ANL Vehicle Technologies Analysis Modeling Program

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Argonne National Laboratory

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Project ID: VAN017

Project Overview

Timeline	Barriers
• Project start date: 10/01/2015 • Project end date: 09/30/2018 • Percent complete: 25%	• Indicators and methodology for evaluating environmental sustainability • Evaluate energy and emission benefits of vehicle/fuel systems • Overcome inconsistent data, assumptions, and guidelines
Budget	**Partners**
• Total project funding: $4.5 M (100% DOE) • Funding received in FY 2015: none (new AOP from prior separate projects) • Funding for FY 2016: $1.5 M	• National labs: ORNL, NREL • Industries: OEMs and energy companies via USDRIVE • Agencies: EIA, EPA, DOT • Other org: UIC, Jacobs

Project Overall Objectives

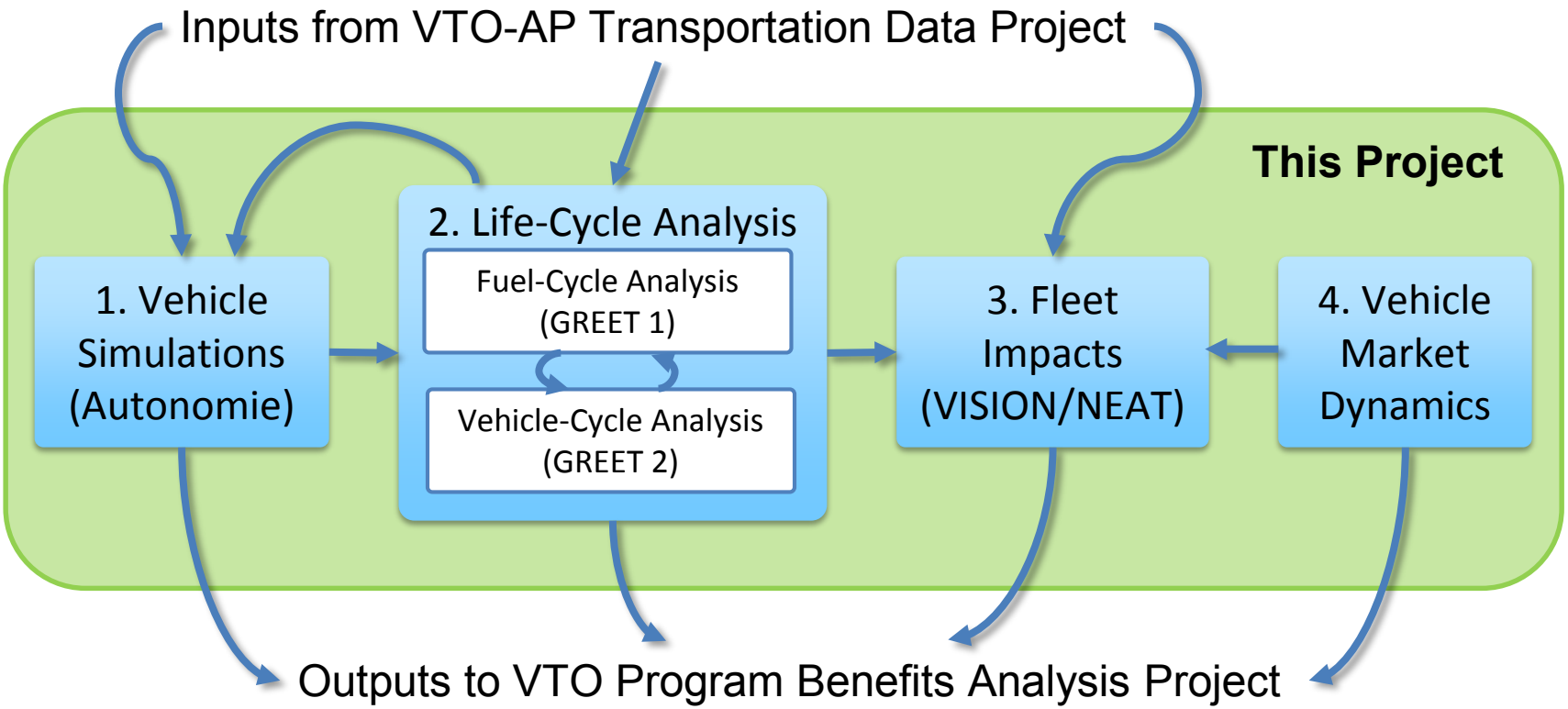
- Overcome inconsistent data, assumptions, and guidelines by developing transparent models
  - The **Autonomie** model: Dynamically quantify vehicle energy consumption and cost impacts of advanced vehicle technologies
  - The **GREET** life-cycle analysis (LCA) model: Holistically address energy and environmental impacts of vehicle/fuel systems with fuel cycle and vehicle cycle
  - The **VISION/NEAT** and **household-level** vehicle purchase/use models: Systematically assess energy and emission effects of vehicle technology deployment scenarios

- To develop indicators and methodology for environmental sustainability and evaluate energy and emission benefits of vehicle/fuel systems, the suite of models includes:
  - Energy use, especially related to petroleum reductions of advanced vehicle technologies and alternative transportation fuels
  - Greenhouse gas (GHG) emission impacts of vehicle/fuel systems
  - Air pollutant emission impacts (NOx, PM10, SOx, VOC, etc.)
  - Water consumption of different transportation fuels

Task objectives

- ***Task 1:*** Leverage high-fidelity dynamic vehicle modeling with **Autonomie** to quantify energy and cost impacts of a wide range of technologies (vehicle, powertrain, component, control, cost, etc.) and vehicle classes (light duty to heavy duty)
- ***Task 2:*** LCA of vehicle/fuel systems with **GREET** covers the supply chain of a large number of fuel production pathways and vehicle manufacturing processes to generate LCA energy use, emission and water consumption results
- ***Task 3:*** Fleet-wide energy and emission assessment of advanced vehicle/fuel systems with **VISION/NEAT** by considering market potentials of vehicle technologies and fuels
- ***Task 4:*** **Market dynamics** modeling of household-level vehicle ownership provides improved projections of market shares and utilization of advanced vehicle technologies

Internal Linkage Among Project's Tasks and External Interaction with Other VTO-AP Analysis Efforts

