

ParaChoice Model



PRESENTED BY

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SAND2019-5313PE



Project ID# van019

Date: 6/13/2019

2019 DOE
Vehicle Technologies
Office
Annual Merit Review

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

3 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:

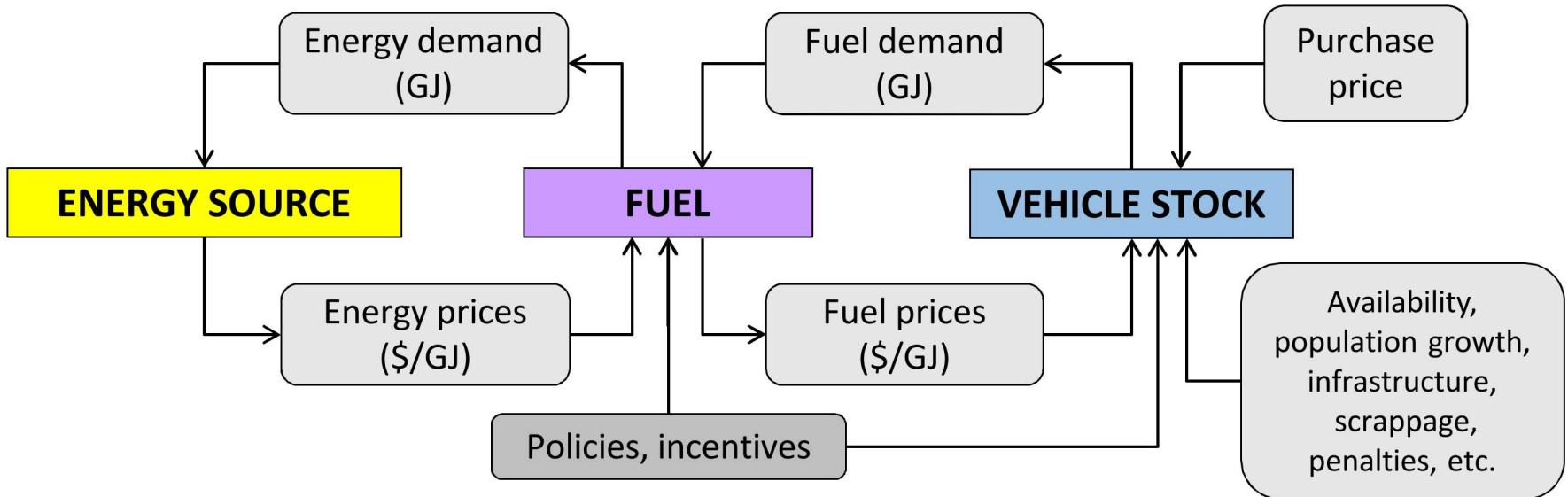
- Build HDV capability
 - Update HDV model capability to handle Fuel Cell Electric, Battery Electric, and Plug-in Hybrid Electric Vehicles (FCEV, BEV, PHEV)
 - Conduct a gaps analysis to identify and assess data sources and quality to answer current analysis questions and provide context and planning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

