



APTA Sustainability Conference  
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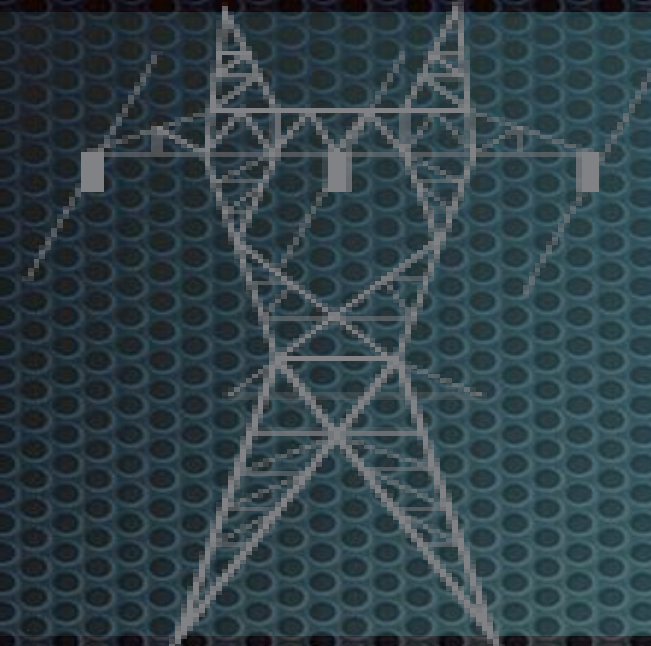
## Wireless Charging Infrastructure for Battery Electric Buses in Public Transportation

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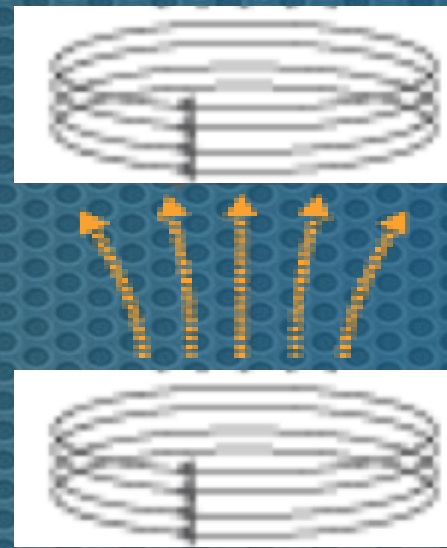




# Electrified Bus Transportation | WAVE Solutions



Electric Grid



Wireless Charger



Vehicle

WAVE Technology:

