Project ID # VAN030

Assessing Energy and Cost Impact of Advanced Technologies for Medium and Heavy Duty Vehicles

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Project Overview

Timeline	Barriers*
• Project start date : Oct FY18 • Project end date : Sep FY19 • Percent complete : 60%	• Risk aversion • Constant advances in technology • Cost • Computational models, design, and simulation methodologies *from 2011-2015 VTP MYPP

Budget	Partners
• FY19 Funding : $250K	• Energetics • Sandia National Laboratory • DOE tech teams • 21CTP members

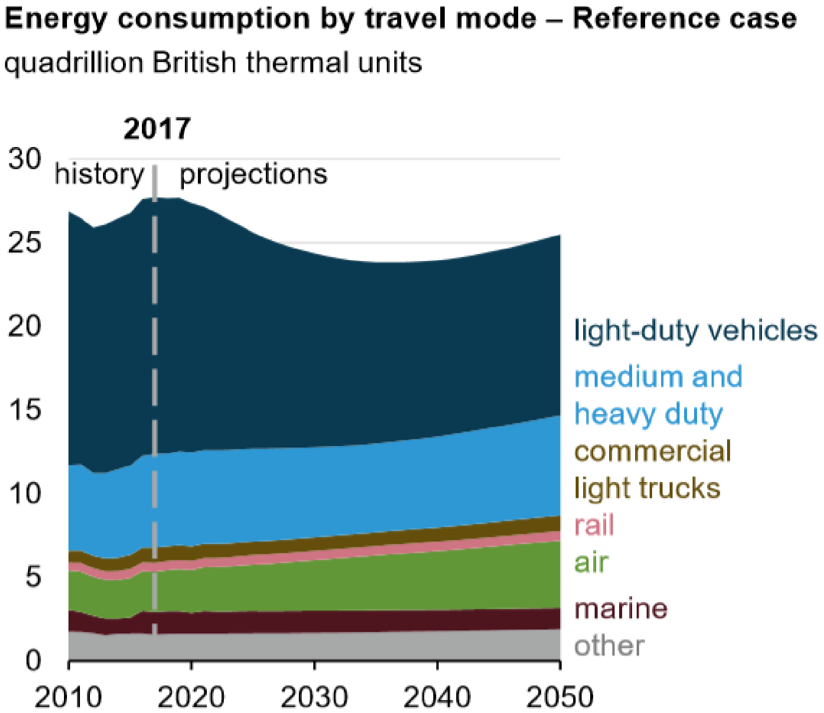
Project Relevance

Quantify energy and cost benefits of vehicle technology improvements for medium & heavy duty vehicles

- Medium duty (MD) & Heavy duty (HD) vehicles consume more than a quarter of energy in transportation sector. Benefits of vehicle technology improvements for these vehicles are not well understood.

- A large scale analysis of multiple classes and vocations is needed to quantify the fuel saving potential of various vehicle technologies.

- Results will be combined with market penetration data to quantify the overall petroleum displacement potential of a technology.



Ref: EIA, Annual Energy Outlook 2018

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Objectives

- **What are the benefits of VTO technologies?**
  - *Quantify the petroleum displacement potential of advanced vehicle technologies.*
  - *Provide energy consumption and cost estimates to market penetration experts.*
- **What are the impacts of achieving the targets?**
  - *Compare two scenarios for technology improvements in specific components. Business as usual vs. DOE/VTO/FCTO targets.*
  - *Quantify the improvements attributable to success of DOE programs*
- **What are the impacts on Total Cost of Ownership (TCO)?**
  - *Estimate the cost impact of improving technologies.*
  - *Compare the initial investment against fuel/operational cost savings*
- **Who should be the early adopters of new technologies ?**
  - *Identify use cases and technologies which*
    - *Minimize energy consumption (DOE's goal)*
    - *Minimize cost of ownership (Fleet Operator's goal)*

This work provides feedback to DOE managers about implications of the technology targets and supports the market penetration analysis work (**VAN-018)**