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

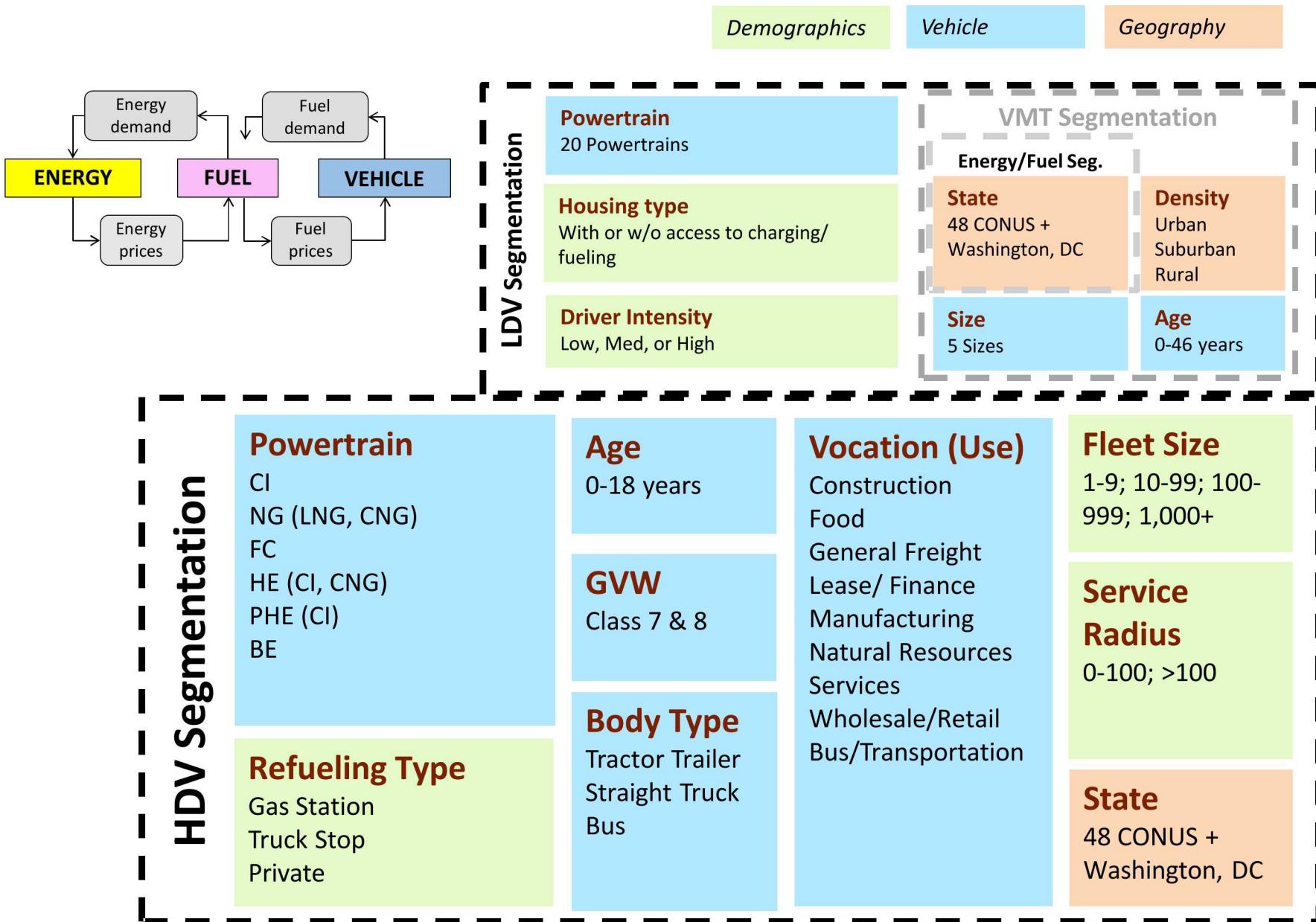
- At each time step, vehicles compete for share in the stock based on value to consumers and external factors such as policies

Variety of output options, including:

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

Variables change with time and demand

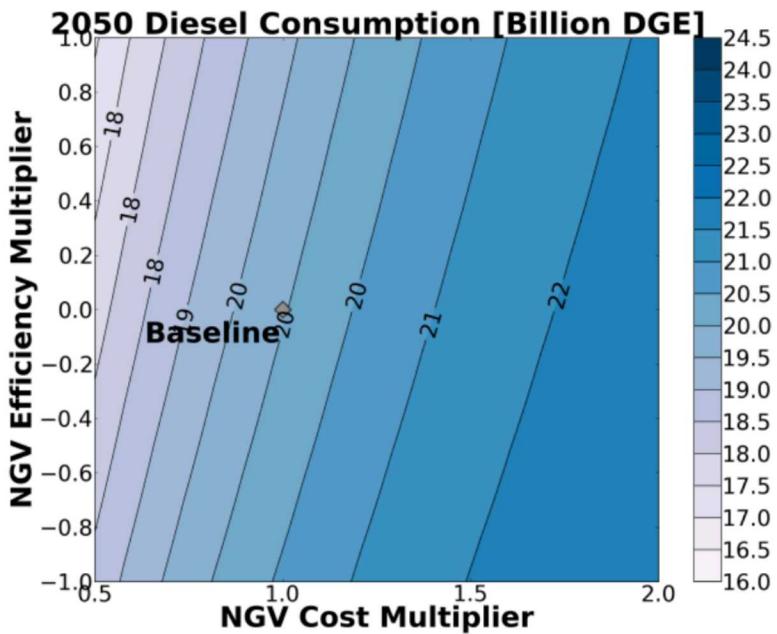
Approach: ParaChoice segments vehicles, fuels, & population to understand competition between powertrains & market niches



