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

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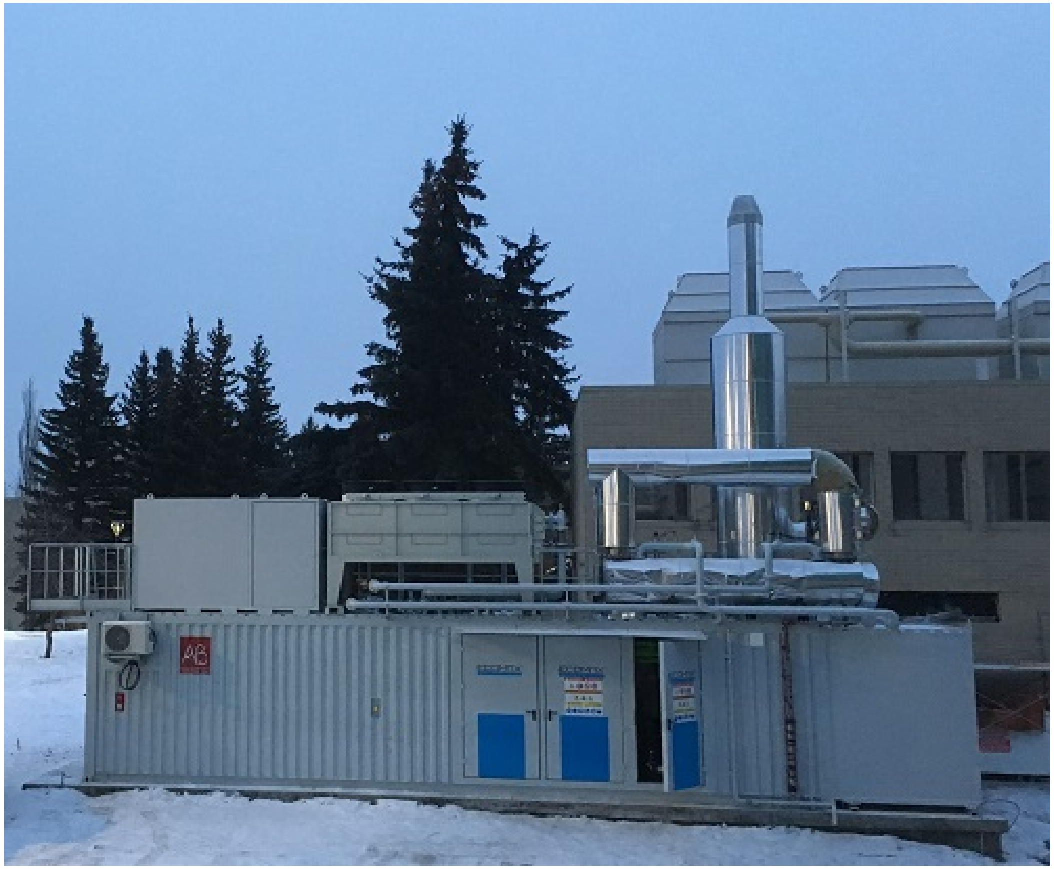

Campus Energy Plant (1988–2016)

- 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)

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Campus GHG Mitigation Program

1. Solar Panels (2016)

Qty (100) X 1..44 kWe Solar Panels

Total 144 kWe

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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

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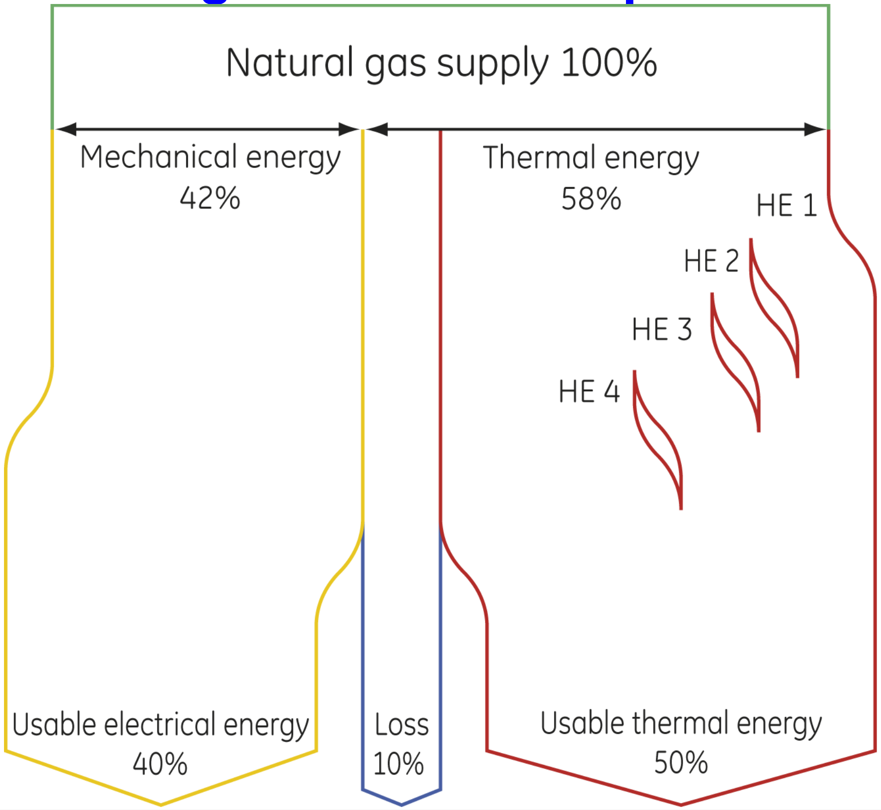
Campus GHG Mitigation Program
3. Cogeneration System (CHP) (2016)

