Estimates of BEV and PHEV market penetration Potential

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by C. E. (Sandy) Thomas, Ph.D.,
Clean Energy Consultant
former-President H_2Gen Innovations, Inc. (ret.)
Alexandria, Virginia

www.CleanCarOptions.com

Outline

- **Market Penetration Potential**
  - **BEV size and range limitations**
  - **BEV Sales Potential in US**

Why not longer range BEVs?

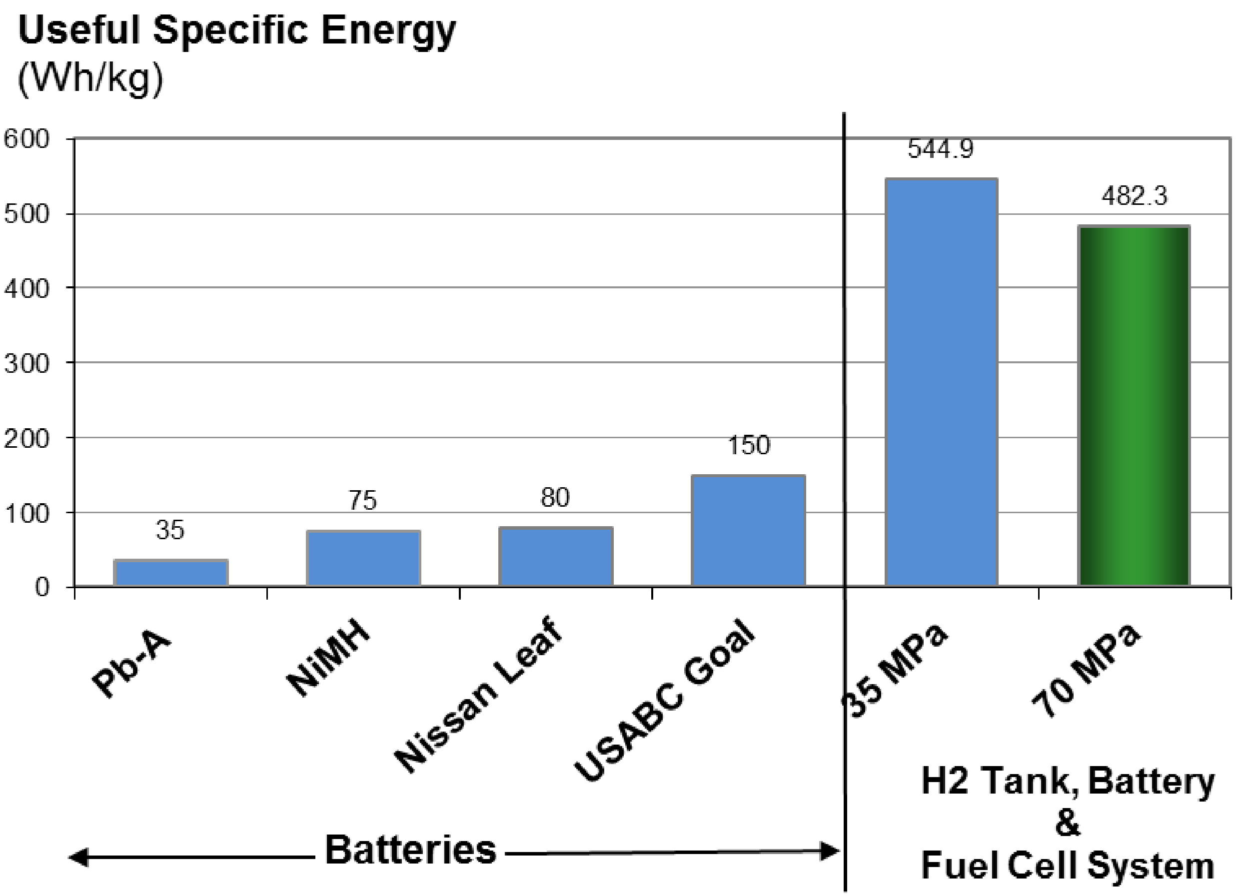
- Low Specific Energy (kWh/kg)
- Low   Energy Density (kWh/liter)
- *MASS COMPOUNDING*

Nissan Leaf Battery Parameters compared to USABC long-term goals

	Specific Energy	Specific Power	Power Density	Energy Density
	Wh/kg	kW/kg	kW/L	kWh/L
Nissan Leaf Battery	80	0.3	0.3	0.0261
USABC long-term commercialization goals	150	0.46	0.46	0.230

Nissan Leaf Battery: 24 kWh useable energy; 300 kg mass, 90 kW power & 918 liters volume (estimated from two orthogonal photos)

Useful Specific Energy



Mass Compounding

- Adding batteries to increase range requires:
  - Slightly larger mechanical structure
  - Slightly larger suspension systems
  - Slightly larger brakes
- Which requires still more batteries to provide range and acceleration required

