Micro-CHP Technologies for Distributed Generation in Canada

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Advanced Combustion Technologies
CANMET Energy Technology Centre

DG Energy Technologies

- Fuel cells
- Microturbines
- Stirling engines
- Diesel generators
- Renewables
- Others (TE, TPV, etc.)

Micro- CHP Generation Issues

- Technology – cost, reliability, availability, etc.
- Interconnect – standards, regulations
- Integration with existing house's thermal systems
- Overall system optimization and control strategies

Fuel Cell (FC)

Government of Canada
Gouvernement du Canada
Canada
Hydrogen and Fuel Cell Activities
Newfoundland
• Memorial University (St. John's)
British Columbia
• National Fuel Cell Research Facility (Vancouver)
• University of Victoria
• BC Hydro (Vancouver)
• Ballard Power Systems Inc. (Burnaby)
• Xcellsis (Burnaby)
• QuestAir Technologies Inc. (Burnaby)
• Simon Fraser University (Burnaby)
• Powertech Labs Inc. (Surrey)
• ASA Automated Systems (Sidney)
• Statpower (Burnaby)
• Nexcel (Richmond)
Alberta
• Global Thermoelectric (Calgary)
• Dynetek (Calgary)
• CERI (Calgary)
• University of Calgary
Saskatchewan
• Saskatchewan Research Council (Saskatoon)
• University of Regina
Manitoba
• New Flyer Industries (Winnipeg)
Ontario
• Ontario Hydro (Toronto)
• University of Toronto
• Hydrogenics Corporation (Toronto)
• The Electrolyser Corporation (Toronto)
• Canadian Hydrogen Association (Toronto)
• Fuel Cell Technologies (Kingston)
• Armstrong Monitoring (Nepean)
• McMaster University (Hamilton)
• University of Guelph
• University of Ottawa
Québec
• Hydro-Québec (Montreal)
• TISEC (Montreal)
• H Power Enterprises of Canada (Montreal)
• McGill University (Montreal)
• CRIQ - BNQ (Sainte-Foy)
• HRI - UQTR (Trois-Rivières)
• Stuart Energy Systems (Grand-Mère)
• INRS (Varennes)
• École Polytechnique (Montreal)
• Laval University (Québec)
• University of Sherbrooke
• Tektrend International (Dollard)

PEM and SOFC for micro generation

ISSUES	PEMFC	SOFC
Operating Temp.	80 – 100°C	650 – 1000°C
Fuel Reforming	Complex multistage external reformer for all normal fuels	Single stage internal reformer for natural gas or propane
Contaminants	Intolerant to CO Intolerant to sulphur	No CO sensitivity More tolerant of sulphur
Water Management	Sensitive to dehydration. Water management required.	Intrinsic to process. No water management required.
Cogeneration Capability	Low grade waste heat: 60 to 70°C	High quality waste heat: 200 to 600°C
Overall Efficiency	Up to 70% (using H_2)	> 90% (using NG)
Catalysts	Expensive noble metals: Platinum and palladium	Low cost nickel and perovskites

GTE Manufacturing Process

Screen Printing

50' Tape Caster

Source: GTE

Residential/Commercial Size SOFC

SOFC 110kW/250kW atmospheric type

SOFC 5kW residential

5 kW SOFC FCT Corp.

SOFC Demonstration Project

- Cost - $14 million
- Participants - SWPC, US DOE, Ontario Hydro, NRCan
- Site – Kinectrics/OPG
- Stack - 250kW , atmospheric pressure
- Demonstration- for 5,000 h

STIRLING ENGINE

Stirling Engine

The Stirling Engine (SE) operates on a closed thermodynamic Stirling cycle which repeatedly heats and cools a mass of nitrogen gas. The changing gas pressure causes the pistons to move up and down, and via a mechanical linkage rotate an alternator to produce electricity.

Stirling Engine

- 6 kW (~20,000 BTU/hour) heat generated
- 750W electrical generated; 575W useable on the grid
- 115kg
- 400mm x 550mm x 850mm (w x d x h)

- Startup time before core reaches 70°C ranges from 0 - 30 min, depending on setup. The shortest uses no cooling water until core is at 60°C

- Shutdown time is 20-35 mins. Shortest uses fresh cooling water and dumps the heated cooling water.

- Since startup and shutdown times are long, it is most efficient to run the engine continuously.

1. Combustion space. 2. Hot heat exchanger. 3. Cold heat exchanger. 4. Wobble yoke mechanism. 5. Hermetically sealed alternator. 6. Microprocessor management system. 7. Control panel. 8. Fiberglass enclosure.

SE Performance Parameters

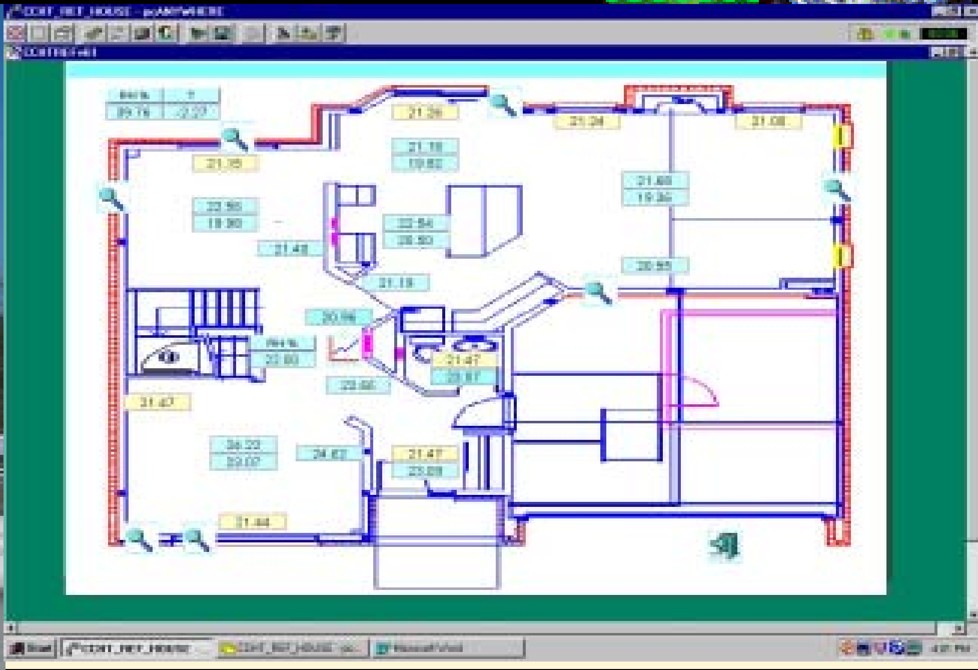
- **Start up – (10-30min) 30min***
  - » 1min for the gas burner to light up
  - » 6min for the SE to start
  - » 32min for the core to reach 70C
- **Shut down – (30-65min) 44min***
  - » 7min for the gen to stop producing electric energy
  - » 3min for motoring the SE
  - » 34min after the burner turns off to “Standby”

