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USABC Development of 12 Volt Energy Storage Requirements for Start-Stop Application

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USABC Overview

Development Partners
Technical Expertise
Tangible Cost Data
Applied Research Capability
Manufacturing Capability
Hardware Deliverables
Cost-Shared Funding

Automotive OEM's
Technical Expertise
Funding Coordination
Program Management
Test Method Development
Industry Experience & Input
Development Partner Assistance
Real World Requirement Perspective

National Labs
Life Prediction
Abuse Testing
Development Partner Assistance
Long Term Fundamental Research
Performance & Benchmark Testing
Thermal Analysis & Design Support
Battery Simulation and Model Development

DOE
Funding Coordination
National Lab Management
Governmental Perspective

- The United States Advanced Battery Consortium (USABC), comprised of General Motors, Ford and Chrysler funds pre-competitive electrochemical energy storage R&D to support the commercialization of fuel cell, hybrid and electric vehicles
- Fund development activity through a cooperative agreement between USABC and U.S. Department of Energy (DOE).
- Demonstrate cooperation that allows for the combined technical and financial resources of the DOE, OEM's, development partners, and U.S. National laboratories to jointly conduct advanced battery research and development.

Motivation

- Start-stop systems eliminate engine idling when the vehicle is stopped but in a key-on state
- This technology is popular in Europe and increasingly so in the United States
- Widespread adoption could significantly reduce the cumulative vehicle fleet CO_2 emissions & fuel consumption
- Accordingly, the USABC has identified **requirements/targets** for developing such energy storage technology to encourage advancement of start-stop vehicles in US.
- Purpose of this presentation is to document the target analysis process

Approach

- Collaborative effort with the DOE's National Renewable Energy Laboratory to perform analysis of the start-stop application
- Leverage drive data from real-world drivers to compute duty cycles
- Apply duty cycles to simplified vehicle simulation to calculate energy storage requirements and impact on vehicle performance
- Develop test protocols that faithfully recreate expected in-vehicle conditions

Vehicle Data

- Collected 1,984 second-by-second vehicle speed histories from multiple studies across three US cities.
  - Austin, TX
  - San Antonio, TX
  - Los Angeles, CA

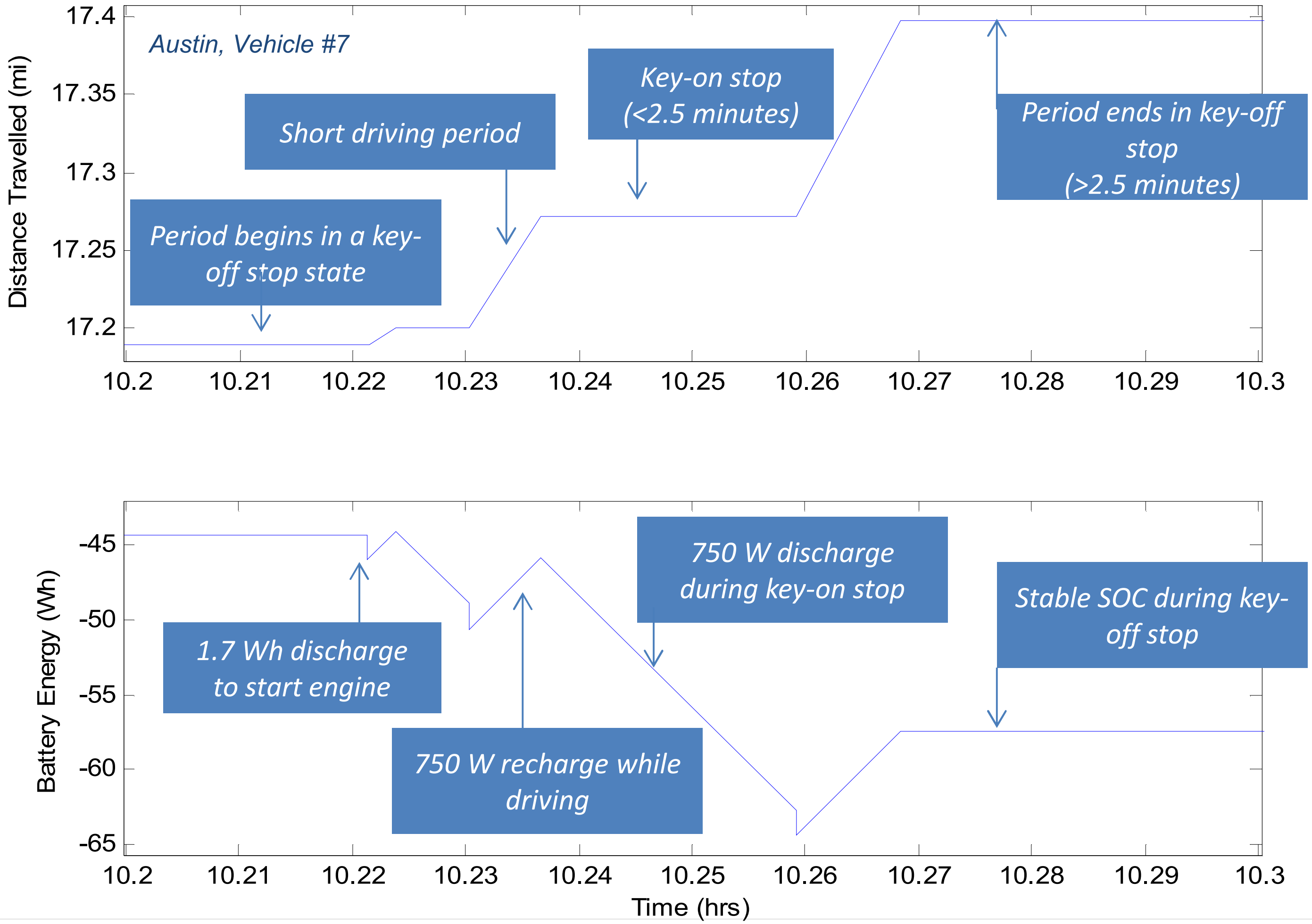
- Reduced drive data to time and tri-modal state history.
  - Driving
  - Key-on stop
  - Key-off stop