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%.



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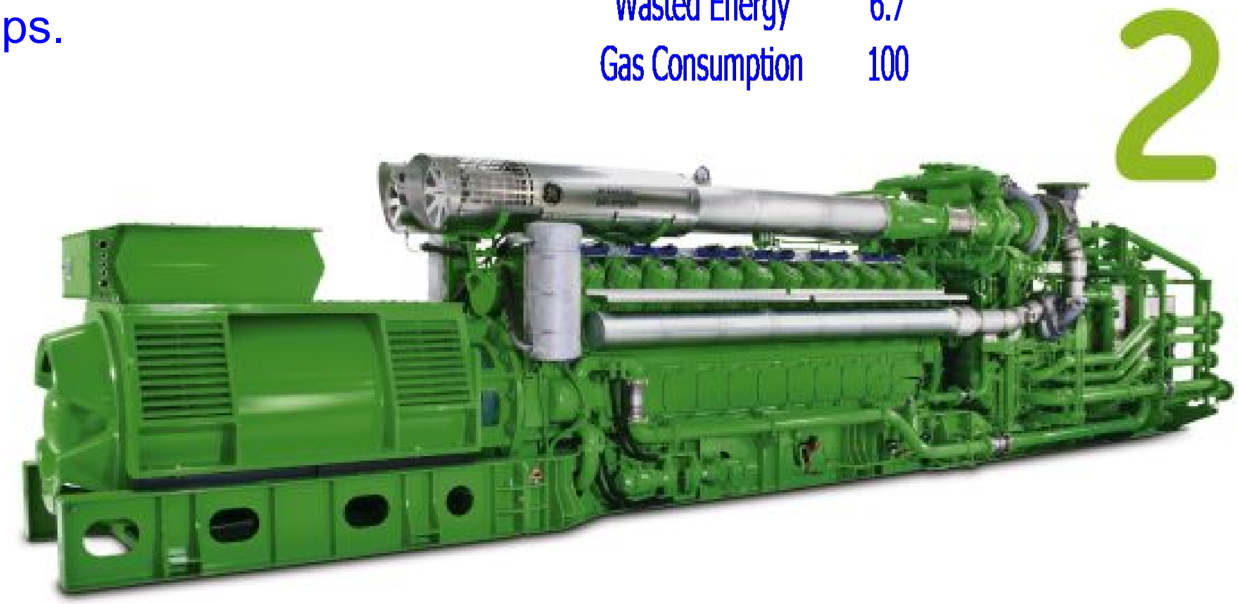
Recip Cogen Plant's generate highly efficient electrical power and use heat exchangers to extract thermal energy from the engines exhaust gas flows, jacket water cooling, oil cooling and intercooler cooling loops.

GE-JMS-624-H11	η(%)
Electrical Power	45.4
HT1 (125 °C)	18.7
HT2 (96 °C)	22.3
LT1 (37 °C)	6.9
Wasted Energy	6.7
Gas Consumption	100



