Alternative Fuel Vehicles by Type: Pros, Cons, and Case Studies

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Alternative Fuels
Plug-In Electric Vehicles
**PEV Types**

**Battery Electric Vehicles (BEVs)**

- **Electric motor** only power source
- Batteries charged from electric grid and regenerative braking

**Plug-in Hybrid Electric Vehicles (PHEVs)**

- Operates like a hybrid electric vehicle, but **battery > 4 kw-hours**
- Batteries can be charged with electricity like a pure **battery electric vehicle**
Electricity generates zero tailpipe emissions
### PEV Costs

#### Higher MSRP:
- Deals sometimes available
- VA Group Buy, GSA Lease

#### More affordable to fuel:
- $1.07/gge residential in VA
- Discounts at large facilities

<table>
<thead>
<tr>
<th>FEDERAL</th>
<th>PRIVATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Ford Focus</td>
<td>Electric Nissan Leaf</td>
</tr>
<tr>
<td>MSRP: $29,120</td>
<td>MSRP: $30,680</td>
</tr>
<tr>
<td>GSA Offer: $16,160</td>
<td>Virginia Group Buy: $15,650 with Tax Credits</td>
</tr>
<tr>
<td>Federal Lifecycle Costs: $23,318</td>
<td>Private Lifecycle Costs: $18,296</td>
</tr>
<tr>
<td>Gasoline Ford Focus</td>
<td>Gasoline Nissan Versa Note SV</td>
</tr>
<tr>
<td>MSRP: $16,775 (manual)</td>
<td>MSRP: $16,380</td>
</tr>
<tr>
<td>GSA Offer: $14,645 (automatic)</td>
<td></td>
</tr>
<tr>
<td>Federal Lifecycle Costs: $25,032</td>
<td>Private Lifecycle Costs: $22,186</td>
</tr>
</tbody>
</table>
## PEV Charging: EVSE

<table>
<thead>
<tr>
<th>Charging Level</th>
<th>Vehicle Range Added per Charging Time and Power</th>
<th>EVSE Unit* Cost Range (single port)</th>
<th>Installation Cost Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AC Level 1</strong></td>
<td>4 mi/hour @ 1.4kW&lt;br&gt;6 mi/hour @ 1.9kW</td>
<td>$300-$1,800</td>
<td>$0-$3,000</td>
</tr>
<tr>
<td><strong>AC Level 2</strong></td>
<td>10 mi/hour @ 3.4kW&lt;br&gt;20 mi/hour @ 6.6kW&lt;br&gt;60 mi/hour @ 19.2 kW</td>
<td>$400-$6,500</td>
<td>$600-$12,700</td>
</tr>
<tr>
<td><strong>DC Fast Charging</strong></td>
<td>24 mi/20min. @24kW&lt;br&gt;50 mi/20min. @50kW&lt;br&gt;90 mi/20min. @90kW</td>
<td>$10,000-$40,000</td>
<td>$8,500-$51,000</td>
</tr>
</tbody>
</table>

*Margaret Smith and DOE EVSE Cost Report
PEV Pros and Cons

Lower emissions
Lower fuel and maintenance costs
Better performance
Domestic fuel

Limited range (100-240 in BEVs)
EVSE installation
Limited vehicle types available
## 2017 EVs on GSA Schedule

<table>
<thead>
<tr>
<th>Make and Model</th>
<th>Purchase Price</th>
<th>Vehicle Class</th>
<th>BEV/PHEV</th>
<th>Lease Rate</th>
<th>Incremental Cost</th>
<th>Mileage Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford Focus</td>
<td>$16,160.00</td>
<td>Subcompact</td>
<td>BEV</td>
<td>$199.00</td>
<td>$0.00</td>
<td>$0.063</td>
</tr>
<tr>
<td>Ford C-Max Energi</td>
<td>$27,143.75</td>
<td>Subcompact</td>
<td>PHEV</td>
<td>$182.00</td>
<td>$12,837.10</td>
<td>$0.083</td>
</tr>
<tr>
<td>Chevrolet Volt</td>
<td>$30,300.00</td>
<td>Subcompact</td>
<td>PHEV</td>
<td>$182.00</td>
<td>$15,993.35</td>
<td>$0.083</td>
</tr>
<tr>
<td>Hyundai Sonata</td>
<td>$27,961.85</td>
<td>Compact</td>
<td>PHEV</td>
<td>$184.00</td>
<td>$9,590.96</td>
<td>$0.095</td>
</tr>
<tr>
<td>Ford Fusion Energi</td>
<td>$28,209.30</td>
<td>Compact</td>
<td>PHEV</td>
<td>$184.00</td>
<td>$9,838.41</td>
<td>$0.095</td>
</tr>
<tr>
<td>Chrysler Pacifica</td>
<td>$38,458.78</td>
<td>Minivan</td>
<td>PHEV</td>
<td>$228.00</td>
<td>$17,342.00</td>
<td>$0.13</td>
</tr>
</tbody>
</table>
PEV Case Study: Army

