Applying Cogeneration to Facilities with Industrial Refrigeration

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The learning objectives are:

1. Develop basic understanding of cogeneration and its application to industrial refrigeration
2. What are the key elements of a good technical application.
3. What are the key elements of a financially feasible application.
4. What added value opportunities exist for a total energy solution
What is Cogeneration and why explore it for facilities with Refrigeration?

Answer: Operating Cost Savings

• Cogeneration is using fuel to simultaneously produce electrical power and useful heat

• Properly applied Cogeneration results in lower cost of operation for a facility.

• The by product heat of Natural Gas power generation provides economical industrial and commercial refrigeration
The Cogen + Refrigeration Concept

Natural Gas (LHV)

- Useful Energy: 86.6%
- Electrical Output: 41.7%
- Thermal Output: 44.9%
- Low Temperature Refrigeration
Basic Natural Gas Engine Cogeneration Unit Diagram
Basic Ammonia Water Absorption Refrigeration System Diagram

Figure 6: Ammonia-water absorption refrigeration system.
The “Axiom Cycle” Cogen System
The Economics of Cogeneration coupled to Ammonia Absorption Refrigeration Depend On:

• Efficiency of Engine Generator
• Cost of The Plant
• Cost of Capital
• Cost of Maintenance
• Cost of Fuel i.e. Nat Gas
• The Cost of Utility Electrical Energy
• Annual operating Hours
• Percent of byproduct heat used beneficially
• COP of Absorption Unit
The Economics of Cogeneration are greatly affected by Public Policy

- Air Quality Regulations
  - Can significantly increase Cost of Plant
- Utility interconnection requirements
  - Can increase cost and extend schedule
- Incentives and Tax Policy
- Utility Rate Structures
- Carbon Footprint Concerns
Developments Reducing First Cost

• Factory Packaged Modular Cogeneration Units
• Factory Packaged Modular Ammonia Absorption Refrigeration
• Standardization of Designs
• Automation with Remote Monitoring and Control
Developments Reducing Operating Cost

• Shale Gas development
• Higher efficiency natural gas engines
  – Above 40% fuel to electric efficiency is common
• Longer Maintenance Intervals
  – Up to 60 K hours before Major Overhaul
• Smart On Board Control and Remote Monitoring
  – Ability to maintain efficiency and minimize unplanned service outages
• Factory Standard Designs for optimum efficiency
So, when does Cogeneration with Absorption Refrigeration Make Sense?

Build a Spreadsheet Model and Test for Variations in:

- First Cost
- Fuel Cost
- Capital Recovery Cost
- Operating Hours
- Maintenance Cost
- Absorption Unit COP
- Generator Efficiency
- % Heat Recovery
Example Spreadsheet Model for 8200 annual operating hours

<table>
<thead>
<tr>
<th>HHV BTU Per Deca-therm</th>
<th>Plant Cost per Deca-therm Power Out</th>
<th>LHV BTU per Deca-therm</th>
<th>Electrical Eff. (LHV)</th>
<th>BTU/kWh</th>
<th>kWh per DecaTherm</th>
<th>Heat Recovery Potential (LHV)</th>
<th>Potential Recovered Heat (LHV) BTU per kWh</th>
<th>Potential Rec. Heat (LHV) BTU per kWh</th>
<th>COP of Absorpti on Refrig</th>
<th>BTU of Refrig per kWh</th>
<th>Refrig tons (RT)/kWh</th>
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<th>Fuel Cost per kWh</th>
<th>Maint. cost per kWh</th>
<th>Capital Recovery Cost Total Operating Cost</th>
<th>% of Potential Rec Heat Used</th>
<th>kWh at COP of 0.5</th>
<th>Net Cost per kWh after heat recovery</th>
<th>% of Potential Rec Heat Used</th>
<th>Value per kWh at COP of 0.5</th>
<th>Net Cost per kWh after heat recovery</th>
<th>% of Potential Rec Heat Used</th>
<th>Value per kWh at COP of 0.5</th>
<th>Net Cost per kWh after heat recovery</th>
<th>% of Potential Rec Heat Used</th>
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Electrical Cost with NG Generator with Absorption Refrigeration

Generator Fuel to Elec Eff. 41% (LHV)
Absorption Refrigeration COP 0.5
Plant Cost $3000/kW, .009 Lease Rate
6000 operating hours per year

