Project ID # VAN023

Assessing the Energy and Cost Impact of Advanced Technologies through Model Based Design

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Project Overview

Timeline	Barriers*
• Project start date : FY16 • Project end date : FY18 • Percent complete : 60%	• Risk aversion • Constant advances in technology • Cost • Computational models, design, and simulation methodologies *from 2011-2015 VTP MYPP
Budget	**Partners**
• FY16 Funding : $350K • FY17 Funding : $259K	Formal Collaborator • All USDrive Partners, MD&HD OEMs Interactions • All USDrive Partners, outside companies (OEMs, suppliers…)

Project Relevance

Objective : Quantify energy and cost benefits of vehicle technologies improvements for light, medium & heavy duty vehicles

- Benefits of vehicle technology improvements in Medium duty (MD) & Heavy duty (HD) vehicles are not well understood.
- Several initiatives have shown in the potential of improvements in specific classes/vocations
- Analysis of more types of MD & HD vehicles is needed to identify potential areas where vehicle technologies can make a large impact.

Strengths

- Experience of a similar effort on LD vehicles
- Learnings from Supertruck & other efforts
- Use of Autonomie as a platform

Weaknesses

- Limited MD&HD test data

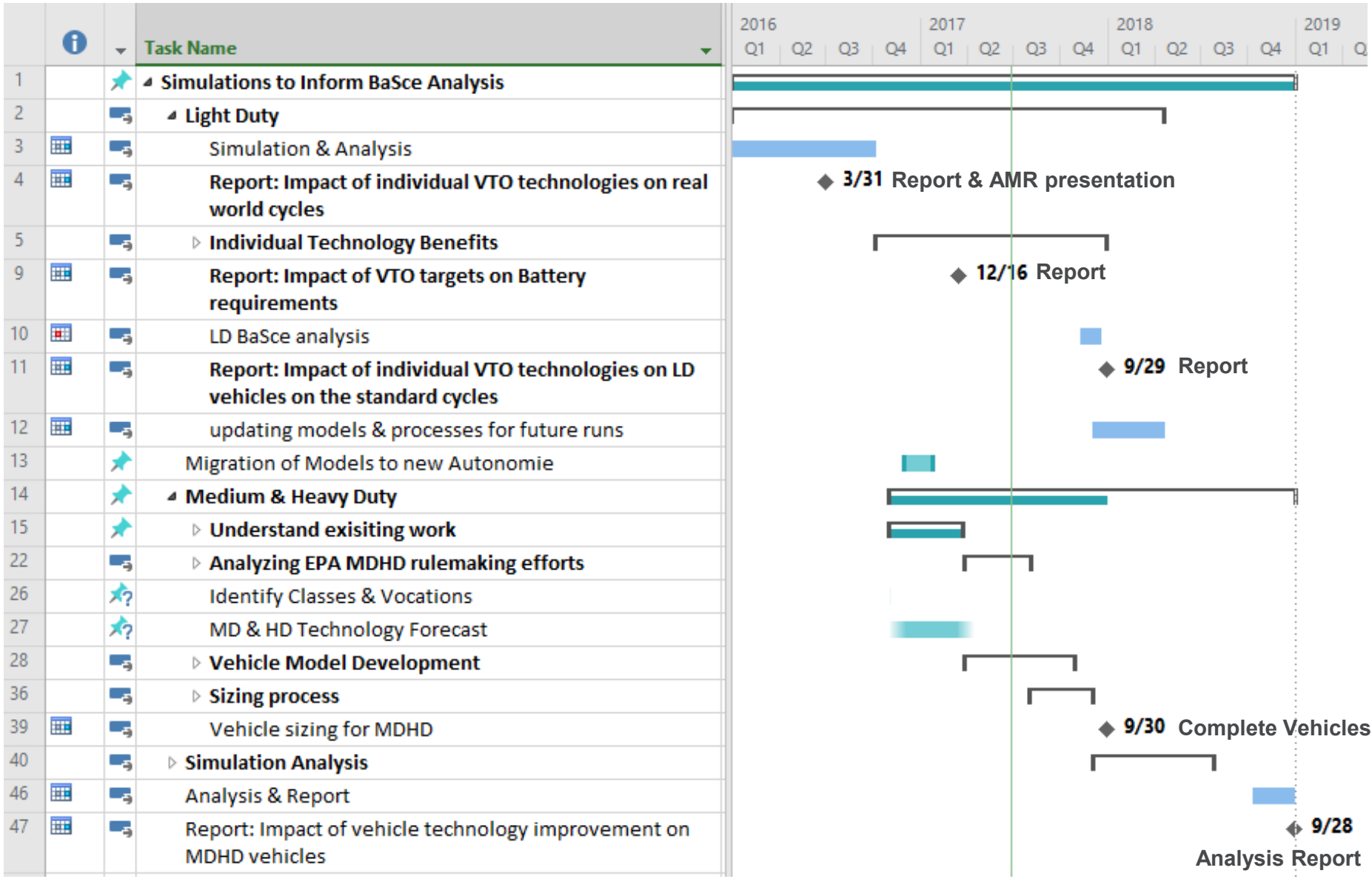
Opportunities

- Identify technologies suitable for specific classes/vocations
- Expand interaction with industry
- Expand the model library in Autonomie

Threats

- EPA procedure changes necessitates resizing of models developed earlier
- Numerous variants of trucks make it difficult to evaluate every class & vocation

Project Milestones



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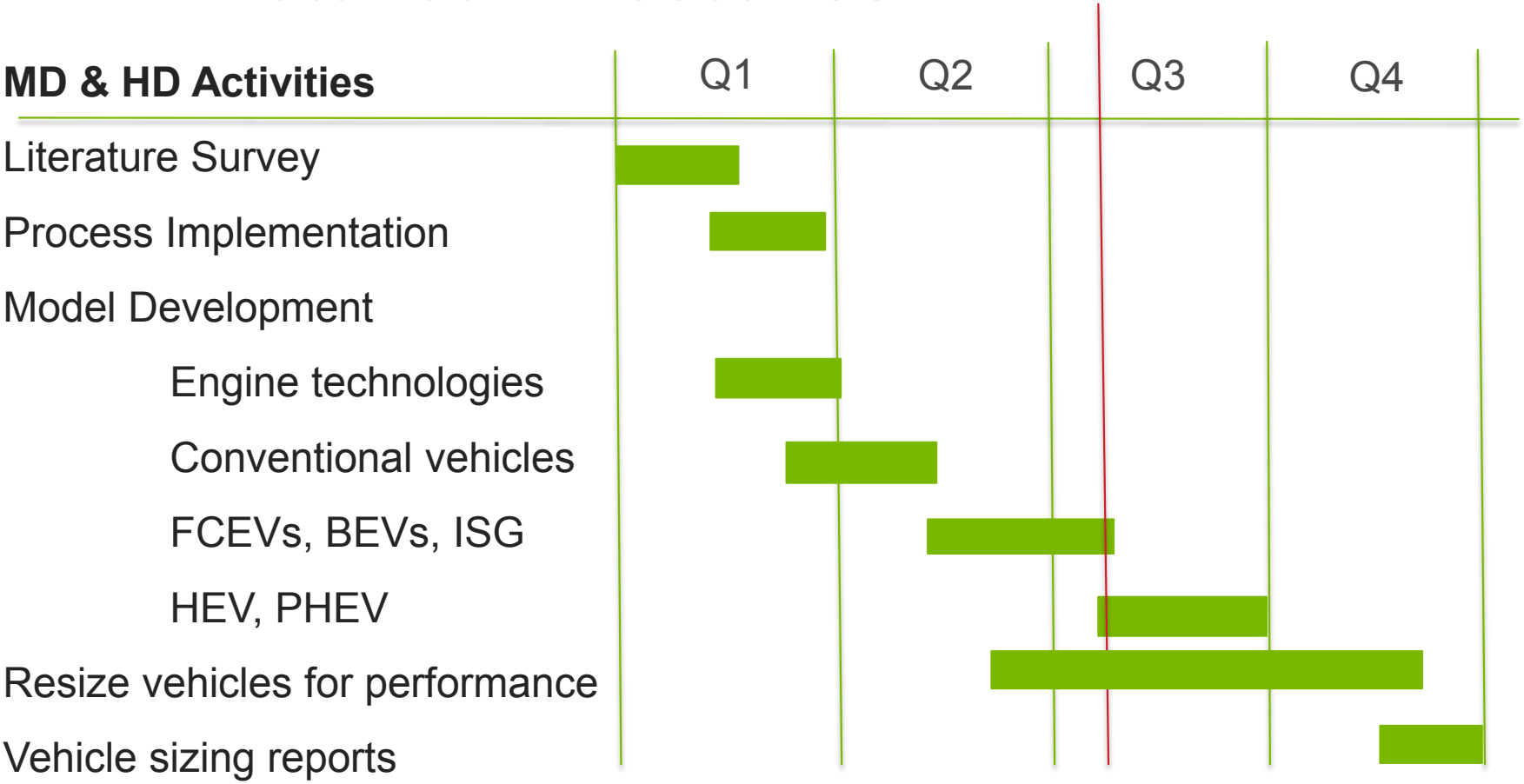
FY17 Detailed Milestones



