All-Electric
Mitsubishi iMiEV in Manitoba

Summary of Operational Experience: First Year Report

Prepared by the Electric Vehicle Technology & Education Centre,
Red River College, in cooperation with Manitoba Innovation, Energy and Mines

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EVTEC
ELECTRIC VEHICLE TECHNOLOGY & EDUCATION CENTRE

RED RIVER COLLEGE
OF APPLIED ARTS, SCIENCE AND TECHNOLOGY

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Objectives and Reporting

In April 2011, the Government of Manitoba began testing two all-electric iMiEVs. The objectives were to understand the practicality and public perception of using fully electric vehicles in our climate conditions, and to publicize and publicly demonstrate the benefits of these vehicles. The intent of this report is to be able to address a variety of questions that potential users may have, including:

- What is it like to drive one of these vehicles?
- How far will such a vehicle travel, particularly in the winter?
- What does it cost to operate?
- What are issues in the operation of these vehicles?
- What are the most suitable uses for these types of vehicles?

Introduction

MOU on Electric Vehicles

The Government of Manitoba signed a Memorandum of Understanding (MOU) with Mitsubishi Motor Sales of Canada (MMSCan) in April 2011 regarding electric vehicles. A key part of this collaboration has been the testing of two European-version iMiEVs. Testing of the two vehicles began on April 20, 2011, and will potentially continue for three years, up to the spring 2014. Annual reports on experience with the two vehicles are being prepared at the end of each of the three years.

iMiEV Specifications

The iMiEV has an unusual name that requires some explanation. The vehicle was based on the platform of a small gasoline-powered vehicle in Japan called the "i". It was adapted to operate all-electrically and then slightly renamed, adding "Mitsubishi innovative Electric Vehicle" to its descriptor.

The iMiEV is intended as an urban commuting vehicle, with the capacity to carry up to four passengers. The vehicle has some stowage space, but is not intended for any significant hauling. The iMiEV is fully electric. It has no internal combustion engine and requires no gasoline or other liquid fuel. It is recharged using grid-based electricity. This means within Manitoba it uses renewable energy and generates almost no emissions of any kind.

The two iMiEVs being tested are European versions, slightly different from the North American iMiEV, commercially released by MMSCan in fall 2011 (See side bar on page 4). Specifications for the two vehicles tested are summarized in the table on page 5.

Photograph used with permission courtesy of Mitsubishi Motor Sales of Canada.

North American iMiEV

The North American version of the iMiEV was commercially released in Canada in fall 2011, roughly six months after testing began with the two cars. The first purchase of a 2012 model year iMiEV by a private individual in all of Canada happened in Winnipeg (December 2011). The North American version of the iMiEV is slightly different, being most notably longer and wider, with some more-cosmetic differences in appearance. More information is available from the manufacturer (www.mitsubishi-motors.ca/en/i-miev/).

Vehicle Designations

The two iMiEVs tested were each given a unique designation number for reporting purposes, but the vehicles and specific drivers were not otherwise identifiable. The two vehicles are listed respectively as:

- Unit #AJ; and
- Unit #BA.

Licensing and Insurance

The two vehicles were both registered for operation in Manitoba with Manitoba Public Insurance (MPI), and were each covered under standard automobile insurance policies. There was nothing special required in the registration process or insurance for these electric vehicles, in particular as compared to conventional vehicles. Since April 2011, the numbers of new all-electric and plug-in hybrid electric vehicles (PHEV) registered with MPI has continued to increase. Registration and insurance are not practically different from conventional vehicles.

Data-Logging Devices

With permission from MMSCan, on-board data-logging systems were implemented on both of the vehicles. These involved the OTTO-Link and associated OTTO-Driving-Companion data-loggers as manufactured by Manitoba-based Persentech. The units used on the iMiEVs had been previously installed on vehicles that were part of the Manitoba PHEV Demonstration, a project completed in fall 2011 and administered by the non-profit Centre for Emerging Renewable Energy Inc.

The OTTO-Link provides a log of all accessible vehicle-status data at time intervals. Normally it would connect to the standard on-board diagnostic port of a vehicle. Given the nature of the European-version of the iMiEV, MMSCan provided an adaptor unit called the "CAN Gateway" for each of the vehicles. Instructional staff from the automotive program at Red River College assisted by installing the CAN Gateway adaptors. Then staff from Persentech modified the connectors on the OTTO-Link devices to attach to the CAN-Gateways. Although a bit convoluted, this procedure permitted functional logging of data from the vehicles.

The OTTO-Driving-Companion, shown in the photograph on page 6, is a dashboard-mounted device associated with the OTTO-Link. It provides audio-enunciated feedback to drivers on both driving and road characteristics. It also acts as an autonomous data logger to generate standardized, GPS-linked trip reports about a vehicle. The OTTO-Driving-Companion reports were employed to quickly obtain two relevant parameters to understand vehicle-use characteristics of the two iMiEVs, specifically:

- trips per day; and
- daily travel distance.

A second monitoring device was also used, but in this case, not actually mounted on the vehicles themselves.

