Plug-in Hybrid Electric Vehicles

Presentation of NRC Report Results

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Hydrogen Technical Advisory Committee

February 23, 2010

COMMITTEE ON ASSESSMENT OF RESOURCE NEEDS FOR FUEL CELL AND HYDROGEN TECHNOLOGIES

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PHEV Study Considerations

- Supplement to Hydrogen report
- Examines PHEVs on same basis
- PHEVs like HFCVs need large subsidies to transition to cost effectiveness
- PHEV infrastructure easier to transition than HFCVs, but greater driver behavior changes required (did not study)

Hydrogen Fuel Cell Report

- Completed in 2008
- Analyzed costs & CO2/oil impacts of HFCVs at maximum practical penetration rate
- Also analyzed impacts of biofuels and high efficiency vehicles on CO2/oil
- Did not consider PHEVs or EVs

PHEV Study

- Review the current and projected technology status and costs of PHEVs
- Consider factors affecting how rapidly PHEVs could enter the marketplace
- Determine a maximum practical penetration rate for PHEVs
- Estimate PHEV impacts on oil and CO_2

Major Findings

- PHEVs are likely to remain expensive without a breakthrough in battery technology.
- PHEVs have the potential to reduce fuel consumption and emissions of CO_2 significantly.
- HEVs have similar, but somewhat less, potential than PHEVs
- PHEV-40s are unlikely to achieve cost-effectiveness before 2040, PHEV-10s may get there before 2030. Achieving DOE costs goals could make PHEVs cost completive in 10- 15 years.
- The U.S. could have tens of millions of PHEVs on the road in several decades. but that would require tens or hundreds of billions in subsidies.
- No major problems are likely to be encountered for several decades in supplying the power to charge PHEVs, as long as most vehicles are charged at night.

Batteries are key question

- Need acceptable cost for reasonable range, durability, and safety
- Looked at 10 and 40 mile midsize cars
- Battery packs with 2 and 8 kWh
  - Start of life, not after degradation
  - 200 Wh/mile
  - 50% State of Charge range

PHEV Battery Pack Costs

- Battery pack cost now $625 to 875/kWh*
- Probable cost in 2030 $500/kWh
- Optimistic cost in 2030 $360/kWh

* These costs are based on the nameplate size of the battery pack. The report also lists costs on a useable energy basis, which initially at least is about half the battery capacity. Current costs are for batteries to be installed in vehicles starting in 2010, which were ordered at least 2 years ago.

Current Cost Estimates Compared

- $700-1500/kWh (McKinsey Report)
- $1000/kWh (Carnegie Mellon University)
- $800-1000/kWh (Pesaran et al)
- $500-1000/kWh (NRC: America's Energy Future report)
- $875/kWh (probable) NRC PHEV Report
- $625/kWh (optimistic) NRC PHEV Report
- $560/kWh (DOE, adjusted to same basis)
- $500/kWh (ZEV report for California)

Future Cost Estimates Compared

- $600/kWh (Anderman)
- $400-560/kWh in 2020 (NRC PHEV)
- $420/kWh in 2015 (McKinsey)
- $350/kWh (Nelson)
- $168-280/kWh by 2014 (DOE goals adj.)

DOE Battery Goals

- *Battery pack cost.*
  - PHEV-10: (3.4 kWh available energy at end of life)
    $500/kWh or $1,700 battery cost achieved in 2012
    vs. $1,000/kWh today
  - PHEV-40: (11.6 kWh available energy at end of life)
    $300/kWh or $3,400 battery cost achieved in 2014
- *Battery life.*
  - PHEV-10: 10+ years by 2012 vs. 3+ years today
  - PHEV-40: 10+ years by 2014

Vehicle Costs

PHEV-40

- Total Pack cost now $14,000
- Total PHEV cost increment over current conventional (non-hybrid) car: $18,000
- PHEV cost increment in 2030: $11,000

