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Assessing Microgen in Canada

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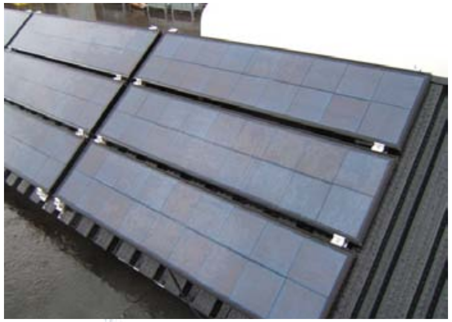
CanmetENERGY Microgen Activities



CanmetENERGY Microgen Activities

Solar Thermal
PVT
Micro-CHP
...

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Stirling Engine Micro-CHP

- CHP: Combined Heat and Power
  - More efficient than separate production
- Micro: Scale of one residence up to a couple of apartments, small commercial
- Stirling Engine micro-CHP assessed:
  - Electrical output: up to 750 W
  - Heat production: ~ 7 kW

Enhanced Deployment of Residential CHP Systems

Project Overview

- *Objective:* Address practical barriers to widespread use in Canadian homes
- *Strategy:* Assist market channel players to gain experience with technology
- *Outcomes:*
  - installation codes/standards/approvals
  - O&M knowledge
  - economic attractiveness for the delivery agent, end user, utilities
  - Canadian performance data

Outline of WhisperGen Deployment in Canada

- *Canadian Centre for Housing Technology:*
  - MkIV in Visitors' Centre (Jan-Sept 2005)
  - MkVb in test house (Feb 2009)
- *Calgary:* MkIV in occupied single family home (Dec 2007-May 2008)
- *Ottawa:* MkVb in occupied townhouse (March 2009 - present)
- *Toronto:* MkVb at Kortright Centre for Conservation (Toronto and Region Conservation Authority) (Apr-May 2010)

CCHT (2005)

- First 'market-ready' (Europe) AC Stirling installation in **Canada**
  - Electrical grid connection challenges identified
- Integration with gas-fired HWT and PV
- Performance data
  - Reliability, emissions, output capacity, cycle efficiency, seasonal efficiency

NRC Canadian Centre for Housing Technology Visitors' Centre

Calgary (2007/2008)

- MkVb designed for North American grid
- Occupied single family detached home
- Provided space and water heating
- Low cost instrumentation and web enabled datalogging

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Calgary (2007/2008)

- First occupied home gas and electrical certifications in **Canada**
- Integration with radiant floor heating and Latento XXL thermal storage tank with aquastat CHP controller
- Emissions test by NRCan
- Data owned by Enmax (Alberta utility)

CCHT (2009)

NRC Canadian Centre for Housing Technology

- Side-by-side energy comparison with reference house
- Integration with forced air gas furnace
  - Stirling provided space heat via heating coil at furnace inlet and DHW to indirect HWT
- Honeywell μCHP smart controller
- Instrumented by NRCan & NRC for energy performance evaluation and cost analysis

Ottawa (2009-)

- Townhouse with zoned forced air heating
- Stirling coupled to dedicated coil in air handler *and* to 60 gal tank for DHW storage
- Second coil in air handler to ground source heat pump
- Stirling controlled by Honeywell

Ottawa demonstration home for WhisperGen MkVb

Ottawa (2009-)

- First occupied home gas and electrical certifications in **Ontario**
- Integration with forced air / DHW combo system and ground source heat pump
- Navien boiler for performance comparison and backup
- Instrumented by NRCan for energy monitoring with web enabled datalogging

Toronto (2010)

Kortright Centre for Conservation (Toronto and Region Conservation Authority) concept drawing

- Environmental and renewable energy education and demonstration centre
- A duplex with each home showcasing different sustainable technologies

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Toronto (2010)

- High visibility deployment
- Integration with radiant floors, multi-zone forced air system, and solar DHW heating
- High traffic space heating and unique DHW loads
- Honeywell µCHP smart controller
- Instrumented by Ryerson University