Upgraded versions of the IPLC-PM2 meter, manufactured by Manitoba-based Vantera Inc., provide the capability for interactive monitoring of electricity consumption of vehicles when plugged into the grid. These updated versions of the IPLC-PHEV Meter, as shown in the photograph on page 6, had also been used in the latter stages of the Manitoba PHEV Demonstration, and had been adapted from Vantera's Intelligent Parking Lot Controller (IPLC). In this case, the meters were simply carried with the iMiEVs and externally plugged into any Level 1 plug-points (i.e., 110 V, 15 A) where the vehicles were being recharged.

iMiEV (European) Technical Specifications

Dimensions	3.4 m long x 1.5 m wide x 1.6 m high
Curb Weight	1.1 tonnes (2,400 lb)
Turning Radius	4.5 metres
Motor	Permanent magnet synchronous; 47 kW max output; 180 Nm torque
Battery	Lithium ion chemistry; capacity of 16 kWh; 330 V (direct current)
Speed	130 km per hour maximum
Range	110 to 120 km under normal operating conditions
Energy Consumption	13.5 kWh per 100 km (under normal conditions; measured at battery)

Although vehicle range is ultimately most important for drivers to understand in the operation of an electric vehicle, range estimates tend to be very vague. In order to objectively address vehicle range, precise measurements of vehicle electricity consumption were taken at the wall plug under different conditions using the IPLC-PM2 device. The range of an all-electric vehicle depends directly on the available battery capacity, and on electricity consumption under the conditions of operation. As such, expected range is inversely related to any change in energy consumption, i.e., higher energy consumption means lower expected range.

Decals

With permission from MMSCan, a set of colourful decals was installed on each vehicle, as illustrated in the photograph of the iMiEV on page 3.

Operational Results

Driver Feedback / Response

During their first year of operation, the two iMiEVs were driven by roughly twelve different drivers, but primarily by three individuals associated with Manitoba Innovation, Energy and Mines.

A common reaction of drivers to the iMiEV was one of serendipity, i.e., a positive but unexpected experience. Although appearing outwardly small, the vehicle was surprisingly roomy, and carried upwards of four adults without feeling excessively cramped. As noted by one driver, "I expected more of a golf-cart experience, but it drove like any other small car. The ride and the overall comfort level were both good."

The overall quietness, and lack of noise from the engine were strongly positive features. There was also a noticeable "smug-satisfaction" among drivers that the iMiEV did not actually require any gasoline to operate. But, perhaps seemingly odd, drivers still found they had to periodically take one of the iMiEVs to a neighbourhood service station for washer fluid or a car wash.

The very rapid acceleration and the agility of the iMiEVs in traffic were noted in particular. Although not necessarily expected, such performance aspects were logical given the nature of electric motors, with high initial torque and almost instantaneous power, when compared to conventional engines. When cornering at high speed, the vehicle felt a bit unsure for some drivers, this given the relatively tall height and very short wheel base.

The speed and quiet of the iMiEV created additional subtle issues. With seamless acceleration and without typical noise clues as to the speed of the vehicle, drivers had to spend more attention than usual minding the speedometer. It was very easy to exceed the speed limit. As such, the iMiEVs required an orientation more toward "driving on instruments" rather than "driving by feel."

The iMiEVs featured relatively simple dashboard displays. These elicited different reactions from drivers, with responses ranging from "basic" to "intuitive." One concern was that the vehicle did not provide sufficient feedback when it was desired. Reactions also reflected differing driver preferences. Different types of electric vehicles, just like different types of conventional vehicles, will appeal to different drivers. One key display was the vehicle's battery indicator, which involves a total of 16 bars, one each per kWh of battery capacity remaining.

The major on-going issue with the iMiEVs for drivers was associated with "range." This was not necessarily a negative reaction, but more of a reorientation. Unlike a conventional vehicle, it was much more important for drivers of the iMiEVs to be aware of available range and to adapt. Drivers were generally more aware of their habits, including being more cautious about "heavy-footing" the vehicle. Some drivers also noted paying much more attention to pre-planning of trips to ensure they would have enough range, even on occasions reducing heating somewhat during the winter in order to preserve range.

OTTO-Driving-Companion on dashboard

IPLC PM2 Meter for electricity consumption

No driver of either iMiEV ever drained a vehicle completely to dead during the first year. No one was ever left stranded. The lowest levels reached by drivers were two to three bars out of 16 on the battery display (i.e., 2 to 3 kWh capacity), corresponding to 12% to 18% of total available energy remaining. Range was most important as a concern during winter operation. Winter range and other cold-weather issues are described in more detail later.

Vehicle-Use Characteristics

Over the first year of operation, approximate total mileages for the two iMiEVs were about:

- 6,800 km for Unit #AJ; and
- 7,100 km for Unit #BA.

Ongoing data from Statistics Canada's annual Canadian Vehicle Survey shows that vehicles within Manitoba tend to be consistently driven annually an average of about 16,000 km. As such, the iMiEVs were only driven about 40% to 45% of more typical annual distances. This makes sense given their use essentially as commuter vehicles. Both iMiEVs were driven in the vicinity of Winnipeg, for which typical commuting distances tend to be no more than about 30 km. Assuming 30 km daily travel, five days per week, for 50 weeks per year, translates to 7,500 km.

