ELECTRIC POWER RESEARCH INSTITUTE

Future Innovations in Electric Transportation

Lincoln Electric Systems Webinar

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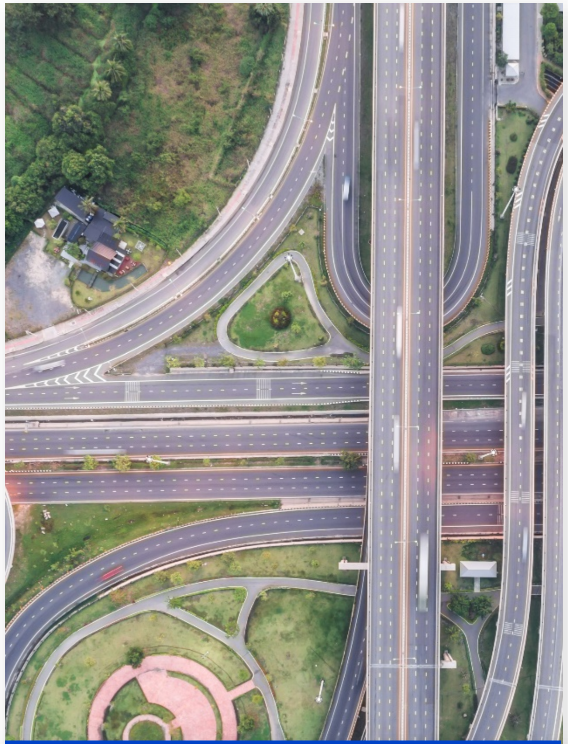
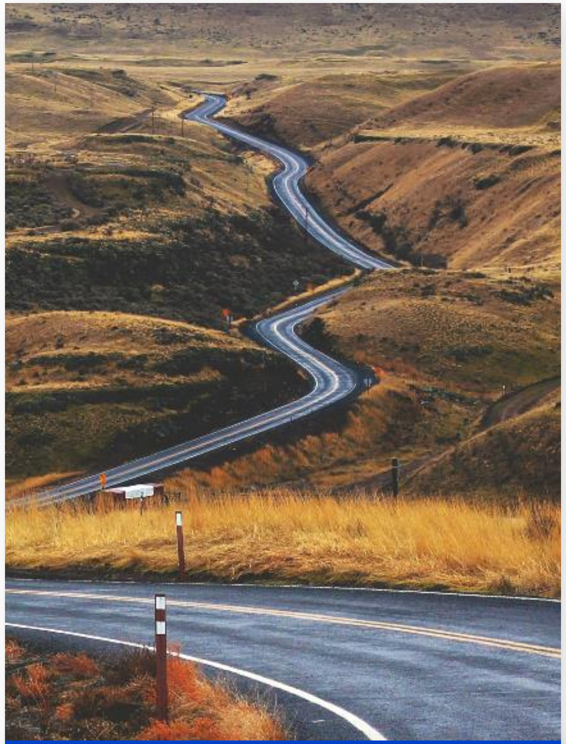
August 5, 2020

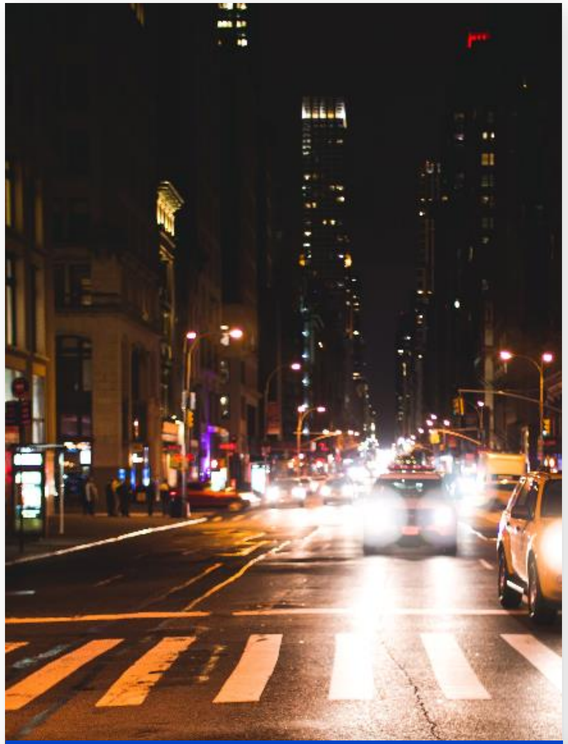
Agenda



New EV
Truck Models



Evolution of Battery
Technology



Developments in
Mass Transit

The Future of
Autonomous Vehicles

New EV Truck Models

CROSSOVERS, PICKUPS, AND SUVS


Rivian R1T


Bollinger B2

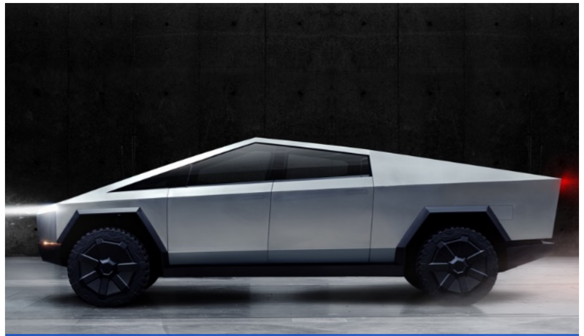

Ford 150

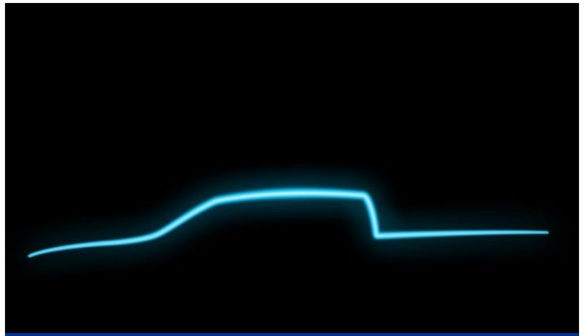

Mercedes EQC


Ford Transit Cargo Van


GMC Hummer EV SUT


Cadillac Lyriq SUV


Tesla Cybertruck


Chevrolet Pickup


Lordstown Endurance


Nikola Badger


Toyota RAV4 Prime Plug-in Hybrid

Electric Trucks are Coming Soon

Rivian R1T

Bollinger B2

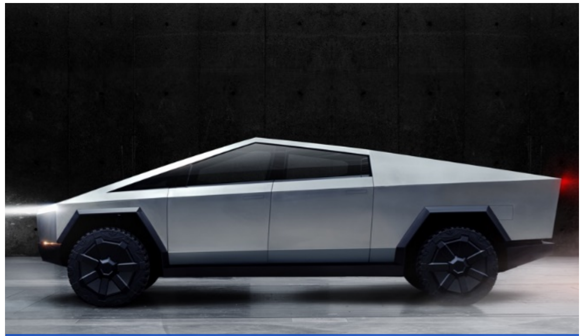
Ford 150

Mercedes EQC

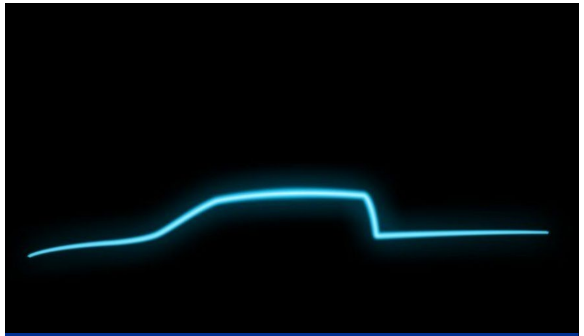
Ford Transit Cargo Van

GMC Hummer EV SUT

Cadillac Lyriq SUV



Tesla Cybertruck



Chevrolet Pickup

Lordstown Endurance

Nikola Badger

Toyota RAV4 Prime Plug-in Hybrid

All-Electric Trucks Available in 2021

Rivian R1T

180 kWh Battery (105, 135 kWh)	**230 to 400** miles range	**550** kW
< 6.0 seconds 0-60 mph	**125** mph	**$70,500** to **$80,500**

Bollinger B2

120 kWh Battery	**200** miles range	**450** kW
4.5 seconds 0-60 mph	**~$125,000**	**900** Nm

All-Electric Trucks Available in 2021

Ford 150

300
miles range

Mercedes EQC

80
kWh Battery

200
miles range

296
kW

4.8
seconds 0-60 mph

760
Nm

All-Electric Trucks Available in 2022

Ford Transit Cargo Van

GMC Hummer EV SUT

2
Models- SUT and SUV

800
V Battery

35kW
kW
Fast Charge Capable

$70,000

EPRI ELECTRIC POWER RESEARCH INSTITUTE

All-Electric Trucks Available in 2022

~$75,000

200
kWh Useable Battery

465
miles range

0.42
kWh/mile

$39,000
to $69,000

All-Electric Trucks Available in 2023

Chevrolet Pickup

400
mile range

800
V Battery

350
kW
Fast Charge Capable

Plug-in Hybrid Trucks Available in 2021

Lordstown Endurance

60
kWh Battery
(40 kWh Useable)

