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Vehicle Mass Impact on Vehicle Losses and Fuel Economy

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Advanced Vehicle Testing Activity (AVTA)

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Overview

Timeline

- FY11 – Project planning, Vehicle procurement, test plan preparation
- FY12 – Vehicle coastdown testing and dynamometer fuel economy and energy consumption testing
- FY13 – Final report written, multiple presentations delivered

Barriers

- A change in vehicle mass changes the energy consumption; Is this change the same for all vehicle technologies?
- Difficult to isolate mass impact from other factors (aerodynamic change from ride height change, vehicle fuel economy repeatability, etc)
- Maintaining environmental conditions repeatability during coastdown testing

Budget

- FY11 – $ 125,000
- FY12 – $ 225,000
- FY13 – $ 100,000

Partners

- Idaho National Lab - lead
- ECOtality North America – coastdown testing
- Argonne National Lab – dynamometer testing

Objective / Relevance

- Determine for BEV, HEV and ICE the Impact of Vehicle Mass on:
  – Vehicle drag forces
  – Vehicle fuel economy or energy consumption (MPG and Wh/mi)
- Technology dependence of Mass Impact (HEV to ICE to BEV)
  – i.e. is mass reduction more beneficial for certain technologies?
- Share results of study with DOE, Tech Teams, OEMs, etc.

Approach

- Three vehicle tested (BEV, HEV, and ICE)
  - Nissan Leaf
  - Ford Fusion Hybrid
  - Ford Fusion V6
- Multiple test weights tested for each vehicle
  - Increase and decrease from stock weight (EPA certification weight)
- On test track, coastdown testing is conducted to determine the impact of mass change on vehicle drag forces
- Road load coefficients determined from coastdown testing are used to configure the chassis dynamometer
- Chassis dynamometer testing is conducted over standardized drive cycles to determine the impact of mass change on vehicle fuel economy and energy consumption (MPG and Wh/mi)

Approach - Coastdown Testing (ECOtality)

- For each vehicle, at each test weight
  - 14 coastdowns conducted to reduce sensitivity to external variables
    - 7 in each direction to nullify any track grade variability
    - Wind, ambient temp, and humidity limits strictly adhered to
- To reduce testing variability
  - Vehicle warmed up for 30 min. prior to testing
  - Ride height is held to a small tolerance at the various vehicle test weights
  - Temperatures monitored and recorded to ensure vehicle is functioning at steady state operating conditions
    - Transmission fluid temperature
    - Tire side wall temperature (non-contact temperature sensor)
  - Consistency between coastdown and dynamometer testing
    - Same vehicle operating mode utilized
    - Same three vehicles are used for all testing

	Fusion ICE (V6)	Fusion HEV	Leaf BEV
+500 lbs	4250	4500	4250
+250 lbs	4000	4250	4000
EPA cert. weight	3750	4000	3750
-100 lbs	3650	3900	3650
-250 lbs	3500	3750	3500

Approach - Chassis Dynamometer Testing (Argonne)

- For each vehicle, at each test weight
  - Standardized drive cycles used for dynamometer testing
    - UDDS
    - HWFET
    - US06

	Fusion ICE (V6)	Fusion HEV	Leaf BEV
+500 lbs	4250	4500	4250
EPA cert. weight	3750	4000	3750
-250 lbs	3500	3750	3500
-500 lbs	3250	3500	3250

- To reduce testing variability
  - Vehicle warmed up per dynamometer test procedures prior to testing
  - Same dynamometer driver for all tests
  - Temperatures monitored and recorded to ensure vehicle is functioning at same steady state operating conditions as on test track
    - Transmission fluid temperature
    - Tire side wall temperature (non-contact temperature sensor)
  - Consistency between coastdown and dynamometer testing
    - Same vehicle operating mode utilized
    - Same three vehicles are used for all testing