Safe Power Transfer through Road & Weather

Fast Charging

Large Air Gap – No Mechanical Movement

Efficient > 90%



# Electrified Bus Transportation | WAVE Solutions



## Problem

Limited Range & Anxiety

Ugly & Unsafe

Expensive & Heavy Batteries

Impractical

## WAVE Solution

- In-Route Wireless Charging
- Charge at Stops
- Double the Range

- Low Profile
- Invisible Infrastructure
- Hide It Underground

- Carry Less
- Reduces Vehicle Weight
- Improves Efficiency

- No Hulking Wires
- Never Plug In
- Automated

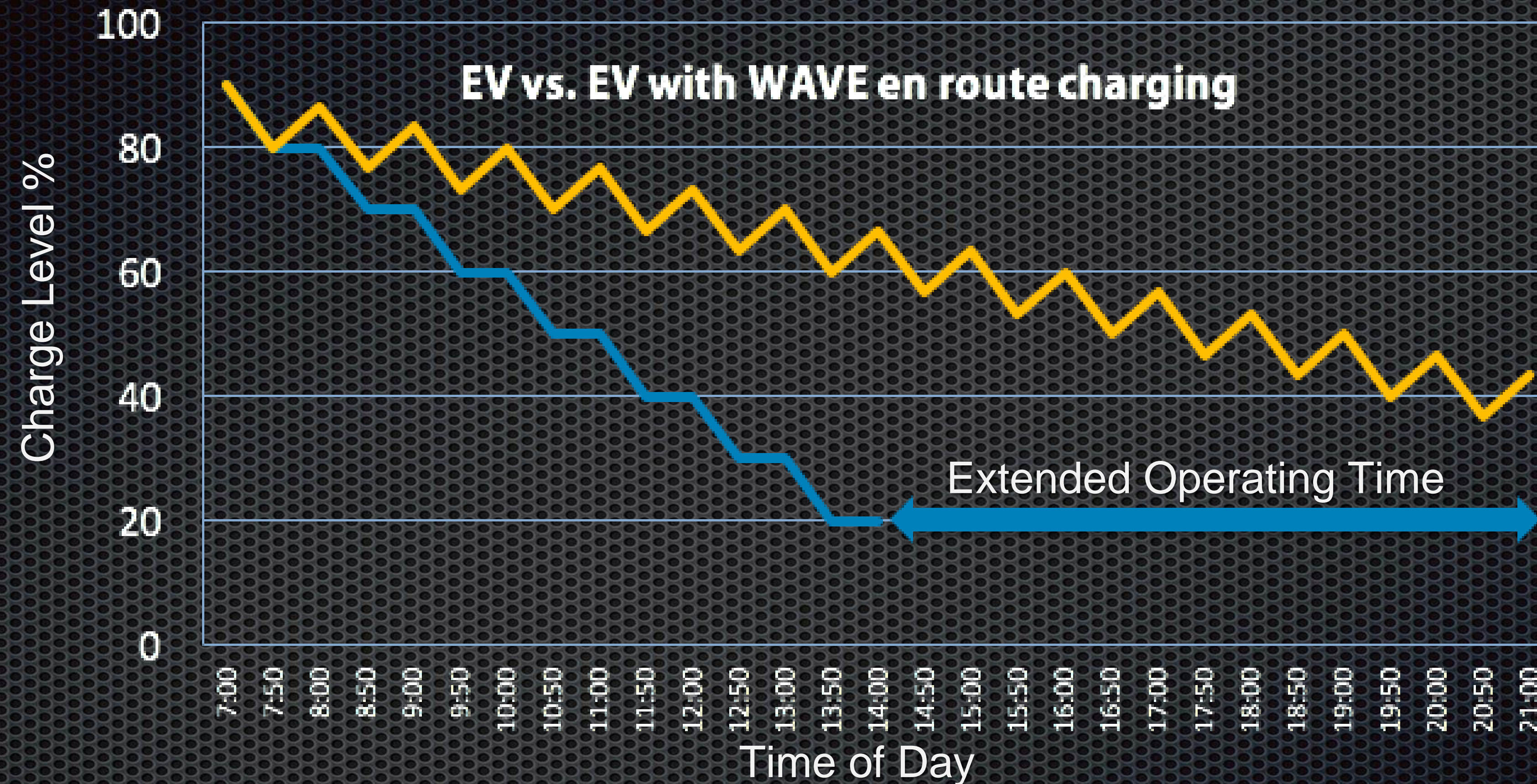


# WAVE Wireless Charging | Metro McAllen TX





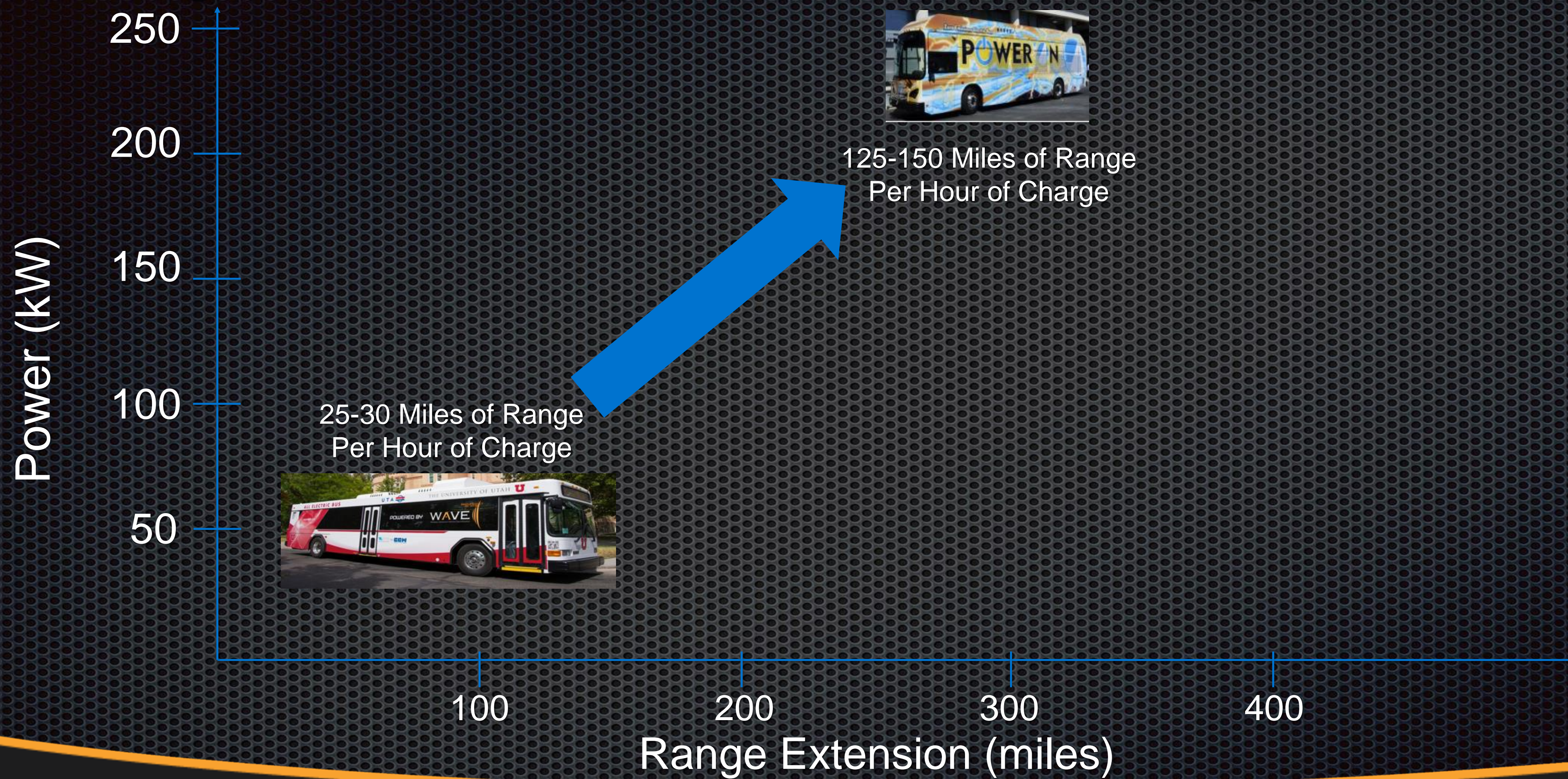
# Opportunity Charging | Range Extension



“The charging pad is positioned at the bus terminal for layovers, which are typically about 10-15 minutes, and during this time the bus will be charging,” Mario Delgado, City of McAllen Transit Director



