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Introduction to Combined Heat and Power

November 8, 2016 11:00 PST / 2:00 EST

(1PDH issued by Cummins)

Cummins Power Generation

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Course Objectives

Participants will be able to:

- Define CHP project concepts and terminology to discuss customer CHP opportunities
- Identify economic, design, and operational criteria to propose different CHP configurations and equipment
- Identify the key tools and data required to create informed CHP feasibility studies

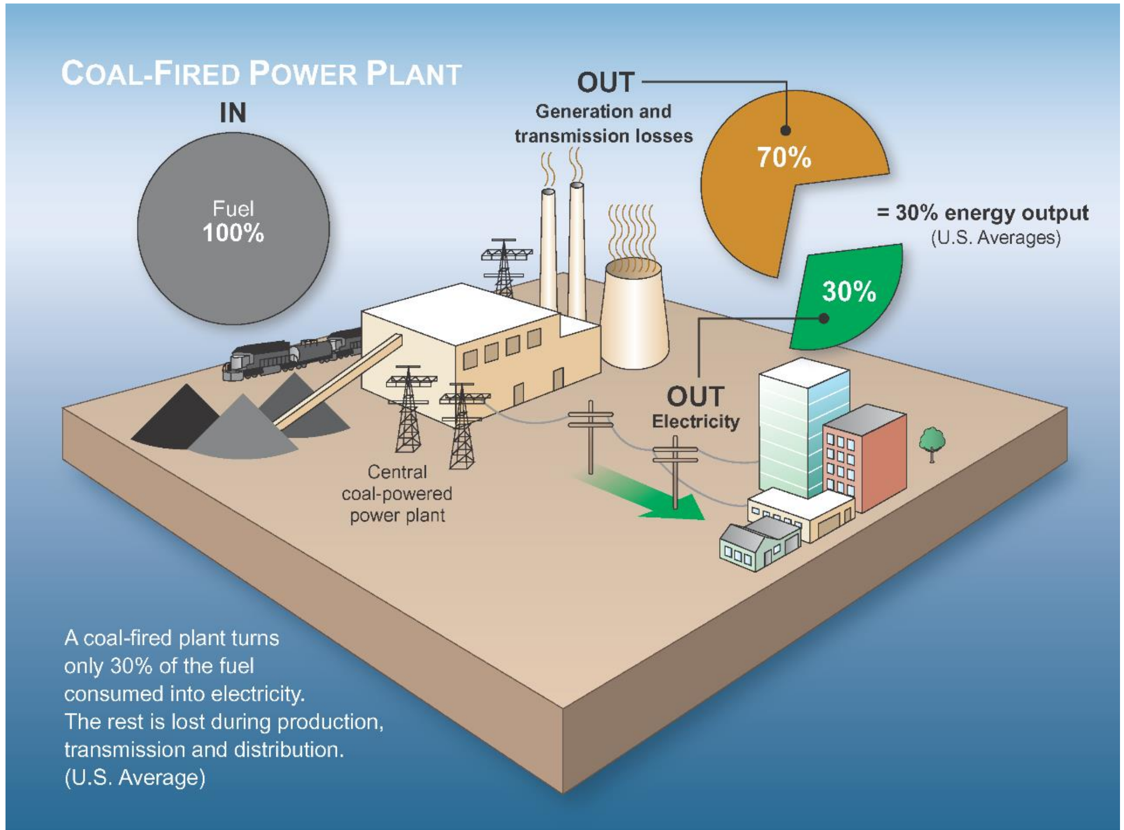
CHP Overview

- CHP, Combined Heat and Power
  - The utilization of both heat and electric energy from a Genset
  - Also known as Co-generation or Co-Gen
    - US EPA uses the term Co-generation
- CHP is not a new technology
  - Used in Thomas Edison's first electric generating plant in 1891
  - Used in industrial, institution, and municipal applications today
- Cogeneration systems can provide hot water, steam, chilled water, or all 3 simultaneously

