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Véhicules électriques et hybrides rechargeables
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PHEV-Québec Test Program: A Real-World Test Study on Financial, Technological and Social Aspects of PHEVs.

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EMC MEC
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Mobilité électrique Canada

Content

1. **PHEV-Québec test program main focus.**
2. First results: Performance comparison between a Li-based PHEV and a HEV (May 08 – August 09)
3. Second results: cost & performance between Li-based PHEV & Pb-acid based PHEV

PHEV market potential and viability: a need for more real-world, large-scale field studies.

- PHEV cost-benefit equation is strongly affected by a range of factors that cannot easily be taken into account in models or laboratory tests. Examples:
  - Driving habits affect PHEV fuel economy and price,
  - Climate affects PHEV performances and costs,
  - Consumer behaviour in charging situations,
  - Real impact on the utility grid,...

- **A need for more real-world, large-scale studies.**

PHEV Québec test program contribution.

PHEV Québec project overview.

- PHEV Québec test program aim:

  Examine PHEV market potential viability taking into account engineering, V2G, environmental and economical concerns, by conducting real-world field tests.
- How?

  Experimental studies on a PHEV fleet owned by real consumers.
- Where?

  Université Laval, Québec city, Canada. Central position, 35 000 people, independent electrical grid, large temp. gradients climate.
- Who?

  A team of engineers and financial analysts with industrial (ModEnergy, Bell Mobility, Hydro-Quebec) and financial partners (Desjardins).

PHEV Québec project overview.

- Université Laval's campus infrastructure:

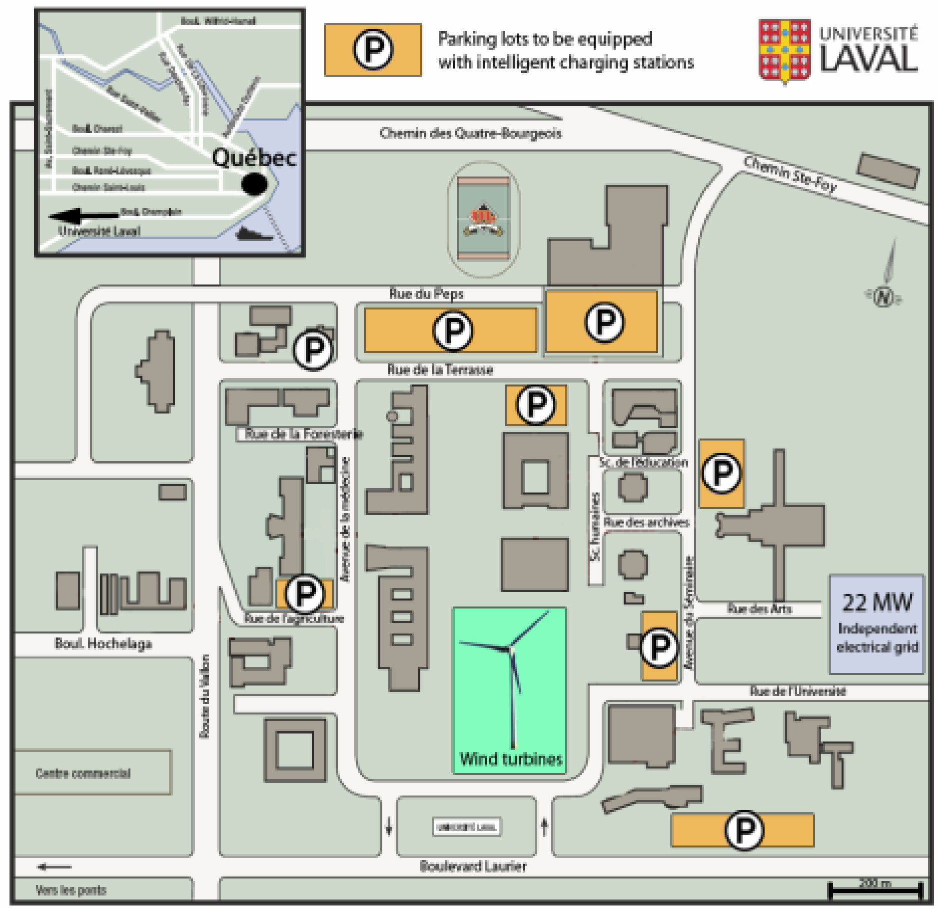
- 22 MW electrical grid capacity;

