

# Analysis of Plug-in Electric Vehicle Usage

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 **Air Resources Board**

# OEM Data Analysis

- In 2012, the California Air Resources Board directed staff to study in-use data for range extended battery electric vehicles (BEVx) and plug-in hybrid electric vehicles (PHEV)
  - How are plug-in vehicles (PEV) used and charged?
  - What are the criteria pollutant impacts?
  - What are the greenhouse gas impacts?

# 2014 Idaho National Labs Analysis

*Minimally Charged Vehicles are Not Excluded. These data include 14% of Accord PHEVs that achieve between 0-50 monthly eVMT*

	Nissan LEAF	Chevrolet Volt	Ford Focus Electric	Ford C-Max Energi	Ford Fusion Energi	Honda Fit EV	Honda Accord PHEV	Toyota Prius PHEV
Number of Vehicles	4,039	1,867	2,193	5,368	5,803	645	189	1,523
Number of Vehicle Months	35,294	20,545	12,622	38,096	32,022	6,090	1,437	15,676
Total Vehicle Miles Traveled VMT (miles)	28,520,792	20,950,967	10,043,000	39,376,000	33,098,000	4,912,920	1,794,494	19,772,530
Total Calculated Electric Vehicle Miles Traveled eVMT (miles)	28,520,792	15,599,508	10,043,000	12,918,000	11,572,000	4,912,920	399,412	3,224,981
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Avg. Monthly VMT	808.1	1,019.8	795.7	1,033.6	1,033.6	806.7	1,248.8	1,261.3
Avg. Monthly eVMT	808.1	759.3	795.7	339.1	361.4	806.7	278	207.0
estimated Annual VMT	9,697	12,238	9,548	12,403	12,403	9,680	14,986	15,136
estimated Annual eVMT	9,697	9,112	9,548	4,069	4,337	9,680	3,336	2,484
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Data Format Description	Key-On / Key-Off	Key-On / Key-Off	Enhanced Key-On / Key-Off			Trip Summary		Trip Summary
Geographic Characterization	CA, OR, WA, AZ, TX, TN, GA, D.C., PA, IL	CA, OR, WA, AZ, TX, TN, GA, D.C., PA, IL	Nationwide			CA, OR, NJ, MD, CT, MA, RI, NY	CA, NY	ZEV States and other states

# Data Collection and Analysis

- ARB asked OEMs to submit available data
  - Ford, Honda, Toyota, Nissan, BMW, Tesla, and GM responded with in-use activity data
  - Large variance in data formats and detail
  - Some include only CA vehicles, others include nationwide vehicles
- Additional data collection
  - Contract for UC Davis Household study
  - Emission testing of various PHEVs at ARB's lab

# Quantifying Usage of PHEVs Relative to BEVs: *How “BEV-like” are they?*

- OEM-provided data is activity data, not tailpipe emission data
- Needed to develop surrogates to quantify GHG and criteria pollutant (HC, NOx) emissions
- Started with alternate ways of analyzing portions of the total vehicle miles traveled (VMT)
  - eVMT, e-trips, and zVMT

# Defining eVMT, e-Trips, and zVMT

eVMT – Electric Vehicle Miles Traveled	
<p>Cumulative miles attributed to grid energy</p> <ul style="list-style-type: none"><li>• Includes a portion of miles where IC engine and grid energy are used simultaneously</li><li>• Does not include <u>all</u> engine off miles</li></ul>	<p>Correlates well to GHG (tailpipe CO<sub>2</sub>) emissions</p>
e-Trips – Electric only Trips	
<p>Number of trips where the ICE did <b>not</b> start</p>	<p>Indicator of engine start-up HC/NOx emissions that are avoided</p>
zVMT – Zero-emission Vehicle Miles Traveled	
<p>Cumulative e-Trip miles</p>	<p>Indicator of engine start-up HC/NOx emissions avoided relative to total VMT</p>

