NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Medium Duty ARRA Data Reporting and Analysis



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National Renewable Energy Laboratory
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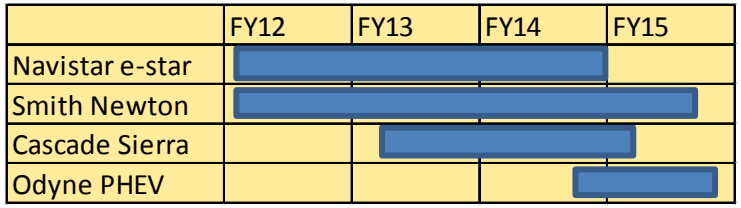
Project ID VSS124

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

Overview

Timeline

- **Multiple Sites/Projects**: varies by project
- **Project Length:** varies by project
- **For FY14:** Some "in-process," some "new"
- **Percent Complete:** ~70%



Budget

- **Total Project Funding : ~$700K**
  - **DOE Share: $250K in FY14**
  - Participant cost share: in-kind support (data supplied to NREL)
- **DOE Funding Received in FY13: $200K**

Barriers

- **Unbiased Data:** Commercial users and OEMs need unbiased, 3rd-party data for better understanding of state-of-the-art technology performance to overcome technical barriers
- **Variable Commercial Vehicle Use:** Variable performance by technologies due to multiple and wide-ranging duty cycles (makes data and analysis of data valuable in overcoming this barrier)

Partners

- **Industry collaboration required for successful studies. Current Partners in FY14:** Smith, Navistar, Cascade Sierra Solutions, Shorepower, Odyne, South Coast Air Quality Management District (SCAQMD), Electric Power Research Institute (EPRI)
- **Project Lead:** National Renewable Energy Laboratory (NREL)

Relevance

This project compiles medium-duty (MD) aggregated deployment data and compiles detailed analysis to industry :

- The U.S. Department of Energy's (DOE's) American Recovery and Reinvestment Act (ARRA) deployment and demonstration projects are helping to commercialize technologies for all-electric vehicles (EVs), electrified accessories, and electric charging infrastructure.
  - Over 3.2 million miles of in-service medium all-electric duty truck data from 560 different vehicles have been collected since 2011
  - Usage data from over 1,000 truck electrification sites have been collected since 2013

- Through the DOE's Vehicle Technologies Office, NREL is working to analyze real-time data from these deployment and demonstration projects to quantify the benefits
  - Results and summary statistics are made available through the NREL website as quarterly and annual reports
  - 23 aggregated reports have been published on the performance and operation of these vehicles
  - Detailed data are being extracted to help further understand battery use and performance

Milestones

Month / Year	Milestone or Go/No-Go Decision	Description	Status
Q1	Milestone	Status Report on all Projects	Complete
Q2	Milestone	Status Report on all Projects	Complete
Q3	Milestone	Status Report on all Projects	On-Track
Q4	Milestone	Final Report & Data on all Projects	On-Track

- **In addition to the above reports, aggregated quarterly and aggregated cumulative reports will be published**

Approach/Strategy

- Obtain 25+ parameters at 1 Hz from each vehicle to be stored and analyzed by NREL
- Obtain truck stop electrification (TSE) usage records that detail each time a site is used
- Securely collect, store, analyze, and back up this dataset
- Refine and optimize processing routines to handle increased volumes of data
- Continue to increase the number of metrics used, and cross-correlate this data with other fleet evaluations to better understand petroleum and emissions displacement
- Work with industry partners to understand what metrics are most useful for analyzing and growing these technologies
- Report data and progress back to DOE and the general public

Technical Accomplishments and Progress

Smith Electric Vehicles – Newton

- **500 Newtons being deployed in the U.S.**
  - Manufactured in Kansas City, MO
  - $32-million ARRA award
  - Currently reporting
    - 259 of 309 first generation
    - 200 of 203 second generation
  - 80 – 120 kWh Li-ion battery packs
  - Service and delivery applications
  - Deployments include:
    - Coca Cola (NY)
    - Kansas City Power and Light (MO)
    - AT&T (MO)
    - Staples (CA, OH)
    - PG&E (CA)

GVW	22–27K lbs.
Drag Coefficient	~0.5
Charging Standards	J1772 or 3-phase
Onboard Charger Power	5–6 kW
Battery Capacity	80 – 120 kWh
Inverter Efficiency	94%
Motor	
Peak Motor Power	134 kW

GVW = gross vehicle weight

Smith Newton Vehicle Performance

Number of vehicles (Gen1 / Gen2): 259 / 200

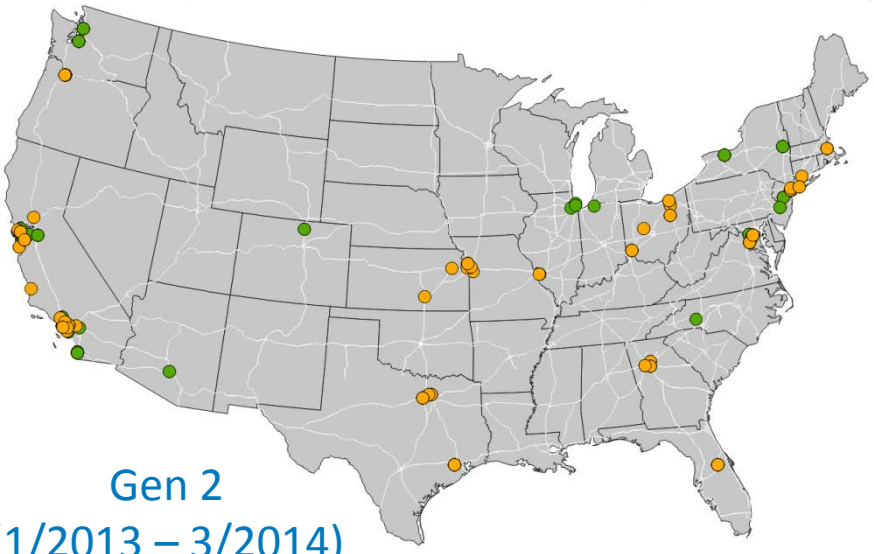
Number of vehicle days driven: 83,799 / 29,247

Number of operating cities: 81 / 40

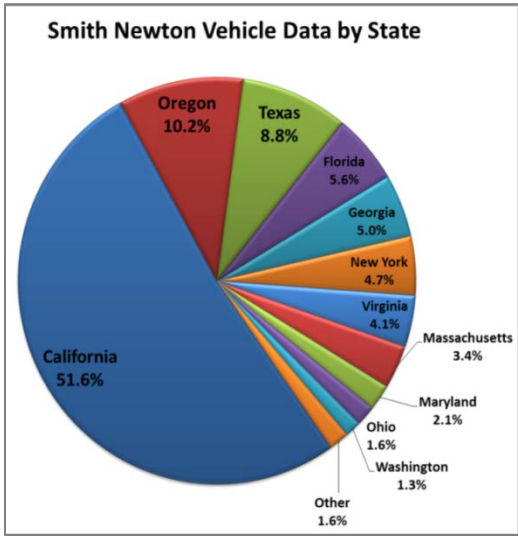
Objective:

Performance evaluation of ARRA-funded Smith EVs deployed throughout the United States in MD delivery applications

- Using automated analysis and reporting routines
- Gen 1 vehicles: 309 unique IDs / 259 processed
- Gen 2 vehicles: 203 unique IDs / 200 processed
- Gen 2 vehicles showing improved performance