Conclusion: SE should be operated as a base load with as few interruptions as possible

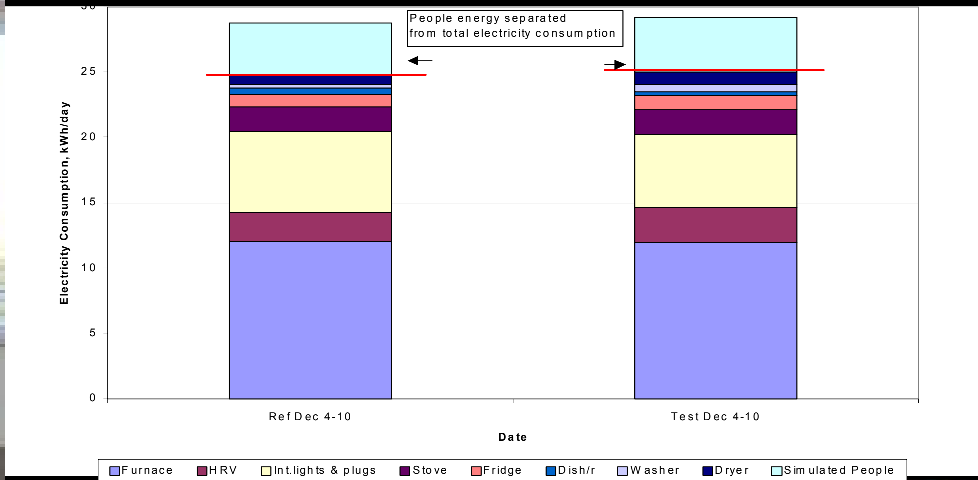
Canadian Centre for Housing Technologies (CCHT)

- Located in Ottawa and operated by three agencies – NRC, CMHC and NRCan
- Consists of two identical research houses and info centre
- Houses Design Heat Loss – > 40,000 BTU/hr
- Both houses are operated under Simulated Occupancy Protocol

Since the Stirling Engine only generates ~20,000 BTU/hour, it cannot provide enough heating by itself on the coldest days (design conditions) and an additional heat source is required.



CCHT Weekly Performance Comparisons



Buildings Group

CETC

CCHT micro-CHP project

Objectives

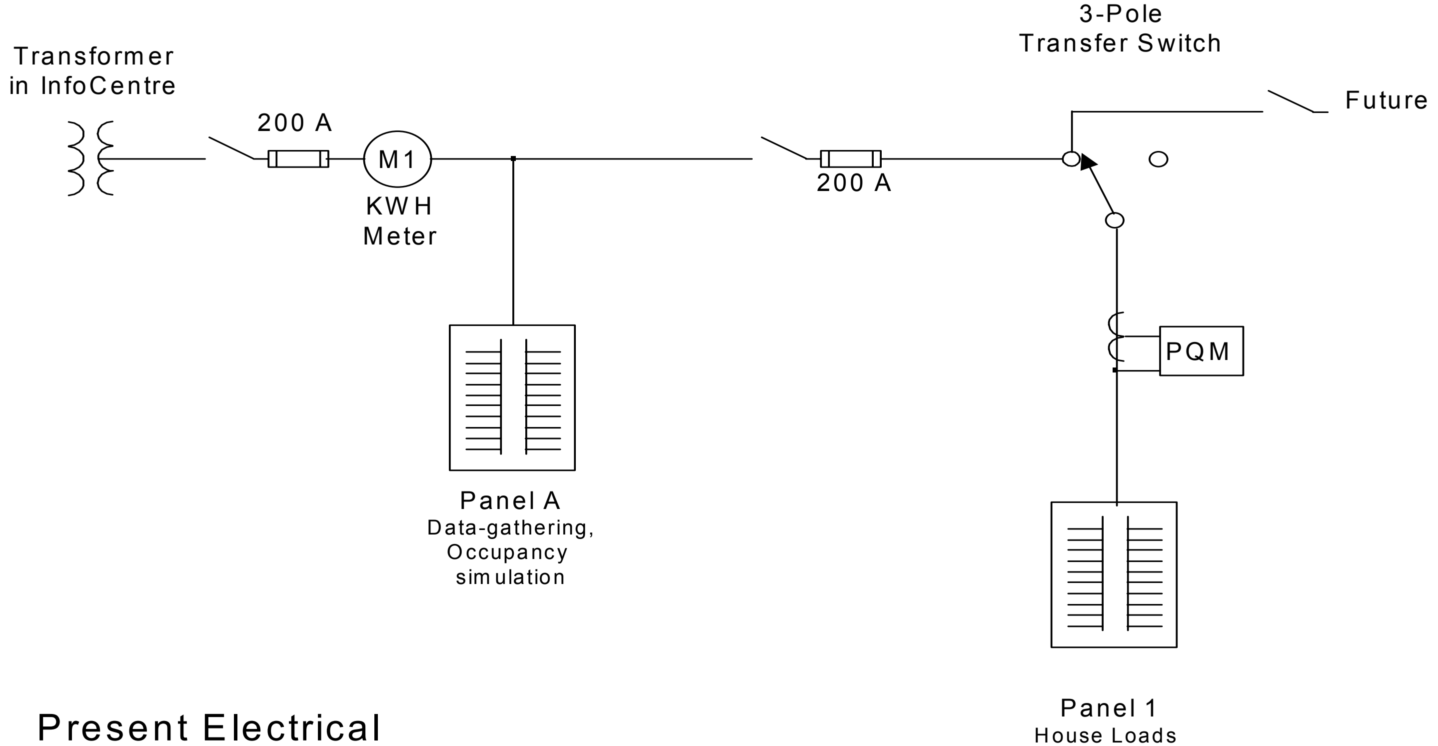
- To demonstrate micro-CHP technology
- To convert the house to accept micro-CHP
- To assess the micro-CHP performance under SOC
- To gain knowledge re micro-CHP integration with house's energy systems

Questions

- How much energy and what percentage of the load does the CHP deliver?
- How much electricity from the grid is replaced by the CHP?
- What are the net cost savings?
- What are the GHG implications?

