Hybrid Electric Vehicles – Evaluating Emission Reductions and Cost Benefits for a University Motor Vehicle Fleet

No. 07-2598

Jeongran [chung-nan] Yun & Terry L. Miller

TRB Meeting Session #647

January 24th, 2007

The University of Tennessee

Purpose

- To evaluate potential emission reductions and cost benefits by the replacement of university's conventional vehicle fleet with hybrid vehicles

Introduction

- 1. The available 2006 HEVs
- 2. The fact about the UTK current motor pool

The Available 2006 HEVs for Each Category and Detail Information

	Manufacturer	Model	MSRP	Seating	Engine Size	Cylinder	City/Highway MPG	Combined MPG	Air Pollution Score
SEDAN	HONDA	ACCORD HYBRID	$30,140.00	5	3	6	29/37	32.1	6
	HONDA	CIVIC HYBRID	$21,850.00	5	1.3	4	49/51	49.9	9
	TOYOTA	PRIUS	$21,275.00	4	1.5	4	60/51	55.6	8
SUV	FORD	ESCAPE HYBRID	$27,515.00	5	2.3	4	36/31	33.6	7
	LEXUS	RX 400H	$45,355.00	5	3.3	6	33/28	30.5	8
	MAZDA	TRIBUTE HYBRID	$29,225.00	5	2.3	4	33/29	31.1	7
	MERCURY	MARINER HYBRID	$29,840.00	5	2.3	4	33/29	31.1	7
	TOYOTA	HIGHLANDER HYBRID	$33,030.00	7	3.3	6	33/28	30.5	8
PICKUP TRUCK	CHEVROLET	SILVERADO HYBRID	$32,175.00	5	5.3	8	18/21	19.2	3
	GENERAL MOTORS	SIERRA HYBRID	$31,205.00	5	5.3	8	18/21	19.2	3

The fact about the University motor pool

- The inventory from UT Transportation Services
- 553 vehicles, 52 models as of August of 2005
- 254 vehicles, 18 models in the study
- life cycles:
  - 3yr/50,000 miles (sedan), 4yr/60,000 miles (SUV), and 8yr/50,000 miles (pickup truck)

Grouping of the 254 Vehicles and the Detail Information

	MANUFACTURER	MODEL	COUNT	PRICE (MSRP)	SEATING	ENGINE SIZE	CYLINDER	CITY/HIGH WAY MPG	COMBINED MPG	AIR POLLUTION SCORE
SEDAN	CHEVROLET	IMPALA	24	$24,760.00	5	3.9	6	19/25	21.3	6
	DODGE	STRATUS SE	32	$23,555.00	5	2.7	6	21/28	23.7	3
	DODGE	STRATUS SXT	65	$20,575.00	5	2.4	4	22/30	25.0	6
	FORD	TAURUS LX	63	$20,830.00		3	6	20/27	22.6	6
SUV	FORD	ESCAPE XLT	8	$22,494.00	5	3	6	19/23	20.6	6
	FORD	EXPLORER	2	$26,530.00	5	4	6	15/20	16.9	7
	JEEP	CHEROKEE	3	$27,165.00	5	3.7	6	17/22	18.9	6
	JEEP	LIBERTY	11	$21,040.00	5	3.7	6	17/22	18.9	6
	CHEVROLET	TAHOE	2	$34,115.00	5	4.8	8	16/20	17.6	3
	DODGE	DURANGO	3	$28,300.00	7	3.7	6	16/21	17.9	1
	CHEVROLET	SUBURBAN	2	$36,965.00	9	5.3	8	15/19	16.6	3
	FORD	EXPEDITION	2	$32,660.00	7	5.4	8	14/19	15.9	3
PICKUP TRUCK	CHEVROLET	COLORADO	1	$17,705.00	5	2.8	4	16/22	18.2	6
	CHEVROLET	SILVERADO 1500	1	$25,375.00		4.3	6	15/18	16.2	1
	DODGE	DAKOTA	3	$20,090.00	3	3.7	6	15/19	16.6	1
	DODGE	RAM 1500	6	$20,900.00		3.7	6	16/21	17.9	1
	FORD	F150	7	$18,930.00		4.2	6	16/20	17.6	3
	FORD	RANGER	19	$14,450.00	3	2.3	4	21/26	23.0	3
TOTAL			254							