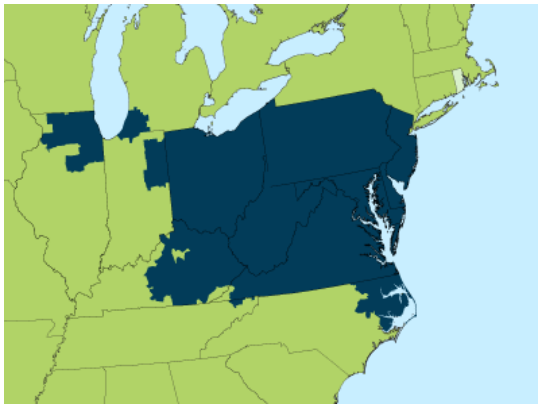


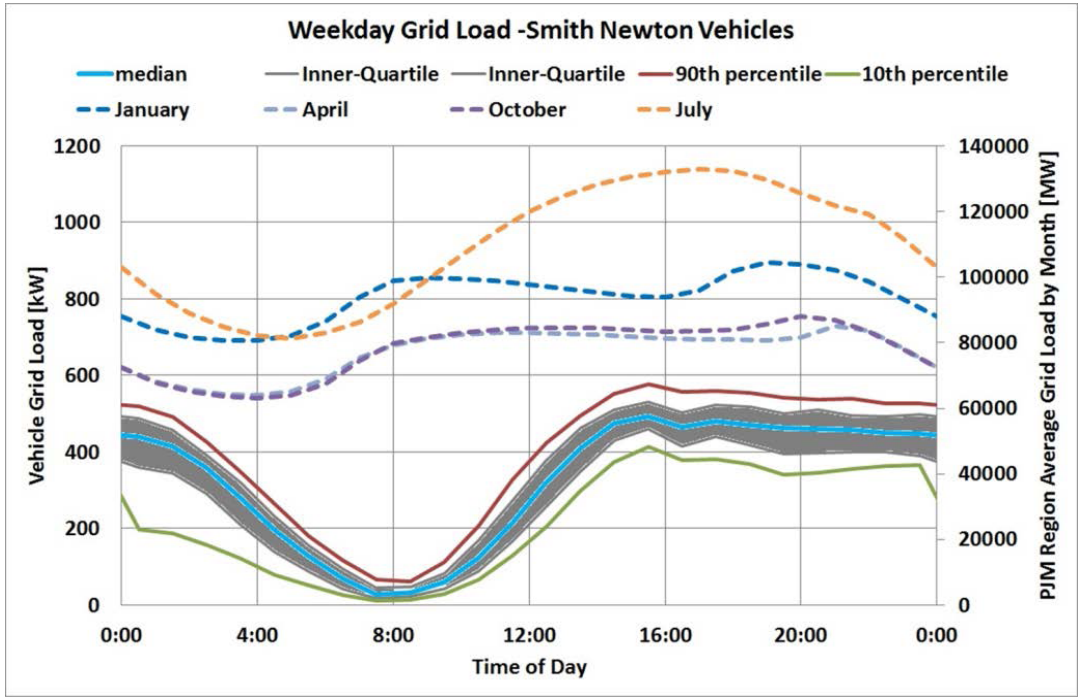
Trip Data	Gen 1 (11/2011 – 3/2014)	Gen 2 (1/2013 – 3/2014)
Overall Diesel Equivalent Fuel Economy	24.7 mpge	28.1 mpge
Overall AC Energy	1,858.0 Wh/mi	1,796.5 Wh/mi
Overall DC Electrical Energy Discharged	1,519.5 Wh/mi	1,338.7 Wh/mi
Driving DC Electrical Energy Consumption	1,412.8 Wh/mi	1,278.8 Wh/mi
Total Number of Charges	155,057	54,280
Total Charge Energy Delivered	3,953,616 kWh	1,375,464 kWh
Total Distance Traveled	2,127,895 miles	765,642 miles
City | Highway Distance	1,381,555 | 752,060 miles	48,220 | 320,168 miles
City | Highway Distance	64.9 | 35.3 %	58.5 | 41.8 %



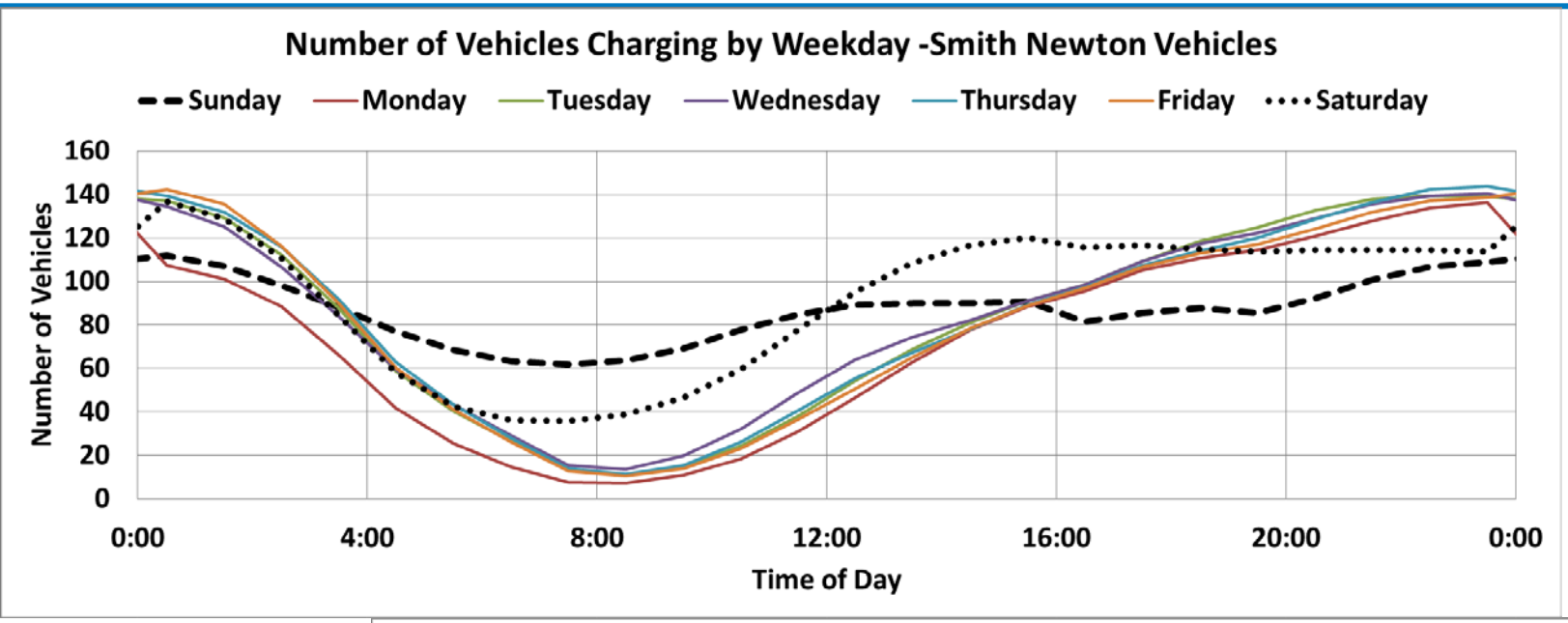
Smith Newton Vehicle Performance

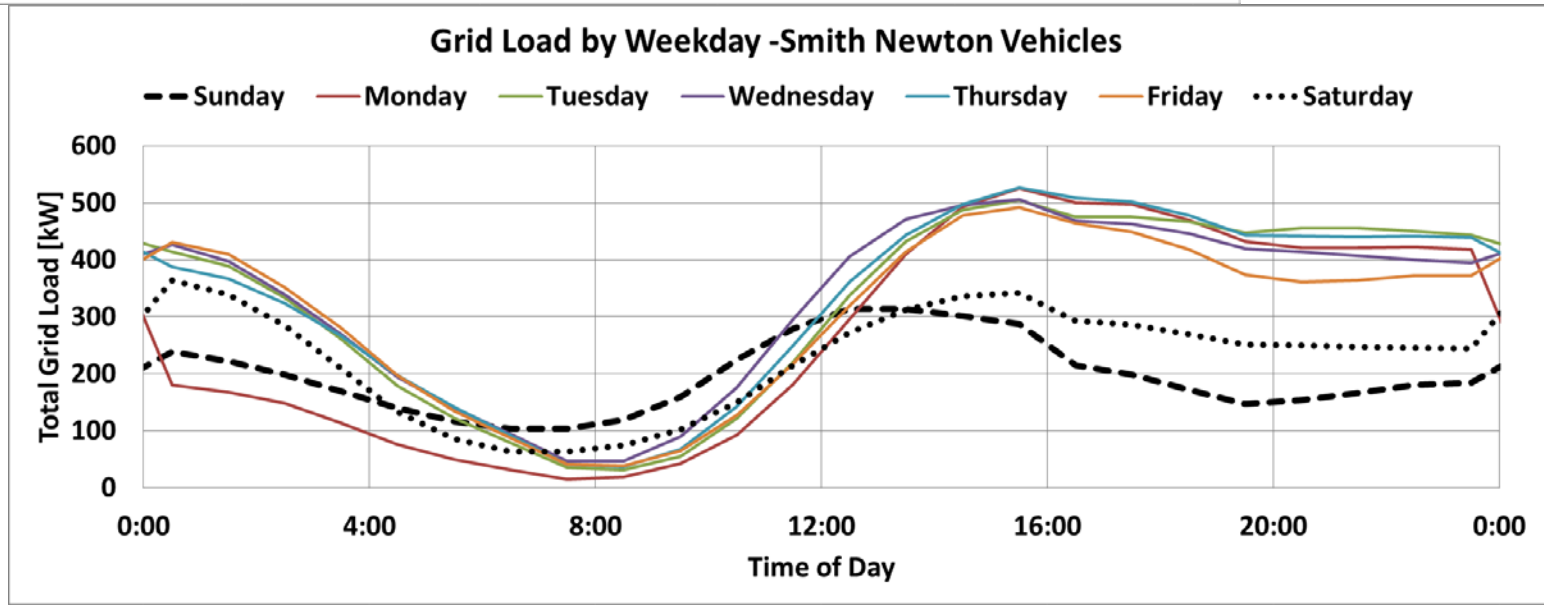
- Potential grid load effects and how these vehicles may impact the electrical demand for a given depot
- Depot electrical demand can impact time of use demand charges and transformer sizing
- Quarterly reports: http://www.nrel.gov/vehiclesandfuels/fleettest/research_electric_smith.html





