

# Momentum Dynamics

Automatic Fast Charging of All Types of Electric Vehicles

Ruter Introduction. 08.Nov.2021



All types of light commercial,  
municipal and utility vehicles  
Delivery Operations



All sizes of electric buses  
Public Transit Operations



Passenger vehicles  
Taxi Operations

All classes of electric trucks  
Bulk Delivery Operations



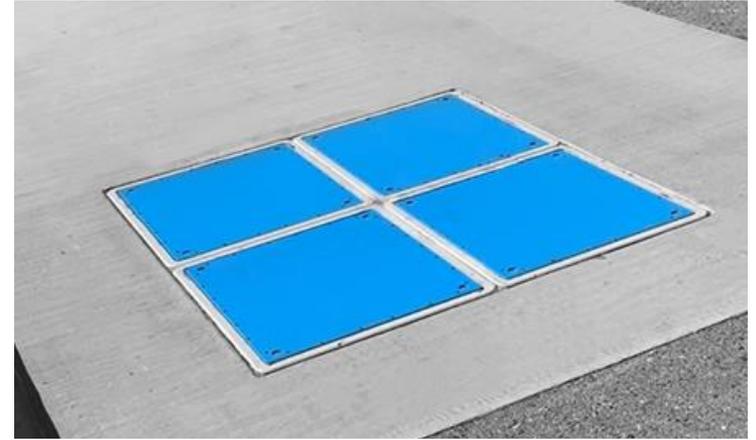
Free of cables, plugs and electric terminals, we  
could offer a solution for electric boats  
Port / Ferry Operations

# Momentum Dynamics Corporation - Overview

- Founded in 2009, privately held, based in Malvern, Pennsylvania
- Global leader in **high-power wireless charging technology**
- The only company with high-power solutions in multiple markets (using one common technology that can be fit to any vehicle):
  - Buses/Transit
  - Automobiles/Taxis
  - Trucks/Vans/Light commercial
  - Industrial Vehicles
- Modular systems, scalable to customer specifications
- Turnkey system installation

## Sustainability Goals

- Opportunistic charging facilitates the use of **significantly smaller traction batteries** (reduced cost, rare materials use, CO2 footprint, with improved efficiency)
- **Increased and predictable asset utilisation**, on closed loop transit systems
- Battery **life increased up to 8.5 times** through optimised charging\*
- **Safer** cable-free environment, no moving parts, and **vandal-proof design**



CARTA 200kW  
Chattanooga, TN



Link Transit 200kW  
Wenatchee, WA



NREL 25kW  
Golden, CO



RTA 50kW  
Howard County, MD

# Key Features and Benefits

## Economic Features



### Lowest Total Cost of Ownership

Low acquisition, installation, O&M costs in comparison to alternatives



### Efficient

Energy efficiency is more than 90%, better than most conductive chargers



### Easy to Maintain

No moving parts, very little maintenance



### Interoperable and Sharable

Multiple vehicle types and power levels use the same pads

## Operational Features



### Modular and Scalable

Modularity allows for scalability from 50kW to 450kW+ (1-6 pads)



### Automatic and Contactless

Automatic and contactless with non-hackable, anti-theft features



### Meets key standards

Operates under guidelines of FCC, IEEE, UL, ICNIRP, and CE safety standards across power levels



### All-weather

Operates through rain, ice, snow, leaves, mud, and even underwater with no loss of efficiency



