Impacts of Mileage Accumulation and Charge Rate on EV Range and Energy Usage

Interim Status Update for the 22nd UN ECE EVE IWG Meeting
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Transport Canada's ecoTECHNOLOGY for Vehicles (eTV)

- eTV tests, evaluates and provides expert technical information on advanced light-duty vehicle (LDV) and heavy-duty vehicle (HDV) technologies that are available or anticipated to be available in the Canadian market over the next 10-15 years.

- eTV program testing and evaluation results:
  - guide the proactive development of codes, standards, and regulations;
  - support the development of non-regulatory industry codes and standards that anchor industry efforts to integrate new vehicle technologies.

- eTV testing priorities are focussed on addressing knowledge gaps, particularly where new innovations have potential environmental or safety implications.

- Current eTV LDV projects deal with a range of technologies such as electric vehicles, advanced aerodynamic devices, low rolling resistance tires, advanced ICEs, alternative fuels, and hydrogen fuel cell vehicles.

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Introduction and Objectives

- **Previous Studies**
  - A 2012 study found reduced driving range for a BEV after mileage accumulation of 12,000km in Ottawa
  - A 2015 INL/Intertek study quantified BEV battery capacity loss at between 25% and 35 % with 80,000km accumulated in a hot climate (Arizona)
    - Accelerated capacity loss with DCFC and hot ambient temperatures

- **Objectives of this Study**
  - Evaluate the impact of mileage accumulation on the usable battery energy (UBE), full-recharge energy (FRE), FRE_{DC}, range and energy consumption (ECdc) of a 2015 BEV
  - Investigate how fast charging (DCFC) affects these performance metrics
  - Investigate the impact of cold temperature mileage accumulation

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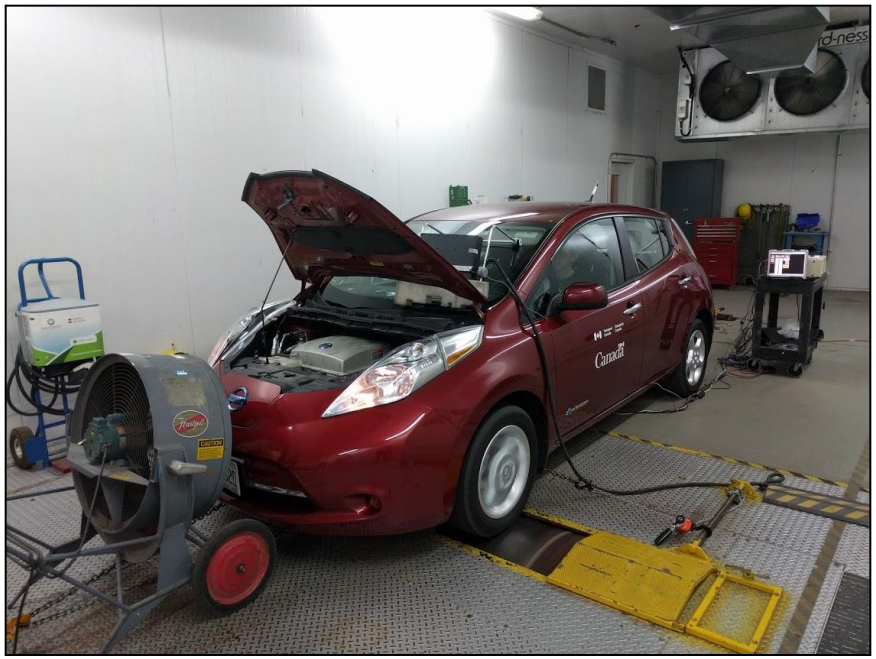
Test Design

- 2 identical 2015 model year BEVs
  - BEV1 charged exclusively on DCFC
  - BEV2 charged exclusively on SAE AC Level 2 (ACL2)
- Mileage accumulation on-road in Ottawa
- CAN bus data and thermocouples to capture operation metrics, including cabin temperatures
- Dynamometer testing at each ~15,000km intervals, with initial baseline testing at 1,600km