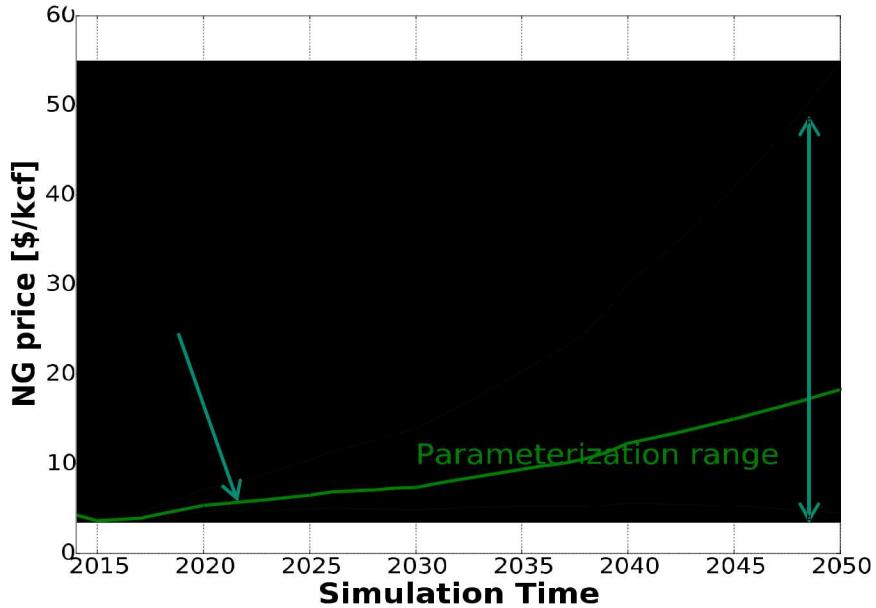
Approach: Use parameterization to understand and mitigate uncertainty introduced by data sources and assumptions

Parametric approach enables:

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

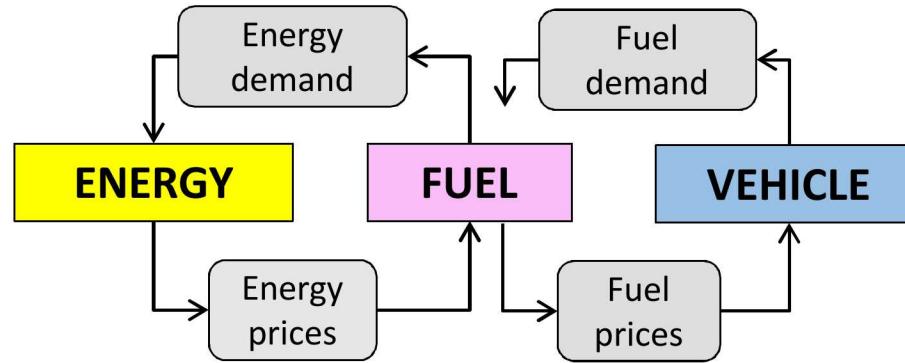


Example parameterization of natural gas prices with multiplier on AEO projection



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

Approach: ParaChoice brings unique strengths to the Analysis Portfolio



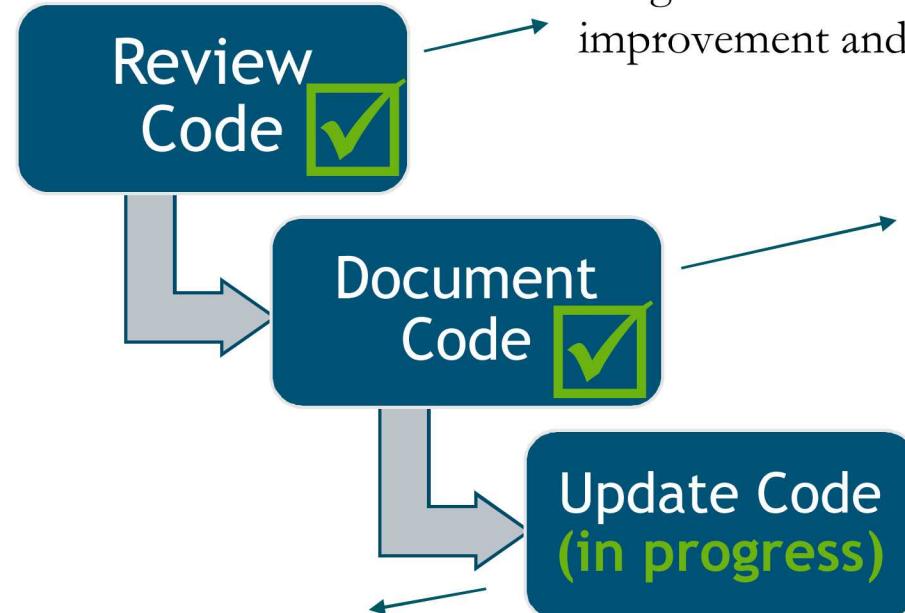
Uniqueness from other DOE models:

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

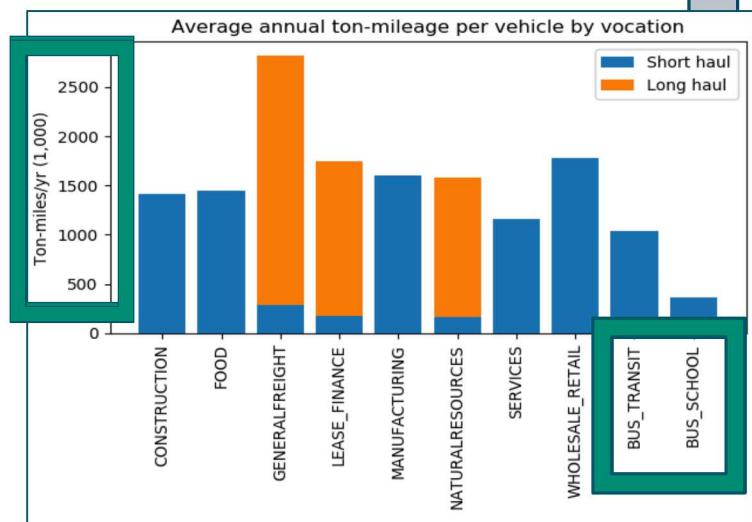
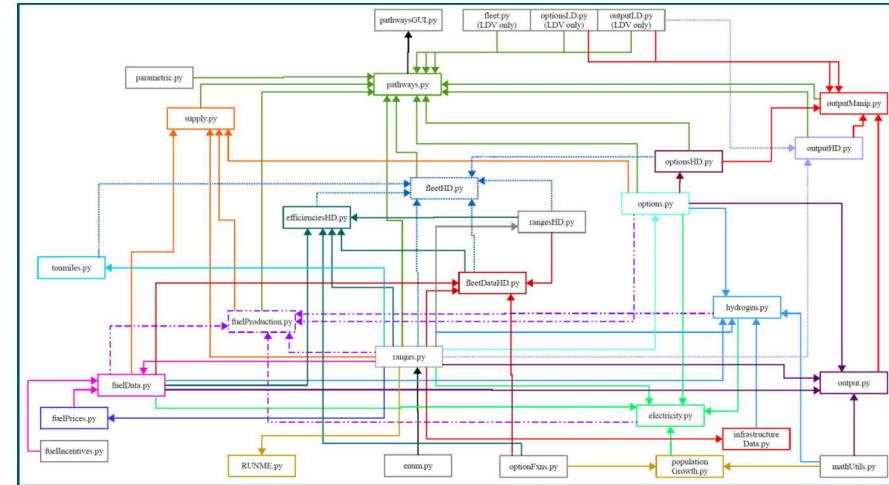
- Core simulation is a system-level analysis of the **dynamic, economic relationship** between energy, fuels, & vehicles with baseline values from trusted DOE sources
- Technologies compete in the simulation, and are allowed to flourish or fail in the marketplace
- Simulation is run 1000s of times with 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

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



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	Opportunities
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.