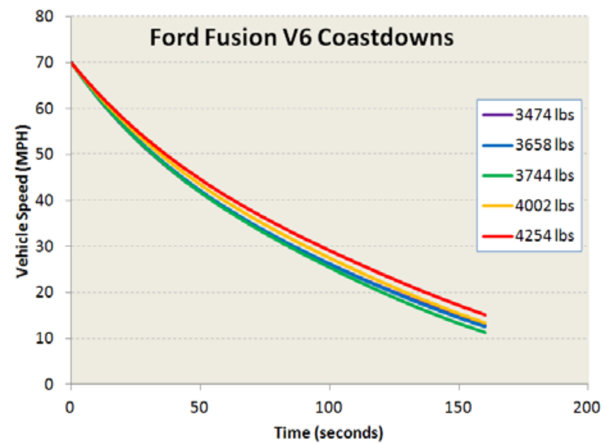
Milestones

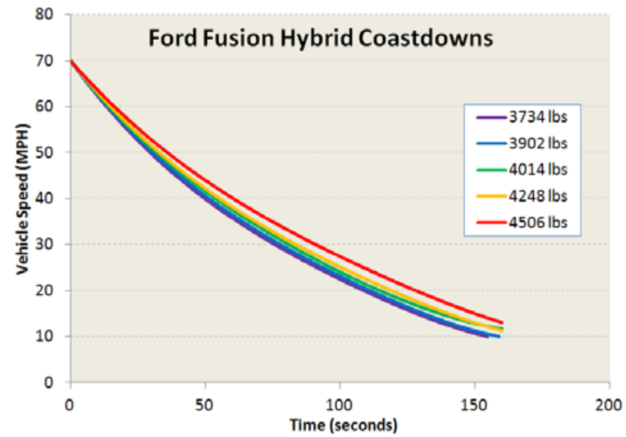
- Aug 2011 – Project planning and test plan complete
- Nov 2011 – Vehicles acquired and break-in miles accumulated
- Jan 2012 – Coastdown testing complete
- Feb 2012 – Analysis of coastdown data complete

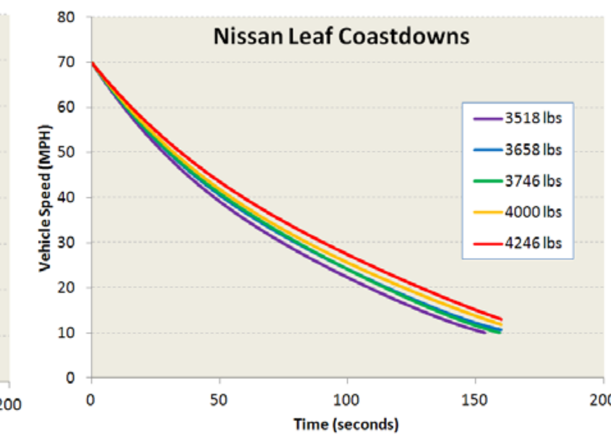
- May 2012 – Chassis Dynamometer testing complete
- Nov 2012 – Results presentations to Vehicle Systems & Analysis Tech Team (VSATT) and Materials Tech Team (MTT)
- Jan 2013 – Technical paper: 2013 SAE World Congress complete
- Feb 2013 – Technical paper accepted into SAE International Journal of Alternative Powertrains