# Range Extension | Increased Charging Power Level





# Wireless Charging vs. Overhead Charging



Wireless Charging

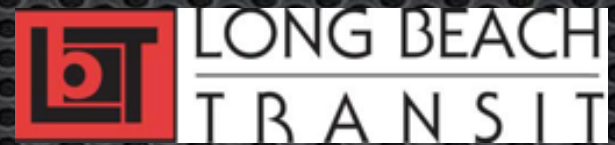


Overhead Conductive  
Charging



# Commercial Deployments

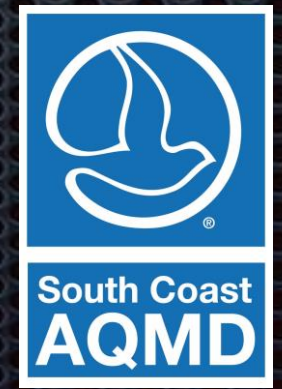
In-Service



In Progress



Sustainable



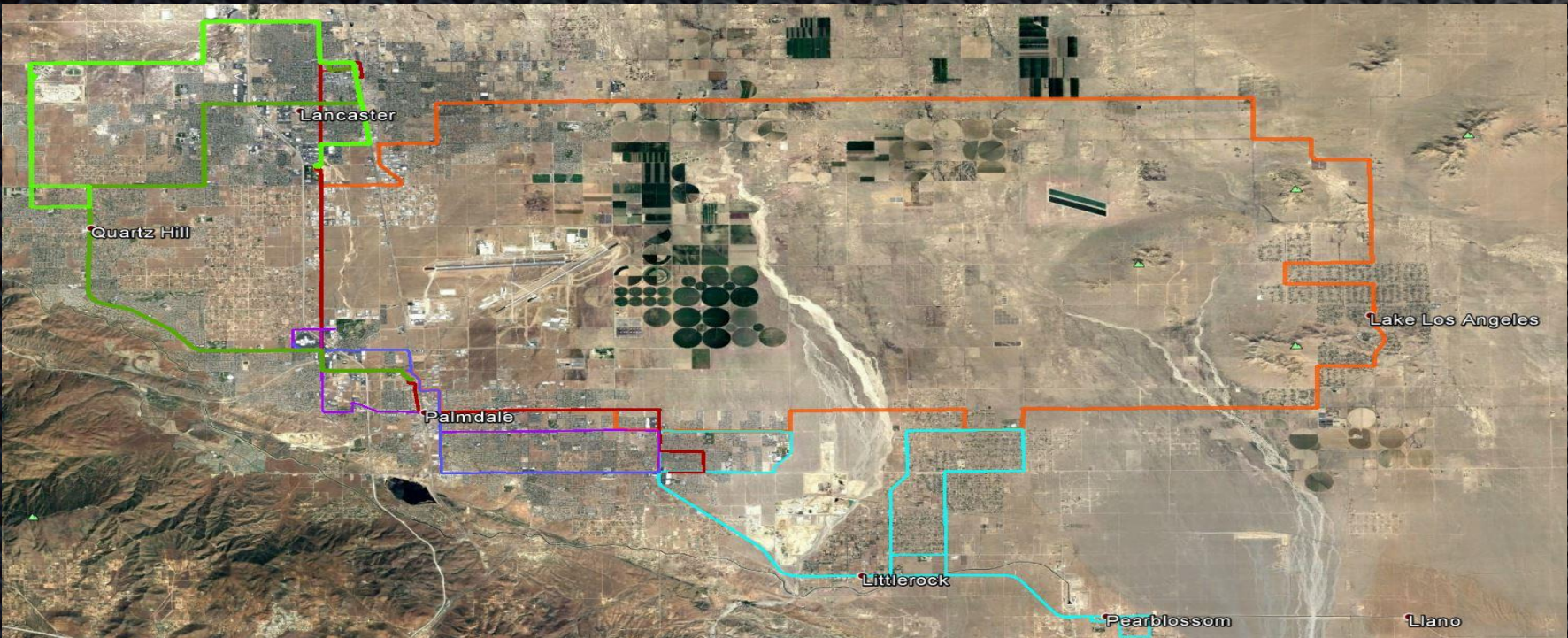


# 1<sup>st</sup> US Fleet 100% Battery Electric | 250kW

In-Route Charging



Route Planning



WAVE 250kW  
Wireless Charging



Depot Charging

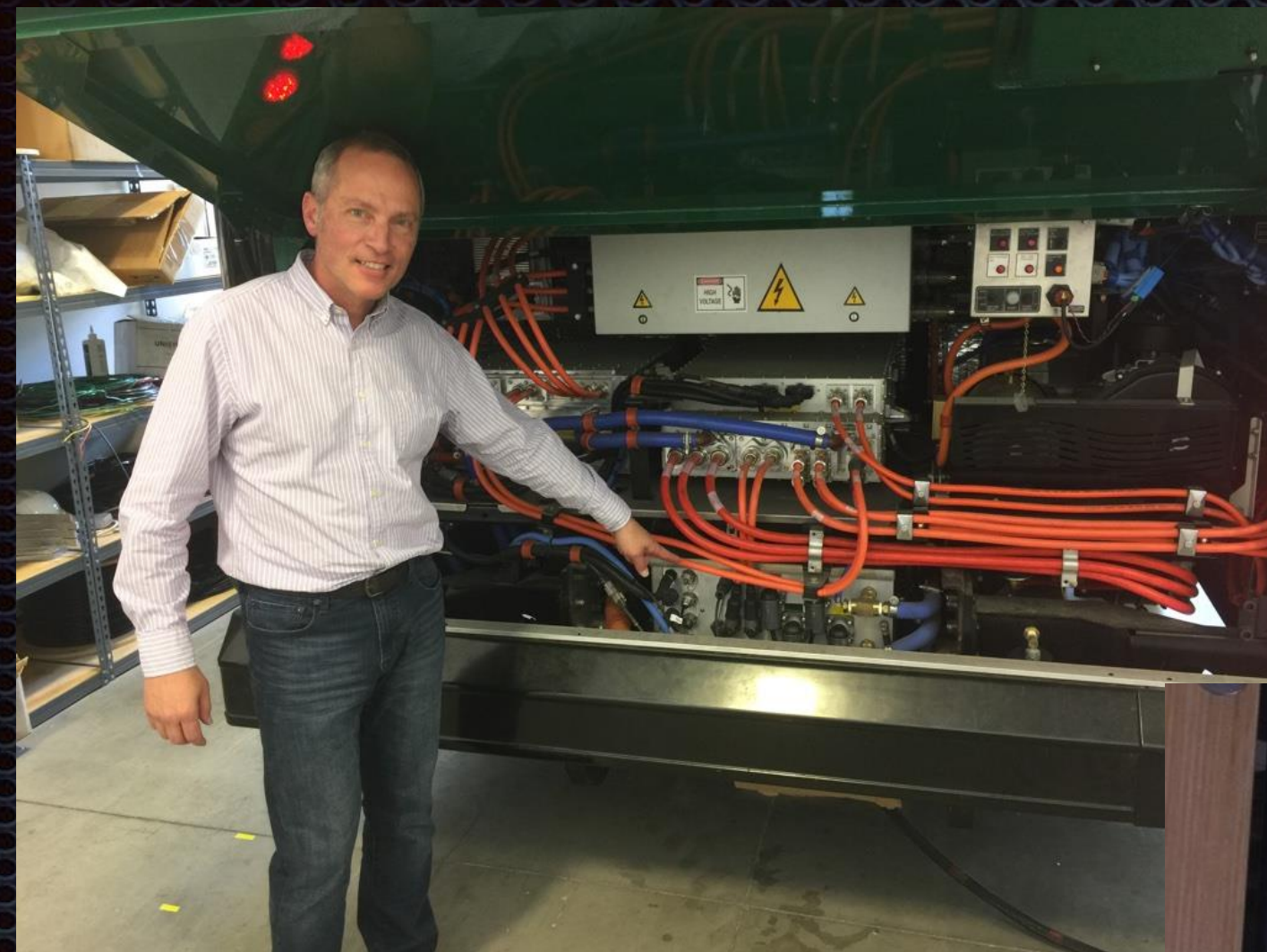


BYD 60ft Artic



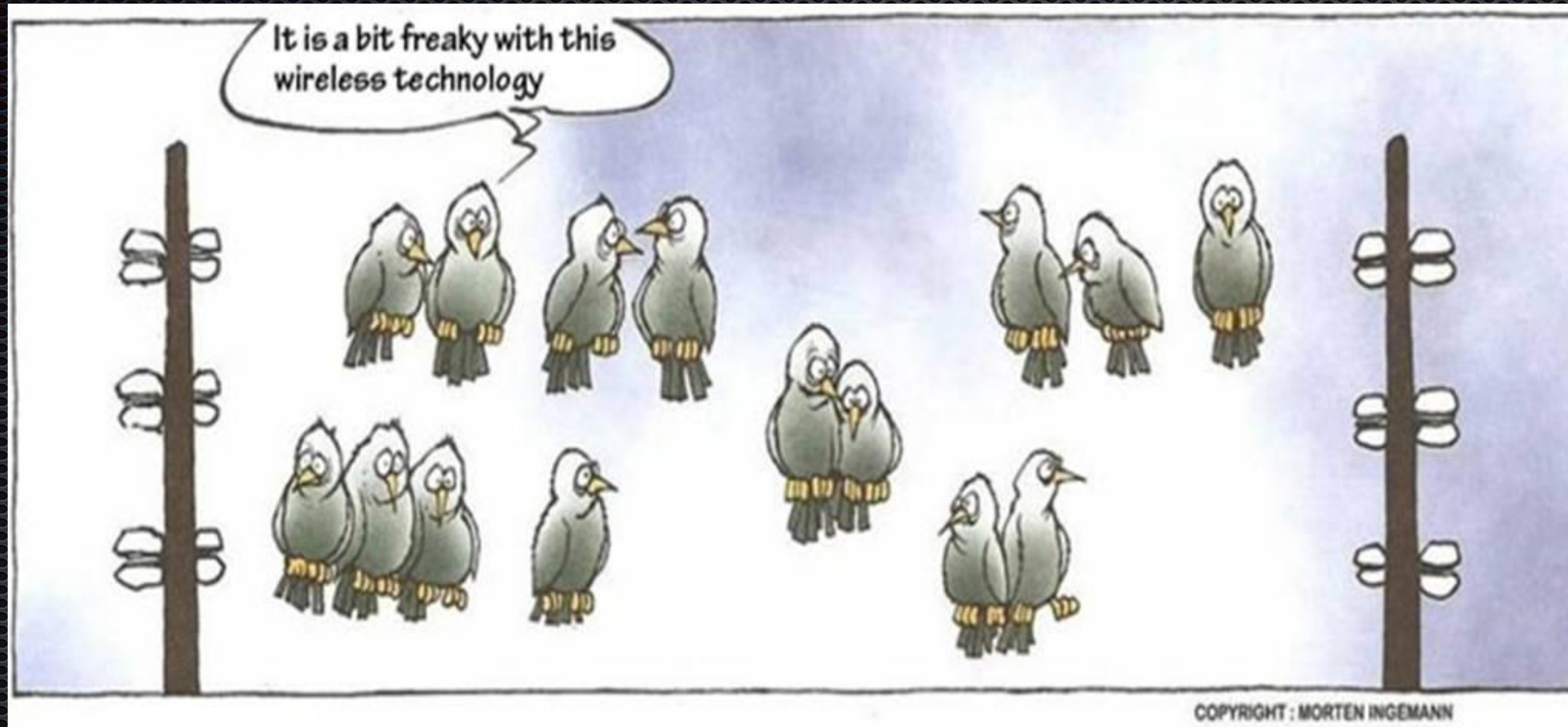


# Full OEM Vehicle Integration





# Wireless | Freaky & Scary?



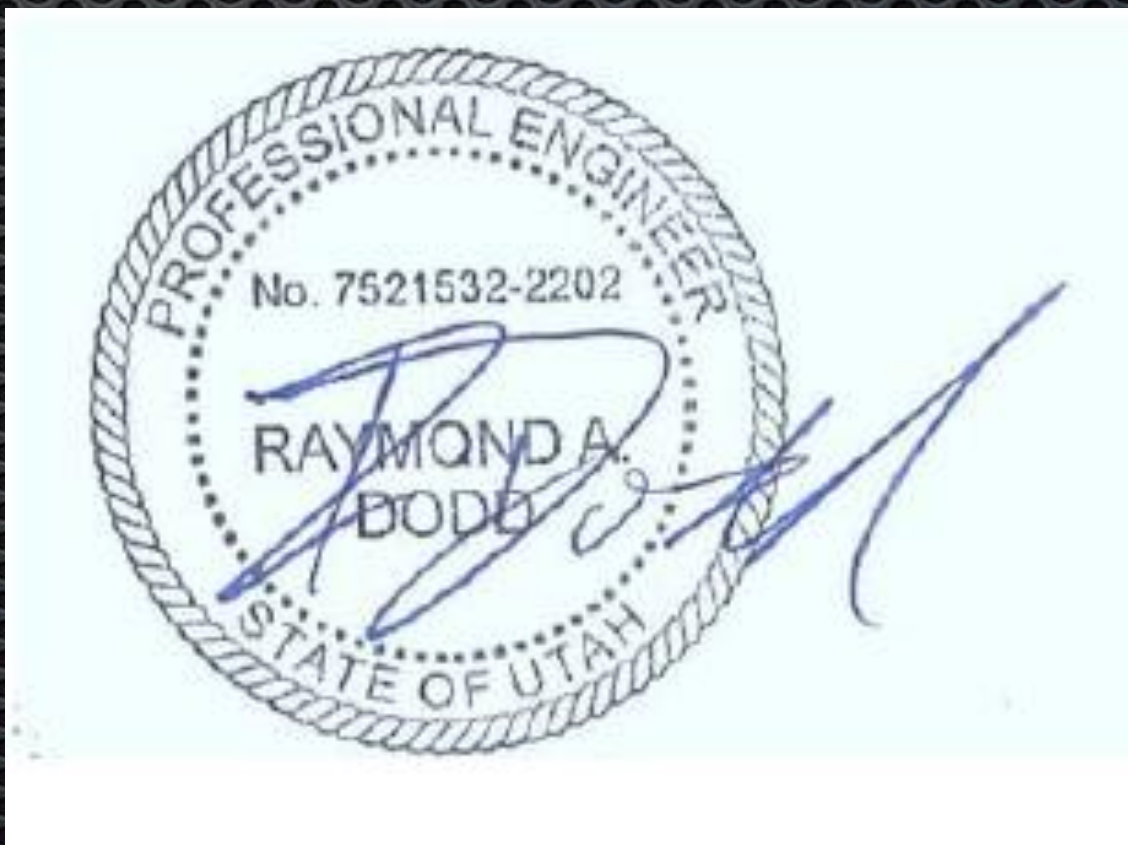


