Mount Royal University Cogeneration

MRU Calgary, Alberta

Founded 1910

Enrollment;
10,000 students

Campus Facilities;
~ 3,000,000 sq. ft.
~ 118 acres

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Energy Profiles

Electricity Consumption
~ 15,000,000 kW-hrs/year

NG consumption
~ 80,000 GJ/year

Typical Canadian home
11 kW-hrs
92 GJ/year of NG

- Qty (2) X 800 hp HW boilers
- Qty (1) X 300 hp steam boiler

2016 facility began to experience end-of-life equipment failures from antiquated automation, controls, pumps, water treatment and electrical systems.

2016 MRU Facilities Operations Group redesigned their energy profile with goals to;
1. Maximize Efficiency
2. Maximize Sustainability Design by;
   - Replacing all pumps
   - Replace existing automation
   - Replace existing controllers
   - Modifying existing boilers.
3. Add resiliency by investigating all technologies including Cogeneration (CHP)
Campus GHG Mitigation Program


- Qty (100) X 1.44 kWe Solar Panels
- Total 144 kWe
Campus GHG Mitigation Program

2. Boilers Retrofit (2016)

Retrofit increased boiler efficiency
- Qty (2) X 800 hp Hot Water Boiler upgrades achieved 10% efficiency upgrade
- Qty (1) 300 hp Steam Boiler upgrade achieved 30% efficiency improvement.
- MRU’s operating costs decreased by $385,885 first year of operation.
- Improved critical infrastructure
Campus GHG Mitigation Program

Combined Heat & Power
- Fuel Energy In = 2,216 kW (LHV)
- Fuel Energy In = 8.9 GJ (LHV)
- Electrical Power Out = 850 kWe
- Thermal Power Out = 1,089 kWth
- Total Energy Out = 1,949 kW
- Electrical Efficiency = 38.2%
- Thermal Efficiency = 49.1%
- Total Efficiency = 87.3%
- MRU’s operating costs decreased by $400,000 per year of operation.
CHP fundamentals:
CHP systems utilize the waste heat incurred during engine operation to generate overall plant efficiencies of more than 90%.

Natural gas supply 100%

- Mechanical energy 42%
- Thermal energy 58%
- Usable electrical energy 40%
- Loss 10%
- Usable thermal energy 50%

HE 1
Mixture intercooler

HE 2
Oil heat exchanger

HE 3
Engine jacket water heat exchanger

HE 4
Exhaust gas heat exchanger

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Recip Cogen Plant’s generate highly efficient electrical power and use heat exchangers to extract thermal energy from the engines exhaust gas flows, jacket water cooling, oil cooling and intercooler cooling loops.

<table>
<thead>
<tr>
<th>GE-JMS-624-H11</th>
<th>( \eta ) (%)</th>
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</thead>
<tbody>
<tr>
<td>Electrical Power</td>
<td>45.4</td>
</tr>
<tr>
<td>HT1 (125 °C)</td>
<td>18.7</td>
</tr>
<tr>
<td>HT2 (96 °C)</td>
<td>22.3</td>
</tr>
<tr>
<td>LT1 (37 °C)</td>
<td>6.9</td>
</tr>
<tr>
<td>Wasted Energy</td>
<td>6.7</td>
</tr>
<tr>
<td>Gas Consumption</td>
<td>100</td>
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Typical heat demand curve
Annual heat demand curve

Maximal yearly heat requirement

Operating hours per year

Thermal output (kW)

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- Multi-engine concept for flexibility in operation
- Target >5,000 operating hours per unit to optimize economical results
- Increased operation time in connection with heat storage tank
Mount Royal University Cogeneration

Typical Cogen Schematic

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Benefits of Turbines &/or Recips in the Cogen Configuration

Exhaust gas characteristics and steam requirements
- Gas Turbine exhaust gases can reach 600°C
- Recip Engines exhaust gases can reach 360°C
- HRSGs for GTs can produce steam at (3) pressures and if required can have (3) three sets of heat exchanger modules; HP, IP, LP
- HRSGs designed for reciprocating engine power plants are much simpler in design, creating steam at one pressure level – usually LP ~15 bar.
- Each reciprocating engine generator set has its own associated HRSG.
- Reciprocating engines can be used to preheat HRSG exhaust gas boilers with steam to keep the HRSGs hot and enable fast starting.

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Cogen Energy Options

Recip Engine Cogen Systems Can Deliver The Following:

- Electricity (208V up to 13.8 kV)
- Steam (up to 200 psig)
- Hot Water (up to 200°F)
- Hot Air
- Hot Oil
- Emergency Standby Power (also for life safety loads)
- CO2 (greenhouse applications)
- Cooling (absorption chiller)
Benefits of Multiple Recips in the Cogen Configuration

- Recip Multi Unit Scalability
- Capabilities for expansion and contraction
- Heat recovery Systems
- Extracted Thermal Energy can be used to;
  - Generate low pressure steam
  - Pre-heat water to be used in the steam production and/or
  - Heat water for process.
- Reciprocating Power Plant Efficiencies
Benefits of Multiple Recips in the Cogen Configuration

The preferred method of electricity generation for independent power producers:
Multiple-engine approach

In a highly competitive environment where the ability to offer flexible, low-cost, reliable and high efficiency power can mean the difference between winning or losing a bid for an electricity supply contract, independent power producers must explore the most mutually beneficial options for constructing a generating facility that meets the customer needs. The stakes increase in developing areas where demand is growing and on Bamp may be the only power supplier supporting the grid.

High fuel efficiency, availability and reliability supplemented with flexibility are the most important advantages of multiple gas engine plants.

