SASKATCHEWAN RESEARCH COUNCIL

Micro Combined Heat and Power (CHP) Technology

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Energy Management Task Force

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Outline

- What is Combined Heat and Power (CHP) Technology?
- State of CHP
- Saskatchewan Potential Benefits
- Project Objectives & Prototype Unit Development
- Host Selection, Installation, Commissioning and Observations
- Results
- Benefits to the Utilities
- Key Accomplishments
- Conclusions
- Future Demonstrations

What is Distributed Combined Heat and Power Technology (CHP)?

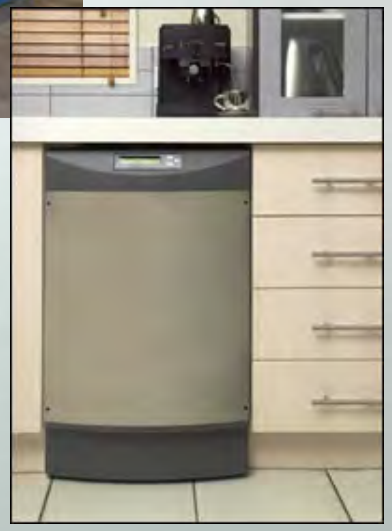
- *CHP = Combined Heat and Power;*
- *mCHP = Micro Combined Heat and Power;*
- *Distributed power generation* = electric power generation close to the point of end use;
- *CHP/Cogeneration* = simultaneous production of heat and power;
- Installed where there is a fuel source (natural gas, biogas, etc.) and a large annual heat demand (space heating, DHW, process load, etc.)

Examples of CHP Installations

District Heating
260MW$_e$

Apartment Building
75kW$_e$

Small Commercial Bldg
4.7 kW$_e$



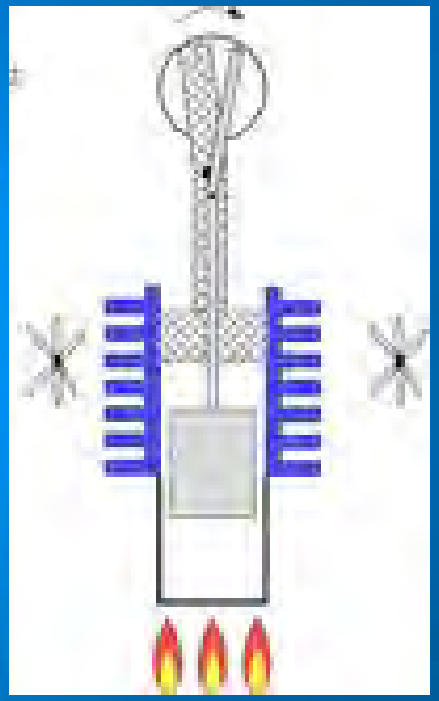
Residential Unit
1 kW$_e$

State of mCHP

- External combustion engines (Stirling engines)
- Internal combustion engines (ICE)
- Small turbines
- Fuel cells

Stirling Engine CHP

- External combustion engine (combustion occurs external to working cylinder);
- Low electrical efficiency (10-15%);
- Quiet operation, small footprint;
- Targeting the replacement boiler market in the UK/Europe;
- Whispergen has a 1kWe product on the market.



Internal Combustion Engines

- Developed for long life, long service interval;
- Many sizes available from 1 kWe to 500+ kWe;
- Higher electrical efficiency than Stirling (20-30%);
- Recent developments include improved emissions ratings, longer service life;
- Marathon, Yanmar, Honda Freewatt, Baxi, and others have IC CHP Products on the market.

Honda Freewatt/Marathon IC mCHP

Fuel Cell CHP

- In development stage;
- High electric efficiency ~ 40%;
- Proton Exchange Membrane (PEM);
- Solid Oxide Fuel Cell (SOFC);
- Performance degrades over time (similar to batteries);
- High Cost $$$;
- Thermal output close to electrical output which will increase run time.