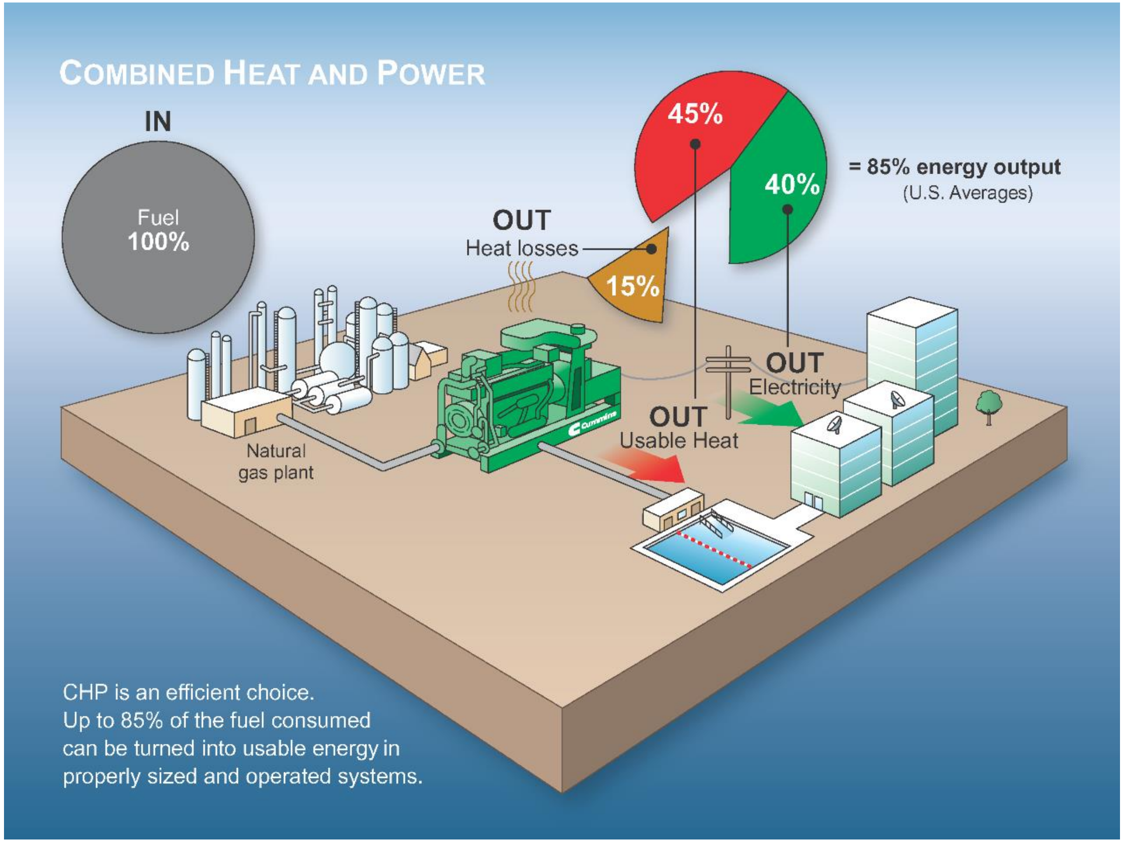
CHP Benefits

- Energy efficiency
  - Could reach 90% global efficiency
- Financial savings
  - Energy cost savings
  - Attractive return on investment (ROI)
  - Potential incentives for fuel efficiency and emissions reduction benefits of CHP
- Environmental
  - Reduced environmental footprint
    - Reduction in CO_2, NO_x, and particulates compared to central power plant
  - Higher efficiency means better conservation of natural resources

Traditional Generation



Generation with CHP



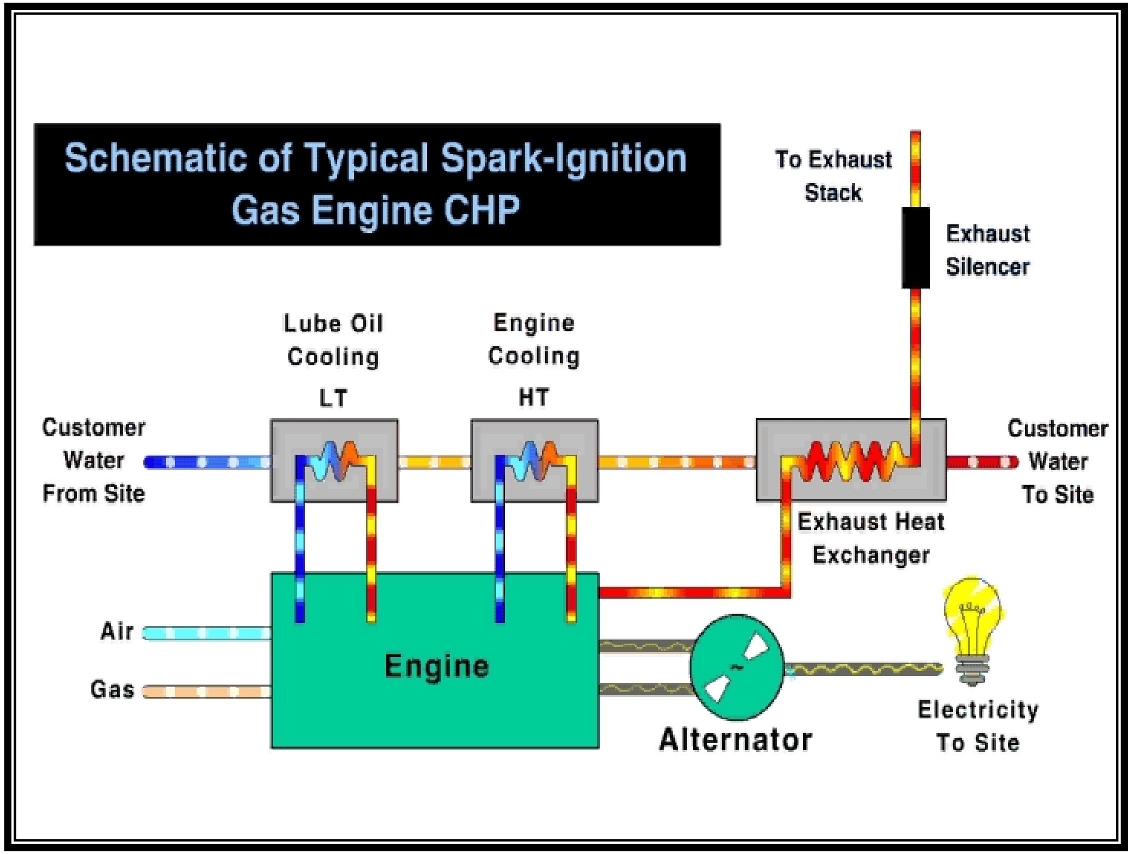
Application Considerations

- Electrical loads
  - Sufficient base electrical load or export capability
- Thermal loads
  - Sufficient equipment or process that can use the heat energy
- Balance between electrical and thermal loads is critical for optimum CHP performance
  - Available heat energy is dependent on the electrical output
  - If not balanced, either the excess heat must be dumped or the excess electrical power exported.

