UNDERSTANDING REAL-WORLD ACTIVITY DATA FOR LIGHT-DUTY CONVENTIONAL, HYBRID AND ELECTRIC VEHICLES

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Outline

- Background
- New Analysis
- Preliminary Findings
- Future Analysis

Background

- At the 2016 and 2017 CRC Workshops, we presented the preliminary results from an analysis of Verizon Telematics data on all vehicles
  - Over 48,000 vehicles in five states operating for 12 months in 2015-2016
  - Presented data analysis on VMT, soak distribution, idling fractions, urban/rural, truck/car, weekday/weekend distributions

- Research Questions:
  - Are hybrids and plug-in electric vehicles (PHEVs) being used similar to conventional gasoline or diesel vehicles?
    - What are their real-world activity patterns?
  - Does the design of the plug-in hybrid (PHEV) or EV technology impact real-world usage patterns?

Verizon Telematics Background

- Verizon Telematics has a nationwide light-duty data gathering program

- Data loggers record data such as:
  - Vehicle Data: model year, make, manufacturer, engine size, fuel type, vehicle identification number (VIN) stem, and home zip code location of vehicle

- Verizon Telematics data purchased included only trip-based data
  - Trip Based Data: start and end times, time in vehicle speed bins, time in engine speed and load bins, engine coolant temperatures, malfunction indicator light on, diagnostic trouble codes, etc.

Data and New Analysis

- We purchased Verizon Telematics data from 5 States covering the 2015-2016 timeframe recently
  - California, Colorado, Georgia, Illinois, New Jersey
  - States selected for mixture of variables including environmental, urban/rural areas, number of vehicles in the Verizon program
- Significant Data Quality Assurance conducted previously
  - Verizon Telematics data quality was very high!
  - QA process only found issues on 0.13% of trips
- New data analysis conducted on full dataset separating into different engine technologies - conventional, hybrids, plug-in electric hybrids (PHEVs) and EVs

Trip and Vehicle Breakdown

All States: Over 48,000 vehicles and over 39,000,000 trips

CALIFORNIA	COLORADO	GEORGIA	ILLINOIS	NEW JERSEY
2,300 vehicles	**7,122 vehicles**	**18,159 vehicles**	**15,261 vehicles**	**5,773 vehicles**
63% cars, 37% trucks	*56% cars, 44% trucks*	*63% cars, 37% trucks*	*61% cars, 39% trucks*	*64% cars, 36% trucks*
1,886,940 trips	**5,358,195 trips**	**14,592,843 trips**	**12,249,460 trips**	**4,918,906 trips**

Conventional Vehicles	**Total Vehicles:**	**47,325**	**Trips: 38,032,155**
Hybrids		**1,226**	**1,146,465**
Plug-in Hybrid Electric Vehicles		**29**	**18,494**
Electric Vehicles	Not Included in Analysis	**1**	**348**

Hybrid Vehicles

Vehicle	Model Years	# of Vehicles	Location
Acura ILX	2013	3	GA, IL
Cadillac Escalade Hybrid	2009, 2010, 2012	3	GA, IL
Chevrolet Malibu Hybrid	2009	1	GA
Ford Escape Hybrid	2006 - 2009	18	CA, CO, GA, IL, NJ
Ford Fusion Hybrid	2009 - 2015	14	CO, GA, IL, NJ
Ford C-Max Hybrid	2013, 2014	5	CO, GA, IL, NJ
GMC Yukon	2008	1	GA
Honda CRZ	2011 - 2013, 2015	10	CO, GA, IL, NJ
Honda Insight	2000, 2010 - 2013	36	CA, CO, GA, IL, NJ
Honda Civic	2003 - 20010, 2012 - 2015	92	CA, CO, GA, IL, NJ
Honda Accord	2005, 2006, 2007, 2015	19	CO, GA, IL, NJ
Hyundai Sonata Hybrid	2011 - 2016	37	CA, CO, GA, IL, NJ
Infiniti Q50 Hybrid	2015	1	CO
Infiniti QX60 Hybrid	2014	1	GA
Kia Optima Hybrid	2011 - 2015	22	CO, GA, IL, NJ
Lexus CT 200H	2011 - 2015	26	CA, CO, GA, IL, NJ
Lexus ES 300H/NX 300H	2013 - 2016	18	CA, CO, GA, IL, NJ
Lexus RX450H/GS450H	2008, 2010-2015	19	CA, CO, GA, IL, NJ
Lexus RX400H	2006 - 2008	18	CA, CO, GA, IL, NJ
Lexus HS250H/NX300H	2010, 2011, 2015	9	CO, GA, IL, NJ
Lincoln MKZ Hybrid	2011 - 2015	6	CO, GA, IL, NJ
Mercury Mariner Hybrid	2006 - 2009	7	CO, IL, NJ
Mercury Milan Hybrid	2010	1	IL
Nissan Altima Hybrid	2007, 2009, 2010	4	GA, IL, NJ
Saturn Vue/Aura	2007, 2009	5	CA, GA, IL
Subaru SV Crosstrek	2014, 2015	5	CO, GA, IL
Toyota Avalon Hybrid	2013 - 2016	16	CO, GA, IL, NJ
Toyota Camry Hybrid	2007 - 2016	122	CA, CO, GA, IL, NJ
Toyota Highlander Hybrid	2006 - 2015	41	CA, CO, GA, IL, NJ
Toyota Prius	2002 -2015	531	CA, CO, GA, IL, NJ
Toyota Prius C	2012 -2015	77	CA, CO, GA, IL, NJ
Toyota Prius V	2012 -2015	38	CA, CO, GA, IL, NJ
Volkswagen Jetta Hybrid	2013	2	CO, IL