# Product Safety Certifications

## Safety Certification



## Magnetic Field Exposure





# The Plug-In Nightmare!!! | Can Wireless Charging Avoid This?

# Plug-In Around the EV World

## Accepted Plug Types:

**Type C**

Type C or CEE 7/16 electrical plug (aka Europlug) is a two-wire plug that has two round pins. They are used in all countries of Europe with exceptions like the United Kingdom, Ireland, Cyprus and Malta.

CEE 7/16 / Type C plugs:  
Amps: 2.5  
Volts: 110-240  
Hz: 50-60

**Type A**

Type A or NEMA 1-15 electrical plug (or flat blade attachment plug) is an ungrounded plug with two flat parallel pins. Japanese plug can be used in the US but often not the other way around.

NEMA 1-15 / Type A plugs:  
Amps: 15  
Volts: 100 - 127  
Hz: 50-60

**Type F**

Type F or CEE 7/4 electrical plug has two 4.8 mm round pins spaced 19 mm apart and a hole for the socket's male grounding pin. The CEE 7/4 plug is mainly used in Germany, Austria, the Netherlands, Sweden, Finland, Norway, Portugal, Spain and Eastern Europe.

CEE 7/4 / Type F plugs:  
Amps: 16  
Volts: 110-240  
Hz: 50-60

**Type B**

Type B or NEMA 5-15 electrical plug has two flat parallel pins and a round grounding (or earth) pin. The Type B plug is mainly used in the USA, Canada, Mexico & Japan. As with the type A plugs, the American and Japanese versions vary slightly.

