
Current Development and Future Opportunities of the Fuel cell Mining Program
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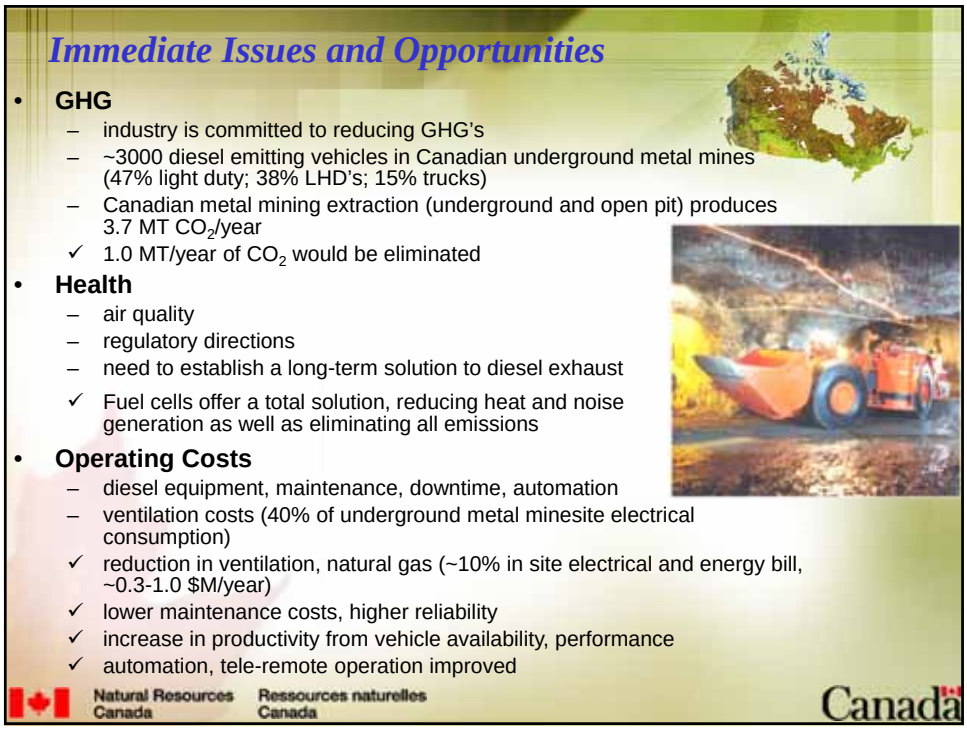
Immediate Issues and Opportunities
• GHG
– industry is committed to reducing GHG's
– ~3000 diesel emitting vehicles in Canadian underground metal mines (47% light duty; 38% LHD's; 15% trucks)
– Canadian metal mining extraction (underground and open pit) produces 3.7 MT CO_2/year
✓ 1.0 MT/year of CO_2 would be eliminated
• Health
– air quality
– regulatory directions
– need to establish a long-term solution to diesel exhaust
✓ Fuel cells offer a total solution, reducing heat and noise generation as well as eliminating all emissions
• Operating Costs
– diesel equipment, maintenance, downtime, automation
– ventilation costs (40% of underground metal minesite electrical consumption)
✓ reduction in ventilation, natural gas (~10% in site electrical and energy bill, ~0.3-1.0 $M/year)
✓ lower maintenance costs, higher reliability
✓ increase in productivity from vehicle availability, performance
✓ automation, tele-remote operation improved
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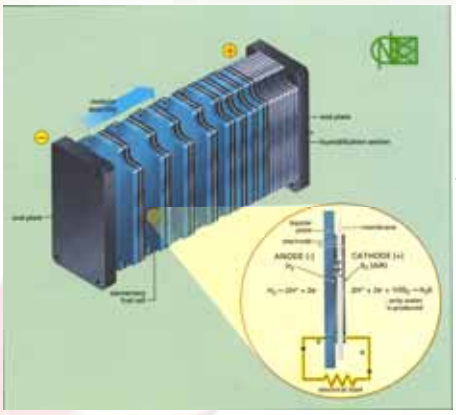
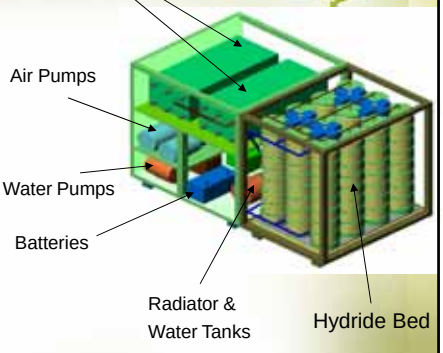
Technology



