DISTRIBUTECH® CONFERENCE & EXHIBITION

RUN ON LESS ELECTRIC

LARGE LOADS: Electric Semi's & Their Charging Systems

Dave Schaller

May 2022

North American Council for Freight Efficiency

- Unbiased, fuel agnostic, non-profit
- Mission to double freight efficiency
- All stakeholders
- Scale available technologies, guide future change and Run on Less demonstrations.

www.NACFE.org

www.RunOnLess.com

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NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY

IN PARTNERSHIP WITH

RMI
ENERGY. TRANSFORMED.

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WILLIAM + FLORA Hewlett Foundation

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CATENA FOUNDATION

2022 Fiscal Supporters

Guidance on Electric Trucks

 # 1

Electric Trucks: Where They Make Sense

May 2018

MD Electric Trucks:

Cost Of Ownership

October 2018

 # 2

Viable Class 7 & 8 Electric, Hybrid & Alt Fuels Tractors

 # 4

December 2019

 # 3

Electric Trucks: Charging Infrastructure

March 2019

High Potential Regions

 # 5

November 2020

Heavy-Duty Hydrogen Fuel Cell Tractors

 # 6

December 2020

Now Free Online at https://nacfe.org/emerging-technology/electric-trucks-2/

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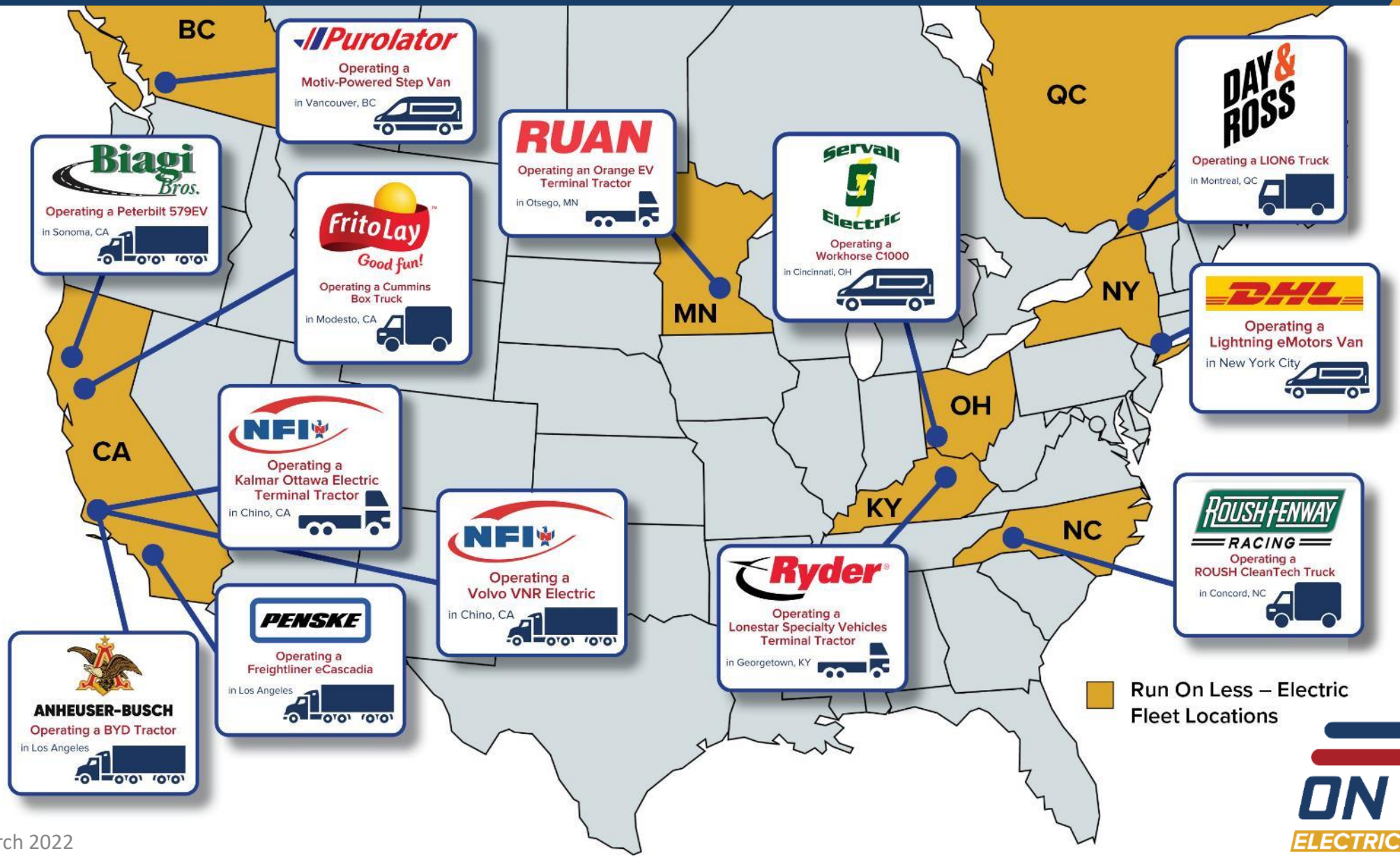
4

September 2021

Run on Less – Electric Participants



RUN ON LESS ELECTRIC

Run on Less – Electric Videos

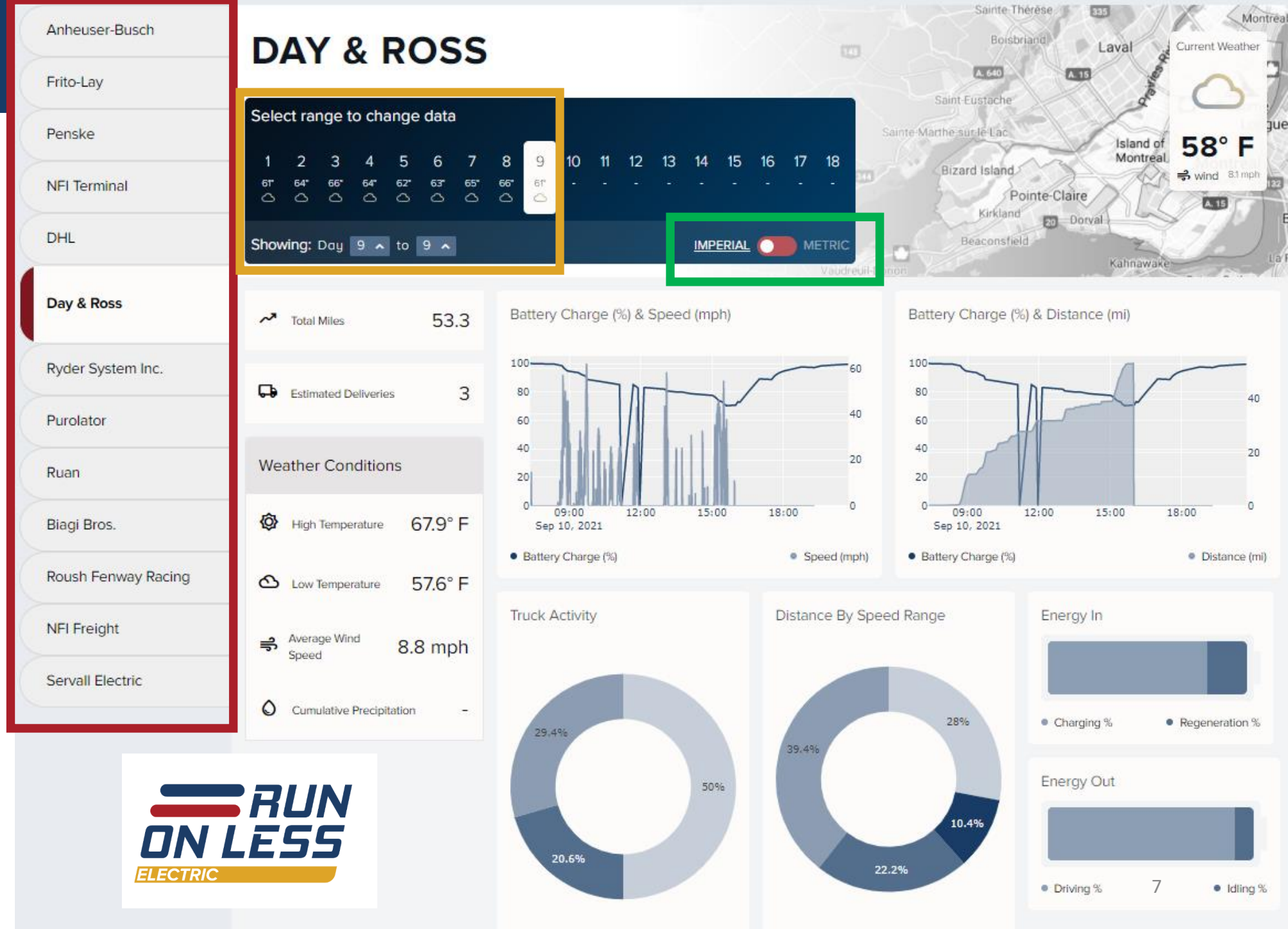
Real World, Real Time Case Studies

- Video for each fleet & OEM
- Fleet Interviews: Drivers & Leaders
- OEM Interviews & more

May 2022

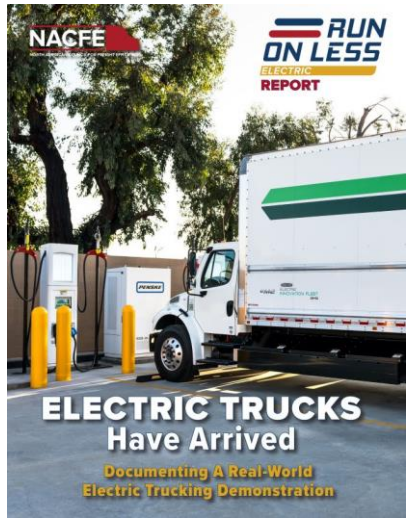
Metrics

1. Select any of the 13 fleets
2. Select a day or range of days
3. Select Units of Measure
4. Enjoy the data!

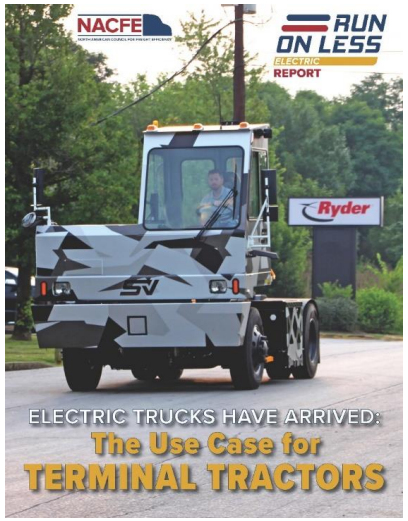


RUN ON LESS ELECTRIC

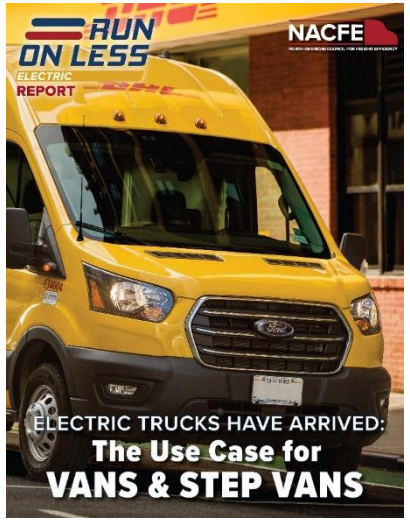
RoL–E Reports



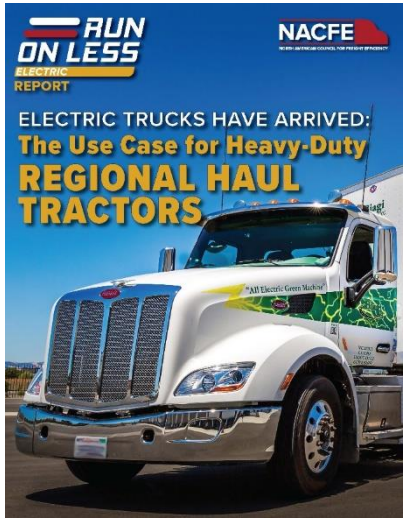
January 12, 2022
Review Of Complete Demonstration:
Electric Trucks Have Arrived



March 6, 2022
The Use Case For
TERMINAL TRACTORS



April 11, 2022
The Use Case For
VANS & STEP VANS



May 9, m2022
The Use Case For
REGIONAL HAUL TRACTORS

In Development:

The Use Case For
MEDIUM DUTY BOX TRUCKS

4 Market Segment Fact Sheets

RUN ON LESS ELECTRIC

Regional Haul Tractors Segment

HD REGIONAL HAUL TRACTORS

Jennifer Wheeler, Senior Program Manager, NACFE

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NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY

Market Segment & Fleet Profile Fact Sheet

Operational Characteristics

Duty Cycle	Return to Base
Use Case	Regional Haul
Average Range	Less than 300 miles / day
Routes	Fixed
Fueling	Centralized, at night
Miles per Gallon	7.23
Replacement Cycle	6.8 years
Average Age	5.1 years
Axle Configuration	6X4

Battery Size Range: 396 to 440 kWh

File Link

RUN ON LESS ELECTRIC

Electric Truck Bootcamp

ELECTRIC TRUCK BOOTCAMP

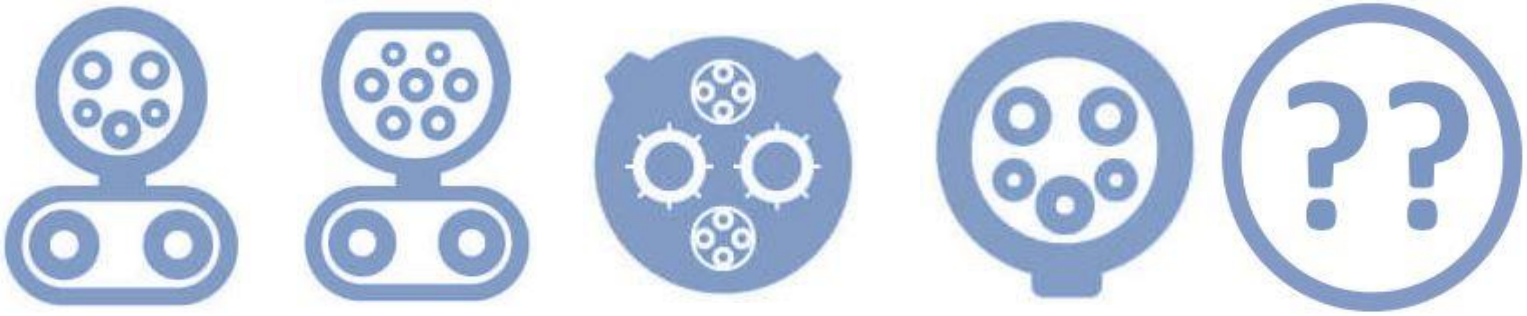
SESSION

1. Why Electric Trucks?
2. Charging 101 — Planning & Buildout
3. Charging 201 — Power Management & Resilience
4. Working with Your Utility
5. Incentives for Electrification
6. Maintenance, Training & Safety
7. Finance & Innovative Business Models
8. Battery Supply Chains & End of Life
9. Global Perspectives
10. Drivers & Electric Trucks

RUN ON LESS ELECTRIC

SCAN for Training Videos, Quizzes and Badges

WWW.RUNONLESS.COM



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Let's Stay Connected…
… And charged up!

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LinkedIn **NACFE** (& Spanish: NACFE LATAM)

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@NACFE_Freight & @RunOnLess

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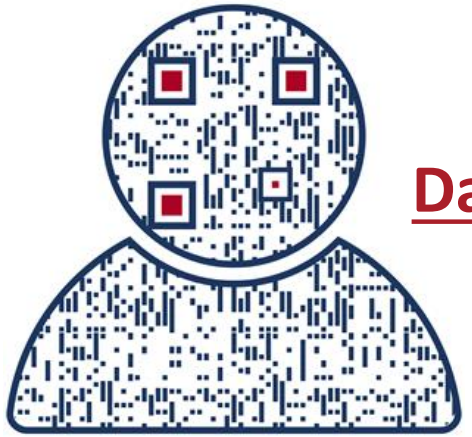


