The Perfect Storm

- Petroleum consumption has steadily increased while domestic production has continued to decline
- World oil production predicted to peak within the next 5-15 years
- Recent increase in gasoline price is indicator of growing tension between supply and demand

Gasoline price - 85% rise in 5 years!
Oil Use Reduction with HEVs

Light Duty Fleet Oil Use - Impact of HEVs on Consumption

This highly aggressive scenario assumes 100% HEV sales from 2010 onwards.

HEVs unable to reduce consumption below today’s consumption level

Produced using VISION model, MBPD = million barrels per day
Oil Use Reduction with PHEVs

Light Duty Fleet Oil Use - Impact of PHEVs on Consumption

This highly aggressive scenario assumes 100% HEV sales from 2010 and 50% PHEV40 sales from 2020 onwards…

Oil use reduction!

PHEVs reduce oil consumption with a transition to electricity

Produced using VISION model, MBPD = million barrels per day
Recent PHEV Prototypes

EnergyCS Plug-In Prius

HyMotion Escape PHEV

DaimlerChrysler Sprinter PHEV

Renault Kangoo Elect’road

AC Propulsion Jetta PHEV

Esoro AG H301

AFS Trinity Extreme Hybrid™
PHEV Batteries

Johnson Controls / SAFT

Cobasys

Valence Technologies

Hymotion

National Renewable Energy Laboratory
Battery Characteristics

Lower power to energy ratio leads to lighter, smaller, and less expensive energy storage system.
All-Electric vs Blended Strategy

**All-Electric**

- Engine turns on when power exceeds battery power capability
- Engine only provides load that exceeds battery power capability

**Blended**

- Engine turns on when battery reaches low state of charge
- Requires high power battery and motor

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[Graph showing power and SOC for All-Electric and Blended strategies]
Blended vs. AER Consumption Tradeoff

- Reducing ESS power should reduce cost, mass, volume
- 50% reduction in power still provides almost all of the fuel consumption benefit

* CD = Charge Depleting

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PHEV Battery Sizing Alternatives

![Diagram showing PHEV Battery Sizing Alternatives with different energy and power levels for PHEV20 and PHEV40 in Blended and AER modes, including 70% and 50% SOC window markers.](image)
Battery Life

• PHEV battery likely to deep-cycle each day driven: 15 yrs equates to 4000-5000 deep cycles
• Also need to consider combination of high and low frequency cycling

Data presented by Christian Rosenkranz (Johnson Controls) at EVS 20
What’s value of other benefits
• Less trips to gas station
• Being “Green” 
• …

Projected battery costs

$2.15/gal.
Conclusions

• Plug-in hybrid technology can reduce petroleum consumption beyond that of HEV technology

• The study highlighted some of the PHEV design options and associated tradeoffs
  — Expansion of the energy storage system usable state of charge window while maintaining life will be critical for reducing system cost and volume
  — A blended operating strategy as opposed to an all electric range focused strategy may provide some benefit in reducing cost and volume while maintaining consumption benefits

• The key remaining barriers to commercial PHEVs are battery life, packaging and cost