Smith Newton Vehicle Performance





Technical Accomplishments and Progress

Navistar – eStar

- **The Navistar eStar**
  - 12K lbs. GVW (class 3)
  - Lithium ion, A123 Systems
  - Manufactured in Elkhart, IN
  - Planned deployments
    - FedEx (CA)
    - Cascadia Dealer (OR)
    - Pacific Gas and Electric (CA)

GVW	12,122 lbs.
Payload (Max)	5,100 lbs.
Curb Weight	7,022 lbs.
Charging Standard	J1772
Battery Capacity	80 kWh
Motor Power	70 kW
Top Speed	50 mph
Advertised Range	Up to 100 miles

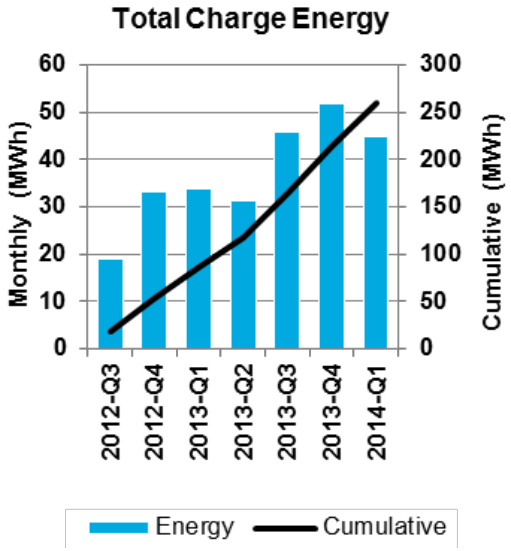
Navistar eStar Vehicle Performance

Number of vehicles reporting: 101
Reporting period: (7/1/2012 to 3/31/2014)
Number of vehicle days driven: 15,623
Number of operating cities: 35

- **Evaluate the performance of class 3 Navistar eStar EVs deployed throughout the United States in MD delivery applications**
- **Leverage NREL-developed tools for automated data filtering and processing**
- **Monthly usage has continued to increase; 2013-Q4 was the highest yet**

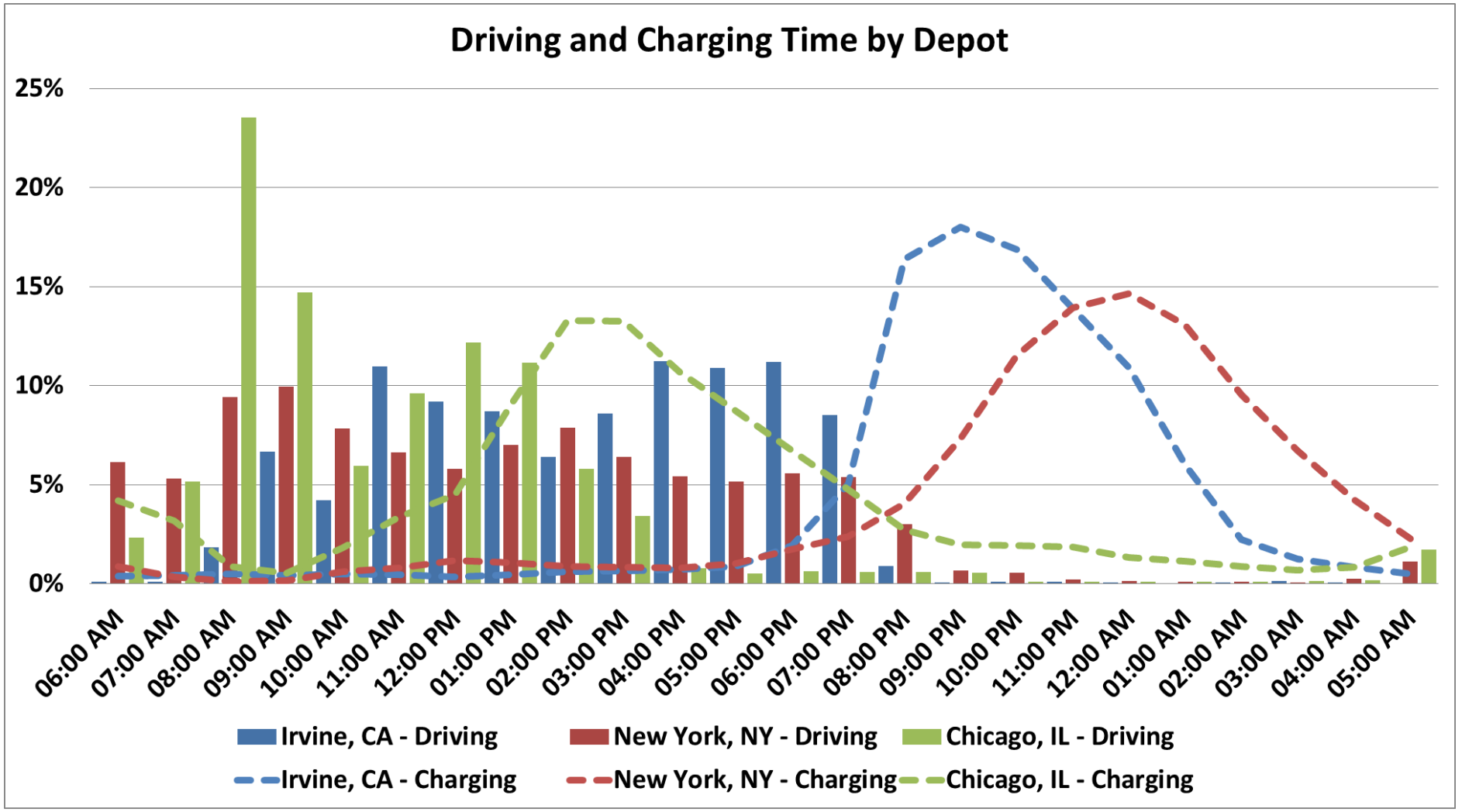
Trip Data

Overall Diesel Equivalent Fuel Economy	45.7	mpge
Overall AC Electrical Energy Charged	902.6	Wh/mi
Overall DC Electrical Energy Charged	852.8	Wh/mi
Overall DC Electrical Energy Discharged	821.9	Wh/mi
Driving DC Electrical Energy Consumption	741.1	Wh/mi
Total Number of Charge Events	14,473	
Total Charge Energy Delivered	269,001.9	kWh
Total Distance Traveled	315,451.9	miles
City | Highway Distance	240,893 | 74,559	miles
City | Highway Distance	76.4 | 23.6	%