The OTTO-Link and OTTO-Driving-Companion units were installed in early November 2011 and data were collected for the remainder of the first year. As such, data logging with these devices covered about 45% of the year, including, importantly, the winter period. Summary data on trips per day and daily travel distance are presented in the table on page 7. These data were based only on the days that the vehicles were actually driven, but the proportion of days the vehicles were unused were also recorded.

Cumulative travel distance data from the OTTO-Driving-Companion were compared to actual odometer results for Unit #BA and was found to be very close. For the three-month period of December through February, the OTTO-Driving Companion was less than 1% low compared to the vehicle odometer. Considering the entire logged period, data were less than 3% high compared to the vehicle odometer. As such, the OTTO-Driving Companion data could be relied upon with some confidence.

As seen from the data, Unit #AJ was driven on significantly less days per week, but when driven, had both a much higher number of trips, and further travel distances. Not surprisingly, the mean daily travel distances for the two vehicles corresponded closely to the respective round trip distances between the residences of the two most common users of the vehicles and the downtown offices of Manitoba Innovation, Energy and Mines. These were approximately 24 km for Unit #AJ and approximately 14 km for Unit #BA.

In terms of considering vehicle range, the OTTO-Driving-Companion data could not indicate the maximum allowable distance the vehicles could travel, but could indicate the maximum travel distances that they actually achieved on a daily basis in each individual month. These data are summarized in the table on page 8 for both vehicles. These showed that maximum daily travel distances varied quite randomly, without any apparent systematic connection to the general temperature conditions, i.e., maximum daily distances for the vehicles were not significantly lower during colder months.

Driving Mode Selection

The European iMiEV has three available driving modes, as follows:

- D-mode or Drive, which provides full power and normal regenerative braking, and can be used for city driving and highway driving;
- B-mode or Brake, which reduces power and increases regenerative braking, and is effectively the "Eco" mode for the vehicle; and
- C-mode or Comfort, which provides full power and lower regenerative braking, and is intended primarily for highway driving.

In the North American version the three settings are slightly different. The D-mode is the standard mode, which provides full power access and normal regenerative braking, and is best for merging onto highways, and on hills/inclines. The Eco-mode slightly reduces overall power output, conserving energy, slightly increases regenerative braking, and is best used when travelling at a steady speed. The B-mode provides full power with the strongest regenerative braking, and is best used in stop-and-go traffic and when going downhill.

Although the selector configuration in the vehicle, being between the two front seats, looks like a transmission shifter, it is really a selector switch that can be easily changed on the go by drivers. Given the relative newness of the iMiEV and lack of familiarity with all-electric vehicles, the drivers of the vehicle at IEM during the first year all employed only the D-mode, and did not make use of the B-mode that would enhance regenerative braking. This can be a common mistake for drivers transitioning from conventional to all-electric vehicles. As such, all of the energy consumption data collected for the vehicles during the first year were based solely on D-mode operation. One of the priorities for the next year is to make better use of B-mode operation, in order to enhance efficiency.

Electricity Consumption

The two iMiEVs are each equipped with two charging ports:

- SAE J1772-compliant port at the rear passenger-side for charging at Level 1 (i.e., 110 V; 15 A), or at Level 2 (i.e. 220 V, 20 A); and
- CHAdeMO protocol compliant port on the rear driver-side to allow for Level 3 charging (i.e. direct DC, rapid charging).

Each of the iMiEVs were provided with two cord-sets for recharging,

Vehicle-Use Characteristics of iMiEVs Over First Year of Operation

Parameter	**Unit #AJ**	**Unit #BA**
Mean Trips per Day	4.5 ± 2.5 trips	3.0 ± 2.0 trips
Median Trips per Day	4.0 trips	3.0 trips
Mode Trips per Day	3.0 trips	1.0 trips
Mean Daily Travel Distance	25.8 ± 16.4 km	13.9 ± 9.5 km
Median Daily Travel Distance	23.8 km	13.0 km
Mode Daily Travel Distance	21.0 km	12.7 km
Proportion of Days Not Driven	33.5% (≈ 2.3 days per week)	22.4% (≈ 1.5 days per week)
Total Monitored Days	161 days	161 days

one for Level 1 and one for Level 2, both compliant with SAE J1772.

The main method of charging the two vehicles was at Level 1, primarily using standard garage-based plug-in points. Level 1 charging was also possible at parking lots equipped with plug-ins. Although Level 2 is well known to be about twice as fast as Level 1, the broadly available, low-cost Level 1 recharging was found to be satisfactory for both vehicles.

Unit #AJ was solely recharged at Level 1, but Unit #BA was successfully recharged at Level 2 on several occasions for testing purposes. The first occasion involved using an adaptive connector at Red River College to connect to an available 220 V, 30 A circuit. The second occasion involved an at-home connection to a 220 V, 20 A circuit.

Electricity consumption for both vehicles was monitored "at-the-wall-plug" using IPLC PM2 meters for Level 1 charging. Most intense monitoring was done on Unit #BA.