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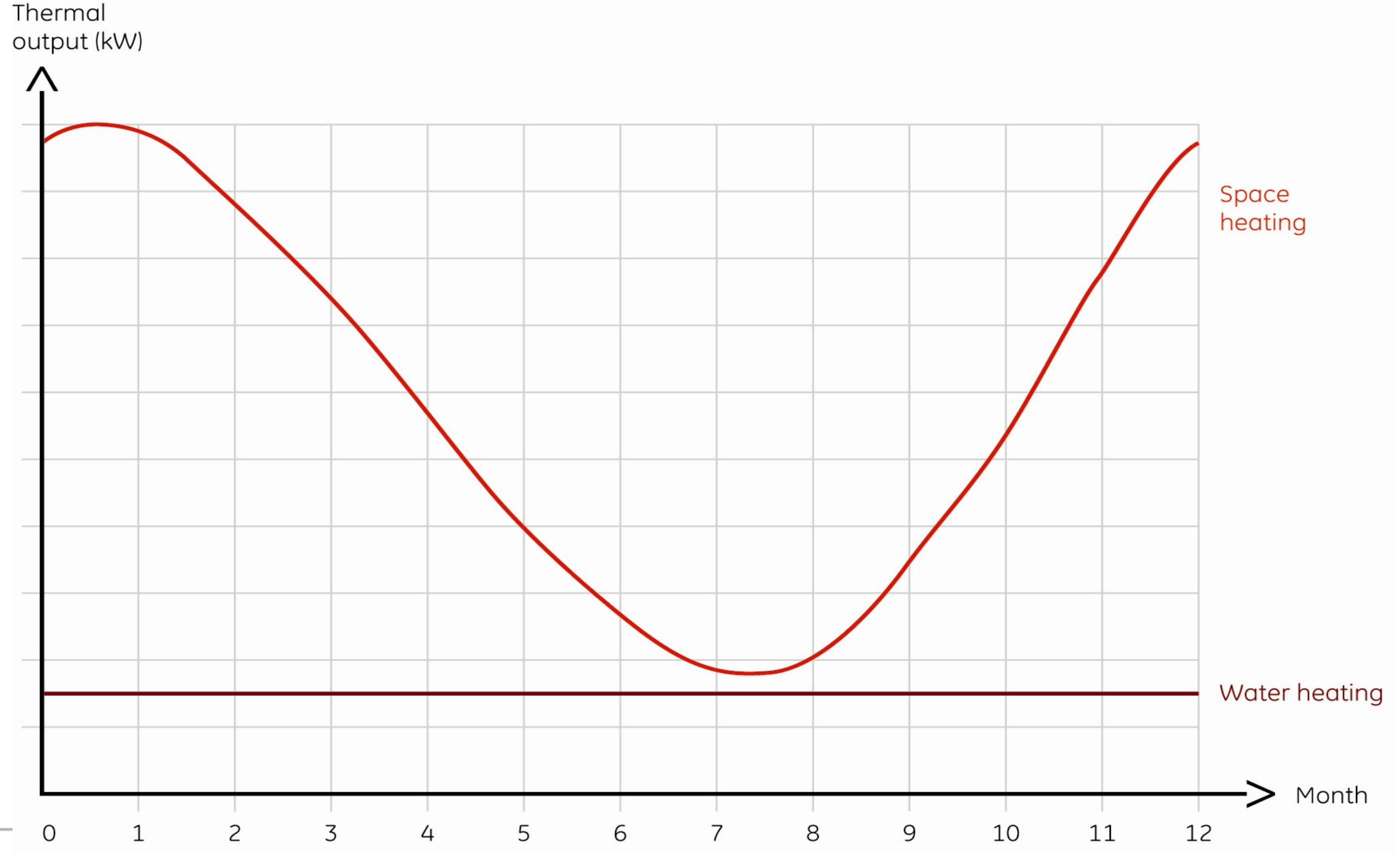
Typical heat demand curve



