Opportunities to Extend BEV Range

June 27, 2023

IN PARTNERSHIP WITH

DEPOTS Electric Truck Bootcamp Series

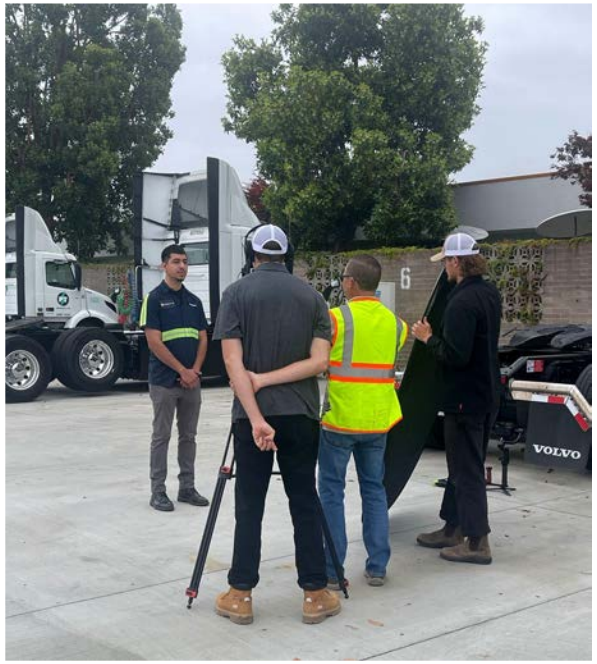
1. **Best Practices for Utility-Fleet Relationships** (April 25th) ✓
2. **Grants and Incentives for the Trucks and Infrastructure** (May 16th) ✓
3. **Electric Truck Developments** (May 30th) ✓
4. **Faster Charging — Opportunities and Challenges at 350KW and higher** (June 13th) ✓
5. **Opportunities to Extend BEV Range** (June 27th)
6. **Electricity Resiliency and Availability** (July 11th)
7. **Current and Future Regulations for Zero Emission Trucks** (July 25th)
8. **Managed Charging to Improve Availability, Cost and Range** (August 8th)
9. **Scaling Charging Infrastructure Equipment** (August 22nd)
10. **Electric Depot Site Planning and Construction** (September 5th)

2021 Bootcamp is still available at: https://runonless.com/electric/bootcamp-electric/

RUN ON LESS ELECTRIC DEPOT

2023 DEPOT Fleets

Update from The Run Planning…



Follow the Fleets, Drivers, OEMs, EVSEs, Utilities and more:

RunOnLess.com and on Twitter @RunOnLess

RUN ON LESS ELECTRIC DEPOT

NACFE
NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY

Today's Bootcamp Sponsor

Official Data Partner for RoL-E DEPOT

GEOTAB®

RUN ON LESS ELECTRIC DEPOT

ELECTRIC DEPOT BOOTCAMP

Quiz for Today's Session

Completing Today's Quiz:

- Go to runonless.com and click back into the session
- Click 'Take Quiz' button
- Create username and password to keep track of your progress
- Spend a few minutes answering the questions and receive your 2023 RoLE - DEPOT badges

RUN ON LESS ELECTRIC DEPOT

What You Should Know

Q&A

Submit your questions to the host using the Q&A box in the upper right-hand corner

Recording

A recording of today's webinar will be available on runonless.com

Technical Issues

Contact Stephane Babcock at

stephane.babcock@gladstein.org

RUN ON LESS ELECTRIC DEPOT

NACFE NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY IN PARTNERSHIP WITH RMI ENERGY. TRANSFORMED.

ELECTRIC DEPOT BOOTCAMP

Today's Bootcamp Speakers

Opportunities to Extend BEV Range

Andreas Kammel
Vice President Alternative Drivetrains
TRATON

Andrew Kotz
Senior Research Engineer – Commercial Vehicle Technologies
National Renewable Energy Laboratory (NREL)

John Kresse
Director – Advanced Electrification Technologies
Cummins Inc.

Jason Schieck
Sr. Director of Product Marketing and Strategy
Hyliion

Hosted by:

Rick Mihelic

Director of Emerging Technologies

RUN ON LESS ELECTRIC DEPOT

ELECTRIC DEPOT BOOTCAMP

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Opportunities for Reducing EV Barriers in Depot/Terminal Settings

Andrew Kotz Ph.D. – Senior Research Engineer
Commercial Vehicle Technologies
Andrew.kotz@nrel.gov

NREL Center for Integrated Mobility Sciences

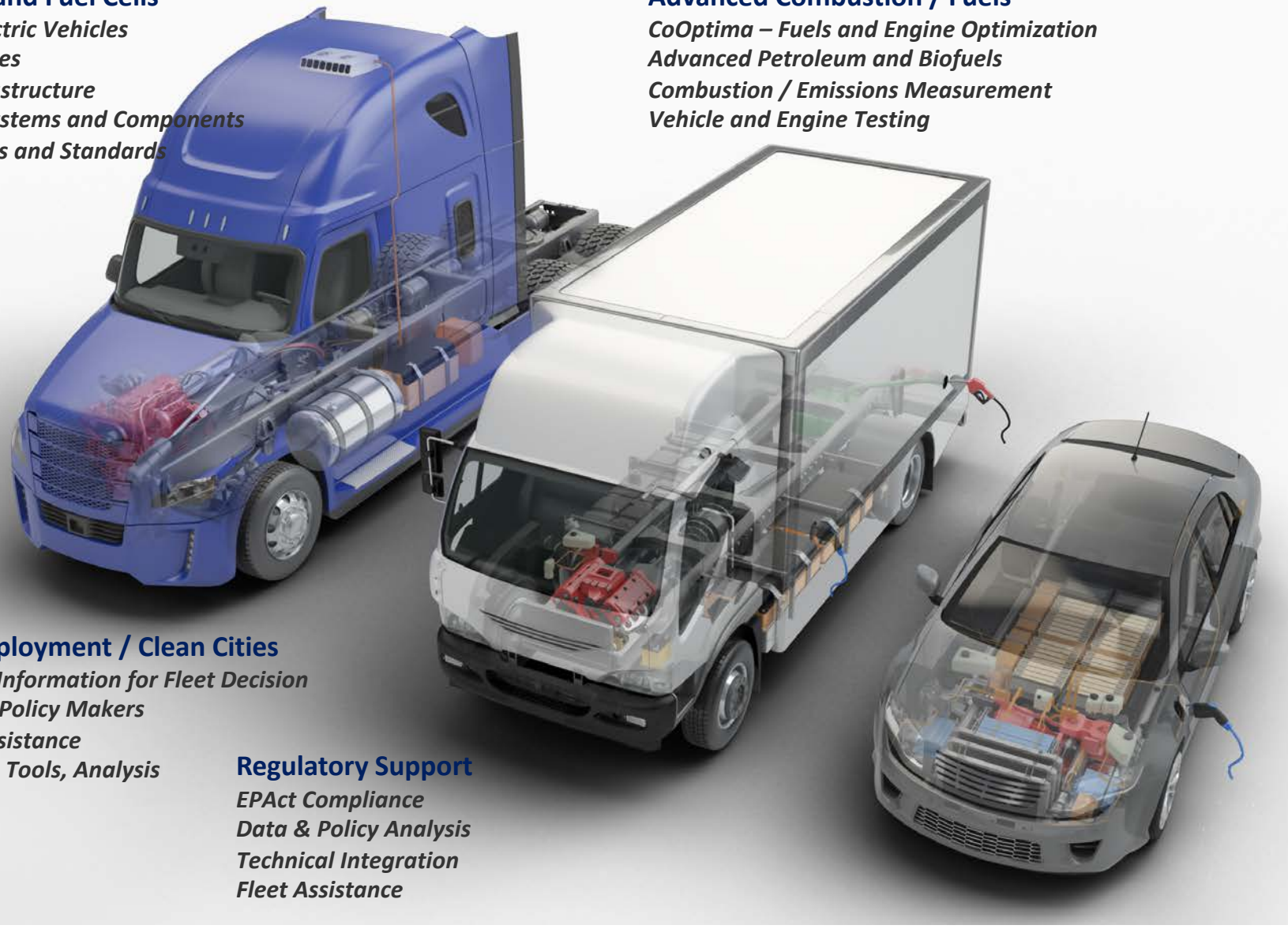
https://www.nrel.gov/transportation/research.html

Hydrogen and Fuel Cells

Fuel Cell Electric Vehicles
Fuel Cell Buses
Fueling Infrastructure
Hydrogen Systems and Components
Safety, Codes and Standards

Advanced Combustion / Fuels

CoOptima – Fuels and Engine Optimization
Advanced Petroleum and Biofuels
Combustion / Emissions Measurement
Vehicle and Engine Testing



Vehicle Deployment / Clean Cities

Guidance & Information for Fleet Decision Makers and Policy Makers
Technical Assistance
Online Data, Tools, Analysis

Regulatory Support

EPAct Compliance
Data & Policy Analysis
Technical Integration
Fleet Assistance

Commercial Vehicle Technologies

Technology Field Testing & Analysis
Big Data Collection, Storage & Analysis
Vehicle Systems Modeling
Super Truck and 21st Century Truck
Vehicle Thermal Management

EV Grid Integration

Extreme Fast Charging – 1+ MW
Vehicle-to-Grid Integration
Integration with Renewables
Charging Equipment & Controls
Fueling Stations & Equipment

Advanced Energy Storage

Thermal Characterization / Management
Life/Abuse Testing and Modeling
Computer Aided Engineering
Electrode Material Development

Advanced Power Electronics and Electric Motors

Thermal Management
Advanced Heat Transfer
Thermal Stress and Reliability

Mobility Systems

Energy Efficient Mobility Systems

Connected and Autonomous Vehicles
Vehicle Systems Modeling
Technology Adoption
Cost of Ownership Modeling
SMART Cities Columbus