### Robust Technology

Key innovations from our expert R&D team



### Seamless

Can be embedded invisibly in public infrastructure and roadways cost effectively



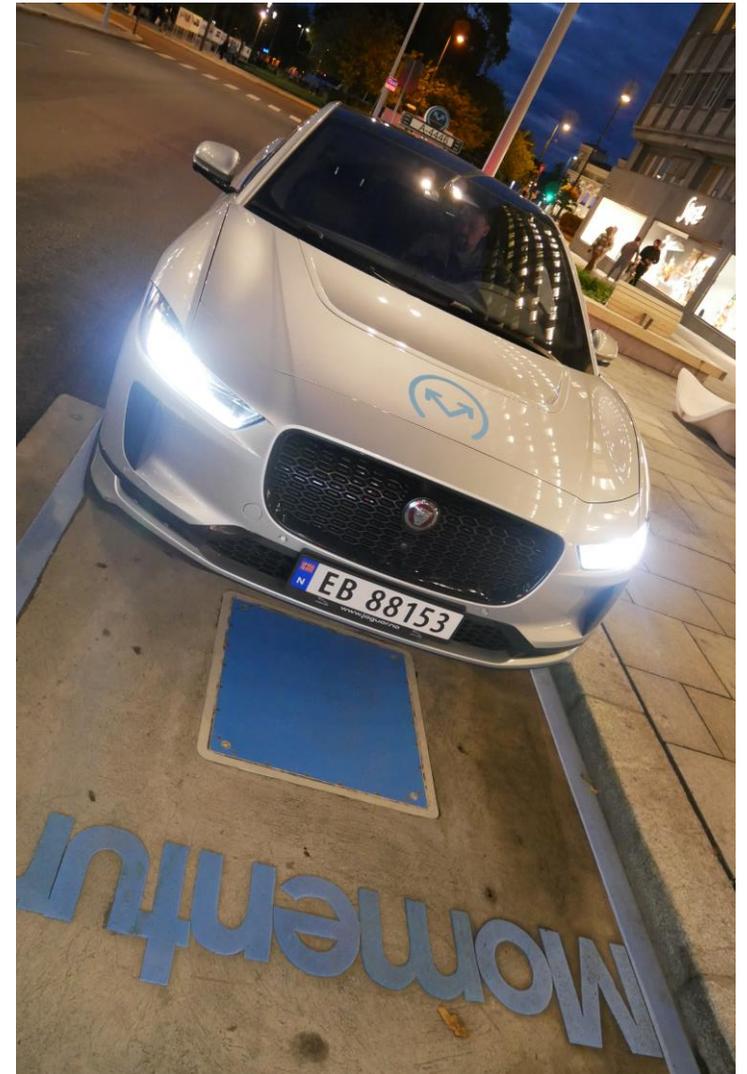
### Wireless Data Link

Patented, secure, ultra high speed, near-field communication for control, data, and billing