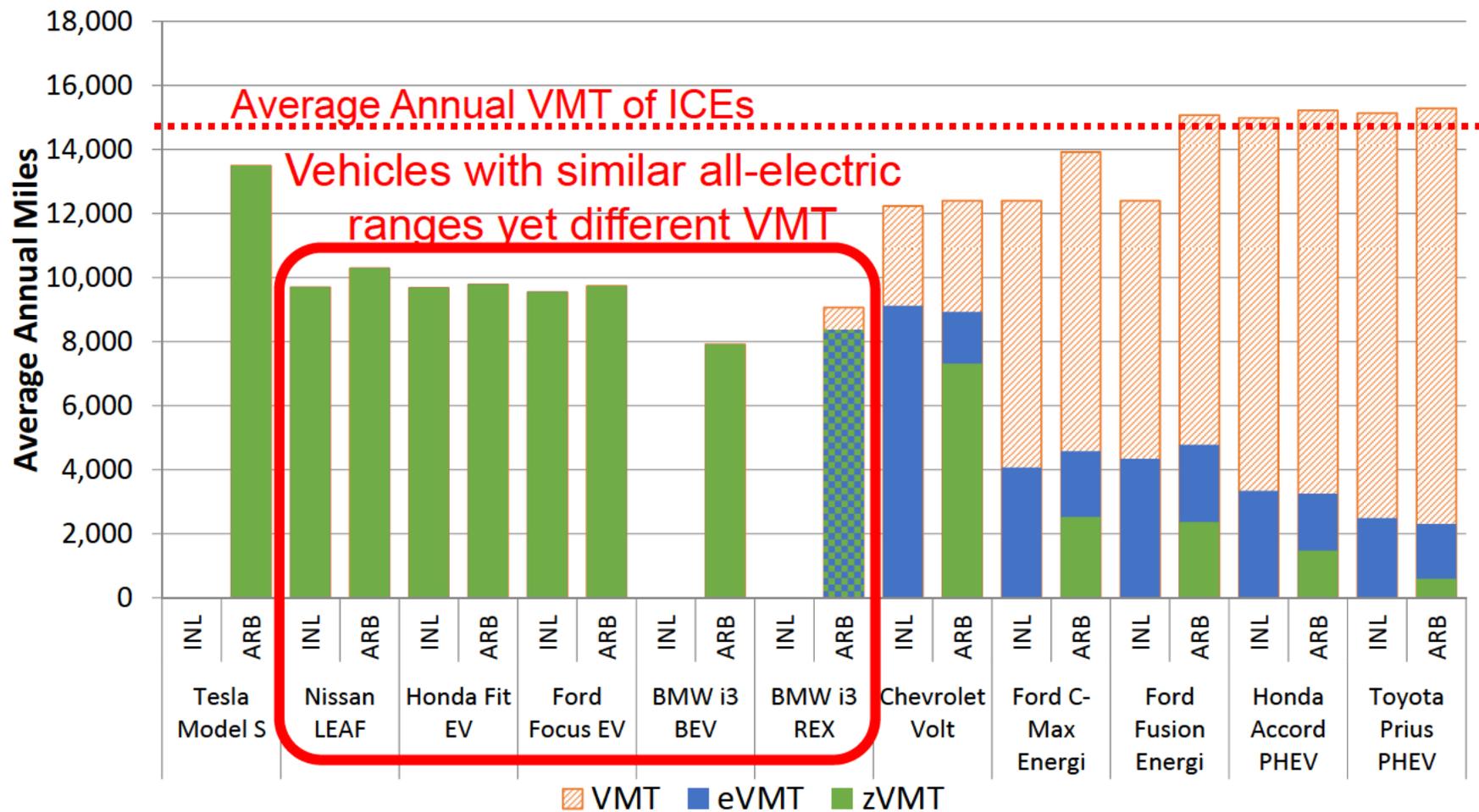
# In-use data received from OEMs

Lighter shading: data analyzed by ARB and INL

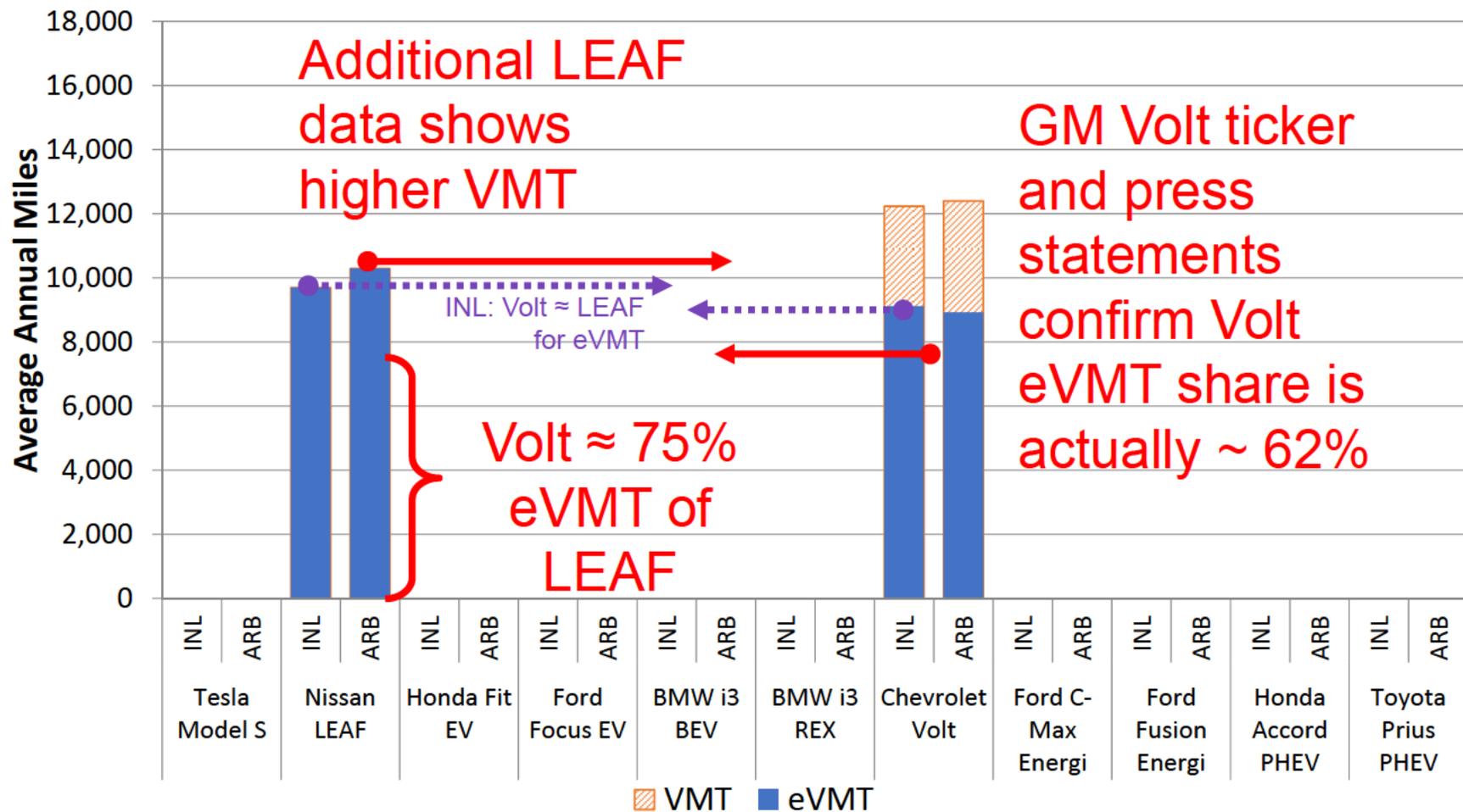
Darker shading: data analyzed by ARB only

