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ParaChoice

Parametric Transportation Pathways Analysis

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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OVERVIEW

Timeline
- Start date: FY14 Q4
- End date: End of FY2015
- Percent complete: 0%

Budget
- FY14 funding: in processing
- FY14 Expenditures: $0
- As of April 15, 2014

Barriers
- Risk aversion
- Infrastructure
- Computational simulation models
- Constant advances in technology

Partners
- Interactions / Collaborations:
  - Ford: Real World Driving Cycles
  - GE: CNG home compressors
  - Westport: NG HD engines

Project was **not** reviewed in previous Merit Reviews

ParaChoice Relevance/Objective: parametric analysis across factors that influence the vehicle, fuel, & infrastructure mix

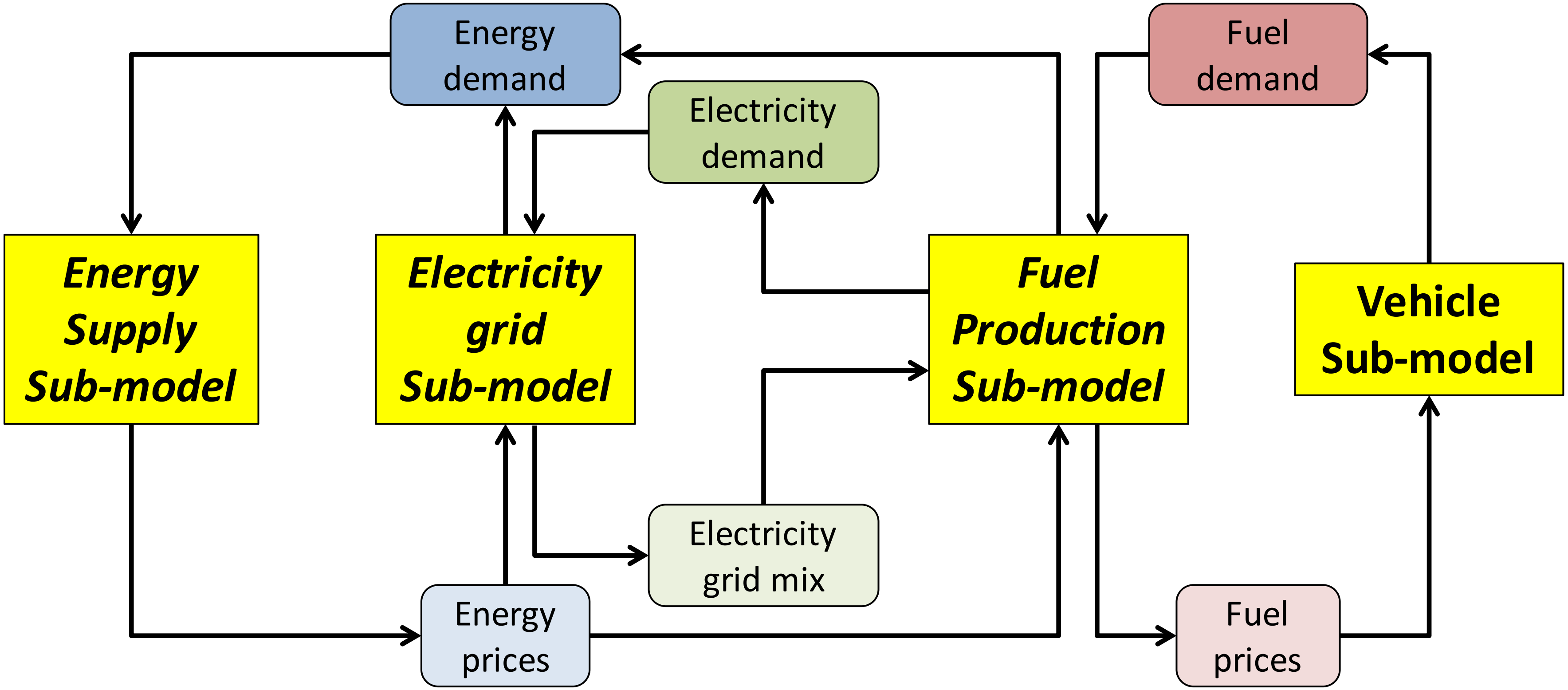
- *Objective*: ParaChoice captures the **changes to the Light Duty Vehicle (LDV) stock through 2050** and its dynamic, economic relationship to fuels and energy sources

- *Uniqueness*: The model occupies an **system-level analysis layer with input from other OVT models** to explore the uncertainty and trade space (with 10,000s of model runs) that is not accessible in individual scenario-focused studies

- *Approach*: Model the **dynamics and competition** among LDV powertrains and fuels using **regional-level** feedback loops from vehicle use to energy source
  - Technologies are allowed to flourish or fail in the marketplace

- *Targets*: By conducting parametric analyses, we can identify:
  - The set of conditions that must be true to reach performance goals
  - Sensitivities and tradeoffs between technology investments, market incentives, and modeling uncertainty

Modeling Approach: The high-level model diagram depicts the feedback loop of energy supply<-->energy carrier<-->vehicle



Modeling Approach: The model has many segments to capture the different niches of LDV consumers

