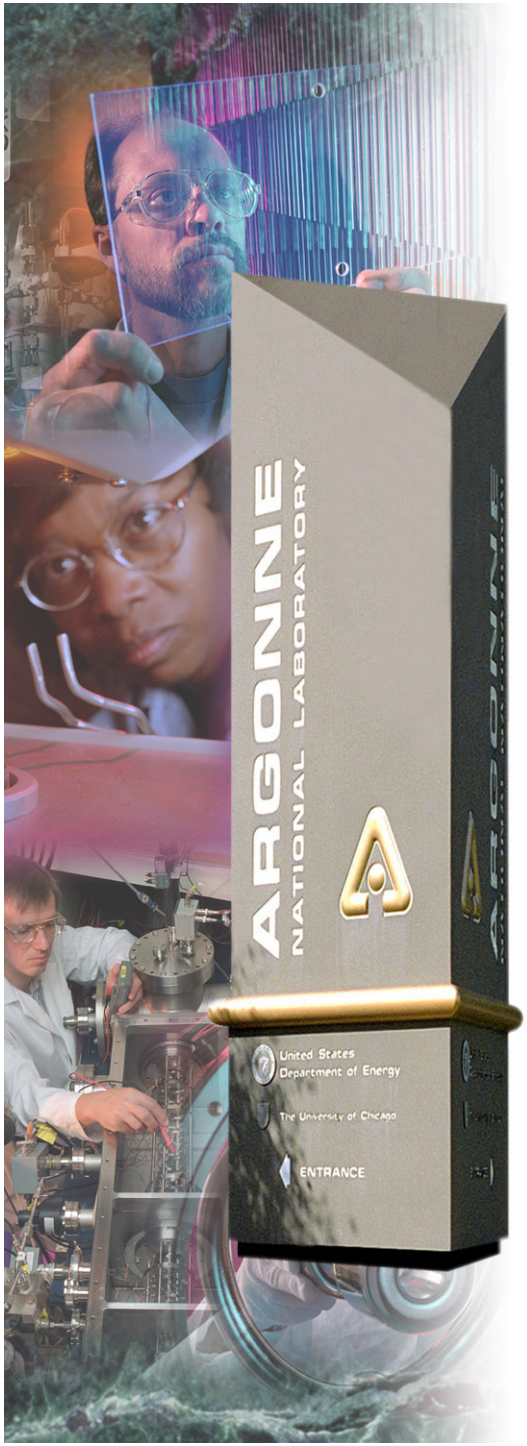

Grid-connected Hybrids: Another Option in the Search to Replace Gasoline

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Grid-connected or plug-in hybrids (PHEVs) use grid electricity for some of their daily vmt

- **PHEVs have larger batteries and motors than "normal" HEVs, operate in "charge depletion" mode, recharge overnight.**
- **Majority of gasoline usage is on short daily trips:**

  31-39% of annual miles are the "first 20 miles" of daily driving, 63-74% are "first 60 miles"….
- **so PHEVs with 20 (60) mile ranges (PHEV20/PHEV60) can use electricity to power about 35% (70%) of annual miles!**
- **Potential for PHEVs to offer "vehicle to grid" (V2G) services, e.g. rolling reserves, regulation**

Deployment of PHEVs offers several substantial benefits.

- **Oil use reduction**
- **Improved electricity system cost structure**
- ***Potential* reduction of greenhouse gases**
- **Transportation "emergency reserve"**
- **Reduction in most criteria emissions in urban areas**
- **Vehicle-to-grid services**
- **Efficient electricity use compared to FCVs**

Others have noticed: National Commission on Energy Policy, several Op-Ed pieces (including Tom Friedman), 2005 EPACT legislation.