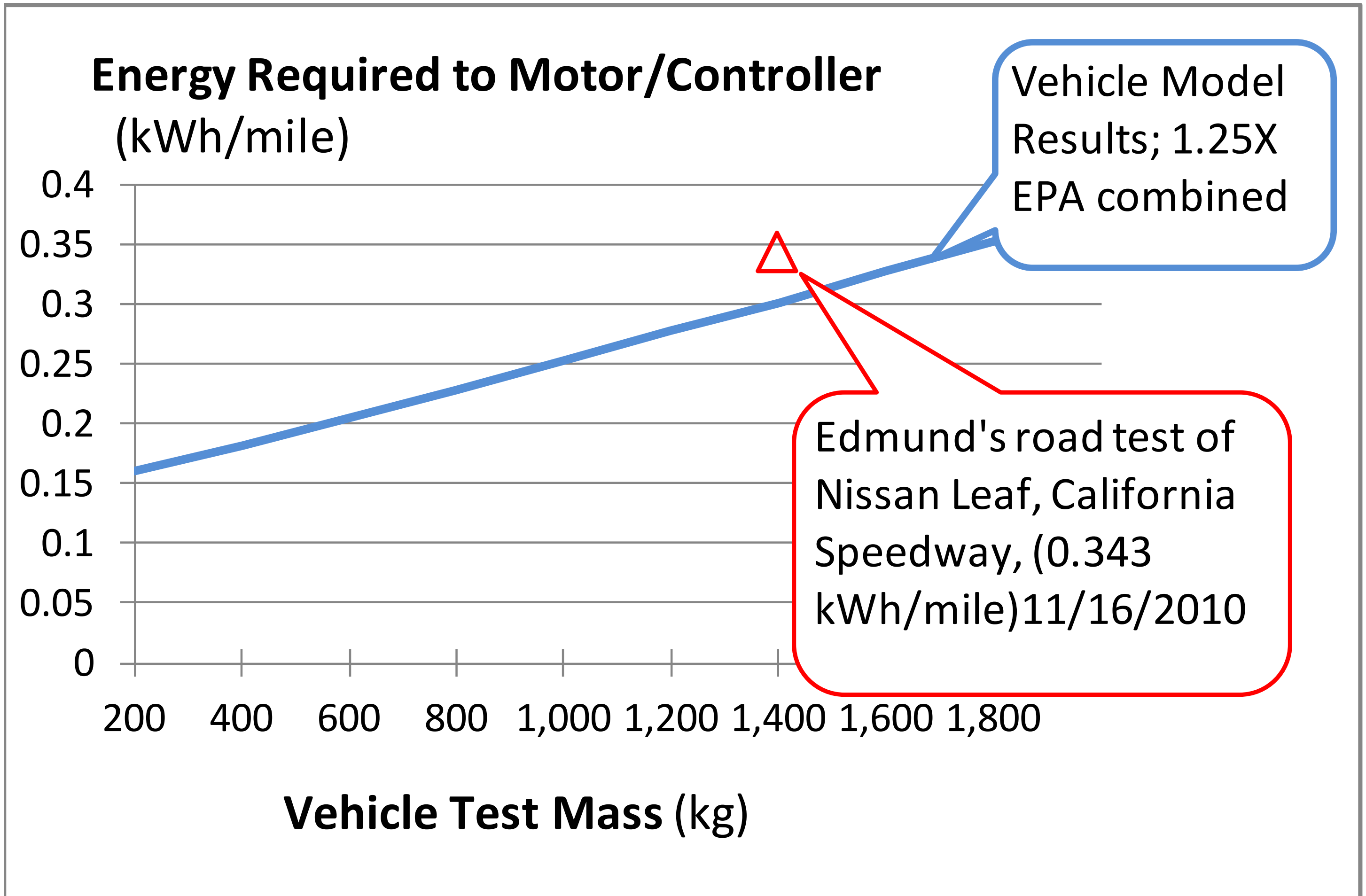
Mass Compounding of Late Model US cars

- Malen & Reddy (U. of Michigan) determined that adding 100 kg of batteries to a vehicle requires 59.8 kg of added mass to non-powertrain vehicle subsystems*.

- The **EV motor mass** increases with increased vehicle mass
- **Battery mass** increases with increased vehicle mass to maintain safe acceleration and to achieve the desired range

- *D. E. Malen & K. Reddy, "Preliminary vehicle mass estimation using empirical subsystem influence coefficients," University of Michigan, May 9, 2007 (revised June 26, 2007), available at: http://www.a-sp.org/database/custom/Mass%20Compounding%20-%20Final%20Report.pdf

Energy per mile required from battery or FC



work/vehicles/battery/Vehicle.XLS; Tab 'FUDS'; V662 - 10 / 9 /

BEV test mass estimation with and without mass compounding

		Est Range	Battery capacity:		
	kWh/mile	Miles	24	kWh	
Model	0.337	71.2		2 people	1681 kg
Edmund's road test	0.343	70.0		2 people	1681 kg
Model	0.367	65.4		5 people	1921 kg
			Leaf curb mass: 1521 kg		

work/vehicles/battery/Vehicle.XLS; Tab 'FUDS'; AC 654 - 10 / 11

Without mass compounding: to increase range from 65 miles to 100 miles requires the addition of 35miles x .367 kWh/mile = 12.8 kWh / .08 kWh/kg = 161 kg of extra battery for a total test mass of 1921 +161= **2,082 kg**

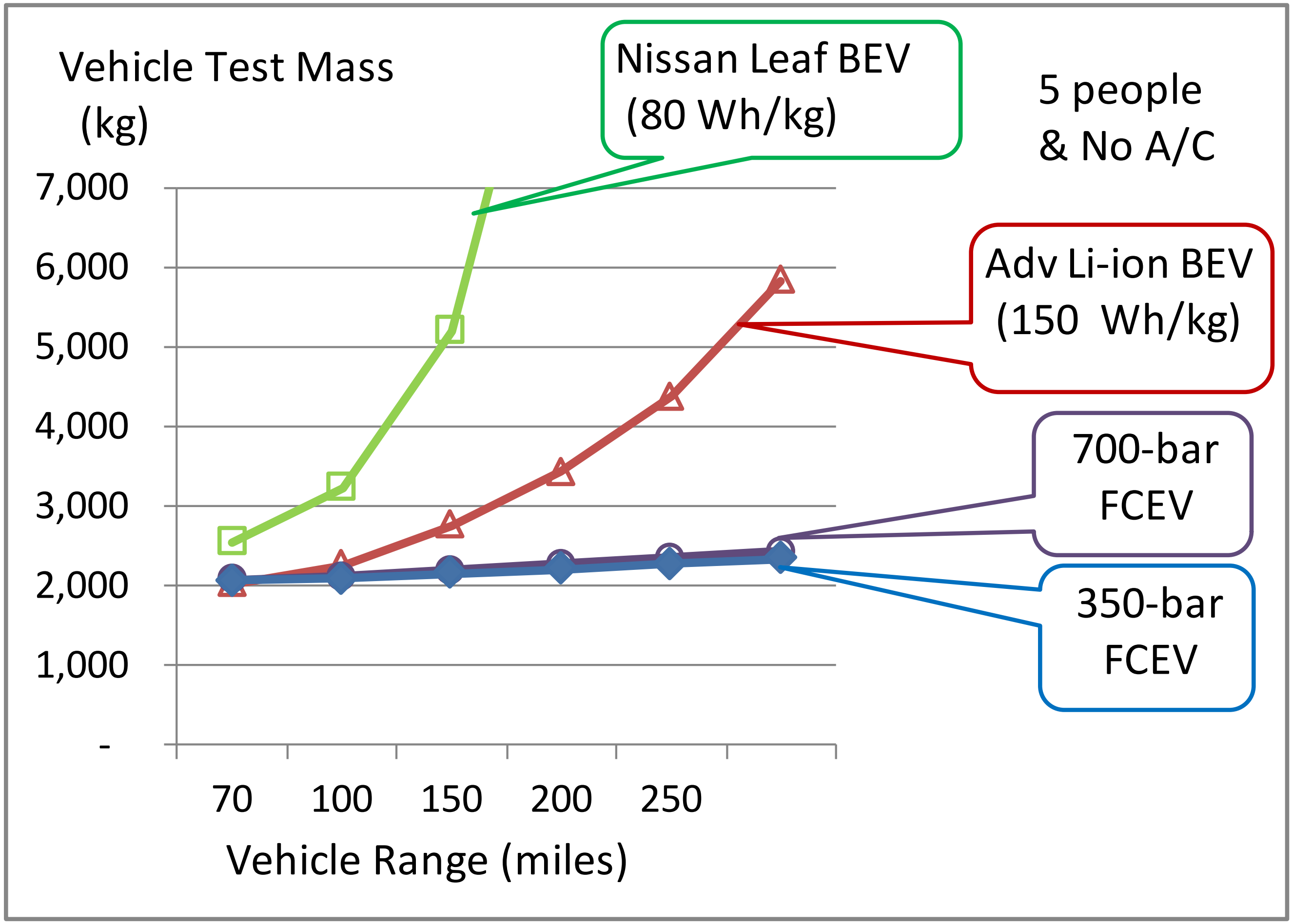
With mass compounding, the final BEV test mass for 100 miles range is **3,236 kg**, a 55% increase over the simple linear calculation!