NEMA 5-15 / Type B plugs:  
Amps: 15  
Volts: 100 - 127  
Hz: 50-60

**Type I**

The Type I plug has two flat pins in a V-shape as well as a flat grounding pin. A version of the plug, which only has the two flat pins, exists as well. The Type I Plug is mainly used in Australia, New Zealand, Papua New Guinea, China and Argentina.

Type I plugs:  
Amps: 10  
Volts: 120-240  
Hz: 50-60

**Type G**

The Type G electrical plug has three rectangular blades in a triangular pattern and has an incorporated fuse for smaller appliances such as a computer and 13 amps for heavy duty appliances. This plug is mainly used in the United Kingdom, Ireland, Cyprus, Malta, Malaysia, Singapore and Hong Kong.

Type G Plugs:  
Amps: 13  
Volts: 110-240  
Hz: 50-60

## Common Connectors Types:

**SAE J1772**

The SAE J1772-2009 connector is designed for single phase electrical systems with 120 V or 240 V AC and is now used in both America and Japan. The rated AC maximum voltage is 250 V. The connector has two pins, with three different pin diameters. (AC Line 1, AC Line 2, Ground Pin). Priority Detection, Control Pilot, DC power +, DC power -.

Connector: SAE J1772  
Current: 32 A  
Voltage: 220 - 240 V AC DC (supercondensator)  
Power: 3.3 kW - 14.3 kW (maximum current)  
Charge Mode: 1 - 3

**GB/T 20234.2-2011 AC**

The GB/T 20234.2-2011 AC Connector is designed for alternating current (AC) electrical systems with 220 V or 400 V AC and is now used in China. The connector has seven pins, with three different pin diameters. (AC Line 1, AC Line 2, AC Line 3, Neutral, Positive Detection, Priority Detection, Control Pilot, Grounding).

Connector: GB/T 20234.2-2011 AC  
Current: 32 A  
Voltage: 220 - 440 V AC DC (supercondensator)  
Power: 3.3 kW - 14.3 kW (maximum current)  
Charge Mode: 1 - 3

**SAE J1772 DC CCS Combo 1 Type 1**

The SAE J1772 Combined Charging System (CCS) is designed for direct current electrical systems with 200 V or 500 V AC and is now used in both America and Japan. The 17 pin version connector has two pins, with three different pin diameters. (AC Line 1, AC Line 2, Ground Pin). Priority Detection, Control Pilot, DC power +, DC power -.

Connector: SAE J1772 Combined Charging System Type 1  
Amps: 200 A  
Volts: 200 - 500 V DC  
Current: 150 kW (maximum current)  
Charge Level: 3 - 4

**Chademo Yazaki**

The latest Chademo connector is designed for direct current electrical systems with 250 V or 400 V AC and is now used in both Europe countries and Japan. The 17 pin version connector has two pins, with three different pin diameters. (Priority Detection, Control Pilot, DC power +, DC power -). The pins are used, needs to change color. Please the regular, Please the colorless, priority detection, communication +, communication -, Control Pilot (GND).

Connector: Chademo Yazaki  
Amps: 100 - 120 A  
Volts: 500 V DC  
Current: 60 kW (maximum current)  
Charge Level: 3  
Charge Mode: 4

**IEC 62196 Type 2**

The IEC 62196-2 connector is designed for single phase electrical systems ranging from 250 V or 400 V AC and is now used in Europe. The 65 pin version connector has seven pins, with three different pin diameters. (AC Line 1, AC Line 2, AC Line 3, Neutral, Priority Detection, Control Pilot, Grounding).

Connector: IEC 62196-2 Mennekes Type 2  
Current: 63 A Single to Three-Phase  
Voltage: 250 V - 440 V Single to Three-Phase  
Power: 43 kW (maximum current)  
Charge Mode: 1 - 3

**GB/T 20234.3-2011 DC**

The GB/T 20234.3-2011 DC Connector is designed for Direct Current (DC) electrical systems with 400 V or 750 V AC and is now used in China. The connector has seven pins, with three different pin diameters. (AC Line 1, AC Line 2, AC Line 3, Neutral, Positive Detection, Priority Detection, Control Pilot, Grounding).

Connector: GB/T 20234.3-2011 DC  
Current: 200 A  
Voltage: 400 - 750 V DC  
Power: 13 kW - 185.5 kW (maximum current)  
Charge Mode: 1 - 3

**EU DC CCS Combo 2 Type 2**

The IEC 62196-3 Type 2 Combined Charging System (CCS) Combo 2 Connector is designed for direct current electrical systems with 200 V or 500 V AC and is now used all over the world. The connector has two pins, with three different pin diameters. (AC Line 1, AC Line 2, Ground Pin). Priority Detection, Control Pilot, DC power +, DC power -.

Connector: IEC 62196-3 Type 2  
Current: 200 A  
Voltage: 200 - 500 V DC  
Power: 13 kW - 170 kW (maximum current)  
Charge Mode: 1 - 4

**Telsa Charging**

The Tesla connector is designed for single phase electrical systems ranging from 110 V AC - 240 V AC or 500 V DC. The connector has two pins, with three different pin diameters. (AC Line 1, AC Line 2, AC Line 3, Neutral, Priority Detection, Control Pilot, Communication +, Communication -).