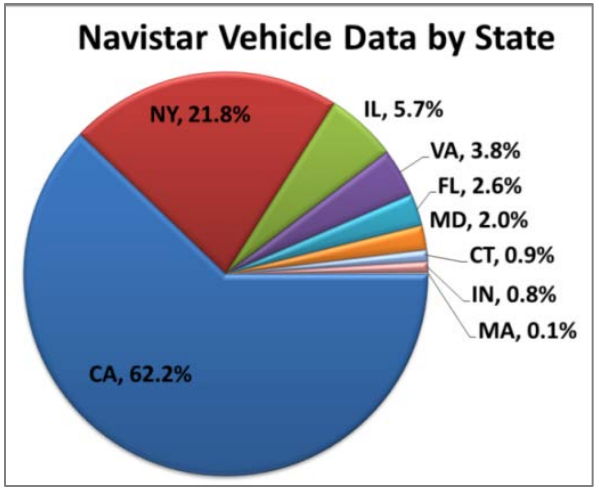
Navistar eStar Vehicle Performance

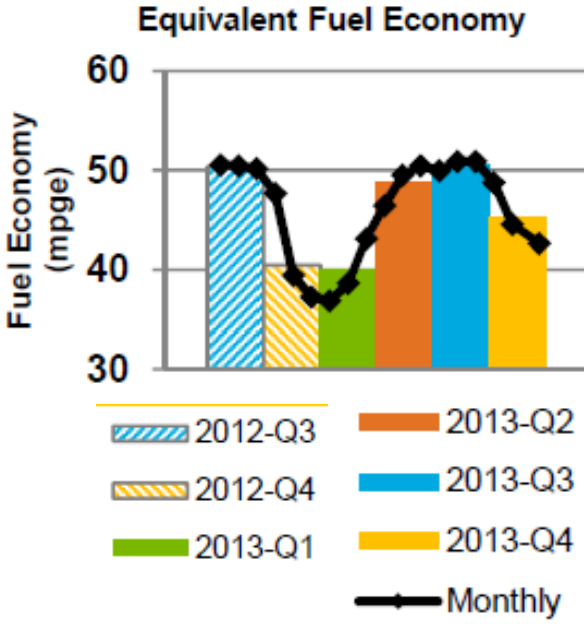
Explore regional and vocational differences

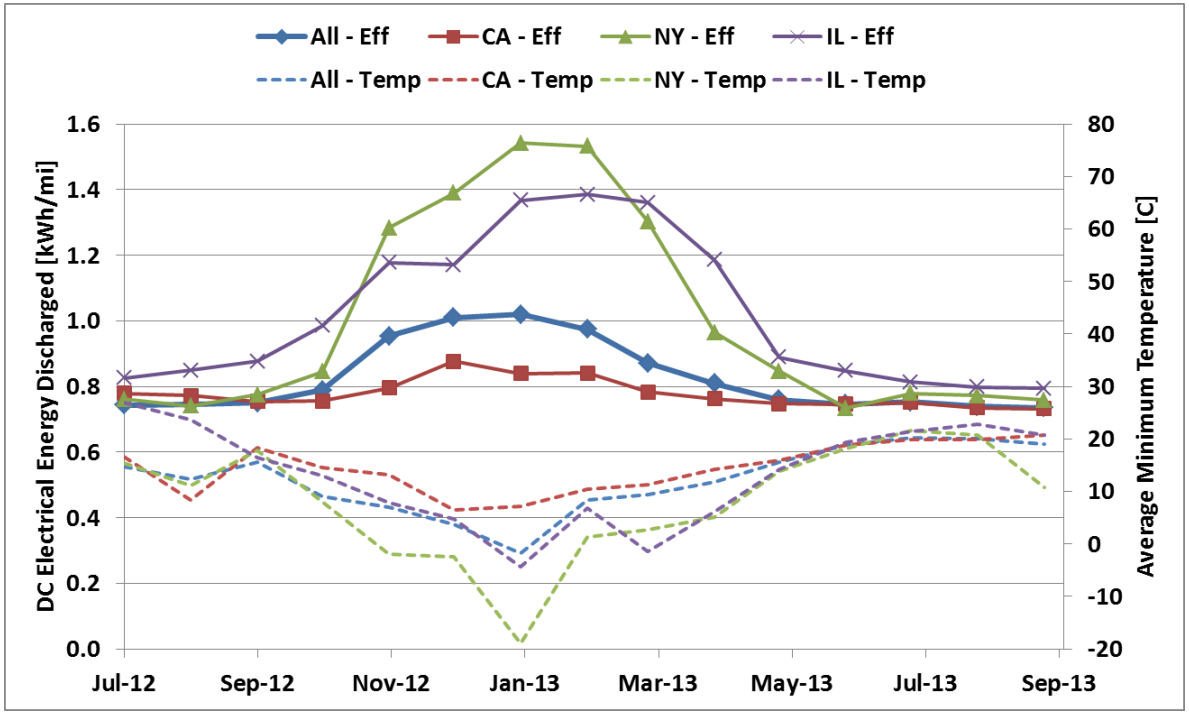


Navistar eStar Vehicle Performance

- **Seasonal effects primarily driven by the energy penalty from the resistive heater**
- **Outputs**
  - Quarterly reports: http://www.nrel.gov/vehiclesandfuels/fleettest/research_electric_smith.html





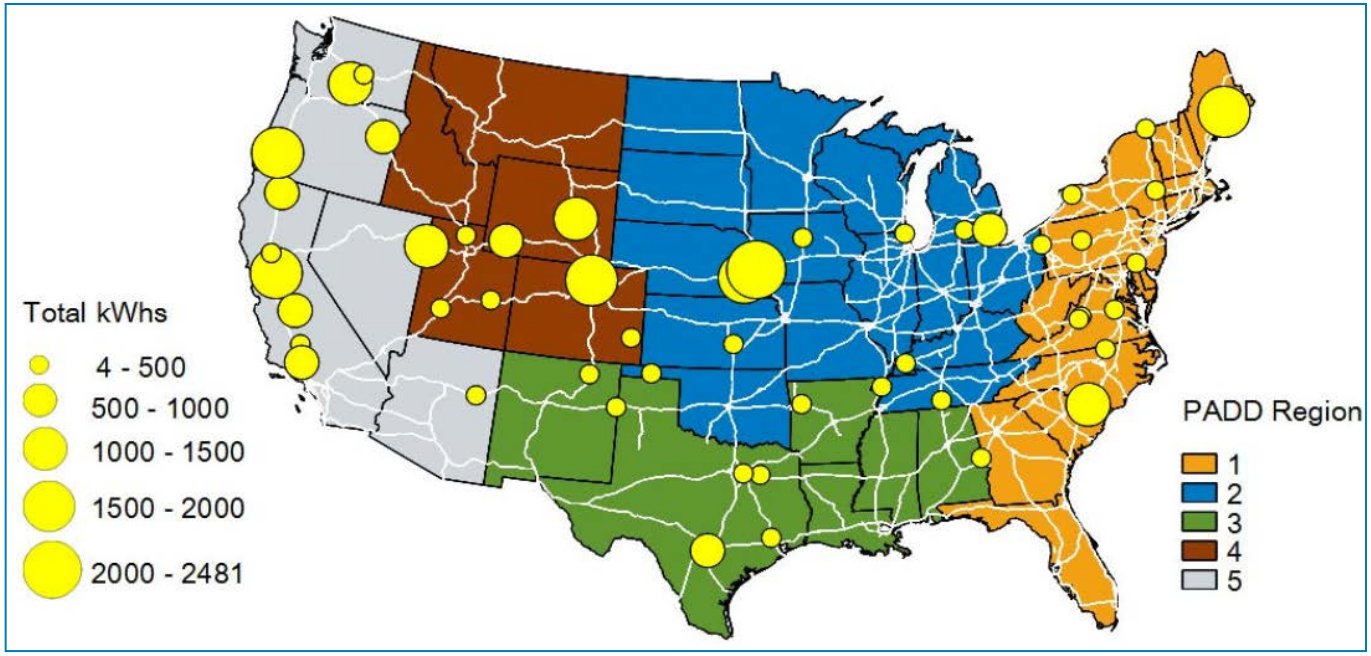


Truck Electrification Project

- **TSE allows truck operators to stop their engines and pull power from the grid for accessory loads that would otherwise required extended idle**
- **All 50 ARRA-funded sites are now operational**