Approach

Build on existing large scale simulation process

Component Specs

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

Classes & Vocations

- EPA regulation
- VIUS Database
- DOE & Industry feedback

Test Procedure

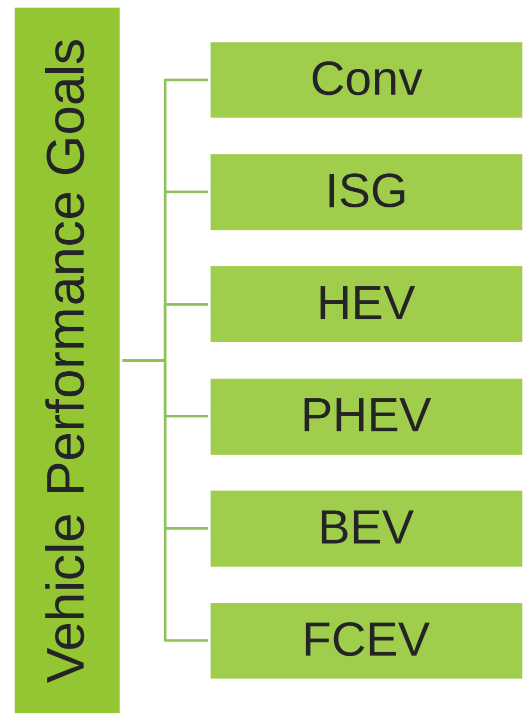
- EPA Regulatory Cycles

Sizing Parameters

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

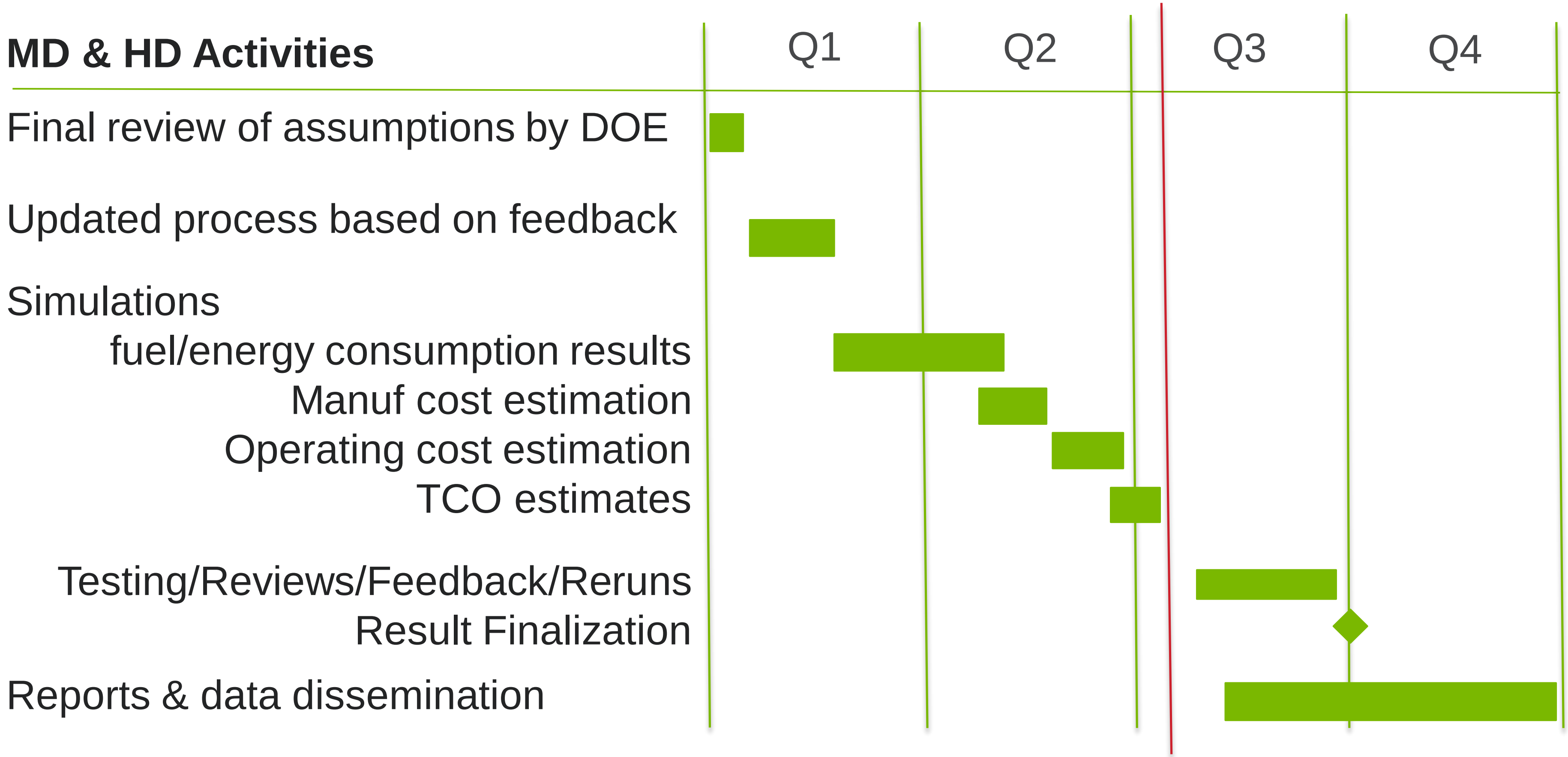
Technology Forecast

- National Labs
- Supertruck
- VTO, 21st Century Truck, NACFE



Performance based sizing approach

Project Milestones



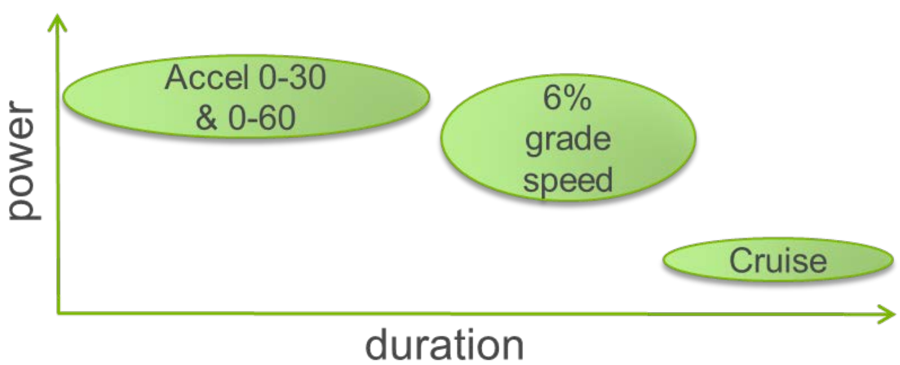
Market penetration analysis (VAN 18) performed in parallel