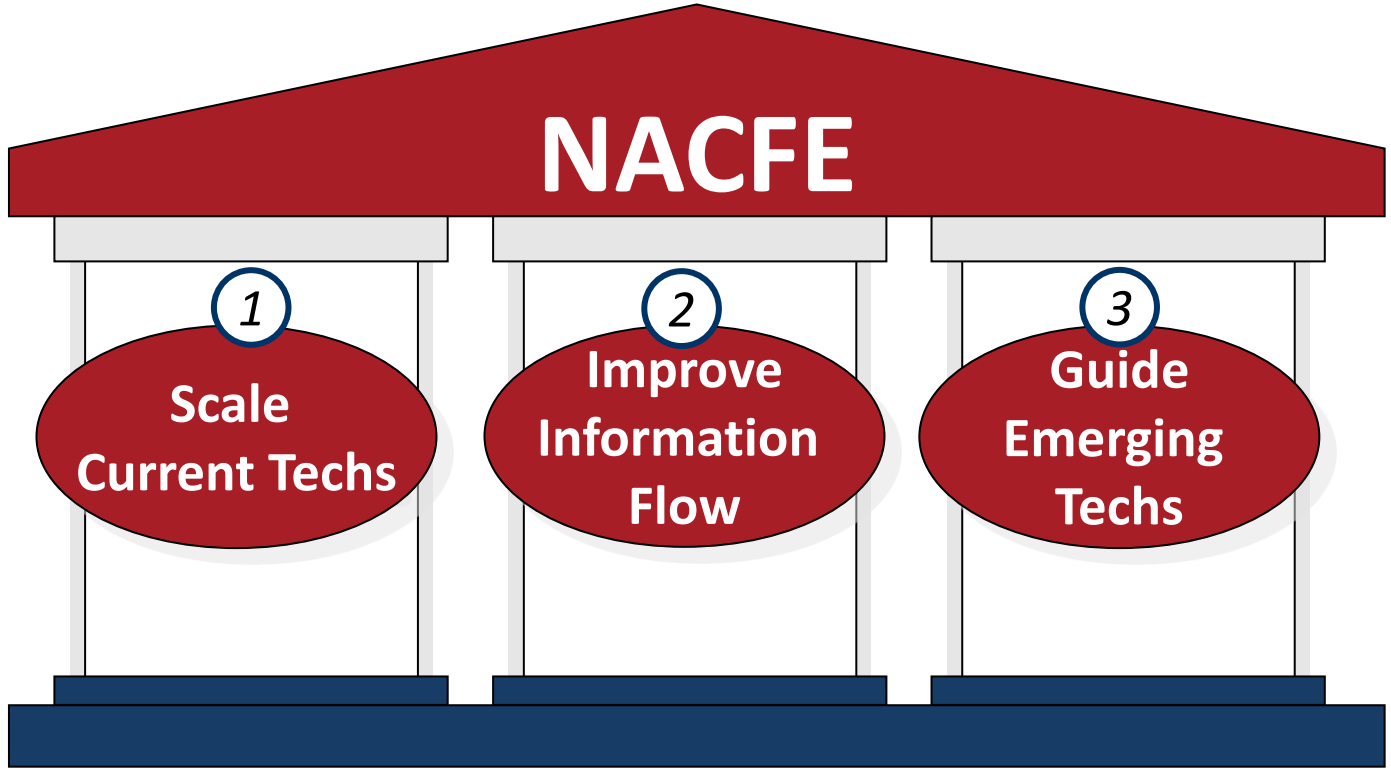
Dave Schaller

David.Schaller@NACFE.org

260-602-5713

Appendix of Extra Slides

Three Pillars of NACFE Work



NACFE.org
RunOnLess.com

Confidence Reports

Trade Shows

Annual Fleet Fuel Study

Run On Less Demonstrations

Thought Leadership

Electrification Guidance Reports

Collaboration Reports

Workshops

HD Tractors Green Future

PRESENT: 2020

Technology immature

Many unknowns & challenges

"MESSY MIDDLE": 2030

Many optimized solutions

Growing infrastructure

Multi fuel choices

Innovation & maturation

Facts replace estimates

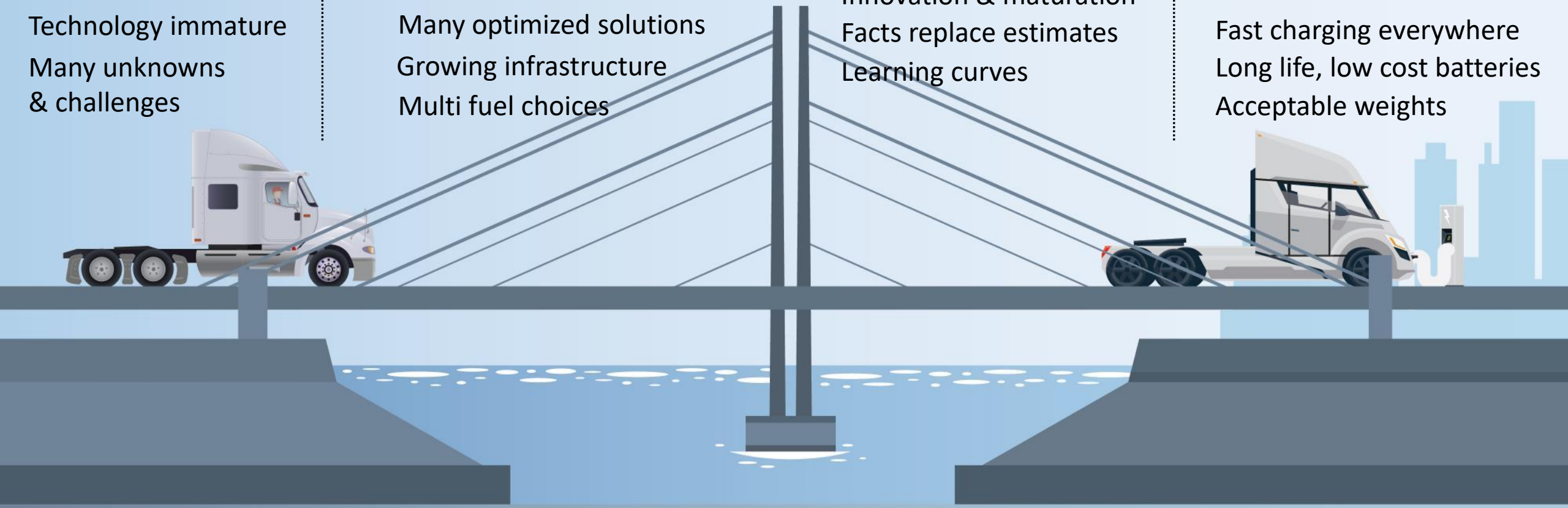
Learning curves

FUTURE: 2050

Fast charging everywhere

Long life, low cost batteries

Acceptable weights



Legacy Diesels
Natural Gas

Diesel Advancements
Natural Gas
Hybrids

Battery Electric
Hydrogen Fuel Cells
Renewable Natural Gas & Diesel

CBEV & HFCEV from Clean Energy

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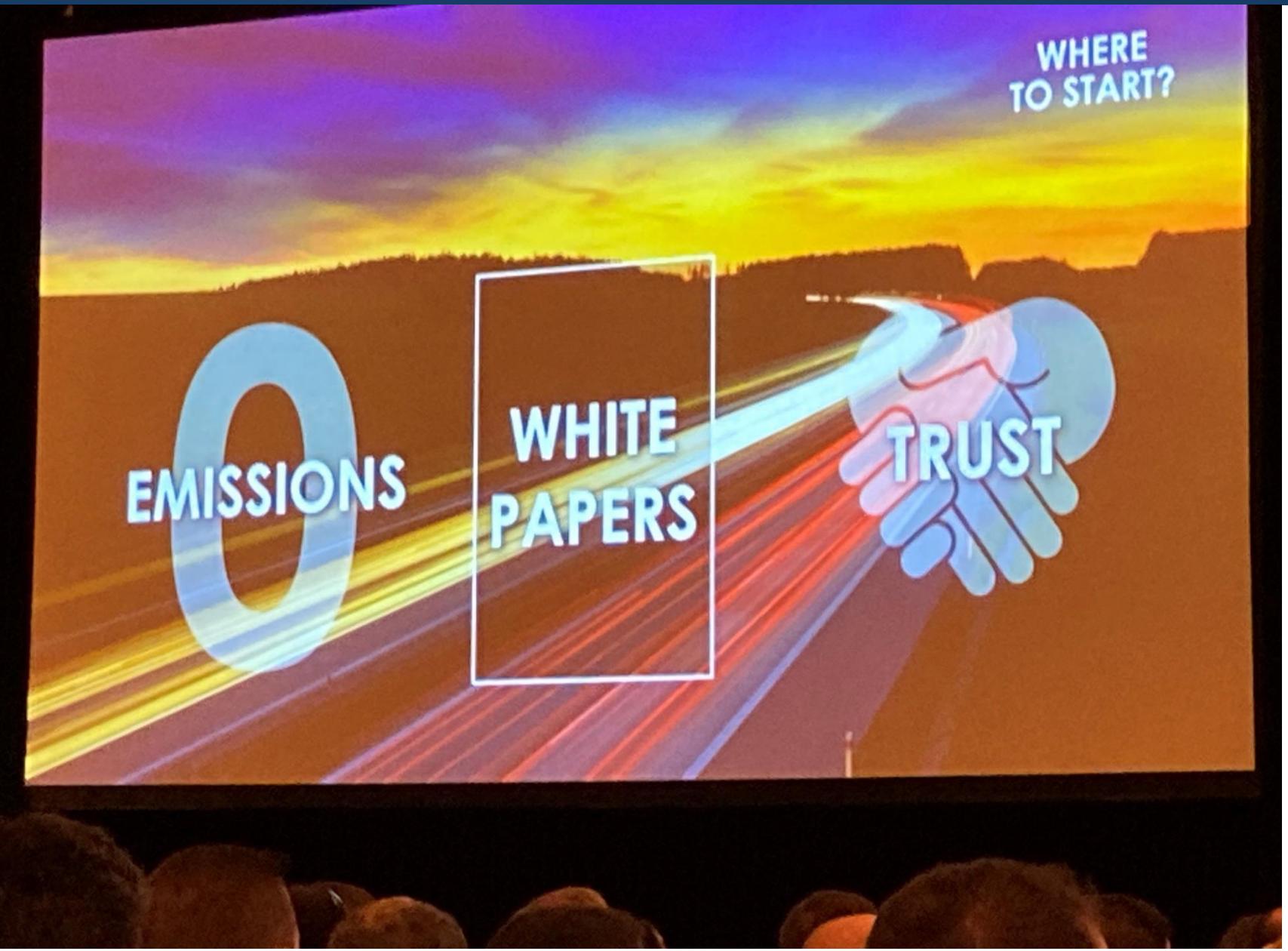
ZEV: Where to Start



Mathias Carlbaum

Navistar CEO & President

Address to ATD

(American Truck Dealers)

Las Vegas, NV

March 11, 2022

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Run on Less by NACFE

2017

RUN ON LESS BY NACFE

Long Haul

7 Fleets

10.1 MPG

2019

RUN ON LESS REGIONAL

Regional Haul

10 Fleets

8.3 MPG

2021

RUN ON LESS ELECTRIC

All BEVs

13 Fleets

New metrics!

Run on Less - Electric

Fleet	OEM	Location	Truck Class
Servall Electric	Workhorse C1000	Cincinnati, OH	3
Anheuser-Busch	BYD tractor	Los Angeles, CA	8
Biagi Brothers	Peterbilt 579EV	Sonoma, CA	8
NFI	Kalmar terminal tractor	Chino, CA	8
NFI	Volvo VNR Electric	Chino, CA	8
Penske	Freightliner eCascadia	Los Angeles, CA	8
Frito-Lay (PepsiCo)	Cummins box truck	Modesto, CA	6
Purolator	Motiv-powered step van	Vancouver, BC	3
Roush Fenway Racing	ROUSH CleanTech truck	Concord, NC	6
Ruan	Orange EV terminal tractor	Otsego, MN	8
Ryder System Inc	Lonestar Specialty Vehicles terminal tractor	Georgetown, KY	8
Day & Ross	LION6 truck	Montreal, QB	6
DHL USA	Lightning eMotors truck	New York City, NY	3

The Real World

Run on Less: Terminal Tractors

Findings

1. Great first step in electrification
2. Drivers rave about these vehicles
3. Maintenance costs lower
4. Positive environmental impact
5. Payback time without incentives is long
6. Plan tight data tracking to prove ROI

Terminal Tractor Video

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Terminal Tractors Segment

TERMINAL TRACTORS

Jennifer Wheeler, Senior Program Manager, NACFE

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Market Segment & Fleet Profile Fact Sheet

Operational Characteristics

Duty Cycle	Single to multiple shifts
Operation	High idle and high run rate
Daily Range – On Road	Less than 150 miles
Daily Range – Off Road	Less than 100 miles
Routes	Fixed
Fueling	Between shifts
Fuel Consumption	2.5 gallons/hour
Replacement Cycle	10 -12 years
Average Age	6 years
Axle Configuration	4x2 (most common) & 6x2

Battery Size Range: 132 to 224 kWh

File Link

RUN ON LESS ELECTRIC

Run on Less: Vans & Step Vans

Findings

1. E-commerce is leading the doubling of the huge van and step van market.
2. Electrifying smaller commercial vehicles is easier &
3. TCO is approaching parity with IC engines.
4. EVs improve driver attraction and retention.
5. Transition will be challenging, but planning can mitigate risks.

[Vans & Step Vans Video]

Vans Fuel Cost Comparison

Gasoline	
Average Miles per Gallon	7.4
Price per Gallon of Gasoline	$2.98*
Daily Range	100
Operational Days	250
Gallons Burned per Mile	0.135
Gallons Burned per Day	13.51
Cost of Fuel per Day	$40.26
Estimated Annual Fuel Cost	**$10,065**

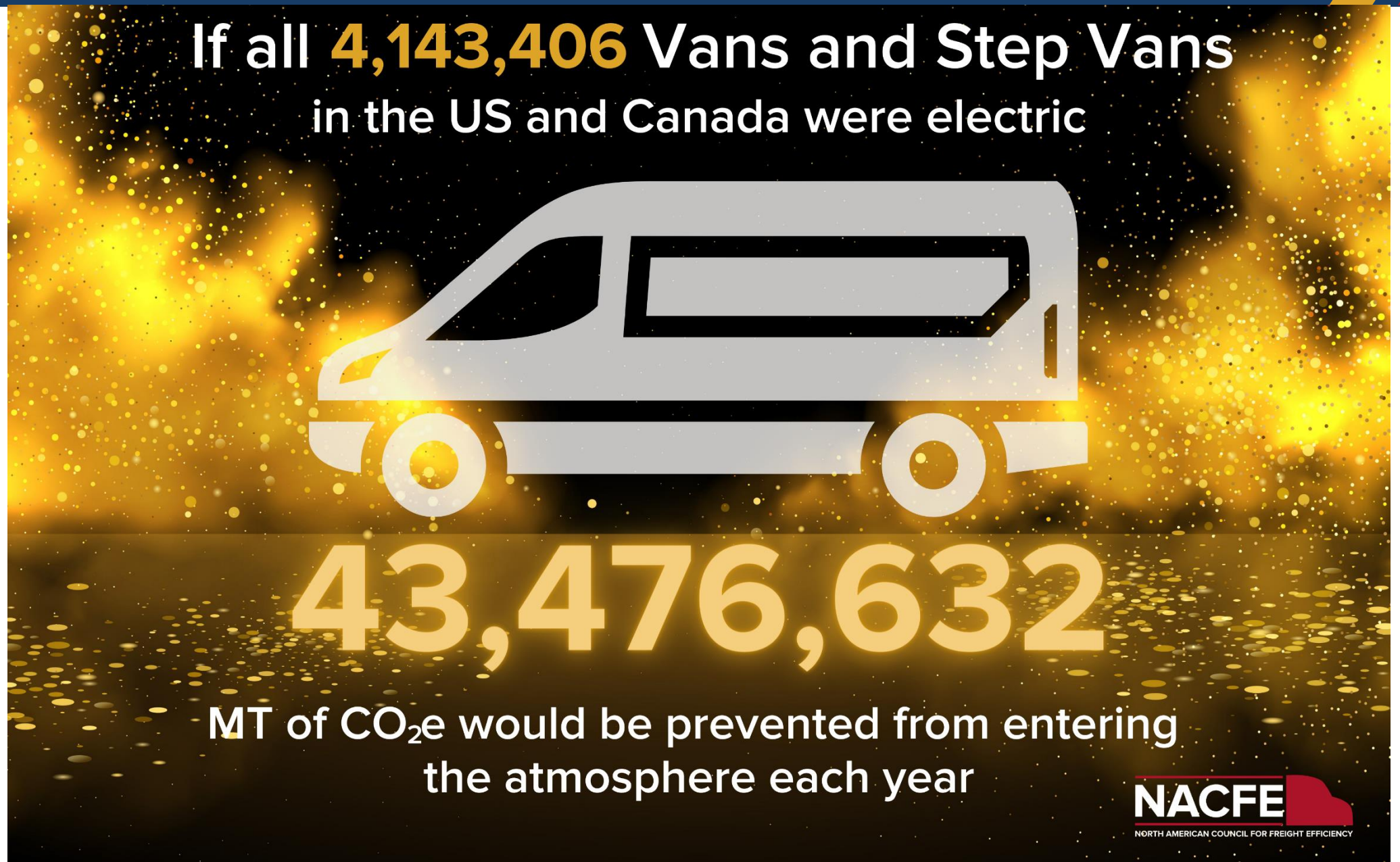
* 2021 average U.S. price of gasoline – all sectors

Electric	
Miles per Kilowatt Hour (kWh)	1.43
Price of Electricity per kWh	$0.112*
Daily Range	100
Operational Days	250
Electricity Consumed Per Mile (kWh/mi)	0.699
Electricity Consumed Per Day (kWh)	69.93
Cost of Electricity Per Day	$7.83
Estimated Annual Electricity Cost	**$1,958**

* 2021 average U.S. price of electricity – all sectors

Approximate Annual Fuel Savings per Vehicle:
$8,107

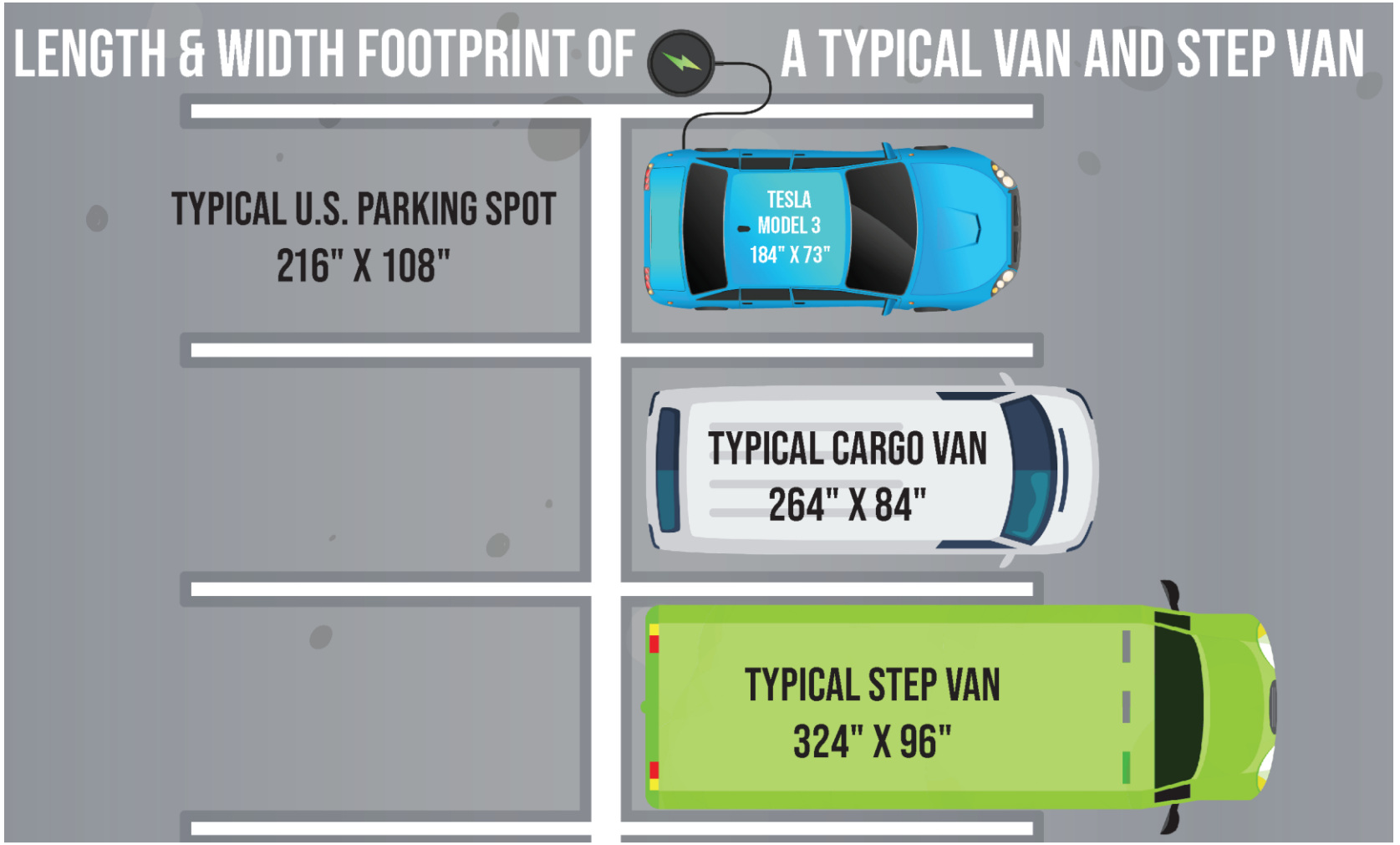
Vans, Step Vans & the Environment



Vehicle Footprint & Charging

Of the commercial trucks in Run on Less – Electric, only the vans and step vans can fit into typical public parking spots.

This may enable public charging in some instances.