	CY2011	CY2012	CY2013	CY2014	CY2015	CY2016
Toyota Prius PHEV			1,523 vehicles			
Honda Accord PHEV			189 vehicles			
Ford C-MAX Energi			5,368 vehicles	+ 4,885	= 10,253	
Ford Fusion Energi			5,803 vehicles	+ 7,039	= 12,842	
Chevrolet Volt			1,867 vehicles			
			BMW i3 REX		8,309 vehicles	
			BMW i3 BEV		4,193 vehicles	
Ford Focus EV			189 vehicles	+ 7,039	= 4,218	
Honda Fit EV			645 vehicles			
Nissan LEAF			4,039 vehicles	+ 7,039	= 12,215	
Tesla Model S			37,635 vehicles			

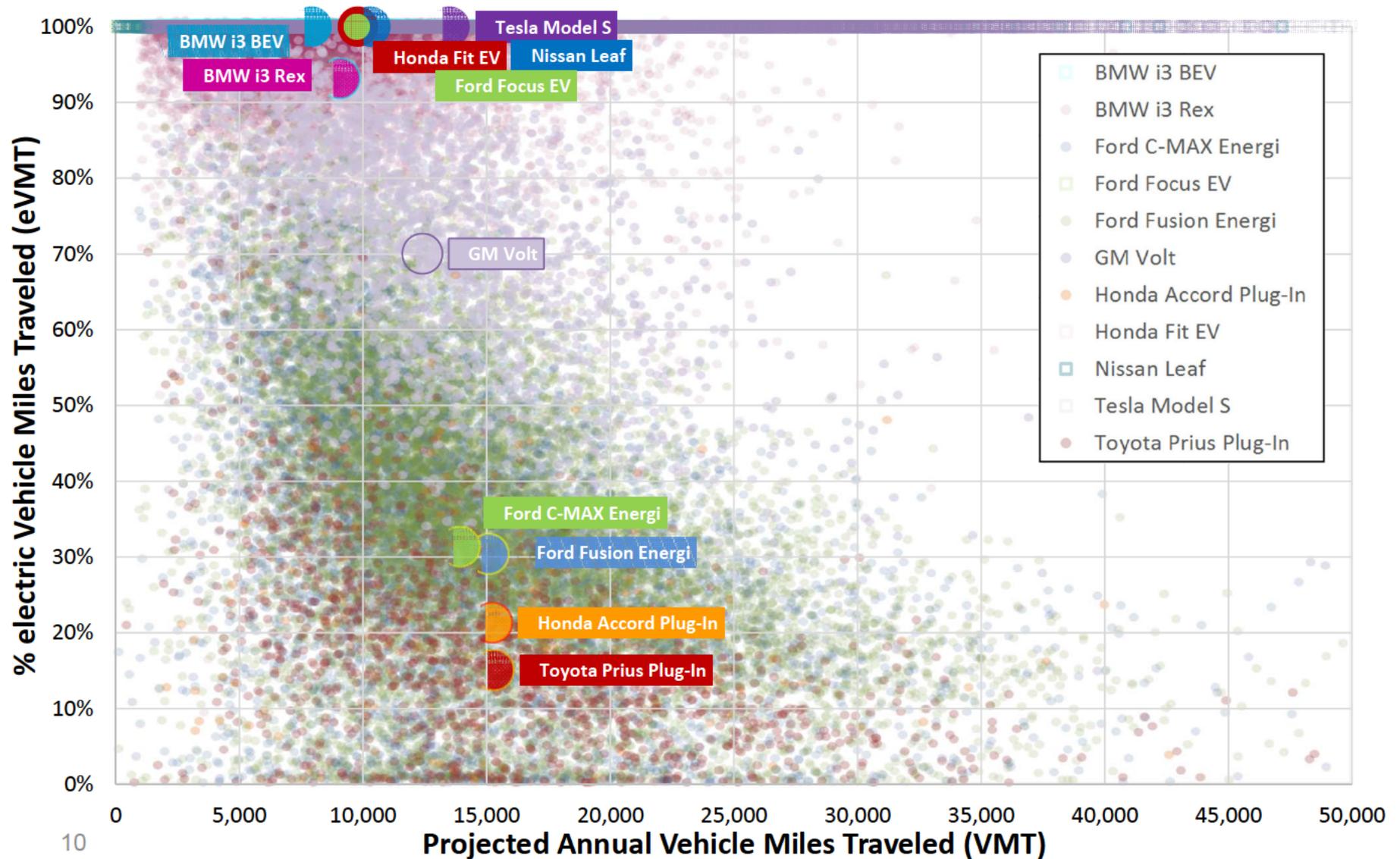
# Comparison of eVMT and zVMT



# Comparison of eVMT and zVMT

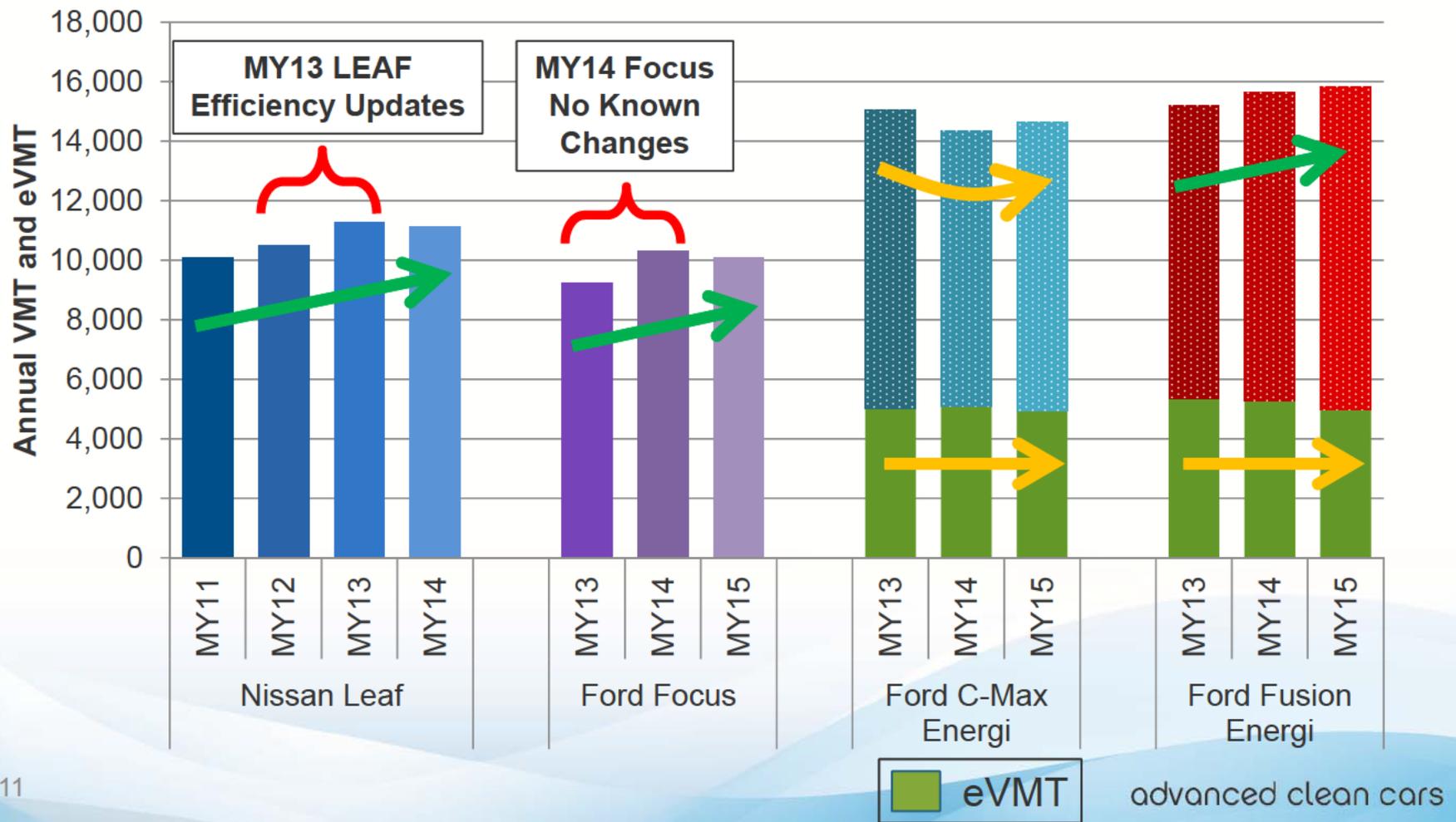


# Significant Variability in Actual eVMT - Both across and within PHEV models



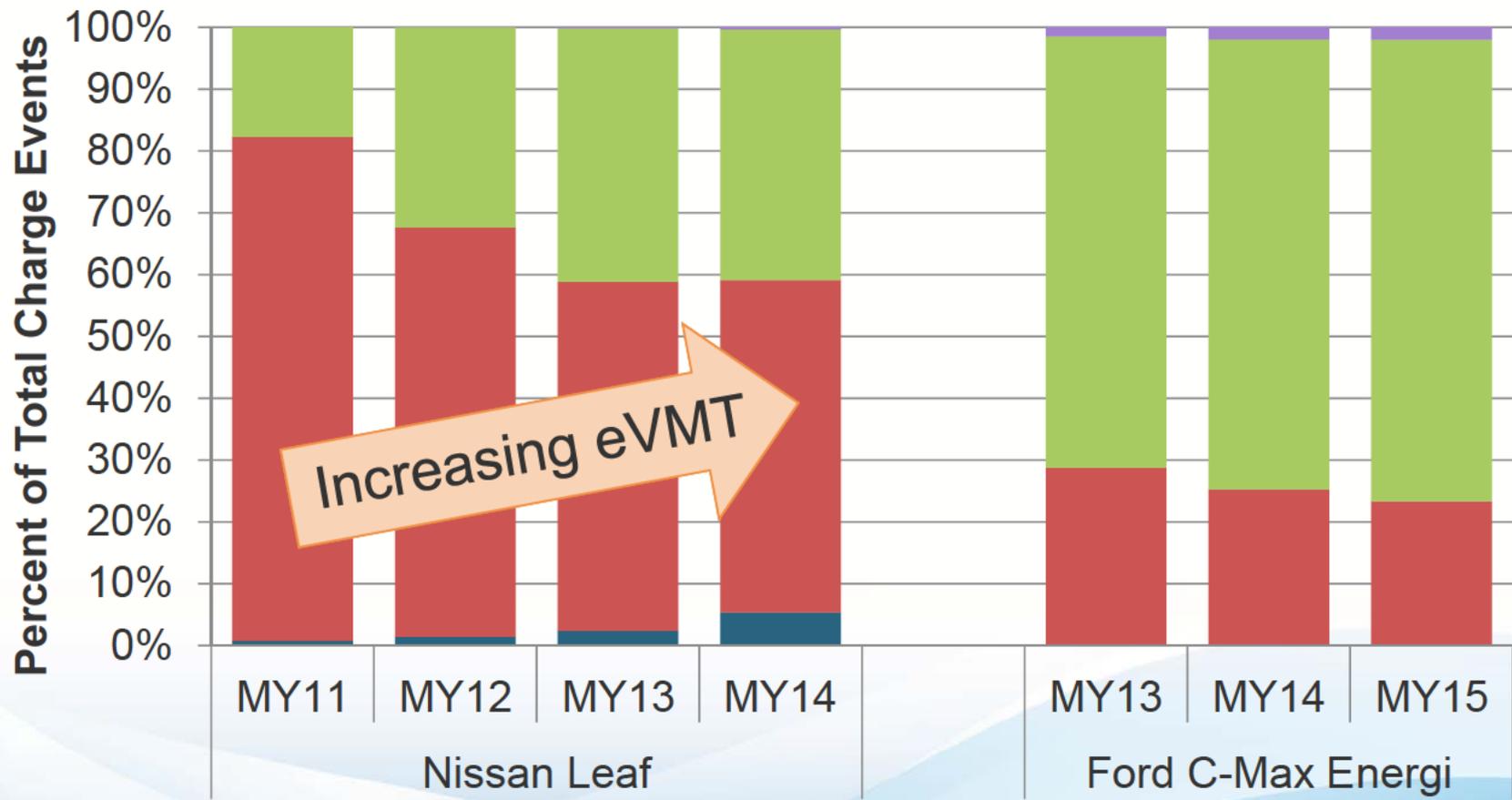
# Most Most Newer Drivers Using PEVs More than Early Adopters