Deloitte survey" Unplugged: electric vehicle realities versus consumer expectations*"

- **63% of potential EV buyers expect greater than 300 miles range** on one charge
- 23% expect charging in less than 30 minutes

*Deloitte Survey "Unplugged: Electric vehicle realities versus consumer expectations"
Published October 05, 2011, http://www.foxnews.com/leisure/2011/10/05/survey-says-electric-cars-dont-meet-expectations-customers/

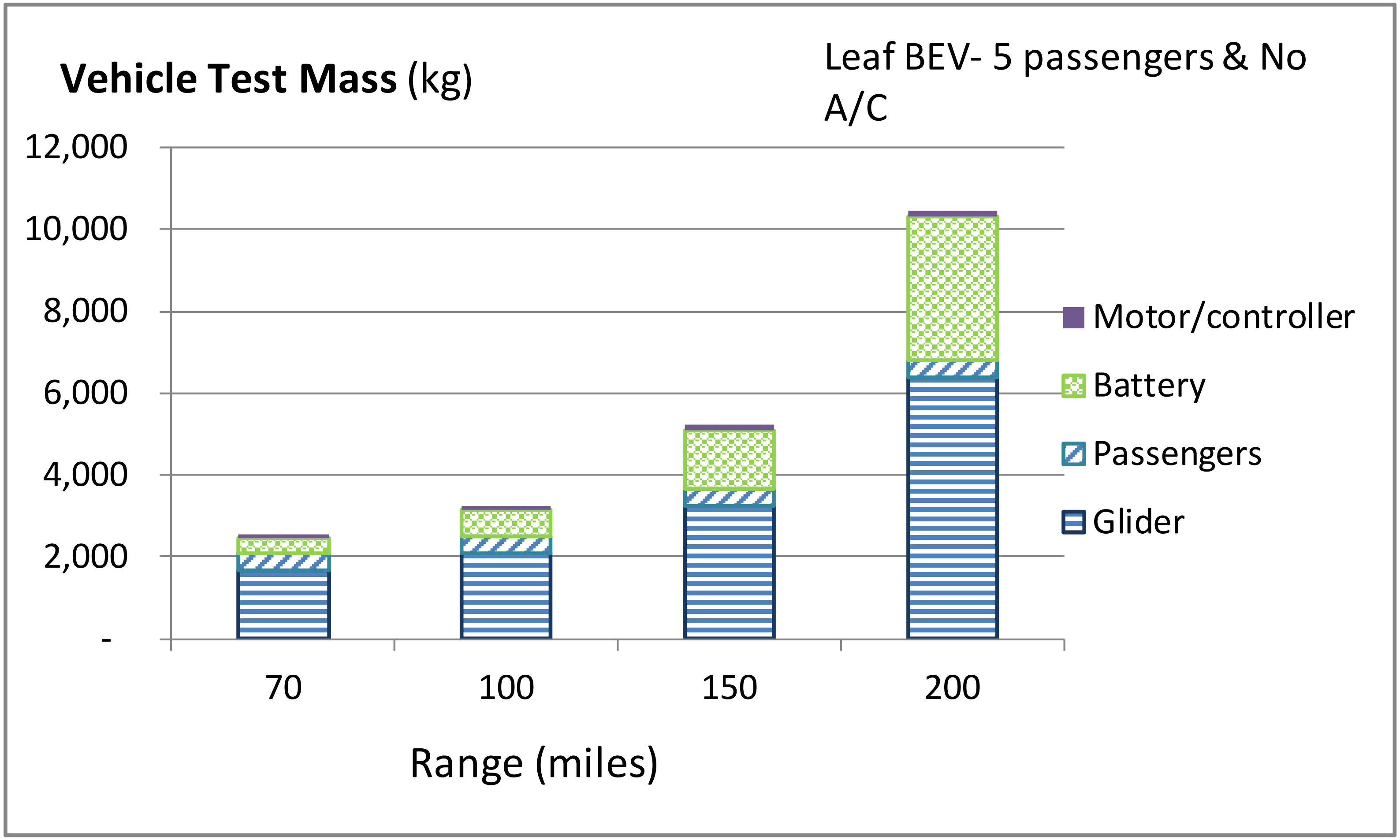
Vehicle Test Mass with Mass Compounding for BEVs & FCEVs



BPEV mass,vol,cost vs range charts RevB.XLS; Tab 'Equation-Leaf'; BR58 - 10 / 9 /