Heat Energy Sources

- When to use each heat source?
- Heat source temperatures
  - Low temperature (LT), or after cooler circuit (~ 40-60 °C, 104-140 °F)
  - High temperature (HT), or jacket water circuit (~90-110 °C, 194-230 °F)
  - Exhaust (~450-550 °C, 842-1022 °F)
- Typical heat uses and components
  - Steam production → Boiler (exhaust)
  - Hot water → EGHE, Engine Cooling HX (exhaust and/or HT, LT)
    - LT circuit sometimes used as pre-heat to prevent thermal shock
  - Cold water → Chiller (exhaust and/or HT)

Simplified CHP Schematic



Required Information

Customer

- Electrical load profile
- Thermal load profile
  - Heat transfer media
    - Steam, water, oil, etc.
  - Process temperatures
    - Input and output
  - Process flowrates

Cummins (Datasheet)

- Genset kW rating
- Thermal energy from each heat source
- Heat source flowrates temperatures

Sample Data Sheet

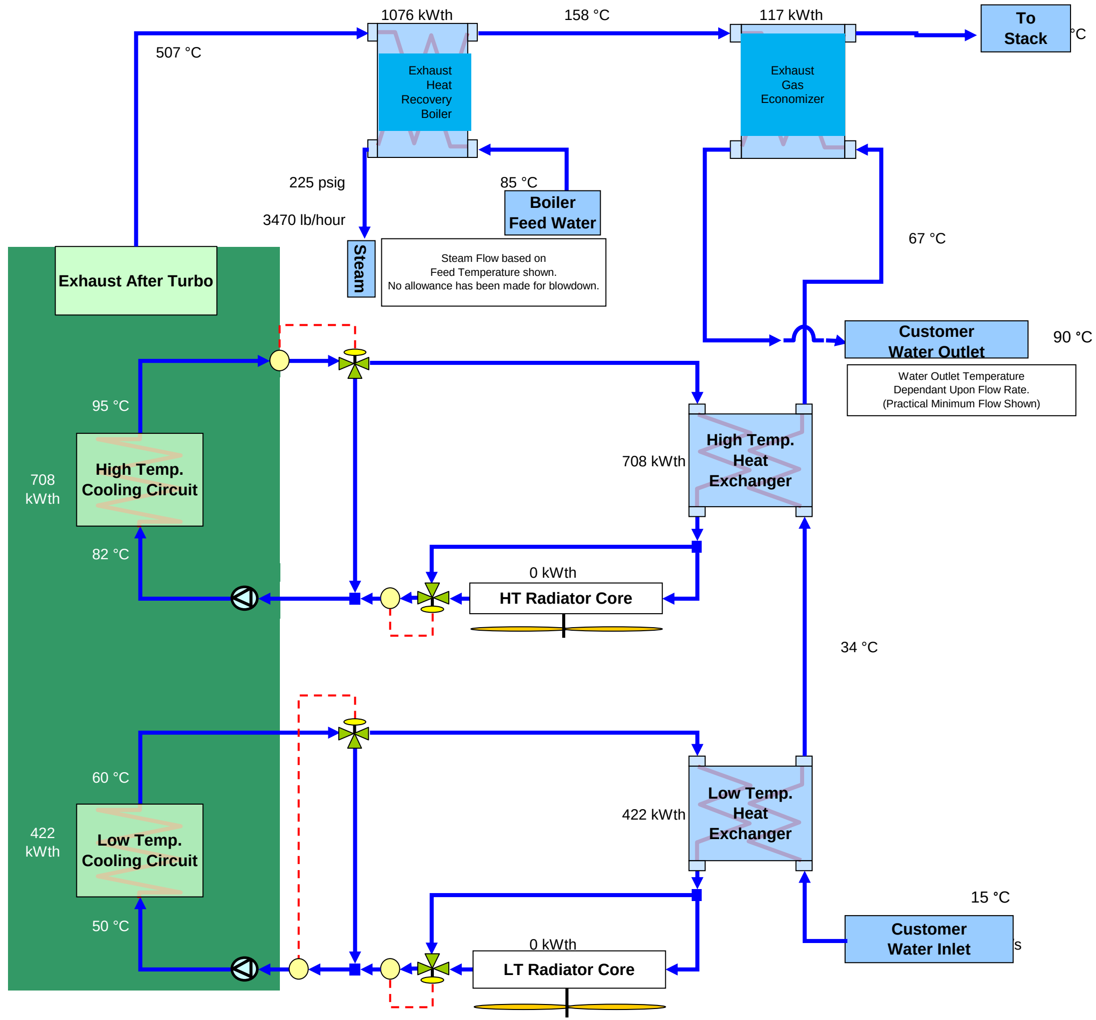
Model: C1750 N6C
Frequency: 60 Hz
Fuel Type: Natural Gas MI 80 +