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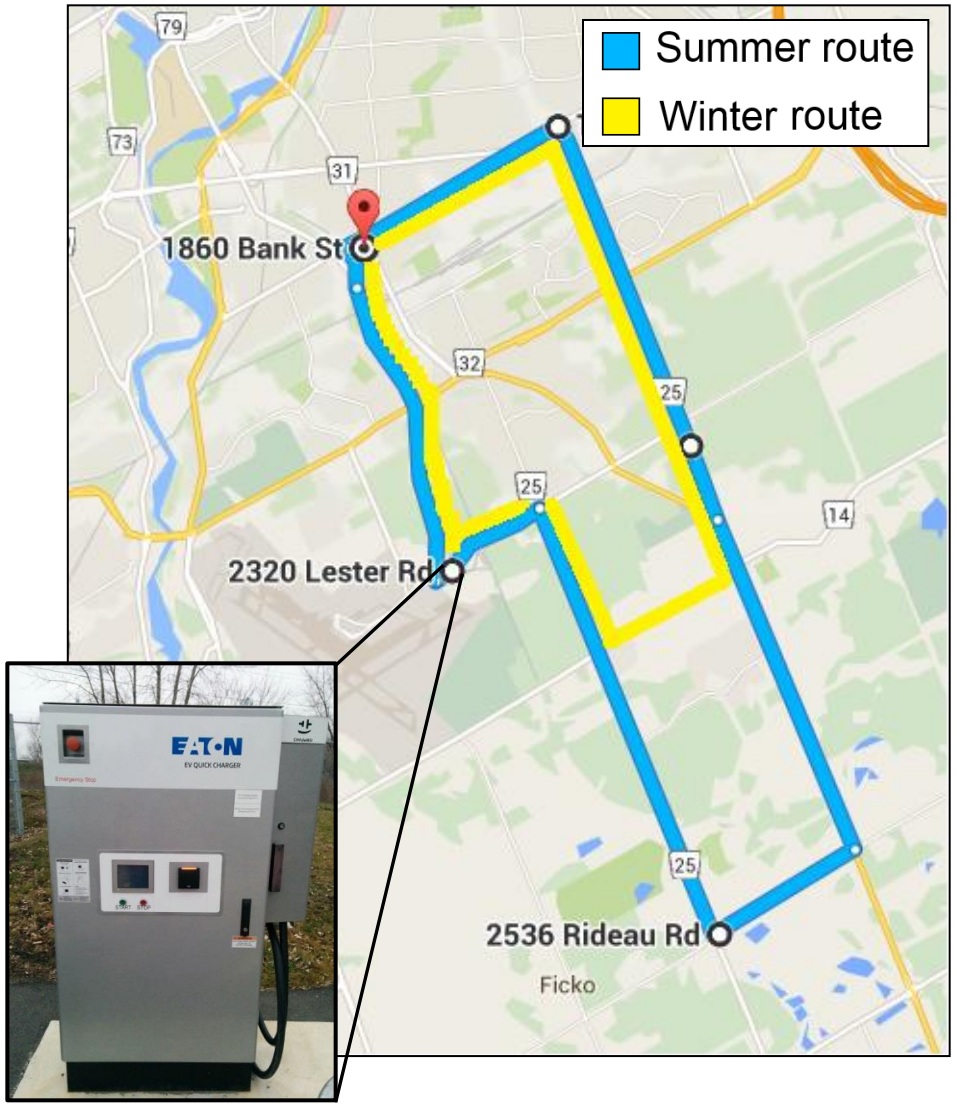
On-Road

- Route consisted of driving a set path:
  - Summer route – 33.6 km
  - Winter route – 22.8 km
- Mix of free-flow driving and city driving
- Drivers alternated between BEVs



