Cold Weather Travel Range and Energy Consumption of the Chevrolet Volt PHEV

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Outline

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- Motivation
- Test Methods & Results
- Next Steps & Conclusions
- Acknowledgements

Introduction

- For electric vehicles, the effect of **operating under variable climate conditions** is important to understand, particularly in cold climates where ambient temperatures can plunge to relatively low levels

- The **impacts of cold weather** are still not quantitatively well characterized. This applies to **electric travel range** available on a single charge and the **electrical energy consumption**

Introduction – Red River College

- Manitoba's largest institute of applied learning
- Ranked Top 10 Canadian Research College
- Electric Vehicle Technology & Education Centre (EVTEC)
- Leads the College engagement in battery electric transit bus project

CANADA'S TOP 50 RESEARCH COLLEGES 2014 RESEARCH Infosource

EVTEC ELECTRIC VEHICLE TECHNOLOGY & EDUCATION CENTRE

Applied research | **Public outreach** | **Education**

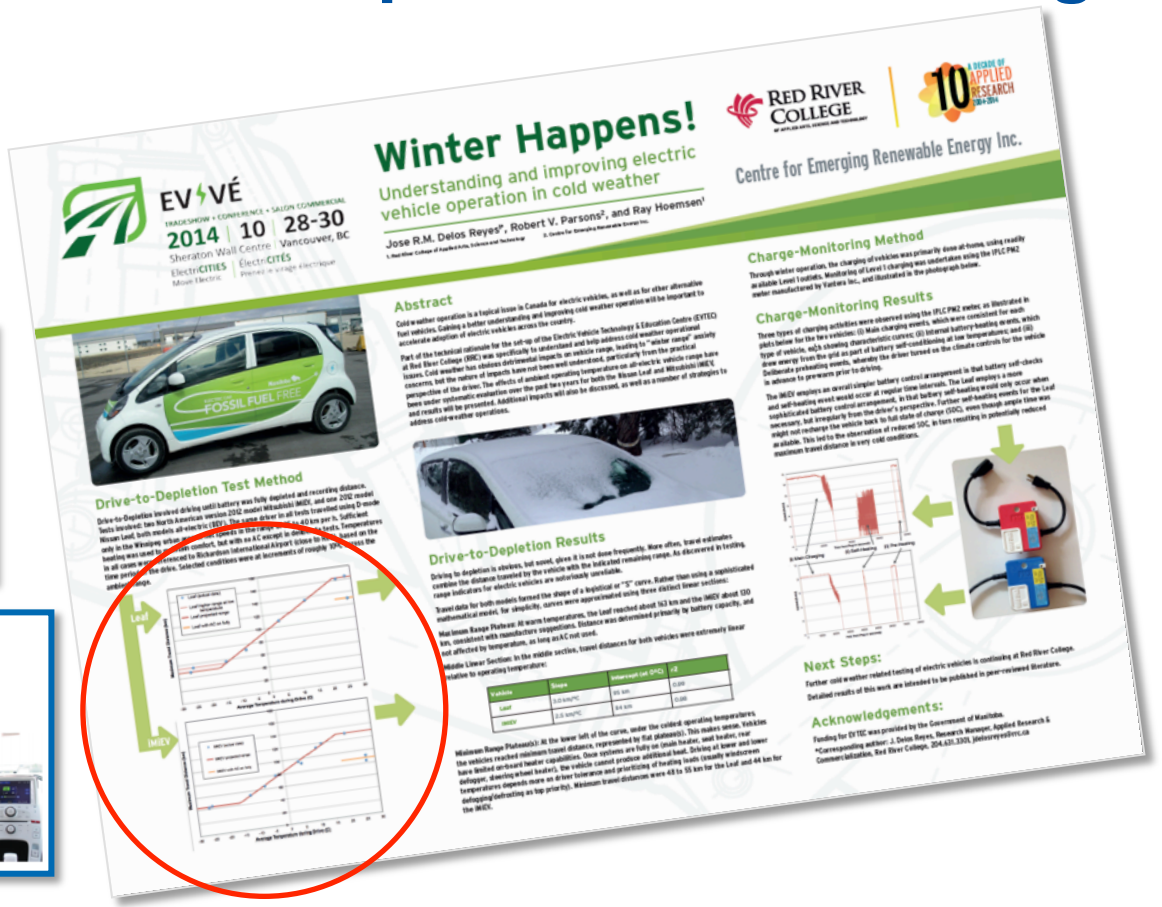
Introduction - EVTEC

Demonstration/cold weather performance testing

All-Electric
Mitsubishi iMiEV in Manitoba

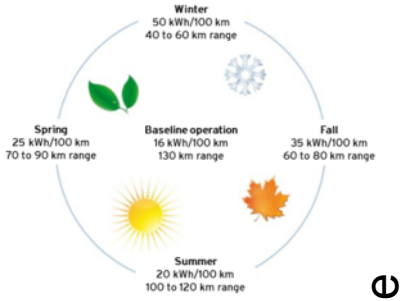
All-Electric
Nissan Leaf in Manitoba

Plug-in Hybrid Electric
Chevrolet Volt in Manitoba

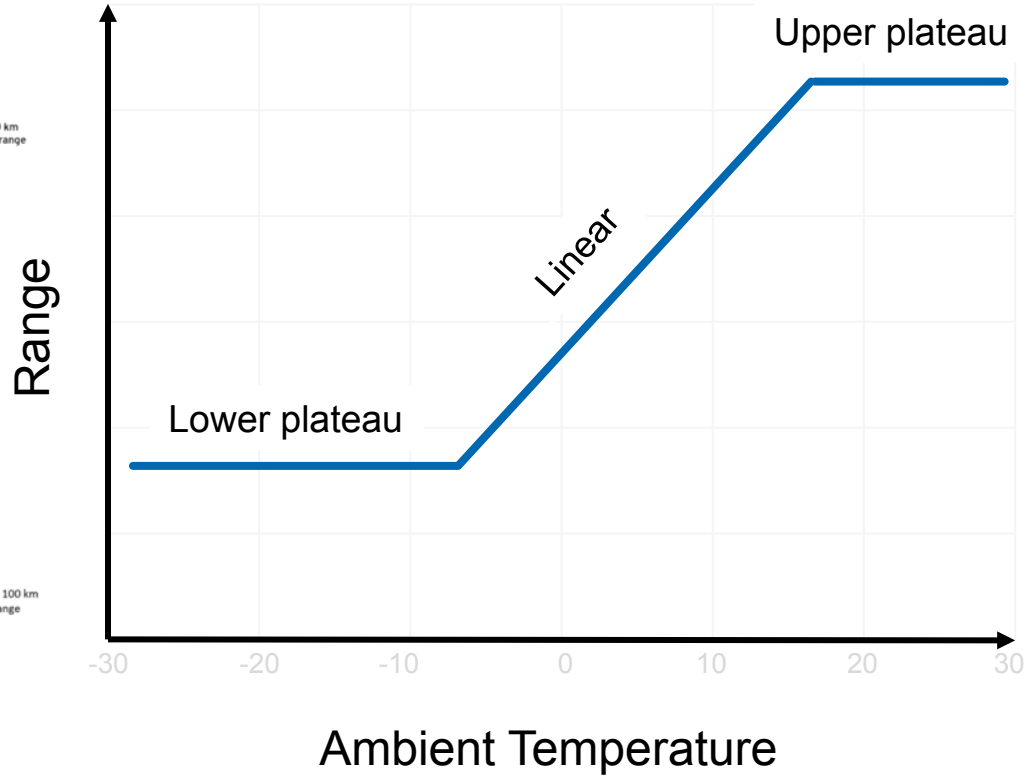


EVTEC Range Model

Mitsubishi iMiEV



Nissan Leaf



Winnipeg climate data

Avg Lo (°C)	Month	Avg Hi (°C)
-21.4	Jan	-11.3
-18.3	Feb	-8.1
-10.7	Mar	-0.8
-2.0	Apr	10.9
4.5	May	18.6
10.7	Jun	23.2
13.5	Jul	25.9
12.1	Aug	25.4
6.4	Sep	19.0
-0.5	Oct	10.5
-9.2	Nov	-0.5
-17.8	Dec	-8.5