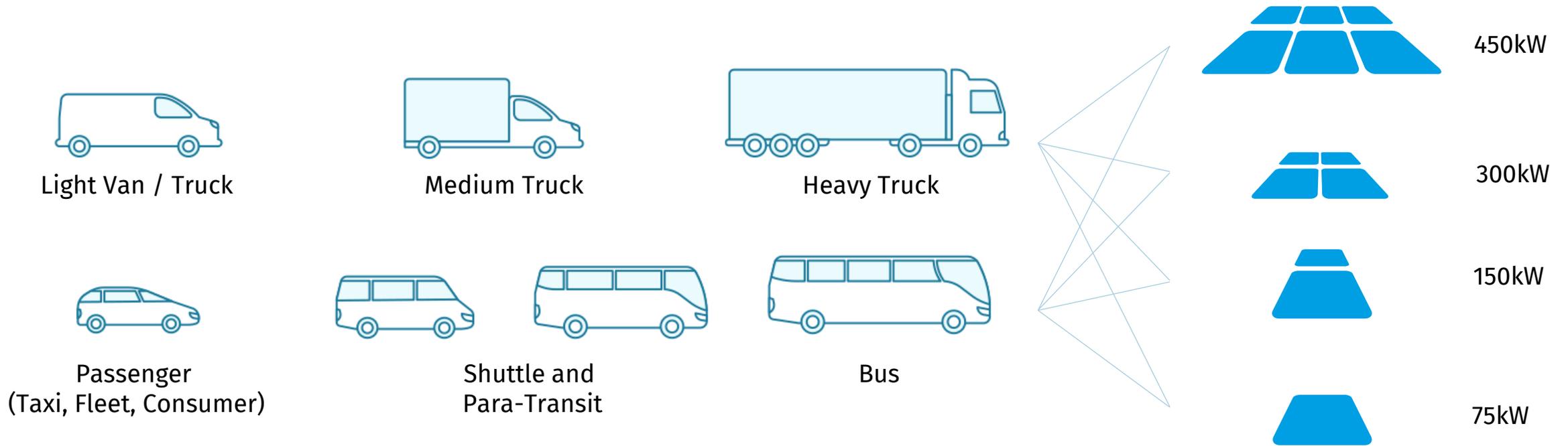


### High Customer Retention

All customers are expanding operations with wireless once pilots are done



# Flexible EV operations with interoperable, automatic charging



**Any vehicle can park over any charger and receive power**

# Momentum's Solution is Modular & OEM Agnostic

## Vehicle Assembly

- Wireless Charging Receivers
- Modular Configuration – up to 6 pads (each is 50kW-75kW)
- Single pad pictured on 2021 I-Pace for Oslo

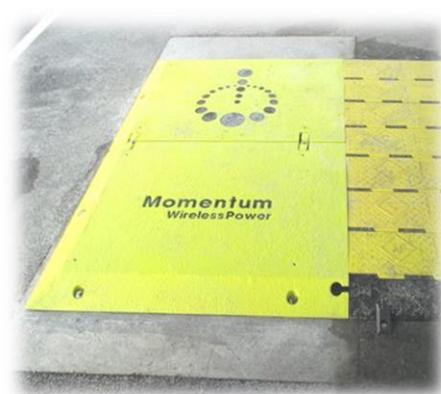


Momentum's modular component design philosophy facilitates:

- Sharing components across vertical markets to achieve scale
- Scaling power levels up/down easily
- Interoperability across vehicle types and power levels, and geometries (e.g., buses, paratransit, commercial vehicles, taxis)



