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Sandia National Laboratories

# Parametric Analysis of Technology and Policy Tradeoffs for Conventional and Electric Light-Duty Vehicles

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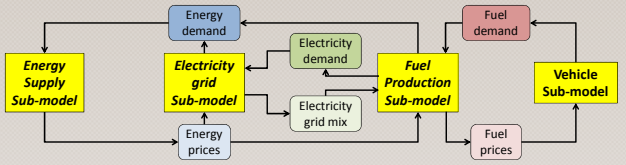
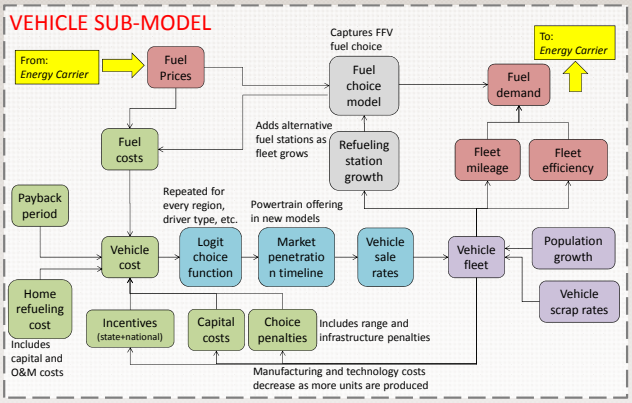
## OBJECTIVES

- Capture the changes to the Light Duty Vehicle (LDV) fleet through 2050 and its dynamic, economic relationship to fuels and energy sources
- Other performers/models are hypothetical scenario-focused
  - Reference set of input values often with optimistic and pessimistic perturbations
- The Transportation Pathways Model does more than just hypothetical scenarios; **parametric analyses** allow for:
  - Tradeoffs between concepts such as technology and market incentives
  - Sensitivity analyses of market, technology and model uncertainty
- Model the **dynamics and competition** in the transportation sector using **regional-level** feedback loops from vehicle use to energy source

## SYSTEM DYNAMICS MODEL




## VEHICLE SUB-MODEL




## MODEL SEGMENTATION

**Fleet Segmentation**

**Powertrain**

| | |
|---|---|
| SI | E85 FFV |
| SI Hybrid | E85 FFV Hybrid |
| SI PHEV10 | E85 FFV PHEV10 |
| SI PHEV40 | E85 FFV PHEV40 |
| CI | BEV150 |
| CI Hybrid | $H_2$ Fuel cell |
| CI PHEV10 | |
| CI PHEV40 | |

**Housing type**
- Single family home
- Other

**VMT Segmentation**

**State**
48 CONUS + Washington, DC

**Density**
Urban
Suburban
Rural

**Size**
Compact
Midsize
Small SUV
Large SUV
Pickup

**Age**
0-46 years

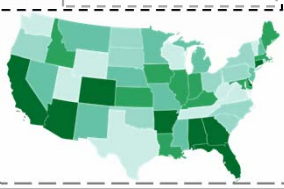
**Driver Intensity**
High
Medium
Low

*Geography*
*Vehicle*
*Demographics*

**Fuels**
Gasoline
Diesel
Biodiesel
Ethanol
Electricity
Hydrogen

**Energy Sources**
Petroleum
Natural Gas
Coal
Biomass
Solar/Wind

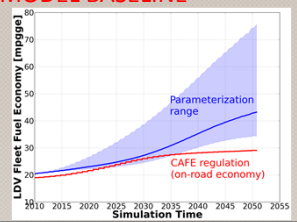
**State-level Variations**
- Vehicles
- Driver demographics
- Fuels
- Energy supply curves (as appropriate)
- Policies and incentives

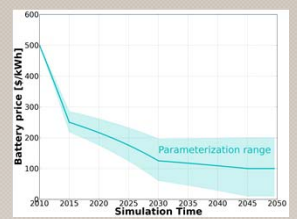


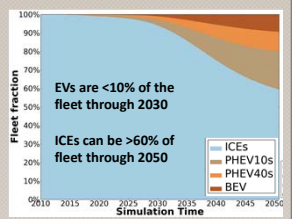
## CONCLUSIONS

- ICEs still dominate the fleet for next 30-40 years
- ICE efficiency improvements beyond CAFE guidelines are the most direct path to meeting GHG emissions targets
  - Even if EVs have deep penetration in the fleet, the PHEVs still rely heavily on combustion technology
  - Aggressive GHG reduction targets cannot otherwise be met without imposing a significant carbon tax, cleaning up the electricity grid sources and/or removing carbon from the fuel
- Obama's electric vehicle target is feasible, but greater EV adoption could occur with if consumers considered lifetime ownership costs