0.65L
two cylinder engine

310 miles
range with engine

7.2
kW
Export Power

< 6.0
seconds 0-60 mph

$52,500

Nikola Badger

BEV/FCEV

160
kWh Battery

~ 600
Miles range

666
kW
and 1230 Nm

2.9
Seconds 0-60 mph

75
mph Max Speed

Plug-in Hybrid Trucks Available in 2021

Toyota RAV4 Prime Plug-in Hybrid

2.5L
four cylinder Atkinson engine

39
miles range

90
MPGe EPA Economy

130
kW and 228 Nm

5.8
seconds 0-60 mph

$39,200

Summary of Near-term Trucks, SUVs, and Vans

OEM	Model	Style	Type	Available	Range (miles)	Battery Energy (kWh)	0-60 mph time (sec)	Fuel Cell Power (kW)	# of Motors	Starting Price	Towing (pounds)
Bollinger	B2	Truck	EV	2021	200	120	4.5	-	2	$125,000	7,500
Ford	150	Truck	EV	2021	300			-	1	$30,000	> 11,000
Ford	Cargo Van	Van	EV	2022				-			
Ford	Lincoln	SUV	EV					-			
GM	Hummer	SUT	EV	2022				-		$70,000	
GM	Hummer	SUV	EV	2022				-			
GM-Cadillac	Lyriq	SUV	EV	2022				-		$75,000	
GM-Chevrolet	Silverado	Truck	EV	2023	400			-			
Mercedes	EQC	SUV	EV	2021	200	80	4.8				
Nikola	Badger	Truck	EV	2021	300	160	2.9	-	4		
Rivian	R1T	Truck	EV	2020	>230	105	6.0	-	4	$70,500	11,000
Rivian	R1T	Truck	EV	2021	>300	135	6.0	-	4	$75,500	11,000
Rivian	R1T	Truck	EV	2021	>400	180	6.0	-	4	$80,500	11,000
Rivian	R1S	SUV	EV	2021				-			
Tesla	Cybertruck	Truck	EV	2022	>250			-	1	$39,900	7,500
Tesla	Cybertruck	Truck	EV	2022	>300			-	2	$49,900	10,000
Tesla	Cybertruck	Truck	EV	2022	>500			-	3	$69,900	14,000
Nikola	Badger	Truck	EV /H2	2021	600	160	2.9	120	4		>8,000
Lordstown	Endurance	Truck	PHEV	2021	310 w/eng		6.0	-	4	$52,500	
Toyota	RAV4 Prime	SUV	PHEV	2021	42	103	5.8	-	1	$39,220	

Evolution of
BATTERY TECHNOLOGY

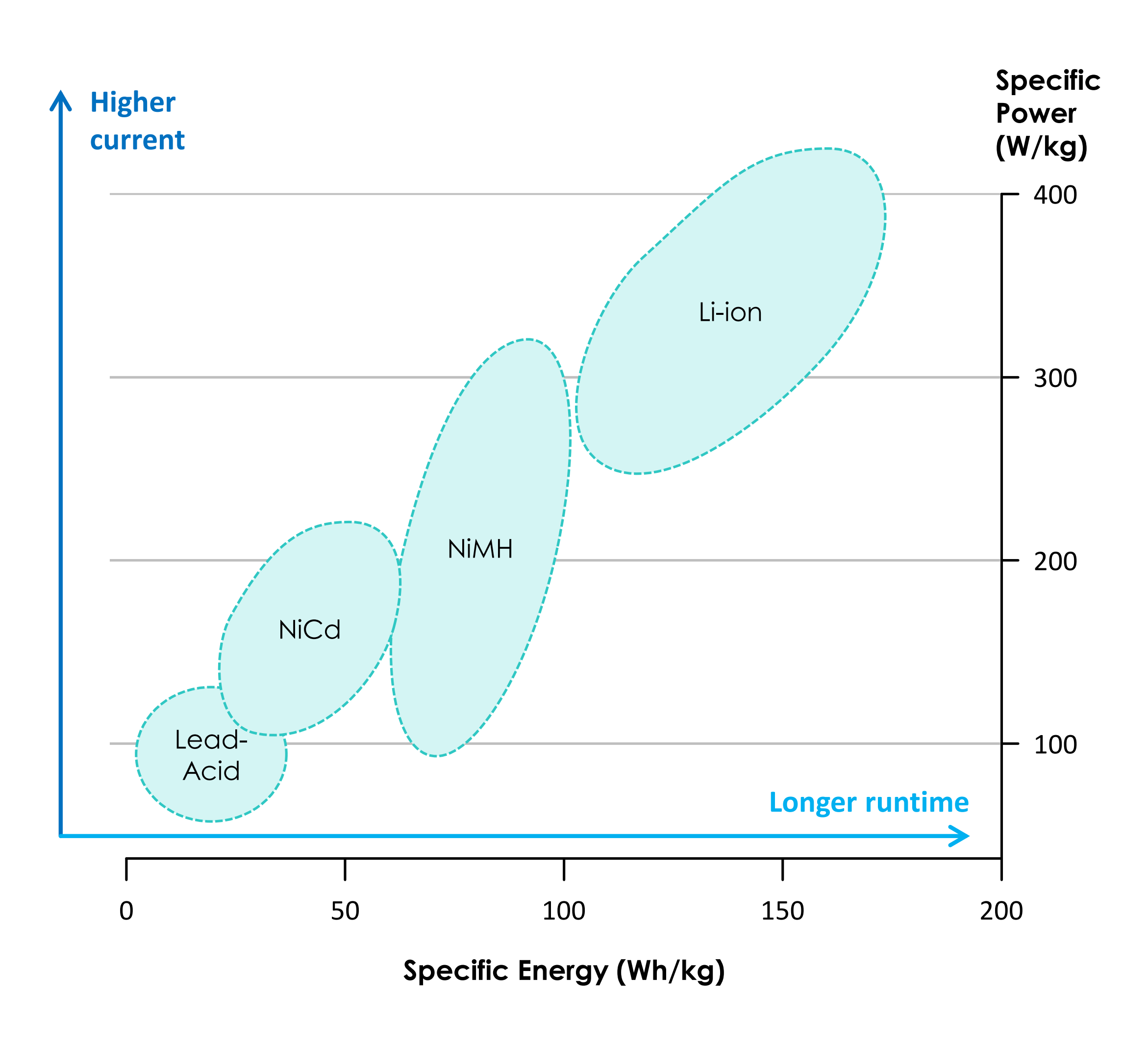
Chargeable Batteries

Specific Energy

is like the amount of water in a tank. It's the amount of energy a battery holds in total.

Specific Power

is the speed at which that water can pour out of the tank. It's the amount of current a battery can supply for a given use.



Battery Evolution for Vehicles

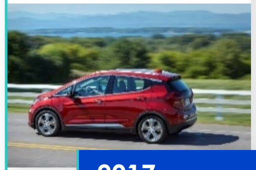
Li-Ion

2010
GM Volt
16 kWh

Nissan Leaf
24 kWh

2012
Tesla Model S
65-85 kWh

2016
GM Bolt
60 kWh

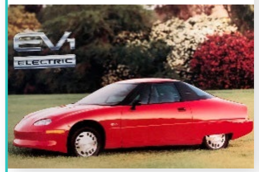


2017
Tesla Model 3
54-75 kWh

2022
Tesla Cybertruck
>200 kWh

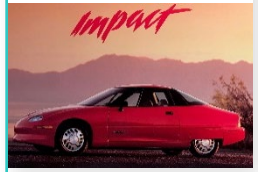
Nickel-Metal Hydride

1997
GM EV1
33 kWh

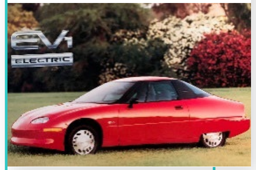


Recombinant Lead Acid

1990
GM Impact
16 kWh



1996
GM EV1
16 kWh



Transit

BUSES AND FLEETS

US Transit Bus Fleets

168

different known transit programs as of the 4th Quarter of 2019

46
States

11
Airports

12
Universities

3
Privately owned

1
Utility

1
National park

Electric buses cost $200,000 more than diesel alternatives on average, but they save an estimated $400,000 in fuel and maintenance over their 12 year or 500,000-mile lifespan