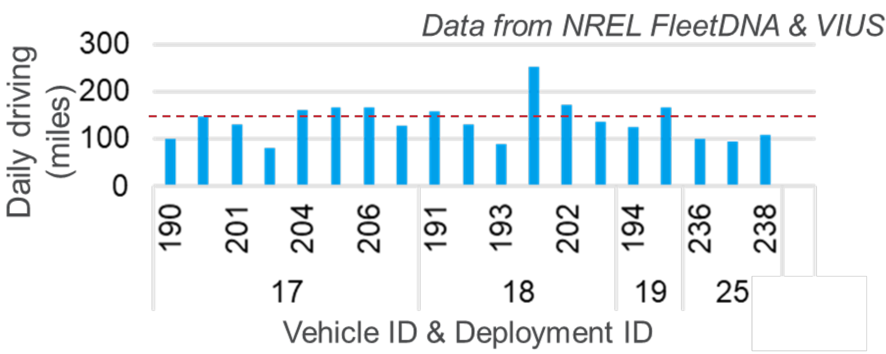
Approach

Performance Based Sizing Ensures Fair Comparison Between Different Powertrains

- No trade off on payload or performance
  - Fixed payload across all powertrains
  - Match or better the conventional vehicle in performance
- BEVs range will depend on the application.
  PHEVs will have 50 % all electric range as the BEV.

Powertrain	Engine	Motor	Battery
Conventional	Acceleration Grade & Cruise		
ISG		Size based on Starter & Alternator	Energy: Sustain electric loads for at least 1 minute*
HEV		Maximize regen in ARB Transient	Power: to sustain peak motor output
PHEV	Grade & Cruise	Acceleration Grade & Cruise	Energy: Electric Range Driving Range in EPA 65. Power: Sufficient power to support motor & aux loads
BEV			





As performance parameters are not widely published for heavy vehicles, the baseline values are estimated through simulations.

Accomplishments

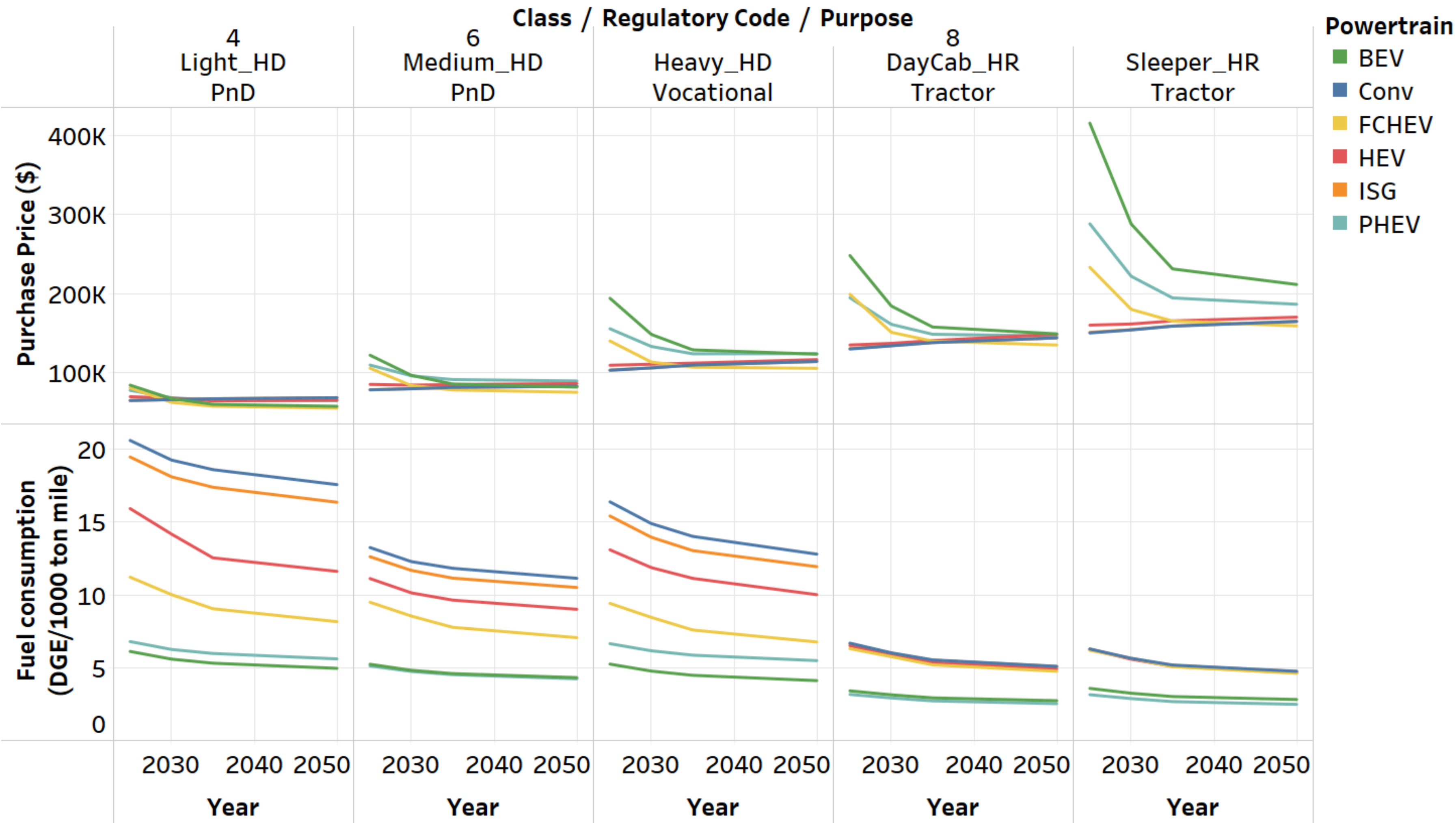
Large Number of Classes and Applications Considered