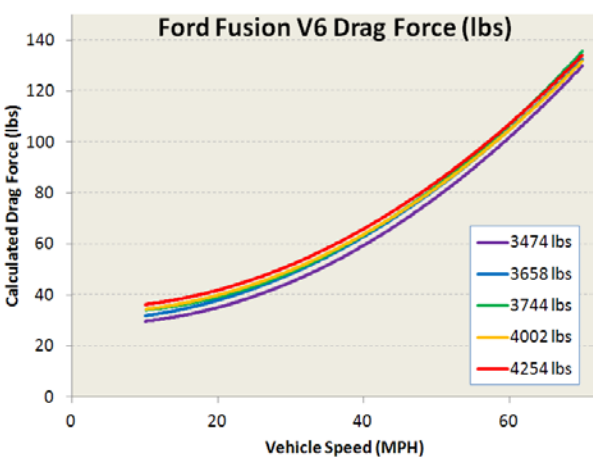
Technical Accomplishments

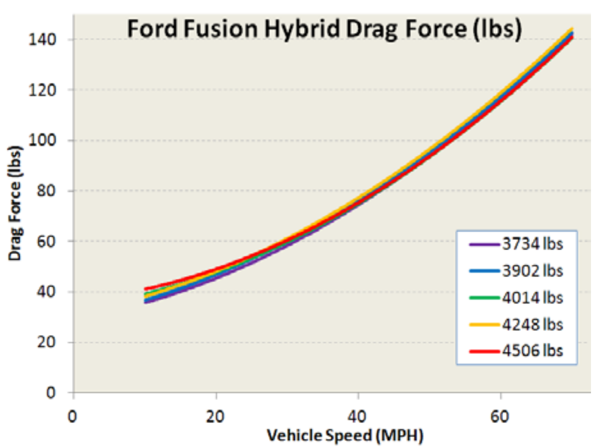
- A change in vehicle mass has shown a change in low speed rolling drag but less significant change in high speed drag forces