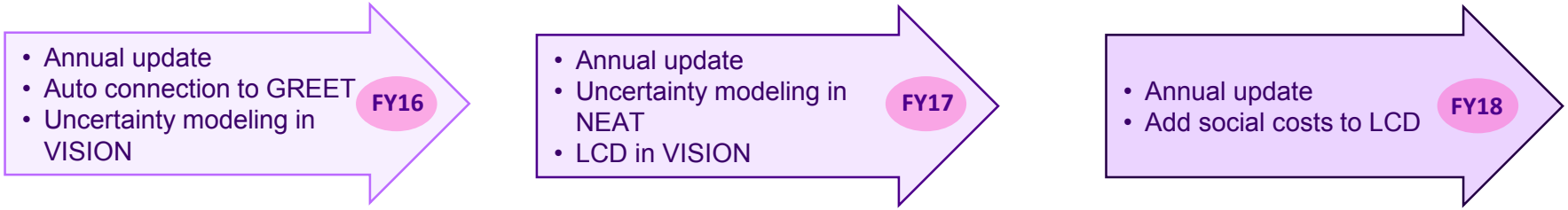


Schedule/Milestones

Schedule/milestones are determined through:

- Quarterly updates to VTO-AP sponsors
- Semi-annual ANL visits by VTO-AP sponsors
- Regular meetings with key stakeholders via USDRIVE etc.
- Reviewer inputs from VTO Annual Merit Review

Task 1: VTO Energy and Cost Impact



Task 3: Fleet Impacts with VISION/NEAT

Schedule/Milestones (continued)

- Collect and analyze water consumption data — FY16
- Develop water consumption factors for vehicle/ fuel systems — FY17
- Evaluate implications of system boundary
- Examine regional differences — FY18

Task 2.1: GREET Water Consumption LCA

- Collect and analyze vehicle materials/ manufacturing data — FY16
- Analyze critical LCA issues related to vehicle lightweighting — FY17
- Develop PDFs
- Conduct uncertainty analysis — FY18

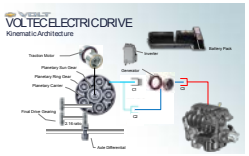
Task 2.2: Vehicle Cycle Analysis (GREET2)

- Develop regional analysis capabilities
- Expand HDV and rail — FY16
- Incorporate additional vehicle classes
- Update fuel economy and vehicle materials — FY17
- Include stochastic simulations
- Develop user tutorials — FY18

Task 2.3: GREET Development in the .net Platform

Approach of Autonomie Vehicle Dynamic Modeling

Vehicle Powertrain

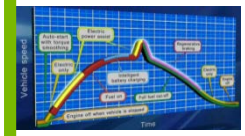


i.e. GM Voltec Development

Component Models

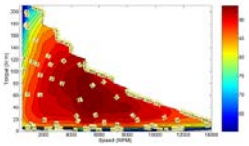
i.e. Advanced Transmission (e.g. DCT)

Vehicle Control



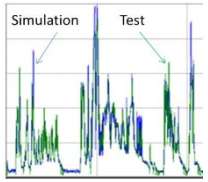
Integrate advanced control algorithms such as instantaneous optimization or route based control

Component Benchmarking



Vehicle Energy & Cost

Validation

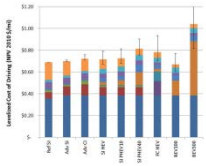


Standard Procedures

Large Scale Simulation

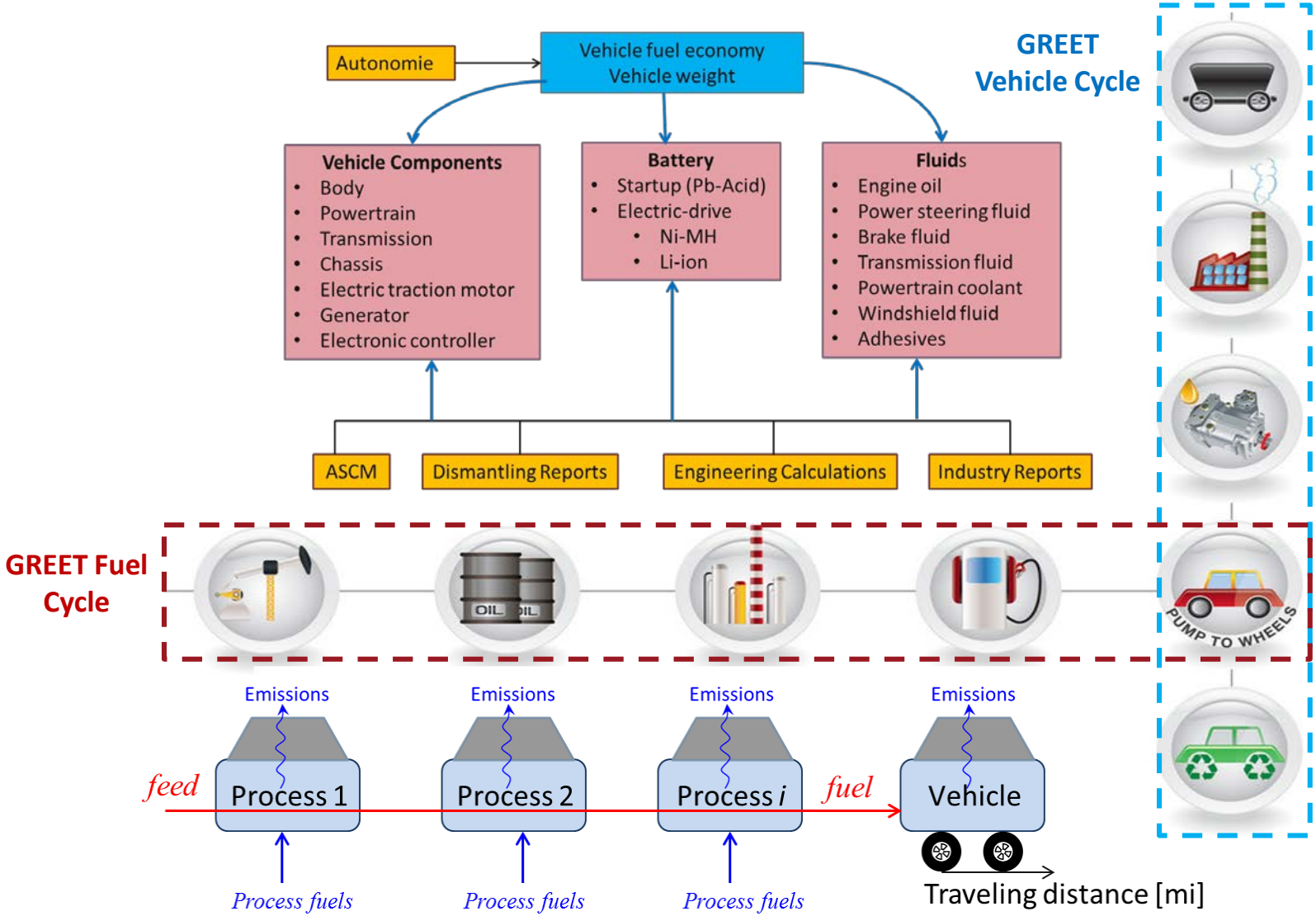
Numerous processes, including vehicle sizing algorithms, distributed computing, parametric study, SOC correction… are used to evaluate a large number of options