Initial year usage by model year

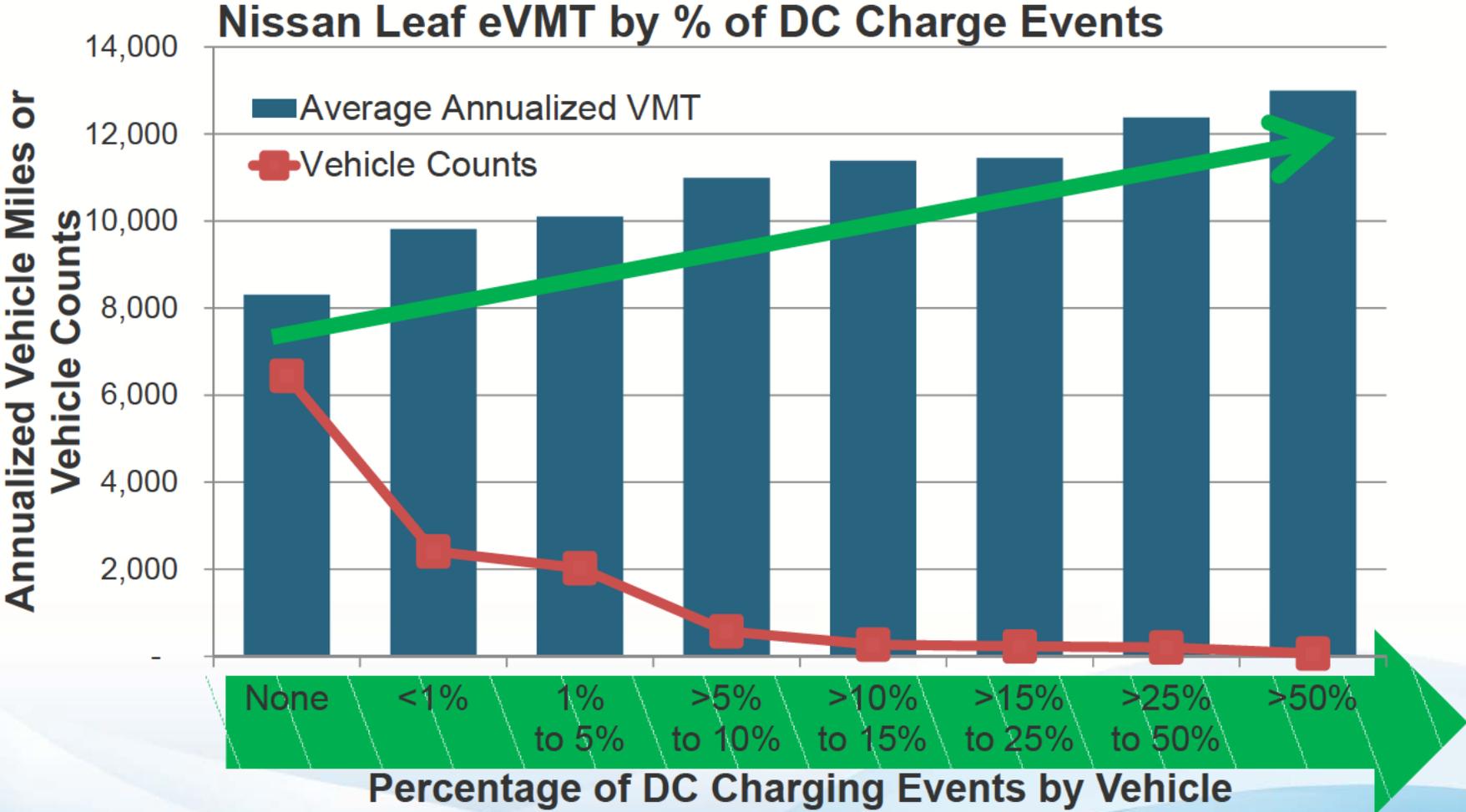


# More Drivers Choosing to Use Level 1 Charging

■ DCFC ■ Level 2 (240V) ■ Level 1 (120V) ■ Unknown

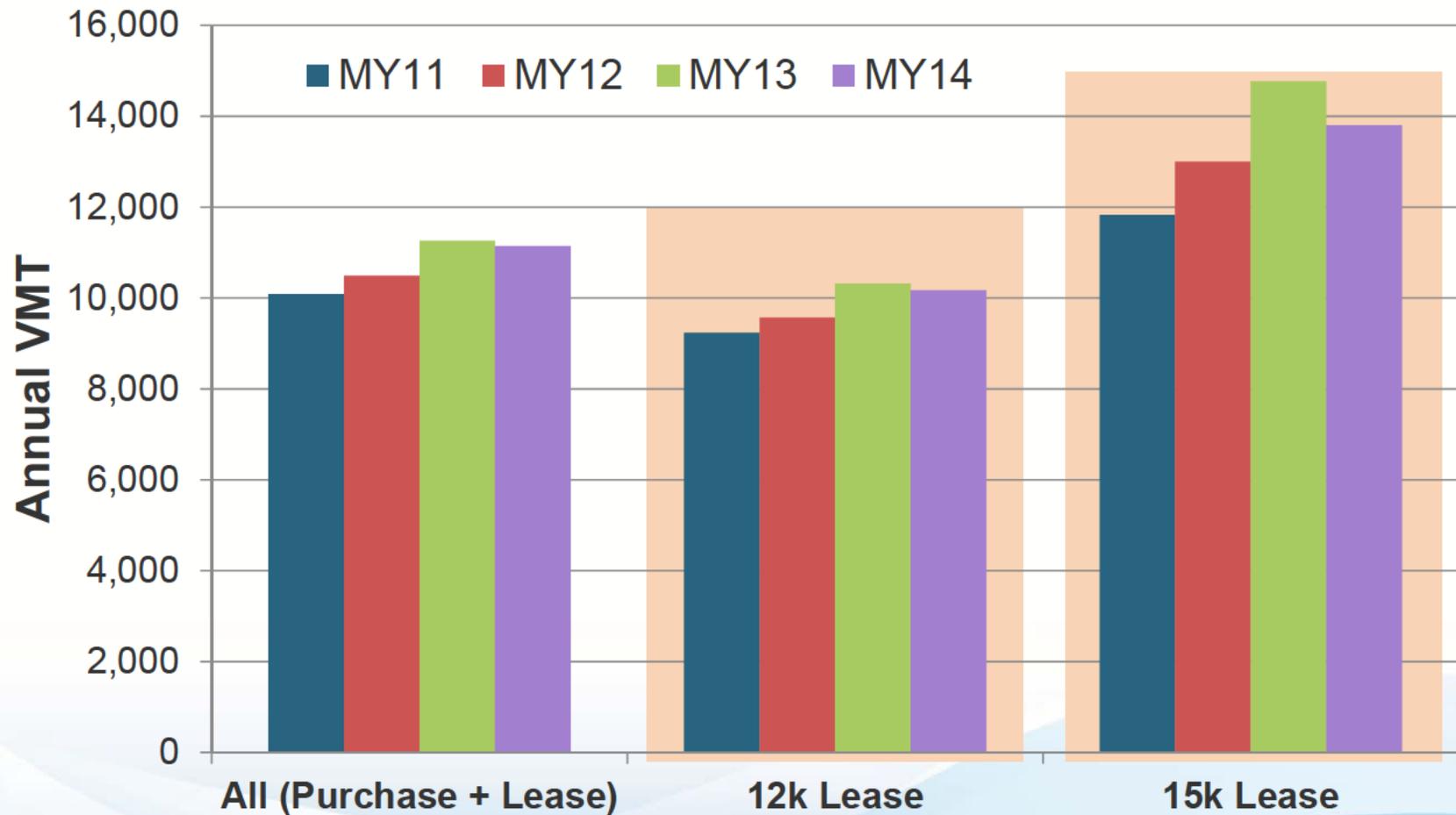


# DC Fast Charge Usage Related to Higher VMT



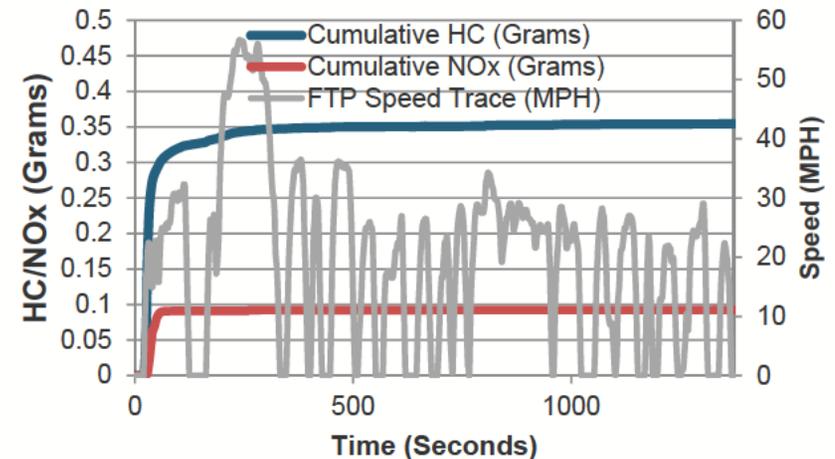
# Impact of Lease Terms on VMT

Nissan Leaf initial year usage by model year