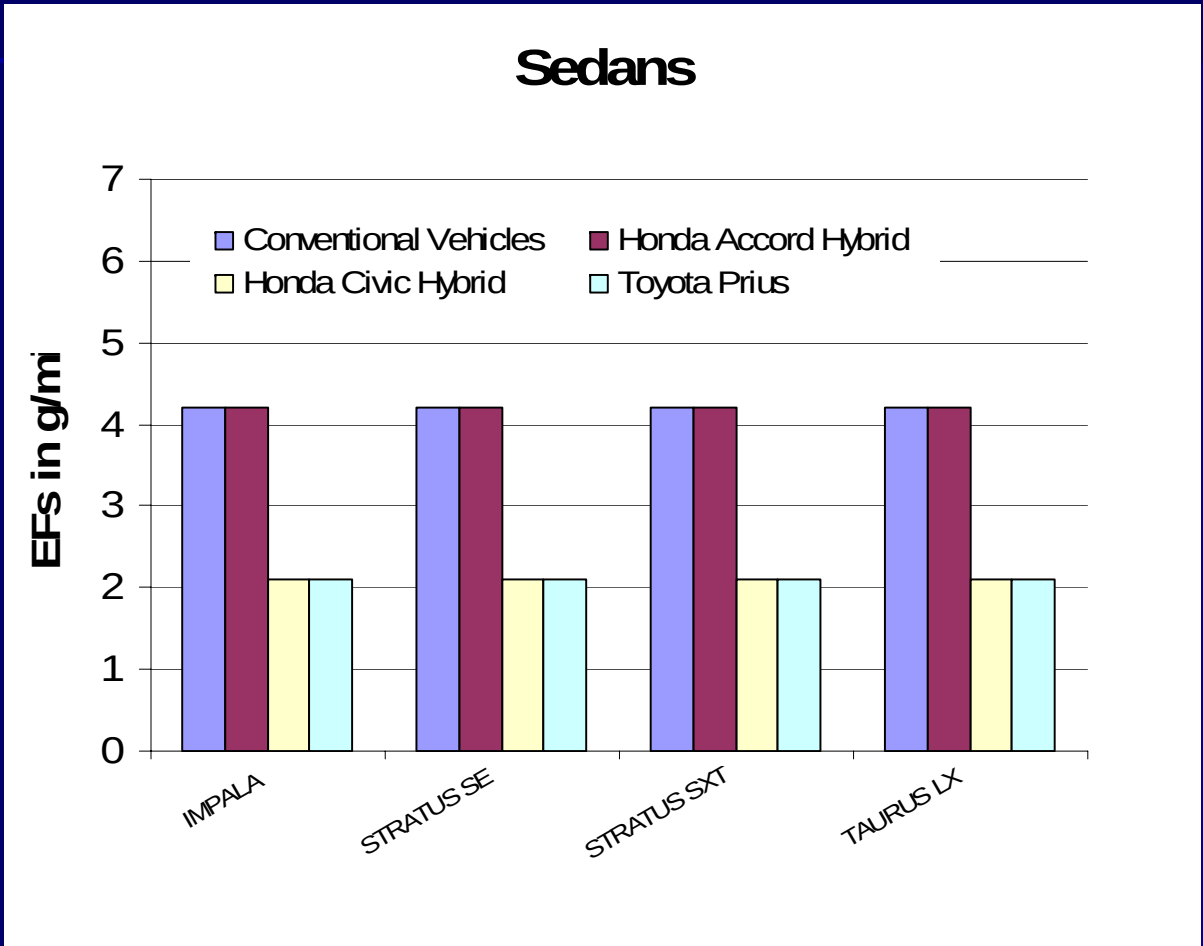
254 out of 553

Air Pollution Score

Air Pollution Score	Emission Limits at Full Useful Life (100,000-120,000 miles)				
	Maximum Allowed Grams per Mile				
	NOx	NMOG	CO	PM	HCHO
10	0	0	0	0	0
9	0.02	0.01	2.1	0.01	0.004
8	0.03	0.055	2.1	0.01	0.011
7	0.04	0.07	2.1	0.01	0.011
6	0.07	0.09	4.2	0.01	0.018
5	0.1	0.09	4.2	0.01	0.018
4	0.15	0.09	4.2	0.02	0.018
3	0.2	0.156	4.2	0.02	0.018
2	0.3	0.18	4.2	0.06	0.018
1	0.6	0.28	6.4	0.08	0.027
0	0.9	0.28	7.3	0.12	0.032

