DOCKETED	
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Project Title:	Food Production Investment Program (FPIP)
TN #:	258959
Document Title:	Presentations - Dairy Decarbonization Workshop
Description:	Presentations for Dairy Decarbonization Workshop on 08/30/2024
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Dairy Decarbonization in California Workshop

Food Production Investment Program (FPIP)

Energy Research and Development Division, California Energy Commission
Food Production Unit
August 30, 2024 | 09:30 a.m.

Housekeeping

<u>This workshop will be recorded.</u>

Participants will be muted during the presentation. Please chat your questions in the Q&A window.

Virtual participation options:

- Chat questions in the Q&A window
- Raised hand on Zoom
- Press *6 on the telephone during the Q&A period.

Workshop materials, including all presentations and a Zoom recording will be posted on the Grant Funding Opportunity's webpage: https://www.energy.ca.gov/event/workshop/2024-08/dairy-decarbonization-workshop

Workshop Agenda

- Opening Remarks
- CEC Food Production Investment Program
  - Food Production Investment Program: Matthew Stevens
- Industry Expert Presentations
  - San Francisco State University Industrial Assessment Center: Ahmad R. Ganji
  - Danish Energy Agency: Claus Andreasson
- Dairy Product Processing Facility Presentations
  - Joseph Gallo Cheese Company: Peter Gallo
  - California Dairies, Inc: Darrin Monteiro
- Technology Vendor Presentations
  - Johnson Controls: Curtis Rager
  - GEA: German Robledo
- Researcher Presentation
  - Skyven Technologies: Arun Gupta
- Discussion Panel
- Questions & Answers

Opening Remarks

Commissioner J. Andrew McAllister

Food Production Investment Program (FPIP)

Dairy Decarbonization In California

FPIP Background - Motivation

Food manufacturing is highly energy-and carbon intensive:

- 3.2M CO2e equivalent emissions

Unique barriers and challenges:

- Quality and quantity control of different food products
- High capital equipment costs and perceived risks
- Integration into complex systems and processes.

FPIP Background - Purpose

The purpose of FPIP is to:

- Help California food processors work towards a low-carbon future,
- Demonstrate reliability and effectiveness of advanced energy and decarbonization technologies and strategies,
- Enhance and benefit the electrical grid, especially during net peak periods and
- Benefit or improve public health and the environment, particularly in priority populations

FPIP by the Numbers

Awarded

$140.8M

Projected Annual Emissions Reduction

181,000 MT CO2e*

64 Projects

- Animal Feed & Ethanol: **4**
- Prepared Food Producers: **15**
- Beverage, Breweries, & Wineries: **10**
- Meat & Rendering: **12**
- Dairy Processing: **9**
- Fruits, Nuts & Vegetables: **14**

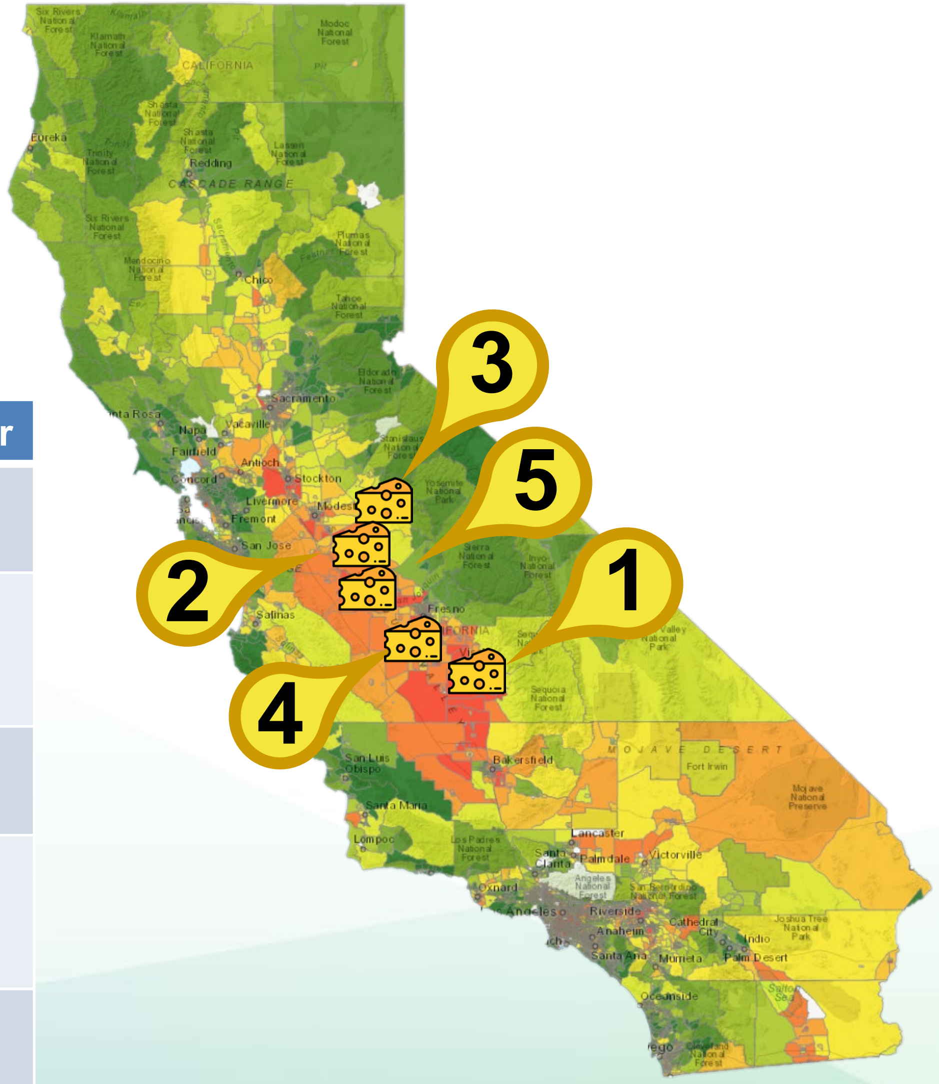
*Preliminary staff estimate – actual results will be quantified during project measurement & verification.

Past FPIP Dairy Projects

Project Benefits:

- Reduced emissions of the facilities
- Improved efficiency and lowered operation costs
- Increased quality and quantity of products

#	Company	Project	MT CO2e/yr
1	California Dairies, Inc.	Zero-Emissions Thermal Energy Storage	540
2	Hilmar Cheese Company, Inc.	Refrigeration, Boiler, & Compressed Air Systems Optimization	3,500
3	California Dairies, Inc.	Heat Recovery System on Dryers and Boilers	7,800
4	Producers Dairy Foods, Inc.	Refrigeration and Compressed Air System Overhaul	900
5	Joseph Gallo Cheese Company, LP	Net-Zero Refrigeration System Upgrade	4,500



Industry Expert Presentations

Dairy Decarbonization In California

IAC Experience in Dairy Processing Plants

Ahmad R. Ganji
Professor of Mechanical Engineering
Director of Industrial Assessment Center (IAC)
San Francisco State University

CEC Workshop on Dairy Decarbonization in California

August 30, 2024

Contact Information: aganji@sfsu.edu

Industrial Assessment Center (IAC)

- IAC is a US DOE Program, continuously operating since 1976
- There are 37 IACs in the country
- IAC at San Francisco State University (SFSU) is one of the four IACs serving the industrial plants in California
- SFSU IAC has served the industrial establishments for over 30 years
- SFSU IAC has performed comprehensive energy assessment of over 625 industrial and process plants.
- SFSU IAC has served 19 dairy processing plants

Industrial Assessment Center (IAC)

- Our recommended projects include,
  - Electrical and gas energy efficiency measures
  - Renewable energy measures
  - Demand management measures
  - Cogeneration (CHP) measures
  - water saving measures
- Historically about 60% of the recommended projects are implemented!
- Energy efficiency is considered the first and essential step in the decarbonization process.

Major Energy Consumers in Dairy Processors

Electrical Energy:

- Refrigeration systems and related equipment, fans, pumps
- Air compressors
- Various pumping systems
- Fans and blower, a small percentage
- Lighting, a small percentage
- HVAC, a small percentage

Natural Gas

- Steam production (for various heating processes and hot water production)
- Hot air (e.g. milk powder production)

Assessment Process

- We have a holistic approach, considering various aspects of production processes and their interaction with support equipment.
- Our assessments do not evaluate major overhaul or changes in the production process.
- Our assessments cover a broad range of measures/projects (so far 35 for dairy processors).
- IAC assessments are usually done in one day, although two day assessments are authorized by DOE for large plants.
- DOE requires us to survey the plants on their decisions about the recommended projects.
- Historically over 60% of our recommended projects are implemented!

The Case of Crystal Creamery (2014)

- Plant area: 530,000 ft2
- Plant Electrical Demand: 6,600 MW
- Plant's Natural Gas Consumption: 280,000 MMBtu/yr

	Recommended	Implemented
Energy Conservation Measures	16	8
Water Conservation Measures	1	1
Electrical Energy Savings	11%	8%
Natural Gas Savings	5%	5%
Water Savings	11%	11%
Cost Saving	$665,000	354,000
Simple Payback	Immediate – 3.6	Immediate – 2.7

The Case of Crystal Creamery

1. Repair Steam Leaks and Steam Traps
2. Repair Air Leaks
3. Floating Head Control on Ammonia Compressors
4. Move Ammonia with Mechanical Pumps Instead of Compressed Ammonia
5. Install VFDs on Glycol Pumps
6. Heat Recovery from Boiler's Blowdown
7. Improve Boilers' Thermal Insulation
8. Reduce Air Compressor Discharge Pressure
9. Install VFDs on Captive Loop Cooling Tower Pumps
10. Install VFDs on Captive Loop Cooling Tower Fans
11. Sequence Air Compressors' Operation
12. Sequence Ammonia Compressors' Operation
13. Replace Low Efficiency Lighting LEDs
14. O2 Trim Control and Combustion Air VFD Control of Boilers
15. VFD Control on Evaporator Fan Motors
16. Lighting Controls
17. Recycle Fresh Water From Various Areas

The case of a Dairy Processor Assessed in the Past Year

- Plant area: 170,000 ft2
- Plant Electrical Demand: 2,700 MW
- Plant's Natural Gas Consumption: 170,000 MMBtu/yr

	Recommended	Implemented
Energy Conservation Measures	7	7
Electrical Generation Measure	1	0
Electrical Energy Savings	4.7%	4.7%
Natural Gas Savings	4.4%	4.4%
Estimated Cost Saving per Year	$171,000	$171,000
Estimated Simple Payback	1 Year	1 Year

The case of a Dairy Processor Assessed in the Past Year

1. Repair Air Leaks
2. Repair Steam Leaks
3. Preheat Boilers' Make-Up Water by Recovering Heat from the Boiler Blowdown
4. Recover Heat from the 300 hp Air Compressor to Preheat Hot Water for Cleaning
5. Install VFDs on the Glycol Circulation Pumps
6. Install Lighting Controls in the Warehouses and Loading Dock
7. Install VFDs on the Glycol Fan Banks in the Cold Storage Building

Based on IAC Experience

- There are significant opportunities for energy savings in dairy processing facilities.
- There are significant opportunities for heat recovery from refrigeration and air compression systems that can be tapped for high temperature heat pump systems.
- There are significant opportunities for use of heat pumps for producing hot water for various applications including sanitation
- There are opportunities for electrification of processes
- Major challenges exist for application of heat pumps and electrification of high temperature large gas consuming equipment such as large boilers.

Major opportunities discussed in CEC sponsored draft report

"An Assessment of Gas Technologies, Their Efficiency and Alternatives in the Food Processing Industry in California"

Danish Energy Agency

Workshop

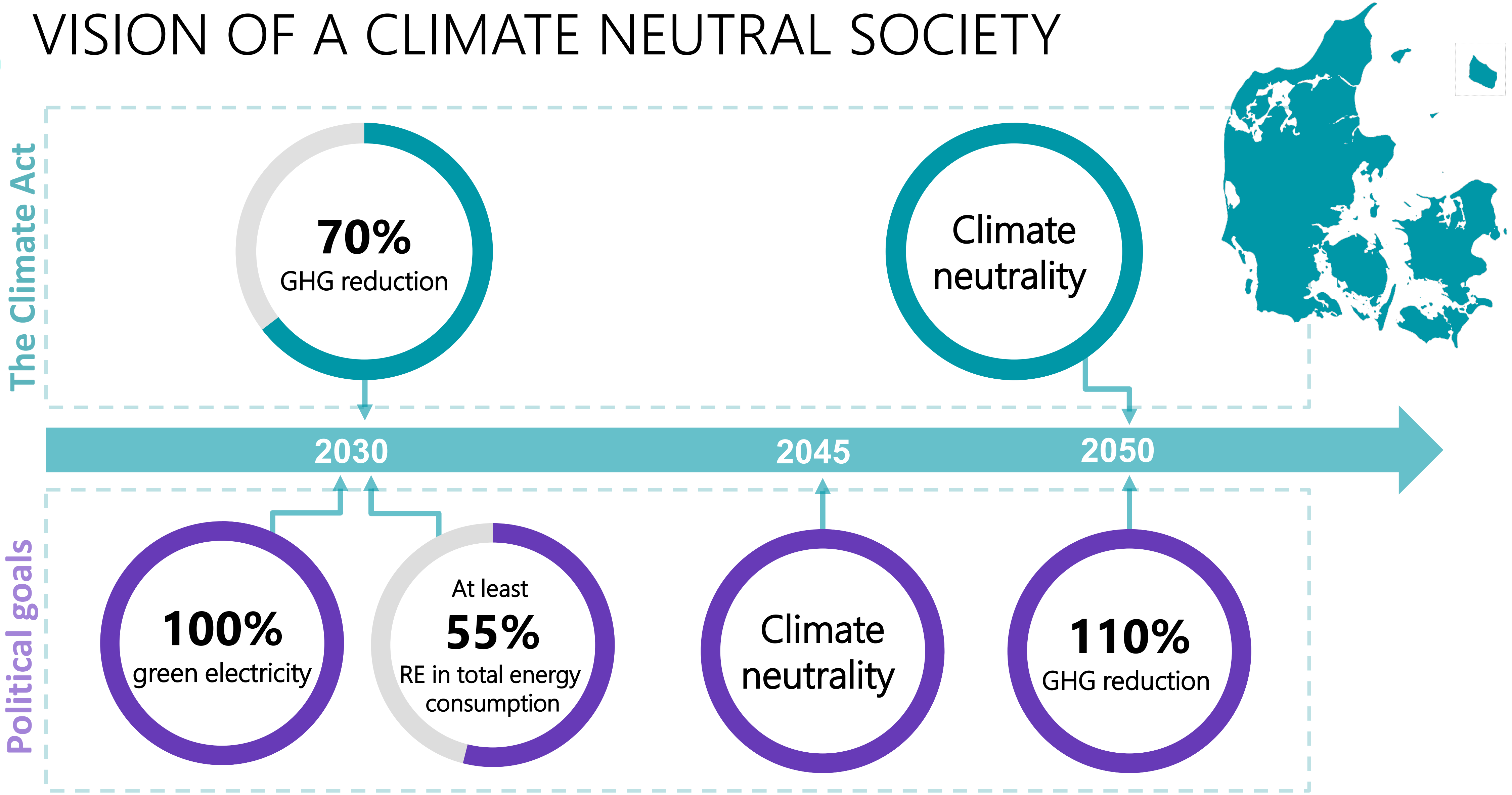
August 30th 2024

Dairy Decarbonisation in California

The Danish Energy Agency

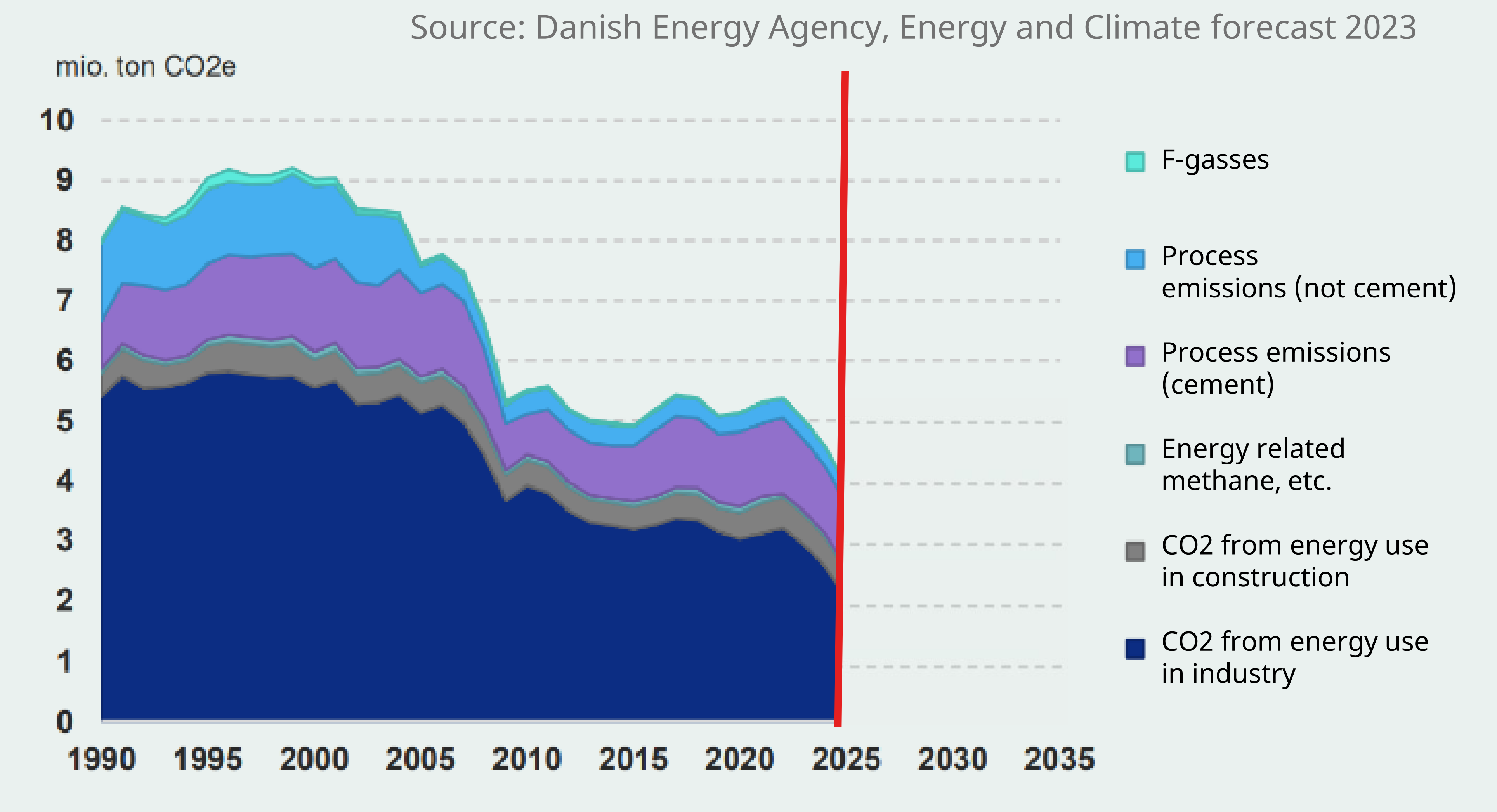
Claus Andreasson
Chief Advisor on EE
clndr@ens.dk

