WAVE

Wireless Advanced Vehicle Electrification

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WAVE Company Overview

- Founded 2011 with main office in Salt Lake City, Utah, USA
- Commercial spin-off of Utah State University (USU) with strong partnership
- Deep value and innovation generation in-house
- Team of business and technology driven engineers and specialists

WAVE
Wireless Advanced Vehicle Electrification

UtahStateUniversity

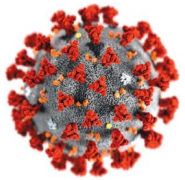
Often only hurdles for electrification are a topic

- Limited range and anxiety

- Expensive and heavy batteries

- Space consuming and poor aesthetics

- Impractical
- "Contagious"



But benefits are a reality with Wireless Charging

WAVE Technology:

- Safe and effective in all weather conditions
- Largest air gap in the industry
- No moving parts
- Efficiency greater than 92%

Output
power to vehicle

Current

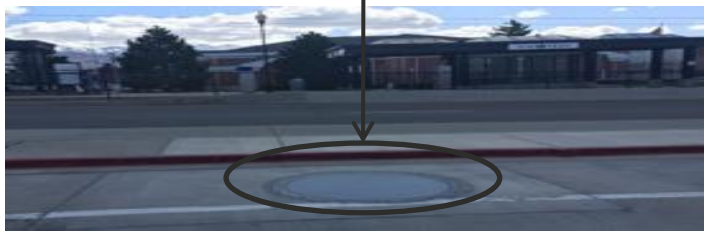
Receiver
Electronics

Magnetic Field

Input
power from grid

Transmitter
Electronics

Current

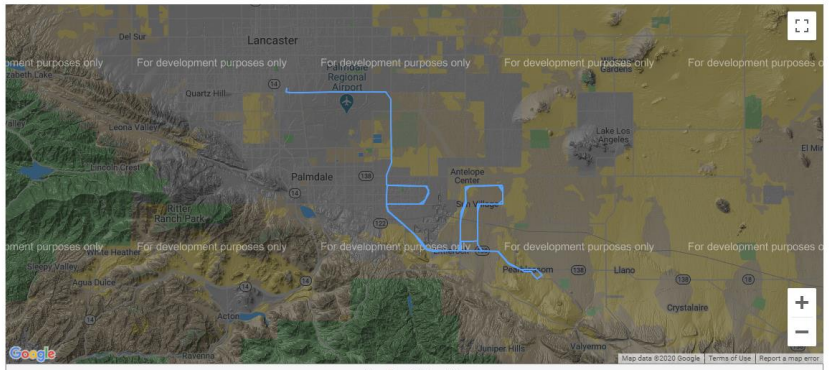


Extending range and supporting operations

Electric Bus + Overnight Plug — 80 - 120 miles

Electric Bus + WAVE 50kW — 100+ added mile

Electric Bus + WAVE 250kW — 300+ added miles



Charging Concept:

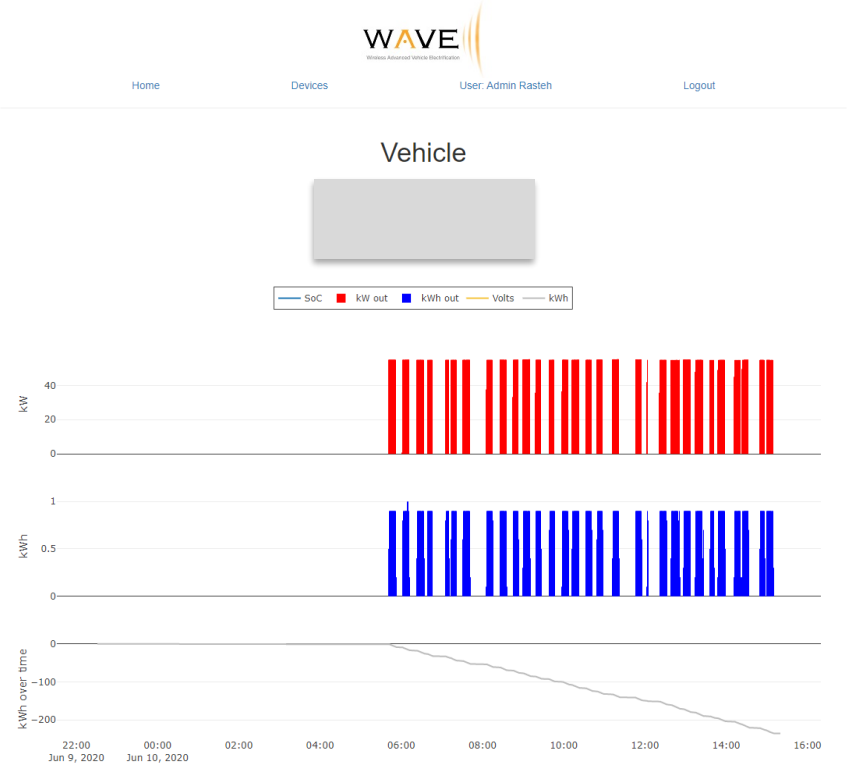
- Find best charger locations
- Increase utilization

Data Monitoring:

- Real-Time Charge Minutes
- Real-Time kWh/day
- Real-Time # Charges

Event Notification:

- Range Extension
- Incur Demand Charges?
- Driver Differences

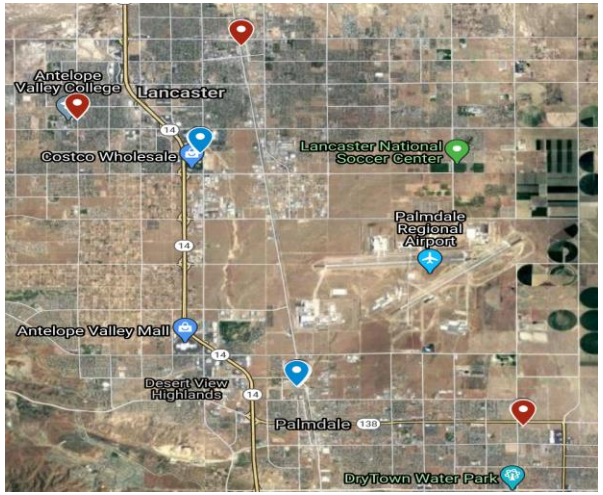


Antelope Valley Transit (AVTA) 250kW

Transit Hub Charging at 250kW

Short Video: https://vimeo.com/331630371
Full Video: https://vimeo.com/375512034

Network of 15 Chargers



- Installed Chargers

- Over 460km of real daily range
- Milestone of over 1MWh in a day on one charger
- About 4 to 7 MWh weekly on individual charger

Invisible and safe infrastructure

Wireless Charging

- Safe For Pacemakers
- Fast Ramp to Full Power
- Safe Shut Down

Underwriters Laboratories Inc.®

SAE INTERNATIONAL

ISO International Organization for Standardization

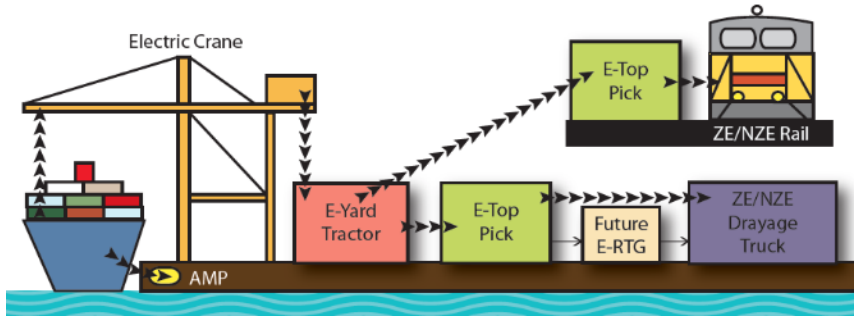
WAVE Wireless Advanced Vehicle Electrification

WBCT Port of Los Angeles | 125kW

Diesel (current)

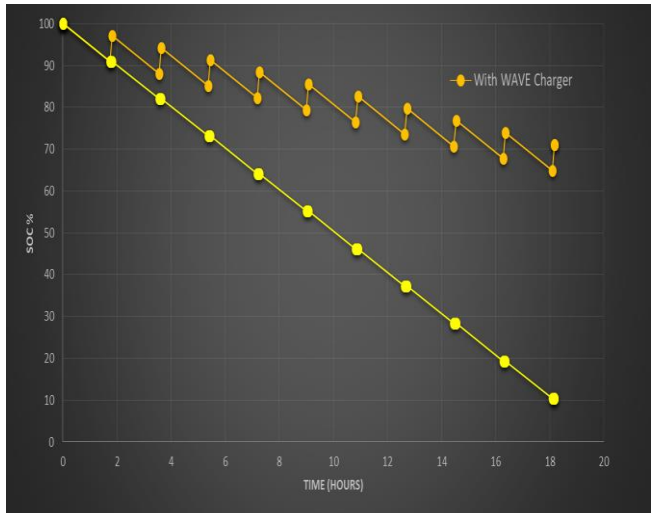
WAVE

- 12 **WAVE 125 kW** wireless chargers will be deployed at the Port of Los Angeles
- Ten Class-8 Yard Trucks
- Maintains Same Duty Cycle as Diesel
- Smaller footprint than diesel
- Battery Energy Storage