**In-Ground Installation**

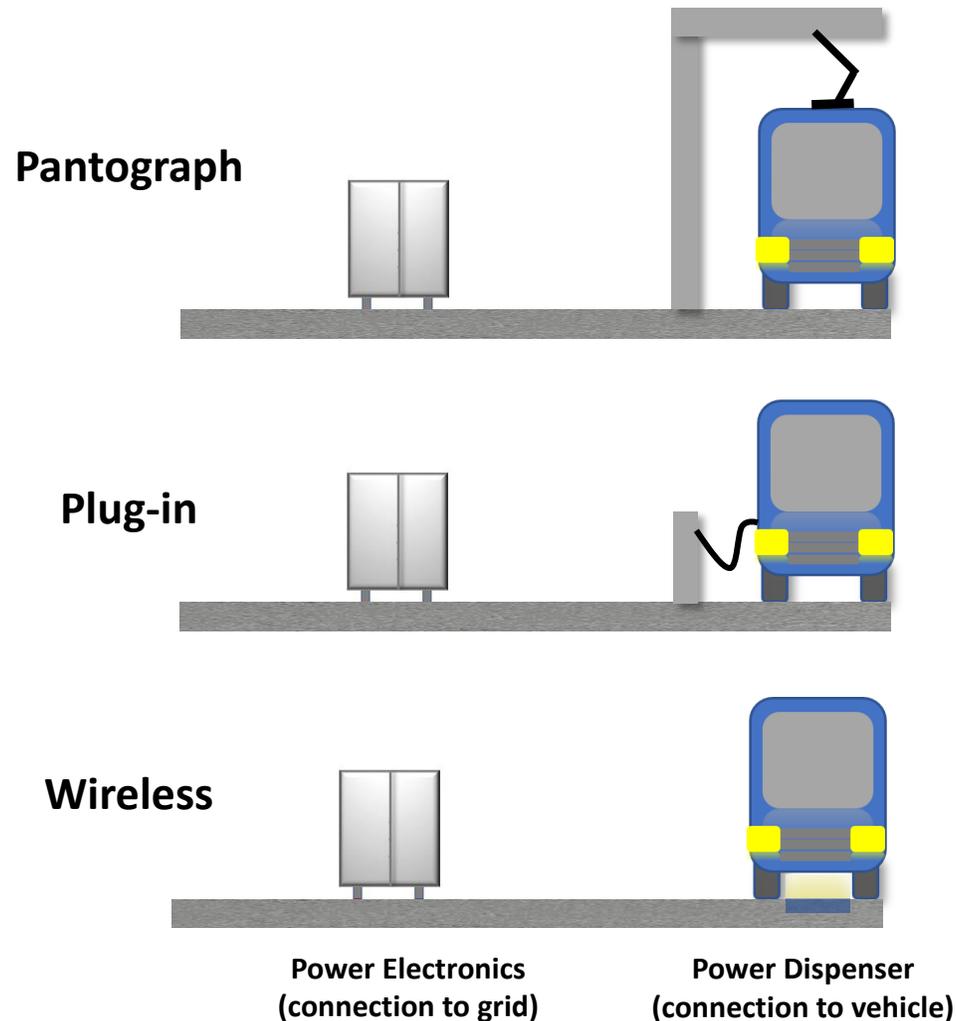


**Surface-Mounted Pads**

## Ground Assembly

- Charging Pads (in ground or surface mounted)
- Power Electronics Cabinet (surface, wall, or vault)

# DC Fast Chargers Operation at ~90-92% Efficiency



- Most losses in all DC Fast Chargers occurs in the power electronics
- Contact based chargers have an additional power transfer step in the power electronics that is not required in inductive systems, i.e., a galvanic isolation transformer for safety
- Inductive systems have shorter runs of resistive copper that contact-based systems (especially vs. pantograph)
- The air gap in inductive systems is NOT a source of loss (99.99% transmission efficiency)
- The net result is that inductive systems are as efficient or more efficient than conductive systems
- **MDC solution efficiency >96%**

# Safety Implications of Wireless Power

## Human/Animal Safety

- Magnetic field is highly localized between the charging plates with less than 0.01% of the magnetic energy reaches the vehicle edge
- Driver and passengers can remain in or around vehicle during charging – vehicle provides shielding
- Field levels detectable in and around the vehicle are well below stringent international standards for magnetic field exposure (see next page)

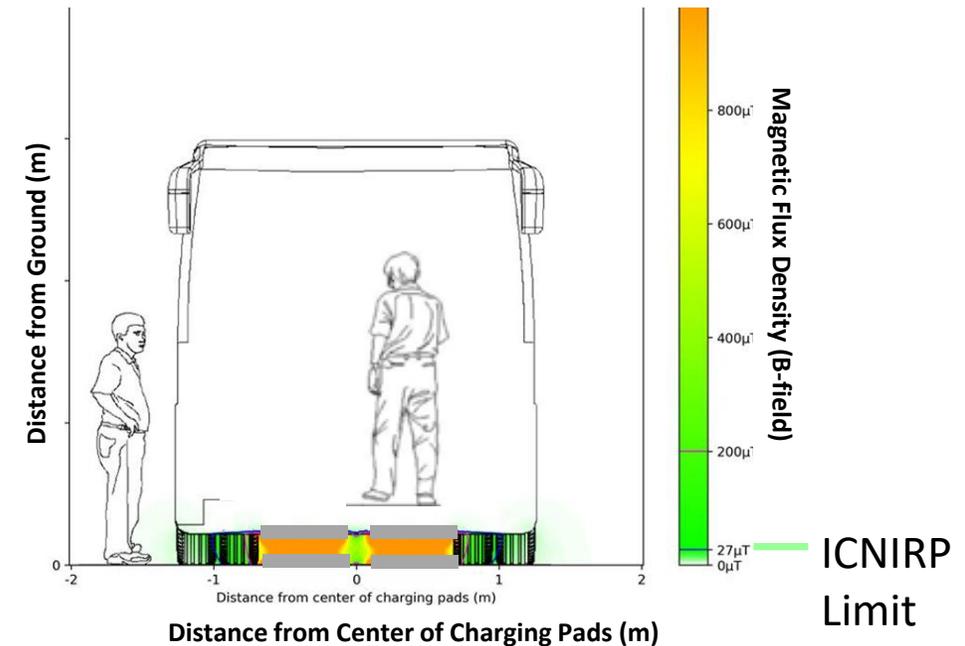
## Device/Signal/Object Interference and Interaction