VISION OF A CLIMATE NEUTRAL SOCIETY

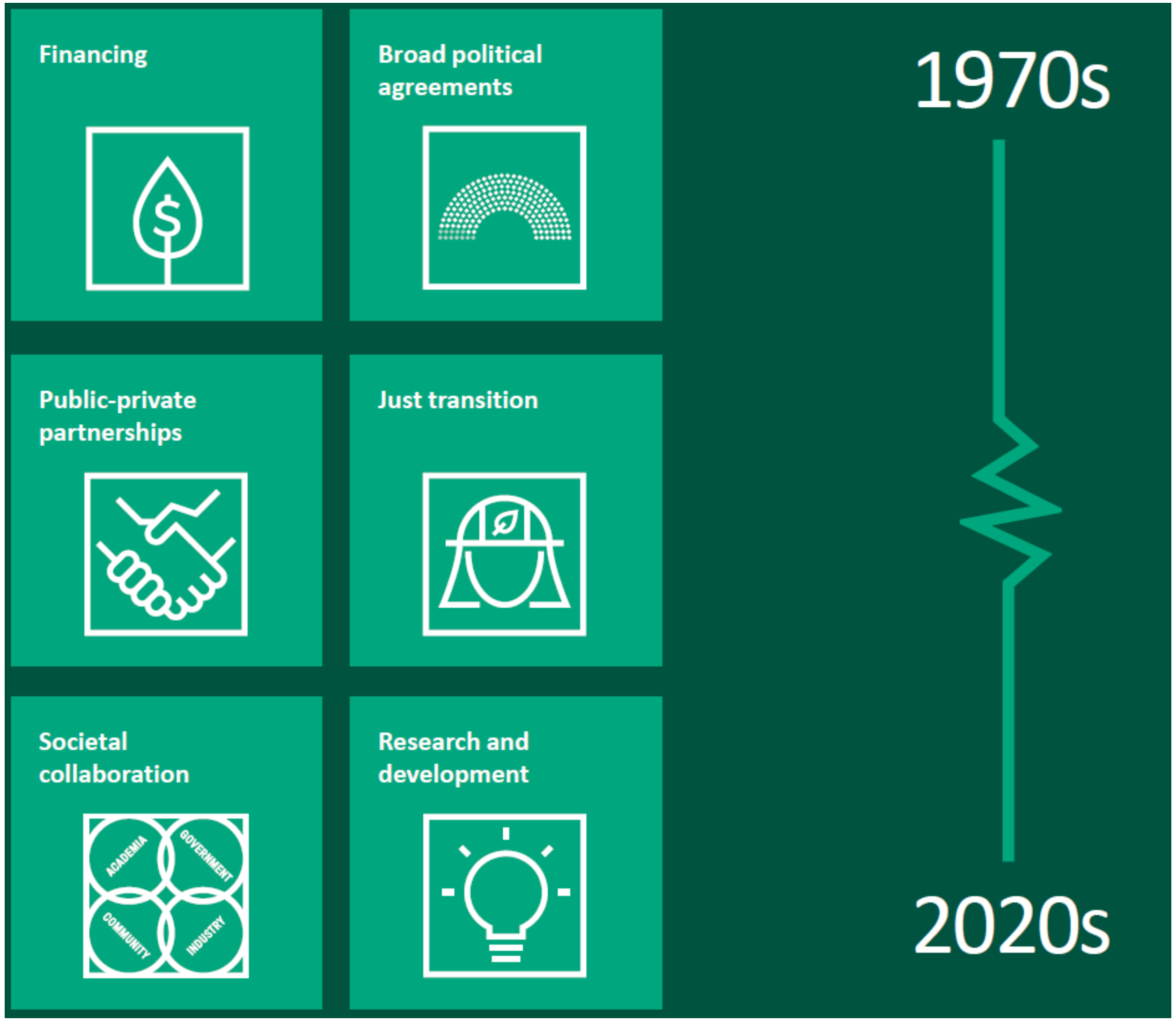


Source: Energinet, IPCC

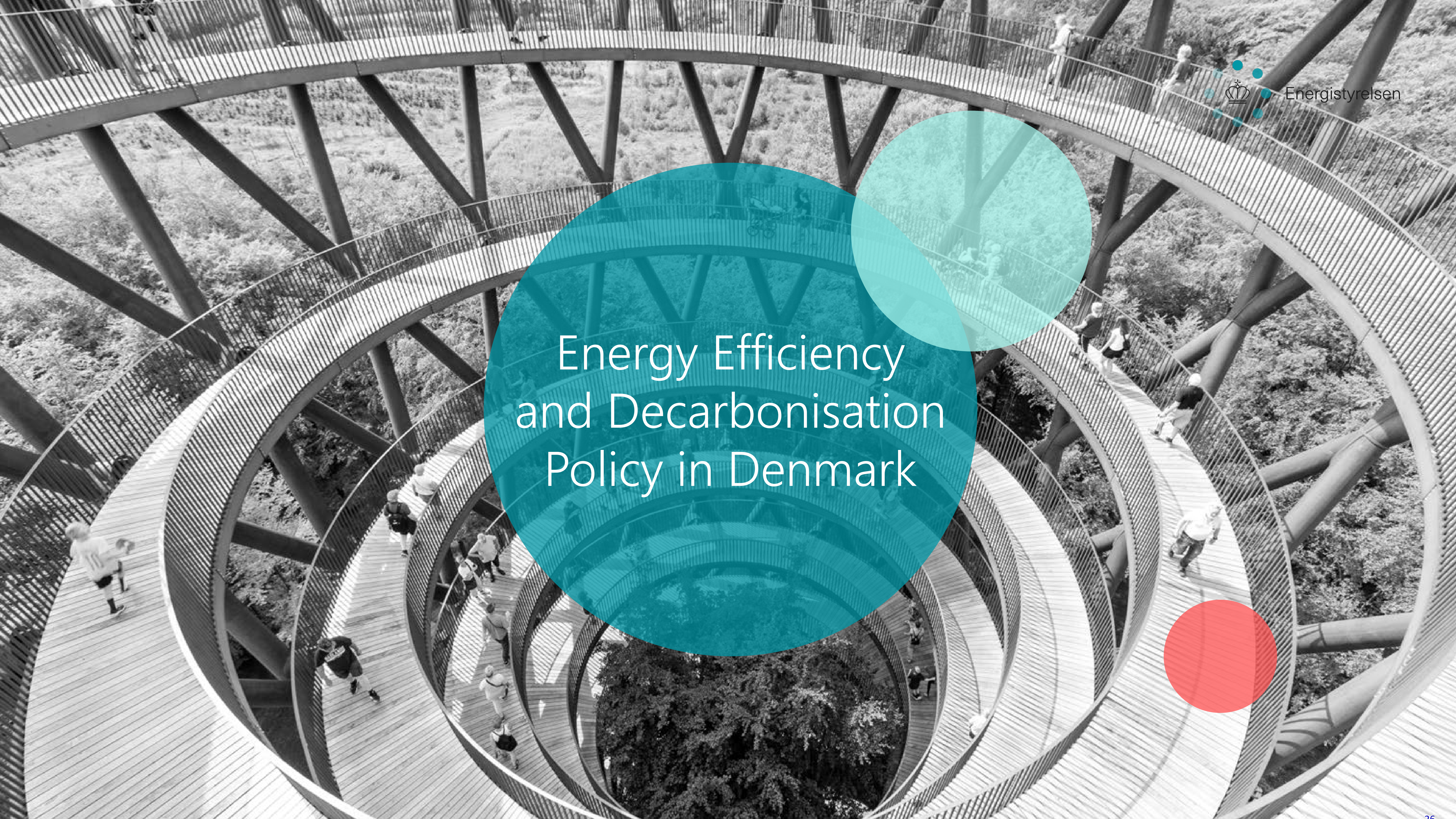
EMISSIONS – INDUSTRY AND CONSTRUCTION



WHAT HAVE WE LEARNT FROM 1970 TILL TODAY



Energy Efficiency and Decarbonisation Policy in Denmark



Energistyrelsen

CLASSIC APPROACH TO DECARBONIZING THE INDUSTRY

1) REDUCE
ENERGY
CONSUMPTION

2) REUSE
ENERGY
FLOWS

3) RE-SOURCE
REMAINING
ENERGY NEED

EXAMPLES:

Policies to promote energy efficiency measures. Classic economic cost-benefit concern.

EXAMPLES:

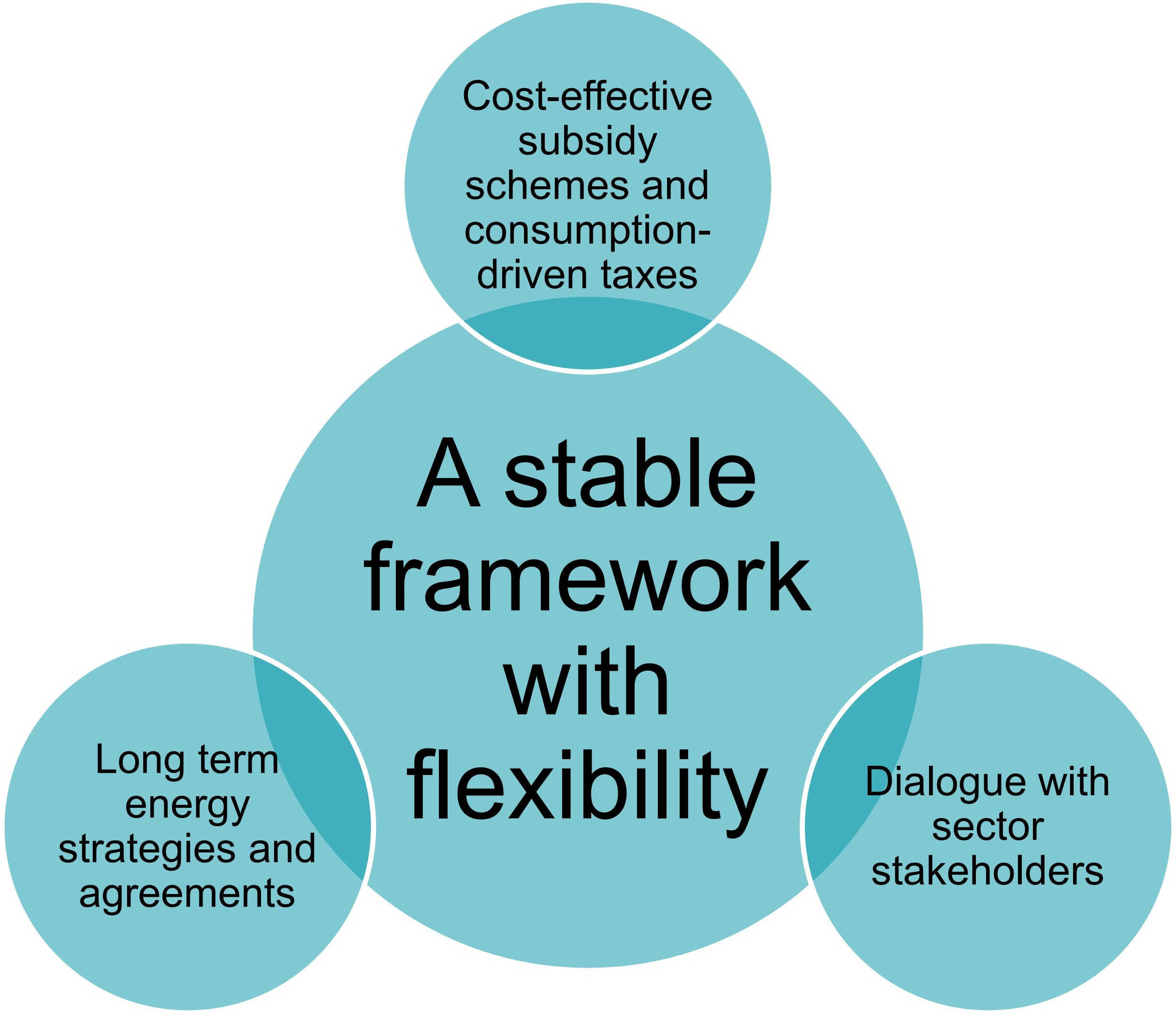
Reuse excess heat for internal processes or external consumers (sector integration → industrial symbiosis).

EXAMPLE:

Direct electrification and indirect electrification ("PtX").

Premise: Large share of renewables in energy mix.

KEY ELEMENTS OF DANISH ENERGY POLICY OVER TIME



THE CLIMATE PARTNERSHIPS

In November 2019 the Danish government established 14 public-private climate partnership.

Partnerships cover amongst others:

- Food and agricultural sector
- Manufacturing activities
- Energy and utilities sector
- The Blue Denmark
- Energy-intensive industry
- Financial sector

FOOD AND AGRICULTURAL INDUSTRY

The Danish Governments Partnership for Food and Agricultural Industry – suggested for Dairy Industry:

- Reuse of side streams in the manufacturing process
- Energy Efficiency
- Face out of fossil fuels
- Electrification
- R&D – new less energy intensive products and processes
- Waste products to be used in biogas production

INSTRUMENTS FOR ENERGY EFFICIENCY

The administrative setup has not one single instrument – but many:

- Energy & CO_2 taxes
- Voluntary agreements
- Subsidies & Grants
- Energy efficiency obligations
- Mandatory energy audits (EU)
- Research & Development
- Qualified energy consultant scheme
- Access to Information

GREEN TAX REFORM - 24 OF JUNE 2022

"Stick"

New and ambitious CO_2 tax

- Higher and more uniform taxes on CO_2 emissions
- 4.3 mio. tons CO_2 reductions in 2030
- Minimum price for the CO_2 tax

"Carrot"

Transition support

- 1 bn. euros to investments in green transition
- 0.8 bn. euros in targeted tax reliefs
- 7.2 bn. euros towards 2040 in a Green Fund financed by an in advance taxation of pensions

Revenue recycling

THE BUSINESS POOL

2020-2029:
500 $ mio Funding

Funding 30/40/50 % of project sum depending on company size

Up to 1 $ cent per kWh saved,

or

70 $ per ton CO_2 minimized

CO2 & Energy Efficiency

Projects from most production industries and businesses

Focus on Additionality/Real effect

Not for Energy producing facilities

Targets and performance

Targets 300.000 tonnes CO_2 in 2030

2023 to date: 100.000 tonnes

Dairy Industry

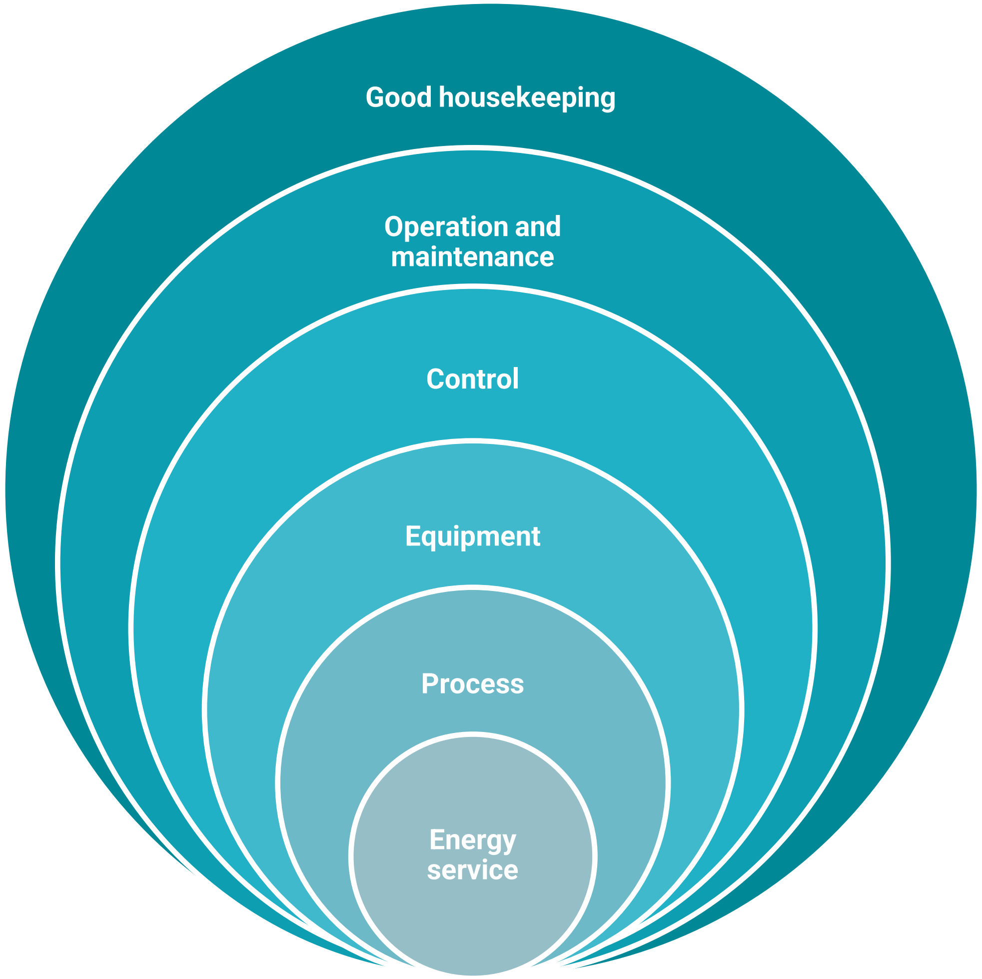
Drill down to the core of Energy Efficiency

Dairy Industry Approach - Energy Audits

"Energy savings can be found in many areas of the company's operations, but often companies only focus on utility systems"

Energy efficiency include:

- Process optimization
- Utility tune-up
- Heat recovery
- Operator performance
- Maintenance routines
- Procurement policies
- Etc.



CASE OF DAIRY PRODUCTION

Large Cheese Producer

- Energy Efficiency investigation and investments
- Conversion of heat supply from steam to hot water
- Heat pump for process heat
- Biogas production and cogeneration
- Sector Coupling – excess heat to district heat

HEATPUMP UTILIZATION

Example:

Heat pump for spray drying at Danish Dairy Facility

COP: 4.5

Savings: 4.6GWh / year

Payback period: 2.3 years (no subsidies)

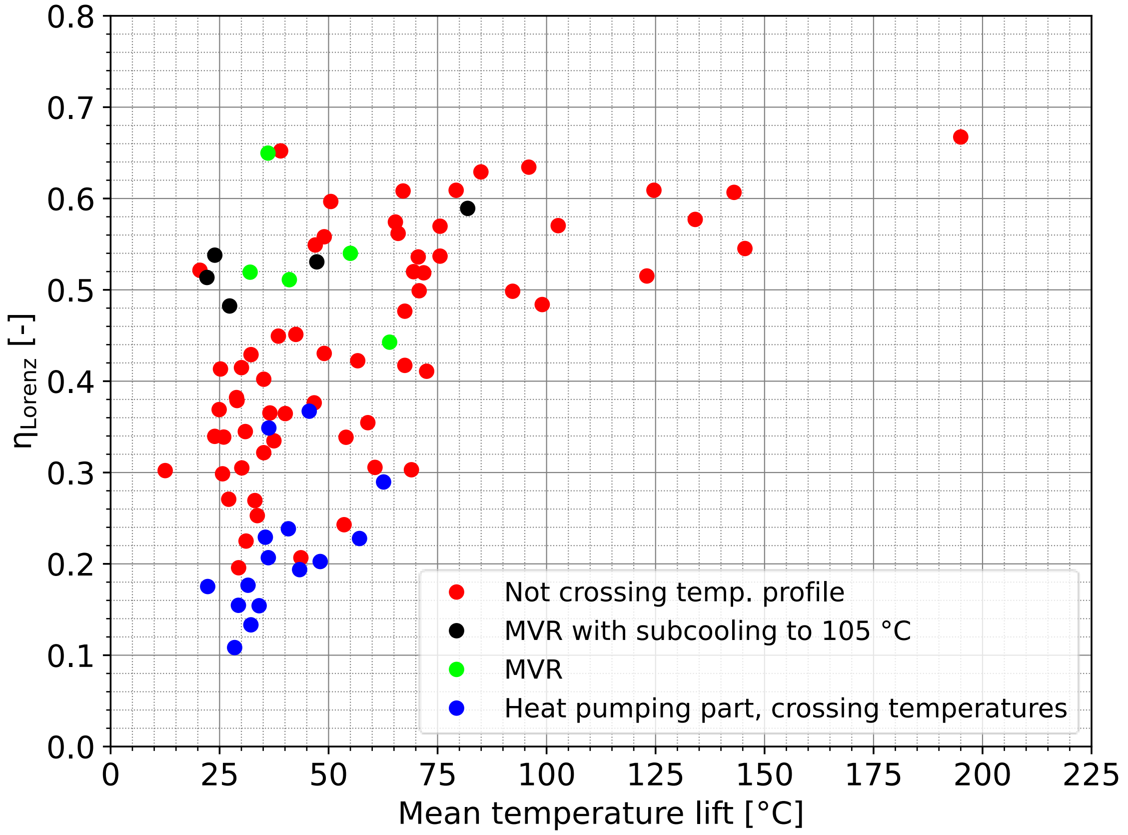
Source: Strengthening Industrial Heat Pump Innovation – Decarbonizing Industrial Heat

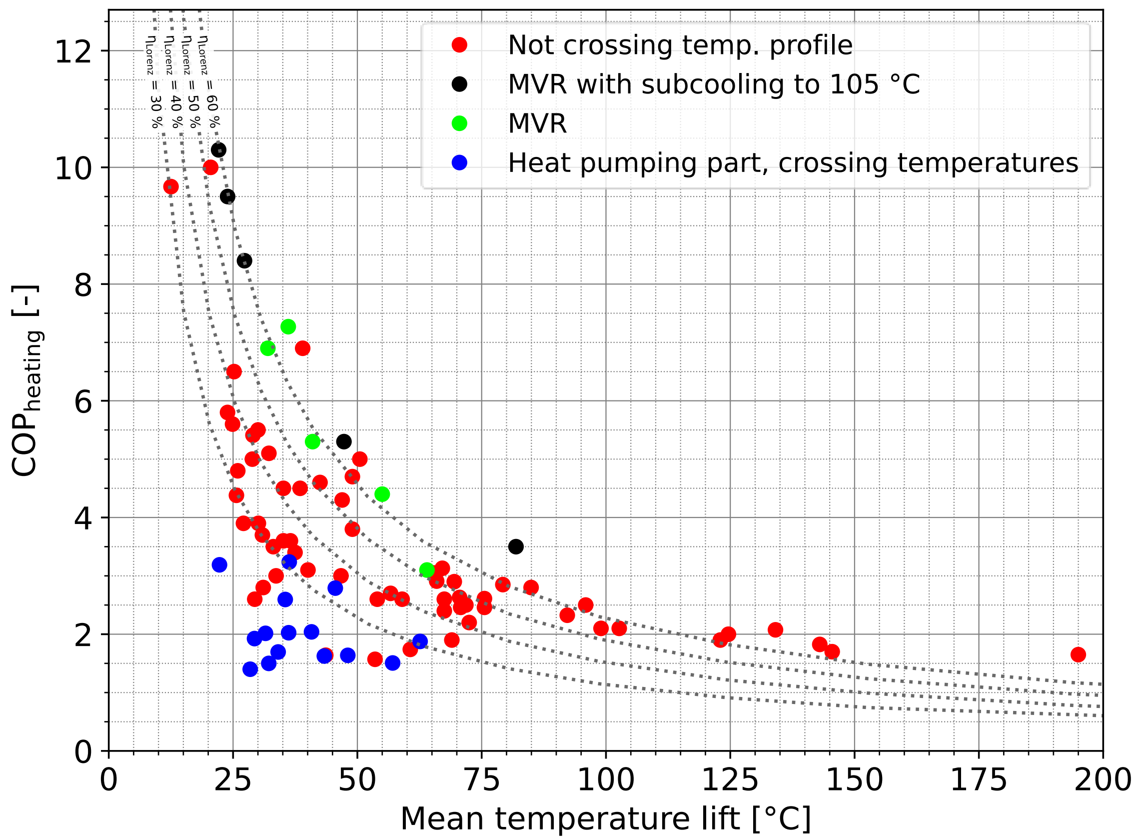
WHY HEATPUMPS AND WHERE ?

- Instead of using steam – then use heated water
- Only use the temperature needed at curtain productions points
- Reuse waste heat by boosting temperature using Heat Pumps
- Heat Pumps have high efficiency – COP
- Select the use of Heat Pumps based on temperature increase and capacity needed

→ Next some explanations using information from Danish Technological Institute delivered by Benjamin Zühlsdorf, Innovation Director

COP and Lorenz efficiency as a function of temperature lift



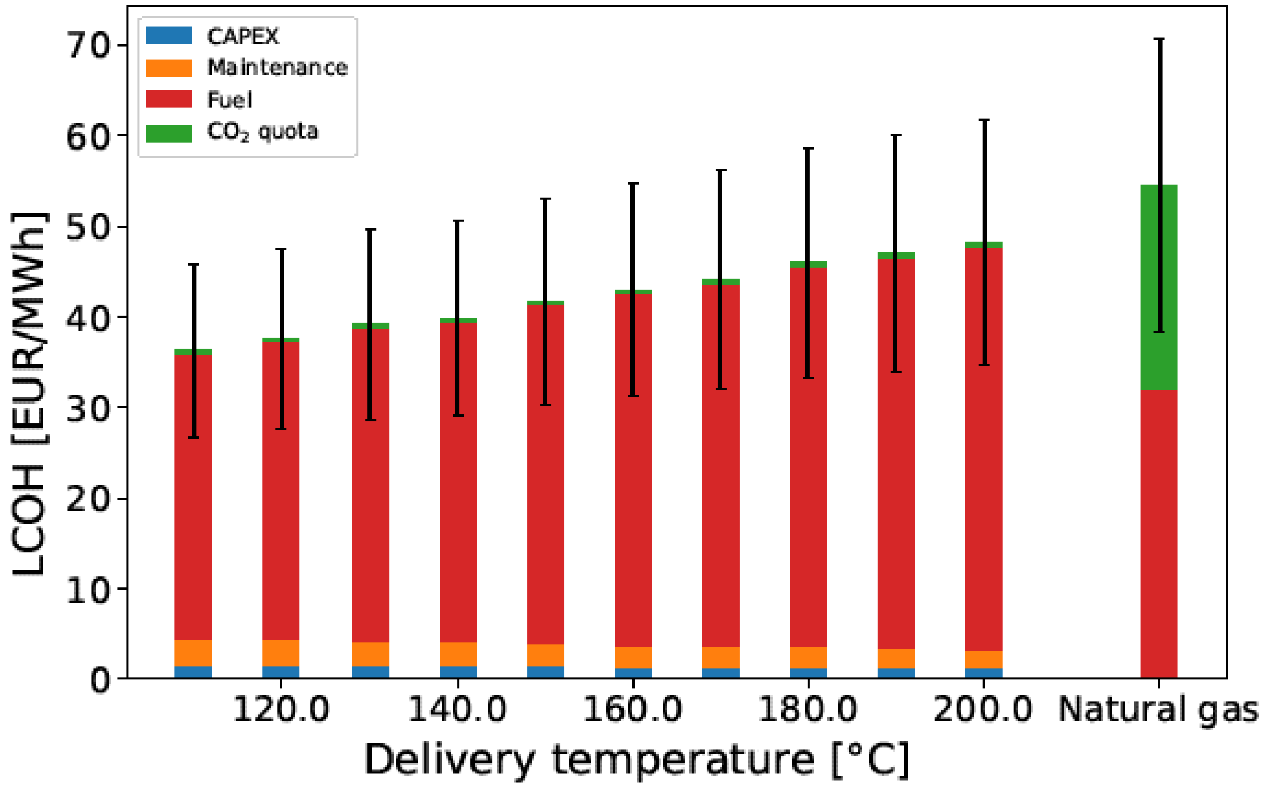


- Higher Lorenz efficiency for higher temperature lifts.
- Depends on application type.