HT Cooling Circuit			
HT Circuit Engine Coolant Volume, l (gal)		424 (112)	42
HT Coolant Flow @ Max Ext Restriction, m^3/h (gal/min)		60 (264)	6
Maximum HT Engine Coolant Inlet Temp, °C (°F)	8	97 (207)	9
HT Coolant Outlet Temp, °C (°F)	8	110 (230)	1
Max Pressure Drop in External HT Circuit, bar (psig)		1.0 (15)	1
HT Circuit Maximum Pressure, bar (psig)		4.5 (65)	4
Minimum Static Head, bar (psig)		1.5 (22)	1
LT Cooling Circuit			
LT Circuit Engine Coolant Volume, l (gal)		295 (78)	29
LT Coolant Flow @ Max Ext Restriction, m^3/h (gal/min)		38.00 (167)	38.0
Maximum LT Engine Coolant Inlet Temp, °C (°F)	9	50 (122)	5
LT Coolant Outlet Temp, ~~o~~C (°F) Reference Only	9	60.0 (140)	60
Max Pressure Drop in External LT Circuit, bar (psig)		1.0 (15)	1
LT Circuit Maximum Pressure, bar (psig)		4.5 (65)	4
Minimum Static Head, bar (psig)		1.5 (22)	1

Configuration | V 18

Steam & Hot Water

GQPB -- 1514 RPM -- 11.4:1 -- 1.22 g/hp-h (ISO 8178) NOx -- 100% Load -- 750 m altitude -- 25 °C -- Data Sheet #3307



Title	Unit	Value
Water Inlet Temperature	°C	15
Water Outlet Temperature	°C	90
Hot Water Heat Rate	kWth	1248
Water Flow Rate	kg/s	5.2
Steam Pressure Selected	psig	225
Saturation Temperature	°C	203
Feed Water Temp. Selected	°C	85
Steam Heat Rate	kWth	1076
Steam Production	lb/hour	3470
Net System Efficiency	% (LHV)	80.7%

Properties for Single Genset at Rated Altitude and Temperature	Unit	100%	90%	75%	50%
Energy input (LHV)	kW	4799	4334	3708	2655
Electrical Output	kW	1750	1575	1313	875
Total heat rejected to LT. Circuit	kWth	422	382	348	283
Total heat rejected to H.T Circuit	kWth	708	634	524	378
Available Exhaust Heat To 105 deg.C	kWth	1200	1079	946	698
Maximum LT. engine water inlet temperature	°C	50	50	50	50
Maximum LT. engine water outlet temperature	°C	60	60	60	60
Maximum HT engine water inlet temperature	°C	82	82	82	82
Maximum HT engine water outlet temperature	°C	95	95	95	95
Exhaust gas temperature after turbine	°C	507	514	528	549

Equipment

- CHP system design must integrate the facility process to the available Genset heat
  - Heat exchangers
  - Radiators
  - Heat transfer media: steam, water, oil, etc.
  - Pumps, flows, piping design, thermal storage
  - CHP Control system(s)
  - Paralleling switchgear

HT and LT Heat Exchangers

Shell & Tube heat Exchanger

Operational Weight: 130kg (285lbs.)