ID Vehicle Types

- Sedans and Minivans

ID Targets

- Motor Pools (PHEVs)
- Commands (BEVs)

ID Exact Locations

- Tiger Team Site Visits
- Existing transformer
- GOV sedan parking
- Recommended EVSE location
Natural Gas Vehicles
NGV Types

**Natural Gas Vehicles (NGVs)**

- Operate like gasoline vehicles – spark-ignition
- CNG – Refill with high pressure gas at fast-fill station or low pressure gas at time-fill station
- LNG – Refill with liquefied gas for long-haul truckers
Medium/Heavy Older Diesel Reductions:
- 33% GHGs
- 90% NOx
- 43% VOCs
Higher MSRPs
Fueling stations expensive

More affordable to fuel
• As cheap as $1.40/gge
• More stable prices

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>4x2 Pickup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Type</td>
<td>CNG/GAS</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>FCA</td>
</tr>
<tr>
<td>Model</td>
<td>2500</td>
</tr>
<tr>
<td>Engine</td>
<td>5.7L, V8 HEMI</td>
</tr>
<tr>
<td>Price (GSA)</td>
<td>$31,267.58</td>
</tr>
</tbody>
</table>
NGV Pros and Cons

- Lower fuel costs
- Lower emissions
- Public fast fill or private time fill
- Less after-treatment than diesel
- Domestic fuel

- Incremental vehicle cost
- Limited vehicle availability
- Fewer stations
- Potentially expensive stations
NGV Case Study – Colorado

Commitment to Purchase NGVs

- Multi-state MOU
- Purchased 233 NGVs in 2013 and 2014

Strategies for Success

- Targeted deployment by location
- Solicit more agency input in bid process
- Improved tracking yields better data
- Replacement before retirement age as appropriate

Education, Training, and Incentives

- CNG fueling video
- Motor Vehicle Advisory Committee
- FleetDASH tool
- Incentives for operators
Flex Fuel Vehicles
**Flexible Fuel Vehicles (FFVs)**

- Operates like gasoline vehicles
- Use combination of ethanol and gasoline to fuel vehicle
- Refill at stations offering E85 or another blend of “flex fuel”
Far fewer tier one emissions
FFV Costs and Stations

Fuel is usually more expensive on energy equivalent basis

Little to no incremental vehicle cost
Stations widely available
FFV Pros and Cons

Lower emissions
Abundant stations
Little/no incremental cost
Higher octane
Domestic fuel

Energy density translates to lower fuel economy and often higher price per mile
E85 Case Study

Alabama DOT

- 1,800 FFVs/3,000 vehicles
- Nine sites around state have on site-fueling
- 220,000 gallons/year E85 in 2015
- Addressed fuel quality concerns with additive requirements in contracts
- Two tanks had leakage issues but were replaced under warranty
Biodiesel
**Biodiesel – Conventional Diesel Vehicles**

- No difference between conventional diesel vehicles and biodiesel vehicles
- Note: Some engine warranties limit use of biodiesel blends greater than B5
- Biodiesel is fuel derived from oils and fats
B100 Emissions

Only biodiesel portion of fuel counted as alternative fuel (e.g. 20% for B20)
Biodiesel Costs and Stations

Biodiesel fuel is typically more expensive than diesel |
No incremental cost Vehicles are same as conventional diesel

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Cargo Van</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Type</td>
<td>Diesel/B20 Capable</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Ford</td>
</tr>
<tr>
<td>Model</td>
<td>Transit 250</td>
</tr>
<tr>
<td>Engine</td>
<td>3.2L, 5 cylinders</td>
</tr>
<tr>
<td>Price (GSA)</td>
<td>$26,207.48</td>
</tr>
<tr>
<td>Monthly</td>
<td>$281.00</td>
</tr>
</tbody>
</table>