- Higher COP at low temperature lifts.
- Depends on application type.

Cost of temperature

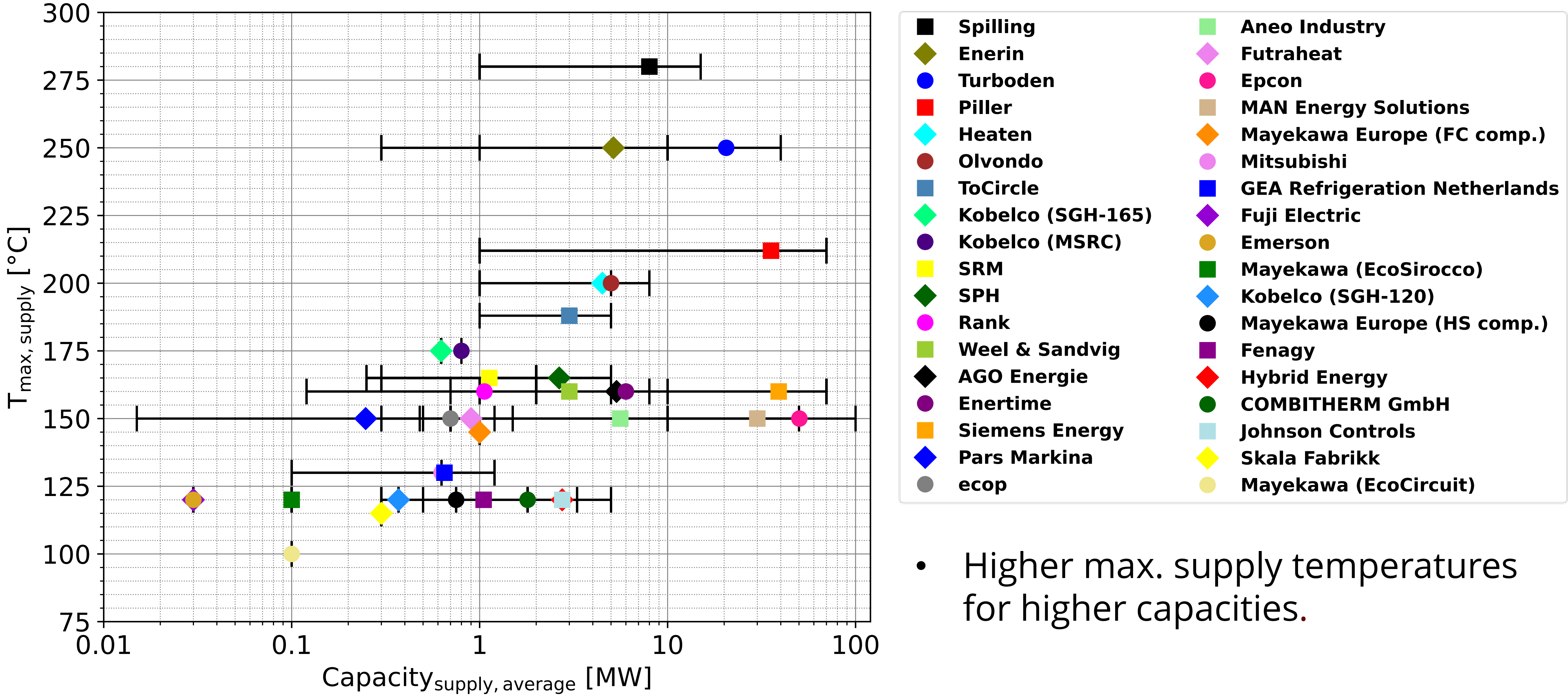
Decrease of 10 K → **Decrease of LCOH by around 5 %**



Source: M. Pihl Andersen, B. Zühlsdorf, B. Elmegaard, *Steam generating heat pumps – Economic potential and practical challenges*, Steam Systems Symposium, London, 07/2023

- **Process integration** is key to find overall optimal solutions
- **Heat exchangers** are key to implement overall optimal solutions

Maximum supply temperature as a function of capacity



- Higher max. supply temperatures for higher capacities.

Development Perspectives for HTHPs towards 2030

Heating capacity	Temperature	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
200 kW to 10 MW	< 120 °C	Prototypes available		Demonstrators available		Commercial roll-out		Established as preferred technology				
	120 °C - 160 °C		Prototypes available		Demonstrators available		Commercial roll-out		Established as preferred technology			
	> 160 °C			Prototypes available		Demonstrators available		Commercial roll-out		Established as preferred technology		
>10 MW	< 120 °C		Technology transfer & commercial project sales		Demonstrators available		Established as preferred technology					
	> 120 °C			Technology transfer & commercial project sales		Demonstrators available			Established as preferred technology			

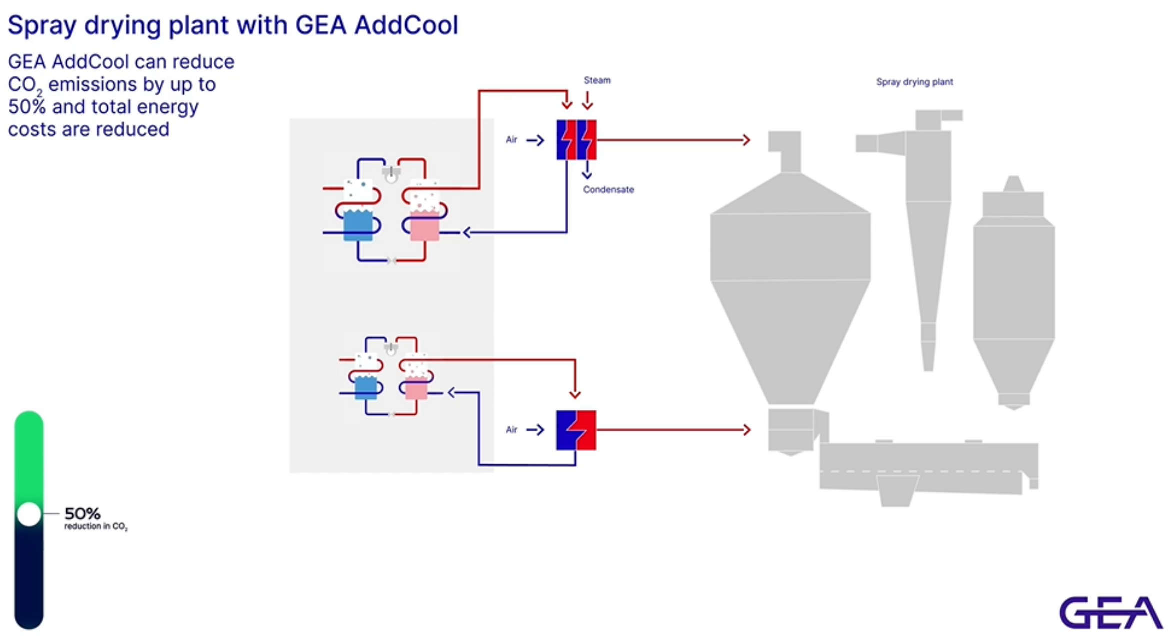
Source: IEA HPT Annex 58, Task 1 Report – B. Zühlsdorf et al. 2023

HTHPs for Spray Drying

Arla Foods orders sustainable heat pump solution from GEA

https://www.dairyindustries.com/news/42384/arla-foods-orders-sustainable-heat-pump-solution-from-gea/
Image: GEA

- Fuel consumption: 50 % reduction
- CO_2 emissions: 50 % reduction



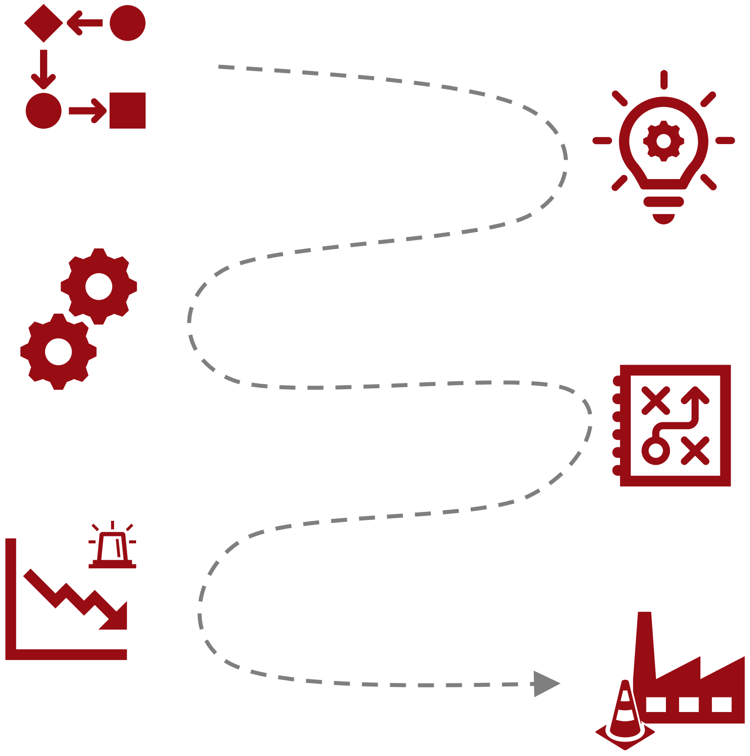
https://www.gea.com/de/articles/add-cool-sustainable-spray-drying-process.jsp

Long-term planning is key to success

Mapping of existing processes

Analysis of technology availability and perspectives

De-risking of decarbonization projects



Development of **concept solutions**

Development of **decarbonization roadmap**

Implementation of decarbonization roadmap

Danish Energy Agency

Thank you

Claus Andreasson
Chief Advisor
Danish Energy Agency

CLNDR@ens.dk

Dairy Product Processing Facility Presentations

Dairy Decarbonization In California

JOSEPH GALLO FARMS

MAKER OF JOSEPH FARMS CHEESE

JOSEPH FARMS

CALIFORNIA NATURAL CHEESE

CALIFORNIA ENERGY COMMISSION

Family Farm Since 1946

Maker of Award Winning Joseph Farms Cheese
Est. 1982

2024 American Cheese Society Competition

- 1st Place - Monterey Jack

2024 Los Angeles International Dairy Competition

- Gold Medal - Best of Competition - Sharp Cheddar
- Gold Medal - Best of Class - Monterey Jack

Walmart
Costco Wholesale
Kroger
amazonfresh
Food 4 Less
Sprouts Farmers Market
WinCo Foods
Trader Joe's
Fry's Food Stores
Vallarta Supermarkets
Cardenas
Superior Grocers
Northgate Market
El Super
Organic Valley

Environmental Stewardship

- 2014-US Dairy Sustainability Award by The Innovation Center for U.S. Dairy for Outstanding Dairy Processing & Manufacturing Sustainability
- 2012-Governors Economic Environmental Leadership Award, Californias highest environmental honor
- Wildlife Preserves & Regenerative Farming
    - Organic composting
    - Recharged >10,000 acre feet of ground water

Michael Gallo, Co-Founder & CEO

Michael Gallo, Co-Founder & CEO

Anaerobic Methane Digester

2004-2022

- 7 acre covered lagoon Methane Digester among the longest running & most successful in California
- Generates 10 million kWh's/YR of green energy to power our plant
- Captured > 165,000 verified metric tons of CO2E over 20 years

Equivalent of eliminating 33,000 cars from the road or powering 22,000 homes for a year.

2 MW Solar Array

2016- Current

- 8 acres containing 7,800 solar panels
- 2MW array powers < 100% of farming electrical needs
- Eliminating 27,500 Metric Tons of CO_2 over 20 years

Equivalent of planting 706,000 trees or Removing 292 cars from the road and powering 282 homes for a year.

Peter Gallo, Executive Vice President

Therm Absorption Chiller

2017-Current

- Initial cost $1.6M of that budget CEC funded $1.2M
- Offset 200 tons of piston type compressors

Electrical Savings

1.4M kW Hrs/ YR

Natural Gas Savings

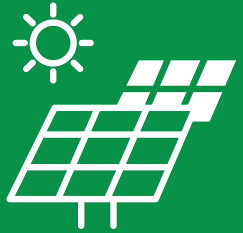
149,000 Therms Annually

josephfarms.com

7 MW Solar Array

2023-Current

- To meet our goal of carbon neutrality & part of decommissioning our digester we'll complete new 7MW solar
- Array of 13,053 panels will capture 9,922 metric tons/ YR of CO_2
- Provides up to 100% of our plant's electricity including charging stations for our electric delivery truck, farm tractors, & forklifts.



Equivalent of powering 1,250 homes &/or eliminating 2,138 cars/ YR from the road

Public - Private Partnerships Are Vital to Sustainable Food & Ag in California

Peter Gallo

- 3rd Generation California cheese maker
- 4th Generation California Farmer
- Pgallo@josephfarms.com

Learn More at JosephFarms.com

California Dairies, Inc.

CEC Dairy Decarbonization Workshop

Darrin Monteiro – SVP, Sustainability and Member Relations
California Dairies, Inc.

Major Milestones Along Our Journey…

1999 CDI formed from the merger between three of California's most financially successful dairy cooperatives: **California Milk Producers, Danish Creamery Association and San Joaquin Valley Dairymen**.

2012 CDI acquired the assets of **Security Milk Producers Association**, a California milk marketing cooperative, adding more than 30 member dairy farms to its membership.

CDI Today

Owned by 280 California dairy families.

From San Diego County in the south to Sacramento County in the north, our independent, family-owned member dairies dot California's rural landscape. All of the milk used to produce our high quality, safe and nutritious dairy products originates at one of our member-owners' dairy farms. CDI is the second largest milk marketing cooperative in the United States with 6 processing facilities throughout CA.

17 **BILLION POUNDS** of average annual member milk production

99 **PERCENT** of our member-owner farms are located within 100 miles of a CDI facility

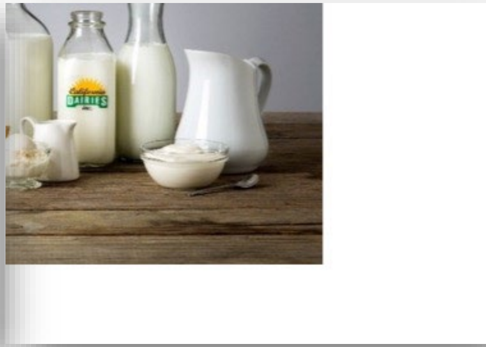
$4B **AVERAGE ANNUAL SALES**

2,000 **AVERAGE HERD SIZE** at our member-owner farms

40 **PERCENT** of California's total milk production is from CDI member-owners

CDI Family Of Products

Raw Milk



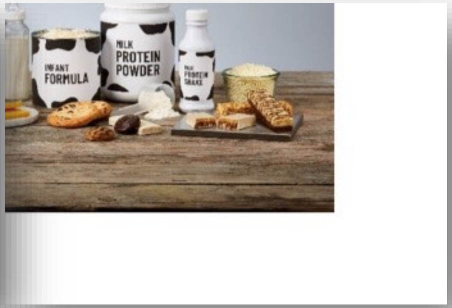
Processed Fluids

Branded Butter

Bulk Butter

Retail Butter

Milk Powder



Nutritional Milk Powder

Partnerships

CDI is a founding member of California's sustainable dairy farming coalition. In 2001, CDI organized and joined with dairy-related groups in California to form **Dairy Cares**, a voluntary organization dedicated to ensuring the long-term sustainability of California farming families.

As a founding member, CDI has invested more than $1.5 million to date to improve research and understanding of sustainability issues related to dairy farming, such as air and water quality climate change, land use and animal well-being.

Sustainability Team

Darrin Monteiro

SVP of Sustainability and Member Relations

Dixie Martinho

Sustainability Manager

Bryan Castillo

Sustainability Specialist

Sustainability Goals

Total Greenhouse Gas Reductions

- CDI is aligned with the U.S Dairy Net Zero Initiative (NZI) to achieve carbon neutrality or better by 2050.
- CDI is committing to a 30% reduction by intensity in direct and supply chain greenhouse gases from 2020 levels by 2030.

Environmental Impact

- By the end of 2025, 100% of CDI farms will be assessed for their environmental footprint via FARM ES.
- Increase California Dairy Quality Assurance Program (CDQAP) 3rd party environmental certification on eligible CDI farms from 82% to 100% by 2025.

Electricity Usage

- 70% of electricity use within CDI plants will be renewable or carbon-free by 2030 and 100% by 2045.
- 80% of on-farm electricity use will be renewable or carbon-free by 2030 and 100% by 2045.

Decarbonization Strategies

In efforts to meet established carbon neutrality goals, CDI partnered with Skyven Technologies implementing new projects at both the Visalia and Turlock processing Facilities.

Implemented Projects

- Skyven and CDI have installed three state of the art decarbonization technologies at both of CDI's largest facilities.
- Each plant has one of the largest solar thermal systems for industrial process heat in the world.
- Smart steam trap solutions using internet connected sensors were installed to reduce steam loss and are integrated to the solar thermal systems.
- Boiler heat recovery systems were also integrated to the systems and are boosting boiler efficiencies by nearly 10%.
- These strategies have resulted in 75,106 MMBtus of Natural gas saved and have reduced 3,981 MT of CO_2.

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Visalia, CA 93291 U.S.A.
P: 1(559)625.2200
F: 1(559)625.5433

www.californiadairies.com
info@californiadairies.com

Technology Vendor Presentations

Dairy Decarbonization In California

Industrial Heat Pumps
Dairy Facilities

August 2024

Curtis Rager

Product Manager – Heat Pumps

Johnson Controls / Frick

Johnson Controls

Industrial Dairy Facility – Ammonia Refrigeration System

- Most Dairy Plants use a distributed Ammonia system
- Ammonia refrigeration is pumped throughout the facility