Proton exchange membrane fuel cell



Power plant
(PLC controlled)

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Technology - Current Applications

- **space missions**
- **submarines**
- **city buses**
- **large power plants**
- **residential**

- **mining first industrial sector set to gain benefits of fuel cell technology**

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CANMET MMSL Fuel Cell Mine Vehicle Initiative

- Impact of underground environments on fuel cells (C)
- Mine vehicle duty cycles (C)
- Risk evaluation methodology (C)
- Cost-benefit analysis (C)
- Mine production locomotive (C)
- Locomotive automation design & long-term testing
- Mine production loader
- Light duty mine vehicle
- Hydrogen production and delivery
- Commercial hydrogen production
- Mining regulation development
- Partial fleet testing at a mine site
- Maintenance training program

C=completed

POWER RANGE

Mine loco	15-75 kW
Light duty	50-100 kW
LHD	150-300 kW
Truck	300-500 kW

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Completed "Proof of Concept" Projects

Impact of underground environments on fuel cells 2001-02

CANMET MMSL, FPI, INCO, Ontario MOL, H-Power, Sandia

$80k value (task shared)

- dust and gas effects on the generation of electricity and on fuel cell materials
- shock and vibration effects on stack integrity

Aux. vent.

Muck pile

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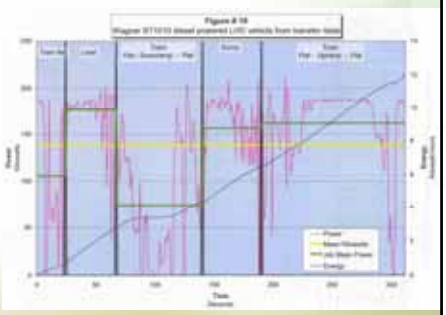
Completed Projects (cont'd)

Duty cycles 2002

CANMET MMSL, FPI, Joy, Sandvik Tamrock, Placer Dome
Cambior, Noranda, Peabody Coal
$70k value (U.S. DOE funding)

- Basis for fuel cell powerplant design
- Energy used during duty cycles, routes of production vehicles:
  - mine locomotive
  - LHD
  - coal mine shuttle car



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Completed Projects (cont'd)

Cost-benefit analysis 2002-03

		Louvicourt Mine	LaRonde Mine	Doyon Mine
Active LHD's		6	17	18
Maintenance, fuel, cooling, manpower	Diesel	$1,318,310	$2,037,100	$2,391,770
	Fuelcell	$1,501,280	$1,962,870	$2,585,950
	Benefit	($182,970)	$74,230	($194,180)
Ventilation	Diesel	$1,081,727	$2,792,036	$1,595,176
	Fuelcell	$808,796	$2,054,690	$1,171,706
	Benefit	$272,931	$737,346	$423,470
TOTAL	Diesel	$2,400,037	$4,829,136	$3,986,946
	Fuelcell	$2,310,076	$4,017,560	$3,757,656
	Benefit (%)	**$89,961 4%**	**$811,576 17%**	**$229,290 6%**
		McCreedy East Mine	**Creighton Mine**	**Copper Cliff North Mine**
Active LHD's		6	17	7
Maintenance, fuel, cooling, manpower	Diesel	$7,183,000	$321,200*	$1,814,560
	Fuelcell	$7,085,910	$618,080	$2,030,740
	Benefit	$97,090	($296,880)	($216,180)
Ventilation	Diesel	$3,375,023	$3,120,304	N/A
	Fuelcell	$2,186,441	$1,935,862	N/A
	Benefit	$1,188,582	$1,184,442	N/A
TOTAL	Diesel	$10,558,023	$3,441,504	N/A
	Fuelcell	$9,272,351	$2,553,942	N/A
	Benefit (%)	**$1,285,672 12%**	**$887,562 26%**	**N/A**

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Mine Locomotive

12 partners

*$2.4M value (U.S. DOE, NRCan ETP, * Action Plan 2000 Climate Change, Placer Dome funding, task shared)*

- ***Locomotive selection and base control design (*) (C)***
- **Evaluate reliability, response, practicality, productivity and safety (C) aspects in representative underground conditions (C)**
- **Compare to conventional battery locomotive (C)**
- **Familiarization for stakeholders (C)**
- **Regulatory tests (C)**
- **Electrolysis plant refueling tests (C)**
- **Full field tests at 2 mine sites (C)**
- **Reliability/automation (*)**