Vehicle Stock Segmentation

Powertrain

SI
SI Hybrid
SI PHEV10
SI PHEV40
CI
CI Hybrid
CI PHEV10
CI PHEV40
E85 FFV
E85 FFV Hybrid
E85 FFV PHEV10
E85 FFV PHEV40
BEV75
BEV100
BEV150
BEV225
CNG
CNG Hybrid
CNG Bi-fuel

Housing type

- Single family home without NG
- Single family home with NG
- 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
CNG

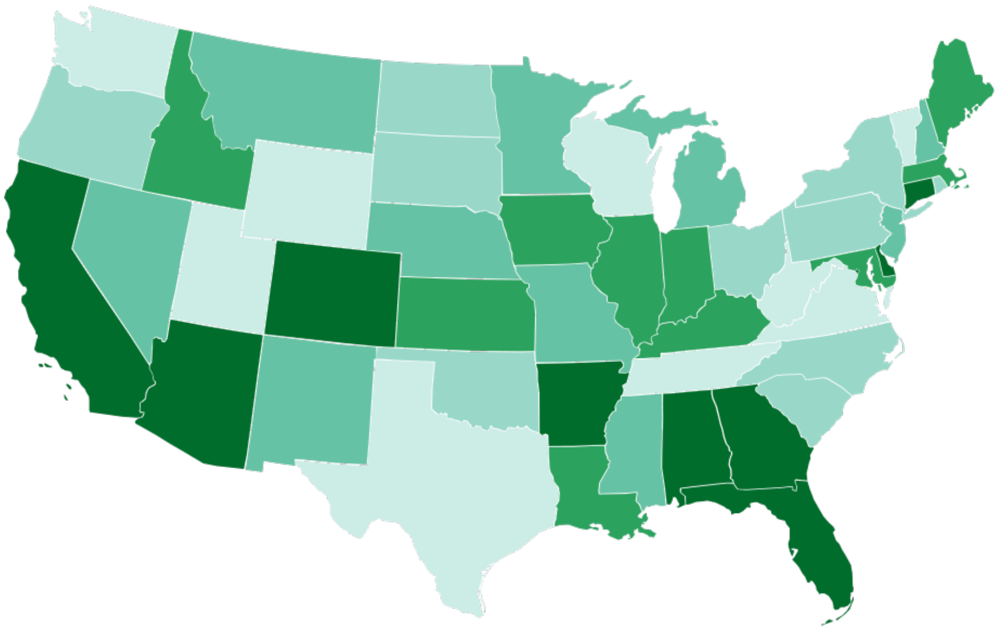
Energy Sources

Petroleum
Natural Gas
Coal
Biomass
Solar/Wind

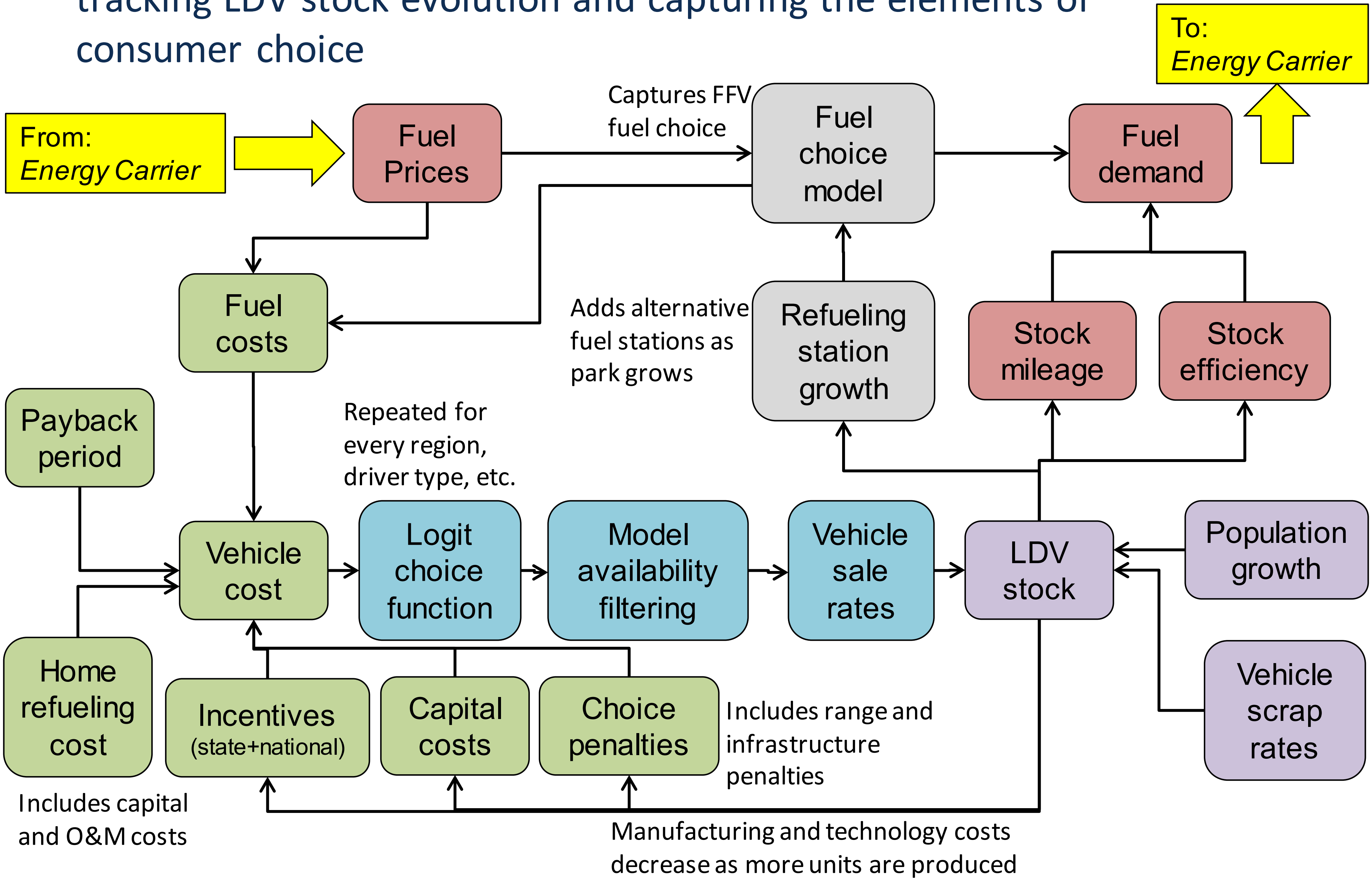
Modeling Approach: Energy supplies, fuels, and vehicle mixes vary by state