A plot of current as a function of time is presented in the figure on page 5 for Unit #BA being charged at a residential location. This typical charge profile for the iMiEV involved current first rising rapidly, then remaining very constant for most of the charging event, and finally ramping down progressively at the last stage. This sort of charging pattern was consistently observed during all monitored occasions for both of the iMiEVs. This plot shows firstly that the electric vehicle represents a relatively steady load where it is plugged in. Secondly, the electric vehicle only draws power until the batteries are recharged. Electrical devices of certain types have been known to create so-called "phantom" loads by continuing to draw power while in standby-mode. This did not occur for the iMiEVs. They stopped drawing power once fully charged.

During the summer of 2011, parallel electricity-consumption testing was undertaken on several electric vehicles, including one of the iMiEVs, specifically Unit #BA. Testing occurred between late-July to late-August 2011, while temperature conditions were relatively consistent. For the testing, the iMiEV was driven on five separate occasions each with (1) air conditioning (AC) off, and (2) AC fully on. The travel distance was approximately 20 km for each test undertaken. Electricity consumption data was monitored at the end of each trip using the IPLC-PM2 meter. Assembled data were then evaluated using sophisticated statistical techniques.

For summer-based operation of the iMiEV, involving no heating, average electricity consumption was found to be as follows:

Summer Electricity Consumption

16.3 ± 0.8 kWh per 100 km (n=5) for D-mode only with AC off or set low

20.2 ± 1.1 kWh per 100 km (n=5) for D-mode only with AC fully on

The calculated average value of 16.3 kWh per 100 km was used as the baseline electricity consumption for the iMiEV. Turning-on AC fully during the summer was found to be very important. Energy consumption was increased by roughly 25%, which translated to vehicle range being reduced by 25%. Winter impacts on electricity consumption were found to be more significant, and are discussed in more detail later.

Comparing electricity consumption at the wall plug with the listed energy consumption of 13.5 kWh per 100 km at the battery (page 5), suggested that the efficiency of energy conversion was approximately 83%. Electric vehicles are well known to be much more energy efficient that conventional gasoline-powered vehicles. The U.S. Department of Energy suggests that no more than about 20% of the energy contained in gasoline is actually delivered to move a conventional vehicle. For an electric vehicle approximately 60% of input electrical energy can be delivered to the wheels to move the vehicle, roughly three times better than a conventional vehicle. Combined battery and battery-charger efficiency is indicated to be typically around 81%, which is consistent with findings for the iMiEVs. A more

Maximum Daily Travel Distances by Month during First Year[1]

Month	Unit #AJ	Unit #BA
November 2011	36.5 km	37.2 km
December 2011	65.4 km	30.4 km
January 2012	52.1 km	44.0 km
February 2012	47.2 km	47.9 km
March 2012	54.8 km	50.7 km
April 2012	48.2 km	18.0 km

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[1] Note these data reflect how far the vehicles actually travelled, not the expected range.

detailed technical comparison of energy consumption data is provided on page 13.[2]

Winter impacts on electricity consumption were found to be significant, and are discussed in more detail later.

Maintenance Impacts

The extent of maintenance for the iMiEVs was lower overall compared to conventional vehicles, but appropriate maintenance was still required. For both iMiEVs, trained service personnel at a local Mitsubishi dealership undertook diagnostic reviews every six months, i.e., in October and in April. The selected timing for this service interval also permitted the simultaneous changing of seasonal tires that had been provided for the vehicles, i.e. to winter or summer version as required.

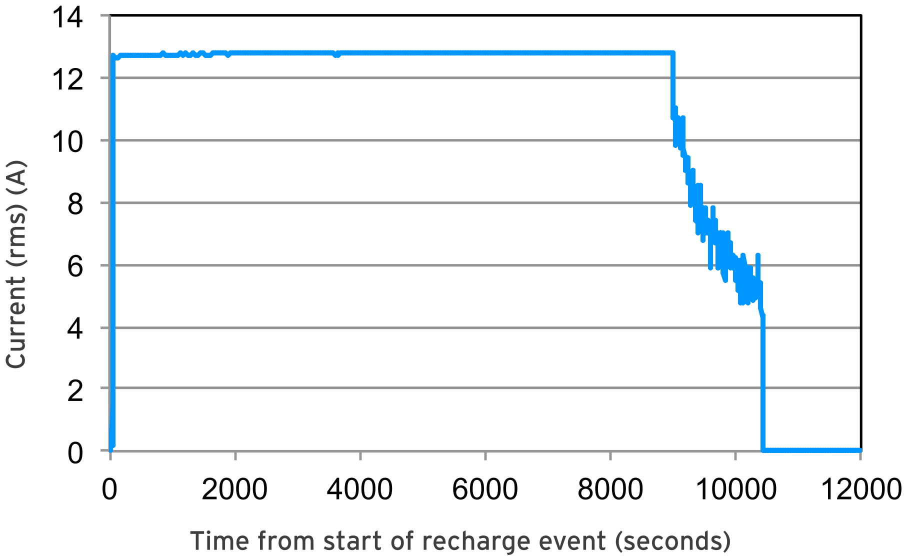
Although the two vehicles are involved in deliberate testing activities, a twice-yearly maintenance review would be appropriate to anticipate for any such vehicle. For the drivers, aside from ongoing charging of the vehicles, the only noticeable requirement to "lift-the-hood" of the iMiEV was for washer fluid addition.