Light Duty activities since last AMR

- Battery specific report was published.
- Process was developed to identify benefits attributable to individual technologies. (follow up study planned with Sandia)

Approach

Build on existing work from various agencies

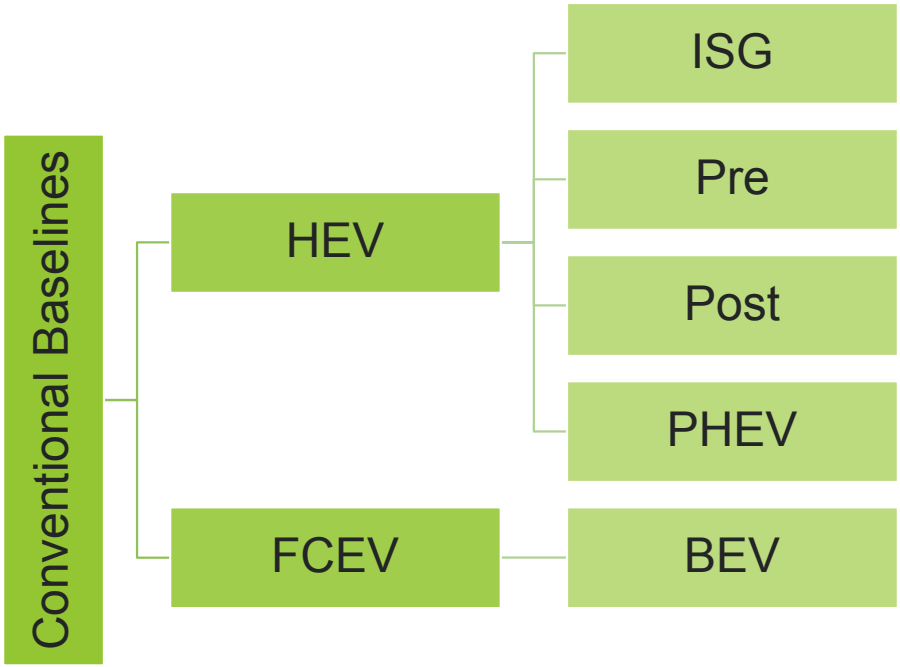
Component Specs
- EPA, GEM, SmartWay
- LLNL, SWRI, DOT, DOE

Classes & Vocations
- EPA regulation
- VIUS Database
- DOE & Industry feedback

Test Procedure
- EPA Regulatory Cycles

Sizing Parameters
- 6% grade speed
- Acceleration time
  - 0-30mph, 0-60mph
- Cruising speed
- Range

Technology Forecast
- National Labs
- Supertruck
- VTO, 21st Century Truck



Model building & simulation approach

Approach

Verify Consistency of Autonomie MD HD Models & Develop More Powertrain Options

- **FY 16**
  - Impact of Cd, Rolling resistance & Engine technology changes were verified against NHTSA Report *
  - Class 3, 6 & 8 were considered. (Dodge Ram, T270, T700)
  - Engine data taken from SWRI reports and EPA GEM model
- **FY 17**
  - Implement new MDHD regulatory test procedures from EPA
  - Expand the vehicle models to cover more classes/vocations
    - Define more powertrain options
  - Technology forecast based on
    - Technology progress seen in SuperTrucks
    - Discussions with OEMs, Suppliers
    - Public reports from National Laboratories and others

* DOT HS 812 146:
Commercial Medium- and Heavy-Duty Truck Fuel Efficiency Technology Study – Report #1

Approach

Expand Process Developed for Light Duty BaSce Analysis

Vehicles

- class 2 Van
- class 3 EnclosedVan
- class 3 SchoolBus
- class 3 Service
- class 4 WalkIn
- class 5 Utility
- class 6 Construction
- class 7 SchoolBus
- class 7 TransitBus
- class 8 Construction
- class 8 Linehaul
- class 8 Refuse
- class 8 Tractor