DC Charger

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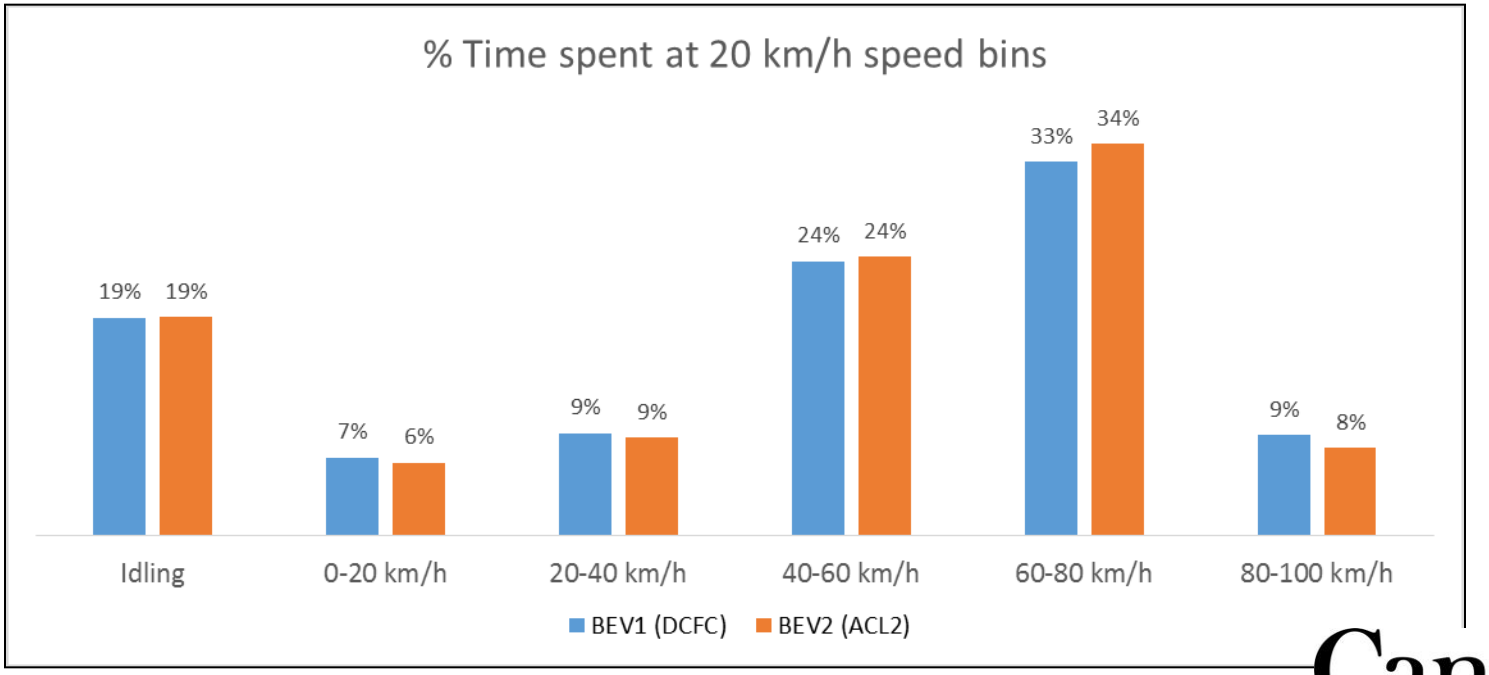
Driving Characteristics

- CVUS (Canadian Vehicle Use Study [2015]) Vs. BEV1 and BEV2

	Distance [km/year]	Speed [km/h]	% time spent idling
CVUS (2015), LDVs	16,509	43.0	22.5%
BEV1 (DCFC)	26,111	46.7	19.0%
BEV2 (ACL2)	25,656	47.0	19.0%

- % Time spent at various speeds



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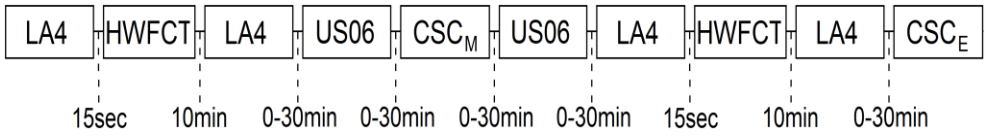
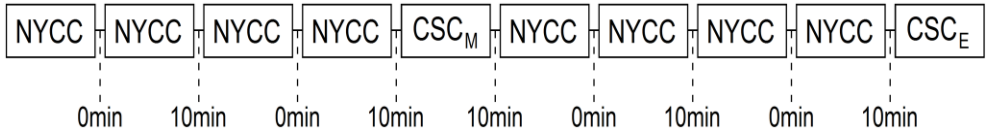
Chassis Dynamometer Test Cycles

Drive Schedule	Description
LA4	Moderate speed city cycle: part of the Canadian and U.S. 5-cycle fuel economy test
HWFCT	Highway fuel consumption test: part of the Canadian and U.S. 5-cycle fuel economy test. Simulates free-flow high driving
CSC	Constant speed driving at 55mph. Used to deplete the battery between transient cycles
US06	Aggressive high-speed driving cycle: part of the Canadian and U.S. 5-cycle fuel economy test
NYCC	New York City Cycle: Simulates congested urban driving
SC03	Low speed city cycle with high ambient temperature: part of the Canadian and U.S. 5-cycle fuel economy test. Used to simulate cabin air cooling driving conditions