- Isolated from the public grid;

- Installed wind turbines ;

- 6 MW controllable load resistor (boiler) ;

- Many parking lots ;



Engineering concerns:

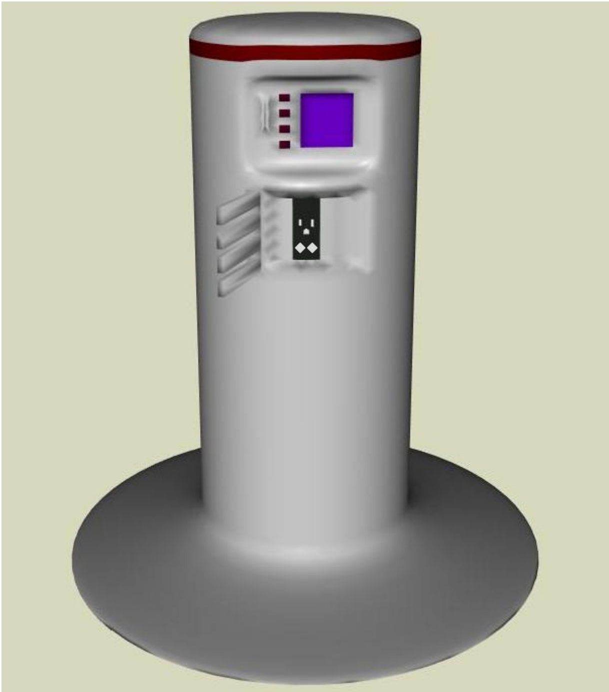
Goal: conduct field tests to determine optimal PHEV systems patterns.

- Build a PHEV fleet (50 PHEVs over 5 years) from existing HEV platforms. Ex: Toyota Prius.
- Consider different battery techno. & various battery pack sizes.
  ➡ **Identify optimal trade-offs.**
- Evaluate the impact of the climate on PHEV performances.
  ➡ **Québec's climate = large temperature gradients.**
- Study driver – PHEV interactions.
  ➡ **Identify driving trends & optimal PHEV systems.**

Charging stations installation & development

Goal: Achieve real bi-directional energy exchanges with the university's electrical grid.

- Bi-directional charging stations with slow & fast-charging rates.
  - ➡ **Experience real energy flows.**
  - ➡ **Experiment grid support.**
- Charging stations will be equipped with energy management and billing systems.
  - ➡ **Evaluate customer charging behaviours.**
  - ➡ **V2G technologies testing.**



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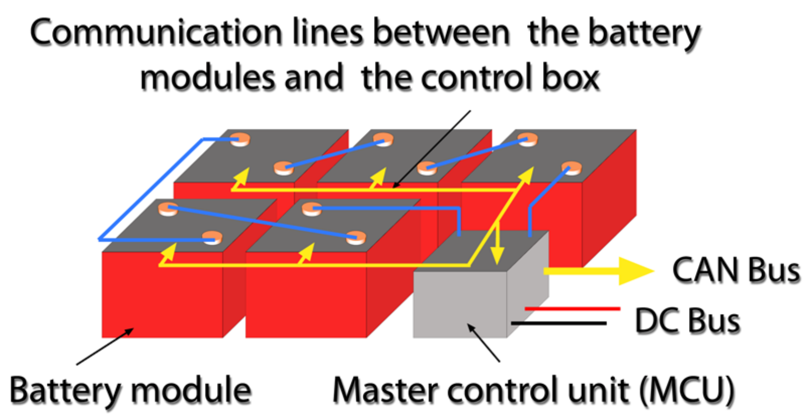
PHEVα characteristics.