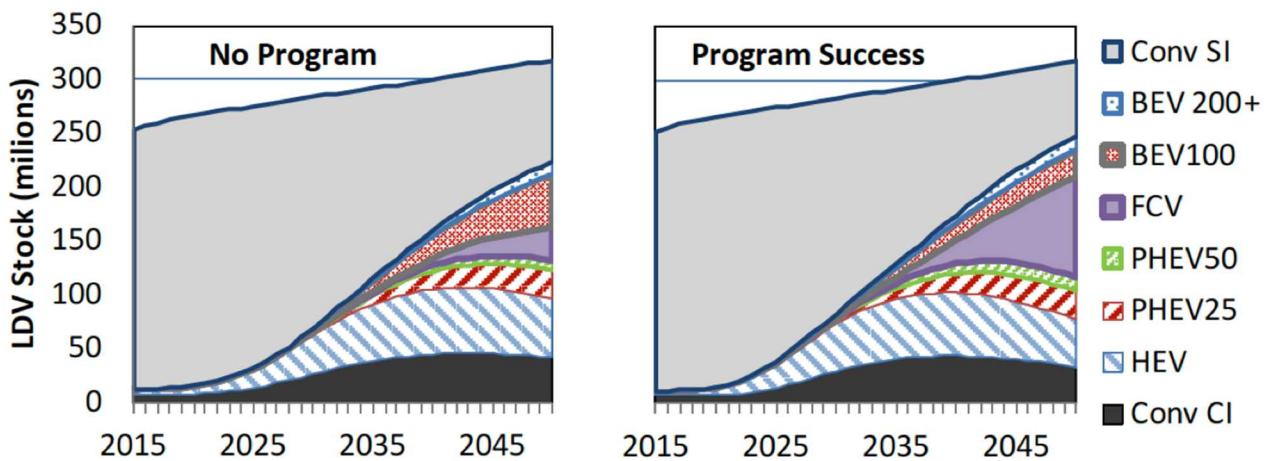


FIGURE B-5 LDV Stock by Powertrain Type for the No Program (left) and Program Success (right) Cases Projected by the ParaChoice Model

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

- GREET
- Autonomie
- Vision

Responses to 2017 AMR Reviewer Comments

Comments from FY17 AMR

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.

The reviewer commented that the project has no university collaborators or technical critiques by academic researchers.

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.



Responses

Added Data needs to Gaps analysis to support answering these questions at a future date.

Re-engaged with UC Davis STEPS/ITS Programs. Leveraging having 2 Alumni as team members

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



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

Recent

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

Uncertainty in AFV Market:

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

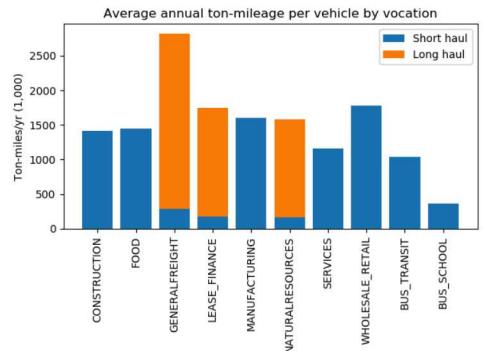
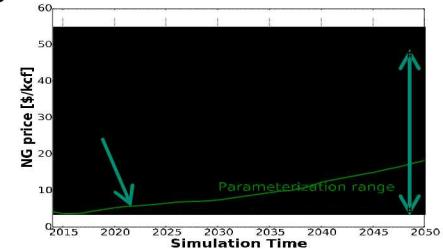
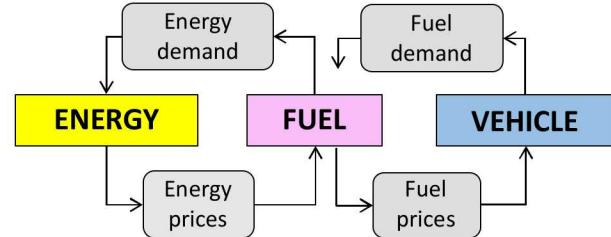
- Rigorous review and documentation of legacy code
- Updates to HDV functionality including new powertrains, body types and fuels
- Gaps analysis (Database and planning tool)

Collaborations

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

Future Work

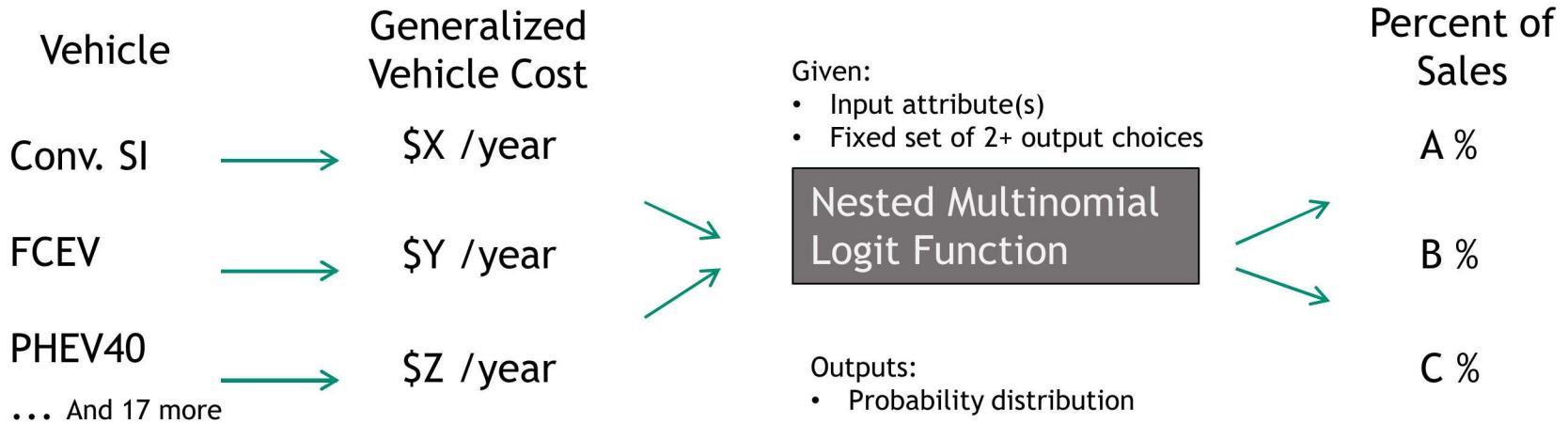
- Finish Phase 1 of gaps analysis
- Participate in TCO & BaSce efforts



