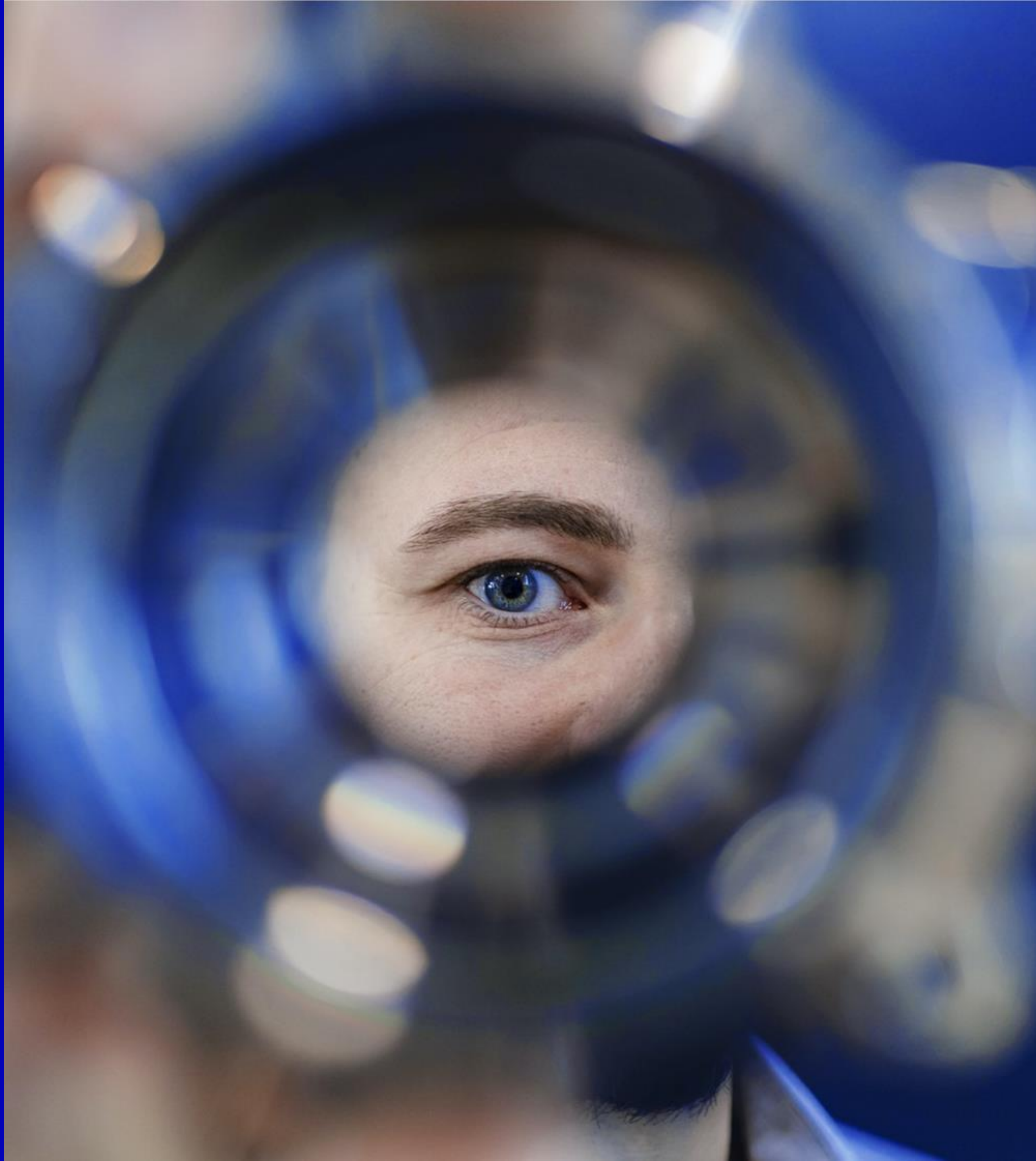
PROJECT SNAP SHOTS

September 11th 2024

German Robledo
Industrial Heat Pump Sales Manager
GEA HRT North America



GEA heat pumps references

Overview GEA North America

1x RedGenium 950 (K)
5,800 MBH / 1.7 MW

1x RedGenium 550 (K)
3,412 MBH / 1 MW

1x RedGenium 950 (K)
7,000 MBH / 2.05 MW

2x RedGenium 950 (W)
14,672 MBH / 4.3 MW total

2x 2-stage heat pumps
13,650 MBH / 4 MW total

2x RedGenium 950 (K)
14,332 MBH / 4.2 MW total

Applications

- Dairy
- District Heating
- Brewery
- Food Processing

The map shows the location of current heat pump projects for GEA North America.
The heat pumps may be at different stages (in operation, commissioning, in production).