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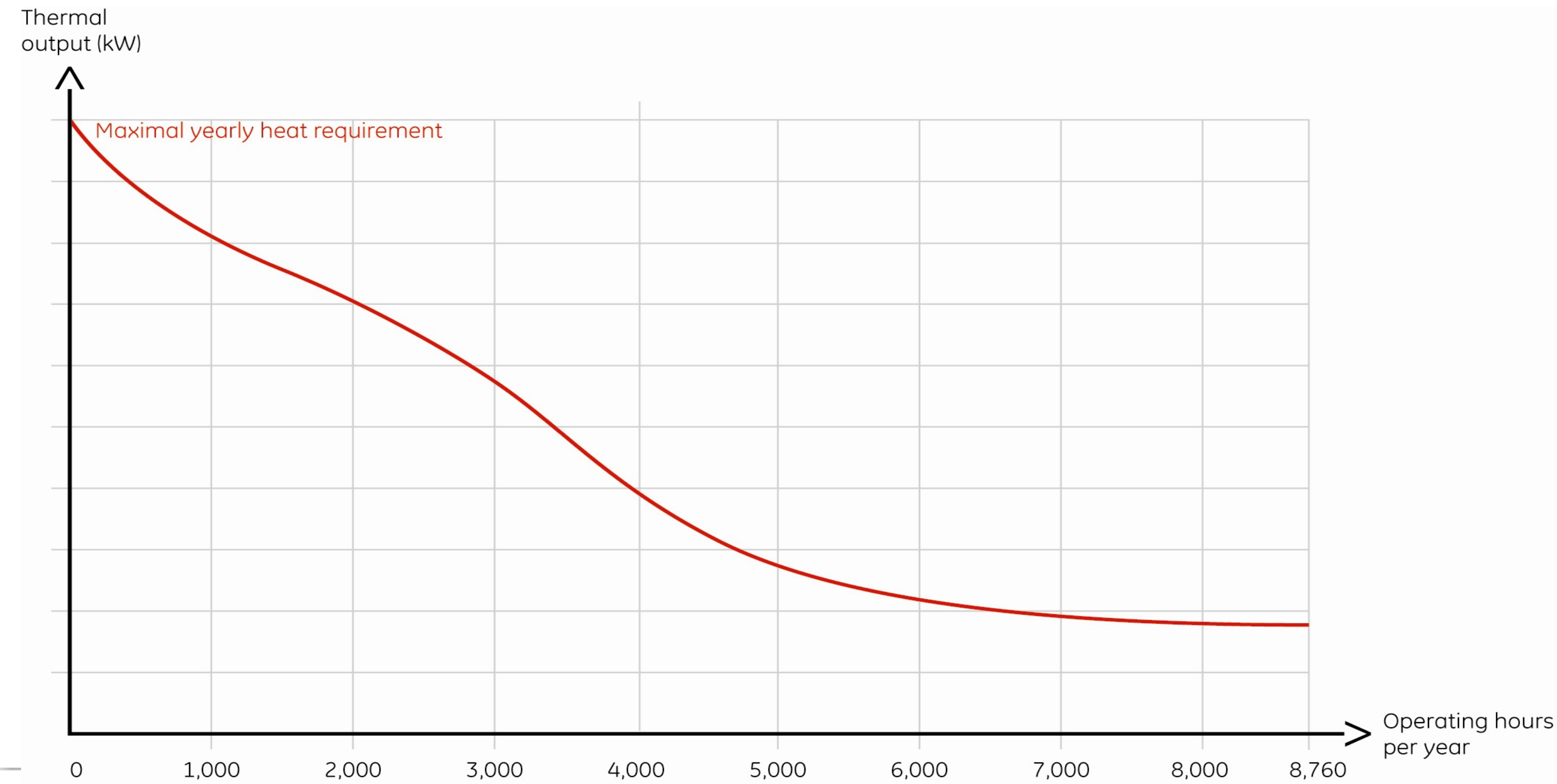
Annual heat demand curve