MD Box Truck Segment

MD BOX TRUCKS

Jennifer Wheeler, Senior Program Manager, NACFE

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Market Segment & Fleet Profile Fact Sheet

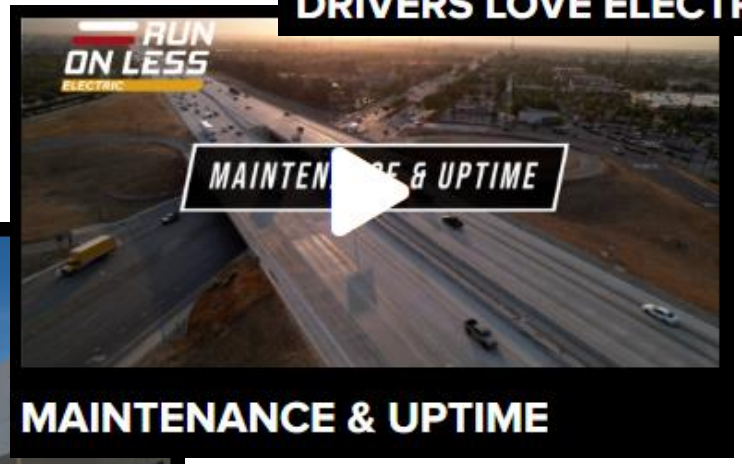
Operational Characteristics

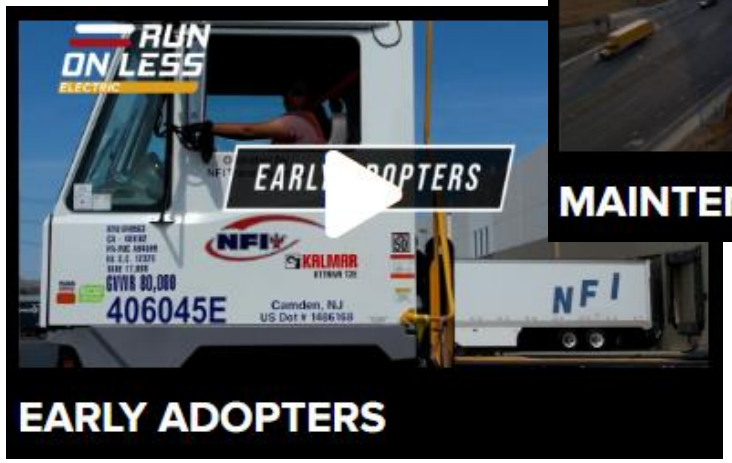
Duty Cycle	Return to Base
Use Case	Pickup & Delivery
Average Range	Less than 100 miles
Routes	Variable
Fueling	Centralized
Miles per Gallon	10.0
Replacement Cycle	10.2
Average Age	8.4
Axle Configuration	4X2

Battery Size Range: 138 to 232 kWh

File Link

Run on Less – Electric Videos





“Stories from the Road”

- New video every day
- All commercial truck EV related
- Pulled from several dozen interviews

RUN ON LESS ELECTRIC

Specs: Anheuser-Busch

Truck

Truck Class	Class 8
Type	Heavy-Duty Tractor
OEM	BYD
Model	8TT Tandem Axle
Production Level	In Series Production
Battery Capacity	435 kWh
Estimated Range	150 - 200 Miles
Components	Cabover

Truck

RUN ON LESS ELECTRIC

Charger & Utility Company

Charging Station

Max Charge Rate	40 kW (GB/T)
Parking Configuration	Pull in with Trailer
Utility	Southern California Edison

Driver

Driver

Name	Rene Solis
Years Driving	30 Years
Home Base	Pomona, CA

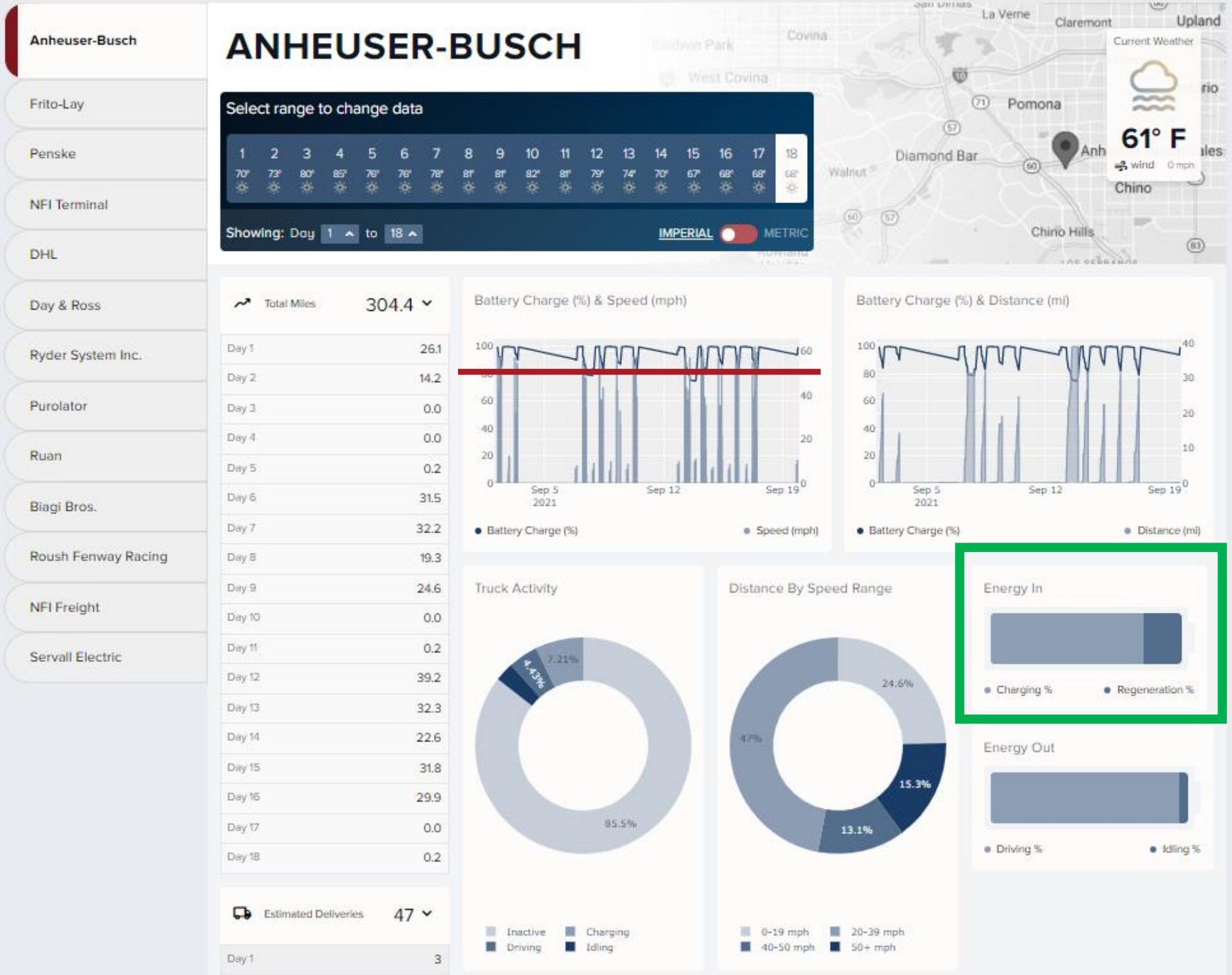
Duty Cycle

Route

Route Type	Diminishing Load (7-10 stops per day)
Goods	Beer and Seltzer
Payload Range	Usually heavy, up to 82,000 lbs

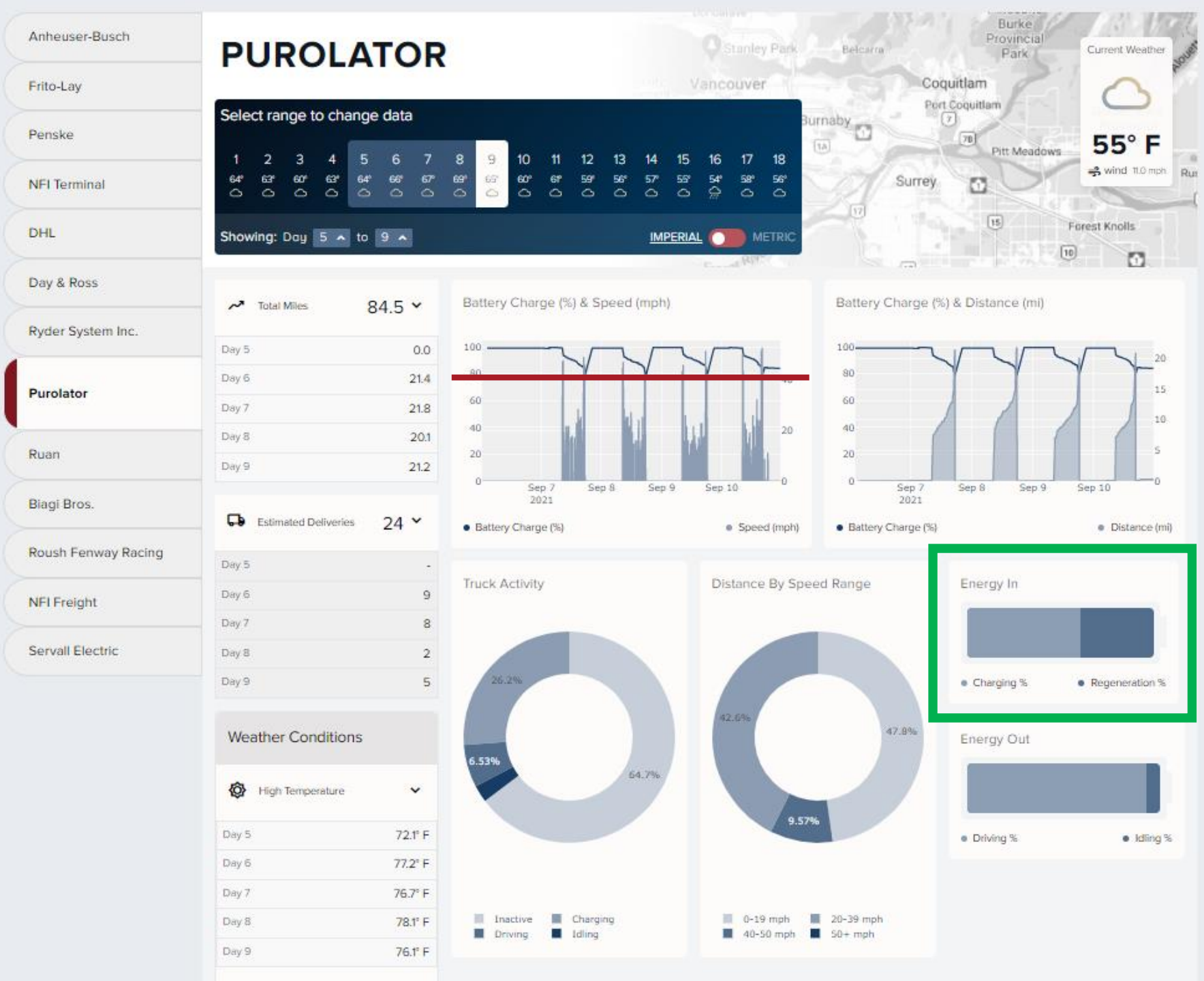
HD Beverage

- All 18 days.
- Delivers beverages to stores, pubs and restaurants.
- SOC >75%
- Good amount of regen
- Very quick charge



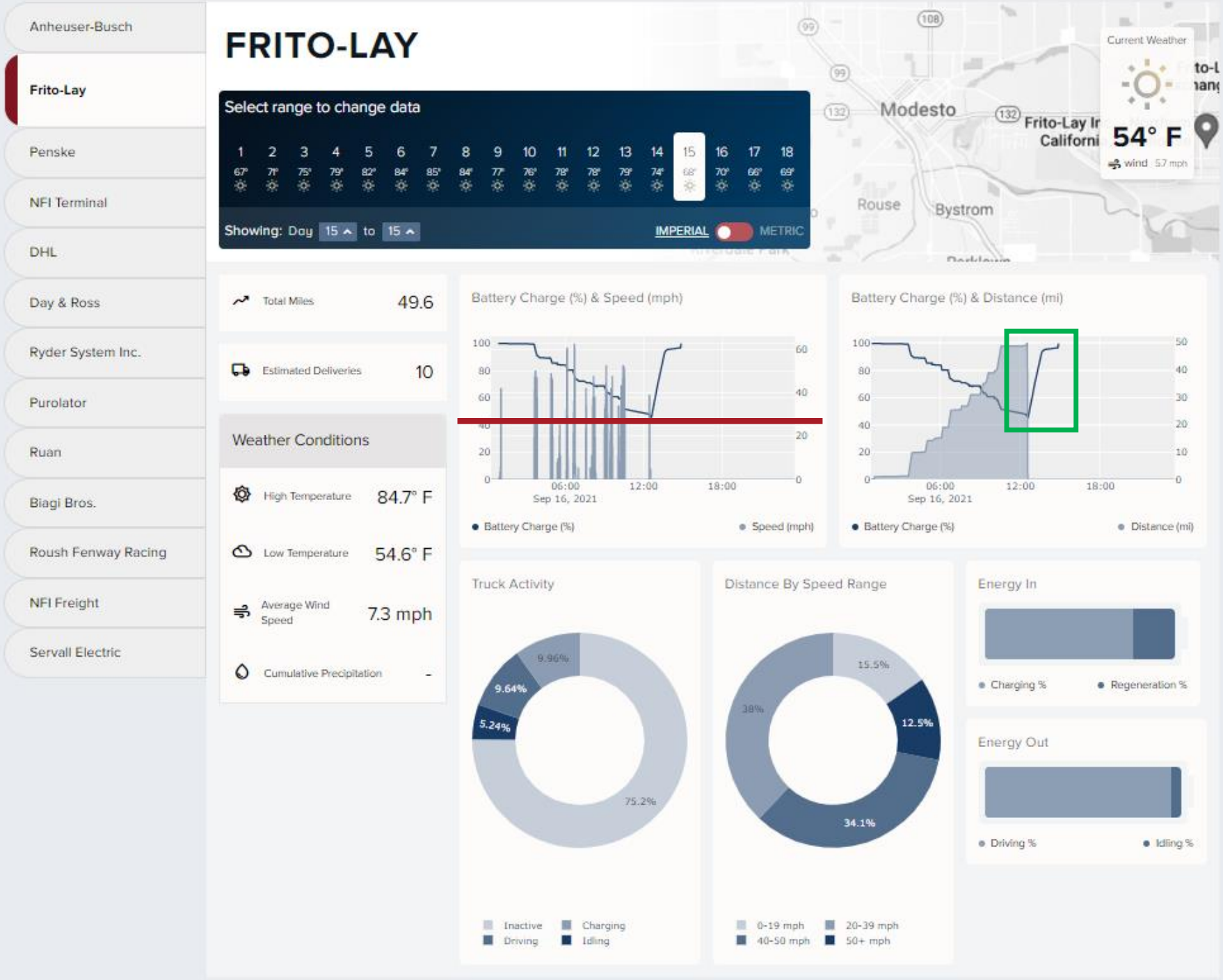
Step Van

- One week.
- Drives out to neighborhood, delivers and returns.
- SOC >80%
- High Regen
- Quick charge



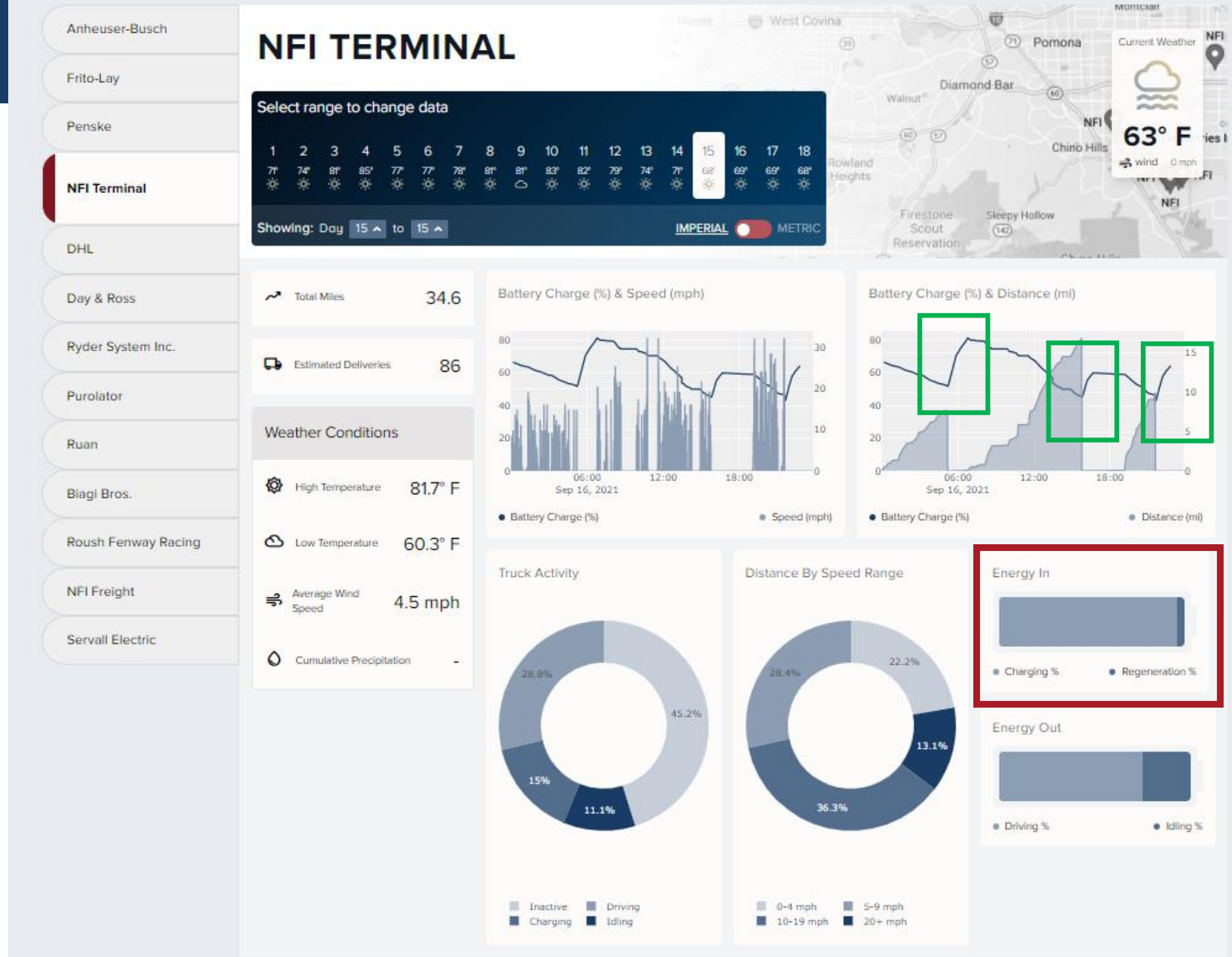
Box Truck

- One day, early morning
- Drives to loading area, loads snacks, makes deliveries, returns to base.
- 10 deliveries
- After 49.6 miles SOC = 45%.
- Quick charge



