MINISTRY OF
INDUSTRY AND TRADE

EU - VIET NAM SUSTAINABLE ENERGY TRANSITION PROGRAMME (SETP)

Global Gateway

Funded by the European Union

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Project "Accelerating energy efficiency (EE) in large industries through energy management system, system optimisation and the promotion and adoption off EE in SMEs" (IEEP)

VENDOR TRAINING PROGRAMME
STEAM SYSTEM OPTIMISATION

Ho Chi Minh, 16/12/2024

AGENDA

HALF-DAY VENDOR TRAINING ON STEAM SYSTEM OPTIMIZATION

Time: 8h30 – 12h00, 16/12/2024

At Victory Hotel - 14 Vo Van Tan Street, District 3, Ho Chi Minh City

Time	Content	Speaker
8.00-8.30	Registration and welcome	
8.30-8.40	Opening speech	Representative of IEEP Office
8.40-10.00	The Systems Approach New developments for steam system optimization (FD&D SMART, Heat Exchanger, Thermal Energy Storage, Steam Accumulators, Industrial Heat Pumps, Thermocompressors, etc.)	International Expert
10.00-10.15	**Coffee-break**	
10.15-10.55	New developments for steam system optimization (FD&D SMART, Heat Exchanger, Thermal Energy Storage, Steam Accumulators, Industrial Heat Pumps, Thermocompressors, etc.)	International Expert
10.55-11.25	Thermal Oil Boilers and Combination of Heat and Power (CHP)	International Expert
11.25-11.50	Discussion	
11.50-12.00	Closing speech	Representative of IEEP Office
12.00-13.30	**Lunch**	All participants

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UNIDO

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Industrial Steam System Optimization (SSO) – Vendor Discussion

Developed by:

Riyaz Papar, PE, CEM, Fellow – ASME, ASHRAE

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Acknowledgments

- UNIDO Team – Vienna, Austria
- UNIDO Team – Vietnam
- United States Department of Energy, USA
- Oak Ridge National Laboratory, USA

Riyaz Papar, P.E., CEM, Fellow – ASME, ASHRAE

Education:

- M.S. (Mechanical Engineering), University of Maryland, College Park
- B.Tech. (Mechanical Engineering), Indian Institute of Technology, Mumbai

Professional Experience:

- UNIDO – International EMS and ESO Expert
- Oak Ridge National Laboratory – Industrial Energy Efficiency & Decarbonization Advisor
- Hudson Technologies Company – Engineering Fellow
- Other Past Employers - Enron Energy Services, Lawrence Berkeley National Laboratory, Energy Concepts Company (all in USA)

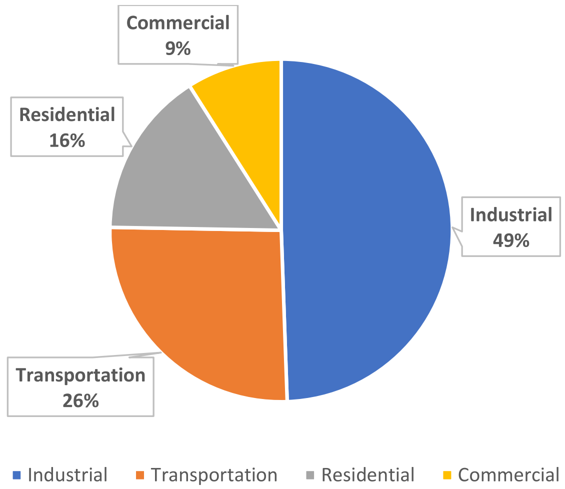
Other Qualifications & Affiliations:

- Chair, ASME Process Industries Division, 2003-04
- Chair, ASHRAE Technical Committee 8.2: Centrifugal Machines, 2009-10
- Chair, ASHRAE Technical Committee 1.10: Cogeneration Systems, 2010-11

Contact Information: Email – r.papar@unido.org; LinkedIn page (Riyaz Papar); Phone: +001 346 610 8787

SSO Training Objectives

- Help industry assess steam systems and achieve energy and cost savings through
  - Proper operation and controls
  - System maintenance
  - Appropriate process uses of steam
  - Cogeneration and
  - Application of state-of-the-art technologies
- Introduce and demonstrate the functionality of US DOE publicly available steam system optimization assessment software tools



Total World Energy production ~ 620 quad Btu

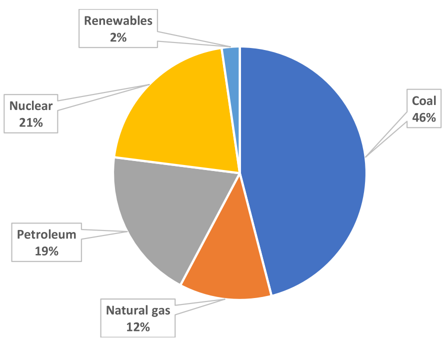
Industrial Energy = ½ World's Energy

1 quad Btu = 1.055 EJ

Source: US DOE EIA; International Energy Agency (2019 data)

Vietnam Energy Production – Consumption

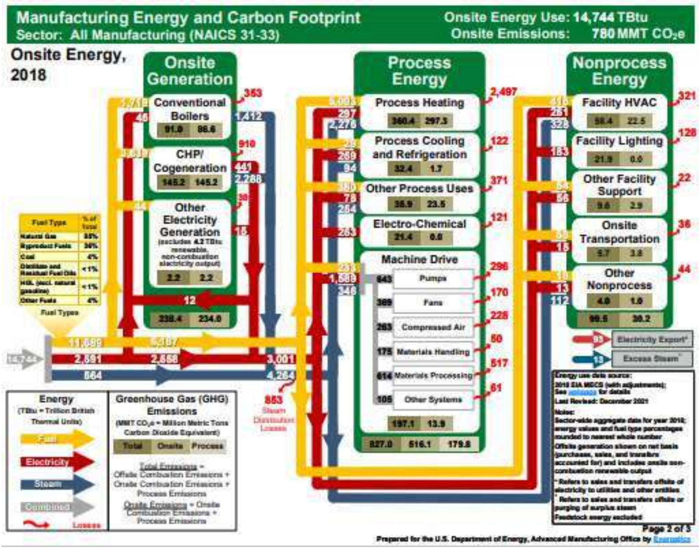
- Vietnam imports – Coal, Natural gas, Petroleum and other liquid fuels



Production: 2.56 quad Btu

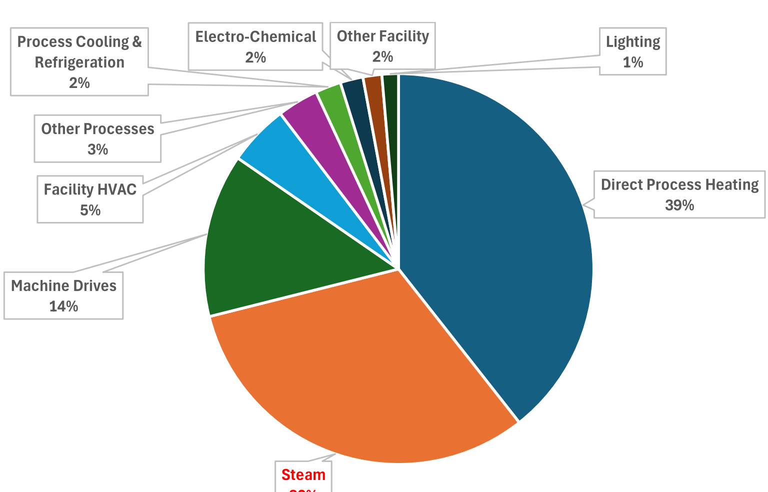
Consumption: quad Btu

Source: International Energy Agency Data - 2019



Overall Manufacturing Energy Consumption and Carbon Footprint

Source: 2018 US MECS data; Energy & Carbon Footprints (developed by Energetics)



Typical Industrial Plant Energy Consumption

Note: Does not include off-site losses

Source: 2018 US MECS data; Energy & Carbon Footprints (developed by Energetics)

Heavy Steam Users

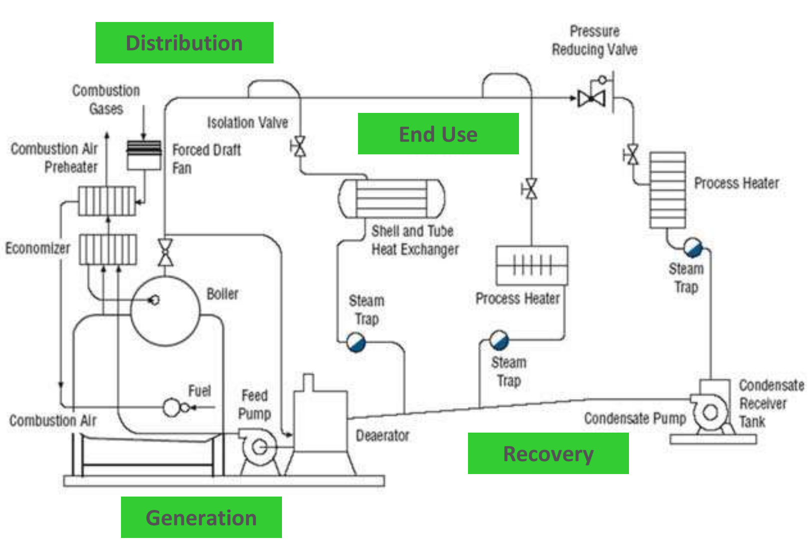
- Petrochemicals
- Petroleum Refining
- Forest Products (Pulp & Paper)
- Food & Beverage
- Plastics
- Rubber
- Textiles
- Pharmaceuticals
- Manufacturing Assembly

Why Use Steam?

- Extremely efficient as a heating source – constant temperature, highest heat transfer (condensing) coefficients
- Extremely cost effective to distribute to point-of-use
- Can be controlled very accurately
- A very flexible energy transfer medium – can be used for process heating as well as power generation
- Technology and applications are tried and proven at large as well as small-scale
- Significant system benefits!

The Systems Approach

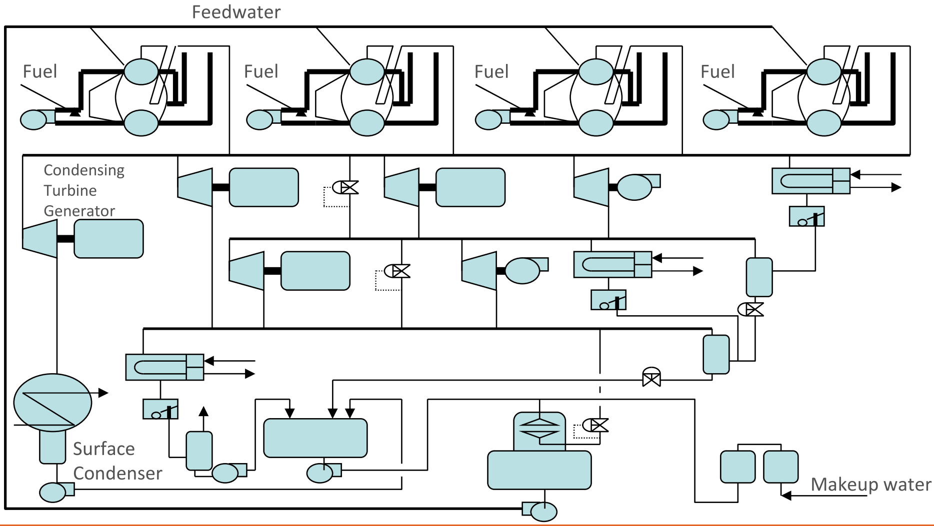
- Key to cost-effective plant utility system operations and maintenance
- Pay attention to the system as a whole, not just to individual pieces of equipment
- Analyze both the supply and demand sides of systems and how they interact
- Most industrial systems will need a Systems Approach for proper analysis
- Will lead to significantly higher energy and cost savings than a “component level analysis”



Generic Steam System

Source: US DOE Steam Best Practices Program

3-header System

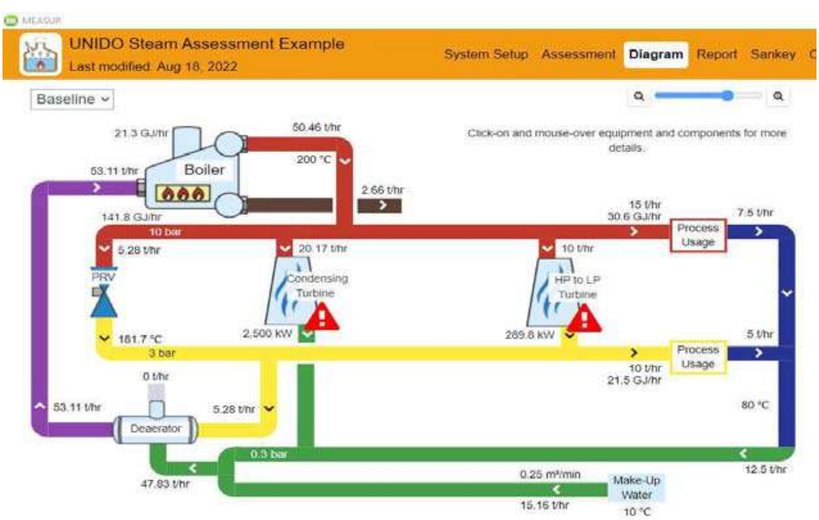


Source: US DOE Steam BestPractices Program

Steam System Optimization – Tools & Resources

US DOE MEASUR Tool

Measur.ornl.gov



Steam System Diagram

Steam System Summary

RESULTS | HELP

STEAM SYSTEM SUMMARY

Steam Generated
50.5 t/hr
Total Operating Cost
$10,050,894

CO_2 Emissions (tonne CO_2/yr)	
Emissions From Fuel	62,480.81
Emissions From Selling Electricity	0
Emissions From Change in Electricity Imports	0
Total Emissions	62,480.81

Fuel	
Boiler Fuel Use	1,242,410.19 GJ/yr
Boiler Fuel Cost ($)	$6,808,408

Electricity	
Electricity Generated	2,789.79 kW
Electricity Imported	5,000 kW
Electricity Cost ($)	$2,190,000

Make-Up Water	
Make-Up Water Required	132,803.12 m³
Make-up Water Cost ($)	$1,052,486

COST SUMMARY

Power Balance	
Generation	2,789.8 kW
Demand	7,789.8 kW
Import	5,000 kW
Unit Cost	$0.05 /kWh
Total $/yr	$2,190,000

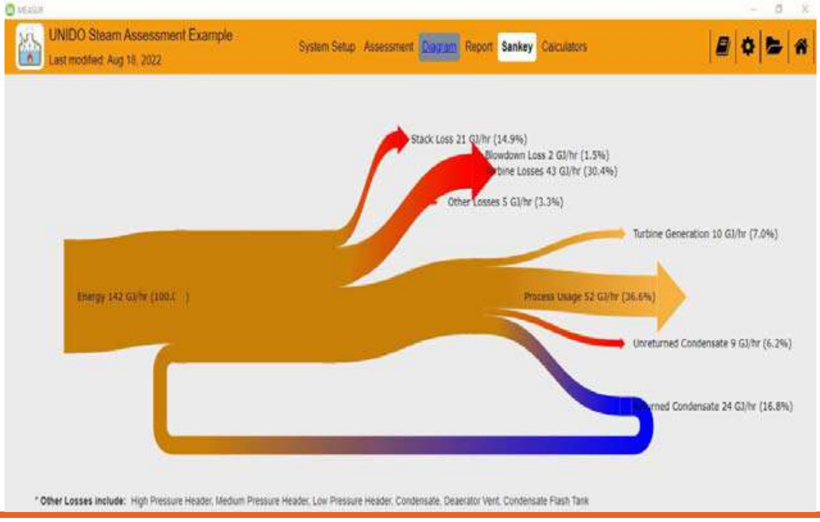
Fuel Balance	
Boiler	141.83 GJ/hr
Unit Cost	$5.48 /GJ
Total $/yr	$6,808,408

Make-Up Water	
Flow	0.25 m³/min 132,803.12 m³
Unit Cost	$7.9252 /m³
Total $/yr	$1,052,486