Levelized Cost of Driving



Integrate LCD calculations to evaluate the technology benefits using $/mile

Approach of GREET Life Cycle Analysis



Approach of VISION/NEAT Fleet Impact Modeling

Major Inputs (User defined)
- Market share
- Fuel efficiency
- Travel volume
- Economic factors

Internal Calculations
- Vehicle stock
- VMT per vehicle
- VMT per technology
- Emission and energy rate

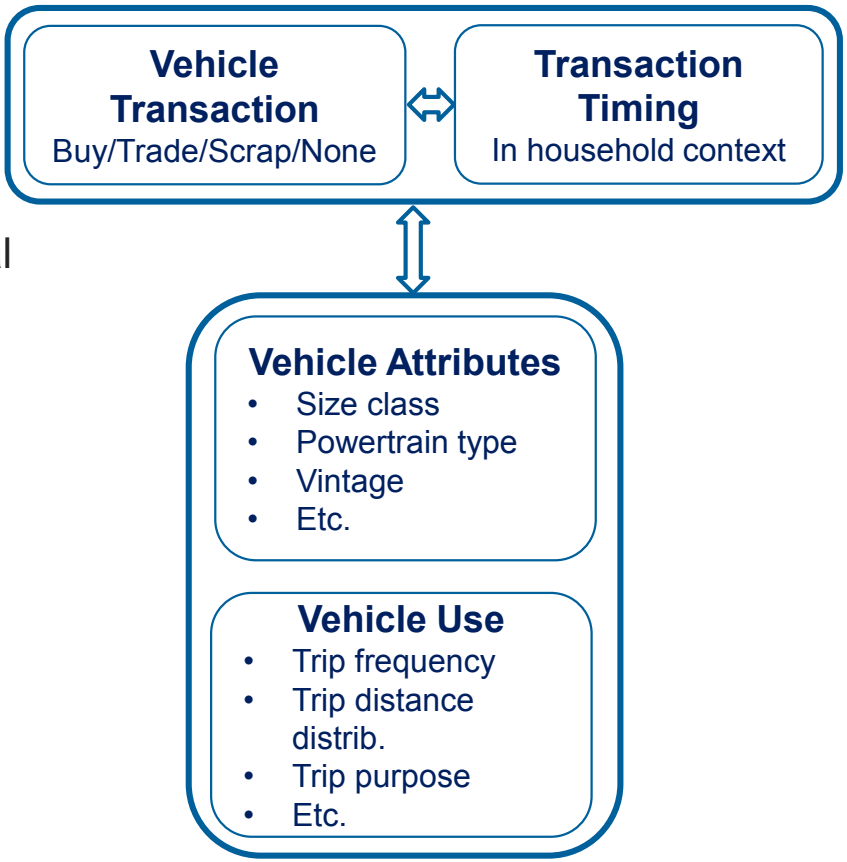
- Energy use and GHG emissions by vehicle tech, vehicle type and fuel type

Major Outputs

Vehicles	Technology & Fuel	Fuel Pathways
 Cars  Light Trucks	4 ICEVs (gasoline, diesel E85, CNG) 3 HEVs (gasoline, diesel, E85) 3 PHEVs (2 gasoline types, diesel) 2 EVs 1 FCEV	Crude oil to gasoline and diesel Natural gas To CNG, LNG, F-T diesel Soybeans to biodiesel Corn, sugarcane, Switchgrass, etc. to ethanol Coal, nuclear, Renewables, etc. to electricity NG, coal, Biomass, etc. to H2
 Class 3-6 Trucks	Gasoline ICEV, diesel ICEV, CNG ICEV, diesel HEV	
 Class 7-8 Single Unit Trucks	Gasoline ICEV, diesel ICEV, CNG ICEV, diesel HEV	
 Class 7-8 Combination Trucks	Diesel ICEV and LNG ICEV	

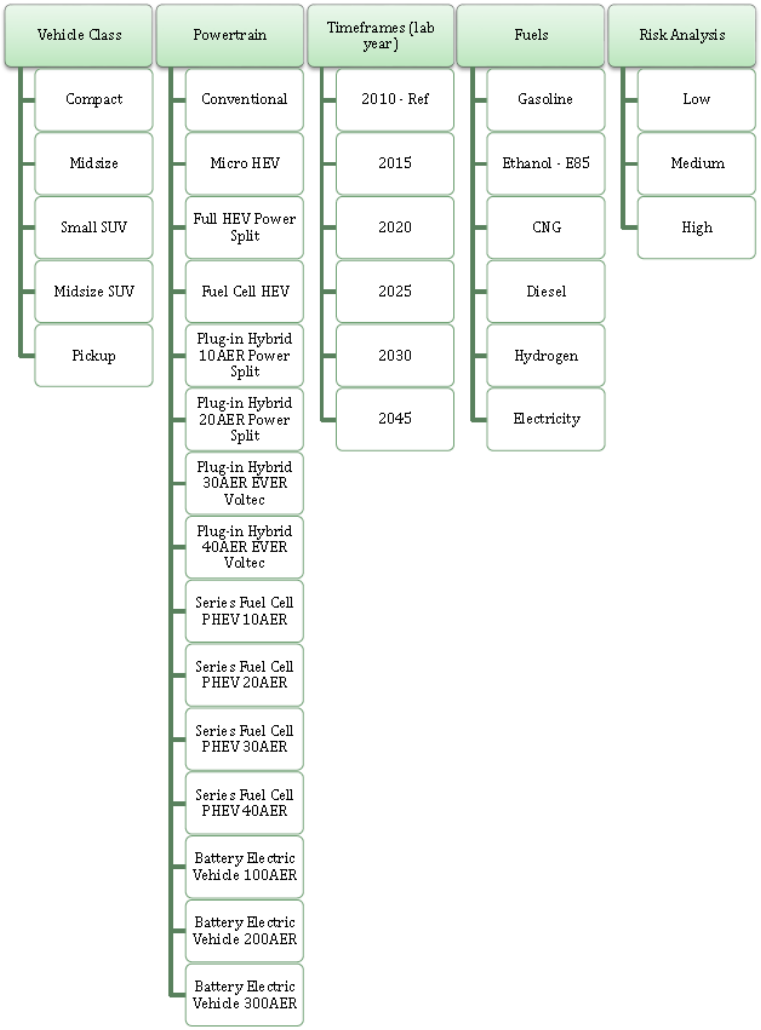
Approach of Household Vehicle Ownership Modeling