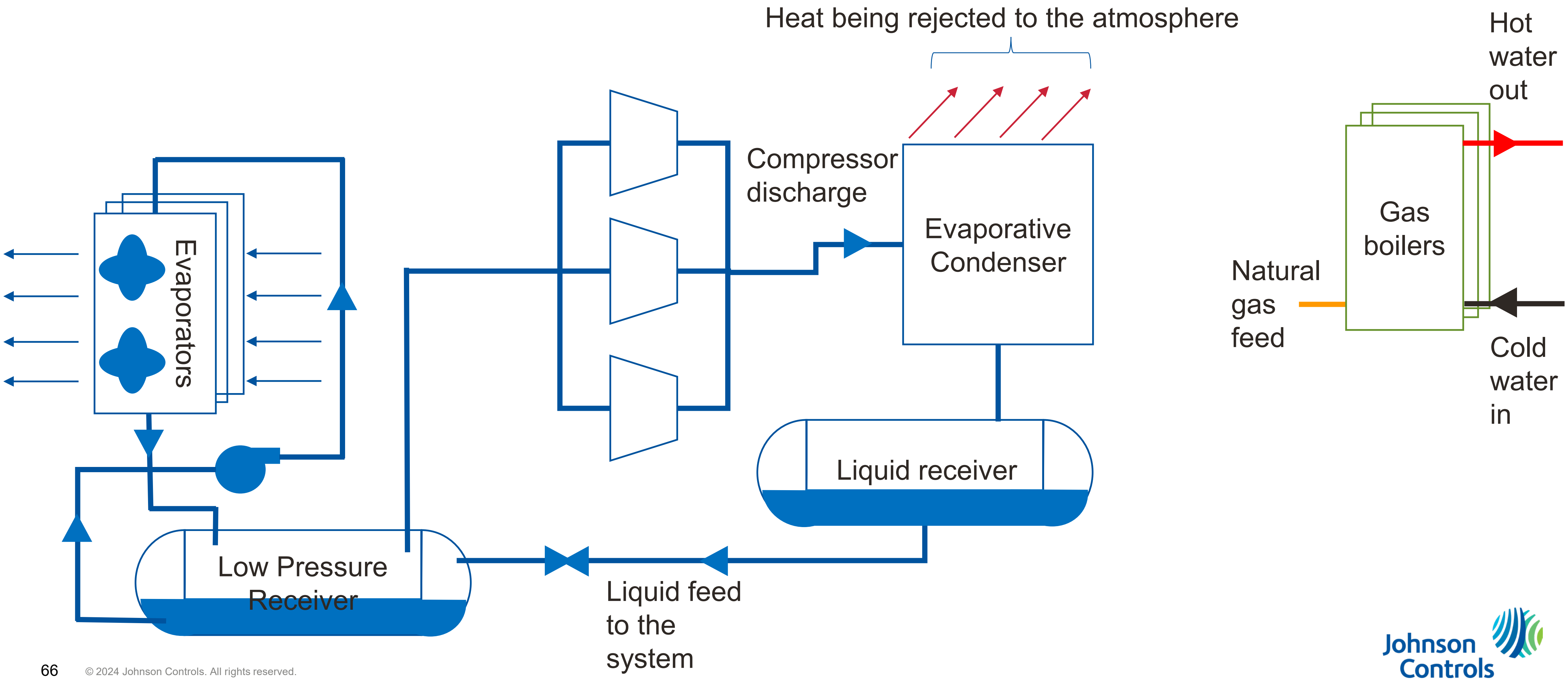
- Energy is absorbed at point of use

- Extracted heat is discharged to the atmosphere via Evaporative Condensers

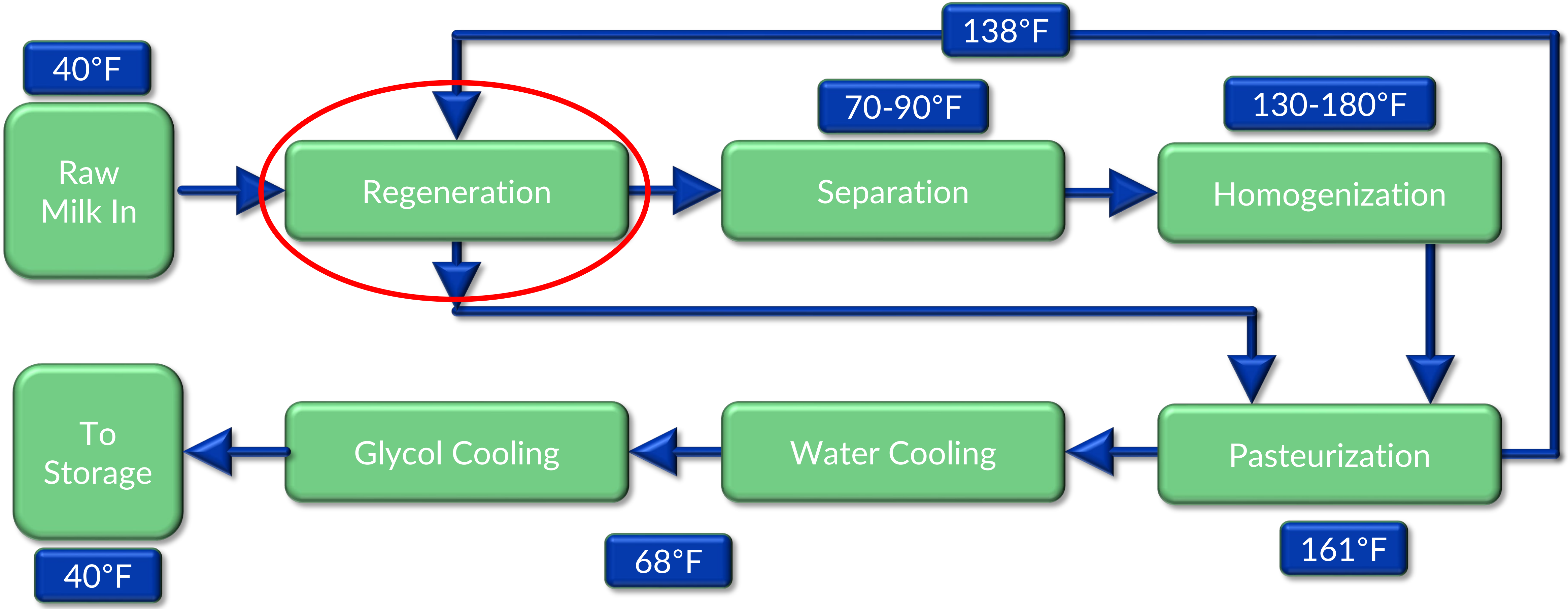
Johnson Controls

Industrial Dairy Facility – Ammonia Refrigeration System

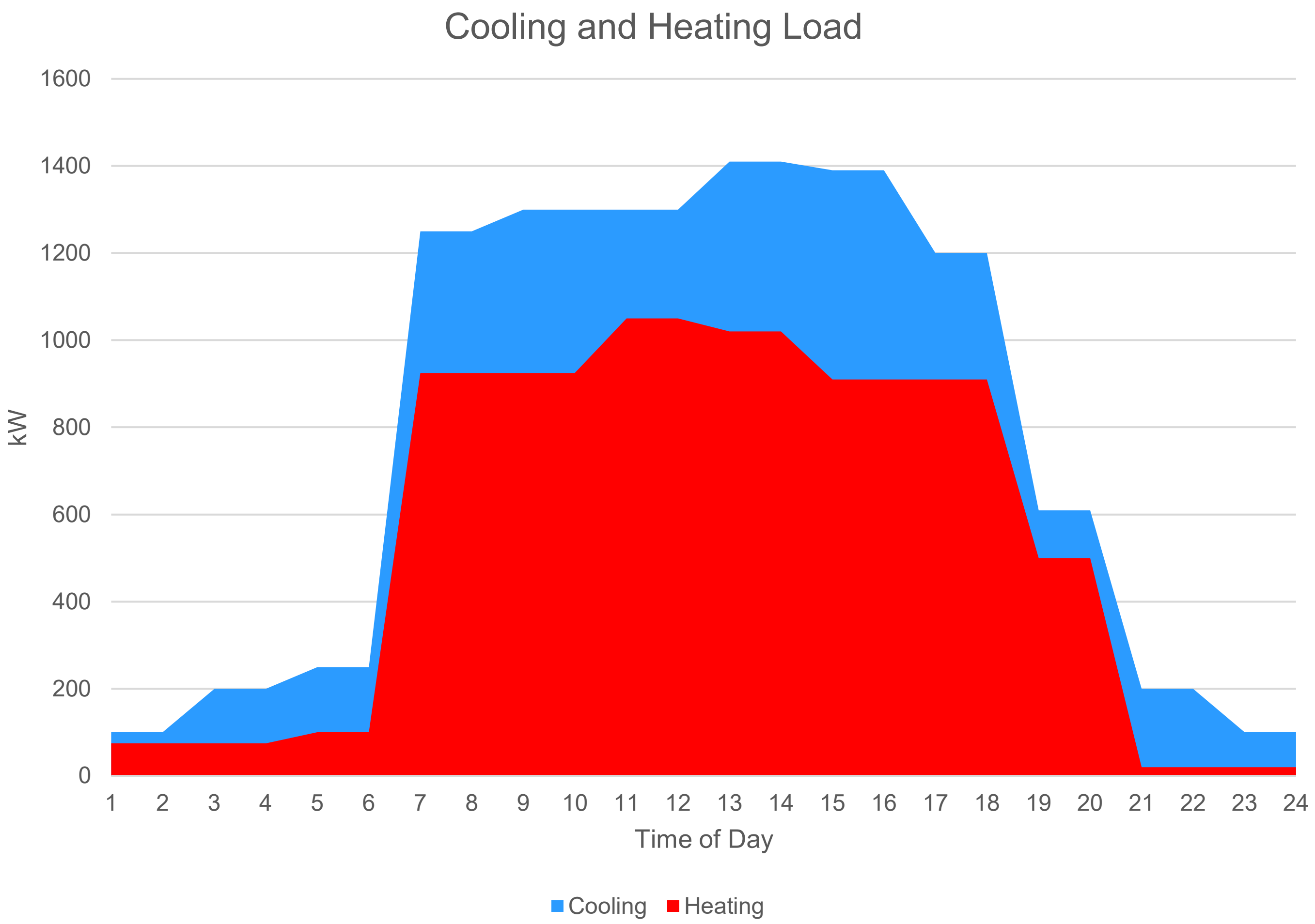
Block Diagram of a Traditional Ammonia System with Gas Boilers for Process Heating



Industrial Dairy Facility – Milk Processing



Industrial Dairy Facility – Load Profile



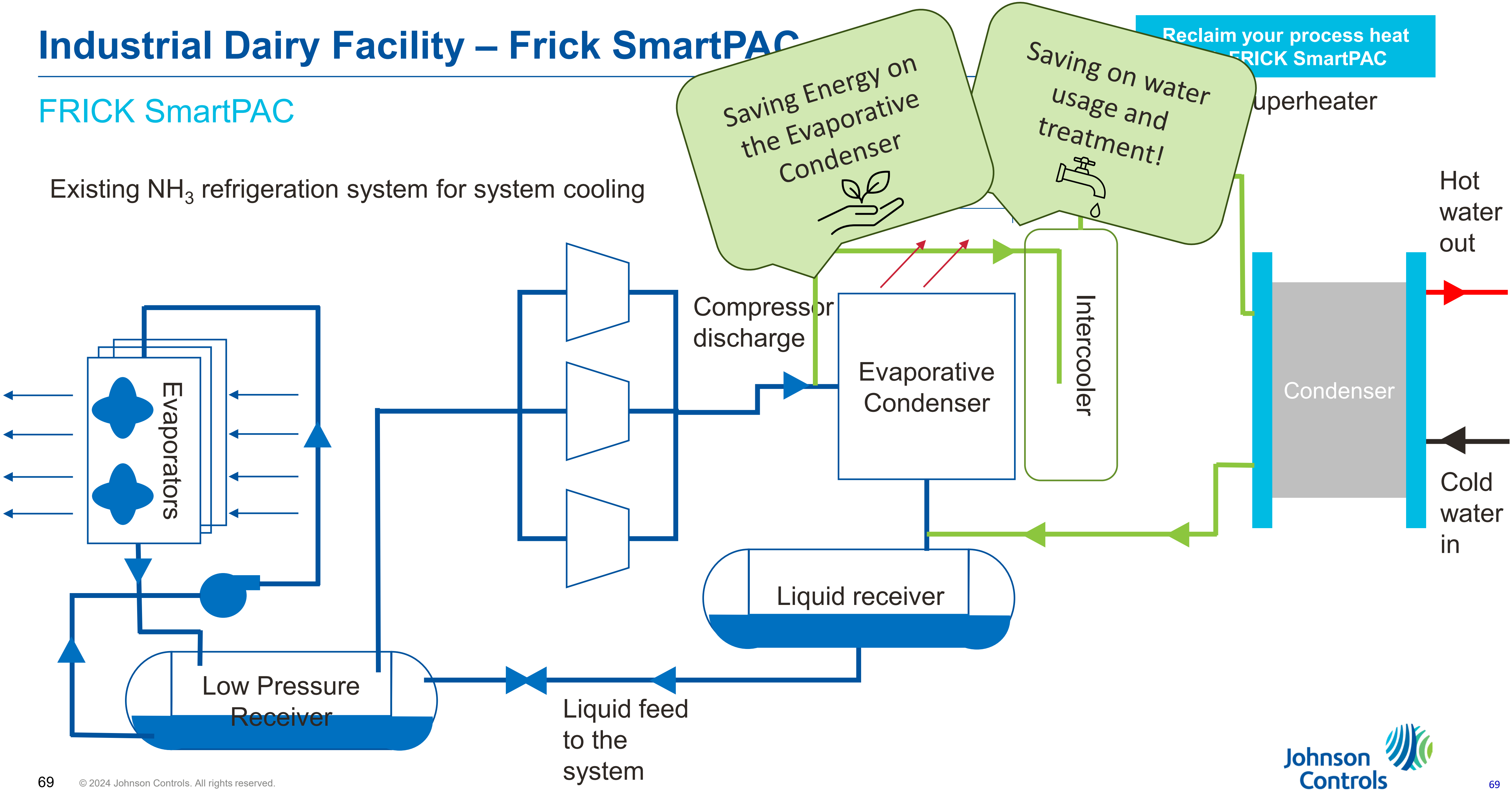
- Heating and Cooling happen at the same time
- Cooling load is larger than the heating load
- The load profile for a typical dairy plant is optimal for a heat pump

Industrial Dairy Facility – Frick SmartPAC

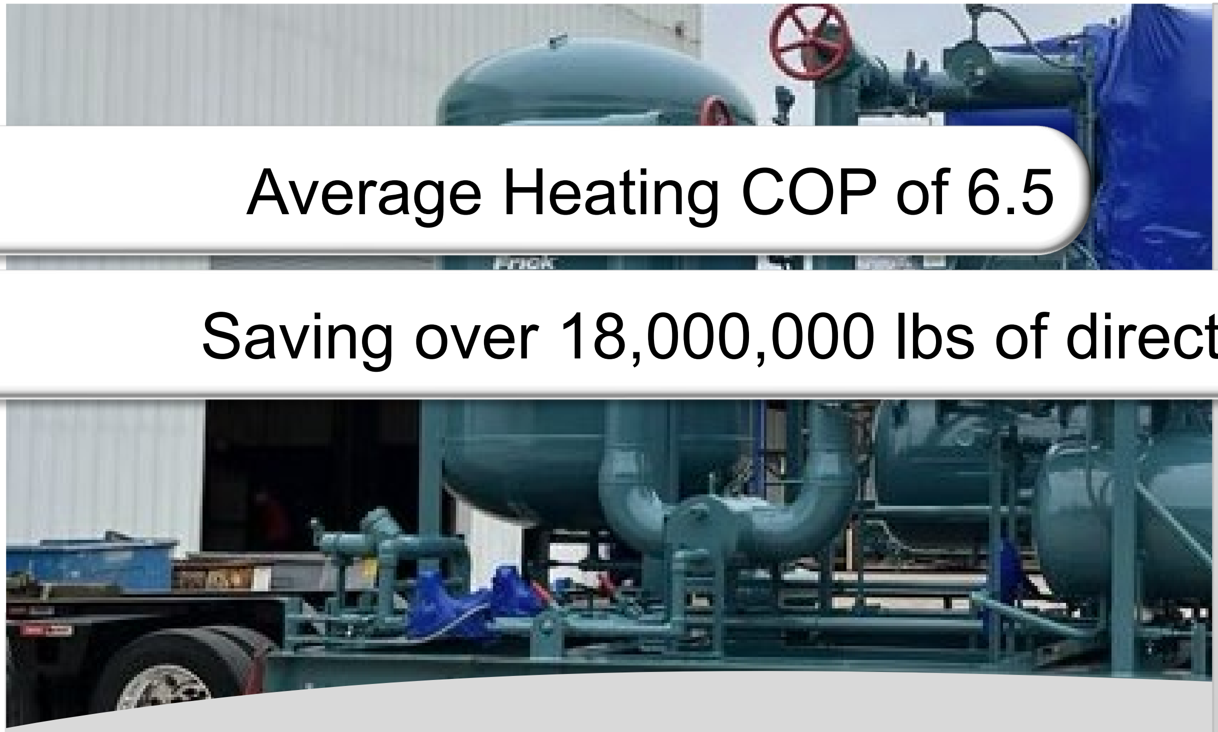
FRICK SmartPAC

Reclaim your process heat
FRICK SmartPAC

Existing NH_3 refrigeration system for system cooling



Industrial Dairy Facility – Real World Results

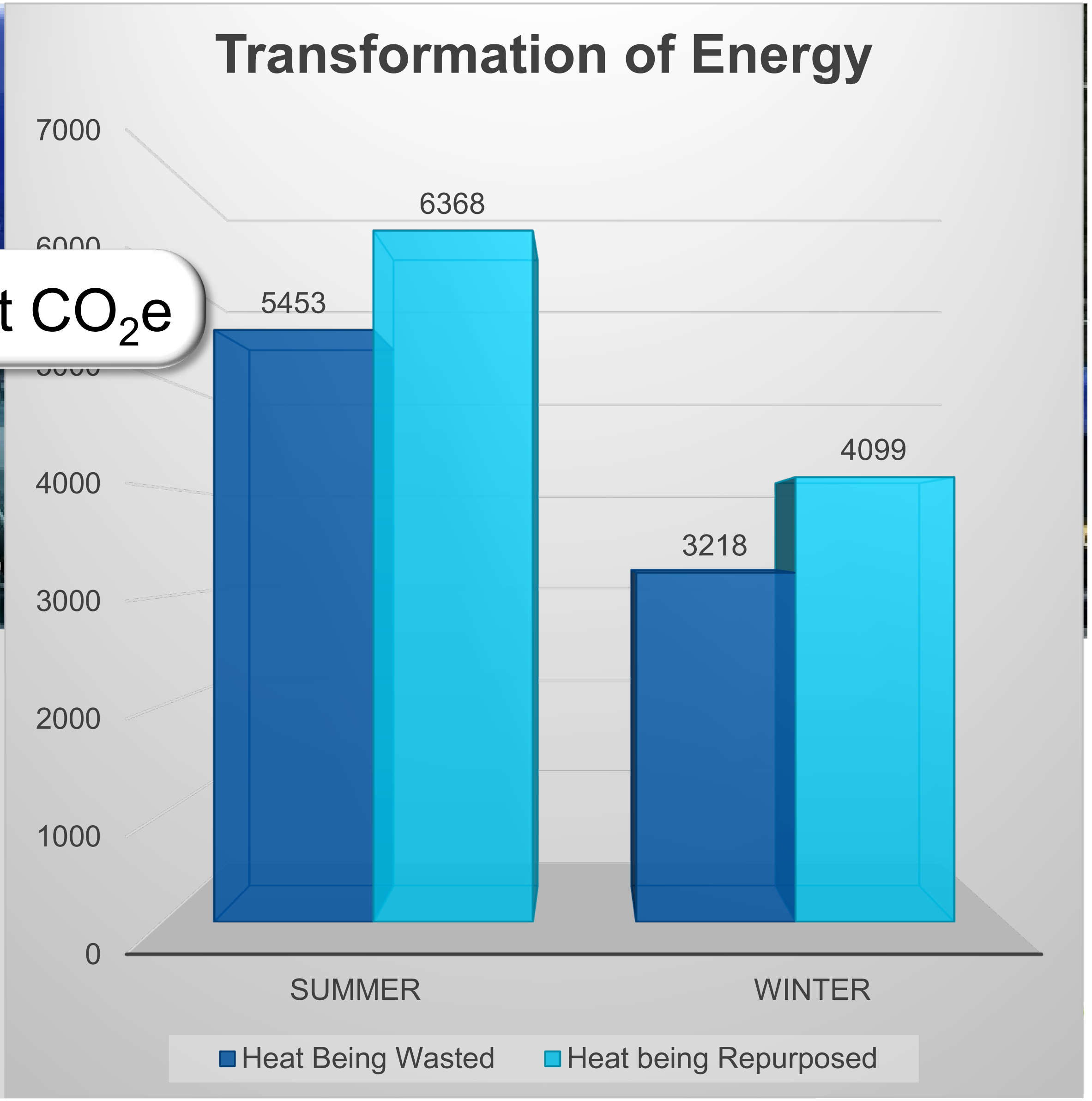


Average Heating COP of 6.5

Saving over 18,000,000 lbs of direct CO_2e

<u>Heat Being Wasted from the Existing System</u>:
Summer – 18,605 kBtu/hr (5,453 kW)
Winter – 10,980 kBtu/hr (3,218 kW)

<u>Total Heat generated by the SmartPAC</u>:
Summer – 21,726 kBtu/hr (6,368 kW)
Winter – 13,988 kBtu/hr (4,099 kW)



Engineering for a better world.

DAIRY DECARBONIZATION IN CALIFORNIA

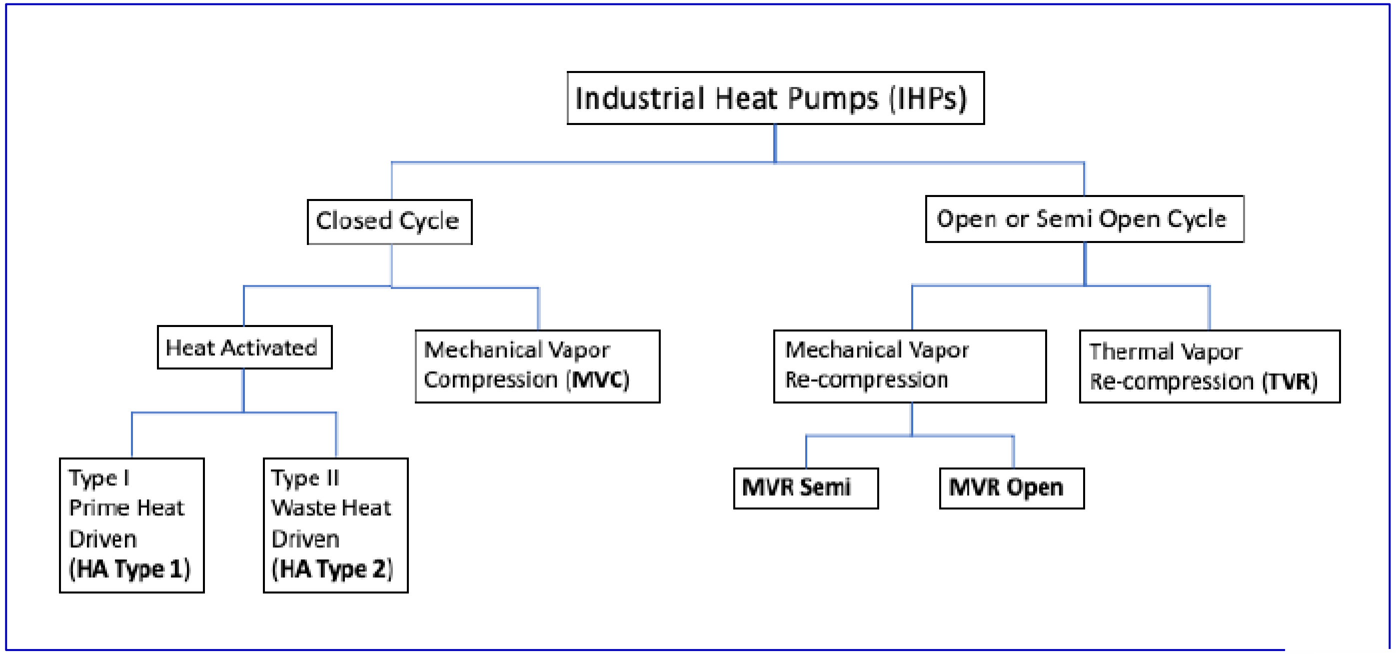
California Energy Commission

August 30th 2024

German Robledo
Industrial Heat Pump Sales Manager
GEA HRT North America

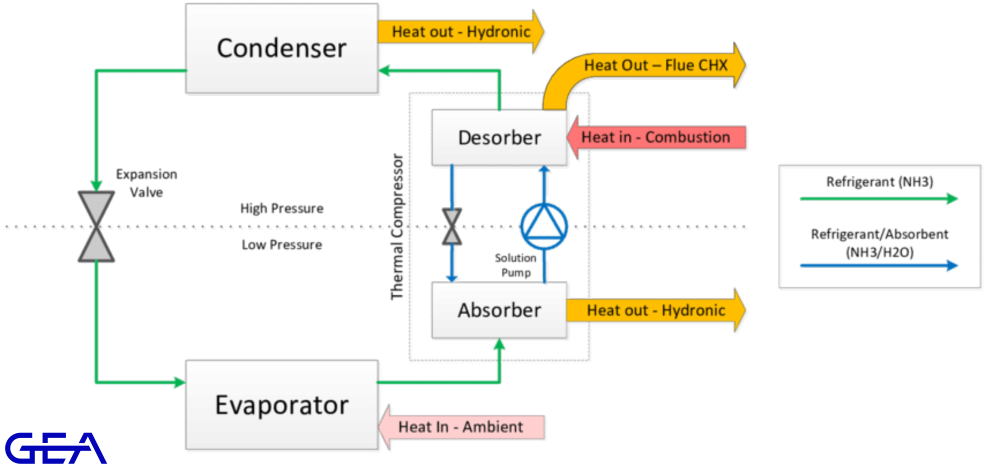
Heat Pump Fundamentals

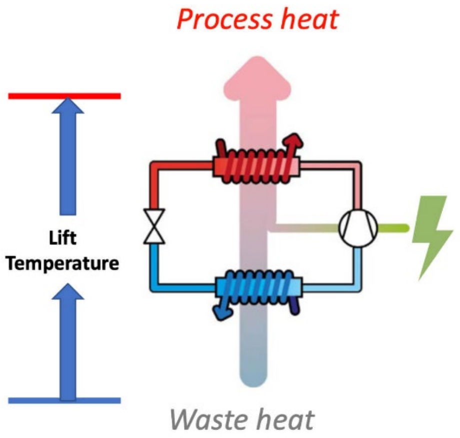
HIGH TEMPERATURE - HEAT PUMP - TECHNOLOGIES

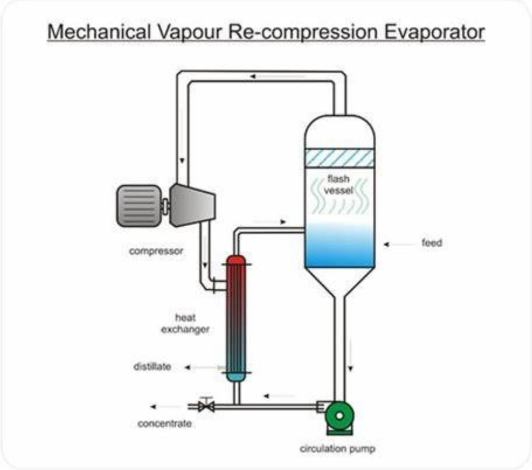


Can be driven by:

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







HEAT PUMP APPLICATIONS

Possible Industries Applications & Commercial Technology Available

Technology Readiness Level (TRL)	
(light grey)	conventional HP < 80°C / 176°F, established in the Industry
(blue)	commercial availbale HP 80-100° C / 176-212°F key technology
(yellow)	prototype stauts, technology development, High Temperature Heat Pump HTHP 100-140°C/ 212-284°F
(red)	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

°C	20	40	60	80	100	120	140	160	180	200
°F	68	104	140	176	212	248	284	320	356	392

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

Prototype

LAB RESEARCH

SECTOR	PROCESS	TEMP RANGE	
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

INDUSTRIAL HEAT PUMP - Fundamentals

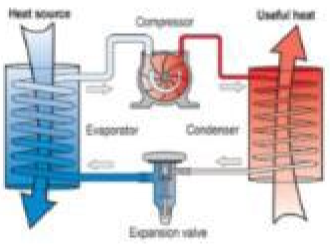
1. Industrial heat pumps are recovering excess heat from the same process as they are supplying to.

