Economics, Logistics and Environmental Impacts of Hybrid Electric Veh

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Hybrids are in Widespread Use

- **Honda**
  - Insight
  - Civic
- **Toyota**
  - Prius

Picture Source: Honda Motor Co.
New Models Are Coming

• Ford
  – Escape
• Dodge
  – Ram Truck
• GMC
  – Sierra SUV
  – Saturn VUE
• Lexus
  – RX330

Picture source: Toyota Motor Co.
Military Interest

- Army
  - Humvee
  - COMBATT
  - FCS
- Marines
  - RSTV
- Air Force

Picture source: National Automotive Center
Topics To Be Covered Today

• Technology of hybrids

• Economics in military use

• Logistics

• Environmental impacts
Hybrid Electric Veh Tech
Features of HEVs

- Combine 2 sources of power; electric motor and internal combustion engine
- Regenerative braking
Series Hybrid

IC Engine

Generator

Controller

Energy Storage System (batteries)

Electric Motor/Generator
Properties of Series Hybrids

• 10-15% gain in fuel efficiency
• Flexibility with regard to engine location
• Can be configured for onboard power generation
• Proven technology – used in train engines, diesel submarines
• Most hybrid trucks use series design
Properties of Parallel Hybrids

- Motor, engine work together
- Significant gains in fuel efficiency
- Used in Toyota Prius, Honda Civic
- Being tried in trucks
- Can be configured for onboard power generation
Economics of Hybrids in Military Use
Potential Savings

- Reduced fuel consumption
- Reduced brake maintenance
- Reduced need for standalone generators
Incremental Costs

- Higher initial cost (addition of electric motor, batteries)
- Periodic battery replacement
Economics of th Humvee: Meth

• Comparison to Conventionally Powered Humvee

• Net present value analysis (20 year life)

• Picture Source: IDT PEI
Economics of the Hybrid Humvee: Key Assumptions

- Value of onboard power generation = incremental cost of vehicle
- Cost of fuel reflects underlying logistics network (estimated at $10/gal.)
- Conventional Humvee gets 9 mpg, driven 3500 miles per year
- Hybrid provides 30% efficiency gain
- 3 year battery life; $3000 replacement cost
## NPV of Hybrid Humvee Relative to Conventionally Powered

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>$15/gal</th>
<th>4-year battery repl.</th>
<th>$2000/battery repl.</th>
<th>50% mpg gain</th>
<th>5,000 miles/year</th>
<th>7% v. 6% ROI</th>
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<td>$90</td>
<td>$5,237</td>
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Humvee Breakeven Battery Cost vs. Life at Different Fuel Costs

- A: $15/gal
- B: $10/gal
- C: $5/gal

Frequency of replacement (yrs)

Battery Cost ($K)
HEV Logistics Gains
Logistics Footprint: What Does Onboard Power Generation Imply for Fuel and Weight Savings?

- Assume onboard generating capability = 30KW of power

- Assume otherwise need two 15KW portable generators and vehicles to pull each

- Assume hybrid Humvee in power generation mode uses same fuel as two 15KW generators
Assumed Equivalency of Hybrid Onboard Power Generation With Standalone Generators

Source: Army Program Office, Light Tactical Vehicles
Best Case Results

- 1 fewer conventional Humvee tow vehicle
- 2 fewer standalone generators
- Weight savings:
  - 1 Humvee (11,500 lbs)
  - 2 15KW generators (3324 lbs each)
  + 1 hybrid weight increment (600 lbs)
  = Net reduction of 17,548 lbs

- Fuel savings of 1 less vehicle plus 30% fuel efficiency gain for the other
Alternative Case Result
(Assume 15KW Onboard Generator)

• -1 fewer standalone generator (-3324 lbs)
• +1 hybrid weight increment (+600 lbs)
• = Net reduction of 2724 lbs

• 30% gain in fuel efficiency
Potential Logistics Savings for Weapons Systems

- THAAD
- SHORAD
THAAD –30 KW Hybrid Humvee Could Provide Power to Two Shelters

- Eliminate 2 15 KW towed generators + towing vehicle
- 25-30% reduction in fuel use

Source: Army Program Office, Light Tactical Vehicles
Plus Fewer Required Airlift Sorties

Picture source: National Automotive Center
Potential Logistics Savings for SHORAD System

Current System

- Stowed Sentinel Radar
- C2 Vehicle
- Crew / Maintenance Vehicle

Hybrid System

- Stowed Sentinel Radar On Hybrid Humvee
- Combined C2/Crew Vehicle Powered by Hybrid Humvee

Source: Army Program Office, Light Tactical Vehicles
Net SHORAD Savings

- 2 trailers
- 1 Humvee
- Up to 50% of fuel consumption
- Volume, mass reduction of 40-45%
- 1-2 men
Environmental Impacts
Potential Environmental Advantages

- Reduced fuel use
- Reduced air emissions
- Reduced equipment mass
- Reduced air sorties to deliver equipment
Reduced Air Emissions
(Tons/15 Year Service Life)

<table>
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<th>HD Truck (diesel)</th>
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Potential Environmental Challenges

- Battery disposal
- Increased mass of hybrid vehicle
- Parallel maintenance operations
Conclusions

- Economics of hybrids look favorable for military
- Potentially important logistics savings
- Net environmental impacts probably positive:
  - Reductions in air emissions
  - Net reduction in material mass
- But operational, economic, environmental challenges exist:
  - Performance under operating conditions
  - Incremental cost
  - Battery disposal