Eight Model Types Represent > 80%

Plug-in Hybrid Electric Vehicles

Vehicle	Model Years	# of Vehicles	Electric Range (miles)	Location
Chevrolet Volt	2012, 2014, 2015	8	35-38	CA, CO, GA, IL
Fisker Karma	2012	1	33	CO
Ford C-Max Energi	2013, 2015	4	0-19	GA, CA
Ford Fusion Energi	2013, 2015	4	0-19	CA, CO, GA, IL
Toyota Prius Plug-in	2012-2015	12	0-6	CA, CO, NJ, IL
	Total PHEVs	29		

Vehicle Activity Patterns

Vehicle Type	Average Trips Per Day	Average Trip Length (Miles)	Median Trip Length (Miles)	Maximum Trip Length (Miles)	90th Percentile Trip Length (Miles)	Average Miles Traveled Per Day	Total Trips
Conventional	5.0	7.0	3.1	1,075	16.3	34.9	38,032,155
Hybrid	4.9	7.7	3.2	634	17.9	37.6	1,146,465
PHEV	4.5	10.3	4.2	310	26.2	46.5	18,494

- Average Number of Trips Per Day: Very similar to each vehicle type
- Median Trip Length: Similar for all Vehicle Types
- 90th Percentile Trip Length: PHEVs trips are longer
- Average Miles Traveled Per Day:
  - Conventional and Hybrids are similar
  - PHEVs travel the greatest number of miles
- Limitation: PHEVs have relatively few trips, more data needed

Are Hybrids or PHEVs Used Only for Commuting?

Vehicle Type	Total Trips	Weekend Miles Fraction	Weekend Trip Fraction	Number of Vehicles
Conventional	38,032,155	28.7%	26.5%	47,189
Hybrid	1,146,465	27.9%	26.1%	1,207
PHEV	18,494	27.2%	25.4%	23

In general, the fraction of trips and miles traveled on weekends compared to weekdays does not vary by vehicle technology

Limitation: PHEVs have relatively few trip, more data needed

Do Hybrids and PHEVs Idle More?