Capacity: 120kW

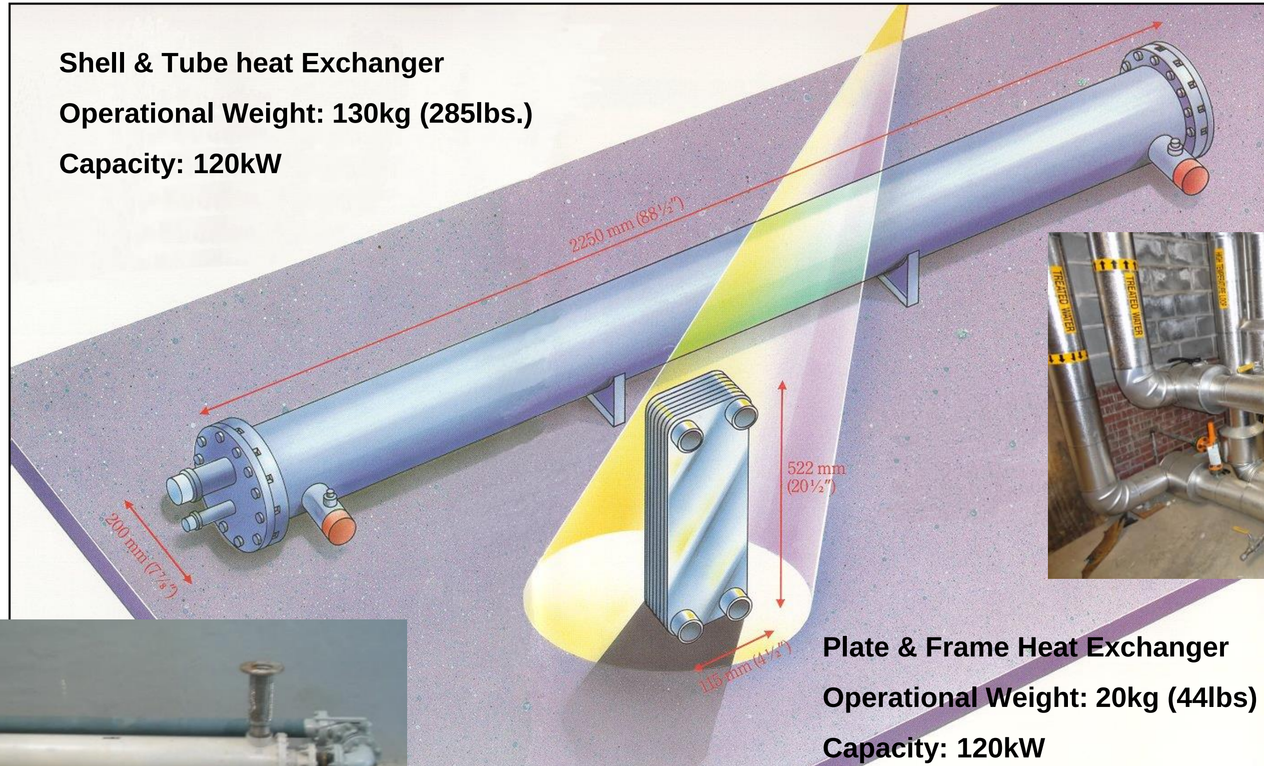


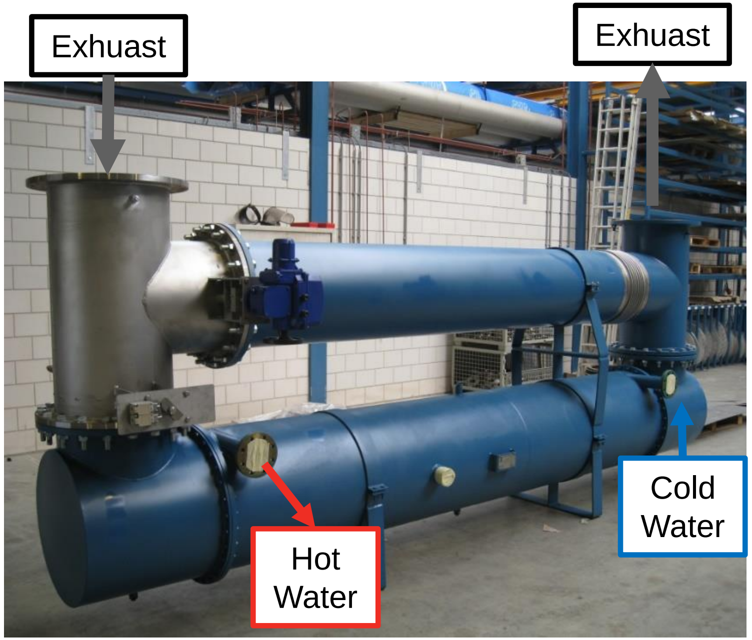
Plate & Frame Heat Exchanger

Operational Weight: 20kg (44lbs)

Capacity: 120kW

Exhaust Heat Exchangers

Exhaust Gas HX (EGHE)



Boiler

QSV91G 1750 kW produces approximately 1.37 Ton/hr (2740 lb/hr) of steam at 8 bar(g) (116 psig)

Boiler Requirements

- Steam pressure and flow rate
  - Steam tables are great reference
- Water inlet temperature and flow rate
- Safety equipment
  - Pressure relief valve
  - Pressure gauges
  - Water level sensor
  - Applicable pressure vessel local regulations
  - Insulation
- Water treatment

Utilizing the Exhaust

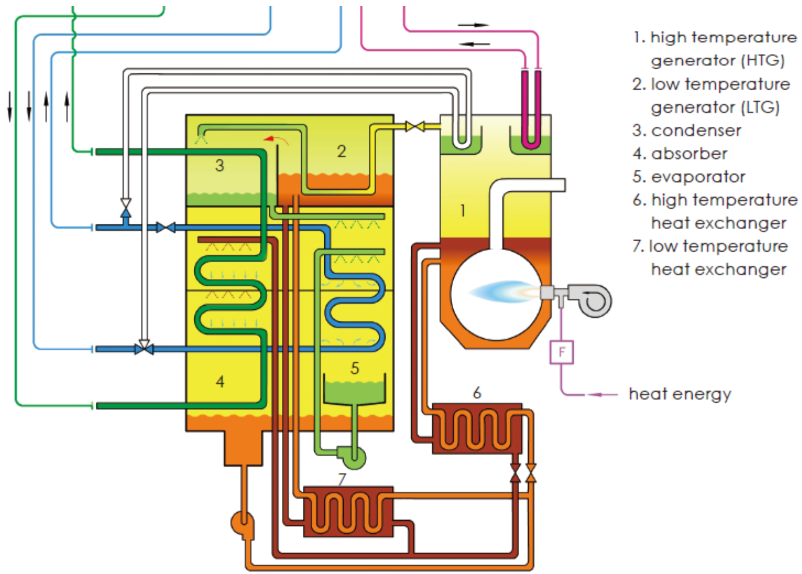
- Equipment using exhaust as heat source must be bypassed during engine start-up
- Water, or heat transfer media, must be running through heat exchanging equipment before start-up
- Having a common exhaust pipe will affect heat output when not all engines are running
  - Affects heat exchanging equipment size
- Valve, bypass pipe, non-common exhaust, control, purging
- After-treatment equipment must be installed upstream heat exchangers/boilers
  - After-treatment has a specific temperature operating range

Absorption Chillers

BROAD Multi-Energy(exhaust +hot water) driven chiller on Cummins engine

Cummins Model		C334N6C	C1000N6C	C1100N6C	C1250N6C	C1400N6C	C1750N6C	C2000N6C
Power Output	kW	334	1000	1100	1250	1400	1750	2000
BROAD Chiller Model		BHE50	BHE125	BHE125	BHE125	BHE200	BHE200	BHE250
Cooling Capacity	RT	139	286	295	416	533	615	626

chiller



The cooling principle

The input heat energy heats LiBr solution to generate vapor, which is then condensed into water by cooling water. When the refrigerant water enters evaporator (in high vacuum condition), its temperature goes down immediately. And it is sprayed over the copper tubes to make cooling. The water absorbs heat from air conditioning system and evaporates, then is absorbed by concentrated LiBr solution from the generators. The cooling water takes away the heat and rejects it into the air. Diluted solution is pumped into HTG and LTG separately to be heated to begin the process all over again.

