Distribution of US Car Fleet by Car Class

By C.E. (Sandy) Thomas, Ph.D.[1]

1.0 Introduction One of the key findings of the McKinsey & Company report on alternative vehicles in Europe was that 50% of all vehicles in the EU that generate 75% of all light duty vehicle (LDV) greenhouse gases (GHGs) are too big and/or travel too far to be comfortably and economically powered by batteries, and therefore hydrogen-powered fuel cell electric vehicles are required to make substantial cuts in GHG emissions and oil consumption. The purpose of this analysis is to derive the corresponding numbers for the US car fleet that generally has larger cars that travel farther than our European counterparts.

2.0 Conclusions: From this analysis, we conclude (Table 1) that BEVs could at best replace less than 40% of all US vehicles[2], and these vehicles account for less than 28% of vehicle miles traveled, and they account for at most 26% of all gasoline consumed, and less than 26% of all LDV greenhouse gases (GHGs) generated[3]. In addition, the BEVs will generate GHGs at the power plant. Based on the Argonne National Laboratory's estimates of the average US grid mix in 2015, we estimate that the BEVs would generate 16.2% of GHGs such that the maximum GHG displacement of 29.4% by replacing small IC Vehicles would be reduced to 9.4% net reduction in GHG emissions: So BEVs could at best reduce gasoline consumption by 26%, and GHGs by 9.4% in 2015,and at most by 26% once the average US grid generated no GHGs, far below the 80% GHG reduction goal. Fuel cell electric vehicles (FCEVs), on the other hand, have no such restriction as to vehicle size. Several car makers have developed and are road-testing SUVs, and fuel cells have been tested in transit buses and one company is testing fuel cells in large Class 8 heavy duty trucks for hauling freight in the port of Los Angeles.

Table 1 Estimated % of vehicles on the road, VMT, and % gasoline and GHGs reduced by replacing all small cars, small pickup trucks, small SUVs, small vans and 50% of all Midsize passenger sedans with BEVs

	# of LDVs on the road	% VMT	% gasoline	% GHGs	% ICV GHG savings	% BEV grid GHGs	Net GHG Savings (2015)
Small cars & trucks suitable for BEVs:	**39.8%**	**27.5%**	**25.5%**	**25.5%**	**-25.5%**	**16.2%**	**-9.32%**
Larger cars & trucks:	**60.2%**	**72.5%**	**74.5%**	**74.5%**	N/A	N/A	N/A

EPA f.e. vs. veh class OTR by class (rev B).XLS; Tab 'Sales by class';AN132 - 6 / 30 / 2011

3.0 Analysis procedure. We have not been able to find any US entity that routinely publishes data on LDV vehicle miles traveled (VMT) as a function of vehicle size/class or even the number of vehicles in each car class on the road. (See Table 2 for the EPA vehicle size categories used for fuel economy data[4].) The DOE and DOT publish data segregated into only two broad categories: light duty vehicles and light duty trucks.

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[1] For more details on alternative vehicles, see http://www.cleancaroptions.com

[2] This analysis assume that BEVs could replace all small cars and all small wagons, all small vans, all small pickup trucks, all small SUVs and 50% of all Medium sized sedans.

[3] Since smaller cars generally have higher fuel economies, they consume less gasoline and generate less GHGs per mile driven than larger vehicles.

[4] See this link for EPA vehicle size classifications: http://www.fueleconomy.gov/feg/info.shtml#sizeclasses

4.0 The VMT estimation model. A model was therefore created based on the annual new car sales for each vehicle class over the last 30 years. To estimate the number of vehicles of each class still on the road, we multiplied each category's annual sales[5] times the estimated survival rates, taken from the Oak Ridge National Laboratory's Transportation Energy Data Book[6].(See Table 3 for survival rates.) Thus for light duty cars, after 30 years 6.6% of all MY1990 cars would still be on the road, while 4.2% of light duty trucks would still be on the road. We used the MY1990 survival rates for all cars sold in the 1990's and later, and MY 1980 survival rates for all cars sold in the 1980's, etc.

Based on current BEVs under development or road test, we included all small vehicles plus small vans, small pickups and small SUVs in the category of possible BEVs (see Table 4 for current examples of BEVs in most of these classes. Since the Nissan Leaf is in the lower half of the midsize sedan category with 113 ft^3 of total passenger plus luggage space with the midsize sedan vehicle defined as those with total cabin space between 110 to 119 ft^3, we included half of all midsize sedans and midsize wagons as part of the group of vehicles that could be powered by batteries with advance lithium-ion battery technology[7]. The results of this model are shown in Table 6 in terms of the percentages of each EPA vehicle class on the road in 2010, as well as the percentage of new cars sold in each class for 2010.