Vehicle Simulation: Inputs

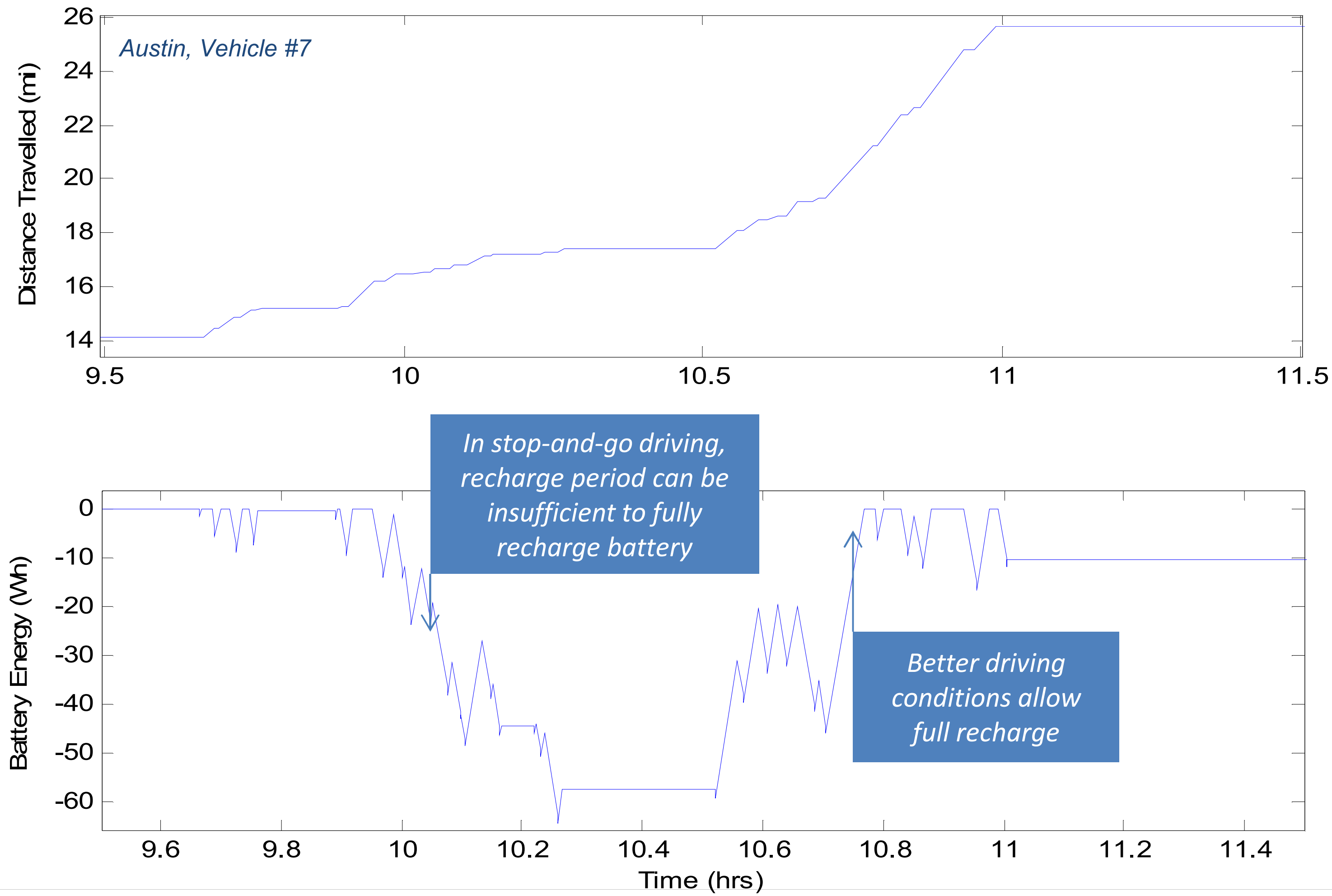
- Applied USABC and NREL simulation and test data to select reasonable assumptions for input values