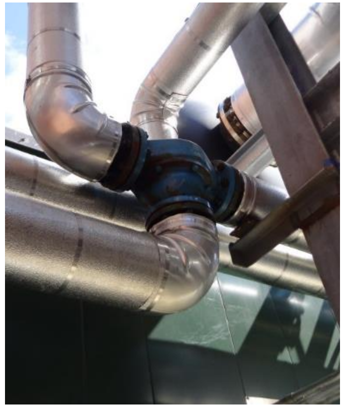
John Wayne Airport, Los Angeles, CA

- 2x 535 Ton Hot Water Absorption Chillers
- 4x C1750N6C gensets

Radiators

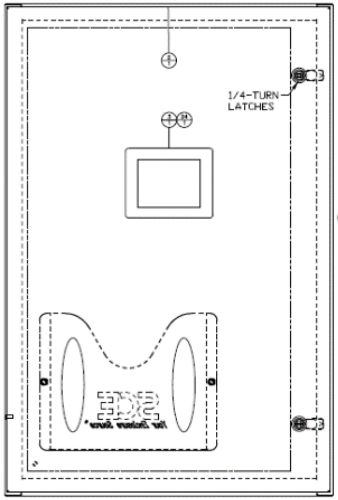
General Installation Considerations

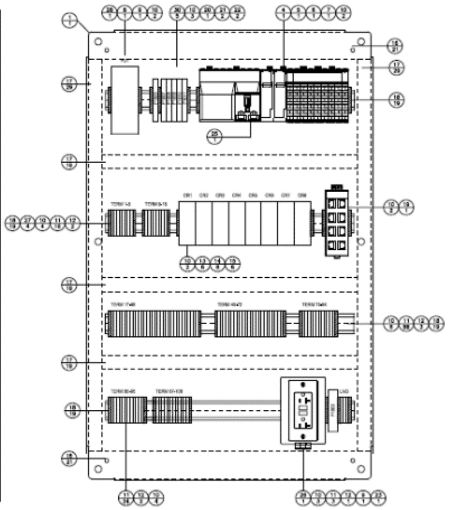
- Pressure & temperature indicators
- Thermostatic valves
  - Better temperature control
  - Higher efficiency
  - Lower temperature to the cooling circuit affects heat energy output, temp, flow rate
- Pipe insulation
- Pumps need to be installed before heat exchanging equipment
  - Pressure relief valve needs to be installed right after pump outlet to protect downstream equipment
- Isolation valves are recommended for each equipment for better serviceability

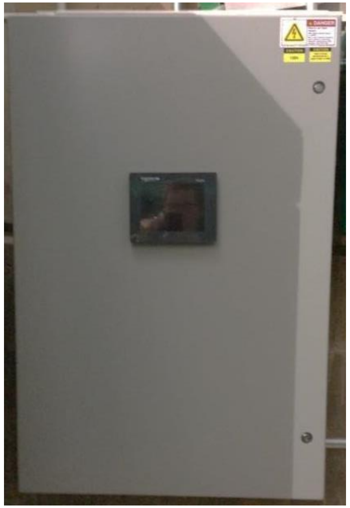


CHP Control System

- CHP system requires a dedicated control system
  - Typically, PLC with HMI
  - Genset and Master Controls do not operate the CHP system





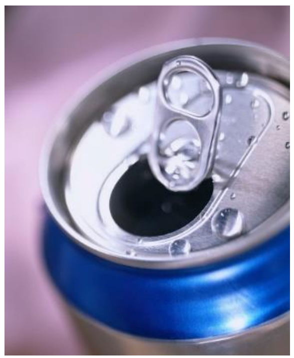


Paralleling Switchgear

- For optimum performance, CHP system runs at a constant load parallel to the utility
- Electric power could be used internally or exported

