End-to-End Use of ALPHA Vehicle Simulation in EPA's GHG Standards Assessments: From Baseline to Future Fleets

SAE Government-Industry Meeting

January 25, 2018

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Overview

- Where are we?
  - Recent EPA initiatives
  - Stakeholder input
- EPA work on the assessment of technology effectiveness estimates
- End-to-End ALPHA Modeling
  - ALPHA, start – Simulation of Baseline Fleet
  - ALPHA, middle – Large scale simulation of possible future packages
  - ALPHA, end – Simulation of Future Fleet
- Conclusions

Consideration of New Data/Analysis since 2016 Proposed Determination

March 22, 2017 FR Notice from Administrator Pruitt - Announces EPA's plans to reconsider the January 2017 Final Determination, and to issue a new Final Determination by end of March, 2018, in accordance with EPA's regulations

- EPA's regulations provide a specific list of technical information EPA will consider

Following the Administrator's March 22, 2017 FR Notice announcing that he would be reconsidering the Final Determination, the Administrator sent a letter (May 2, 2017) to California Governor Brown saying:

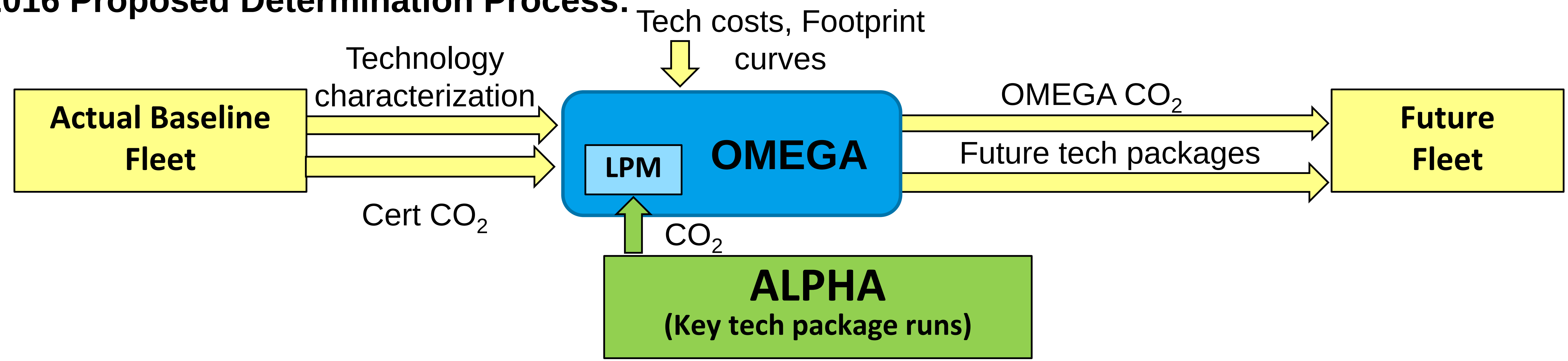
- "*this reconsideration will be based on the **best available data** and part of a robust, timely and inclusive process*"

Administrator's August 21, 2017 FR Notice:

- "*EPA is announcing that it is reconsidering whether the light-duty vehicle greenhouse gas standards previously established for model years 2022-2025 are appropriate under section 202(a) of the Clean Air Act and invites stakeholders to **submit any comments, data, and information they believe are relevant to the Administrator's reconsideration of the Final Determination** and in particular, **highlight any new information**.*"
- "*This additional comment period provides an opportunity for commenters to submit to EPA **additional studies and other materials** as well as to complete the preparation of their comments, or **submit additional comments in light of newly available information**.*"

Stakeholder input on EPA's effectiveness modeling approach

2016 Proposed Determination Process:



Themes from Stakeholder Comments:

Comment: It is important to appropriately asses the level of technology in current vehicles

Comment: Methodologies for calibrating the Lumped Parameter Model (LPM) and generating tech package effectiveness values are not transparent

Comment: Uncertainty when applying tech effectiveness values for vehicle classes to individual vehicles

- The LPM 0-D modeling introduces uncertainty
- The modeled benefits of mass reduction should be consistent with the benefits in certification
- The OMEGA model output proliferates the number of engine displacements

Response to Stakeholder input on EPA's effectiveness modeling approach: Expanded application of ALPHA simulation

Expanded application of ALPHA simulation end-to-end throughout process, from baseline fleet to future fleet:

- Comment: It is important to appropriately asses the level of technology in current vehicles

Start

New: Refine technology characterization through simulation of individual baseline vehicles

- Comment: Methodologies for calibrating the Lumped Parameter Model (LPM) and generating tech package effectiveness values are not transparent