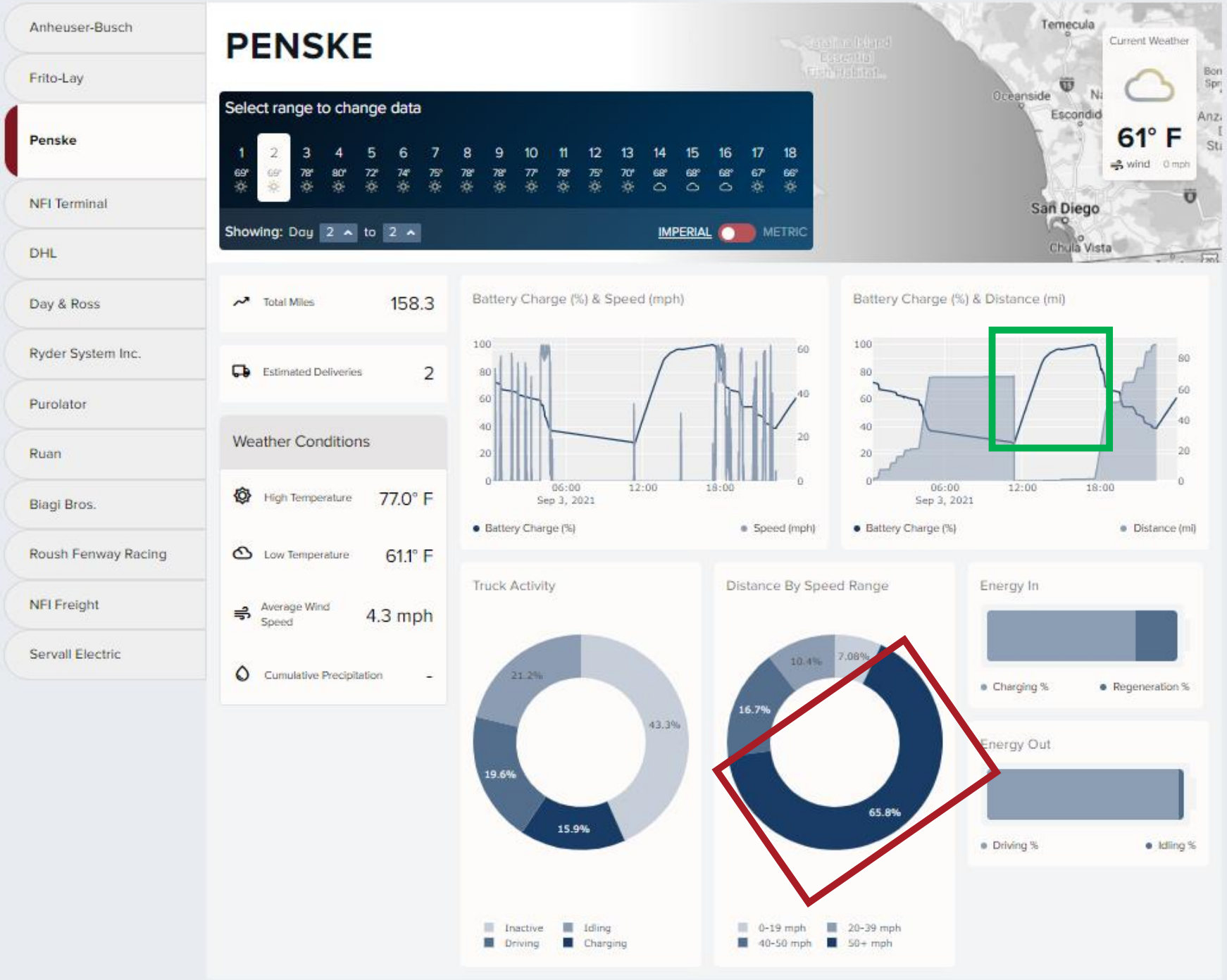
Terminal

- One day, 24 hours
- Low Regen
- Charged during shift change, but on many days at every driver rest.
- Not enough time to get to 100% SOC
- Low of 45% SOC, stopped charging at about 4pm.



HD Tractor

- One day, 5pm-5am
- 65% over 50 MPH
- 158 miles with 35% SOC remaining.
- Charge rates higher to 80% then slower to 100%.
- Reducing SOC due to some sort of idling.



Fleet Electrification Waves

Electrification waves drive Run On Less - Electric scope

1. Forklifts
2. ***Yard Tractors***
3. ***MD Urban Delivery***
4. ***Drayage***
5. ***Regional Haul Tractors***
6. Long Haul Tractors

MD & HD Industry Segments

Market Size

MD Delivery (Box trucks & step vans)
Total Population: **1,900,000**
Miles: **125/day 25K/year**

Regional Haul (Day cabs & some sleepers)
Total Population: **800,000**
Miles: **450/day 80K/year**

Long Haul (Sleeper Tractors)
Total Population: **1,200,000**
Miles: **600**/day **100K**/year

School Bus (yellow or white)
Total Population: **480,000**
Miles: **??**/day **12K**/year

MD Work Trucks (Dump, stake, service, waste…)
Total Population: **470,000**
Miles: **125/day 25K/year**

Vocational Class 8
(Construction, waste, dump…)
Total Population: **800,000**
Miles: **300/day 65K/year**

Transit Bus (public transportation)
Total Population: **150,000**
Miles: **??**/day **35K**/year

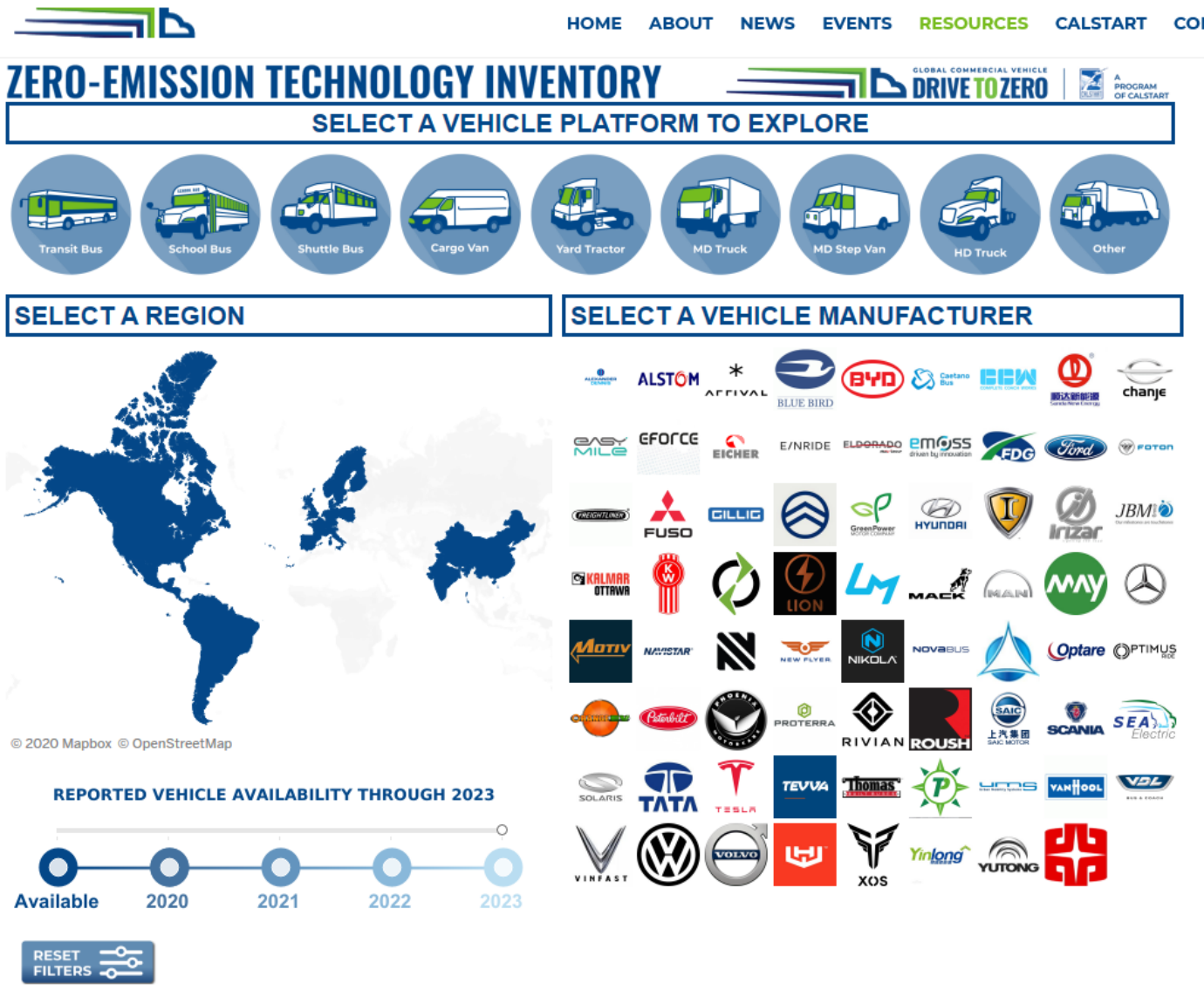
Yard Tractors (holsers, shuttles…)
Total Population: **35,000**
Miles: **10-20**/day @ 10 MPH

Expeditors Class 5-8
(MD & HD rush deliveries…)
Total Population: **25,000**
Miles: **500/day 90K/year**

This slide is under development

Electrification Time Frame

Electric/Hybrid Trucks Catalog



- "ZETI"
- Calstart on-line tool
- Part of ***Drive to Zero*** program at Calstart
- Launched March 2020
- Current & future production models
- Links to OEM web pages

https://globaldrivetozero.org/resources/zero-emission-technology-inventory/

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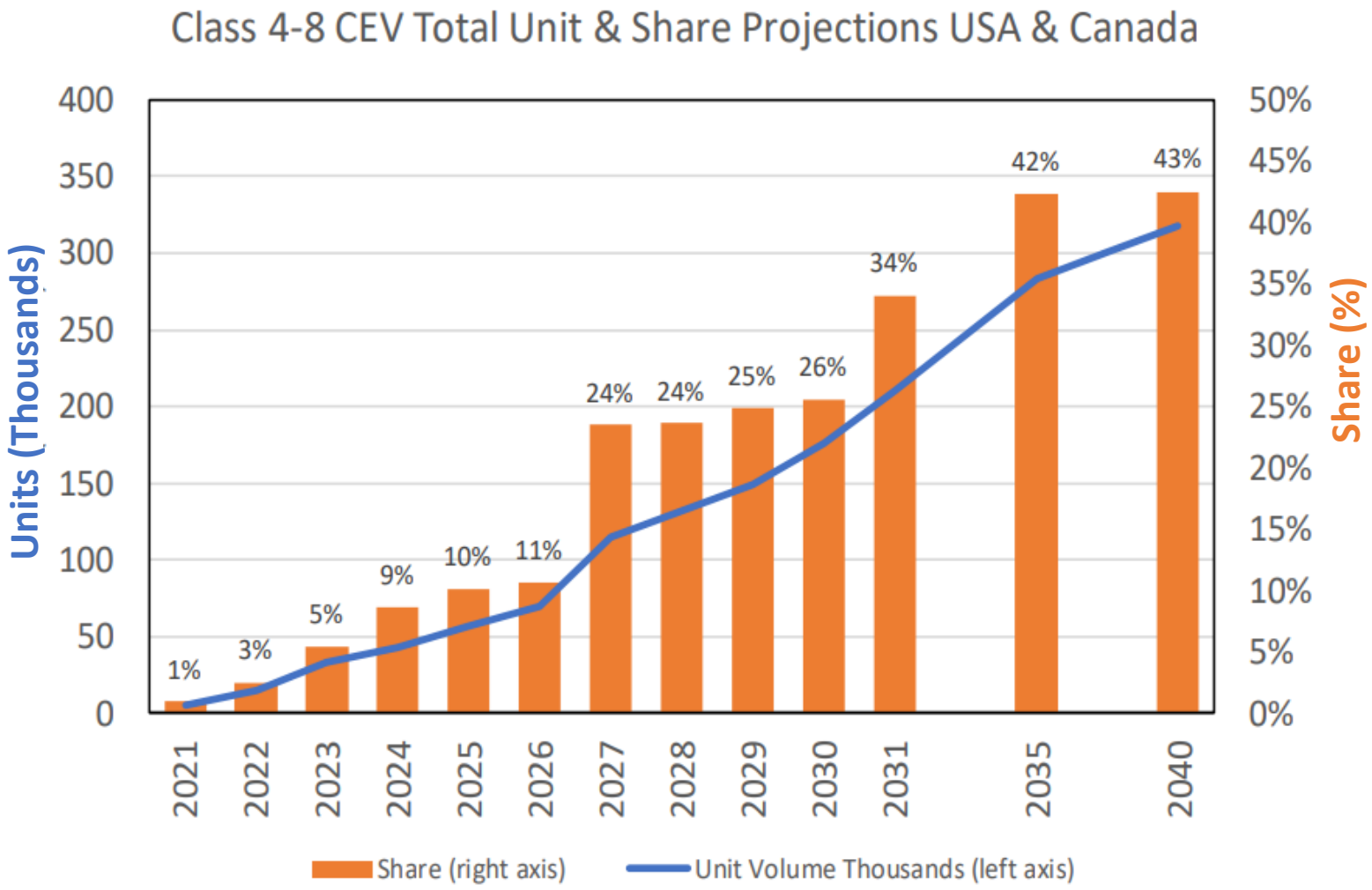
Commercial Electric Vehicle Market



Impacting Factors

- Better Total Cost of Ownership
- Decreasing Battery Costs
- Growing Customer Demand
- Regulatory Pressures

Projections by ACT Research 2021

Dealership Service Tools for EVs

Required Tools Examples:

- Scan tool – enhanced from today's for additional capabilities
- High Voltage/Current Capable DVOM
- DC and 3 Phase AC current clamps
- Shielded/insulated tools
- Insulated Gloves and overgloves
- Experts may need protocol analyzers and oscilloscopes

Technical Support

- Repair and Diagnostic documentation – delivered in user friendly way and compatible with 'Right to Repair' requirements
- Available expert help on demand to evaluate fault codes/symptoms
- This will be initially supplied by OEMs and Service Providers, but portions will eventually trickle down to fleets

Dealership Training for EVs

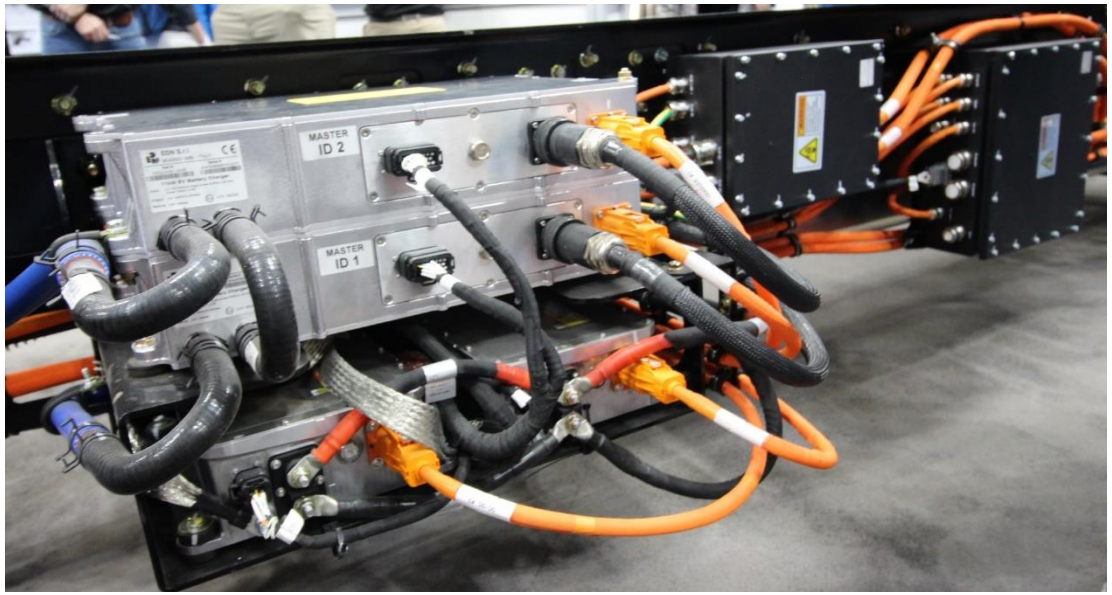
Still in development by numerous OEMs

Expect new training for drivers, technicians, parts personnel and others. These will differ in content and length.

Think days, probably not hours.

Here is a starting point if you want to study ahead of time:

Training for Work on Vehicles with High Voltage Systems



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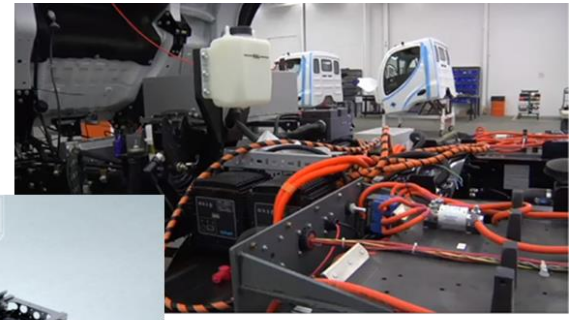
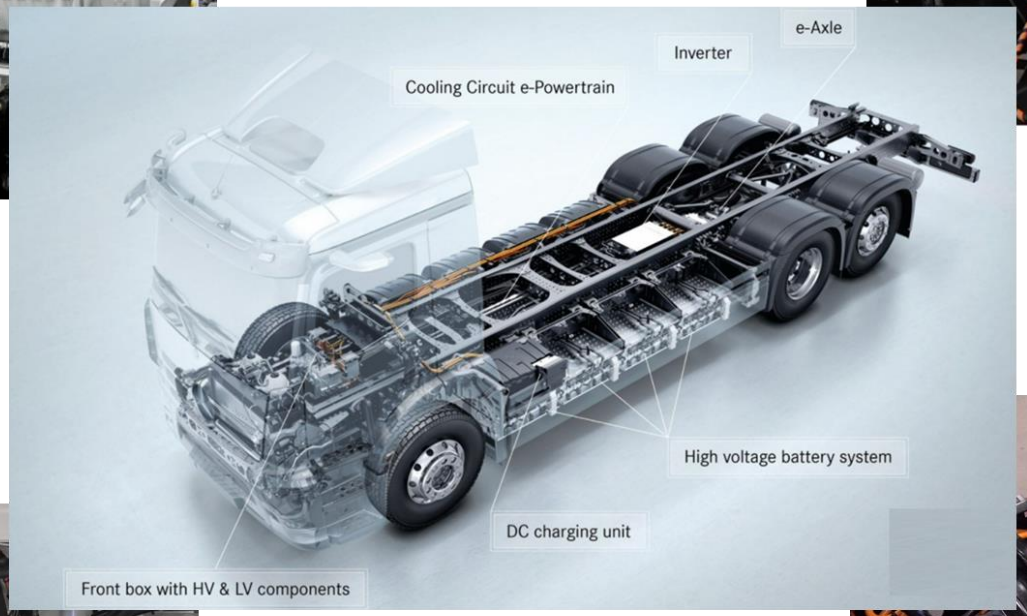
Parts Support for Future Trucks

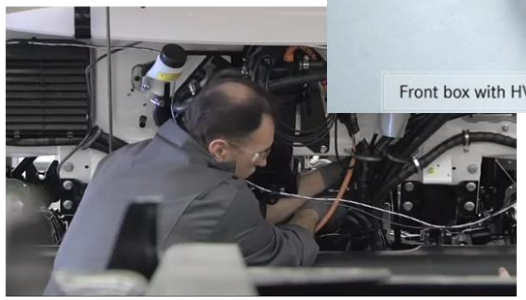
Fewer Parts…BUT

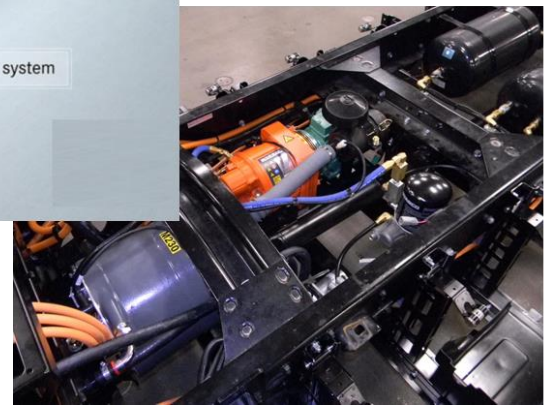
New Families of Electric Parts & Accessories
With Different Failure Modes

- Battery Management
- Motor Operation & Cooling
- Electric Steering
- Electric Pumps for Fluids
- Electric Pumps for Air
- Electric HVAC
- High Voltage Wires & Cables (up to 900V)
- Battery Disconnects
- Discharge Capacitors
- Grounding
- Autonomous / Active Safety Devices & Software





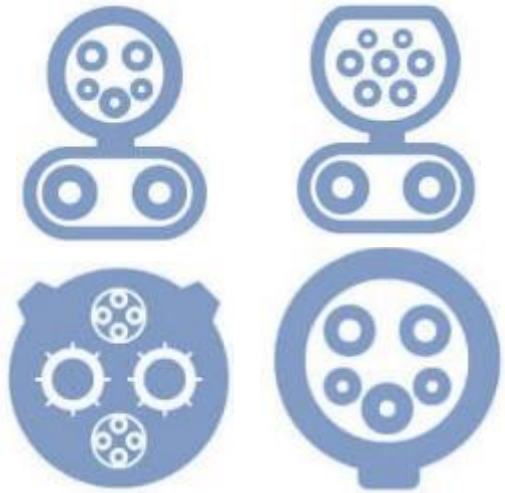




Slide courtesy Travel Centers of America

EVSE: Electric Vehicle Supply Equip.