The annual vehicle miles traveled (VMT) were estimated based on data provided by the Argonne National Laboratory[8] (Table 5), which estimate the annual VMT as a function of vehicle age for several of the EPA vehicle classes. Argonne estimated VMT for vehicles through age 16, and the model extrapolates those data out to 30 years age for each vehicle class.

The detailed results of this analysis are shown in Table 7 in terms of the percentages of each vehicle class on the road, the VMT for each group, and the weighted average fuel economy for each vehicle class, grouped by small cars and trucks that could be affordably powered by batteries, and cars and trucks that would need a breakthrough in battery technology to be powered by batteries alone.

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[5] Annual sales taken from the EPA Appendix E *fuel economy data stratified by vehicle type and size*, available at: http://www.epa.gov/otaq/fetrends.htm#appendixes

[6] Stacy Davis, Susan Diegel & Robert Boundy, "*Transportation Energy Data Book*, Oak Ridge No. ORNL-6985, VOl 28 July 2010, Tables 3.11 &3.12

[7] We did not, however, include any midsize wagons, which have an internal space between 130 and 159 ft^3, on the basis that these larger cars would be too heavy and batteries would take up too much space to permit a affordable BEV.

[7] VMT data by vehicle class and age generated by Anant Vyas at Argonne National Laboratory, and provided by Amgad Elgowainy.

Table 2. EPA Light duty car and truck classes

CARS		
Class	**Passenger & Cargo Volume (Cu. Ft.)**	
Two-Seaters	Any (cars designed to seat only two adults)	
Sedans		
Minicompact	Less than 85	
Subcompact	85 to 99	
Compact	100 to 109	
Mid-Size	110 to 119	
Large	120 or more	
Station Wagons		
Small	Less than 130	
Mid-Size	130 to 159	
Large	160 or more	
TRUCKS		
Class	**Gross Vehicle Weight Rating (GVWR)***	
Pickup Trucks	**Through Model Year 2007**	**Beginning Model Year 2008**
Small	Less than 4,500 lbs.	Less than 6,000 lbs.
Standard	4,500 to 8,500 lbs.	6,000 to 8,500 lbs.
Vans	**Through 2010**	**Beginning 2011**

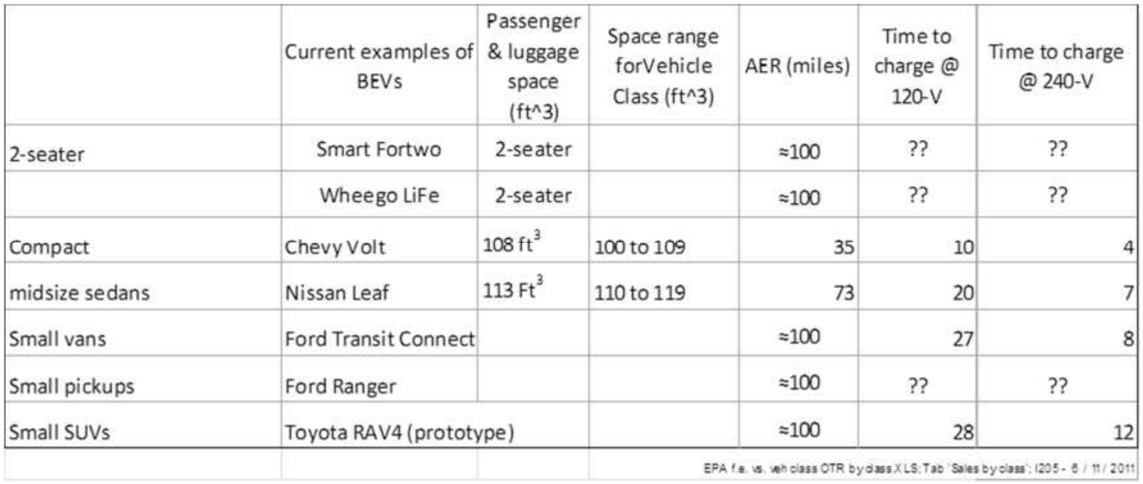
Passenger	Less than 8,500 lbs.	Less than 10,000 lbs.
Cargo	Less than 8,500 lbs.	
Minivans	Less than 8,500 lbs.	
Sport Utility Vehicles (SUVs)	**Through 2010**	**Beginning 2011**
	Less than 8,500 lbs.	Less than 10,000 lbs.
Special Purpose Vehicles	**Through 2010**	**Beginning 2011**
	Less than 8,500 lbs.	Less than 8,500 lbs. or less than 10,000, depending on configuration

