Evaluation of Hybrid Vehicle Business Strategies

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Should Next-Generation Hybrids Use Li-Ion or NiMH Batteries?

- Fixed Plan: Design new platform using NiMH Batteries
  - Currently cheaper
  - Chemistry is close to limits imposed by fundamental material properties
- Flexible Plan: Design new platform using Lithium-Ion Batteries
  - Enables a flexible platform: Limited electric range (plug-in hybrid), conventional hybrid, or a mild-hybrid
  - Costs likely to drop over time, but may stay higher than NiMH throughout the life of the project
  - Technical risk due to questions about battery durability

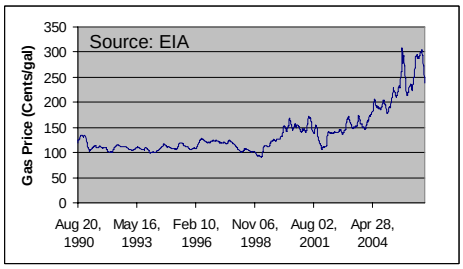
Model Overview

- Project Lifetime: 18 Years
- Demand for a vehicle is a function of its NPV
  - NPV = (Lifetime savings on fuel - HEV Price premium
- Vehicle Parameters (Shaded = Flexible Options):

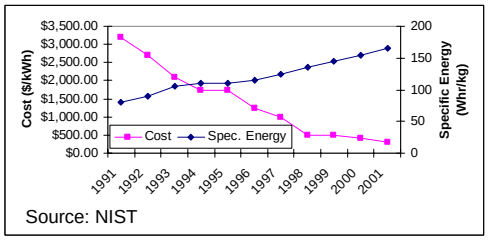
Vehicle Config	FC. Imp	% of Mi Electric	MPG	Gallons Saved/Yr	Price Premium
Full Hybrid, NiMH	25%	0%	40.0	125	$2,500
Mild Hybrid, LI	15%	0%	36.6	90	$2,500
Full Hybrid, LI	25%	0%	40.0	125	$3,300
PHEV-10, LI	25%	20%	50.0	200	$5,000
PHEV-20, LI	25%	30%	67.1	238	$6,000

Key Uncertainties

1.) Gas Price Volatility:
-Assume $2.75 start point
-0.5% growth per year
-10% volatility

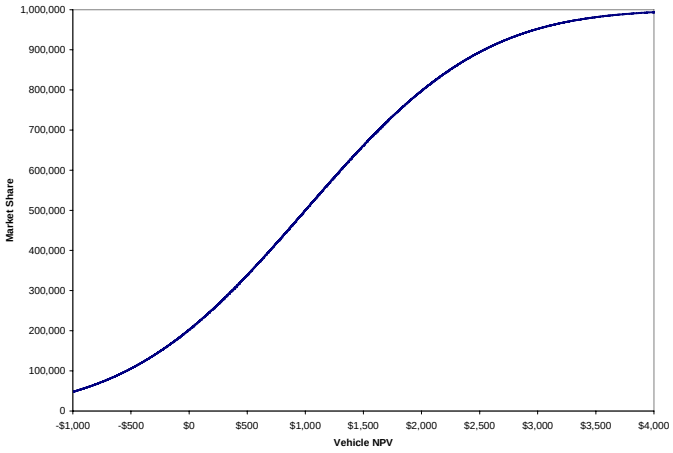


2.) Technology-driven cost reduction:
-Assume 1.75% per year baseline
-Analyze sensitivity to different rates
-Analyze effect of volatility using Monte Carlo



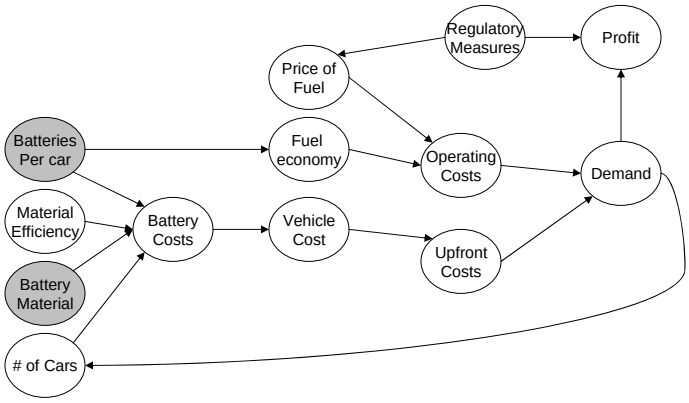
3.) Regulatory Structure: Subsidy/Rebate Programs
- Test 0, $0.25/gal, and $0.50/gal rebates

Demand Model

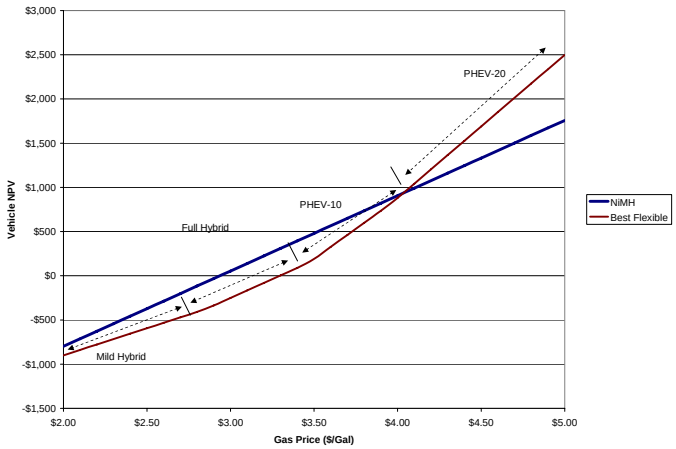


- Sales volume is normally distributed around NPV = $1000, with Std Dev = $1200. Max. Sales = 1,000,000 vehicles