Fleet DNA Data

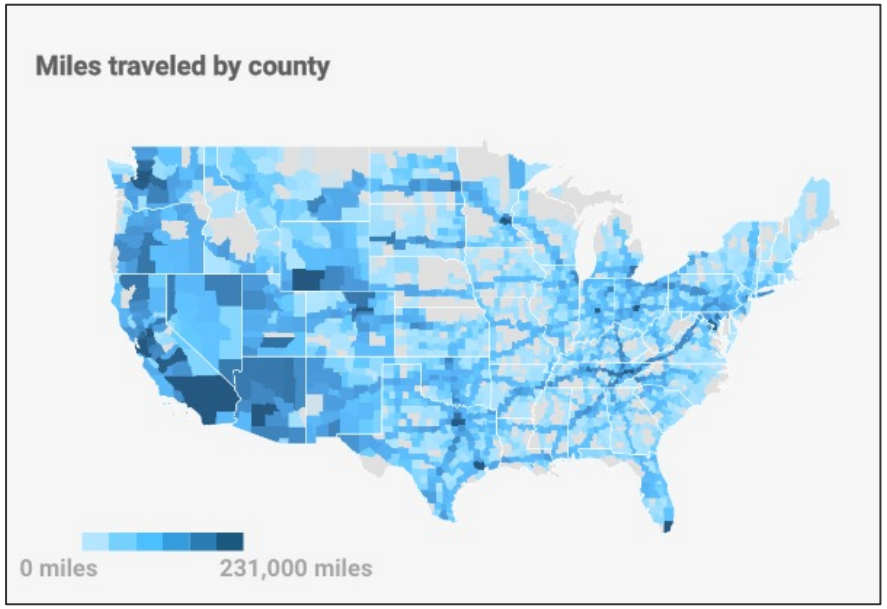
Fleet DNA

- Database of advanced technology MD and HD truck data have been collected, documented, and analyzed since 2002
- Provides data in an aggregated and detailed manner that would not normally be shared by industry
  - Guide R&D for new technology development
  - In-use CAN data recorded at 1-Hz
  - Help fleets/users understand all aspects of advanced technology













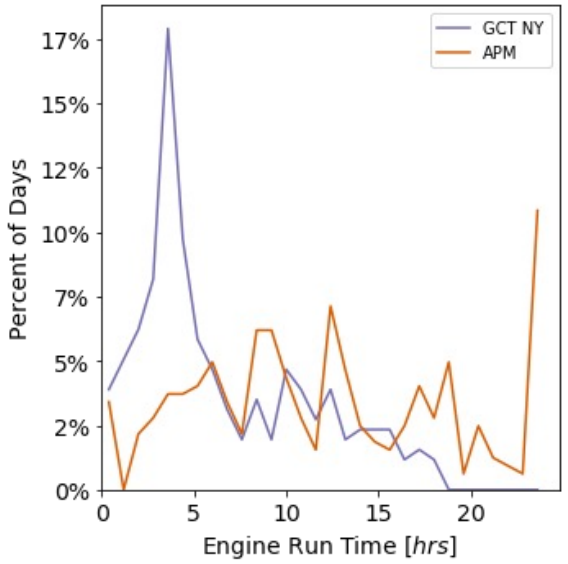


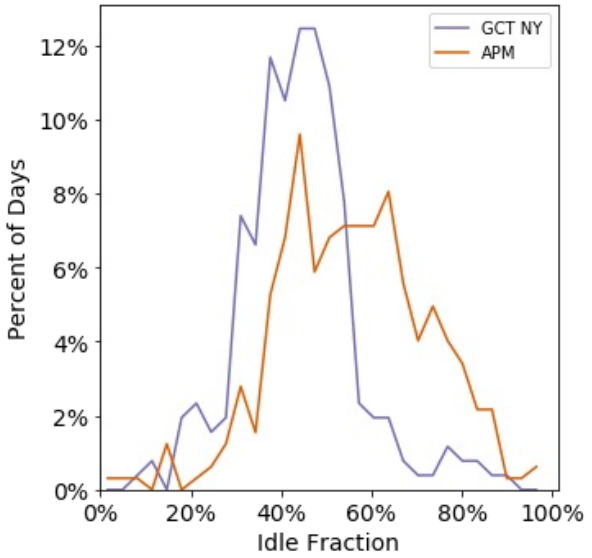





Yard Tractor Electrification

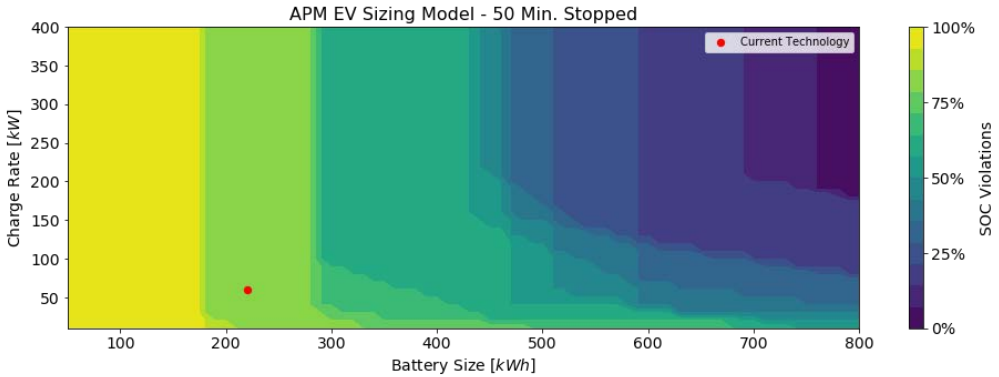
- Objective: Analyze yard tractor operations to understand electrification potential
- Data: Collect second by second J1939/GPS data for
- Analysis Questions:
  - Battery size required
  - Charging opportunity
- Findings:
  - Two terminals have >50% electrification potential
  - 3-shift operation challenging to electrify (<15%) – **limited charge time**
- **Options**:
  - **Increase battery size**
  - **Reduce charge time**
  - **Add vehicles**

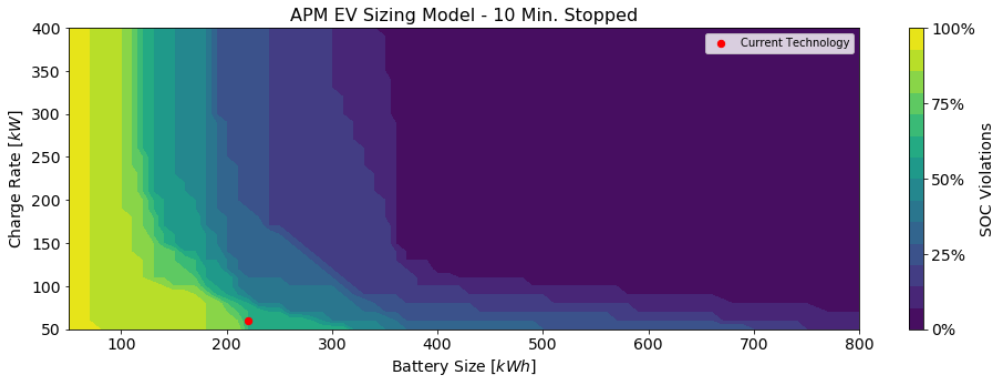


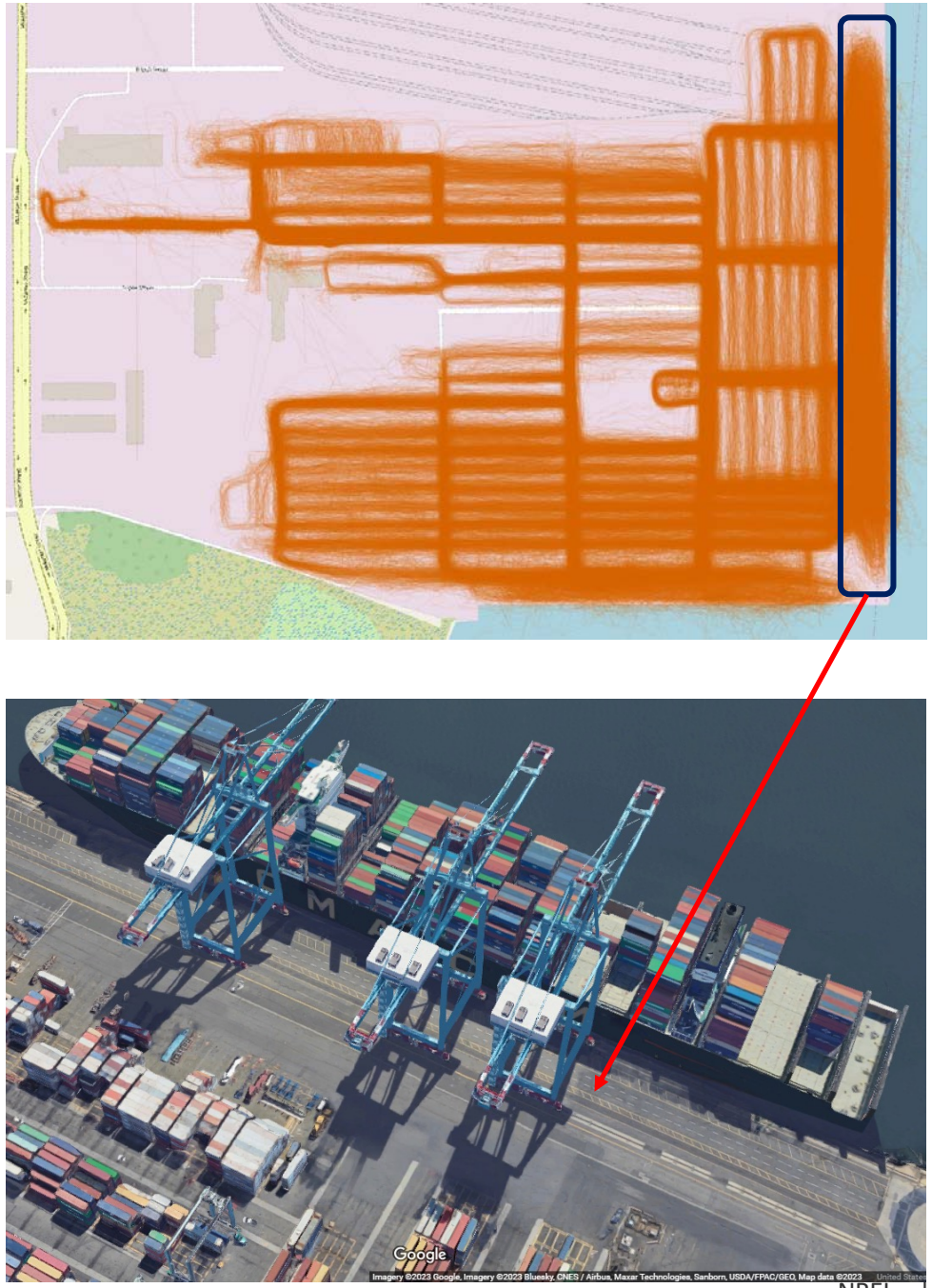


Electrification Analysis

- **Wireless opportunity charging improves electrification potential**
- Location shows frequent short periods spent under crane loading zones – may be semi-dynamic charging opportunity