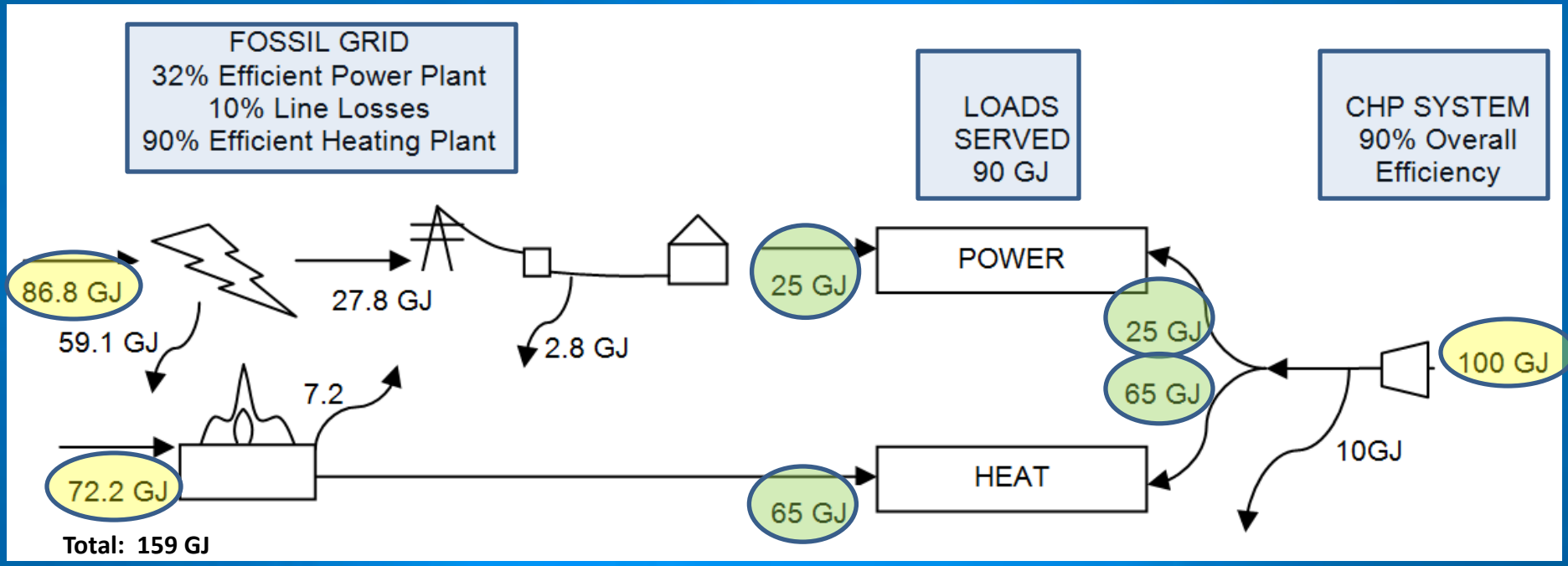
State of CHP (worldwide)

- From 1993-2009; 4,487 MW of CHP systems installed in Japan (peaking at 6,006 commercial units);
- 30,000 mCHP units installed in Germany;
- Seen as a very viable option for the rest of Europe and UK for boiler replacement;
- Very little market uptake in North America
  - Forced air heating systems, low availability

State of mCHP

- New developments with mCHP technology
  - lower equipment costs and increased number of products on the market
  - grid parallel / off grid operation
- *At time of demonstration*, no units initially available that met Canadian regulatory requirements;
- Two additional manufacturers now have units available to the Canadian market in this size range (Marathon, Yanmar).

Saskatchewan Potential Benefits – SRC Target Spec's



- A 90% overall efficient CHP system requires roughly 37% less primary input energy.
- GHG emissions can be reduced by up to 47% of that compared to a typical system with a high efficiency boiler and conventional Saskatchewan power production.

Applicability to Saskatchewan

- SaskPower's peak electrical demand generally takes place in winter months.
- Saskatchewan has a high reliance on coal-fired electrical power (GHG intensive).
- Over 90% of Saskatchewan residences and businesses are connected to the SaskEnergy natural gas network.
- CHP systems can be configured to provide power backup.
- Saskatchewan's cold climate is well-suited for long system runtime, when installed for heating purposes, maximizing benefits.

mCHP Demonstration Project Objectives

- Source a mCHP unit in the 5 to 10 kWe output range;
- Demonstrate the technical performance and institutional issues surrounding mCHP installation and operation in a Saskatchewan commercial building;
- Identify regulatory issues, advantages and disadvantages;
- Evaluate the overall performance;
- Better understand the economics and environmental performance;
- Findings will be of interest to those planning distributed generation initiatives and related incentives.

We couldn’t purchase what we wanted so we built it

mCHP Prototype Unit Development:

- SRC commissioned Advanced Engine Technology Limited (AET) to develop the unit in partnership with Kubota Canada and Cummins-Onan.
- Commercially available components were used for development.
- Unique features include:
  - Can back-feed to grid (grid interactive operation)
  - Can start-up and run off-grid during outage (back-up operation)
  - Capable of high overall thermal efficiency (77% HHV in condensing operation)
  - Capable of starting down to -35°C

Things to know about CHP

Mechanical Perspective

- System life typically 35,000-60,000 hours prior to significant maintenance
  - Large Scale CHP Mfg's guarantee 15 years operation (20 years max).
- CHP units
  - Sized to maximize runtime in facility (ideal 3,500-8,760 hrs)
  - not typically sized to handle peak space heating load due primarily to cost.
    - Baseload heating
- CHP unit - implemented as the first line of heating
  - Supply Temperature: 165°F-180°F (120°F low temperature systems yield the highest efficiency with condensing CHP systems)

Things to know about CHP

Electrical Perspective

- CHP is typically sized so the majority of the power produced is utilized within the building (dependent on rates and programs)
- It is not economically feasible to operate a CHP unit if you have no use for the heat.
- SaskPower Net Metering & Small Power Producer's Program is currently for renewables only.
- This project was granted special permission to feed back to SaskPower via the Small Power Producers program.
  - up to 100 kW - Small Power Producer ($0.09421/KWh)
- Projects such as these guide decisions for the utilities.