Renewable Diesel

Another petroleum diesel substitute can be used to reduce emissions
Primarily hydrocarbons rather than oxygenates
Drop-in fuel
## Biodiesel Pros and Cons

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple way to reduce emissions</td>
<td>Fuel can be more expensive</td>
</tr>
<tr>
<td>Use existing diesel vehicles</td>
<td>Potential maintenance and cold flow issues</td>
</tr>
<tr>
<td>Higher lubricity</td>
<td></td>
</tr>
<tr>
<td>Higher cetane</td>
<td></td>
</tr>
<tr>
<td>Domestic fuel</td>
<td></td>
</tr>
</tbody>
</table>
Biodiesel Case Study

American University

- 10 shuttle buses
- 50,000 gallons/year, bought in bulk
- Switch to on-site fueling improved productivity
- B5 in winter months to avoid potential cold flow issues

http://www.afdc.energy.gov/case/2203
Hydrogen Fuel Cell Electric Vehicles
Hydrogen FCEVs

**Fuel Cell Electric Vehicles (FCEVs)**

- Electric motor (operates like BEV)
- Uses hydrogen gas to produce electricity via a fuel cell stack
- Refill with high pressure hydrogen gas at station
- Regenerative braking
- Hydrogen produced from hydrocarbons or renewable sources
Hydrogen Emissions

Zero tailpipe emissions
Can be produced entirely from renewable resources

Bar chart showing kg CO2e/GGE for various fuels:
- Diesel
- Gas
- LPG
- B20
- CNG
- LNG
- HEV
- E85
- PHEV
- B100
- BEV

Hydrogen is highlighted and indicated as (100%).
Hydrogen Costs and Stations

FCEVs MSRP are high but costs rapidly declining
Hydrogen fuel cost

Cost of fuel cells has dropped 50% since 2006
Fast fueling at hydrogen stations
Long range (e.g. 300 miles)

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Sedan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Type</td>
<td>Hydrogen</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Toyota</td>
</tr>
<tr>
<td>Model</td>
<td>Mirai</td>
</tr>
<tr>
<td>Price (MSRP)</td>
<td>$57,500</td>
</tr>
</tbody>
</table>

Honda and Hyundai also have commercially available FCEVs

Mostly in California and the Northeast
Vehicles only leased or sold where fuel is available
Hydrogen Pros and Cons

Long driving range
Only tailpipe emissions are water vapor
Various production methods (e.g. natural gas reformation and electrolysis)
Domestic production

Vehicles and fuel currently more expensive
Limited availability of vehicles and fuel
Hydrogen Case Study

Fuel Cell Transit Buses

• Early production – 21 active in August 2016 with 43 more coming
• Better fuel economy than diesel or CNG

DOE Goals and Current Performance

• Early focus on reduced costs and improved availability and reliability
• $600k/bus by 2020 (industry projected $1M in 2016 for order of 40 buses)
• Miles between roadcalls already exceeded 2020 goals in 2016

http://www.nrel.gov/docs/fy17osti/67097.pdf
Propane Vehicles
LPGVs

Propane / Liquefied Petroleum Gas Vehicles (LPGVs)

• Similar to CNG vehicles with lower pressure (120 psi)
• Available in bi-fuel configurations
• Public and private fast fueling infrastructure
LPGV Emissions

(16%)

kg CO₂e/GGE

Diesel Gas LPG B20 CNG LNG HEV E85 PHEV B100 BEV Hydrogen
LPGV Costs and Stations

Vehicles are usually more expensive than gasoline, but often not much higher than diesel.
Publicly available propane is often more expensive than gasoline per gge.

Fuel can be purchased inexpensively through contracts.
Station costs can be as low as $45,000 (and as high as $300,000)*

Vehicle Type | School Bus
Fuel Type     | Propane
Manufacturer  | Blue Bird
Model         | Vision
Engine        | 6.7L, 6 cylinders
Price (GSA)   | $90,459.64
Incremental   | $3,744.07

A gallon of propane has 27% less energy than gasoline.

Propane has octane ratings of 104-112.
Some dedicated propane engines use the high octane to improve performance and fuel economy.

LPGV Pros and Cons

- Lower emissions
- Affordable private stations
- Potentially very cheap fuel
- Higher octane

- Some incremental vehicle cost
- Limited and expensive public fuel
- Lower energy density
LPGV Case Study

Super Shuttle Fort Collins

- E350s and a long term contract
- Paying only $1/gallon ($1.32/gge)
- Save $14,000/year

Questions?

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