- Size
- Location
- Connector(s)
- Interoperability (OCPP = Open Charge Point Protocol)
- Support
- Software for charge management
- Utility Interface
- TOU: Time of Use charges



Why Consider Electrification Now?

Financial

- Incentives are/will be available that can cover some of the costs of conversion

Facilities

- Obtain required power levels BEFORE your neighbors
- Obtaining power/infrastructure can take years
- Might be easier to relocate than upgrade
- Physical layout of your lot will change

Change is Coming: Even with diesel

- Regulations & tech changes for NOx & GHG

Pathways to HD Truck Charging

1) Fleet Depot Based

2) Opportunity Charging
Stores, Ports, Warehouses…

3) Shared Card Lock Locations

4) Truck Stops

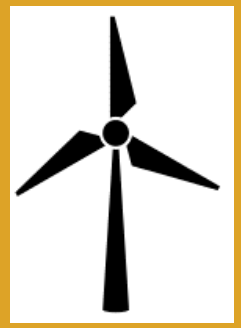
5) Toll Road Rest Areas

6) Interstate Rest Areas

7) **Mobile Roadside Charging** (emergencies & service calls)
8) **In Motion Charging**

Getting to Know Each Other

FLEETS



Primer: UTILITIES on FLEETS

RMI
ENERGY. TRANSFORMED.

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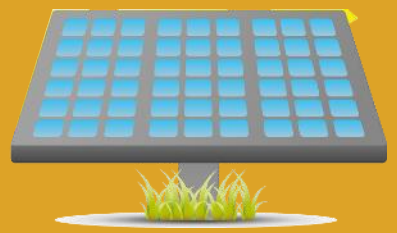
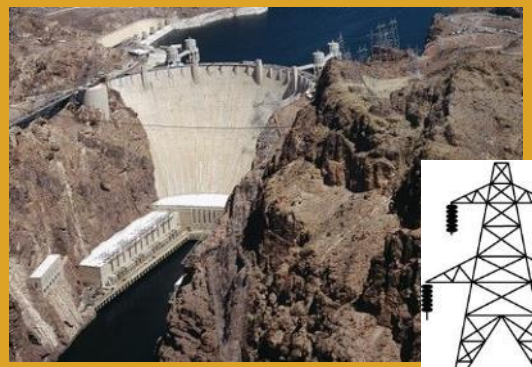
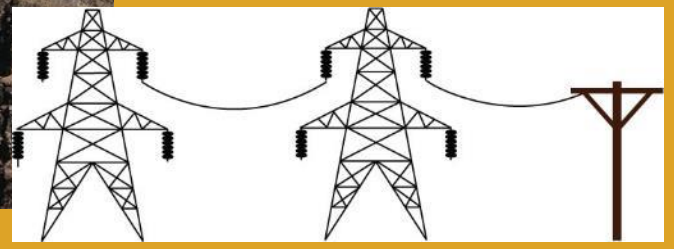
Primer: FLEETS on UTILITIES







UTILITIES

March 2022

Utilities & Truck Electrification

Challenges

- Difficult to forecast MD & HD Electrification (loads & locations)
- Most truck fleets don't currently warrant an account manager
- Utilities know about bucket trucks and pickup trucks, but may well be unfamiliar with other applications

Opportunities

- Work with truck dealers (who themselves may need charging systems)
- Investigate the large industrial parks & distribution centers in your area
- Research ports including water, air and rail as potentials
- Join your state trucking association

Electric Trucks







Collaboration

- Fleets
- OEMs (Existing ***& New***)
- Suppliers
- Dealerships (Sales/Service)
- Governments
- ***Charging System Suppliers***
- ***Utility Companies***



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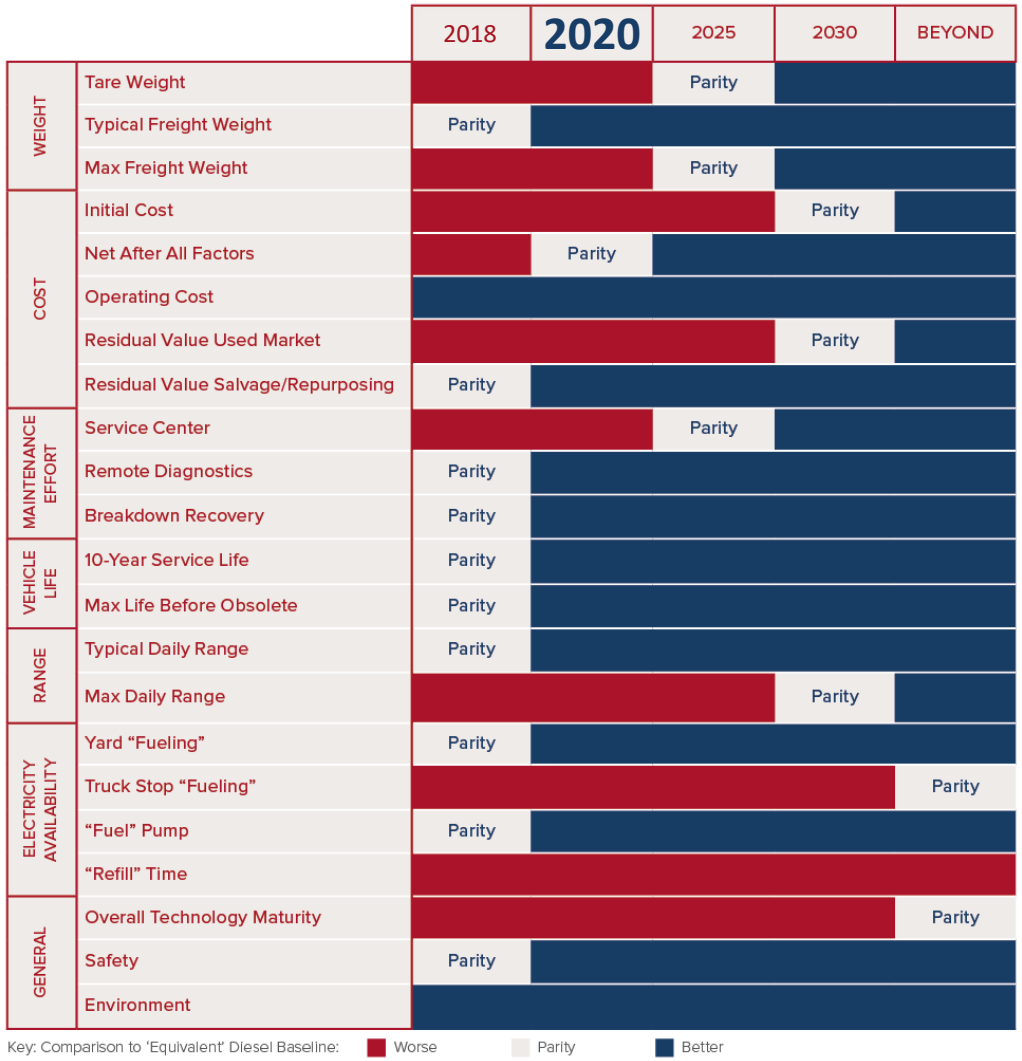
Hydrogen & Battery Electric Trucks

Both Competitors *AND* Teammates

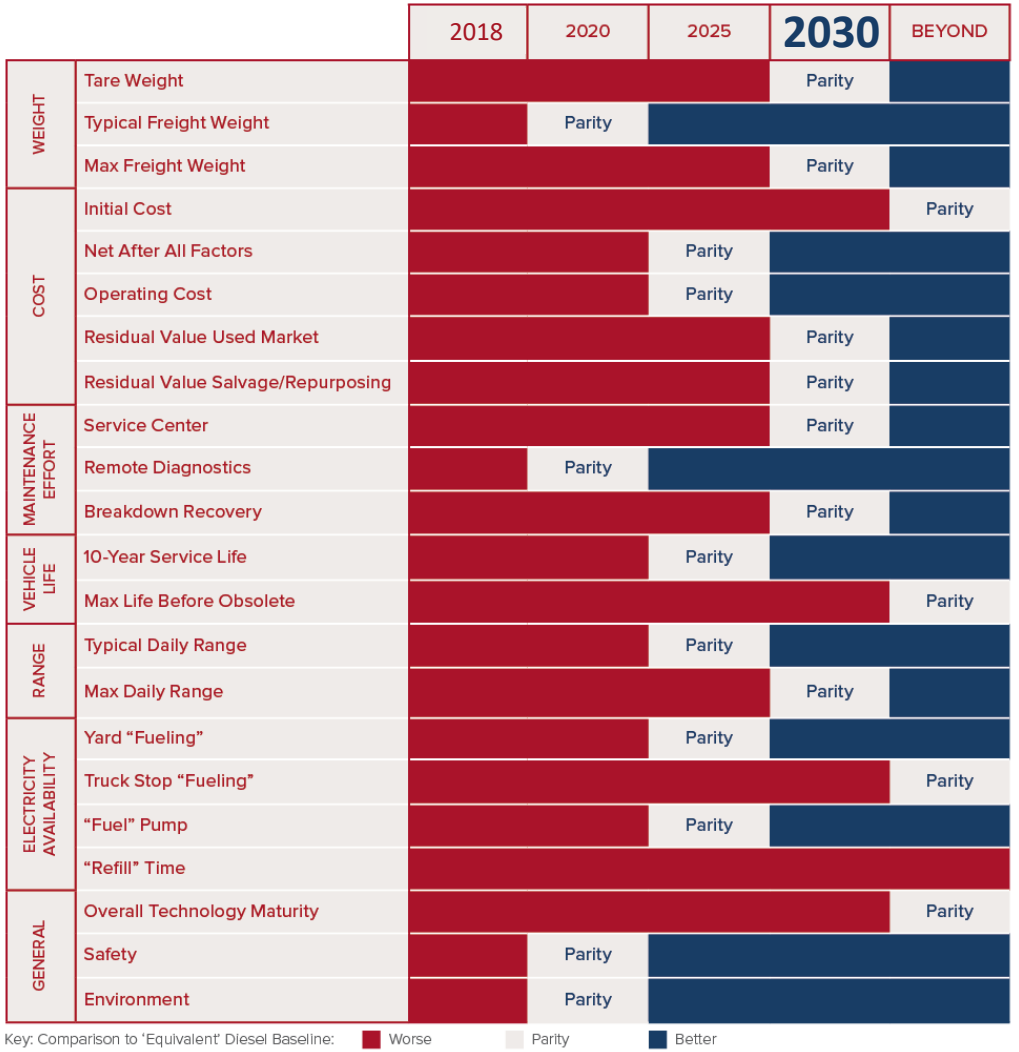
Hydrogen Fuel Cell Trucks	Truck Subsystem	Battery Electric Trucks
Yes (but less)	Rechargeable Batteries	Yes
Yes	Electric Drive Motors	Yes
Yes	High Power Cables	Yes
Yes	Software Management	Yes
Yes	Regenerative Braking	Yes
Yes	**Hydrogen Fuel Cell**	--
Yes	**Hydrogen Fuel Tank**	--
Hydrogen Station	Refueling	Electric Charging Station
Large	Electricity Consumption	Large

Findings: Parity To Diesel

CLASS 3 THROUGH 6 CBEV PARITY VS. DIESEL SYSTEM (NACFE)



CLASS 7 AND 8 CBEV PARITY VS. DIESEL SYSTEM (NACFE)



Class 3 - 6

Dark Blue = EV is Better

Class 7 & 8

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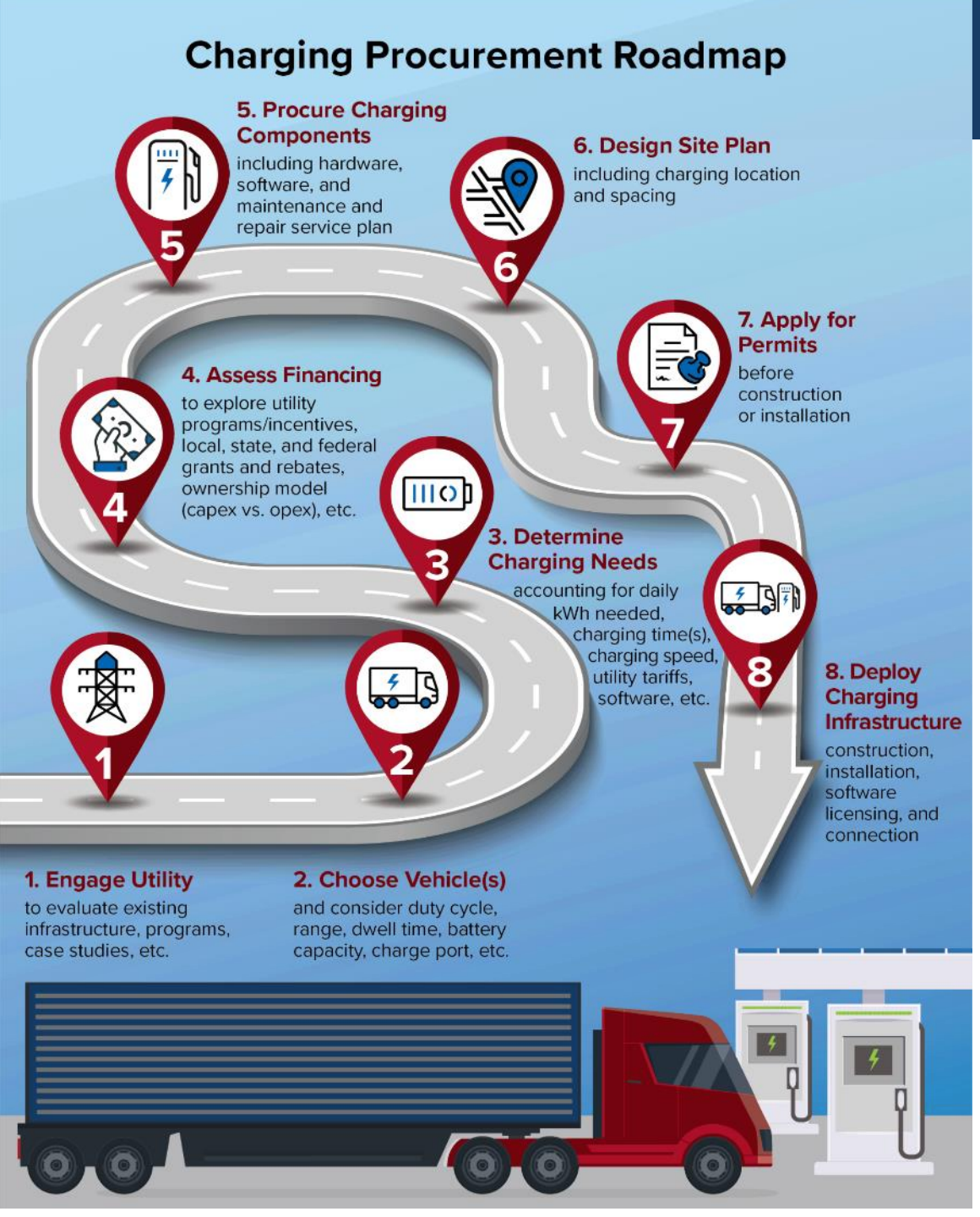
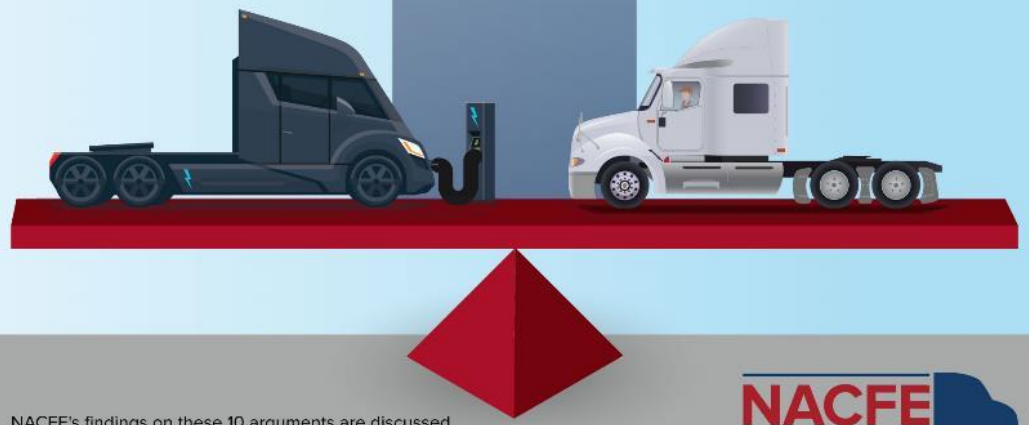
Infrastructure



- Complex
- Large amount of power fast
- Involve all stakeholders early
- Time to complete with truck availability
- Be flexible

10 ARGUMENTS
FOR AND AGAINST ELECTRIC TRUCKS

Argument FOR Electric Trucks	VS.	Argument AGAINST Electric Trucks
1 Commercial battery electric vehicle (CBEV) weight is not an issue	WEIGHT	1 Vehicle tare weight is too high to support my freight needs
2 CBEV technology is proven and here now	TECHNOLOGY	2 Technology is not ready
3 Maintenance will be less costly		3 Maintenance may not be less costly
4 CBEVs will last beyond 10 years		4 Vehicle life is too short
5 CBEVs will be competitively priced	COST	5 Vehicle purchase price is too high for a positive ROI
6 CBEVs will be less expensive to operate		6 Vehicle operating costs are too great for positive ROI
7 CBEVs will command a premium at resale		7 Vehicle residual value is questionable
8 Trust the market to provide CBEV charging solutions	CHARGING	8 Charging infrastructure is not ready
9 Trust the market to provide CBEV charging solutions		9 Charging Infrastructure is not fast enough
10 The grid and market will evolve with CBEVs		10 The electric grid cannot support growth in electric vehicles



NACFE's findings on these 10 arguments are discussed in detail in its Electric Truck Guidance Report

