ParaChoice Model

Project ID# van019

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2019 DOE
Vehicle Technologies
Office
Annual Merit Review

PRESENTED BY

Camron Proctor

Team members: Steven Wiryadinata, Timothy Berg, Julie Fruetel (PM)

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Overview

Timeline

- Start date: FY14
- End date: Project continuation determined annually
- Percent Complete: FY19 50%*

Budget

- Total FY 2019 Project Funding:
  - DOE Share: $200K
  - Contractor Share: N/A
- Funding for FY 2017: $350k
- Funding for FY 2018: $200k

Barriers and Technical Targets

- Accelerate the development and adoption of sustainable transportation technologies by highlighting sensitivities and tradeoffs in the highly uncertain transportation sector.

Partners: Interactions/ Collaborations

- Argonne National Lab (ANL)
- National Renewable Energy Laboratory (NREL)
- Energetics
- Lawrence Berkeley National Lab (LBNL)
- University of California, Davis
- Nikola Motor Company
- Gillig Transit Bus Manufacturing

*As of 4/1/2019

Relevance & Objective

Lifetime Project Goal: Systems level analysis of the dynamics within the light-duty vehicle (LDV) and heavy-duty vehicle (HDV) fleets, fuels, infrastructure mix, and emissions

- Use parametric analysis to:
  - Identify trade spaces, tipping points & sensitivities
  - Understand & mitigate uncertainty introduced by data sources and assumptions

Project objective: Assess the evolving integration potential of LDV and HDV technologies, fuels, and infrastructure and their contributions to lowering emissions and petroleum consumption

This year:

- Build HDV capability
  - Update HDV model capability to handle Fuel Cell Electric, Battery Electric, and Plug-in Hybrid Electric Vehicles (FCEV, BEV, PHEV)
  - Conduct a gaps analysis to identify and assess data sources and quality to answer current analysis questions and provide context and planning for future work
- Leverage existing LDV capability
  - Participate in Benefits Analysis (BaSce)

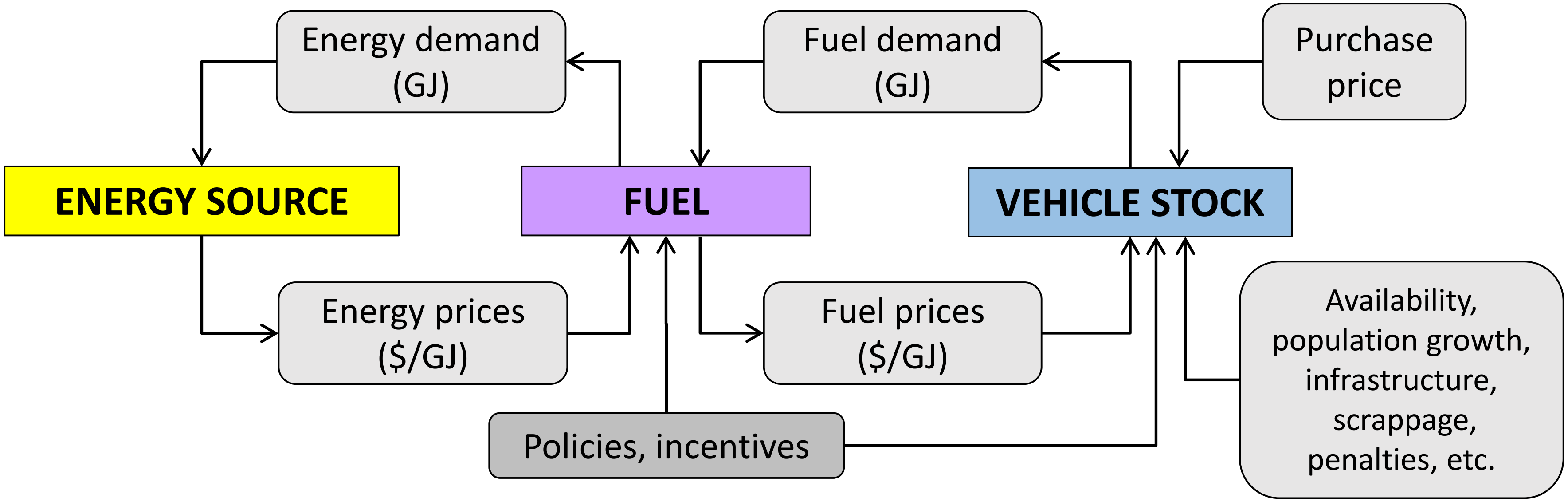
ParaChoice provides decision & investment guidance despite significant uncertainty