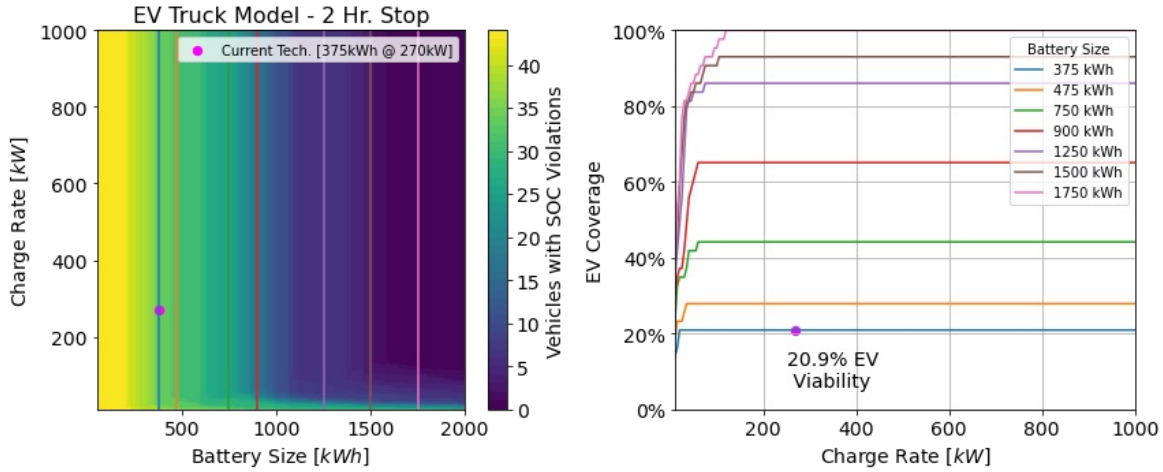


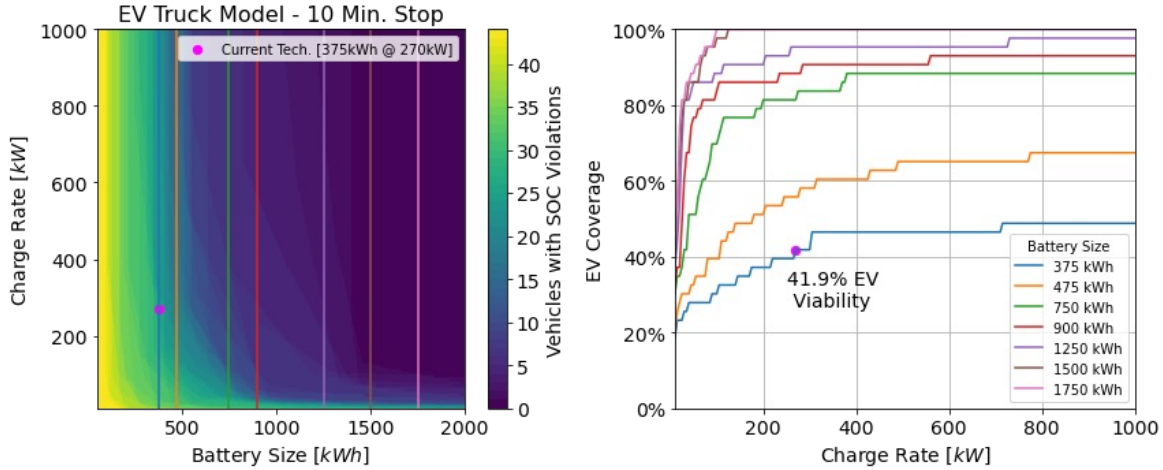


Drayage Application

Opportunity charging can improve EV viability in drayage application

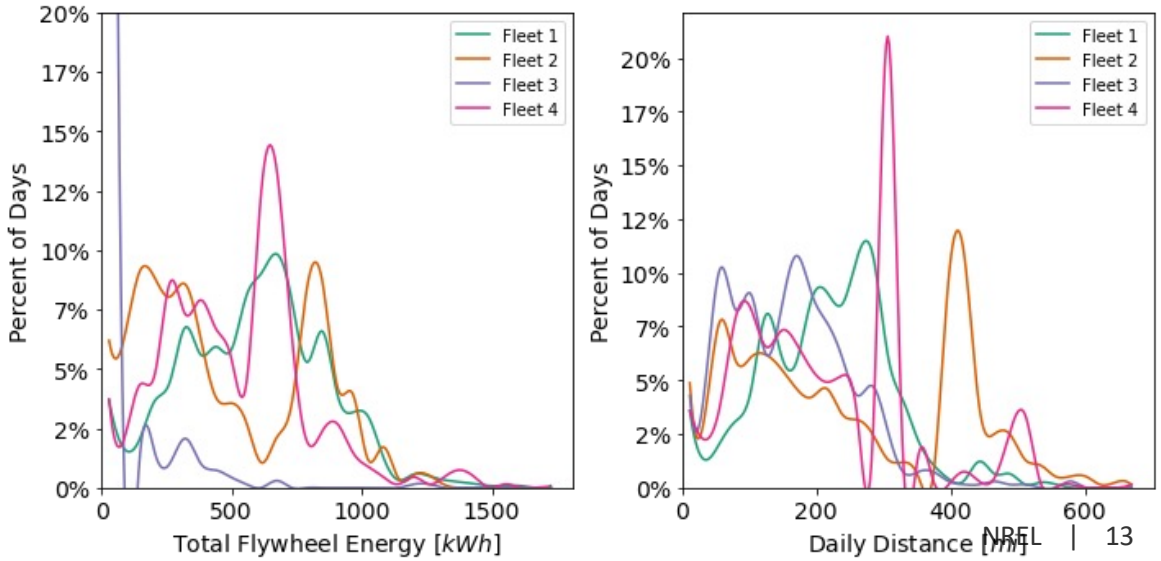
- Consistent charging lanes may be tricky
- Time in a terminal is typically limited





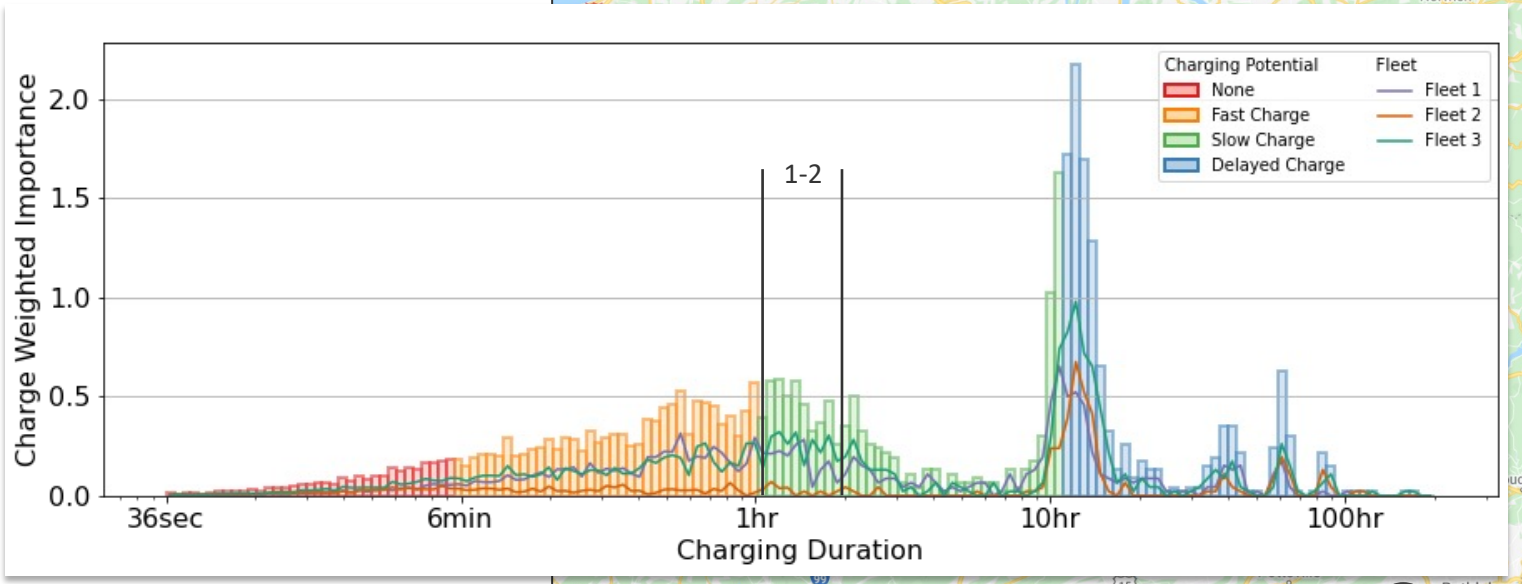
Zero- and Near-Zero-Emission Freight Facilities (ZANZEFF) “Shore to Store” Project

- **Adopting H2 can be an alternative in reduce refueling times compared to battery-electric**
- 300 mile range – 10 minute refuel



Hot Spot Analysis

Hotspot analysis shows that frequent **stop locations at depot's loading docks can be charging opportunity**