Class	Vocation
2b	Small Van
3	Enclosed Van
3	School Bus
3	Service, Utility Truck
4	Walk In, Step Van
4	Light HD
5	Utility, Tow Truck
6	Construction, Dump Truck
6	Medium HD
7	School Bus
7	DayCab (3)
7	Medium HD
8	Construction, Dump Truck
8	Sleeper NACFE
8	Refuse, Cab over type
8	Tractor Trailer
8	40' Transit Bus
8	Heavy HD
8	DayCab (3)
8	Sleeper (3)

- 20 class vocation combinations are available. This covers more than half of the medium and heavy vehicle population in US.
- Different market penetration models use subsets of this list for their analysis
- FCEVs were added to this analysis work in FY19 to include FCTO benefit analysis
- 6 powertrains are available for each of these trucks.
    - Gasoline & CNG variants are being added for some of the classes
- Result templates are developed in discussion with Energetics, Sandia and DOE to share the simulation results with other agencies

Accomplishments

Estimated Fuel Economy and Cost for Medium & Heavy Duty Trucks

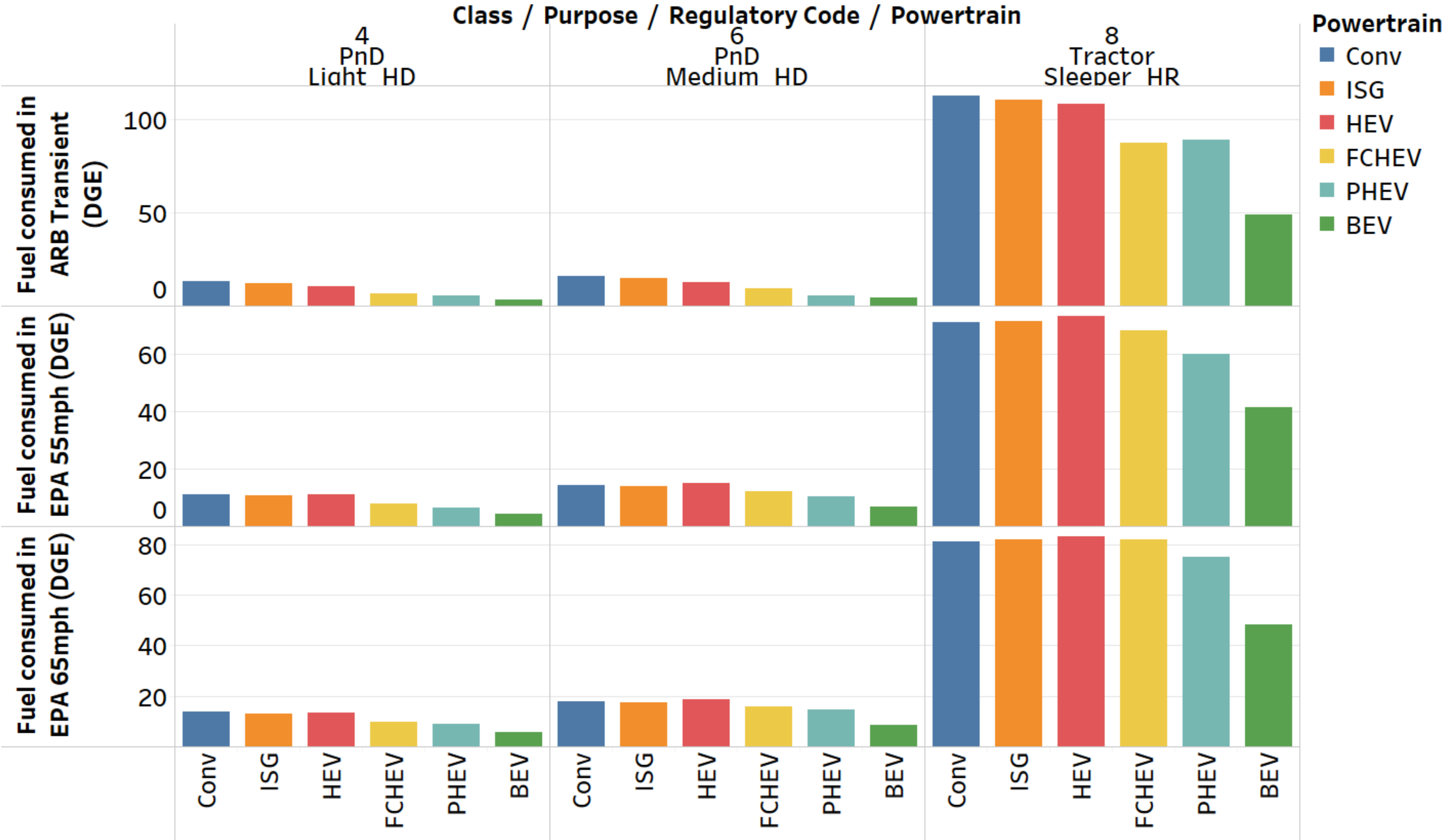


Class 4, 6 and 8 vehicles are used by Energetics for VTO benefit analysis

Fuel consumption is in diesel gallon equivalent (DGE)