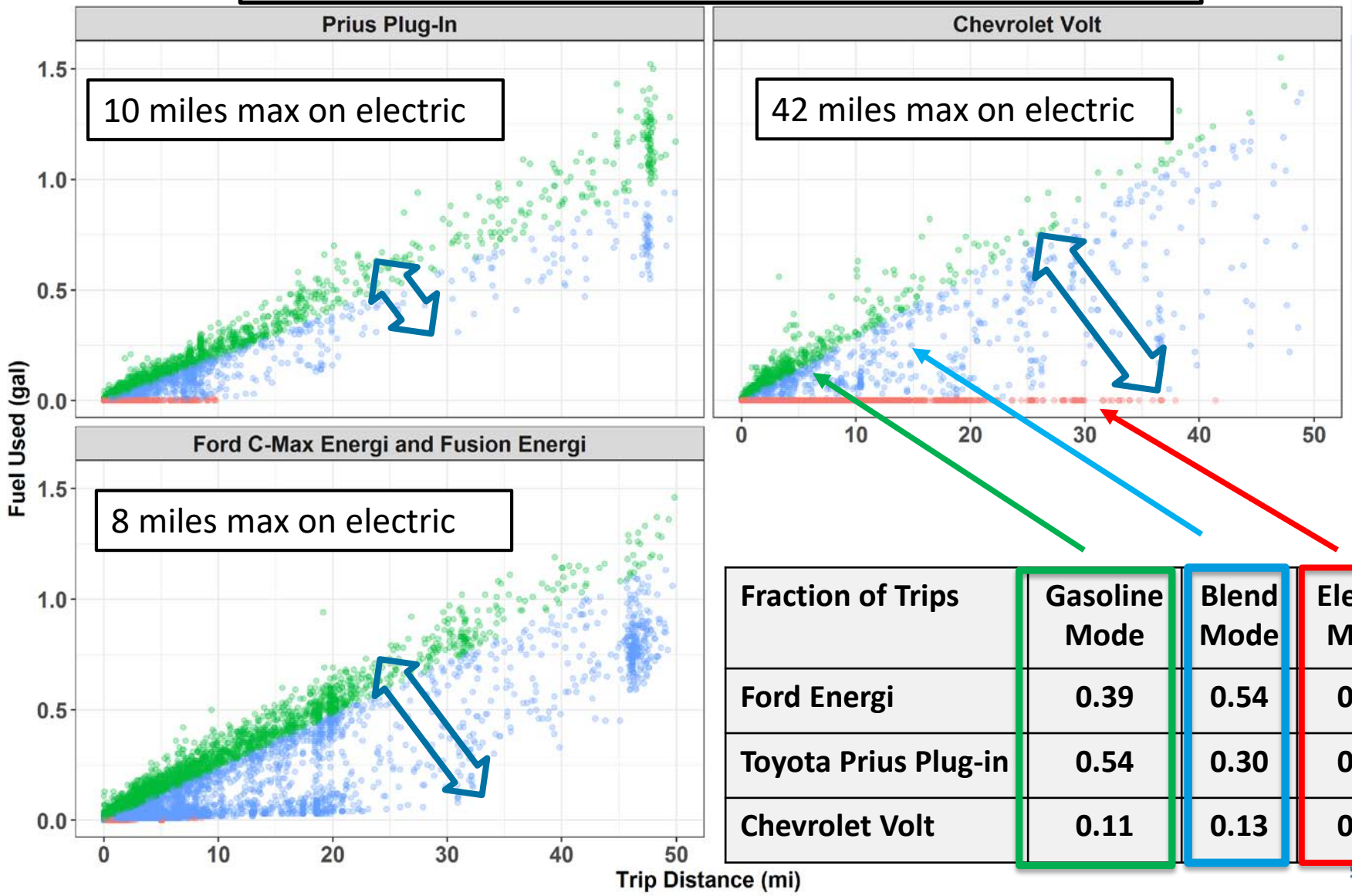
Vehicle Type	Total Trips	Idle Fraction	Number of Vehicles
Conventional	38,032,155	26.9%	47,189
Hybrid	1,146,465	24.6%	1,207
PHEV	18,494	26.8%	23

In general, the idle fraction is similar between the Conventional, Hybrid, and PHEV.