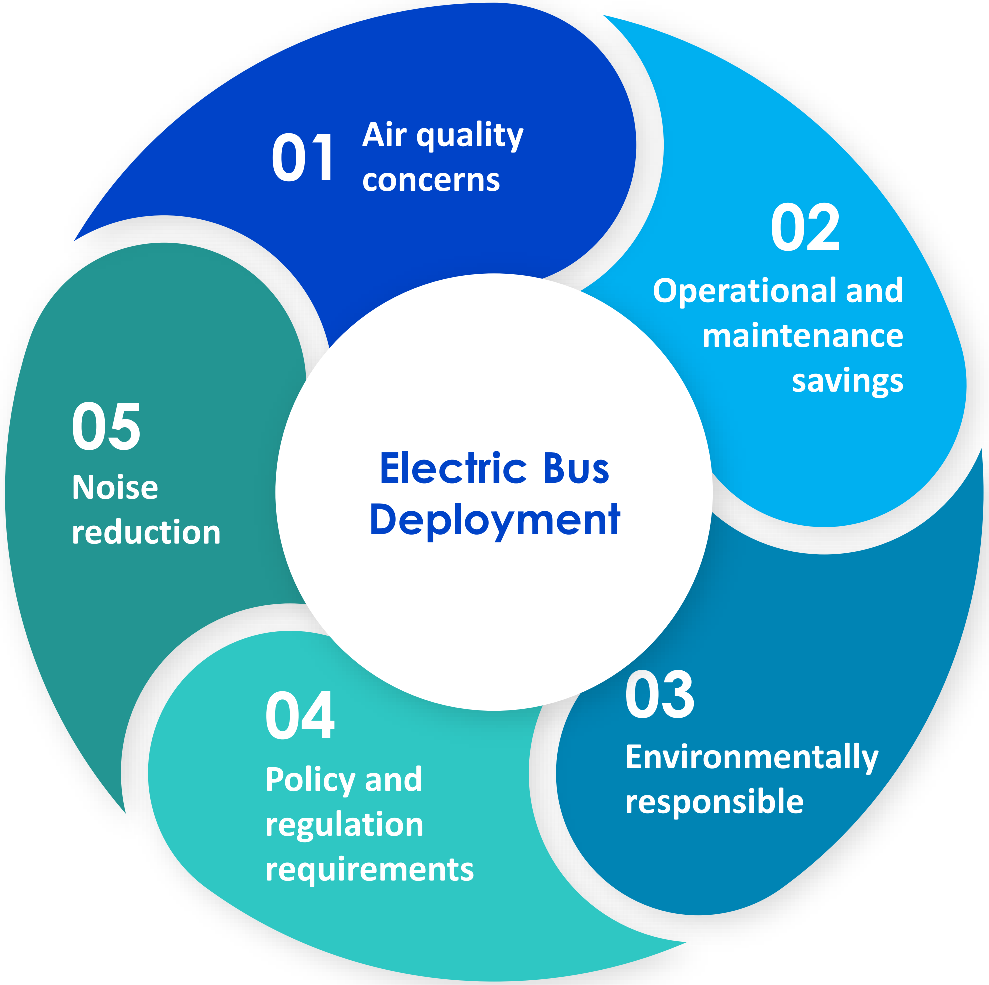
According to the U.S. Department of Transportation, one zero-emissions bus can eliminate 1,690 tons of carbon dioxide over its 12-year life span, the equivalent of removing **27 cars** from the road.

Greensboro, South Carolina Transit Authority (GTA) expects to save $350k in fuel and maintenance over the typical 12-year lifespan of each bus and reduce carbon dioxide emissions by 687,500 lbs./year.

Transportation District Commission of Hampton Roads, (HRT) Virginia estimates they spend $19k/year to fuel for one diesel bus compared to $3,200/year to electrifying one bus per the 2017 rates.

82% of the fleets are federally funded.

Why battery electric buses?

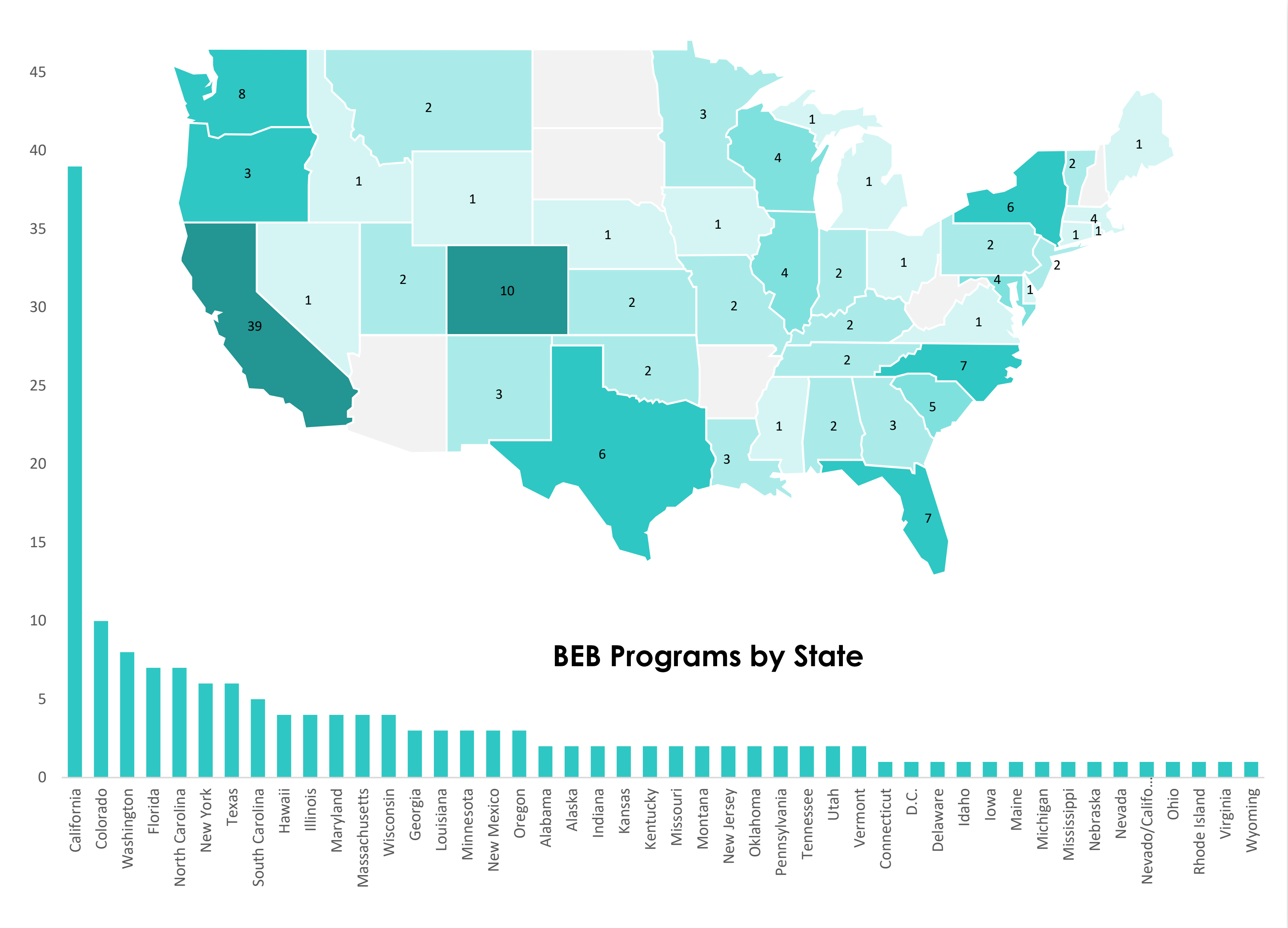


Place	Year planned to go all electric
Antelope Valley, CA	2018
Park City, UT	2022
Los Angeles County, CA	2030
Indianapolis, IN	2032
King County, WA	2034
San Francisco, CA	2035
California	2040
New York	2040
Portland, OR	2040
Washington D.C.	2045

Electric Bus Pilots in the U.S. by State

Solar examples:

Alabama's A&M University
Fresno County Rural Transit Agency
Via Mobility Services Boulder, Colorado
Jacksonville Transportation Authority (JTA)
City and County of Honolulu
Connect Transit, Bloomington Illinois
Martha's Vineyard Transit Authority (VTA)
City of Rochester, Minnesota
Chapel Hill, North Carolina
Via Metro Transit, San Antonio
San Diego International Airport



Fleet sizes estimated. If grant has been awarded but no decision has made yet fleet size was considered one.

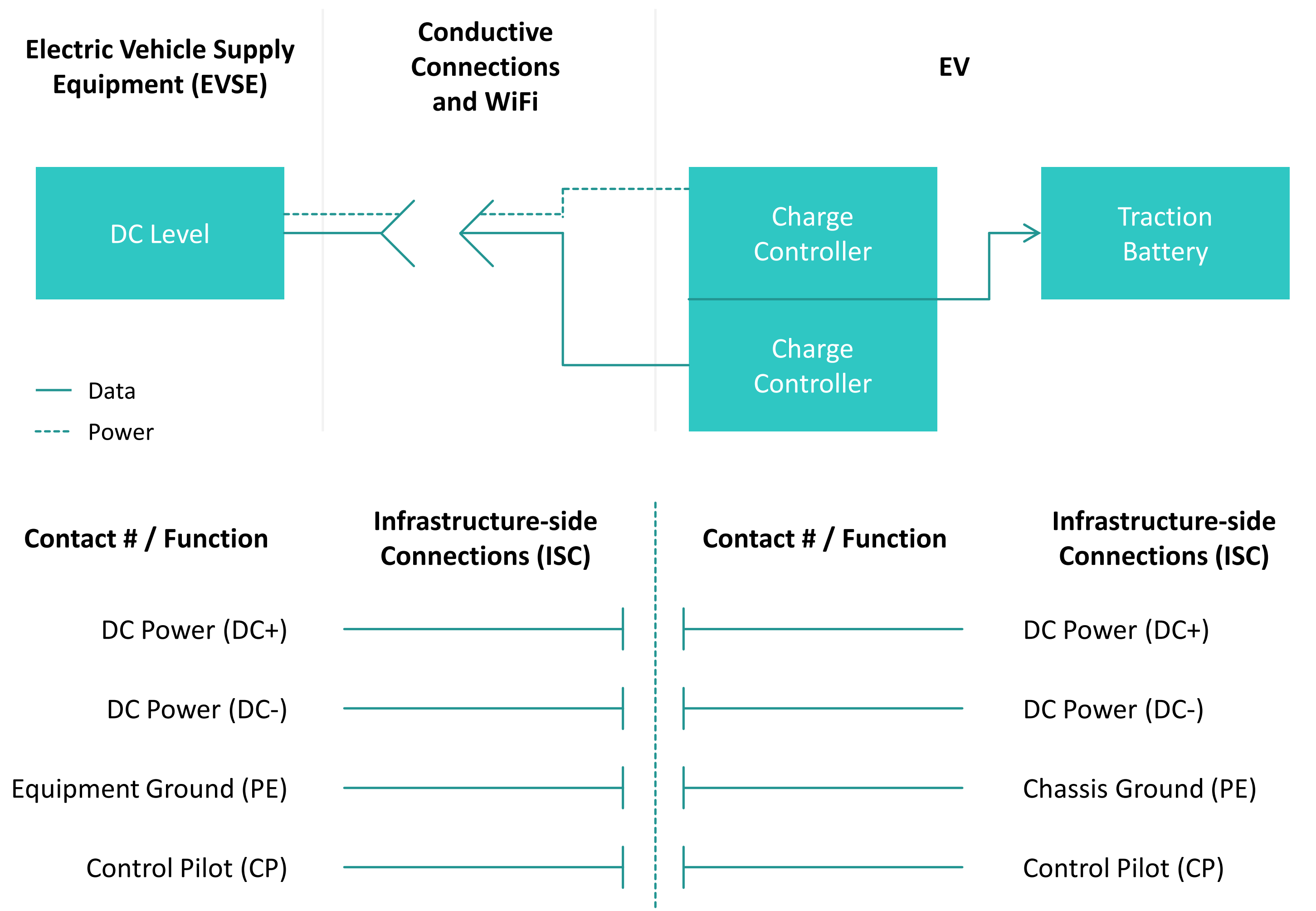
Automatic Charging
CONDUCTIVE AND INDUCTIVE