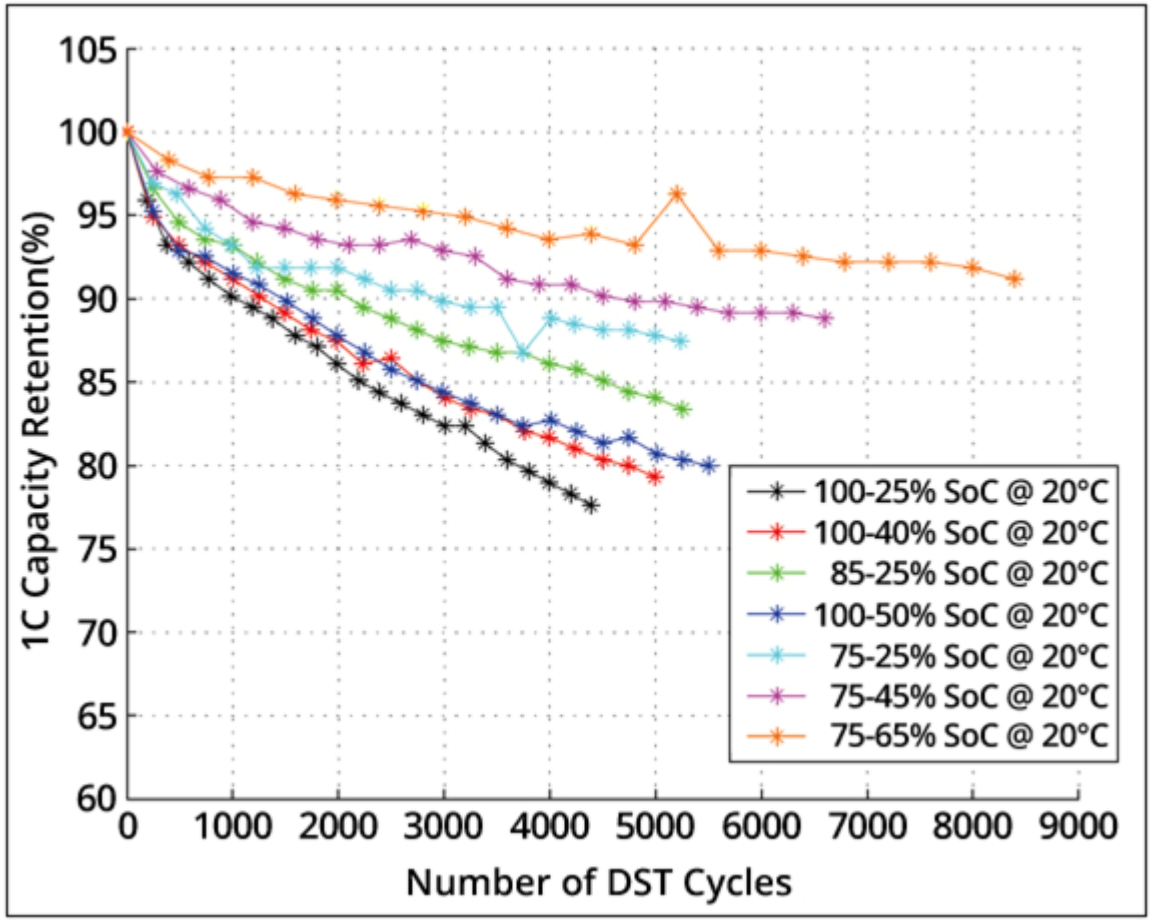


Extending battery life and reduce battery size

Capacity loss of Li-ion as a function of charge and discharge cut-off points

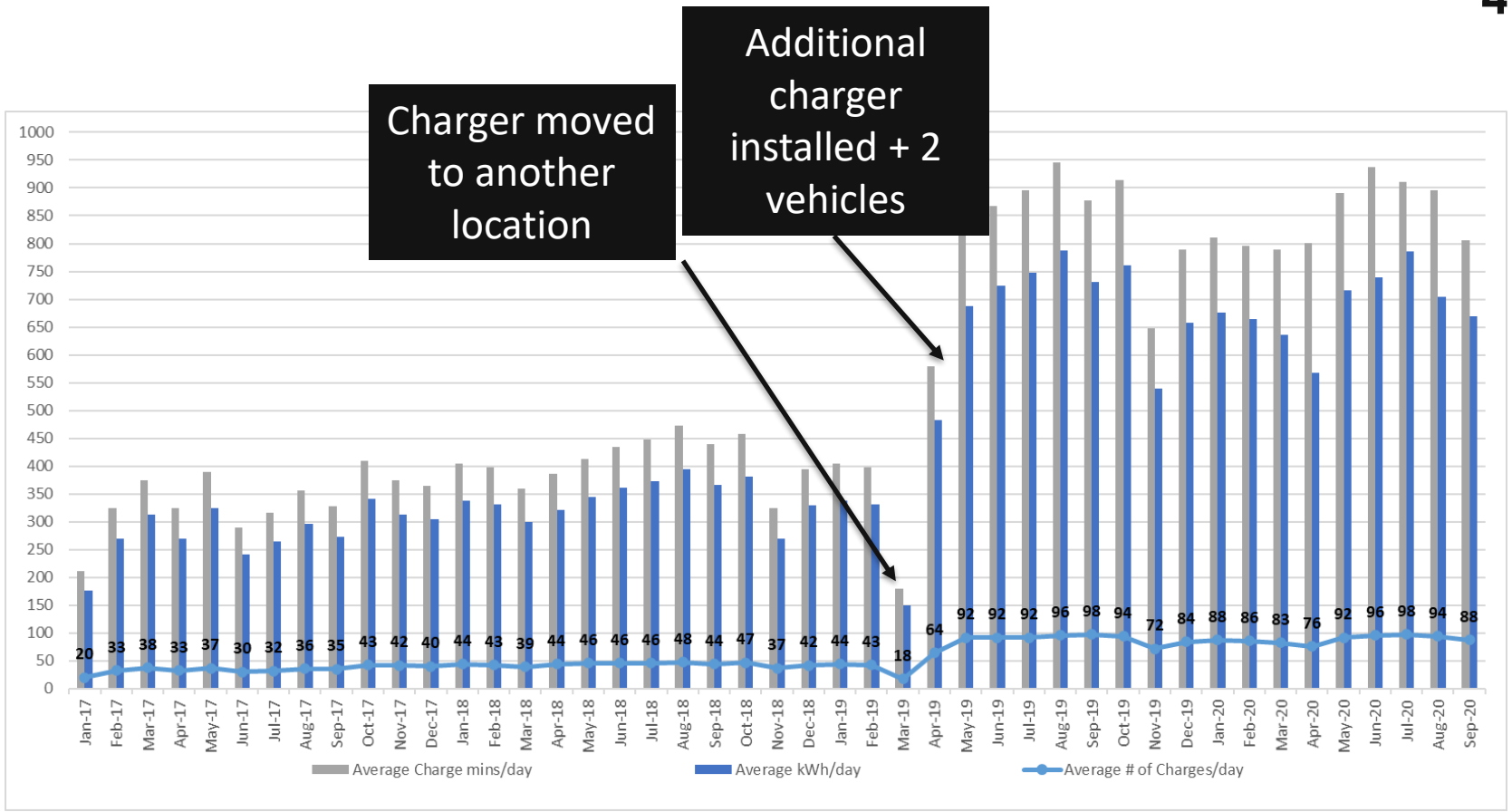


Limiting a full charge and discharge prolongs battery life



Source: Xu, Bolun & Oudalov, Alexandre & Ulbig, Andreas & Andersson, Göran & Kirschen, D.s. (2016). Modeling of Lithium-Ion Battery Degradation for Cell Life Assessment. IEEE Transactions on Smart Grid. 99. 1-1. 10.1109/TSG.2016.2578950.

Over three years of wireless bus charging

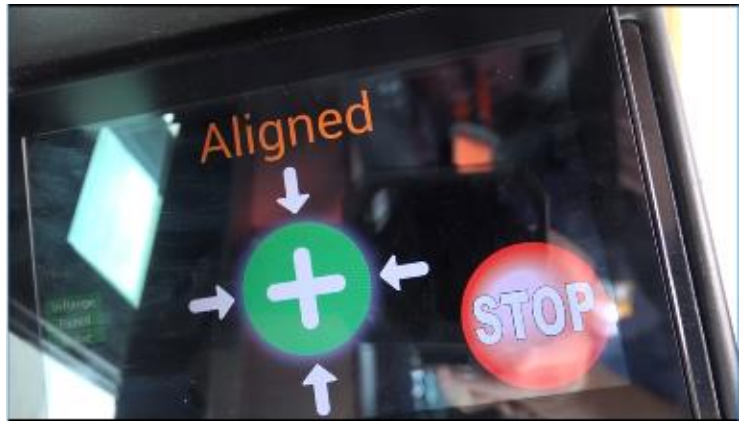


4 Years Continuous Operation

- 16 hours of operation daily