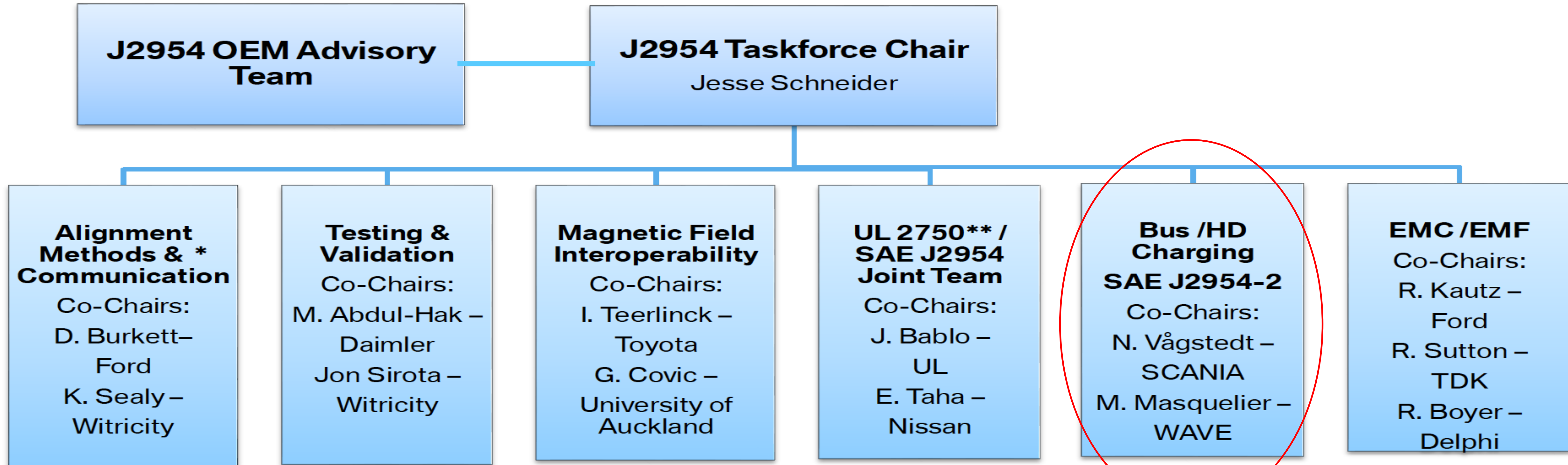
Connector: Tesla  
Current: 32 A - 60 A - 200 A Single to Three-Phase  
Voltage: 110 V AC - 240 V AC - 500 V DC Single to Three-Phase  
Power: 120 kW - 19.25 kW - 120/135 kW  
Charge Level: 1 - 3  
Charge Mode: 1 - 4

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# SAE J2954 Taskforce Structure: OEM/ Supplier Co-Chairs



## Liaisons:

ISO\*\*/IEC : J. Sirota (Witricity)/ I. Teerlinck (Toyota)

SAE EMC Committee: R. Kautz (Ford) / R. Boyer (Delphi)

AAMI/ ANSI/CISPR: R. Boyer (Delphi) / Sutton (TDK RF)

FCC/FDA: Schneider / Kautz / Sutton / Boyer

\*In Coordination with ISO & SAE Hybrid Communications & DSRC Committees

\*\*SAE J2954 MOU with UL established. ISO MOU under discussion.



# Event Notification | Real-Time SOC & Consumption

## Data Monitoring:

- ✓ Real-Time SOC
- ✓ kWh Capacity (Range)
- ✓ Real-Time Consumption
- ✓ Battery Depth of Discharge



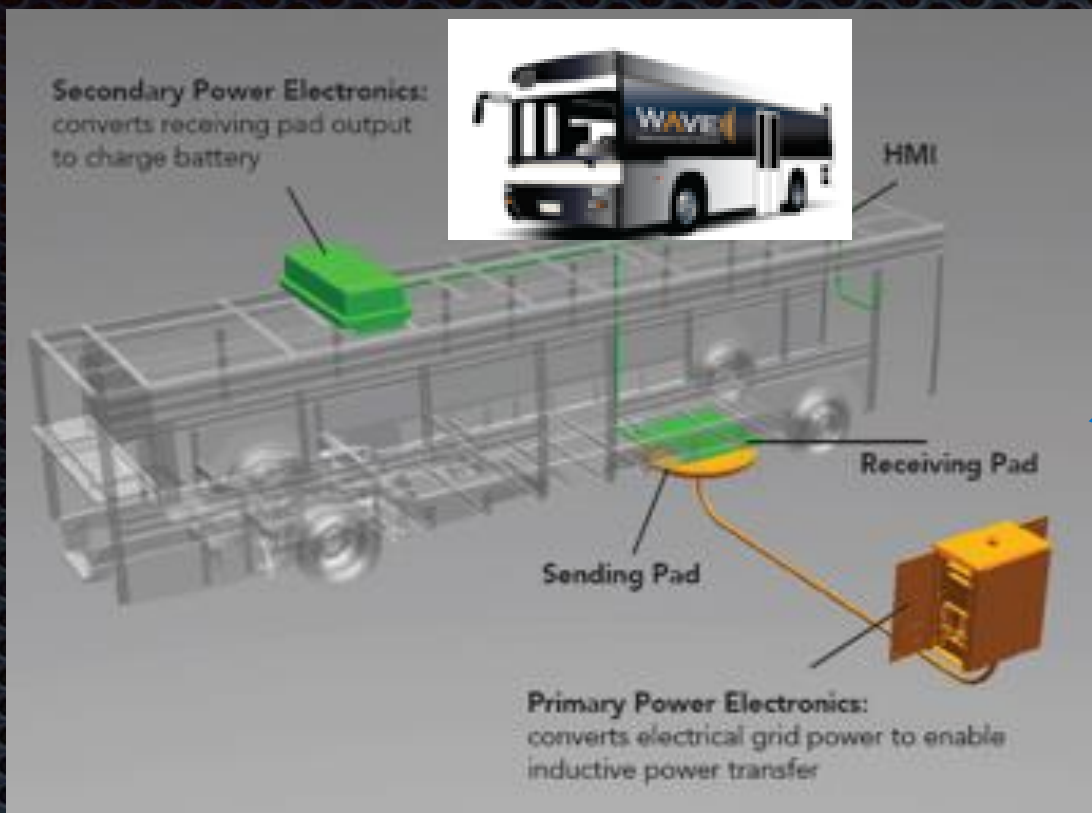
## Event Notification:

- ✓ SOC Drops below Threshold
- ✓ Can't Make it Back to Depot
- ✓ Driver Differences
- ✓ Battery Capacity Fade





# Energy Storage Balance | A Juggling Act



Haul It



Feed It



Store It



# Technology Costs | Wireless vs. Wired

- Inductive vs. Conductive
- Unknown Costs of Conductive Charging
- Case Study:
  - Connection Time
  - Cable Damage
  - Connector Failures
- Cable Theft



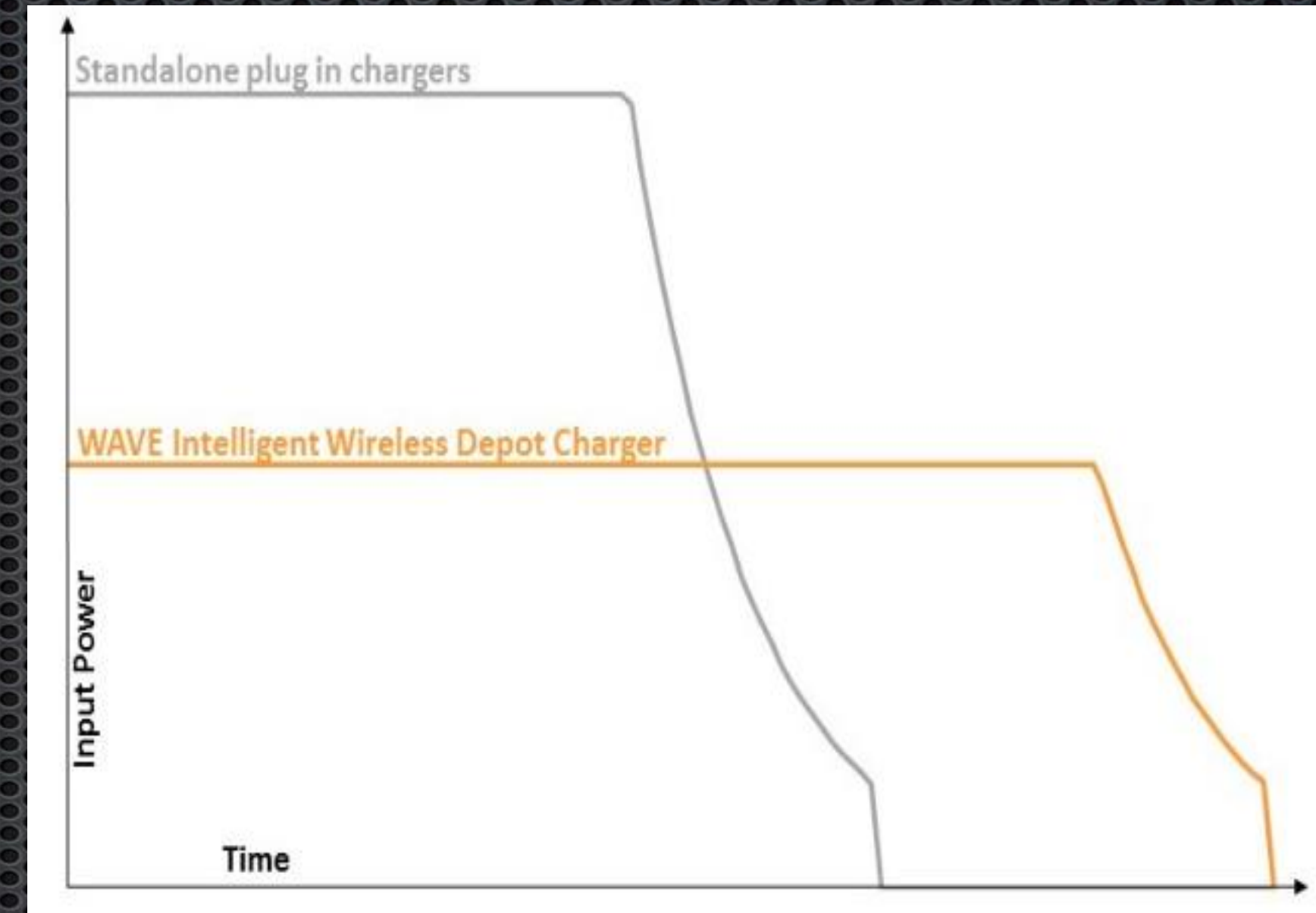


# Wireless Depot Charging | No More Plugs

No Plugs



Charge Smart



- Convenience of in-route wireless charging at the depot
- 50-250kW per bus
- No connectors or cables to maintain, no HVDC to handle.
- One Depot Charger can serve up to 12 buses

- Eliminates need for multiple on-board chargers
- Intelligent charging levels utility loads to reduce peak demand
- Just in time charging maximizes battery life
- Adjustable loading to avoid paying peak electricity rates



# Interoperability | Shared Charging Infrastructure



Interoperability