Automated Connectors SAE J-3105 Recommended Practice

The Recommended Practice published in January 2020 as a family of documents connected together by a main document.

The main document J-3105 will contain the significant common parts of the system (about 90%). It will include:

- Electrical Interface
- Power Flow (up to 600 kW)
- Communications
- Safety
- Systems



Automated Connectors SAE J-3105

SAE J-3105-1

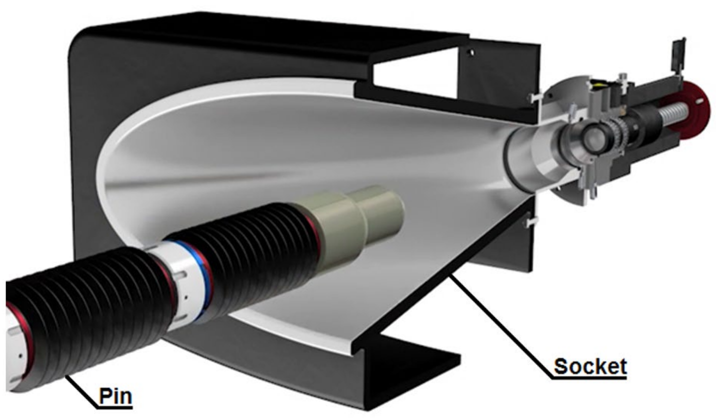
Infrastructure-mounted Cross Rail Connection

(Most prevalent in the US)

SAE J-3105-2

Vehicle-mounted Pantograph Connection

(Most prevalent in Europe)



SAE J-3105-3

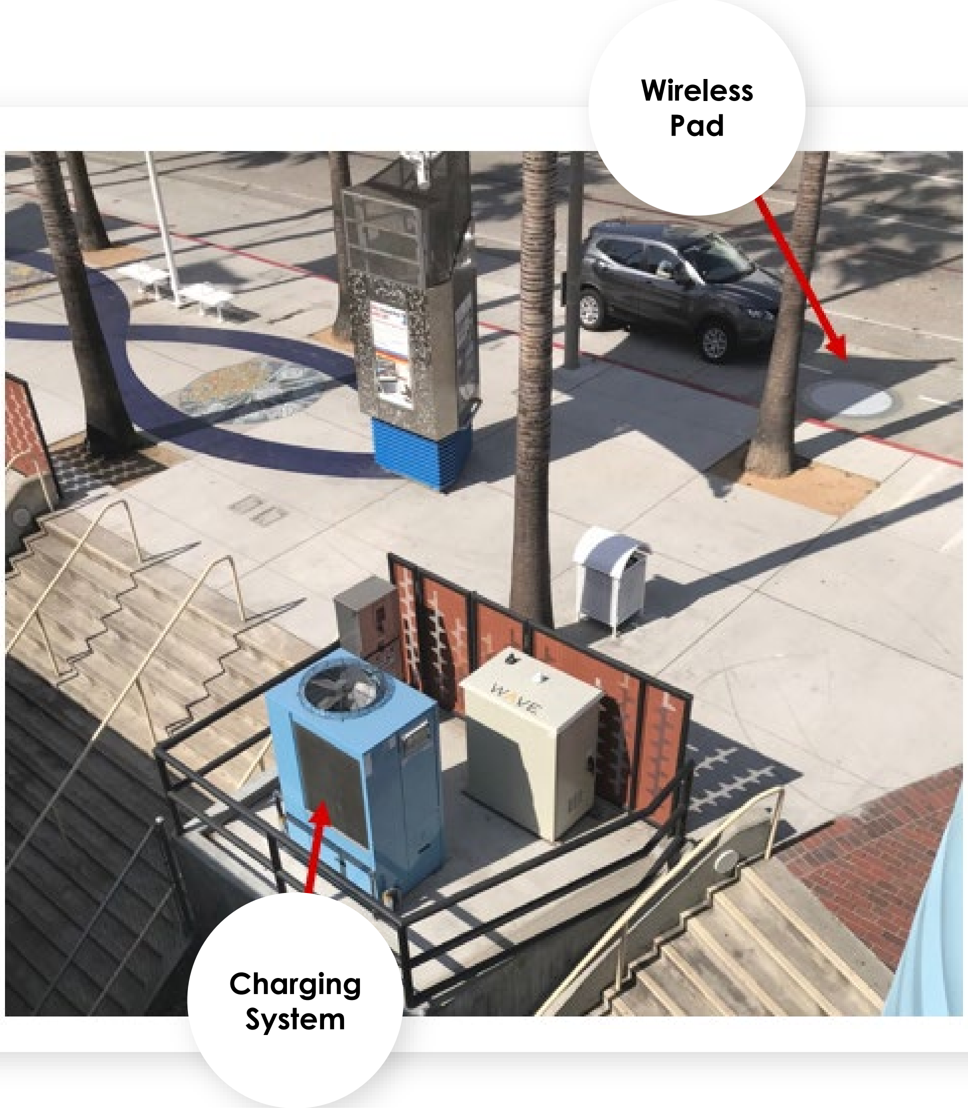
Enclosed Pin and Socket Connection

(Most prevalent on shipping docks)

Automated Wireless Connectors

In front of the Long Beach Convention Center, is a 50 kW Wireless (Inductive) charge station.

- 250 kW stations are available as well as developments for 500 kW and 1000 kW.
- Bus stops above the pad and charging begins over a 8 to 10 inch air gap. Effectively at about 85%. The frequency is about 10 kHz. Signal is rectified on the bus to DC.
- Alignment of the bus is important.



All-Electric Transit Buses

Most transit buses are equipped with SAE J-1772 CCS #1 manual connectors for charging up to 150 kW

Many transit buses are equipped with automatic charging based on SAE J-3105 connections with power levels up to 500 kW and developing up to 1000 kW

Many transit buses are using wireless charging based on SAE J-2954-2 up to 250 kW