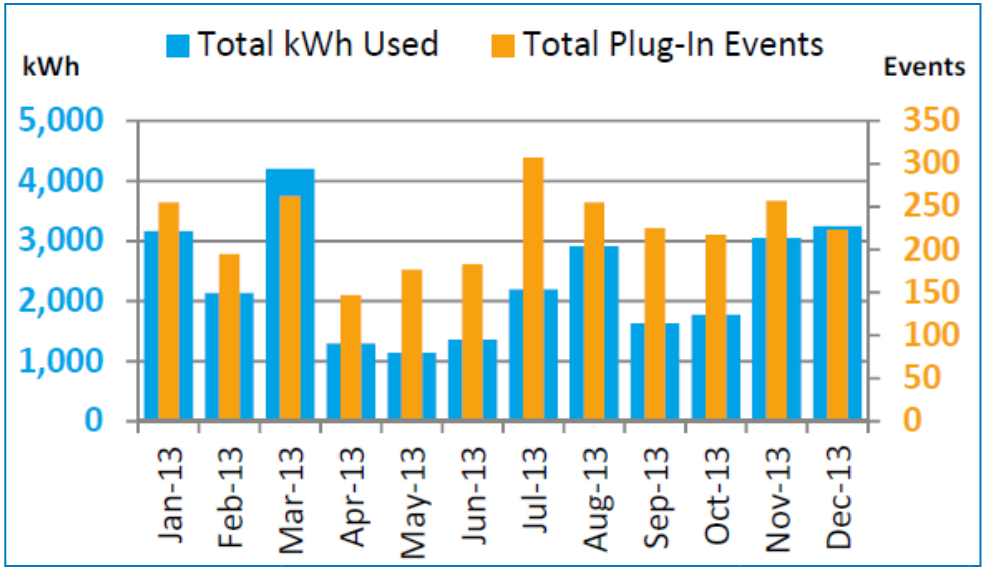
Plug-In Infrastructure

Reporting period:	01/01/2013 - 12/31/2013	Number of TSE sites completed:	50
Input Power:	208/240/480 V (min 50 A) 4 wire circuit	Number of pedestals installed:	313
Output Power:	120/208/240/480 V, 20/30 A outlets	Total vehicle capacity:	1,252



Truck Electrification Project

- **Utilization at ARRA-funded locations surpassed 40K hours, and 28 MWh in CY 2013**
- **Offsetting an estimated 32,592 gallons of diesel fuel that would have otherwise been used during idle**

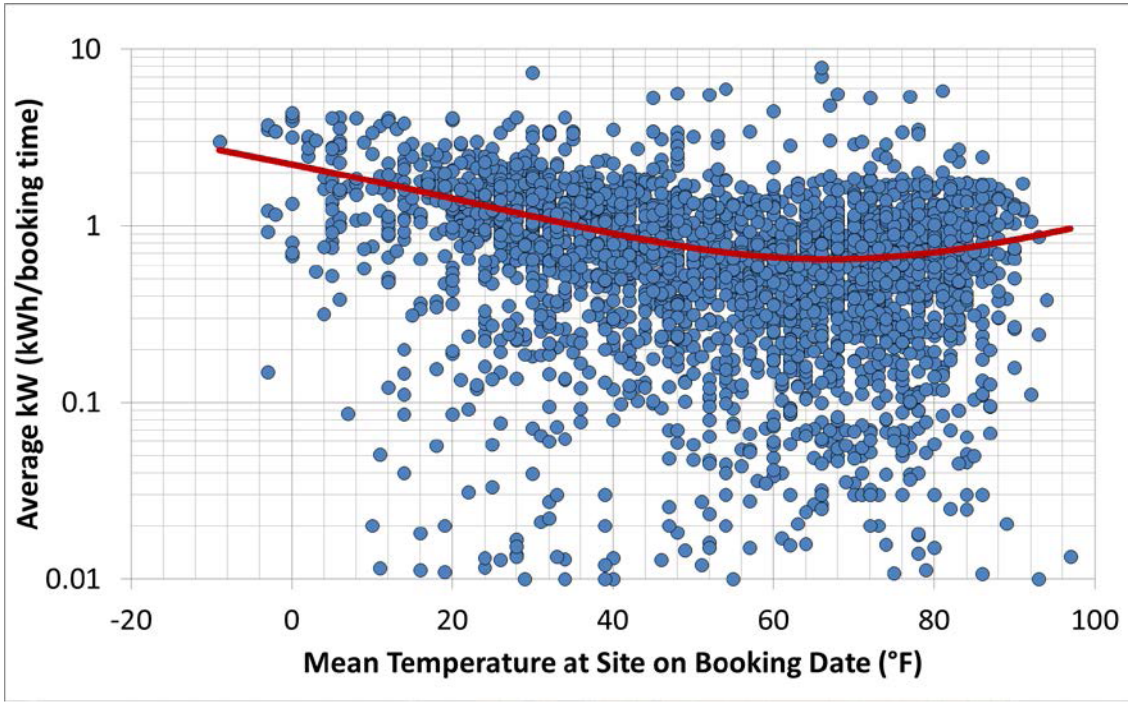


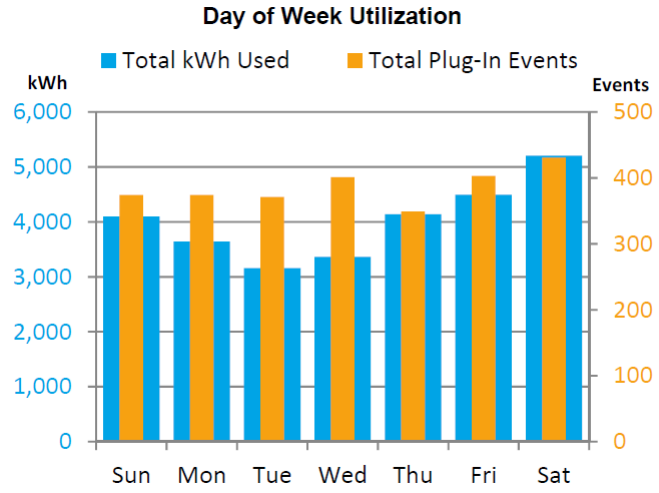
Utilization Summary

Idle-reduction rebate approvals:	4,370
Completed equipment installations:	4,353
Number of TSE sites with >90% uptime:	50
Number of plug-in events:	2,703
Total hours booked:	40,740
Total kWh used:	28,089
Average kWh/event:	10.4
Estimated gallons of diesel fuel saved:	32,592
Metric tons of CO_2 avoided:	332

Truck Electrification Project

- Continue to investigate usage trends and factors that may impact utilization
- Chart on the right shows average power draw per event as a function of ambient temperature
- Seasonally cooler months show higher utilization
- Highest weekly use Friday – Sunday





Monthly Utilization Data

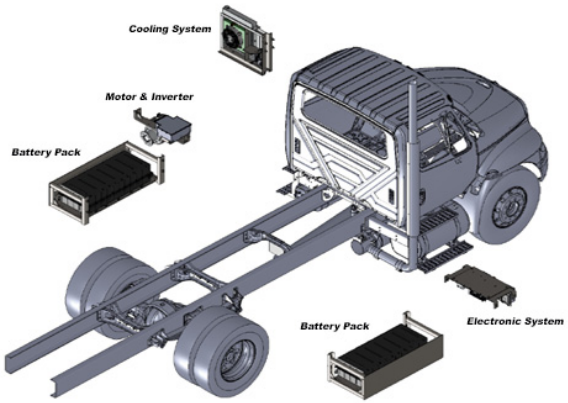
	2013-Q1	2013-Q2	2013-Q3	2013-Q4
Number of plug-in events:	712	507	787	697
Number of plug-in events using STEP IDs	46	39	62	34
Total hours booked:	14,251	6,560	10,452	9,477
Total kWh used:	9,504	3,790	6,731	8,065
Average energy used per event (kWh):	13.3	7.5	8.6	11.6
Average power per event (kW):	0.667	0.578	0.644	0.851