PHEV-10

- Total Pack cost now $3,300
- Total PHEV cost increment over current conventional (non-hybrid) car $6,300
- PHEV cost increment in 2030: $4,100

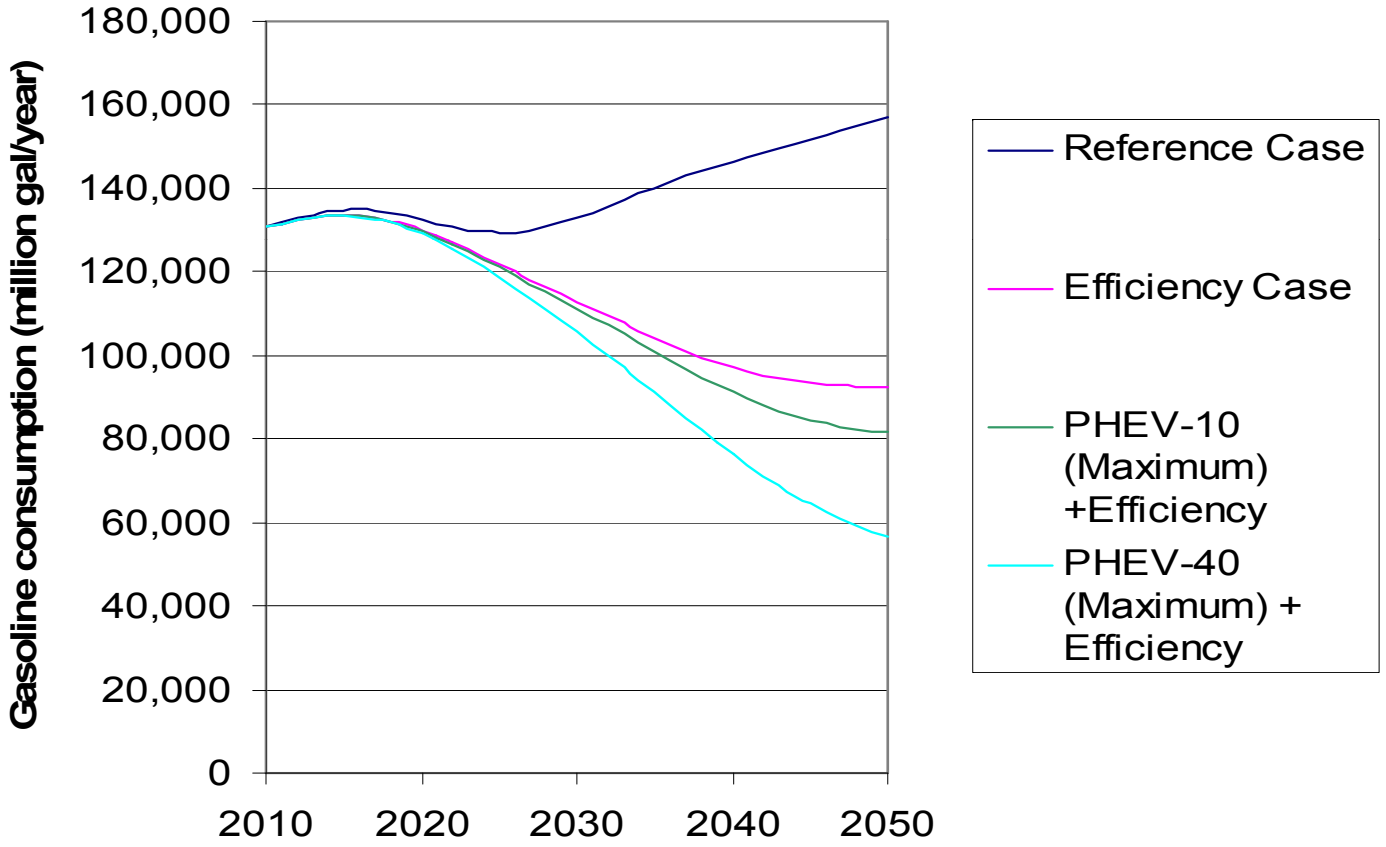
Electric Infrastructure

- No serious problems with capacity to charge PHEVs
- May need smart meters with TOU billing and other incentives to charge off-peak
- Infrastructure costs for home hookups, distribution upgrades, public charging stations