# Understanding Criteria Pollutant Emissions from PHEVs

- HC/NOx emissions dominated by initial engine start
  - 65-80% of FTP HC & NOx emissions emitted in first 40 secs
  - 90-98% within first 120 secs
- Accordingly, focus on understanding PHEV start emissions
  - Frequency of starts; and
  - Condition of starts (in spectrum of hot → warm → cold)



# Average # of Starts per Day

Vehicle Technology	Average # trips/day	Average # e-trips/day	Average # of trips/day with IC Engine start
Conventional ICE (CHTS 2012)	4.75	0	4.75
Toyota Prius PHEV	4.66	0.64	4.02
Honda Accord PHEV	4.15	0.35	3.80
GM Volt	3.96	3.08	0.88

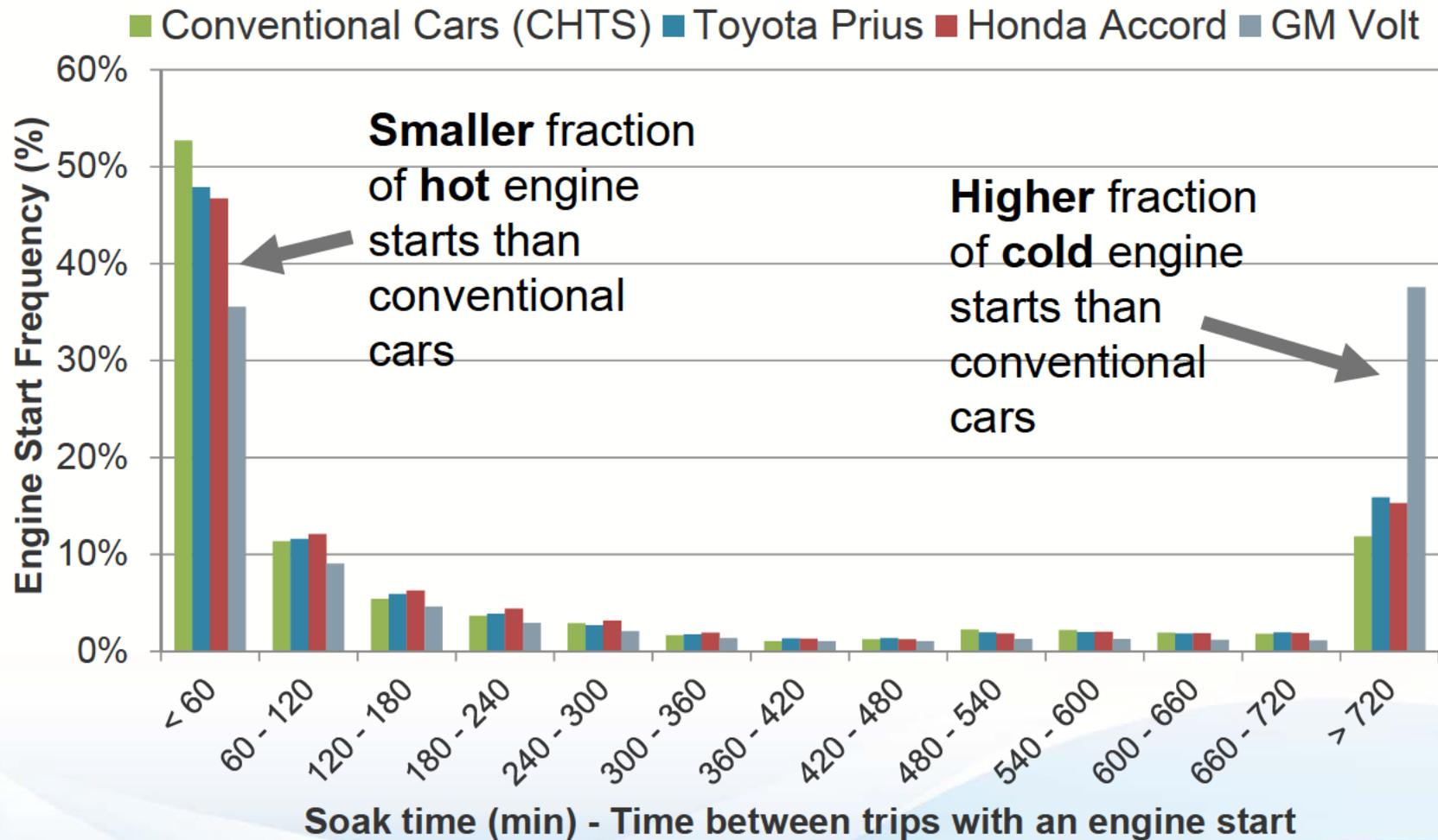
Fewer trips per day = fewer start emissions