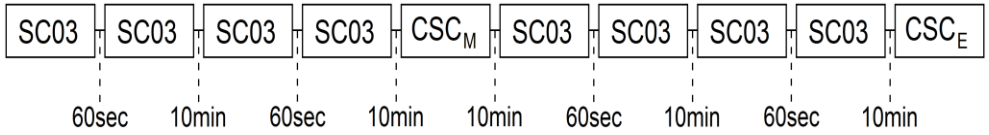
SAE J1634 US06 MCT

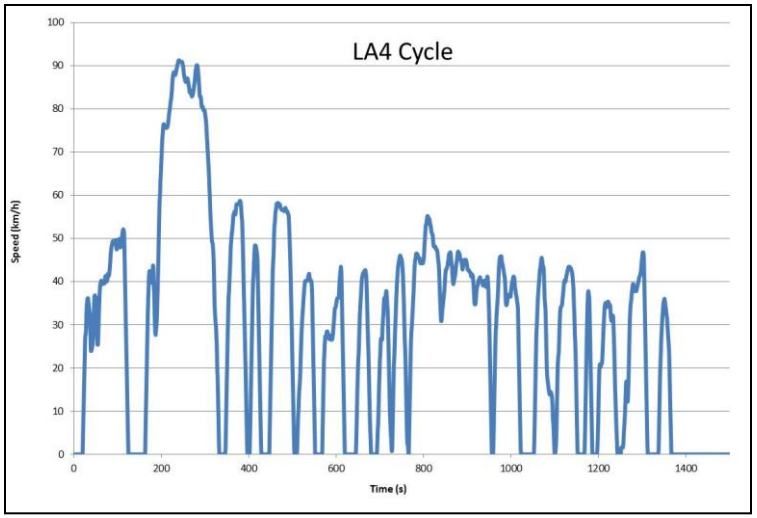


NYCC FDT



SC03 FDT





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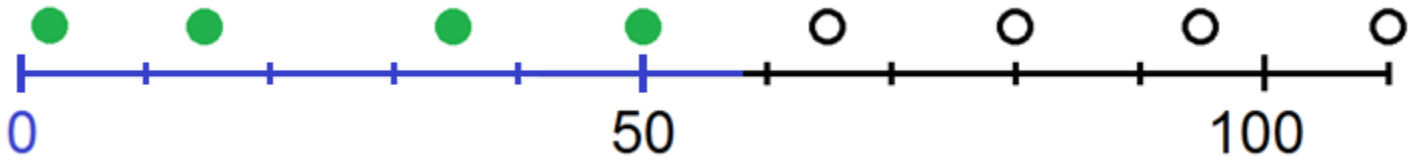
Test Matrix

Baseline (Round 1) and Final (Round 8)

Test Sequence	Ambient Temperature [°C]		
	35	25	-7 w cabin heat
SAE J1634 US06 MCT		3	3
NYCC FDT		2	2
SC03 FDT	2		

Rounds 2 to 7

Test Sequence	Ambient Temperature [°C]		
	35	25	-7 w cabin heat
SAE J1634 US06 MCT		3	
NYCC FDT		2	
SC03 FDT	2		



Odometer [km x 1000]