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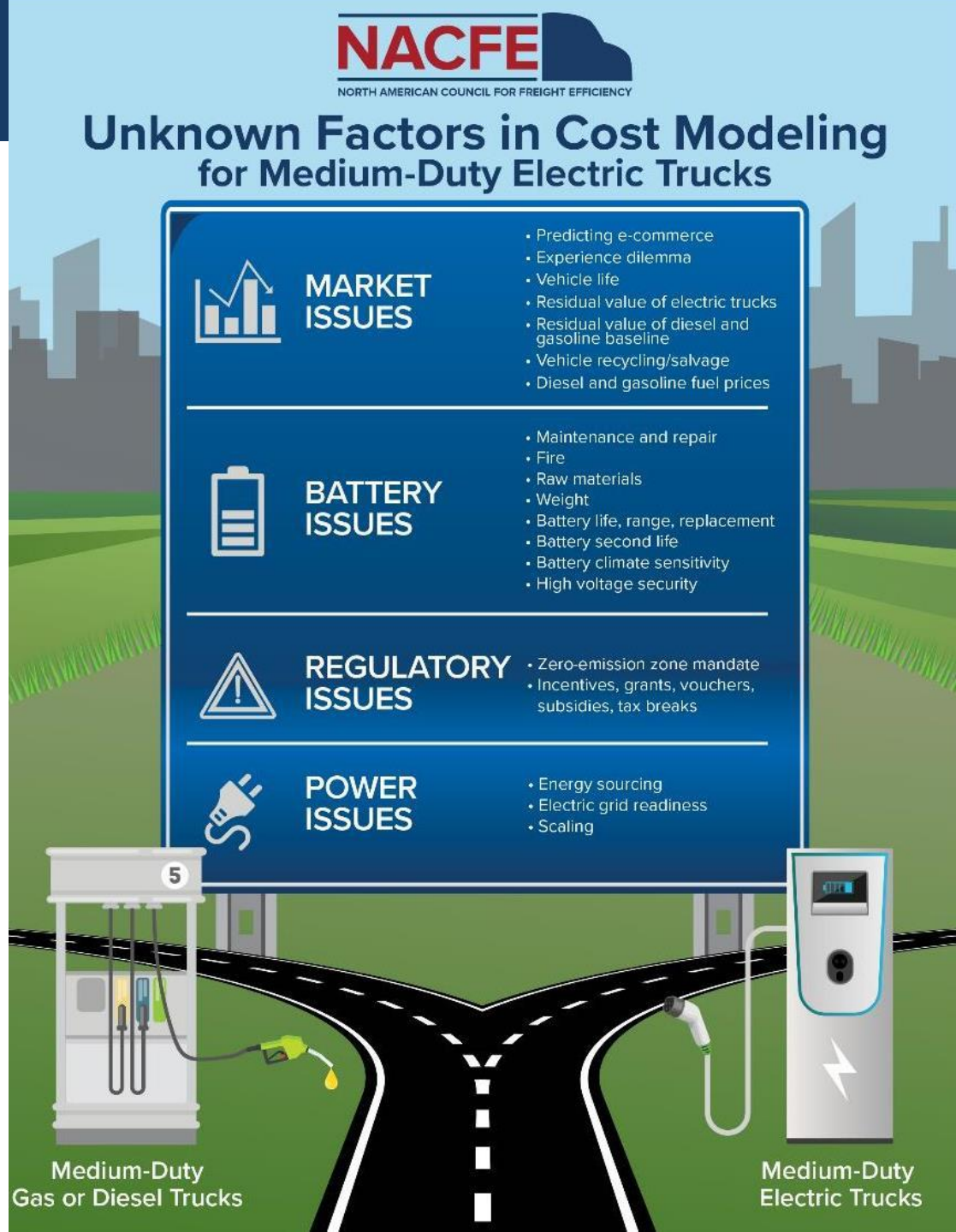
Where they make sense?

- Arguments for and against
  - Reality in the middle
- Weight
- Maintenance
- Cost
- Market for infrastructure

Medium Duty Trucks

- Close to base
- Limited range
- Consistent, dedicated routes
- Total cost calculator
- “Unknown…difficult to monetize benefits”
  - Noise
  - Design flexibility
  - And on



Confidence Reports

Diesel Fuel Savings & Alternative Fuel Range Extenders








1. Tire Pressure Systems
2. Tires: LLR & Wide Based
3. Idle Reduction
4. Automated Transmissions
5. Engine Parameters
6. Lightweighting
7. Downspeeding
8. Maintenance
9. Trailer Aerodynamics
10. Tractor Aerodynamics
11. Lubricants
12. Platooning
13. Solar
14. 6x2 Axles
15. Engine Accessories







Complete, unbiased review of available technologies

Sustainability in Trucking

CSR = Corporate Social Responsibility

- Directional
- Communicates (internally & externally) the company's plans to be more sustainable
- Aims to make a business accountable

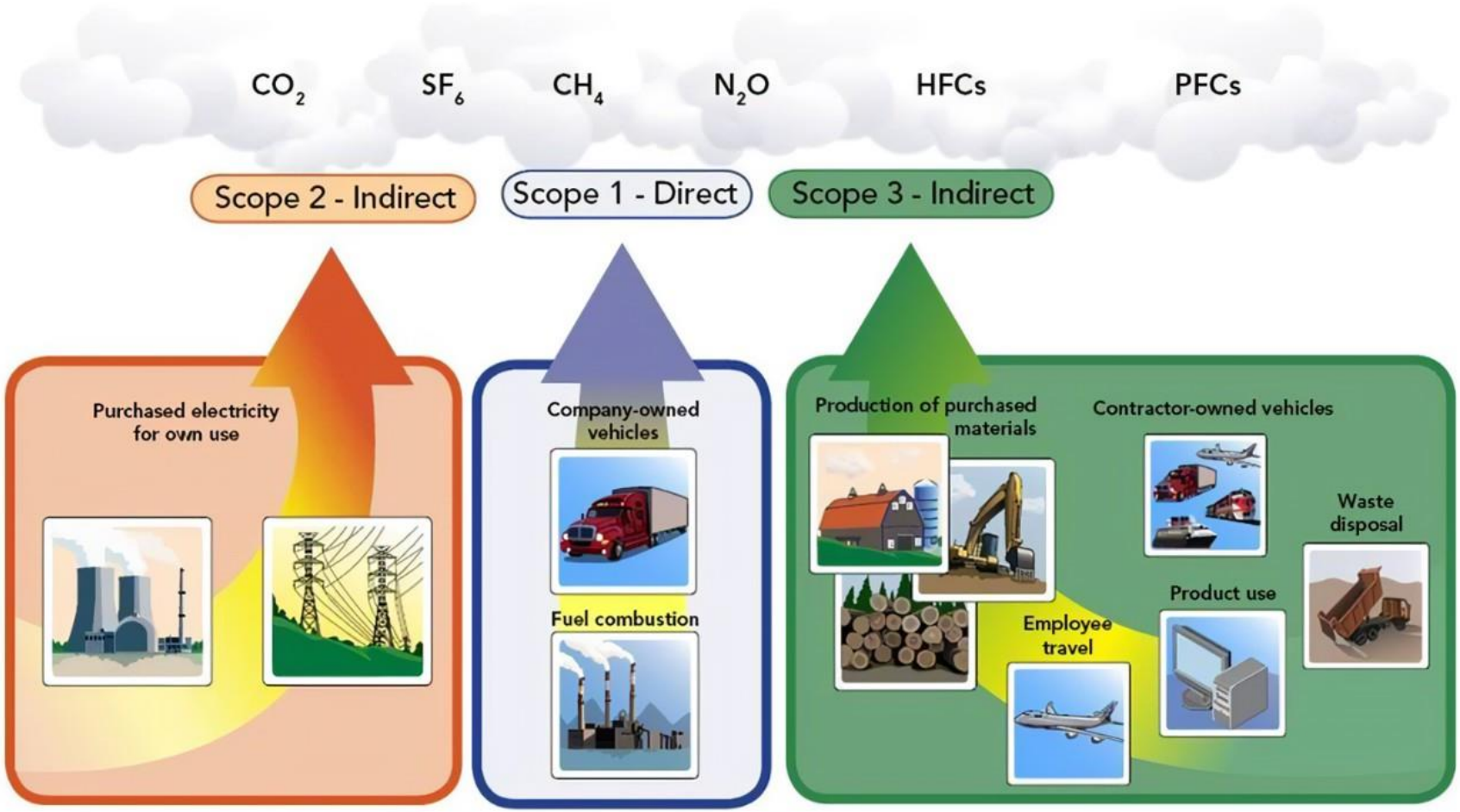
ESG = Environmental, Social & Governance

- Qualitative
- Criteria make a business' efforts measurable
- Examples:
  - a 20% increase in fuel economy over the next 5 years
  - 30% of truck fleet in 2030 will be battery electric

Examples From Industry Leading Fleets:

- Schneider: Schneider outlines next steps on ESG | Schneider
- FedEx: Environmental Reports | FedEx and FedEx fleet electrification
- Covenant: Covenant's Corporate Social Responsibility Report (covenantlogistics.com)
- US Xpress: Corporate Responsibility - USX Corporate (usxpress.com)

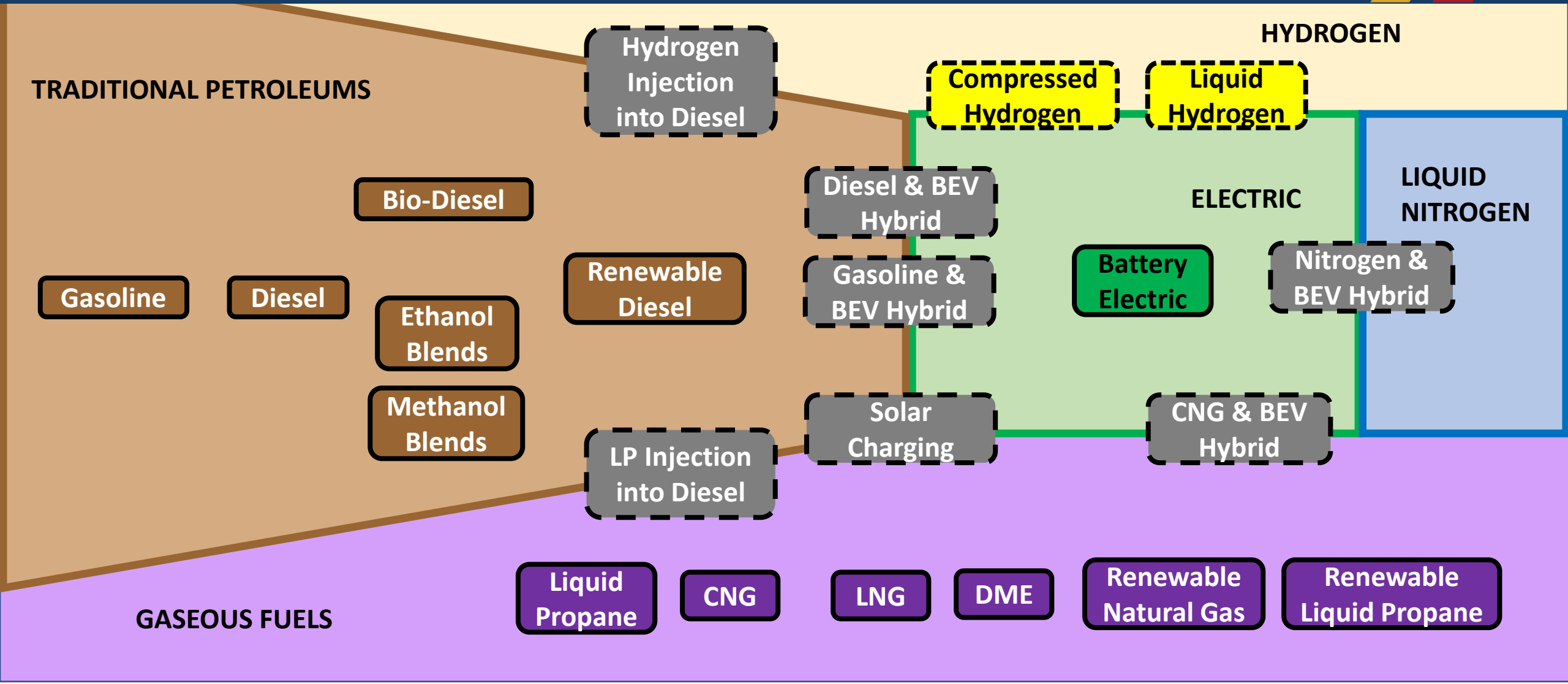
Corporate Emissions Concerns



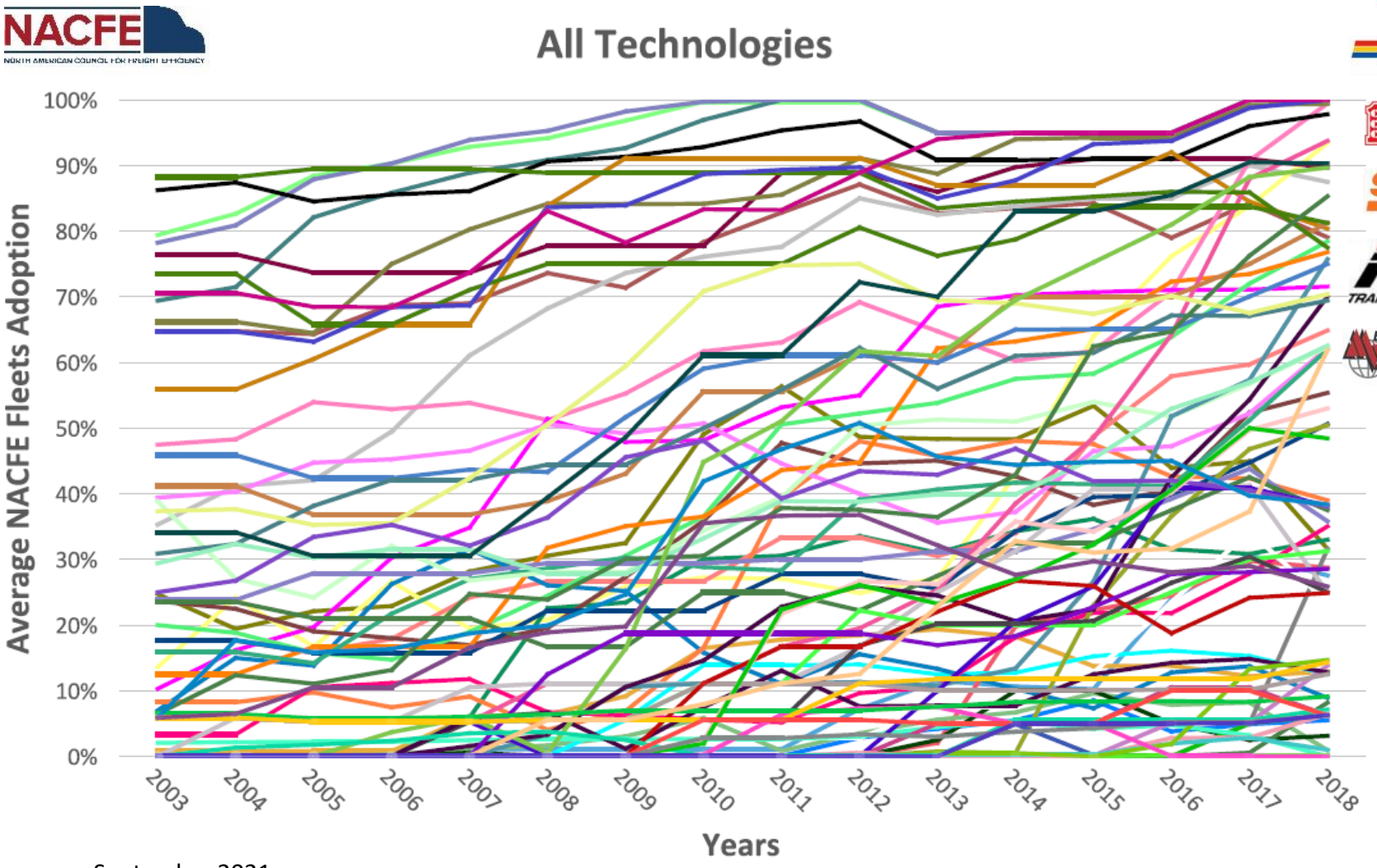
Transportation

- Scope 1 with company owned vehicles
- Scope 3 with all vehicles in product distribution channel

Alternative Fuels



2019 Annual Fleet Fuel Study



https://nacfe.org/annual-fleet-fuel-studies/

September 2021

Vans & Step Vans Segment

VANS & STEP VANS

Jennifer Wheeler, Senior Program Manager, NACFE

NACFE
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Market Segment & Fleet Profile Fact Sheet

Operational Characteristics

Duty Cycle	Return to Base
Use Case	Urban delivery / Last mile
Average Range	50 miles
Routes	Fixed
Fueling	Overnight
Miles per Gallon	7.4
Replacement Cycle	10 years
Average Age	8.4 years
Axle Configuration	4x2

Battery Size Range: 43 to 127 kWh

File Link

Lessons Learned: Vans/Step Vans

ELECTRIC
VANS & STEP VANS

RUN ON LESS ELECTRIC

Fleets are aggressively expanding their purchases of electric vans and step vans after successful pilot programs.

In addition to charging at a depot, vans and step vans also can be charged at home or at public charging locations.

Range is typically not a major factor in urban delivery vans and step vans.

Drivers love these simple and fun to drive vans and step vans.

Vans and step vans are the public face for zero emission trucking and electrifying the last mile is a key area of focus for many fleets.

Typically vans and step vans use Level 2 chargers, which is considered a slow charge.

E-commerce is spurring the rapid growth in the vans and step vans market segment.

Electric vans and step vans are being operated in areas with cold winters and hot summers.

Vans and step vans are a big and somewhat easy market to scale.

Traditional and new OEMs are bringing innovative new vans and step vans to the market. Marketplace barriers are lower for new OEMs.

Terminal Tractors: Lessons Learned

ELECTRIC TERMINAL TRACTORS

For more detailed information on these lessons learned, click here.

The terminal tractor market segment is the best way to learn about BEVs.

Simple designs and avoiding emissions requirements is sparking development of electric terminal tractors.

Electric terminal tractors are a good fit for firms already using electrified materials handling equipment.

Track and verify the costs of battery electric terminal tractors to manage TCO.

Battery electric terminal tractors can be used inside warehouses not just outside in yards.

Electric terminal tractors provide more uptime and simplify operations.

Battery electric terminal tractors can be a very visible sustainability first step.

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Explicitly know your duty cycles, range requirements, dwell time, etc.	Charger efficiency is important in estimating total energy demand.	Measuring maintenance and downtime requires a long-term project to capture seasonal effects as well as sufficient mileage.	Have a system perspective on electrifying a facility.	Weather conditions at the vehicle at all times requires higher resolution sensors and equipment not installed on today's vehicles.	Use managed charging to minimize electricity demand and cost.
Validate what is actual measured and where in the vehicle it is measured.	Standards for reporting EV specifications need to be established to provide uniformity in reporting metrics.	Given the ease of operation, drivers of CBEVs want the technology to succeed.	Opportunity charging can help extend the range of vehicles during a work shift.	Consumption and efficiency can be confusing metrics.	Fleets may not always have a receptive contact at utilities with respect to electrifying their fleets.