Fast Sim EV Model

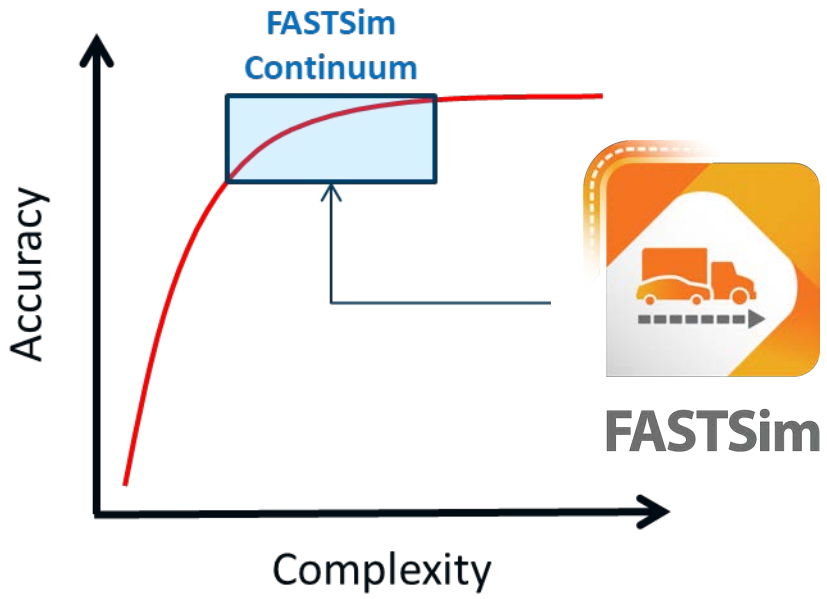
FASTSim Vehicle Model

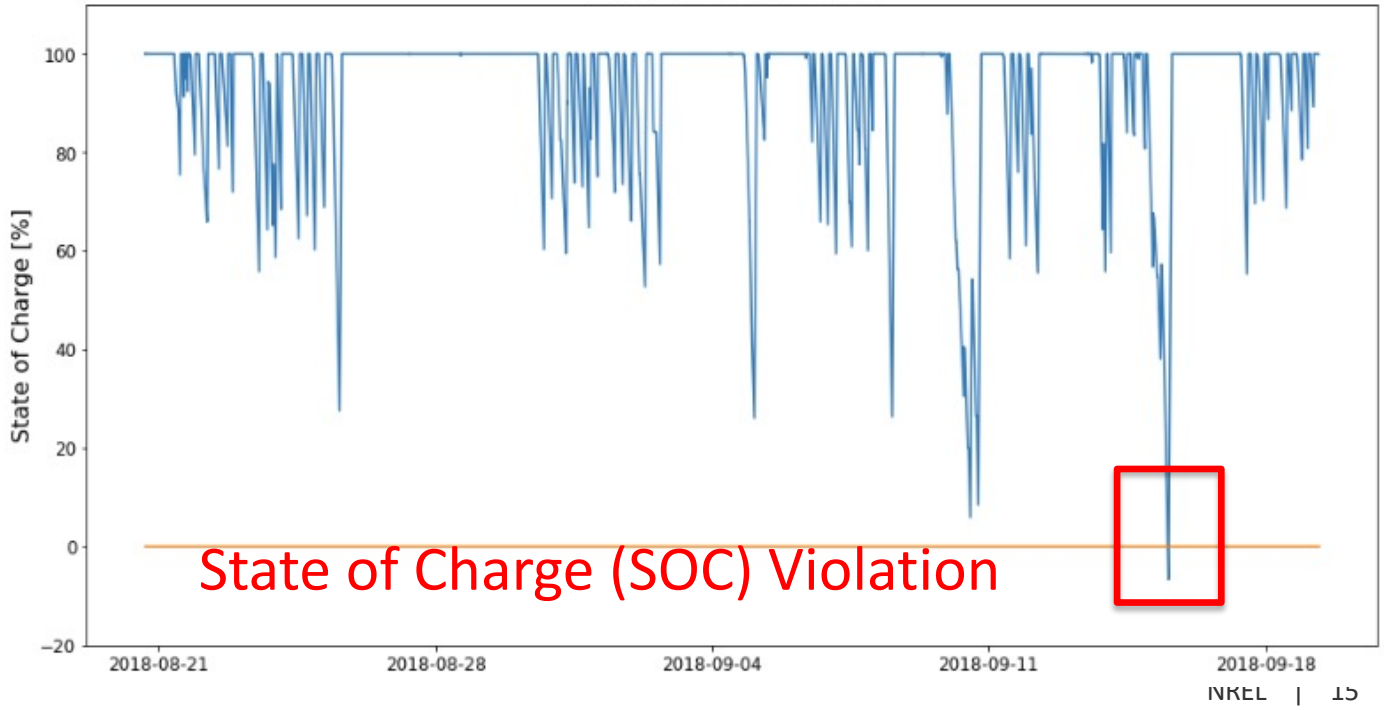
- Vehicle Mass: Variable
- Drag coefficient: 0.8
- Frontal area: 10.34 m^2
- Motor power: 300 kW

eCascadia Specs

Class	8
Horsepower	360-500 HP
GCWR	82,000 lbs
Range	250 Miles
Battery	375 kWh (usable)
Charge	270 kW

$$P_{road} = mav + mgsin(\theta)v \ + mgC_{rr}\cos(\theta)v + C_{dl}v^3$$





Thank you

Andrew Kotz Ph.D. - andrew.kotz@nrel.gov

NREL
Transforming ENERGY

TRATON

NAVISTAR

Extending range – opening up line haul for BEV

Overview – TRATON GROUP

Four strong brands under one roof

SCANIA / MAN / Truck Bus / NAVISTAR

$ 43 bn.

Sales revenue

"Transforming Transportation Together."

Sustainability as a core principle and responsible behavior as a top priority in the Group's strategy

100,356

Employees worldwide[1]

28 production and manufacturing sites worldwide in 15 countries on 4 continents[1]

305,485

Unit sales (trucks, buses and vans)

Note: Data based on Full Year 2022 results [1] As of December 31, 2022

Battery improvements & fast charging have brought BEV into play in line haul

The view of BEV in line haul, recent past

"A truck capable of going **375 miles a day hauling 45,000 lbs** would need a battery weighing 35,000 lbs, and could only carry about **10,000* lbs of cargo**."

"And because a heavy-duty truck battery is so heavy and large, charging takes too long – typically **12 hours or more**."

Just a few years ago, few expected BEV to ever be suited for line haul usage

The reality of BEV in line haul, near future

"A truck capable of going **750 miles a day hauling 45,000 lbs** would need a battery weighing 11,000 lbs, but could still carry about **40,000** lbs of cargo** with a quick top-up during the mandatory rest period."

"The maximum charging speed of a battery grows in step with its size. A truck can be charged to 80% **in around 30 minutes** without significant wear utilizing next year's *Megawatt Charging System* standard."

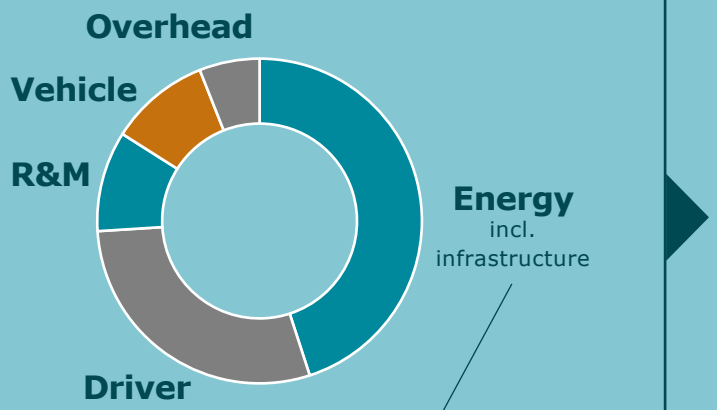
Now, even *1st gen* line haul BEV trucks only come with moderate drawbacks

* adapted linearly from original claim

** includes *past* battery improvements, removed Diesel components & 2,000 lbs in exemptions

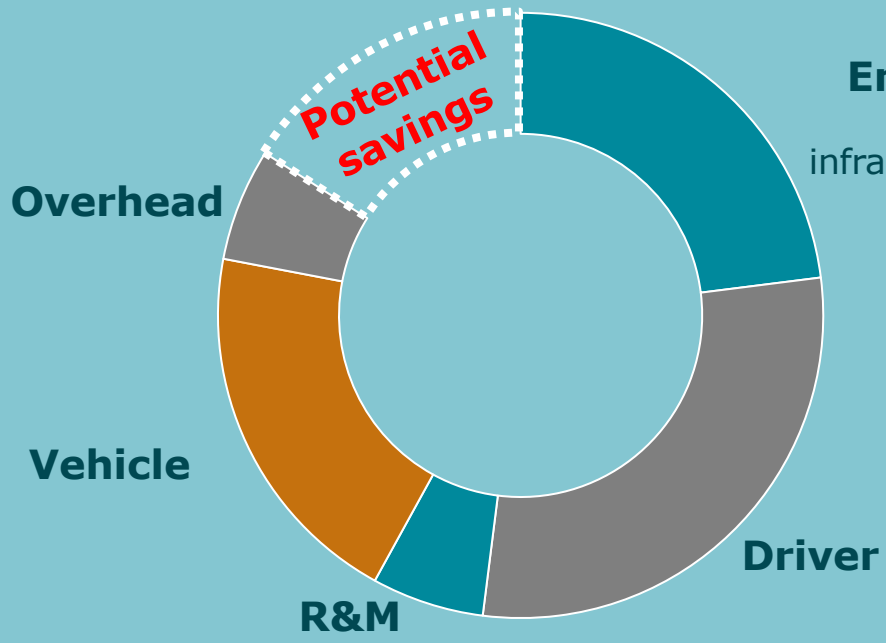
Line haul is the *best* BEV business case, due to its strong energy cost dominance

Cost distribution of a typical line haul heavy duty truck



Stronger dominance than in any other truck (or car) application

Future BEV cost distribution (indicative)



The high efficiency of using electricity yields massively lower energy expenditures vs. e.g. hydrogen or even Diesel – few publications "talk fuel cost"

Cost increasing with e-mobility

Cost decreasing with e-mobility

Energy is the most crucial cost driver in trucking – and is most dominant in line haul operations

➔ **Fast charging infrastructure** enables BEV in line haul without meaningful payload or charging time losses, while retaining the full energy cost advantage

The cost advantage for BEV is only set to grow – over distance and over time

The basics

As **energy efficiency** is the key driver behind energy cost and emissions, **BEV will be substantially cheaper** than Diesel or other trucks, even without subsidies*

This is particularly true for **regular, long-distance usage** where the battery can be amortized most easily – and where the **margin pressure** is especially high

Meanwhile, improved payload, ranges & charging times are quickly **closing any remaining usability gap**

The future

Costlier products are also being **used more intensively**, especially with **Autonomous Driving**, further deteriorating other business cases

Charging infrastructure could even help **stabilize the electricity grid** (esp. during mid-day solar peaks), reducing relative infrastructure and energy costs

System perspective crucial!