Total Operating Cost
$10,050,894

MARGINAL STEAM COST

High Pressure	$21.71 /t
Medium Pressure	$0.00 /t
Low Pressure	$21.68 /t

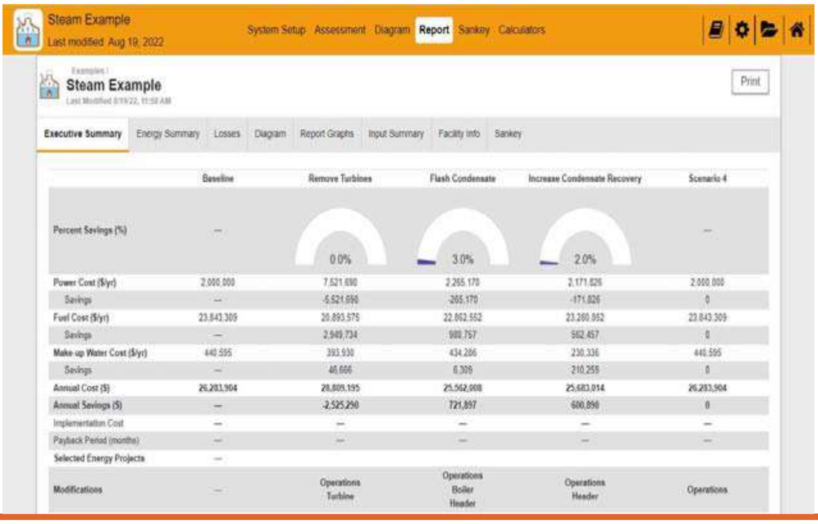


Steam System Sankey Plot

The MEASUR Steam Assessment Can Evaluate Key Steam Improvement Projects

- Steam Demand Changes
- Boiler Efficiency
- Alternative Fuels
- Steam Turbines
- Boiler Blowdown Energy Recovery
- Condensate Recovery
- Heat Recovery
- Flash Steam Recovery

…. And many more project scenarios



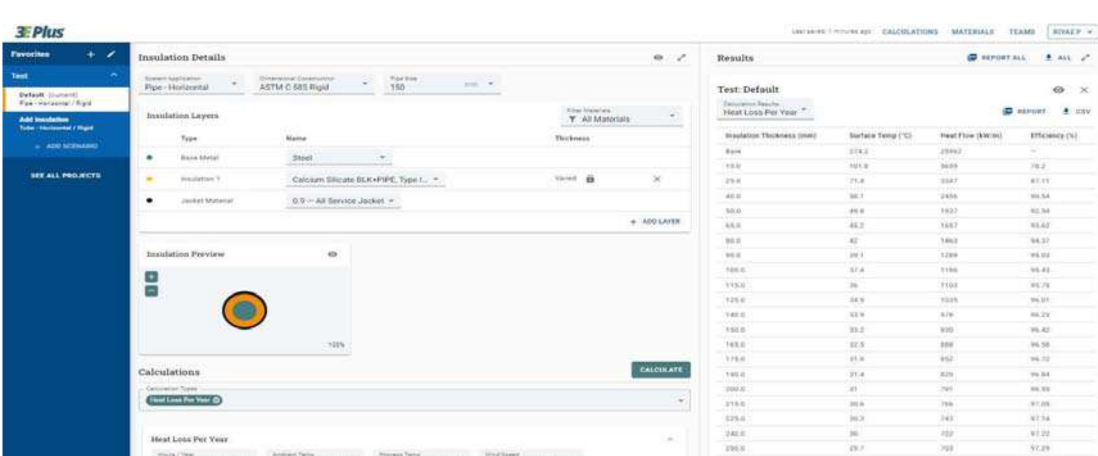
	Baseline	Remove Turbines	Flash Condensate	Increase Condensate Recovery	Scenario 4
Percent Savings (%)	—	0.0%	3.0%	2.0%	—
Power Cost ($/yr)	2,000,000	7,521,690	2,265,170	2,171,826	2,000,000
Savings	—	-5,521,690	-265,170	-171,826	0
Fuel Cost ($/yr)	23,843,309	20,893,575	22,862,552	23,280,852	23,843,309
Savings	—	2,949,734	980,757	562,457	0
Make-up Water Cost ($/yr)	440,595	393,930	434,286	230,336	440,595
Savings	—	46,666	6,309	210,259	0
Annual Cost ($)	26,283,904	28,809,195	25,562,008	25,683,014	26,283,904
Annual Savings ($)	—	-2,525,290	721,897	600,890	0
Implementation Cost	—	—	—	—	—
Payback Period (months)	—	—	—	—	—
Selected Energy Projects	—				
Modifications	—	Operations Turbine	Operations Boiler Header	Operations Header	Operations

Report (Executive Summary)

3EPlus Available ONLINE

3Eplus.org

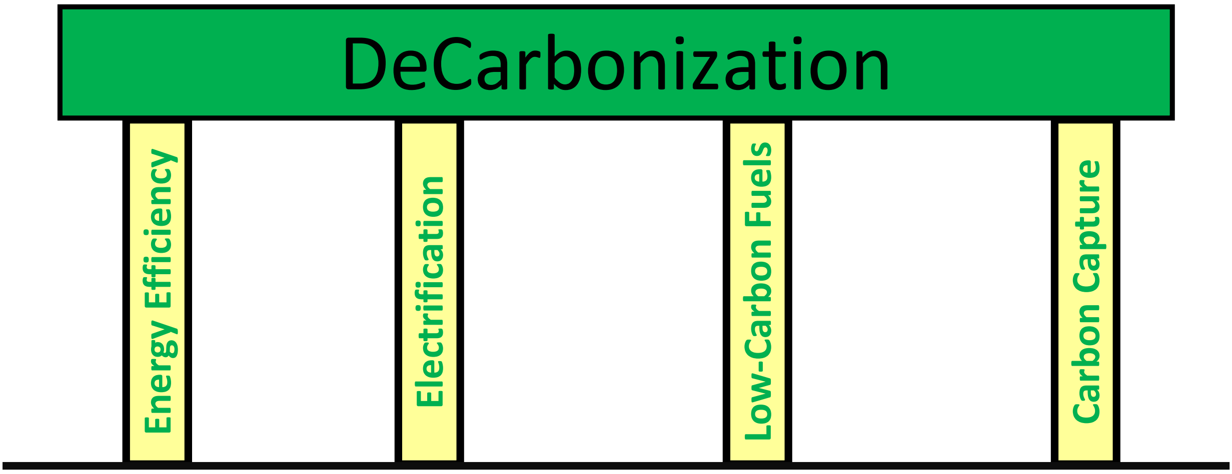
3EPlus ONLINE Version



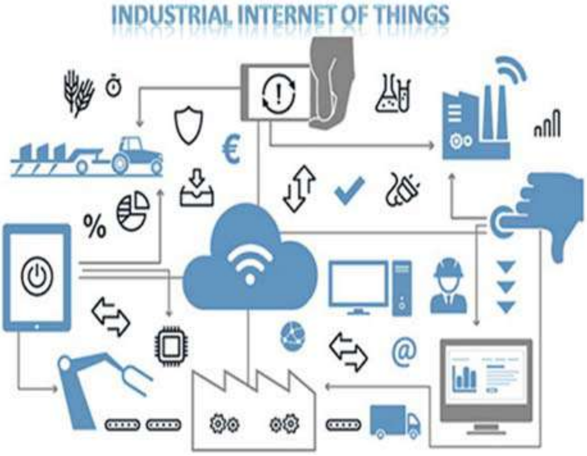
Steam End-Use Optimization

- Identify sources of waste heat
  - Stack / flue gas from process heaters
  - Product / intermediates rejecting heat to cooling tower water
  - Product / intermediates rejecting heat in fin fans
  - Incinerators and waste byproduct boilers
    - — May have a limitation on the lowest stack temperature
  - Use a pinch analysis on the unit operations / entire site
- Different heat recovery technologies are available
  - Circulating hot water / oil loop
  - Heat pipes
  - Direct heat exchange where heat source and sink proximity is close

The 4 Pillars of DeCarbonization



Steam System Optimization – Fault Detection & Diagnostics



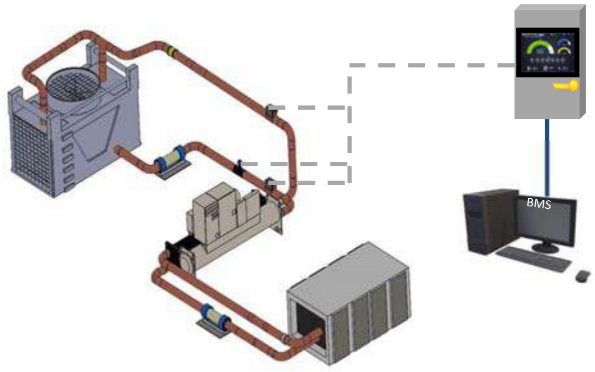
SMART Systems with FD&D

- SMART refers to the state-of-the-art Industrial Internet of Things (IIOT) managed intelligent systems
- Technology has advanced with Artificial Intelligence and Machine Learning
- Fault Detection & Diagnostics (FD&D) leads to Real-Time Optimization
- Continuous Commissioning

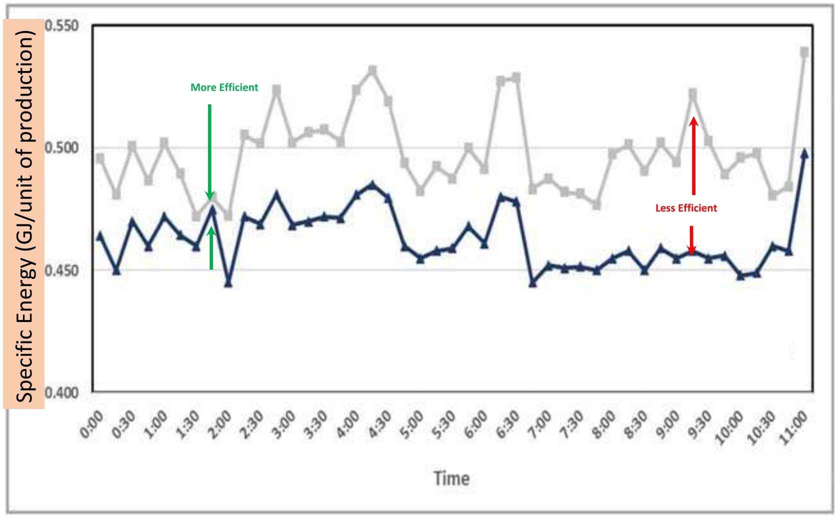
Basic Ingredients of SMART Systems

- Continuous monitoring of key data
- Trending of performance metrics
- Cloud-based system analytics
- Performance gap quantification with part load simulation (digital twin)
- Fault Detection & Diagnostics
- Seamless integration with plant's DCS
- Closed loop feedback control for optimizing system
- Ability to benchmark operations and verify energy savings
- Multiple unit (boilers, chillers) optimization
- Cyber-security

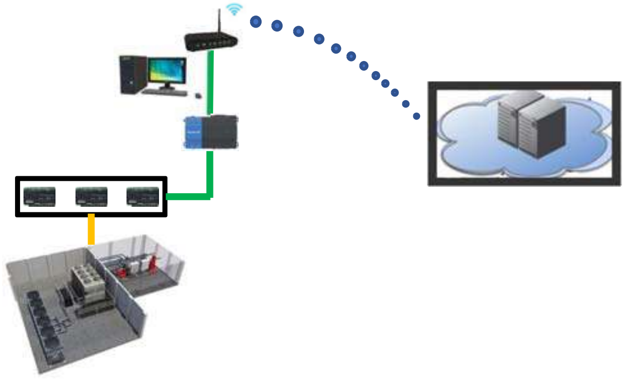
Applying FD&D on Thermal Systems



- Every system is unique
- "Critical" and "Necessary" data is specific to each individual system
- Common faults do exist
  - HX fouling / scaling
  - Flow issues
  - System hunting
- Strength of FD&D – true (+ve) identification of faults



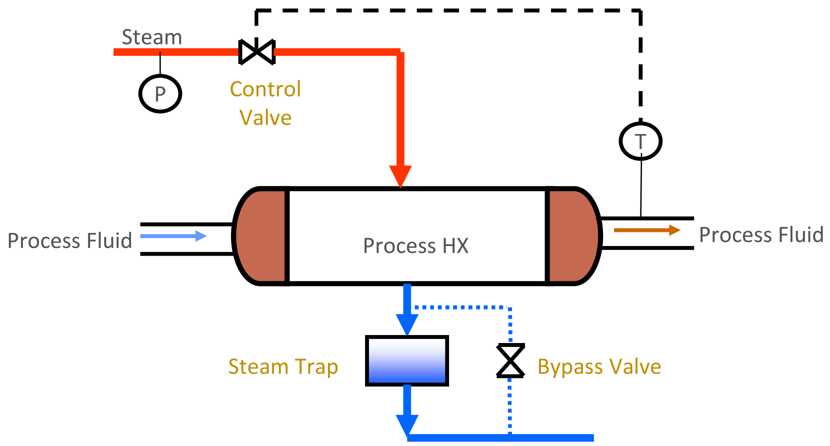
Performance Gap – Identify & Quantify

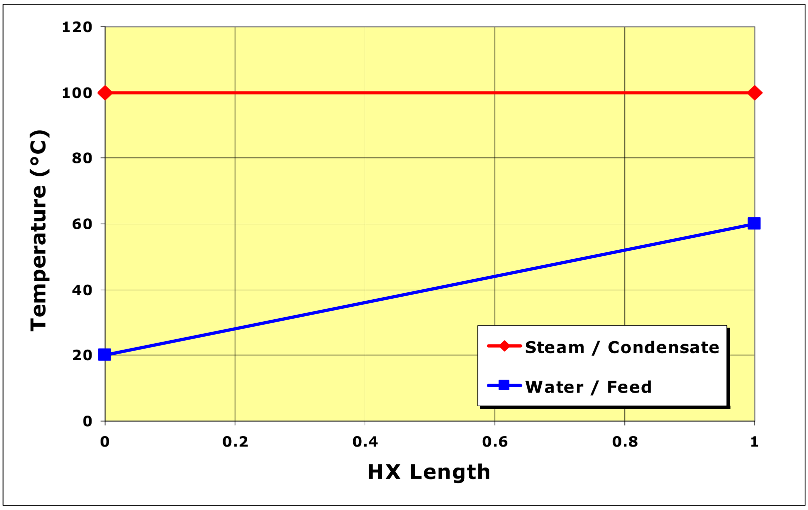


Seamless Integration w/Plant's SCADA & Historian

- Edge Control
- Very remote equipment can also be monitored easily
- Elimination of long cabling, wires and conduits – no maintenance