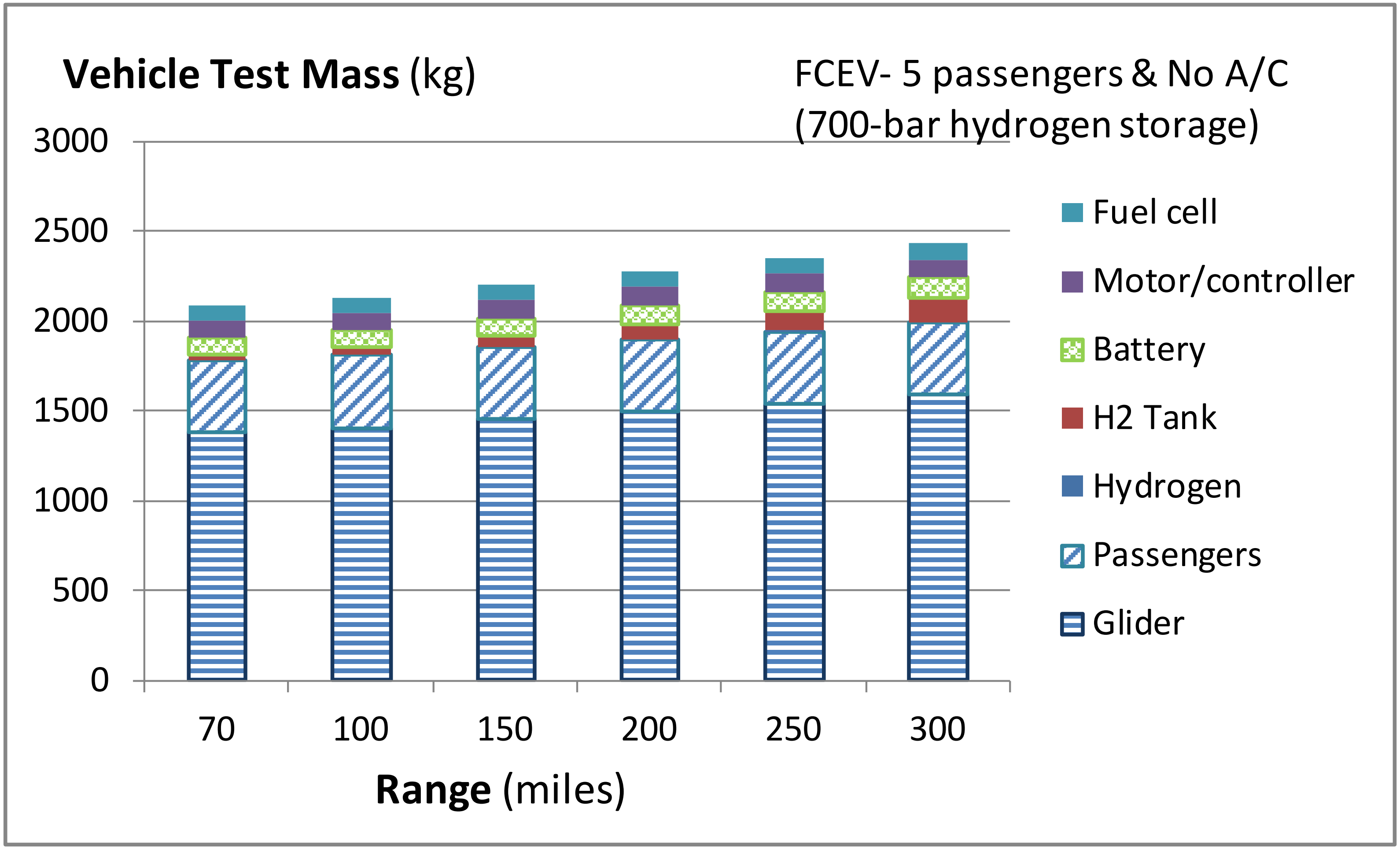
"Adv Li-ion battery" assumes that the USABC long-term commercialization goals are achieved (150 Wh/kg; 230 Wh/Liter).

BEV Mass Compounding Elements



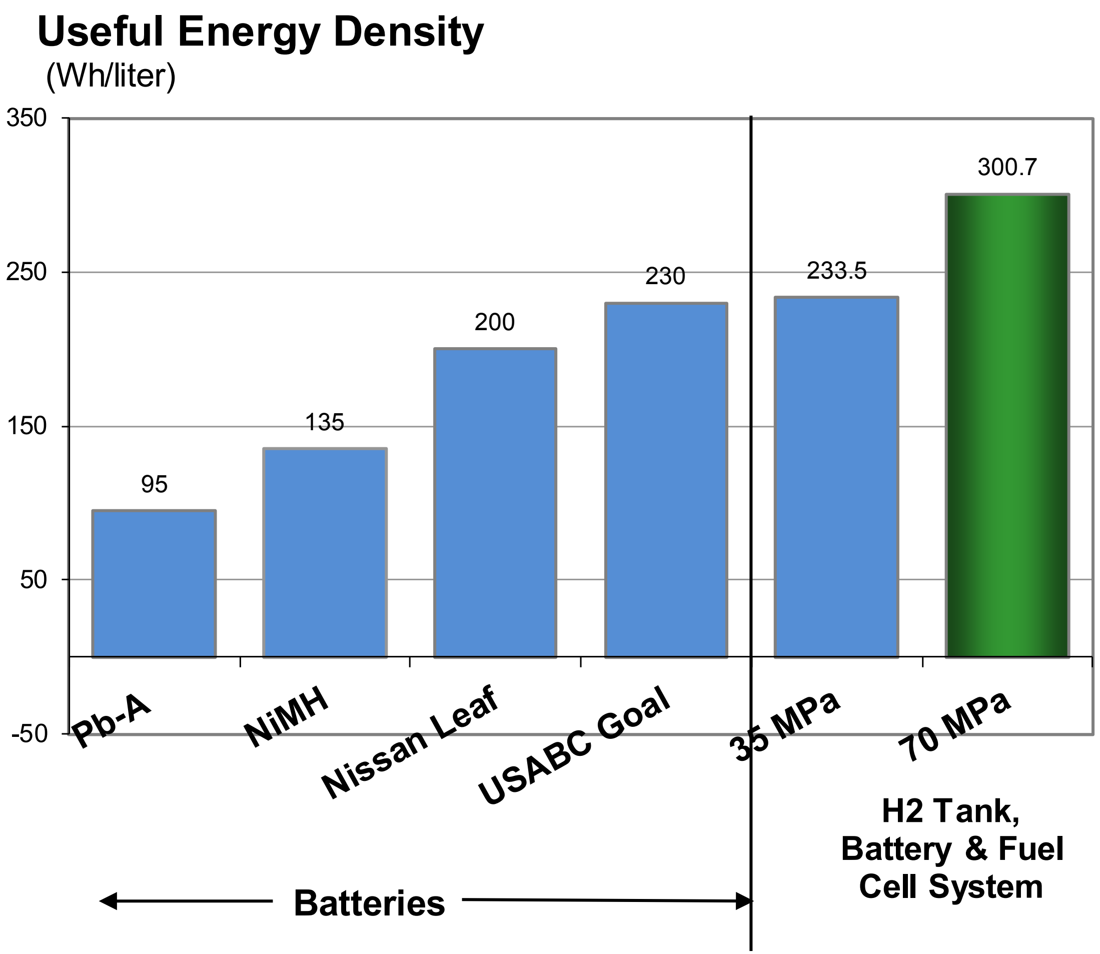
BPEV mass,vol,cost vs range charts RevB.XLS; Tab 'Equation-Leaf'; Q-163 - 10 / 10 /