Winter Impacts

Manitoba's cold, winter weather presents a challenge to many new technologies, and this included the iMiEVs. During the first year, both of the vehicles were operated continuously through the winter period, without interruption. They were confirmed to have operated successfully under ambient conditions as low as at least -27°C.

At the same time, four specific issues were identified during cold-weather operation, including:

- Fogging concerns when passengers were present;
- Interior cabin warmth;
- Significantly increased electricity consumption; and
- Small tire size limiting snow depth traverse.



Each of these issues is discussed in more detail.

For cold-weather operation, the two iMiEVs are equipped with several heating systems. Most important is the main cabin glycol-loop system, which heats air for the cabin and the front windshield. It is essentially identical to conventional vehicle systems, except that instead of being heated via waste heat from an engine, it employs electric resistive-heating using power from the main battery. Importantly, unlike the North American version, the two European version vehicles had less insulation, important both for warmth and sound reduction, and had no remote pre-heating capability that could be activated while the vehicle was plugged-in.

The two iMiEVs also have an electrically heated driver seat, and an electric rear-window defogger, both powered from the 12-volt auxiliary battery. Although powered using a different battery, these systems too draw energy from the electrical grid.

During the winter of 2011-2012, both of the iMiEVs were stored overnight and recharged inside non-heated garages. When driven to work, one of the vehicles was usually plugged in, while the other was not. As such, during the day neither vehicle had any heating while stationary and parked.

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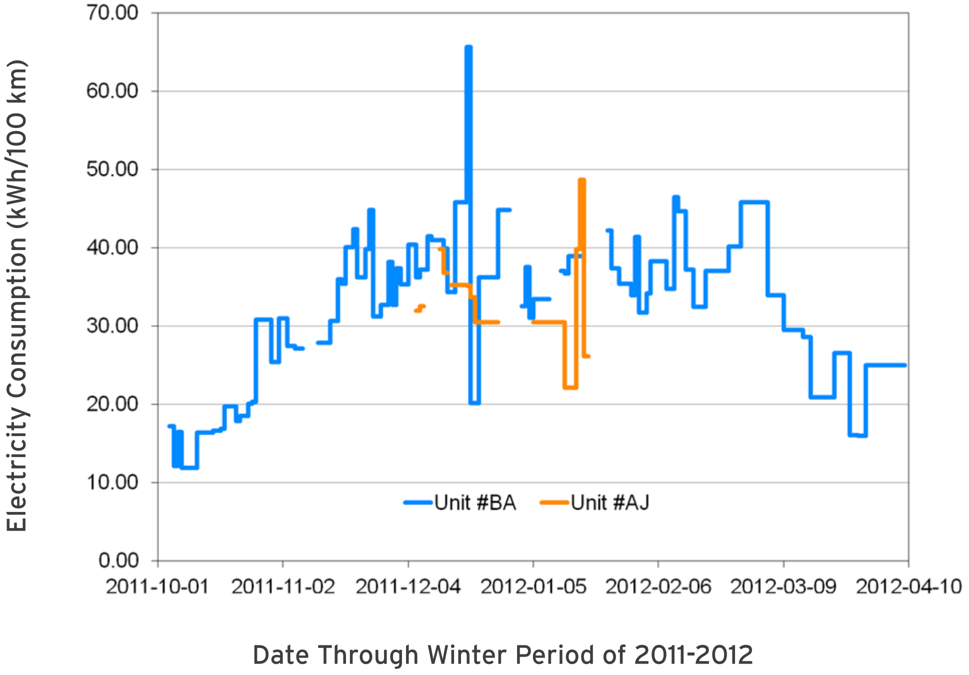
[2] U.S. DOE data available at: http://www.fueleconomy.gov/feg/evtech.shtml

Window fogging was the first noticeable issue during the winter, however, this is a general concern for vehicles during winter operation. Observations were based solely on driver perceptions. It was difficult to make objective comparisons to other vehicles. Window defogging was generally satisfactory when the driver was alone in the vehicle. But when one or more passengers were added, the heating system had difficulty keeping up, with ice formation starting at the back of the rear-door windows, and progressing forward. This was particularly a problem when the vehicle had been outside and turned off for any significant period of time. The rear window was always kept adequately clear by the electric defogging unit.

Interior cabin warmth was a concern, particularly given the priority need to divert the heating system to the windshield. During mid-winter, the vehicles were found to be noticeably cold, but not intolerable, given that travel times were generally not long, i.e., no more than around 20 minutes per trip. The heated driver seat was found to be a decidedly advantageous feature. Drivers in particular tended to note cold feet and cold hands, the latter given that the steering column was not heated. It was typical during the winter to carry an extra pair of mitts for driving the vehicle.