Parameter	Value	Source
Charge power	750 W	USABC Workgroup
System round trip efficiency	90%	
Engine-off accessory load	750 W	Supported by vehicle test data (NREL and USABC Workgroup)
Engine-start energy, hot	1.7 Wh *(6 kW for 1s)*	USABC Workgroup, supported by vehicle test data
Engine-start energy, cold (Cold cranking energy)	9.2 Wh *(6 kw * 0.5 s + 3 kW * 10 s)*	USABC Workgroup
Recharge engine efficiency	22%	Supported by vehicle test data and vehicle simulation over real world drive cycles
Fuel rate at idle	1.0E-4 gal/s (0.28 g/s)	Supported by vehicle test data
Regen. Percentage	0%	Regen not considered here

Vehicle Simulation: A Few Minutes



Vehicle Simulation: A Few Hours



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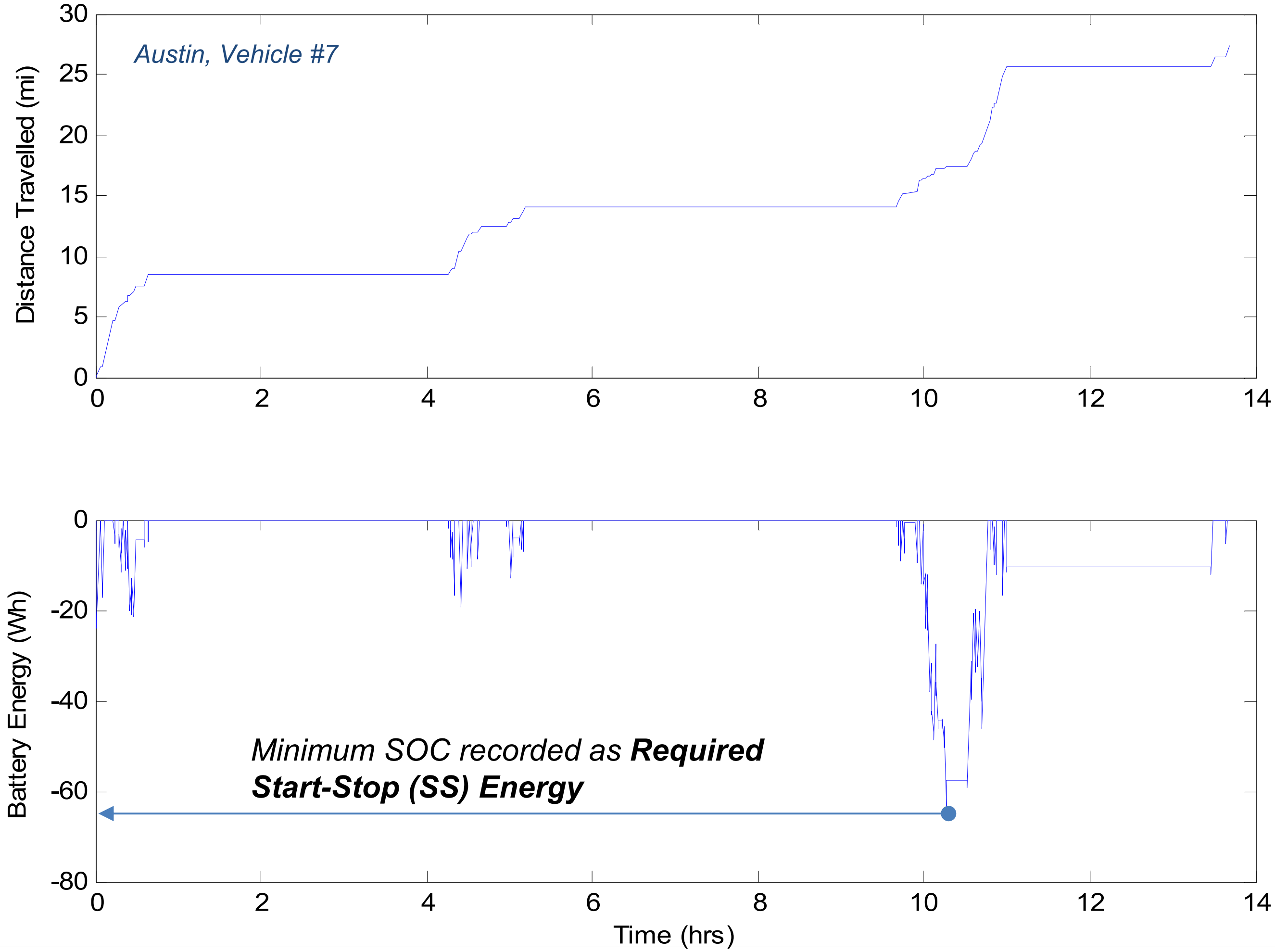
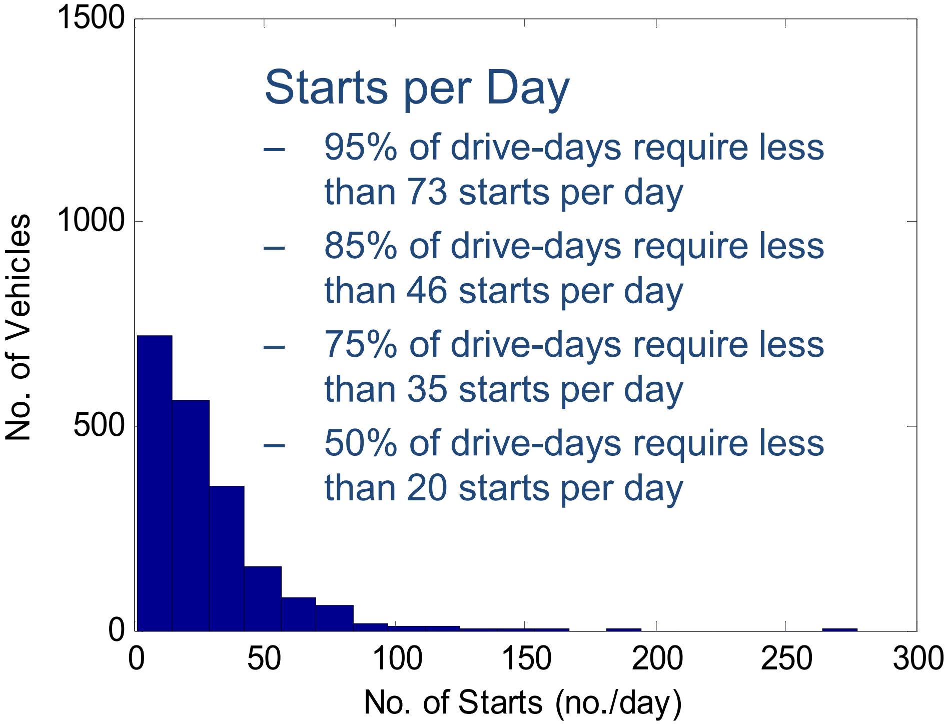
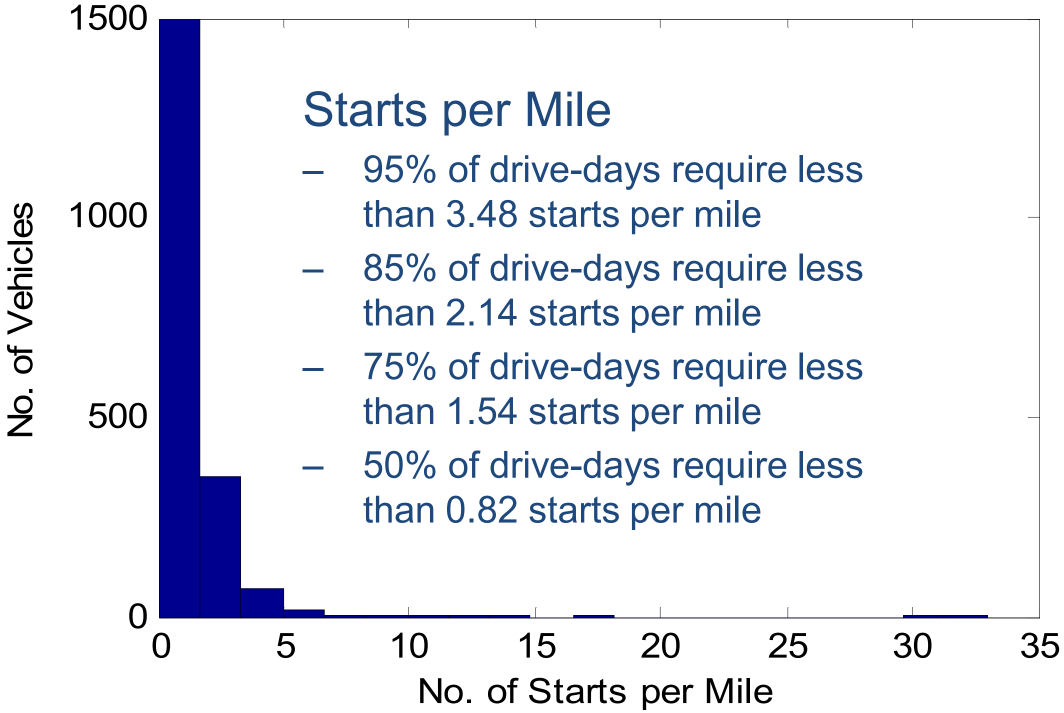
Vehicle Simulation: Many Hours