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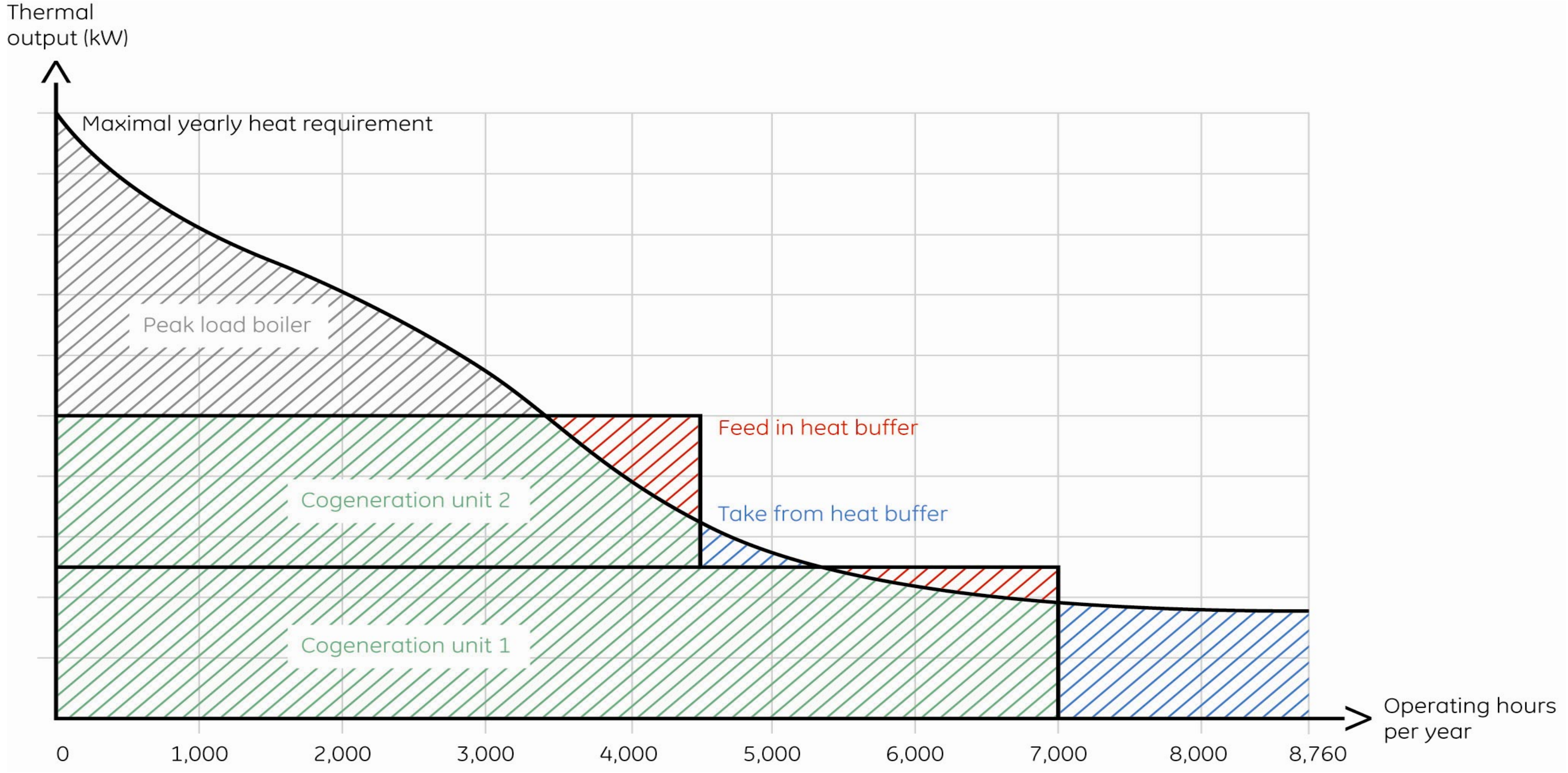
- Multi-engine concept for flexibility in operation
- Target >5,000 operating hours per unit to optimize economical results
- Increased operation time in connection with heat storage tank



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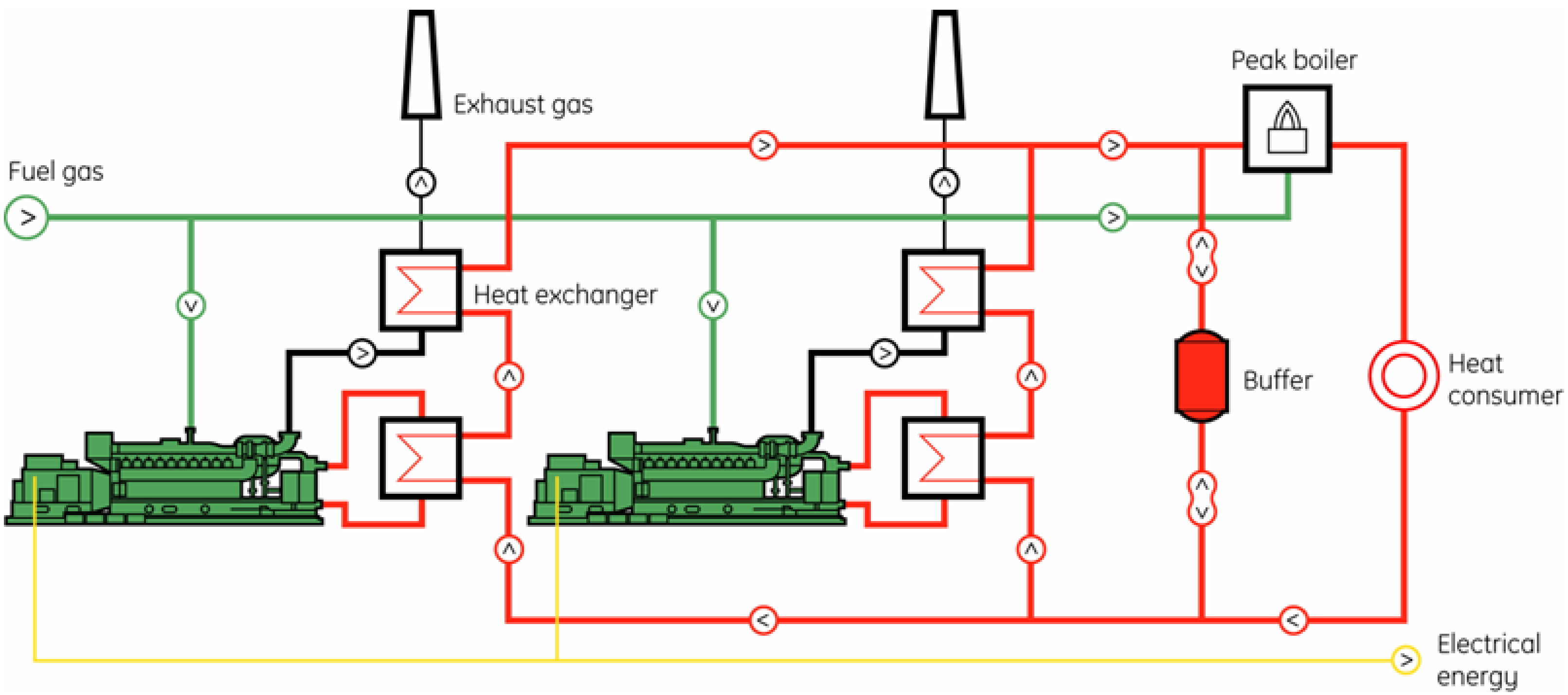
Typical Cogen Schematic