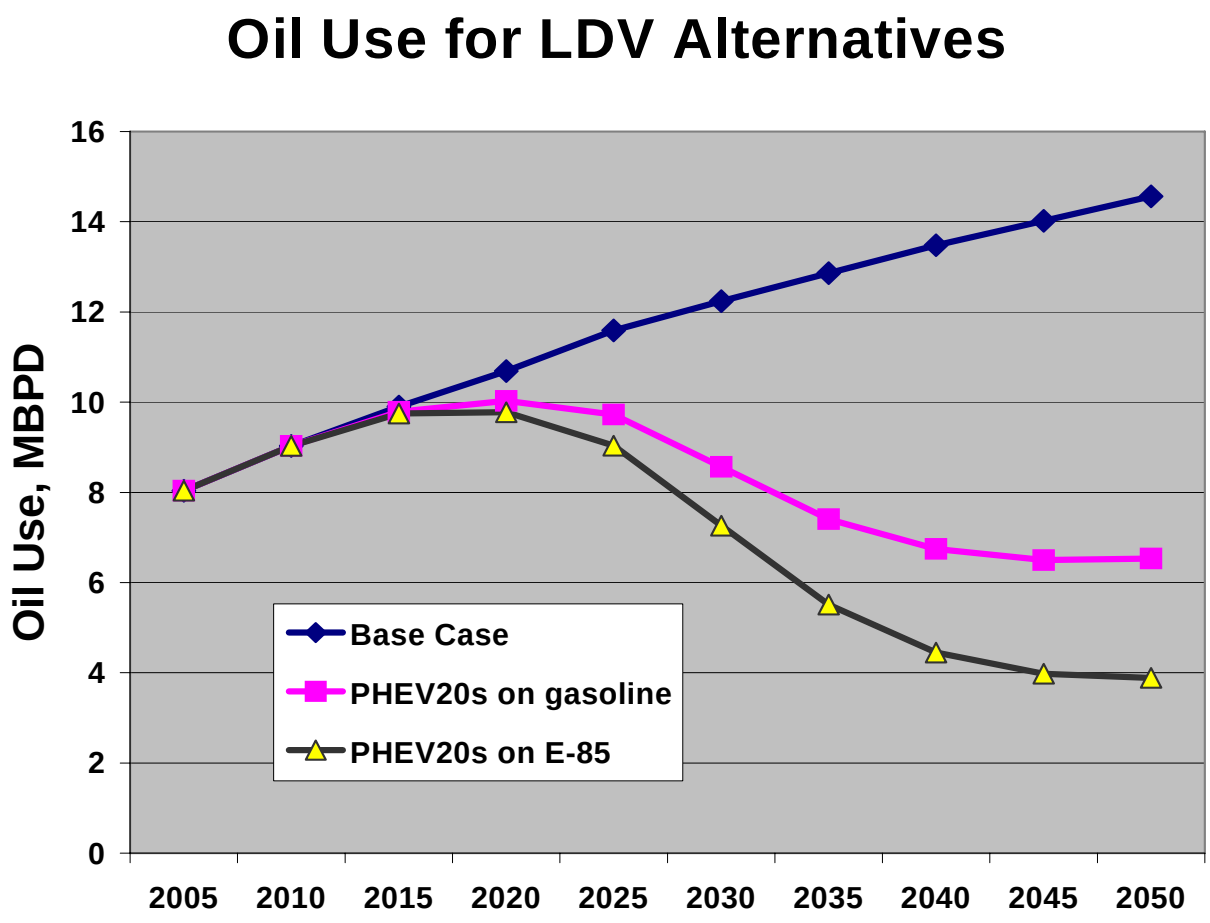
PHEVs can cut gasoline use drastically……..

Vehicle	Annual gasoline use, gallons
CV	**523**
HEV	**378**
PHEV20	**219**
PHEV60	**83**

Source: EPRI

and even out the daily demand curve (assuming most charging is off-peak).

And the effect is magnified if renewable fuels are used.