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

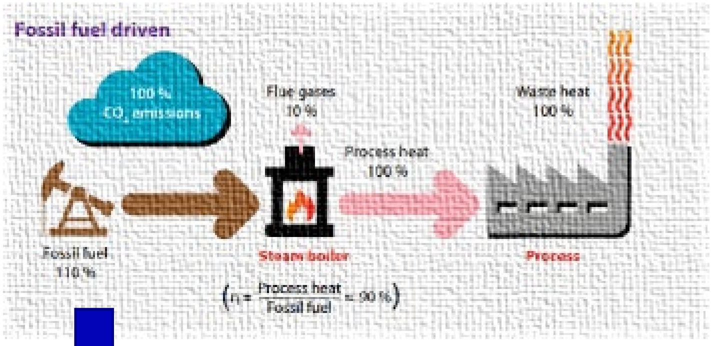
3. A Mechanical Vapor Compression Cycle, when used in Refrigeration it provides Cooling Benefit.

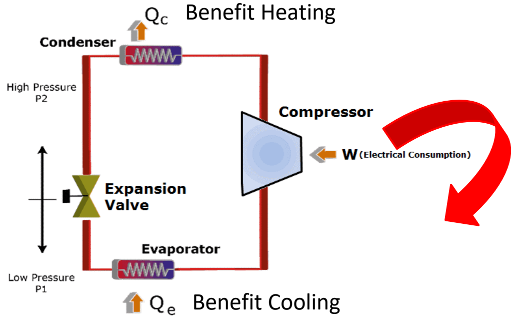
4. When used in Heat Pump, it provides Heating Benefit

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

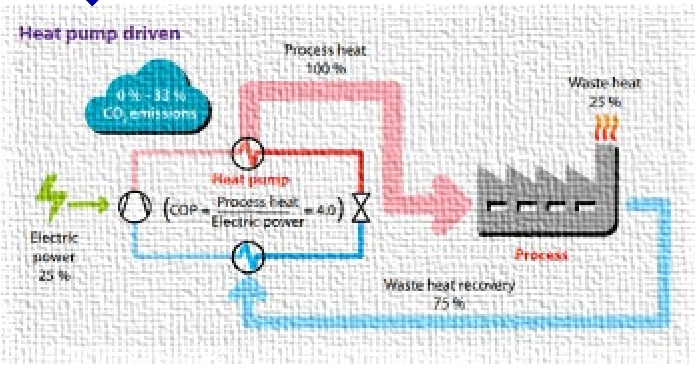


COMBUSTION ENERGY



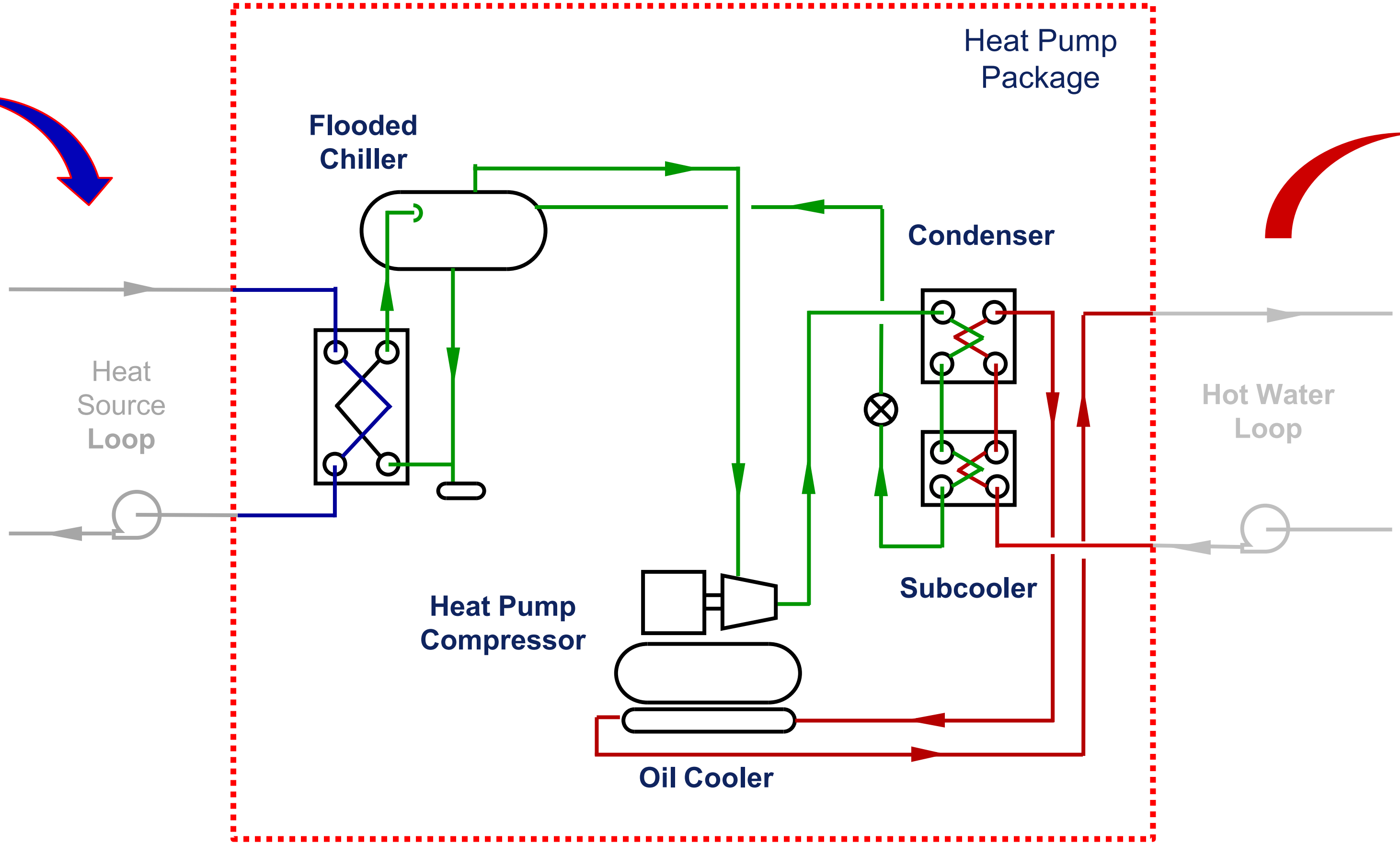


ELECTRIC ENERGY



HEAT SOURCE = AIR – WATER - GROUND – PROCESS HEAT

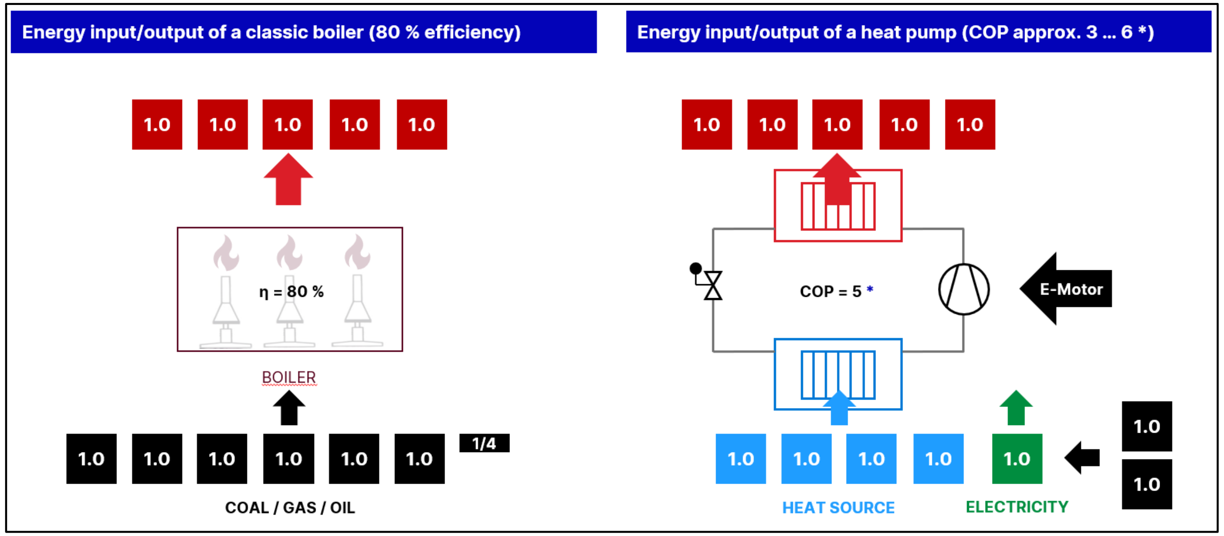
1. Air Source
2. Water Source
3. Ground Source
4. Industrial Waste Heat
5. Chilled Water Loops
6. Cooling Tower Loops
7. Others



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

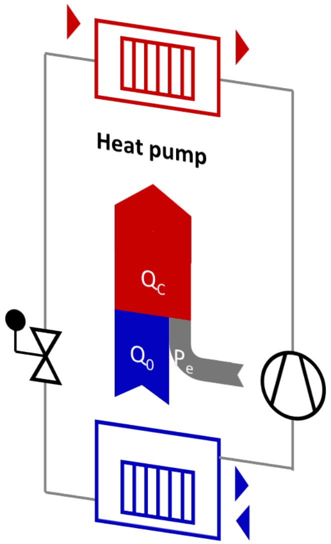
EFFICIENCY
COP - COEFICIENT OF PERFORMANCE

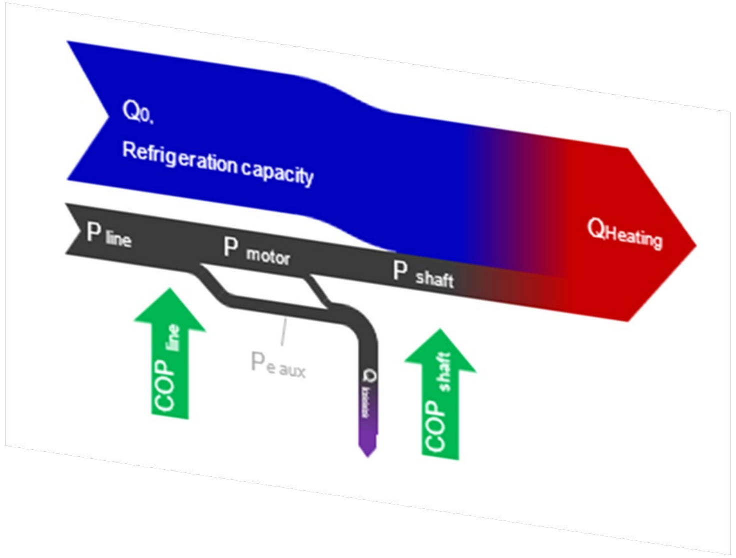
Heat Pump Efficiency (COP)



BOILER EFFICIENCY vs HEAT PUMP EFF

- The efficiency of a heat pump is commonly called COP_H (coefficient of performance heating)
- The heat source capacity (cooling capacity) Q_0 plus the electrical power added is the heating capacity Q_H, where P_e is normally smaller than Q_0.
- $Q_h = Q_0 + P_e$
- $Q_h = Heating\ capacity,$
- $Q_0 = Cooling\ capacity,$
- The heating efficiency of this process is described as a heating COP_H (coefficient of performance).
- Typical values achieved are between 3 and 6
- $COP_H = \frac{(Q_0+P)}{P}$ $P = driving\ power$





COST ENERGY COMPARISONS and COP

HEAT PUMP COP 3.0

Boiler Calculations					
Heat Capacity REQUIRED	kW	1500	HEAT PUMP COP	3.0	
Boiler Efficiency	%	90%			
Running hours	h / y	5,400	18 hours/day * 6 days * 50 weeks / year		
Energy Consumed	BOILER	1,667	HEAT PUMP	500	kW
Naturals Gas Burned	kWh/y	9,000,000	Electricity Used kW / y	2,700,000	

Assuming $800 / kW
Capital Cost of Heat Pump = $1,200,000

CO_2 Emmission Reduction 505 Metric Tons

Cost / kw/h	Electricity kW/h	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	$ 0.0216	2.2	$ 194,400	$ 129,870	$ 64,530	18.6
Nevada	$ 0.1047	$ 0.0370	2.8	$ 333,000	$ 282,690	$ 50,310	23.9
Trulock, CA	$ 0.1129	$ 0.0464	2.4	$ 417,600	$ 304,830	$ 112,770	10.6
Fort Morgen, CO	$ 0.0432	$ 0.0288	1.5	$ 259,200	$ 116,640	$ 142,560	8.4
Jerome, ID	$ 0.0543	$ 0.0196	2.8	$ 176,400	$ 146,610	$ 29,790	40.3

$$\text{Savings on Energy Costs} \approx \frac{Gas\ Price - \left(\frac{electric\ price}{COP}\right)}{Gas\ Price}$$

	MW/ h	MW /h		Savings on Energy Costs
Lubbock, TX	$ 48.10	$ 21.60	≈	25.8%
Nevada	$ 104.70	$ 37.00	≈	5.7%
Trulock, CA	$ 112.90	$ 46.40	≈	18.9%
Fort Morgen, CO	$ 43.20	$ 28.80	≈	50.0%
Jerome, ID	$ 54.30	$ 19.60	≈	7.7%

HEAT PUMP COP 4.0

Boiler Calculations					
Heat Capacity REQUIRED	kW	1500	HEAT PUMP COP	4.0	
Boiler Efficiency	%	90%			
Running hours	h / y	5,400	18 hours/day * 6 days * 50 weeks / year		
Energy Consumed	BOILER	1,667	HEAT PUMP	375	kW
Naturals Gas Burned	kWh/y	9,000,000	Electricity Used kW / y	2,025,000	

Assuming $800 / kW
Capital Cost of Heat Pump = $1,200,000

CO_2 Emmission Reduction 559 Metric Tons

Cost / kw/h	Electricity kW/h	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	$ 0.0216	2.2	$ 194,400	$ 97,403	$ 96,998	12.4
Nevada	$ 0.1047	$ 0.0370	2.8	$ 333,000	$ 212,018	$ 120,983	9.9
Trulock, CA	$ 0.1129	$ 0.0464	2.4	$ 417,600	$ 228,623	$ 188,978	6.3
Fort Morgen, CO	$ 0.0432	$ 0.0288	1.5	$ 259,200	$ 87,480	$ 171,720	7.0
Jerome, ID	$ 0.0543	$ 0.0196	2.8	$ 176,400	$ 109,958	$ 66,443	18.1

$$\text{Savings on Energy Costs} \approx \frac{Gas\ Price - \left(\frac{electric\ price}{COP}\right)}{Gas\ Price}$$

	MW/ h	MW /h		Savings on Energy Costs
Lubbock, TX	$ 48.10	$ 21.60	≈	44.3%
Nevada	$ 104.70	$ 37.00	≈	29.3%
Trulock, CA	$ 112.90	$ 46.40	≈	39.2%
Fort Morgen, CO	$ 43.20	$ 28.80	≈	62.5%
Jerome, ID	$ 54.30	$ 19.60	≈	30.7%

HEAT PUMP COP 5.0

Boiler Calculations					
Heat Capacity REQUIRED	kW	1500	HEAT PUMP COP	5.0	
Boiler Efficiency	%	90%			
Running hours	h / y	5,400	18 hours/day * 6 days * 50 weeks / year		
Energy Consumed	BOILER	1,667	HEAT PUMP	300	kW
Naturals Gas Burned	kWh/y	9,000,000	Electricity Used kW / y	1,620,000	

Assuming $800 / kW
Capital Cost of Heat Pump = $1,200,000

CO_2 Emmission Reduction 592 Metric Tons

Cost / kw/h	Electricity kW/h	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	$ 0.0216	2.2	$ 194,400	$ 77,922	$ 116,478	10.3
Nevada	$ 0.1047	$ 0.0370	2.8	$ 333,000	$ 169,614	$ 163,386	7.3
Trulock, CA	$ 0.1129	$ 0.0464	2.4	$ 417,600	$ 182,898	$ 234,702	5.1
Fort Morgen, CO	$ 0.0432	$ 0.0288	1.5	$ 259,200	$ 69,984	$ 189,216	6.3
Jerome, ID	$ 0.0543	$ 0.0196	2.8	$ 176,400	$ 87,966	$ 88,434	13.6

$$\text{Savings on Energy Costs} \approx \frac{Gas\ Price - \left(\frac{electric\ price}{COP}\right)}{Gas\ Price}$$

	MW/ h	MW /h		Savings on Energy Costs
Lubbock, TX	$ 48.10	$ 21.60	≈	55.5%
Nevada	$ 104.70	$ 37.00	≈	43.4%
Trulock, CA	$ 112.90	$ 46.40	≈	51.3%
Fort Morgen, CO	$ 43.20	$ 28.80	≈	70.0%
Jerome, ID	$ 54.30	$ 19.60	≈	44.6%

HEAT PUMP COP 6.0

Boiler Calculations					
Heat Capacity REQUIRED	kW	1500	HEAT PUMP COP	6.0	
Boiler Efficiency	%	90%			
Running hours	h / y	5,400	18 hours/day * 6 days * 50 weeks / year		
Energy Consumed	BOILER	1,667	HEAT PUMP	250	kW
Naturals Gas Burned	kWh/y	9,000,000	Electricity Used kW / y	1,350,000	

Assuming $800 / kW
Capital Cost of Heat Pump = $1,200,000

CO_2 Emmission Reduction 613 Metric Tons

Cost / kw/h	Electricity kW/h	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	$ 0.0216	2.2	$ 194,400	$ 64,935	$ 129,465	9.3
Nevada	$ 0.1047	$ 0.0370	2.8	$ 333,000	$ 141,345	$ 191,655	6.3
Trulock, CA	$ 0.1129	$ 0.0464	2.4	$ 417,600	$ 152,415	$ 265,185	4.5
Fort Morgen, CO	$ 0.0432	$ 0.0288	1.5	$ 259,200	$ 58,320	$ 200,880	6.0
Jerome, ID	$ 0.0543	$ 0.0196	2.8	$ 176,400	$ 73,305	$ 103,095	11.6

$$\text{Savings on Energy Costs} \approx \frac{Gas\ Price - \left(\frac{electric\ price}{COP}\right)}{Gas\ Price}$$

	MW/ h	MW /h		Savings on Energy Costs
Lubbock, TX	$ 48.10	$ 21.60	≈	62.9%
Nevada	$ 104.70	$ 37.00	≈	52.8%
Trulock, CA	$ 112.90	$ 46.40	≈	59.4%
Fort Morgen, CO	$ 43.20	$ 28.80	≈	75.0%
Jerome, ID	$ 54.30	$ 19.60	≈	53.8%

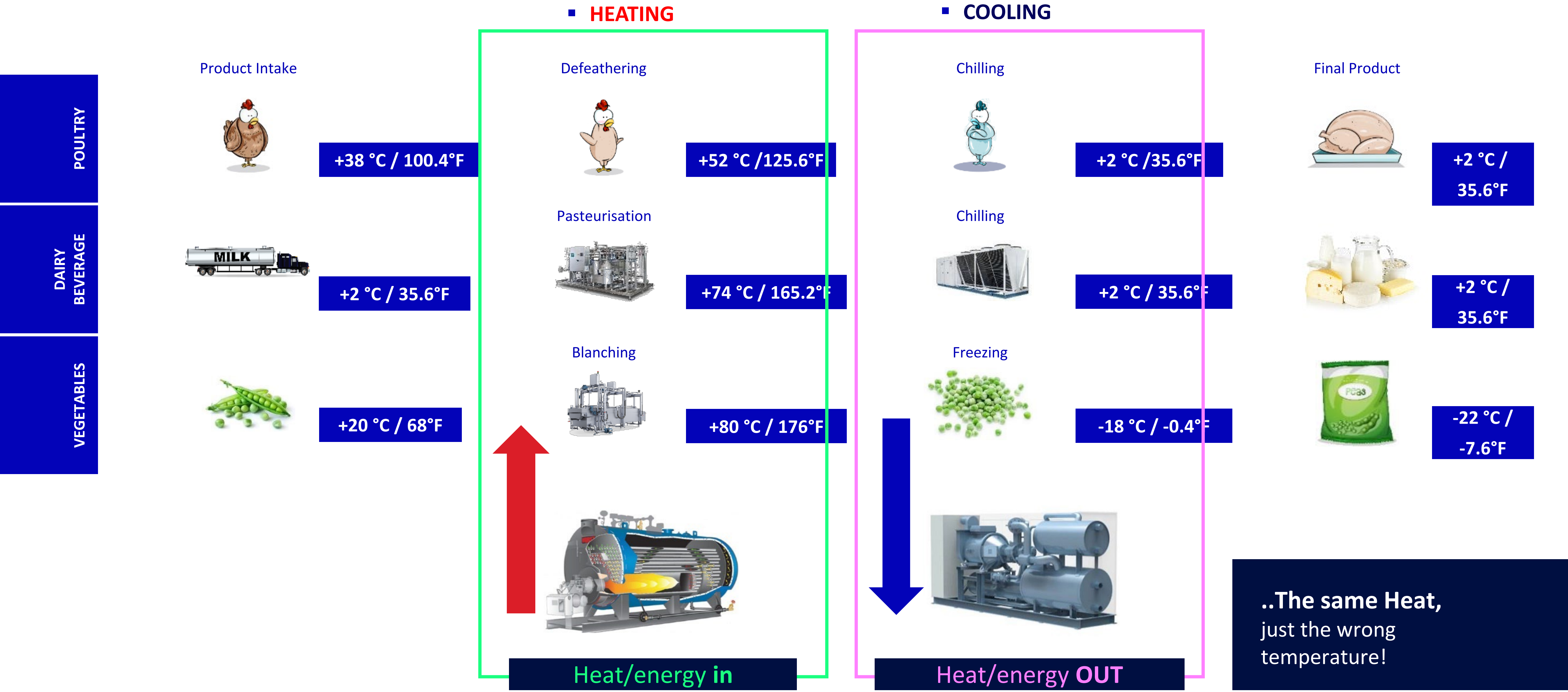
COP Increase:

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

THERMAL NEEDS

Heat pumps

understanding our thermal needs!