Scenarios

- Used same reference case and reference vehicles as in hydrogen report
- Market penetration projections
  - Maximum Practical (with optimistic technical development estimates): 4 million PHEVs in 2020 and 40 million in 2030
  - Probable (with probable technical development): 1.8 million PHEVs in 2020 and 13 million in 2030

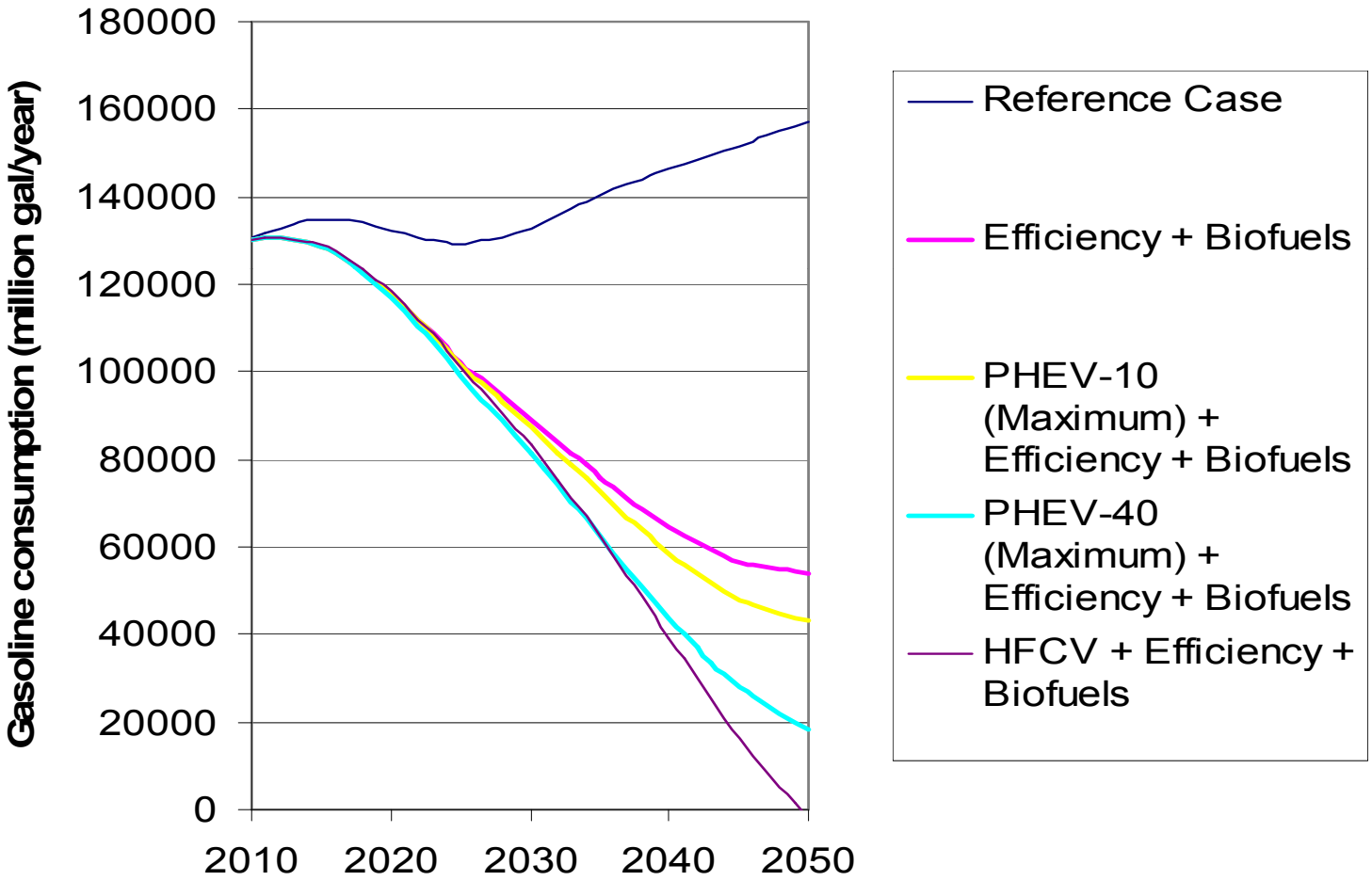
PHEV Fuel Savings Relative to HEVs



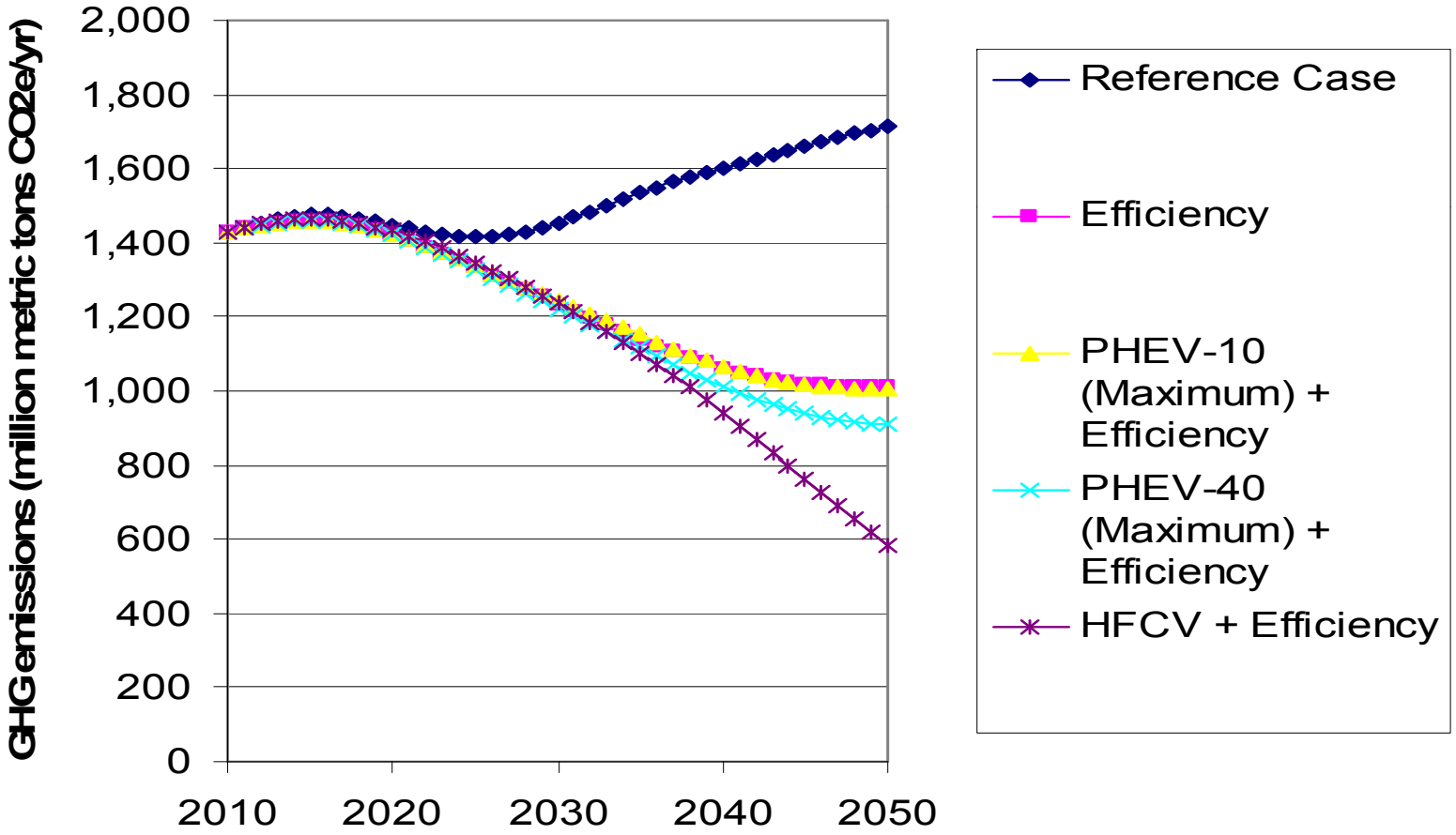
PHEV Fuel Savings

- Large fuel savings relative to reference vehicle
- PHEV-10 yields very small savings relative to HEVs until after 2025
- PHEV-40 yields significant savings relative to HEVs after 2030