Table 3. Estimated LDV survival rates from Oak Ridge National Laboratory

	Car survival rates		Table 3.11		Truck survival rates		Table 3.12	average
Age	1970 MY	1980MY	1990MY		1970 MY	1980MY	1990MY	1990 MY ave.
30	0.4%	0.8%	6.6%		5.2%	3.8%	4.2%	5.4%
29	0.5%	1.1%	8.2%		6.6%	4.9%	5.3%	6.8%
28	0.8%	1.6%	10.0%		8.2%	6.2%	6.7%	8.4%
27	1.1%	2.2%	12.1%		10.1%	7.7%	8.4%	10.3%
26	1.6%	2.9%	14.5%		12.2%	9.6%	10.3%	12.4%
25	2.2%	3.9%	17.1%		14.7%	11.7%	12.6%	14.9%
24	3.1%	5.2%	20.2%		17.5%	14.2%	15.2%	17.7%
23	4.2%	6.7%	23.5%		20.7%	17.1%	18.1%	20.8%
22	5.6%	8.7%	272.0%		24.2%	20.3%	21.4%	146.7%
21	7.4%	11.0%	31.1%		28.0%	23.8%	25.0%	28.1%
20	9.6%	13.8%	35.4%		32.1%	27.7%	29.0%	32.2%
19	12.3%	17.0%	39.9%		36.4%	32.0%	33.3%	36.6%
18	15.5%	20.8%	44.6%		41.1%	36.5%	37.9%	41.3%
17	19.3%	25.0%	49.5%		45.9%	41.3%	42.7%	46.1%
16	23.7%	29.8%	54.6%		50.8%	46.3%	47.7%	51.2%
15	28.7%	35.1%	59.7%		55.9%	51.5%	52.8%	56.3%
14	34.2%	40.8%	64.9%		61.0%	56.8%	58.0%	61.5%
13	40.3%	46.9%	70.0%		66.0%	62.1%	63.3%	66.7%
12	46.9%	53.3%	75.0%		70.9%	67.3%	68.4%	71.7%
11	53.8%	60.0%	79.8%		75.7%	72.4%	73.4%	76.6%
10	60.9%	66.6%	84.4%		80.2%	77.3%	78.2%	81.3%
9	68.1%	73.3%	88.7%		84.4%	82.0%	82.7%	85.7%
8	75.2%	79.7%	92.7%		88.3%	86.3%	86.9%	89.8%
7	82.0%	85.7%	96.3%		91.8%	90.2%	90.7%	93.5%
6	88.4%	91.3%	99.4%		94.9%	93.7%	94.1%	96.8%
5	94.1%	96.3%	100.0%		97.5%	96.6%	96.9%	98.5%
4	99.0%	100.0%	100.0%		99.7%	99.1%	99.3%	99.7%
3	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%	100.0%
2	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%	100.0%
1	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%	100.0%
0	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%	100.0%

EPA f.e. vs. Veh. Class on-the-road.XLS; Tab 'Sales by class'; AM 77 - 6 / 13 / 2011

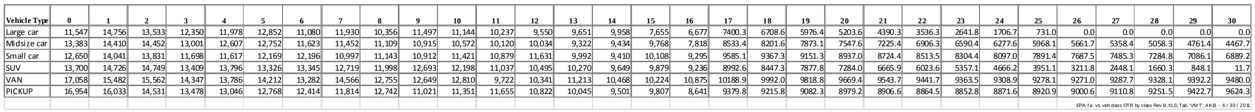
Table 4. Examples of current BEVs in the various EPA vehicle classes



	Current examples of BEVs	Passenger & luggage space (ft^3)	Space range forVehicle Class (ft^3)	AER (miles)	Time to charge @ 120-V	Time to charge @ 240-V
2-seater	Smart Fortwo	2-seater		≈100	??	??
	Wheego LiFe	2-seater		≈100	??	??
Compact	Chevy Volt	108 ft^3	100 to 109	35	10	4
midsize sedans	Nissan Leaf	113 Ft^3	110 to 119	73	20	7
Small vans	Ford Transit Connect			≈100	27	8
Small pickups	Ford Ranger			≈100	??	??
Small SUVs	Toyota RAV4 (prototype)			≈100	28	12

EPA f.e. vs. veh class OTR by class.XLS; Tab 'Sales by class'; I205 - 6 / 11 / 2011

Table 5. Estimated annual VMT as a function of vehicle age for various EPA vehicle classes



Vehicle Type	0	1	2	3	4	5	6	7	8	9	10
Large car	11,547	14,756	13,533	12,350	11,978	12,852	11,080	11,930	10,356	11,497	11,144
Midsize car	13,383	14,410	14,452	13,001	12,607	12,752	11,623	11,452	11,109	10,915	10,572
Small car	12,650	14,041	13,831	11,698	11,617	12,169	12,196	10,997	11,143	10,912	11,421
SUV	13,700	14,726	14,749	13,409	13,796	13,326	13,345	12,719	11,998	12,693	12,198
VAN	17,058	15,482	15,562	14,347	13,786	14,212	13,282	14,566	12,755	12,649	12,810
PICKUP	16,954	16,033	14,531	13,478	13,046	12,768	12,414	11,814	12,742	11,021	11,351

