INL/EXT-14-32135

How many electric miles do Nissan Leafs and Chevrolet Volts in The EV Project travel?

John Smart

May 2014

The INL is a U.S. Department of Energy National Laboratory
operated by Battelle Energy Alliance

INL/EXT-14-32135

How many electric miles do Nissan Leafs and Chevrolet Volts in The EV Project travel?

John Smart

May 2014

Idaho National Laboratory

Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

How many electric miles do Nissan Leafs and Chevrolet Volts in The EV Project travel?

May 2014

Key Conclusions

- Between October 2012 and December 2013, Nissan Leaf drivers in The EV Project averaged 808.1 electric vehicle miles traveled per month. Chevrolet Volt drivers in The EV Project Volt averaged 759.3 electric vehicle miles traveled per month and 1,019.8 total vehicle miles traveled per month.
- The distributions of electric vehicle miles traveled per month for Leafs and Volts overlap significantly, indicating that many Volts drove the same or more electric miles than Leafs, despite a large difference in electric range.
- Change in electric vehicle miles traveled from month to month over the 15 month study period was similar for Leafs and Volts, suggesting that seasonal effects influence drivers of both vehicles in the same way.

Introduction

Battery electric vehicles, such as the Nissan Leaf, are powered exclusively by electricity. The maximum driving range between refueling – in this case recharging – of a battery electric vehicle is limited by the energy storage capacity of the vehicle's battery. Extended-range electric vehicles, such as the Chevrolet Volt, can also be powered exclusively by electricity; however, they have smaller batteries and, therefore, shorter electric vehicle (EV) mode range than battery electric vehicles. Extended-range electric vehicles provide range extension using an internal combustion engine. The electric ranges of battery electric vehicles and extended-range electric vehicles are quantified by auto manufacturers and third parties such as the U.S. Environmental Protection Agency (EPA). However, it is the owners' driving and charging behavior that determines how much distance is actually traveled using electric power.

This paper investigates the observed monthly distance traveled when powered solely by electricity, or electric vehicle miles traveled (eVMT) of Nissan Leafs and Chevrolet Volts enrolled in The EV Project.

Which Vehicles Are Being Studied?

Private owners of Nissan Leafs and Chevrolet Volts in 19 metropolitan areas across the United States participated in The EV Project. They agreed to allow project researchers to electronically monitor the usage of their vehicles throughout the project.

Data collection from Leafs and Volts in The EV Project began in January 2011 and August 2011, respectively. It ended for both groups of vehicles on December 31, 2013. Parameters recorded by the vehicle telematics system included the vehicles' odometer reading. The set of parameters logged by EV Project Volts was expanded on October 1, 2012, to include the EV-mode odometer. This parameter provides the distance driven in EV mode. In order to compare Leaf and Volt eVMT, this study considers data from Leafs and Volts logged from October 1, 2012, through December 31, 2013. Table 1 describes the size of the Leaf and Volt data sets that were analyzed in this study.

Table 1. Description of the EV Project Leaf and Volt data sets.

	Nissan Leaf	Chevrolet Volt
Number of vehicles	4,039	1,867
Number of vehicle months	35,294	20,545
Total distance traveled (miles)	28,520,792	20,950,967
Distance traveled in EV mode (miles)	28,520,792	15,599,508
Percent of distance traveled in EV mode	100%	74.5%

Discussion of Results

Monthly eVMT was determined by calculating the change in the Leaf's odometer and the Volt's EV-mode odometer across each vehicle month when sufficient data were reported. Monthly total vehicle miles traveled (VMT) by Volts was also calculated in the same way using the Volt odometer. Volt VMT includes all distances driven, either when in EV mode or in extended-range mode. VMT and eVMT in each vehicle month in the Leaf and Volt data sets were averaged to provide a simple comparison. Table 2 shows these results.

Table 2. Average monthly total and electric vehicle miles traveled.