## MODEL BASELINE



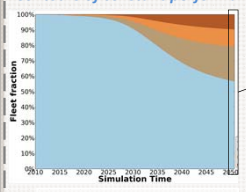



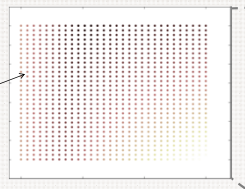

## APPROACH

### FOCUSED PARAMETRIC STUDIES

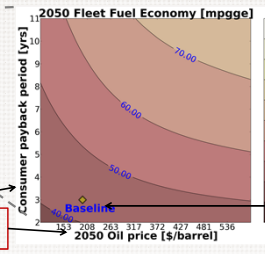
*Contours of constant performance indicate how performance targets can be achieved*




*Parameter space is sampled 1000 times to explore tradeoffs*



*Tradeoff between technology investment and market incentives*



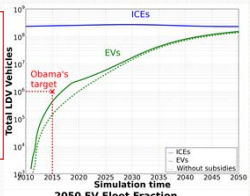

*Baseline value denoted by yellow diamond*

## ANALYSIS

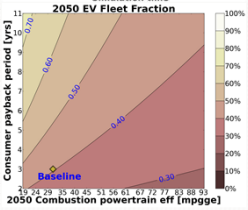
### INCREASING ELECTRIC VEHICLE MARKET SHARE

*"With more research and incentives, we can break our dependence on oil with biofuels, and become the first country to have a* ***million electric vehicles on the road by 2015****."*
President Barack Obama, 2011 State of the Union Address

"Baseline" scenario projects missing Obama's goal, but there is significant uncertainty in such small percentages



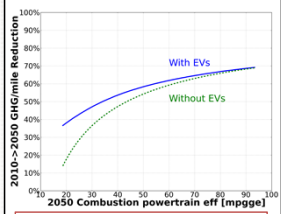

Extending the consumer perceived payback period alone to 10 years can dramatically increase the number of EVs




Improving ICE efficiency does not dramatically harm EV adoption rates because PHEVs benefit as well

**Are they a worthy means to an end?**

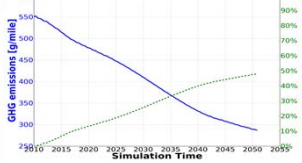
***By turning EVs on of off in the model, we can evaluate their contribution to other metrics***

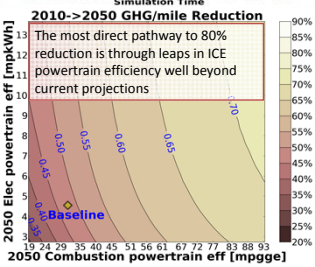



EVs can have a noteworthy impact on GHG/mile reduction, depending on IC efficiency, assuming natural gas displaces some coal from the mix

### MEETING A GHG REDUCTION TARGET OF 80% BELOW 1990 LEVELS

Baseline GHG emissions/mile is projected to decrease 50% from 2010 values by 2050 *(Absolute GHG emissions are heavily dependent on fleet growth assumptions, so we normalize by fleet mileage)*



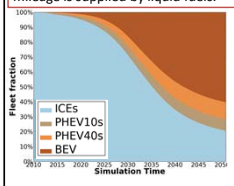




The most direct pathway to 80% reduction is through leaps in ICE powertrain efficiency well beyond current projections

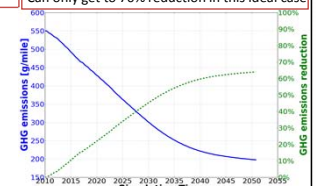
**Could an ideal EV world meet GHG reduction targets without extensive ICE powertrain improvements?**

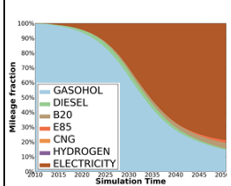
***Ideal conditions: 1) NG displacement of coal 2) Free batteries 3) 9+ year payback period 4) No range or recharging penalties 5) High vehicle turnover rate***

20% ICEs in the fleet and 20% of the mileage is supplied by liquid fuels.




Can only get to 70% reduction in this ideal case




**To achieve aggressive 80% GHG reduction targets without a leap in ICE efficiency must:**
- Use extreme policy measures to discourage GHGs
- Charge EVs using zero-carbon sources (solar or wind)
- Remove carbon from the fuel

U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

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