Limitation: PHEVs have relatively few trip, more data needed

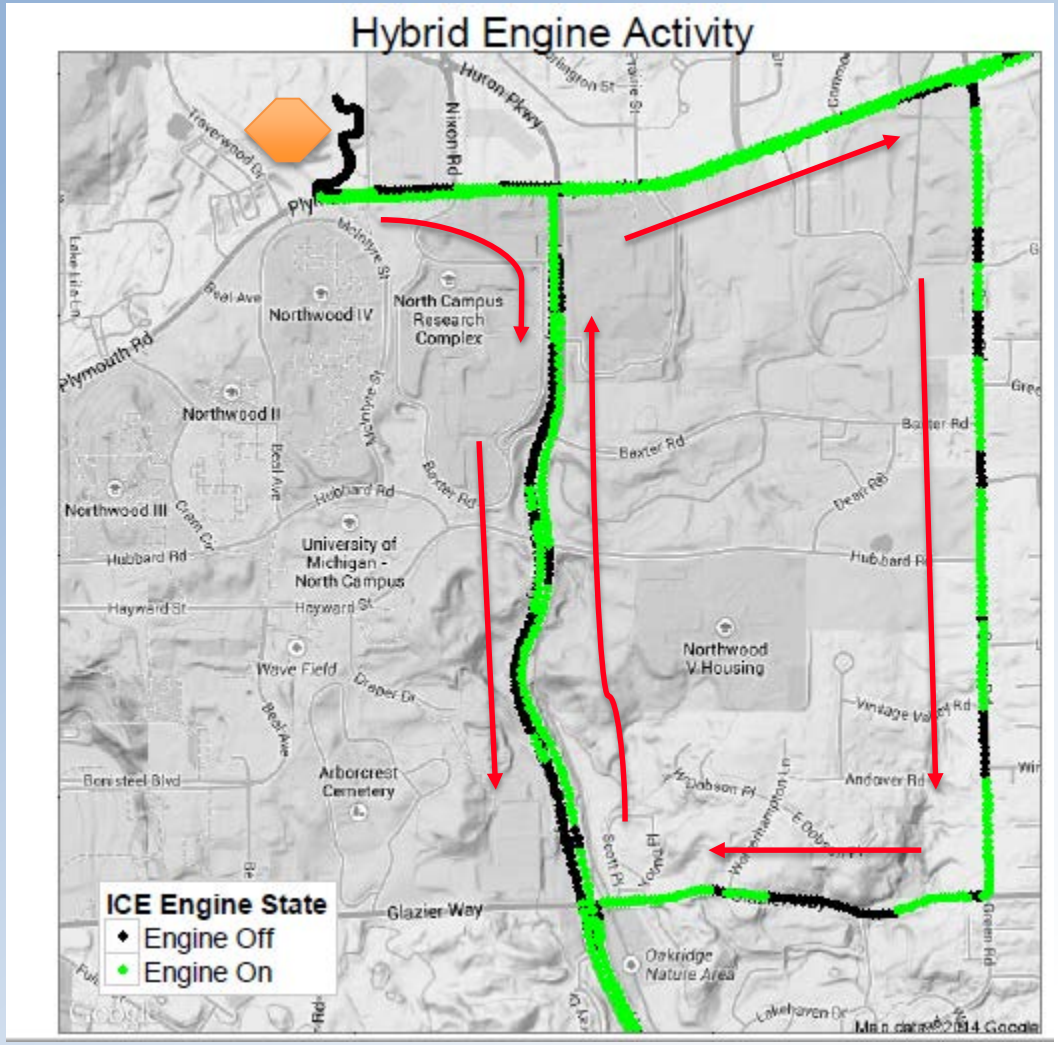
Hybrids/PHEVs: Are they the same?

Each PHEV Technology has a different emission profile



Fraction of Trips	Gasoline Mode	Blend Mode	Electric Mode
Ford Energi	0.39	0.54	0.06
Toyota Prius Plug-in	0.54	0.30	0.16
Chevrolet Volt	0.11	0.13	0.76

Real-World Driving (Hybrids & PHEVs)