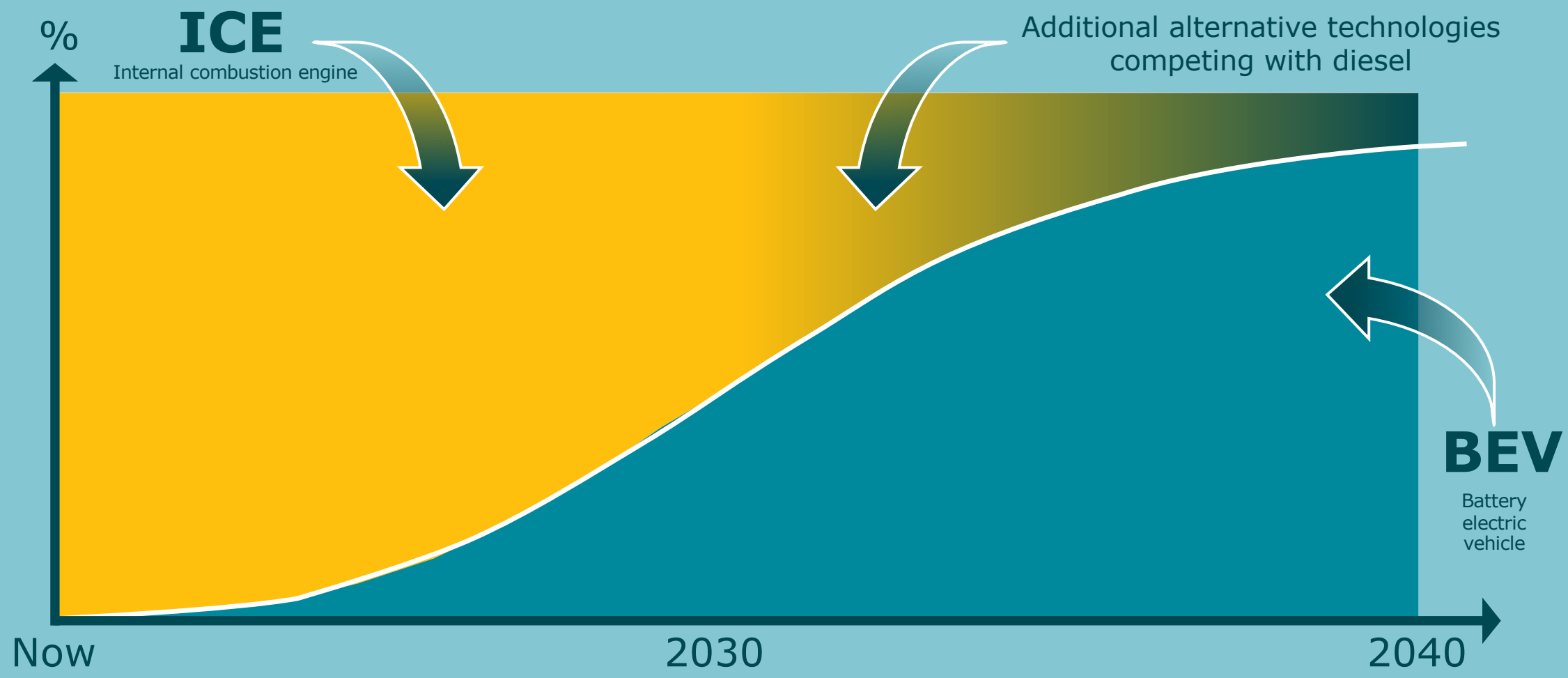
Even with ample cheap hydrogen, **stationary reconversion would be more efficient*** than direct usage in an FCEV

Line haul is not the first, but the most profitable BEV use case, leaving the least room for other solutions

➔ The **main driver for displacing Diesel will be margin pressure** – some players who can "make BEV work" are enough to force the rest to join in

* Top quartile vs. bottom quartile in hydrogen merit order for reconversion during spikes vs. usage in electrifiable trucking applications

We thus see battery electric vehicles as our future mainstream technology, including in line haul



What is Hyliion?

Our Mission

Be the leading provider of electrified solutions for the commercial vehicle industry

Core focus points

- **Reduce Carbon Emissions**
- **Reduce Cost of Operation**
- **Leverage Existing Infrastructure**

Company Overview

AUSTIN, TX
150k sq. ft. Headquarters

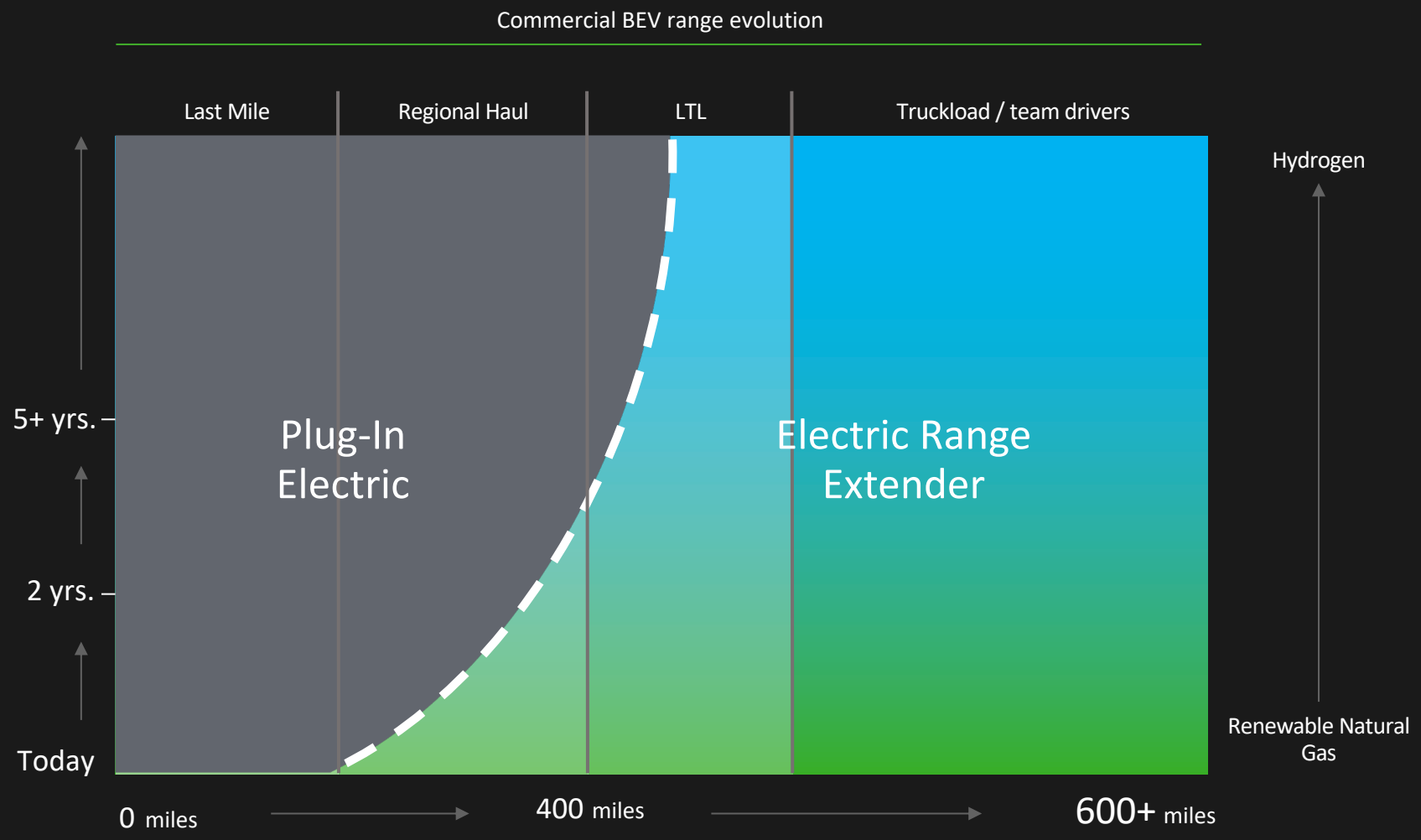
Cincinnati, oh
KARNO™ Development Center

Pittsburgh, pa
Northeast Regional Office

250+
Employees

HYLN
NYSE

Powertrain evolution



Why Hypertruck ERX?

Full EV benefits without the limitations

= No new infrastructure

= Long & short range

= Self & plug-in charging

= ESG goals

= Next-generation operational experience

Hypertruck ERX applications

Long Haul

+ Up to 1000 miles of total range without refueling[1]
+ Infrastructure in place
+ 670 peak HP – on tap
+ eAPU for driver comfort

Regional

+ Up to 75 all-electric miles[1]
+ Zero-emission zone capable
+ Near silent operation
+ Plug-in charging supported