Heat Exchanger Operation



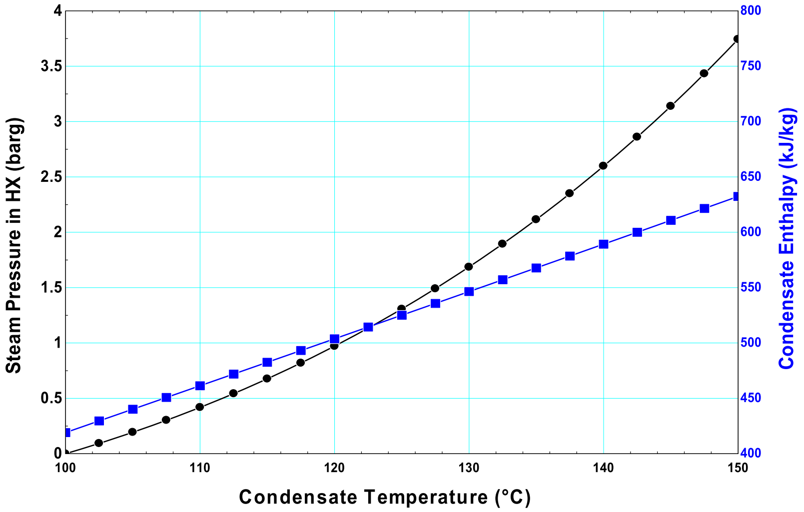


Heat Exchanger Performance

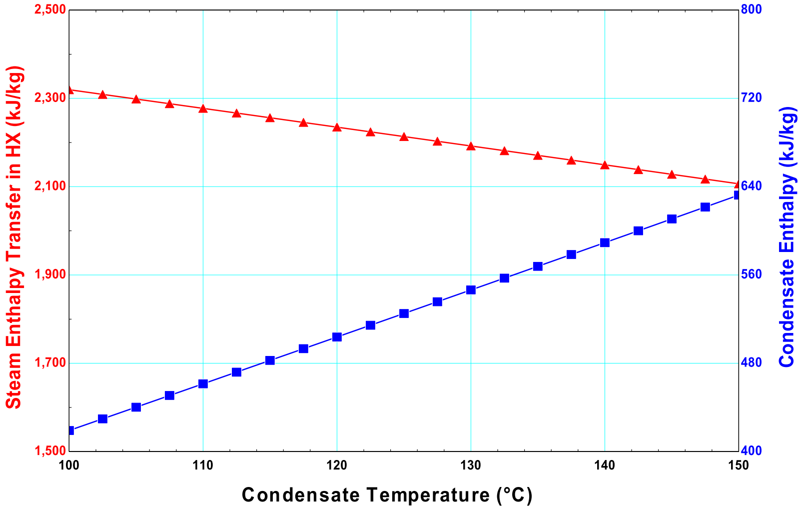
Heat Exchanger Performance

$$Q = m_{steam} * \left(h_{steam} - h_{cond}\right)$$

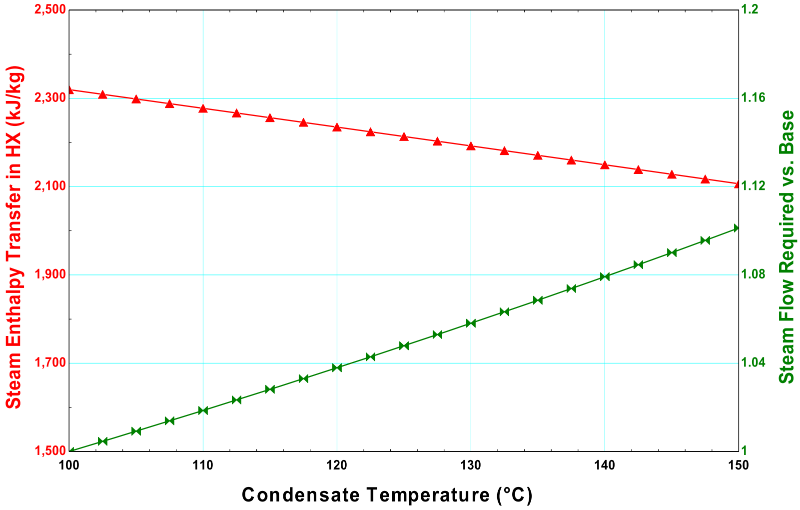
- Heat Exchanger Fouling
  - Driving temperature (steam) increases
  - Steam Pressure increases
  - Condensate enthalpy increases
  - Enthalpy difference (steam and condensate) reduces
  - For the same heat duty, more mass flow of steam is required
  - If condensate is not collected – leads to additional penalty
  - If condensate goes to atmospheric flash – energy loss occurs due to more flashing



Heat Exchanger Performance

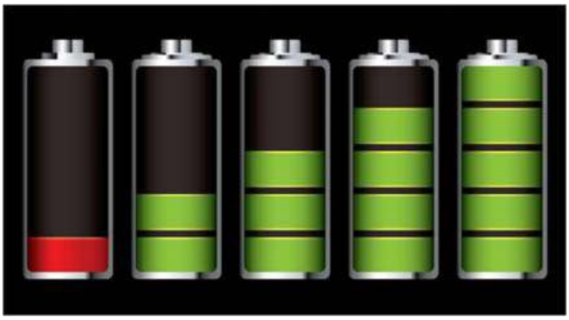


Heat Exchanger Performance



Heat Exchanger Performance

Steam System Optimization – Thermal Energy Storage



Industrial Thermal Systems with Storage

- Thermal Energy Storage is NOT new and neither NEXT GENERATION
- Its application is what makes it unique
- Its impacts are system-wide

What is Thermal Energy Storage (TES)?

- It is a battery which serves as a source or sink for energy
- Thermal storage
  - Cold – stratified water, ice, etc.
  - Hot – steam, water, oil, etc.
- Several different methods of thermal energy storage and can be used very effectively to
  - Minimize both operating and capital costs
  - Reduce electrical / thermal demand
  - Reduce overall energy consumption & increase system efficiency
  - Reduce greenhouse gas emissions (w/renewables mix)

Benefits of TES

- Energy cost savings
  - Reduce peak on-time electricity demand
  - Decouple time-of-use (load) and pricing
  - Higher system efficiency – constant set-point operations
- Decarbonization benefit
  - Use of renewables – solar and wind
  - Elimination of fast-acting electric grid and peaker plant response
- Reduced equipment size
  - Systems can be designed for average year-round load rather than peak loads which occur for less than 5% of the operating hours

Benefits of TES

- Capital cost savings
  - Downsizing large boilers and heating equipment at design-level
  - Smaller systems and equipment – pumps, fans, transformers, etc.
- System benefits
  - Optimization of system assets – eliminate part-load operations
  - Operate systems at favorable conditions allowing for higher system efficiency
- Increased reliability and redundancy
  - TES can provide additional capacity always and N+1 redundancy
  - Primary equipment operations are more stable enhancing reliability
  - Ability to do periodic and preventive maintenance to enhance reliability

Steam Accumulators

- Primary purpose - Thermal Energy Storage
- Significant impact on operations
  - Boiler plant capacity
  - Energy efficiency
  - Water savings
  - Environmental issues
  - Noise issues, etc.
- Classic applications
  - Batch operations
  - Intermittent high and low steam demands
  - Periods of very small high peaks of steam demand

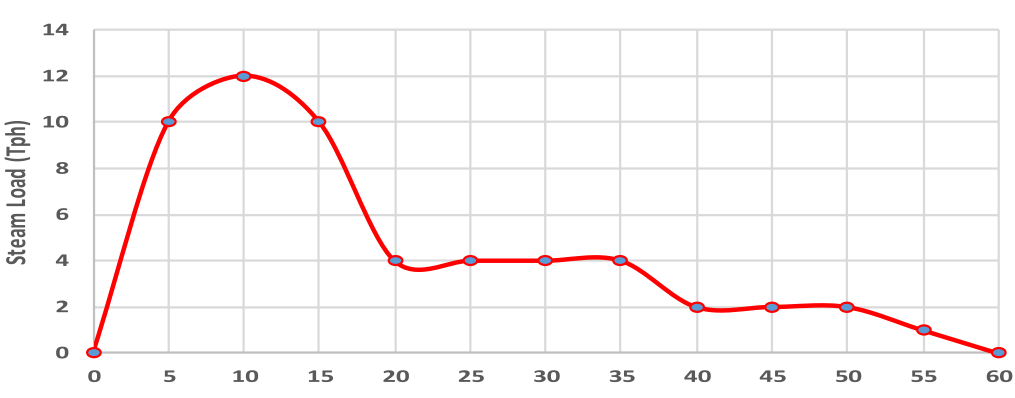
Steam Accumulators

Batch Operation

Venting – Difficult Boiler Control

Accumulate Excess Steam

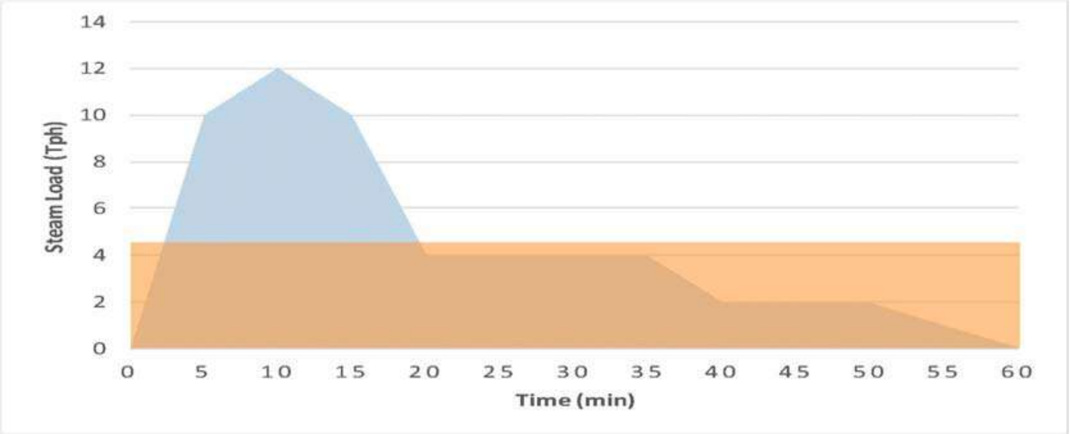
Steam Accumulators - Steam Load Profile: Cycle time



Steam Accumulators

- Add a properly sized steam accumulator
- Maintain boiler at steady state operations
- Ramp up time for 15 minutes
  - Steam from boiler and accumulator
- Slow down for 25 minutes
  - Steam from boiler and/or accumulator
  - Steam supply to accumulator
- Next 20 minutes
  - Steam from boiler
  - Steam supply to accumulator

Steam Accumulators



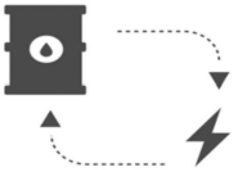
Steam Accumulators

- Boiler runs a steady load of 4.6 Tph
- Total steam supplied in an hour = 4.6 Tonnes
- Area under the profiles is the same
- Plant benefits
  - Energy savings due to better boiler efficiency
  - Operating minimum number of boilers
  - No steam venting
  - Higher reliability of operations
  - Other system optimization opportunities (steam turbines)

Most Favorable Scenarios for TES

- High (or very high) steam demand of relatively short duration
  - Think of heating demand having a compressed air system profile
- Expansion on a very limited budget
- Mission critical systems that still need to operate with minimal backup generation capability
- Industry looking to decarbonize and use higher amounts of renewables mix when available
  - Electric or Electrode boiler applications

Steam System Optimization – Industrial Heat Pumps



Energy Substitution: **Beneficial Electrification**

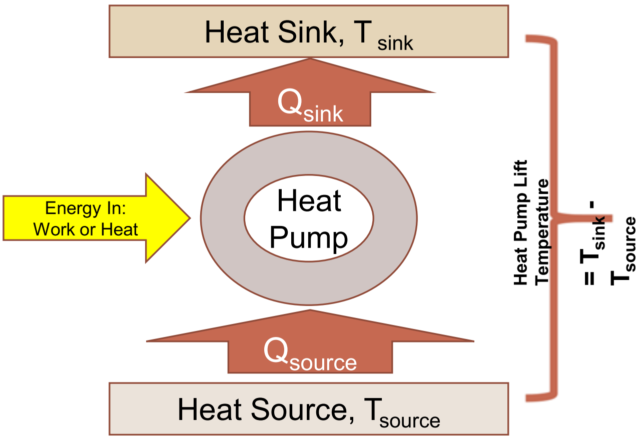
Industrial Heat Pumps (IHPs)

- Technology Advancements
  - New working fluids
  - New compressor innovations
  - New heat-activated heat pumps
- Benefits
  - Key technology in electrification portfolio of technologies
  - Energy, non-energy benefits, GHG reductions
  - Improved control
  - Speed of response

Heat Pump Systems

- Energy (heat) always flows downhill – in the natural irreversible process
  - 2nd law of thermodynamics dictates the direction of heat flow
- There are systems which can reverse this downhill flow
  - Those systems are heat pumps!
- Heat pumps take energy at a lower temperature and transfer it to a higher temperature
  - Doesn't the chiller or refrigeration system do the same thing?
- On paper and thermodynamically, the cycles are the same – operating conditions are different, equipment may or may not be different and the "useful effect" determines the terminology

Fundamentals of Heat Pumps



$COP_{heating} = Q_{sink}$/Energy In

$COP_{carnot, heating} = T_{sink} / (T_{sink} – T_{source})$

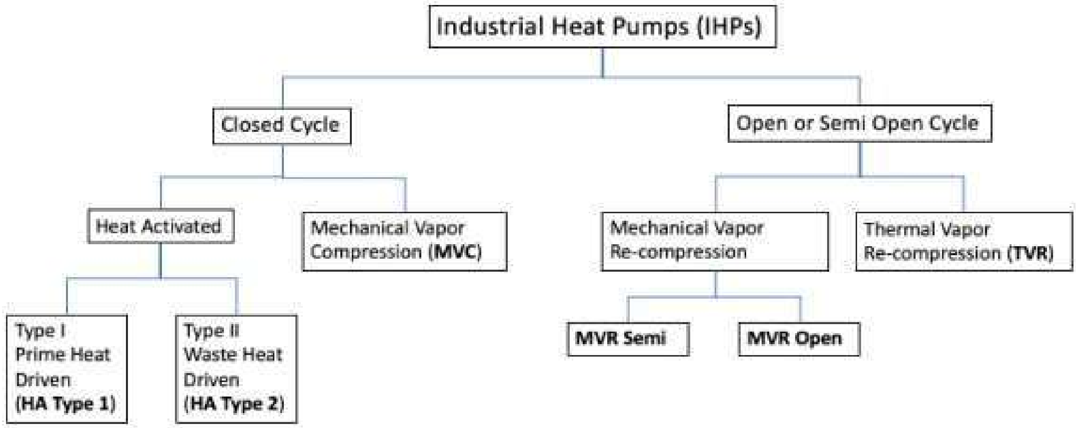
$COP_{heating} =$ Carnot Eff. * $COP_{carnot, heating}$

Heat pump Carnot Eff. ranges from ~30 - 60%

Less lift temperature equals greater heat pump efficiency

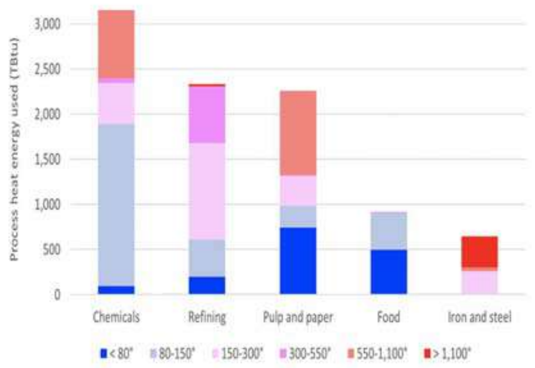
Courtesy: Paul Scheihing, 50001 Strategies, LLC

Types of Industrial Heat Pumps

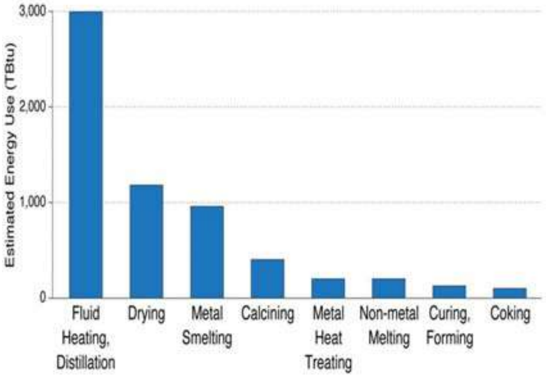


Adapted from Gluckman & McMullan 1988

Process Heat Energy in Industry

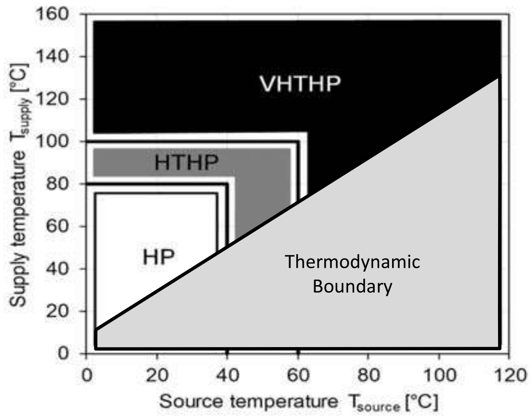


Data source: McMillan et al. 2019



Data source: DOE 2016

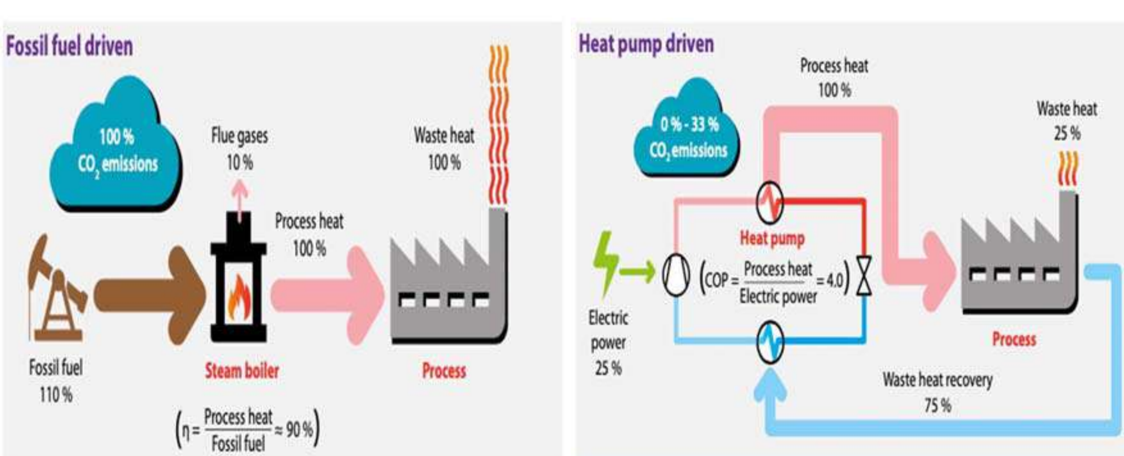
Temperature Ranges for Heat Pumps



- HP: Conventional Industrial Heat Pump
- HTHP: High Temperature Heat Pump
- VHTHP: Very High Temperature Heat Pump

Source: Arpagaus et al. (2018): Review on High-Temperature Heat Pumps, https://doi.org/10.1016/j.energy.2018.03.166

IHP Basics



De Boer, R., Strengthening Industrial Heat Pump Innovation | Decarbonizing Industrial Heat, DTU, 2020.

