AIChE® 12th SOUTHWEST PROCESS TECHNOLOGY CONFERENCE

VIRTUAL

OCTOBER 1–2, 2020

COGENERATION

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USE OF COGENERATION IN LARGE INDUSTRIAL PROJECTS

(RECENT ADVANCES IN COGENERATION?)

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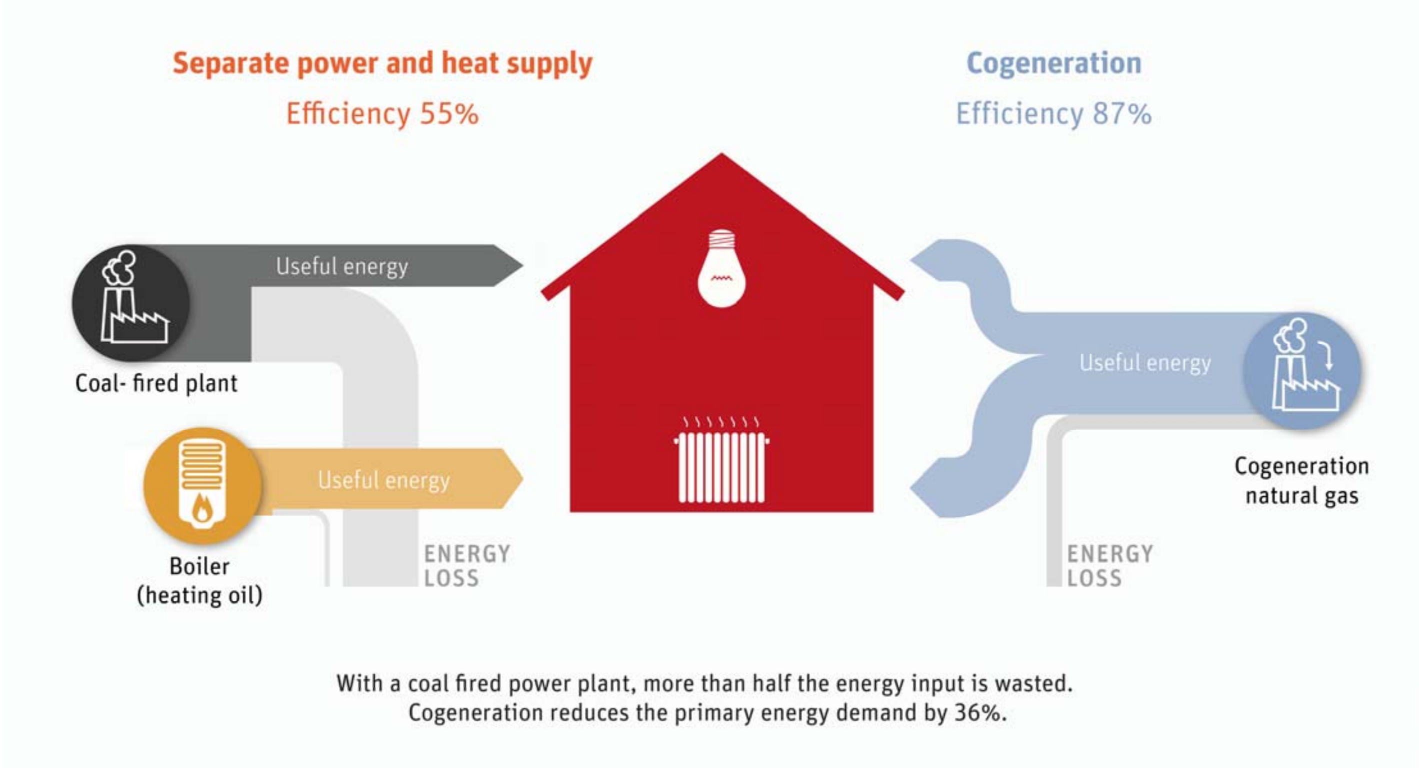
COGENERATION

- **WHAT IS COGENERATION?**
  - Simultaneous generation of electricity and useful thermal energy (steam in most cases)

- **WHY COGENERATION?**
  - Cogeneration is more efficient
  - Rankine Cycle – about 40% efficiency
  - Combined Cycle – about 60% efficiency
  - Cogeneration – about 87% efficiency
  - Why doesn't everyone use only cogeneration?