- Dynamic vehicle ownership model
  - Vehicle transactions depend on the utility derived from the household vehicles within the household context
  - *Transaction timing* is the **central variable**
  - Vehicle attributes can be modeled conditional on transaction decisions **or jointly**
- Dynamic timing models can be linked to new or existing vehicle choice models to better represent market dynamics
- Based on longitudinal vehicle transaction data from various regions
  - Supplemented with small-scale panel study focusing on new vehicle technology
- The focus on fundamental household behaviors enables national applicability



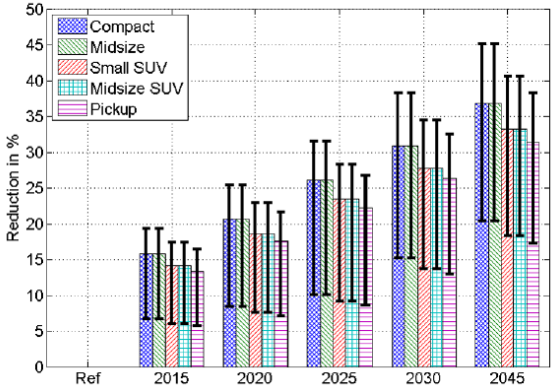
Autonomie Modeling

Vehicle Classes, Powertrains, Timeframes, and Fuels Considered

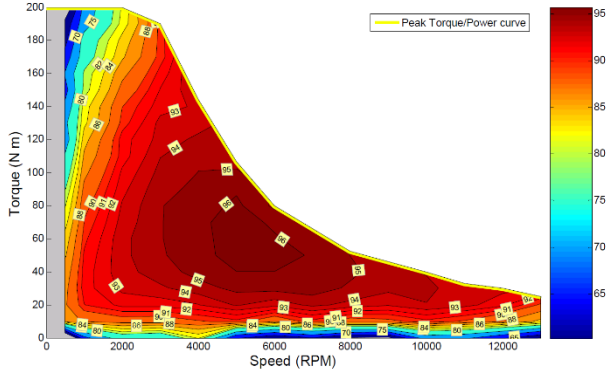


Component Assumptions

Some provided by DOE VTO (Targets)
Example: light weighting

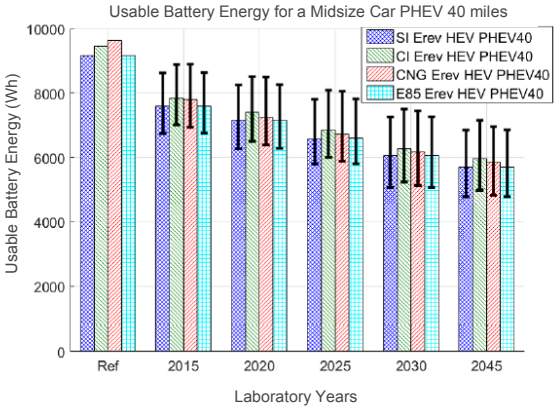


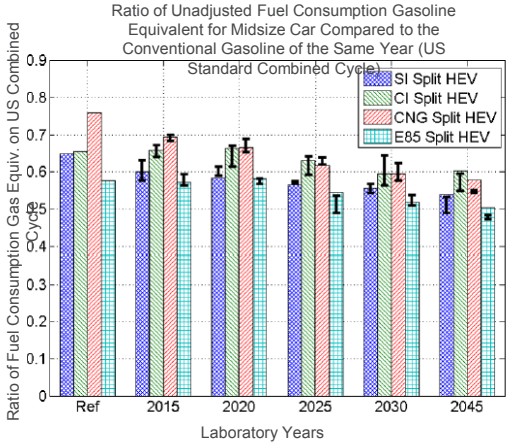
Some provided by OEMs, Nat. Labs, Univ.…
Example: Electric machine data from ORNL



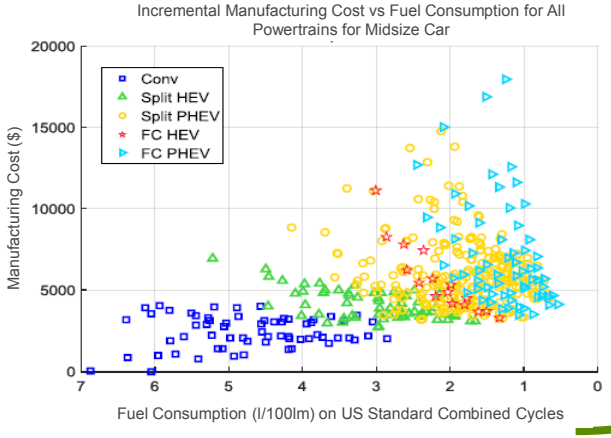
Autonomie Modeling (continued)