FCEV Mass Compounding Elements



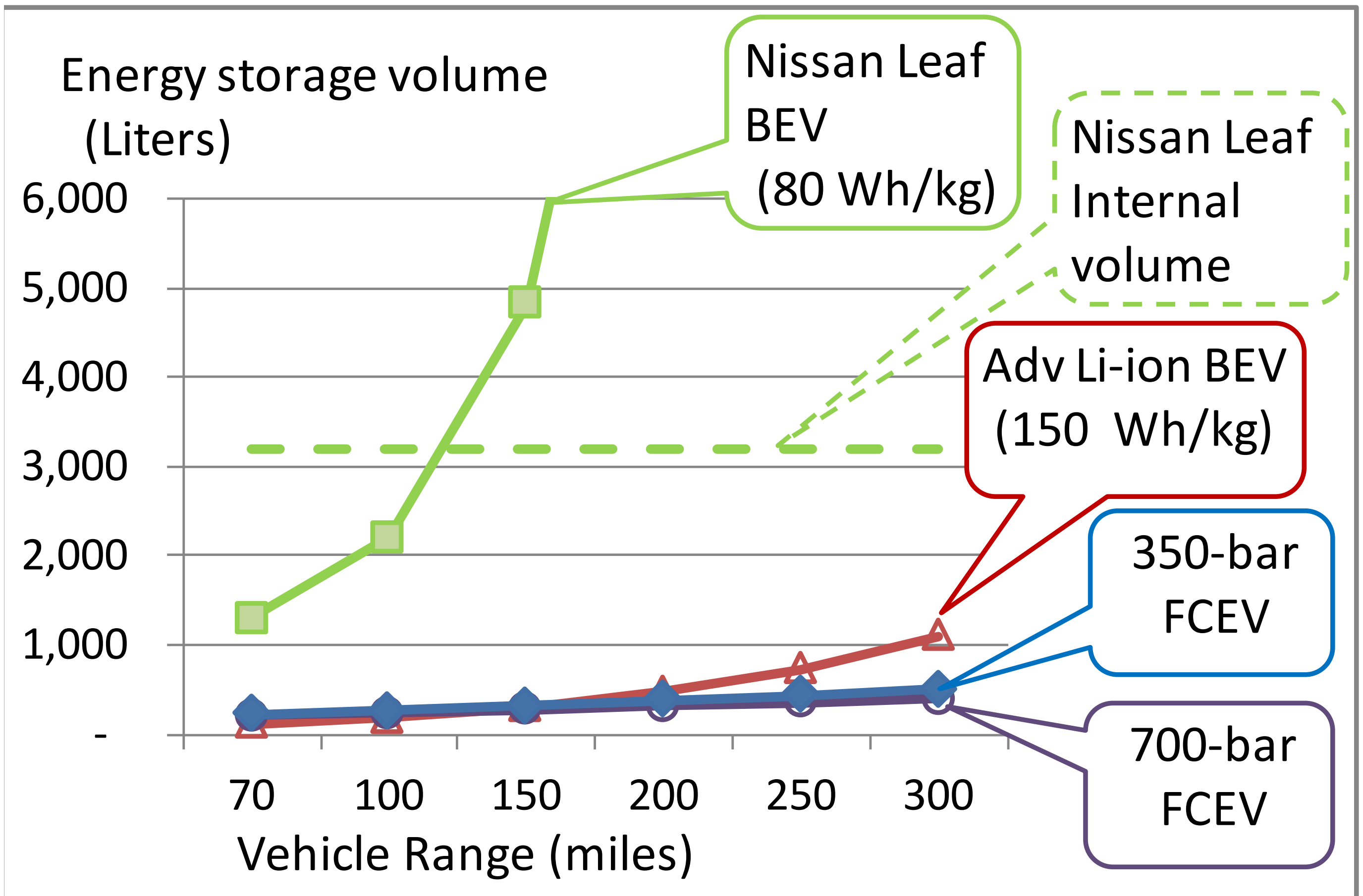
BPEV mass,vol,cost vs range charts RevB.XLS; Tab 'Equation-Leaf'; I163 - 10 / 11

Useful Energy Density



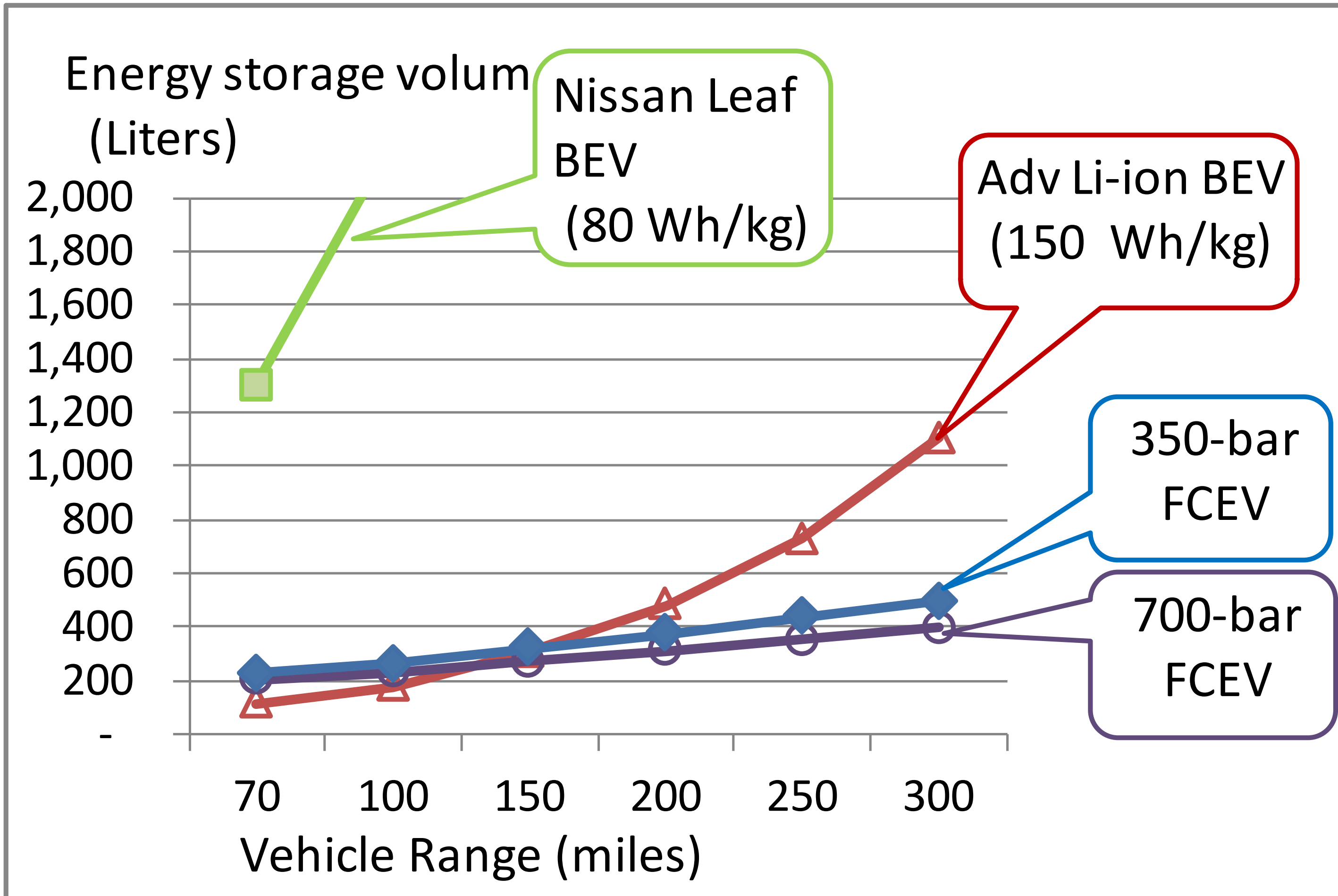
Battery & H2 Tank Wt_Vol_Cost.XLS; Tab 'Battery'; S37 - 10 / 25 /