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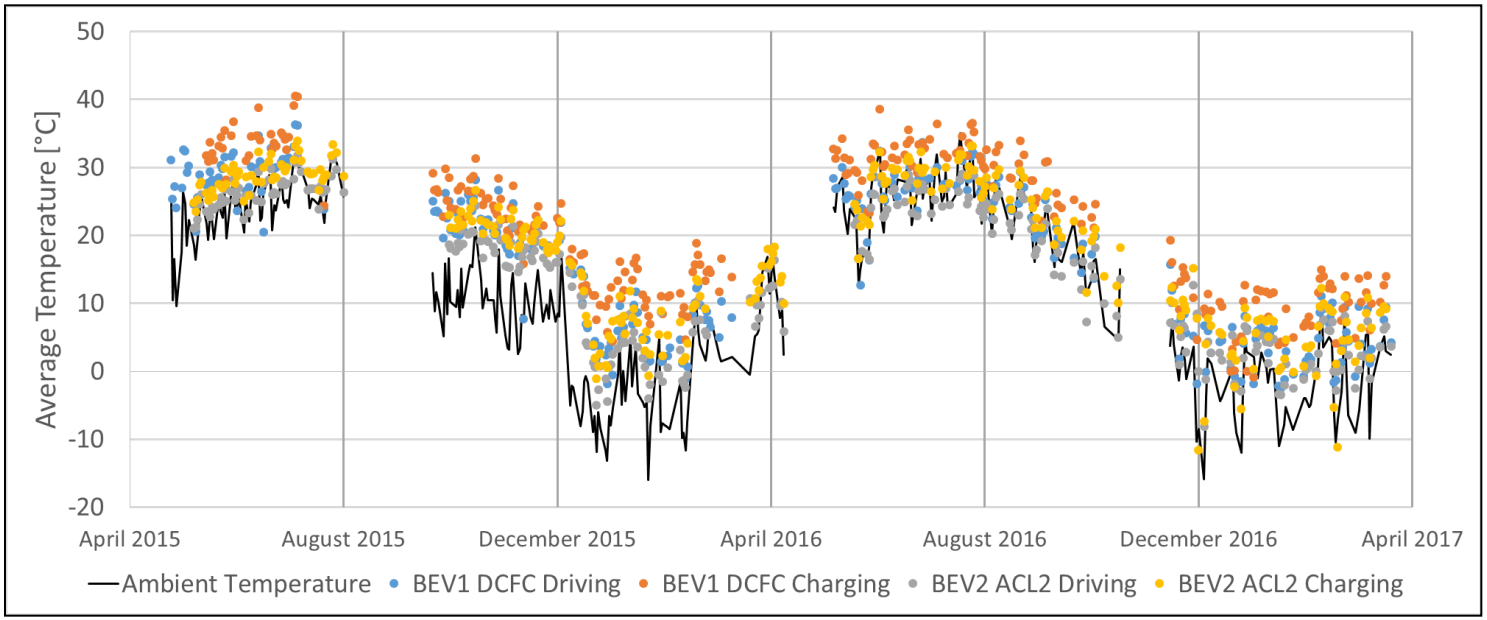
On-Road: Temperatures



- BEV1 experienced higher battery temperatures during driving periods throughout all seasons
- BEV1 and BEV2 experienced similar battery temperatures during charging periods
- During winter months, ambient temperatures reached -15°C during mileage accumulation

Season	Average Battery Temperature [°C]			
	Charging		Driving	
	BEV1	BEV2	BEV1	BEV2
Spring (Apr-Jun)	30.6	23.0	26.5	20.1
Summer (Jul-Sep)	31.9	28.4	27.4	25.4
Fall (Oct-Dec)	21.1	16.9	17.0	13.9
Winter (Jan-Mar)	10.4	5.3	4.8	2.7

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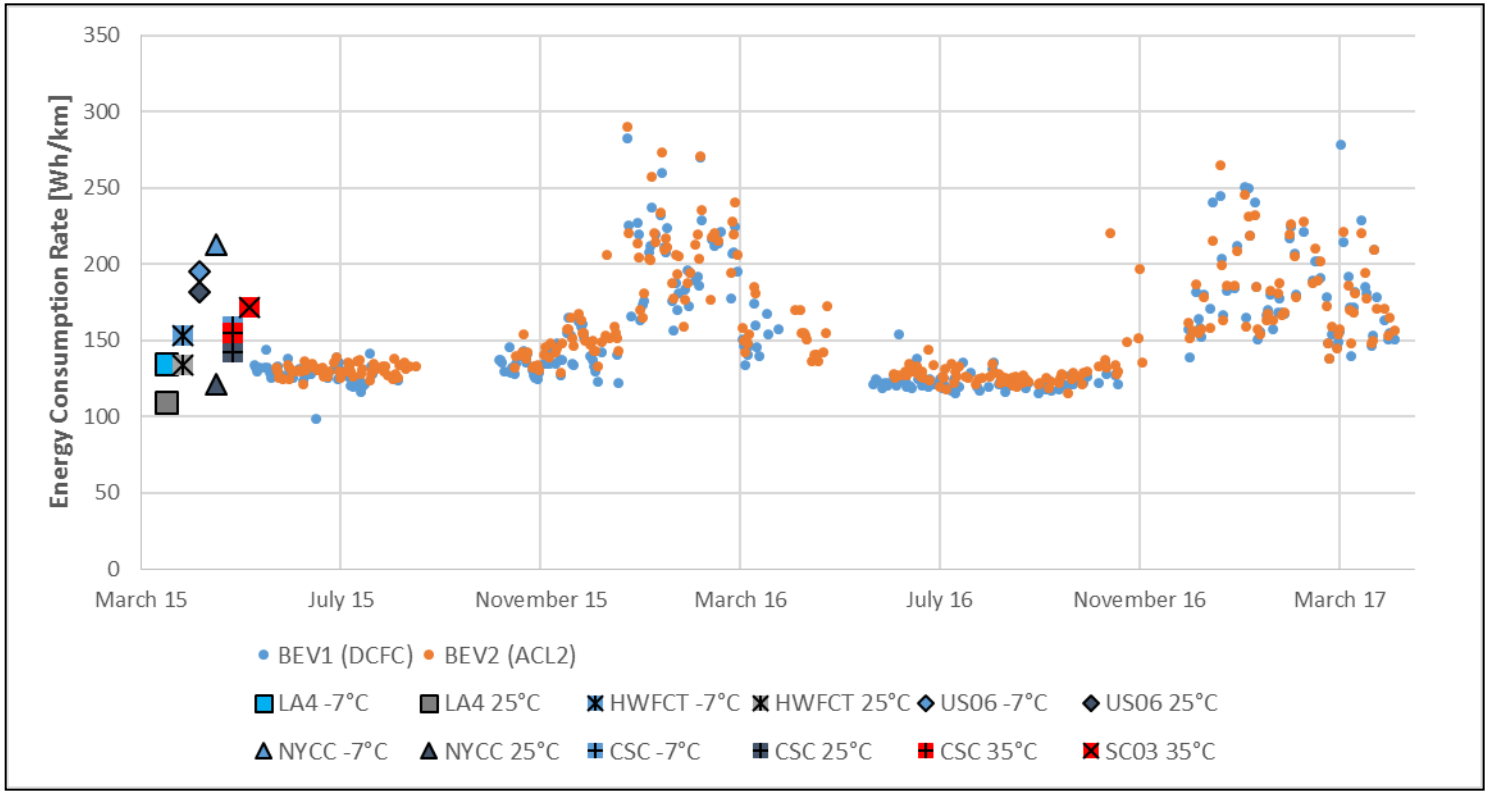
On-Road: Energy Consumption Rates



