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Drive Electric Innovation

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Practical Impacts of Ambient Temperature and Aging Combined on Maximum Travel Range of the Nissan Leaf

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Red River College of Applied Arts, Science and Technology

A Decade of Applied Research 2004-2014

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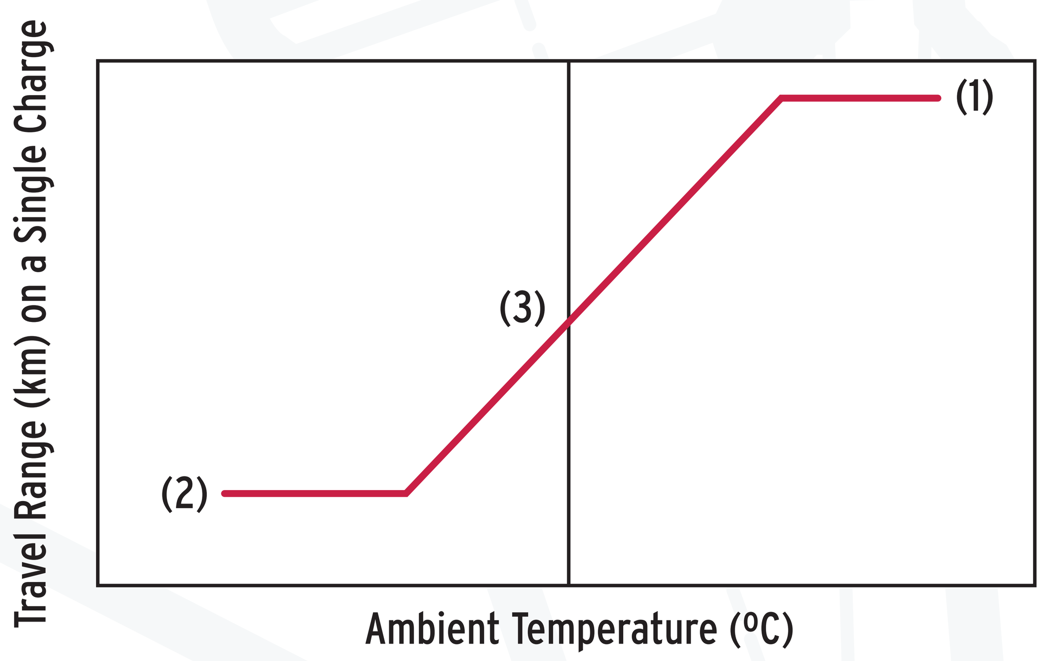
EVTEC Model for Vehicle Travel Distance

Maximum travel range of a battery electric vehicle (BEV) for a single charge as a function of ambient temperature shows the shape of a logistic curve. This function, however, is mathematically complex, and provides little in the way of underlying explanation beyond just fitting data to a curve. A simpler, and more useful, representation of BEV travel range has been developed, dubbed the "EVTEC" model, involving three "linear" segments:

(1) Flat range plateau at temperatures above around +20ºC;
(2) Flat range plateau at temperatures below around -15ºC; and
(3) Middle linearly-varying section from +20ºC down to -15ºC



Why EVTEC Model makes Sense?

Having a maximum travel range at nominal conditions that does not change with ambient temperature (i.e., higher temperature plateau where heating and air conditioning are not used) is exactly what is experienced with conventional cars.

BEV have only limited maximum heating system output, so a low temperature range plateau makes sense as long as battery energy capacity decline is less significant than heating system impacts.

Heat capacity of air and vehicle materials of construction all vary linearly with temperature so seeing linear decline of range as temperature reduces (and heating increases) makes sense.