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Timeframes

- Current
- 2022
- 2032
- 2042
- 2055

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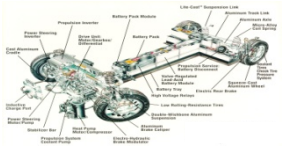
Powertrain Configurations

- Conventional 
-  ICE HEV
- PHEV 
-  Fuel Cell
- Electric 

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Fuels

- Gasoline 
-  Diesel
- Ethanol 
- H_2
- 

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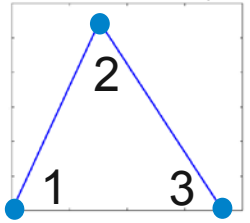
Triangular Uncertainty



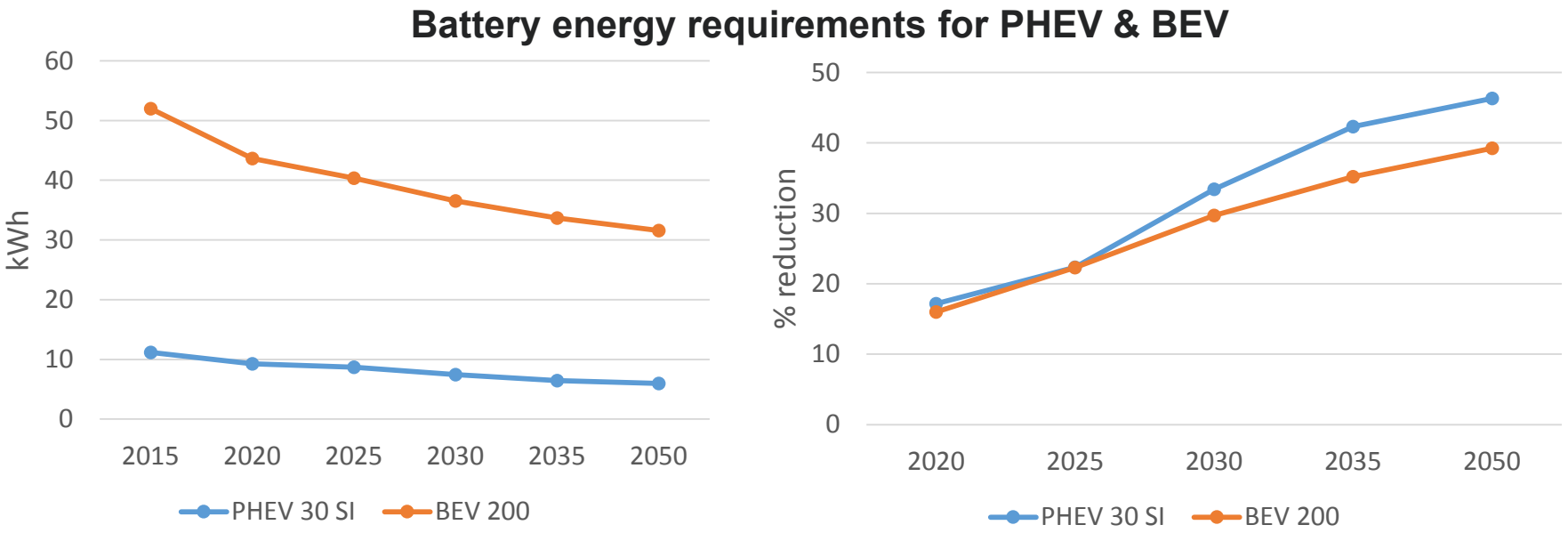
1 = 10%
2 = 50%
3 = 90%

~ 4000 Vehicles

Technical Accomplishments

Impacts of VTO Targets on Battery Requirements for LDV Report Released

- The goal of this analysis is to provide key figures and trends related to the battery
- The main dimensions reviewed include power requirements, energy requirements, power to energy (P/E) ratio, weight, and cost. We look at how those dimensions evolve over time, across vehicle platforms, and across vehicle powertrain (PWT) options..