- 7 days a week
- ~618MWh total power delivered
- Additional charger installed
- 8 BEBs – from Gillig
- Zero Maintenance

Hassle free and zero touch

- Fully Automated
- Zero Driver Intervention



Easier than fueling an ICE

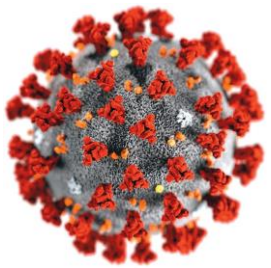
No connection time

No cable damage

No connector failures

No cable theft

No cleaning



Port of Los Angeles | 250kW + 380kW

- **WAVE 250 kW** wireless charger
- Electric Top Loader Infrastructure

HYSTER-YALE GROUP

FENIX MARINE SERVICES

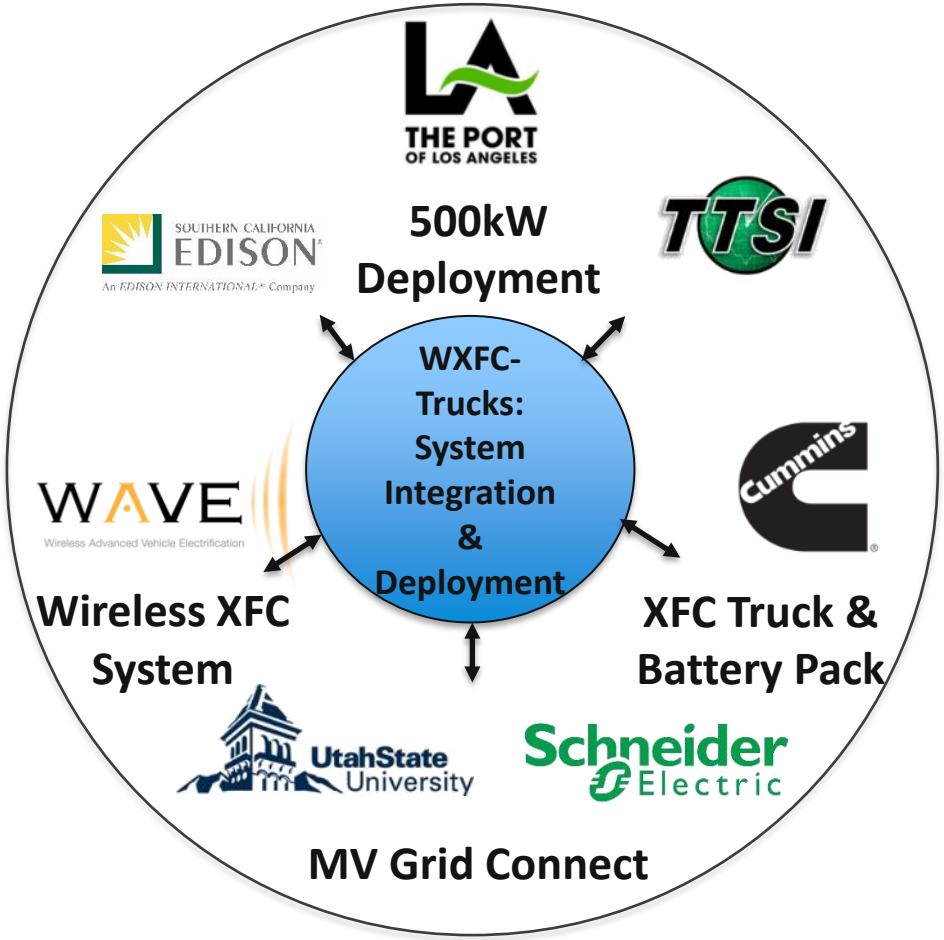
- **WAVE 380 kW** system
- HYG 52-ton Container Handler
- Maintains Same Duty Cycle as Diesel