Component Sizing



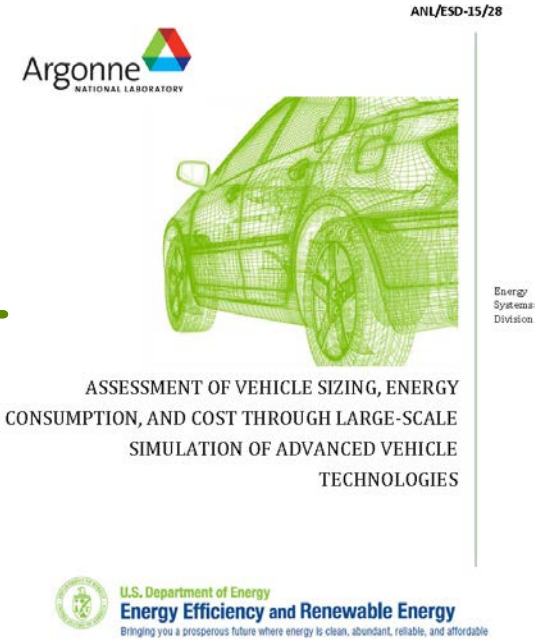


Vehicle Energy Consumption



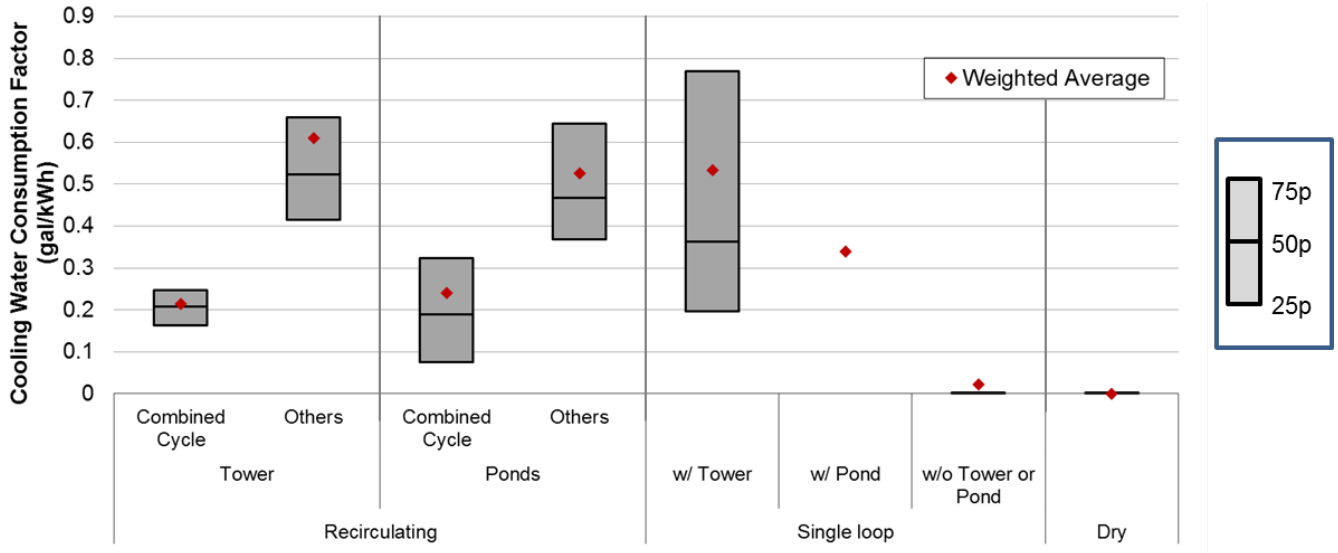
Component & Vehicle Cost

Report[1]



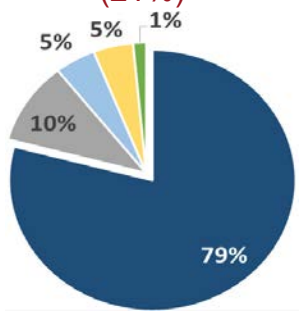
(1) Full report, assumptions and detailed results are available at http://www.autonomie.net/publications/fuel_economy_report.html

GREET LCA: Cooling Water Consumption for Thermoelectricity Generation

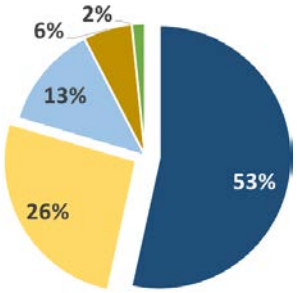


Thermoelectricity makes up 87% of U.S. total power generation (for 2015)

NG Combine Cycle (21%)

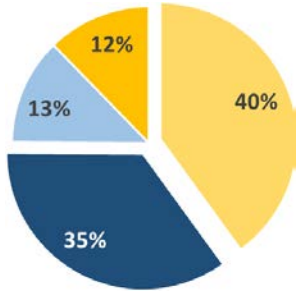


Other Combustion (46%)*



* Coal: 40%, NG: 5%, Residual Oil: 1%

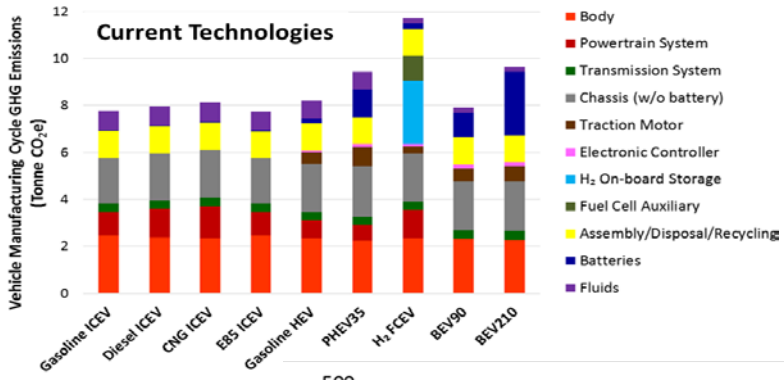
Nuclear (20%)