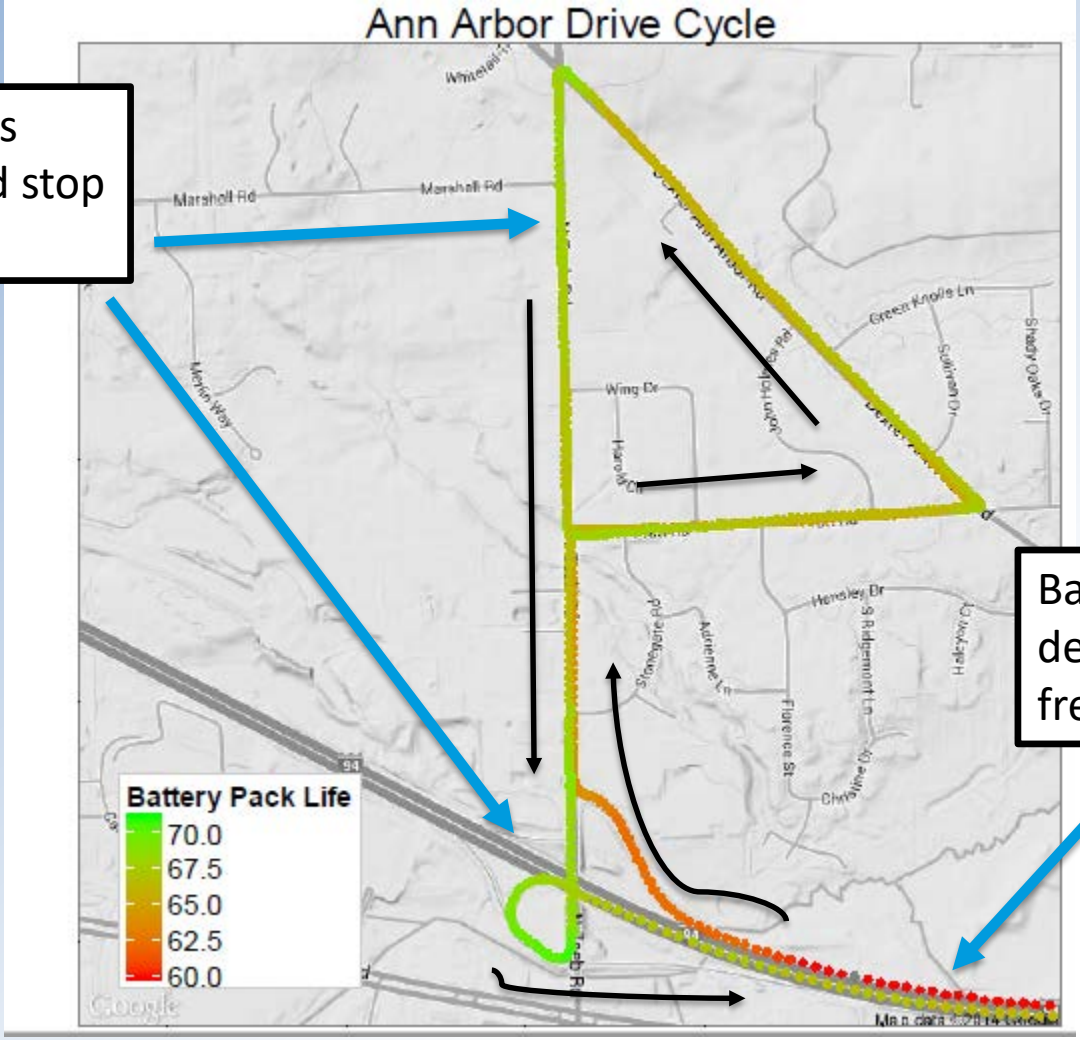
New Technologies (engine, battery, emission technology and software managing them)

Research Questions:

- How is the public using them?
- Where are emissions occurring?
- Are some OEM methodologies better for the environment?
- Do new technologies age the same as conventional vehicles?

Battery Life and Emissions

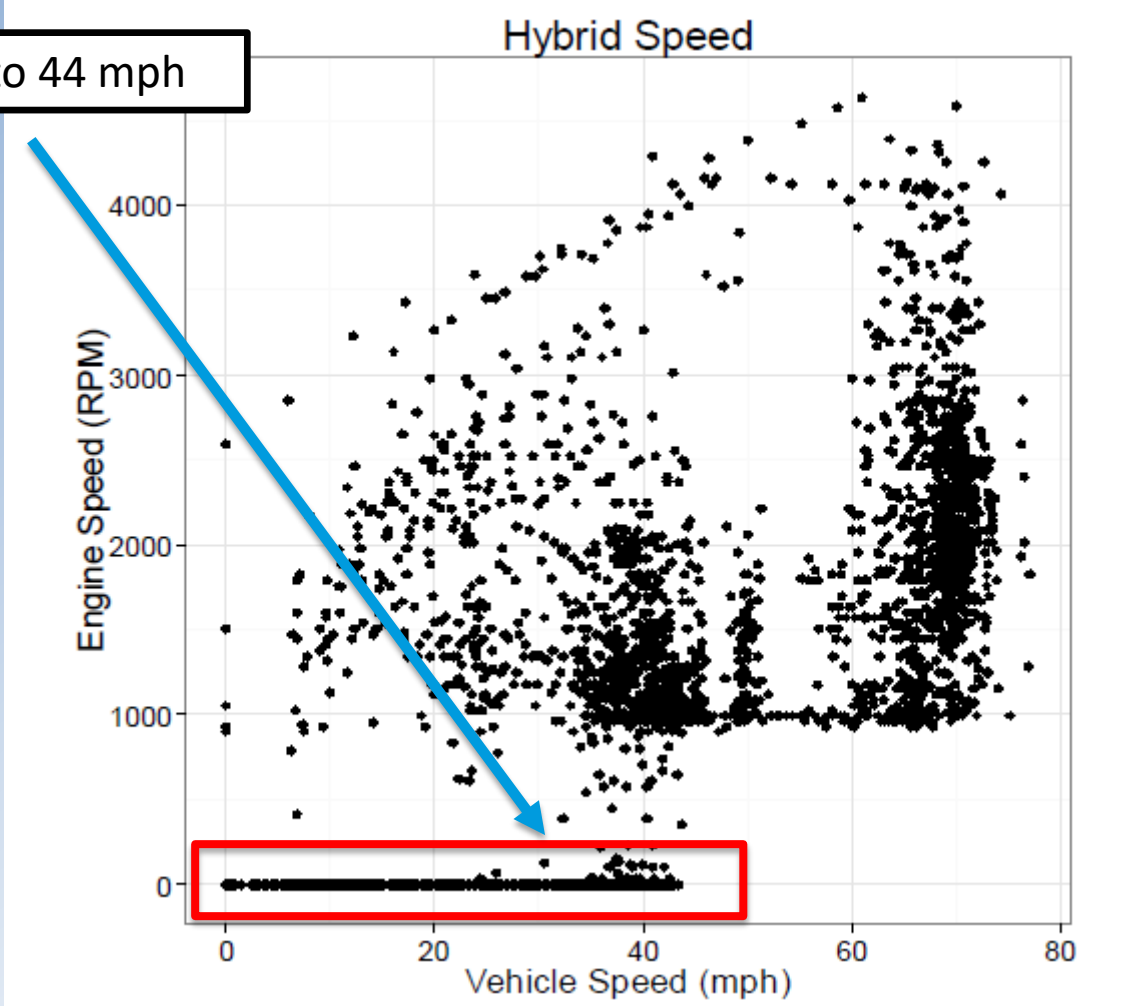
Battery life increases through braking and stop and go traffic