All-Electric Transit Buses

Solaris

Nova

All-Electric Transit Buses

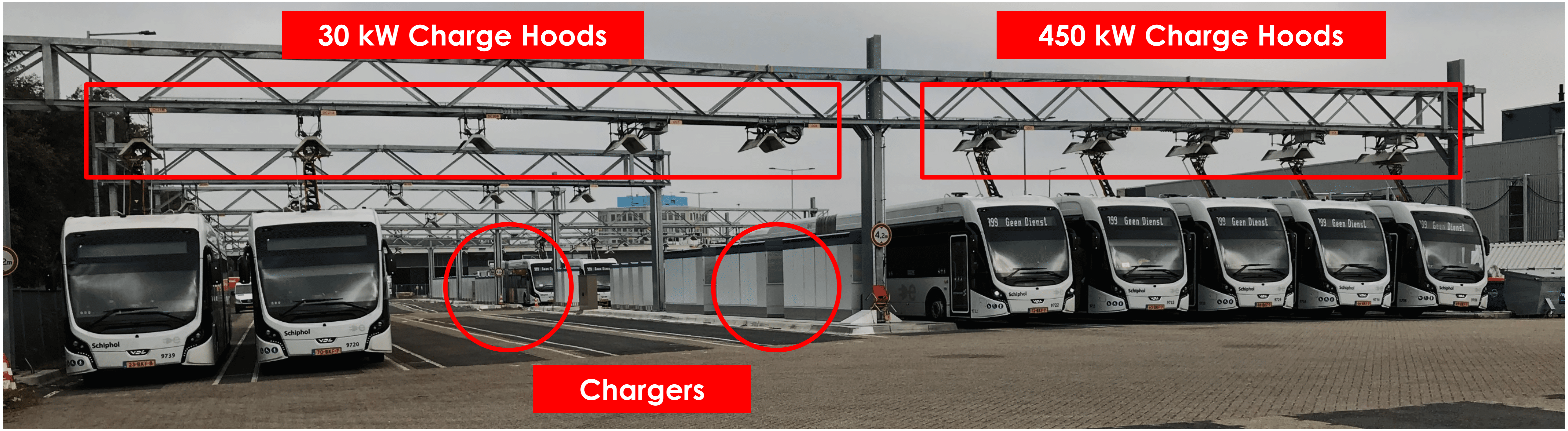
Gillig

Proterra

All-Electric Transit Buses and H2-Electric Transit Buses

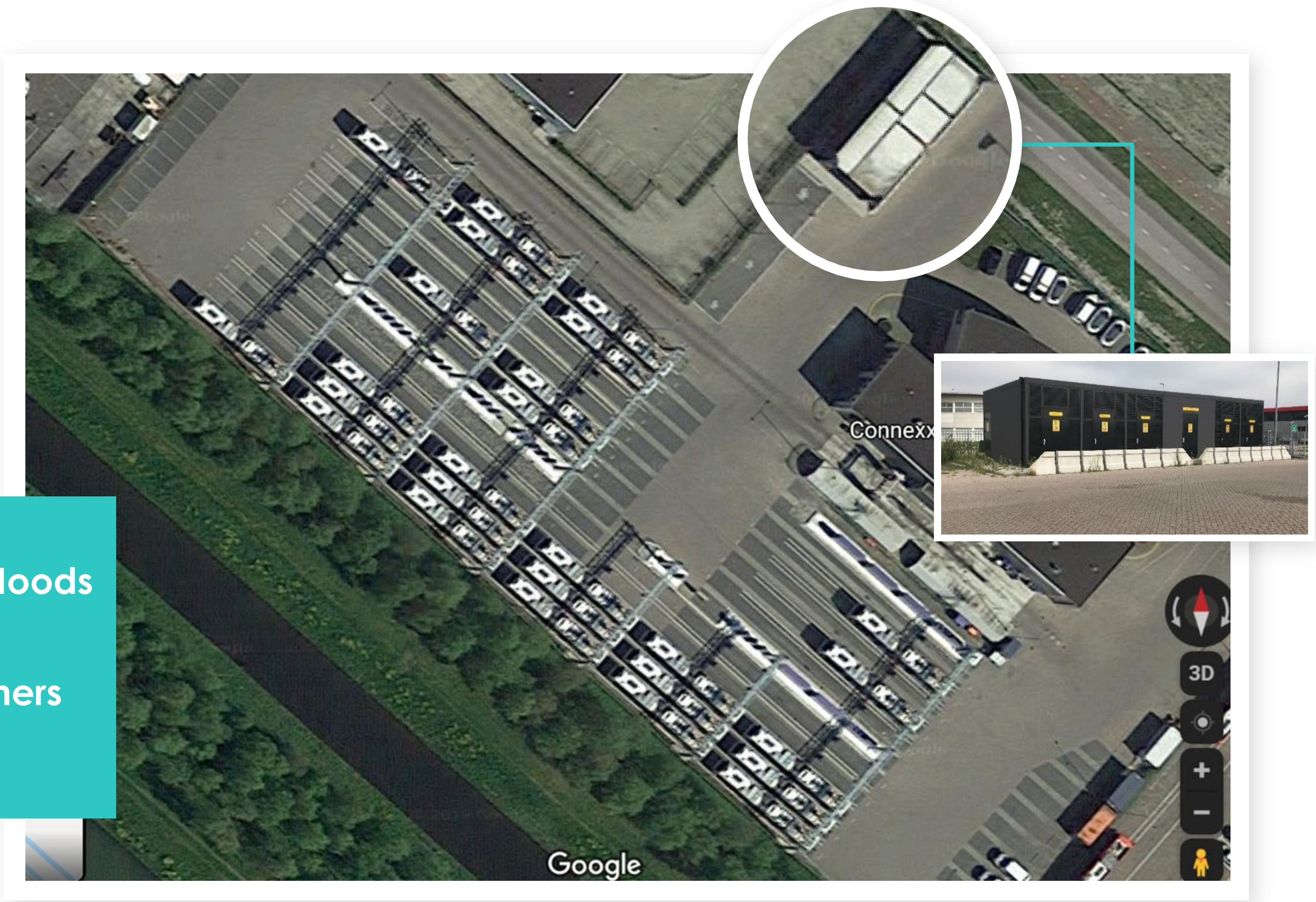
Outdoor Charging
AMSTERDAM SCHIPHOL FLEET

Schiphol Airport All-Electric Transit Bus Fleet- Amsterdam



100 x 60-foot Transit Buses (VDL)	Four Locations Outside Depots or Opportunity Charging
13 MW installed Power	Full Operation with 24/7 Service
84 x 30 kW Charging Hoods (J-3105-2)	Six different lines gathering more than 18,000 miles/day (6.8M miles/yr)
23 x 450 kW Opportunity Charging Hoods (J-3105-2)	Buses are equipped with 169 kWh of battery
2 x 25 kW Mobile Chargers in the Workshop	Greenfield build