- Compliant with ICNIRP and IEEE C95 requirements
- Temperature of the metallic frame of the vehicle does not get hot
- At these low field levels, there is no detectable effect on metal plates, prosthetics, or surgical screws

## Safety Protocols

- System has multiple safety interlocks and defaults to “off” if any safety parameter is violated
- System automatically shuts down when foreign metal objects enter the central field
- Full-duplex, constant carrier, and low latency system (10s of microseconds) for fast response to fault or safety events vs. high latency packet-based systems (10s of milliseconds) like Wi-Fi and Bluetooth

## Field Levels In and Around Vehicle



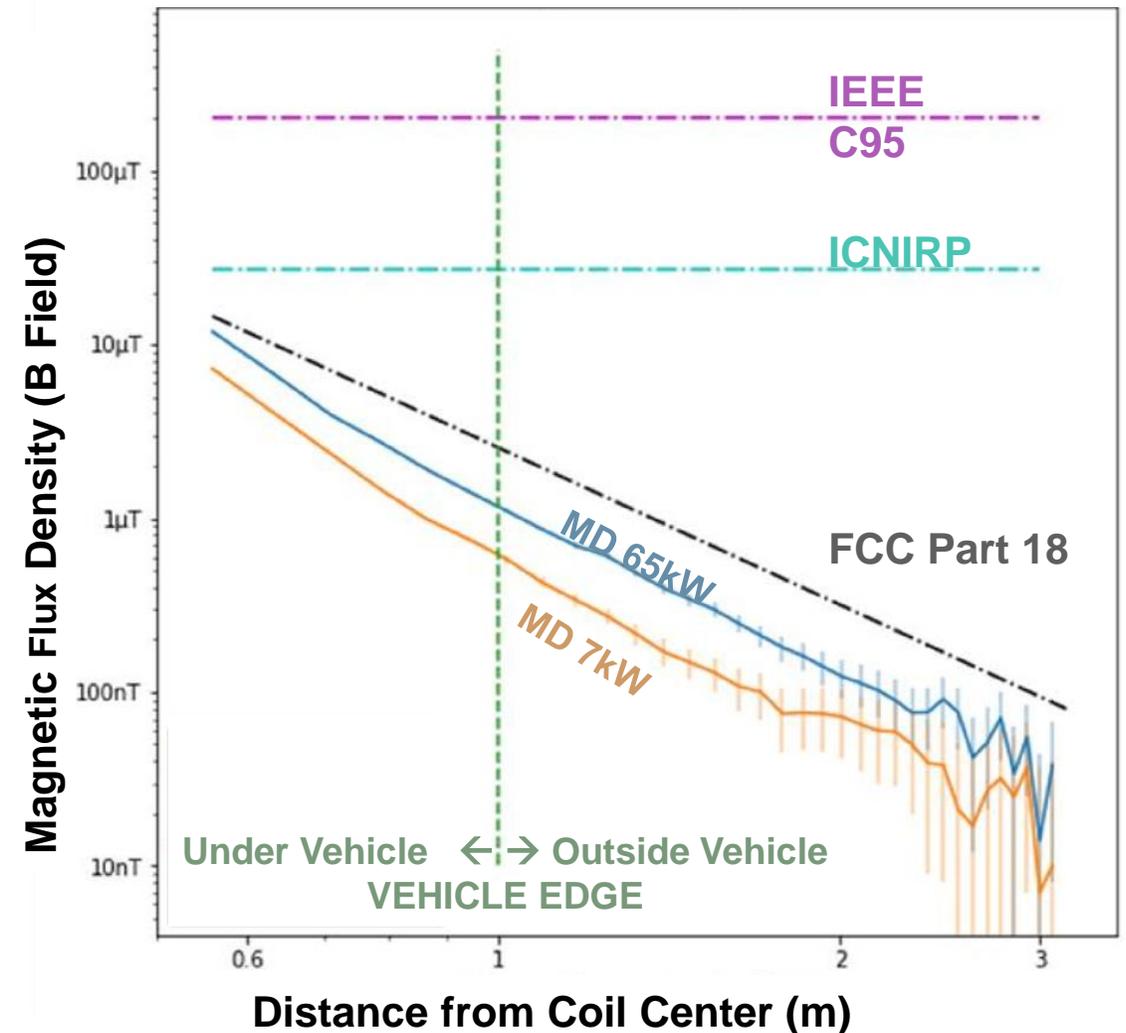
Source: Momentum Dynamics laboratory testing and system modelling