RUN ON LESS ELECTRIC

LESSONS LEARNED

What NACFE learned while conducting Run on Less – Electric

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Early adopters of CBEVs may choose duty cycles that reduce risks from range anxiety, keeping battery use above 50% SOC each shift.	Determine what sampling rate you can afford and if it is sufficiently accurate.	Vehicle telemetry data does not describe why a vehicle performed a maneuver.	Terminology like idling used for diesels may not directly apply to CBEVs.	The trucking industry could benefit from standardizing CBEV data buses and interfaces.	CBEVs must be specified for four-season operations and road grades and account for extremes in sizing battery packs.
State of Charge readings should be standardized across the industry.	Regenerative braking can reduce demands for grid energy or conversely help in range extension.	There are many opportunities in the fleet-utility relationship to negotiate net electricity pricing models.	Choose battery capacity and charging based on those duty cycles with some safety factor to account for battery aging.	A vehicle designed for a maximum power of 150 kW cannot charge at 350 kW without risking damage.	**For more detailed information on these lessons learned, click here.**

RoL – Electric: Lessons Learned

Explicitly know your duty cycles, range requirements, dwell time, etc.	Charger efficiency is important in estimating total energy demand.	Measuring maintenance and downtime requires a long-term project to capture seasonal effects as well as sufficient mileage.	Have a system perspective on electrifying a facility.	Weather conditions at the vehicle at all times requires higher resolution sensors and equipment not installed on today's vehicles.	Use managed charging to minimize electricity demand and cost.
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State of Charge readings should be standardized across the industry.	Regenerative braking can reduce demands for grid energy or conversely help in range extension.	There are many opportunities in the fleet-utility relationship to negotiate net electricity pricing models.	Choose battery capacity and charging based on those duty cycles with some safety factor to account for battery aging.	A vehicle designed for a maximum power of 150 kW cannot charge at 350 kW without risking damage.	RUN ON LESS ELECTRIC

[Link]

Terminal Tractors: Sustainability

Idle an internal combustion engine all day

OR

Instant on air conditioning and heat with an electric terminal tractor

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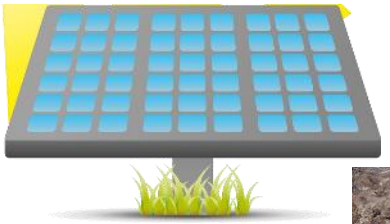
Getting to Know Each Other

Primer: UTILITIES on FLEETS



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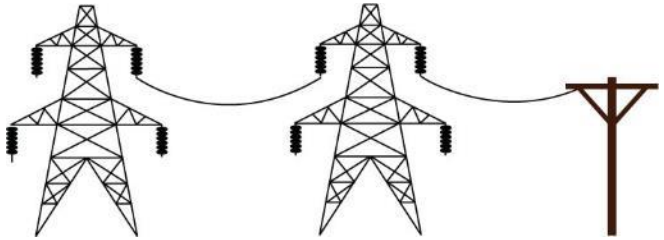
FLEETS

UTILITIES



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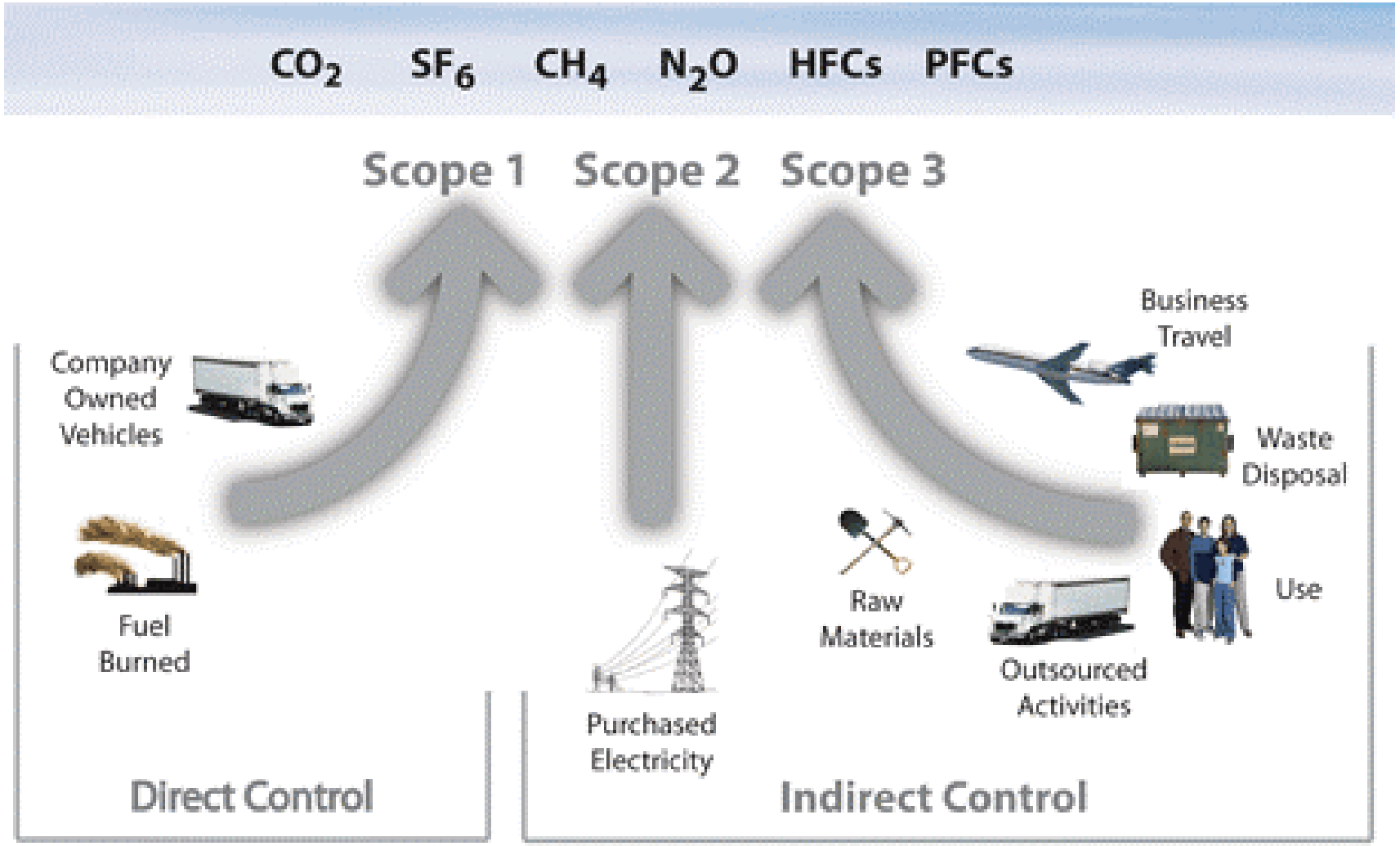
Primer: FLEETS on UTILITIES

Corporate Emissions Concerns



Transportation

- Scope 1 with company owned vehicles
- Scope 3 with all vehicles in product distribution channel

Guidance on Hydrogen

Hydrogen Color Spectrum

GREEN
Hydrogen produced by electrolysis of water, using electricity from renewable sources like hydropower, wind, and solar. Zero carbon emissions are produced.

TURQUOISE
Hydrogen produced by the thermal splitting of methane (methane pyrolysis). Instead of CO_2, solid carbon is produced.

PINK/PURPLE/RED
Hydrogen produced by electrolysis using nuclear power.

BLACK/GRAY
Hydrogen extracted from natural gas using steam-methane reforming.

YELLOW
Hydrogen produced by electrolysis using grid electricity.

BLUE
Grey or brown hydrogen with its CO_2 sequestered or repurposed.

WHITE
Hydrogen produced as a byproduct of industrial processes.

BROWN
Hydrogen extracted from fossil fuels, usually coal, using gasification.

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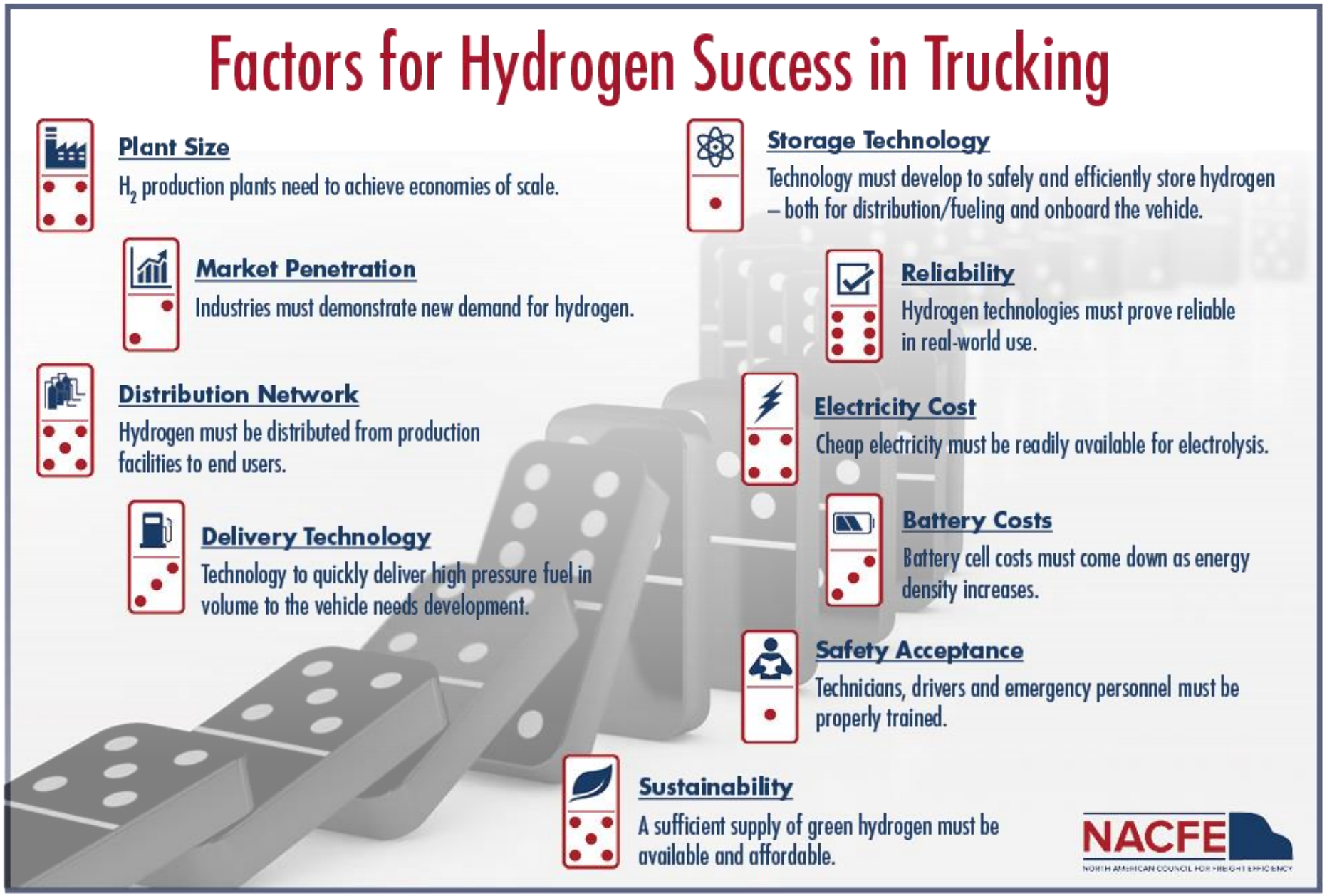
Note: There are no official definitions of these colors, but the above represents common industry nomenclature.

Guidance on Hydrogen



Hydrogen Fuel Cell Trucks

Current Status

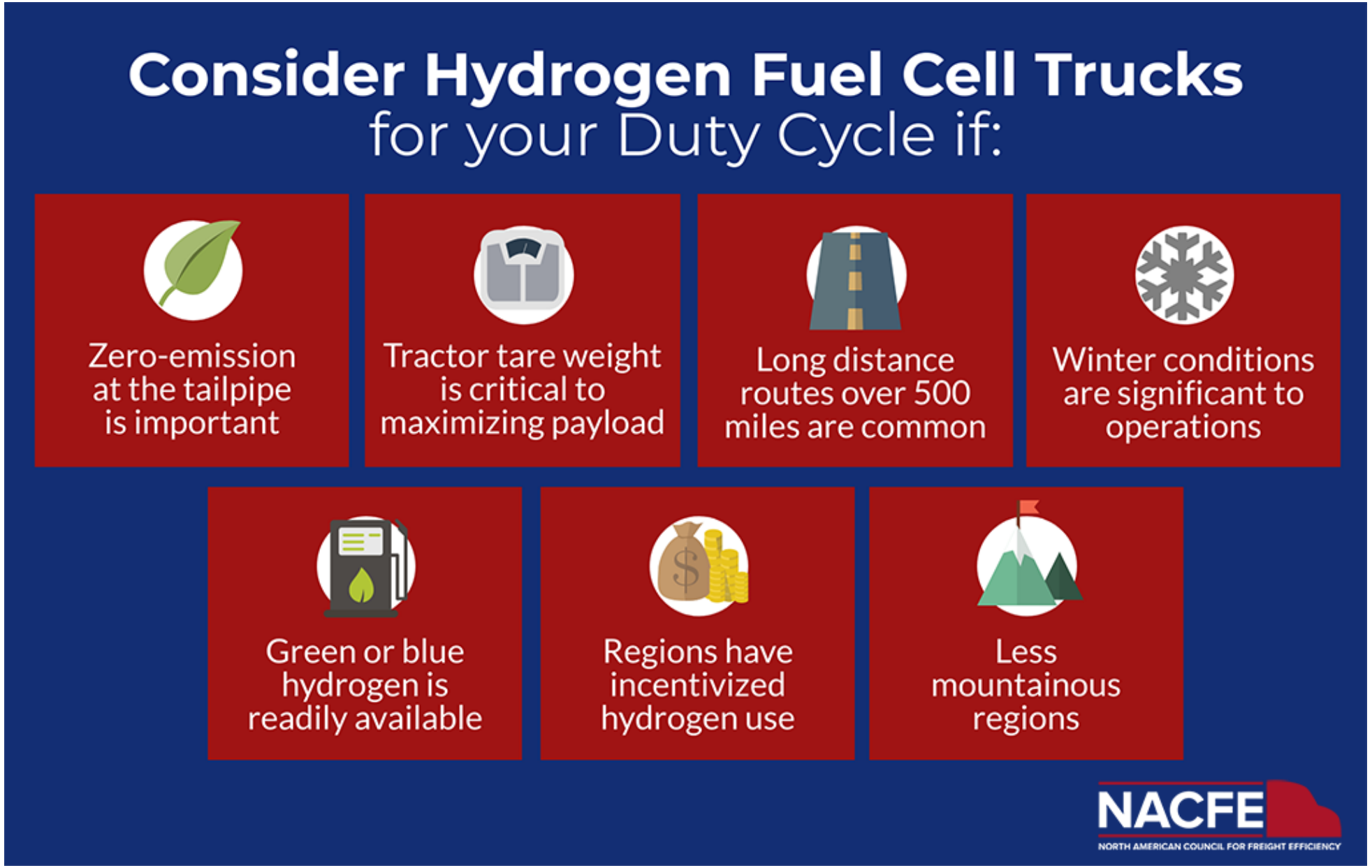
- Several trucks under fleet test
- Others under OEM development
- Both Compressed & Liquid Hydrogen trucks planned

Guidance on Hydrogen

https://nacfe.org/emerging-technology/electric-trucks-2/making-sense-of-heavy-duty-hydrogen-fuel-cell-tractors/

Published December 2020

Guidance on Hydrogen



Hydrogen Fuel Cell Conclusions

- Hydrogen fuel cell trucks are just starting to see real-world use and their adoption is being driven by regional or national considerations that are much bigger than what exists for trucking fleets.
- Battery electric trucks should be the baseline for hydrogen fuel cell electric vehicle (HFCEV) comparisons, rather than any internal combustion engine alternative.
- As for all alternatives, fleets should optimize the specifications of HFCEVs for the job they should perform while expecting that the trade cycles will lengthen.
- The future acceleration of HFCEVs is likely not about the vehicles or the fueling but more about the creation and distribution of the hydrogen itself.
- Finally, the potential for autonomous fuel cell trucks to operate 24 hours a day adds significant opportunity for making sense of capital and operational investment in hydrogen.

Preliminary Findings

- Early adopters of electric vehicles (EVs) are validating an acceptable total cost of ownership in urban medium-duty vans and trucks, terminal tractors and short regional haul applications.
- EV adoption is occurring throughout North America, but for longer haul heavy-duty semi-trucks use has been somewhat limited to California.
- There are benefits to EVs (quiet operation and reliability) as well as challenges (infrastructure and range).
- EV truck ecosystem inertia is in its early stages with many solutions emerging that will support adoption in the next several years.
- The industry needs to develop standards in the areas of charging, repair, maintenance and training.

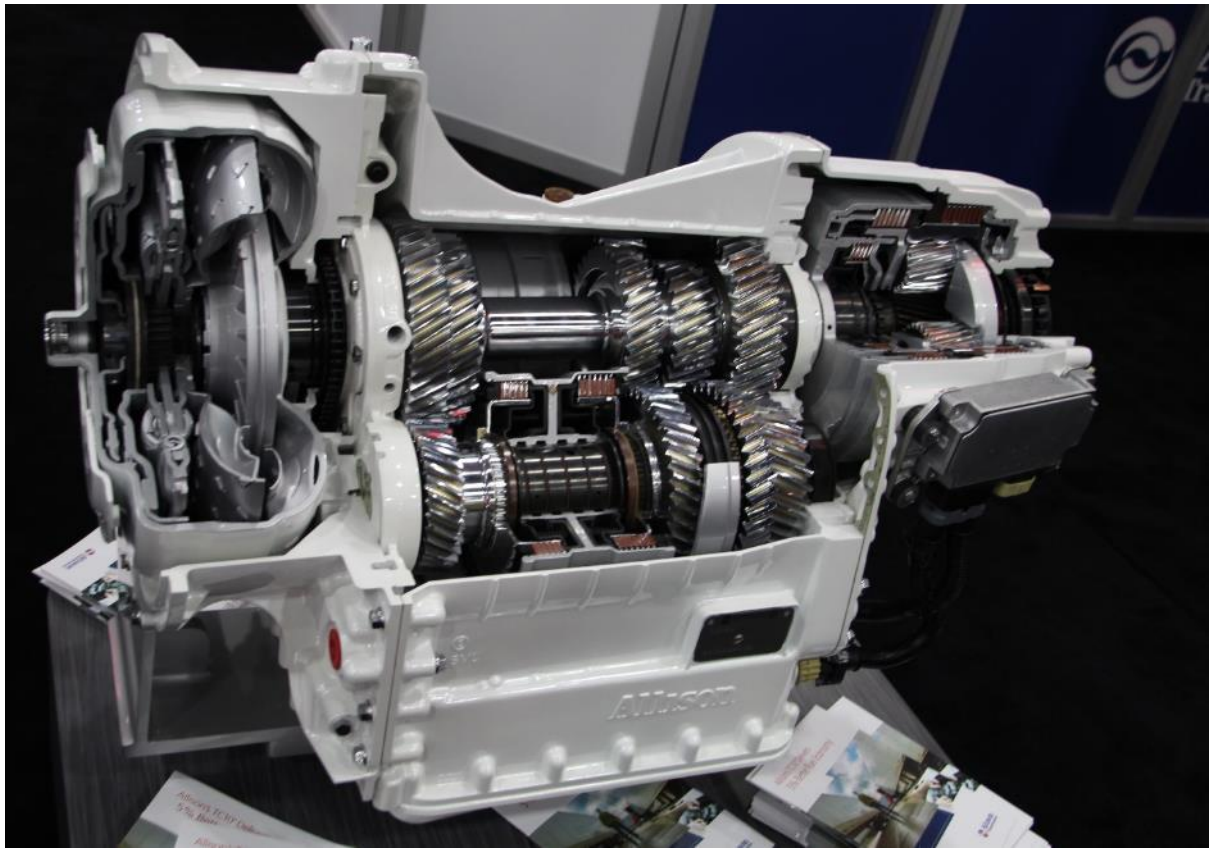
Preliminary Findings

- There is a huge demand for real-world information on EVs in commercial applications and on charging infrastructure.
- The mix of startups and traditional truck OEMs and component manufacturers is expediting the development of creative and practical solutions.
- More thought is needed on the best way to gather and manage the necessary data for fleets and manufacturers to measure and monitor their EVs.
- Early adopters of EVs are having an influence on improving trucks and infrastructure.
- EVs present operational challenges, for example longer charging times than fueling, which these fleets are working to mitigate.