- Energy consumption (ECdc) increased by up to 2 times during the winter months
- Energy consumption rates over various cycles in-lab were comparable to on-road consumption rates between April and December

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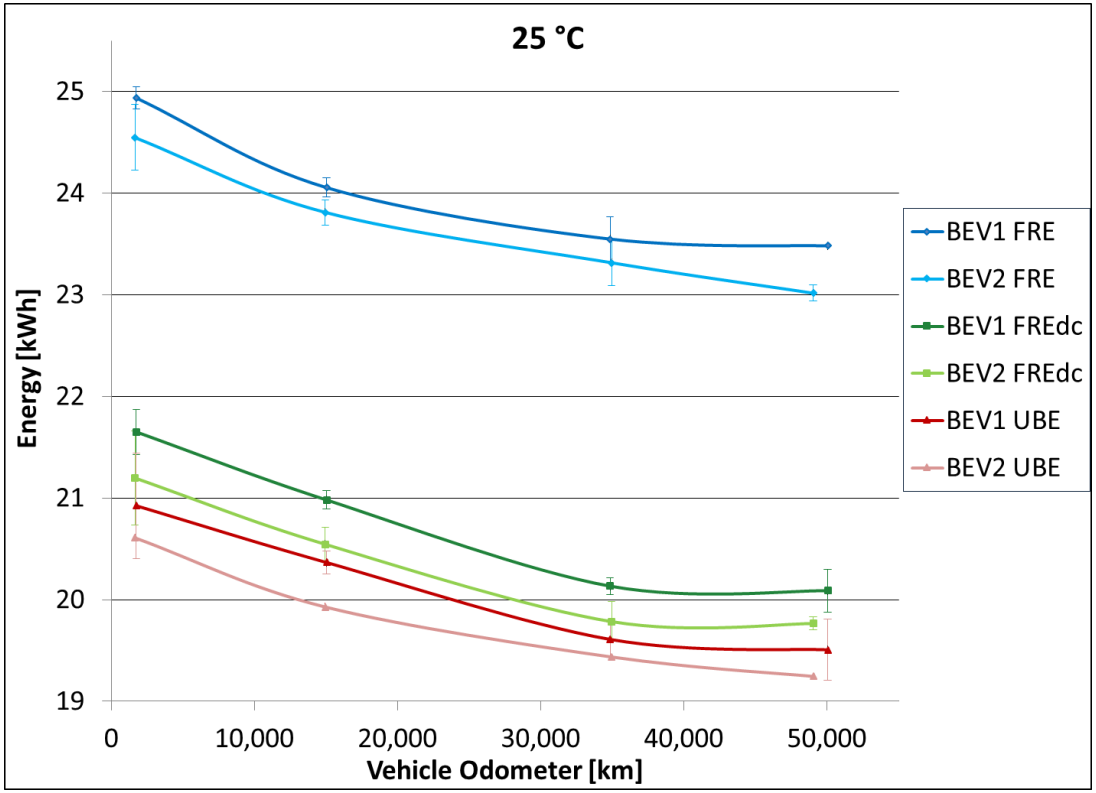
Charging and Usable Energy at 25°C