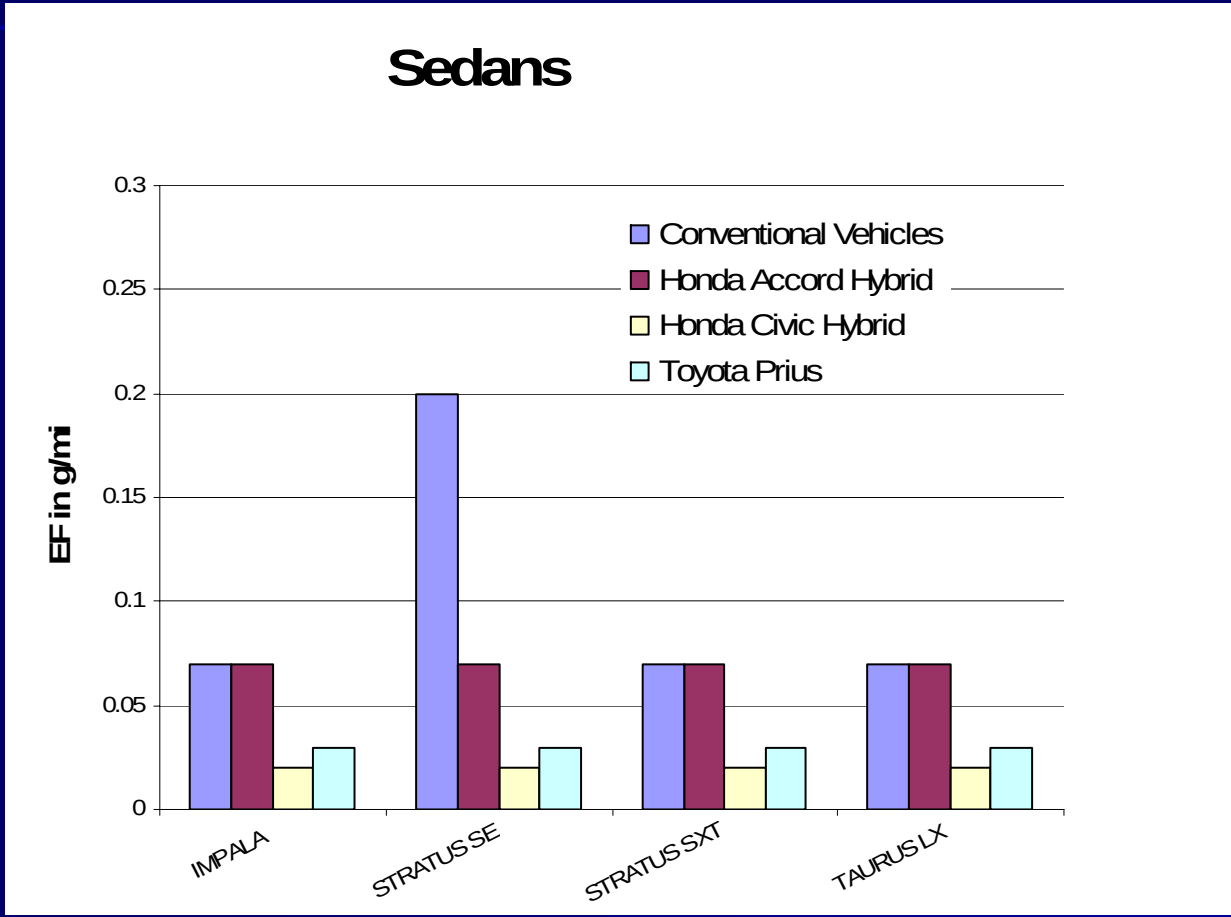
From EPA's Green Vehicle Guide

CO Emission Factors for Sedan Category



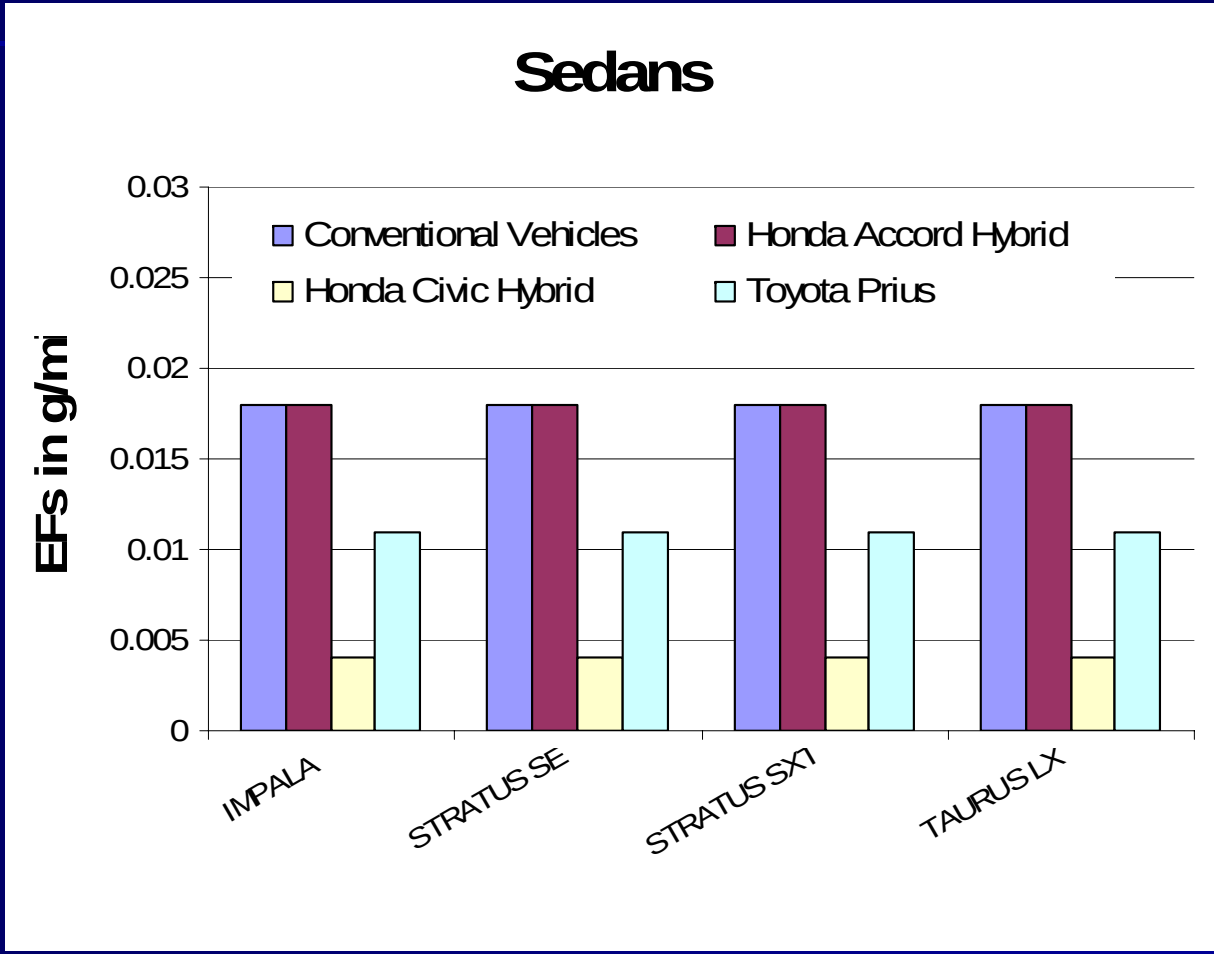
Emission Factors are from EPA's Green Vehicle Guide

NOx Emission Factors for Sedan Category



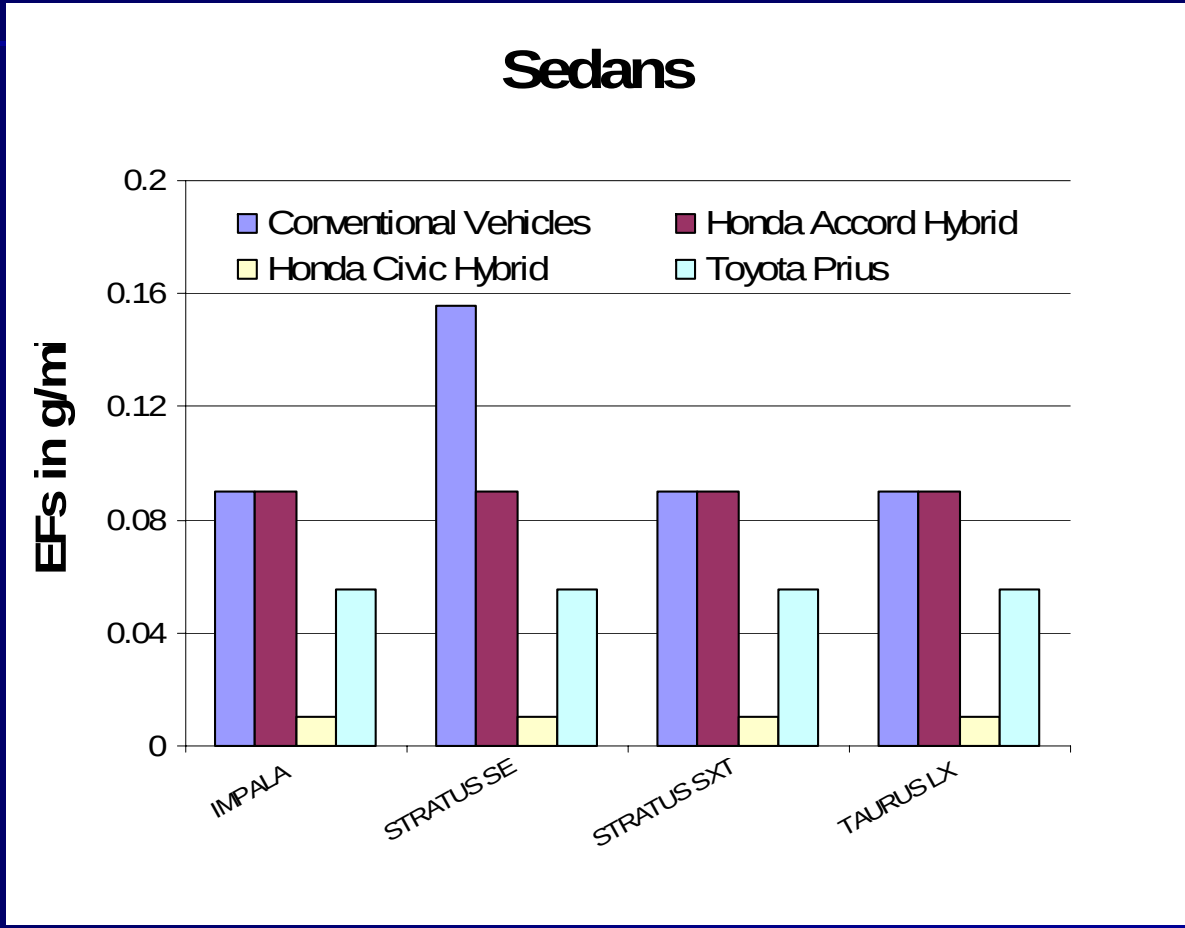
Emission Factors are from EPA's Green Vehicle Guide