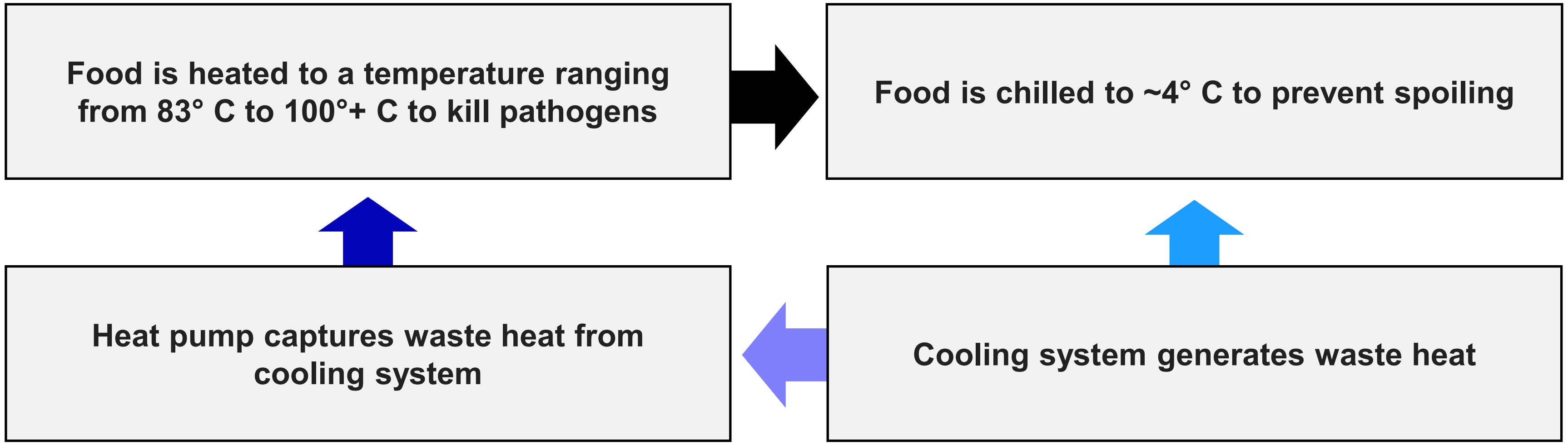


Pasteurizing with Heat Pumps

How Heat Pumps Can Be Used for Pasteurization

- Primarily applied to liquids, pasteurization uses heat to kill pathogens and increase the shelf life of foods and beverages. Though some foods are pasteurized with steam, exposure to much lower temperatures can effectively pasteurize many foods (see table for temperatures used in milk pasteurization).

- **Waste Heat Recapture**
- Most non-acidic foods need to be chilled after pasteurization. The cooling systems used to do this generate waste heat that can be recaptured to serve as the source heat for a heat pump.



Food and Drug Administration Milk Pasteurization Specifications[19]

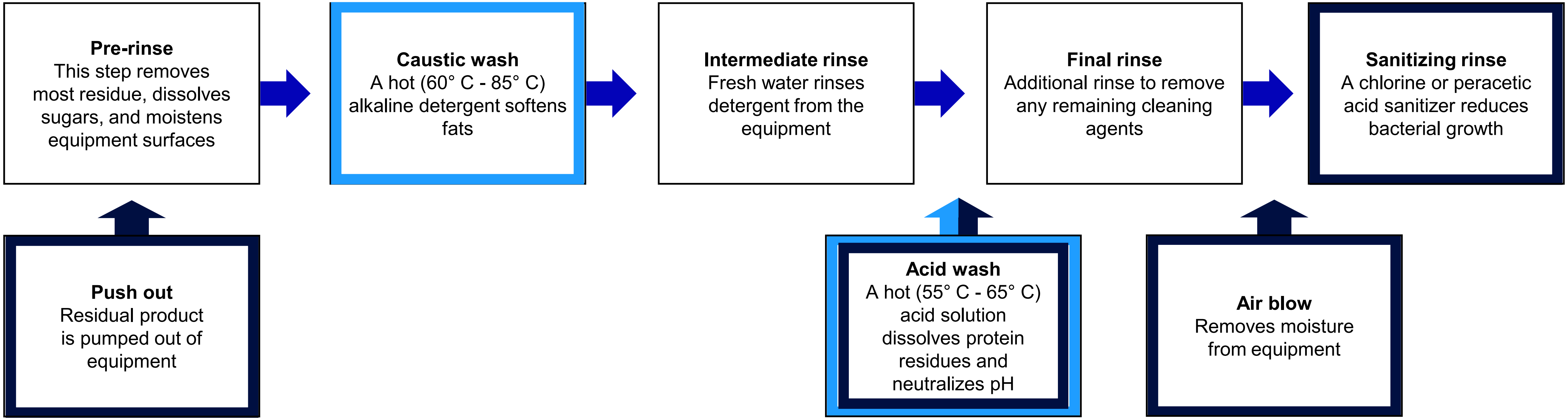
TEMPERATURE	TIME
Batch (Vat) Pasteurization	
83° C	30 minutes
Continuous Flow High-Temperature-Short-Time (HTST) Pasteurization	
72° C	15 seconds
Continuous Flow Higher-Heat-Shorter-Time (HHST) Pasteurization	
89° C	1.0 seconds
90° C	0.5 seconds
94° C	0.1 seconds
96° C	0.05 seconds
100° C	0.01 seconds
Ultra-Pasteurization (UP)	
83° C	30 minutes

Cleaning-in-Place with Heat Pumps

- How Heat Pumps Can Be Used to Supply Heat to CIP Systems

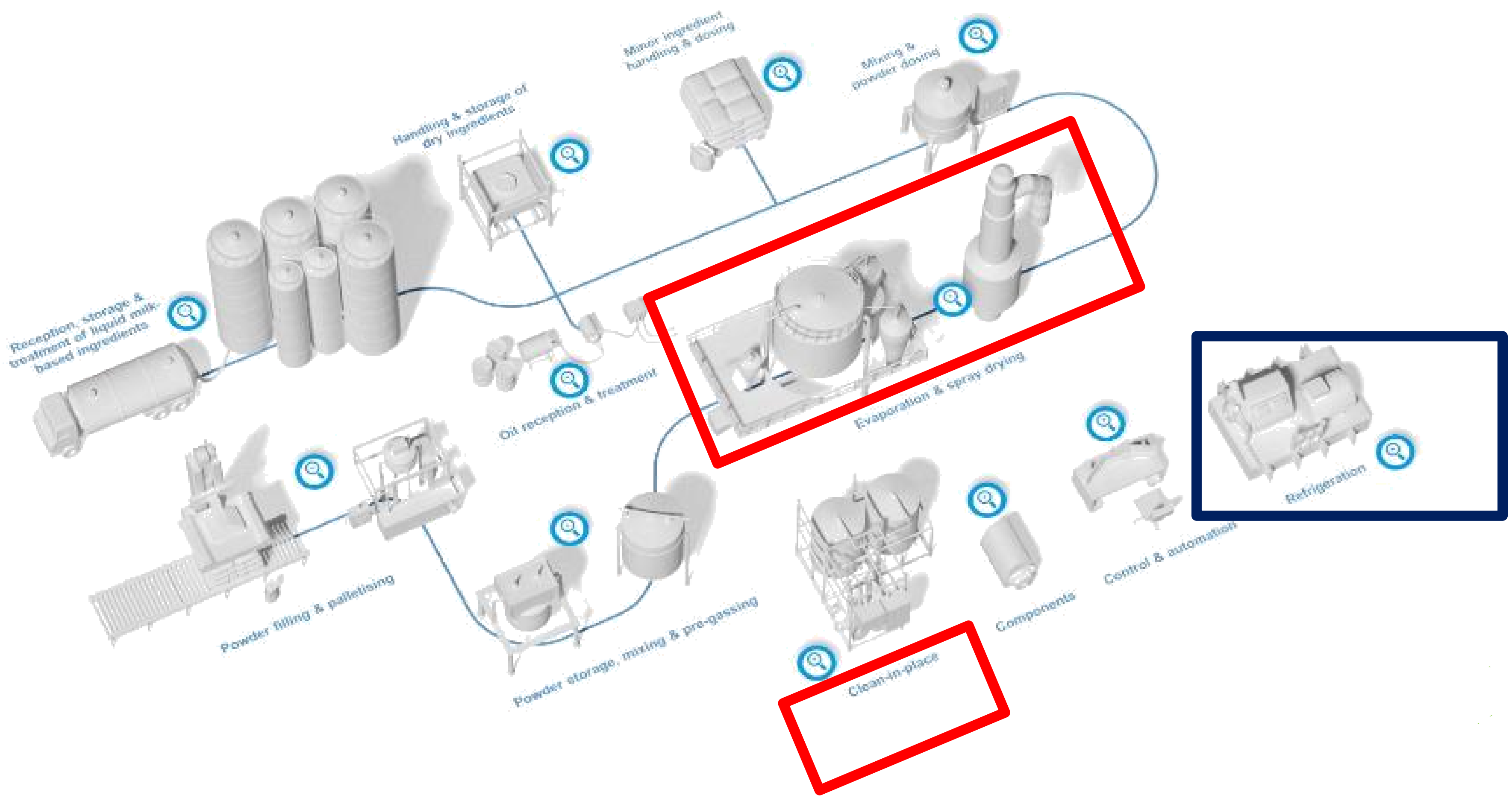
Opportunities for heat pump use

Optional steps

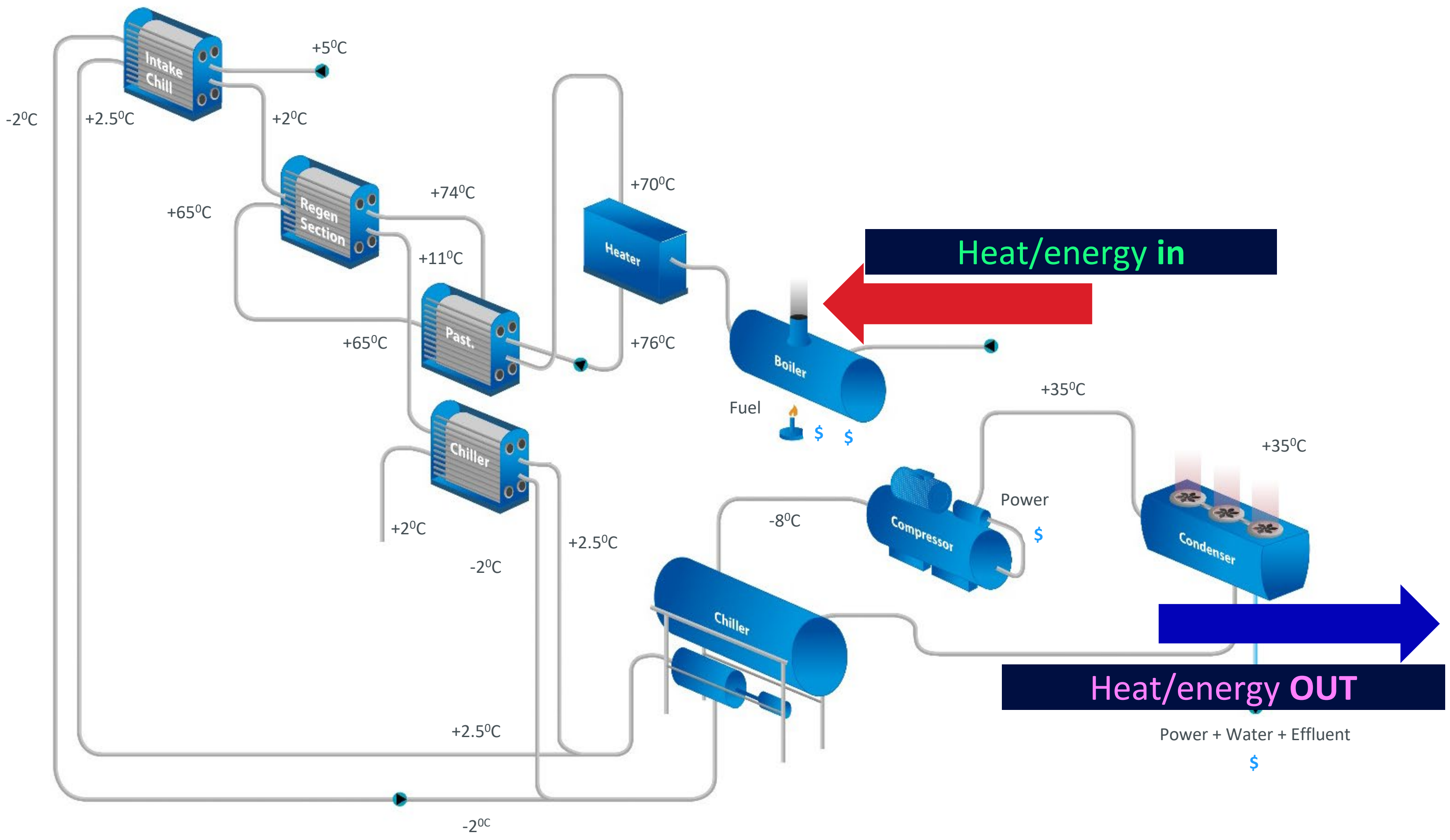


Heat pumps can provide temperatures up to 100 ° C and, therefore, act as the heat source for the highlighted processes.

GEA Sustainable Energy Solution
Dairy Application



Heating/Cooling in Traditional Dairy



9.5 Million ltr/wk Fresh Milk

Heating Cost
72,000kwhr/wk Natural Gas (7 day/week):
x 52 = 3.74 million kWh/year energy (fuel) used

Refrigeration Cost
14,280kwhr/wk (7day/week):
x 52 = 0.74 million kWh energy (electricity) used

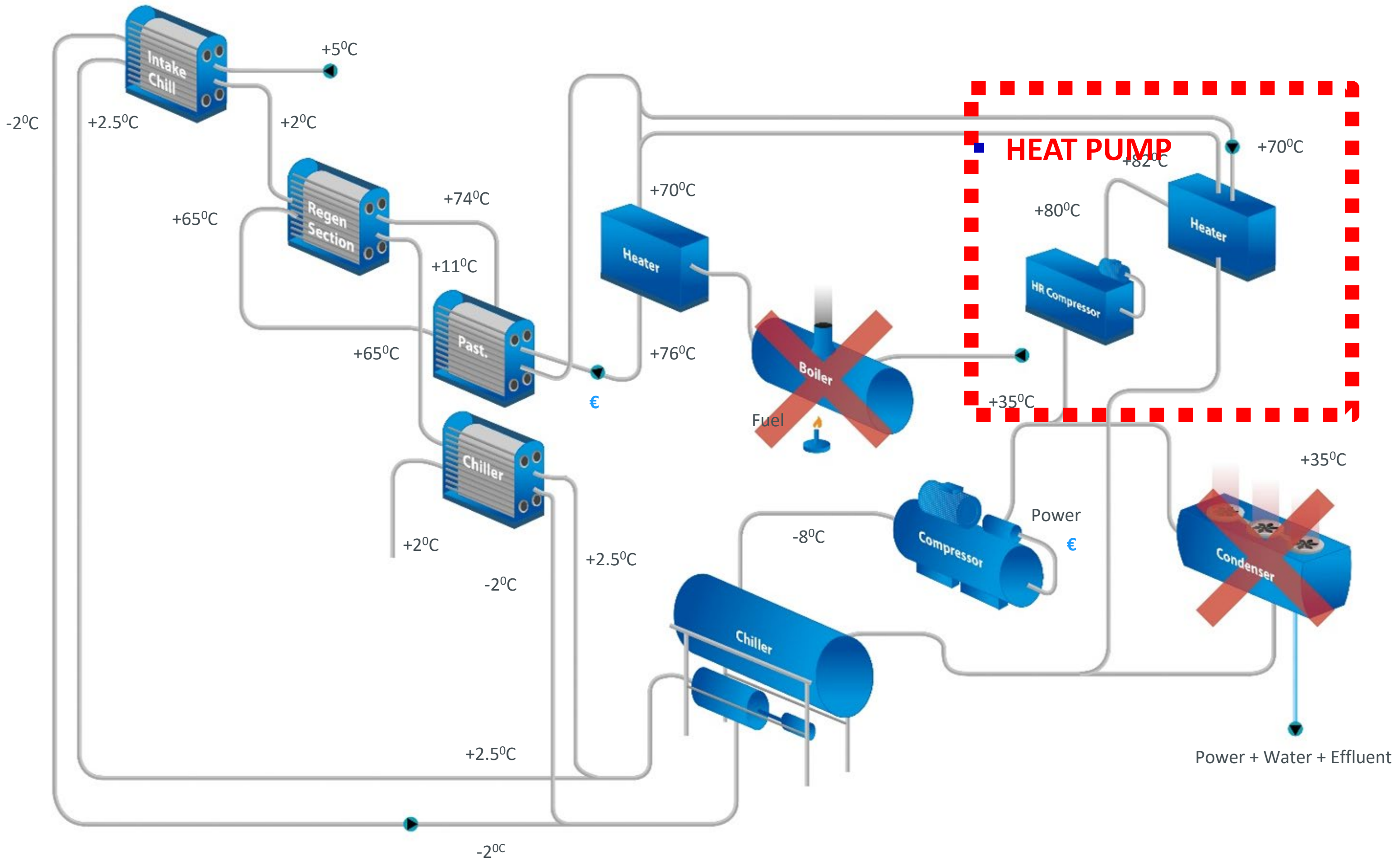
Water used
407m3/wk (7day/wk): x 52 = 21k m3/year

Total energy = 4.48 million kWh/year

Emissions = 970 tons CO_2e

GEA

Heating/Cooling in Dairy with Heat Pump



9.5 Million ltr/wk Fresh Milk

Heating Cost
6,440kwhr/wk (7 day/week): x 52 = 0.33 million kWh/year energy (electricity) used

Refrigeration Cost
14,280kwhr/wk (7day/week):
x 52 = 0.74 million kWh energy (electricity) used

Water used
242m3/wk (7day/wk): x 52 = 12.5k m^3/year

Total energy = 1.07 million kWh/year

Emissions = 321 tons CO_2e

GEA

HEAT PUMPS PRODUCT

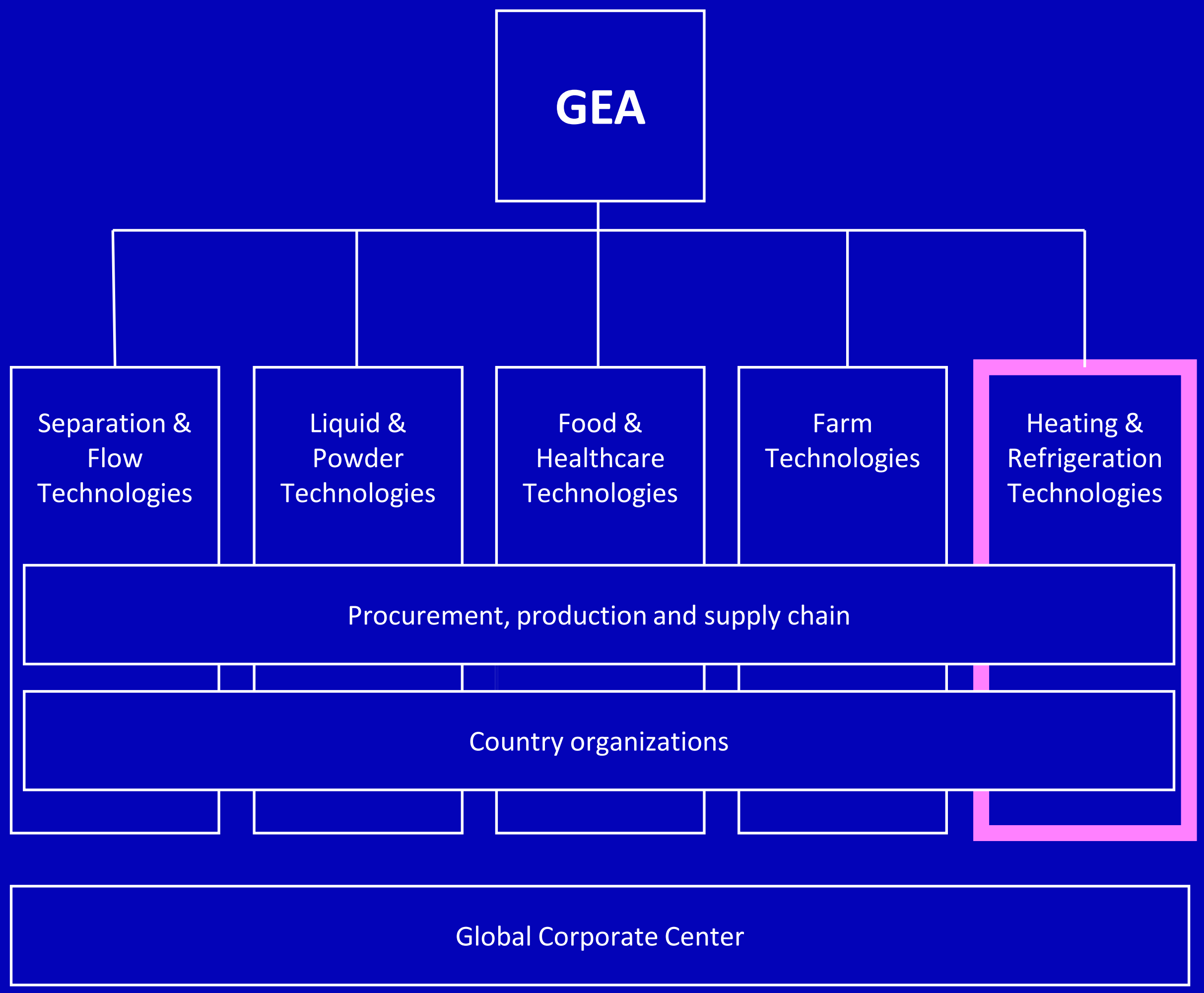
AND

CASES IN NORTH AMERICA

Our organization

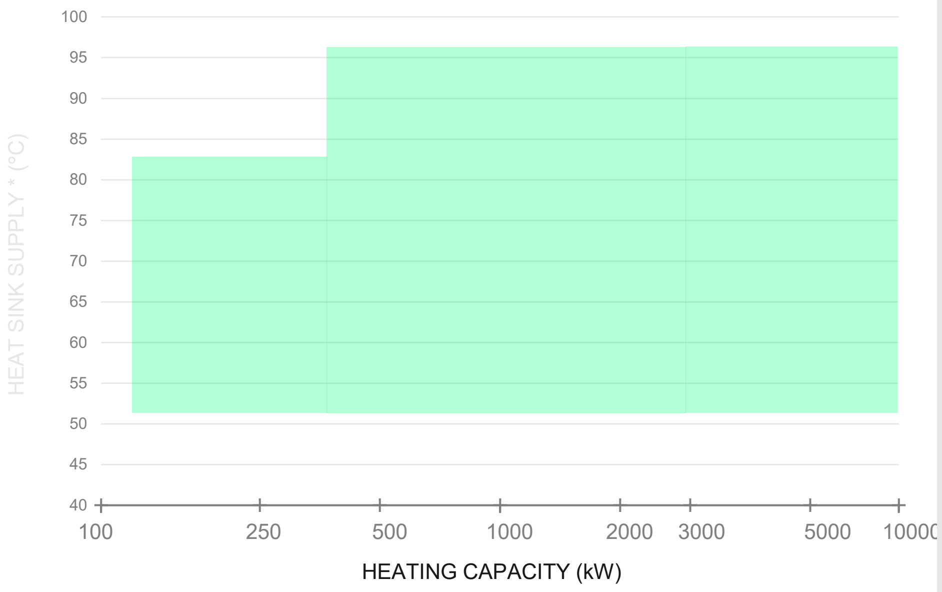
GEA is divided into **five divisions**, each with up to six business units. The units are based on comparable technologies and have leading market positions.

The **country organizations** stand ready to serve their respective customers as a central point of contact, offering them local access to an extensive portfolio of products and services.