Schiphol Depot

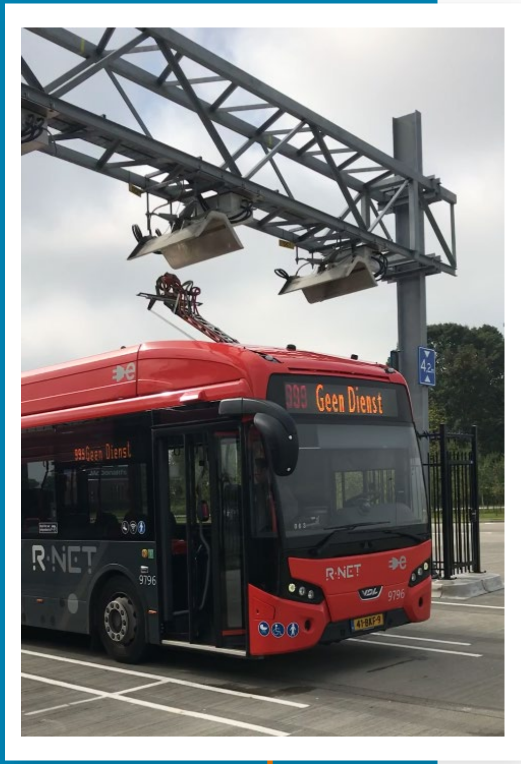


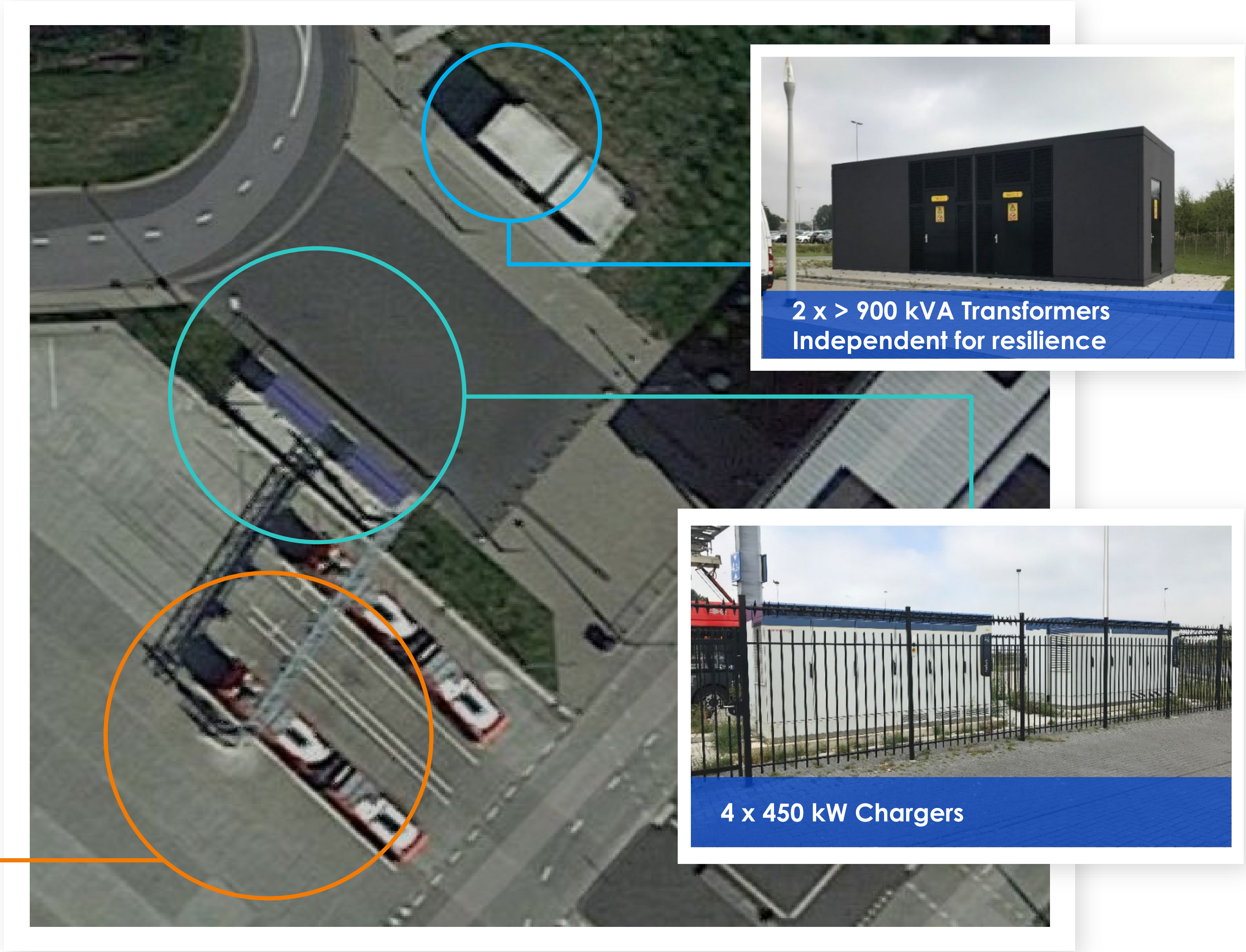
Forty-Eight 30 kW Charge Hoods

Five 450 kW Charge Hoods

Five Independent transformers for resilience

Schiphol Opportunity Charging





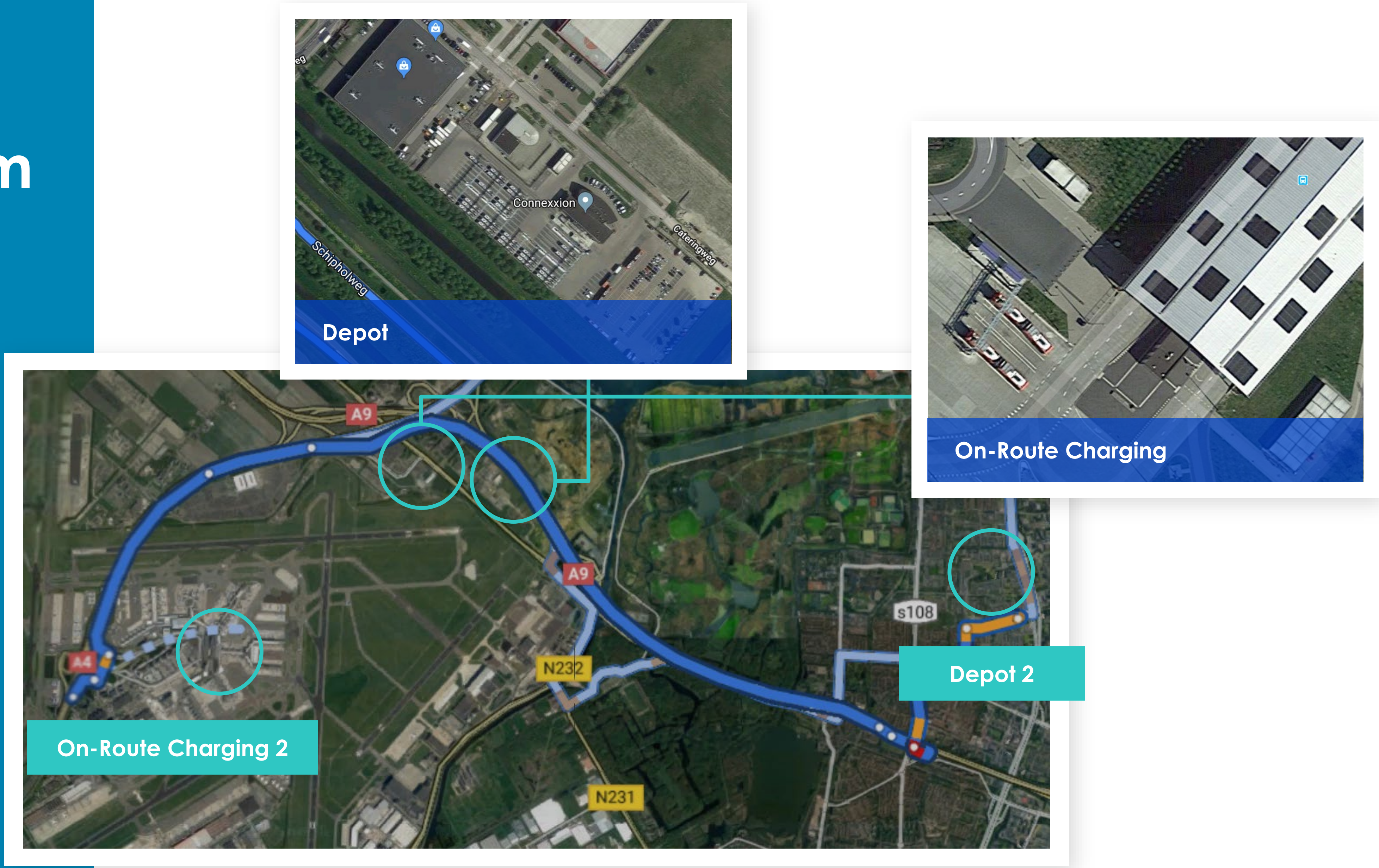
Schiphol Opportunity Charging

UL Listed DC Chargers

50 kW	$ 62k
450 kW	$ 333k

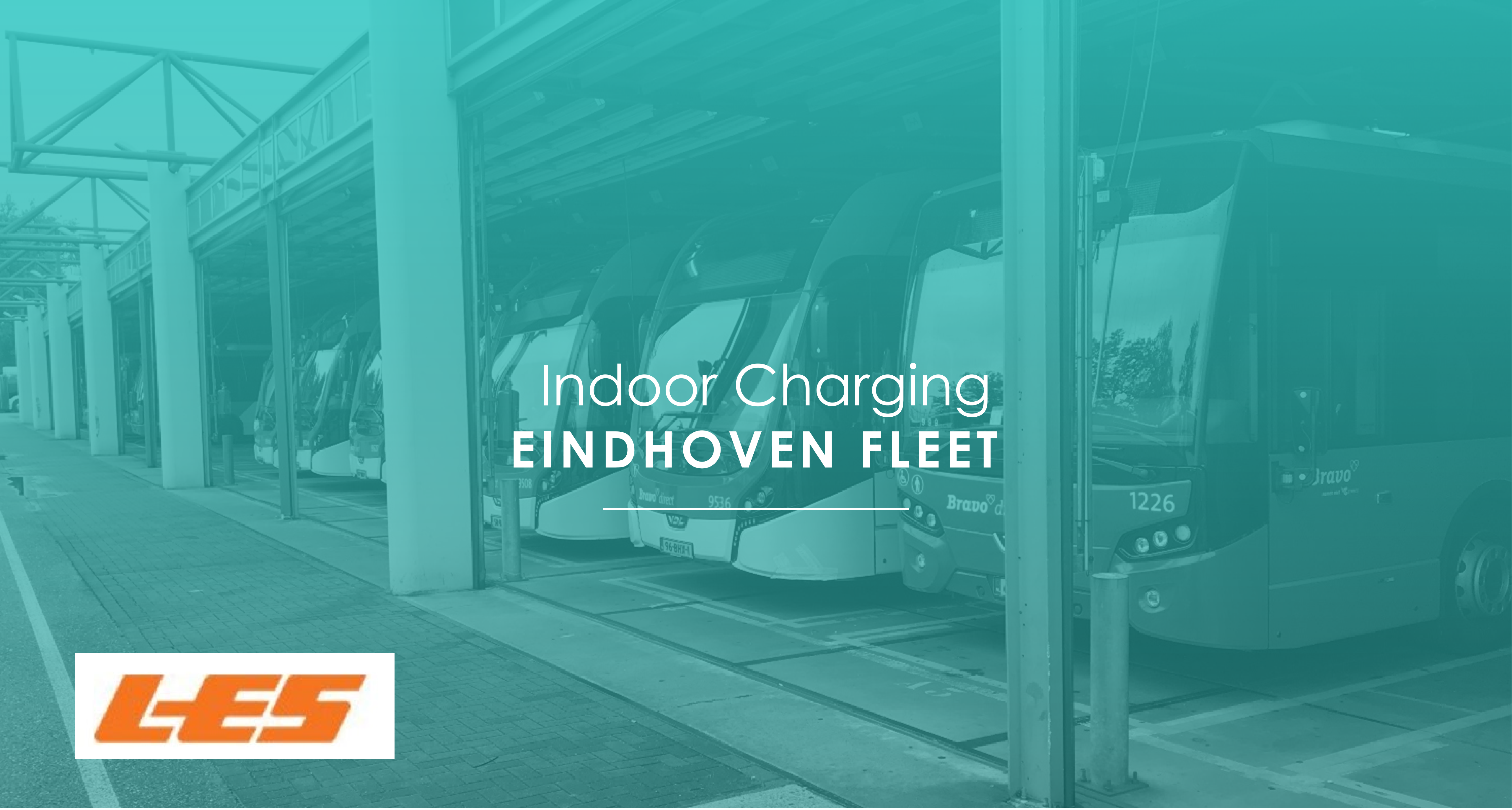
Schiphol Opportunity Charging

Schiphol Airport, Amsterdam



Vehicle-mounted Pantograph Connection

SAE J-3105-2



Indoor Charging
EINDHOVEN FLEET

Eindhoven Opportunity Charging

Eindhoven is one hour south of Amsterdam

43 All-Electric Buses with Automatic Depot Charging Indoors

Heliox and VDL initial deployment

Heliox and VDL headquarters and manufacturing is near Eindhoven

Eindhoven Opportunity Charging Alignment

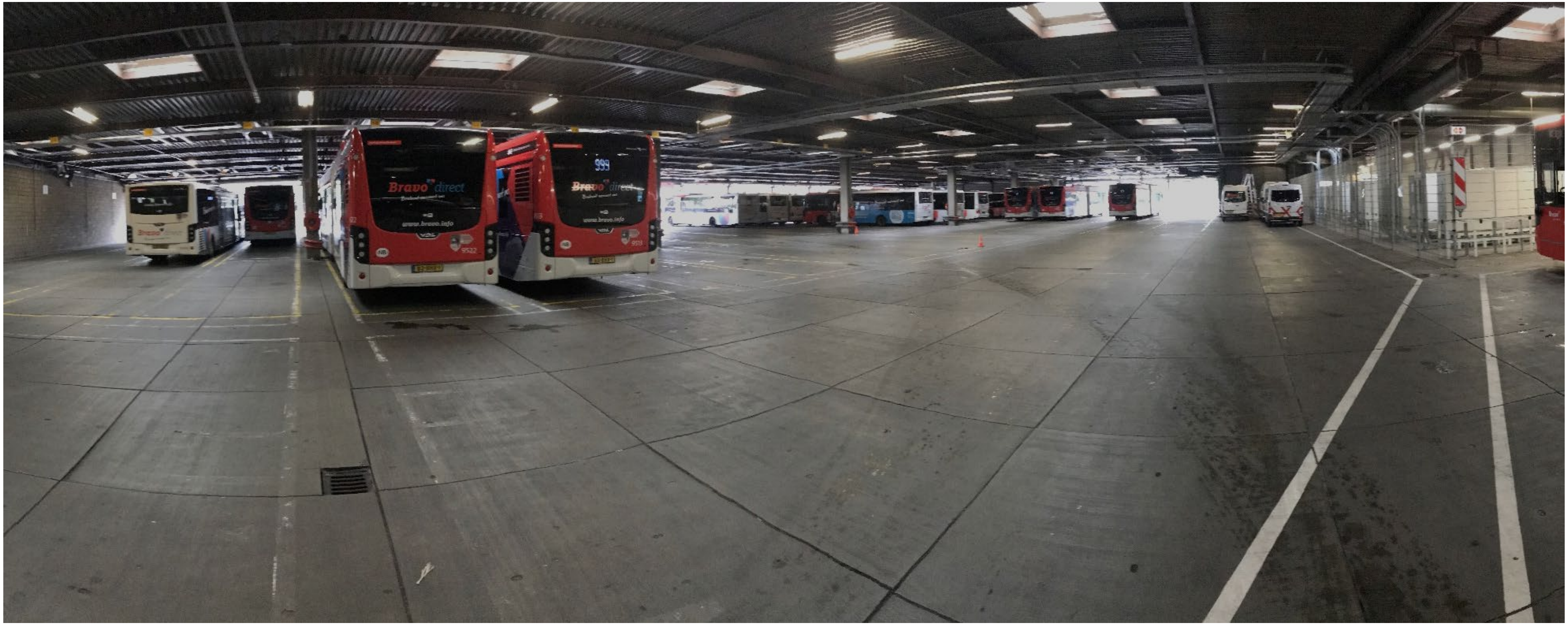