North America Cases

Project Overview

GEA Heat Pump Solutions: Dairy Processing

Application
A United States-based producer of myriad dairy products selected GEA to supply a decarbonizing heat pump system.

Heat Pump Specifications
This GEA RedGenium heat pump features the GEA Grasso V 550XHP six-cylinder reciprocating compressor and utilizes the natural refrigerant ammonia. Designed to meet unique customer requirements, the heat pump will be used for process heating.

Cooling Capacity: 230 TR / 810 kW
Heating Capacity: 3,400 MBH / 1,000 kW
Heat Source: Heat rejection from refrig. system (92°F / 33°C)
Heat Sink: Process heat (176°F / 80°C)
Motor: 350 HP
COP: 4.78
Compressor Motor Control: VFD
Control: GEA Omni control panel

Weight: 24,000 lbs / 10,900 kg
L: 22.5 ft / 9 m | W: 6.7 ft / 2 m | H: 9.9 ft / 3 m

The Heart of the System
Driving the GEA RedGenium heat pump is the high-pressure GEA Grasso V XHP reciprocating compressor. This high-efficiency, best-in-class, ammonia compressor reduces the total cost of ownership thanks to less power consumption and maximum reliability.

Available in 4-, 6-, 8- and 10-cylinder versions, the GEA Grasso V XHP series provides water temperatures up to 203°F / 95°C and a larger capacity range with a maximum design pressure of 913 psi / 63 bar. The state-of-the-art GEA Omni control panel with built-in control apps unlocks the sophisticated operating options of the compressor.

GEA Engineering for a better world.

GEA.com/heating-refrigeration

Project Overview

GEA Chiller & Heat Pump Solutions: Food & Beverage Processing

Application
A major, global food & beverage producer selected GEA to supply twin heat pump systems and nine chillers for its new, technologically advanced, decarbonizing production facility in the United States.

Chiller Specifications
Featuring GEA V Series reciprocating compressors, and utilizing the natural refrigerant ammonia, the chillers will be used for process and HVAC cooling.

Each process chiller provides 461 TR / 1621 kW of glycol at 34°F / 1°C and the HVAC chillers provide 571 TR / 2008 kW water cooling at 44°F / 6.6°C. The chillers supply the heat source for the heat pumps at 104°F / 40°C water temperature.

Weight: 27000 lbs / 12300 kg
L: 25 ft / 7,6 m | W: 7 ft / 2,1 m | H: 10 ft / 3,0 m

Heat Pump Specifications
Featuring GEA V Series reciprocating compressors, and utilizing the natural refrigerant ammonia, the heat pumps will be used for process heating.

Delivering a total of 13648 MBH / 4 MW heating capacity for their pasteurization, CIP and other needs, each heat pump provides 7336 MBH / 2150 kW of hot water at 203°F / 95°C. Delivering a heating COP of 4.3, this project features the new GEA V XHP reciprocating compressor, which is a GEA V Series extra-high-pressure design. High-side design pressure is 900 psi / 62 bar.

Like the chillers, the heat pumps feature the industry-leading GEA Omni control panel, high-efficiency plate & shell heat exchangers, and variable-frequency drives used to control the speed of the electric motors. The result is a sustainable and optimized solution.

Weight: 30500 lbs / 13900 kg
L: 25 ft / 7,6 m | W: 7 ft / 2,1 m | H: 8 ft / 2,4 m

Project Overview

GEA Heat Pump Solutions: District Heating

Application
A leading, sustainability-focused Canadian refrigeration and heating contractor, selected GEA to supply heat pump units for an Ontario, Canada-based thermal energy utility for six million square feet of building space.

Specifications
Two GEA RedGenium heat pump systems in a two-stage design utilizing the natural refrigerant, ammonia. The heat pumps are used for both district heating and cooling.