Vehicle Type	11	12	13	14	15	16	17	18	19	20
Large car	10,237	9,550	9,651	9,958	7,655	6,677	7400.3	6708.6	5976.4	5203.6
Midsize car	10,120	10,034	9,322	9,434	9,768	7,818	8533.4	8201.6	7873.1	7547.6
Small car	10,879	11,631	9,992	9,410	10,108	9,295	9585.1	9367.3	9151.3	8937.0
SUV	11,037	10,495	10,270	9,649	9,879	9,236	8992.6	8447.3	7877.8	7284.0
VAN	9,722	10,341	11,213	10,468	10,224	10,875	10188.9	9992.0	9818.8	9669.4
PICKUP	11,655	10,822	10,045	9,501	9,807	8,641	9379.8	9215.8	9082.3	8979.2

Vehicle Type	21	22	23	24	25	26	27	28	29	30
Large car	4390.3	3536.3	2641.8	1706.7	731.0	0.0	0.0	0.0	0.0	0.0
Midsize car	7225.4	6906.3	6590.4	6277.6	5968.1	5661.7	5358.4	5058.3	4761.4	4467.7
Small car	8724.4	8513.5	8304.4	8097.0	7891.4	7687.5	7485.3	7284.8	7086.1	6889.2
SUV	6665.9	6023.6	5357.1	4666.2	3951.1	3211.8	2448.1	1660.3	848.1	11.7
VAN	9543.7	9441.7	9363.5	9308.9	9278.1	9271.0	9287.7	9328.1	9392.2	9480.0
PICKUP	8906.6	8864.5	8852.8	8871.6	8920.9	9000.6	9110.8	9251.5	9422.7	9624.3

EPA f.e. vs. veh class OTR by class Rev B.XLS; Tab 'VMT'; AK13 - 6 / 30 / 2011

Table 6. Estimated percentage of LDVs on the road in 2010 and also the % of cars sold in 2010 by EPA class

	% on the road	% of 2010 Sales
two-seaters	0.9%	0.8%
Minicompact	0.5%	0.4%
subcompact	8.2%	7.8%
Compact	16.7%	14.6%
Small wagons	1.8%	4.5%
All Small cars	28.1%	28.1%
Small vans	0.1%	0.1%
Small pickups	1.1%	0.0%
Small SUVs	1.6%	0.5%
All Small Vehicles	30.9%	28.7%
Midsize sedans	17.6%	21.9%
Midsize vans	7.2%	3.3%
Medium wagon	1.2%	0.8%
Large wagon	0.2%	0.1%
Midsize pickups	3.6%	1.4%
Midsize SUVs	12.0%	14.0%
Large cars	8.5%	8.0%
Large vans	0.7%	0.1%
large pickups	10.2%	11.2%
large SUVs	8.0%	10.4%

EPA f.e. vs. veh class OTR by class.XLS; Tab 'Sales by class'; E186 - 10/29/2011

Table 7. Estimated number of LDVs on the road for each EPA vehicle class, and the annual VMTs and fuel economies and GHGs of each class, grouped by small vehicles suitable for battery-only energy, and larger cars and trucks.

	No. of vehicles on the road (thousands)	ave f.e. (miles-US gal^{-1})	Total VMT (million miles)	Gasoline (Million gallons /yr)	BEV gasoline (Million gallons/yr)	Net Oil Savings (million Liters per year)	ICV GHG grams /mile	ICV GHGs (Tonnes per yr CO$_2$-eq.)	BEV g/mile	BEV GHGs (Tonnes per yr CO$_2$-eq.)	Net GHG Savings
Vehicles suitable for BEVs									(2015)		
Small cars & wagons	64,525	24.31	318.0	13.1	0.21	(48.70)	543	172,615	372	118,430	(54,186)
Small vans	155	25.2	1.7	0.1	0.00	(0.25)	523	898	359	616	(282)
Small pickups	2,428	24.7	24.9	1.0	0.02	(3.76)	535	13,328	367	9,144	(4,184)
Small SUVs	3,643	23.8	42.5	1.8	0.03	(6.66)	555	23,591	380	16,185	(7,405)
50% of midsize sedans	20,125	22.2	221.7	10.0	0.16	(37.13)	594	131,603	407	90,292	(41,312)
Total or wgt. ave. "small cars"	90,876	23.84	608.8	25.5	0.41	(95.08)		342,035		234,667	(107,368)
"small cars+ 50% midsize" % of total	39.6%		27.2%	24.9%	0.11%	-24.5%		25.2%		17.3%	-7.91%
Larger cars and trucks:											
50% of midsize sedans	20,125	22.2	221.7	10.0	0.16		594	131,603			
Midsize wagons	2,775	21.6	30.0	1.4	0.02		612	18,377			
Midsize vans	16,418	23.3	200.6	8.6	0.14		566	113,428			
Midsize pickups	8,141	23.6	89.9	3.8	0.06		560	50,323			
Midsize SUVs	27,548	22.5	342.2	15.2	0.25		586	200,431			
Large cars	20,057	20.8	211.9	10.2	0.17		634	134,252			
Large vans	1,599	17.9	18.9	1.1	0.02		737	13,917			
large pickups	23,289	19.0	276.5	14.5	0.24		694	191,939			
large SUVs	18,391	19.8	241.6	12.2	0.20		667	161,138			
Total or wgt. Ave. large cars and LD Trucks	138,344	21.37	1,633	76.9	1.25			1,015,409			
% of total	60.4%		72.8%	75.1%				74.8%			