Industrial Heat Pumps

- System integration using a PINCH ANALYSIS sheds light on heat sinks and heat sources in an industrial plant
- Process industries have several unit operations that can be overwhelming and it is advisable to breakdown the processes by temperature blocks
- Aligning amount of heat matching with an appropriate lift provides an optimal solution for an industrial heat pump application
- Industrial heat pumps when applied properly can
  - Increase the energy efficiency of the overall industrial operations
  - Reduce greenhouse gas emissions
  - Reduce primary energy use and hence, reduce operating energy costs
- First cost of heat pumps will be higher than conventional systems

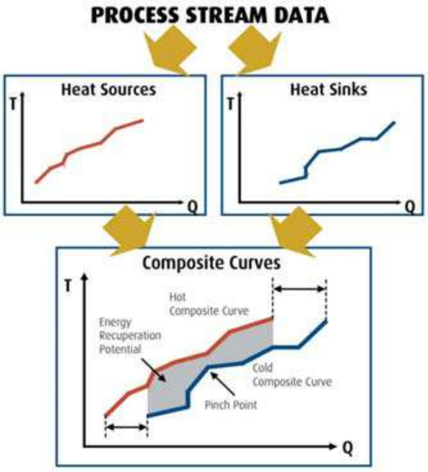
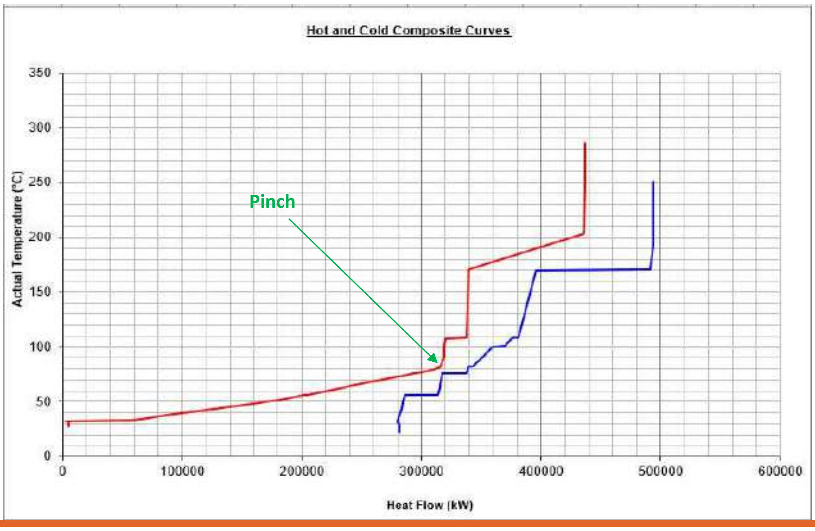


Figure. 8 – Explanation of pinch composite curves (NRCan, 2003)

Pinch analysis to ensure proper IHP placement within process

- Heat sources reject the heat – Cooling Streams
- Heat sinks pick up the heat – Heating Streams
- Overlapping the heat sources and sinks (cooling and heating streams) creates composite curves and determines external (additional) process heat needed and process cooling needed



Example Plant:

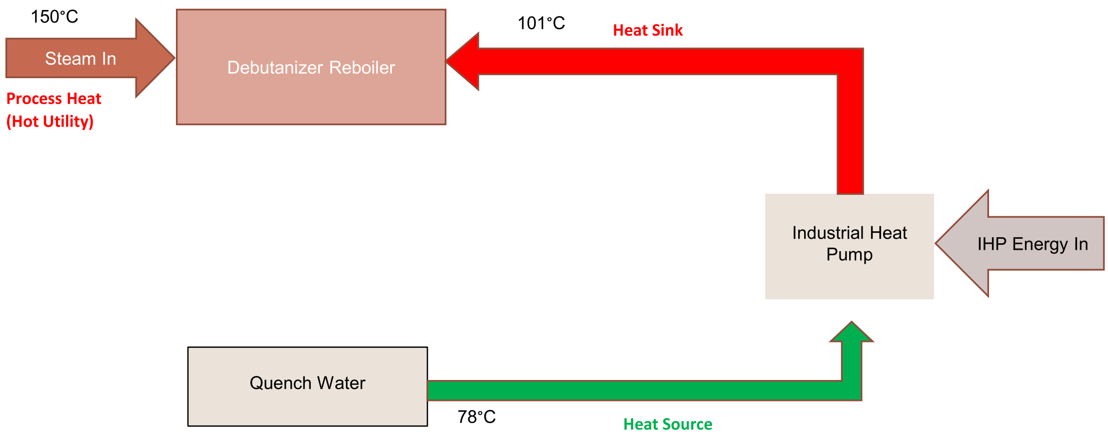
Ethylene (Above ambient) Pinch Analysis

Ref: IChemE Pinch Analysis Model

Application of IHPs with Pinch Analysis

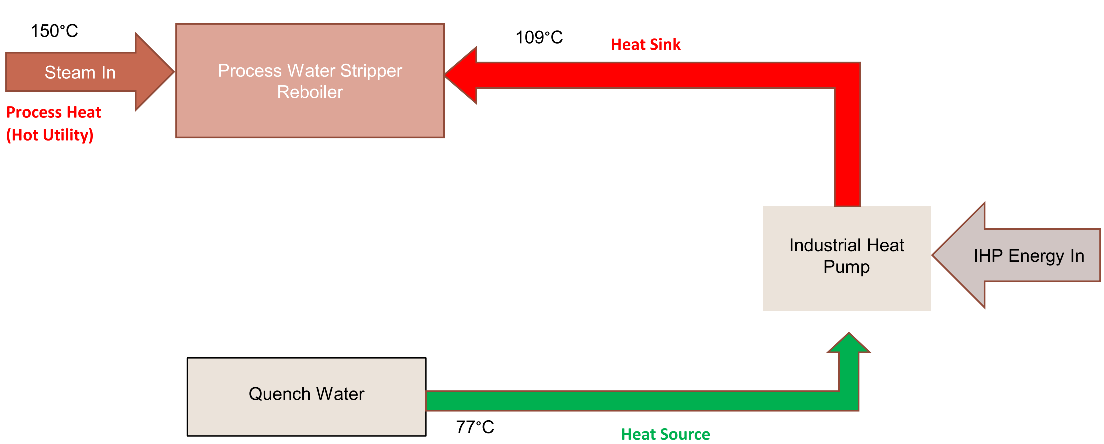
- There is always a heat demand (hot utility requirement) above the pinch temperature
- There is always a heat surplus (cold utility requirement) below the pinch temperature
- Hence, NEVER
  - Reject heat to ambient above pinch temperature
  - Add heat to process below pinch temperature
- Always add an IHP with a heat source below the pinch temperature and a heat sink above the pinch temperature

Example Plant: Ethylene (Above ambient)



Ref: Industrial Heat Pumps: Electrifying Industry's Process Heat Supply, ACEEE Report, 2022

Example Plant: Ethylene (Above ambient)

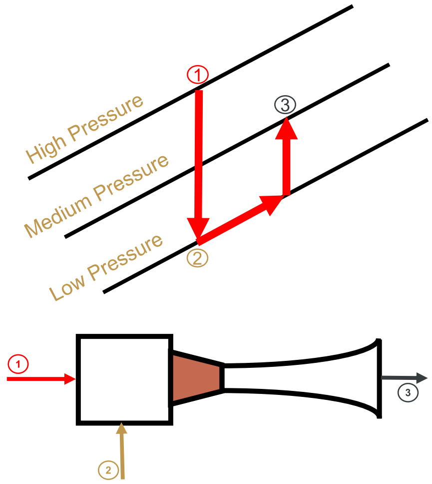


Ref: Industrial Heat Pumps: Electrifying Industry's Process Heat Supply, ACEEE Report, 2022

Industrial Heat Pumps – Favorable Scenarios

- Continuous operations with available low temperature heat / waste heat in process/facility
- Close geographical proximity of heat source and sink (Useful)
- Temperature lifts within equipment availability and material / fluids compatibility
- Large operating hours to allow for quicker paybacks
- Higher fuel and energy costs
- Corporate mandate to decarbonize and reduce carbon footprints

Steam System Optimization – Thermocompressors

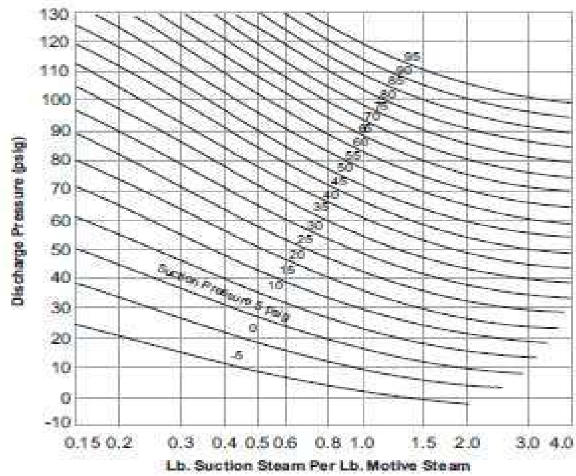


TVR - Thermocompressors

- Provide the ability to upgrade low pressure (waste) steam to medium pressure steam thereby reducing the amount of high pressure steam required
- Mechanical vapor compression can also be an alternate option for thermocompressor applications

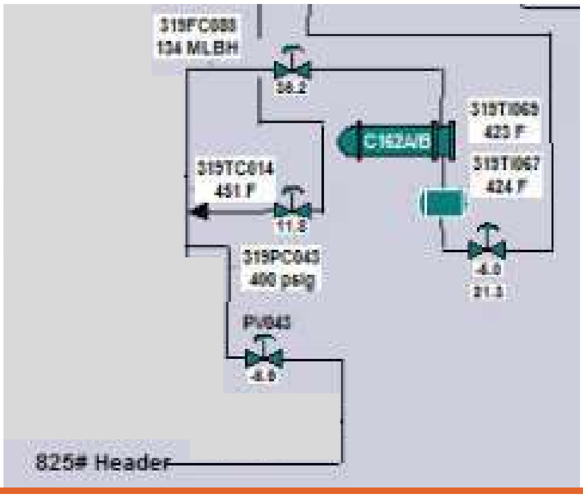
Thermocompressor Analysis

- Thermocompressor analysis requires a thorough understanding of process needs
- Identify the source of waste (or low pressure) steam that is currently vented
- Identify a process that requires steam and is currently using high or medium pressure steam
- Identify motive steam (typically, highest pressure steam) available in the plant
- Work with a manufacturer to select a thermocompressor
  - Pressure ratios
  - Steam flows



Thermocompressor Analysis

- Mass balance
- Energy balance
- Bernoulli's equation
- Motive steam
  - Eg. 20 barg
- Suction pressure
- Ratio
- Discharge pressure

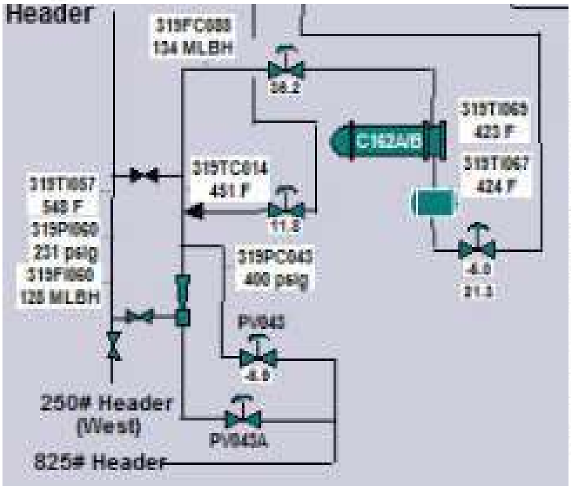


Case Study: TVR

- Petroleum refinery
- Steam demand
  - Pressure ~27 barg
  - Temperature ~220°C
  - Flow rate ~60 Tph
- Current Operation
  - Use Pressure Reducing Valve
  - HP steam header ~ 57 barg; 450°C superheated
  - Desuperheating with boiler feedwater

Case Study: TVR

- Energy assessment revealed that the process has exothermic reactions and generates 17 barg saturated steam
- New Operation
  - Use an industrial heat pump – TVR - thermocompressor
  - Motive steam - HP steam header ~ 57 barg; 450°C superheated
  - Suction steam – 17 barg
  - Discharge steam – 27 barg; 220°C
  - Desuperheating, if needed, with feedwater



Case Study: TVR

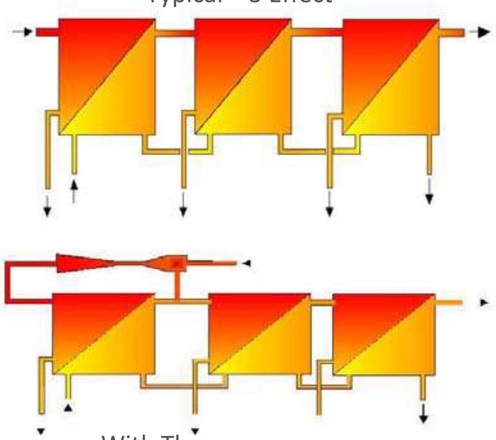
- TVR Operation
  - Motive steam - HP steam header ~ 57 barg; 450°C superheated
  - Suction steam – 17 barg
  - Discharge steam – 27 barg; 220°C

Case Study: TVR

- Implemented TVR as recommended
- Benefits
  - Reduction in HP steam generation
    - Fuel: Natural gas ($8/GJ)
    - Energy savings ~ 6.4 GJ/hr
- **Annual Cost savings ~$450,000**
- Installed cost ~$150,000
  - Explosion proof refinery environment
- No moving parts – no maintenance costs for life
- Reduced feedwater usage
  - Estimated savings ~$20,000

Evaporators & Use of Thermocompressors

Typical – 3 Effect



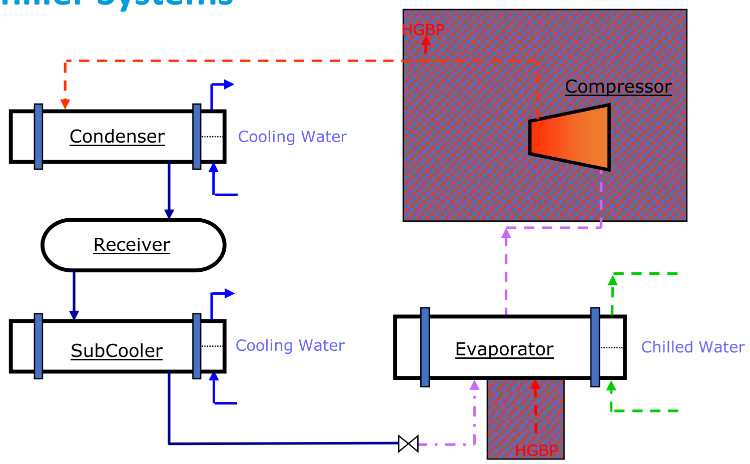
With Thermocompressor

- Contamination in condensate?
- Temperature difference / Pressure ratio
- Very application and site specific