Both defogging and cabin warmth relate to issues of overall vehicle heat energy management, particularly for a vehicle that is cold at the start of operation. These types of concerns were precisely the same as had been found during the Manitoba PHEV demonstration for converted Toyota Prius units. Conventional vehicles, which are typically inefficient, have ample waste heat from the engine that can be diverted to the cabin. But as the efficiency of the vehicle improves, the available waste heat decreases, and in the case of all-electric cars, like the iMiEVs, there is no waste heat available. Heat provision must rely directly on drawing power from the vehicle batteries, requiring a much more careful balance. It is important to not oversize the heating system given that battery capacity is limited and also has to provide motive energy for the vehicle. Investigations of cabin warmth will continue as a priority for the next years of the project.



The third main winter operational issue was increased electricity consumption, and thus by implication reduced available vehicle range. Through the course of the winter of 2011-2012, the electricity consumption for Unit #BA was monitored almost continuously using an externally mounted IPLC PM2 meter at the wall plug. A time track of data is summarized in the figure on page 10, starting in October 2011 through to April 2012. Importantly, during this period Unit #BA was only recharged once per day at home, using Level 1, and was not plugged in at work. Unit #AJ was also monitored, although not as thoroughly, and selected data is also presented in the same plot.

Starting in mid-October 2011, electricity consumption for Unit #BA began to increase significantly. This was obviously due to colder weather, requiring operation of the vehicle's electrical heating systems. By the end of March 2012, electricity consumption had returned back to a more normal level. Data for Unit #AJ was more limited. As illustrated, electricity consumption varied but was not systematically different from Unit #BA, being essentially within the same band range.

Over the three coldest months (December, January, and February), vehicle recharging of Unit #BA was logged for 38 events. The aggregate electricity consumption over this period was calculated as 36.9 kWh per 100 km (i.e., 356 kWh to travel 964 km). Average electricity consumption was 38.1 ± 6.8 kWh per 100 km. These data meant that over the winter, electricity consumption, on average, was 2.3 time higher than the baseline value, or that vehicle range

was reduced by 2.3 times. Based on an expected baseline travel range of 110 to 120 km for a single charge, the expected range during the three coldest months was roughly 45 to 50 km for a single charge.

There were also significant high and low excursions of electricity consumption that were evident for both vehicles during the winter. The highest was 65.6 kWh per 100 km on one occasion for Unit #BA, or just over four times the expected baseline summer value. This most severe experience was noted to be due to a combination of cold temperature and slow traffic, reducing the effective range of the vehicle to around 30 km at that time.

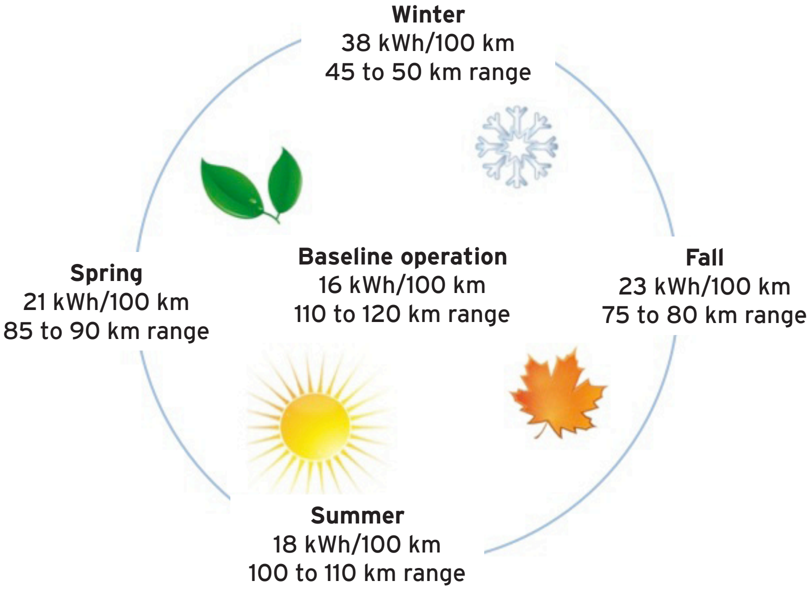
As noted previously, an average light-duty vehicle within Manitoba travels only 16,000 km annually, which corresponds to approximately 43 km per day. Daily commuting distances within Winnipeg, however, tend to be shorter, being typically not greater than about 30 km per day. As such, although the electricity consumption and expected range of the iMiEV were significantly affected by winter operation, typical Winnipeg commuters would be still able to complete their daily travel using a single daily charge, and not be compromised.

A further implication of the monitored electricity consumption was that if a vehicle were used strictly for commuting to and from work, the ability to plug-in at a secondary location other than at home would not be critical for vehicle motive operation, but could be important in terms of keeping the vehicle warm. If on the other hand a vehicle were driven more extensively than just commuting to and from work, a secondary plug-in location could be critical during the winter for ensure adequate motive operation.

The last winter issue identified was associated with the small-sized tires on the vehicles, and was not temperature related. The iMiEVs were both equipped with high-quality winter tires. These provided generally very good traction and handling characteristics. However, given their small size, an issue did emerge for certain drivers if a vehicle had to “plow” through fresh snow of any significant depth on an unplowed road. This was an issue with the small size of the car, not it being electric. Once onto a main street, this was not a concern.