EPA f.e. vs. veh class OTR by class Rev B.XLS; Tab 'Sales by class'; T153 - 10/29/2011

It has also been suggested that households with two or more cars could purchase BEVs to replace their smaller cars. As shown in Table 8, the latest household survey[9] reveals that 38.1% of US homes have 2 cars, and 20.1% have three or more cars per household. If all households with two or more cars purchased one BEV, this would result in 67.2 million BEVs on the road, or 27.3% of all LDVs. If those households with three or more cars purchased two BEVs, this would result in 87 million BEVs, or 36.7% of all LDVs. So both of these BEV sales figures would be less than the 39.6% of all LDVs that were judged to be suitable for BEVs from Table 7. If we apply the same ratios of % VMT and % GHG and % oil consumption, then the multicar household construct would result in GHG and gasoline consumption reductions of only 26% to 35%, as summarized in Table 9, and GHGs would be reduced by 3.4% to 4.6% after accounting for grid GHGs from charging BEVs in 2015.

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[9] 2008 Community Survey, available at: www.publicagenda.org

Table 8. Estimated BEV sales from multi-car households

Muliple car households - 2007									
		Households		BEVs per Household	BEVs	BEVs per Household	BEVs	Total Vehicles	
		111.162	million		(Millions)			237.4	million
zero	8.7%	9.7		0%	0				
one	33.1%	36.8		0	0				
two	38.1%	42.4		1	42.35272	1	42.3527		
Three or more	20.1%	22.3		1	22.34356	2	44.6871		
	100.0%	111.2			64.7		87.0	million BEVs	
			% of all vehicles:		27.3%		36.7%		

Source: 2007 American Community Survey from Sept 2008.
www.publicagenda.org

BEVoutlet costs, charging times, multi-car households.XLS; 'Multi-car households' J 11 6/13/2011

Table 9. Estimated % of GHGs and gasoline consumption as a result of BEV purchases by multi-car households

	% of all LDVs on the road	% of all VMT	% Gasoline consumption	% of GHGs (zero carbon grid)	Net GHG reductions (Ave US 2015 Grid)
One BEV per multi-car household	27.3%	18.8%	16.9%	17.3%	-5.4%
Two BEVs per 3+ car household	36.7%	25.3%	22.7%	23.3%	-7.3%

BEV outlet costs, charging times, multi-car households.XLS; 'Multi-car households' F 17 10/29/2011

5.0 Why are BEVs limited to small vehicles? In principle, anyone could add more and more batteries to a BEV to increase range to any arbitrary distance. While true, these longer range BEVs would be extraordinarily heavy, and the batteries would take up too much space, leaving little room for passengers and luggage. They would also be very expensive

5.1 Vehicle Weight. Consider first the useful specific energy[10] (Wh/kg) of batteries and hydrogen fuel cell systems. As shown in Figure 1, even advanced lithium-ion batteries have lower specific energy than a hydrogen/fuel cell system. Thus the total weight of the fuel cell, the hydrogen storage tank and a peak power battery[11] for a FCEV would be less than the weight of an advanced Li-ion battery with the same stored energy. For a given range, then, BEVs will be much heavier than FCEVs as shown in Figure 2. The upward sloping

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[10] "Useful" specific energy refers to the energy that can actually be used to propel the vehicle. For example, a battery pack might store 100 kWh of energy, but if the battery can only be used between 20% and 90% state of charge (SOC), then the useful energy would be only 70 kWh. Similarly, a hydrogen tank might store 10 kg of hydrogen, but if only 9.8 kg can be withdrawn to keep a minimum pressure in the tank, then the useful energy would be based on 9.8 kg or 326.5 kWh (LHV). The denominator of the Wh/kg specific power must include all energy system components including all cooling equipment, all power management electronics, etc.