Odyne – PHEV Utility Trucks

- **Objective**
  - In-use performance evaluation of Odyne's electrified power-take-off (PTO) hybrid system
  - Quantify fuel savings from idle reduction at the jobsite
  - Quantify fuel savings from regenerative braking and launch assist during normal driving
- **Approach**
  - In-use data supplied by Odyne through EPRI will be available soon
  - Integrate into NREL's automated drive cycle analysis and reporting database
- **System Specifications**
  - Li-ion batteries from Johnson Controls, 14.2 kWh, 350 lbs
  - 320-V electric motor, 69 hp continuous, 107 hp peak


Photo courtesy of Odyne Systems LLC

Photo courtesy of Odyne Systems LLC



Courtesy of Odyne Systems LLC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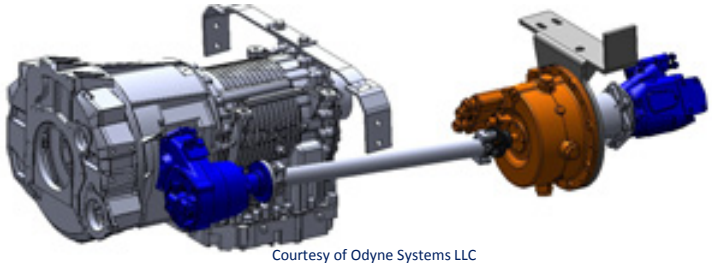
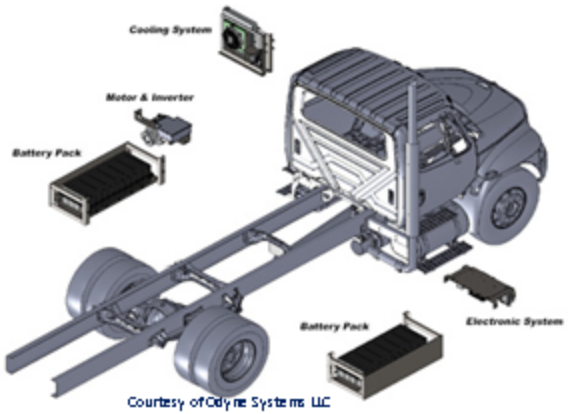

Courtesy of Odyne Systems LLC

Odyne – Expected Dataset

		Driving	Charging	Staionary
Signal	Units	Minimum sample rate	Minimum sample rate2	Minimum sample rate3
Vehicle ID				
Timestamp	dd/mm/yyyy hh:mm:ss	1 Hz	1 Hz	1 Hz
Operating mode	Driving, Charging, Stationary	1 Hz	1 Hz	1 Hz
Vehicle speed	mph	1 Hz	n/a	1 Hz
Odometer	miles	1 Hz	1 Hz	1 Hz
Accelerator pedal position	%	1 Hz	n/a	1 Hz
Brake pedal position or force	% or N	1 Hz	n/a	1 Hz
Fuel flow or volume	L/s or L	1 Hz	n/a	1 Hz
Battery pack SOC	%	1 Hz	once per 60 sec	1 Hz
Battery pack DC power	DC W	once per 5 sec	once per 60 sec	once per 5 sec
Charger AC Current	AC A	n/a	once per 60 sec	n/a
Charger AC Voltage	AC V	n/a	once per 60 sec	n/a
Ambient temperature	deg C	once per 5 sec	once per 600 sec	once per 5 sec
Mechanical Air Conditioning State	on/off	once per 5 sec	n/a	once per 5 sec
Electric Air conditioner state	on/off	once per 5 sec	n/a	once per 5 sec
PTO State	Boolean	n/a	n/a	1Hz



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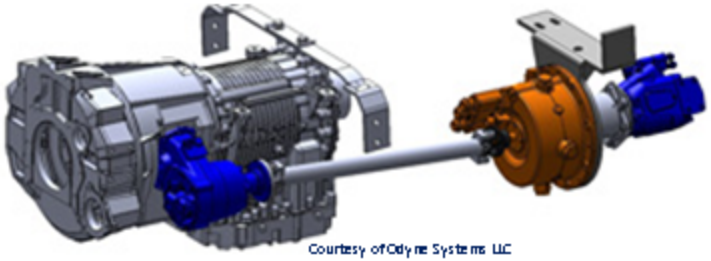
Courtesy of Odyne Systems LLC

Responses to Previous Year Reviewers' Comments

Comment #1:

The reviewer stated that there ought to be a partnership with the General Services Administration (GSA) to provide this performance data directly to government fleet managers interested in procuring EVs. Ideally, the data could be provided as part of AutoChoice (the system by which fleet managers procure vehicles from GSA).

Response: In FY14, the PI was able to reach out to the FEMP/GSA coordinator and begin to work with tools to understand the duty cycle and usage data for potential GSA vehicles. A specific response will be made available to GSA in FY14 that will apply energy usage metrics from the dataset to GSA usage patterns and provide potential GSA fleets with more direct performance information for their fleet so they can make better informed decisions.

Comment #2:

The reviewer was looking forward to a deeper analysis of the EV performance data for lessons learned. As stated previously, the reviewer was primarily hoping for suggestions to improve the technology and secondarily was interested in operational best practices to improve the performance of the existing technology.

Response: The funding for this project was primarily intended to gather, process, and report on the performance of the vehicles as deployed. In FY14, an effort was made to begin to explore EV performance data and factors such as environment, cargo load, and drive cycle variability. These analysis efforts begin to explain some of the root causes (i.e., such as temperature effect on vehicle range). The dataset is also being made available to the DOE VT Energy Storage group to help model and better understand better battery control measures that might affect performance and life of the battery. For FY15, a proposal will be made to initiate a cross-cutting analysis of the data to help improve performance of the vehicles and/or optimize the use of the vehicles to maximize range and ROI.

Collaboration and Coordination with Other Institutions

This project absolutely requires industry collaboration required for successful studies.

Past industry partners included:

Smith, Navistar, Cascade Sierra Solutions, Shorepower, Odyne, SCAQMD, EPRI

FY14 Collaborations & Coordination with Others				
Partner	**Relationship**	**Type**	**VT Program or Outside?**	**Details**
Smith Electric Vehicles	OEM Partner	Government Collaboration	VT Program	Smith has provided data and data analysis support to make the aggregated data available to the public
Navistar	OEM Partner	Government Collaboration	VT Program	Navistar has provided data and data analysis support to make the aggregated data available to the public
Cascade Sierra Solutions & Shorepower	Industry Partner	Government Collaboration	VT Program	Cascade Sierra Solutions has provided data and data analysis support to make the aggregated data available to the public
Odyne	OEM Partner	Government Collaboration	VT Program	Odyne will provide data and data analysis support to make aggregated data available to the public
SCAQMD / EPRI	Research Partner	Government Collaboration	VT Program	SCAQMD and EPRI will work together with NREL to acquire analyze and make data available.

Top 2 Remaining Challenges and Barriers

1. **Adoption of New EVs into Commercial Fleets**
   - Fleets remain tentative in procurement based on ROI projections – limited rollout of EVs in MD sector
   - Effects of "demand charges" adding to costs

2. **Unknown Life and Secondary Use of Large Commercial EV Battery Systems**
   - Better understanding and modeling of battery life estimations for MD commercial energy storage is needed
   - Use of large packs after useful life is mostly unknown

Proposed Future Work

- FY15 will continue to collect data on Odyne and Smith vehicles
- Navistar and Cascade Sierra Solutions data collection periods will end prior to FY15
- New effort in FY15 and FY16 (once all data have been collected) will be proposed to use data to analyze opportunity for energy efficiency (range improvements), energy storage cost improvements for improved ROI, and better placement of vehicles into fleet to optimize ROI
- Analysis will also show seasonal effects of range as well as battery life estimations vs. vehicle duty cycle

Summary

- MD EV data collection and analysis will help drive design, purchase, and research investments:
    - Making data publically available helps drive development
    - Feeding vocational database for future analysis – better understanding of usage will result in better design
    - Data made available enable more accurate modeling and simulation efforts
    - Performance of vehicle varies with drive cycle and cargo load – MD vehicles are “multi-functional”
    - Environment and accessory loads affect vehicle range, add cost by adding battery capacity
    - MD EV vehicles can function in vocations traditionally serviced by gasoline or diesel vehicles
    - Facility implications (i.e., demand charges) need to be understood as part of site-based analysis for EV implementation

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Technical Back-Up Slides

(Note: please include this “separator” slide if you are including back-up technical slides (maximum of five). These back-up technical slides will be available for your presentation and will be included in the DVD and Web PDF files released to the public.)