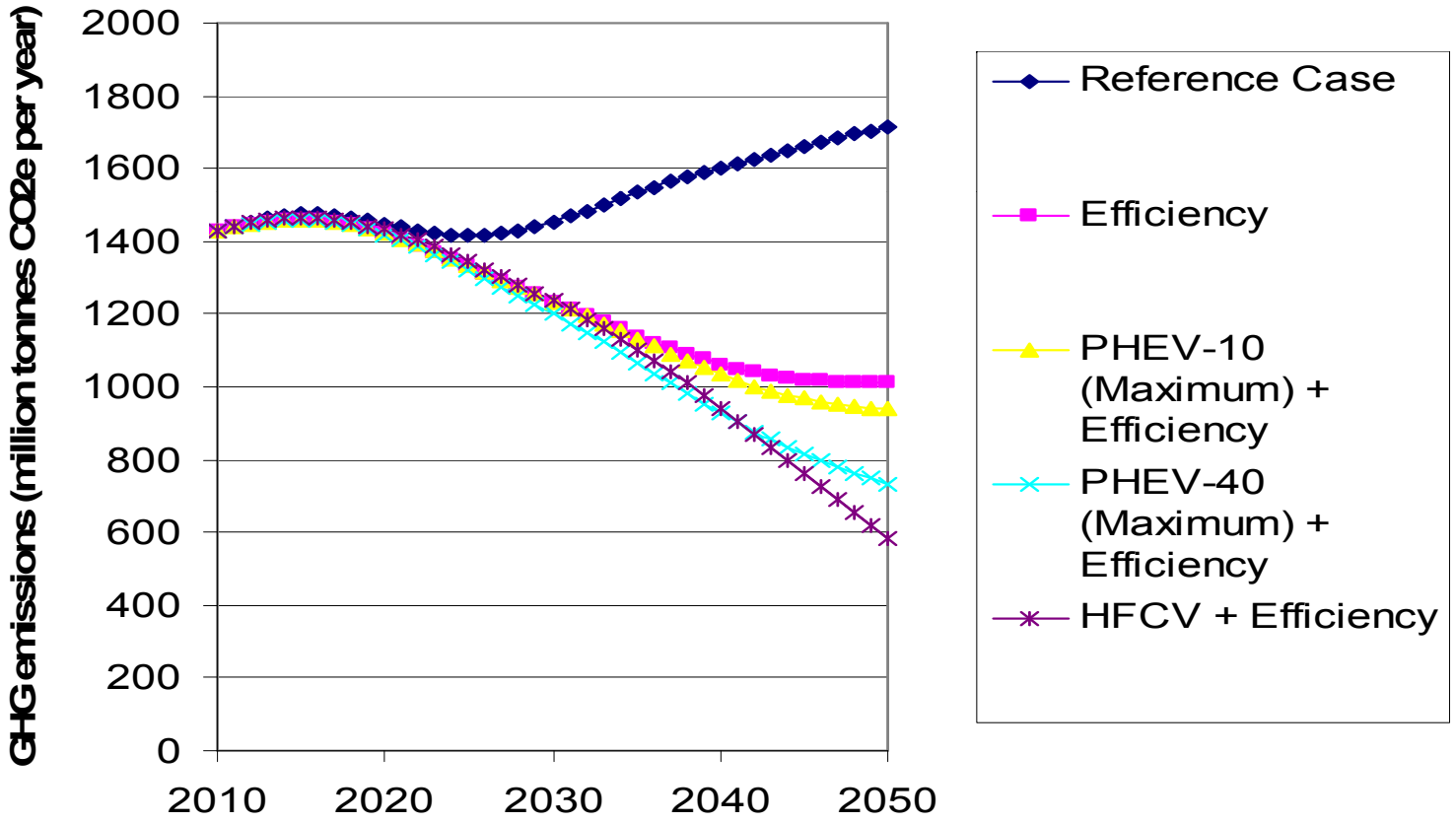
Portfolio Fuel Savings



GHG Emissions with a BAU Electric Grid



GHG Emissions with a De-carbonized Electric Grid



Transition Costs

- Function of vehicle costs, driving costs and number of vehicles
- Breakeven when PHEV fleet fuel savings equal new vehicle subsidies
- Results sensitive to vehicle costs and oil price

Transition Cost continued

	PHEV	DOE[e]	High Oil Price[f]	PHEV-10	30/70 PHEV-40/PHEV-10 Mix	
	Maximum Practical	Maximum Practical	Maximum Practical	Maximum Practical	Maximum Practical	Probable
Breakeven year[b]	2040	2025	2025	2028	2032	2034
Cumulative cash net flow[c] until the breakeven year	$408 billion	$40 billion	$100 billion	$33 billion	$94 billion	$47 billion
Cumulative vehicle retail price difference[d] until the breakeven year	$1,639 billion	-	-	$133	$363 billion	$179 billion
Number of PHEVs at breakeven year (millions)	132	18	28	24	48	20

[a] Does not include infrastructure costs for home rewiring, distribution system upgrades, and public charging stations which might average over $1000 per vehicle.

[b] Year when annual buydown subsidies equals fuel cost savings for fleet.

[c] Subsidies for new PHEVs minus fleet fuel savings.

[d] Cost of PHEVs minus the cost of Reference Case cars.

[e] Technology progress meets DOE goal ($300/kWh) for the PHEV-40 in 2020.

[f] Oil at twice base case, or $160/bbl in 2030 for the PHEV-40.

Conclusions

- **Lithium-ion battery technology has been developing rapidly, especially at the cell level, but costs are still high, and the potential for dramatic reductions appears limited.**