Energy Storage Volumes for Nissan Leaf size BEVs and FCEVs



BPEV mass,vol,cost vs range charts RevB.XLS; Tab 'Equation-Leaf'; BR41 - 10 / 9 /

Energy storage volume (expanded scale)



Advanced Li-Ion assumes USABC Long-Term Commercialization Goals are Achieved

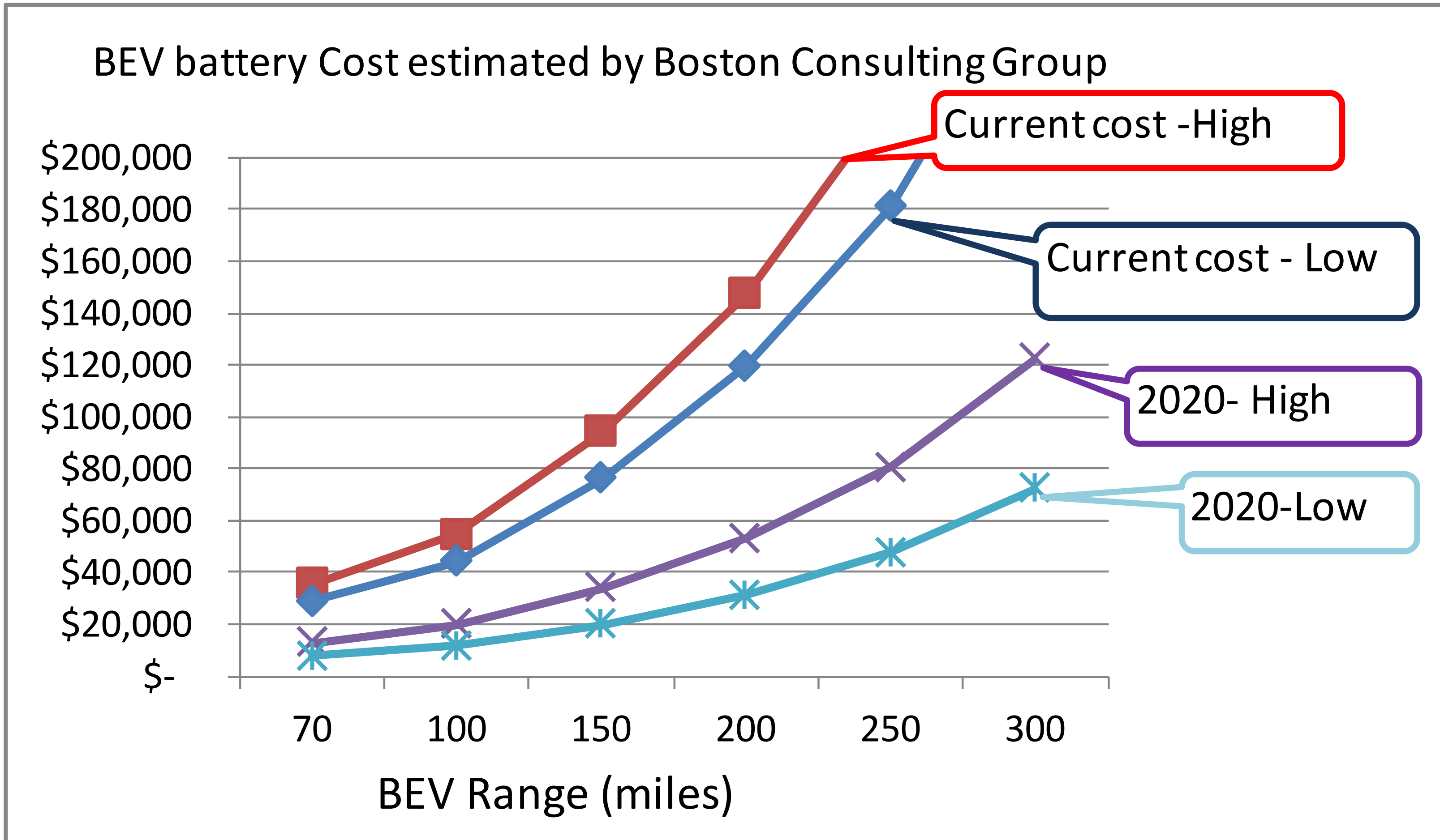
Boston Consulting Group* Battery Cost Estimates

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

work/vehicles/battery/BPEV mass,vol,cost vs range charts RevB.XLS; Tab 'Equation-Leaf'; AD 104 - 10 / 25

* A. Dinger et al, "Batteries for Electric vehicles: challenges, opportunities and the Outlook to 2020, The Boston Consulting Group (no date). Available at: http://www.bcg.com/documents/file36615.pdf