Portion of Recovered Heat Used for Refrigeration

- 100% Used
- 90% Used
- 80% Used
- 70% Used
- 60% Used
- 50% Used
- 40% Used
- 30% Used
- 20% Used
- 10% Used
- None Used

Cost per kWh with credit for recovered heat

Cost per Decatherm Natural Gas
Electrical Cost with NG Generator with Absorption Refrigeration

Generator Fuel to Elec Eff 41% LHV
Ammonia Refrigeration COP 0.5
Plant Cost $3500/kW, .011 Lease Rate
8200 operating hours per year

Portion of Recovered Heat Used for Refrigeration:
- 100% Used
- 90% Used
- 80% Used
- 70% Used
- 60% Used
- 50% Used
- 40% Used
- 30% Used
- 20% Used
- 10% Used
- None Used
Impact of Plant Cost, Lease Rate Operating Hours, and Fuel Cost On Produced Electricity Cost Ammonia Absorber COP 0.5
So, where is this solution competitive?

Obviously depends on the factors discussed:

• High utilization, cost of Capital, First Cost
• Economical Natural Gas
• States with High Industrial User Power Rates
• California, New England (exc Maine), New Jersey
• Commercial Users with Significant Refrigeration in above states plus New York
Case Study: Precut Packaged Salad Plant

• Challenge: No requirement for hot water, daily variable power demand profile

• Motivation: Their electrical cost of operation for new facility was three times the pro-forma business case

• Constrained Site, no room for solar, building not built for structural load of solar panels

• Solution: A 633 kW natural gas fueled cogeneration plant also producing 125 TR
633 kW 125 RT Cogeneration
Ammonia Absorption Refrigeration
Fresh Venture Foods
Santa Maria, California
Future Steps and Opportunities

• Net Zero Challenges
  – High energy intensity utility customers such as food processors cannot achieve net zero onsite energy use

• Combine with Battery and Solar
  – Greater Reliability
  – Increased Utility bill savings
    • Reduced Demand Charges
  – Lower Carbon Footprint
One week Electrical use profile for precut bagged salad plant
Salad Plant Case Study

- 633 kW Cogen Unit with 125 RT absorption unit
  - With refrigeration effect from absorption refrigeration system reduces demand peak 780 kW
  - Peak Daily Demand in previous Slide 1055 kW
  - Prior to Cogen system coming on line demand charges were >40% of electrical billing
  - After Cogen online demand charges >70% of remaining electrical bill
Salad Plant Case Study

<table>
<thead>
<tr>
<th>Rate Schedule</th>
<th>Customer Charge/Meter Charge</th>
<th>Season</th>
<th>Time-of-Use Period</th>
<th>Demand Charges ($/kW)</th>
<th>Energy Charges ($/kWh)</th>
<th>PDP¹ Charges</th>
<th>PDP² Credits DEMAND (per kW)</th>
<th>PDP² Credits ENERGY (per kWh)</th>
<th>Power Factor Adjustment ($/kWh/%)</th>
<th>&quot;Average&quot; Total Rate³ ($/kWh)</th>
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- Maximum demand charge $17.87/kW plus peak summer demand charge of $19.02/kW
  - Potential to avoid 275 kW X $36.89 = $10,145 each summer month and 275 X $17.87 = $4914 each winter month for a total annual savings of $90,000.
Salad Plant Case Study

- 3 Li Ion battery units at 220 kWh each with 100 kW inverters will meet requirement
- Cogen can charge during lower load night hours
- Only delta operating cost is cost of fuel
- What battery cost makes economic sense?
  - 5 year simple payback for an installed battery system cost of $682/kWh. (Current Pricing without incentives)
  - 3 year simple payback requires $409/kWh (2020 Price)
  - 1.5 year simple payback @ $200/kWh (Predicted 2024)
Salad Plant Case Study

• Does a combined Cogen plus battery solution make sense? Simple Answer: yes
  – Rapidly declining battery costs, Accelerated Depreciation, 30% ITC if solar charged, California $400/$290 kWh incentive
  – Battery storage also protects against unplanned “trips” of the Cogen Unit causing a monthly demand charge spike. Improves reliability
• Can couple with solar to reduce carbon footprint of facility
Questions?

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