Middle

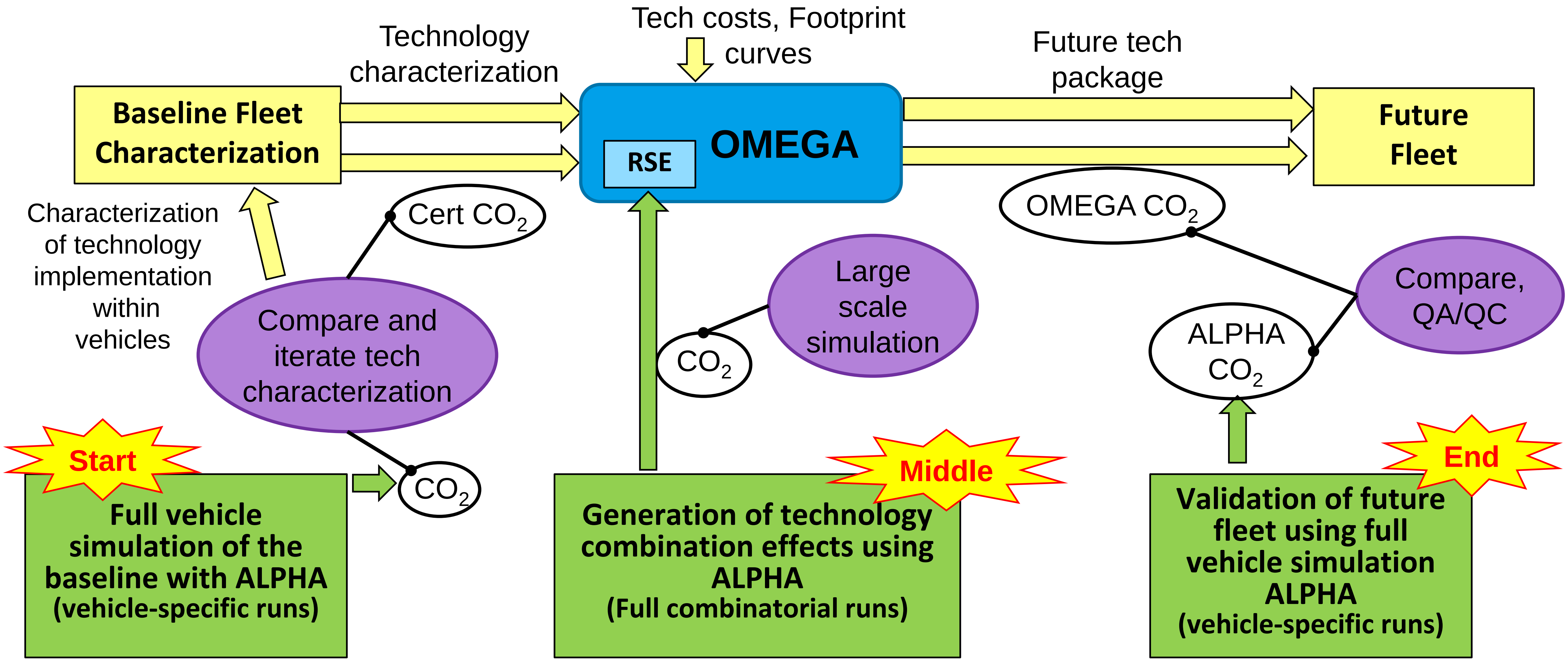
New: Replace LPM with Response Surface Equations based on full combinatorial simulation

- Comment: Uncertainty when applying tech effectiveness values for vehicle classes to individual vehicles
  - The LPM 0-D modeling introduces uncertainty
  - The modeled benefits of mass reduction should be consistent with the benefits in certification
  - The OMEGA model output proliferates the number of engine displacements

End

New: ALPHA simulation of OMEGA future tech packages for individual vehicles

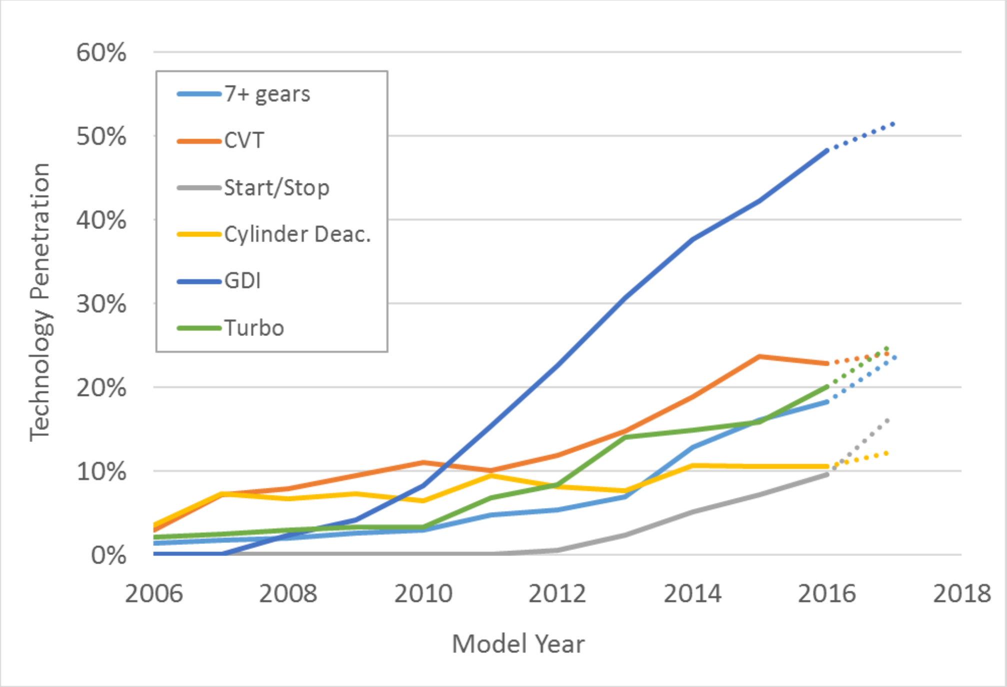
Response to Stakeholder input on EPA's effectiveness modeling approach: Expanded application of ALPHA simulation