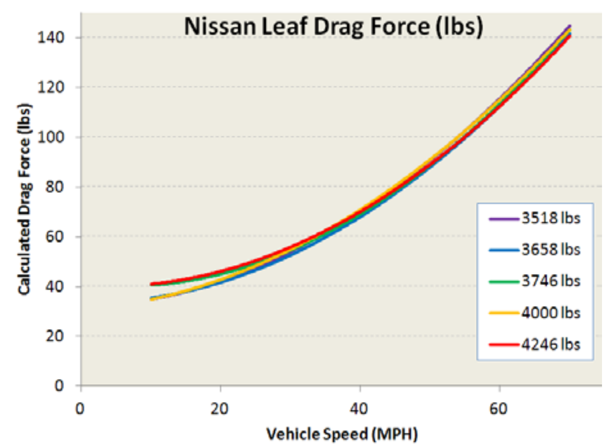










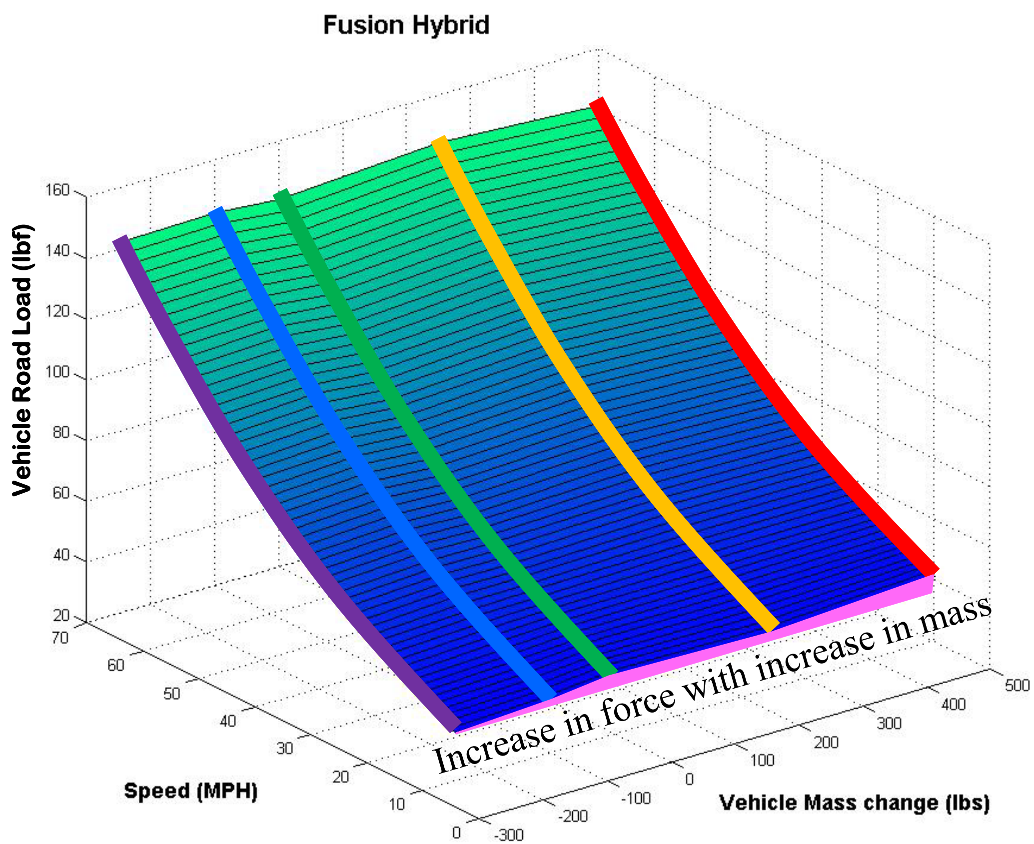


Technical Accomplishments (continued)

- Drag forces and vehicle road load are calculated from each coastdown time and the measured mass of the vehicle

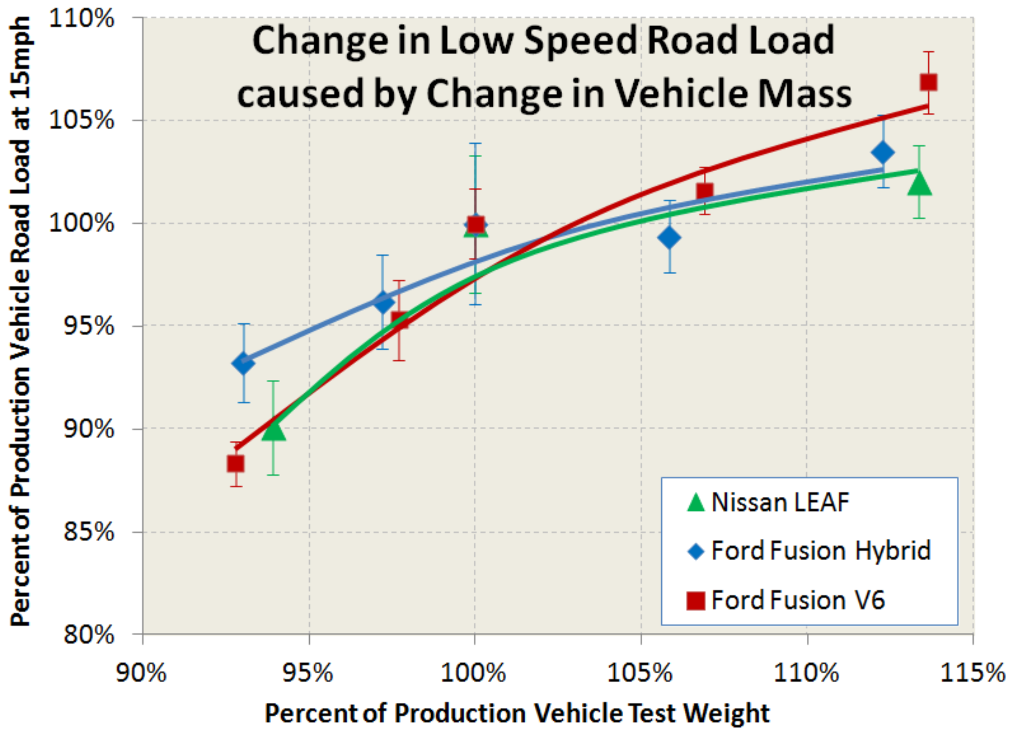
- Road load is substantially greater at higher speed (MPH)
  - Mainly due to aerodynamic drag forces

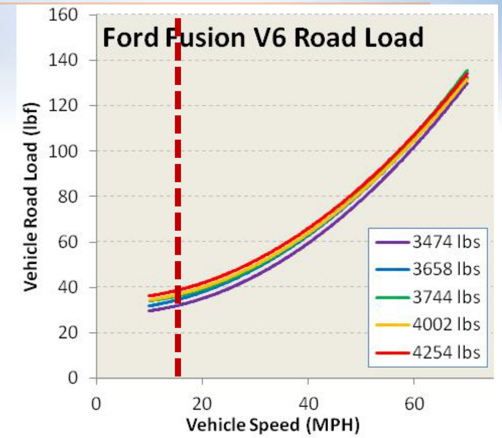
- Slight increase in road load force with respect to increase in mass
  - Most notable at lower speeds