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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 600ºC
- Recip Engines exhaust gases can reach 360ºC
- 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 200F)
  - ❑Hot Air
  - ❑Hot Oil
  - ❑Emergency Standby Power (also for life safety loads)
  - ❑CO2 (greenhouse applications)
  - ❑Cooling (absorption chiller)

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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

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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 generation facility and meeting capacity needs. The stakes increase in developing areas where demand is high and an IPP may be the only power supplier supporting the grid.

The world is experiencing enormous energy challenges. Thanks in large part to strong economic growth and increasing populations in the world's developing countries, global energy consumption is expected to double by 2030. The electric power utilities industry has been gearing up for this issue of supply and demand for quite some time, exploring many new options to deliver efficient, reliable electricity to its customers.

INDEPENDENT POWER PRODUCERS (IPPS). Still relatively new kids on the block, IPPs aid utilities in meeting power demand by generating the power they need to support area growth and peak demand periods. Not only has the existence of a third-party player introduced incentives like cost savings and performance enhancements, but the highly competitive nature of independent power production means that IPPs are charged to employ, operate and maintain the very best and most efficient generation systems.

Independent power producers may be privately held facilities and most often do not possess their own transmission facilities. IPPs usually operate within the franchised territories of host utilities and make electric energy available for sale to utilities or the general public. But, the equipment and method of generation IPP companies employ is just as important to their businesses and the utilities they support as their ability to maintain and offer it reliably.

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 GE's Jenbacher gas engines to date, independent power producers Doreen Power Generation & Systems, Ltd., and Doreen Power House & Technologies, Ltd., (subsidiaries of Asian Entech Power Corp., Ltd and Saiham Power Plant Ltd, respectively) purchased 28 of GE's Jenbacher J620 natural gas-fueled engines to support a major rural electrification initiative in Bangladesh. Combined, the engines generate approximately 81 MW of electricity at four new power plants in developing areas of the South Asian country. Three power plants were built, each with eight of GE's JGS 620 GS-N.L. Jenbacher generator sets; and a fourth plant features four of the units. Utilizing the region's natural gas supplies as a primary fuel source to generate electricity, the generator sets support the national grid and help Bangladesh to meet its increasing power demand. The move was part of a government initiative to reform the country's power sector, including through the development of IPPs. It also gave GE an opportunity to showcase GE's Jenbacher gas engines as a viable option for growing power demand in rural areas, along with proven success in the industrial sector.

"GE's Jenbacher gas engine technology is already well-known as a cost-effective power generation system approach for the Bangladesh industrial sector. We have chosen Jenbacher gas engines for our rural electrification projects based on the units' reliability and performance record," said Tahzeeb Alam Siddiqui, managing director of Asian Entech Power Corp.

A QUESTION OF PROFITABILITY. Generating electricity with multiple natural gas-fueled engines offers the added benefit of combined reliability and accessibility not available with a single prime-mover, as well as other significant advantages, making this approach a highly economical solution for IPPs.

→ GENERATING ELECTRICITY WITH MULTIPLE GAS ENGINES OFFERS THE ADDED BENEFIT OF COMBINED RELIABILITY AND AVAILABILITY

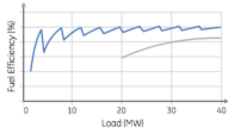
• **HIGH FUEL EFFICIENCY:** Using multiple engines offers near maximum value efficiency with the combined conversion of energy. A multiple-engine approach ensures that the engines are constantly running at or near their projected load, which yields the highest efficiency and the lowest possible maintenance costs. Because of their high fuel efficiency as single engines, multiple gas engines provide a rapid response to load changes. In other words, if demand changes, the output, or delivered electricity, can be easily adopted by switching a number of engines on or off, keeping the combined efficiency high.