Characterizing the Baseline Fleet: Overview

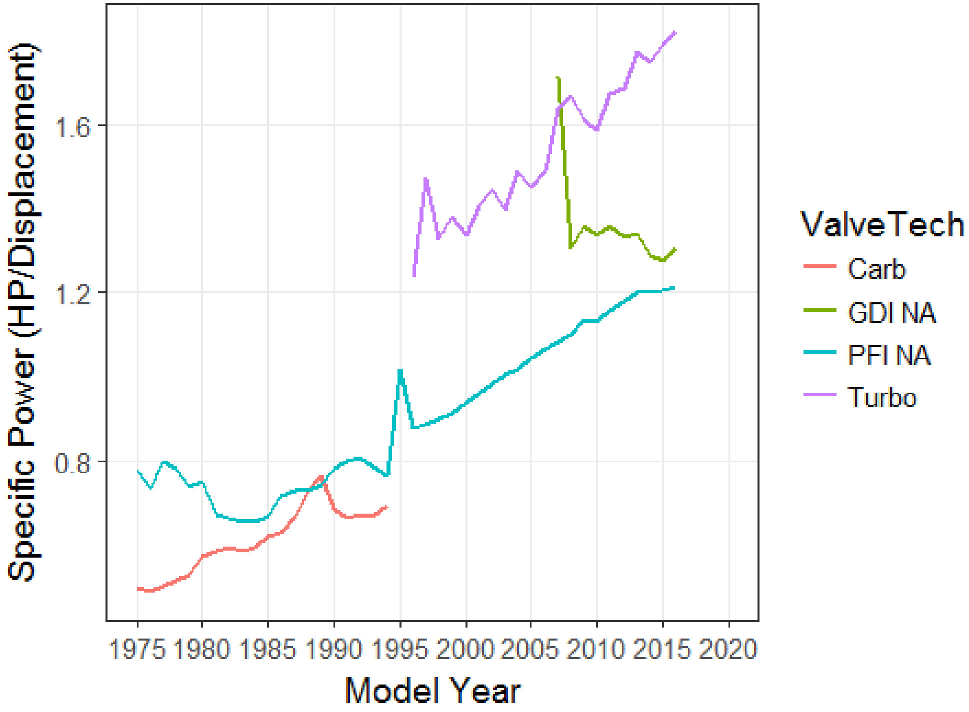
- Every year, emissions-reducing technologies are introduced into the fleet
- Technology must be evaluated each time baseline is updated

(E.g. MYs 2014→ 2015 → 2016)



- Difficult to classify technologies based only on descriptions since implementations may vary
  - Differences in application
  - Technology improvements over time

(E.g. different generations of turbocharged engines)



Characterizing Powertrains in the Baseline Fleet

- Continued expansion of the ALPHA powertrain model library for greater resolution simulating the MY2016 fleet

Key

powertrain models now in ALPHA library*

- Previously available in ALPHA library
- Not previously available in ALPHA library
- Previously available in ALPHA library, but not previously considered for baseline fleet
- Not previously available in ALPHA library, but incorporated into LPM based on Ricardo work

Engine models in ALPHA

PFI I-config	PFI V-config	GDI I-config	GDI V-config	Turbo I-config	Turbo V-config	Atkinson I-config
w/VVT	w/VVT	w/VVT	w/VVT	1st gen	1st gen	w/o CEGR
w/VVT,VVL	w/VVT,VVL	w/VVT,VVL	w/VVT,VVL	2nd gen		w/ CEGR
w/ DEAC	w/ DEAC	w/ DEAC	w/ DEAC			

Transmission models in ALPHA

Step Count & Ratio Spread:

Trans Efficiency & Thermal Mgmt	Low	Medium	High
null	TRX00		
1st gen		TRX11	TRX21
2nd gen		TRX12	TRX22