COGENERATION

GENERATION SYSTEM LOSSES

- Rankine Cycle – about 40% efficiency
  - Steam turbine cycle using fossil fuel
  - Most of the heat loss is from the STG exhaust
  - Some heat losses via boiler flue gas
- Simple Cycle Gas Turbine– about 40% efficiency
  - The heat loss is from the gas turbine exhaust
- Combined Cycle – about 60% efficiency
  - Recover the heat from the gas turbine exhaust and run a Rankine cycle
- Cogeneration – about 87% efficiency

- **What is the problem with cogeneration?**
  - **Reality Strikes**
  - In order to get to 87% efficiency, the heating load has to closely match the thermal energy left over from the generation of electricity.
  - Utility electricity demand typically follows a nocturnal/diurnal sine pattern
  - Steam heating loads follow a summer/winter cycle
  - With industrial users, electrical and heating loads are typically more stable

- **What factors determine if cogeneration makes sense?**
  - ECONOMICS!
  - Not just the economics of the cogeneration unit, but the impact on the entire facility.
  - Fuel cost
  - Electricity cost, including stand-by charges
  - Operational flexibility including turndown ability
  - Reliability impacts
    - Possibly the largest influence
    - If the cogeneration unit has an outage then this may (will?) bring the entire facility down.

- **Fuel cost**
  - The higher the cost of fuel, the more sense cogeneration makes
- **Electricity cost**
  - If electricity cost is comparatively low then cogeneration may not make sense
- **Reliability impacts**
  - The required reliability of the cogeneration system (redundant equipment) can make the system expensive

- **Reliability impacts**
  - Does the facility rely on the electrical grid?
  - Is the grid unstable and prone to trips?
  - Does the facility require the ability to operate in island mode, disconnected from the grid?
  - What level of equipment redundancy is required?
    - N-1 or N-2
    - N-2 may be required if utility and process unit outage schedules are different. For example: gas turbine inspections versus refinery outages.
    - Do steam and electricity generation require different levels of redundancy?

TYPICAL COGENERATION SYSTEM COMPONENTS

- Gas Turbine Generators
- Heat Recovery Steam Generators
  - With or without supplemental duct firing
- Steam Turbine Generators
  - Back-pressure
  - Condensing
  - Condensing/Extracting
- Auxiliary Boilers

EXAMPLES OF COGENERATION SYSTEMS

- Large California Refinery
  - 4 gas turbines ~80 MW each
  - 4 heat recovery steam generators (HRSGs) producing steam for the refinery
  - Electricity exported to the grid
  - PURPA qualifying facility

EXAMPLES OF COGENERATION SYSTEMS

- Enhanced Oil Recovery (EOR)
  - 4 gas turbines ~80 MW each
  - 4 heat recovery steam generators (HRSGs) producing 80% quality steam for EOR injection
  - Electricity exported to the grid
  - PURPA qualifying facility

EXAMPLES OF COGENERATION SYSTEMS

- Large Refinery in Thailand
  - 3 gas turbines ~25 MW each, aeroderivative
  - 3 heat recovery steam generators (HRSGs) with high capacity duct burners
  - 1 steam turbine generator
  - The local electrical grid was prone to outages.
  - All electricity and steam generated was used within the refinery. No electricity was imported normally.

EXAMPLES OF COGENERATION SYSTEMS

- Combined Cycle in Thailand
  - 1 gas turbine ~75 MW
  - 1 heat recovery steam generator
  - 1 steam turbine generator
  - Cogeneration load was steam to a LiBr adsorption refrigeration unit
  - Electricity exported to the grid
  - “Qualifying facility” per Thai regulations which were modelled after USA regulations

EXAMPLES OF COGENERATION SYSTEMS

- Large Combined Cycle
  - 3 gas turbines ~185 MW each
  - 3 heat recovery steam generators (HRSGs) with duct burners using high-hydrogen waste fuel
  - 1 steam turbine generator with a reheat steam cycle
  - Export of 500,000 lb/hr steam to the adjacent chemical facility
  - Production of sodium carbonate for the chemical facility
  - Some power was used by the chemical facility and the remainder sold to the utility grid