CALIFORNIA CLIMATE INVESTMENTS
Cap and Trade Dollars at Work

HYSTER-YALE GROUP

WAVE Wireless Advanced Vehicle Electrification

WAVE & DOE Drayage Trucks | 500kW



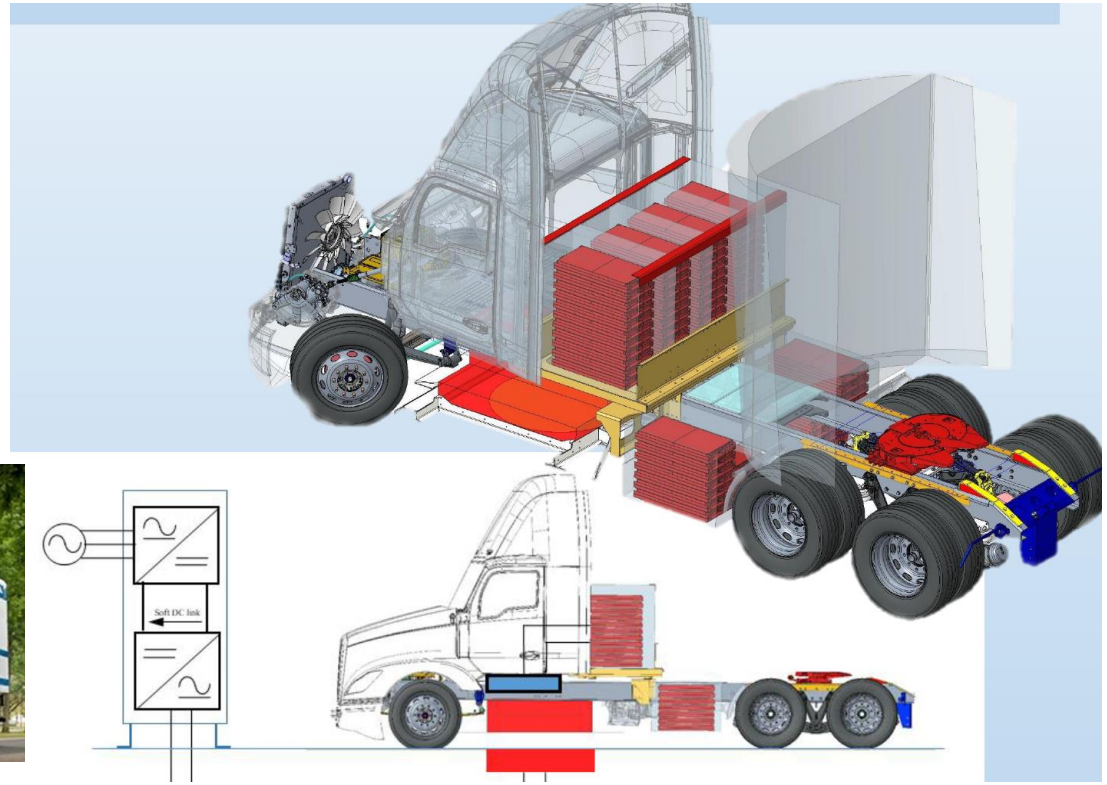
- 500kW extreme wireless fast charger
- 2 all-electric class-8 drayage trucks