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



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.

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

Vehicles

- Numbers, classes, drive-train mixes

Service demographics

- Ton-mileage

Fuels

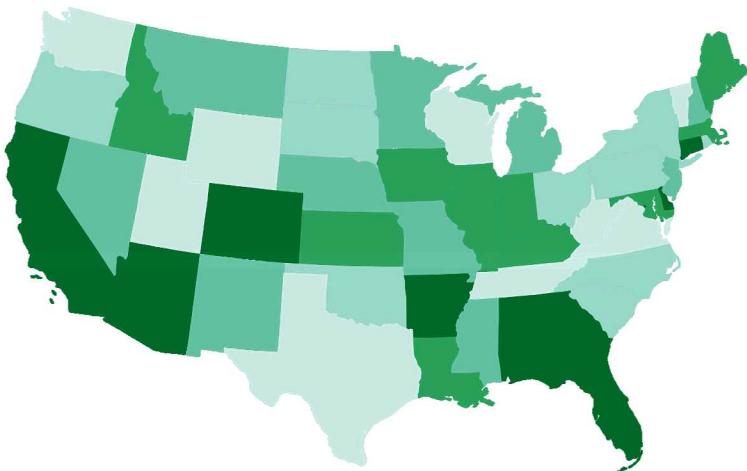
- Costs, electricity mix, hydrogen production pathway, taxes & fees, alternative fuel infrastructure

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

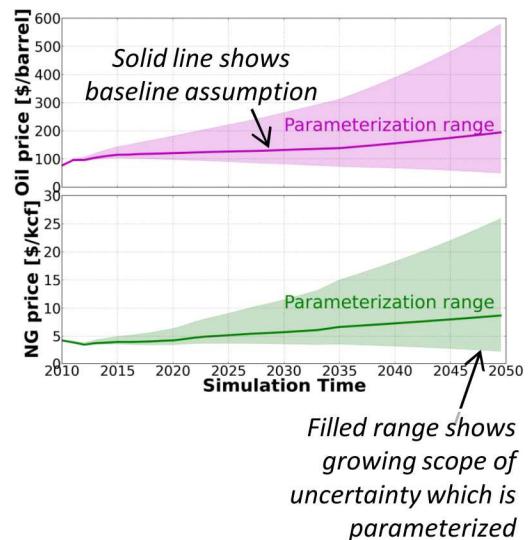
Conversion costs and GHG emissions derived from ANL GREET model

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)

Reviewer Only Slides

Publications

Levinson, R. S., & West, T. H. (2018). **Impact of convenient away-from-home charging infrastructure**. *Transportation Research Part D* 65, pp. 288-299.

Levinson RS, Manley DK & West TH. (2016). History v. Simulation: An analysis of the drivers of alternative energy vehicle sales. *SAE, Int. J. Alt. Power* 5(2)

Askin AC, Barter GE, West TH & Manley DK. (2015). The heavy-duty vehicle future in the United States: A parametric analysis of technology and policy tradeoffs. *Energy Policy*, 81, 1-13.

Barter GE, Tamor MA, Manley DK & West TH (2015). Implications of modeling range and infrastructure barriers to battery electric vehicle adoption. *Transportation Research Letters*, 2502, 80-88

Peterson MB, Barter GE, West TH & Manley DK. (2014). A parametric study of light-duty natural gas vehicle competitiveness in the United States through 2050. *Applied Energy*, 125, 206–217.