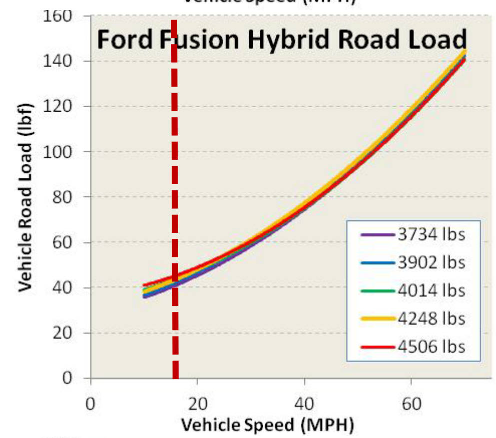


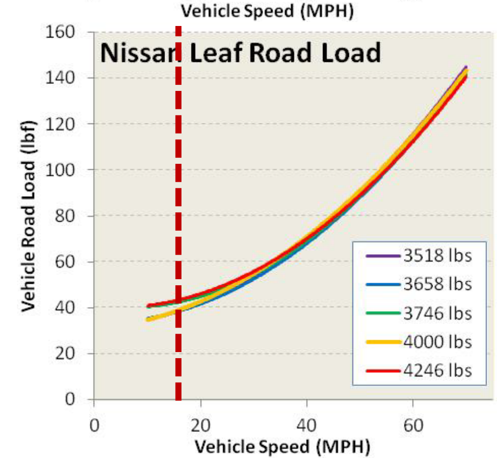
Technical Accomplishments (cont.)

- Overall vehicle road load increases with an increase in vehicle mass
- Low speed (MPH) vehicle drag force increases slightly greater than high speed drag force
- The mass impact on vehicle road load appears to be independent of vehicle powertrain technology and shows a slightly non linear trend