[11] All FCEVs include a peak power battery to augment the FCEV power for acceleration, and to store energy from regenerative braking.

curves in Figure 2 are based on the Nissan Leaf BEV. The curves in Figure 2 are concave upward as a result of mass compounding," the process whereby adding "X" kg of battery to extend the range of a BEV[12] requires a slightly larger motor to maintain adequate acceleration, slightly larger inverter/controller, slightly larger brakes to stop the vehicles, etc. But these added components in turn reduce the range of the BEV, so more batteries are needed to accelerate all that extra mass[13]. Note that a 200-mile range BEV based on advanced Li-Ion batteries would weigh 3,592 kg, which is 48% heavier than a FCEV with 300 miles range at 2,428 kg.

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[12] While the mass compounding is dominant for BEVs due to the heavy batteries required to maintain power, the curves for the FCEV follow this same pattern, but to a much smaller degree since increased power requires only a slightly larger fuel cell, and the range is determined by the size of the hydrogen tank, which does not need to change to maintain a given power level.

[13] For a detailed description of mass or weight compounding including equations to account for this non-linear phenomenon, see Appendix G of this report: C.E. Thomas, B.D. James, F. D. Lomax, Jr. and I.F. Kuhn, Jr. "Integrated Analysis of Hydrogen Passenger Vehicle Transportation Pathways," written by Directed Technologies, Inc. for the National Renewable Energy Laboratory under Subcontract No. AXE-6-16685-01, March 1998.

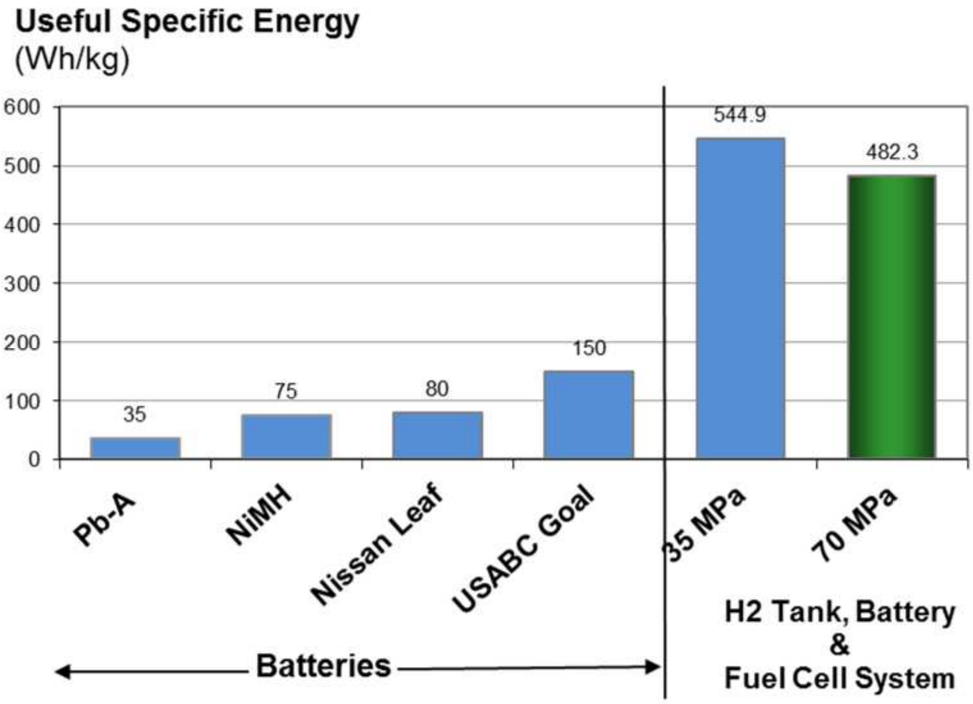
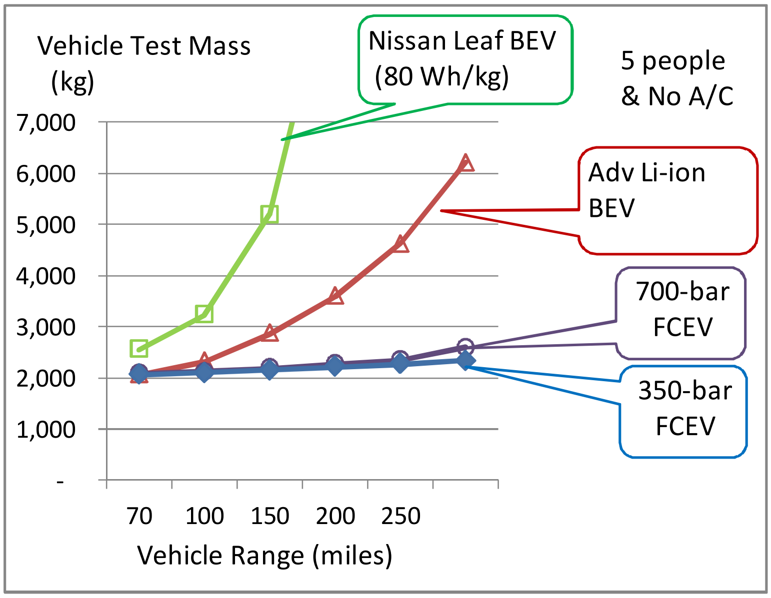