HCHO Emission Factors for Sedan Category



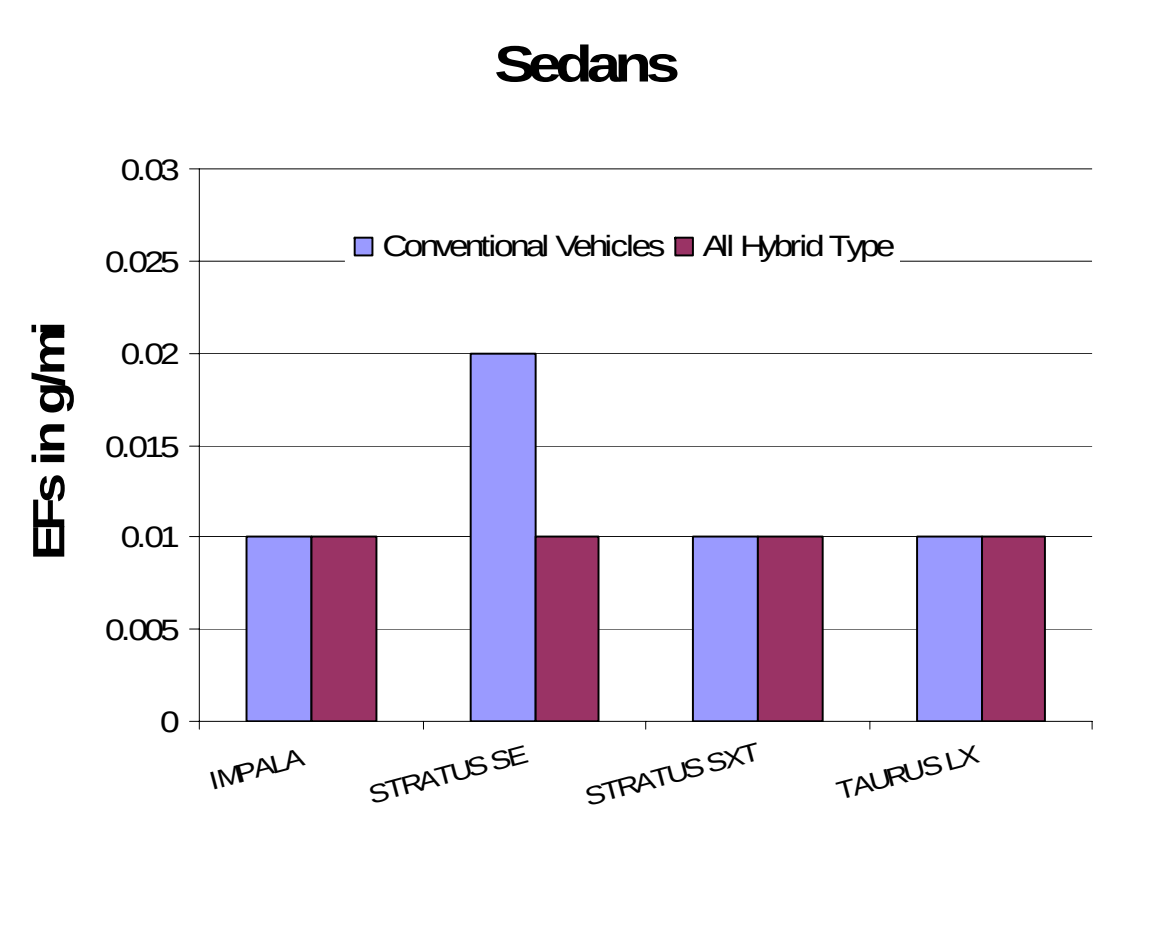
Emission Factors are from EPA's Green Vehicle Guide

NMOG Emission Factors for Sedan Category



Emission Factors are from EPA's Green Vehicle Guide

PM Emission Factors for Sedan Category



Emission Factors are from EPA's Green Vehicle Guide

ANALYSIS

Through the hybrid vehicle replacement

- 1 – Estimation of economic benefits and fuel savings
- 2 – Estimation of emission reductions
- 3 – Estimation of the effects of gasoline price

Each Scenario Option

Category	Scenario	Description of the Replacement
Sedans (184)	1	Honda Accord Hybrid
	2	Honda Civic Hybird
	3	Toyota Prius Hybrid
SUVs (33)	1	Ford Escape Hybrid (26) & Toyota Highlander Hybrid (7)
	2	Lexus RX400h (26) & Toyota Highlaner Hybrid (7)
	3	Mazda Tribute Hybrid (26) & Toyota Highlander Hybrid (7)
	4	Mercury Mariner Hybrid (26) & Toyota Highlander Hybrid (7)
Pickup Trucks (37)	1	Chevrolet Silverado Hybrid
	2	GMC Sierra Hybrid