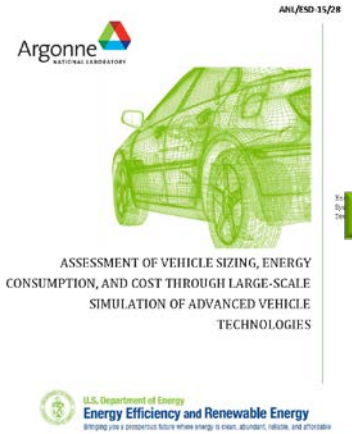
Report available under http://www.autonomie.net/publications/battery_requirements_report.html

Technical Accomplishments

VTO Targets Impact on Energy Consumption and Cost for Light Duty Vehicles Updated

- The benefits were updated for **light duty vehicles**, including new/updated vehicle performance (i.e., 0-60mph), powertrain configurations, component assumptions and vehicle control strategies
- Developed a new **cost benefit analysis tool (BEAN)** to quantify the economic viability of technologies

Reports



usage

- VTO Benefits
- EV Everywhere analysis
- USDRIVE C2G (Cradle to Grave) Working group
- GHG (GREET)
- Market penetration tools (MA3T, LAVE-Trans, LVCFlex, ParaChoice, ADOPT)
- BLAST-V (NREL)
- DOE Advanced Tech Modeling runs with NEMS
- Multiple research organizations (IEA, AVERE, NorthWestern Univ…)
- …

(1) New report under development. Previous reports available under at http://www.autonomie.net/publications/fuel_economy_report.html

Technical Accomplishments

Vehicle Models Developed for 13 Class/Vocation Combinations

- Represents over 50% of vehicle population based on VIUS data
- Distance based driver model is used for all MD & HD vehicles
  - As required by the EPA MDHD test procedure.

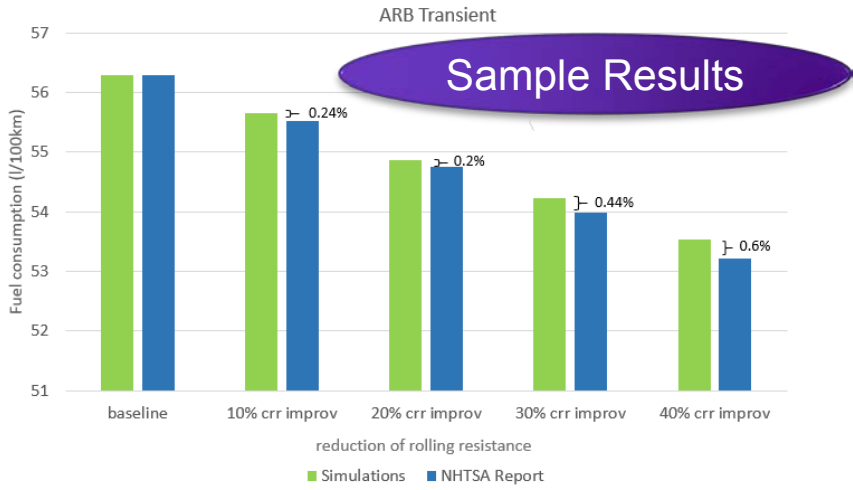
Properties		Class 2	Class 3			Class 4	Class 5	Class 6	Class 7	Class 8				
		Van	Closed Van	School Bus	Service Utility	Walk In	Utility	Constr.	School bus	Transit Bus	Constr.	Line haul	Refuse	Tractor
Summary	Baseline Engine (kW)	130	140	187	298	149	224	150	149	243	160	336	242	261
	Test Mass (lb)	8110	12149	13534	12083	15084	18547	23662	29385	32849	37437	71379	46306	55345
Perf.	Cargo Mass (lb)	1388	5898	5898	5720	7744	10340	14227	17747	4042	19934	43890	27280	31900
	Daily Driving (miles)	153	163	150	150	200	150	200	150	150	200	400	150	400
	Cruise Speed (mph)	70	70	70	70	70	65	65	60	60	60	60	60	60
	6% Grade Speed (mph)	66	49	48	70	40	65	27	33	40	28	31	28	25
	Accel Time 0-30mph (s)	6	6.4	5.6	5.8	7.2	8.8	11.6	18.5	17.1	16.7	16.9	14.7	16.3
	Accel Time 0-60mph (s)	19.1	23.5	20.1	13.7	34.9	23.3	46.3	62.8	49.7	73.9	60.9	56.4	65
Trans.	Auto / Manual	A	A	A	A	A	A	M	M	A	M	M	M	M
	Number of gears	6	5	6	5	5	5	6	6	5	6	10	8	10
	Number of driven axles	1	1	1	1	1	1	1	1	1	1	2	1	2

Technical Accomplishments

Technology Sensitivity Verified for MD & HD Conventional Vehicles

- Verified technologies and their sensitivity against published report from NHSTA
  - Rolling resistance
  - Aerodynamic drag
  - Various engine technologies
- Results were found to be consistent*
- Identified the need to have vocation specific vehicles
  - Eg: Class 8 Linehaul & Transit bus does not get same benefits from Aero improvements
- Indirect benefits
  - Updated Autonomie with MD & HD vehicles