Each heat pump not only provides 569 TR (2 MW) of hot water at 185 °F (85 °C), but also 40 ºF (4.4 °C) chilled water will be provided for chilling requirements. Delivering a heating COP of 3.09, this project features the new V XHP reciprocating compressor (which is a GEA VSeries extra-high-pressure design) on the high side. High-side design pressure is 800 psig. Variable-frequency drives are used to drive the electric motors and high-efficiency plate & shell heat exchangers are used resulting in a highly efficient solution. For this installation, renewable hydroelectric power will be used to power the heat pumps.

Weight: 59,000 lbs / 26,762 kg
L: 32.5 ft / 9.9 m | W: 10.8 ft / 3.29 m | H: 12.7 ft / 3.87 m

Advanced Technologies for a World of Applications
GEA Heating & Refrigeration Technologies is a global specialist in industrial refrigeration, heating, and sustainable engineering solutions for a wide array of industries including, food, beverage, dairy, oil & gas, as well as educational institutions, cities, and municipal utilities. Our proven technologies provide those we serve with what they value most — reliability, operating efficiency, sustainability, and long equipment life cycles that reduce the total cost of ownership.

GEA provides turnkey cooling and heating installations, custom-engineered systems, compressors & compressor packages, heat pumps, chillers, and controls to meet precise temperature requirements. To ensure ongoing, peak performance, our comprehensive service programs support customers throughout the full life cycle of their plant and equipment.

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Learn more about GEA's heat pump capabilities at gea.com/heat-to-cool.

The Dutch Coca-Cola factory
has received CO_2-neutral certification
according to PAS2060

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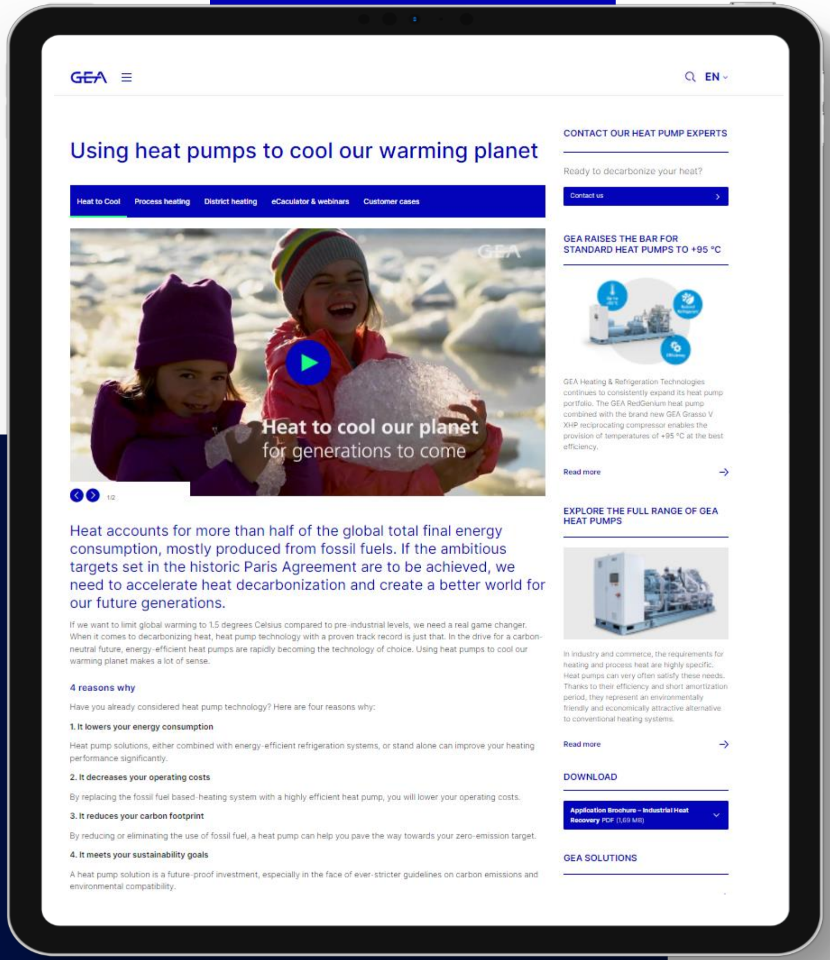
GEA.com/heat-to-cool



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Industrial Heat Pump Sales Manager

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