1. The results of the emission reductions per year for each scenario for each vehicle category

	Vehicle Miles Traveled per Year per Vehicle	Emissions for the Conventional Fleet						Scenario	HEVs	Emission Reductions for the Fleet						
		NOx lbs/yr	NMOG lbs/yr	CO lbs/yr	PM lbs/yr	HCHO lbs/yr	Total Emissions for the Current Fleet (lbs/yr)			NOx lbs/yr	NMOG lbs/yr	CO lbs/yr	PM lbs/yr	HCHO lbs/yr	Sum lbs/yr	% Reduction
184 SEDANs	16,700	626	686	28,393	79	122	29,906	1	Honda Accord Hybrid	153	78	0	12	0	242	0.81%
								2	Honda Civic Hybrid	496	627	14,426	12	96	15,658	52%
								3	Toyota Prius Hybrid	428	318	14,426	12	48	15,232	51%
33 SUVs	15,000	152	129	4,653	20	20	4,974	1	Ford Escape Hybrid & Toyota Highlander Hybrid	111	56	2,366	8.9	8.1	2,550	51%
								2	Lexus RX400h & Toyota Highlander Hybrid	120	69	2,366	8.9	8.1	2,572	52%
								3	Mazda Tribute Hybrid & Toyota Highlander Hybrid	111	56	2,366	8.9	8.1	2,550	51%
								4	Mercury Mariner Hybrid & Toyota Highlander Hybrid	111	56	2,366	8.9	8.1	2,550	51%
37 Pickup Trucks	6,250	155	96	2,439	18	10	2,718	1**	Chevrolet Silverado Hybrid	53	16	303	8.1	1.2	381	14%
								2	GMC Sierra Hybrid	53	16	303	8.1	1.2	381	14%
Total	254						37,598								18,611*	

1. The results of the emission reductions per year for each scenario for each vehicle category

	Vehicle Miles Traveled per Year per Vehicle	Total Emissions for the Current Fleet (lbs/yr)	Scenario	HEVs	Emission Reductions for the Fleet						
					NOx lbs/yr	NMOG lbs/yr	CO lbs/yr	PM lbs/yr	HCHO lbs/yr	Sum lbs/yr	% Reduction
184 SEDANs	16,700	29,906	1	Honda Accord Hybrid	153	78	0	12	0	242	0.81%
			2	Honda Civic Hybrid	496	627	14,426	12	96	15,658	52%
			3	Toyota Prius Hybrid	428	318	14,426	12	48	15,232	51%
33 SUVs	15,000	4,974	1	Ford Escape Hybrid & Toyota Highlander Hybrid	111	56	2,366	8.9	8.1	2,550	51%
			2	Lexus RX400h & Toyota Highlander Hybrid	120	69	2,366	8.9	8.1	2,572	52%
			3	Mazda Tribute Hybrid & Toyota Highlander Hybrid	111	56	2,366	8.9	8.1	2,550	51%
			4	Mercury Mariner Hybrid & Toyota Highlander Hybrid	111	56	2,366	8.9	8.1	2,550	51%
37 Pickup Trucks	6,250	2,718	1**	Chevrolet Silverado Hybrid	53	16	303	8.1	1.2	381	14%
			2	GMC Sierra Hybrid	53	16	303	8.1	1.2	381	14%
Total	254	37,598								18,611*	

2. Results of the Fuel Savings and the Economic Benefits (in $1,000) for Each Scenario for Each Vehicle Category

	The lifecycle	Capital Cost of the Conventional Fleet	Lifetime Fuel Cost of the Conventional Fleet	Scenario	HEVs	Capital Cost of the HEV Fleet	Capital Cost Difference for the Fleet	Lifetime Fuel Cost of the HEV Fleet	Lifetime Fuel Saving for the fleet (total)	The Economic Benefit for the Fleet
184 SEDANs	3 years	$3,998	$1,182	1	Honda Accord Hybrid	$5,546	$1,548	$861	$321	-$1,227
				2	Honda Civic Hybrid	$4,020	$22	$554	$628	$606
				3	Toyota Prius Hybrid	$3,915	-$83	$498	$684	$767
33 SUVs	4 years	$838	$319	1	Ford Escape Hybrid for 26 vehicles	$715	$108	$181	$138	$30
					Toyota Highlander Hybrid for 7 vehicles	$231				
				2	Lexus RX400h for 26 vehicles	$1,179	$572	$194	$125	-$447
					Toyota Highlander Hybrid for 7 vehicles	$231				
				3	Mazda Tribute Hybrid for 26 vehicles	$760	$153	$192	$127	-$26
					Toyota Highlander Hybrid for 7 vehicles	$231				
				4	Mercury Mariner Hybrid for 26 vehicles	$776	$169	$192	$127	-$42
					Toyota Highlander Hybrid for 7 vehicles	$231				
37 Pickup Trucks	8 years	$636	$279	1	Chevrolet Silverado Hybrid	$1,190	$554	$289	-$10	-$564
				2	GMC Sierra Hybrid	$1,155	$519	$289	-$10	-$529
Total	217									$797*

$797* : $797,000 is the total potential savings for replacing conventional sedans with Toyota Prius and SUVs with Ford Escape and Toyota Highlander
Lifetime Fuel Cost = gasoline price/combined MPG * VMT per year * lifetime
Gasoline price= $3.00/gallon