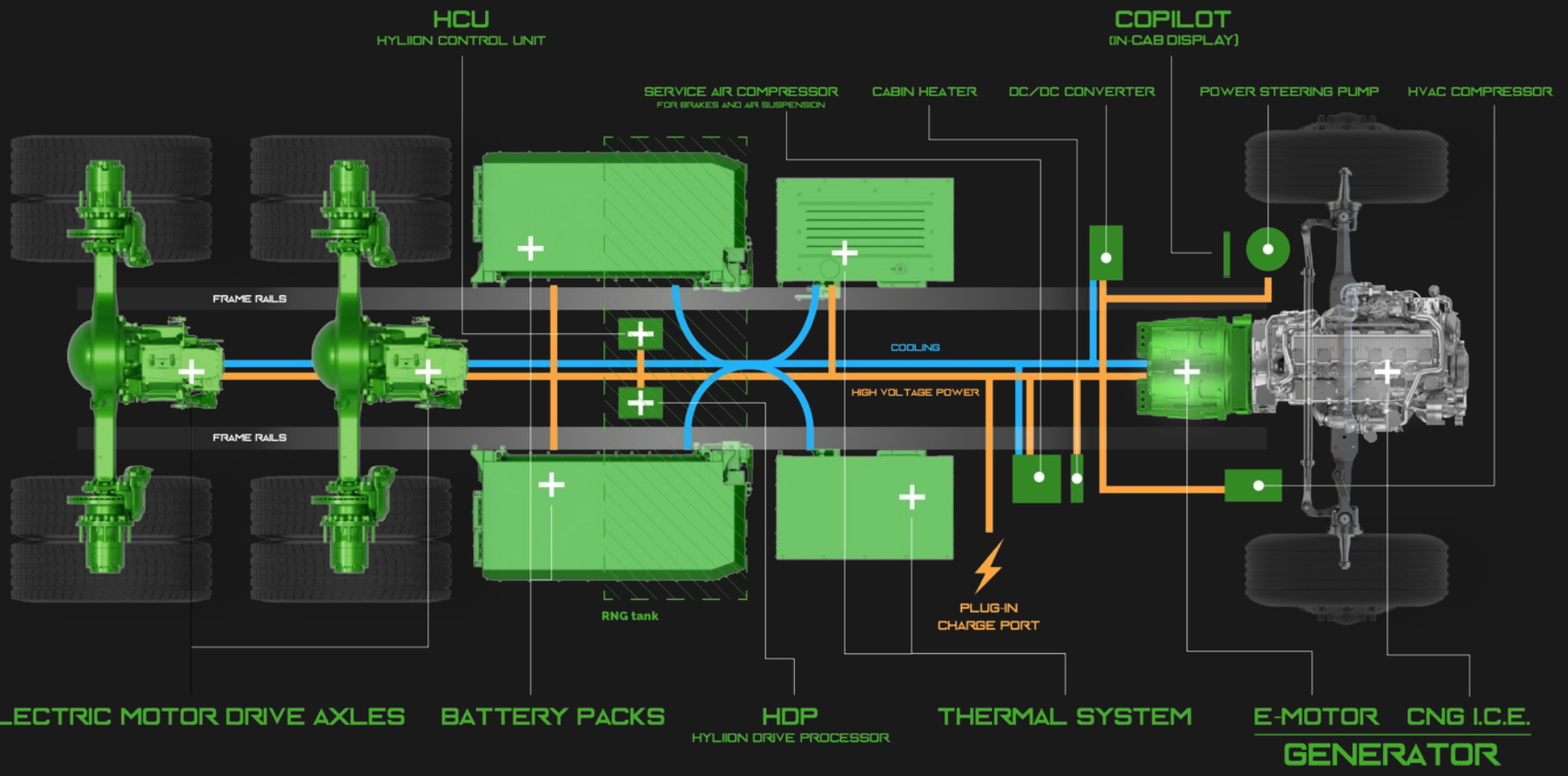
Enhanced performance

+ Improved driver experience & comfort
+ Improved operational performance

[1]Range dependent on multiple factors including vehicle load, terrain, road conditions, battery system state of charge, fuel fill level, and driver operation.

What's in the box

+ Green components = Hypertruck ERX system



670 peak HP + 1650 ft-lb torque (combined motor torque)

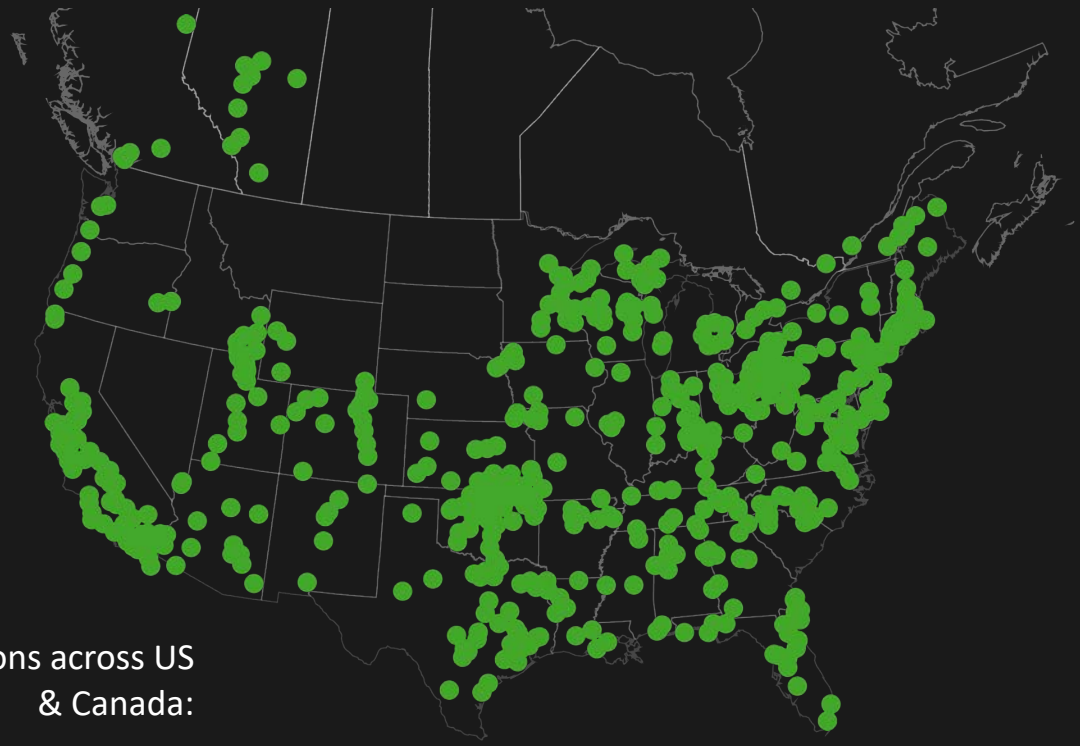
The Hypertruck ERX CoPilot™ is designed to provide a variety of features including; performance and range gauges, selectable drive modes (Auto, Manual charge and Manual EV)**, system overview animations, component information and a comprehensive alert notification system.**

*Product images shown for illustration purposes only and subject to change.

infrastructure

CNG Benefits:

+ Strongest emissions profile compared to diesel, hydrogen and BEV[1]
+ Lower fuel costs than all other alternatives
+ Supports 500+ mile routes
+ On par with diesel in time to complete route



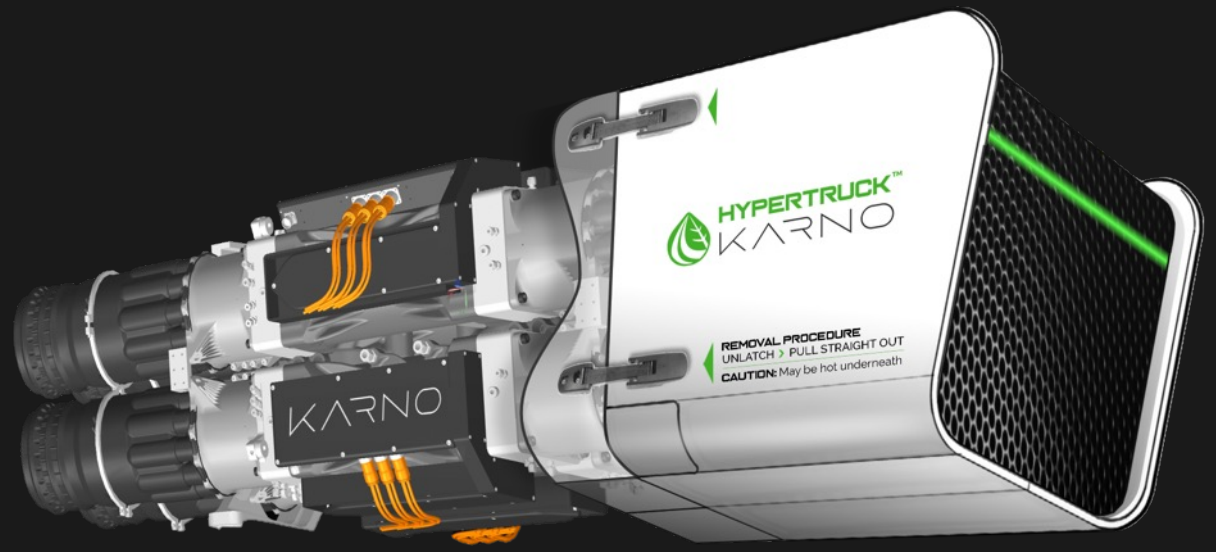
CNG stations across US & Canada:

~700

Alternative Fuels Data Center Class 6-8 vehicles.

[1]When used with RNG, carbon intensity for RNG varies. Based on vehicle configuration and real-world conditions - results may vary depending on a number of factors, including but not limited to, exact route, road conditions, driver, load and fuel pricing.

Karno Technology[1]



HYPERTRUCK™ KARNO

The KARNO generator uses heat to drive a sealed linear generator to produce electricity. The heat is produced by reacting fuels through flameless oxidation.

Hyliion acquired the technology from GE. It emerged out of GE's long-running R&D investments in metal additive manufacturing and in areas such as generator thermal and performance design.

Fuel Agnostic

Over 20 compatible fuel types

Increased Efficiency

Expected 20%+ increase in efficiency over todays leading generators; enabling reduced operating costs

Reduced Emissions

Hydrogen capable and ultra-low emissions on conventional fuels

[1]KARNO advantages are based on preliminary modeling results

Thank you!

Jason Schieck
Senior Director of Product Marketing & Strategy
Jason.Schieck@hyliion.com

NACFE RoL-e DEPOT
Wireless Inductive Charging

John Kresse
Cummins Inc.