Accomplishments

Quantified Fuel Saving Potential of Various Powertrains

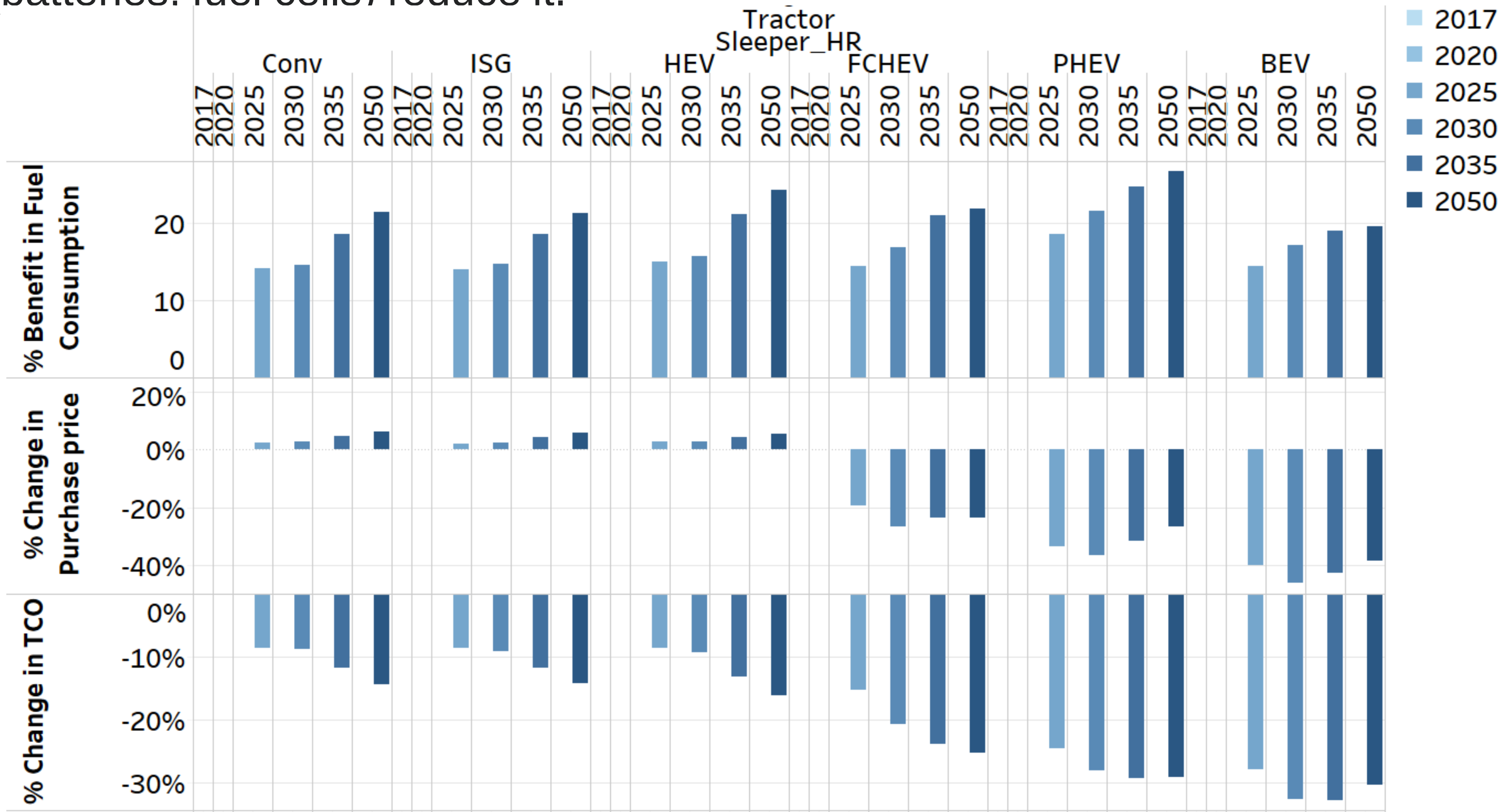


Eg. Class 4&6 vehicles are expected to run 150 miles/day.
All powertrains have the same cargo mass and driving distance

Accomplishments

Quantified Target Impact on Energy Consumption, Price and TCO

- Meeting DOE targets result in lower TCO in all cases. The magnitude differs for each vehicle class and powertrain. Class 8 Sleepers are shown as example.
- Some technology targets (engine, aero, light weighting) increase cost while others (batteries, fuel cells) reduce it.



% change between the ‘business as usual’ and ‘DOE target’ cases

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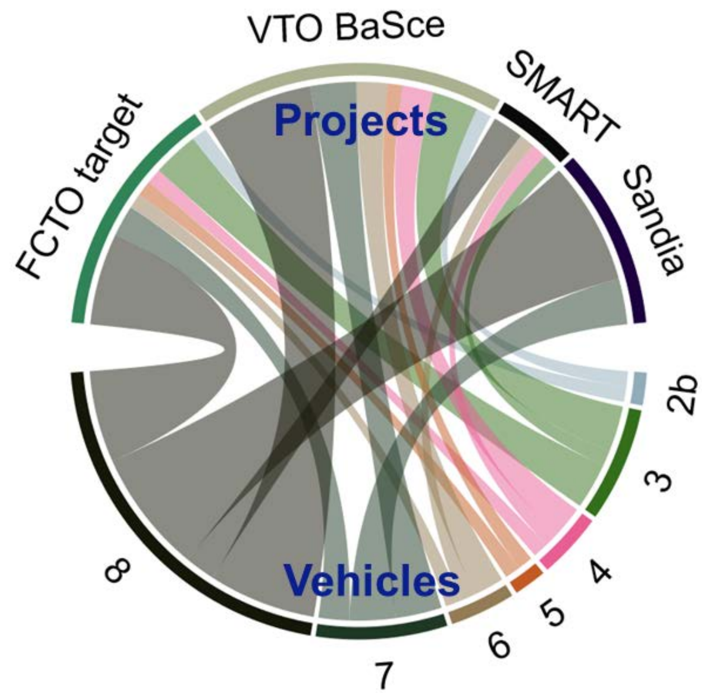
Remaining Challenges and Barriers