EXAMPLES OF COGENERATION SYSTEMS

- Large Methanol Plant
  - Process waste heat boilers produce 1,100,000 lb/hr of steam
  - Auxiliary boilers produce 350,000 lb/hr of steam
  - 5 steam turbine drivers for rotating equipment ~60 MW aggregate
  - 1 extracting/condensing steam turbine generator ~30 MW
  - Only about 10% of the steam generated was condensed from the STG exhaust. The remainder was used for heating or in the process.
  - No power import. Grid serves only as back-up.

EXAMPLES OF COGENERATION SYSTEMS

- RECENT PROJECTS
  - Refinery in California – steam line connecting two previously separate facilities.
  - Refinery in Texas – steam line connecting two previously separate facilities.
  - Refinery in California – modifying the cogeneration unit power/steam split to produce more steam and in turn import more power from the grid to improve carbon footprint.
- POSSIBILITIES
  - Capture CO_2 from flue gas or waste fuel steams to reduce CO_2 emissions.

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DESIGN CONSIDERATIONS FOR COGENERATION SYSTEMS

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- **Establish Steam demand profile**
  - Flow, pressure, temperature at each user
  - Maximum, average, minimum at each pressure level
    - Including maximum and minimum concurrent values
  - Seasonal variations, outage scenarios
  - Reliability requirements and critical users
  - Future steam demand
- **Establish electric power requirements for Facility**
  - Peak demand (KW), average energy (KWH), turndown
  - Peak power demand at concurrent max steam demand
  - Reliability requirements and large or critical loads
  - Black start, Potential for islanded operation
  - Future load growth

- **Power export to grid and backup power from grid**
  - Time of use pricing structure for power sales to grid
  - Cost of standby power from grid
- **Environmental permit requirements**
  - Air emissions and controls within the cogen plant (SCR, CO)
  - Emission limits during startup and shutdown
  - Greenhouse gas emissions
- **Plot Space and Potential Locations**
  - Clearance requirements from nearby process units
  - Constructability and lay down areas

- **Utilities and integration**
  - Natural gas supply conditions and specifications
  - Process gas or waste fuel supply and specifications
    - Hydrogen, olefins, sulfur, heavy ends up to C14
  - Raw water supply specifications and seasonal variations
  - BFW specifications (softened water vs. demin water)
  - Cooling tower and boiler blowdown treatment requirements
  - Integration with common facilities (fire protection, Instrument and plant air, etc.)
- **Review of Host Facility Planned and Forced Outage Scenarios**
  - Trip conditions for specific process unit or major steam or power consumer
  - Potential requirement for dedicated steam dump condenser

- **Control System Integration**
  - Integration with existing control room
  - New control room
  - Integration with existing monitoring and protection systems
- **Site or Owner Specifications**
  - Power industry vs. API specs

- **Steam demand, power demand, reliability, economics**
  - Sets the number of gas turbines required
  - Steam to power ratio influences steam cycle and gas turbine selection
  - Is there an economic case for surplus power sales to grid?
- **Gas turbine selection**
  - Advanced vs. older technology
  - Industrial vs. aeroderivitive
- **HRSG design and selection**
  - Steam conditions and number of pressure levels
  - Duct firing
  - Emission controls (SCR, CO)

- **Steam turbine selection**
  - HP throttle conditions
  - Relative value of steam and power
  - Controlled extraction vs. uncontrolled extraction
  - Condensing vs. backpressure turbine

Typical Design Data and Sources

- Facility Overall Plot Plan
- Facility Steam Balance Diagram/s
- Facility Overall One-Line Diagram/s
- Power Bills from Electric Utility (monthly for typical year)
- Gas Bills from Utility (monthly for typical year)
- Geotechnical Report for Potential Site/s
- Potential Tie-In Locations
- Unit Outage Schedules (to coordinate with Cogen / CHP preliminary schedule)
- Economic Criteria for Value Engineering Studies

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