BEV Battery Pack OEM cost estimates vs. range



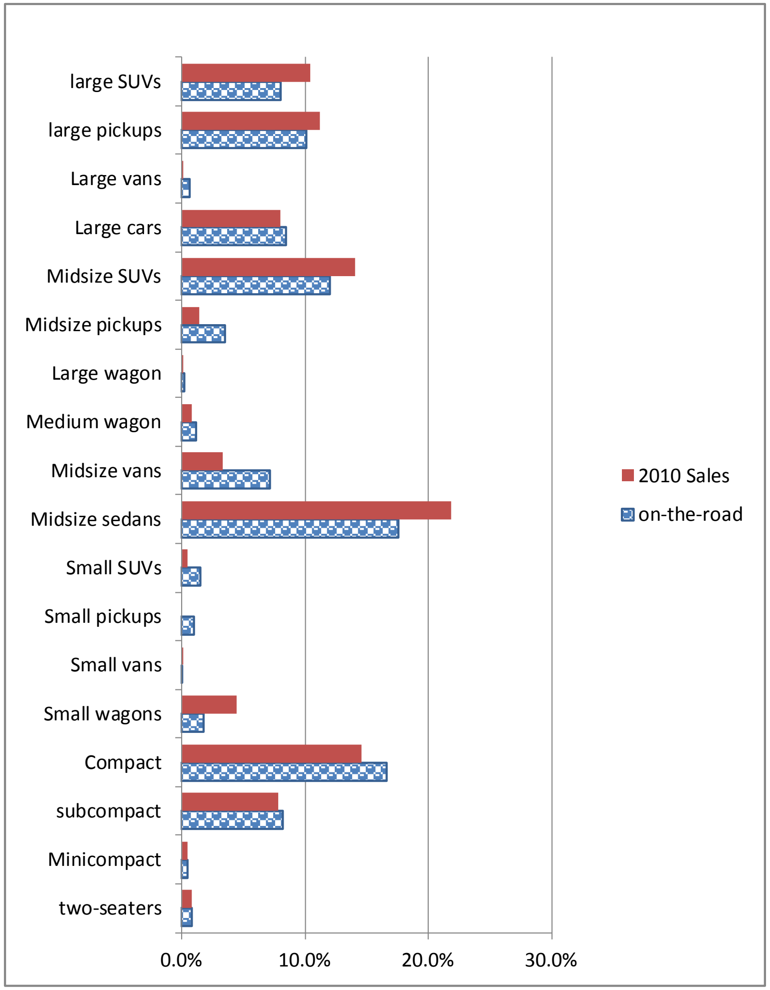
work/vehicles/battery/BPEV mass,vol,cost vs range charts RevB.XLS; Tab 'Equation-Leaf'; AL 103 - 10 / 25

BEV Market Penetration

Market Potential for BEVs

- Assuming that BEVs can only be sold for small vehicles, how many small vehicles are in the current US car fleet?
- And what % of GHGs and oil consumption do these small cars represent?
- (McKinsey & Company estimated that 50% of all vehicles in the EU that generate 75% of all GHGs are too big or travel too far to be affordably powered by batteries.

Distribution of US Car sizes



EPA f.e. vs. veh class OTR by class.XLS; Tab 'Sales by class'; Y206 - 10 / 10 /

	% 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 / 10 /

Previous Assumption for GHG reductions:

- 100% replacement of ICVs with BEVs

New Assumption

- BEVs will replace :
  - All small cars,
  - All small pickup trucks
  - All small SUVs
  - All small vans
  - And 50% of all midsize seda

Table 4. Current BEVs available or under development

			EPA range		Charging Hours	
		Type	(km)	(miles)	120-V	240-V
Nissan	Leaf	5-passenger	117.5	73	21	8
Ford	Transit Connect	Small van	128.7	80	27	8
Toyota	RAV4	Small SUV	129-193	80-120	28*	12*
Smart	Fortwo	2-seater	113-161	70-100		3.5**
Wheego	Life	2-seater	160.9	100		5***
Mitsubishi	i-MiEV	4-passenger	99.8	62	14	7
Think	City	4-passenger	160.9	100	18	8 to 10

*RAV4 charging times for prototype; production unit charging time expected to be shorter

**Smart Fortwo charging from 20% to80% SOC; 8 hours for full charge

***Wheego charging time for 50% to 100% SOC

AEO 2011 US Grid Mix Projections through 2035 assuming no carbon constraints

No Carbon constraints	2010	2015	2020	2025	2030	2035
Coal	44.8%	42.3%	43.5%	45.5%	45.5%	45.2%
Oil	1.1%	1.0%	1.0%	1.0%	0.9%	0.9%
Natural gas	24.6%	23.8%	22.3%	20.8%	22.1%	23.4%
All fossil fuels	70.6%	67.1%	66.7%	67.2%	68.5%	69.5%
Nuclear	19.4%	19.8%	19.7%	18.6%	17.5%	16.7%
renewables	10.0%	13.1%	13.6%	14.2%	14.0%	13.8%

work/electric utilities/ AEO-2011 alternative scenarios.XLS, DD 382;10/24/2011

Impact of small BEVs* on US GHGs and Oil Consumption in 2015

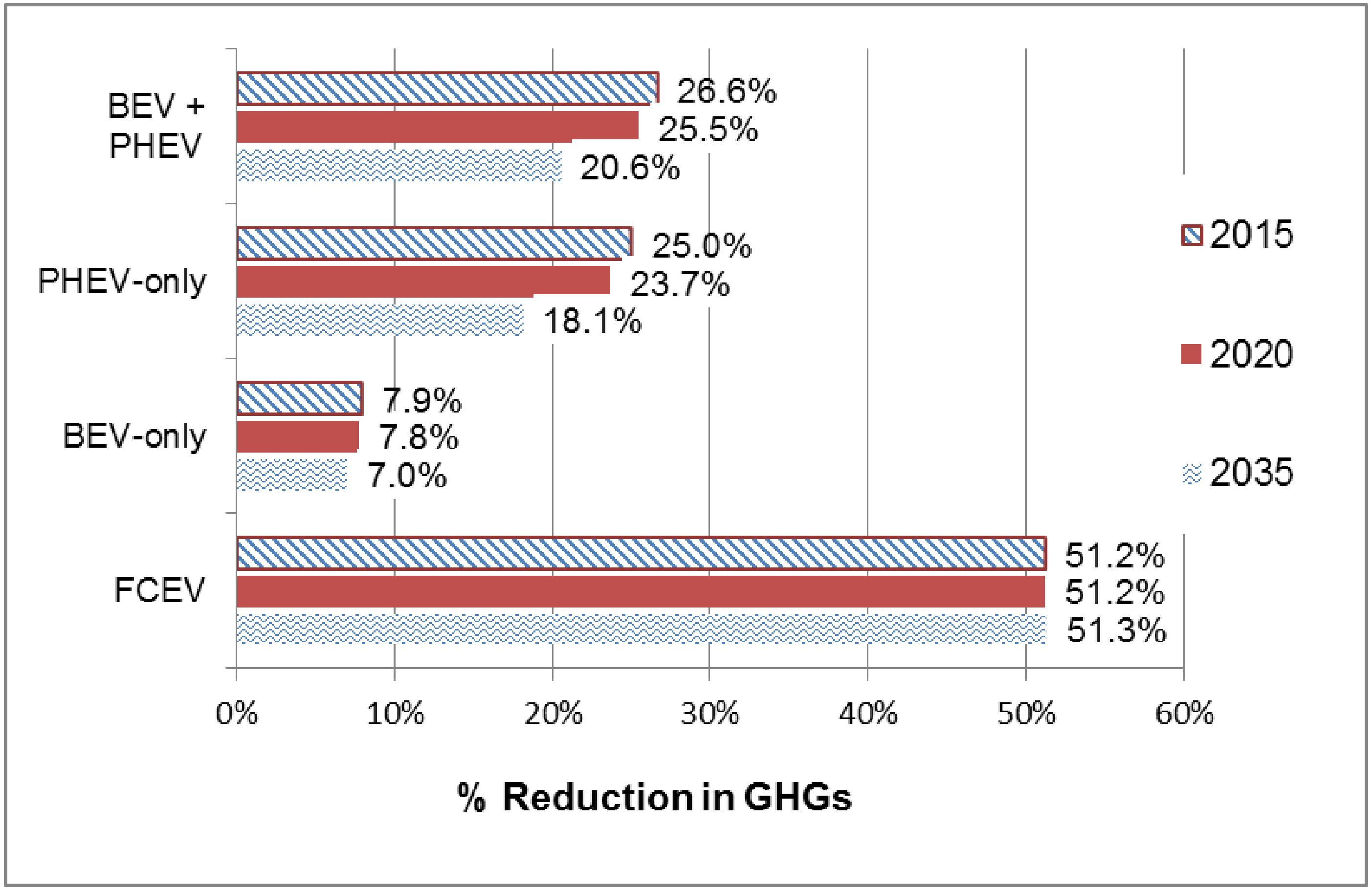
	# of LDVs on the road	% VMT	% gasoline	% GHGs	% ICV GHG savings	% BEV grid GHGs	Net GHG Savings (2015)
Small cars & trucks suitable for BEVs:	**39.6%**	**27.2%**	**24.9%**	**25.2%**	**-25.2%**	**17.3%**	**-7.91%**
Larger cars & trucks:	**60.4%**	**72.8%**	**75.1%**	**74.8%**			