# Momentum's Solution Operates Within Key Standards

- Momentum Dynamics uses a common, modular technology set across all geographies and across vertical markets
- Meets UL requirements & CE requirements
- Meets FCC, IEEE, and ICNIRP industry standards across our operating power range
  - Testing done relative to ground/vehicle pads with ~150 mm magnetic air gap
  - Emission inside the vehicle, between the pads, and around the vehicle are below ICNIRP 1998 standards.
- As power levels increase, stray magnetic field emissions decline even further in Momentum's multi-pad systems (patents pending, IEEE Publication pending)

Source: Momentum Dynamics

MD Field Measurements vs. Guidelines



# Simple System Maintenance

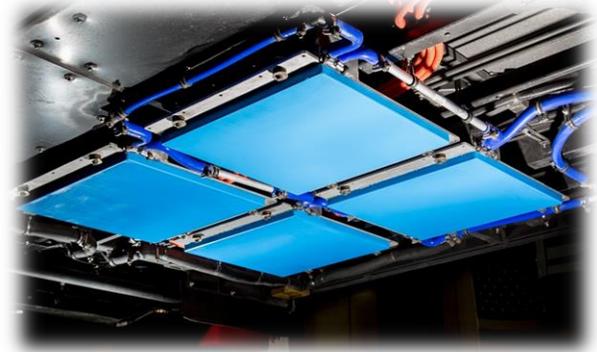
## Power Electronics Maintenance

- Visual inspection of internal components
- Check for no obstructions of fan intake on heat exchangers
- Inspect coil coolant levels, hoses, and leakage
- Electronics are modular and require about 1 hour to swap out



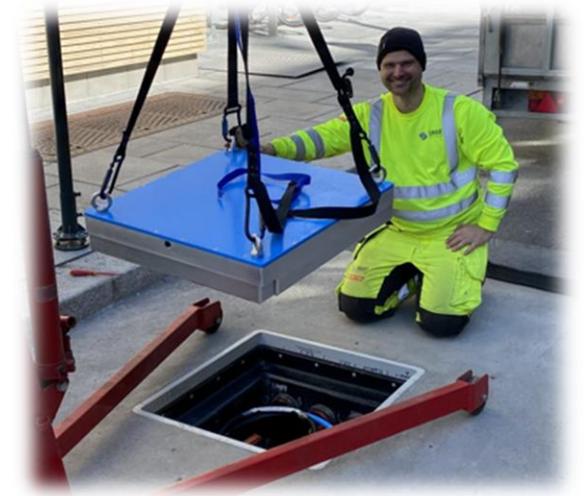
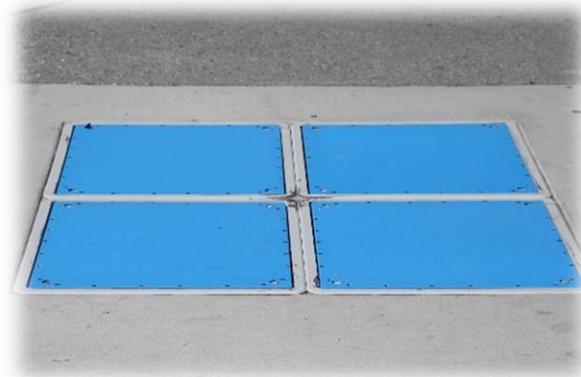
## Vehicle System Maintenance