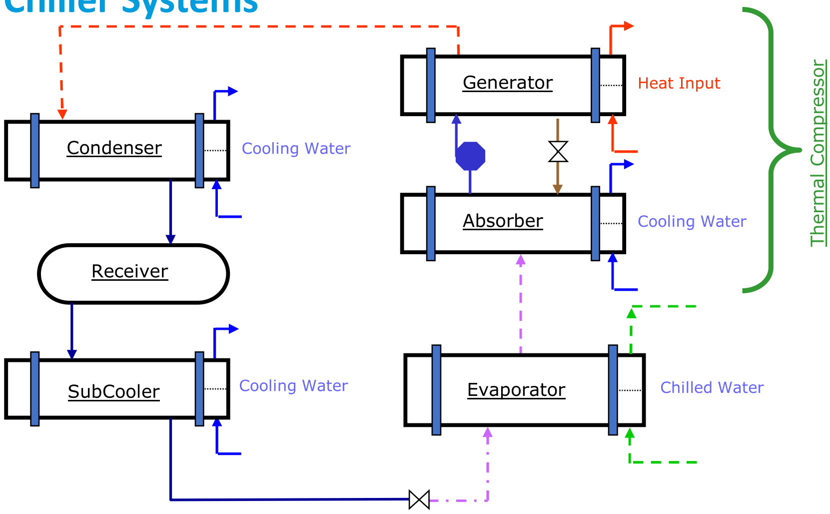
Courtesy: Jim Munch, JMPS

Steam System Optimization – Waste Heat Recovery (Absorption Chillers, Refrigeration & Heat Pumping)

Absorption Chiller Systems



Absorption Chiller Systems



- Working Fluids
  - Refrigerant side
    - Ammonia
    - Water
    - Other organic fluids
  - Solution (Absorbent) side
    - Water
    - Lithium Bromide
    - Other salts
- Nomenclature – refers to level of refrigerant/salt concentration of the solution
  - Rich / Strong
  - Poor / Weak / Dilute
  - Intermediate

Absorption Chiller Systems

- Evaporation and Condensation

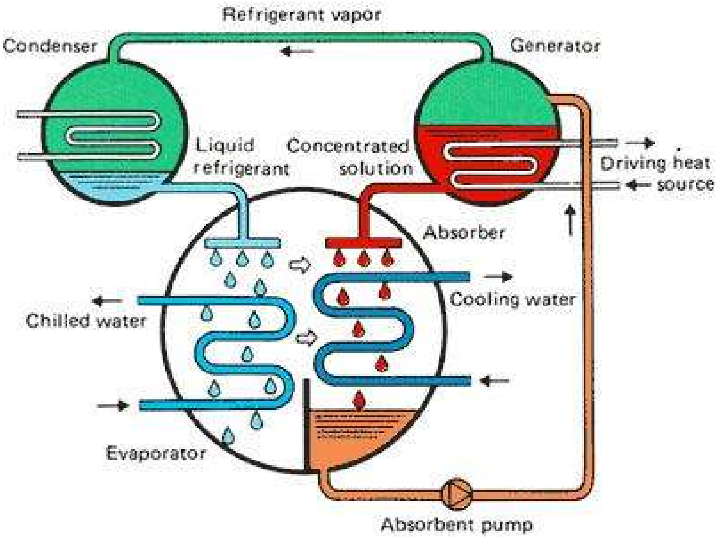
- Generation (Desorption)
  - Refrigerant vapor rich solution is heated to remove the refrigerant vapor
  - Temperature and solution concentration changes but pressure remains the same
  - Significant increase in the enthalpy
  - Heat input can take several different forms
  - Refrigerant vapor travels to the Condenser
  - Solution depleted of the refrigerant returns to the Absorber

Absorption Chiller Systems

- Absorption
  - Refrigerant depleted solution from the Generator absorbs the refrigerant vapor from the Evaporator
  - Temperature and solution concentration change but pressure remains the same
  - Heat is rejected to the cooling tower water
  - Solution rich in refrigerant is pumped back to the Generator
- Sensible Heat Exchange
  - Hot refrigerant depleted solution from the Generator exchanges sensible heat with refrigerant rich solution from the Absorber
  - Temperature changes but concentration and pressure remains the same

Absorption Chiller Systems

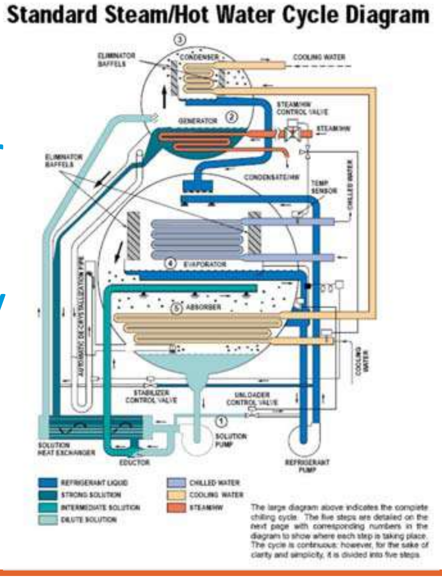
Typical – Single stage Lithium Bromide / Water System



Absorption Chiller Systems

Lithium Bromide / Water System

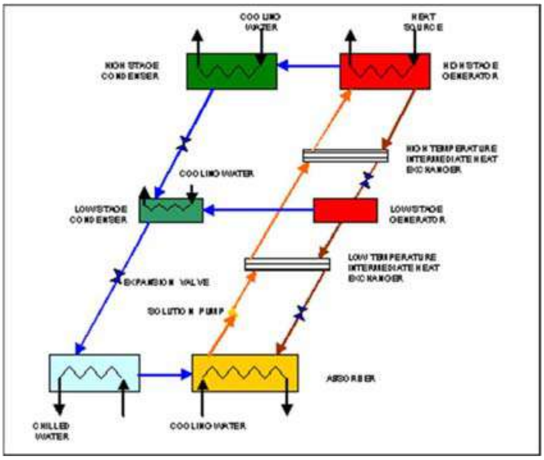
Standard Steam/Hot Water Cycle Diagram



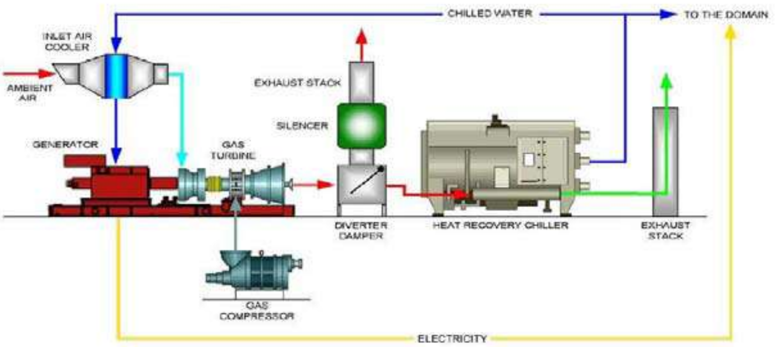
Courtesy: York International / Johnson Controls

- Another classification of LiBr/H_2O absorption chillers
  - Single effect
    - COP ~ 0.5-0.6
  - Double effect
    - COP ~ 1.0-1.1
    - Will require one additional condenser and generator compared to single effect machines
  - Triple effect
    - COP ~ 1.4-1.5
    - Will require two additional condensers and generators compared to single effect machines

Double Effect LiBr/H2O Absorption Chiller Systems

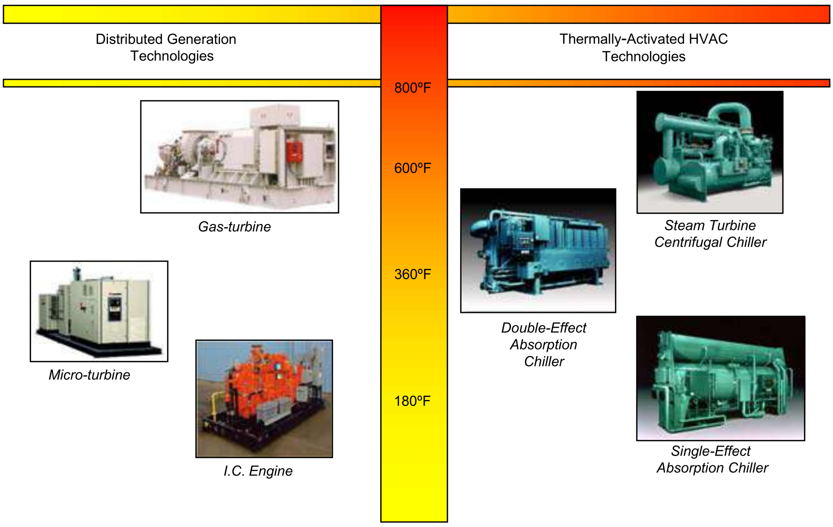


Waste Heat fired Absorption Chillers



- Commercially available – LiBr/water machines
- Provide chilled water only
- http://www.ornl.gov/sci/engineering_science_technology/cooling_heating_power/pdf/ISHPC-095-2005.pdf

Thermally-Activated HVAC Technologies



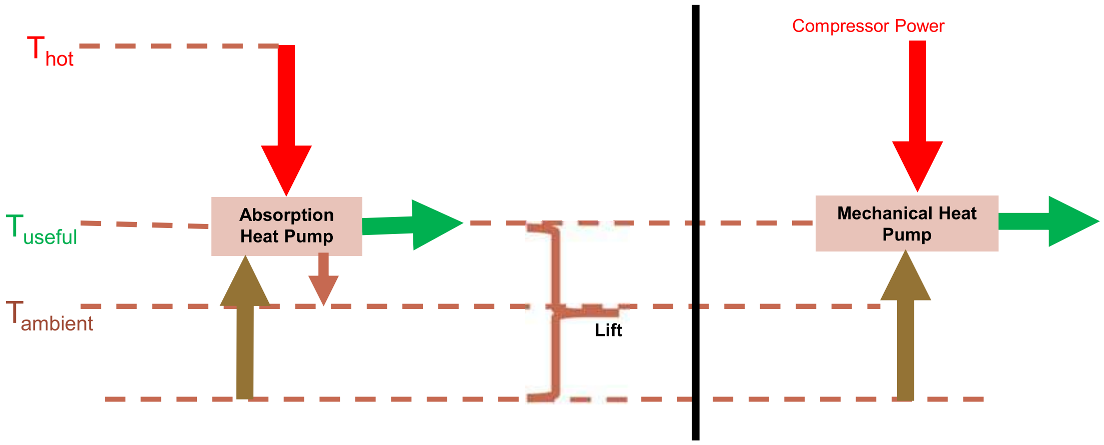
Courtesy: York International / Johnson Controls

Ammonia / Water Absorption Chiller, Refrigeration & Heat Pump Systems

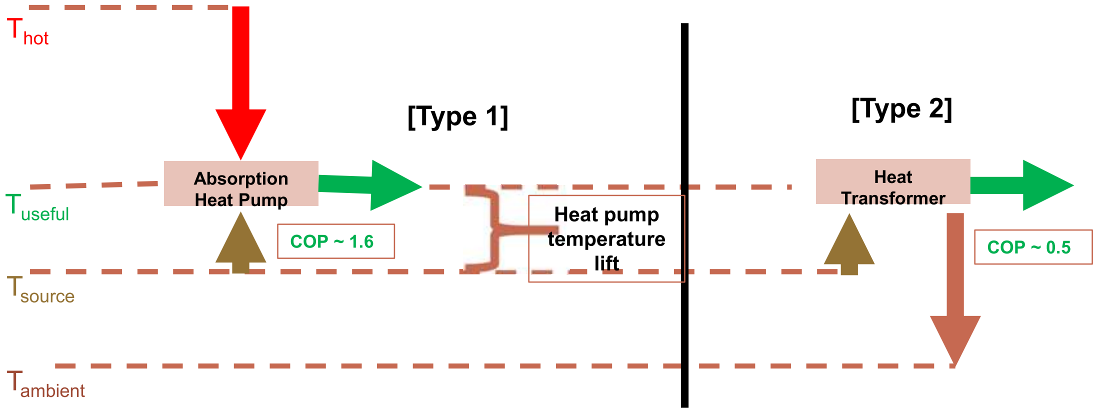
A significant portion of the Ammonia / Water Absorption Chiller & Refrigeration section is developed based on work done by Energy Concepts Company, Annapolis, MD.

The author acknowledges their strong support in preparing this section.

Absorption Chiller (Heat Pump)

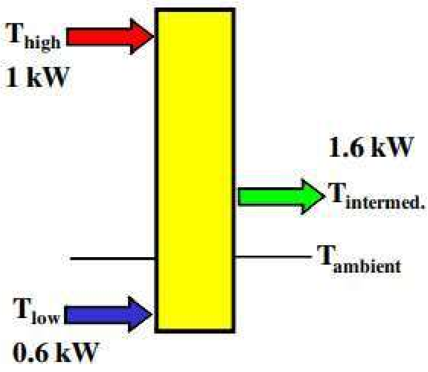


Heat-Activated Heat Pumps – Type 1 and 2

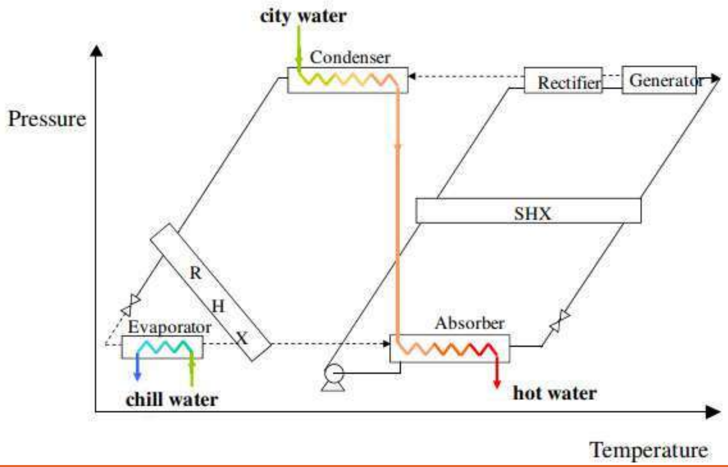


Adapted from Gluckman & McMullan 1988

Heat-Activated Heat Pump / Chiller (HAHP/C)



Heat-Activated Heat Pump / Chiller (HAHP/C)



100 Ton Heat Pump/Chiller (TS100) at Livingston, CA

- The TS100 supplies 1.2 GJ/hr (~100 tons) of chilling and 3.2 GJ/hr water heating
- Driving force - Steam 2 GJ/hr (1 Tph steam)

100 Ton Heat Pump/Chiller (TS100) at Livingston, CA

- The hot water and chilled water are required 20 hours per day, five days per week at a poultry processing plant
- 5ºC chilled water and 58ºC hot water
- Saves 30% of water heating energy and 80% of chilling energy
- Operating cost savings **~$120K per year**
- Installation cost **~$200K**
- Other partners: Pacific Gas & Electric (PG&E) and the California Energy Commission (CEC)

Meat Processing Plant

- Hot water production
  - 3,077 kW
  - 62.8°C
- Chilled water production
  - 1,000 kW
  - 1.1°C
- Steam usage
  - 7.9 bar saturated
  - 3.4 Tph

Poultry Processing Plant

- Hot water production
  - 2,244 kW
  - 57.2°C
- Chilled water production
  - 845 kW
  - 0.6°C
- Steam usage
  - 5.5 bar saturated
  - 3.1 Tph

Poultry Processing Plant

- Hot water production
  - 2,244 kW
  - 57.2°C
- Chilled water production
  - 845 kW
  - 0.6°C
- Steam usage
  - 5.5 bar saturated
  - 3.1 Tph

- **HOURLY SAVINGS**
  - 1,055 kWht @ $0.031/kWht — $32.40
  - 230 kWhe @ $0.09/kWhe — $20.70
  - $53.10/hour
- **ANNUAL SAVINGS (for 20/5 operation)**
  - 5200 HOURS @ $53.10 — $276,120/year
- **INSTALLED COST** — $500,000
- **PAYBACK** — 1.8 Years
- **AVOIDED CO2 EMISSIONS** — 1800,000 kg/year

85 Ton Waste Heat-fired Refrigeration at Bloomfield, NM

- Light ends (propane and gasoline) are recovered and a refinery flare is extinguished
- Installed at a 25,000 bpd oil refinery
- 300°F waste heat from the refinery powers the chiller
- 50 Tons of refrigeration at -32°C
- 35 Tons of refrigeration at -5°C
- 150 bpd of liquid product is recovered, in lieu of being flared
- The US DOE provided cost share support

275 RT Waste Heat-fired Refrigeration in Denver, CO Refinery

- Recovers 200 barrels LPG per day
- Double lift cycle, -32°C from 140°C waste heat from liquid stream
- US DOE provided cost-share

KOHLBACH

www.onekohlbach.com

Kohlbach ORC CHPs

Presentation on Dec 16, 2024, HoChiMinh City, VN

KOHLBACH

www.onekohlbach.com

Today’s Presentation

HoChiMinh City, December 16, 2024

- Part 1: Introduction
  - Kohlbach, the Company
  - Biomass Technology by Kohlbach Intro
- Part 2: KOHLBACH Thermal Oil Solutions
  - Boiler Layout
  - ORC Power Basics
  - ORC Plant Layout
  - KOHLBACH TO-Line-up
- Part 3: CHP with ORC
- Part 4: Local Kohlbach Solutions Offerings

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Company Profile

Presentation on December16, 2024 HooChiMinh City Vietnam

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KOHLBACH

Introducing ourselves

We are an Austrian family company that manufactures biomass energy systems for the international market

With our work we bear the economic, environmental and social responsibility for present and future generations.