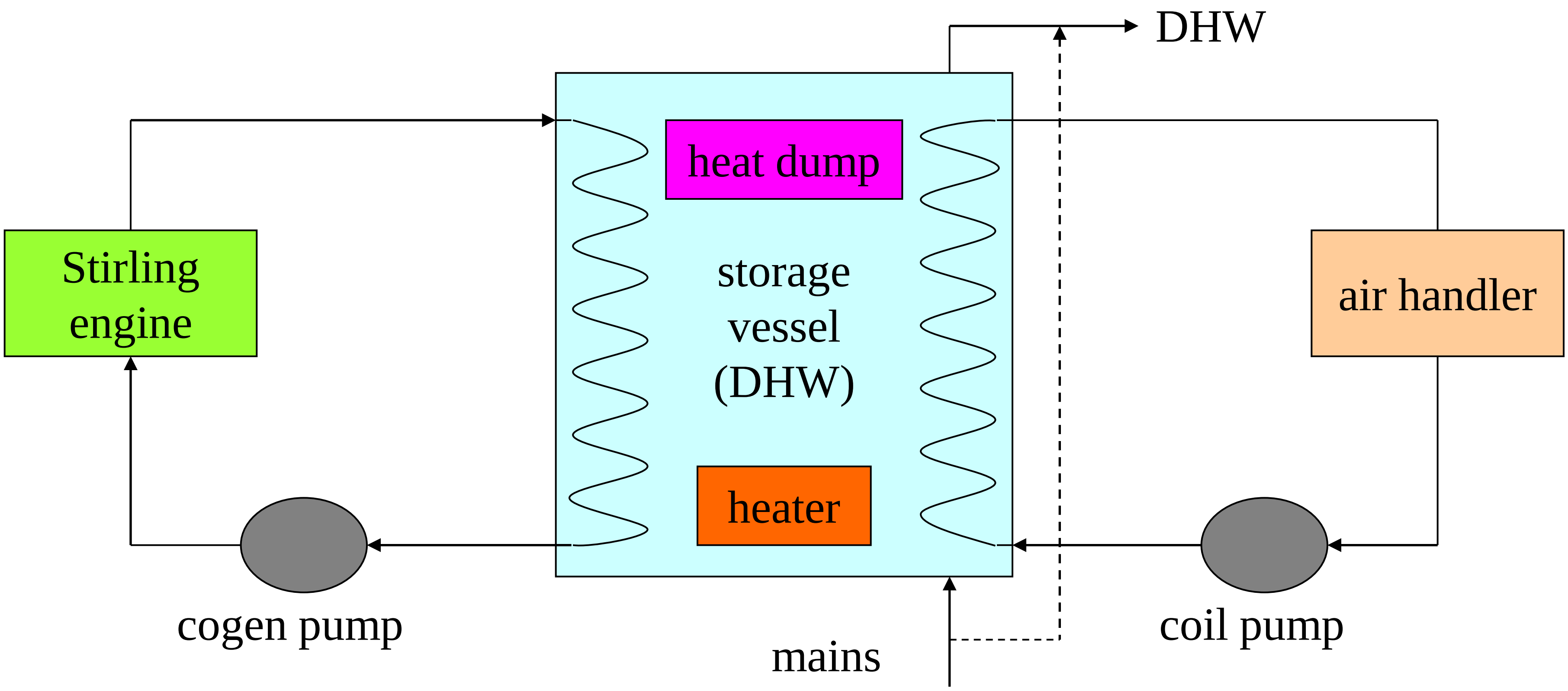
Benefit from Synergy between Field Experiments and Simulations

- Results from Field Experiments used to calibrate and validate Simulation Models
- Results from Simulations gave direction to next Field Experiments

Simulation Studies

- IEA Annex 42 study (2007)
  - *Performance Assessment of* ***Prototype*** *Residential Cogeneration Systems in Single Detached Houses in Canada*
- Performance forecasts of new technology are often too high
  - Only full load efficiency known
  - No insight in internal power consumption, heat losses
- This study used **measured efficiency** of prototype systems
  - 1 kW class Stirling Engine system
  - 5 kW class Solid Oxide Fuel Cell system

System Schematic



Operating modes

- Heat load following
- Electric load following

Efficiencies (HHV) of Prototype SE System

		Heat load following mode	Electricity load following mode
Full load efficiency	Electric eff	8.4 %	
	Thermal eff.	74.4 %	
	Cogen. eff.	**82.8 %**	
Co[illegible] unit [illegible] efficiency	[illegible]	[illegible]	5.9 %
	[illegible]	[illegible]	68.0 %
	Cogen. eff.	**78.9 %**	**73.9 %**
Cogen system efficiency	Electric eff.	5.4 %	2.8 %
	Thermal eff.	60.8 %	55.7 %
	Cogen. eff.	**66.2 %**	**58.5 %**

Electric: 64% of full load eff.
Heat: 82% of full load eff.