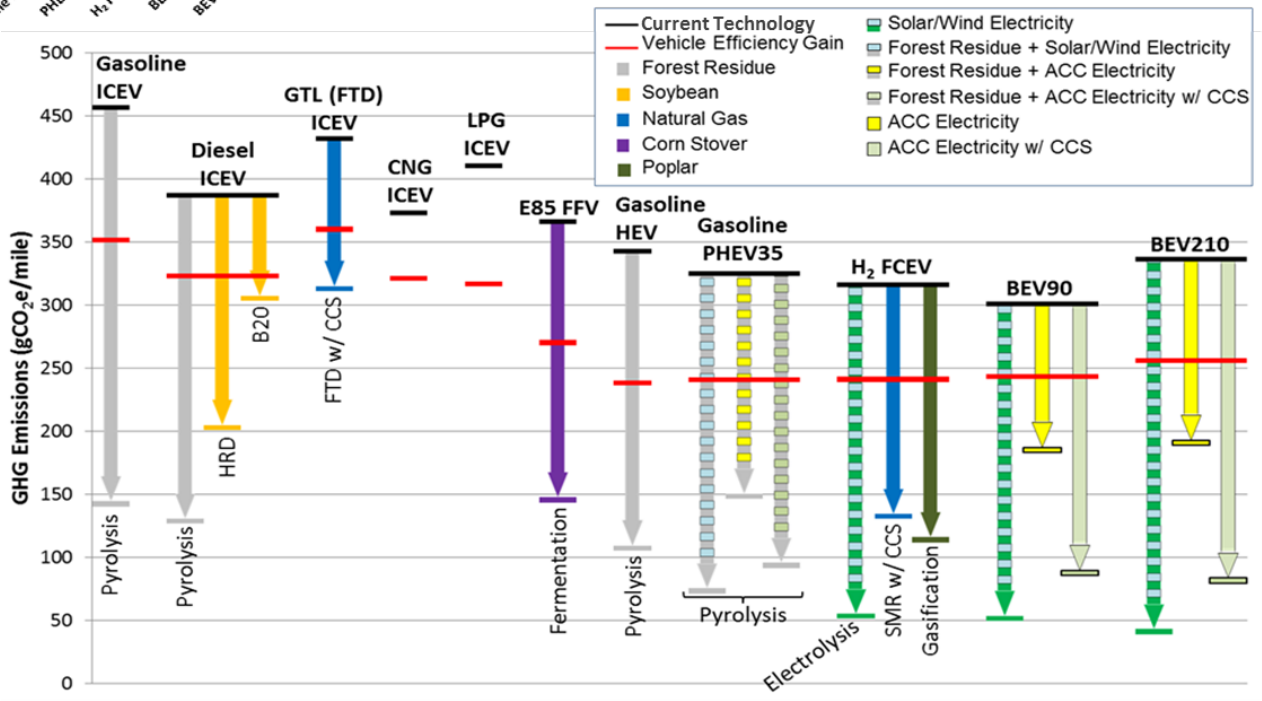
Cooling Technology Shares for Thermoelectricity:

- Recirculating w/ Tower
- Recirculating w/ Pond
- Single Loop w/ Tower
- Single Loop w/ Pond
- Single Loop
- Dry Cooling
- Others

GREET LCA: Cradle-To-Grave (C2G) Analysis of Vehicle/Fuel Pathways



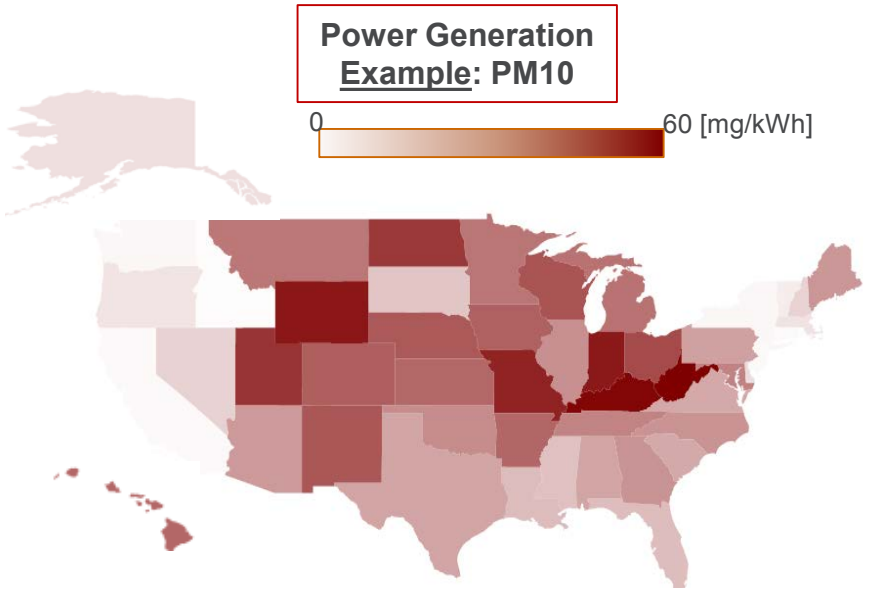
- ✓ Includes vehicle and fuel cycles
- ✓ Fuel economy and vehicle components from Autonomie
- ✓ Inputs vetted by auto and energy industry experts



GREET LCA: GREET.net – A Dynamic LCA Platform for Fuel and Vehicle Cycles

- ✓ Developed regional evaluation capabilities
- ✓ Developed new common vehicle editor for LDV, HDV and rail
- ✓ Linked documents of data sources to the user interface
- ✓ Developed tutorial videos of usability and functionality of model