The company was founded in	Established an industry standard by building over	Kohlbach group number of employee
1946 year	3000 systems	200 employees

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KOHLBACH

Milestones in Company History

01 – 1946: **Founding by Jakob Kohlbach** in the economically difficult post war era.

02 – 1955: First of numerous patents single chamber wood drying & space heating. **First product line.**

03 – 1970: **No.1 address for customers in CEE.** More than 50% of total sales go to export.

04 – 1978: Even more innovation: **First moving grate for wet fuel** the birth of the K8 system.

05 – 1993: Start of ongoing international drive. **Founding of first foreign subsidiary.**

06 – 2000: ISO 9001 QM certification, enhanced by EMAS presented by the environmental minister.

07 – 2011: **New factory** in Bleiburg, reinforcing industry leadership in expertise, quality, and reliability established by our unique manufacturing depth.

08 – 2016: **New global focus.** Reorganization into present Kohlbach Group. Ongoing projects on all continents with great success.

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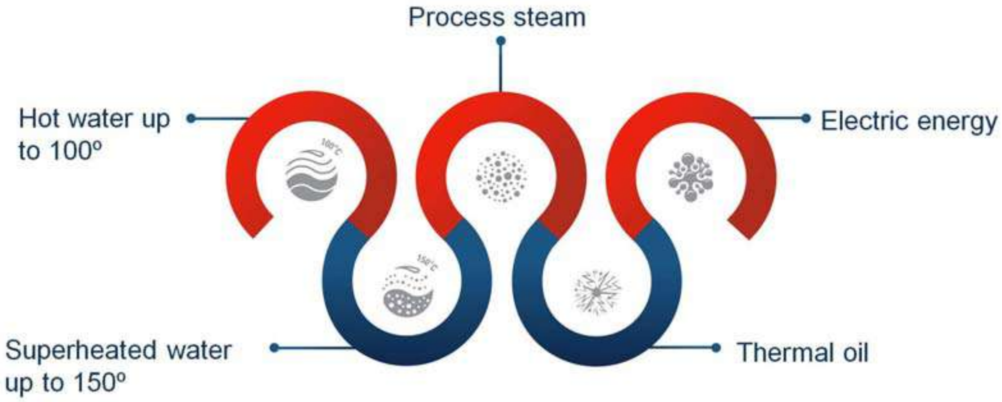
Biomass Energy Basics

From Fuel to Flue



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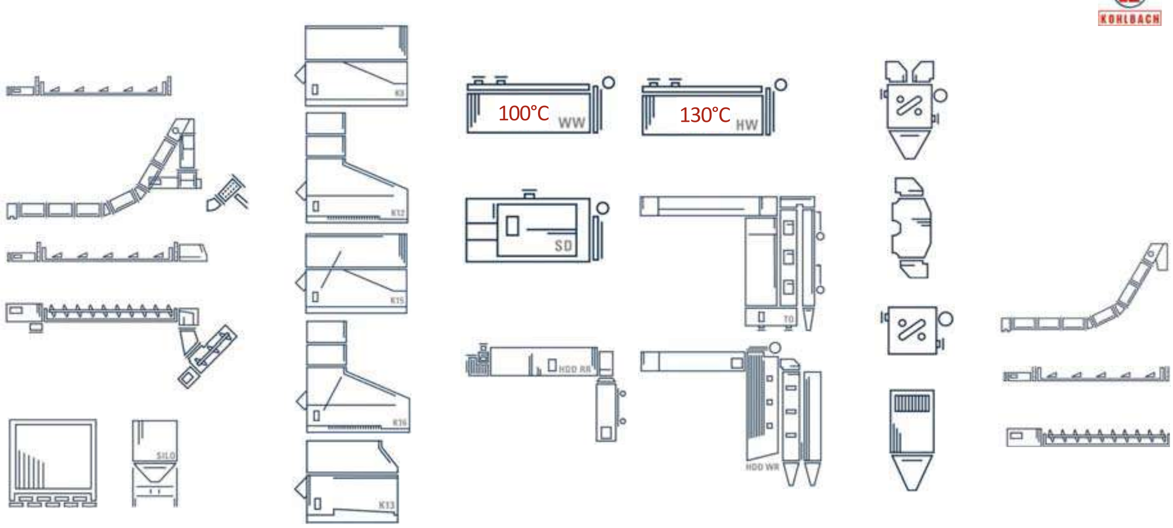

Infeed Combustion Boiler De-dusting / HRC De-Ashing

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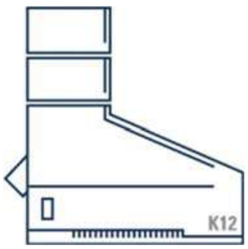
Relevant for today's Topic

Combustion System K12



Combustion Principle:

- adiabatic center stream furnace with
- vertical secondary combustion and
- water-cooled grate frame and compression zone

Output Range:

4,000 kW to **18,000** kW

Fuel:

Bark, Chopped Wood, Sawmill Residue etc.

Maximum Water Content (weight%):

20% to **60**% (depending on configuration)

Maximum Ash Content (weight%):

15%

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Combustion System K12

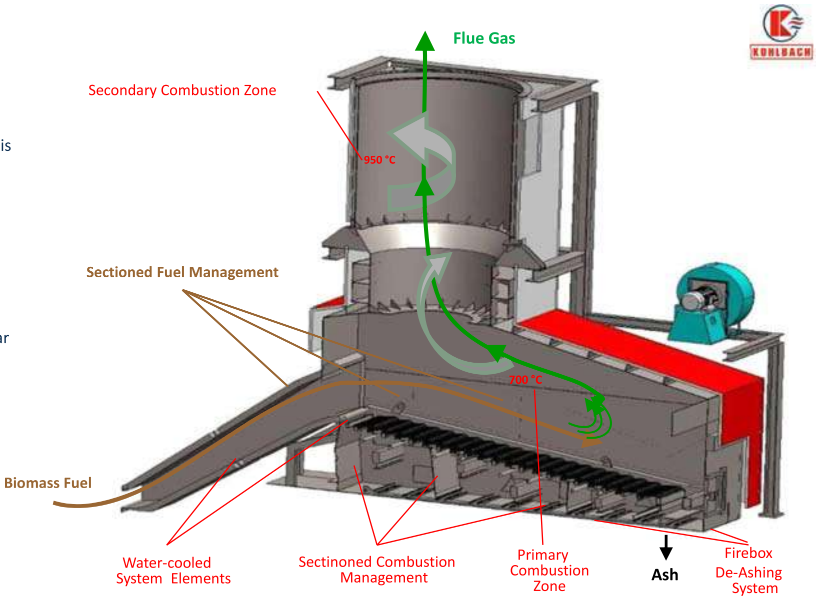
Adiabatic Center Flow System

Due to a new standardization approach the K12 is compatible with

- thermal oil,
- saturated and superheated steam,
- warm and superheated water boilers.

FEATURES:

- improved accessibility for repair & maintenance
- enhanced robustness against wear & wear caused by dirt, rocks and stones
- higher availability of the entire system
- implementable for wide output range
- optional emergency chimney



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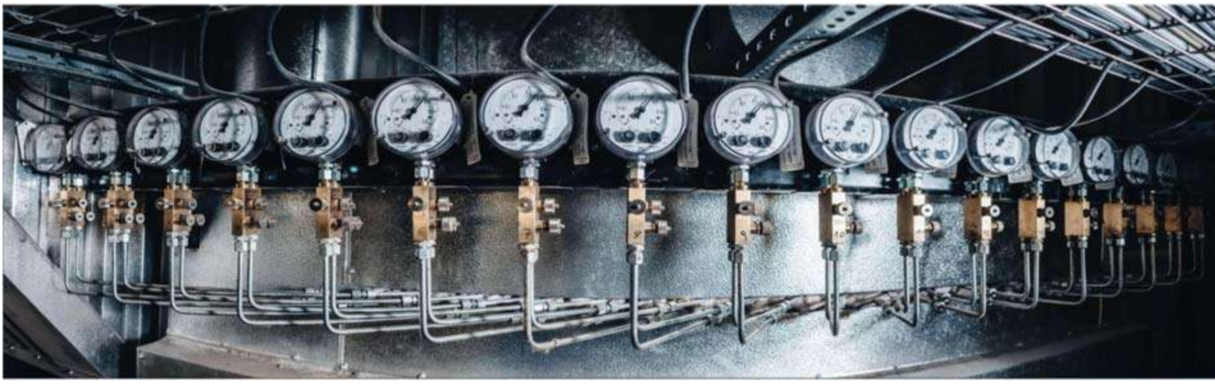
Biomass Basics

Thermal Oil Intro



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System TÖSK

Thermal Oil Boilers for Combustion System K12

DESIGN

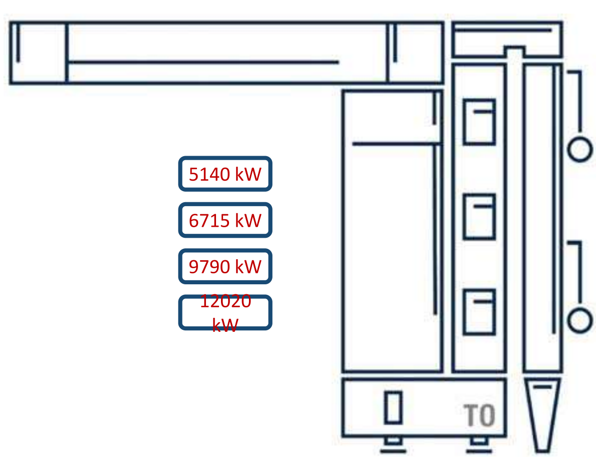
Biomass, Vertical standing, Fluid Tube, Boiler

OUTPUT RANGE

5.140 kW, 6.715 kW,
9.790 kW and 12.020 kW

FEATURES

- Separate heat exchanger passes for radiation and convection heat energy
- Maintenance friendly, easy accsess
- No compressed air necessary for boiler cleaning,
- Walls and transfer sections lined with refractory bricks



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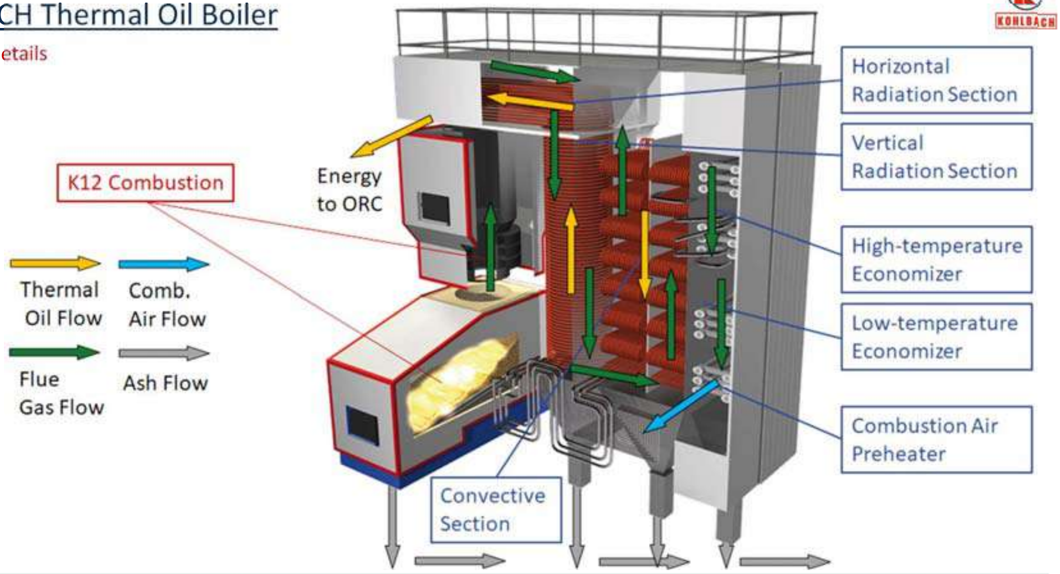
KOHLBACH Thermal Oil Boiler

Functional Details



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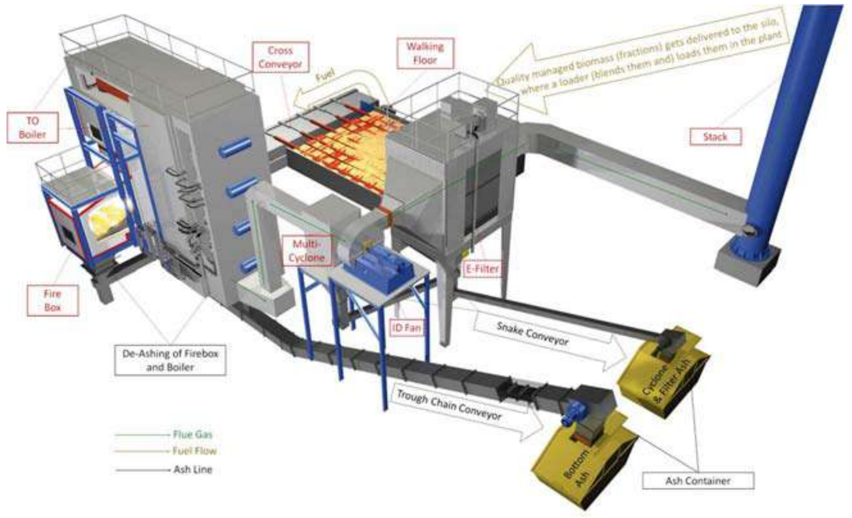
Thermal Oil Plant

Complete System View



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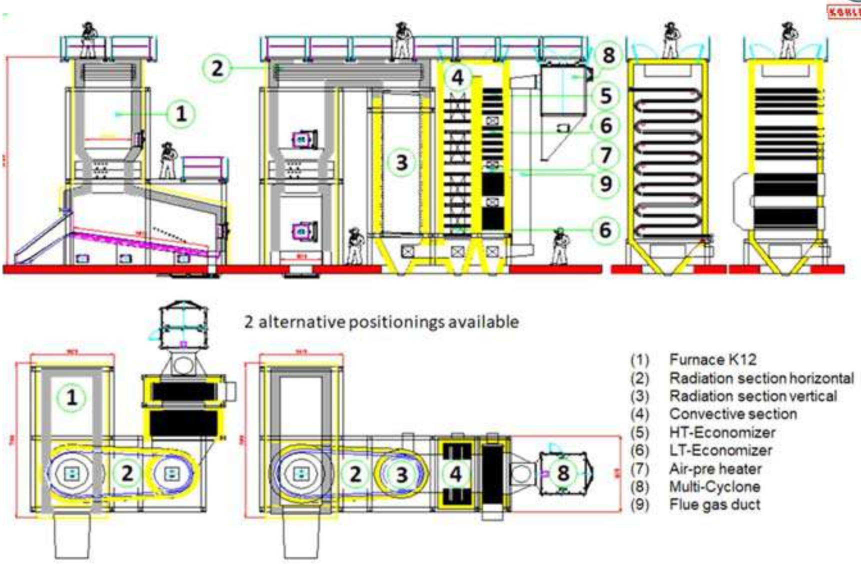
Thermal Oil Plant

Sections' Positioning



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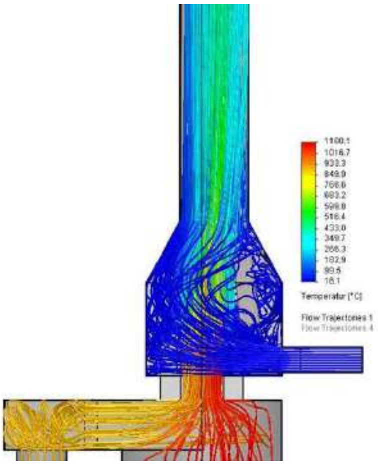
Safety Innovations