PROVEN TECHNOLOGY SUPPORTING LOCAL POWER NEEDS. In one of the largest orders of its kind, Vector Energy has delivered four independent power producers: Distrib Power Generation & Solutions, Ltd., and Distrib Power B.V. & Technologies, Ltd. (the power plants of Hanek Energy Power Corp.), and the Aman Power Plant Ltd., respectively purchased from India’s Majestic Jyothi natural gas-fired engines to support a major regional electricity generation project in Bangladesh. Combined, the engines generate approximately 13 MW of electricity at the new power plant in developing areas of the South Asian country. Three power plants were built, each with eight of the 1.25 and 2.5 MW Jyothi gas engine sets. The fourth plant was built on-site, eight gas engine sets with a total output of 49.5 MW.

A QUESTION OF PROFITABILITY. Generating electricity with multiple natural gas-fueled engines offers the added benefit of combined cycle reliability and best available with a single prime mover. As well, added advantages are the high efficiency and reliability of large engines operating in parallel to generate low maintenance in sequence that has been proven to double plant efficiency.

HIGH FUEL EFFICIENCY. Using multiple engines offers maximum value efficiency with the combined generation of energy. A multiple engine approach ensures that the engine is continuously running at near its projected load, which implies the highest efficiency and the lowest possible maintenance costs. Because of their high efficiency, gas engines, multiple gas engines prove a rapid response to load changes. In other words, if demand changes, the output, or delivered electricity, can be easily adjusted as a number of units are put into service, keeping the combined efficiency high.

AVAILABILITY AND RELIABILITY. In the event of an emergency, the necessity of having spare power is often maximized when multiple units are in operation. The unequaled reliability and performance record is something that simply can’t be matched.

FLEXIBILITY. An added bonus is the ability to meet abrupt changes in demand and other conditions in the multiple engine approach. Rapid changes in demand, this allows the high efficiency, where capacity needs must be increased with gas engines, exceeding or decreasing the plant can be done in a matter of minutes and as little cost as compared to traditional prime mover.

LOW EMISSIONS. Natural gas is characterized by the lowest CO2 emission level among fossil fuel. The ability to operate small engines in gas engines allow for the near-zero emissions of CO2, NOx, and particulate matter.

"Distributed power generation with multiple gas engines provides the highest efficiency and low carbon footprint. By using natural gas-fueled engines, we are able to produce electricity more efficiently and with a lower environmental impact compared to traditional power plants. This is especially true in areas with limited infrastructure. By having multiple units in operation, we can easily adjust the output to meet demand changes, ensuring reliability and efficiency. The availability of spare power is crucial, and with multiple units in parallel operation, we can ensure that we have the capacity to meet unexpected load changes. This flexibility allows us to operate efficiently and reliably, which is essential in today's competitive power generation market. Mike.McElligott@GruppoAB.com
Different Technologies GHG Environmental Footprints

FROM THE DIFFERENT GENERATING OPTIONS

- Hydroelectric: run-of-river: 4
- Nuclear: 6
- Wind: 9
- Hydroelectric with reservoir: 10
- Photovoltaic solar: 38
- Thermal: natural gas: 422
- Thermal: coal: 957

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The reciprocating engine driven generator’s electrical efficiency is 45.4% and its thermal efficiency, when using all 4 cooling loops, is 47.9% for a total efficiency of 93.3%. The SAGD plant owner can take advantage of these benefits by:

1. Avoiding carbon emission penalties and,
2. Collecting GHG Credits.

General rules for competing technologies are:

<table>
<thead>
<tr>
<th>ENERGY APPLICATION</th>
<th>AVG. SYSTEM EFFICIENCY</th>
<th>GHG EMISSIONS</th>
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<tbody>
<tr>
<td>COAL</td>
<td>35%</td>
<td>1000 Tons/MW</td>
</tr>
<tr>
<td>COMBINED CYCLE</td>
<td>65%</td>
<td>400 Tons/MW</td>
</tr>
<tr>
<td>WIND</td>
<td>NA</td>
<td>0 Tons/MW</td>
</tr>
<tr>
<td>NG COGENERATION</td>
<td>85%</td>
<td>250 Tons/MW</td>
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Mount Royal University (MRU) of Calgary, Alberta committed to reducing its carbon footprint and operating in an environmentally responsible way. One of the long term goals of the university’s corporate energy management program is to reduce energy consumption on campus.

- Facilities ~ 3,000,000 sq. ft.
- 10,000 students
- 118 acres
- Main Campus 15,000,000 kW-hrs annually
- NG consumption 80,000 GJ/year
  - for comparison typical Canadian home
    - 11 kW-hrs
    - 92 GJ/year of NG

**Cogeneration (CHP) System**
- 850 kWe/1,089 kWth CHP power plant
- Improve Campus Heating and Power Performance
- CHP System Reduces
  - CO2 emissions by 2,000 tons per year, and
  - Operating costs by $400,000 CDN.
- CHP waste heat used for heating water for washroom services, HVAC systems and heating the whole campus
- CHP electricity supplements campus requirements (~26% of main campus’ requirements).
- Currently considering adding another CHP
- CHP Power Plant’s Electrical system is 30% more efficient than Alberta’s electrical grid
- GHG reduction of 2,000 tonnes per year - similar to removing 425 cars per year

**Economic Benefits of 2016 Energy Management Plan:**
- Boiler upgrades recouped initial savings and payback of $300,000/year
- CHP operations translate to savings of over $400,000 per year
- Total Savings Boiler Upgrades + CHP = $700,000 in operations savings

**Benefits**
- Economic
- Environmental
- Operational
- Resiliency
- CHP backstops existing heating and utility
- Meets mandated sustainability plans