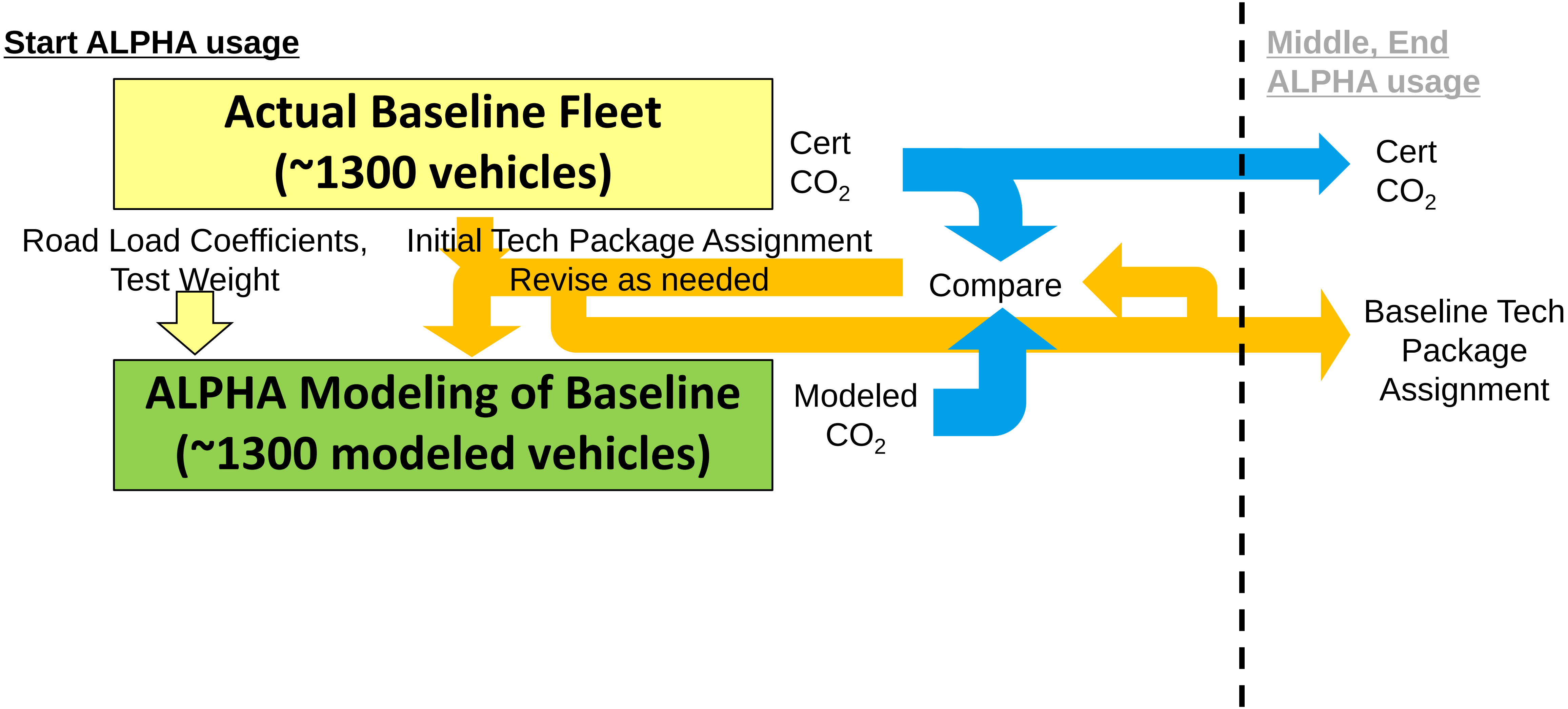
Accessory models in ALPHA

Power Steering

	Electric	Hydraulic
Base Alternator	IACC1 w/ EPS	IACC1 w/ HPS
High Efficiency Alternator	IACC2 w/EPS	IACC2 w/ HPS