State-level Variations

- Vehicles
  - Numbers, sizes, drive-train mixes
- Driver demographics
  - VMT intensity, urban-suburban-rural divisions, single-family home rates
- Fuels
  - Costs, electricity mix, taxes & fees, alternative fuel infrastructure
- Energy supply curves (as appropriate)
  - Biomass, natural gas
- Policy
  - Consumer subsidies and incentives



Modeling Approach: The vehicle sub-model is focused on tracking LDV stock evolution and capturing the elements of consumer choice



Modeling Approach: Model inputs are taken from published sources when possible, but many are parameterized

Energy sources

- Oil: Global price from EIA Annual Energy Outlook (2012)
- Coal: National price from EIA Annual Energy Outlook (2012)
- NG: Regional price from EIA Annual Energy Outlook (2012)
  - Also use differential prices for industrial, power, and residential uses
- Biomass: State supply curves from ORNL's Billion Ton Study
  - Price corrected to match current feedstock markets

Fuel conversion and distribution

- Conversion costs and GHG emissions derived from ANL GREET model
- RFS grain mandate is satisfied first, then cellulosic (but not enforced)
  - Gasohol blendstock allowed to rise from E10 to E15
- Ethanol can be transported from one region to another for cost or supply balance
- Electricity grid
  - State-based electricity mix, allowed to evolve according to population growth and energy costs
  - Intermittent and "always-on" sources assumed to supply base load first
  - Vehicles assumed to be supplied by marginal mix

Modeling Approach: Model inputs are taken from published sources when possible, but many are parameterized

Vehicle model

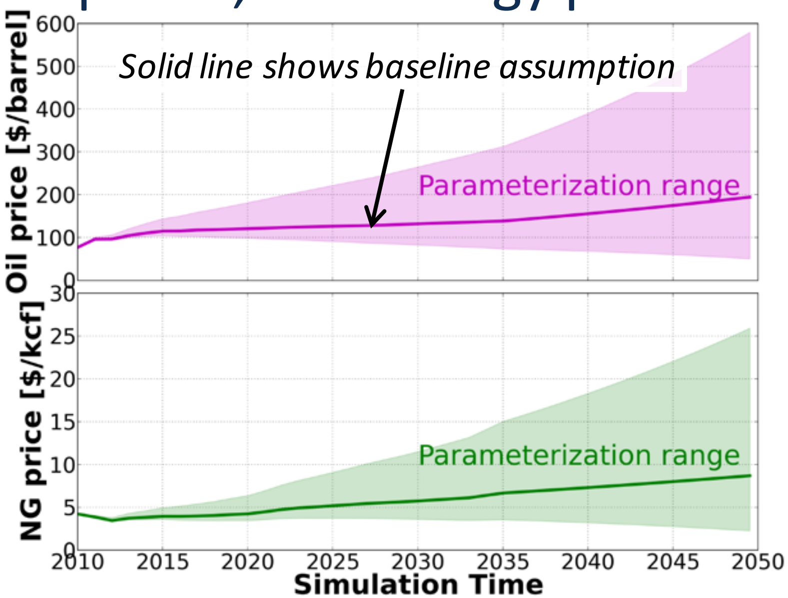
- Consumers do not change vehicle class (size)
- VMT varies by model segmentation, but does not change over time
- LDV stock growth rate is the same as population growth rate (per capita vehicles is constant)
- Consumers have baseline 3 year required payback period with no discounting
- Vehicle efficiency, cost, and battery capacity taken from ANL *Autonomie* model analysis
- CAFE requirements are satisfied
- Consumer choice model is nested, multinomial logit type (like MA3T)
  - Sale shares depend on amortized consumer *utility cost* = vehicle purchase price – subsidies + fuel operating costs + penalties (range and fuel availability)
- Bi-fuel vehicles (E85 FFVs, diesel vehicles, and CNG bi-fuel vehicle) dynamically choose fuel use rate breakdown using:

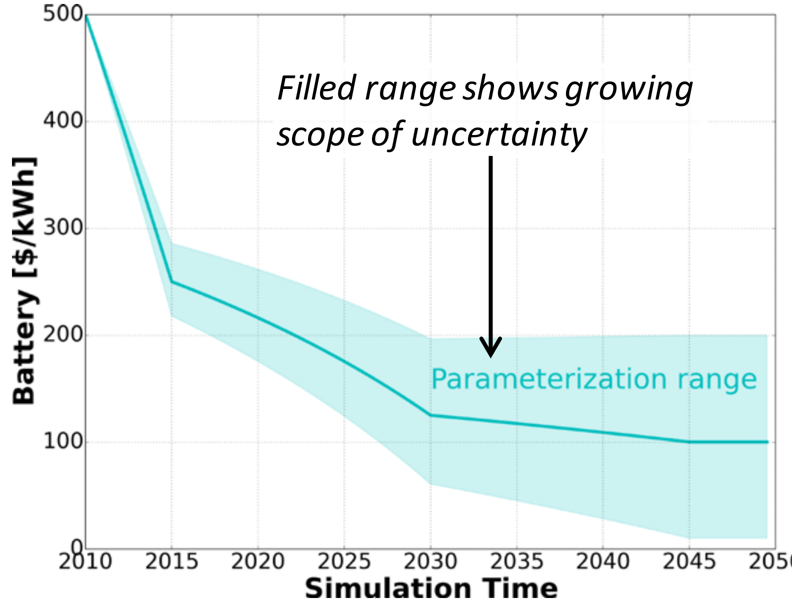
(Probability of visiting a station with CNG) * (Willing-to-pay price premium)

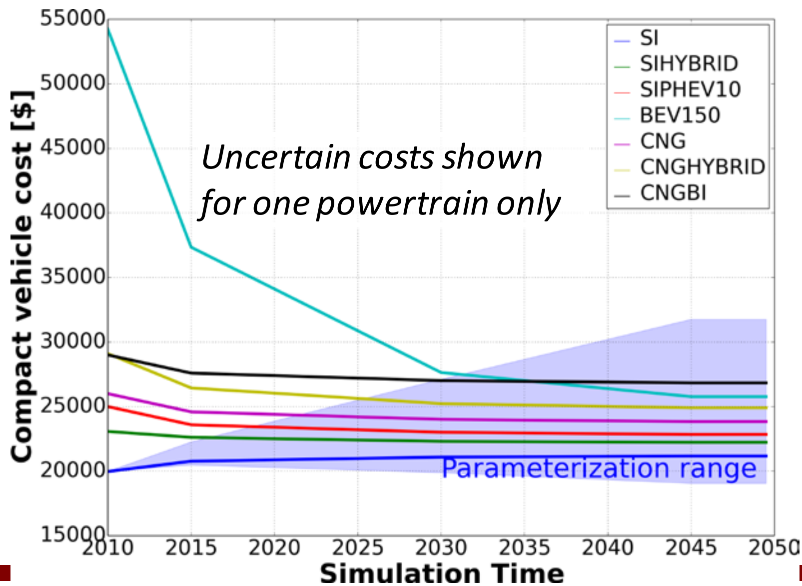
Changes as new pumps are added in response to vehicle sales

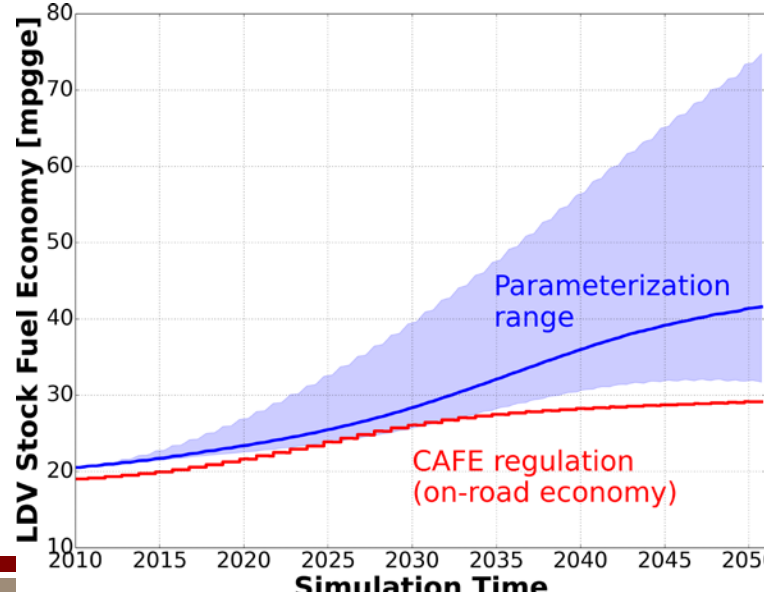
Responds to market conditions (price sensitivity is parameterized)

Parameterization helps account for uncertainty in commodity prices, technology performance, modeling assumptions, etc.