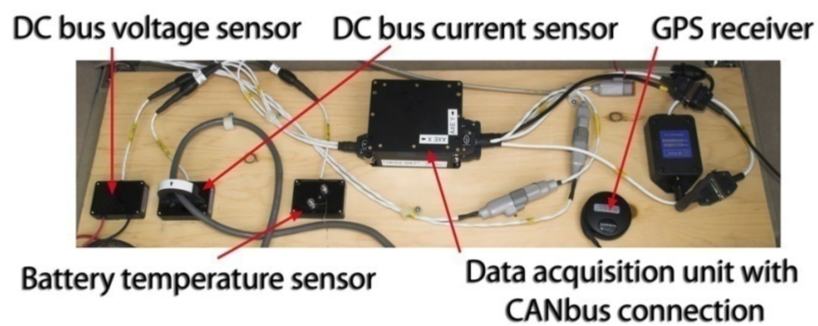
- PHEVα is equipped with a Li-Ion battery pack:

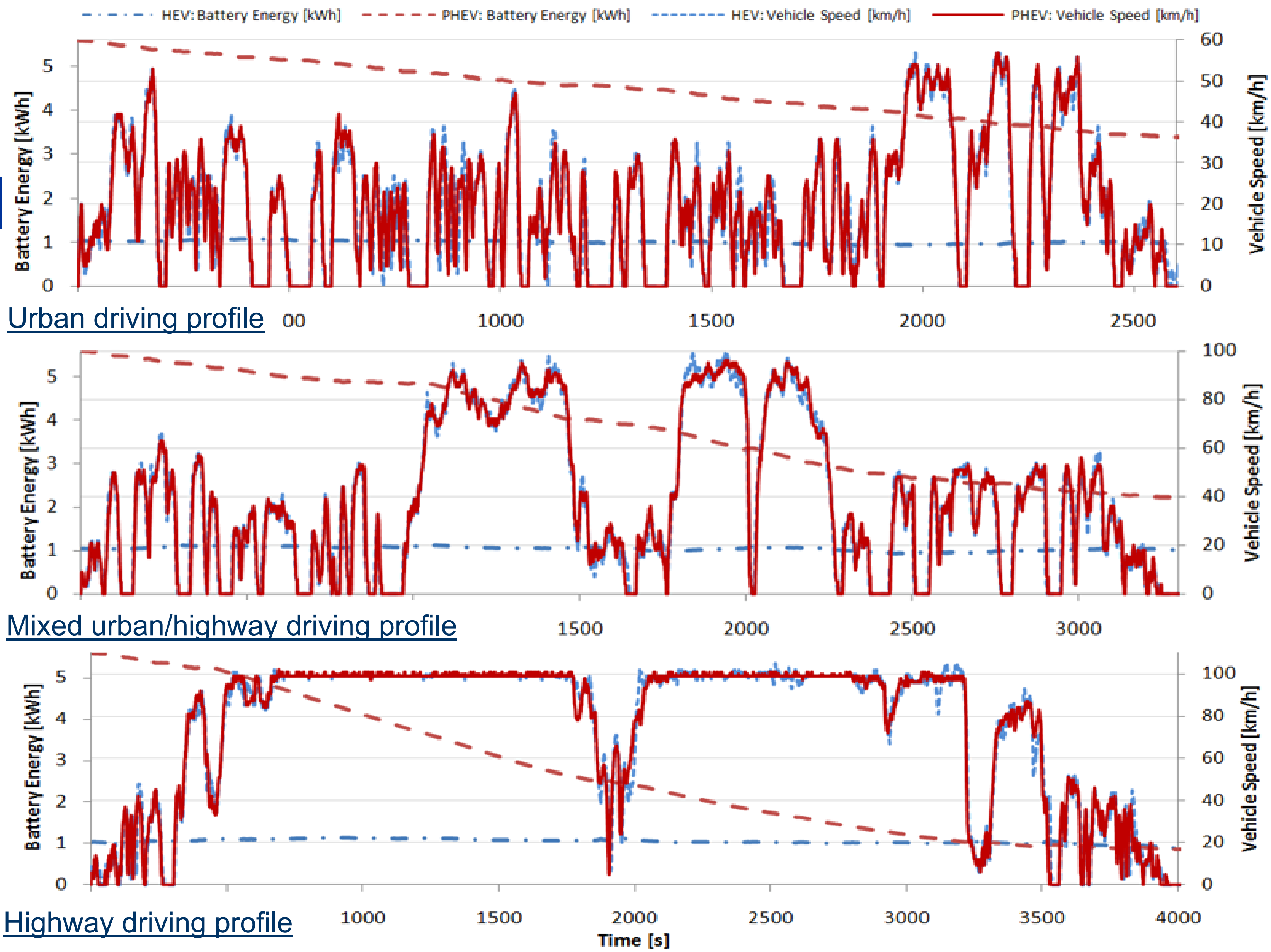
  - 5.6 kWh Li-Ion Manganese,
  - 5 48V/24Ah battery modules,
  - A master control unit manages energy flows & broadcast data,
  - Onboard 120V/800W charger.