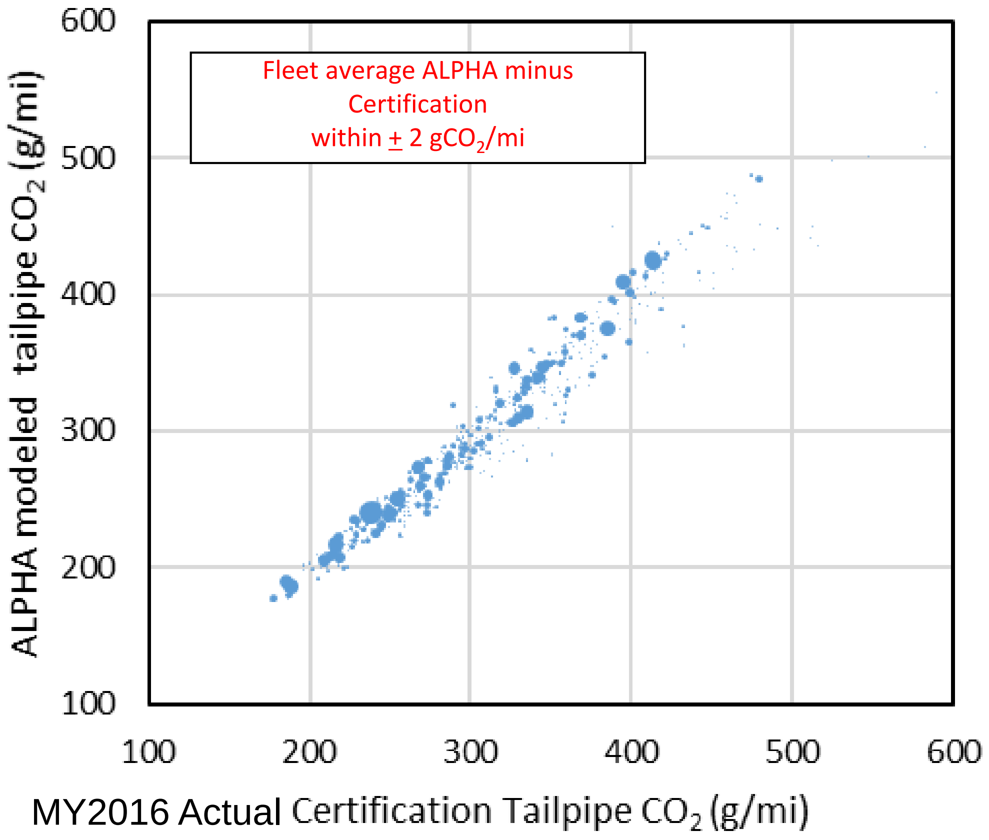
*ALPHA powertrain models applied only to future fleet are not shown

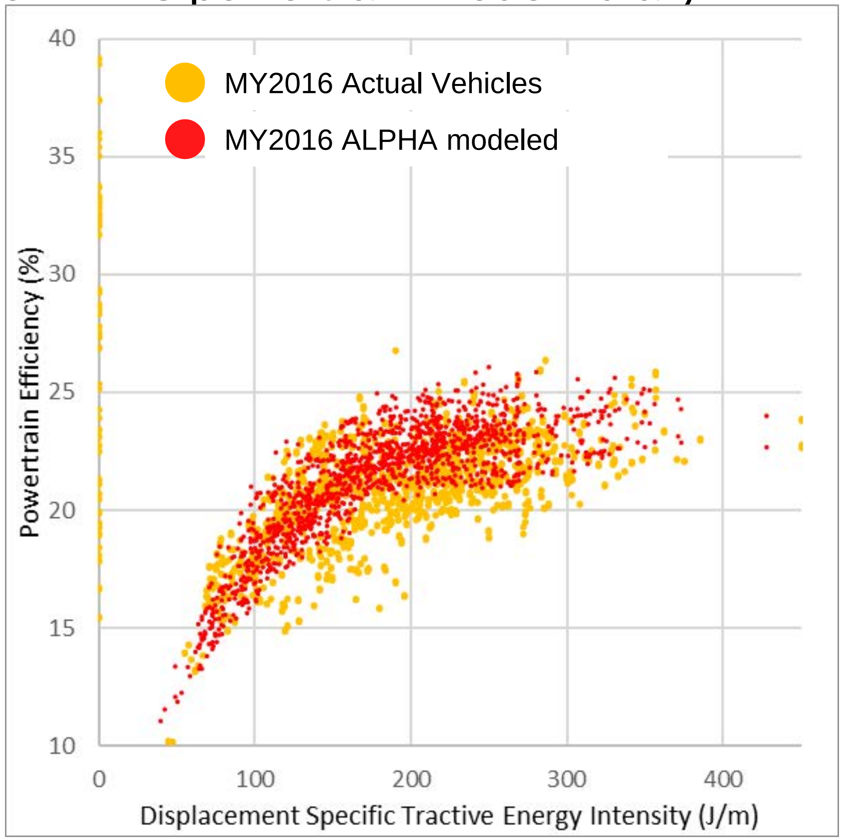
ALPHA Simulation of Individual Vehicles in the Baseline Fleet



Results: ALPHA Simulation of Individual Vehicles in the Baseline Fleet

- ALPHA simulation results for MY2016 fleet within ±2g CO_2/mi (sales-weighted) of actual certification CO_2 values
- Some outliers exist, potentially due to either 1) uncertainty in road load, test weight, or CO_2 values in certification data, or 2) powertrains that fall outside the scope of EPA's powertrain model library





*note: All MY2016 baseline vehicles shown, except those with strong electrification (HEV/PHEV/EV).