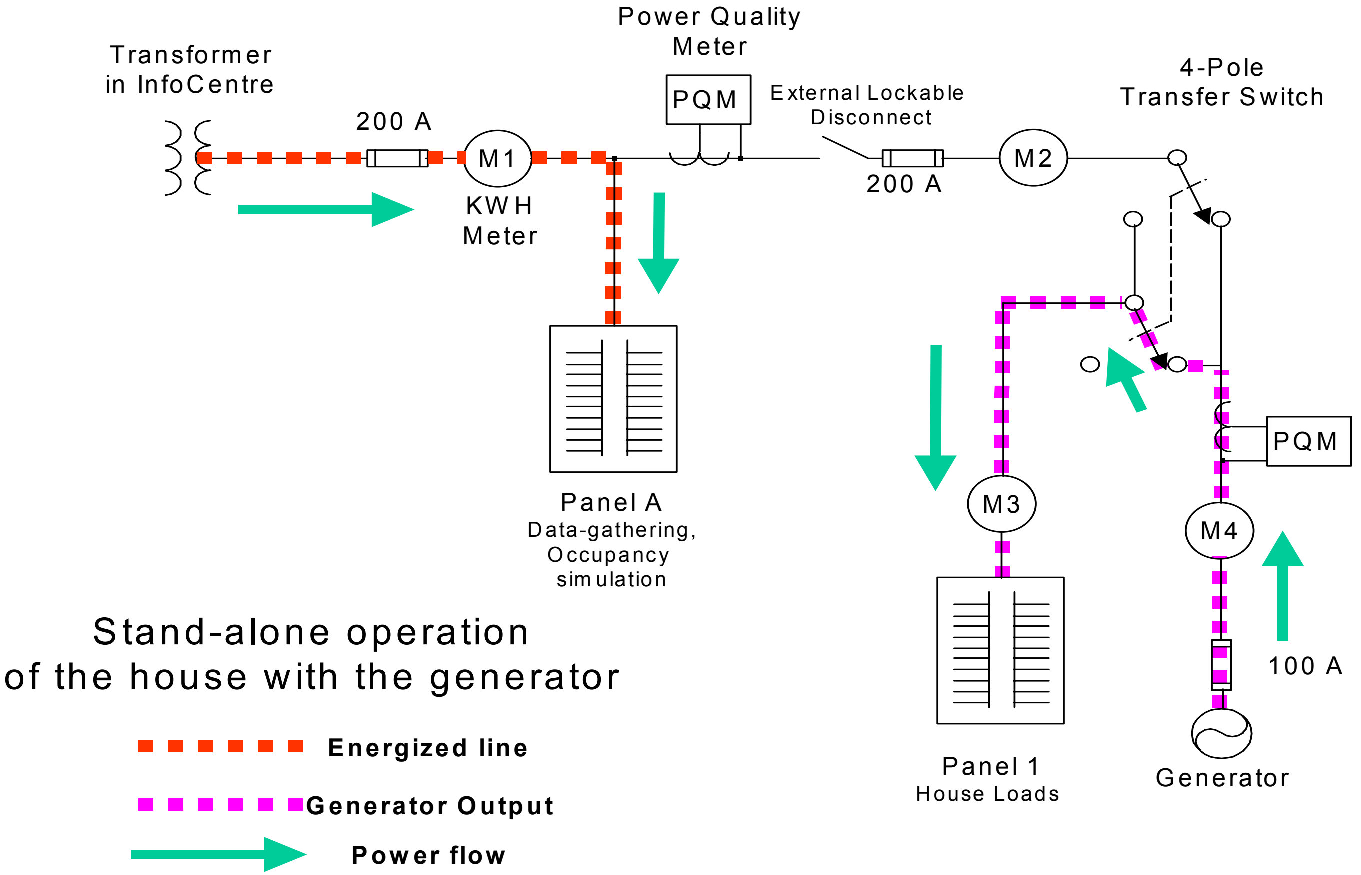
CCHT Electrical Wiring

Existing House Wiring Diagram

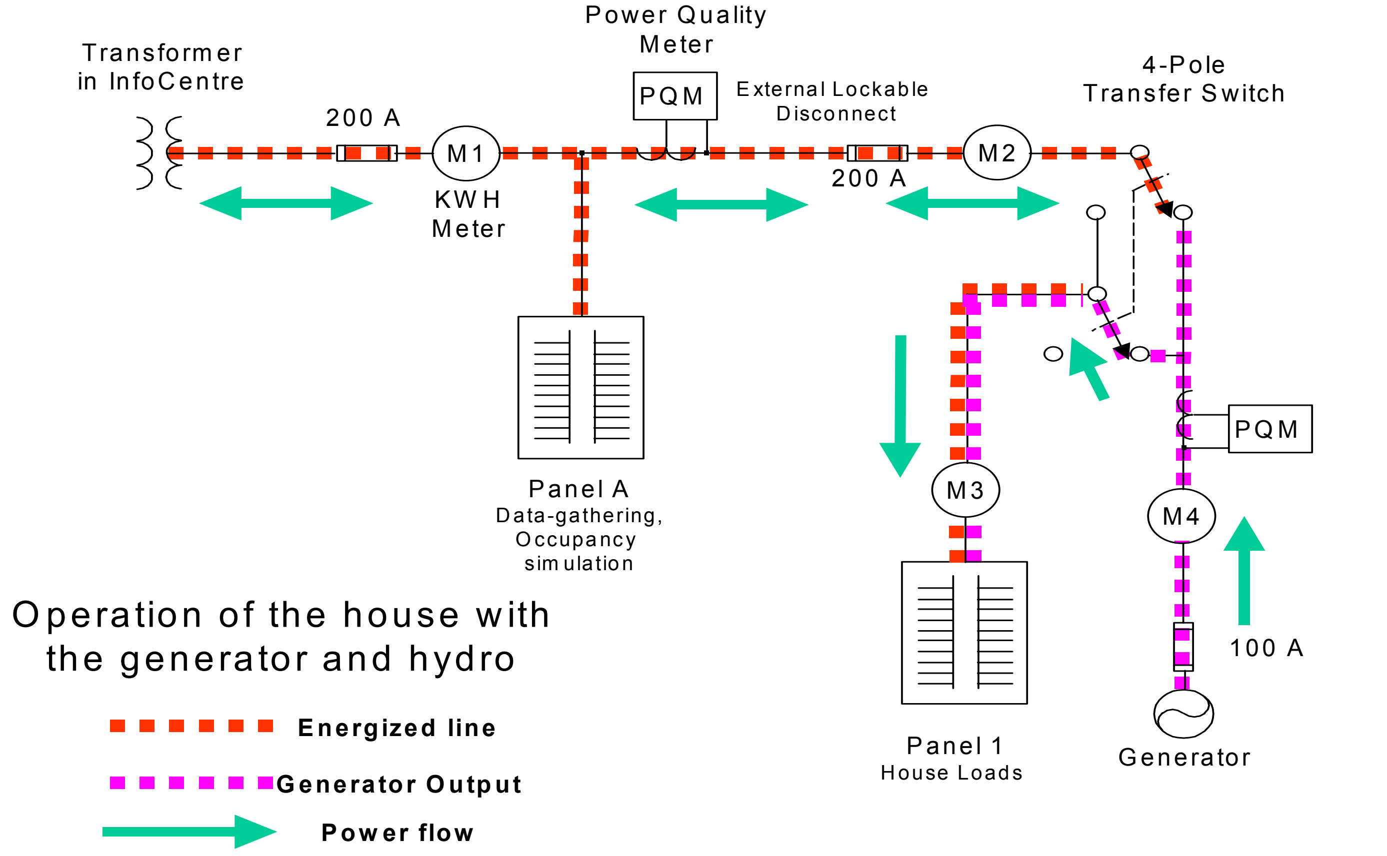


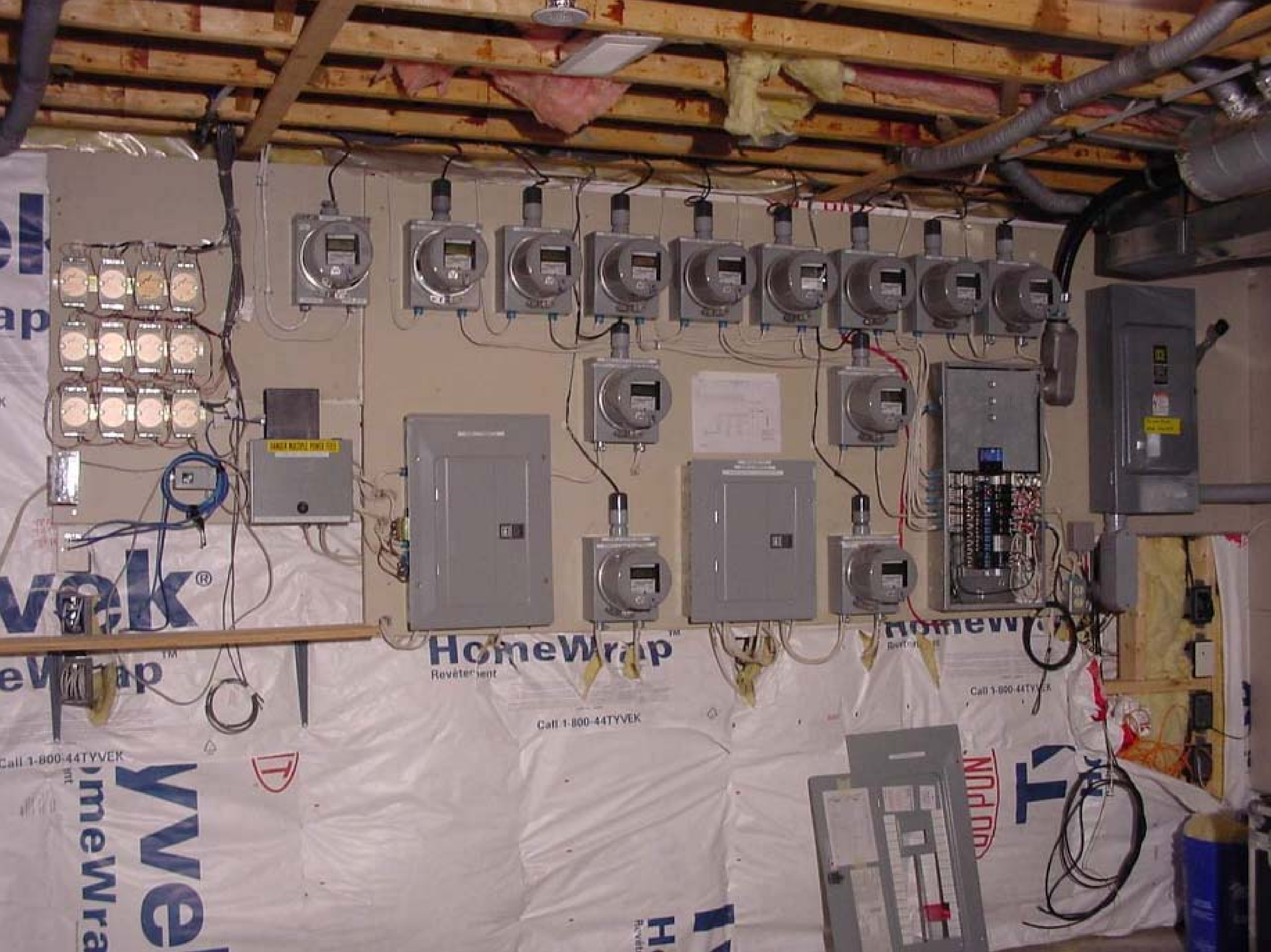
Present Electrical
Wiring Arrangement

Stand-alone Operation with CHP



Operation with Hydro and CHP





HomeWrap
Revêtement
Call 1-800-44TYVEK

Summary of Modifications

1. Three additional Kilowatt-hour meters and an additional power quality meter were added.