Milestones

Date	Milestone & Go/No-Go	Status
FY19 Q1	**Milestone**: Identify and provide list of new personnel to execute project.	Complete
FY19 Q2	**Milestone**: Update Project plan; submit new AOP; attend Analysis Summit	Complete
FY19 Q3	**Milestone**: Presentation to HQ on the gaps analysis	On Track
FY19 Q4	**Milestone**: Presentation to HQ to demonstrate ParaChoice HDV on example vehicle for multiple AEV powertrains	On Track
FY19 Q4	**Go/No-Go Decision**: Provide to HQ a list of powertrains & associated data sources for HDV analysis	On Track

Current team did not form until after the FY started. New AOP was drafted and deliverables are now on track

Approach: ParaChoice – Underlying systems model between energy and LD or HD vehicles



Begins with today's energy, fuel, and vehicle stock and projects out to 2050

- At each time step, vehicles compete for share in the stock based on value to consumers and external factors such as policies

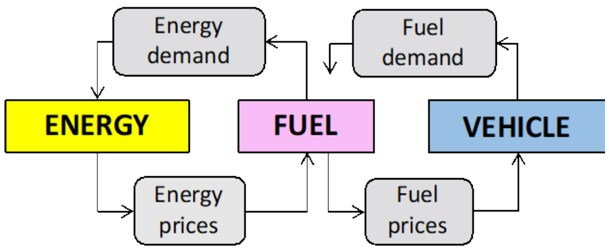
Variables change with time and demand

Variety of output options, including:

- Sales Fractions
- Vehicle Stock
- Emissions
- Fuel Consumption
- Trades & Sensitivities

Approach: ParaChoice segments vehicles, fuels, & population to understand competition between powertrains & market niches

Demographics | *Vehicle* | *Geography*



LDV Segmentation

Powertrain
20 Powertrains

Housing type
With or w/o access to charging/ fueling

Driver Intensity
Low, Med, or High

VMT Segmentation

Energy/Fuel Seg.

State
48 CONUS + Washington, DC

Density
Urban
Suburban
Rural

Size
5 Sizes

Age
0-46 years

HDV Segmentation

Powertrain
CI
NG (LNG, CNG)
FC
HE (CI, CNG)
PHE (CI)
BE

Refueling Type
Gas Station
Truck Stop
Private

Age
0-18 years

GVW
Class 7 & 8

Body Type
Tractor Trailer
Straight Truck
Bus

Vocation (Use)
Construction
Food
General Freight
Lease/ Finance
Manufacturing
Natural Resources
Services
Wholesale/Retail
Bus/Transportation