Seasonal Vehicle Range

The electricity consumption and resulting range for the iMiEV depended significantly on the season. Any combination of heating and/or cooling would have an impact. Based on experience with the vehicles over the first year, approximate seasonal average values were determined, as are presented in the figure on page 11. These values provide preliminary guidelines on what could be expected for the iMiEV. These data will be updated in future reports as more experience is obtained.



Comparative Current Operating Costs per 100 km

Vehicle	Fuel Consumption	Operating Cost
iMiEV (all-electric)	25 kWh/100 km annual	$1.75/100 km
Average conventional car	15 Litres/100 km annual	$18.00/100 km
Efficient conventional car	8 Litres/100 km annual	$9.50/100 km

Vehicle-Application and Costs

The use of electricity as the "fuel" for the iMiEV resulted in dramatically lower operating costs compared to conventional vehicles. Representative current operating costs per 100 km are presented in the table on page 12, comparing the iMiEV to both an average conventional vehicle and an efficient conventional vehicle. The electricity consumption value of 25 kWh per 100 km was calculated as the average of assumed monthly electricity consumption requirements based on the seasonal experience with the iMiEVs as noted earlier. The current cost of electricity is about 7¢ per kWh, versus about $1.20 per litre of liquid fuel used in the conventional vehicles. Even with relatively high annual average electricity consumption, the iMiEV costs less than 1/10th of an average Manitoba vehicle, and less than 1/5th of an efficient conventional vehicle, such as a hybrid. Recharging the iMiEV from completely-dead to full works out to cost only about $1.35. A visit to a conventional gasoline refuelling station today typically costs $20.00 or more. Such price advantages make a compelling case for electric vehicles within Manitoba.

The ideal application for the iMiEV is as a regular short-distance travel vehicle within a limited vicinity. This includes commuting applications, traveling to and from work, and other similar uses. The limited travel distance of the iMiEV means that it cannot be used effectively for longer-distance travel. As such, the iMiEV cannot be a complete replacement for a typical family vehicle that would involve a combination of short-distance commuting and some longer-distance travel, such as to the cottage on the weekend. This constraint has been well understood by the vehicle's manufacturer, and is reflected in the way the vehicle is marketed, as essentially a "second car." For overall application of a single vehicle for families in Manitoba, a PHEV likely makes more sense as a practical replacement.

The overall economics of the iMiEV were considered based on a series of assumptions. These are outlined in the sidebar and figure on page 14 in terms of the present value of total vehicle costs (purchase and operating) over an eight-year life. Total vehicle costs are presented as a function of the averaged cost of gasoline fuel, with costs for the iMiEV being obviously constant in this case. Assuming an eight-year life, the iMiEV costs less overall than an average Manitoba vehicle when the gasoline price reaches just over $1.10 per Litre. This means that the iMiEV is already less expensive than an average vehicle, based on operational assumptions as presented. The total costs for an efficient vehicle are generally the lowest of the three, however, if gasoline prices rise to a level of greater than $3.00 per Litre, even that vehicle becomes more expensive overall than the iMiEV. As conventional fossil fuel prices continue to rise, and electric vehicle purchase prices continue to reduce, the economics of the iMiEV and other electric vehicles will continue to improve.

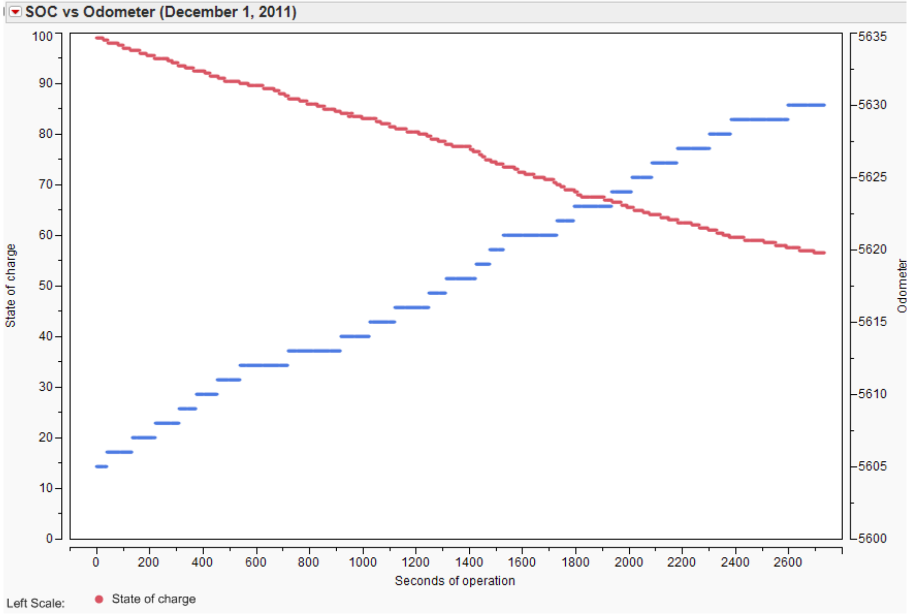
Technical Comparison of Electricity Consumption Data

Installation of the CAN-Gateway units permitted the continuous logging of a broad range of vehicle parameters using the OTTO-Link data-loggers. A large amount of vehicle data were generated that were not possible to completely analyze. A number of insights did begin to emerge, as well as some questions requiring further investigation. Most important was regarding the vehicle state-of-charge (SOC) condition versus vehicle travel distance.