June 27, 2023

Accelera Core Technologies

Electrolyzers

Creating solutions for industrial and commercial hydrogen generation and megawatt-scale energy storage

Industrial processes and fueling stations: PEM generator, alkaline hydrogen generator

Critical and uninterruptible power supply, power-to-gas technology

Fuel Cell Systems

Creating and integrating fuel cells for mobility and stationary power applications

Electric mobility: heavy-duty truck, transit bus, rail

Utility: microgrids, megawatt-scale grid firming and renewable integration

Commercial/Industrial: manufacturing, data centers, water treatment facilities, hotels/resorts

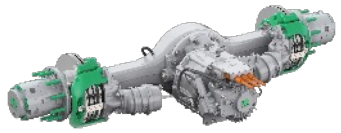
Electrified Components

Creating technologies and products for commercial battery electric vehicles and battery energy storage systems

On-highway: transit bus, school bus, medium-duty truck, walk-in van

Off-highway: construction equipment, terminal tractor, material handling, energy storage systems

Components: battery modules, battery packs



ePowertrain Systems

Creating technologies and delivering eAxles for electrified vehicles

On-highway: medium-duty truck, heavy-duty truck, walk-in van, transit bus, school bus

Off-highway: construction equipment, terminal tractor

Components: integrated eAxles

Traction Systems

Creating technologies and delivering electric traction systems for electrified vehicles

On-highway: medium-duty truck, heavy-duty truck, walk-in van, transit bus, school bus

Off-highway: construction equipment, terminal tractor

Components: motors and inverters for remote mount and eAxle

EV Charging Solutions

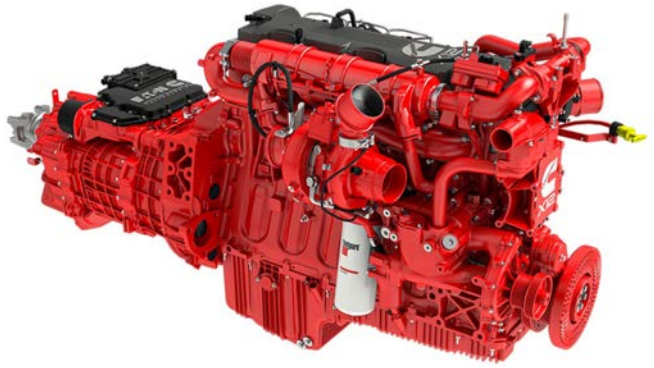
Complement Accelera – Sold & Serviced by Cummins Sales & Service, North America

Electric mobility: heavy-duty truck, transit bus, school bus, medium-duty truck, walk-in van

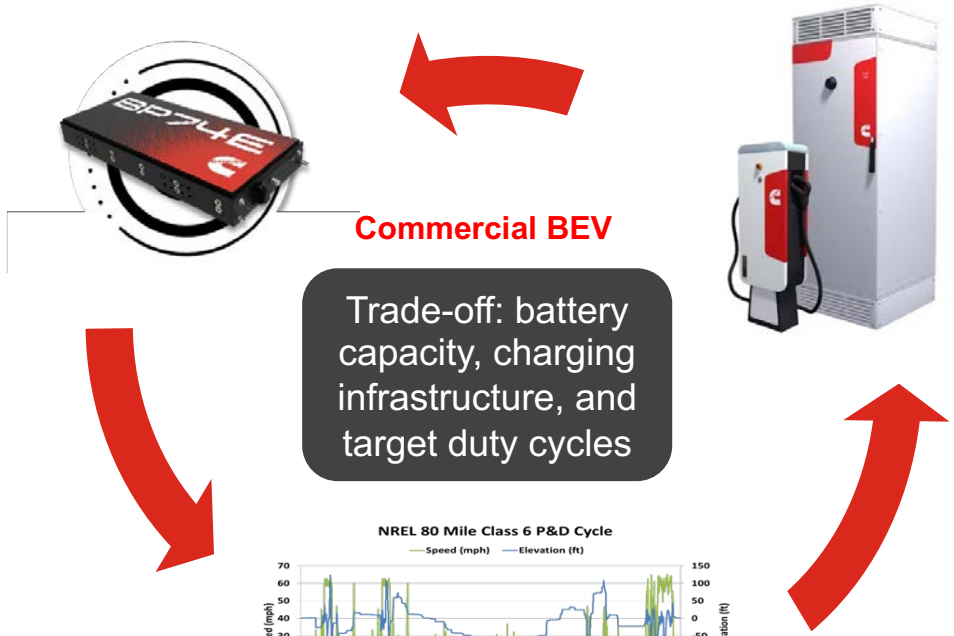
Utility: microgrids, renewable integration

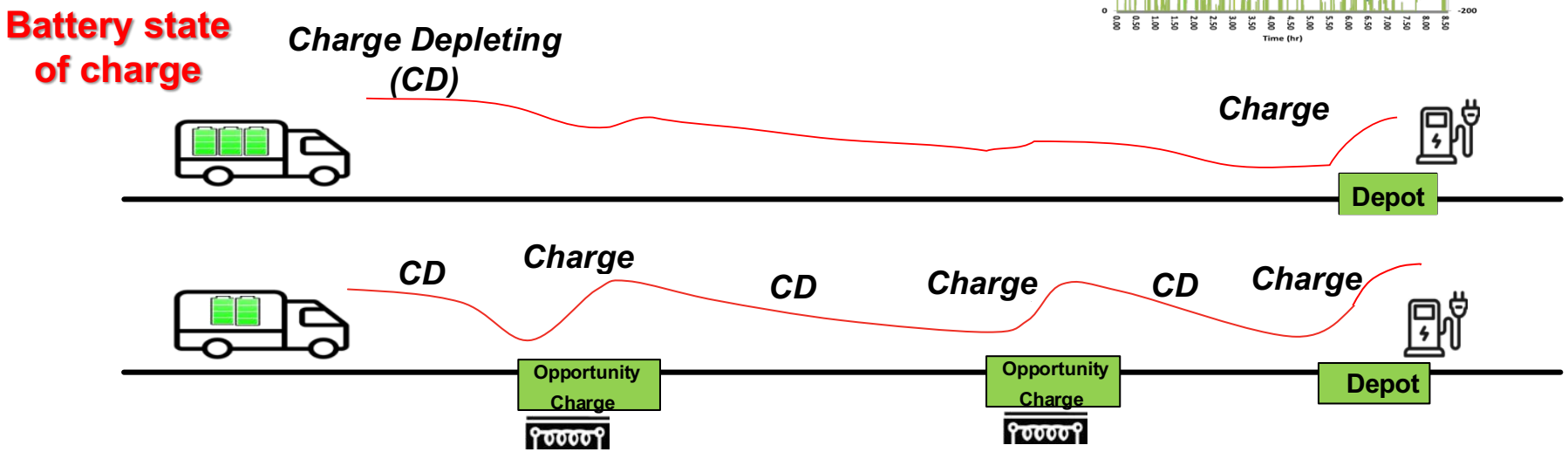
Components: EV chargers (mobile 50 kW, stationary 180 kW)

The Primary Commercial BEV challenge is Energy Management



Development of diesel powertrains is primarily a **power** management problem (including optimizing combustion for emissions and efficiency)



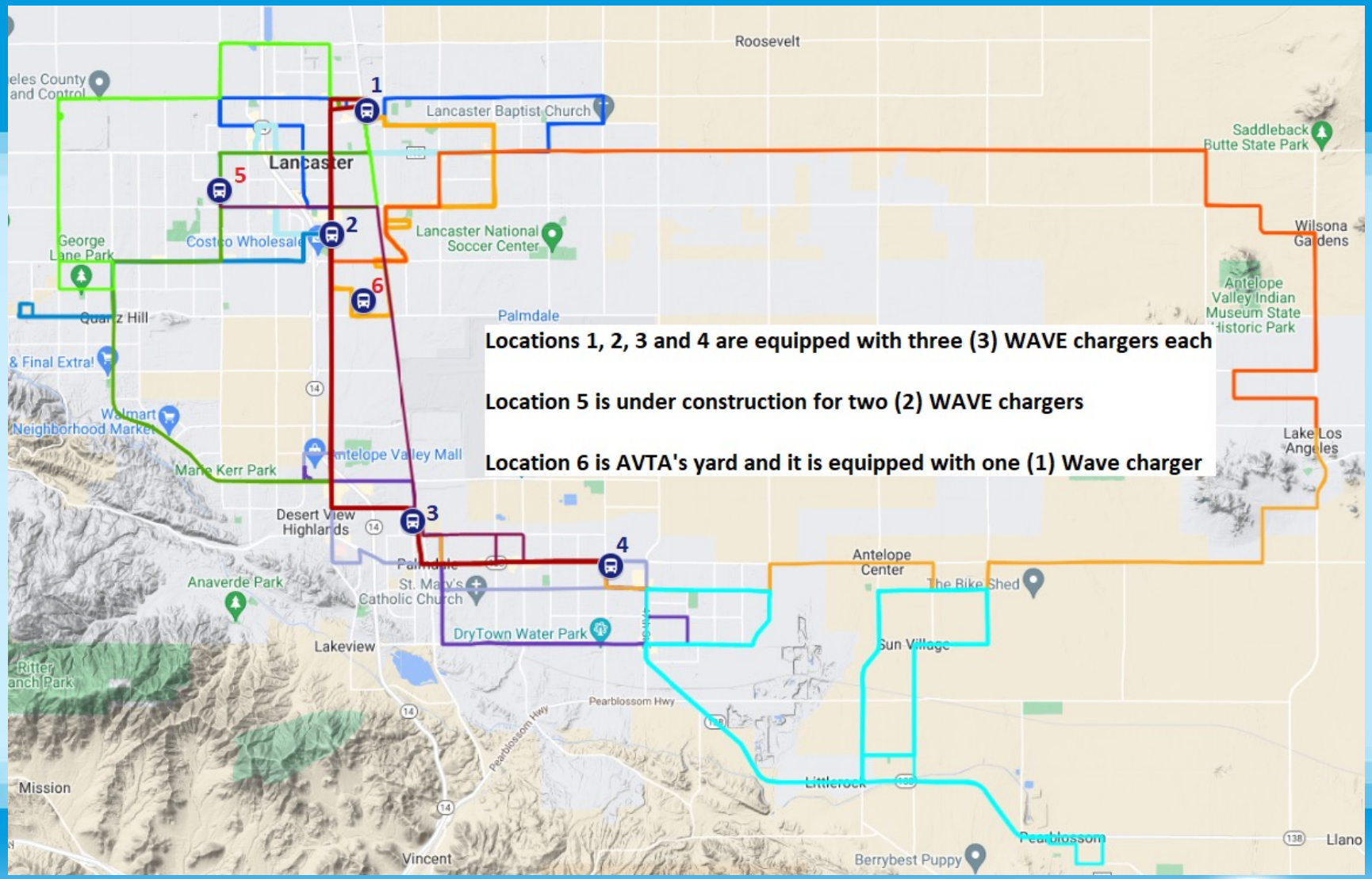


WIRELESS IMPLEMENTATION at AVTA

Slide courtesy of Geraldina Romo of AVTA

- Not a 1 to 1 conversion at the beginning (Diesel to Battery electric bus)
- Process to recharge is seamless to bus operators
- Recharge happens during layover time minimizing impact to passengers
- 10 minutes on 250 kW charger extends the range about 10-13 miles