Carbon Dioxide (CO_2) Recovery

Bottling Companies

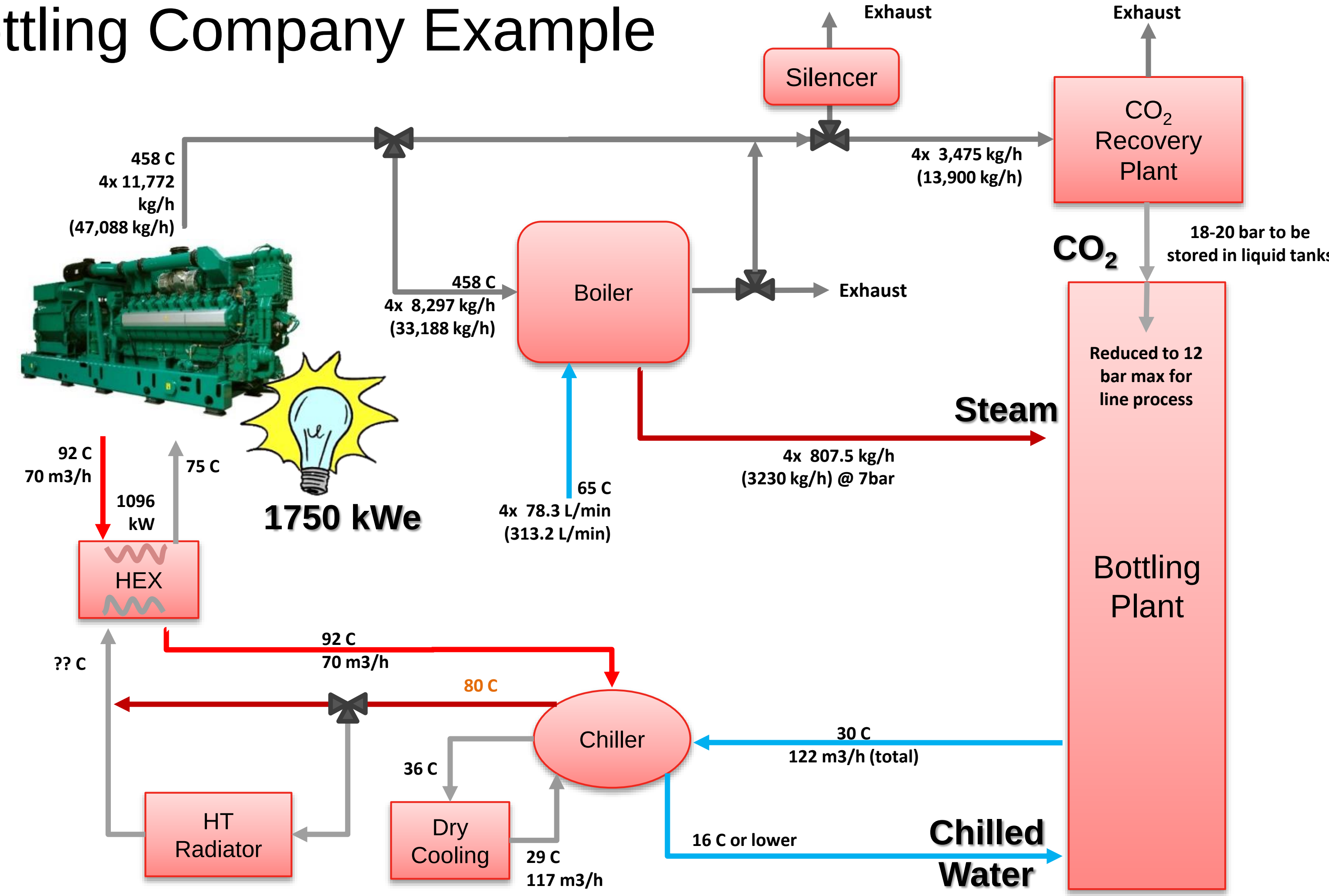


Green House (Ready, Set, Grow)

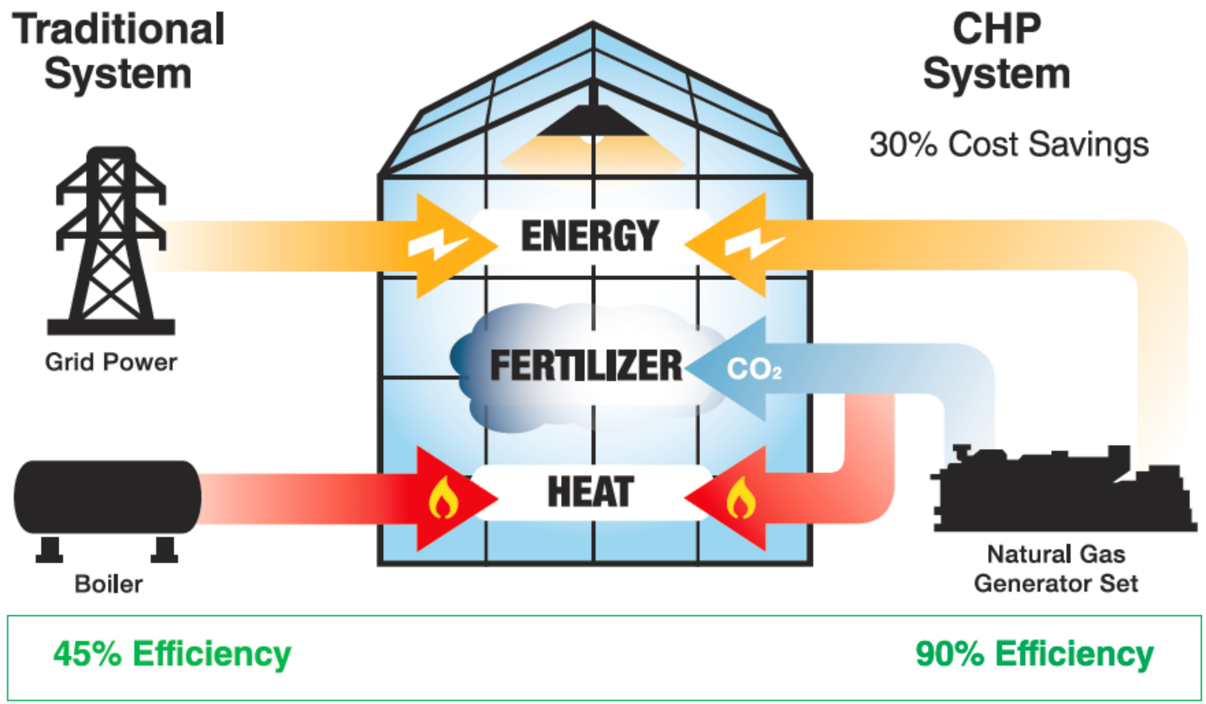
Cummins Green House Campaign

www.cumminsgreenhouse.com

Bottling Company Example



Greenhouse Applications



❖ May be higher due to surplus energy sold, water from exhaust for greenhouse operations, heat storage for later use

Who can use CHP?