Integrated System Model: (Shaded = Model Inputs)



Build Strategy as a Function of Gas Price



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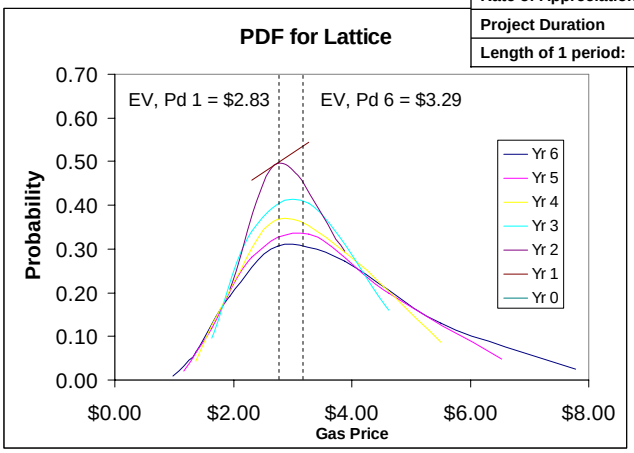
Lattice Calibration: Models Fuel Price Volatility

Initial Value of gas (per Gal):	$2.75
Volatility (per year):	10%
Rate of Appreciation (per year):	0.5%
Project Duration	18 yrs
Length of 1 period:	3 yrs



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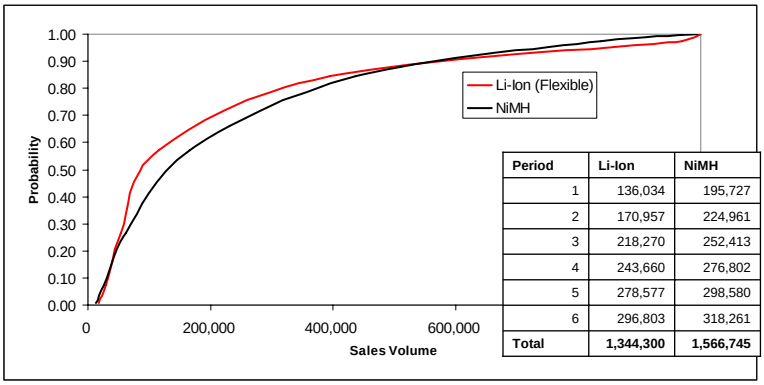
Results: Lattice Evolution of Fuel Price



Period	Li-Ion	NiMH
1	136,034	195,727
2	170,957	224,961
3	218,270	252,413
4	243,660	276,802
5	278,577	298,580
6	296,803	318,261
Total	**1,344,300**	**1,566,745**

- NiMH is the best option: It has a sizeable advantage over mid-range price scenarios.
- LI does better at high-gas prices, but the advantage in terms of sales is slim

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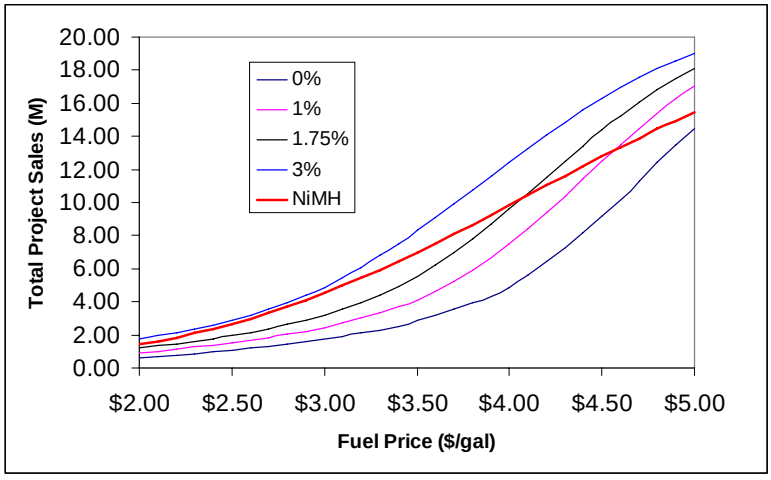
At Li-Ion price reduction >2.5%/Yr, Flexible strategy is better…



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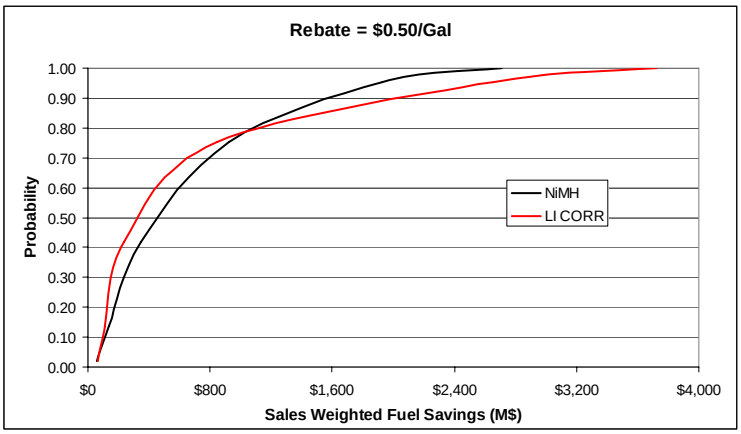
At >$0.40/gal rebate, flexible strategy is better…



Period	1	2	3	4	5	6	Total
Inflexible	$575	$661	$741	$813	$877	$935	$4,602
Flexible	$400	$566	$755	$857	$996	$1,066	$4,639

Conclusions

- Under most moderate scenarios, the NiMH strategy is preferable
- If lithium-ion batteries drop in cost at higher-than-expected rates, or if aggressive regulatory structures are implemented, the flexible strategy becomes a better choice.