• **AVAILABILITY AND RELIABILITY:** In the event of an outage emergency, the necessary quantity of reserve power is also relatively low when multiple units are employed because one unit failure affects only a small sum of the total output.

"It is the combination of benefits, that makes the multiple engine approach an economical and highly attractive solution for Independent Power Producers."

In fact, multiple engine plants have achieved near 100 percent reliability ratings, which gives the customer the advantage of a stable electricity grid. Service maintenance also becomes a more seamless process in the multiple engine approach. Unlike plants run by one prime-mover, where a great deal of supply capacity is needed for scheduled maintenance, smaller engines operating in parallel can receive scheduled maintenance in sequence so that less spare capacity and no outage time is necessary.

ABBILDUNG 1: EFFICIENCY OF MULTIPLE GAS ENGINE PLANT COMPARED TO A SINGLE PRIME-MOVER.



Multiple gas engines
Single prime-mover

• **FLEXIBILITY:** An added bonus is the ability to install or remove engines quickly and alter configurations in the multiple engine approach to satisfy changes in demand. This allows the IPPs high flexibility when capacity needs must be increased. With gas engines, extending or downsizing the plant can be done in a much shorter time and at a lower cost as compared to traditional prime-movers.

• **LOW EMISSIONS:** Natural gas is characterized by the lowest CO_2-emission level among fossil fuel. The utilization of natural gas in gas engines allows for particularly low emissions of SO_2, NO_x, and particulate matter.

"Distributed power generation with multiple gas engines provides high efficiency and maximum reliability at relatively low specific costs. Our engines are characterized by a compact design and high power density, and therefore require a comparatively small footprint", explains Martin Schneider, product line manager at GE's Jenbacher gas engine business. "It is the combination of benefits, that makes the multiple engine approach an economical and highly attractive solution for Independent Power Producers."

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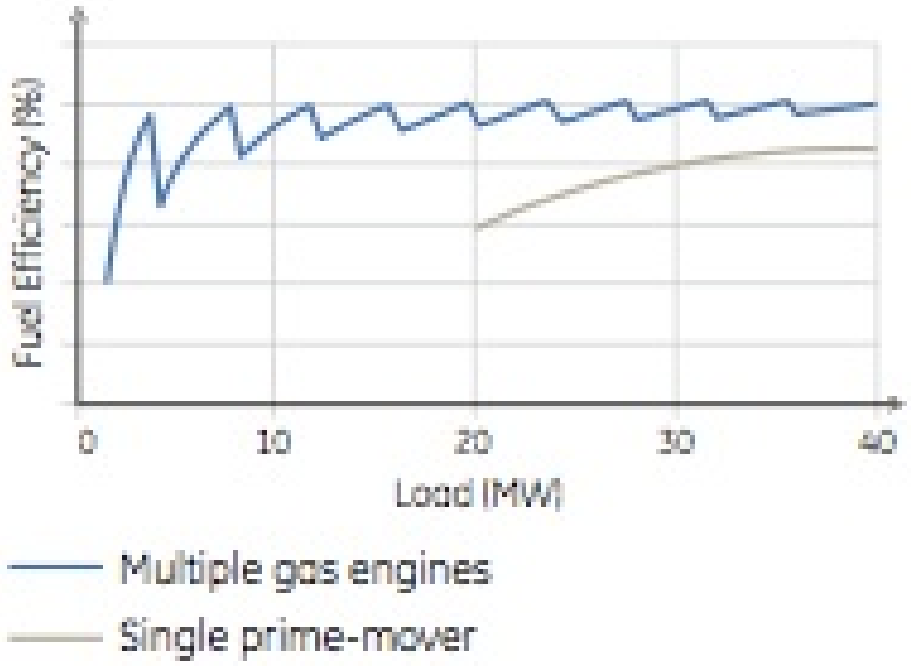
Multiple Recips Efficiency Profile

ABBILDUNG 1: EFFICIENCY OF MULTIPLE GAS ENGINE PLANT COMPARED TO A SINGLE PRIME-MOVER.