Operator aligns the yellow line on the bus floor with the white line on the street

Eindhoven Opportunity Charging

On-route chargers are located at the depot and the Eindhoven Airport

A bumper on the pavement stops the bus for the proper alignment with the hood.

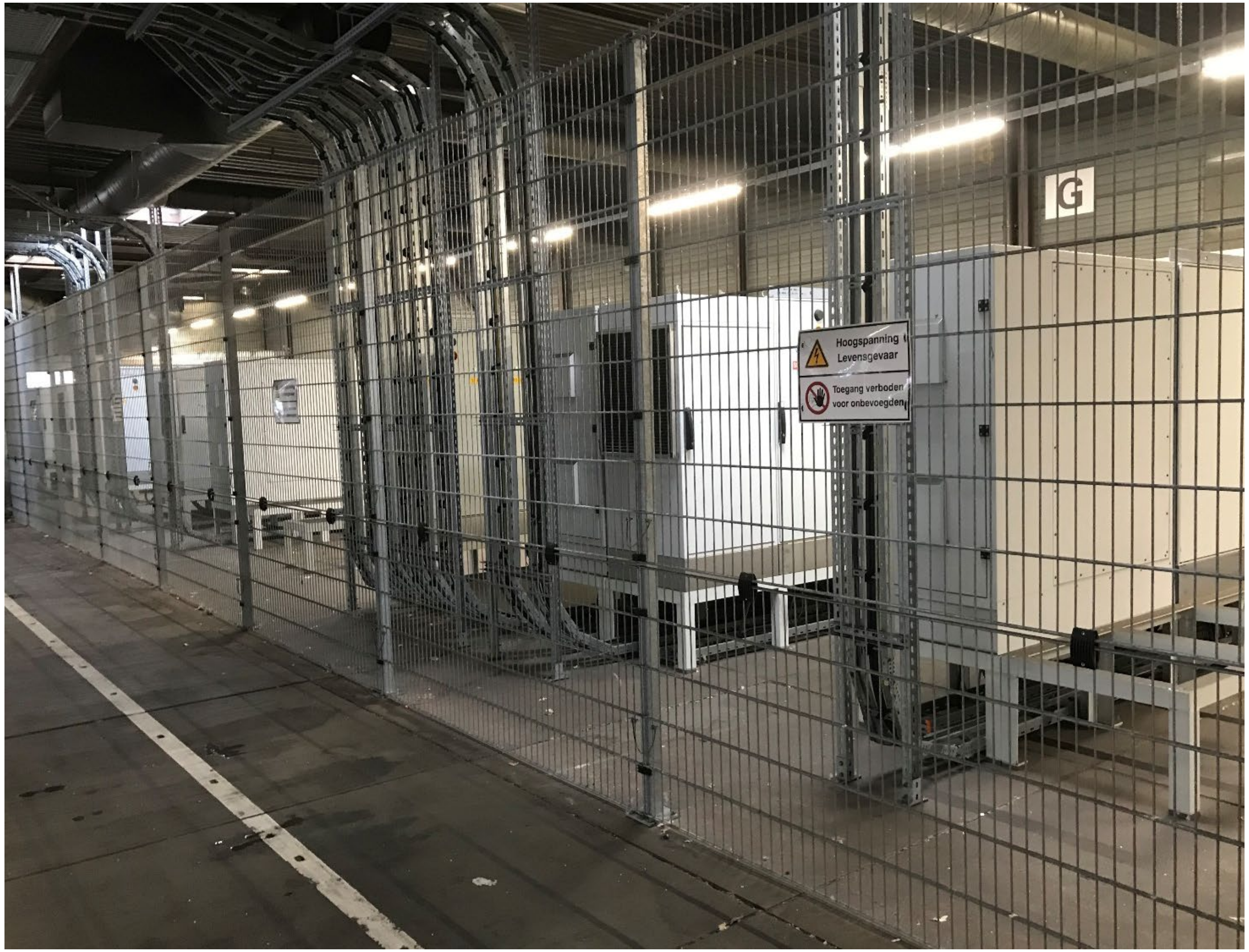
Eindhoven Indoors Depot



Eindhoven Indoors Depot

Charger Cabinets are up off the floor to easily get the power in and out.

Power is routed in conduit to the ceiling and then to each charging hood



CHILE FLEET


HOTEL LIB
418
Tobalaba
Providencia
Alameda - Central
Terminal Buses
General Bonilla
Serrano - J. J. Pérez
PU
WB-23-50

Santiago, Chile

1

A total of 285 BYD buses are currently operational in Chile. A total of 386 electric buses are currently operational in Chile.

2

Charging takes about 5 hours for the 150 miles of range for the buses.