	Nissan Leaf	Chevrolet Volt
Average monthly total VMT	808.1	1,019.8
Average monthly eVMT	808.1	759.3

The EPA's electric range of the Leaf is approximately double that of the Volt.[1] However, Leaf drivers in the EV Project averaged only 6% more actual electric miles per month than Volt drivers.

To see the variation of VMT and eVMT among vehicles and from month to month, the distributions of these metrics were examined. Figure 1 shows the frequency distributions of the average VMT and eVMT from each vehicle. Each data point in the distributions represents a single vehicle's average over the entire study period. The number of vehicles represented is shown in Table 1.

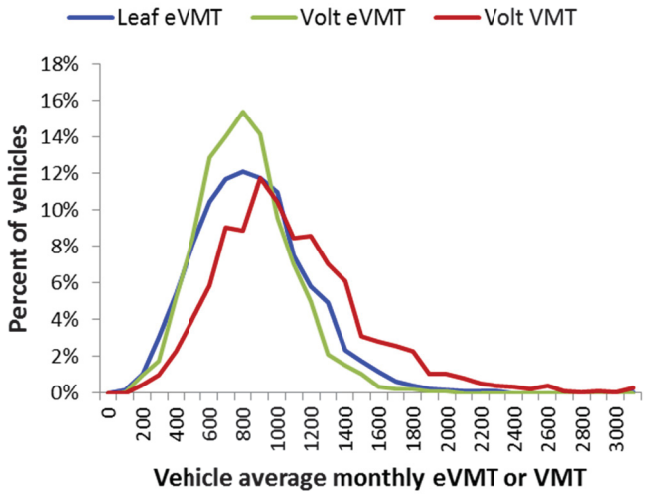

Figure 1. Distribution of vehicle average monthly eVMT and VMT, where each data point in the distributions represents a single vehicle's average over the entire study period.

The range of Volt average monthly VMT extends farther to the right than the range of Leaf eVMT, indicating that some Volt drivers averaged more total miles per month than any Leafs. This is not surprising given that the overall range between refueling of the Chevrolet Volt is five times higher than the Leaf.[2] However, there is significant overlap between the Volt VMT and Leaf eVMT curves. This means that many Leaf drivers averaged the same or more miles per month than many Volt drivers, despite the Volt's much longer overall range. This illustrates the fact that some drivers have a driving routine that accommodates either vehicle. (Naturally, consumers do not make choices based on their average behavior, but rather their day-to-day driving needs. Such analysis is beyond the scope of this paper, however.)

The distributions of Volt and Leaf average monthly eVMT in Figure 1 are remarkably similar. A large number of Volts averaged the same or higher monthly eVMT than many Leafs, despite having a much shorter electric range. The disparity between electric range and eVMT can be explained by three reasons. First, Volt drivers in The EV Project have been shown to charge more frequently, on average, than Leaf drivers.[3] Frequent charging extends the effective EV-mode range of the vehicle. Secondly, Volt drivers can fully deplete their batteries and continue to their destinations in extended-range mode, if necessary. Leaf drivers, on the other hand, are less likely to realize their full electric range, because of the impracticality of planning stops for charging precisely when the battery is fully depleted. Finally, Leaf drivers may have purchased their vehicles with the understanding that they do not require long driving range or they have the option of driving a different vehicle on long trips.

Figure 2 shows the frequency distributions of VMT and eVMT per vehicle month. Each data point in these distributions represents a single vehicle month. All vehicle months in the data sets were included. The number of vehicle months represented is shown in Table 1. The numeric data for the distributions shown in Figures 1 and 2 are included in the tables in the appendix.