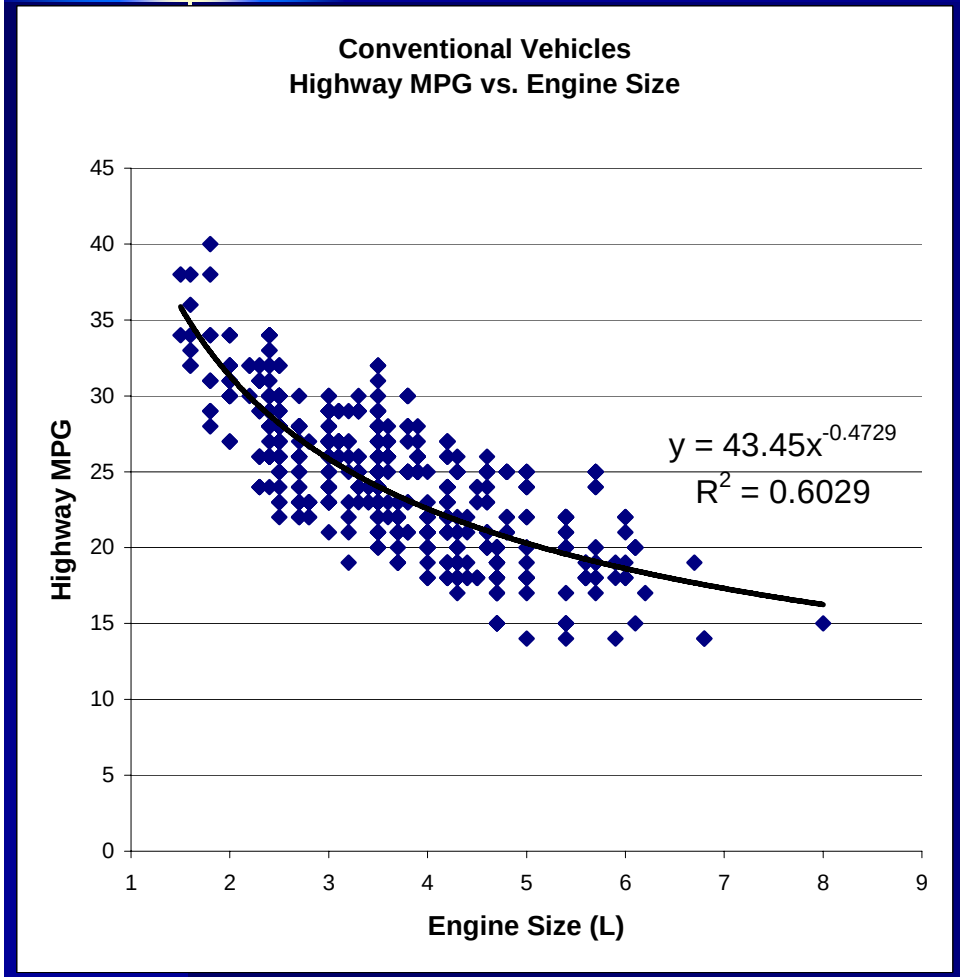
2. Results of the Fuel Savings and the Economic Benefits (in $1,000) for Each Scenario for Each Vehicle Category

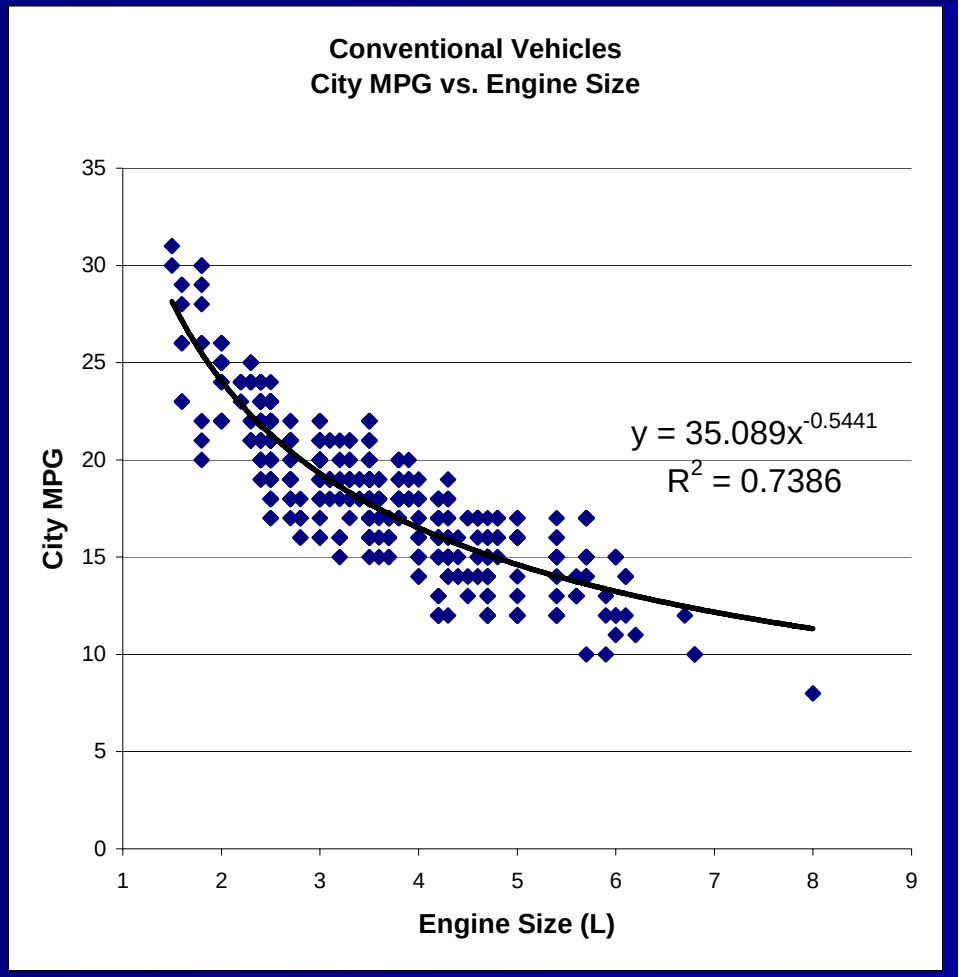
	The lifecycle	Capital Cost of the Conventional Fleet	Lifetime Fuel Cost of the Conventional Fleet	Scenario	HEVs	Capital Cost of the HEV Fleet	Capital Cost Difference for the Fleet	Lifetime Fuel Cost of the HEV Fleet	Lifetime Fuel Saving for the fleet (total)	The Economic Benefit for the Fleet
184 SEDANs	3 years	$3,998	$1,182	3	Toyota Prius Hybrid	$3,915	-$83	$498	$684	$767
33 SUVs	4 years	$838	$319	1	Ford Escape Hybrid for 26 vehicles	$715	$108	$181	$138	$30
					Toyota Highlander Hybrid for 7 vehicles	$231				
Total	217									$797*