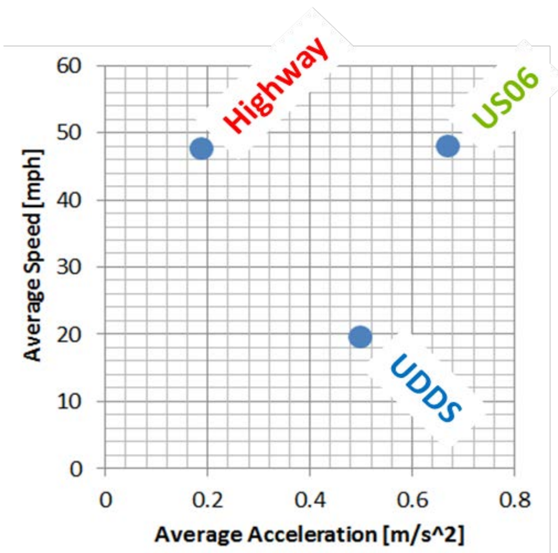


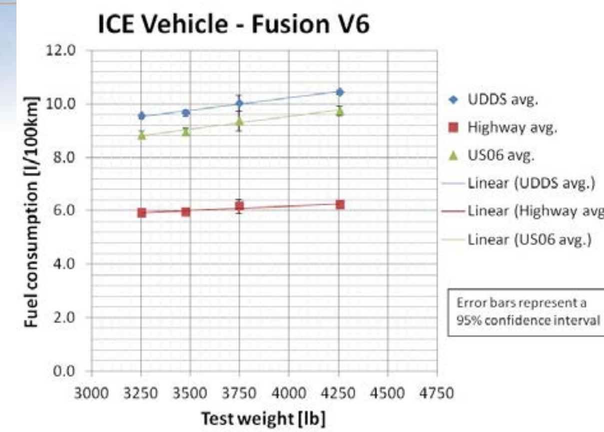


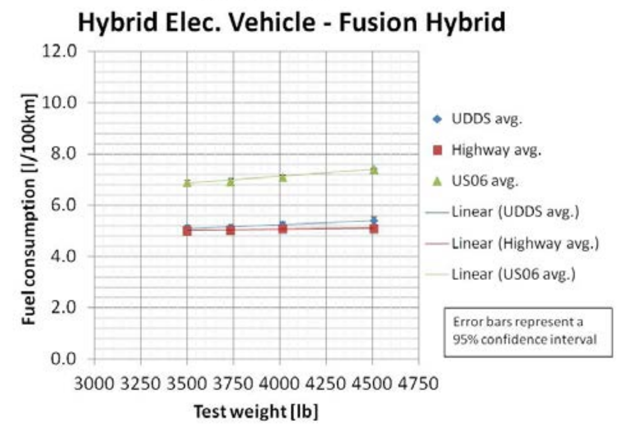


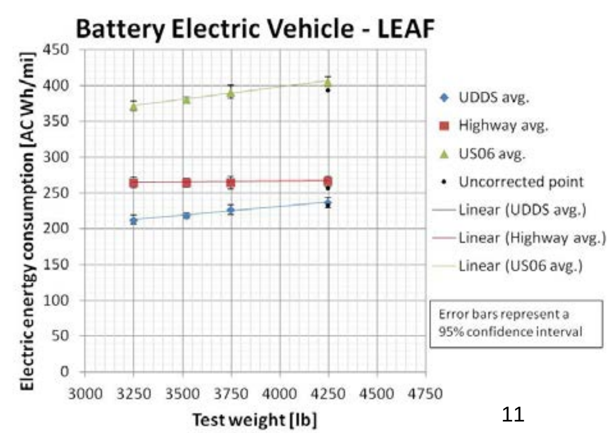
Technical Accomplishments (cont.)

- Vehicle mass has significant impact on Fuel Consumption and Elec. Energy Consumption for stop & go driving
  - UDDS drive cycle
  - US06 drive cycle
- Vehicle mass has minimal impact on Fuel Consumption and Elec. Energy Consumption for constant speed driving
  - HWFET cycle