- An initial offset between BEV1 and BEV2
- After 50,000km, Full Recharge Energy (FRE) and Usable Battery Energy (UBE) decreased by 5.8% and 6.8% for BEV1 (DCFC), and decreased by 6.2% and 6.6% for BEV2 (ACL2)
- Trends are similar for DCFC and ACL2

		15,000 km	35,000 km	50,000 km
BEV1 (DCFC)	FRE	-3.5%	-5.6%	-5.8%
	UBE	-2.7%	-6.3%	-6.8%
BEV2 (ACL2)	FRE	-3.0%	-5.0%	-6.2%
	UBE	-3.3%	-5.7%	-6.6%

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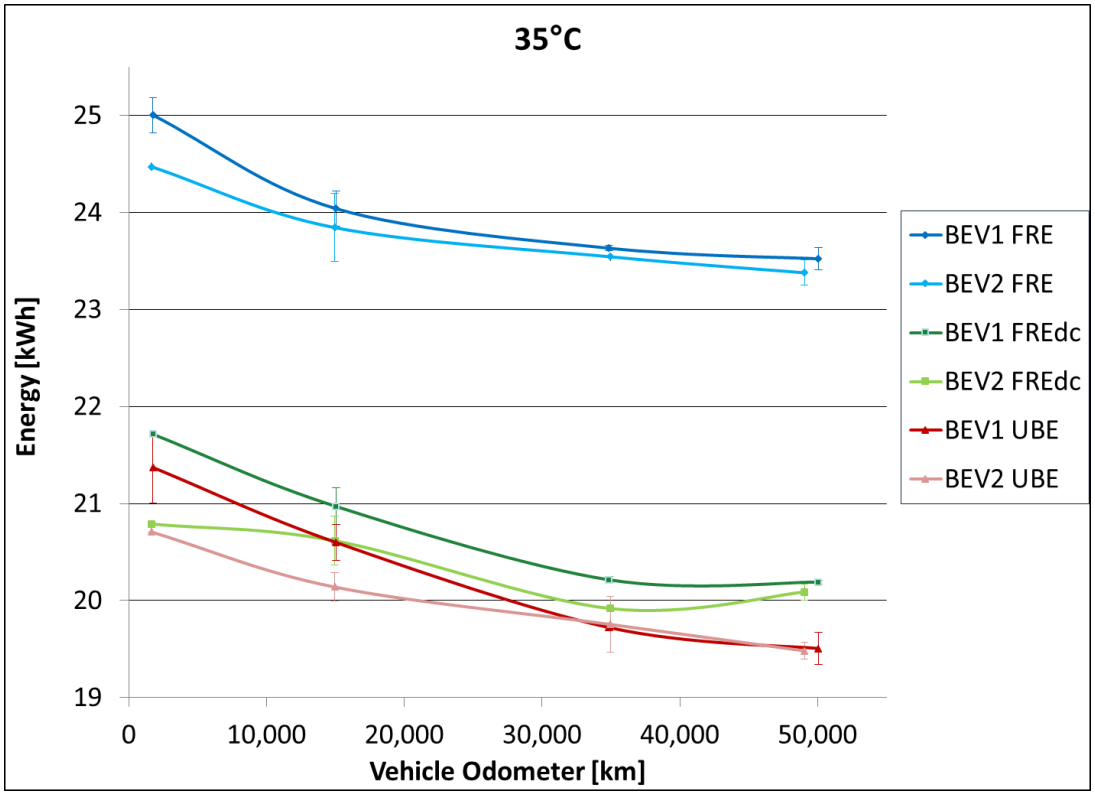
Charging and Usable Energy at 35°C



- An initial offset between BEV1 and BEV2
- After 50,000km, Full Recharge Energy (FRE) and Usable Battery Energy (UBE) decreased by 5.9% and 8.7% for BEV1 (DCFC), and decreased by 4.5% and 5.9% for BEV2 (ACL2)