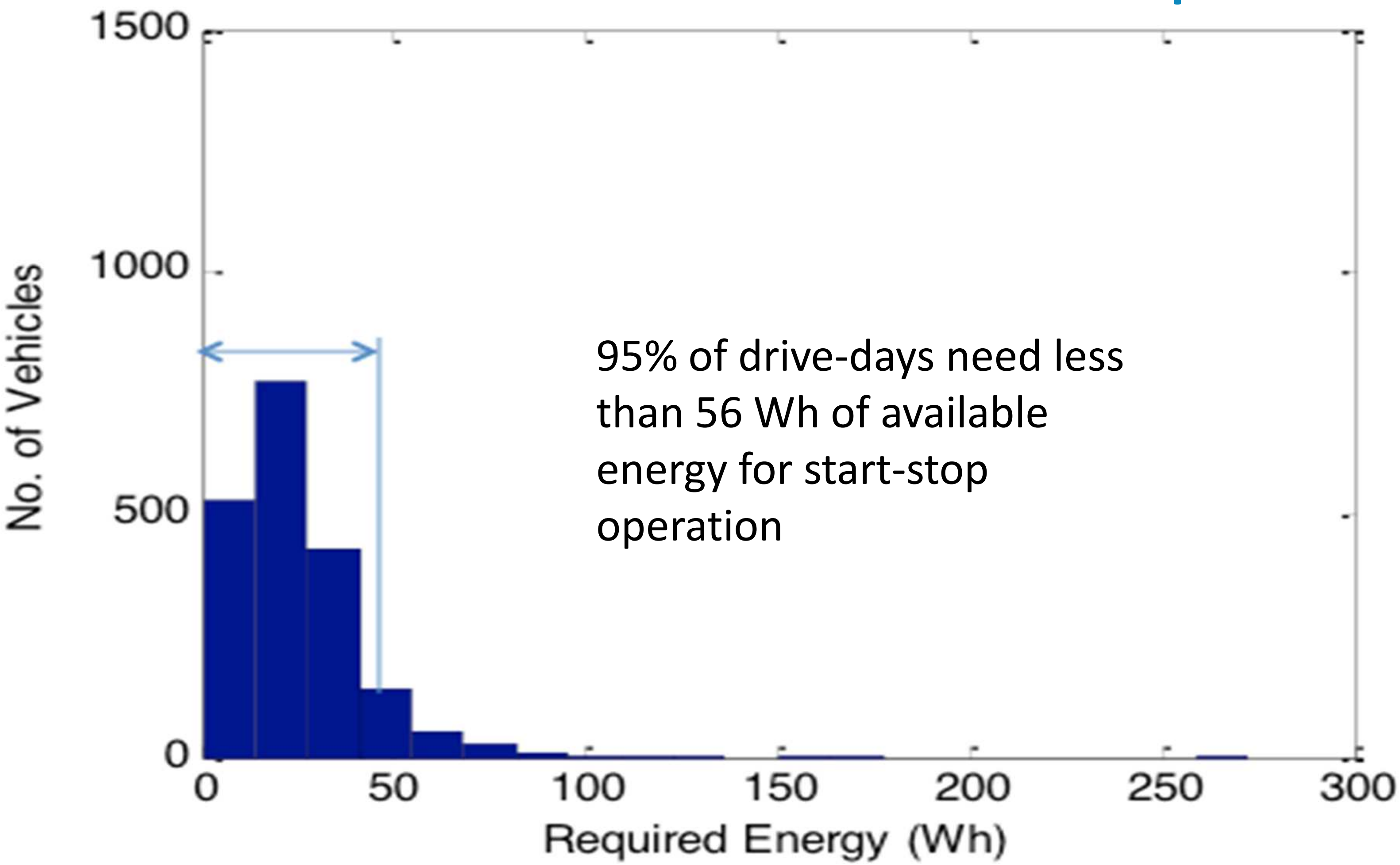


Results: No. of Starts



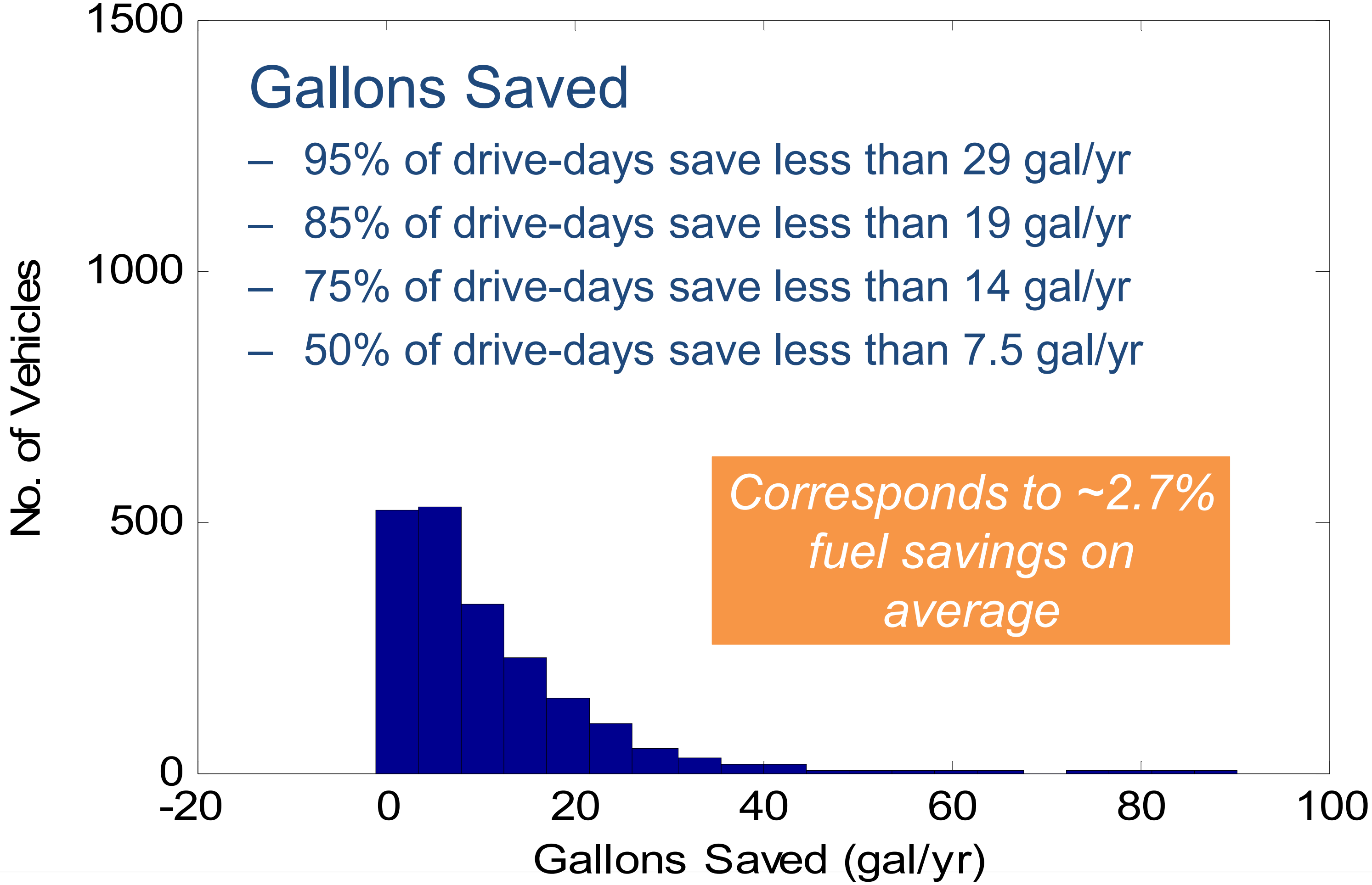


Results: Required Energy

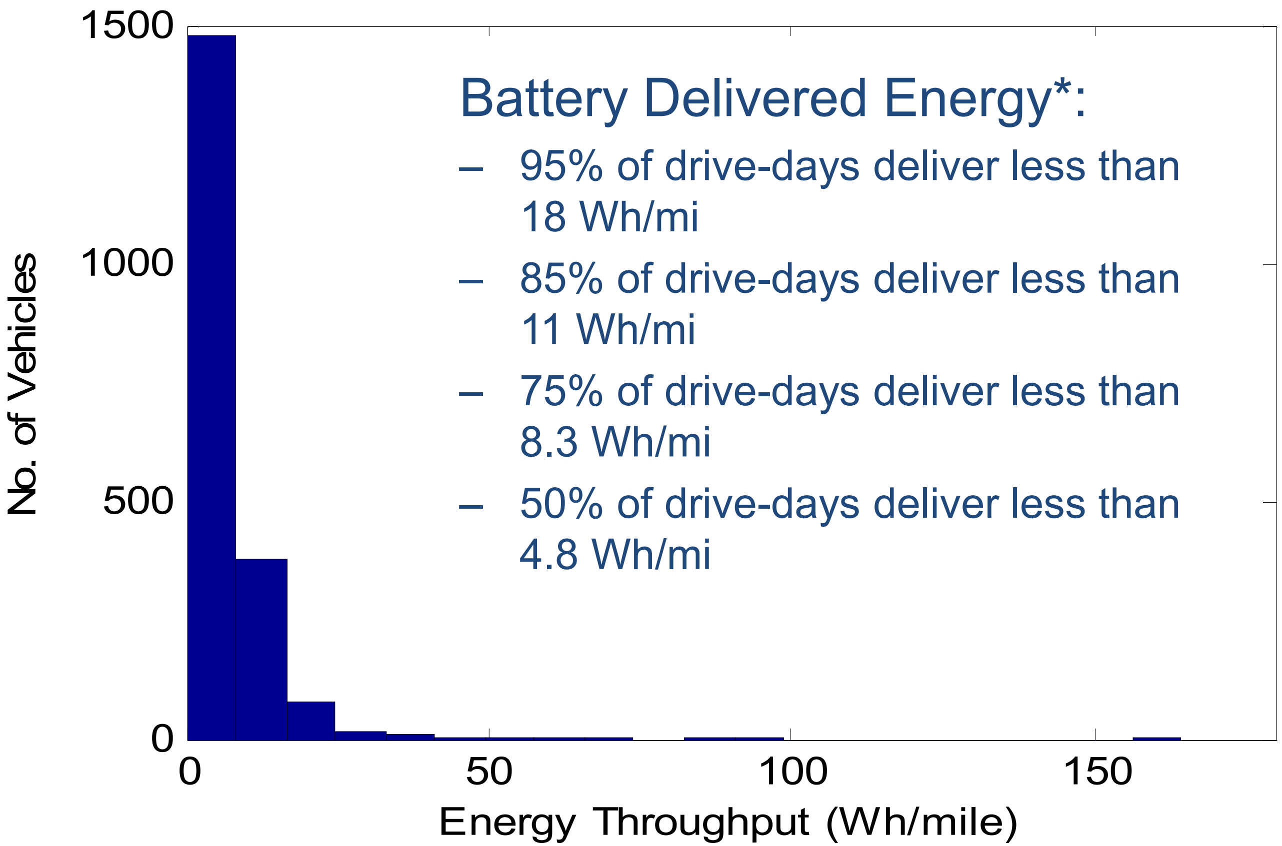


95% of drive-days need less than 56 Wh of available energy for start-stop operation

Results: Fuel Savings