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Underground loader

CANMET MMSL, FPI, Newmont, Placer Dome, INCO, Ontario MOL, CSST Quebec, U.S. MSHA, Caterpillar Elphinstone, University of Nevada, Carleton University, Stuart Energy Systems, AeroVironment, Westinghouse Safety Management, Nuvera, HERA, HATCH

*$13M value (U.S. DOE, NRCan ETP, *Action Plan 2000 Climate Change, Placer Dome funding, task shared)*

- **Phase 1 2001-2003**
- **mine safe refueling system (C)**
- **electrolysis plant site test (*) (C)**
- **cost benefit analysis, GHG study (*) (C)**
- **preliminary design (C)**

- **Phase 2 2004-2005**
- ***power plant assembly, testing* (*)**
- **drive train testing and assembly**
- **power system integration**
- **risk assessment**
- **field tests**

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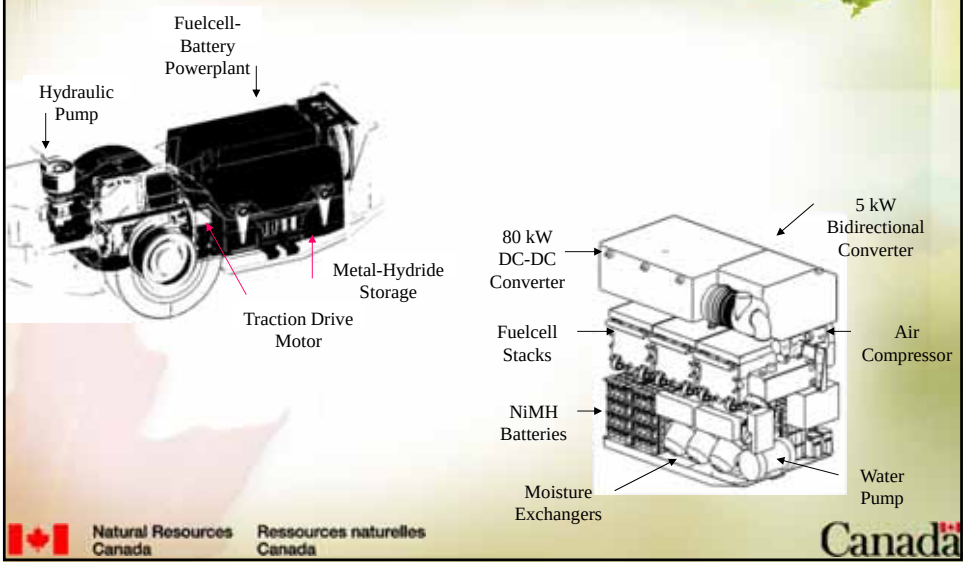
Loader Powerplant Layout



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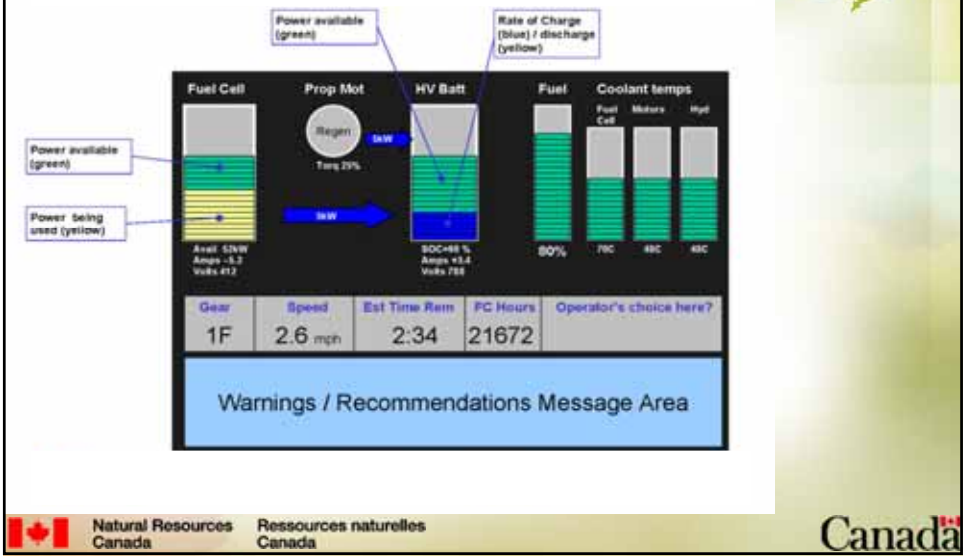
Proposed Display Screen