- **Hospitals**
- **Greenhouses**
- **Hotels**
- **Industrial/Chemical Plants**
- **Manufacturing Facilities**
- **Commercial Facilities**
- **Government Facilities**
- **Colleges and Universities**
- **Food Processing Plants**
- **Health Clubs**
- **Swimming Pools**
- **Nursing Homes**
- **District Heating**
- **Landfills and Sewage Treatment Plants**
- **Coal Mining and Oil Fields**

CHP Case Study:
De Breuck Greenhouses, Belgium

Compared with separate heat and electricity production, the CHP system realizes an energy savings of about 25 percent.

Where:
At the tomato greenhouses of Geert De Breuck in Sint-Gillis-Waas, Belgium

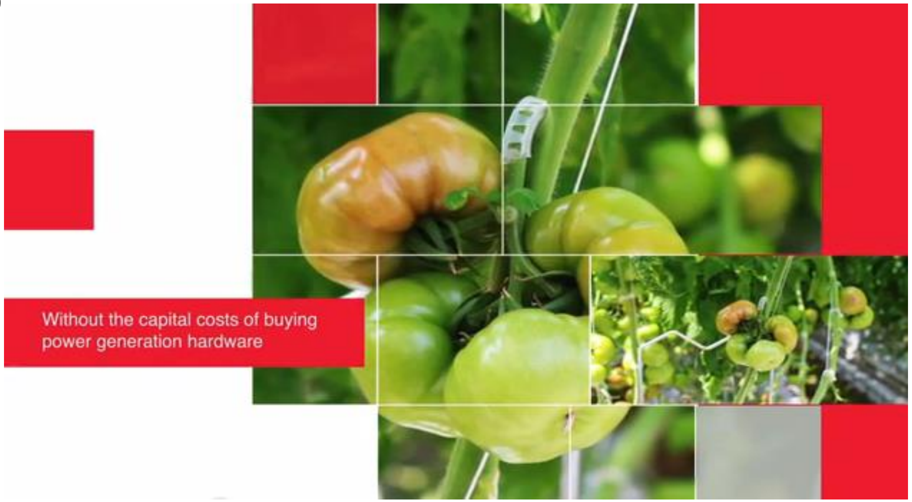
What:
A lean-burn gas generator set producing heat and electric power to reduce energy costs and accelerate growth of tomatoes

Purpose:
Generate electricity for on-site use and for sale to the power grid, while simultaneously producing heat and carbon dioxide for plant growth

Primary choice factors:
High fuel efficiency, reliability, high specific heat output and expert help from Cummins Power Generation to optimize system operating parameters

Desmet Greenhouse, Belgium

- Commercial tomato grower Desmet in Aardooie, Belgium
- 2MWe & 2.7MWth production
- Exhaust gas clean-up allows for CO_2 recovery into the greenhouse
- Global efficiency >90%



CHP Case Study:
Chicago Museum of Science and Industry

"Before we turn the air conditioning on, the system is carrying about 90 percent of the building's total electrical load. It pleases me how well it works,"

Bill Vanderbilt, facilities manager, Museum of Science and Industry

Where:
Museum of Science and Industry, Chicago, IL, USA

What:
Cogeneration installation featuring a Cummins Power Generation 1.75 MW lean-burn gas generator set, heat-recovery boiler and desiccant dehumidifier providing electricity, heating/cooling and domestic hot water

Purpose:
Demonstrate how a cogeneration or combined heat and power (CHP) system can save energy and money

Primary choice factors:
Cummins Power Generation lean-burn engine technology that delivers high fuel efficiency, low emissions and high specific heat output

Facility evaluation for CHP

1. Have all reasonable steps been taken to reduce both electric and heat energy consumption?
2. Is the base electrical load of the facility greater than an available Genset continuous rating?
3. Is the thermal load of the facility greater than the available thermal energy from the Genset?
4. Is the duration of simultaneous need for heating/cooling and electric power greater than 6000 hours/year?
5. Are electric rates high in relation to NG rates?
6. Is the site suitable for installation of a co-gen system?
7. Is reliability of electric service a major economic concern?
8. Has an economic analysis been done?

Summary

- CHP can provide several advantages including energy efficiency, reduced environmental footprint, and financial savings
- Start by understanding site energy use – both heat and electricity
- CHP system design depends on energy utilization, customer processes, site considerations, and Genset characteristics
- Contact Cummins Power Generation for assistance in performing facility evaluation and ROI analysis

Q&A

- Type your questions, comments, feedback in the **WebEx Q&A box**. We will get to as many questions as we can
- We will publish consolidated FAQ along with presentation and webinar recording on powersuite.cummins.com

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