Figure 1. Useful specific energy of batteries and hydrogen fuel cell systems



work/vehicles/battery/BPEV mass,vol,cost vs range charts RevB.XLS; Tab 'Equation-Leaf'; BR58 - 10/27/2011

Figure 2. Estimated test weights of BEVs and FCEVs as a function of range between refueling (all curves based on a light-weight aluminum intensive Mercury Sable glider; Leaf BEV based on Versa steel body glider)

5.2 Energy storage volume. Most people know that batteries are heavy, but many do not realize that batteries require a large volume to store a given amount of energy. This is illustrated by the energy density bars in Figure 3, showing that advanced Li-ion battery systems store slightly less energy per unit volume than a hydrogen/fuel cell system at 35 MPa (350 bar or 5,000 psia pressure), including the volume of the fuel cell itself, the compressed hydrogen tanks, and the peak power battery in the FCEV. Several car companies are now using 70 MPa or 700-bar pressure hydrogen tanks, which further reduces the volume needed for the hydrogen tanks. These specific energy values translate into the total onboard energy storage volumes shown in Figure 4. Although the 35-MPa hydrogen/fuel cell system has only slightly higher energy density than an advanced Li-ion battery system, the battery system requires much larger energy storage since the BEV is much heavier. Thus at 200 miles range, the BEV with advanced Li-ion batteries would occupy 480 liters, or 25% more space than the complete 70 MPa-hydrogen/fuel cell system at 385 liters.

6.0 Energy Storage system cost. While weight and volume are excessive for Li-ion battery systems as range increases, cost is the major deterrent to selling long range BEVs. Energy storage costs for BEVs are shown in figure 5 as a function of vehicle range. We use the Boston Consulting Group report[14] estimates of current battery prices and their estimate of possible lower costs by 2020 as summarized in Table 10.

Thus even with the reduced battery costs estimated by the Boston Consulting Group for 2020, the battery pack for a BEV with 200 miles range would still cost between $30,000 and $55,000.

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[14] The Boston consulting group: ”Challenges, Opportunities and the Outlook to 2020 (no author & no date) available at: http://www.bcg.com/documents/file36615.pdf