Do We Speak The Same Language?

Mental Images May Differ Dramatically

- Transmission
- Gears
- Loads
- Generation
- Driver
- Solar Panel



Vans and Step Vans

MD Box Trucks

November 2021

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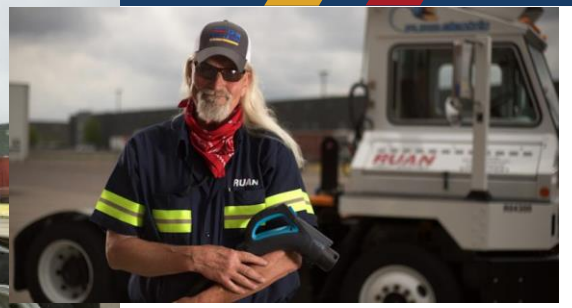
Terminal Tractors



Regional Haul (Mostly)

Short Regional Haul

Some CBEVs: “Range Extended”

Several OEMs and suppliers are working on hydrogen fuel cell powered electric trucks

Hyliion “Hypertruck” is being called ERX: Electric Range Extender and runs on CNG or RNG

CNG Infrastructure

From DOE Alt Fuels Data Center

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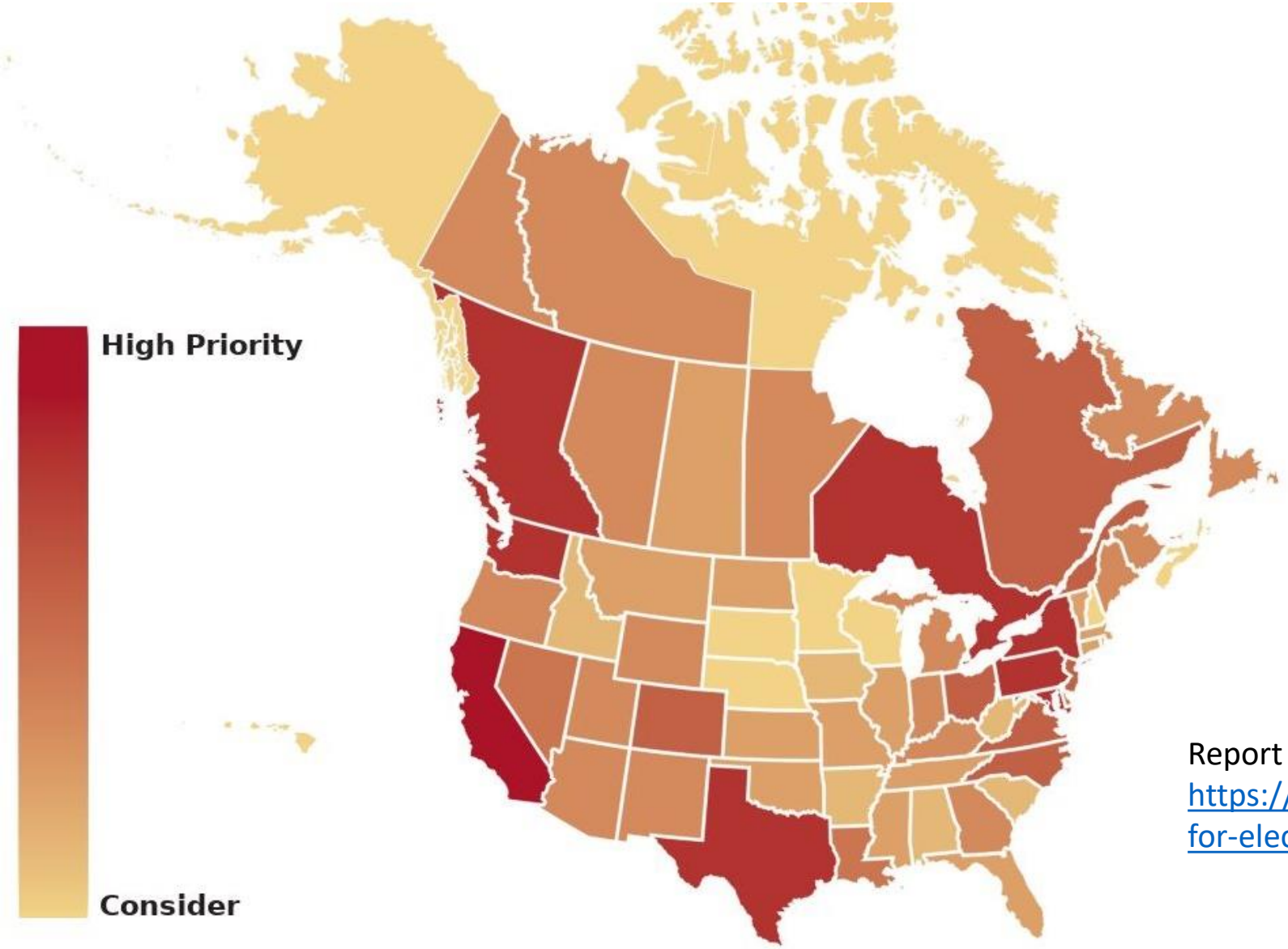
High Potential Regions Report



June 2021

Megaregions with particularly high potential

- Northern California
- Southern California
- Texas Triangle
- Cascadia (WA,OR & BC)
- Front Range (CO & NM)
- Northeast
- Toronto & Montreal

Report Link:
https://nacfe.org/downloads/high-potential-regions-for-electric-truck-deployments-technical-appendix/

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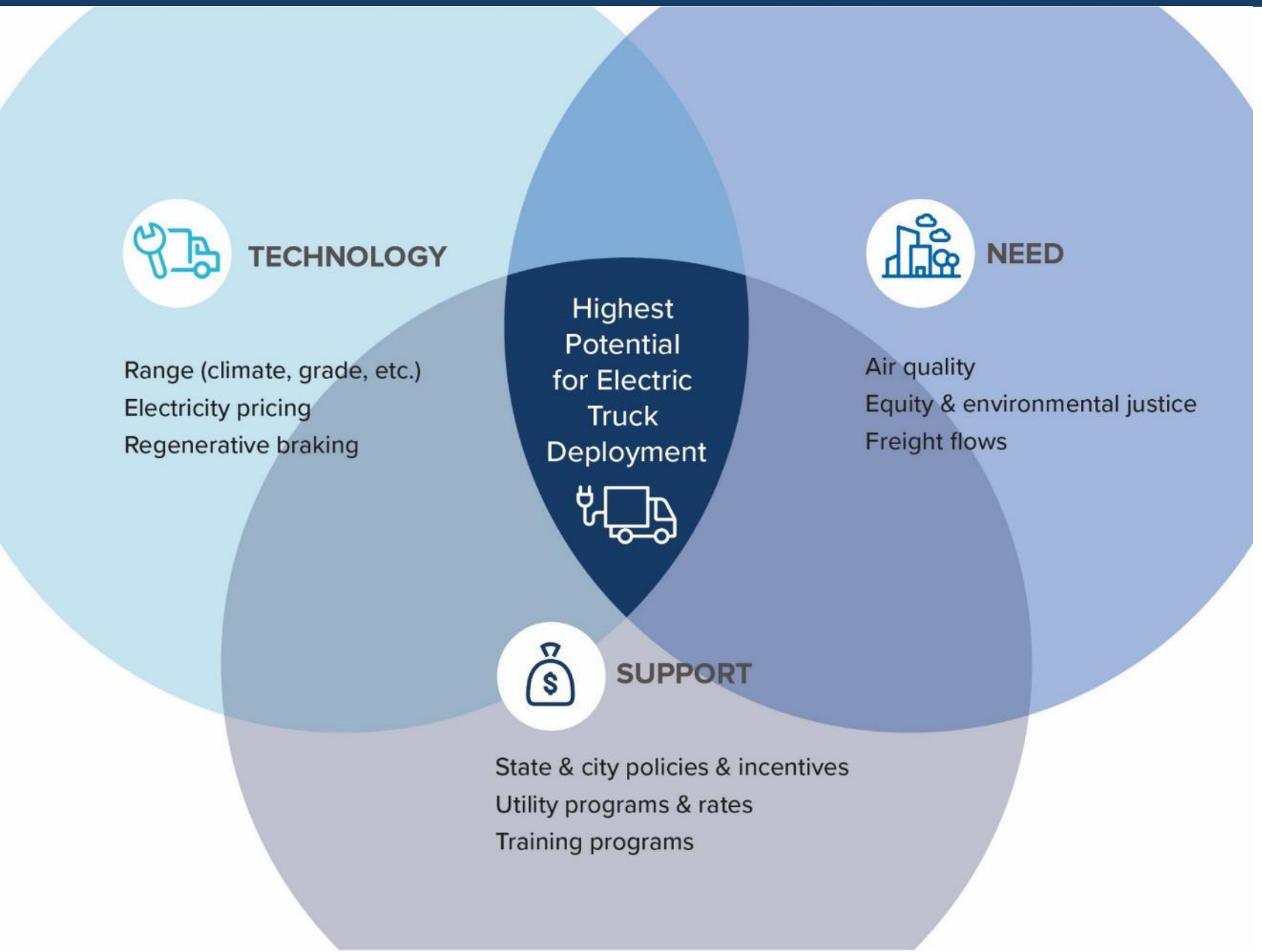
High Potential Regions Report



To develop strategies to advance zero-emission trucks collaboration is needed from:

- fleets
- policymakers
- regulators
- utilities
- suppliers
- other stakeholders in their region

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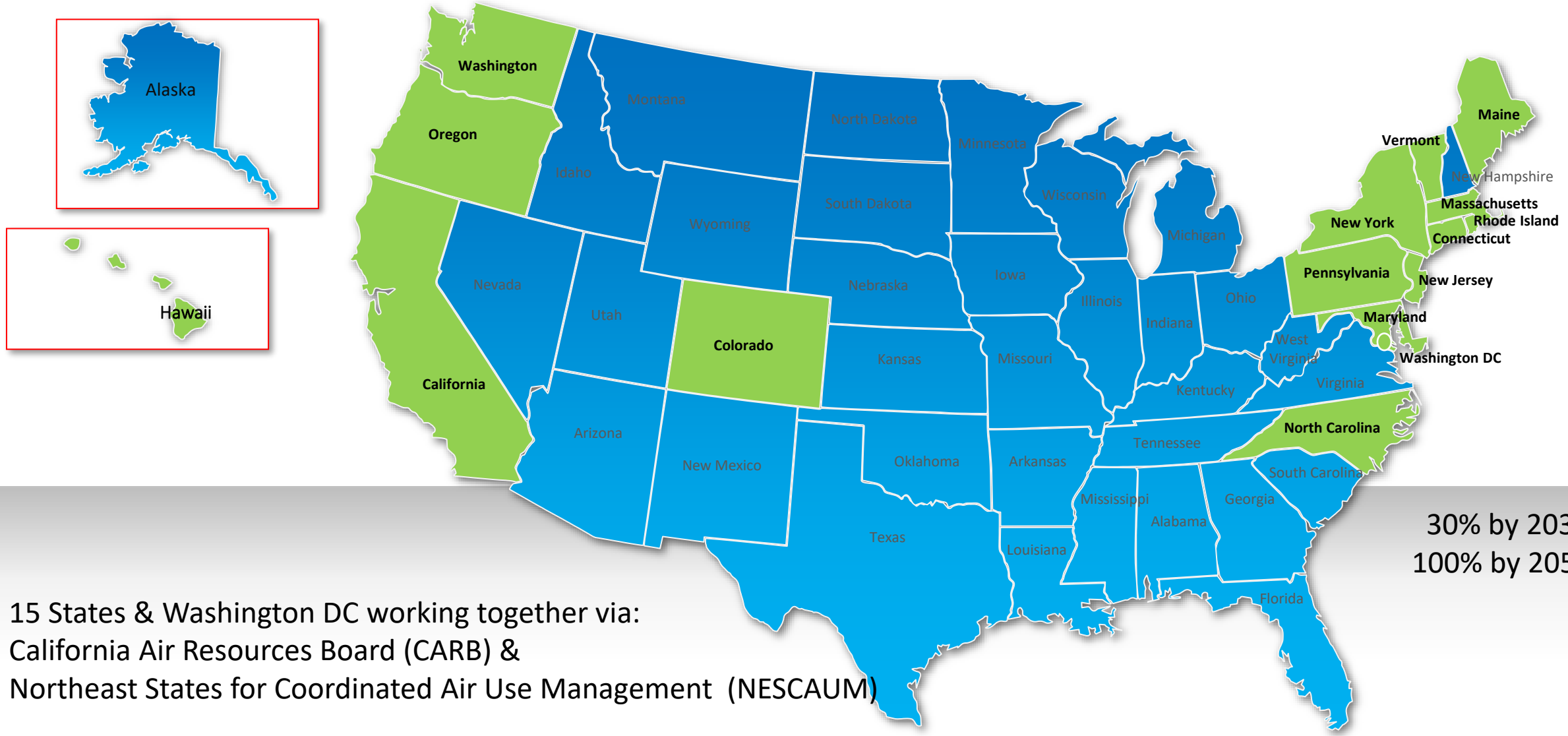
Transition to Zero-Emission Trucks



30% by 2030
100% by 2050

15 States & Washington DC working together via:
California Air Resources Board (CARB) &
Northeast States for Coordinated Air Use Management (NESCAUM)

Memorandum Of Understanding signed July 14th, 2020

June 2021

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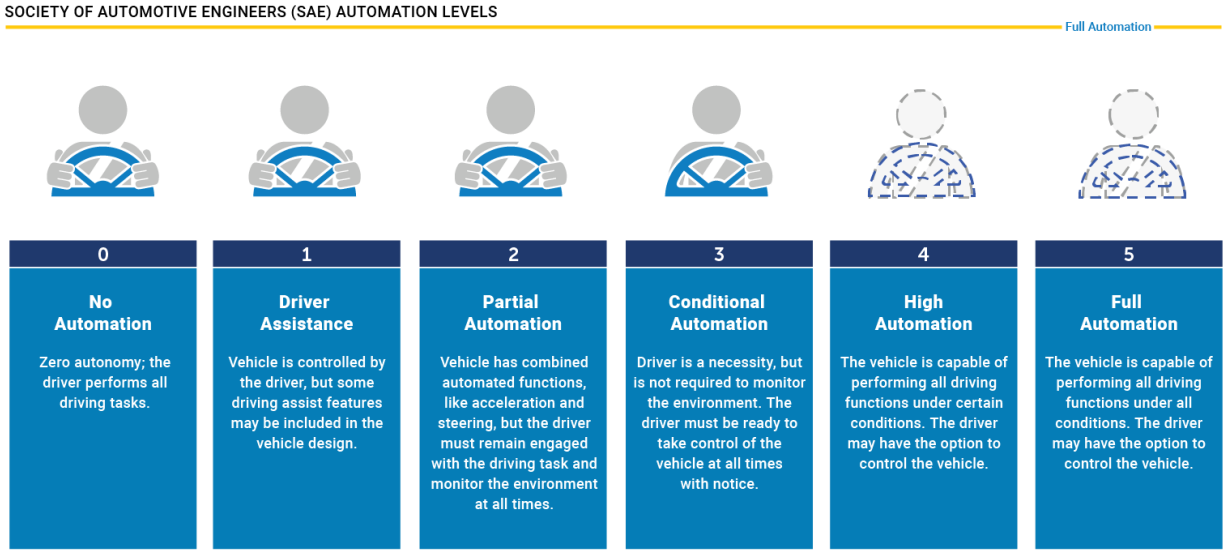
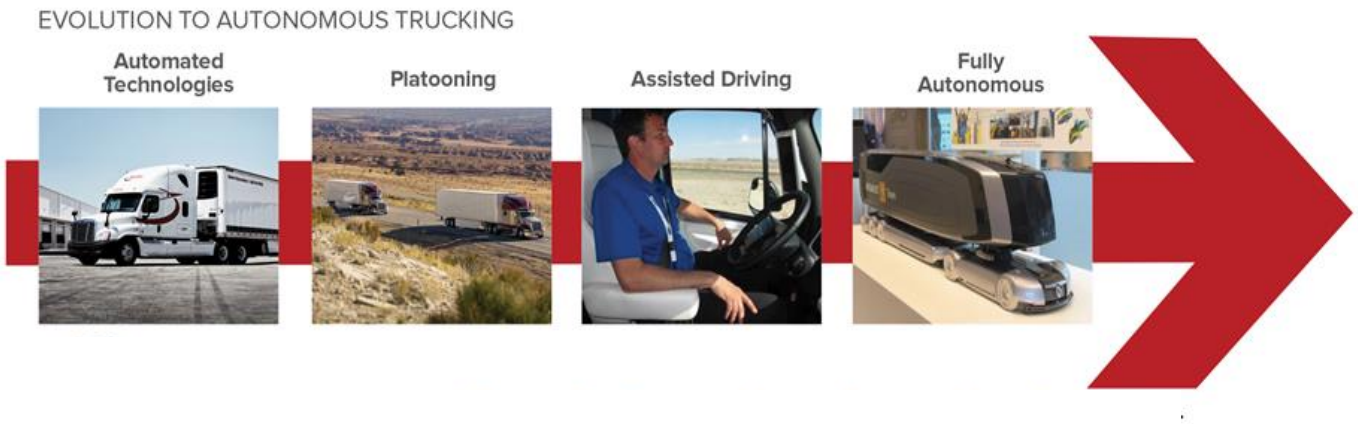
Automated Trucks





Tech Growth For Automation

- Automated Transmission
- Collision Mitigation System
- Active Lane Keeping
- Camera System
- Telematics
- Tire Pressure Monitoring

www.nacfe.org/technology/two-truck-platooning/

New Companies in Truck Autonomy

Why AVs?

FACTORS

People
- Parking Shortage
- Driver Supply v. Demand
- Hours of Service Regulations
- Training Curve
- Drug Testing
- Aging Driver Pool
- Salaries & Benefits
- Diversity
- Experience

Market
- Growing Freight Demand
- eCommerce Growth
- 3PL Growth
- Cost Reduction
- OPEX vs CAPEX
- Interests Rates
- Vehicle Complexity

AV

Accidents
- Accident Rates
- Jury Awards
- Workman's Comp
- Insurance

Different Scenarios for Autonomy

"Autonomous Trucks and the Future of the American Trucker"

By Steve Viscelli September 2018

1. Cooperative Adaptive Cruise-Control Platooning
2. Human–Drone Platooning
3. Exit-to-Exit Autonomous Trucks Plus Drone Operation
4. Driver-in-the-Sleeper Scenario (A.K.A. Autopilot)
5. Exit-to-Exit Autonomous Trucks
6. Facility-to-Facility Autonomous Trucking

ATP: Autonomous Truck Port

https://gspp.berkeley.edu/centers/cepp/news-and-publications