For each vehicle, data were logged daily at each second of actual operation, i.e., when the vehicle was turned on and out of the "park" position. Daily logged timeframes thus seemed short, but made sense given that the actual time of operation for each vehicle was typically less than one hour per day in total. As illustrated in an example plot on December 1, 2011 for Unit #BA (page 13) the SOC value and the odometer value changed in a very linear fashion with operational time. Indeed, when the SOC was then plotted as a direct function of the odometer value, highly linear results were obtained for all days analyzed. It had been thought that the change in SOC might deviate up and down quite significantly due to relative heating loads, but this did not appear to be the case. Data plots were all highly linear for all individual days. The slope in this case was the percent change in SOC per km. Multiplying this value by 16 kWh, corresponding to the value at 100% SOC, provided a calculated estimate of energy consumption values in terms of kWh at the battery per 100 km.

At the same time, additional external data were available for electricity consumption, as measured at the wall plug using the IPLC-PM2 meter. These data were highly robust, based on past experience, and used actual recorded odometer values at plug-in times in order to calculate energy consumption values in terms of kWh at the wall plug per 100 km. For the month of December 2011, data for Unit #BA from the CAN-Gateway for the vehicle SOC change with odometer, were compared to external electricity consumption values. As described earlier in the report, this month involved significant high and low excursions in electricity consumption at the wall plug. Also importantly, those high and low excursions matched driver experience with the vehicle.

When initial data were compared it was found, surprisingly, that there was no correlation between the battery-based energy consumption values, as calculated using data off the CAN-Gateway, versus external electricity consumption values. It was expected that the two sets of values would be related to one another, with some offset errors or systematic differences, but there was no relationship. This situation could not be explained, and will require more in-depth investigation during the second year with the vehicles.



Assumptions for Economic Analysis

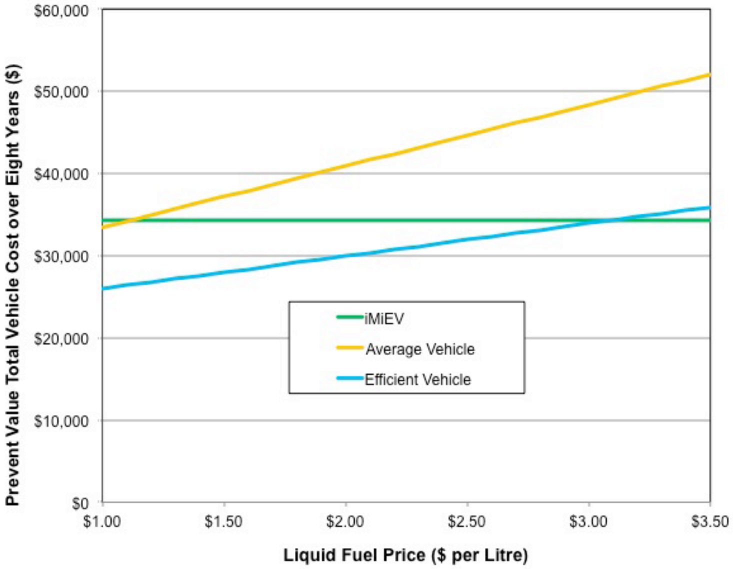
Purchase price of $33,000 for iMiEV, versus $26,000 for a conventional vehicle, and $22,000 for a more efficient vehicle.

Fuel consumption requirements as presented in table on page 12.

Longer term price of 10¢ per kWh for electricity, and price for liquid fuel (gasoline) variable as presented.

Annual travel of 8,000 km.

Cost of money of 6%.



EVTEC

Red River College (RRC) is developing the Electric Vehicle Technology & Education Centre (EVTEC) with the support of the Province of Manitoba to help test and demonstrate electric vehicle technologies, while enhancing its applied research and training programs. EVTEC's mission is threefold:

- To support electric vehicle innovation among Manitoba's transportation sector,
- To enhance electric vehicle education at RRC and in the region, and
- To increase public awareness of electric vehicle technology.

Catalyzing this initiative has been the Province's collaboration with Mitsubishi Heavy Industries, New Flyer Industries, Manitoba Hydro, and RRC on the $3-million, three-year project to develop an all-electric transit bus and charging system.

Contacts

Ray Hoemsen, P.Eng.
Director, Applied Research & Commercialization
Red River College
204.632.2523
rhoemsen@rrc.mb.ca

Jim Crone
Director, Energy Division
Manitoba Innovation, Energy and Mines
204.945.1874
jim.crone@gov.mb.ca

Robert Parsons
Advanced Energy Projects, Energy Division
Manitoba Innovation, Energy and Mines
204.945.6077
robert.parsons@gov.mb.ca