Fleet Size
1-9; 10-99; 100-999; 1,000+

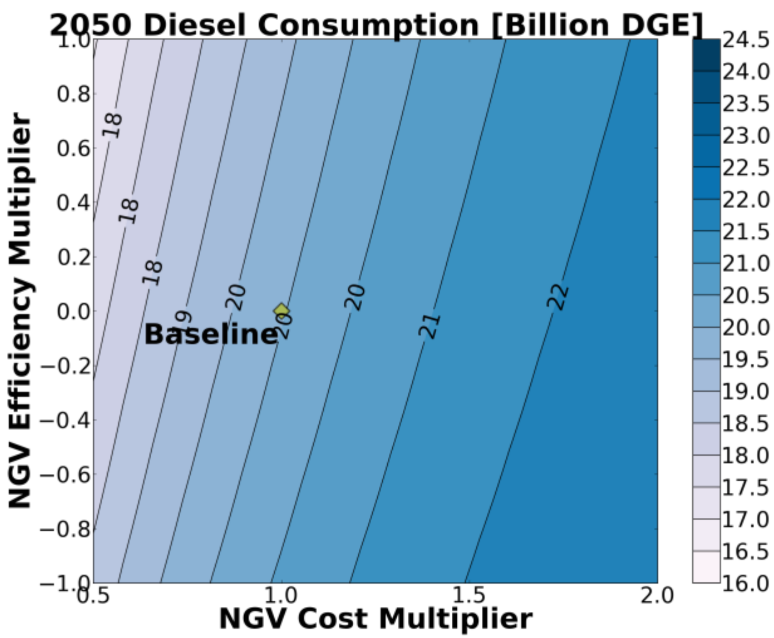
Service Radius
0-100; >100

State
48 CONUS + Washington, DC

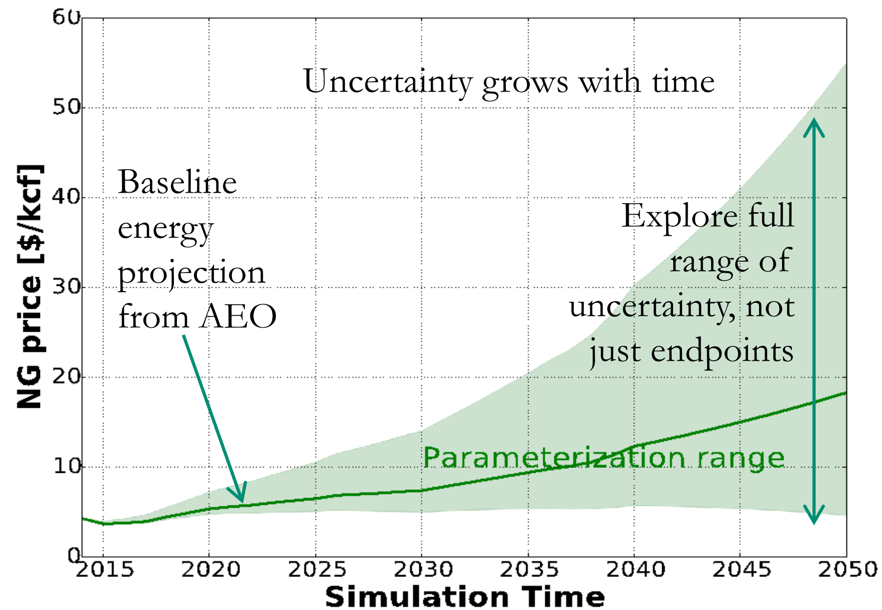
Approach: Use parameterization to understand and mitigate uncertainty introduced by data sources and assumptions

Parametric approach enables:

- Trade space analyses (vary 2 parameters)
- Sensitivity analyses (vary many parameters)

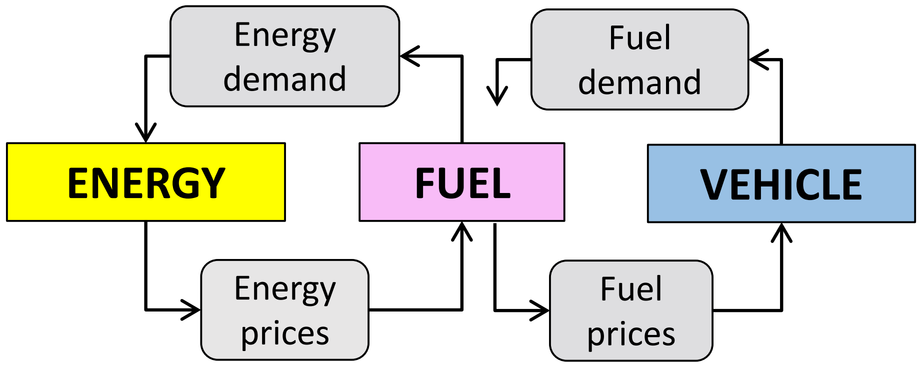


Example parameterization of natural gas prices with multiplier on AEO projection



Parameterization ranges are designed to explore plausible and 'what if' regimes, covering all bases