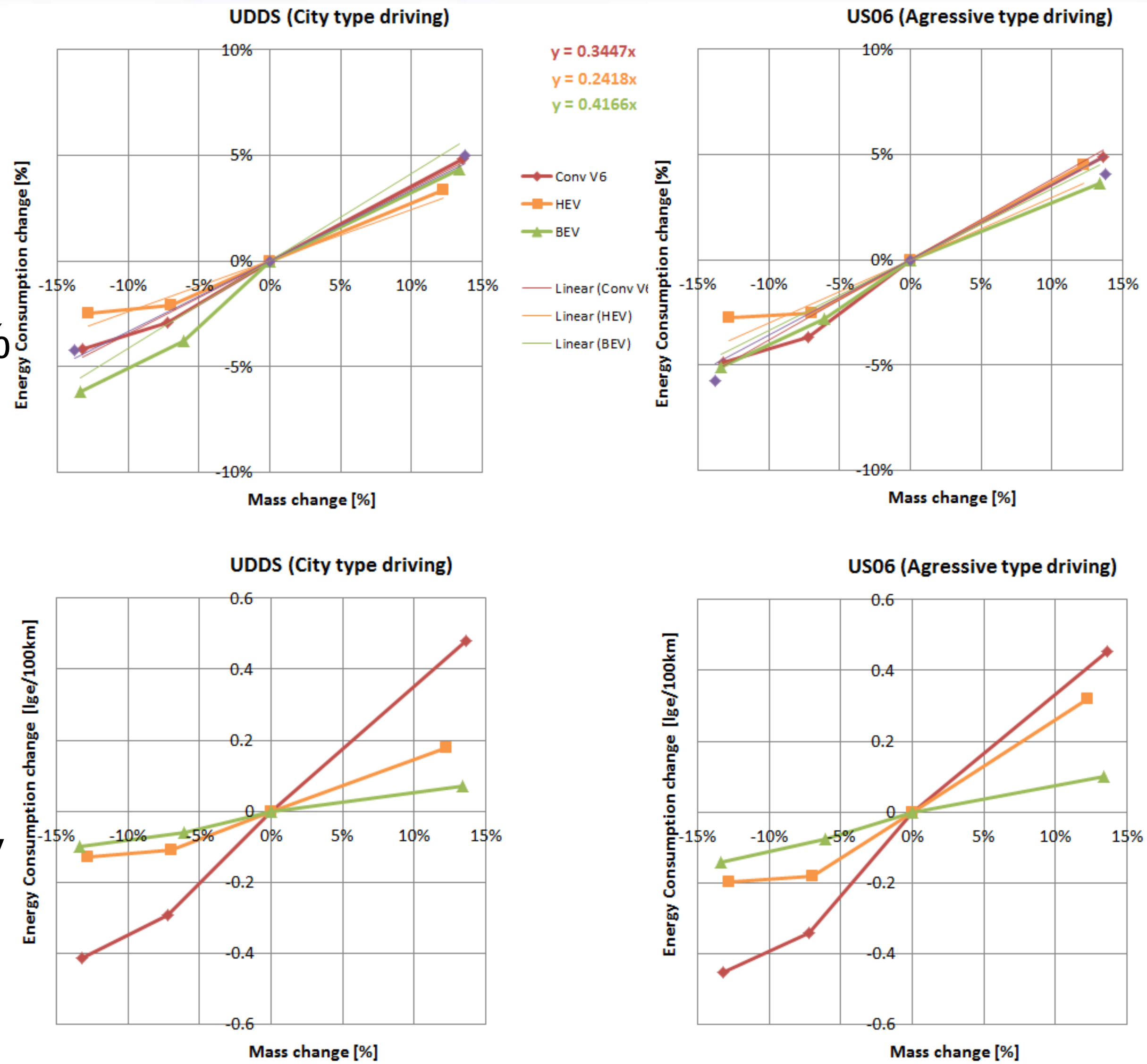




Technical Accomplishments (continued)

- Stop & Go style driving (UDDS and US06) showed approx. 5% change in energy consumption for 10 to 13% change in mass

- Conventional ICE vehicle showed the largest total change in energy consumption
- HEV and BEV significantly less total change in energy consumption due to higher powertrain efficiency



Collaboration

- Results from testing have been shared with US DOE, Tech Teams, OEMs, SAE, and others in support of improving petroleum displacement technologies

Future Work

- Possible investigation of
  - Tire rolling resistance variation
  - Cold temperature impact on road load force and vehicle fuel consumption

Technical Summary

- The light weighting benefits on fuel/energy consumption depends on the driving type.
  - In city type driving and aggressive type driving with many and/or larger accelerations, light weighting any vehicle type will reduce the energy/fuel consumption
  - In highway type driving where a vehicle will cruise at relative steady speed light weighting vehicles does not significantly reduce the energy/fuel consumption
- Light weighting a conventional vehicle will provided the largest improvement in fuel consumption due to the relative lower powertrain efficiency compared to a battery electric vehicle.
- This hardware and testing study maintained the powertrain constant or it did not consider benefits of mass compounding which explain the lower benefits of light weighting compared to other studies.

For a 10 % mass reduction						
	[%] consumption reduction			[Lge/100km] consumption reduction		
Driving type	City	Highway	Aggressive	City	Highway	Aggressive
Conv. V6	~3.5	~3.0	~4.5	~0.35	~0.19	~0.40
HEV	~2.5	~1.5	~4.0	~0.12	~0.06	~0.19
BEV	~5.0	~0.1	~2.5	~0.08	~0.01	~0.10

Study Assumptions and limitations

- Vehicle powertrain remained constant
- Study does not include mass compounding
- Results based on single car per category
- Road load input based on track test data
- Manufacturer recommended tire pressure maintained for all weight cases per vehicle

Summary

- Coastdown testing is complete
- Chassis dynamometer testing is complete
- Analysis is complete
- Study findings reported to Tech Teams, OEMs and others
  - Presentation to:
    - Vehicle Systems & Analysis Tech Team
    - Materials Tech Team
  - 2013 SAE World Congress paper
  - SAE International Journal of Alternative Powertrains

Acknowledgement

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More Information

http://avt.inl.gov