		15,000 km	35,000 km	50,000 km
BEV1 (DCFC)	FRE	-3.9%	-5.5%	-5.9%
	UBE	-3.6%	-7.7%	-8.7%
BEV2 (ACL2)	FRE	-2.6%	-3.8%	-4.5%
	UBE	-2.7%	-4.6%	-5.9%

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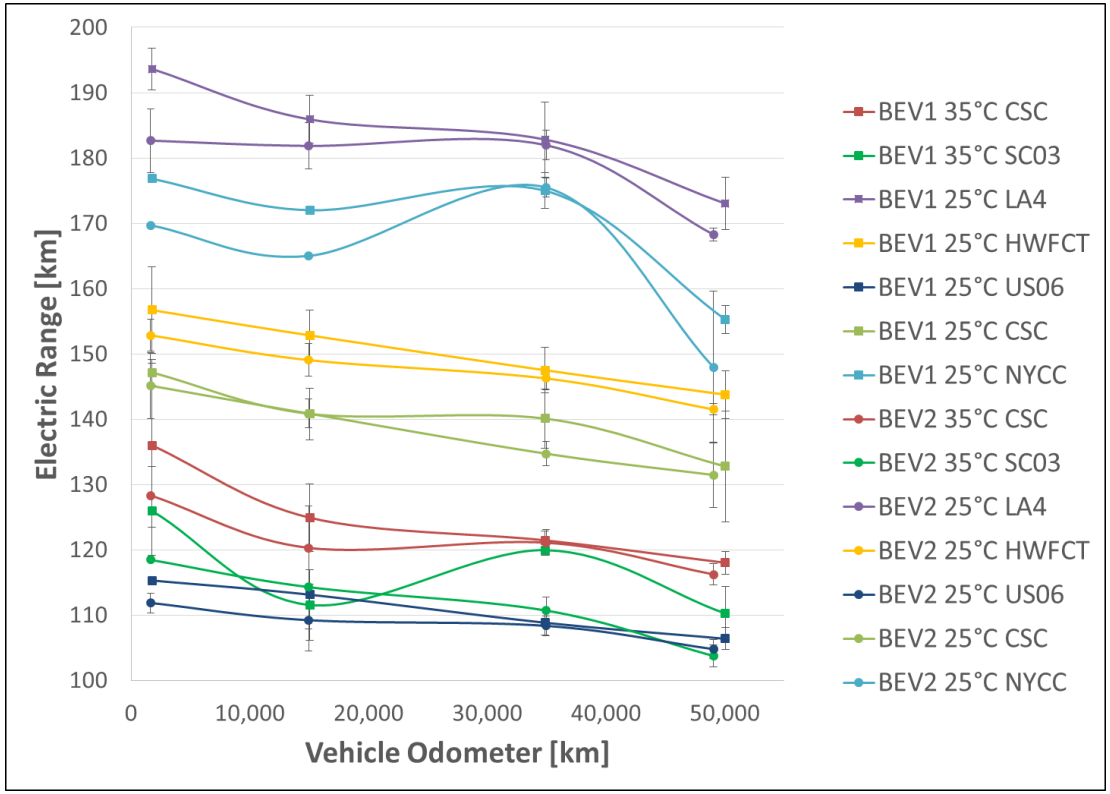
Driving Range

- Range is based on UBE, and cycle energy consumption rate (ECdc)
- Some initial differences between BEV1 and BEV2, where BEV1 has a higher range
- After 50,000 km, range decreased by:

	BEV1	BEV2
35°C CSC	10.9%	9.4%
35°C SC03	12.5%	12.4%
LA4	10.7%	7.9%
HWFCT	8.3%	7.4%
US06	7.7%	6.3%
CSC	9.8%	9.4%
NYCC	12.2%	12.8%



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Summary

- Charging energy and usable battery energy decreased at 50,000 km compared to baseline
  - FRE decreased by 6.2% (BEV2) and 5.8% (BEV1) at 25^{o}C, and 4.5%(BEV2) and 5.9% (BEV1) at 35^{o}C
  - UBE decreased by 6.6% (BEV2) and 6.8% (BEV1) at 25^{o}C, and 5.9%(BEV2) and 8.7% (BEV1) at 35^{o}C
- Driving range decreased by 6-13% with mileage accumulation of 50,000 km
- Similar patterns regardless of charge rate (DCFC and ACL2)
- Mileage accumulation will continue to 105,000km

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Thank You!

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