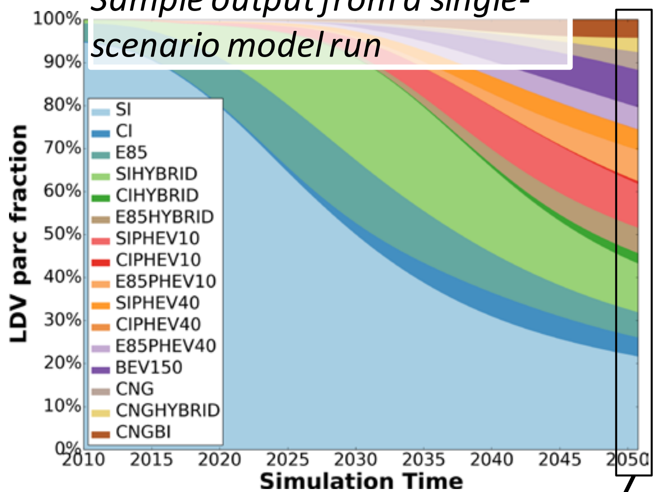




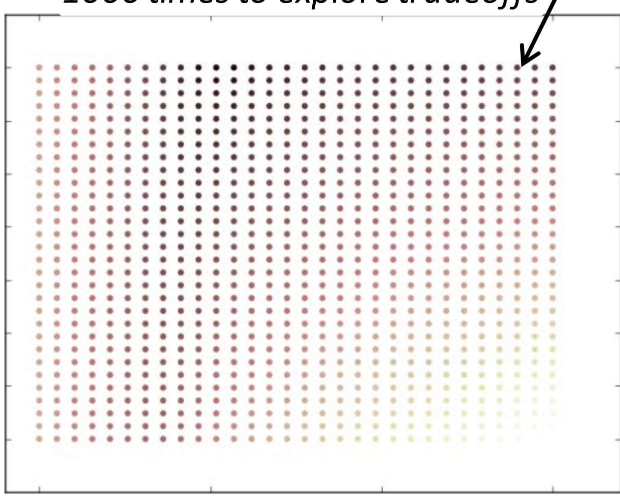


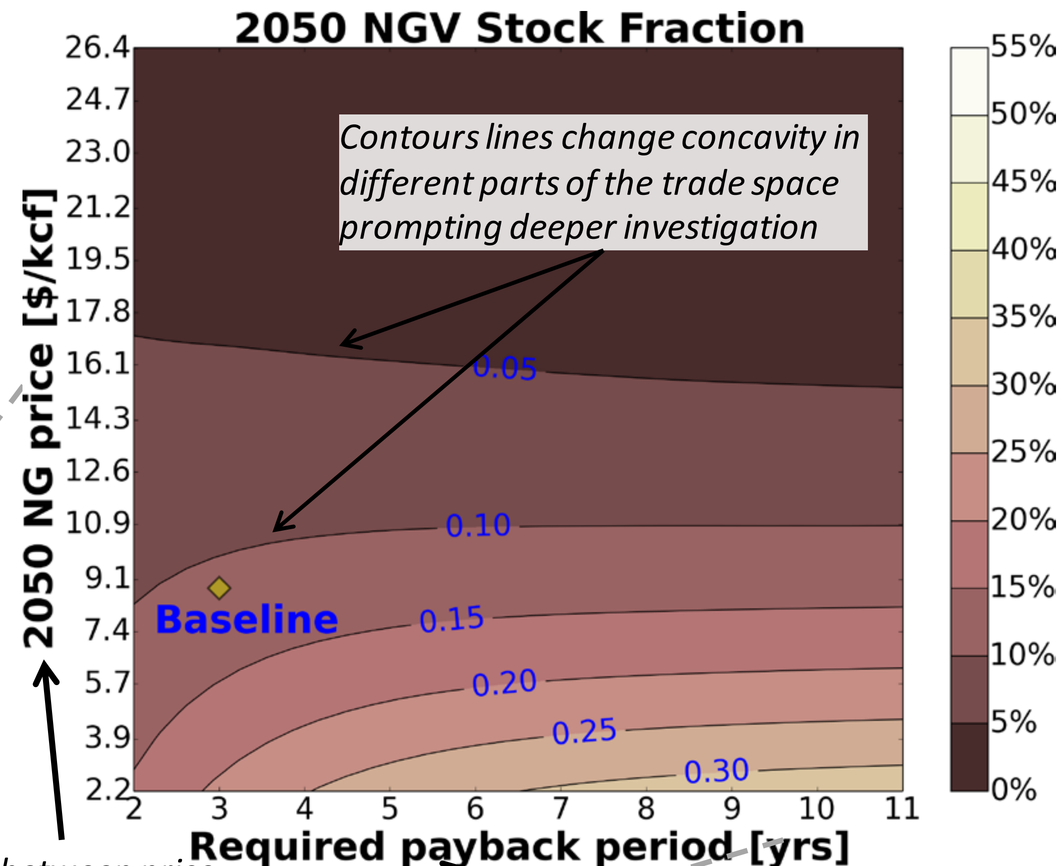


Example results: Parametric studies focus on one, two, and all parameter variations to explore the trade space