'Lessons Learned' from Prototype Stirling Engine System

- ***Real-life efficiency*** of SE systems can be substantially lower than under full-load conditions
- GHG emission reduction potential is mainly determined by the ***emission signature*** of the local power grid
- Highest efficiencies and largest absolute emission reductions are obtained for ***heat load following operation*** in houses with high heating loads
- The SE systems must be ***condensing*** to make a difference compared to the reference system
- Internal power consumption and heat losses (e.g. from hot water storage) must be minimized

Simulation Studies (2)

- NRCan follow-up work (2008)
  - ***Plausible*** *Performance Forecast for Stirling Engine Residential Cogeneration Systems Applied in Single Detached Houses in Canada*
- Apply 'lessons learned' from real-life performance of ***prototype*** systems to come to a plausible forecast of performance for ***mature technology*** systems

Mature Technology SE System

- Fuel input: 8.0 kW
- Electric output: 1.0 kWe (12.5% efficiency)
- Thermal output: 6.4 kWth (79.5% efficiency)
- Overall 92% efficiency (**condensing**)
- Power consumption
  - stand-by: 9 W
  - generating: 100 W
- Pumps: DC motor, 20 We
- Heat load following operating mode
- Applied in single detached house with average heating load in Toronto
- NOx emissions: 54 g/GJ fuel (NRCan test)

Reference Technologies

BEST AVAILABLE TECHNOLOGY

Condensing furnace:

- annual efficiency: **96**%
- NOx emissions: **42** g/GJ fuel input
  - No regulations in Ontario
  - Current California limits used (40 g/GJ heated output)

DHW water heater:

- full load efficiency: **90**%
- annual efficiency: **75**%
- NOx emissions: **53** g/GJ fuel input
  - No regulations in Ontario / current California limits used
- Same technology used for back-up burner and storage vessel of SE system

Grid Power and Emissions

Off-peak

- **On-the-margin** power production technology
  - SE power production displaces next plant to come on
- NRCan methodology to relate on-the-margin fuel source to Hourly Ontario Electricity Price (HOEP)
- Hourly values for GHG and NOx emissions
- Power prod. efficiency: natural gas: 51%, coal: 32%
- Upstream fuel cycle emissions included (off/on-peak)
- Transmission and distribution losses: 8% (off/on-peak)

On-peak

- Clean Energy Standard Offer Program (CESOP)
- 2 GE LM6000 single-cycle gas turbines
- Efficiency: 36% (HHV)
- NOx emissions: 5 ppm (0.61 g/kWh*)

GHG emissions (kg CO_2e / y)

	Cogen	Ref.
▪ Space heating	6095	3900
▪ DHW (back-up heater)	213	1187
▪ HVAC electricity	158	202
▪ SE electricity generation		2504
▪ TOTAL	6465	7784

- SE system reduces GHG emissions by 17%
- SE system reduces NOx emissions by 3.5%

Primary energy saving

- Primary energy input:
  - SE system: natural gas for SE and back-up burner
  - Reference system: natural gas for furnace and water heater and fuel for electric power plant

Mature technology SE system would reduce primary energy input by

- 13% compared to a coal fired power plant (32%, HHV)
- 2.3% compared to a natural gas fired combined cycle (51%, HHV)

Conclusions

- Realistic performance mature technology SE system
  - Proven performance latest generation SE unit
  - Reasonable assumption on condensability
  - SE system optimized by applying lessons learned from prototype system
- Compare to highest benchmark: best available technology
- Still emission reduction – primary energy savings

  (When applied in heat load following mode in Ontario)

Mature technology SE residential cogeneration has a REAL potential for Canada (Ontario)!

Simulation Studies (3)

- IEA Annex 54 study (2010/2011)
  - Hybrid renewable energy – micro-CHP system

Conclusions

- Stirling Engine system successfully deployed in various configurations in 5 different field trials
  - Codes & standards / approvals
  - Installation, O & M
  - Performance (efficiency, emissions)
- Growing knowledge and understanding from different simulations studies
- Stirling Engine Micro-CHP has real potential for reduction of emissions and primary energy use in Canada (ON)

Questions