A note on Characterizing Road Load Reductions in the Baseline Fleet

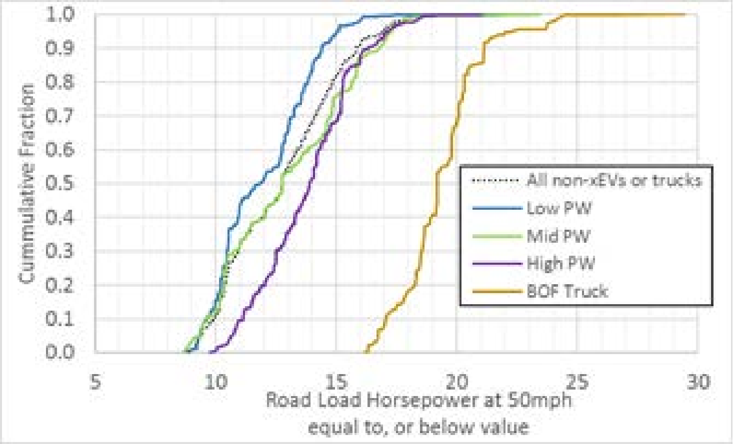
- Simulation of individual vehicles in the baseline fleet can be conducted without specific data for load-reducing technologies by direct use of road load coefficient and test weight values
- However, technology characterization is still needed for cost estimation and for identifying the opportunity for additional improvement
- EPA's goal for characterizing road load technologies is to use publicly available data and methodologies that are replicable by stakeholders, specifically:
  - Aerodynamic and non-aerodynamic technology characterization
    - Utilize road load coefficients and dimensional data from various public sources
    - Generate distributions of aero- and non-aero drag by within market classes
    - Bin vehicles into aero- and non-aero technology groups to indicate potential for improvement
  - Mass reduction characterization (multiple approaches);
    - Longitudinal: Curb weight changes between redesigns, adjusting for key factors (E.g. vehicle size, AWD)
    - Cross-sectional: Curb weight comparison amongst MY2016 vehicles, accounting for differences in various vehicle attributes

Large Scale ALPHA Simulation of Future Technologies : Overview

- Use effectiveness values only for technology combinations modeled in ALPHA
- Adjust class-specific effectiveness values appropriately for application to individual vehicles
- Leverage parallel computing to perform large number of runs in reasonable time
- Conduct runs at a level of resolution that provides accurate effectiveness values while minimizing use of computational resources

Determination of Vehicle Classes

Power-to-weight ratio distribution



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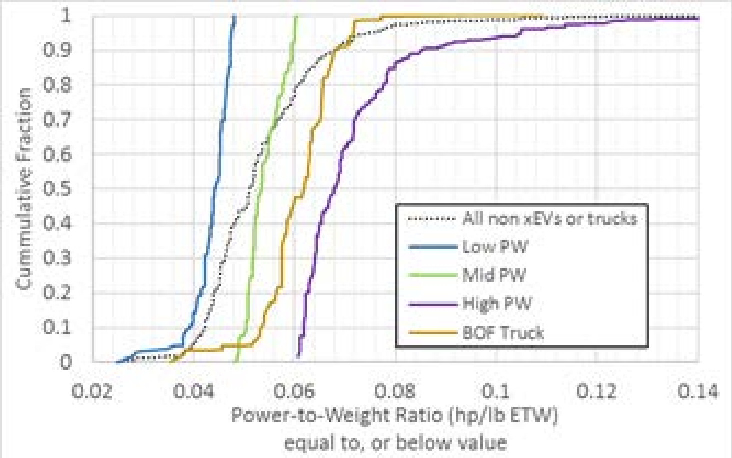
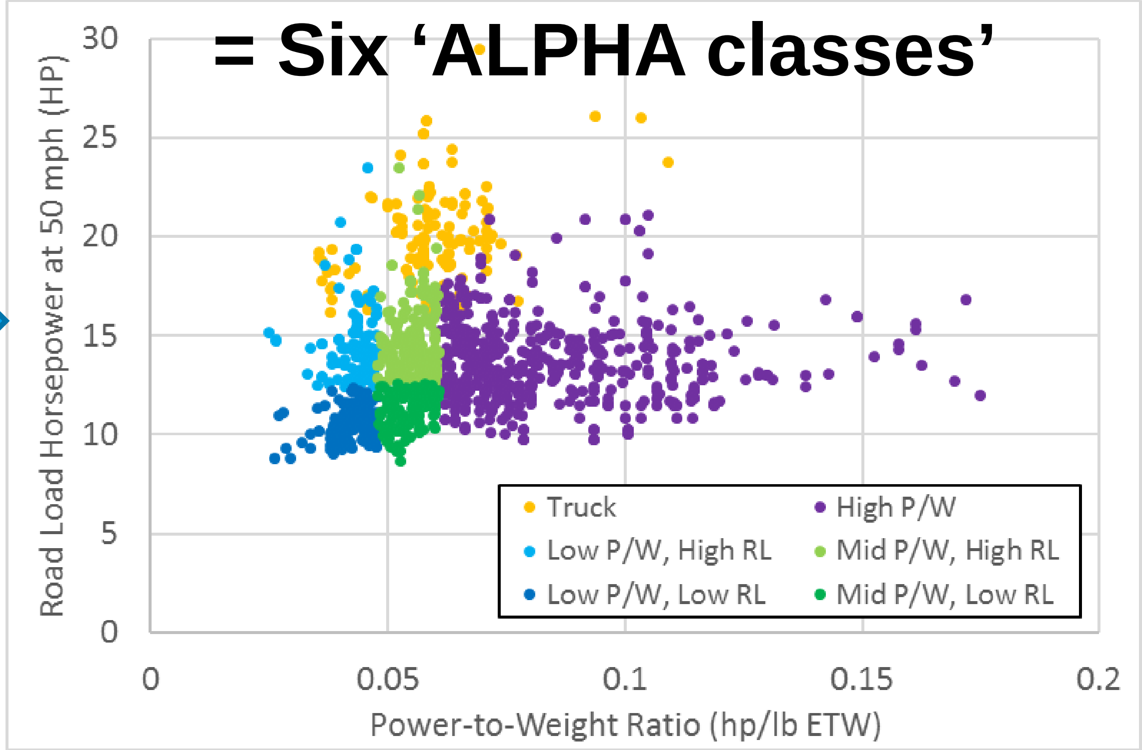
Road load HP @ 50mph distribution