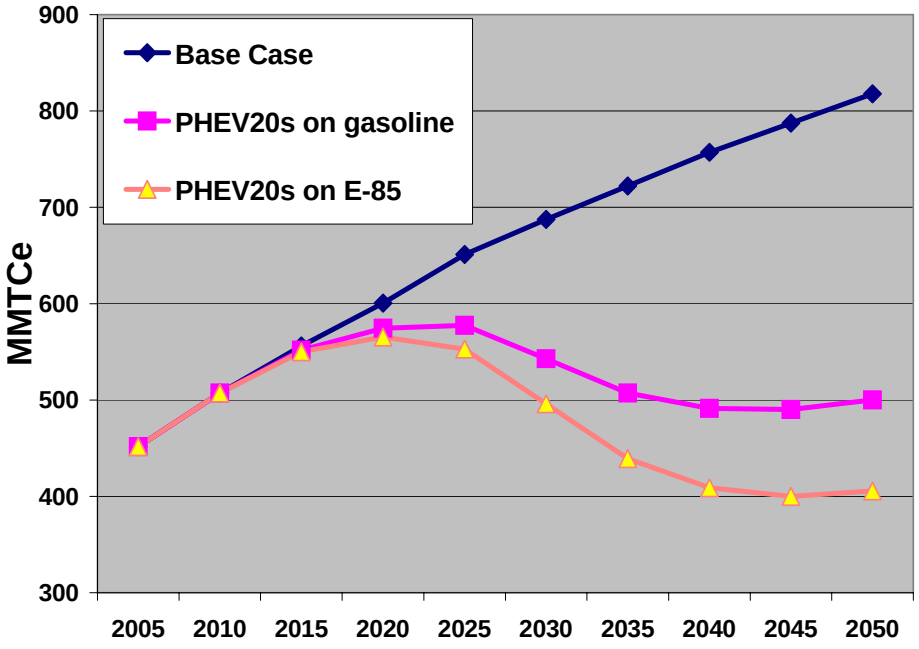


Source: Margaret Singh, ANL, VISION runs

PHEVs can yield strong GHG emission benefits if *the charging electricity is not a high GHG emitter.*

Scenario example: PHEV20s, U.S. electric mix

Carbon Emissions for LDV Alternatives



Source: Margaret Singh, ANL, VISION runs

Vehicle example: PHEV60

For a PHEV60 recharged with electricity from natural gas combined cycle powerplants:

- *58% reduction versus CV*
- *42% reduction versus HEV*

Source: EPRI

A fleet of PHEVs could act like an emergency oil reserve, especially if a fast charge infrastructure were in place.

- **In an oil emergency, “refilling” with electricity every 20 to 30 miles might not seem so onerous….especially with fast charge infrastructure.**
- **Even with limited utility, a fleet of PHEVs would make more (of a limited supply of) gasoline available to conventional vehicles.**

PHEVs can substantially reduce most criteria emissions in urban areas; overall effects, though, depend on the electricity source.

WHEN THE PHEV IS OPERATING ELECTRICALLY:

- **VOC and CO: greater than 90% emissions reductions (on a "per vehicle" basis) everywhere, with all electricity sources**
- **NO_X: large reductions in urban areas, but coal-based electricity increases total emissions**
- **PM_{10}: moderate reduction in urban areas; when coal is involved, *total* emissions increase substantially**
- **SO_X: large emissions increase everywhere, except when natural gas is the electricity source**

Source: GREET1.7, MY2005 mid-size passenger cars, emissions estimated for CY2010

Providing vehicle-to-grid (V2G) service improves PHEV viability, could allow increased use of windpower.

- **V2G allows PHEVs to provide planning, operating, regulation reserves….which are valuable to the utility**
- **Windpower development is hampered by inability to provide full planning and reserves (in relation to windpower capacity) because of its intermittency**
- **NREL analysis of 50% market penetration of PHEVs in 2050:**
  - PHEV20s yield small (30 GW) windpower increase
  - PHEV60s yield large (326 GW) windpower increase
  - Baseline = 220 GW

Key assumption: 50% of PHEV fleet is plugged in at any time

In their use of renewable electricity, PHEVs are much more efficient than FCVs

- FCV "Plug to Motor"
  - Electrolyzer **75%**
  - Compression **90%**
    (to 10,000 psi)
  - Fuel cell system **50%**

  (over the EPA cycle)

  0.75*0.9*0.5 = 0.34

  34% efficiency

- PHEV "Plug to Motor"
  - Charger/ battery in **80%**
  - Battery out **90%**

  0.8*0.9 = 0.72

  72% efficiency

But PHEVs have major *hurdles to overcome before commercialization.*

- Battery lifetime and cost are crucial hurdles **– their operating environment (big charge swings) is much more difficult than in HEVs**
- Vehicle costs are very high **even in comparison to HEVs**
- Will low electricity prices be available? **Even with off-peak charging, will utilities adopt time-of-day pricing? And eventually new plants will have to be built, with electricity prices at baseload levels.**

But Fuel Cell Vehicles have similar or worse hurdles….and they are the "holy grail"!

- On board hydrogen storage **– costs, weight, volume**
- Fuel cell system costs **– esp. membranes, precious metals**
- Hydrogen production and delivery costs
- Major "chicken and egg" issues **– dedicated vehicles and infrastructure must be built simultaneously**

Concluding message:

Applying the technological optimism needed to support a hydrogen fuel cell future to grid-connected hybrids makes PHEVs look like a pretty viable option.