Industry leading Solutions Catalogue

- Thermal Oil Safety Protocol -NEW
- NEW Emergency Exhaust System – Innovation (Proprietary Development)
- Integration of hydraulic systems into safety protocol -NEW
- NEW and improved Emergency Cooling System
- Comprehensive (& integrated) Pump Monitoring System -NEW



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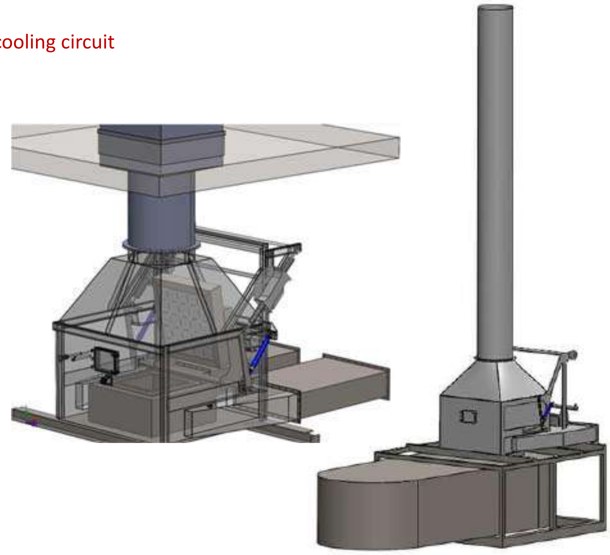
New Emergency Exhaust System

Offering you an extra layer of safety via emergency cooling circuit

ADVANTAGES

- Improved cooling progress in the combustion chamber
- Decoupling of the flue gas path
- Backwash by high intrinsic draft
- Reduction of outlet temperature by fresh air admixture
- Hydraulically closed. Emergency position is on open via spring return
- Implementation of Project-specific trigger criteria possible



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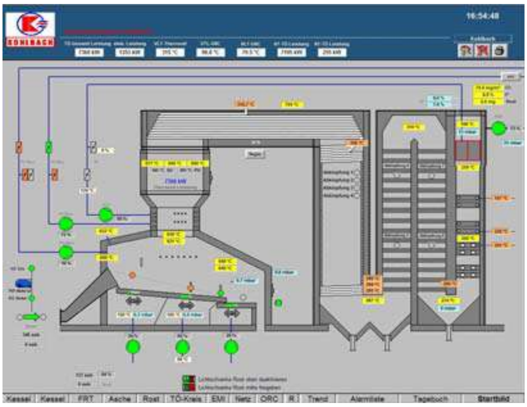
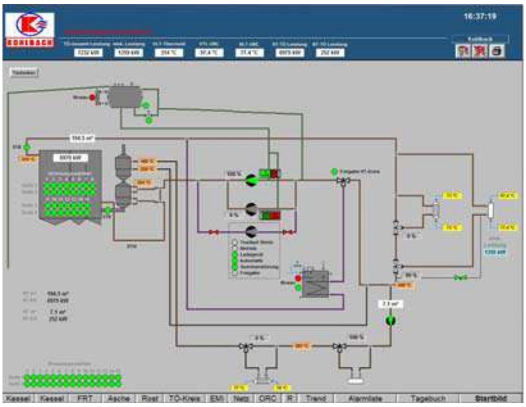
TÖSK 2 Visualization

Improved comprehensive Operation Insight





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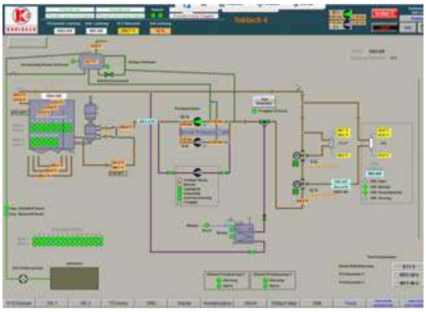
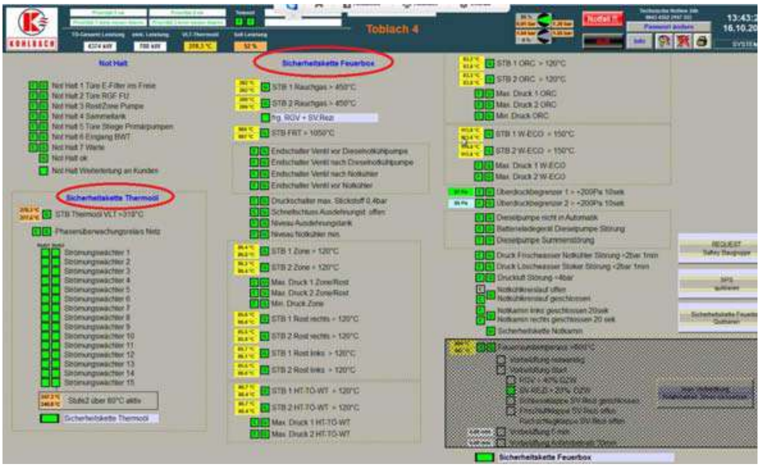
Innovative Features

KOHLBACH Thermal Oil Safety Protocol

Integration of the Safety Exhaust System Hydraulics





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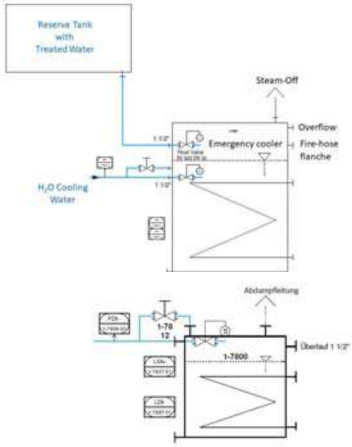
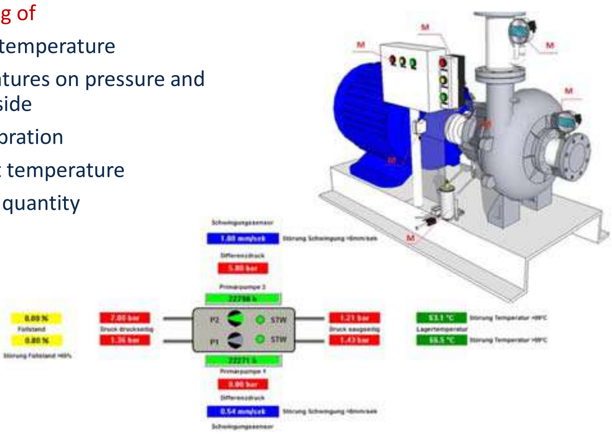
Safety Features

Improved Emergency Cooling System and Pump Monitoring



Safety monitoring of

- Bearing temperature
- Temperatures on pressure and suction side
- Pump vibration
- Ambient temperature
- Leakage quantity



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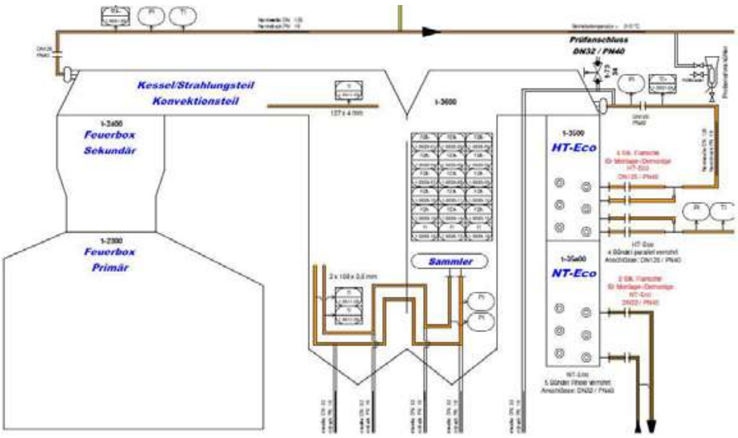
Emergency Cooling

Hydraulic Integration

ADVANTAGES

- Thermal Oil fault mode activates emergency cooler
- Flow sensor activates emergency cooling pump
- Simultaneously, safety chain gets triggered:
  - Fuel supply: STOP
  - Supply air combustion: STOP

- IN CASE OF A POWER BLACKOUT, the primary pump and emergency cooling pump would run in tandem



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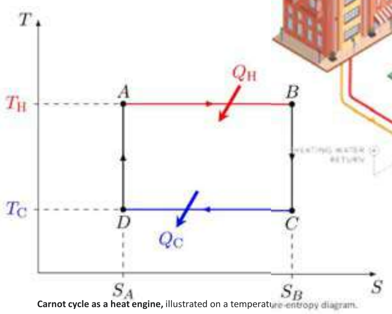
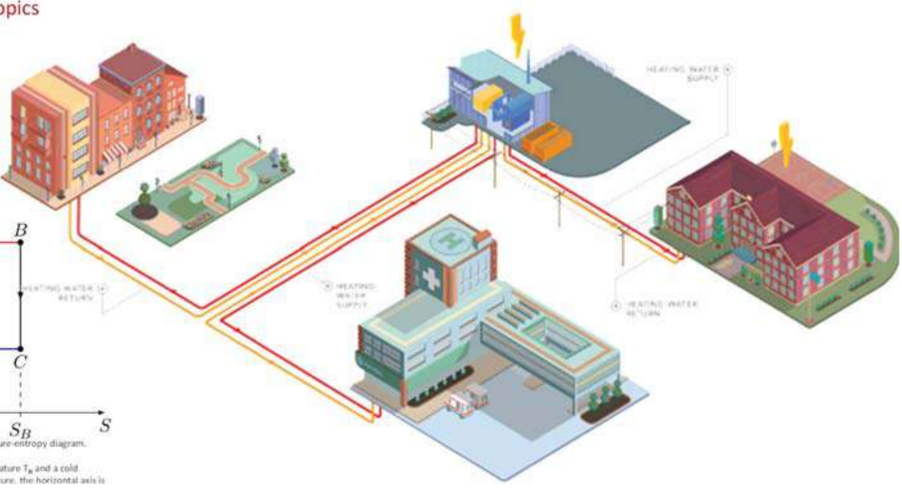
KOHLBACH ORC CHPs

Layout-critical Co-Generation Topics



Carnot cycle as a heat engine, illustrated on a temperature-entropy diagram.

The cycle takes place between a hot reservoir at temperature T_H and a cold reservoir at temperature T_C. The vertical axis is temperature, the horizontal axis is entropy



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KOHLBACH CHPs

An Excerpt … the Top 35 of 70+

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CHP Layout

Choices in Operation with Consequences

As we know, the advantage of CHPs, compared to separated electricity and heat generation is their superior fuel efficiency.

When we lay out a CHP plant for you, we need to know more about your individual energy usage.
There are no 2 identical solutions in the 70+ (SD / HD Steam and TO) CHPs we have built, so far.

In theory, the CHP operator has three options operating a CHP system:

1. In the **heat-controlled** mode of operation, the system is aligned to the required heat demand
2. In the case of **power-controlled** operation, the focus lies primarily on electricity generation, with the entire generated electricity is consumed as far as possible.
3. In a combined mode of operation, the operating models described above are used with the focus on as far as possible low operating costs combined.

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Operating Principles

Comparison

Heat Controlled Operating

- CHP is operated according to the requirements of the heat consumer,
  - like a local heating plant or
  - process heat
- Ideally, the CHP plant covers the base heat load.
- The power output of the CHP plant depends on the current heat demand in the system.
  - Unneeded electricity is fed into the fed into the power grid.
  - Electricity is regarded as the “icing on the cake”

Power Controlled Operating

- CHP operation is based on the electricity requirement
- The output modulation of the CHP plant depend on the current electricity demand.
- The output of the CHP is increased, regardless of whether the heat can be used or not.
  - Unusable heat is either dissipated or stored.
  - This reduces the overall efficiency

CHP Layout

Considerations

Heat-controlled biomass systems can be optimized to operate efficiently on 30-100% load.

As the investment in power generation equipment are substantial. OPEX become the decisve factor, after all.

→ Owner-operators must have a good understanding of the underlying business case which may become complex, especially when they include multiple heat consumers (or external heat customers) into their business case, that in many cases includes outsourcing to professional service providers.

Therefore, in practice we are mostly looking at some variation of combined mode of operation.

Kohlbach ORC Primer

Power Generation with ORC Turbines

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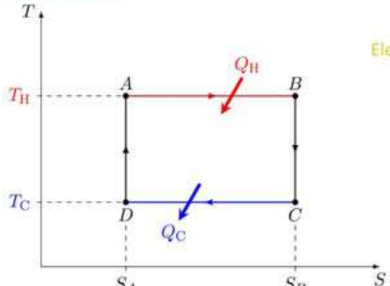
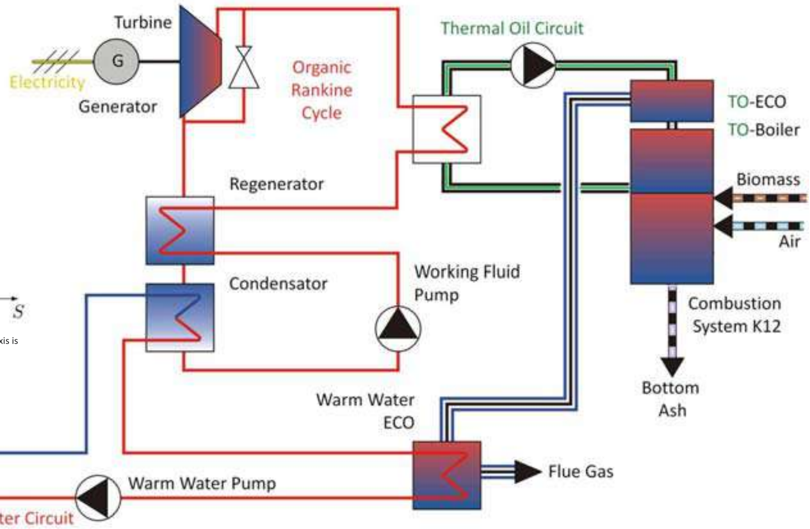
CHP Plant with ORC

Basic Diagram



The cycle takes place between a hot reservoir at temperature T_H and a cold reservoir at temperature T_C. The vertical axis is temperature, the horizontal axis is entropy



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Organic Rankine Cycle

Working Principle

1. The working fluid is pumped to a heat source where it is evaporated,
2. Passed through some form of expander (turbine, screw, scroll), where pressure difference [Δp] is transformed into work
3. And then through a condenser heat exchanger where it is finally re-condensed.

As in any real cycle, not reversible phenomena lower cycle efficiency.

I. During expansion, a part of the energy recoverable from the pressure difference is converted into heat (and so lost)

II. To ensures good heat exchange the working fluid takes a long and sinuous path in the heat exchangers, which causes pressure drops that lower the amount of power recoverable from the cycle.