Field test procedure.

- Performance comparison involving PHEVα and a non-converted Toyota Prius 2005.
- Datalogging system in both cars (CANBus, battery current/voltage, GPS, vehicle fuel cons.).
- Fuel cons. & battery energy use monitored for 3 driving profiles: urban, mixed, highway.
- Snowy conditions & temperature between -10 ºC & 0 ºC.




HEV: Battery Energy [kWh]
PHEV: Battery Energy [kWh]
HEV: Vehicle Speed [km/h]
PHEV: Vehicle Speed [km/h]
Battery Energy [kWh]
Vehicle Speed [km/h]
Urban driving profile
Mixed urban/highway driving profile
Highway driving profile
Time [s]

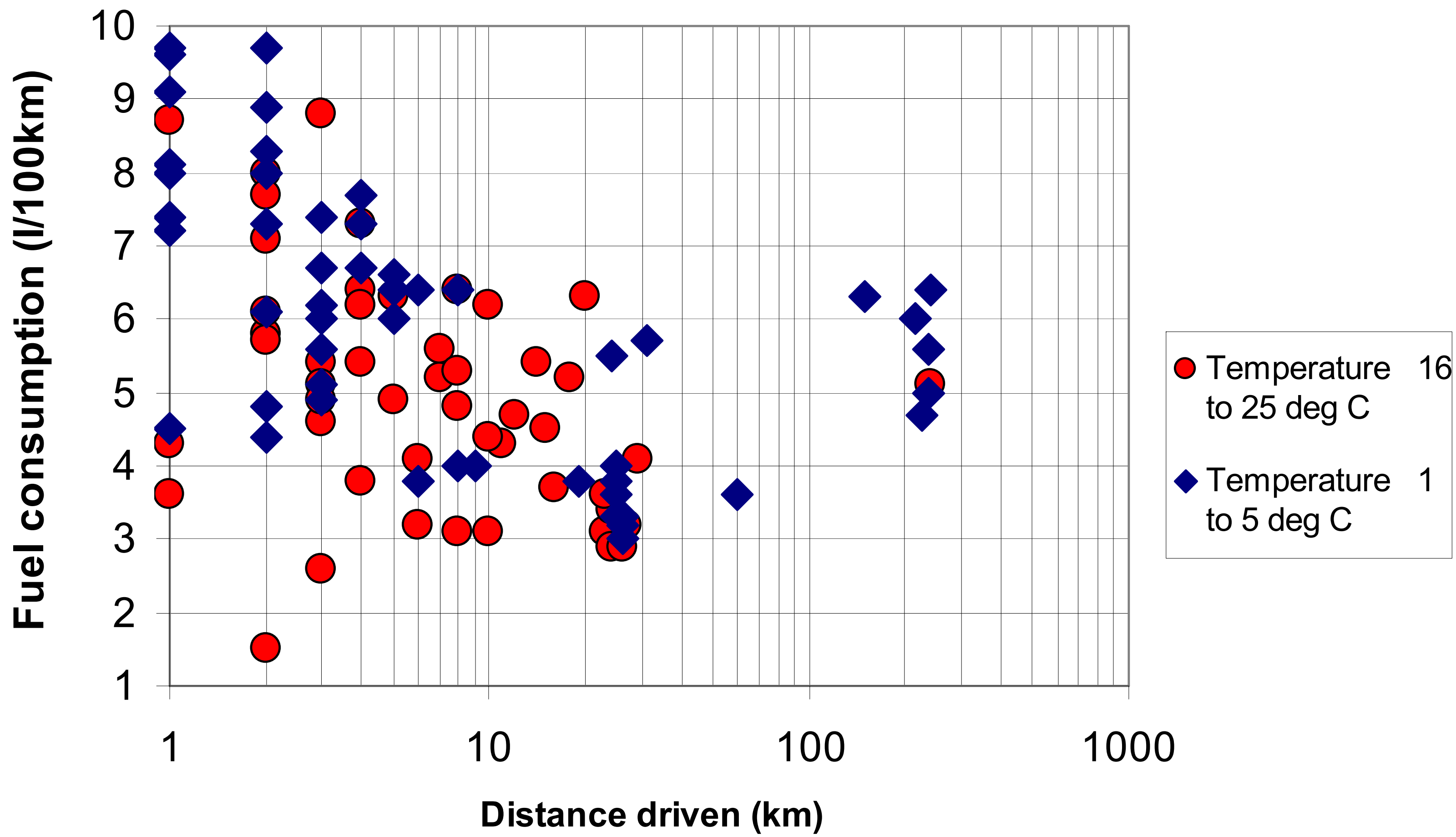
Comparison tests results: PHEV vs HEV

		Urban Cycle (14.5 km)	Mixed Cycle (35.6 km)	Highway Cycle (84.3 km)
Mean fuel consumption	PHEV [L/100 km]	5.00	3.62	3.88
	HEV [L/100 km]	7.72	5.93	5.46
	Gain	35 %	39 %	29 %
Battery energy use	PHEV [kWh]	2.22	3.38	4.73
	PHEV DoD*	40 %	60 %	84 %
	PHEVα	**Highest cycle life**	**Best fuel efficiency**	*DoD = Depth of Discharge

- Highest fuel cons. for shorter trips: cold start-sequences.
- Lower fuel cons. has been obtained in different test conditions.
- The size of the battery pack should be chosen based on driver's use to minimize fuel cons. & maximize battery cycle life.