Approach: ParaChoice brings unique strengths to the Analysis Portfolio



Uniqueness from other DOE models:

ParaChoice is designed to explore uncertainty & trade spaces, easily allowing identification of tipping points & sensitivities

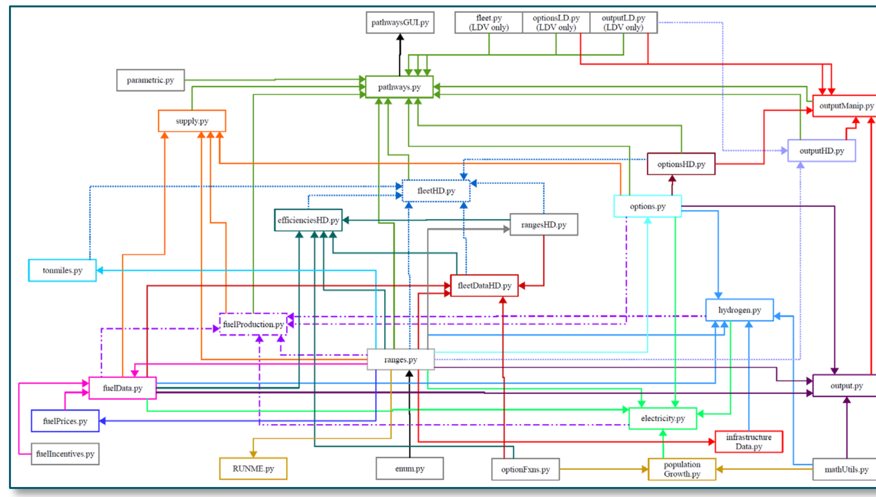
- Core simulation is a system-level analysis of the **dynamic, economic relationship** between energy, fuels, & vehicles with baseline values from trusted DOE sources
  - Technologies compete in the simulation, and are allowed to flourish or fail in the marketplace
- Simulation is run 1000s of times with varying inputs. This parametric analysis provides:
  - Perspectives in uncertain energy & technology futures
  - Sensitivities and tradeoffs between technology investments, market incentives, and modeling uncertainty
  - The set of conditions that must be true to reach performance goals

Accomplishments & Progress: Inheritance of legacy HDV code requires an intentional approach to capability development

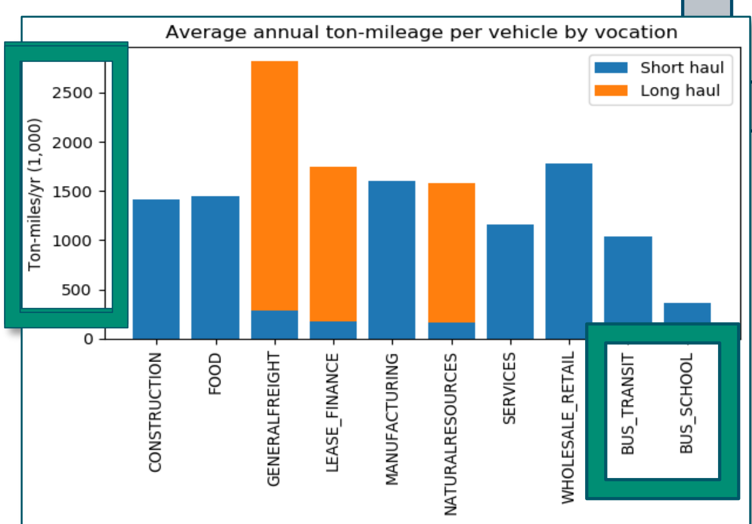
Review Code ✓

A rigorous review of the HDV code revealed opportunities for improvement and leveraging existing capabilities.