Background Work Describing EVTEC Model

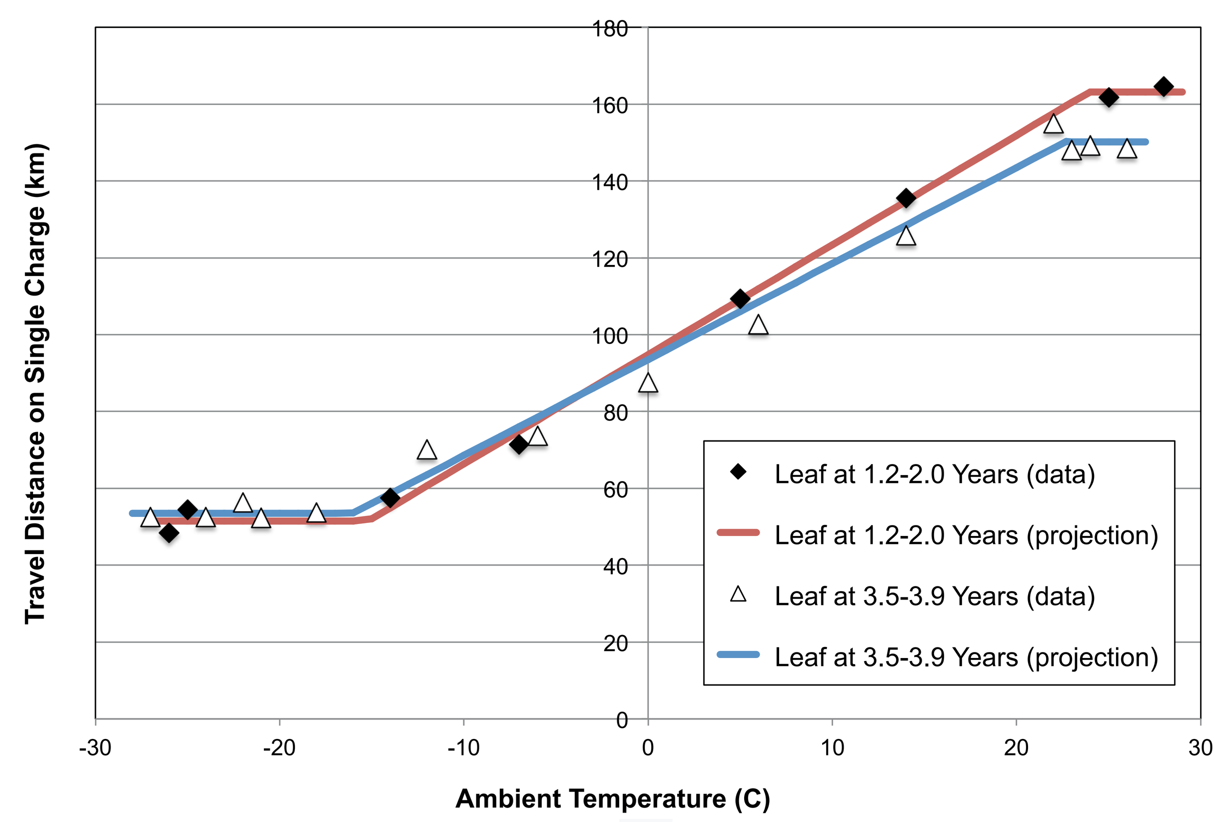
J.R.M. Delos Reyes, R.V. Parsons, R. Hoemsen, Winter happens: the effect of ambient temperature on the travel range of electric vehicles. IEEE Transactions on Vehicular Technology, 2016.

J.R.M. Delos Reyes, R. Hoemsen, R.V. Parsons, Cold weather travel range and energy consumption of the Chevrolet Volt PHEV, IEEE Vehicle Power and Propulsion Conference, Montreal, Quebec, 2015.

J.R.M. Delos Reyes, R.V. Parsons, R. Hoemsen, Winter happens: understanding and improving electric vehicle operation in cold weather. EVVÉ 2014 Tradeshow and Conference, Electric Mobility Canada, Vancouver, British Columbia, Canada, 2014.

Abstract

For electric vehicles, operating under variable climate conditions is an important consideration. In northern regions, including Canada, Northern U.S. states, and Scandinavian countries, for example, it is crucial to understand the practical impacts of cold weather operation during winter, in particular how maximum travel range, using a single full-charge, may be affected. At the same time, electric vehicles, which have been now commercially available for several years, are beginning to age. This paper explores the impacts of vehicle aging and ambient temperature effects, as can occur simultaneously, on vehicle range in order to understand their aggregate effect and their interaction for the Nissan Leaf, a commercial-available electric vehicle.



Drive-to-Depletion Results with Aging

Drive-to-depletion results continued to show consistency with the EVTEC model, but also showed the effects of aging to be complex, i.e. not a simple uniform-factor reduction in travel range for a single charge.

Upper Temperature Plateau: Results at warm temperatures confirmed travel range was not a function of ambient temperature and showed a reduction in maximum possible range from approximately 163 km to approximately 150 km, or roughly 4% reduction per year over two years.

Lower Temperature Plateau: Results confirmed that travel range is not a function of temperature below about -15ºC, and also showed that travel range was unchanged from earlier tests. This has never been previously reported. Although range is obviously reduced at lower temperatures, it is not made worse through aging. This is a relative benefit for locations with colder temperatures.

Middle Linearly-Varying Section: In the middle section, travel distance remained extremely linear relative to ambient temperature, with the effect involving a reduction of slope but essentially no change in intercept value:

Test Set	Slope	Intercept (at 0ºC)	r2	n
Older tests	2.9 km/ºC	94.9 km	0.99	4
New tests	2.5 km/ºC	93.5 km	0.98	7
Change	-14%	-1%		

Drive-to-Depletion Testing

Drive-to-Depletion involved, literally, driving until the Leaf battery was fully-depleted and recording the travel distance. A similar route was employed (see below), traveling within the urban vicinity of Winnipeg, Canada across varying ambient temperatures from as high as around +25ºC down to as low as around -25ºC. Two sets of tests were involved:

- Eight tests from June 2013 through March 2014 (at 1.2 to 2.0 years)
- Fourteen tests from September 2015 through February 2016 (at 3.5 to 3.9 years)

Approximate travel route (but not identical given temperature differences)

Next Steps:

Further testing of electric vehicles is continuing at Red River College, with the intent to look at additional vehicles, additional cold weather conditions, and additional aging of electric vehicles.

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