Test results : PHEV only

PHEV Fuel consumption for various distances and temperature conditions



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Batteries: a few facts

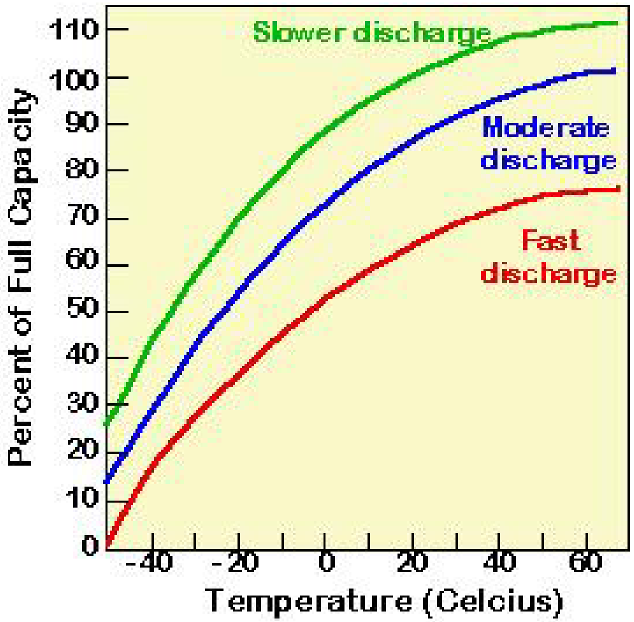
Lithium batteries

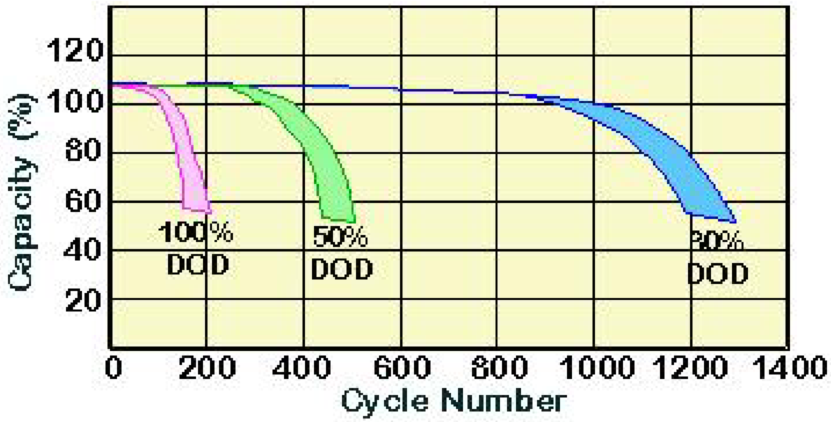
- PHEV-α showed a 2.0 – 2.5 l/100 km fuel saving
- Cost of Li batteries around 1000 $ /kWh
- Number of charge/discharge cycles around 2000
- For 5.6 kWh batteries: cost around 6000 $ and fuel saving is optimal for runs between 20 km to 60 km.
- @ 1 $/ litre for gasoline, daily commuting with runs of 60 kms per day will result in yearly fuel savings of 550 $ and in yearly battery wear of 1100 $!
- Cost of battery wear around 50 cents/kWh >> cost of electricity

Batteries: a few facts

Lead-acid batteries

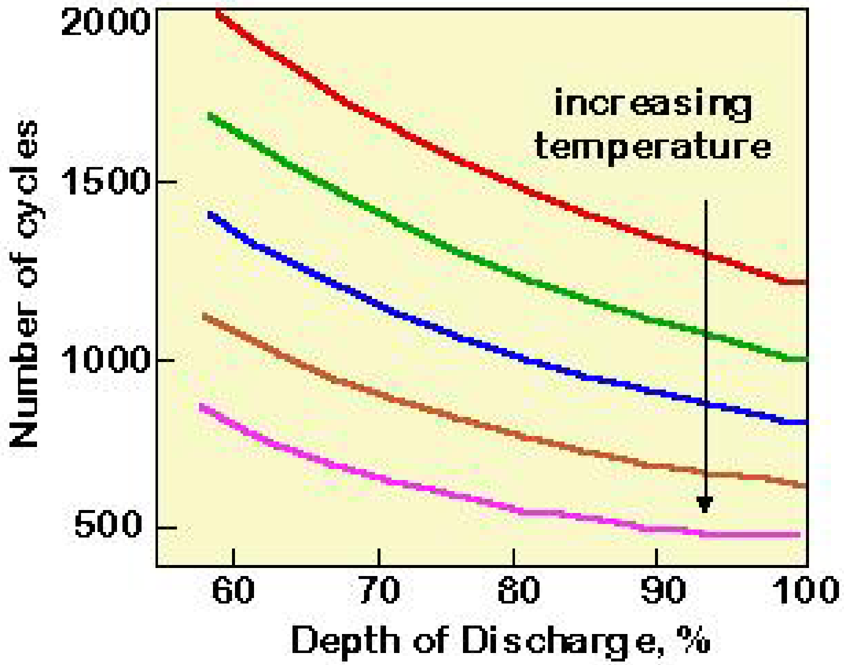
- Cost of Lead-Acid batteries is much lower, around 100 $ /kWh
- However : number of charge/discharge cycles is low