Results: Delivered Energy



**Delivered Energy = sum of all battery discharges (includes both engine start and aux load discharges)*

Results: Stats & Energy Budget

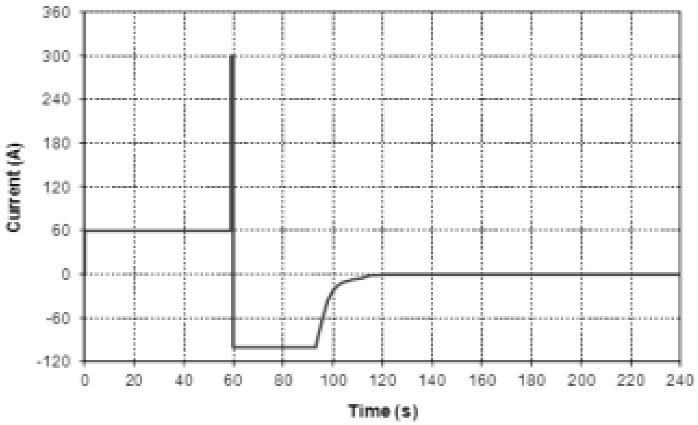
	50^{th} % driver	95^{th} % driver
No. of Starts	**20 /day**	**73 /day**
Total Required Energy	**310 Wh**	**345 Wh**
Start-Stop Energy	21 Wh	56 Wh
Cold Cranking Reserve	9.2 Wh	
Additional Accessory Load (750 W for 12 minutes)	150 Wh	
Parasitic Load (15 mA for 30 days)	130 Wh	
Battery Delivered Energy	**4.8 Wh/mi**	**18 Wh/mi**
Estimated Annual Fuel Savings	**7.5 gal/yr (~2%)**	**29 gal/yr (~6%)**