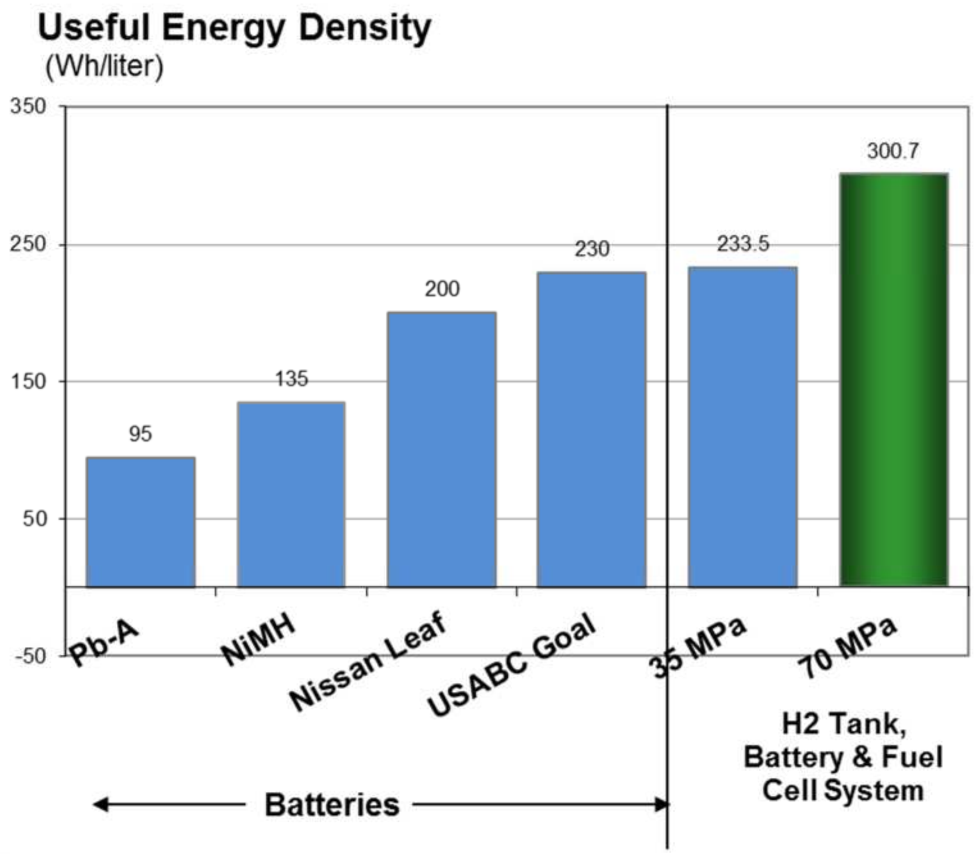
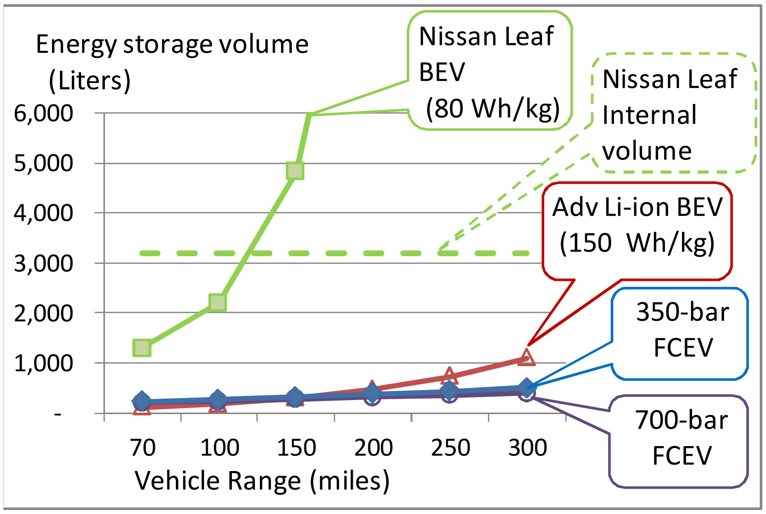


Figure 3. Useful energy density for batteries and hydrogen/fuel cell systems



BPEV mass,vol,cost vs range charts RevB.XLS; Tab 'Equation-Leaf'; BR41- 10/27/2011

Figure 4. Energy storage volume as a function of vehicle range for BEVs and FCEVs.

Table 10. Current and 2020 battery cost ranges estimated by the Boston Consulting Group

	Battery cost ($/kWh)	
	Low	High
Current Cost	$990	$1,220
2020 costs	260	440

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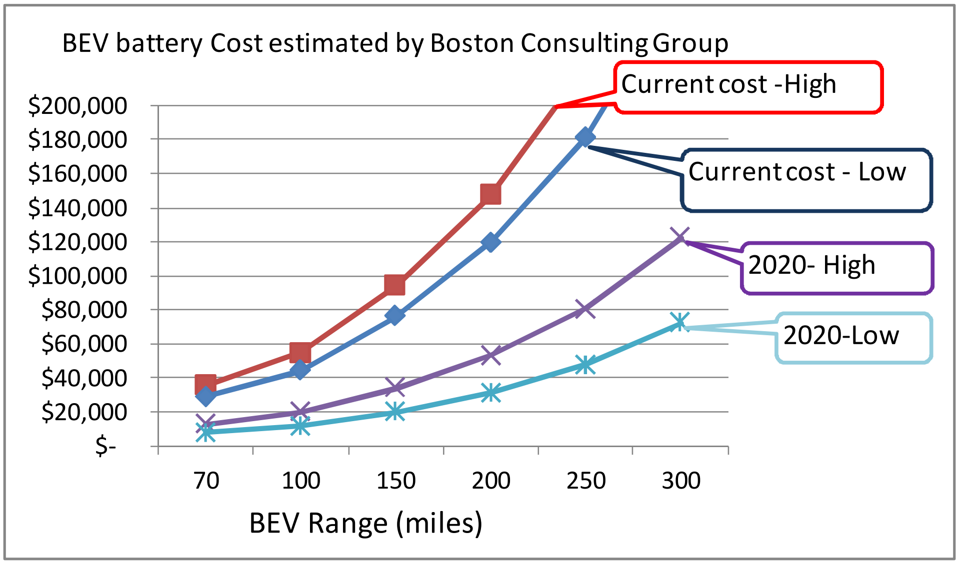

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Figure 5. Estimated cost for energy storage as a function of vehicle range for BEVs using the Boston Consulting Group cost estimates for current and 2020-era Li-ion batteries.