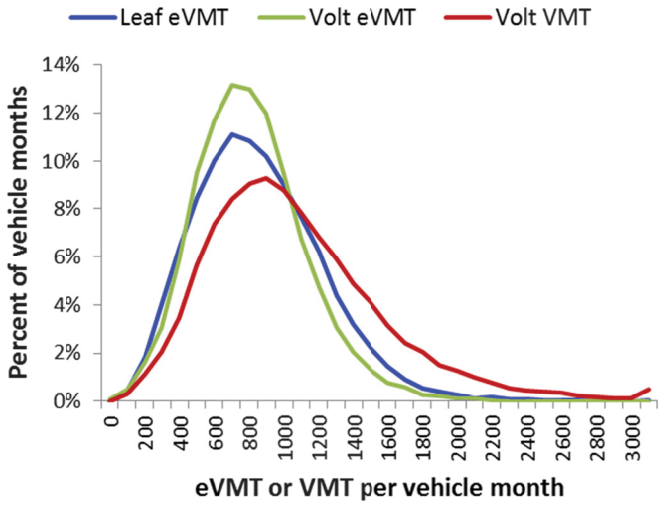

Figure 2. Distribution of eVMT and VMT per vehicle month, where each data point in the distributions represents a single vehicle month.

One would expect the distributions in Figure 2 to be wider than the distributions in Figure 1, because they represent the variation of eVMT and VMT in individual months, rather than variation between one vehicle's average eVMT or VMT to another's vehicle's average. For example, a driver may hypothetically drive 800 miles each month for 14 months and 1,500 miles in 1 month. The single month with an unusually high VMT would not affect the driver's overall average much; therefore, it would not noticeably shift the VMT distribution in Figure 1. However, this single month outlier would be included in the VMT distribution in Figure 2 and it would act to widen the distribution. In light of this, it is significant that the distributions in Figure 2 are only slightly wider than those in Figure 1. This means that the majority of the variation in eVMT and VMT is between drivers, rather than between months for each driver.

In addition to calculating the distributions of eVMT and VMT per vehicle month for the entire study period (Figure 2), these distributions were calculated separately for each of the 15 months in the study period. Descriptive statistics describing these monthly distributions were examined to identify changes in behavior over time. Figure 3 shows lines that connect the median values of the Leaf and Volt eVMT and Volt VMT distributions in each of the 15 months in the study period.

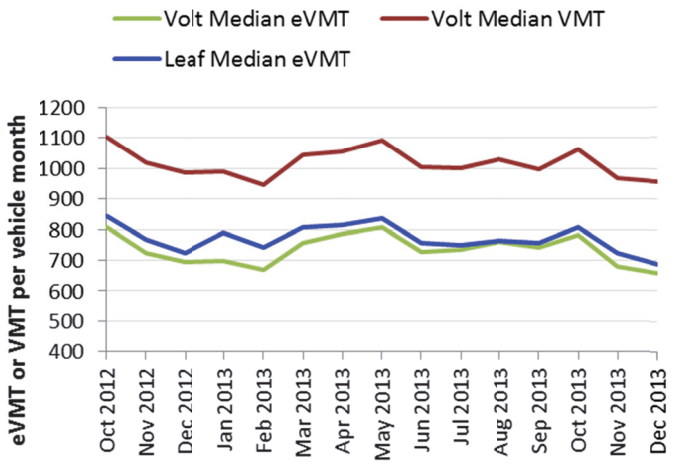

Figure 3. Median eVMT and VMT per vehicle month over time.

The Leaf's median eVMT (blue line) is slightly higher than the Volt's median eVMT (green line) throughout the 15-month study period; however, the medians are nearly equal in August 2013. The eVMT medians rise and fall fairly proportionally, with only a few exceptions. The 25th and 75th percentile values for the distributions each month (not shown) rise and fall with the medians, indicating that the shapes of the distributions are relatively constant month after month. This proportional shifting of the distributions overtime suggests that seasonal effects influence both Leaf and Volt drivers in the same way. Regional analysis is needed to confirm this hypothesis.

The ratio of the Volt's median eVMT to its median VMT (red line) is the percentage of distance traveled in EV mode each month. Visual inspection of Figure 3 shows this value remained relatively consistent. There was seasonal variation, however; the months of April through October saw 74% to 77% of distance in EV mode, whereas vehicles averaged 70% to 74% miles in EV mode in November through March. This metric by month is included in the Table A3 in the appendix, along with descriptive statistics for the monthly eVMT and VMT distributions.