- **Costs to a vehicle manufacturer for a PHEV-40 built in 2010 are likely to be about $18,000 more than an equivalent conventional vehicle, including a $14,000 battery pack. The incremental cost of a PHEV-10 would be about $6,300, including a $3,300 battery pack.**
- **PHEV-40s are unlikely to achieve cost-effectiveness before 2040 at gasoline prices below $4.00 per gallon, but PHEV-10s may get there before 2030. Presently unpredictable battery breakthroughs may accelerate these schedules.**
- **At the maximum practical rate, as many as 40 million PHEVs could be on the road by 2030, but various factors are likely to keep the number lower. A more plausible rate would result in 13 million PHEVs by 2030.**

Conclusions continued

- **PHEVs will have little impact on oil consumption before 2030 because there will not be enough of them in the fleet. More substantial reductions could be achieved by 2050. PHEV-10s will reduce oil consumption only slightly more than can be achieved by HEVs.**
- **PHEV-10s will emit less carbon dioxide than nonhybrid vehicles, but show little advantage over HEVs after accounting for emissions from the electric power generation.**
- **No major problems are likely to be encountered for several decades in supplying the power to charge PHEVs, as long as most vehicles are charged at night.**
- **A portfolio approach to research, development, demonstration, and, perhaps, market transition support is essential.**

PHEV Fuel Savings