3. The Breakeven Point Based on Gasoline Price

	Lifecycle	Scenario	HEVs	Breakeven Point by Gasoline Price*
184 SEDANs	3 years	1	Honda Accord Hybrid	$18.7/gal
		2	Honda Civic Hybrid	$0.11/gal
		3	Toyota Prius Hybrid	$0/gal
33 SUVs	4 years	1	Ford Escape Hybrid for 26 vehicles Toyota Highlander Hybrid for 7 vehicles	$2.34/gal
		2	Lexus RX400h for 26 vehicles Toyota Highlander Hybrid for 7 vehicles	$13.76/gal
		3	Mazda Tribute Hybrid for 26 vehicles Toyota Highlander Hybrid for 7 vehicles	$3.60/gal
		4	Mercury Mariner Hybrid for 26 vehicles Toyota Highlander Hybrid for 7 vehicles	$3.97/gal

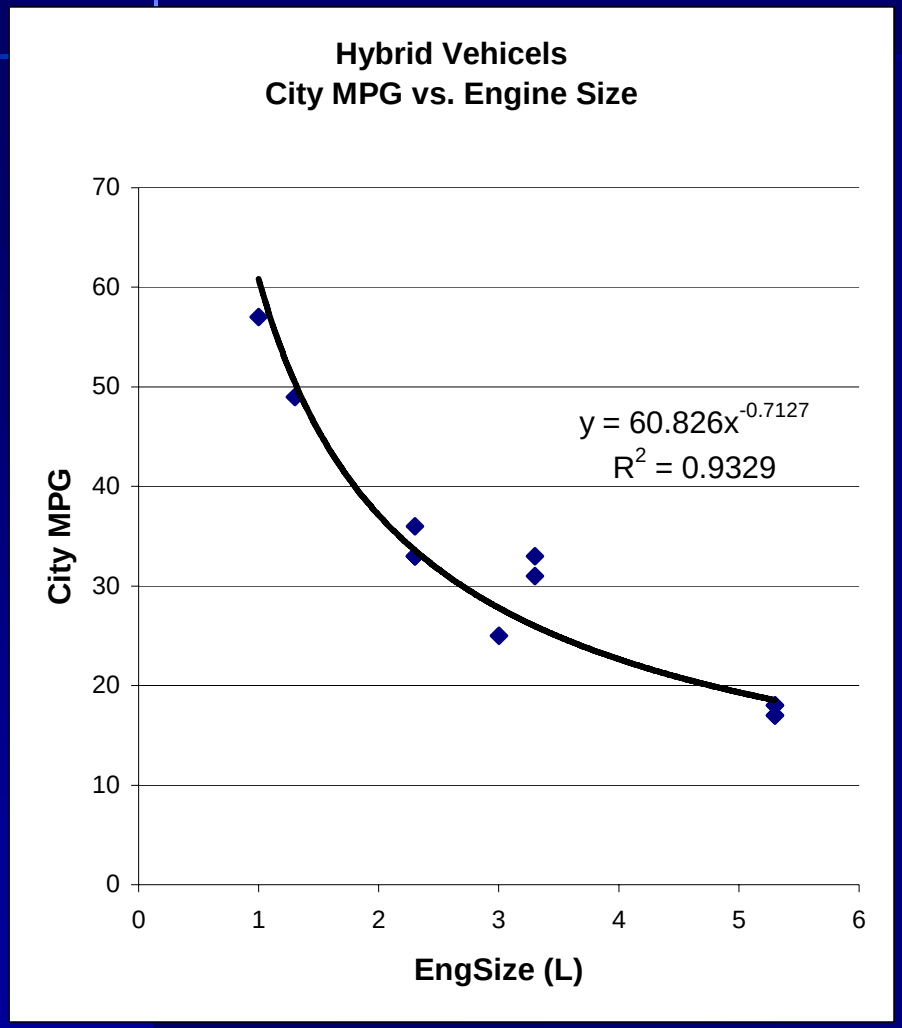
Fuel economy versus engine size for conventional vehicles and its exponential equations.

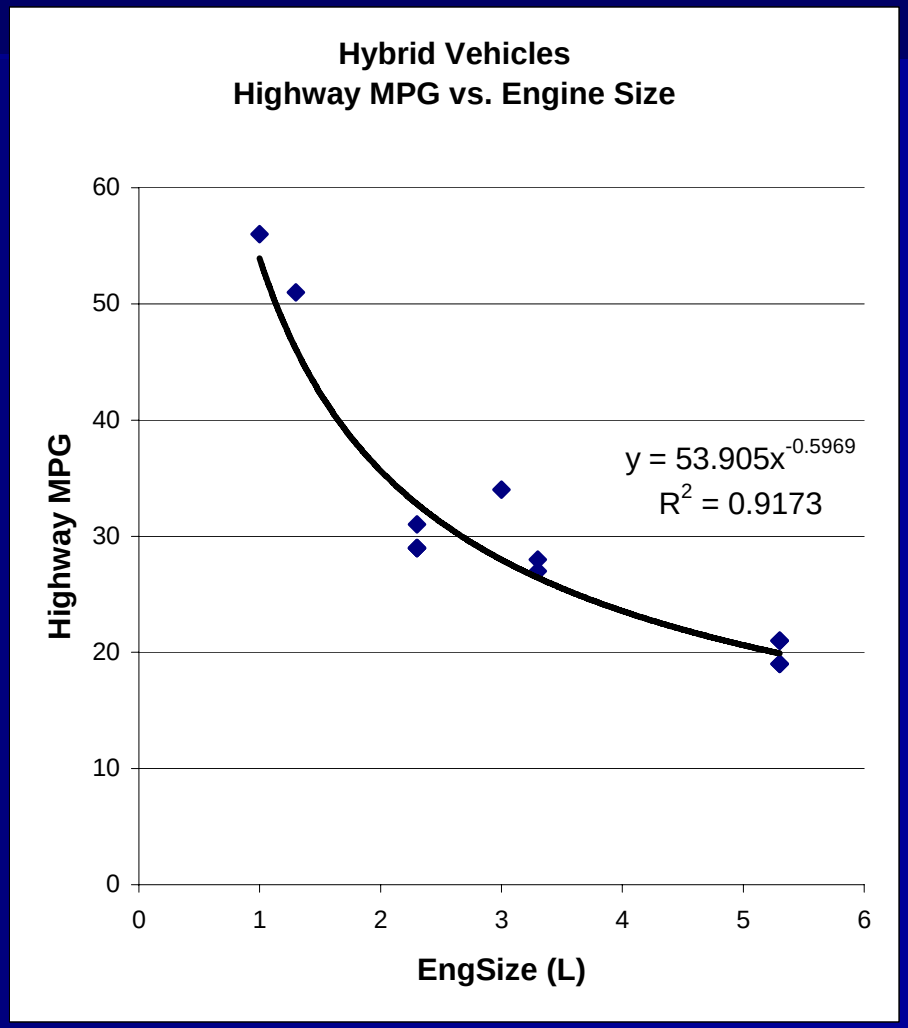




The data are from EPA

Fuel economy versus engine size for hybrid vehicles and its exponential equations