2011

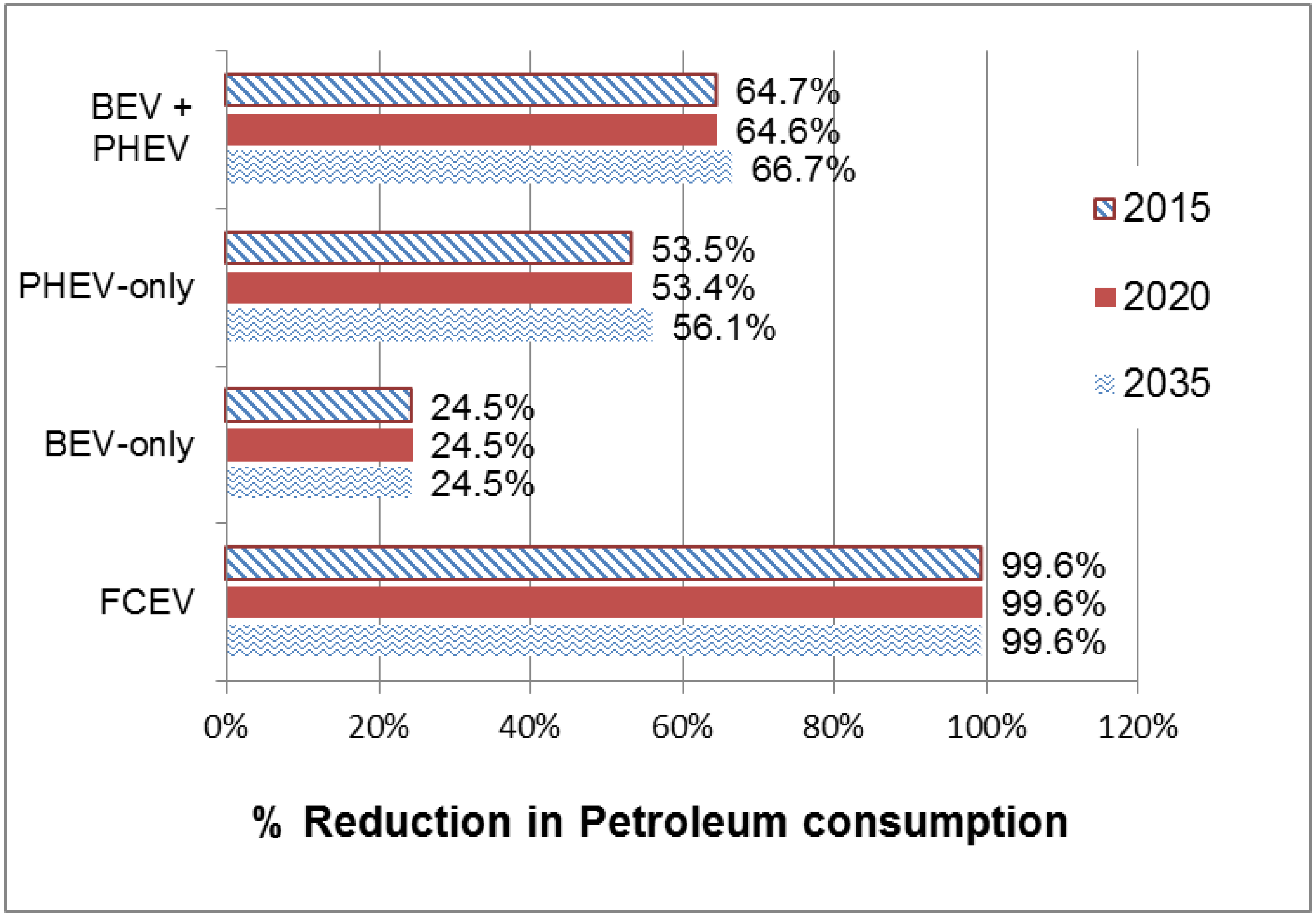
EPA f.e. vs. veh class OTR by class (rev B).XLS; Tab 'Sales by class';AN135 - 10 / 24 /

* Includes all two-seaters, all mini-compact, subcompact, all compact, all small sedans, all small wagons, all small vans, all small pickup trucks, all small SUVs & 50% of all midsize sedans.

Maximum GHG Reductions for BEVs, PHEVs through 2035



Maximum Reductions in Oil Consumption for BEVs & PHEVs Through 2035



Thank You

- Contact Information:

C.E. (Sandy) Thomas, former-President (ret.)
H2Gen Innovations, Inc.
Alexandria, Virginia 22304
703-507/8149
thomas@cleancaroptions.com

- Simulation details at:
- **http://www.cleancaroptions.com**