Document Code ✓



Update Code (in progress)



Input Data

Input updated data through gaps analysis, collaborations and market studies

Show Capability

Demonstrate HDV analysis capability based on defined deliverables

Accomplishments & Progress: Gaps analysis was a response to the recognition that the HDV space is complex and challenging

Engage deeply with new HDV material as an onboarding and planning exercise

Take a systems analysis approach to assessment of data availability

- Met internal needs of organizing and prioritizing effort
- Meets VTO need by highlighting opportunities for future work in this and other programs

Identify Analysis Questions (recurring)

Identify Data Needs (recurring)

Gather Data (in progress)

Perform Gaps Analysis

Data Needs	Model Parameter	Data Quality	Expected Analysis Impact	Analysis Questions	Oppor-tunities
Current & Historical Stock (Vehicle Counts)	Vehicles	4	5	Nearly All	Comparative Analysis
Current and Projected Model Availability	Market penetration	1	5	What is the adoption saturation given market availability	Projection models

Accomplishments & Progress: The gaps analysis will visualize the short-term and long-term needs of HDV ParaChoice

- The first version of gaps analysis is focused on approximately 100 sets of required data.
- Can be used to clearly articulate what analyses could be enabled, what impact we expect they will have, and make suggestions how to get data for the analysis.

Category	Assessment Criteria
Model needs	**What ParaChoice parameter is affected by this data?** Could the data act as a baseline set of values, or be contextualized along with other data?
Data availability	**Does a version of the data already exist in Parachoice with a known source?** If not, can we get it easily? Or is the data unknown?
Data quality	**If available, what is the quality of the data?** Is the data from a trusted source, an aggregate, a best guess, vetted DOE source, etc.?
Expected analysis impact	**Is the data expected to have a significant impact on the analysis** (rate 1-5)? This will be used to prioritize data gathering efforts. Could also be used to identify research areas unlikely to play out in future.
Analysis questions	**What analysis questions will having this data enable us to answer?**
Opportunities	**What opportunities does this data represent?** This could be research opportunities if the data does not exist, collaboration opportunities, or new research directions

The gaps analysis is an opportunity to systematically create a data informed extended development plan

Accomplishments & Progress: ParaChoice participation in the BaSce effort encourages interaction, collaboration and interdependence with other labs to meet VTO needs

BaSce evaluates prospective benefits of VTO R&D activities on the fuel efficiency of vehicles and reduction of petroleum use.

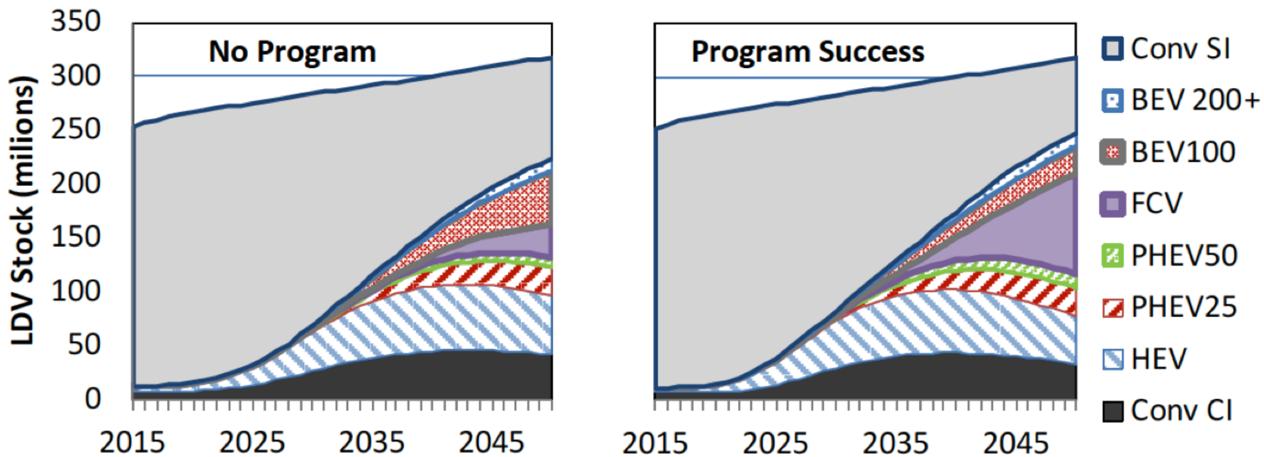


FIGURE B-5 LDV Stock by Powertrain Type for the No Program (left) and Program Success (right) Cases Projected by the ParaChoice Model