About The EV Project

The EV Project was the largest plug-in electric vehicle infrastructure demonstration project in the world, equally funded by the U.S. Department of Energy (DOE) through the American Recovery and Reinvestment Act and private sector partners. The EV Project deployed over 12,000 AC Level 2 charging stations for residential and commercial use, as well as over 100 dual-port DC fast chargers. Approximately 8,300 Nissan LEAFs™, Chevrolet Volts, and Smart ForTwo Electric Drive vehicles were enrolled in the project.

Project participants gave written consent for EV Project researchers to collect and analyze data from their vehicles and/or charging units. Data collected from the vehicles and charging infrastructure represented almost 125 million miles of driving and 4 million charging events. The data collection phase of The EV Project ran from January 1, 2011, through December 31, 2013. Idaho National Laboratory is responsible for analyzing the data and publishing summary reports, technical papers, and lessons learned on vehicle and charging unit use. This material is based on work supported by DOE under Award Number DE-EE-0002194.

Company Profile

Idaho National Laboratory is one of DOE's 10 multi-program national laboratories. The laboratory performs work in each of DOE's strategic goal areas: energy, national security, science, and the environment. Idaho National Laboratory is the nation's leading center for nuclear energy research and development. Day-to-day management and operation of the laboratory is the responsibility of Battelle Energy Alliance.

For more information, visit avt.inl.gov/evproject.shtml.

References

1. www.fueleconomy.gov gives an EPA-estimated electric range of 73 miles for MY2011/2012 Nissan Leafs and 75 miles for the MY2013 Leaf; the EPA electric range is 35 miles for MY2011/2012 Volts and 38 miles for MY2013 Volts. Leafs and Volts enrolled in The EV Project include a mix of these model years.
2. www.fueleconomy.gov gives an EPA-estimated overall range of 380 miles for the MY2011-2013 Chevrolet Volt.
3. The report "Observations from The EV Project in Q4 2013" explains that EV Project Leafs have consistently averaged 1.1 charging events per day driven and Volt have averaged between 1.4 and 1.5 charging events per vehicle day driven since the beginning of the project. See http://avt.inl.gov/pdf/EVProj/EVProjectSummaryReportQ42013FINAL.pdf About The EV Project

Appendices

Table A1. Values used to create the frequency distributions shown in Figure 1.

Distance Bin (miles)	Leaf Frequency	Volt Frequency (Total Miles)	Volt Frequency (EV-mode Miles)
0	0	0	0
>0 - 100	7	0	1
>100 - 200	43	8	18
>200 - 300	122	18	33
>300 - 400	219	42	98
>400 - 500	328	76	157
>500 - 600	423	110	240
>600 - 700	472	169	262
>700 - 800	488	166	287
>800 - 900	475	219	264
>900 - 1000	444	195	179
>1000 - 1100	304	158	131
>1100 - 1200	234	160	93
>1200 - 1300	200	132	39
>1300 - 1400	94	114	28
>1400 - 1500	70	58	19
>1500 - 1600	46	52	6
>1600 - 1700	26	48	4
>1700 - 1800	15	43	4
>1800 - 1900	10	20	2
>1900 - 2000	7	19	2
>2000 - 2100	3	15	0
>2100 - 2200	3	10	0
>2200 - 2300	4	7	0
>2300 - 2400	0	6	0
>2400 - 2500	0	4	0
>2500 - 2600	0	7	0
>2600 - 2700	0	2	0
>2700 - 2800	0	1	0
>2800 - 2900	0	2	0
>2900 - 3000	1	1	0
>3000	1	5	0
	4039	1867	1867

Table A2. Values used to create the frequency distributions shown in Figure 2.