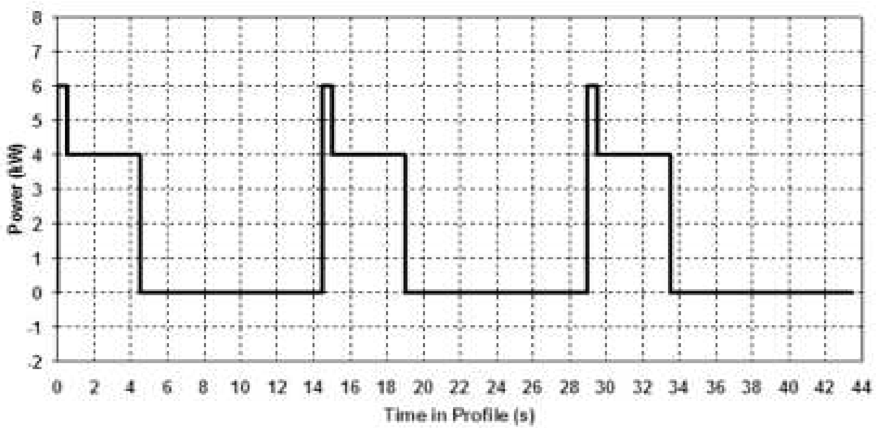
Final Target

End of Life Characteristics	Units	Target	
		Under hood	Not under hood
Discharge Pulse, 1s	kW	6	
Max discharge current, 0.5s	A	900	
Cold cranking power at -30 °C (three 4.5-s pulses, 10s rests between pulses at min SOC)	kW	6 kW for 0.5s followed by 4 kW for 4s	
Min voltage under cold crank	Vdc	8.0	
Available energy (750W accessory load power)	Wh	360	
Peak Recharge Rate, 10s	kW	2.2	
Sustained Recharge Rate	W	750	
Cycle life, every 10% life RPT with cold crank at min SOC	Engine starts/miles	450k/150k	
Calendar Life at 30°C, 45°C if under hood	Years	15 at 45°C	15 at 30°C
Minimum round trip energy efficiency	%	95	
Maximum allowable self-discharge rate	Wh/day	2	
Peak Operating Voltage, 10s	Vdc	15.0	
Sustained Operating Voltage – Max.	Vdc	14.6	
Minimum Operating Voltage under Autostart	Vdc	10.5	
Operating Temperature Range (available energy to allow 6 kW (1s) pulse)	°C	-30 to + 75	-30 to +52
30 °C – 52 °C	Wh	360 (to 75°C)	360
0 °C	Wh	180	
-10 °C	Wh	108	
-20 °C	Wh	54	
-30 °C	Wh	36	
Survival Temperature Range (24 hours)	°C	-46 to +100	-46 to +66
Maximum System Weight	kg	10	
Maximum System Volume	L	7	
Maximum System Selling Price (@250k units/year)	$	$220	$180

OEMs combined analysis results with additional vehicle requirements to complete the technology target

Test Profiles





- Cycle life test profile based on SBA S 0101:2006 from Japan SAE
- Cold cranking profile based on analysis of test data from class 1 ¾ ton pickup truck

Candidate Technologies

Technology	Strengths	Weaknesses
Advanced Lead-Acid Batteries	Potential for low cost; simplicity	Partial SOC cycle life; volume and mass
Li-Ion (x/LTO)	Good cycle life; low volume and mass	High cost; safety
Capacitor variants	Good cycle life; high power	High cost; volume and mass

Active Development Programs

- USABC has funded Leyden Energy to develop an LTO/LMO based li-ion battery using its Li-Imide electroloyte for 12V start-stop applications with a $2.28M / 16 month award.

- USABC has funded Saft to develop an advanced li-ion battery for 12V start-stop applications with a $1.99M / 12 month award.

Summary

- NREL analyzed real-world drive data to calculate usage statistics and duty cycles of start-stop batteries with input from USABC
- USABC developed a start-stop energy storage technology targets/requirements and duty cycles for testing based on these results and other input
- Here, we outlined the process of target development
- Based on a competitive procurement, USABC is funding two companies to develop batteries for 12V start-stop applications