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Mine Utility Vehicle

CANMET MMSL, INCO , SIFTO Salt, Ontario MOL, CSST Quebec, HYDROGENICS, HATCH
*$2.6M value (NRCan Canadian Transportation Fuel Cell Alliance, *Action Plan 2000 Climate Change, task shared)*

- **Phase 1 2004**
  - **Fuel cell power module (*) (C)**
  - **Power requirements, hybridity**
  - **Power plant design**
  - **Risk assessment**

- **Phase 2 2004-2005**
  - **Components manufacturing/purchasing**
  - **Vehicle assembly**
  - **Power plant integration, safety, operator interface**
  - **Factory performance**
  - **Mine site testing**

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Future Mining Opportunities

- **New Mining Approaches: Power**
  - power when and where needed
  - fuel cell power plant size evolution
  - universal power for underground use?
- **New Mining Approaches: Extraction Technology**
  - consideration of extraction approach based on technology
  - higher degree of tele-remote mining
  - continuous 24hrs/day
- **High Impact Example:**
  - narrow vein mining is becoming more mechanized
  - smaller vehicles can be considered

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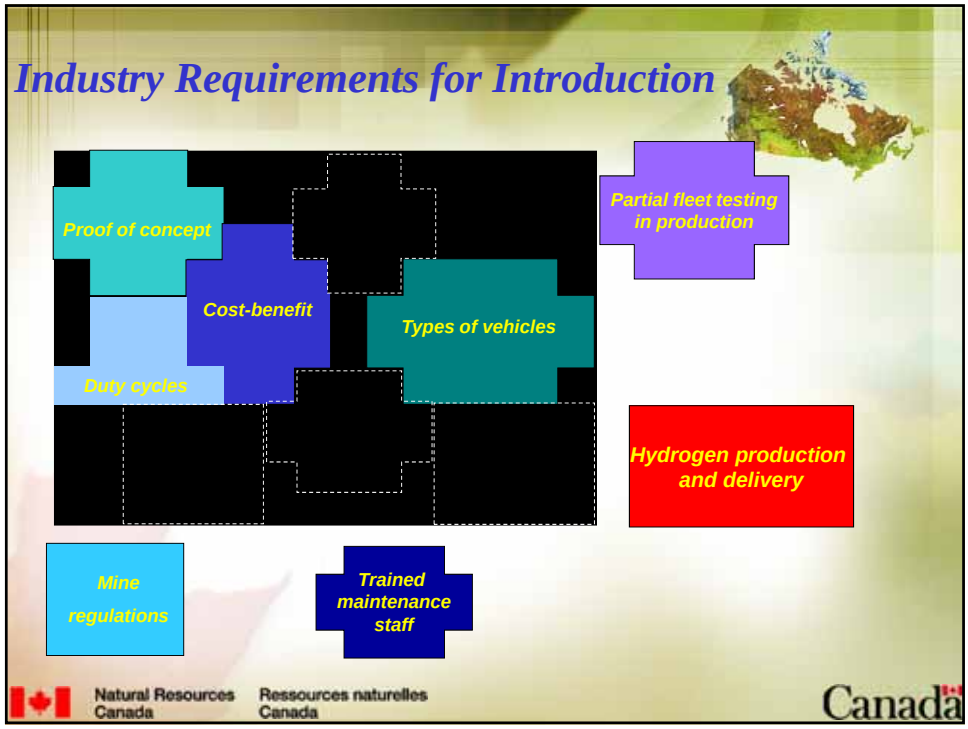
Industry Requirements for Introduction



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Timeline

2000-2005	Demonstrator projects finished
2002-2005	Establishing hydrogen production and delivery protocols
2006 ⇨	Retrofit of some diesel equipment
2007-2008 ⇨	Partial fleet dedication to fuel cells
2008 ⇨	New fuel cell vehicles generation designed and manufactured
2009 ⇨	Major fleet changeover

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Summary

- **Fuel cell technology is being applied to power mine production vehicles**
- **It addresses four important industry issues**
  - improved health benefits
  - automation, higher productivity, lower mine costs
  - reductions in GHG's
  - reduction in energy consumption (electricity, natural gas, diesel)
- **Mine stakeholders, mine regulators, technology developers and governments are participating**
- **Proof of concept projects near completion**
- **Issues to meet introduction requirements being addressed**
- **Significant operating cost savings anticipated, even for deep mines**
- **Other conceptual applications and contributions to mining are being developed**

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