WAVE
Wireless Advanced Vehicle Electrification

WAVE & DOE Long Range BEV | 1MW

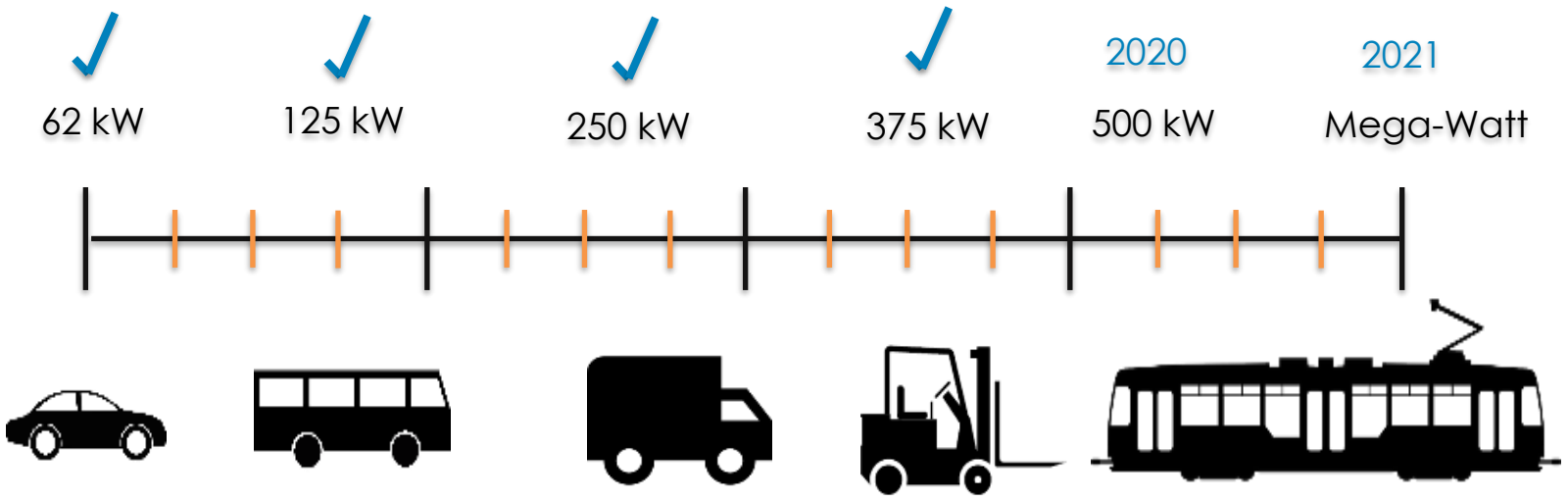
About 547km per day

Long-Range class 8 BEV with Megawatt Wireless Charging



WAVE | Scalable Platform also in other applications

- WAVE scaling technology to support 1MW wireless charging, first in the industry!



Interoperability | Battery Standards

WAVE Wirelessly Charges Buses From Multiple OEMs On The Same Charger

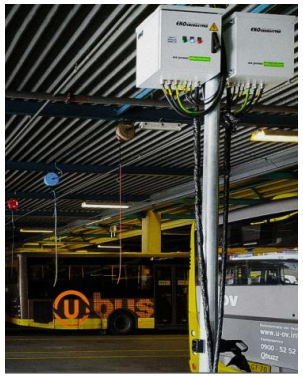
Supports all battery chemistries – compatible with a full range of battery pack voltages

Space is More Valuable at Depot

- Often no room to grow
- Power at site may be limited
- Managing the fleet especially becomes more relevant
- Operation cost are scaled at depot and have a higher impact (plugging 1 EV compared to 100 EVs)

Usual Depot Charging Solutions Have Common Issues

Depots for electric busses



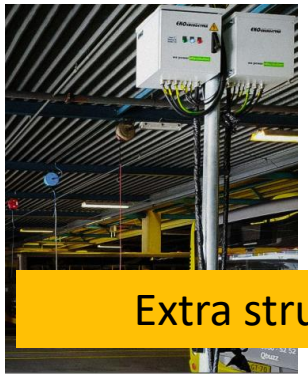
Depots for electric trucks

Usual Depot Charging Solutions Have Common Issues

Depots for electric busses

Extra building constructions

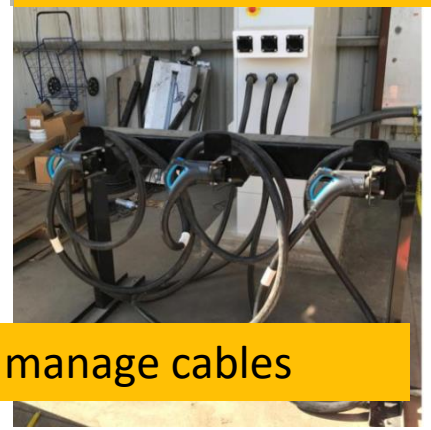
Inefficient parking arrangements to enable plugging in