Distance Bin (miles)	Leaf Frequency	Volt Frequency (Total Miles)	Volt Frequency (EV-mode Miles)
0	0	0	16
>0 - 100	158	62	97
>100 - 200	648	233	339
>200 - 300	1410	416	629
>300 - 400	2235	716	1214
>400 - 500	2987	1161	1952
>500 - 600	3540	1511	2409
>600 - 700	3921	1725	2703
>700 - 800	3818	1860	2671
>800 - 900	3592	1905	2465
>900 - 1000	3173	1800	1942
>1000 - 1100	2701	1604	1377
>1100 - 1200	2200	1400	971
>1200 - 1300	1546	1209	632
>1300 - 1400	1131	1006	420
>1400 - 1500	783	842	267
>1500 - 1600	511	649	161
>1600 - 1700	319	498	119
>1700 - 1800	194	419	56
>1800 - 1900	145	312	41
>1900 - 2000	94	261	28
>2000 - 2100	48	205	21
>2100 - 2200	55	155	9
>2200 - 2300	24	111	2
>2300 - 2400	20	93	1
>2400 - 2500	10	82	0
>2500 - 2600	9	72	0
>2600 - 2700	4	43	1
>2700 - 2800	1	38	1
>2800 - 2900	0	29	1
>2900 - 3000	2	29	0
>3000	15	99	0
	35294	20545	20545

Table A3. eVMT/VMT descriptive statistics by month and overall for the distributions whose median values are depicted in Figure 3.