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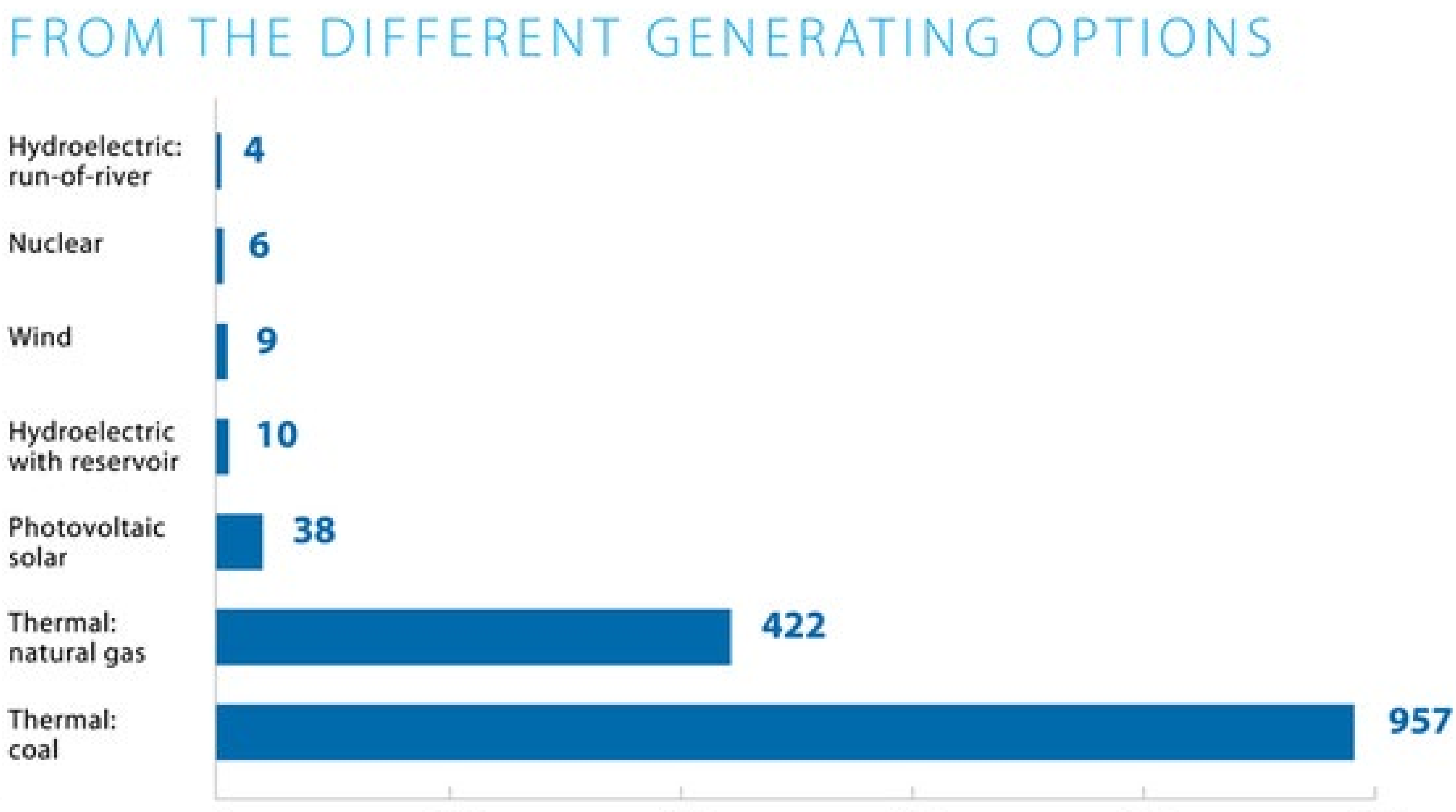
Different Technologies GHG Environmental Footprints



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Recips Environmentals

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;

ENERGY APPLICATION	AVG. SYSTEM EFFICIENCY	GHG EMMISSIONS
COAL	35%	1000 Tons/MW
COMBINED CYCLE	65%	400 Tons/MW
WIND	NA	0 Tons/MW
NG COGENERATION	85%	250 Tons/MW

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Recap Economic, Environmental & Operational Benefits of NG Recip CHP

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

2016 Redesigned Central Heating Plant built in 1988 - 30 years old. Existing

- Qty (2) X 800 hp boilers plus (1) X 300 hp steam boiler
- Antiquated automation, controls, pumps, water treatment, electrical grid,

Design Goals

- ✓ Maximise Efficiency
- ✓ Improve Sustainability
- ✓ Replace all pumps, automation, controls,
- ✓ Modify existing boilers
- ✓ Integrate a CHP system
- ✓ CHP waste heat used heats water for washroom services, HVAC systems and heat for the campus

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

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