Extra structures to manage cables

Depots for electric trucks

Restrictive parking arrangements to enable plugging in



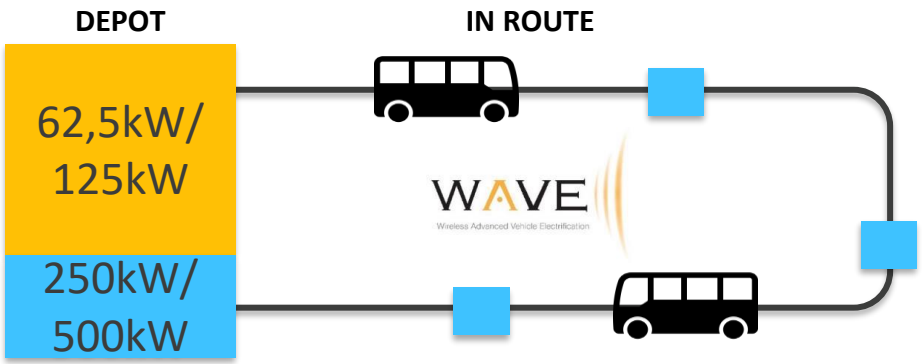
Still space for power electronics used

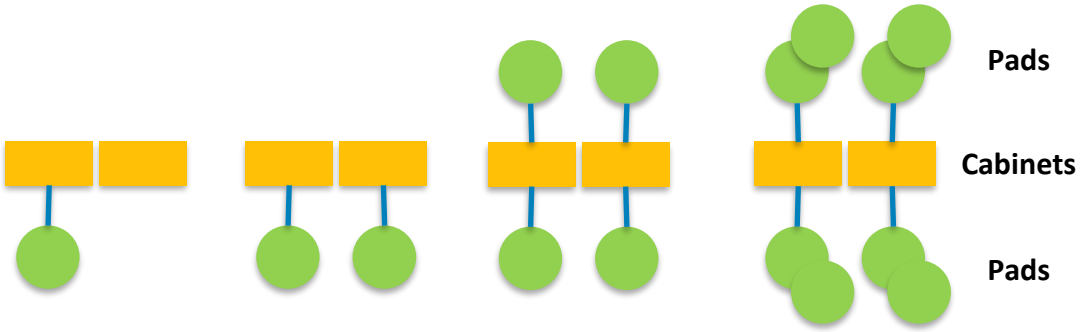
Intelligent Wireless Depot Chargers Solves Painpoints

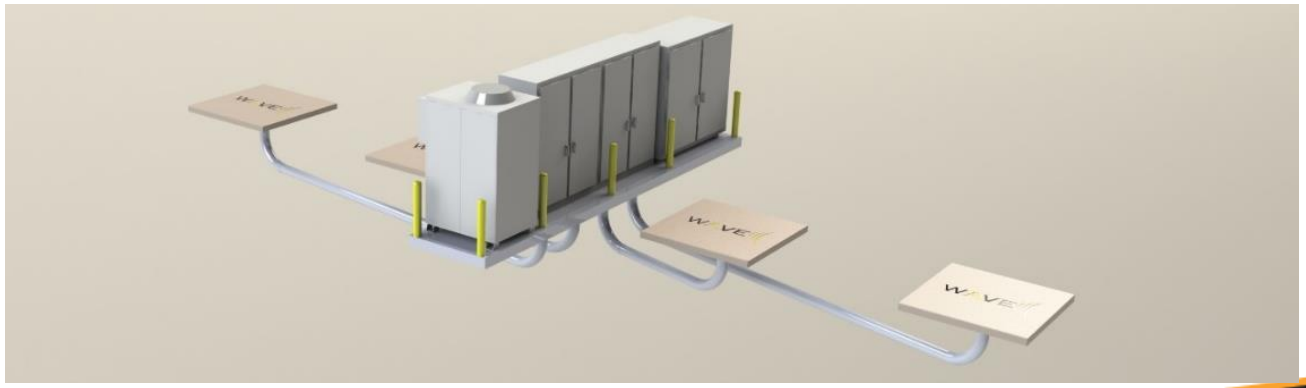
Modular combinations are possible with one formfactor to create desired depot layout:

- 62kw x 8
- 125kw x 4
- 250kw x 2
- 500kw x 1

Offering flexibility on parking arrangements and power level.