Parameter space is sampled 1000 times to explore tradeoffs





Tradeoff between price uncertainty and market incentives

Contour features reveal trade-space insights

Technical Accomplishments

Accomplishments listed derived from a variety of funding sources

- **Ongoing**: Comparison of modeling BEV limitations as economic "penalty" or a threshold of inconvenience
- **Funded by Vehicle Technologies *Fuels Program***: Peterson MB, Barter GE, Manley DK, West TH. *A parametric study of light-duty natural gas vehicle competitiveness in the United States through 2050*. Applied Energy 2014; *In Press*.
- Westbrook J, Barter GE, Manley DK, West TH. *A parametric analysis of future ethanol use in the light-duty transportation sector: Can the US meet its Renewable Fuel Standard goals without an enforcement mechanism?*. Energy Policy 2014;65 pp. 419-431.
- Barter GE, Reichmuth D, West TH, Manley DK. *The future adoption and benefit of electric vehicles: a parametric assessment*. SAE Int J Alt Power 2013;6(1).
- Barter GE, Reichmuth D, Westbrook J, Malczynski LA, West TH, Manley DK, Guzman KD, Edwards DM. *Parametric analysis of technology and policy tradeoffs for conventional and electric light-duty vehicles.* Energy Policy 2012;46 pp. 473-488.

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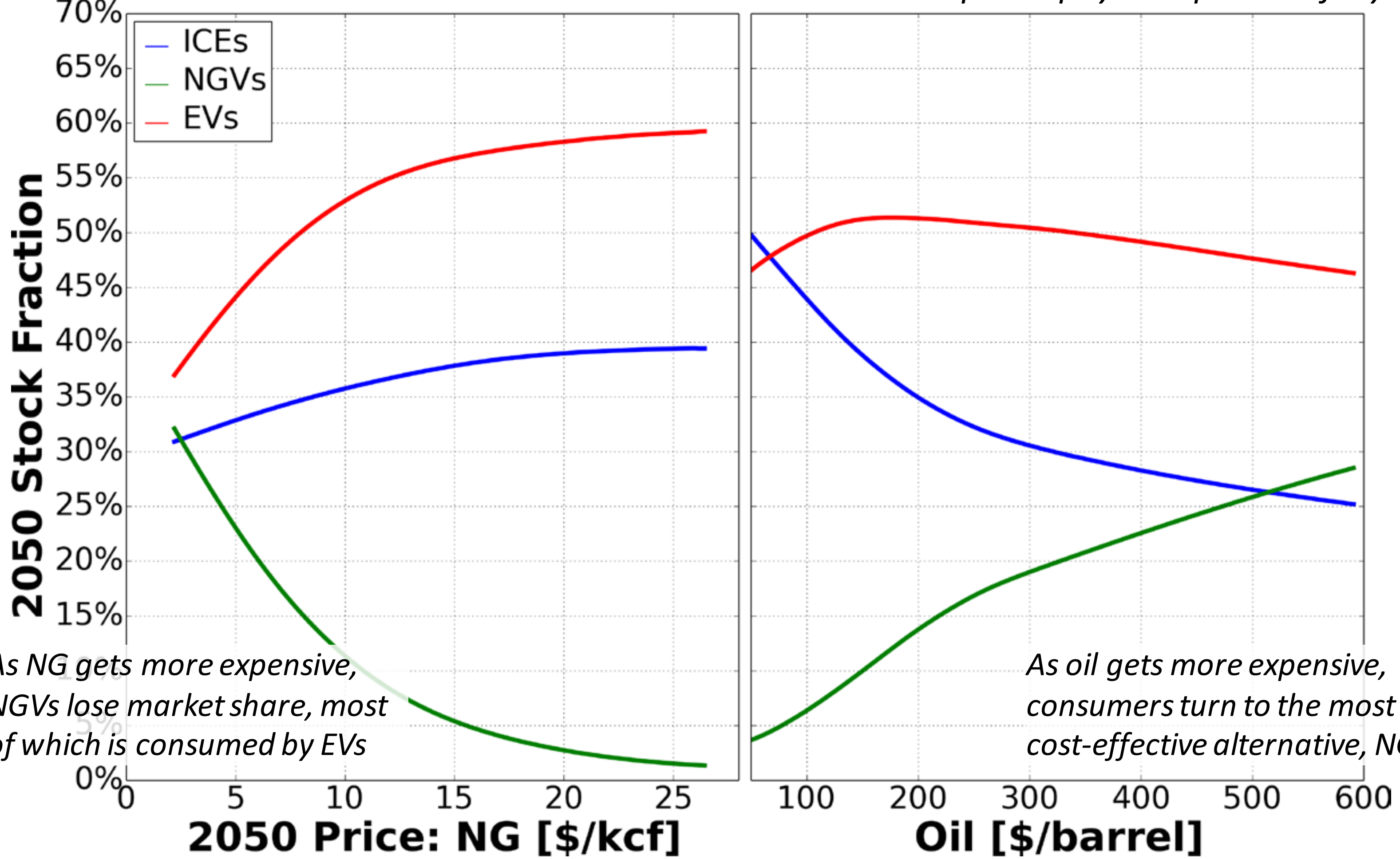
Example result from parametric study: NGVs can compete more with EVs than conventional powertrains, as both compete for high VMT drivers that offset high purchase costs with fuel cost savings