	Month	Number of vehicle months	Total miles	Percent of miles in EV mode	avg	std dev	max	95th	75th	median	25th	5th	min
Leaf	Oct 2012	2304	2043334	--	886.9	399.8	3460.1	1571.5	1127.3	845.5	600.1	303.8	41.4
	Nov 2012	2376	1895713	--	797.9	361.8	3236.9	1408.5	1013.6	767.9	542.1	278.1	68.2
	Dec 2012	2683	2032197	--	757.4	334.2	2221.2	1351.3	961.1	724.8	510.9	275.0	41.0
	Jan 2013	2807	2287247	--	814.8	367.9	3448.7	1441.9	1049.1	788.8	545.1	277.9	32.7
	Feb 2013	2709	2094318	--	773.1	352.0	3139.4	1378.6	990.0	742.7	523.1	252.9	36.1
	Mar 2013	2518	2113081	--	839.2	375.7	3242.5	1497.3	1068.5	807.7	567.6	290.8	25.9
	Apr 2013	2511	2141590	--	852.9	394.8	3658.2	1531.9	1092.6	815.9	564.6	273.3	55.1
	May 2013	2506	2168769	--	865.4	389.5	3485.6	1542.6	1100.5	836.4	583.2	292.1	35.5
	Jun 2013	2472	1954500	--	790.7	362.3	3616.4	1439.9	1007.1	755.0	529.8	264.1	27.8
	Jul 2013	2474	1940921	--	784.5	373.8	4050.0	1432.5	1001.8	748.3	518.7	251.9	59.8
	Aug 2013	2406	1941879	--	807.1	374.0	3822.2	1474.8	1038.6	764.7	542.4	276.3	49.8
	Sep 2013	2255	1776002	--	787.6	358.9	2578.8	1419.9	1019.8	756.9	524.4	255.4	36.4
	Oct 2013	2268	1904190	--	839.6	385.4	3630.1	1497.9	1092.7	806.0	560.2	267.4	23.1
	Nov 2013	1891	1425968	--	754.1	334.4	3074.3	1320.2	956.8	724.1	501.0	284.5	42.0
	Dec 2013	1114	801080	--	719.1	318.8	2311.9	1305.7	913.3	686.9	492.7	259.5	67.8
	Overall	35294	28520792	--	808.1	370.3	4050.0	1457.5	1033.2	772.0	541.5	273.1	23.1
Volt EV mi	Oct 2012	976	802293	0.744	822.0	326.1	2023.4	1417.5	1008.6	808.1	590.6	346.3	70.8
	Nov 2012	981	722734	0.724	736.7	294.2	1778.5	1273.8	909.9	723.6	530.4	302.2	0.0
	Dec 2012	1014	717850	0.718	707.9	278.8	1819.2	1184.9	877.9	696.1	518.8	280.1	0.0
	Jan 2013	1037	749123	0.730	722.4	291.3	2105.5	1248.8	891.0	699.3	518.8	305.2	6.3
	Feb 2013	1119	771020	0.729	689.0	282.0	1831.5	1210.9	850.6	668.8	497.0	251.0	21.6
	Mar 2013	1608	1243684	0.739	773.4	311.0	2270.8	1328.4	949.6	755.5	553.8	315.6	33.8
	Apr 2013	1655	1332180	0.762	804.9	324.2	2115.9	1375.6	990.7	784.3	575.5	328.0	16.7
	May 2013	1647	1369228	0.761	831.3	338.7	2035.3	1424.1	1048.7	805.8	594.4	322.1	0.0
	Jun 2013	1551	1181475	0.757	761.8	304.6	2141.2	1294.1	947.8	727.3	544.4	309.1	39.9
	Jul 2013	1548	1173096	0.757	757.8	324.4	2111.7	1324.0	946.8	735.2	538.6	265.3	0.0
	Aug 2013	1560	1208159	0.752	774.5	336.9	2816.7	1345.7	971.8	759.5	529.9	282.6	0.0
	Sep 2013	1588	1214348	0.766	764.7	326.6	2760.4	1324.5	956.3	741.2	538.1	296.3	0.0
	Oct 2013	1575	1264589	0.756	802.9	336.6	2628.8	1379.9	998.0	783.5	572.3	303.0	0.0
	Nov 2013	1556	1089834	0.724	700.4	290.8	1910.8	1224.0	871.9	679.6	505.9	256.5	0.0
	Dec 2013	1130	759894	0.703	672.5	269.4	1966.1	1133.2	831.0	659.4	482.5	256.6	0.0
	Overall	20545	15599508	0.745	759.3	316.0	2816.7	1319.4	942.1	733.9	537.7	294.1	0.0
Volt total mi	Oct 2012	976	1077949	--	1104.5	561.3	5501.2	2144.2	1376.9	1008.2	707.1	402.8	70.8
	Nov 2012	981	998797	--	1018.1	510.7	3450.3	1973.5	1269.5	932.5	650.6	375.8	66.5
	Dec 2012	1014	1000147	--	986.3	494.8	4507.2	1865.1	1247.8	908.9	648.1	351.2	47.0
	Jan 2013	1037	1025511	--	988.9	489.9	3132.7	1908.8	1213.9	914.2	650.0	366.4	44.2
	Feb 2013	1119	1056934	--	944.5	503.1	4070.0	1873.2	1177.7	858.8	606.1	296.1	21.6
	Mar 2013	1608	1682036	--	1046.0	521.8	5153.7	1966.0	1300.1	960.9	690.1	374.9	33.8
	Apr 2013	1655	1748657	--	1056.6	516.5	3778.9	2022.1	1330.2	961.9	700.5	392.8	16.7
	May 2013	1647	1799082	--	1092.3	530.7	4808.6	2058.3	1392.8	1019.2	710.2	384.0	70.9
	Jun 2013	1551	1560323	--	1006.0	503.8	4499.0	1945.8	1267.6	918.6	652.7	348.6	42.6
	Jul 2013	1548	1549903	--	1001.2	522.7	4993.1	1965.4	1246.7	928.2	651.2	321.5	93.7
	Aug 2013	1560	1606429	--	1029.8	541.1	4581.9	1985.2	1295.4	935.1	652.7	326.4	84.8
	Sep 2013	1588	1585188	--	998.2	493.7	3811.6	1922.9	1277.2	925.2	652.6	347.6	57.0
	Oct 2013	1575	1672355	--	1061.8	529.3	4180.7	2061.2	1334.8	979.1	708.1	350.2	34.1
	Nov 2013	1556	1505982	--	967.9	495.2	4162.9	1876.0	1228.8	875.8	636.5	328.4	49.0
	Dec 2013	1130	1081674	--	957.2	480.1	3651.3	1852.9	1212.0	877.2	617.4	339.3	29.1
	Overall	20545	20950967	--	1019.8	516.1	5501.2	1969.1	1283.0	935.5	660.7	350.1	16.7