ParaChoice is an integrated part of the BaSce effort; receiving data from and providing data to other agencies models like:

- GREET
- Autonomie
- Vision

Stephens, T.S., A. Birky, and D, Gohlke. 2017. *Vehicle Technologies and Fuel Cell Technologies Office Research and Development Programs: Prospective Benefits Assessment Report for Fiscal Year 2018.* Argonne National Laboratory, Argonne, IL, report ANL/ESD-17/22, November,

Responses to 2017 AMR Reviewer Comments

Comments from FY17 AMR	Responses
The reviewer was specifically concerned about the inclusion of several "free" utility parameters (e.g., model availability and alternative specific constants) in the nested logistic regression (logit) model.	Added Data needs to Gaps analysis to support answering these questions at a future date.
The reviewer commented that the project has no university collaborators or technical critiques by academic researchers.	Re-engaged with UC Davis STEPS/ ITS Programs. Leveraging having 2 Alumni as team members
The reviewer noted that the research into which alternative technologies could gain market penetration in the heavy-duty sector could fill a current research gap.	Adding FCV, BEV, and PHEV to HDV model to better project market penetration in HDV space

Any proposed future work is subject to change based on funding levels.

Partnerships/Collaborations/Interactions

Recent

Argonne – Provides data for BaSce analysis. Provides data for powertrains, efficiency and costs

Nikola – Provide context on performance of their electric and fuel cell electric vehicles under development.

NREL – HDV Drive Cycle Data

Energetics, Lawrence Berkeley National Labs – Support as part of VTO analysis portfolio

UC Davis – STEPS symposium, renewed interactions with UC Davis including peer review of publications

Fuel Cells Technologies Office – Provides Joint Funding for this effort

Previous

Incorporation of real-world driving cycles in collaboration with:
Ford Motor Company, General Electric, American Gas Association

Model input and review from:
ANL, ORNL, NREL, Energetics

Technical critiques on modeling and analysis:
DOE, DOT

Workshop Organizing Committee:
Toyota, American Gas Association, DOE

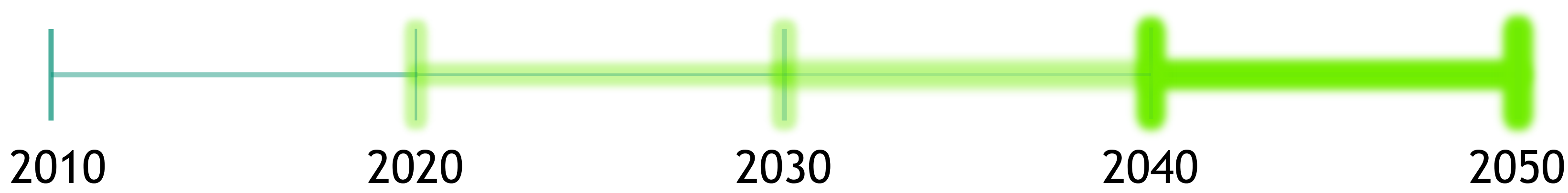
Remaining Challenges and Barriers

<u>Uncertainty in AFV Market</u>:

There are significant limitations in data availability for new powertrains/fuels infrastructure

Some vehicles/powertrains that we are interested in investigating are still in the prototype phase and have no practical real-world data

The transportation community is currently investing heavily in new materials, processes, energy pathways and general technology



Proposed Future Work- We will continue to develop the capabilities of ParaChoice in LDV & HDV

Ongoing

FY19 – [Q3 Milestone] Present Gaps analysis to VTO HQ. Highlight opportunities for new and expanding research.

FY19 – [Q4 Milestone] Demonstrate ParaChoice HDV projection capabilities on an example vehicle with multiple powertrain/fuel options

FY19 – Continue adding capabilities (E.G. Powertrains, Fuels, and Infrastructure) to ParaChoice HDV.