**Evaluated at required payback period of 9 years*



As NG gets more expensive, NGVs lose market share, most of which is consumed by EVs

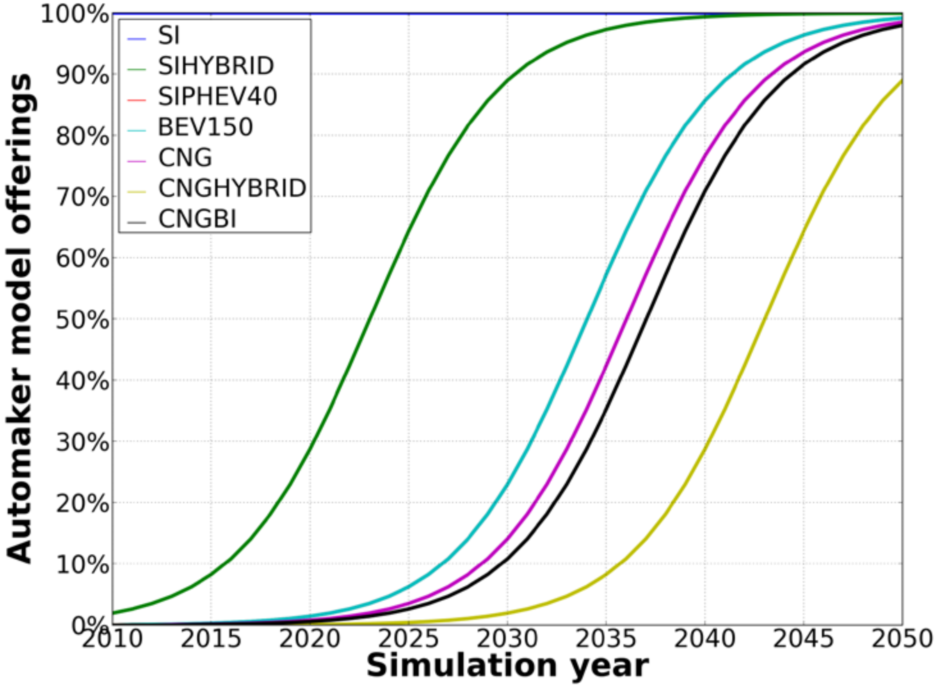
As oil gets more expensive, consumers turn to the most cost-effective alternative, NGVs

Proposed future work for FY14-FY15

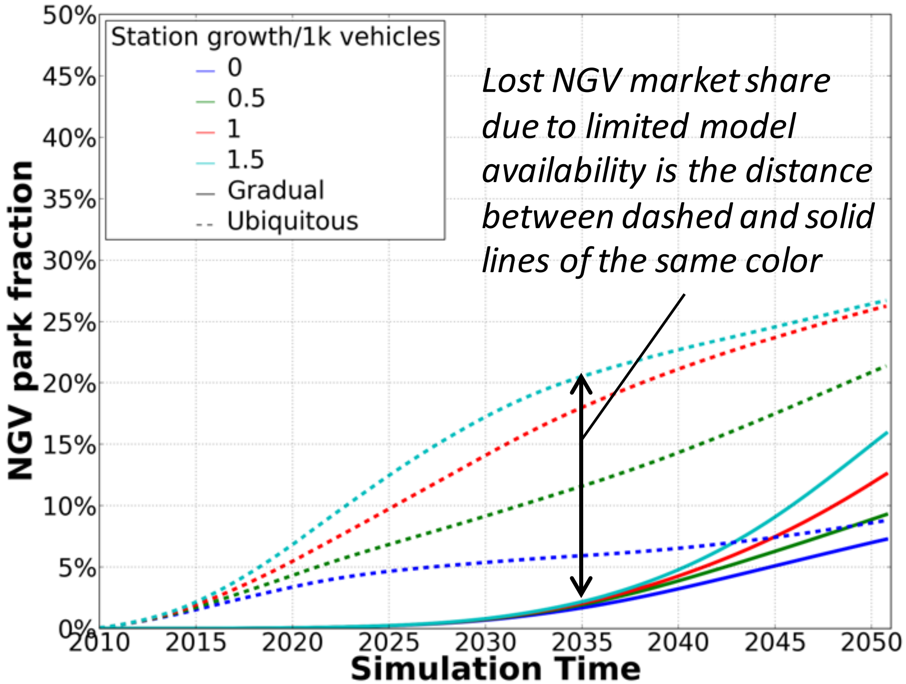
- **Model availability** – characterize decisions by OEMs to offer alternative powertrains in their vehicles
- **Transition technologies** – characterize conditions under which transition technology facilitates another future alternative
- Deliverables
  - Parametric assessments of these factors that influence technology adoption
  - Publications and conference presentations
  - Scenario comparison