CHP Demonstration Project at Inland Metal

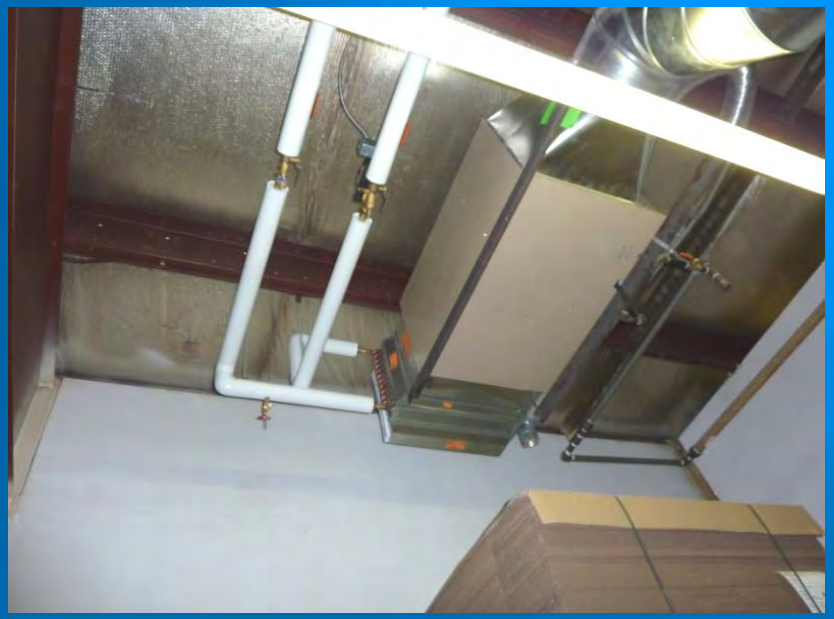
Host Selection:

- An Expression of Interest was utilized to find interested host buildings.
- Inland Metal was chosen as the successful demonstration site for the following reasons:
  - Utility records indicated that the building space heat demand was a good match for the CHP size.
  - Electrically, this site would allow us to demonstrate Black Start capability and Grid Parallel operation sending power back to the grid.

CHP Demonstration Project at Inland Metal

Site Specific Design:

- Existing building heating system consisted of a combination of forced air furnaces and radiant tube heaters.
- Targeted 3,500-5,000 hours of operation



CHP Demonstration Project at Inland Metal

Site Specific Design:

- An enclosure was built to house the prototype CHP Unit.

CHP Demonstration Project at Inland Metal

Electricity is used within the building as required.

Electricity not used in building is sent to the grid

Electricity output

Natural Gas input

Thermal output

Thermal energy distributed to reheat coils

NOTE: If heating is not required within the building, the CHP system does not run.

Observations from Installation

Maintenance Cycle:

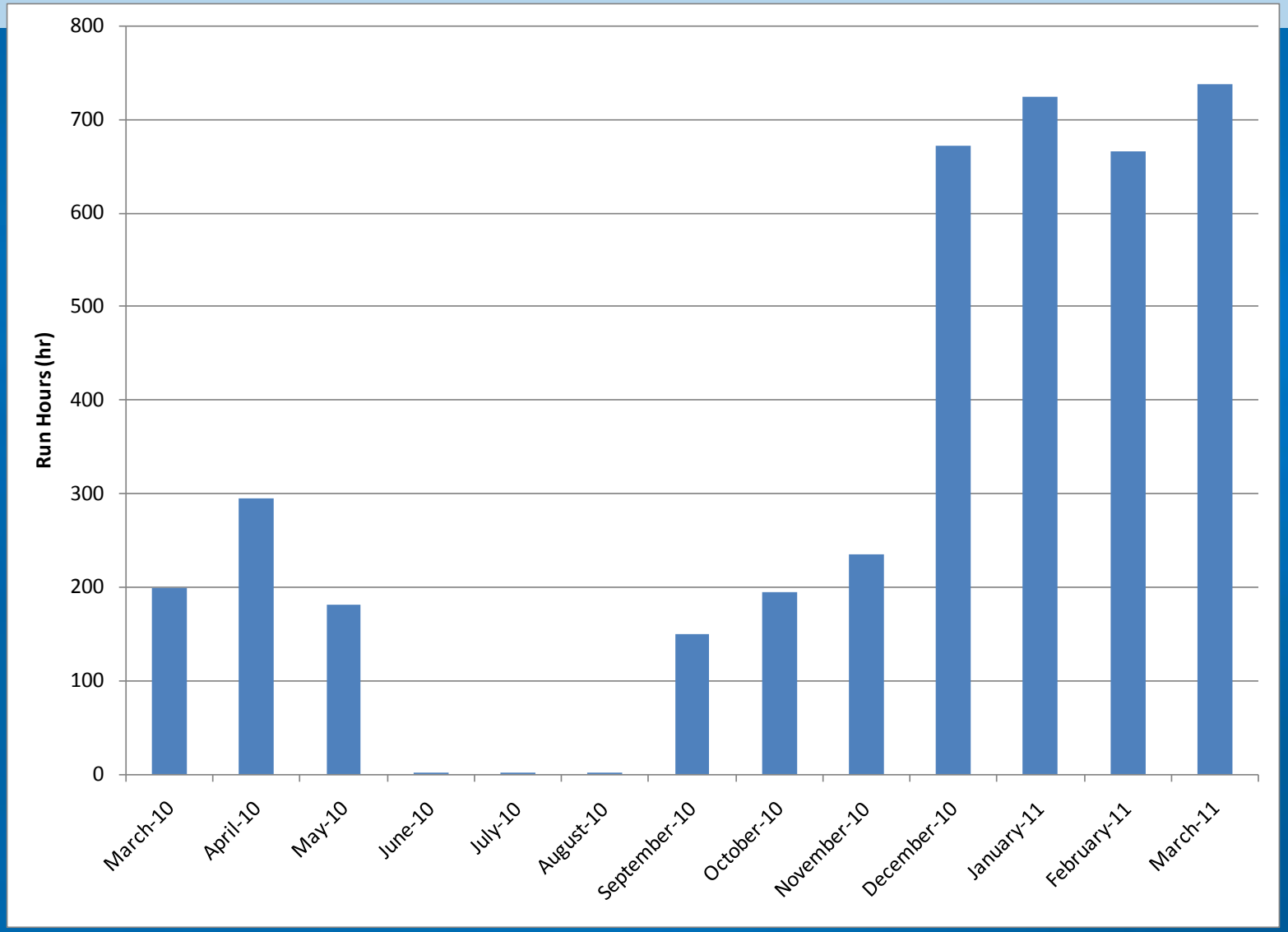
- Most CHP systems on the market have a 4,000-6,000 hr maintenance cycle for oil changes, air filter inspection and spark plug replacement, etc.
- Similar to a car engine, an annual maintenance cycle will be imperative to the success of the technology.
- Regular fluid level checks will be required throughout the year.