Acknowledgements and Contacts

Thanks to:

Vehicle & Systems Simulation & Testing Activity – Lee Slezak and David Anderson
Vehicle Technologies Office – U.S. Department of Energy

For more information:

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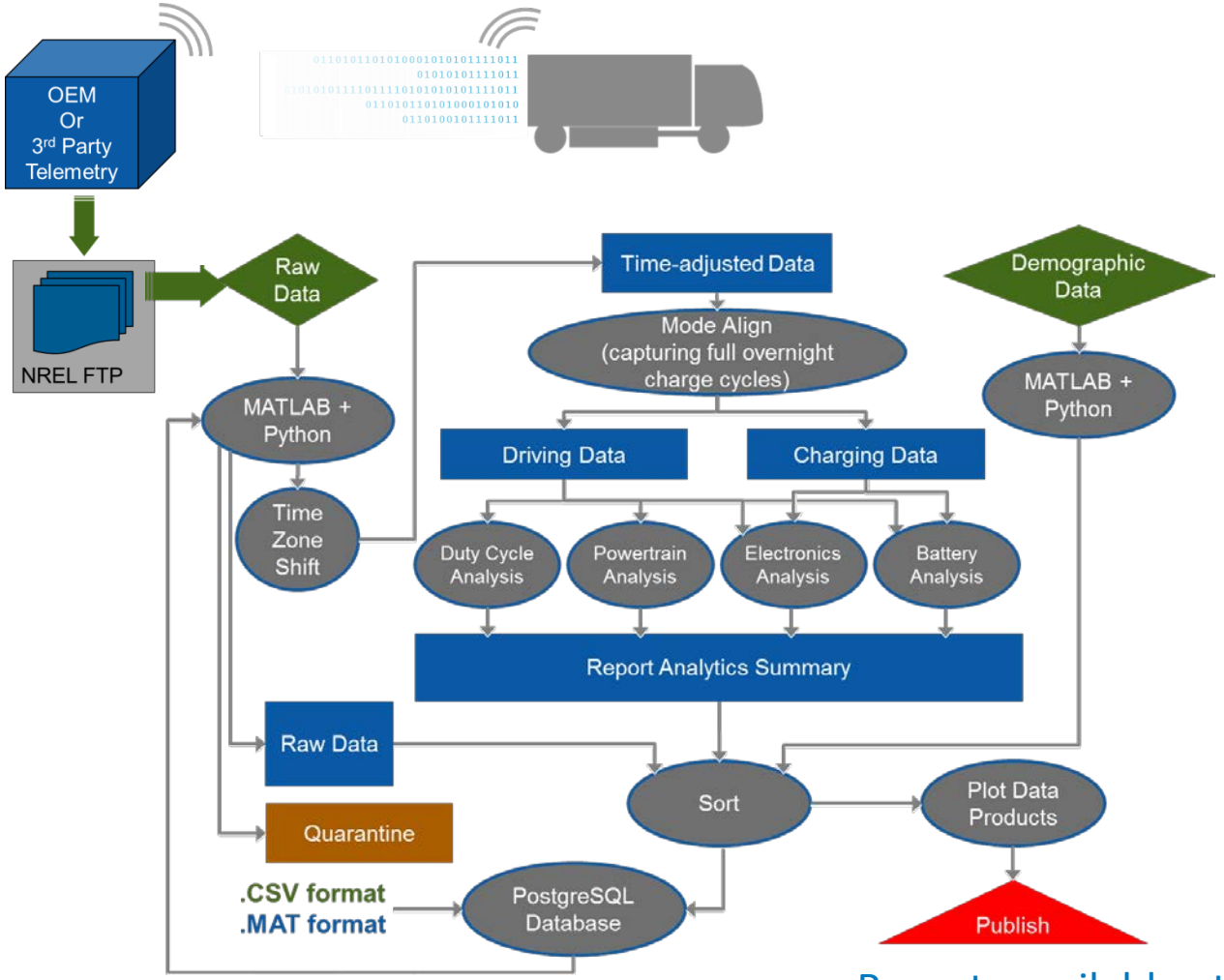
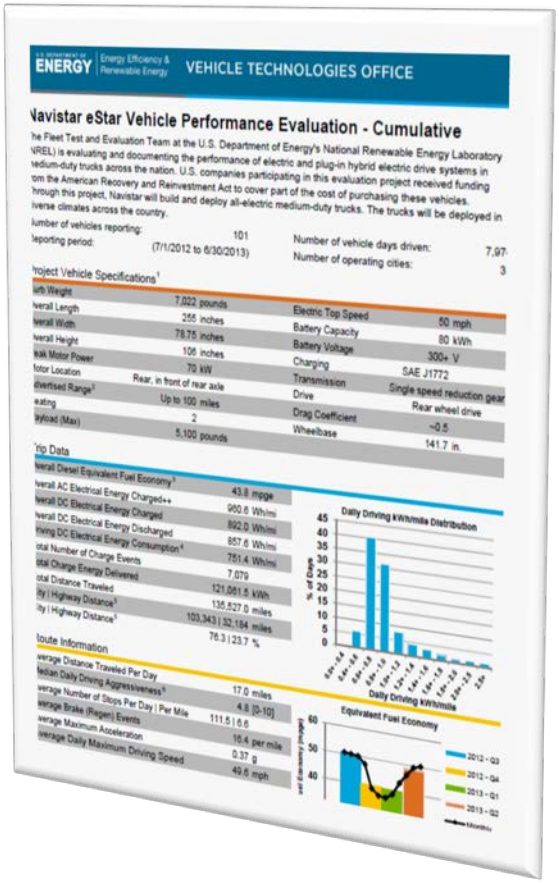
Approach/Strategy