As of January 2022, AVTA is the first all-electric transit agency in North America

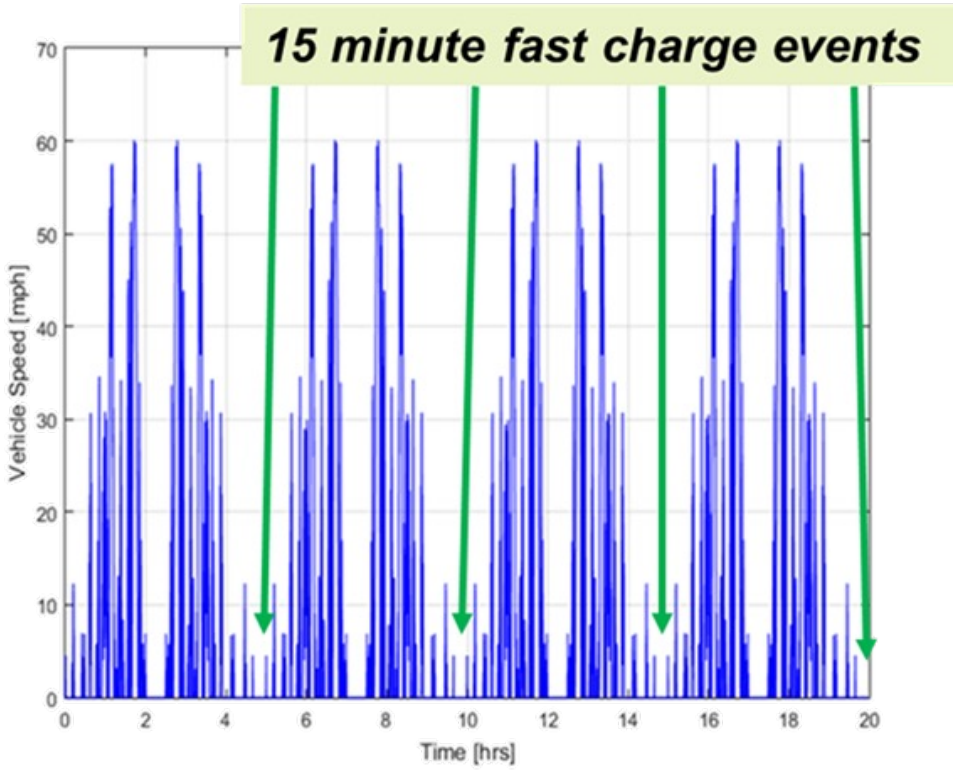


Slide courtesy of Geraldina Romo of AVTA

Antelope Valley Transit Authority

500 kW Stationary Wireless Charging Project

On a DOE-sponsored project, Cummins is working with Wireless Advanced Vehicle Electrification (WAVE) utilizing stationary **500 kW wireless charging** for **class 8** drayage/logistics application



Modified NREL drayage cycle extended to 20 hours incl. bridge grades

Key vehicle metrics	Targets
Vehicle speed on 6% grade @ max GCVW	> 30 mph
Charge power (15 minutes) to 80% SOC	500 kW
Tractor weight	≤ 23.0k lb
Vehicle range (full charge, loaded)	> 45 miles
Work day duty cycle	20 hours / 160 miles

For this class 8 application, a 15-minute 500 kW charge event provides 50-70 miles of range

Target applications

Drayage – transport of shipping containers from port to inland distribution centers

Local logistics – delivery between suppliers and production

500 kW Stationary Wireless (XFC) Charging Project

500 kW WAVE stationary wireless charging system

Secondary Pads
(on-vehicle)

Class 8 BEV day cab (two trucks):

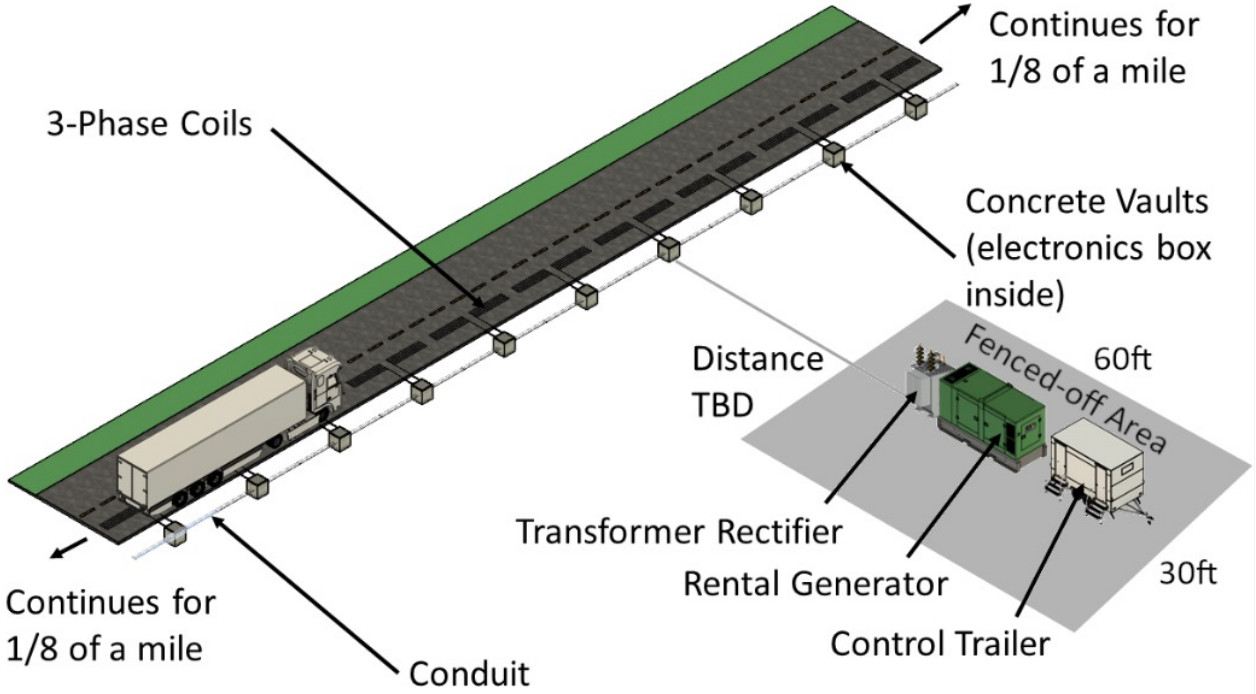
- Cummins-developed 330 kW (continuous) EV traction system
- 212 kW-h battery (650 VDC nominal)
- Meets all target requirements including support of 500 kW wireless charging

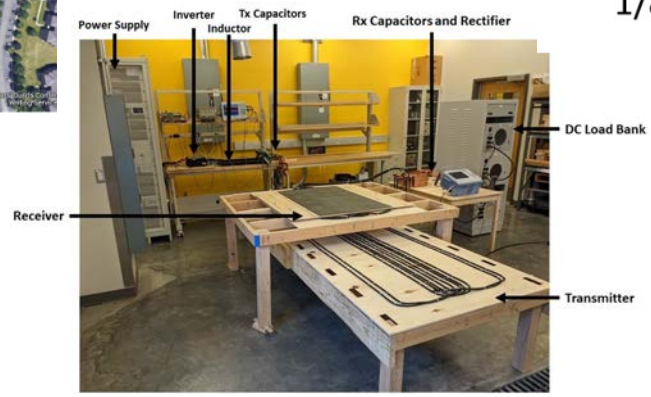
Customer deployment @ Venture Logistics (Lafayette, Indiana) in Q3 2023

Primary Pads
(to be installed in pavement)

Indiana DOT - Purdue Dynamic Wireless Power Transfer Pilot Concept

- West Lafayette, Indiana [US 231/US 52]
- Concrete pavement
- Construction to begin Q4 2023
- Target: 200 kW power transfer





220-kW Prototype (Elec. Eng. Lab.)

Structural/Thermal Testing in Accelerated Pavement Testing Lab (INDOT)

Slide courtesy of Dr. Dionysios Aliprantis (Purdue University)

Thank You

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Q&A

Opportunities to Extend BEV Range

Andreas Kammel

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TRATON

Andrew Kotz

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John Kresse

Director – Advanced Electrification Technologies

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Jason Schieck

Sr. Director of Product Marketing and Strategy

Hyliion

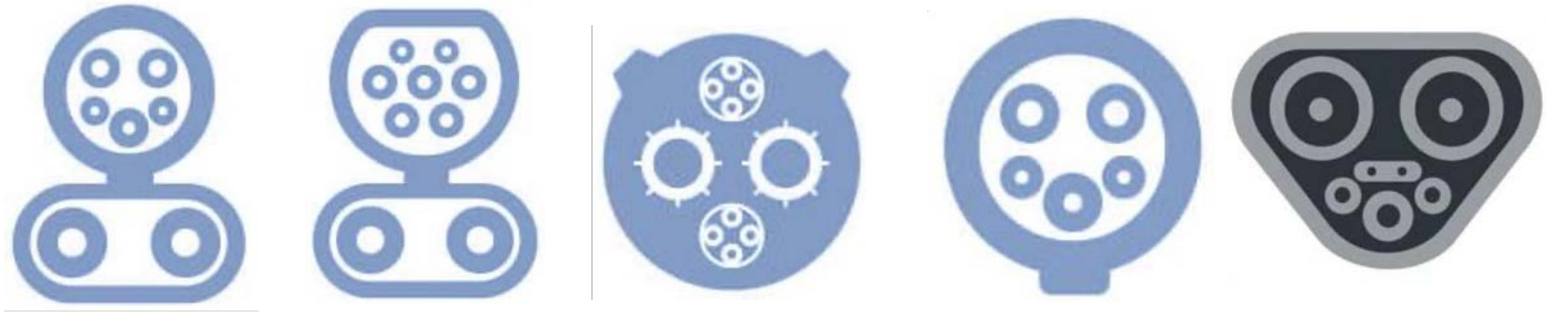
Hosted by:

Rick Mihelic

Director of Emerging Technologies

RUN ON LESS ELECTRIC DEPOT

ELECTRIC DEPOT BOOTCAMP



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