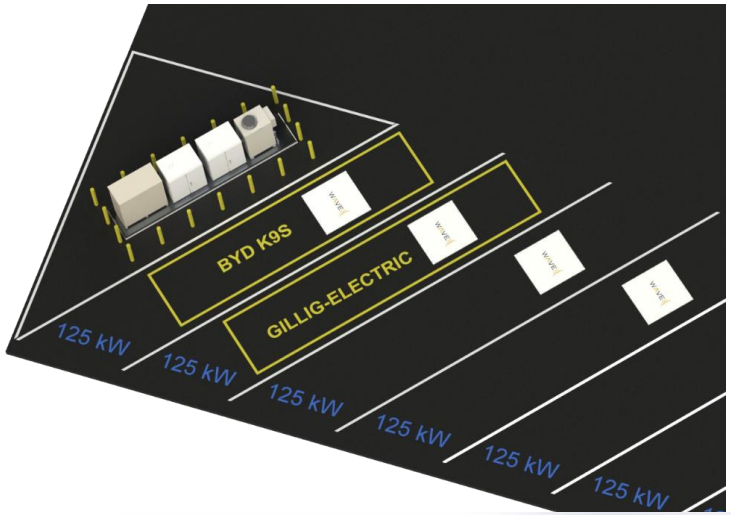


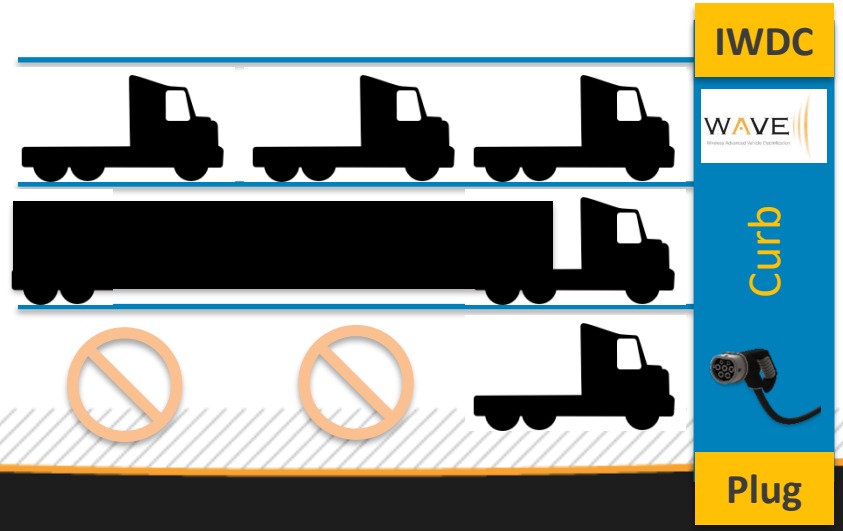


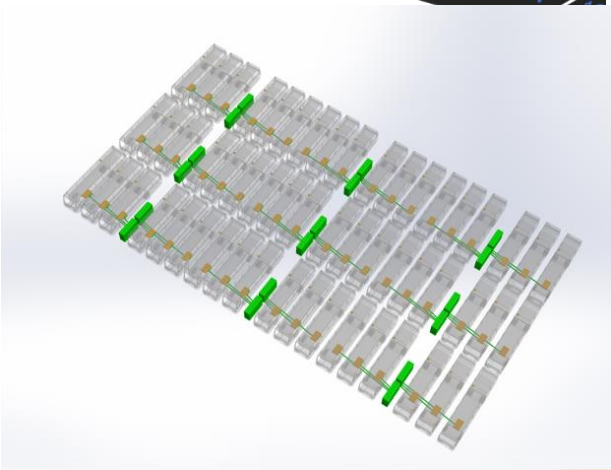


Space Saving with Wireless Depot Charging

- Cabinets can be further away from driving area
- Using Space that is not utilized for vehicles
- Nose to tail and other parking arrangements can be well enabled to maximize parking space utilization
- No extra buildings or constructions are needed
- No extra cable management needed







Footprint can be further reduced with IWDC

Due to existing layout parking arrangement, following units seem best fit for 175 parking spots:

- 8:1 IWDC Qty. 13
- 7:1 IWDC Qty. 5
- 6:1 IWDC Qty. 2
- 4:1 IWDC Qty. 2
- 500kW IWDC Qty. 16

With wireless charging space can be utilized even better if an alternative parking arrangement can be chosen.

Based on specific cost and operation needs an optimization can be made to find the best layout.

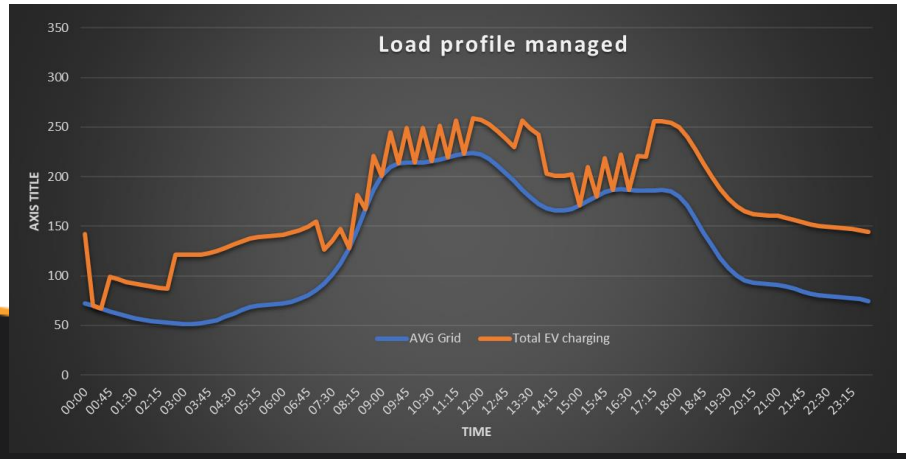
Time Saving and Smart Management with IWDC

- Several minutes can be saved per charge cycle compared to a plug in solution
  - Scaled to a depot it is equivalent to hiring one person just for plugging and unplugging
- Intelligent Wireless Depot Charging (IWDC)reduces the peak loads on the grid resulting in smaller electricity bills
- Intelligence also on the vehicles providing real time telematics and battery data
  - Support vehicle disposition with data and tools

No connection time

No cable damage

No connector failures



WAVE
Wireless Advanced Vehicle Electrification

PROJECT SPOTLIGHT: Antelope Valley Transportation Authority (AVTA)

AVTA is on track to become the first "all-electric" transit bus fleet in the United States with 50 vehicles using in-route wireless charging.

AVTA IMPACT :

50 VEHICLES USING IN-ROUTE WIRELESS CHARGING

15 WAVE 250kW HIGH POWER WIRELESS CHARGERS

285,000 GALLONS OF DIESEL FUEL AVOIDED (SINCE 2016)

1.3 M TONS OF GREENHOUSE GAS EMISSIONS AVOIDED (SINCE 2016)

$65,000,000 OVERALL SAVINGS EXPECTED IN CONVERTING TO ELECTRIC OVER 12 YEAR PERIOD

NO PLUGGING OR UN-PLUGGING

NO MOVING PARTS AND **NO** CHANGES IN BUS OPERATIONS

VEHICLE RANGE

Electric Bus + Overnight Plug	80 - 120 miles
Electric Bus + WAVE 50kW	100+ added miles
Electric Bus + WAVE 250kW	300+ added miles

Thank you!
Takk skal du ha!

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