- Assign vehicles to classes according to where engines operates over certification test cycles
- Inertial (power-to-weight) and road load dimensions considered independently



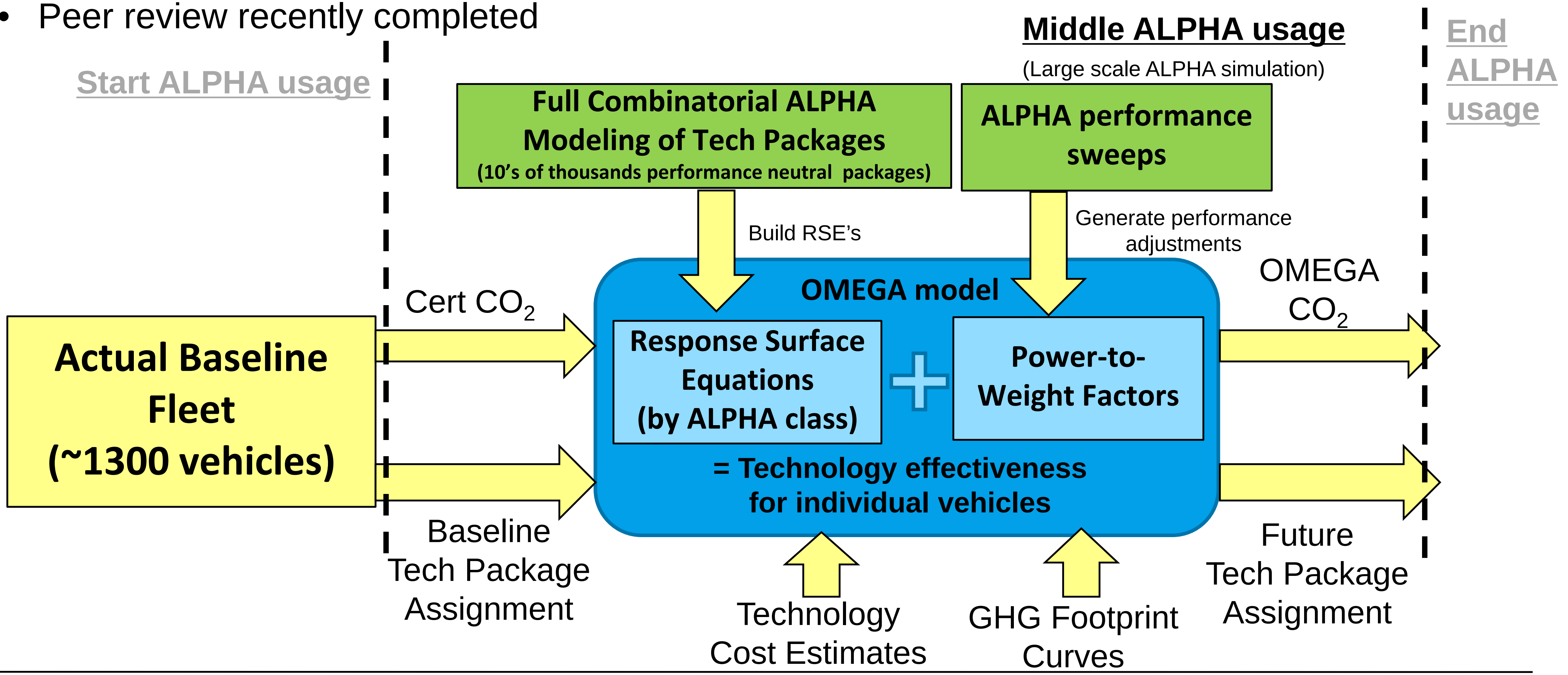
All considered combinations of Future Technologies now simulated in ALPHA

- >500 powertrain combinations (engines, transmissions, accessories)
- Road load sweeps (mass reduction, aero and non-aero drag reduction)
- Six vehicle classes
- Tens of thousands of tech combinations