Commercial Medium- and Heavy-Duty Truck Fuel Efficiency Technology Study – Report #1



*Changes in EPA test procedure diminishes the usefulness of all prior work

Technical Accomplishments

Vehicle Definition and Sizing Completed for Half of the Vehicles

- Scripts developed for initializing a target powertrain using the conventional vehicle information.
- Sizing based on performance
  - FCEV sizing scripts *(2016 AMR: TV032)* updated for new EPA procedure
  - BEV sizing scripts developed.
  - Other hybrids (building & sizing in progress).
    - Modified the MD HD gear shift control logics for hybrid operations.
    - Adapted LD sizing logic for MD HD vehicle

Powertrain	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
Conventional	Done	Done	Done	Done	Done	Done	Done
ISG	Done	Done	Done	Done	Done	Done	Done
Par Pre Trans	Building	Building	Building	Building			
Par Post Trans							
Fuel Cell	Done	Done	Done	Done	Done	Done	Done
Electric	Sizing	Sizing	Sizing	Sizing	Sizing	Sizing	Sizing

Sizing = sizing algorithm completed. Vehicles are currently being sized to meet similar performances as the conventional powertrains

Response to Previous Year Reviewers' Comments

Comments related to Vehicle Modelling Efforts

- The reviewer suggested that the presenter consider the addition of electrification; for example, plug-in hybrid electric vehicles (PHEV) or fuel cell vehicles (FCV), for medium-duty vehicles (MDVs) and heavy-duty vehicles (HDVs).
  - *Medium & Heavy Duty Electrification has been the main focus in FY17*
- The reviewer said that Autonomie should continue to collaborate with industry and others to continue to seek good empirical input and review.
  - *Argonne's development team is in constant communications with multiple OEMs.*
  - *As part of non DOE funded projects*
    - *Autonomie team collaborated with 3 major OEMs to develop and validate vehicle models*
    - *Lessons learnt from these projects are imbued in Autonomie*
  - *21CTP, SmartWay & Supertruck programs also contribute to this effort*

Partnerships and Collaborations

- **Government Agencies**
  - DOE : EV Everywhere analysis, Advanced Tech Modeling runs with NEMS
  - DOT : Collaboration about baseline assumption definition
  - EPA : Autonomie MD & HD vehicle models used for analysis to inform SmartWay program
- **Industry**
  - USDRIVE (e.g., inputs to the C2G working group)
  - Discussions with OEMs, Suppliers
- **National Labs**
  - Market penetration tools (MA3T, LAVE-Trans, LVCFlex, ParaChoice, ADOPT)
  - Life cycle analysis tool (GREET)
- **Other organizations**
  - IEA, AVERE, multiple universities…

Remaining Challenges and Barrier

Need a Formal Mechanism To Capture Industry Inputs On MD&HD Activities

- Current assumptions are based on
  - Lessons learnt from working with OEMs on various projects
  - Informal discussions with various OEMs & Suppliers
  - Field test reports from various agencies

- 21CTP is a potential resource for providing the necessary inputs for this work.

Next Steps & Proposed Future Research

Expand Technology Benefits Forecast

- Light Duty Activities
  - Finalize the summary report
  - Improve vehicle models for future runs based on lessons learnt from industry funded projects
  - Increase number of powertrain configurations and component technologies to represent a larger share of the market
- Medium & Heavy Duty
  - Complete sizing of MD & HD hybrid vehicles
  - Evaluate the vehicle technology benefits as per the “Technology Forecast”
  - Identify potential class/vocations for specific vehicle technologies
    - Eg: Economic viability of hybrid powertrains on delivery trucks
  - Refine class/vocation mix based on feedback
- Deploy the large scale simulation process with the release of AMBER (EEMS013)

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

Summary

LD Study Complete, MD & HD Study on Track.

- Light Duty Activities
  - Report released describing the impact of VTO targets on battery requirements.
  - Completed new analysis of VTO benefits for LDVs
  - Final report expected Q3 FY17
- Medium & Heavy Duty Activities
  - Baseline vehicles have been defined for 13 Medium & Heavy duty class & vocations
  - Automated sizing process is developed for BEVs, FCEVs, ISG and other hybrids
  - Technology sensitivity was verified against NHTSA reports.
  - Sized vehicles and first results expected by Q4 FY17