Planned

FY20 – Finish initial HDV updates of Powertrains, Fuels, and Infrastructure

FY20 – Participate in TCO working group

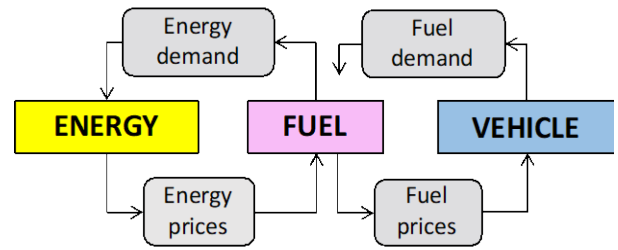
FY20 – Participate in BaSce LDV & HDV

Any proposed future work is subject to change based on funding levels.

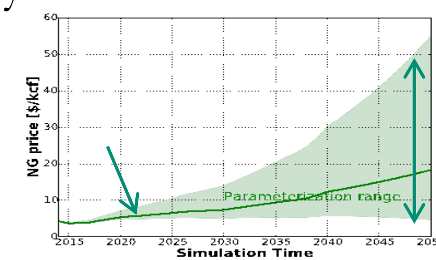
Summary

New ParaChoice team; deliverables are on track

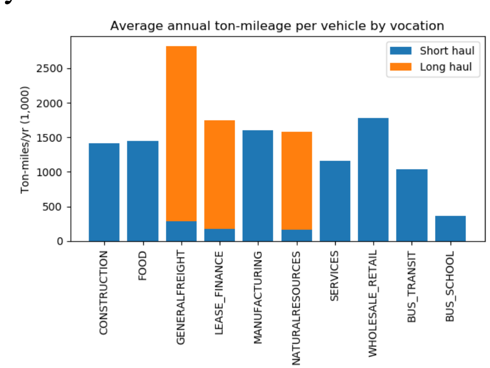
Approach
- Unique Parametric capabilities
- Update HDV ParaChoice
- Conduct thorough gaps analysis



Accomplishments
- Rigorous review and documentation of legacy code
- Updates to HDV functionality including new powertrains, body types and fuels
- Gaps analysis (Database and planning tool)



Collaborations
- Continued collaborations with analysis portfolio laboratories
- Engagement with industry at the cutting edge of technology development
- Reengagement with university partnerships



Future Work
- Finish Phase 1 of gaps analysis
- Participate in TCO & BaSce efforts

Technical Backup Slides

Approach: At every time step, simulation assesses generalized vehicle costs for each vehicle. Choice function assigns sales based on these costs and updates stock.

VEHICLE STOCK

Vehicle	Generalized Vehicle Cost		Percent of Sales
Conv. SI	$X /year		A %
FCEV	$Y /year		B %
PHEV40	$Z /year		C %
… And 17 more			

Given:
- Input attribute(s)
- Fixed set of 2+ output choices

Nested Multinomial Logit Function

Outputs:
- Probability distribution

Generalized Vehicle Cost

Upfront Costs Amortized Over "Required Payback Period"

- Purchase price
- One time incentives
- One time penalties *(Infrastructure penalty)*

Recurring Costs

- Fuel cost
- Annual incentives
- Annualized penalties *(Range penalty)*

An assessment of the current state of the HDV code. Input parameters for Powertrains are for data availability, quality, and importance.

Category	Input parameters	Powertrain													Source(s)
		CI	CIHybrid	CIST	CI HybridST	CNG	CNG Hybrid	CNGST	LNG	LNGST	FC	FCST	BE	BEST	
energy sources															
	supply of energy sources														EIA
	price of sources														EIA
	energy penalty to transport sources														
	criteria +GHG emissions for transporting fuel														
fuel production															
	sources needed to make end-use fuels (unit source/unit fuel)														GREET
	energy consumed by the production plant														GREET
	capital cost of production plant														
	OM cost of production plant														
	capacity of new production plant														
	life expectancy of production plant														
	number and capacity of existing plants														
	criteria +GHG emissions of production method														GREET
fuel at end-use															
	prices at pump														EIA
	fuel taxes														API
	fuel incentives														
	well to pump criteria +GHG emissions														GREET
	pump to wheel criteria +GHG emissions														GREET
	policies enforcing penetration of fuels														
	carbon price														
vehicle															
	existing stock														
	current and projected availability														
	purchase cost														
	OM cost														
	purchase incentives														
	operating life														
	annual distance travelled (ton-miles)														FHWA
	scrap rates														EPA
	used sales and purchases														
	fuel efficiency														EIA
refuel/recharge infrastructure															
	gas station pumping rate														
	station counts														adfc
	policies enforcing station growth														
population															
	population data														census
general															
	discount rate														IRS
	interest rate														IRS