https://greet.es.anl.gov/index.php?content=greetdotnet



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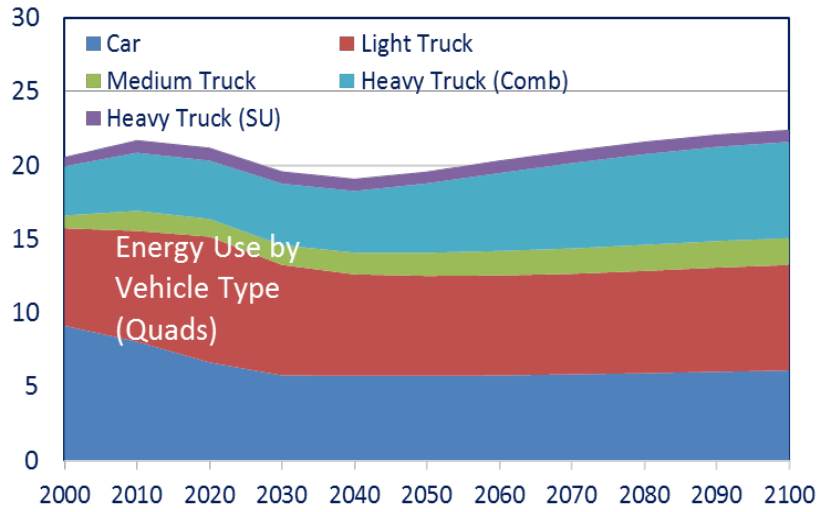
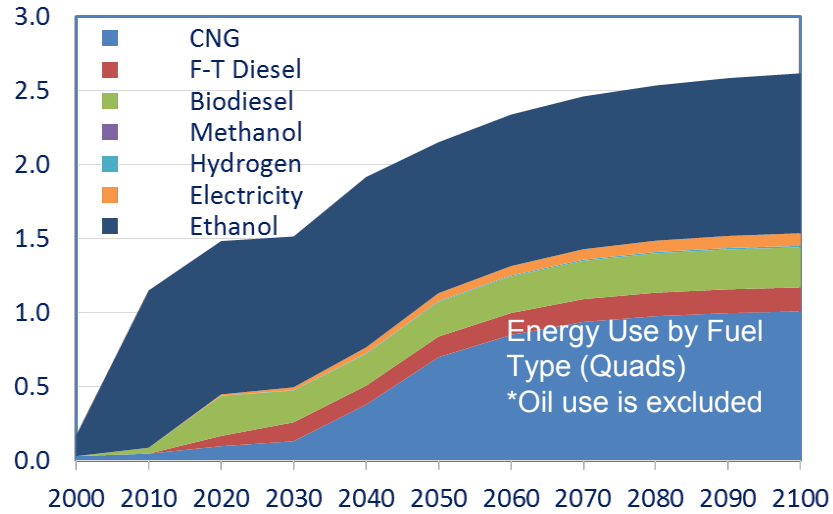
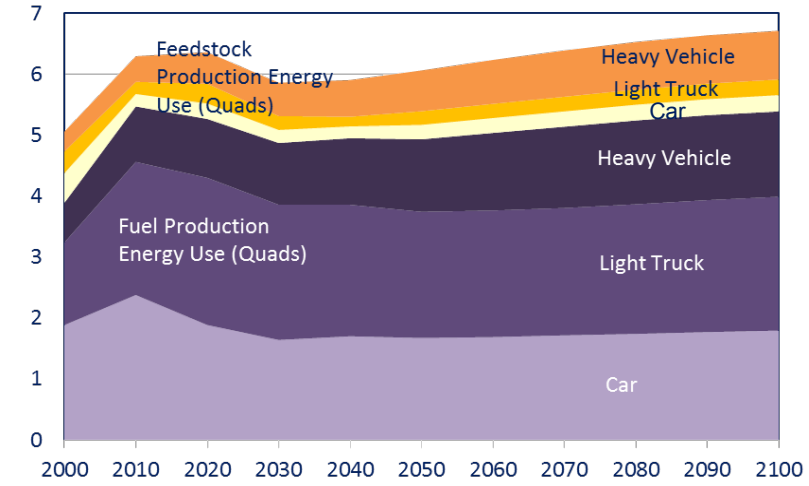
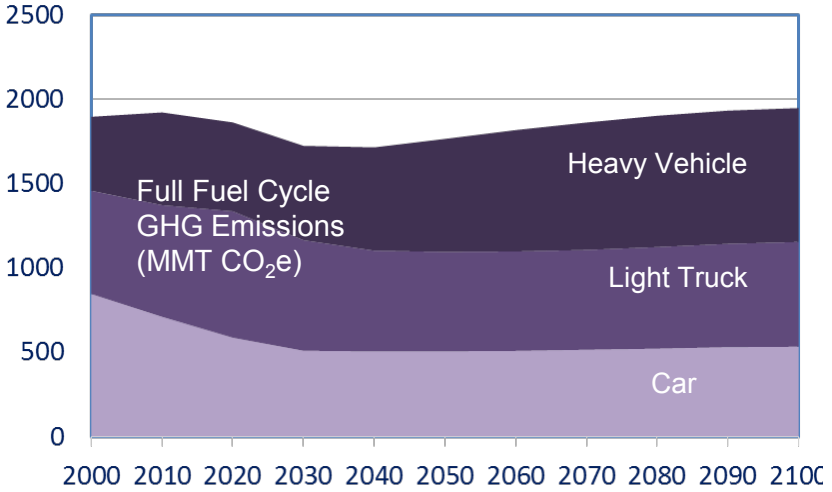
VISION/NEAT: Long-Term Base Case for LDVs and HDVs by Fuel and Vehicle Type
(Calibrated to AEO 2015 Ref. Case)