Observations from Installation

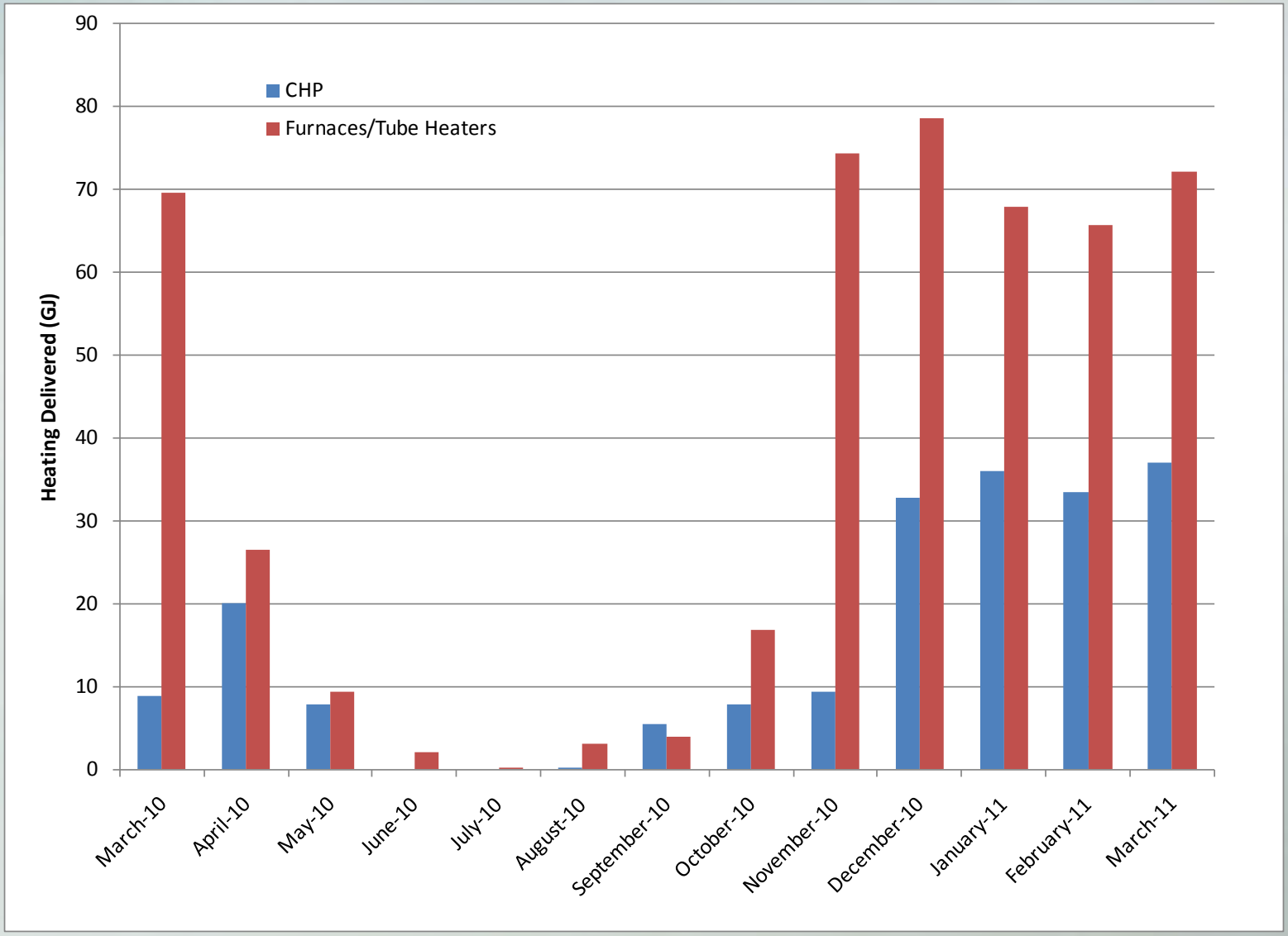
Regulatory requirements:

- CSA approval is required (this is a major barrier to international units coming into the North American Market).
- Major mechanical commitment to install fan coils throughout facility.
- Exterior installation added cost and complexity

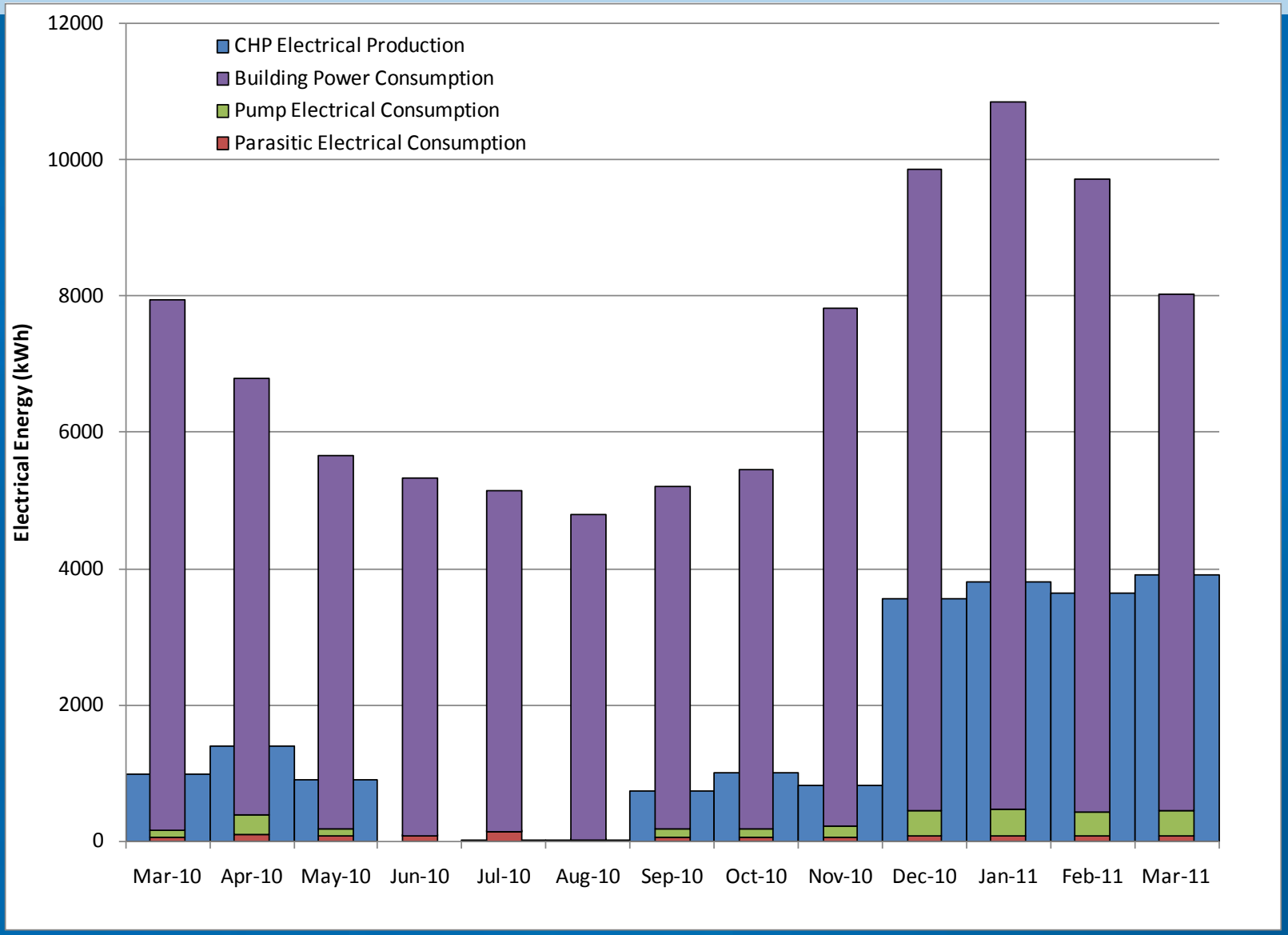
Results – Run Hours



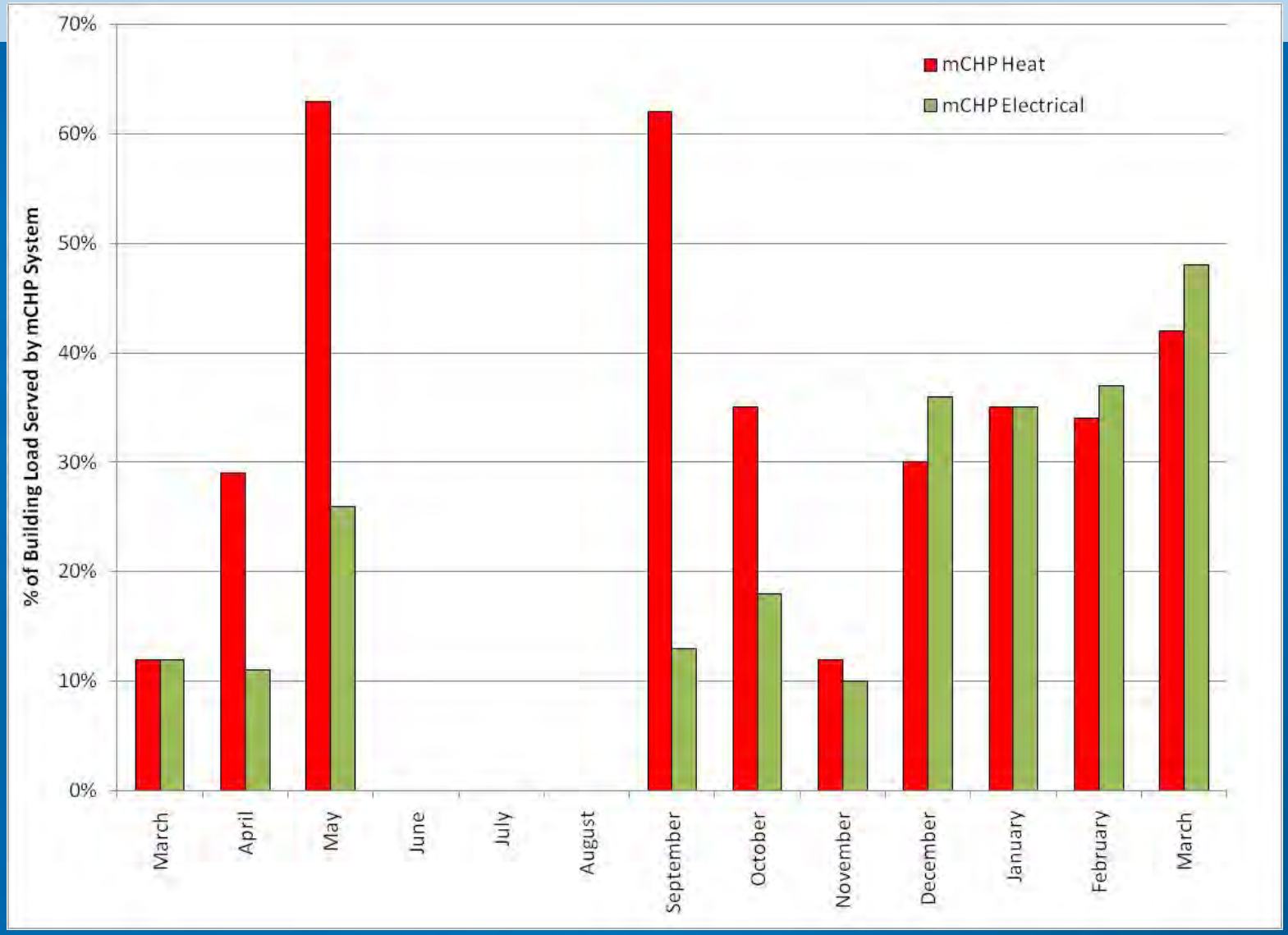
Results – Heat Energy Delivered



Results – Electrical Production



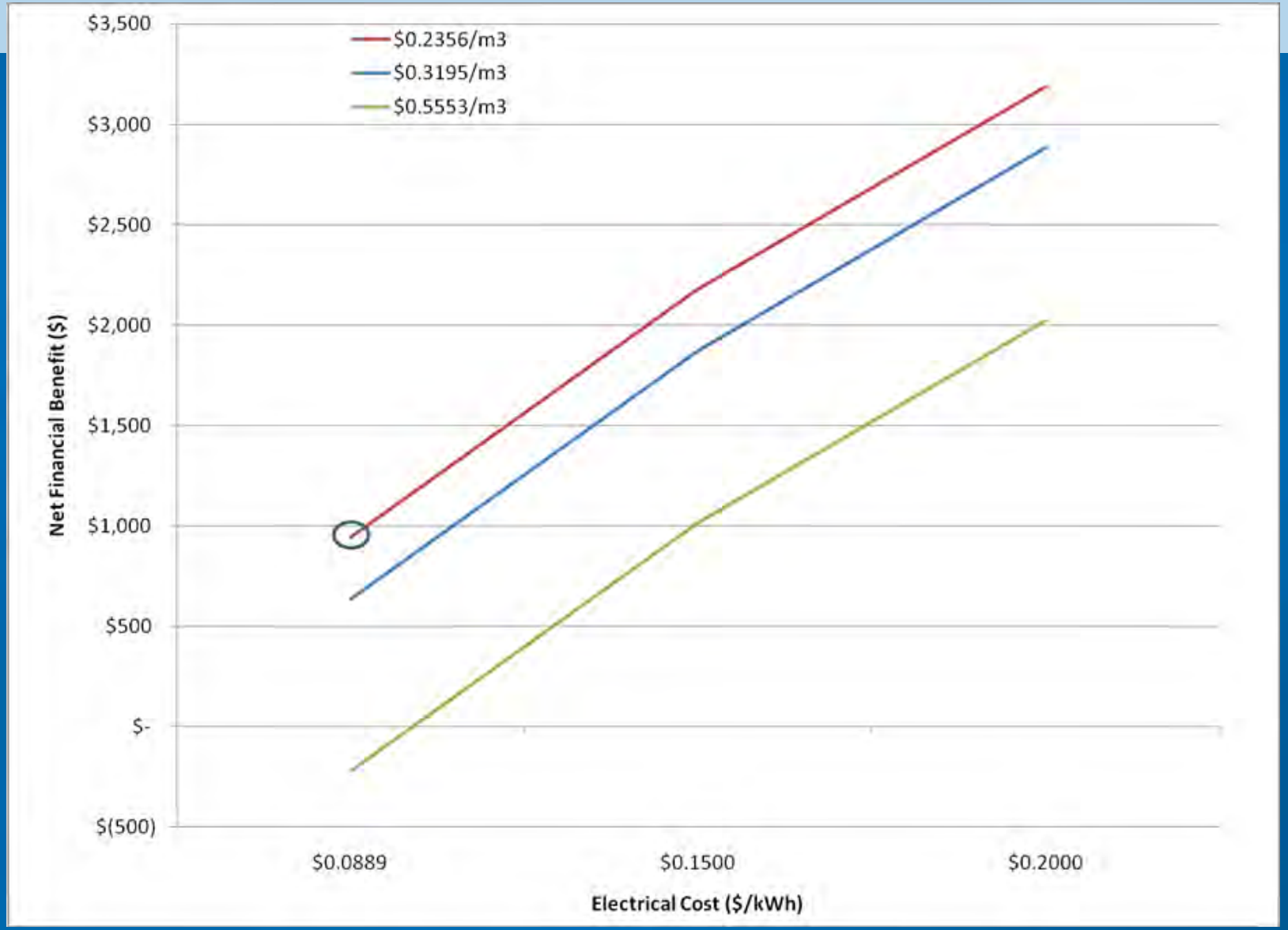