CHTS: California Household Travel Survey 2012

# Frequency of Hot/Cold Starts on PHEVs

How much time between trips where the engine starts?



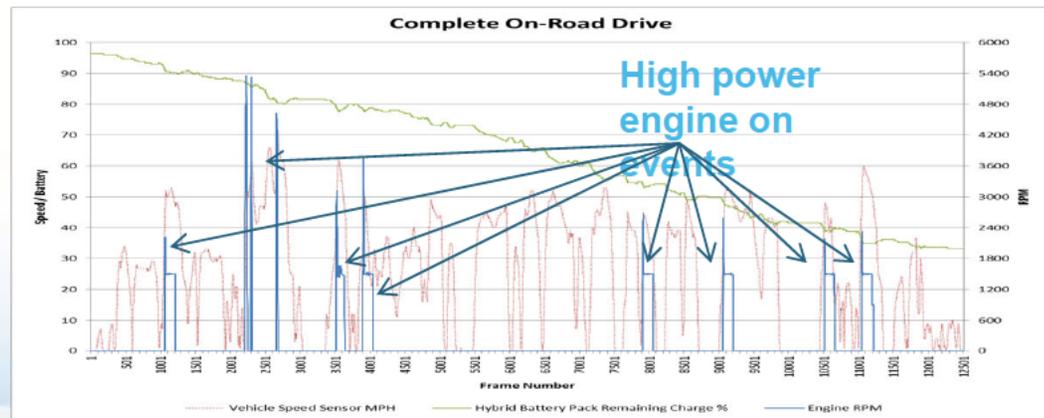
# Cold Start Frequency

Vehicle Technology	Average # trips/day	Average # of trips/day with IC Engine start	% IC engine trips with cold start (Overnight soak)	Average # of Cold Starts/day
Conventional ICE (CHTS 2012)	4.75	4.75	X 12%	= 0.56
Toyota Prius PHEV	4.66	4.02	16%	0.64
Honda Accord PHEV	4.15	3.80	15%	0.58
GM Volt	3.96	0.88	38%	0.33

Not necessarily fewer cold starts per day

# PHEV Start Emissions Analysis

- Covered the easy parts:
  - Fewer trips with an engine start = fewer emissions
  - Different distribution of hot → warm → cold starts
- Hard part:
  - Blended PHEVs, by design, can have initial engine start under “high power” demands
  - FTP initial engine starts not representative of “high power” starts



# 'High Power' Starts Analysis



Use on-road driving to define driving that causes 'high-power' starts

- E.g., freeway on-ramps, merging, passing, uphill events



Recreate maneuvers in emission test cycles in the lab

- Quantify 'high-power' start emissions



Analyze in-use data to determine frequency of such events

- UC Davis data includes sec by sec logging of all driving



Combine data in model to project in-use emissions

- Start (normal and high-power) emission rates
- Distribution/frequency of start conditions (normal/high power across spectrum from hot→warm→cold)

# Summary

- VMT continues to change
  - Increased VMT for BEVs
  - Increased VMT for some PHEVs, but similar or lower eVMT
- Usage among PHEVs and BEVs varies considerably
  - eVMT/zVMT highly variable across a single vehicle type
- Many observed factors beyond electric range that affect in-use results
  - Powertrain architecture, lease terms, charging type/usage, etc.
  - Not to mention energy (gas and electricity) prices, driver habits, vehicle age, etc.
- Criteria pollutant benefits more difficult to assess on blended PHEVs
  - eVMT works well for GHG
  - TBD on what works well for HC/NOx