- Maintenance cost needs to be factored in for advanced powertrains
- Consider driver wages as part of TCO calculation to factor in benefits of CAV technologies
  - Prior estimates by Ricardo & ATRI are being used as starting point for this work
- A short range BEV is a desirable addition to the existing powertrain choices to verify the benefits of fast charging capabilities.
- The major challenge in the overall process is the integration of this workflow into AMBER* to facilitate the use of high performance parallel computing clusters.

* AMBER is the new tool from Argonne to carry out large scale simulations

Collaborations

- Cost estimates for components were reviewed by 21CTP partners through DOE tech managers.
- Vehicle range requirements were updated based on feedback from fleet operators (UPS, Fedex, …) who participated in a workshop conducted by FCTO.
- Past studies conducted by Energetics was useful in cost estimation of technologies.
- Engine testing activities in Argonne provided CNG maps
- CSE & Univ of Texas provided information on their FCEV prototype to aid modelling work.



The models developed as part of this work supports several activities within DOE.

Proposed Future Work

- Improve estimates of vehicle ownership period and real world driving distances
  - Make class/vocation specific estimates
  - Exploring whether 21CTP can provide feedback on this
  - Truck consortium.

- Sandia requested fuel consumption values from real world cycles
  - FleetDNA data is available for some vehicle use cases.
  - Compiling the models will be desirable to evaluate thousands of real world scenarios. Autonomie/AMBER is being updated to automate this process.

Summary

- Estimated fuel saving potential of various powertrain technologies for each class and vocation.
- DOE targets will
  - Save at least 15% in fuel/energy consumption.
  - Increase purchase cost of some trucks due to investment in better technology
  - Reduce TCO for all trucks by 8% or more.
- For petroleum displacement, Class 8 trucks should be the primary choice for implementing new technologies.
- Smaller trucks with urban use cases will likely see more economic benefits from adopting the new technologies.

THANK YOU

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BACKUP

Performance Assumptions

Estimated from simulation results of conventional vehicles, as described in EPA/NHTSA rulemaking documents

Class	Purpose	Regulatory Code	0-30mph (s)	0- 60mph (s)	grade speed 6% (mph)	Max. Speed (mph)	Daily Driving Range (miles)
8	Tractor	Sleeper_HR	18	66	30	65	500
8	*Tractor*	*Sleeper_MR*	*18*	*66*	*30*	*65*	*500*
8	*Tractor*	*Sleeper_LR*	*18*	*66*	*30*	*65*	*500*
8	Tractor	DayCab_HR	18	66	30	65	250
8	*Tractor*	*DayCab_MR*	*18*	*66*	*30*	*65*	*250*
8	*Tractor*	*DayCab_LR*	*18*	*66*	*30*	*65*	*250*
8	Vocational	Heavy_HD	18	66	25	60	200
7	Tractor	DayCab_HR	18	66	30	65	250
7	*Tractor*	*DayCab_MR*	*18*	*66*	*30*	*65*	*250*
7	*Tractor*	*DayCab_LR*	*18*	*66*	*30*	*65*	*250*
7	Vocational	Medium_HD	18	66	25	60	200
6	PnD	Medium_HD	14	50	37	70	150
4	PnD	Light_HD	10	30	50	70	150
3	PnD	Light_HD	8	30	50	70	150

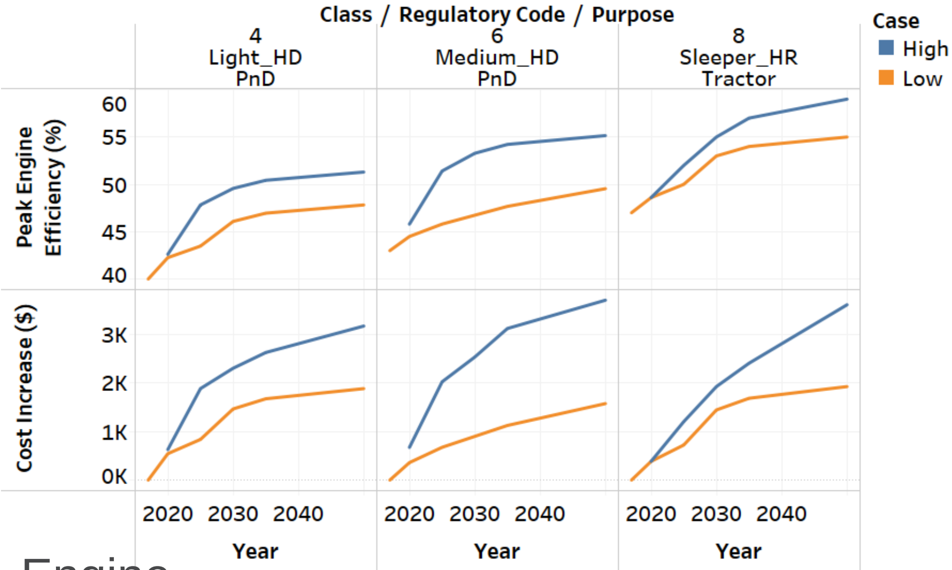
Daily driving range is estimated from VIUS, FleetDNA & feedback from FCTO workshop

– PHEVs AER = 50% of daily driving distance.