Battery life decreased on freeway driving

Battery vs Engine
When is each being used?

Battery Mode up to 44 mph



New Tools: Entry Level

Laboratory Testing:
Chassis and/or Engine
Dynamometer

Equipment Only Costs:

~$3,000,000+

Portable Emissions Measurement Systems (PEMS) - **Real World**

~$200,000-$300,000

Screening Tools: mini-PEMS
Real World

~$20,000-$30,000

Portable Activity Measurement Systems (PAMS) – **Real World**

~$600 -$1,000

Mini-PEMS/PAMS Data Logger: Data Fields

Allows for Modeling Analysis on:

Date/Time Clock: Key On/Off Date and Time **GPS or ECU**: Vehicle Speed	• Soak times, starts, idle times, vehicle miles traveled, speed distributions, drive cycle development, use patterns, etc. • Able to calculate VSP by vehicle speed and acceleration
Additional ECU Fields: Engine RPM, torque %, MAF, etc. Aftertreatment Operation (temps, NOx ppm, etc.) Intake Manifold Air Flowrate or Absolute Pressure, Fuel Rate	• Characterize engine and aftertreatment operation • Able to use equations for calculating exhaust flow • Able to calculate NOx in ppm or grams by VSP (kW/ton), g/mile or as Brake-Specific Emissions (g/bhp-hr)
GPS Fields: Latitude, longitude, altitude, vehicle speed	• Able to cross-check ECU's vehicle speed and acceleration w/ GPS • Identify emissions in specific locations such as within ports, county or city boundaries, or by road types • Road Grade load by altitude or enhanced with GIS maps
Hybrids/PHEVs/EVs Fields: SOC, Battery Life, Current to/from battery	• Able to determine energy used and generated, mode of operation
External Flowmeter	• Able to cross check ECU's MAF/MAP equations w/ independent flow measurement • ECU interface not needed if flowmeter used, but lose engine data
Additional ECU Fields: Mode $06 Messages	• Able to gather On Board Diagnostic messages, DTCs and Monitor Readiness

Note: All Data Gathered at 1Hz – second-by-second

Preliminary Findings

- Large telematics datasets can be used to provide an understanding of general vehicle fleet usage including conventional, hybrids, PHEVs and EVs
- Preliminary analysis shows consistent patterns that hybrids and PHEVs are being used like “normal” conventional vehicles.
  - Little differences between vehicle groups on number of starts per day and trip length: average, median & 90th percentile
  - Usage patterns for weekday and weekend by trip length and mileage are very comparable to conventional vehicles
- Different PHEV technologies are showing different trip emission patterns

Future Analysis

- Larger datasets are needed to better understand how new technologies are being used in real-world:
  - Use telematics data to redesign routes that reflect how the public are driving the vehicles in the real-world: shorter trip lengths, more stop-and-go to reflect average speed, and increase idling fraction time.
  - Need more activity data including engine parameters and GPS to improve usage patterns on hybrids, PHEVs and EVs
    - Second-by-second data and which engine mode (fuel vs electric) are being utilized in the real-world
  - Need to compare how different engine/electric technologies and modes are being used.

Questions

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