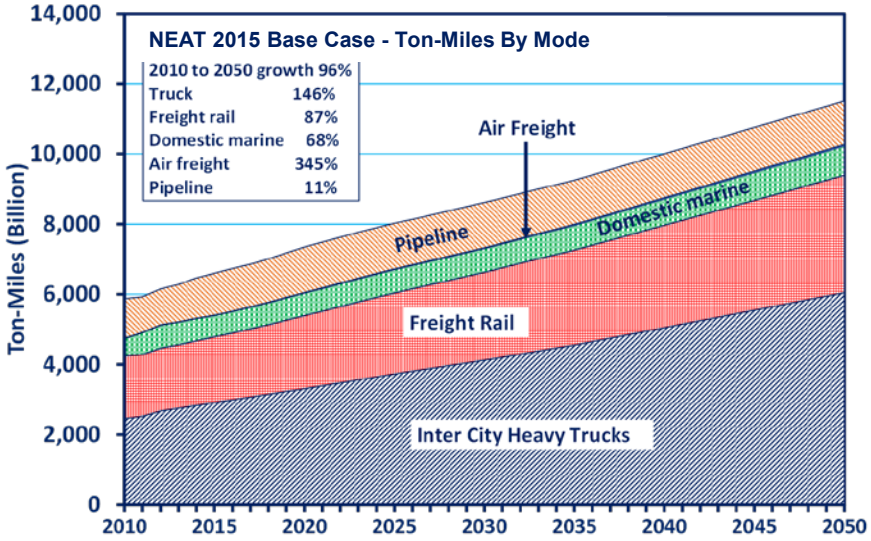






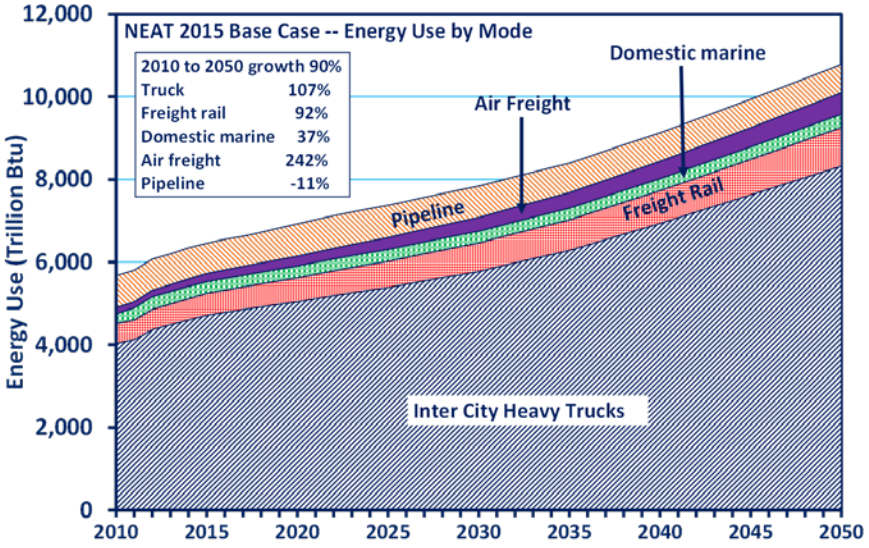


VISION/NEAT: Base Case Results

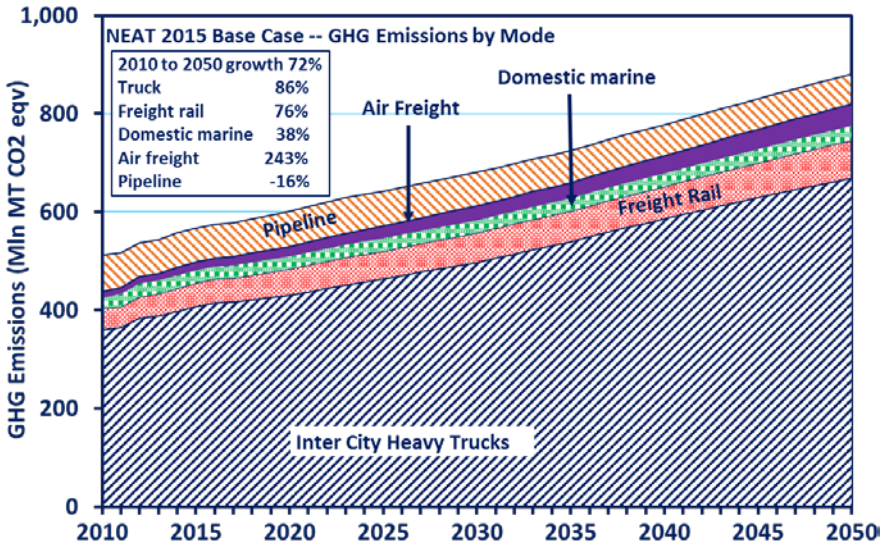


Base case: Domestic freight sector Ton-Miles grow 96% from 2010 to 2050

Energy use would increase by 90% (lower than VMT increase) due to alternative fuel use and improved efficiency



However, upstream energy use would grow by 110% due to alternative fuel use



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External Collaboration

- USCAR via USDRIVE for Autonomie and GREET
  - Inputs on vehicle technology options and fuel pathway choices
  - Verification of key parameters by member companies
- National lab partners for Autonomie, GREET, VISION/NEAT
  - NREL: TEA outputs processed for inputs to GREET for fuel production pathways
  - ORNL: Electric machine performance maps for Autonomie; transportation energy data book provides inputs for VISION/NEAT
- Universities
  - University of Illinois at Chicago (UIC): Household vehicle ownership modeling
- Other government agencies
  - EIA: GREET and VISION/NEAT, annual updates with AEO and other publications/databases
  - EPA: Power plant emissions and renewable fuel standard pathway development
  - DOT: FRA – GREET rail module; FAA – aviation fuels
- Research organizations
  - Jacobs Consultancy: detailed petroleum refinery LP modeling for energy, emissions and water

Remaining Challenges and Barriers

- Data availability and quality: challenges for all three models
  - Collaboration with various organizations
  - Modeling and simulations to produce needed inputs
- Modeling methodologies
  - Autonomie: Inclusion of latest powertrain and component technologies
  - GREET: System boundary expansion and modeling of indirect effects via economics
  - VISION/NEAT: Uncertainty analysis of key parameters and inclusion of social cost
- Technology/market dynamics over time
  - Need to address technology improvements and market changes as time progresses
- Metrics of modeling results
  - Energy, emissions, water, costs so far
  - Only a subset of issues for performance of technologies/systems
- Interpretation of results
  - Users sometime have tendency to interpret results beyond modeling scope

Planned/Proposed Future Work

- Autonomie
  - Include latest component and powertrain technologies (i.e., new GM xEV configurations)
  - Expand QA/QC algorithms
  - Develop web-based post-processing tools to facilitate results analysis by 3rd parties
- GREET
  - Continue development of water consumption factors for feedstocks, fuels and vehicle materials
  - Address LCA system boundary/regional issues
  - Analyze critical LCA issues related to vehicle lightweighting
  - Develop stochastic capabilities and regional database for environmental metrics in GREET.net
- VISION/NEAT
  - Annual update to match AEO reference case projections
  - Develop uncertainty module for key parameters
  - Extend vehicle cost module to allow levelized cost estimation
- Household vehicle ownership modeling
  - Develop model framework in FY16
  - Use existing data and new data (from UIC survey) to calibrate model in FY17

Summary

- Objective of this project is to develop modeling capabilities for VTO-AP to estimate energy, environmental, and cost effects of advanced vehicle technologies and alternative fuels
- Main products of this project include a suite of widely accepted/used models (GREET, Autonomie, VISION/NEAT) to address key barriers in analyzing energy, environmental, costs of vehicle/fuel systems
- Model development efforts of this project are
  - Highly leveraged with ANL's efforts for other EERE programs, other VTO programs, and other VTO-AP efforts
  - Executed by ANL top-of-field experts
- Key factor for project success is the continuing interactions with DOE sponsors, other national labs, OEMs, energy companies, and universities during project