Example – Influence of model availability on *Consumer Choice*

OEM growth curves



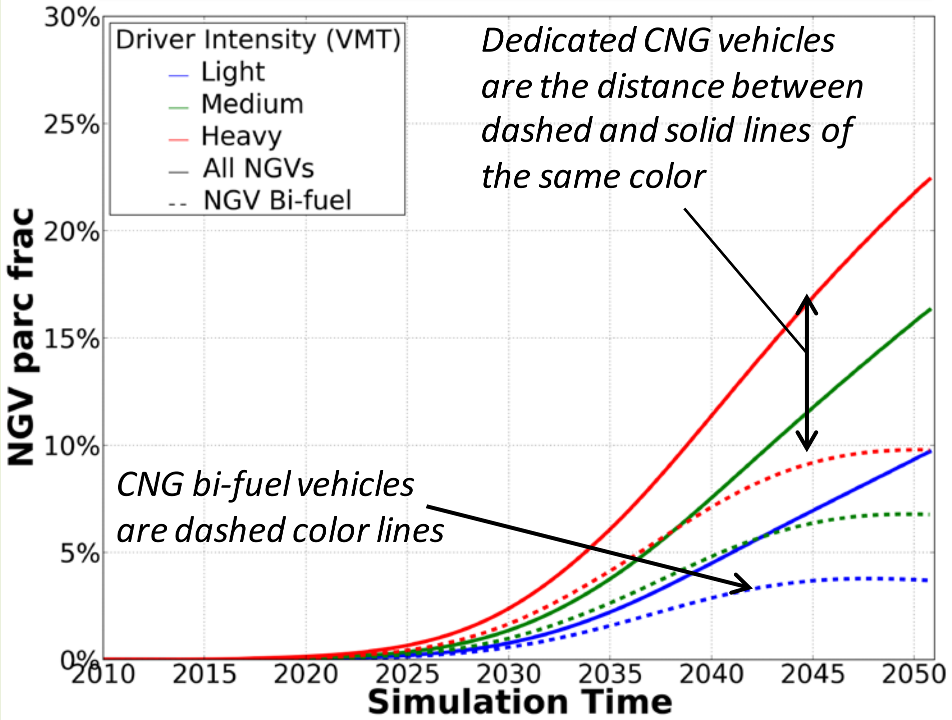
NGV fraction for various infrastructure growth rates, with and without OEM growth curves



- Consider powertrain availability curves based on historical offerings
- If OEMs offered NGV options for all models starting now, NGV stock fraction could be 10% within 10 years

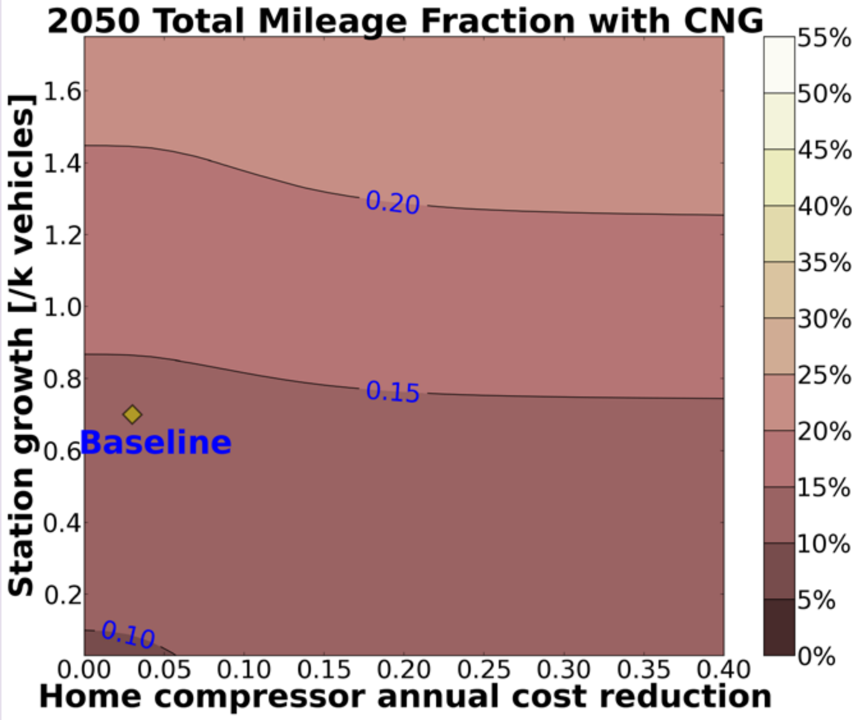
Examples – CNG bi-fuel with home compressors as *Transition Technologies*

CNG bi-fuel vehicles as a *Transition Technology*



CNG bi-fuels dominate NGVs until infrastructure build-out, then dedicated CNGs grow.

Comparison of value of public vs. home-based CNG refueling infrastructure



Greater gains in CNG mileage fraction occur across variations in station growth rates than home compressor cost reduction rate

Collaboration with other institutions

- No funding given to other institution on behalf of this work
- Technical critiques received from Ford Motor Company, General Electric, American Gas Association, and other conference engagements

Summary

- ParaChoice provides a parametric approach to vehicle choice modeling that includes feedback loops to fuel production and raw energy stocks.
- Parametric approach reveals the sets of conditions that must be true to reach performance goals and the tradeoffs present in the uncertainty space.
- Analyses with this model have led to peer-reviewed publications focusing on NGV competitiveness, EV competitiveness, and the Renewable Fuel Standard.
- Future work with Vehicle Technologies' funds will focus on the impact of model availability and transition technologies on powertrain success.