Data Processing Routine – Receive, Filter, Analyze

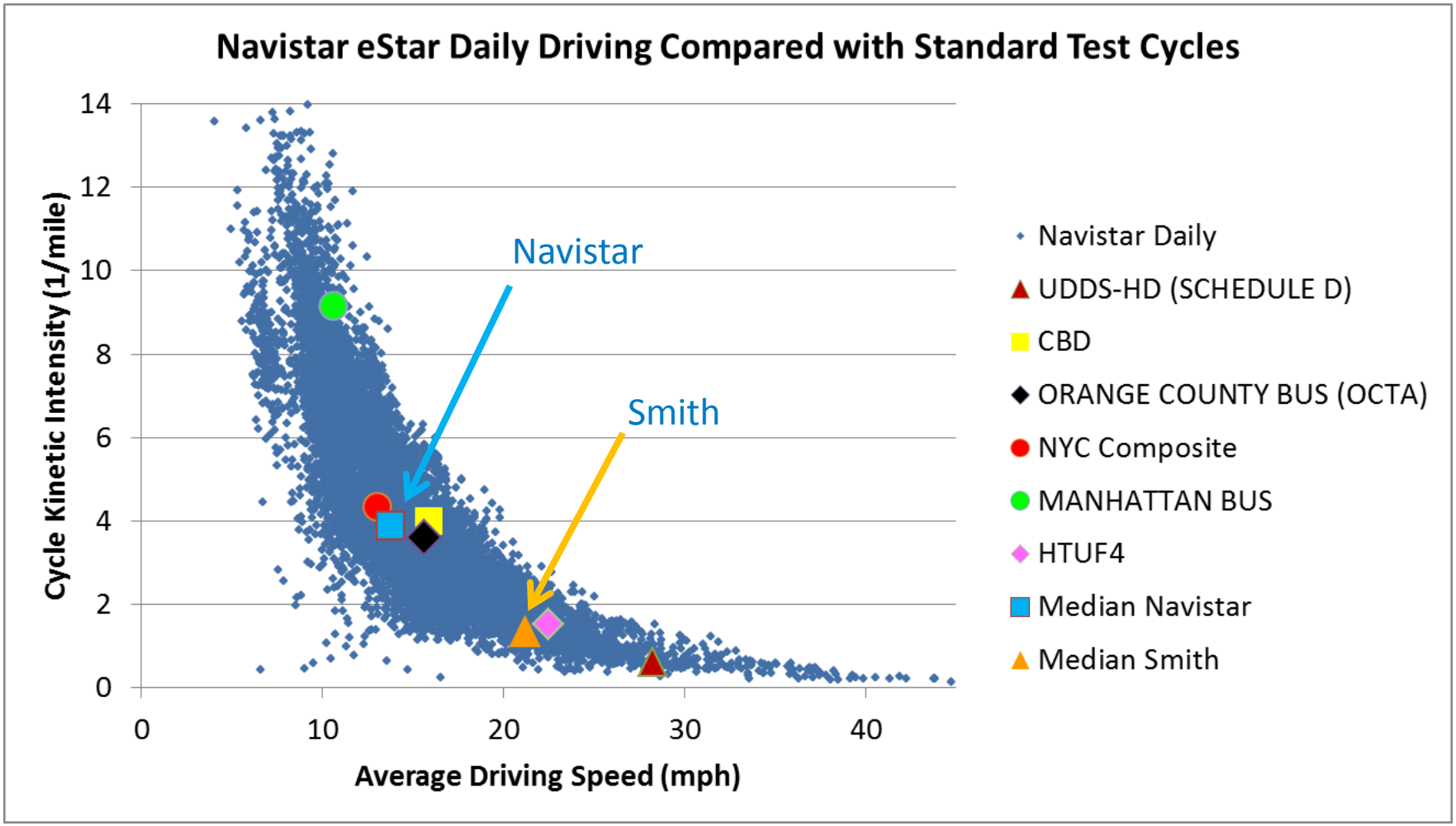




Reports available at:
http://www.nrel.gov/vehiclesandfuels/fleettest/

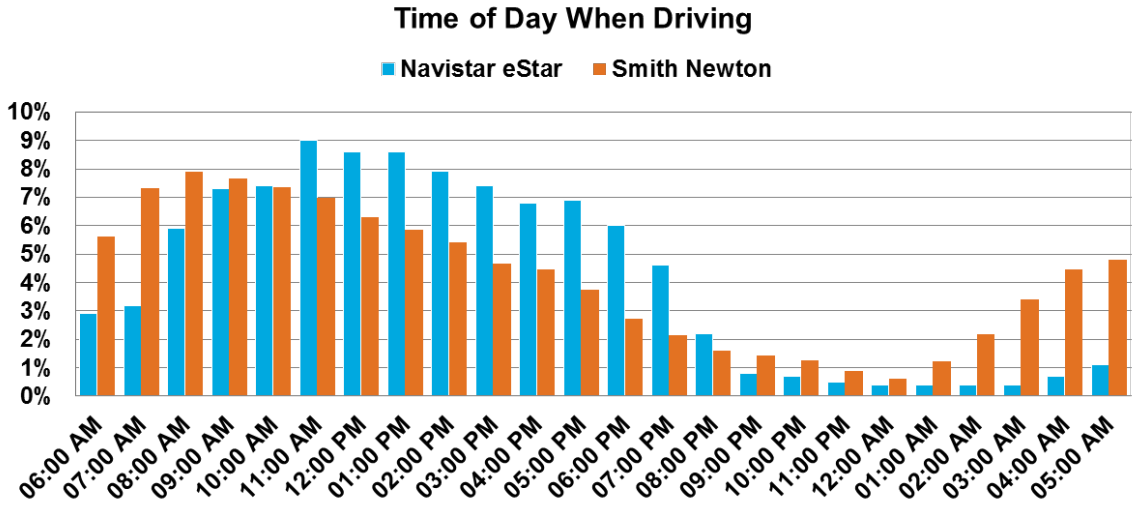
Technical Accomplishments and Progress

Results – Compared with Standard Cycles

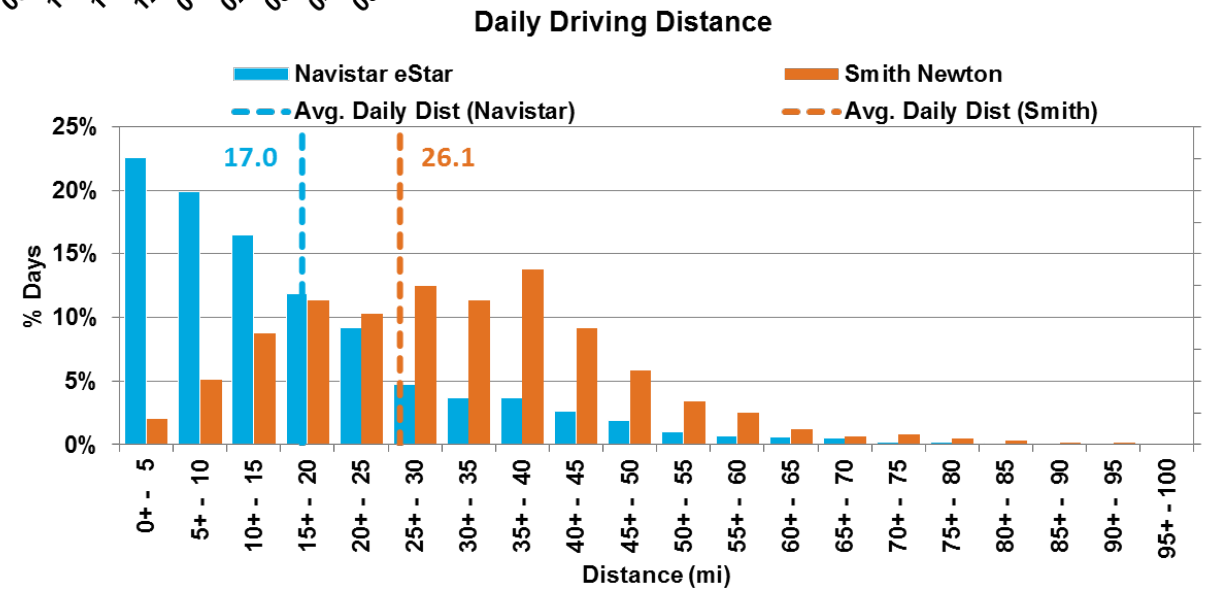


Technical Accomplishments and Progress

Results – Driving Variability



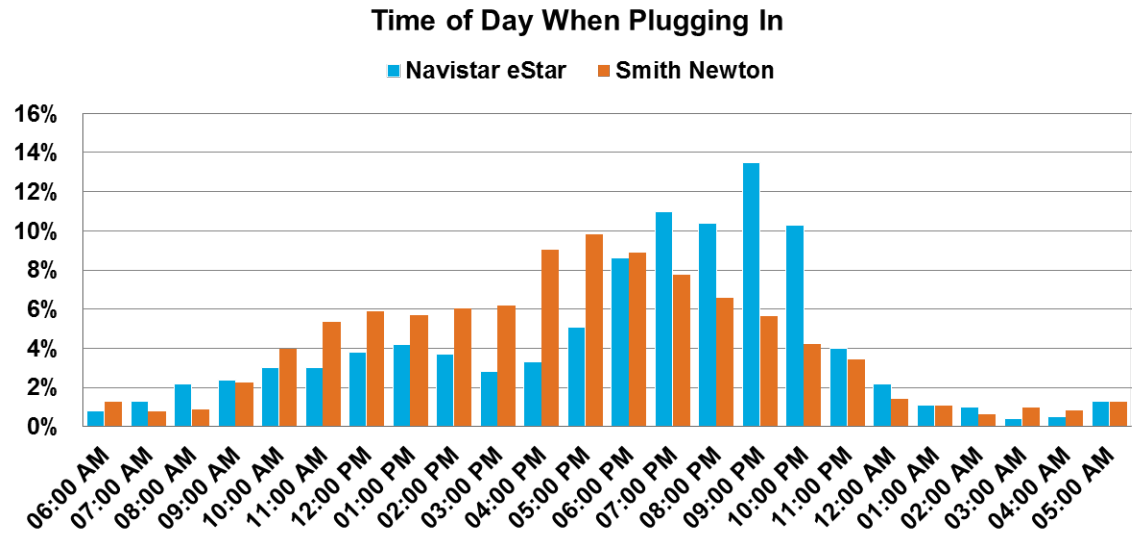
Typical daily commercial operation



More short trips from Navistar eStar

Technical Accomplishments and Progress

Results – Charging



Charging begins late afternoon to evening

Charging duration is longer for Smith vehicles