AUTONOMOUS VEHICLES (AV)

Autonomous Vehicles

Self-driving cars, also known as autonomous vehicles (AV), are a key innovation in the automotive industry

A high growth potential

Acting as a catalyst in the technological developments of automobiles

The global autonomous vehicle market demand is estimated to be at approximately 6,700 vehicles in 2020

Anticipated to expand at a CAGR of 63.1% from 2021 to 2030

Per Barron's Market Watch

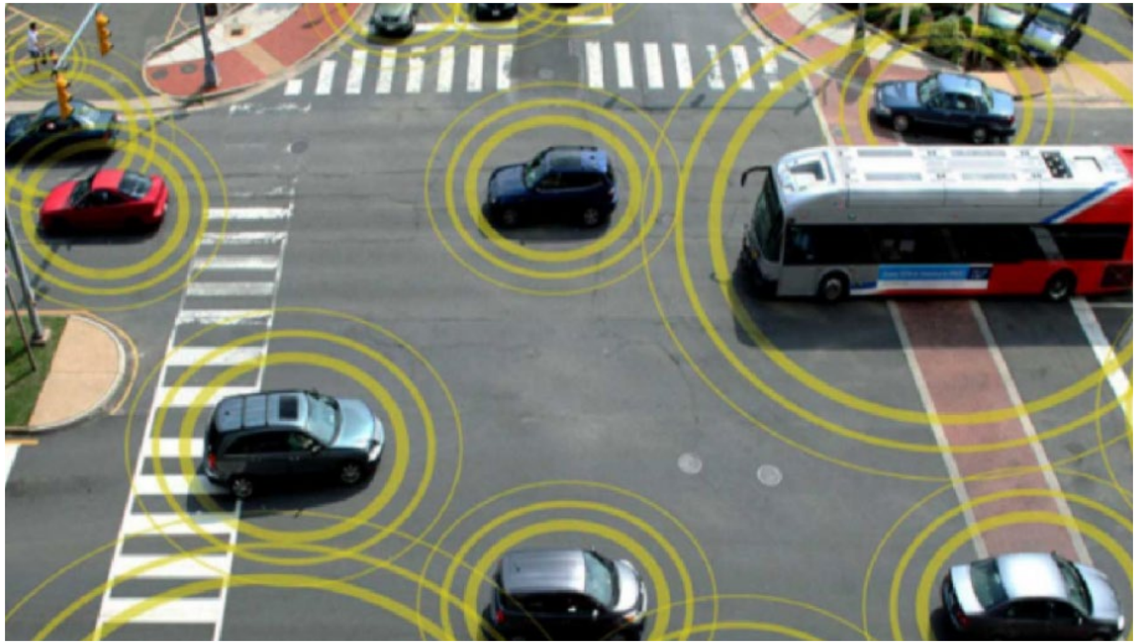
https://www.marketwatch.com/press-release/autonomous-vehicle-market-by-development-trends-investigation-2020-and-forecast-to-2027-2020-07-09

Autonomous Vehicles

Most of the large OEMs have Autonomous development vehicles for experimentation

The equipment on **the roof of this vehicle will be contained** within the production vehicle

Large OEMs have been developing Autonomous vehicles for decades



Many sensors are required to **understand the adjacent traffic and pedestrians**

A significant amount of computing power is required on-board the vehicles

Brake-by wire, Steer-by-wire, and Propulsion-by wire are definite musts

American Center for Mobility (ACM)

ACM, a non-profit product development facility for future mobility, is designed to enable testing, safe validation, and self-certification of connected and automated vehicle technologies.

Located at the historic Willow Run site in southeastern Michigan near Detroit on 500 acres.

It features many assets and a range of testing capabilities including:

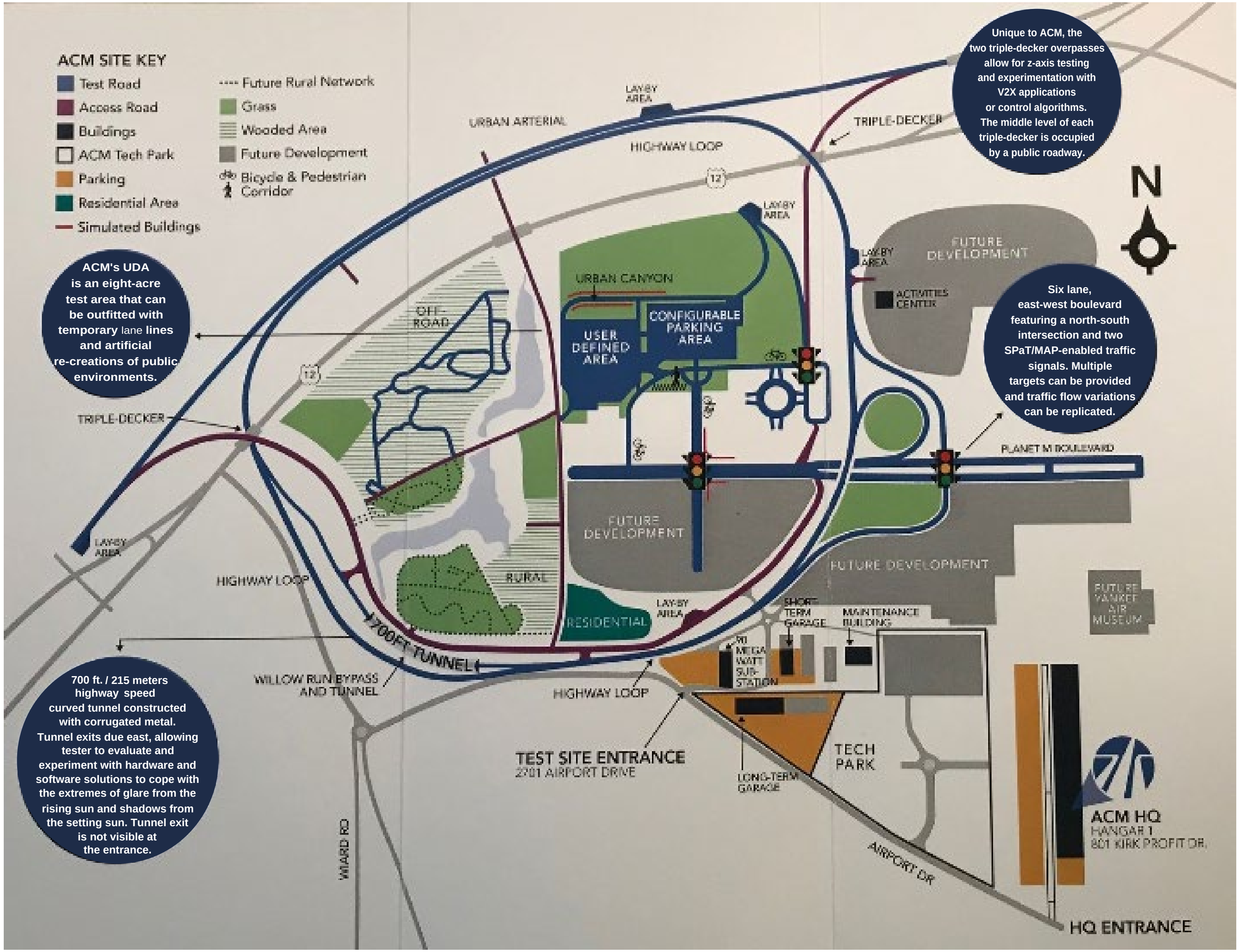
Simulation of virtually any driving condition
(snow, sun, rain, sleet)

Extensive network infrastructure
(private 4G LTE, WiFi, etc.)

Equipped to enable a combination of simulation, track testing, and on-road testing

Map of ACM

- Current Environment includes:
- 2.5 Mile Highway Loop
- 2+ Lanes (50 to 65 mph)
- Exit and Entrance Ramps
- Triple Decker Bridge
- 700 ft Curved Tunnel, 55 mph
- 1.5 mile Urban Arterial Road
- 6-Lane Boulevard
- 6 x 6 Configurable Intersection
- Urban Canyon
- Parking Environment
- 2 Lane Roundabout
- Bicycle and Pedestrian Corridors
- Networks for data
- Garages- Long and short term
- 41 Intersecting Points
- Cold Chamber



ACM

“I had the opportunity to meet with the engineers at ACM and they took me on tour of the facility.”

“I had the opportunity to view an all-day demonstration at the site.”

“It is great place to do autonomous development-secure and safe.”

Autonomous Braking Demo

An example of two autonomous vehicles without drivers one braking behind the other.

Start this video.

Autonomous Vehicles

The rearward vehicle was a Honda with a robot inside steering, braking, and accelerating.

The vehicle in front is a faux robotic vehicle capable of steering, braking, and accelerating with speeds up to 65 mph.

Autonomous Platform

Under the faux vehicle is a platform

About 3 inches high

Four 3” diameter imbedded wheels

2 steerable wheels

GPS and other instrumentation

Battery pack

Top speed about 65 mph

Velcro tape to hold the body in place

Autonomous Faux Vehicle

- Made of plastic panels held together with Velcro
- Panels provide radar signature like a vehicle
- Assembled in about 10 minutes by three or four guys

Try the Experiment Again

Start this video.

Other vehicles

Bicycles

Scooters

Pedestrians

Each of these figures becomes mobile and mixes with autonomous vehicles

History –
Bomber Plant at Willow Run in the early 1940s

More than 40,000 workers from across America came together at Willow Run to build more than **8,600 B-24 Liberator bomber aircraft**

B-24 Liberator bombers rolling down the assembly line at Willow Run in 1942.

Bomber Plant at Willow Run

Home of Rosie the Riveter

The Willow Run project in 1941 included:

- A major airport (still used today)
- A 5 million sq. ft. manufacturing plant designed by famed architect Albert Kahn
- A village for the workers, all rising from scratch on former farm fields in less than a year.
- At its peak during the war years, produced B-24 Liberator bombers at the astounding rate of one airplane every hour!
- Detroit was called the “Arsenal of Democracy”

GM Hydramatic Transmission Plant

1. General Motors purchased the plant in the early 50’s from Ford.

2. GM designed, developed, and built transmissions at the plant until around 2010

3. GM was producing more than 35,000 transmissions per day

4. The GM VOLT transaxle was designed, tested, and validated at this plant

Summary

- We previewed the future of electric trucks
- We took a quick look at the evolution of batteries
- We learned about automated charging
- We looked at different transit fleets to understand how they function
- We talked about Autonomous vehicles and how they are developed

I hope this time was beneficial for you

QUESTIONS?

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TOGETHER…
Shaping the Future of Electricity