Motivations

- Operation of electric vehicles (EV) in cold weather is a growing concern
  - Impact on travel range and energy consumption is not well characterized
- Need to provide a simple but realistic information to consumers on EV performance in order to permit informed purchase decisions
- Range and energy consumption measurements based on standards (SAE J1634) are costly and technically challenging
- Winnipeg's climate and geographical location is ideal as an 'ambient test bed'

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Vehicle Specification

Item	Specification
Dimensions	4.5 m long × 1.8 m wide × 1.4 m high
Curb weight	1.7 tonnes (3,800 lb)
Turning radius	5.5 m
Electric motors	111 kW output primary motor 55 kW output secondary motor (permanent magnet-based)
Back-up engine	1.4 L EcoFLEX 63 kW output at 4,800 rpm
Fuel tank size	35 Litres
Battery	Lithium-ion chemistry 16 kWh total capacity; 10.4 kWh usable
Maximum speed	190 km per hour (limited duration)
Range (all-electric)	Target all-electric range more than 70 km, with practical expected range of 56 km, based on U.S. EPA testing protocol
Additional range (back-up engine)	Up to range of 610 km with full liquid fuel tank

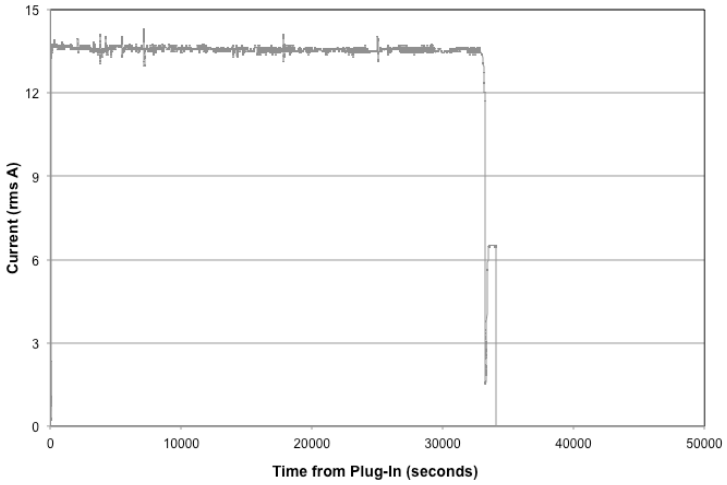
2012 Chevrolet Volt

Test Methods – Travel Range

- "Driving-to-depletion" involves driving the vehicle from full state-of-charge (SOC) until depleted (*June 2013 through March 2015*)
  - Travel distance were obtained by recording odometer difference
- Similar travel route was employed across urban area of Winnipeg with 50,60,70 and 80 km/h speed limits
- Same driver operated the vehicle in all cases
- Headlights and wipers were avoided
- For tests with AC On, it was deliberately set to maximum setting
- For tests with AC Off, climate control set to +21°C

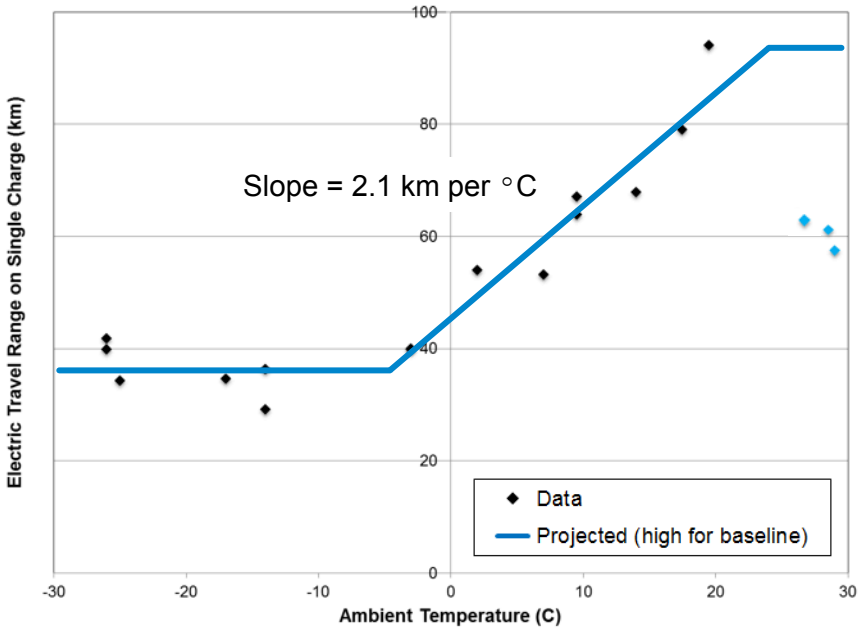
Test Methods – Energy Consumption

- Charging was primarily done at home using Level 1
- Monitoring of energy input during charging was done at **wall plug** using IPLC PM2
  - CSA approved device
  - Logs voltage and current and real power per second