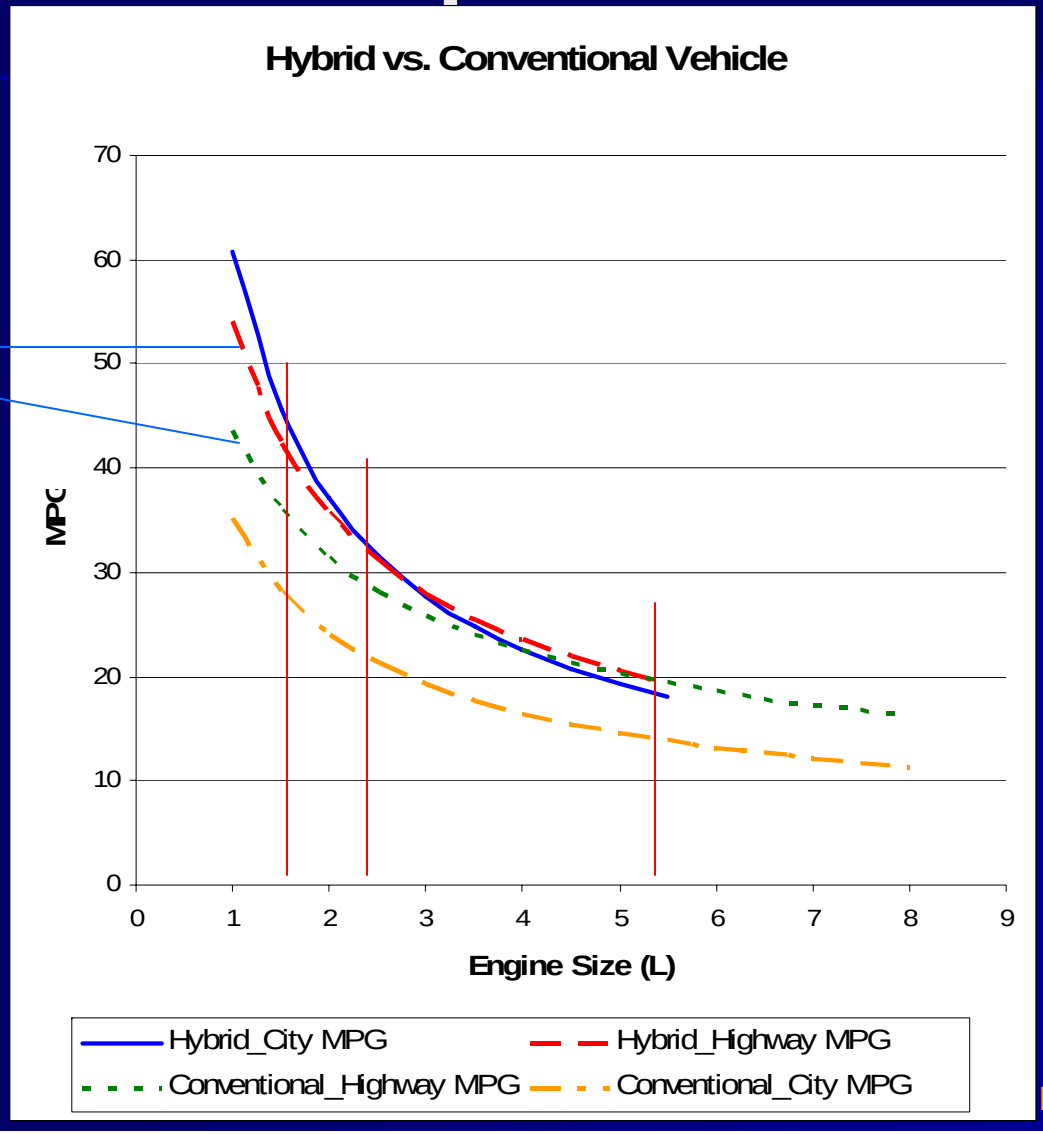




The data points are from EPA

The four graphs for the four exponential equations

highway



The data points are from EPA

SUMMARY and CONCLUSIONS

- For the 184 sedans: Honda Civic hybrid and Toyota Prius hybrid replacement
  - $606,000 - $767,000 potential cost savings
  - 51 – 52% total emission reductions, or 15,200 to 15,700 lbs/yr
- For the 33 SUVs: Ford Escape and the Toyota Highlander hybrid (Scenario 1)
  - $30,000 potential cost savings
  - 51% emission reduction, or 2,600 lbs/yr

SUMMARY and CONCLUSIONS

- The best replacement option (emission reductions)
  - 18,600 lbs/yr overall reductions
    - Honda Civic hybrid
    - Lexus RX 400h and Toyota Highlander hybrid
    - Chevrolet Silverado hybrid or GMC Sierra hybrid
- The best option (money saving)
  - $797,000 savings overall
    - Toyota Prius
    - Ford Escape and Toyota Highlander hybrid
    - No economic benefit from the “pickup truck” category.

Continued…

- Hybrid vehicles for city driving
  - 62 to 30% benefits in fuel economy for 1.5 to 5.5L engine size
- Driving hybrids on the highway
  - 18 to 12% benefits for 1.5 to 2.3L engine size
- Engine size increase up to around 5.5L, little or no fuel economy benefits driving hybrid vehicles on the highway

LIMITATIONS

- The size of vehicles
- The cost effectiveness without considering other factors:
  - battery, insurance, maintenance and repair, etc.
- Federal tax credits

Thank you!

Questions?