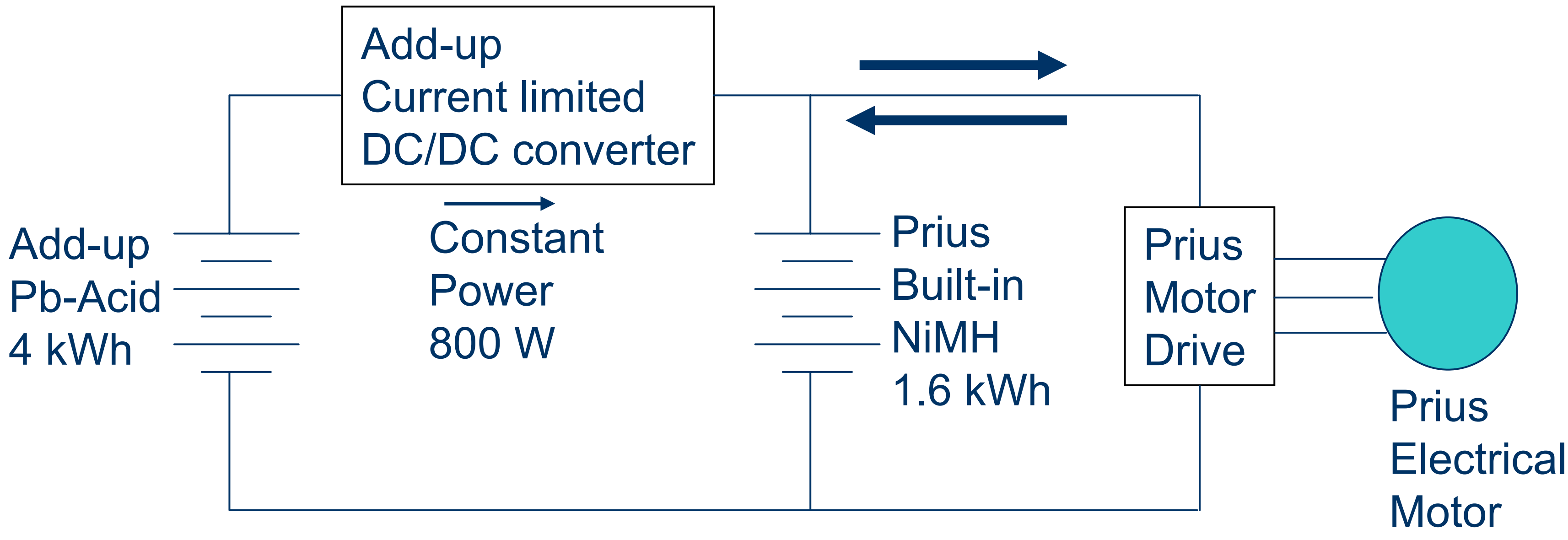


Batteries: a few facts

Lead-acid batteries: influence of temperature and DoD on the number of cycles



PHEV-β: Prius with Lead-Acid & NiMH



PHEV with current limited lead-acid battery

Preliminary results with Pb-Acid batteries

- PHEV-β showed a 1.0 l/100 km fuel saving when current limited at C/5
- Cost of lead-acid batteries around 100 $ /kWh
- Number of charge/discharge cycles around 1500 when current limited at C/5 and DoD limited at 50%.
- For 4.0 kWh batteries: cost around 400 $.
- @ 1 $/ litre for gasoline, daily commuting with runs of 60 kms per day will result in yearly fuel savings of 220 $ and in yearly battery wear of 100 $!
- Cost of battery wear around 15 cents/kWh

Conclusion:

- PHEV-Québec: A University campus is ideal for testing new technologies involving distributed electrical charging.
- 2 Toyota Prius have been converted to PHEV with Lithium batteries (PHEV-α) and lead-acid batteries (PHEV-β).
- Substantial fuel savings (2.5 l/100 km) are observed for runs between 20 km and 60 km using 5.6 kWh Lithium battery.
- PHEV long life lead-acid batteries are achievable when DoD and battery current are closely monitored and controlled, with fuel savings around 1 l/100 km.
- More economical studies with various battery types and sizes are needed, which should consider the whole range of variables.