Results – Travel Range

- There were 17 drive to depletion test covering the full range of temperature and operating condition
  - Strong correlation coefficient between electric range and ambient temperature on linear segment
- Directly verified the lower range plateau behaviour for the Volt
  - It was observed to switch back and forth between electric and gasoline operation



- Results reasonably fit the EVTEC range model

Results – Travel Range

- On the lower plateau, there were nine test from -3°C to -26°C
  - On these conditions, there was no correlation of travel range to ambient temperature
- Electric travel range averaged **36.6 ±4.1km**
  - Statistically similar to range of 41km reported by Loiselle-Lapointe [1]
  - Higher but relatively consistent with the coldest temperature range of 31.5 km reported by Idaho National Lab [2]
- The ratio of travel range was approximately **46%** compared to baseline

Results – Energy Consumption

- Energy consumption at baseline was consistent and close to official values (19.9kWh/100km)
- Fully on AC increase consumption to 26.7kWh/100km
- Under cold conditions, energy consumption was increased significantly to 41.9kWh/100km
- The Volt strongly followed an inverse relationship between energy consumption and travel range.

Operational Case	Energy Consumption (kWh per 100 km)
Testing at baseline conditions	19.9 ± 2.1 (n = 5)
Testing with AC fully-on	26.7 ± 0.5 (n = 3)
Testing at cold conditions	41.9 ± 4.5 (n = 9)
Official value EPA/DOE [3]	21.9
Official value NRCan [4]	22.3

Operational Case	Ratio to Baseline Conditions	
	Travel Range	Inverse Energy Use
AC fully-on	0.75	0.76
Cold conditions	0.46	0.47

Next Steps - Future Testing

- The results derived were based on simplified testing and was obviously limited in terms of repeatability
  - Results are still useful in providing preliminary indication of expected practical performance
- Future testing will be done on EVs including the Volt
  - Verify plateau characteristics of max and min travel ranges
  - Confirm linear variation of travel range with temperature in the middle of the proposed model
  - Investigate upper and lower breakpoints
  - Explore much lower temperature
  - Further evaluate relationship between range and energy use

Conclusion

- The Volt conforms to the simple range model developed by EVTEC but with a lower plateau being a bit different as compared to BEVs
- Operation is significantly affected by cold weather but in a predictable way
- The Volt does conform to an inverse relationship between travel range and energy consumption
- More testing is required to further validate the proposed simplified model

Acknowledgements

Robert V Parsons MBA, PhD

Centre for Emerging Renewable Energy Inc.

Manitoba

Advanced Energy Projects, Energy Division
Manitoba Department of Municipal Government

References

[1] A. Loiselle-Lapointe, A. Conde and H. Ribberink, “Chevrolet Volt on-road test programs in Canada, Part 1: Effects of drive cycle, ambient temperature and accessory usage on energy consumption and electric range,” in *The 28th International Electric Vehicle Symposium and Exposition* (EVS28), Goyang, Korea, May 3-6, 2015.

[2] J. Smart, “Testing Activity – Cold Weather On-road Testing of a 2012 Chevrolet Volt,” Idaho National Laboratory, Report # INL/EXT-14-34030, Idaho Falls, ID, December, 2014. http://avt.inl.gov/pdf/phev/2012VoltColdWeatherTestReport.pdf

[3] U.S. EPA and U.S. Department of Energy (EPA/DOE), “Fuel Economy Guide, Model Year 2012,” 2014 (updated). http://www.fueleconomy.gov/feg/pdfs/guides/FEG2012.pdf

[4] Natural Resources Canada (NRCan), “Fuel Consumption Guide 2012,” 2012.http://oee.nrcan.gc.ca/transportation/tools/fuelratings/fuel-consumption-guide-2012.pdf

Thank you for your attention…