Barter GE, Reichmuth D, West TH & Manley DK. (2013) The future adoption and benefit of electric vehicles: a parametric assessment. *SAE Int. J. Alt. Power*, 6(1).

Westbrook J, Barter GE, Manley DK & West TH. (2013). 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*, 65, 419-431.

Barter GE, Reichmuth D, Westbrook J, Malczynski LA, West TH, Manley DK, Guzman KD, & Edwards DM. (2012). Parametric analysis of technology and policy tradeoffs for conventional and electric light-duty vehicles. *Energy Policy*, 46(0), 473 – 488.

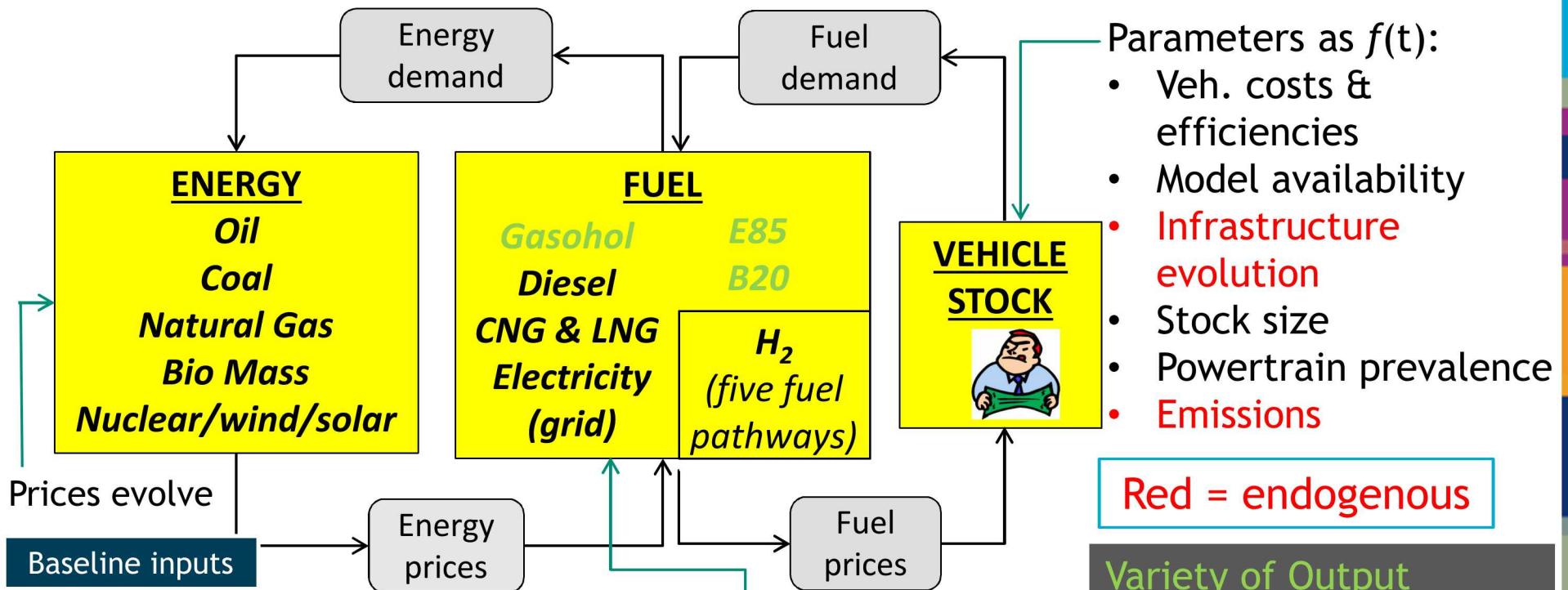
Critical Assumptions and Issues

Complete team turnover

- Every member of the ParaChoice team was replaced with minimal overlap at the beginning of the FY19. Team members replaced include Sandia PM, PI and contributors. Furthermore, the primary focus of the ParaChoice effort has shifted towards developing HDV capabilities. New team members and primary focus have required significant effort dedicated to "onboarding". As such, previously planned deliverables are delayed by 1-1.5 quarters. Current status is in-line with previous goals +1.5 quarters and no further delays are anticipated.

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.