		Engine															
		OMEGA tech map	PFI		PFI + VVL		GDI		GDI + VVL		ATK2	ATK2+CEGR	ATK2+CEGR+DeacPD	TDS11		TDS12	TDS21
			I-config	V-config	I-config	V-config	I-config	V-config	I-config	V-config				I-config	V-config		
Transmission	OMEGA tech																
	Null																
	TRX11		B + DeacPD/FC	B + DeacPD/FC			B + DeacPD/FC	B + DeacPD/FC					C + DeacPD*		B + DeacPD/FC	B + DeacPD/FC	
	TRX12		B + DeacPD/FC	B + DeacPD/FC			B + DeacPD/FC	B + DeacPD/FC					C + DeacPD*		B + DeacPD/FC	B + DeacPD/FC	
	TRX21		B + DeacPD/FC	B + DeacPD/FC			B + DeacPD/FC	B + DeacPD/FC					C + DeacPD*		B + DeacPD/FC	B + DeacPD/FC	
	TRX22		B + DeacPD/FC	B + DeacPD/FC			B + DeacPD/FC	B + DeacPD/FC					C + DeacPD*		B + DeacPD/FC	B + DeacPD/FC	

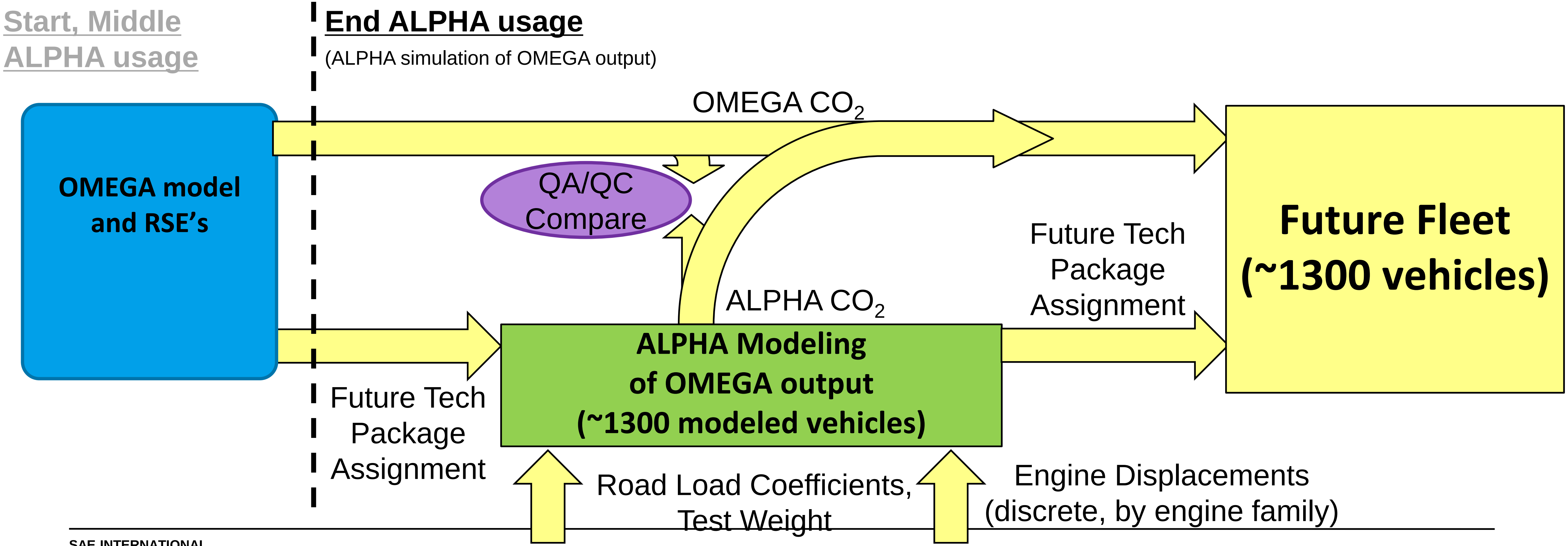
Response Surface Equations (RSEs)

- Response Surface Equations are created to represent the entire set of ALPHA simulations for real-time access in the OMEGA process
- Peer review recently completed



Final CO2 values of future fleets using ALPHA simulation

- Use ALPHA simulation of individual vehicles to validate OMEGA CO_2 values
  - Responsive to stakeholder recommendations for greater use of 1-D vehicle simulation
- Consolidate engine displacements test weight bins
  - Responsive to stakeholder comments about the proliferation of unique engine displacements and the effectiveness benefits of curb weight reductions within test weight bins



Conclusion

- EPA has continued the development of tools and processes for modeling technology effectiveness
- Responsive to stakeholder recommendations
- Use of vehicle simulation for characterizing technology in the baseline
- Use of large scale simulation for building Response Surface Equations, enabling greater transparency in the development of effectiveness values
- Use of vehicle simulation for validating CO_2 values of technology packages applied to future vehicles

Thank you!

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