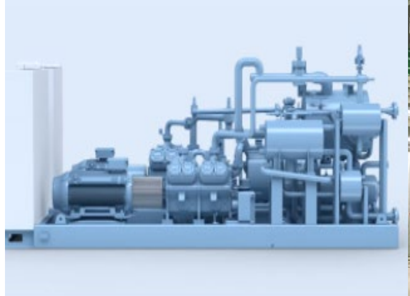


GEA Ammonia Heat Pump Portfolio

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

GEA ammonia heat pump example GEA RedGenium

Design of the standard reciprocating compressor heat pump:

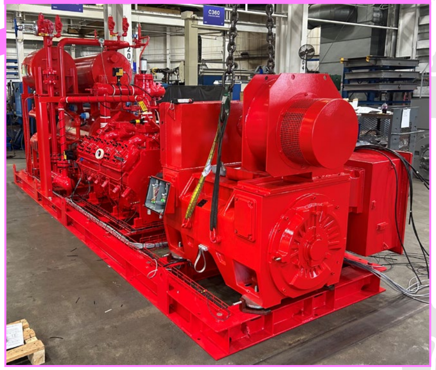
GEA heat pumps references

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 DAIRY Cases

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

GEA Engineering

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.

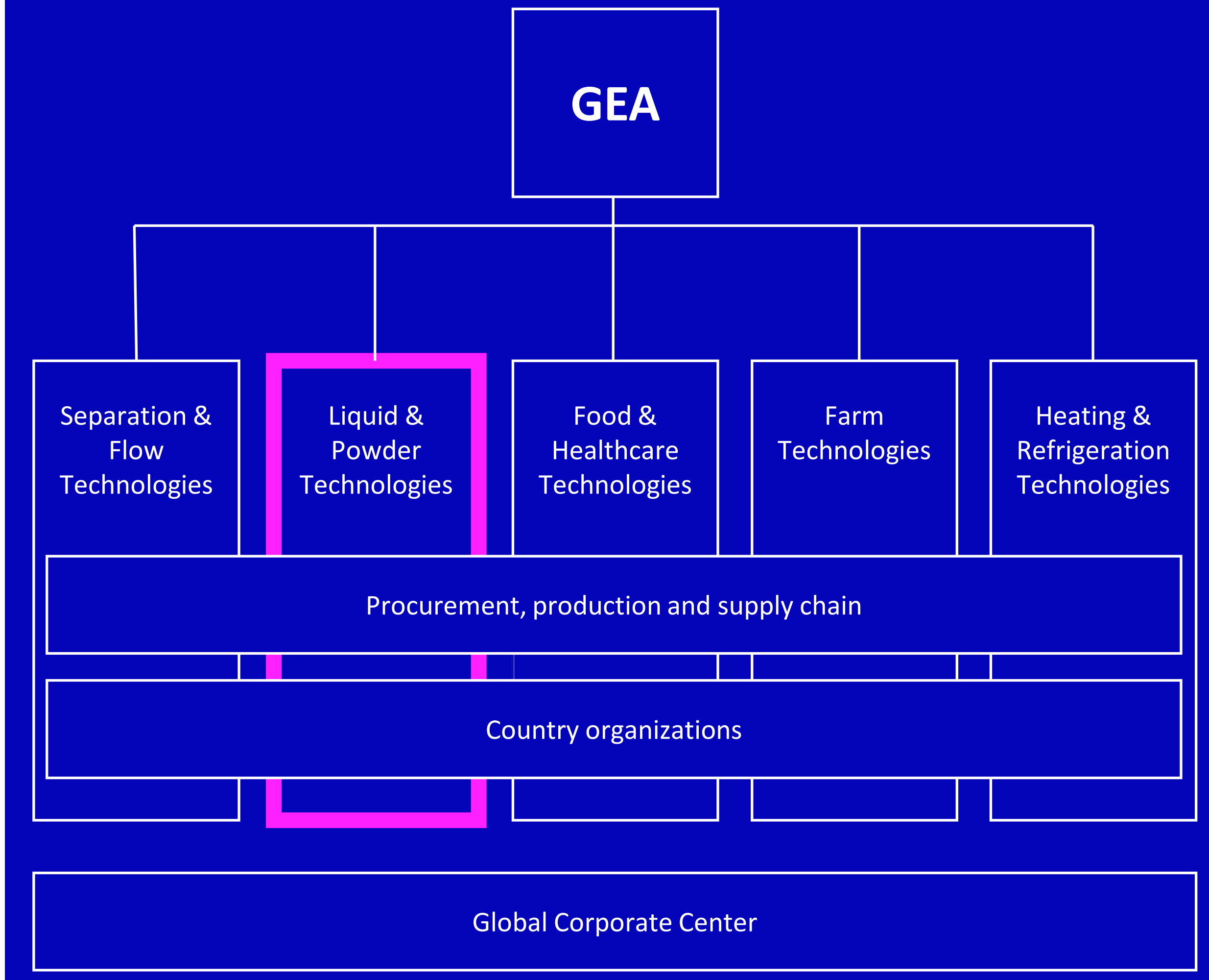
GEA Engineering for a better world.

GEA.com/heating-refrigeration

Our organization

GEA is divided into **five divisions**, each with up to six business units. The units are based on comparable technologies and have leading market positions.

The **country organizations** stand ready to serve their respective customers as a central point of contact, offering them local access to an extensive portfolio of products and services.

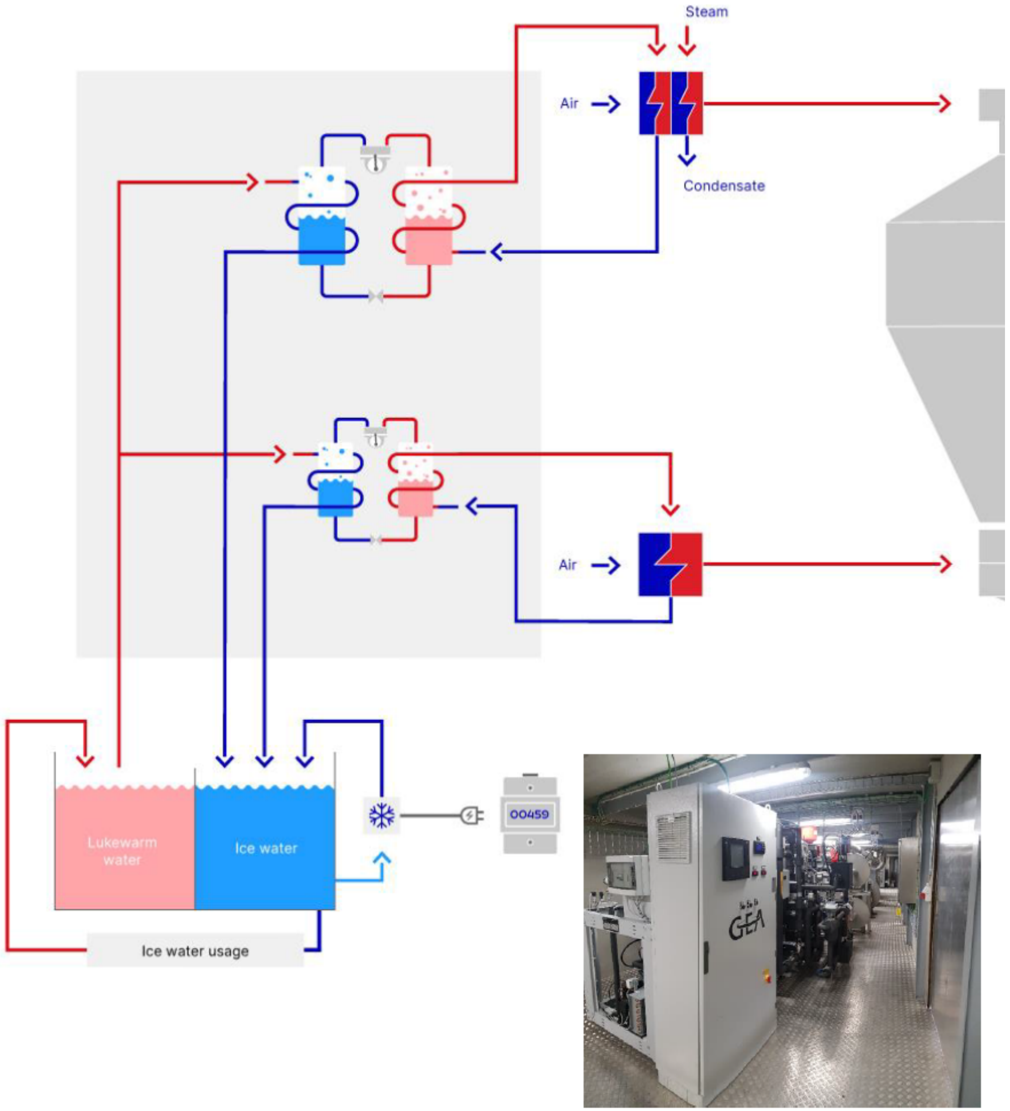


ADD COOL by GEA LPT - Spray Drying (R744 – CO2 Heat Pump)

GEA AddCool

To make spray drying processes more sustainable GEA integrates high temperature heat pumps. This is GEA AddCool technology.

- AddCool makes use of GEA CO_2 transcritical heat pumps to preheat the air to up to 120 °C before it is passed to conventional heaters
- At the same time ice water at 2 °C can be supplied to the existing ice water network reducing electrical power consumption by existing chillers
- Dryer operation and product quality are unaffected
- The heat pump technology is proven in a pilot plant installed in GEA test facility in Denmark



GEA

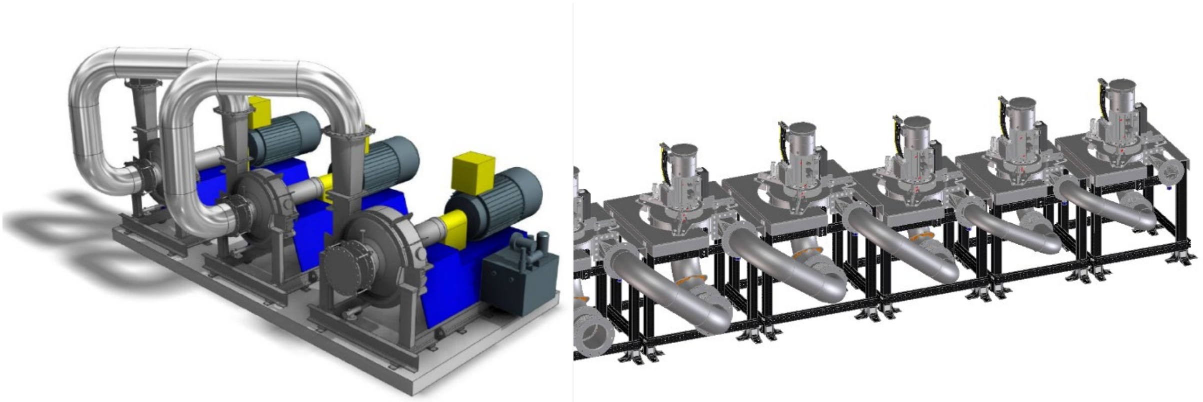
MVR (Mechanical Vapor Recompression)

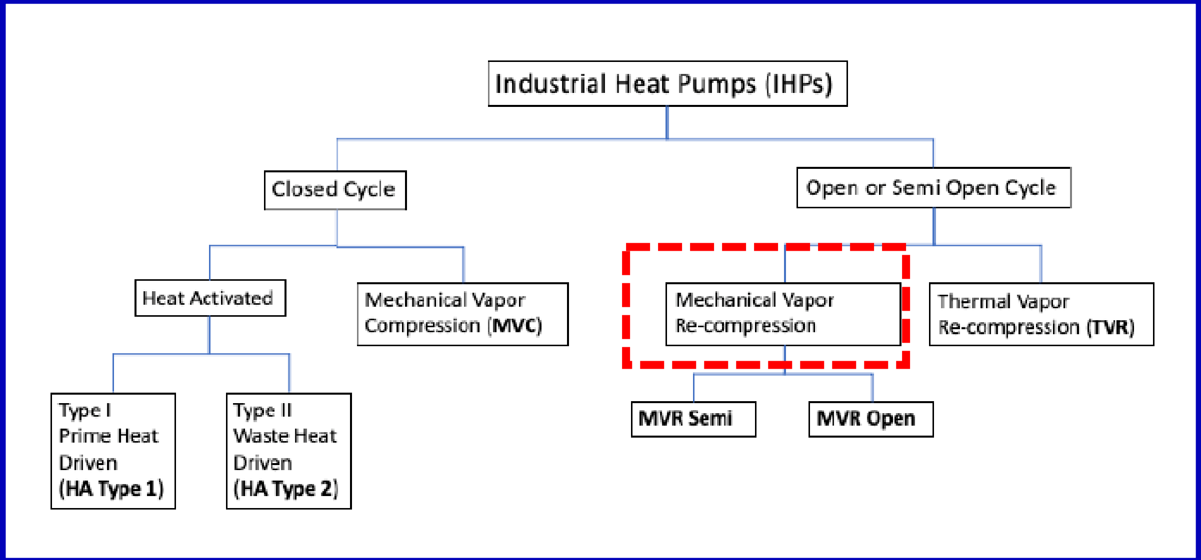
Heat Pump

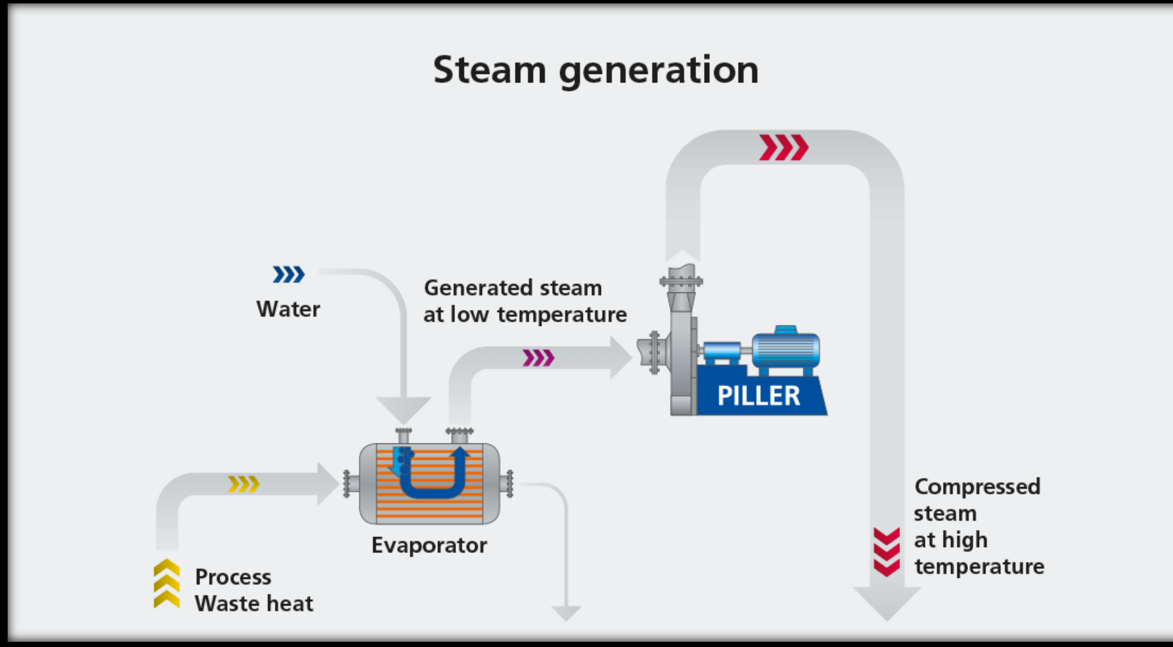
How does a Steam Generating Heat Pump work? How does an MRV works ??

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.

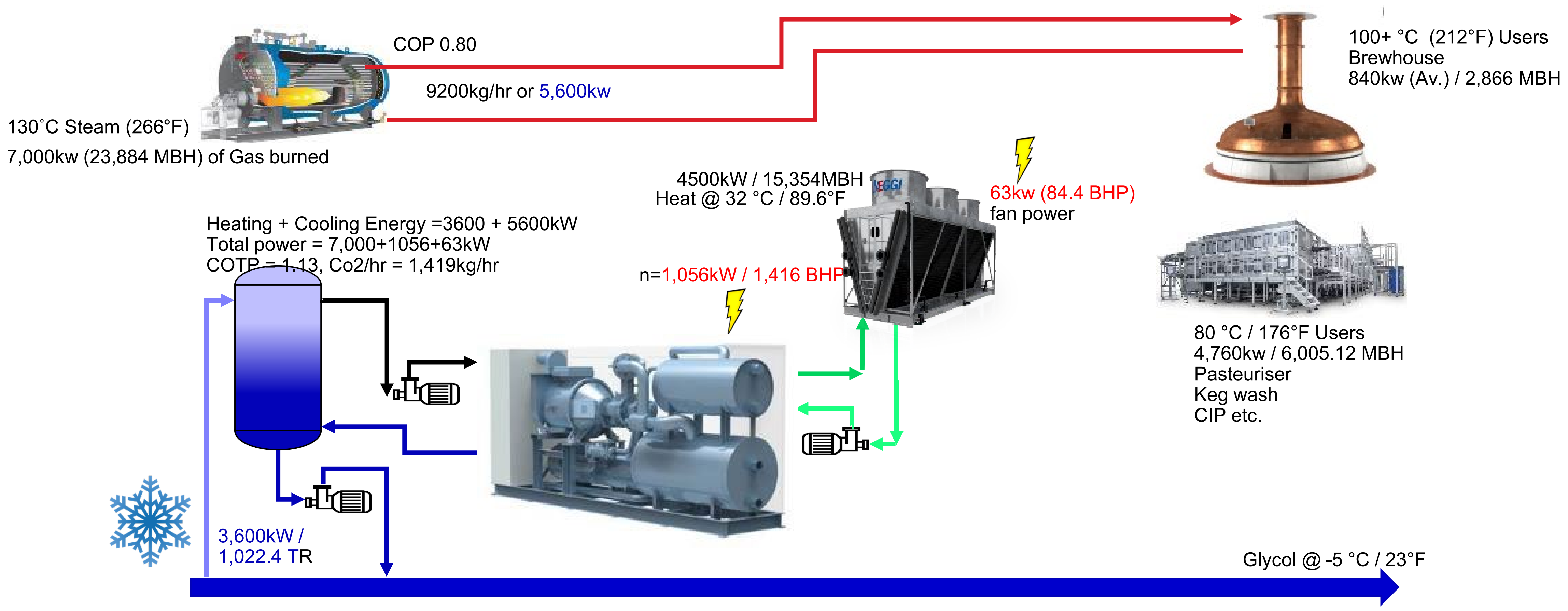






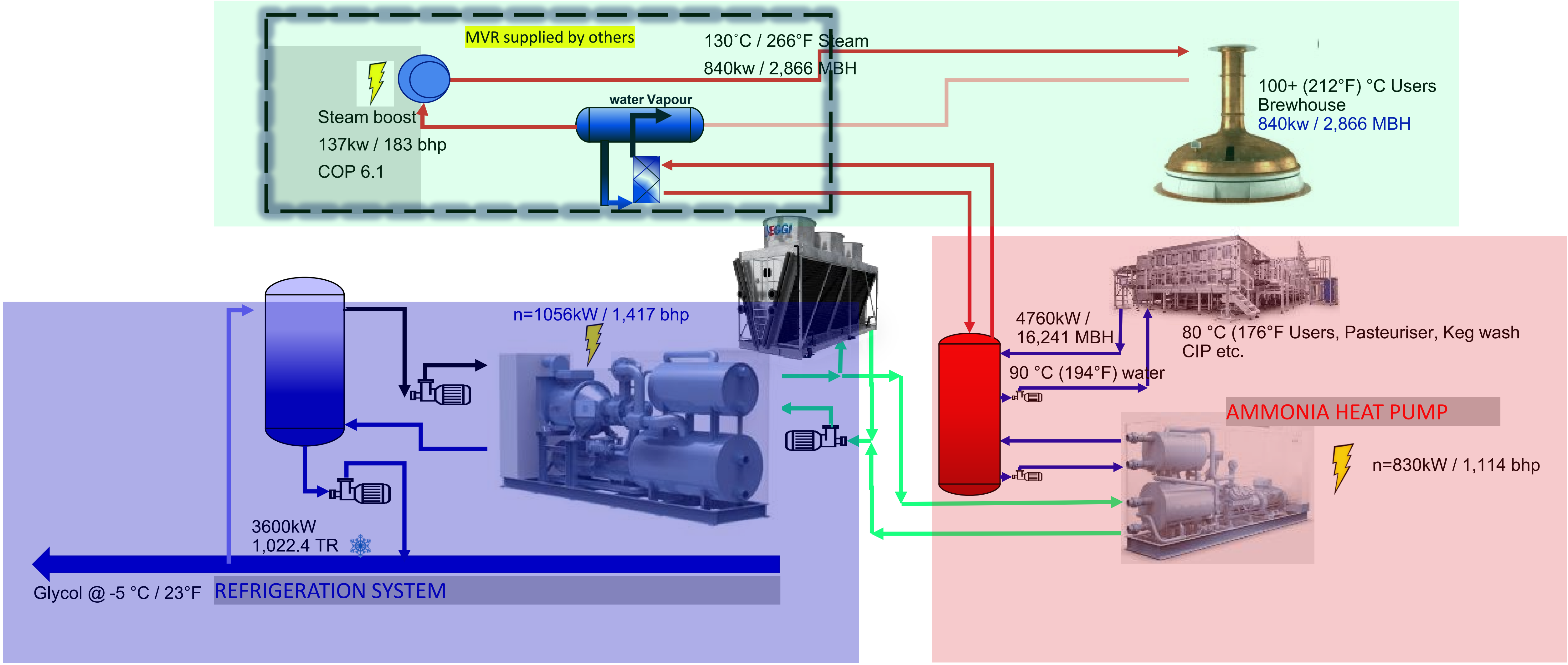
“The Norm in brewing” HEINEKEN – MANCHESTER - UK

Boiler = Heating, Refrigeration = Cooling



HEINEKEN – MANCHESTER - UK

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



BARRIERS of heat pumps

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.

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.

There are more District Heating networks in EU compared to USA

Europe has learned to switch from Steam to Hot Water

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.