- Visual inspection of underbody mounting
- Wipe camera lenses during intake
- Inspect power and coolant connections
- Vehicle components are modular and require about 1 hour to swap out



## Ground System Maintenance

- Visual inspection of pads
- In-ground pads are modular and require about 1 hour to swap out



# Wireless 101

## 1. Power Electronics (up to 100' away)



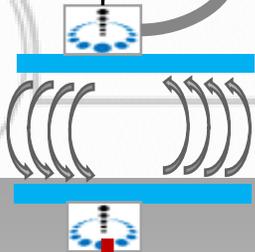
Utility Power



480VAC 60hz

400-800VAC 85khz

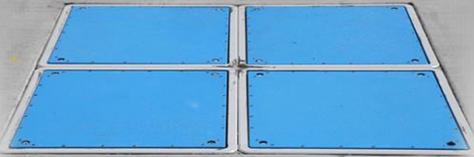
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400VDC to 800 VDC (150 to 450 kW)

Magnetic Field 85khz

## 2. Ground Assembly (1-6 pads)



## 3. Vehicle Assembly (1-6 pads)



BMS

Battery

# Visual and Electronic Alignment Guidance



In-vehicle alignment and power indicator



In-dash "see-through" visual alignment on MY 2021 I-Pace



## Alignment Tolerance

- System operates at full-power, full-efficiency when misaligned up to 20% of pad diameter (+/- ~5in in any direction)
- System adapts to changes in alignment during charging, z-gap changes due to loading/unloading
- System automatically shuts off and give in-cab notification



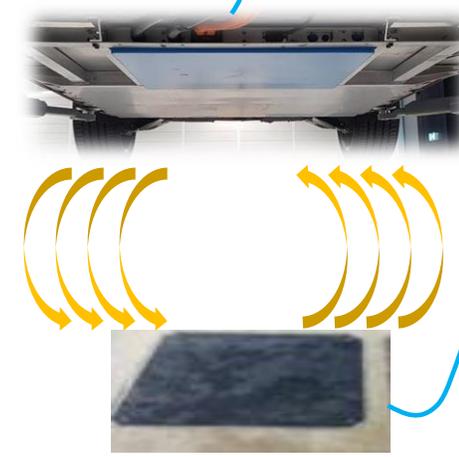
Curb-mounted  
Wheel  
Guide

# Communications, Control, & Commerce

- Communications with BMS via CAN bus command set via low voltage cable
- Interaction with in-vehicle payment account (if available)

Encrypted vehicle to ground ultra high-speed magnetic communications link enables unique vehicle to ground channel for:

- Data transfer of vehicle info
- Control signals
- Safety signals



- Wireless modem in cabinet

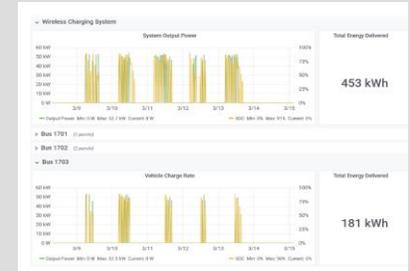


### OCPP 1.6

- Identification
- Authentication
- Control
- Commerce

### MD Network Operations Center

- Performance Dashboard
- Charger system performance analytics/diagnostics



### Charge Point Operator

- Open protocols and API
- Fleet management system integration
- Energy management system integration
- Billing/usage data to facilitate infrastructure sharing and back-end payments

Link Transit 300kW  
Wenatchee, WA



NREL 25kW  
Golden, CO



Link Transit 300kW  
Leavenworth, WA



CARTA 200kW  
Chattanooga, TN



VTA 150kW  
Martha's Vineyard, MA



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