– BEVs assumed to charge once per day.

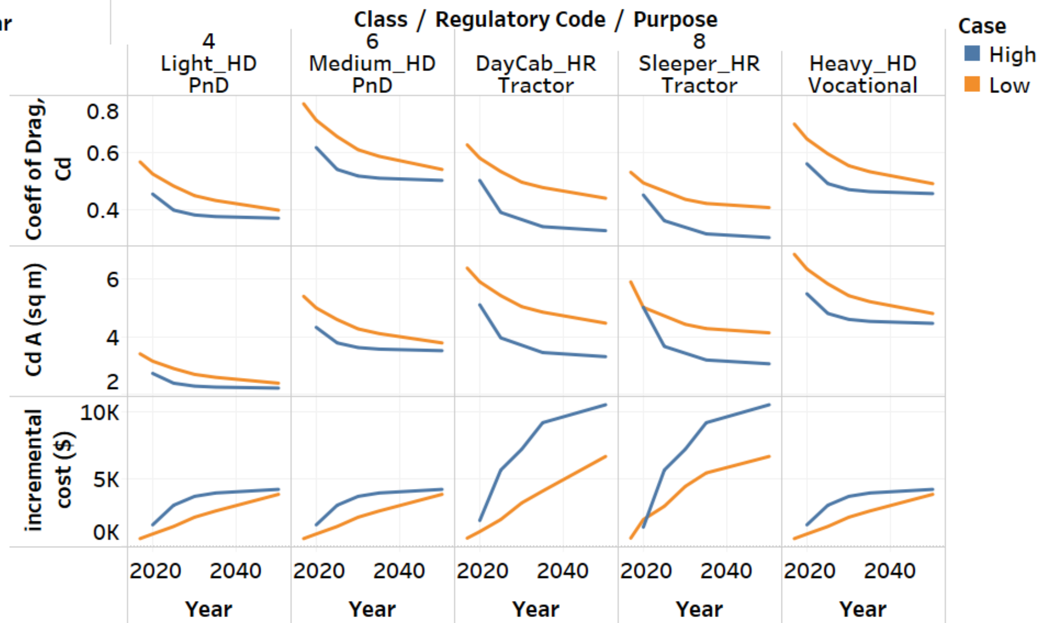
Technology Assumptions

Engine & Aero



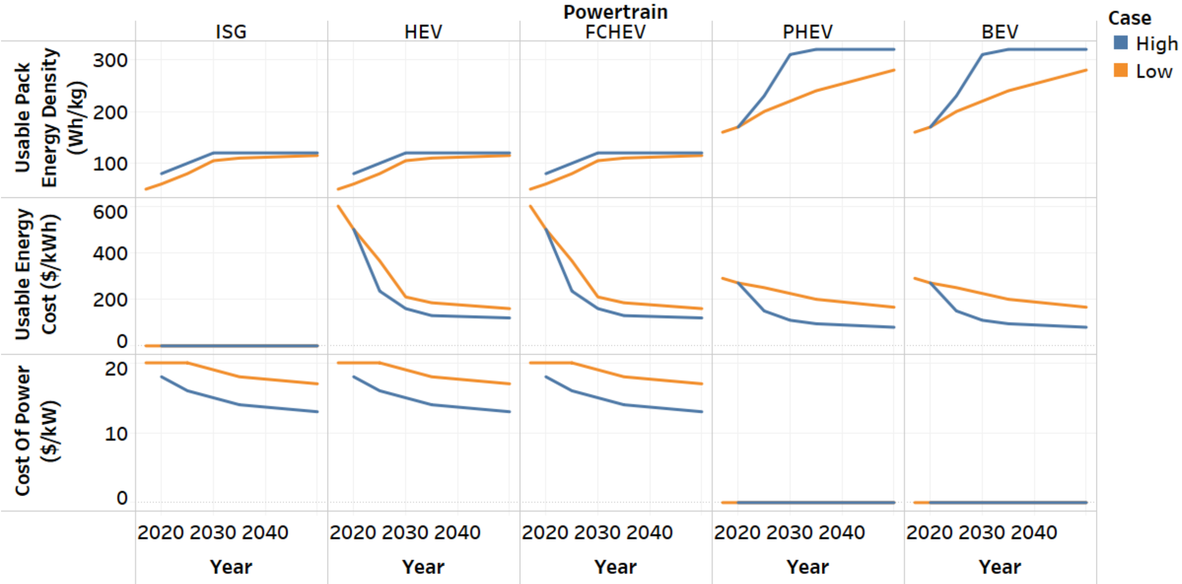
Engine

Aero

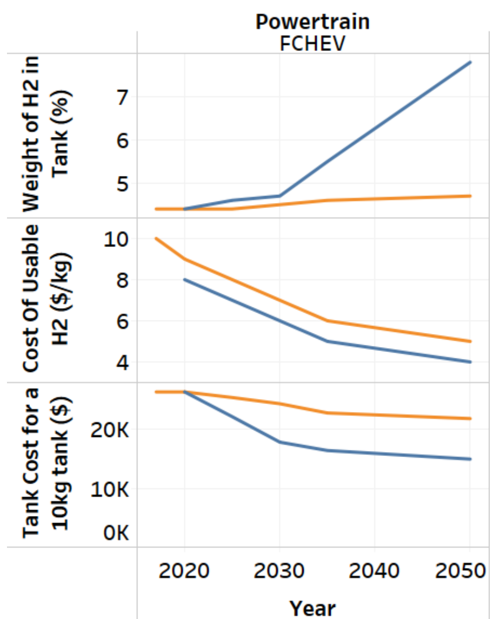


Technology Assumptions

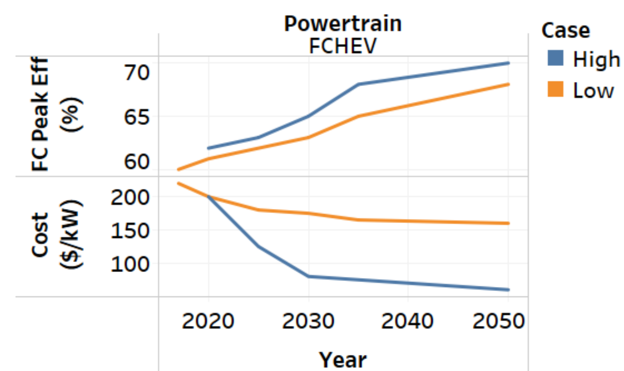
Battery and Fuel cell technologies



Battery

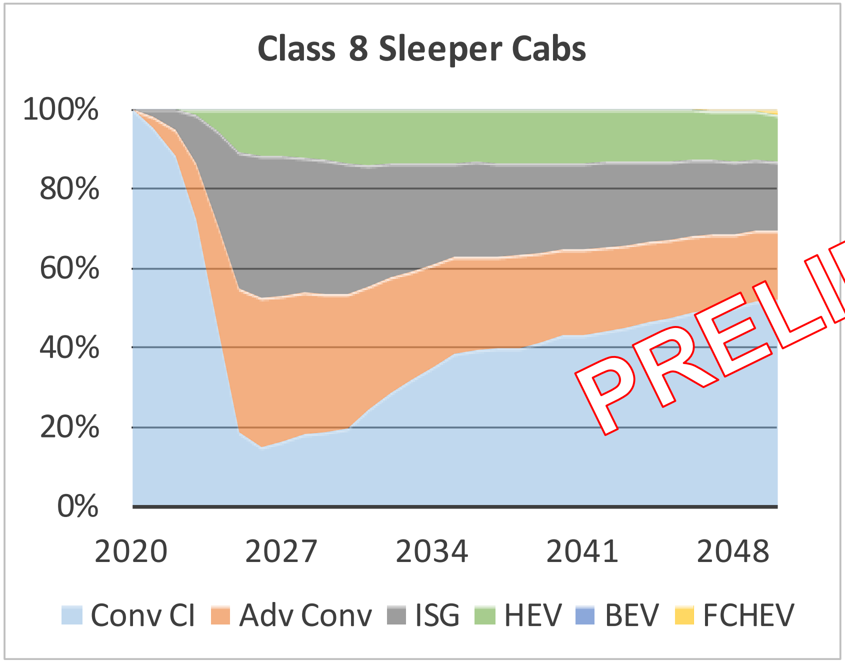