2. An external weatherproof, padlockable disconnect switch was installed to meet requirements of rule 84-028 of the Canadian Electrical Code.
3. A four-pole transfer switch was installed to allow various generator configurations without re-wiring.
4. A 100-amp disconnect / isolating switch with 20-amp fuses was installed to protect and isolate the Stirling Engine.
5. The wiring and equipment was inspected by Ontario's Electrical Safety Authority.

CHP Thermal Utilization Module

WG Thermal Utilization Module (TUM)

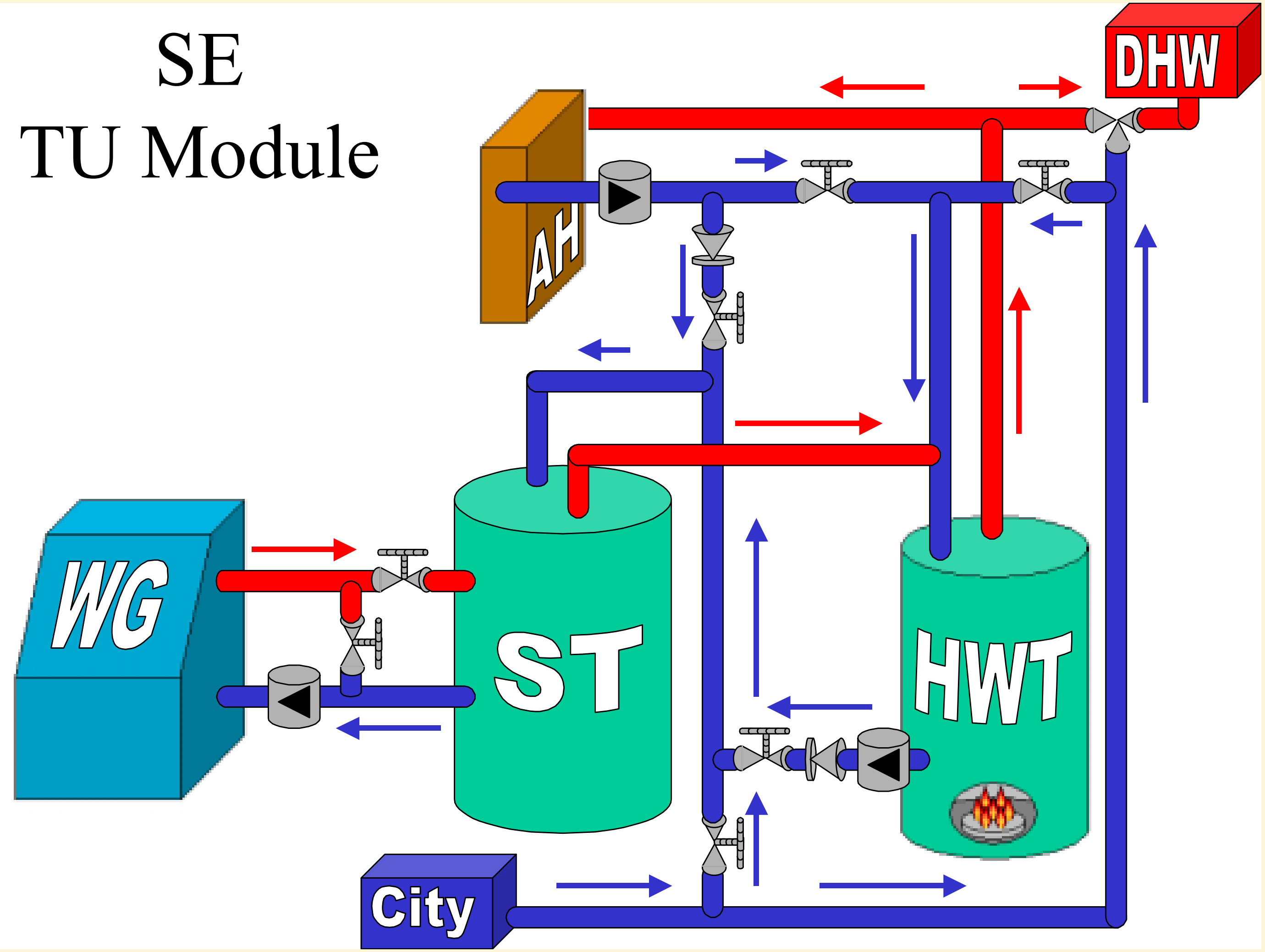
- To provide enough heat sink for the generator normal/continuous operation
- To satisfy house's base energy needs (space heating, water heating, ventilation)
- To be generic
- To be simple