% Building Load Served



Results - Financial

CHP Gas Cost	$ (2,176.07)
Alternative Gas Cost	$ 1,393.86
Net Increase in Gas Usage	$ (782.21)
Electricity Produced	$ 1,683.98
Parasitic Load Cost	$ (79.40)
Net Electrical Benefit	$ 1,604.58
Net Utility Savings	$ 822.36
Exported Power	$ 8.67
Net Benefit to Building Owner	**$ 831.03**

Results – Sensitivity to Utility Pricing



Financial Perspective from Germany

- Natural Gas Price: €0.0615/kWh=> $0.0803/kWh
- Electrical Price: €0.2614/kWh => $0.3415/kWh
- Financial Benefit from our demonstration would be:

  $2,927 (an increase of over 350%!)

Results – GHG Emissions (SK Perspective)

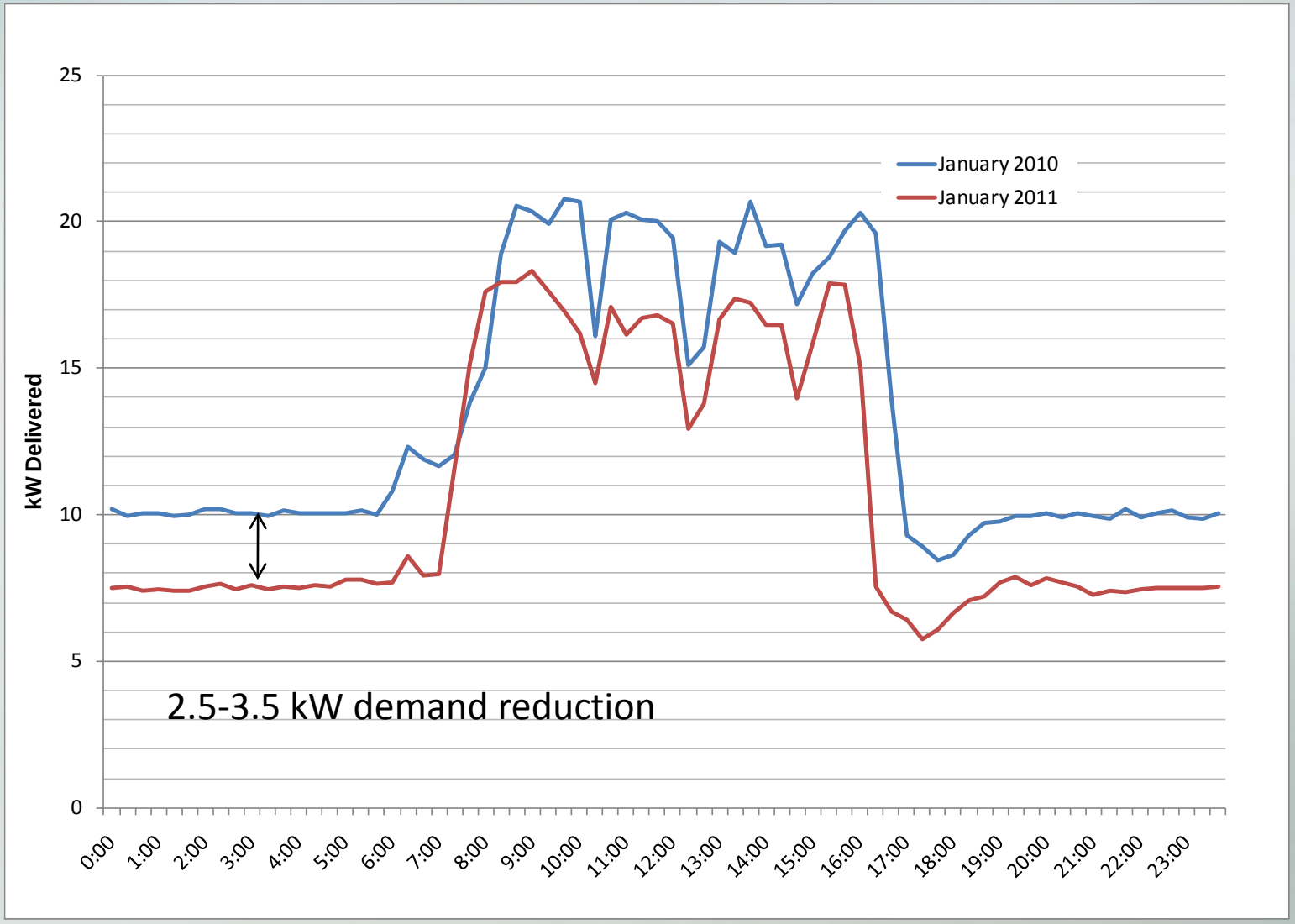
Emissions from	Energy Output	mCHP Emissions	Furnaces and Tube Heaters/SK Power Electricity
Electricity	18,942 kWh	17.05 t CO2e	15.12 t CO2e
Heat	51,194 kWh		10.92 t CO2
Total		**17.05 t CO2e**	**26.04 t CO2e**