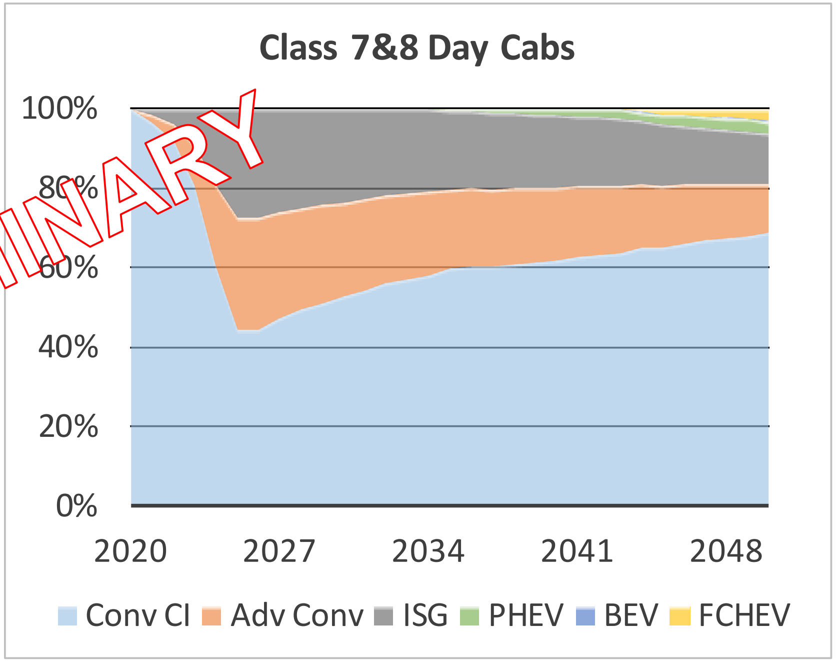
Fuel cell & H_2 storage



From **VAN 018**

Projected Shares of Advanced-technology Vehicle-miles Traveled





- More advanced vehicle technologies penetrate the market early, but higher costs in later years inhibit deep market penetration
- Error bars show ranges based on multiple stock mixes of light-duty vehicles