TU Module Control Strategy

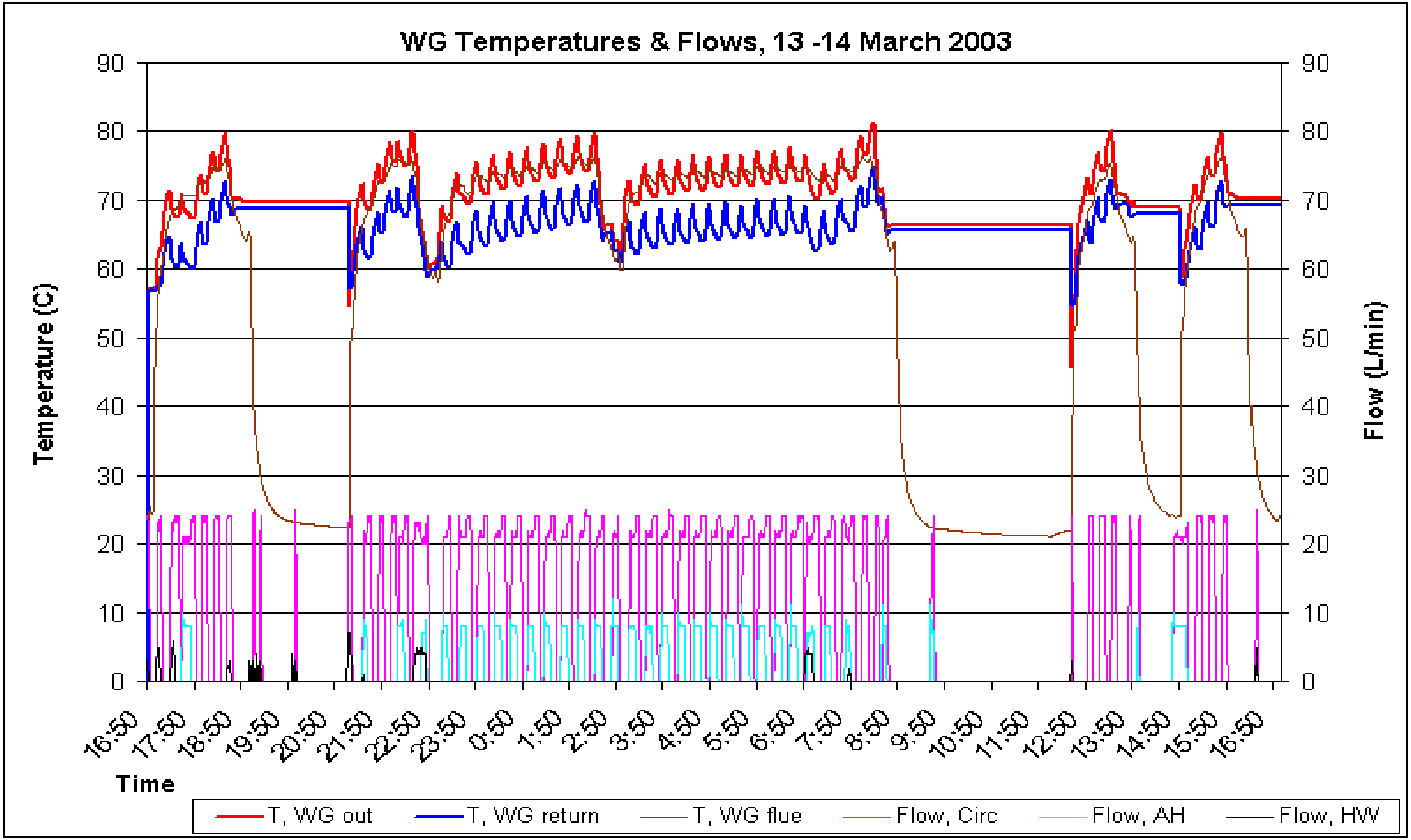
- **To provide optimal operational conditions for combined heat and power generation**
- **To be generic and simple***
- **To minimize the SE interruptions**
- **To minimize water heater burner operation (cycling)**

*For more advanced strategy see article " Residential Fuel Cell Energy Systems Performance Optimization Using "Soft Computing" Techniques" by E. Entchev, Journal of Power Sources, vol.118, pp212-217, 2003