Modeling Approach – Disaggregation by geography, vehicle type, demographics, fuel

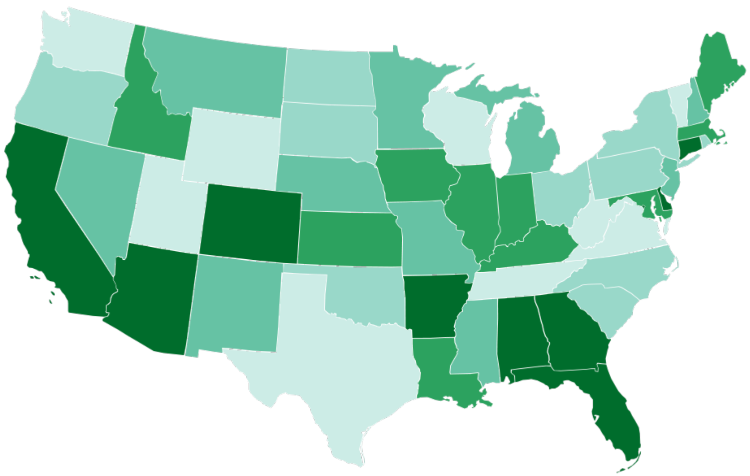
Vehicles
- Numbers, classes, drive-train mixes

Service demographics
- Ton-mileage

Fuels
- Costs, electricity mix, hydrogen production pathway, taxes & fees, alternative fuel infrastructure

Energy supply curves (as appropriate)
- Oil, coal, natural gas, renewable electricity

Policy
- Consumer subsidies and incentives



Modeling Approach – Model inputs are taken from published sources when possible, and many are parameterized

Energy sources

Oil: Global price EIA Annual Energy Outlook (2014)

Coal: National price EIA AEO (2014)

NG: Regional price EIA AEO (2014)

Biomass: State supply curves ORNL's Billion Ton Study

- Price corrected to match current feedstock markets

Fuel conversion and distribution

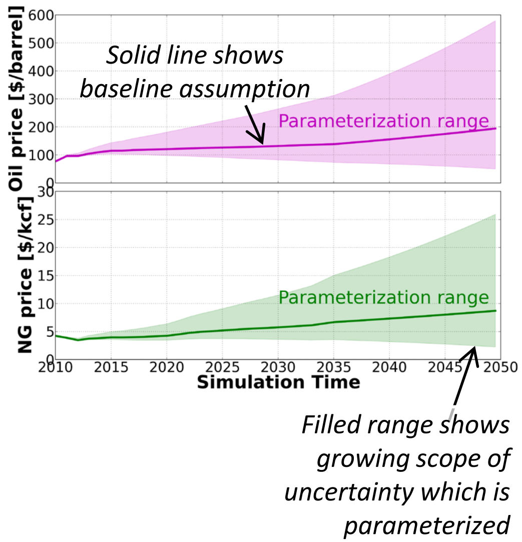
Conversion costs and GHG emissions derived from ANL GREET model

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

Hydrogen production

- Production cost based on least-cost pathway
- Production capacity allowed to evolve according to demand



Modeling Approach – Model inputs are taken from published sources when possible, and many are parameterized

Vehicle model

Consumers do not change vehicle class

Ton-miles varies by model segmentation, but does not change over time

Vehicles segmented by fleet sizes with increasing payback period (larger fleets can tolerate longer payment periods)

Vehicle efficiency, and cost taken from EIA, EPA-NHTSA, AFDC, NPC & ANL Autonomie 2017 prototype model analysis

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 (refuel time)