- Energy prices: AEO 2016
- Emissions: GREET
- Fleet segmentation: NHTS (LDV); Polk (HDV)
- VMT: FWHA, AFDC
- Vehicle price projections: Autonomie; National Petroleum Council (HDV)
- Fueling stations: AFDC
- Policies (by state): AFDC

Policy options as $f(t)$:
RFS, carbon taxes, H₂
production pathways,
electric grid composition

- Variety of Output Options, Including:
 - Sales Fractions
 - Vehicle Stock
 - Emissions
 - Fuel Consumption
 - Trades & Sensitivities

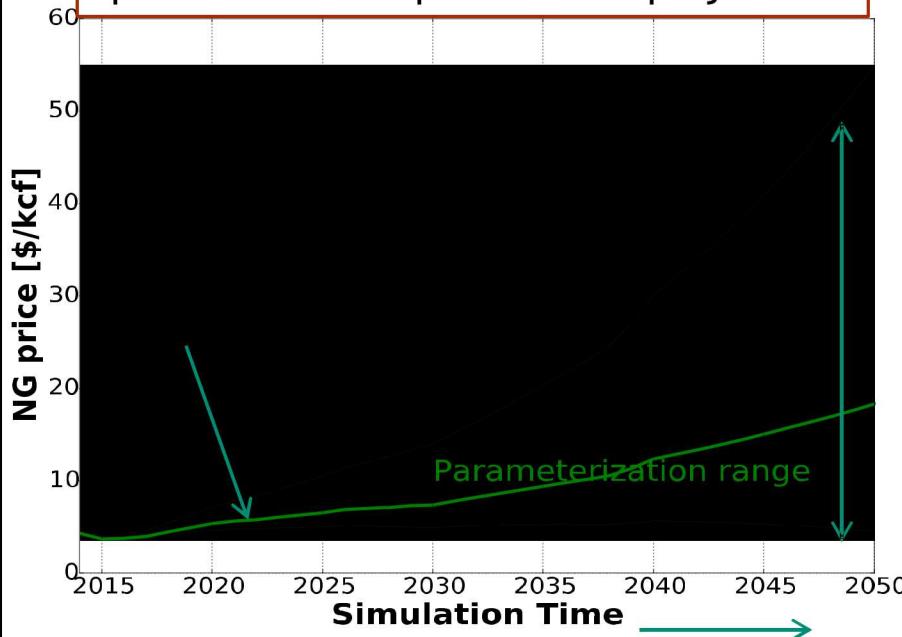
Approach: Use parameterization to understand and mitigate uncertainty introduced by data sources and assumptions

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, are allowed to flourish or fail in the marketplace.**
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 - 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

Example parameterization of natural gas prices with multiplier on AEO projection



- Vary two parameters at once- trade space analysis
- Vary many parameters- sensitivity analysis
- Parameterization ranges designed to explore plausible AND 'what if' regimes, covering all bases

Modification and update of the legacy HDV ParaChoice model will extend these unique capabilities in the HDV segment.

Accomplishments & Progress: Gaps analysis is an opportunity to systematically create a data informed extended development plan

Identify HDV Analysis Questions (in progress)

Reviewed previous LDV and HDV ParaChoice analyses

Attended TRB, and VTO Analysis summit to find ideas for new analysis.

We looked to industry to understand some of their concerns.

Some Example Questions:

- What is the effect of vehicle availability on sales?
- What effect does end-of-life salvage value have on vehicle adoption?
- What powertrains should be considered in the analysis?
- How does infrastructure funding affect adoption?
- Effects of higher charging powers?

The gaps analysis is executed as a spreadsheet backed by a granular database

Row Categories*

- Energy Sources
- Vehicles
- Fuel Production
- Infrastructure
- Consumers
- Economics

*Total of ~100 data types

Column Headers

- Parameter
- In ParaChoice
- Data Quality
- Analysis Impact
- Analysis Question
- Citations
- Opportunities

Fuels

- Diesel Petroleum
- LNG Petroleum
- CNG petroleum
- Biodiesel
- Fisher-Tropsch
- Methane Reformation
- 5 H2 Pathways
- DME
- Electricity (Fossil)
- Electricity (Renewable)
- Electricity (Biomass)

Powertrains

- Conventional
- Biodiesel
- CNG
- LNG
- FC
- BE

Vehicles (Class 7 & 8)

- TT- Van Basic
- TT- Van refrigerated
- TT- Dump
- TT- Flatbed/stake/platform
- TT- Tank
- SUT- Van Basic
- SUT- Van Refrigerated
- SUT- Refuse
- SUT- Construction
- SUT- Dump
- SUT- Flatbed/platform/stake
- SUT- Tank
- Motorhome
- Bus- School
- Bus- Transit