34% Reduction in GHG emissions over existing heating system and purchased electricity.

Benefits to Utilities

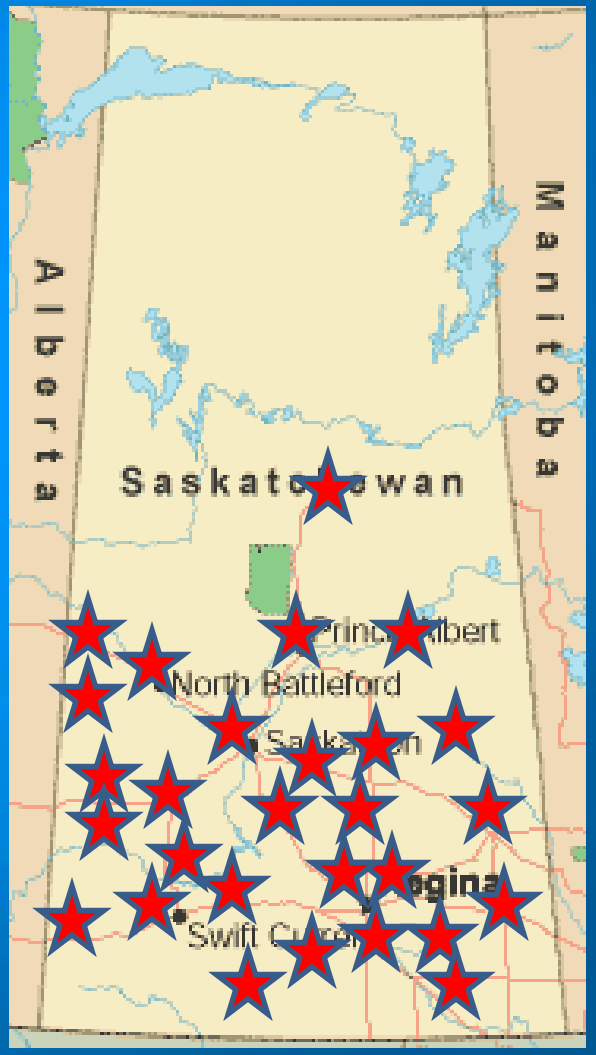
- SaskPower experiences their peak electrical demand in winter months
  - mCHP systems would be running during these times potentially reducing provincial demand (when many units are installed)
- Over 90% of Saskatchewan buildings are connected to the natural gas network.
  - mCHP systems are another venue for SaskEnergy customers to utilize natural gas for heating and producing power

Benefits to Utilities – Demand Reduction



Benefit to Electrical Grid

- Widespread adoption will provide reduced electrical demand to the utility
- Reduced line losses from point source electrical use



Key Accomplishments

- Required functionality and feasibility has been demonstrated.
- 4,500 hrs of successful operation to date.
- Valuable maintenance cycle experience has been gained.
- Lessons learned include: optimal sizing and control logic.

Conclusions

- Successfully demonstrated a prototype mCHP unit with black start capabilities
  - Results are promising towards future technology refinement
- Identified Regulatory Issues with installation through close work with code officials

Future CHP Technology Demonstrations

Small Commercial

- SRC plans to continue the project to pilot CHP systems in other small-to-mid-sized commercial facilities.
- Installation underway for a demonstration of a Marathon ecopower™ 4.7 kW unit for a business in Saskatoon.
- Hydronic installation inside the building

Photo supplied by Marathon Engine Systems

Future CHP Technology Demonstrations

Small/Large Commercial

- SRC plans to pilot other scales of commercially available CHP systems to determine GHG and financial benefits realized by the owner.
- Look at niche markets for extended run hours
  - Process loads
- EOI coming soon…10kWe and 25kWe sized demonstration units.

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Thank you!
Questions?

Saskatchewan Research Council

Combined Heat and Power Event

Major Funders

Natural Resources Canada / Ressources naturelles Canada
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eneraction

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Advanced Engine Technology Ltd.

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