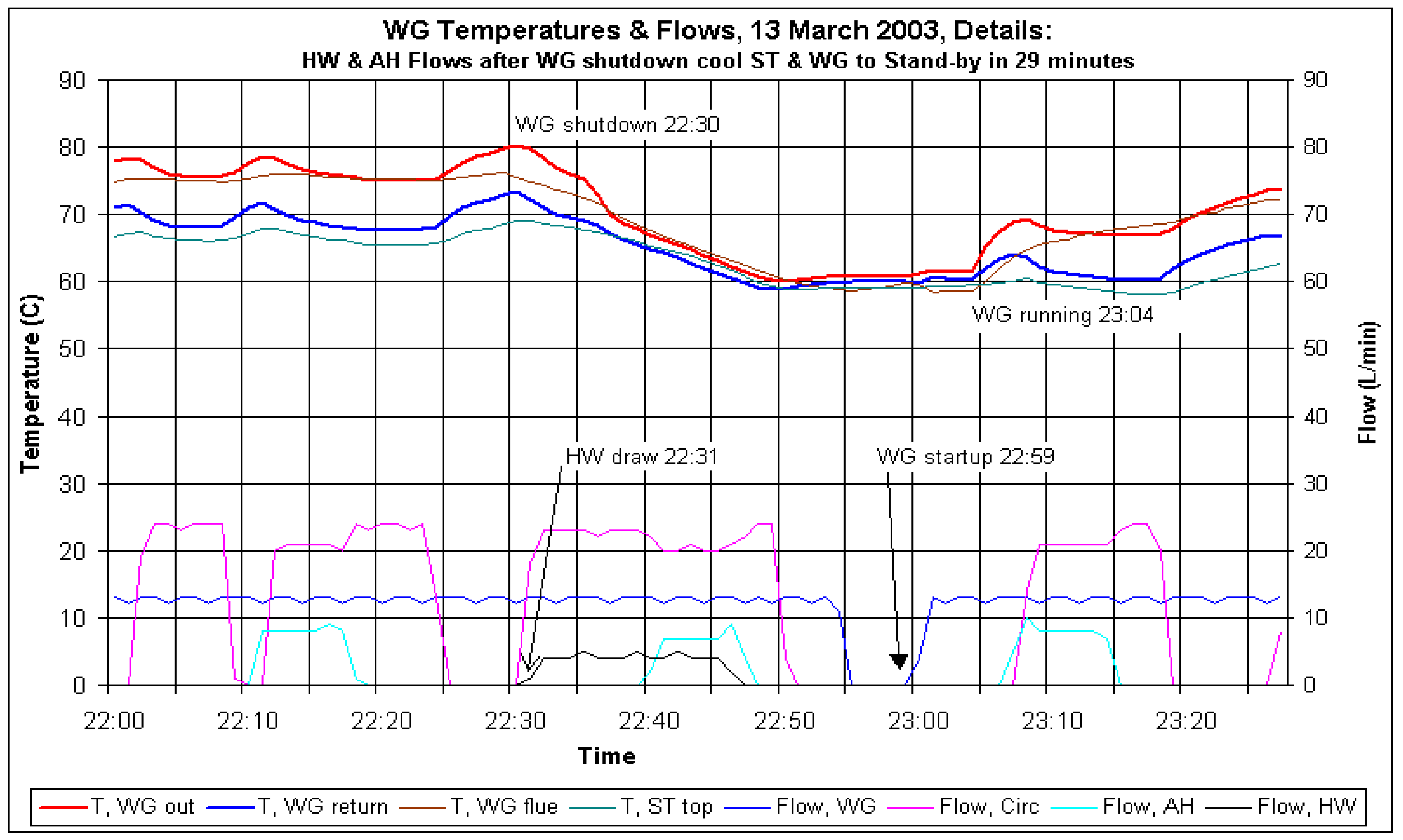
Thermal Utilization Module



SE 24hr Run - Snapshot



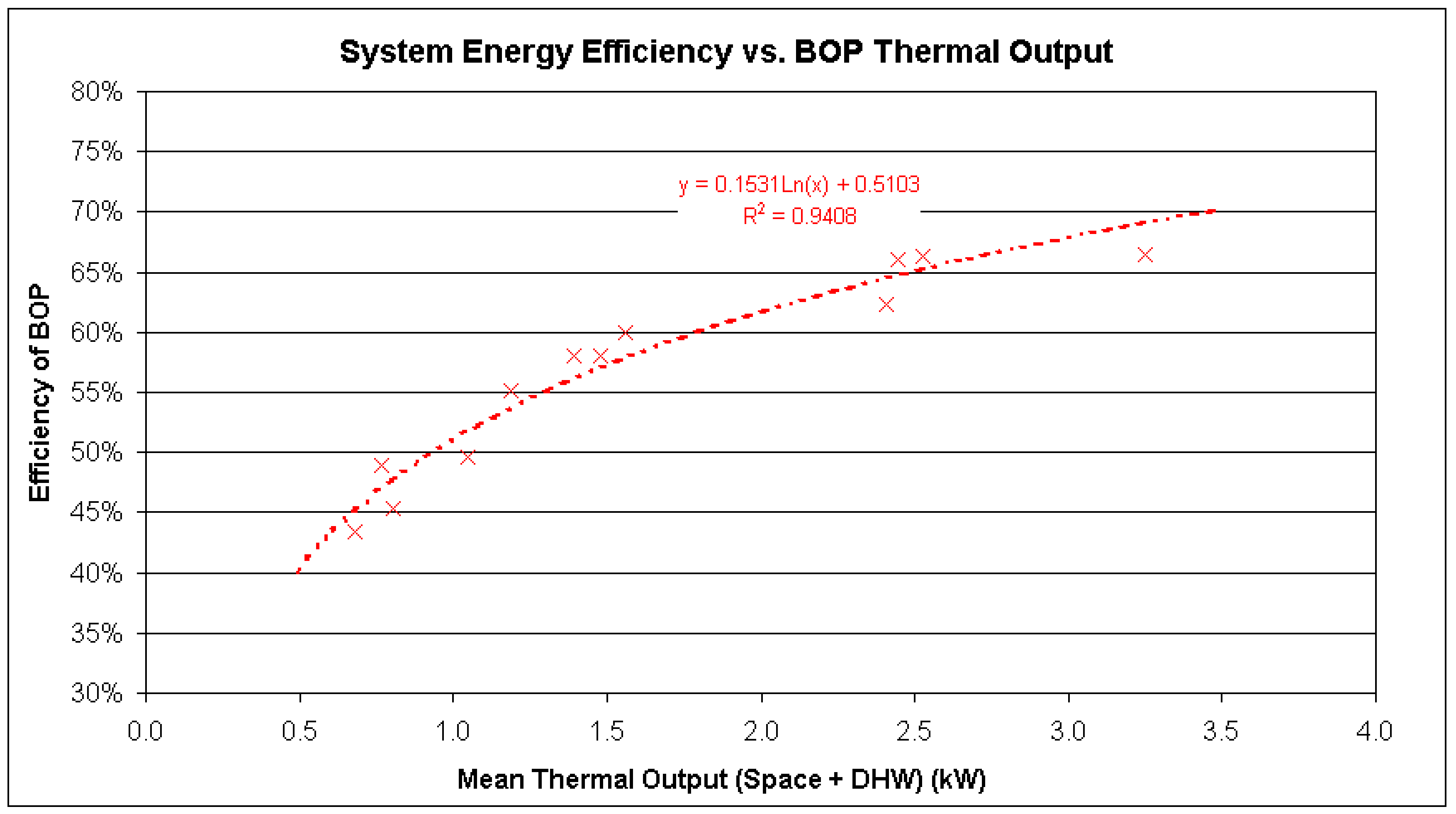
SE Operation - Snapshot



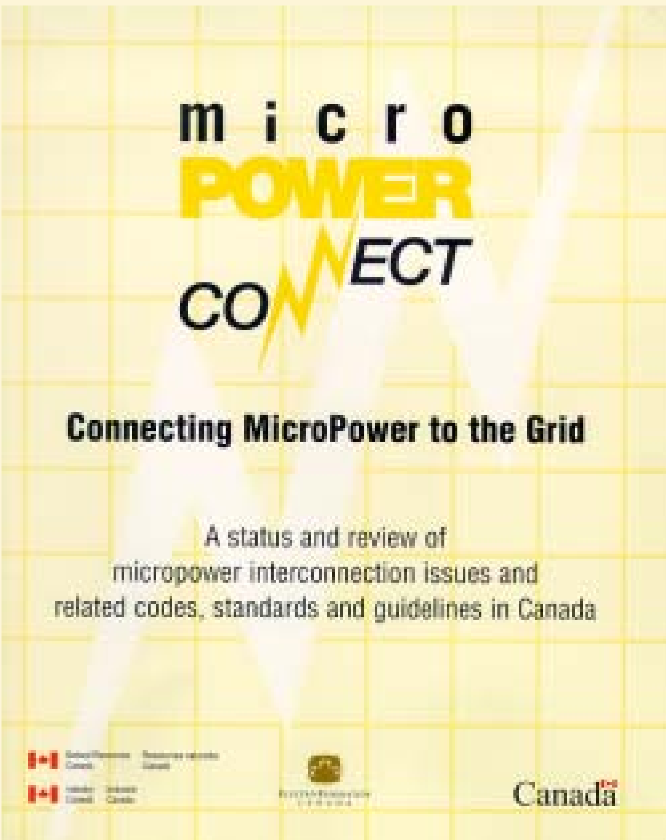
Stirling Engine Efficiencies

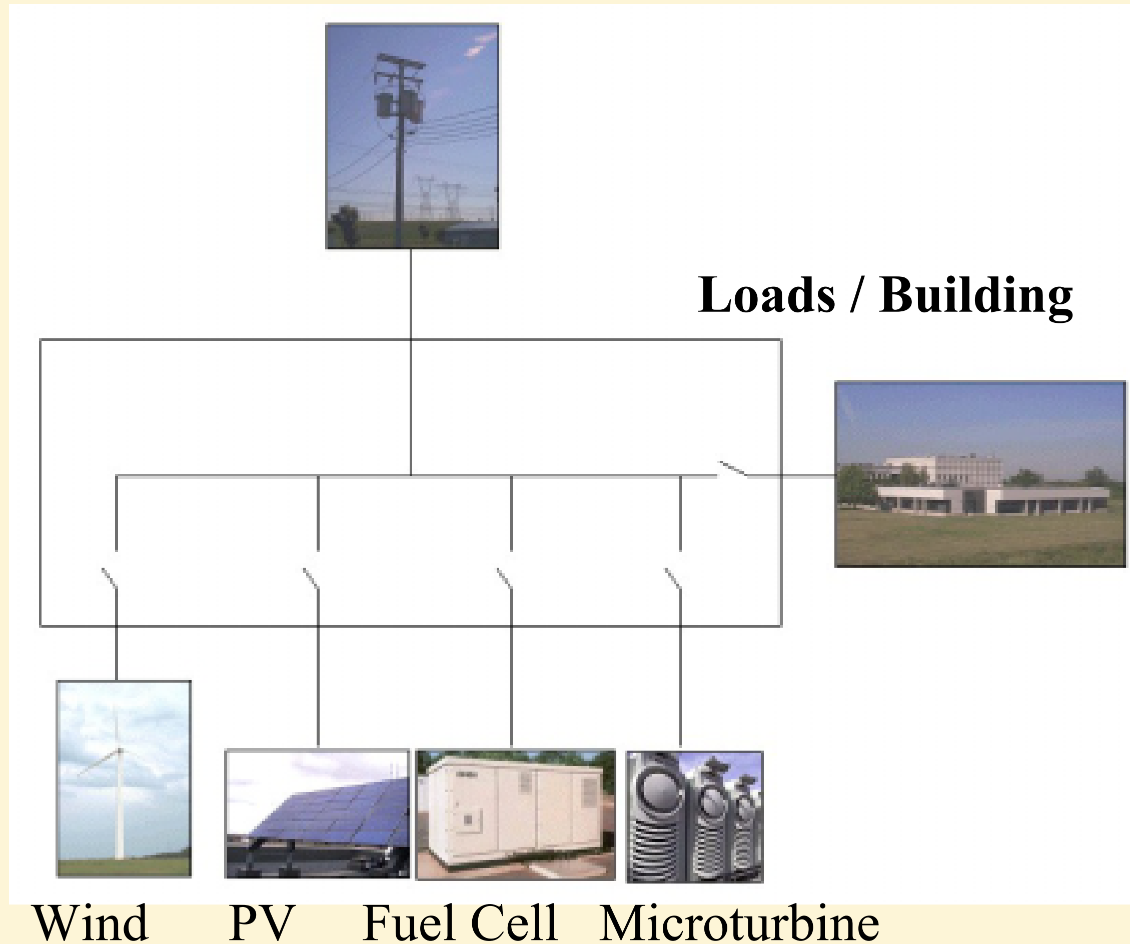
Run	Setup	Heat	Electric	Total
1	1	80.5%	8.3%	88.7%
2	2	79.6%	8.0%	87.5%
3	2	75.0%	9.0%	83.9%
4	2	76.1%	6.7%	82.8%
7	2	74.7%	7.2%	81.8%
8	2	75.3%	7.0%	82.3%
9	2	75.2%	7.3%	82.5%
11	1	76.4%	7.5%	83.9%
13	1	77.1%	7.7%	84.9%
20	1	77.9%	6.4%	84.4%
21	1	74.2%	5.9%	80.1%
22	1	74.0%	5.8%	79.7%
Minimum		74.0%	5.8%	79.7%
Mean		76.3%	7.2%	83.5%
Maximum		80.5%	9.0%	88.7%
Mean, Setup 1:		76.7%	6.9%	83.6%
Mean, Setup 2:		76.0%	7.5%	83.5%

System Efficiency vs BOP



DG on the Grid





MicroPower Connect

Objective:

Remove barriers to interconnection for small DGs by creating a synergy and developing a momentum in the industry

- Develop interconnection guidelines with respect to technical requirements on safety & power quality:
  - For inverter-based systems
  - Up to 600V

Standards' Activities

- **National:**
  - C22.2 No 107.1 General Use Power Supply (includes static inverters)
- **International:**
  - UL 1741 – Static inverters and…
  - IEC TC82-62109 – Static inverters…
  - IEC TC82-62116 – Anti-Islanding Testing…

Opportunities for micro-CHP

- The preliminary results are very promising
- Special attention should be given to the thermal utilization module design
- The development of a thermal cooling will broader the applications
- An optimal control strategy based on AI technologies should be developed
- Micro-CHP technologies have potential for very low GHG emissions

- Virtual utilities
- Effective for peak shaving capabilities
- Potential for retrofit and combination with existing energy systems
- Incremental for high efficiency
- Combination with alternative generation systems

THANK YOU!

ANY QUESTIONS?