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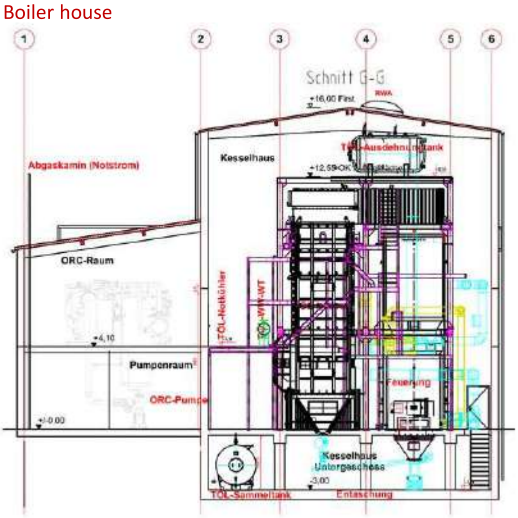
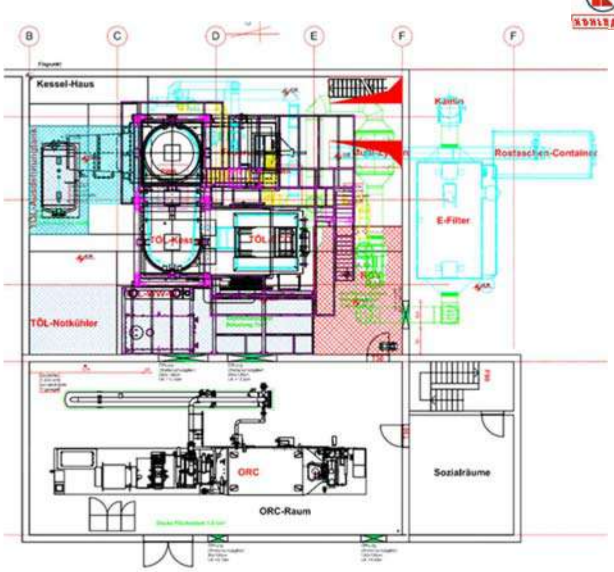
CHP Plant with ORC

Boiler house





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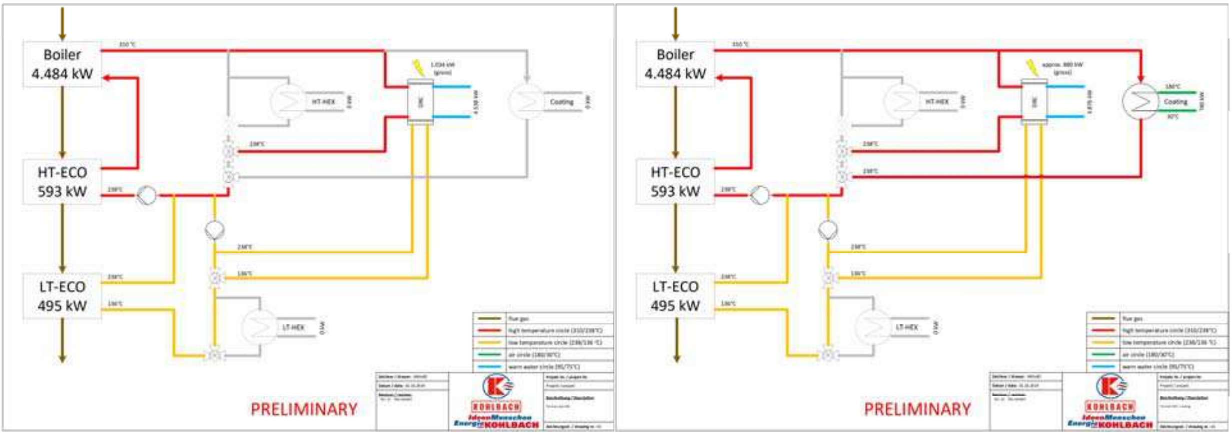
CHP Plant with ORC

Use Case Process heat for Powder Coating



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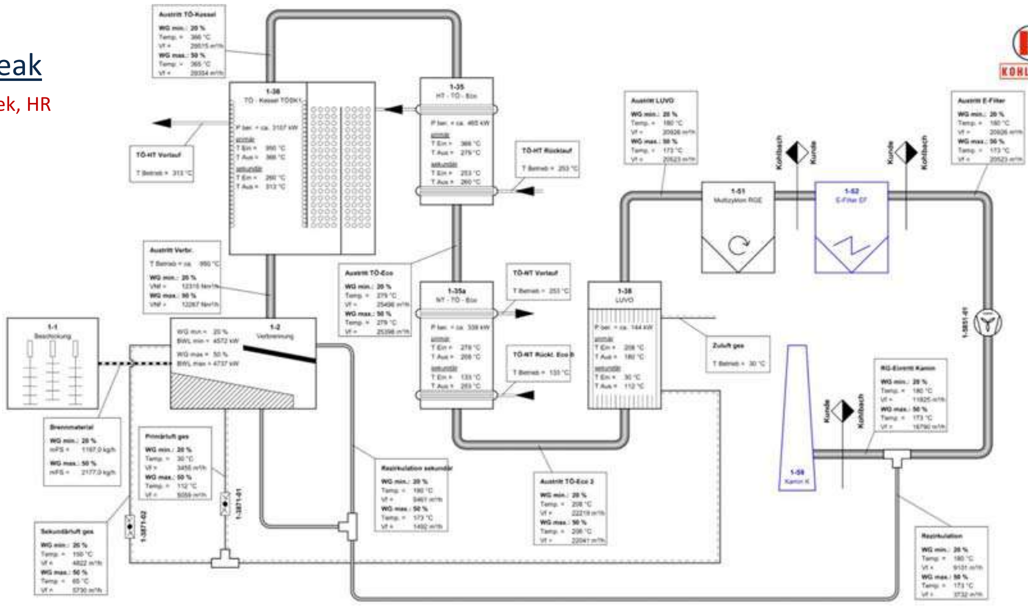
Sneak Peak

Project Kricek, HR



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Your CHP / ORC Project

Decision Making Process

Invest money in science based decision support

Do not switch to biomass.
Make it a transition!

Narrow down and understand your fuel

Go for shared use of systems in
clusters and zones (heat).

Have a plan. In advance please!

Allow mixed systems
for effective solutionss (base load)

Involve all authorities early.

Do not encourage over-engineering
for peak efficiency.

Let permitting guidelines follow
technology and best practices

Prioritize economic and
ecological sustainability

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KOHLBACH International Solutions Approach

Collaboration through Adding Value

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KOHLBACH

Corporate Stucture

Kohlbach Energieanlagen GmbH
Sales, Design Engineering, Manufacturing
Austria

Kohlbach Services GmbH
Sales, Design, Engineering, After-Sales
Germany

KBF Bioenergie France S.A.S.
Sales, Design, Engineering, After-Sales
France

KBR OOO Kohlbach Bioenergetika
Sales, Design Engineering, Manufacturing
Russia

Kohlbach Holding GmbH
Administration & Accounting, PR & Marketing
Austria

Kohlbach Services GmbH
Customer Hotline, After Sales International
Austria

KBE Bioenergie D.O.O.
Sales, Design, Engineering, After-Sales
South-East Europe

Kohlbach Energieanlagen GmbH
Sales, Design Engineering, Manufacturing
Austria

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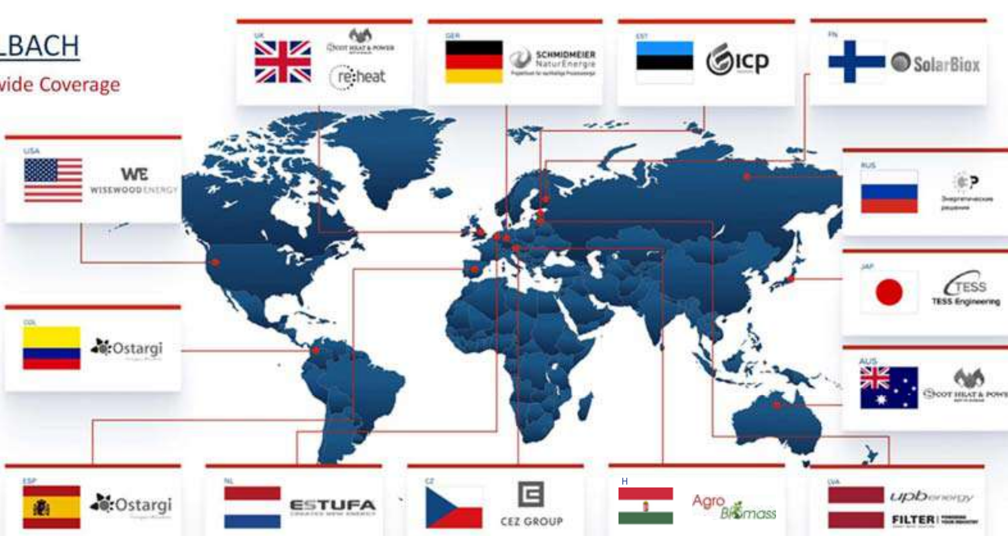
Worldwide Coverage



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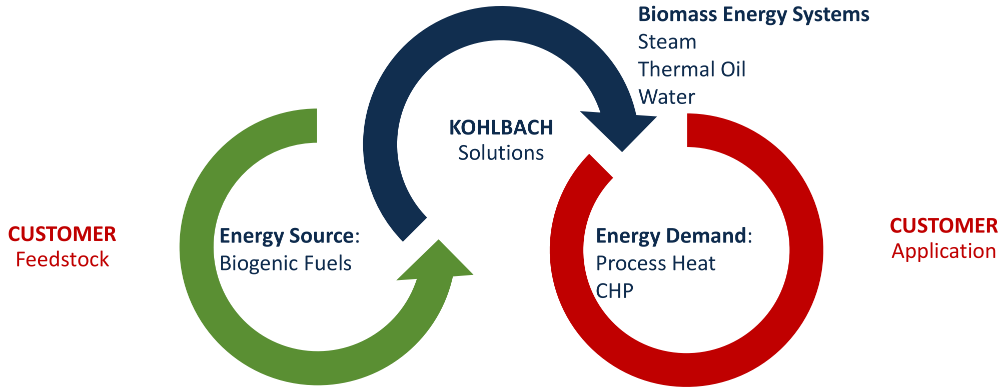
Solutions at the Intersection of Energy Supply and Demand



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Biomass Energy Basics

Essential Fuel Characteristics for Biomass Combustion

Physical Properties

- Bulk density in kg/m³
- Particle size distribution (P) in mm acc. ISO-17225-1 and Fine content (F)
- Water content (wet basis)
- Ash content (water free basis)
- LHV Lower Heatig Value
- LHV Lower Heatig Value (water free basis)
- HHV Higher Heating Value (water free basis)
- Particle sizes Fractional composition P
- Ash Melting point in C°
- Ash Softening points in °C

Chemical Compounds (water free basis)

- Carbon C
- Hydrogen H
- Nitrogen N
- Sulphur S
- Chlorine Cl
- Potassium K
- Natrium Na
- Phosphorus P
- Calcium Ca
- Aluminium Al
- Iron Fe
- Lead Pb
- Copper Cu
- Magnesium Mg
- Manganese
- Zinc Zn

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International Projects with KOHLBACH

Come and Get Us to Know

01
Site visits & demos, Needs analysis, etc.

02
Domestic energy demand analysis, feed-in schemes etc.

03
Detailed fuel supply analysis, sampling, quality mgmt, etc.

04
Preliminary process engineering study, fuel mix recipes, emissions etc.

05
Optimized scope sharing analysis*

06
Combustion tests and preliminary engineering

07
Sampling and Project management plan

08
Collaboration contract

09
Detail engineering for respective scopes

10
Production planing; Quality Mgm Plan

11
Qualitiy Assurance Measures

12
Production, Delivery

13
Installation

14
Commissioning and training of client staff

* Fee based services may be part of the collaboration agreement

Maintenance and Service Operations

- With changing customer requirements: updates, adaptations and optimization
- With ongoing technical development and for competition solutions: System Upgrades, Follow Up Business

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Why KOHLBACH?

The KOHLBACH Way

We have established an industry standard by building over 3000 systems in more than 75 years.

KOHLBACH is well known in the bioenergy business with an industry leading expertise, experience, innovation and dependability.

- Heavy duty design, up-time over 8,200 h/a.
- All capabilities in-house from R&D, engineering, project management, and manufacturing.
- We base business on full and fair partner- enabling. We provide support and training, from your initial project idea to realization, through commissioning and beyond.

- Close to you: 1/3rd of the company is dedicated to after-sales and customer support, reinforced through licensees and regional service partner networks.
- Intense collaboration with key customers in all major bioenergy application fields and close cooperation with partners in all major regional markets

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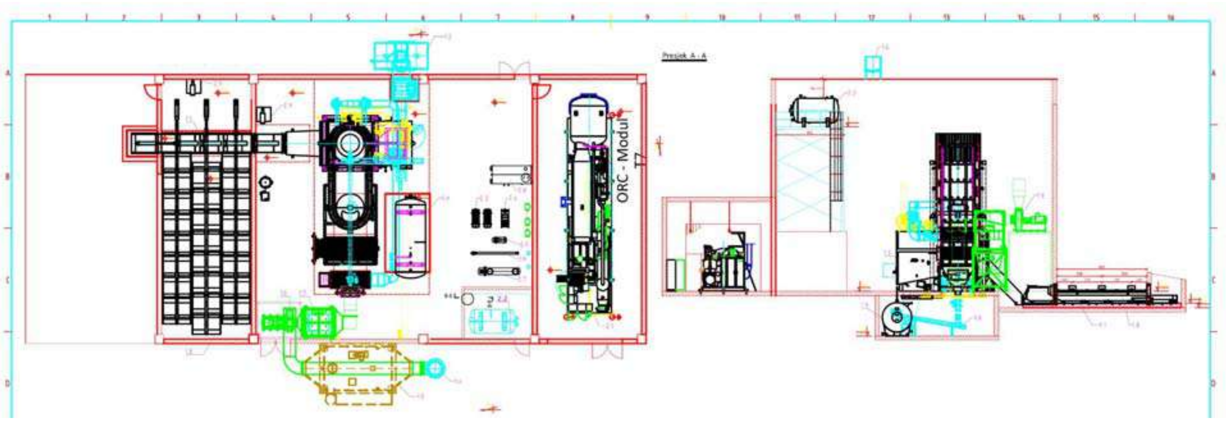
Site Visit



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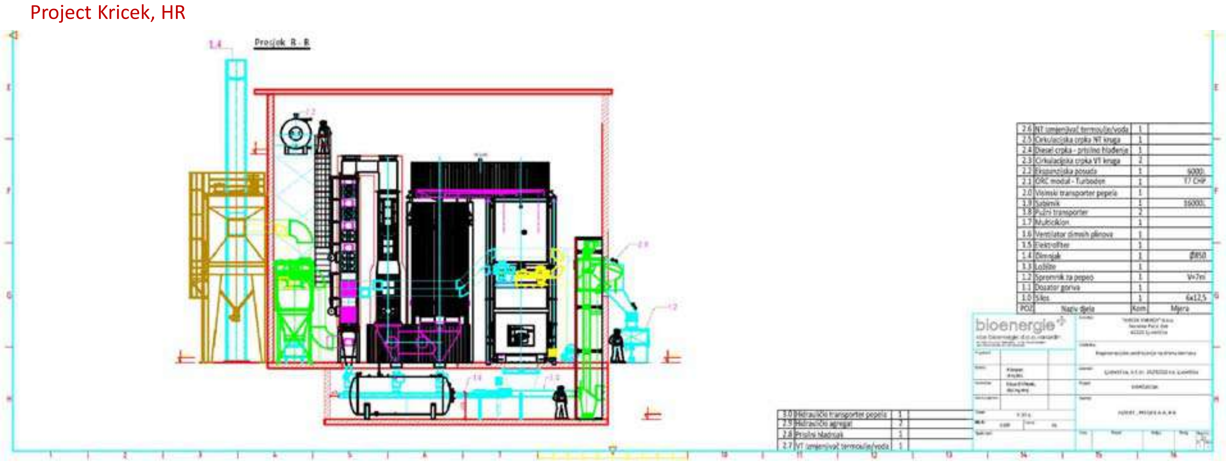
References in all Sizes / Site Visits

Project Kricek, HR



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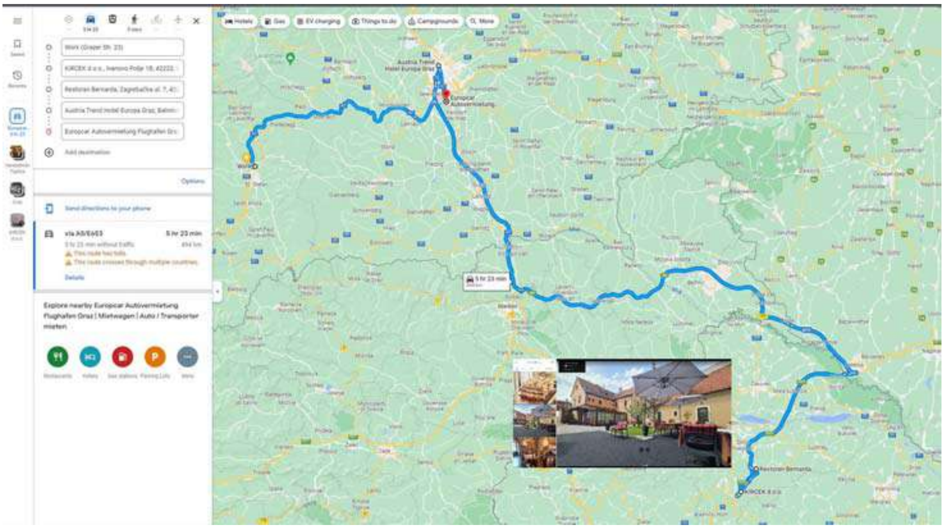
Site Visit

All over Europe
or
Japan



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