COST of Heat Pumps

- **CURRENT BARRIERS**
- **COST**
- **Heat pumps are still over $900k or $1MM at minimum. Lower prices are probably LOW COP or Use of Synthetic Refrigerants that are issue of PFAs and TFAs issue.**
- **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 into a $2MM or $4MM for a 1 MW heat pump.**
- **Depending on Spark Gap Ratio, PayBack may go into 3 years and 10 years.**
- **AVERAGE PAYBACK 7 – 10 YEARS**

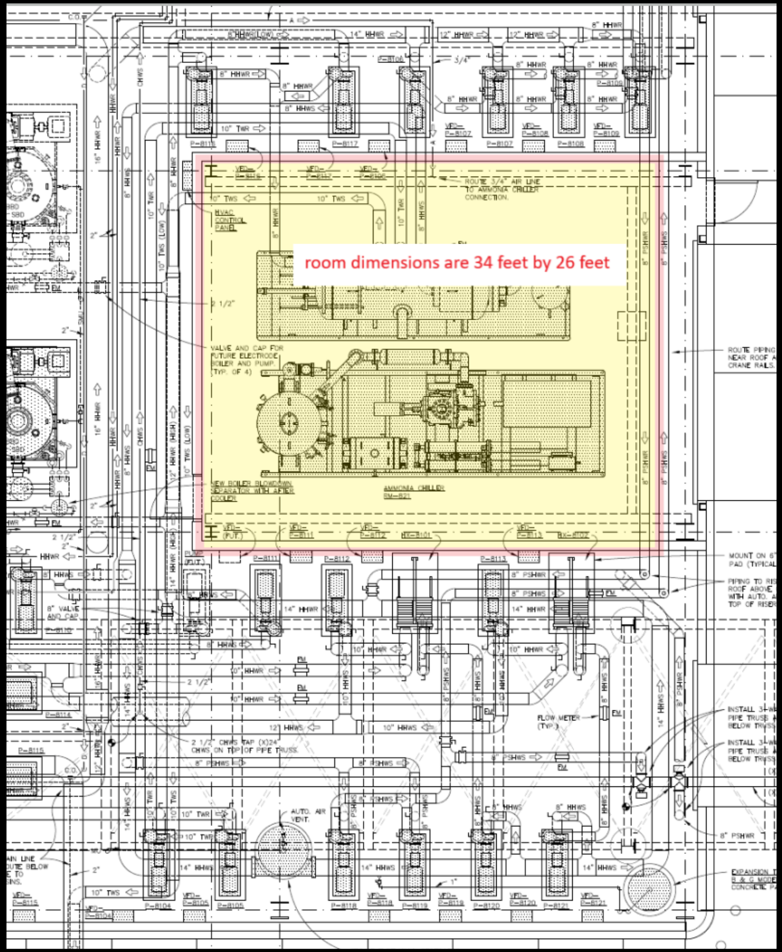
SPACE for HEAT PUMPS

Many Brownfields – Retrofits do not have space for IHP

- <u>**CURRENT BARRIERS**</u>
- <u>**SPACE on BROWN FIELDS - RETROFITS**</u>
- **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 Ammonia Codes, Fire Codes and any building code related to space, building, engine room.**

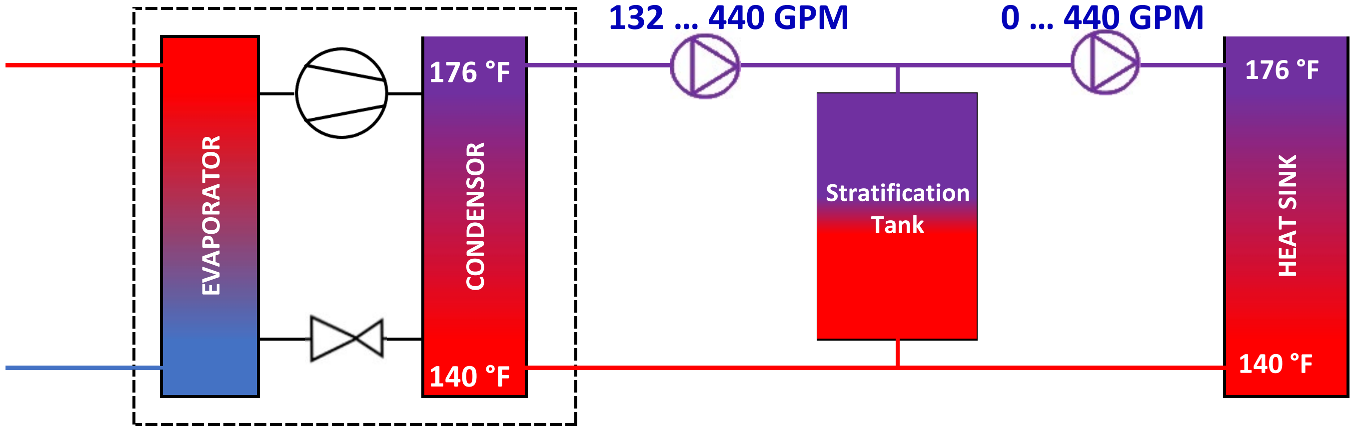


BUFFER TANKS whether at Heat Sink or Heat Source or Both

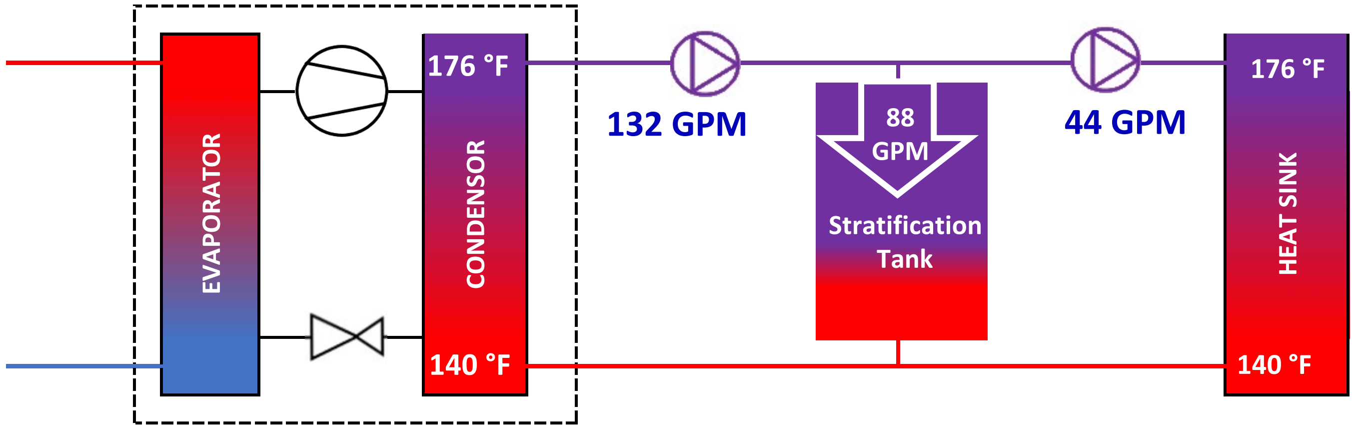
Always best option for Partial Load, Variable Load, Spikes, Start/Stop

▪ Buffer Tank / Heat Storage Vessel

- Partial Load
- Spikes
- Sudden Changes
- Provides a more steady / stable operation



Heat pump can only operate 30 … 100% BUT Heat sink required to operate 0…100 %



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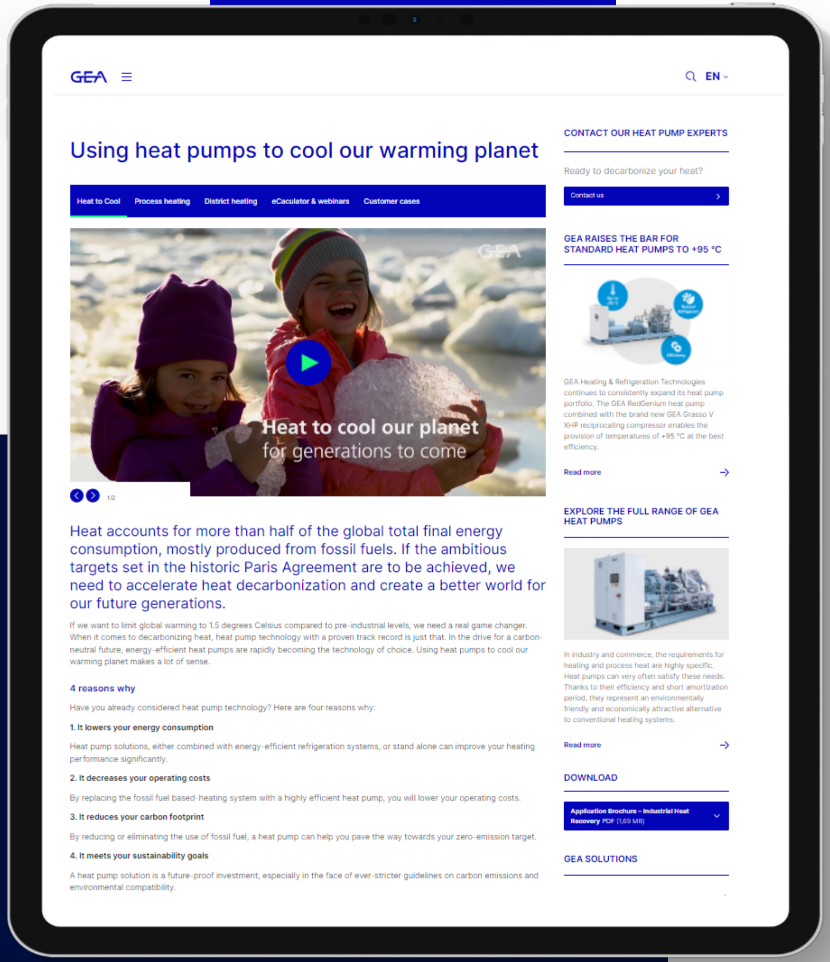


Engineering
for a better
world.

GEA.com

Researcher Presentation

Dairy Decarbonization In California

skyventechnologies

Decarbonizing Dairy Processing

Arun Gupta | agupta@skyven.co | www.skyven.co

FACT

20% of global carbon emissions are caused by industrial heat

half of that is steam

Decreasing fuel usage and emissions at dairy processing facilities can be challenging

- Decarbonization solutions must be cost-competitive with existing boilers
- Existing processes cannot be disrupted for integration into existing on-site heat sources
- Facility downtime is not an option when companies require 24/7/365 uptime

Skyven & CDI Decarbonize Process Heat

Project Summary

7,000
MT of CO2 emissions avoided annually

110,000
MMBtu of natural gas consumption avoided

$0
Total CapEx

$420,000
Net savings to date for CDI

RENEWABLE THERMAL COLLABORATIVE

Decarbonizing Process Heat at California Dairies, Inc. with Skyven Technologies

CASE STUDY
April 2024

CDI's Visalia, California facility

LOCATION
Visalia, California; Turlock, California

INDUSTRY TYPE
Food and beverage

FACILITY TYPE
Butter, milk powder, fluid milk, and dairy processing

TEMPERATURE RANGE
Up to 180°F

TECHNOLOGIES DEPLOYED
Solar thermal, steam traps, heat recovery

EMISSIONS IMPACT
Expected to avoid approximately 7,000 metric tons of CO_2 emissions annually

Project Overview

California Dairies, Inc. (CDI), the largest member-owned milk marketing and processing cooperative in California, partnered with Skyven Technologies, an Energy-as-a-Service (EaaS) company with a mission to decarbonize industrial process heat, to complete a total of six decarbonization projects across CDI's two largest facilities in 2023.

The projects deployed three renewable thermal technologies: solar thermal systems, smart steam traps, and boiler heat recovery systems. Skyven and CDI expect the projects to avoid approximately 7,000 metric tons of CO_2 emissions and over 110,000 MMBtu of natural gas consumption each year.

The multi-technology, integrated energy efficiency and renewable thermal approach achieved more emissions reductions and fuel savings than any one of the measures alone. These projects support CDI's goals to achieve a 30% reduction in direct and supply chain greenhouse gases by 2030 and carbon neutrality by 2050.

CDI implemented the decarbonization technologies with no capital expenditure (CapEx) using a public-private financing structure built on Skyven's EaaS model. The projects combined four funding sources: direct investment from Skyven, third-party financing from renewable thermal investor Kyotherm, Inc., grants from the California Energy Commission's Food Production Investment Program, and incentives from Pacific Gas & Electric and Southern California Gas Company.

Project Description

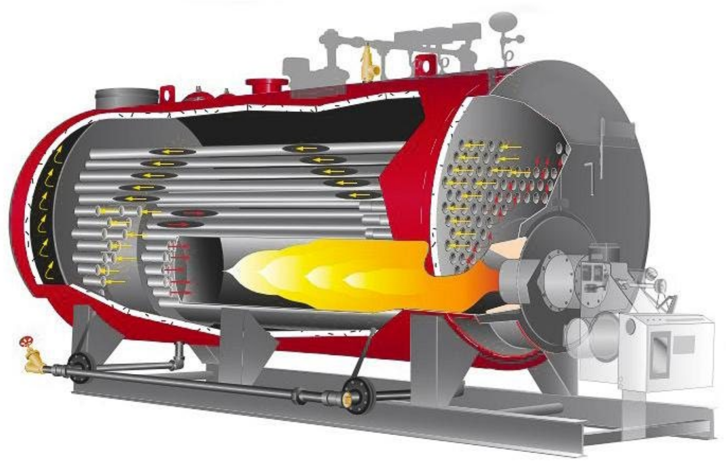
Beginning in 2019, Skyven and CDI worked together to identify, analyze, and ultimately select a set of six projects across CDI's two largest facilities. With an approved project portfolio, Skyven and CDI executed a ten-year Thermal Energy Services Agreement (TESA), the basis for Skyven's EaaS model. Similar to a renewable electricity power purchase agreement (PPA), the TESA deploys third-party capital to fund the thermal decarbonization projects and reduces execution risk for the buyer while providing immediate financial benefits.

www.renewablethermal.org

Learnings from our successful CDI projects have led Skyven to develop the Arcturus steam-generating heat pump

Dairy processors are committed to decreasing factory emissions, but

99% of industrial steam comes from fuel-fired boilers



Fuel-fired boilers: technology from 1867

Historically the only cost-effective option

WHY?

ELECTRIC BOILERS AND RNG

cost 3-5x more than natural gas

EXISTING HEAT PUMPS

cannot produce steam at high enough temps and pressures

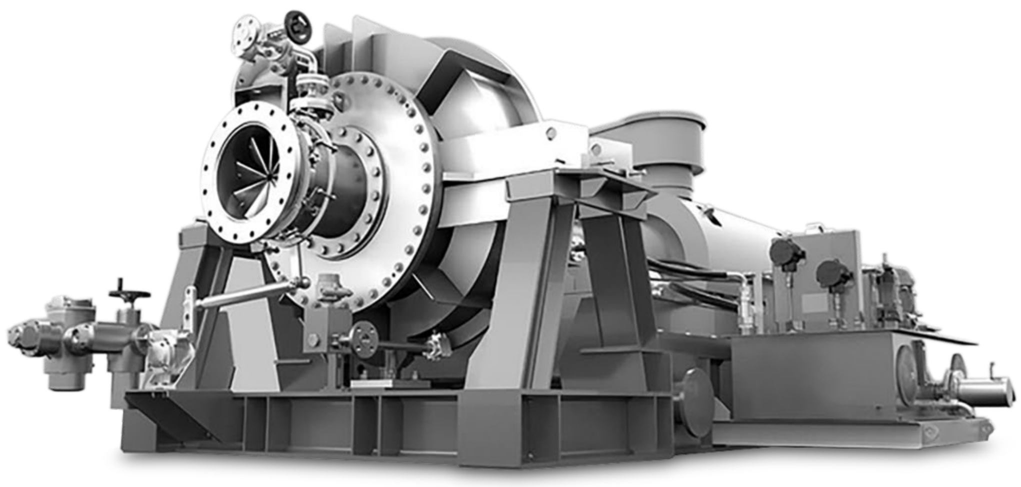
Source: https://www.nrel.gov/docs/fy22osti/81721.pdf
Source: www.siemens-energy.com/global/en/offerings/power-generation/heat-pumps.html
Source: www.edf.org/sites/default/files/documents/MACC_2.0%20report_Evolved_EDF.pdf

Profitably decarbonizing steam

The Skyven Arcturus Steam-Generating Heat Pump

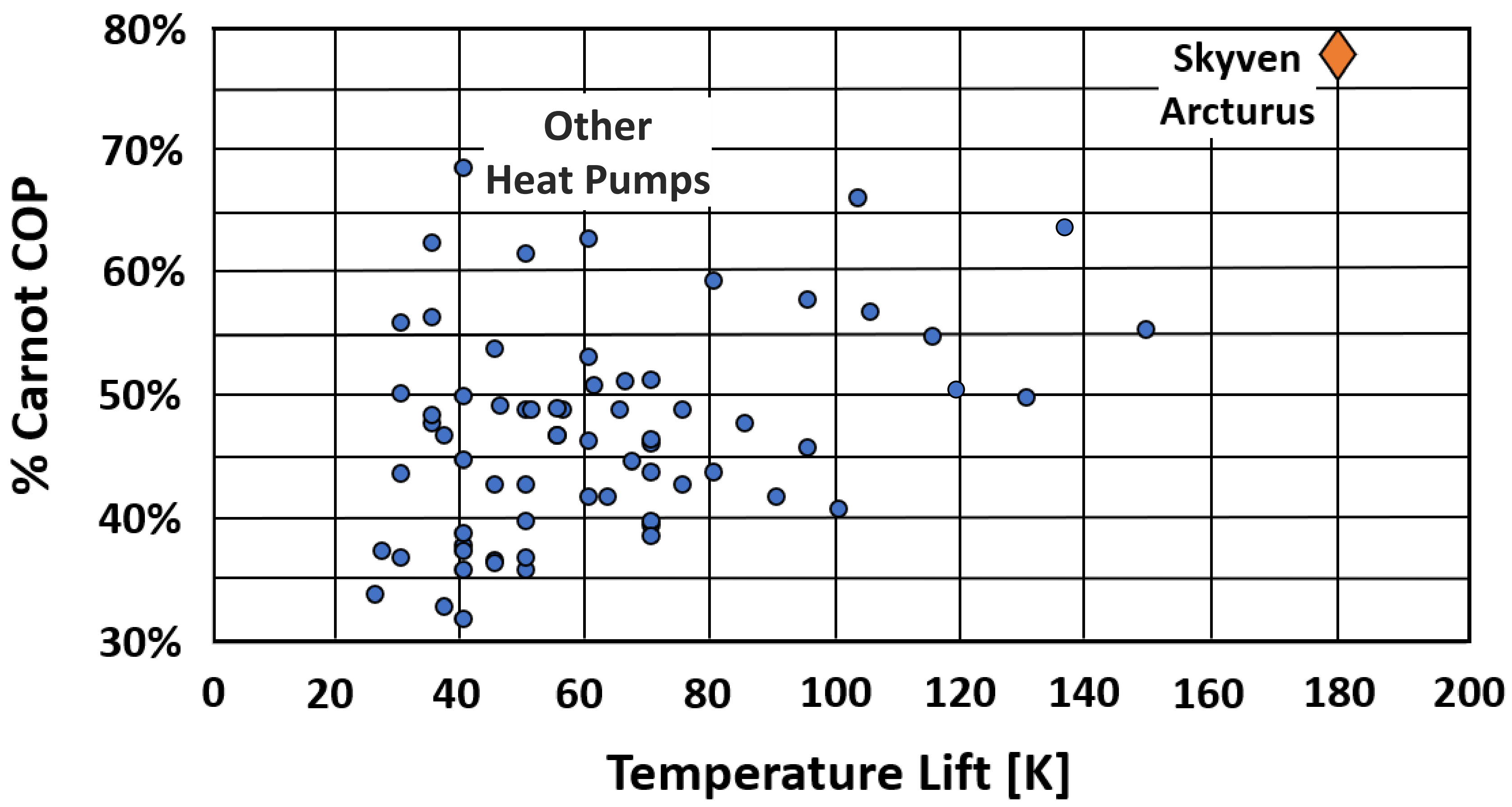
The world's first and only economically attractive solution to decarbonizing industrial steam

- **Emissions-free** steam production using electricity instead of natural gas
- **Costs less than natural gas** due to high COPs that counteract electricity-to-gas price differentials
- **Meets customer needs** for steam temperatures and pressures (up to 420F and 300 psig)
- **Deep decarbonization** – average 57% reduction in facility-level emissions



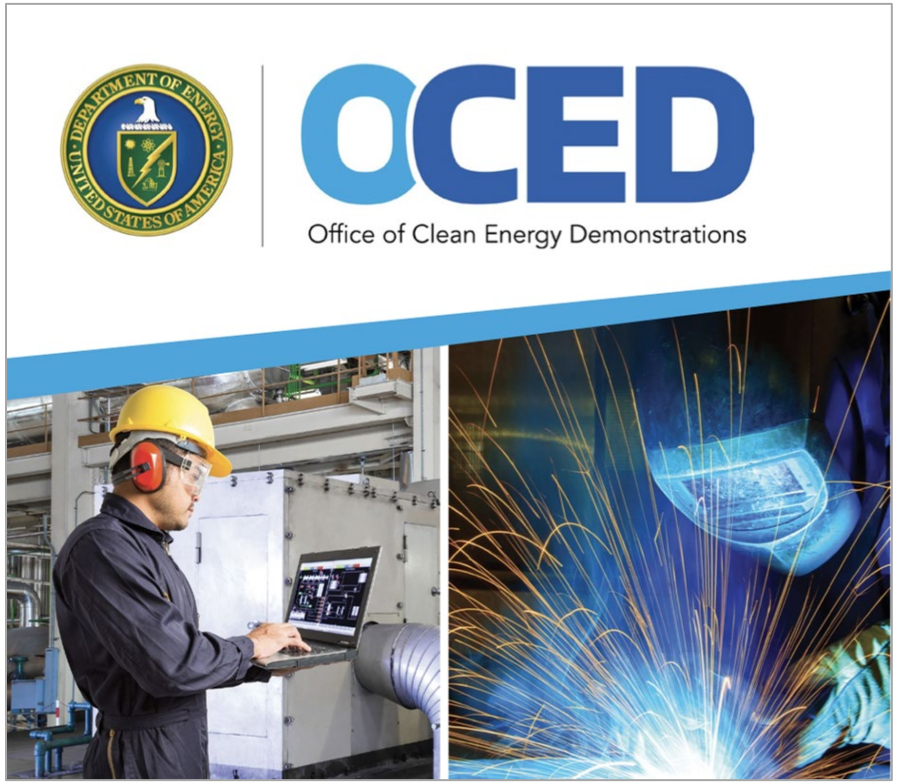
Best economics through highest COPs

Higher efficiencies at higher temperature lifts than other heat pumps on the market or in R&D



$145M DOE Grant for Arcturus Deployment

Deploy multi-site portfolio of Arcturus SGHPs across manufacturing sectors, including dairy processing



Project Goals

- Make heat pumps the **new industry standard** for emissions-free steam
- Reduce **facility-level emissions by 57%**
- **Benefit communities** by improving air quality and creating jobs

Key Metrics

- Reduces annual CO2 emissions by over **400,000 MT** and annual NOx, SOx, and PM emissions
- Creates **good-paying jobs local to project sites**
- Benefits over **300,000 people** in neighboring communities
- **90% of sites** located in disadvantaged areas

The status of industrial heat pump research

Deploying Arcturus at scale will achieve cross-cutting deep decarbonization of industry

Emissions-free steam is crucial to decarbonizing industry

Steam decarbonization technologies must meet technical and economic needs of manufacturers

Arcturus is designed to profitably generate steam at the temperatures and pressures required by manufacturers skyventechnologies

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www.skyven.co

Discussion Panel

Dairy Decarbonization in California

Question & Answers

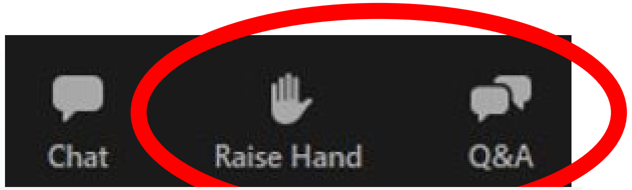
Dairy Decarbonization In California

Questions and Answers

- Please chat your question in the Question and Answers window or raise your hand and you will be called on to unmute yourself. Please remember to introduce yourself by stating your name and affiliation.
- Keep questions under 2 minutes to allow time for others.

<u>Zoom phone controls:</u>

- *6 – Toggle mute/unmute
- *9 – Raise hand



Submit comments via the Food Production Investment Program Docket by September 13, No. 23-ERDD-05: https://efiling.energy.ca.gov/Ecomment/Ecomment.aspx?docketnumber=23-ERDD-05

Thank You!

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