WAVE by Ideanomics

WAVE Wireless Charging Propels AVTA to Zero-Emission Milestone

CASE STUDY: **LARGEST WIRELESS DEPLOYMENT DELIVERS BIG WINS FOR LARGEST U.S. BATTERY-ELECTRIC BUS FLEET**

SUMMARY

One of the most significant barriers mass transit agencies face in the move to zero-emission vehicles is range. **How can we make our battery-electric buses go as far as diesel buses?**

For the Antelope Valley Transit Authority (AVTA), the solution lies just below the surface. The California transit system is operating the nation's largest battery-electric bus fleet, and the majority of its vehicles go well beyond their standard operating range on a daily basis.

AVTA accomplishes this by delivering high-power charging in-route—quickly, safely, and completely hands-free—using wireless inductive charging from **WAVE.**

This case study details the role WAVE wireless charging played in AVTA's transition to becoming the first fully electric local mass transit fleet in the United States.

KEY FINDINGS:

- Increased vehicle range and battery life
- Improved safety from the reduction of high-voltage cables and overhead charging equipment
- Lower maintenance and TCO from reduced vehicle and labor cost
- Cover routes as long as 467 kilometers with a single electric bus

In 2014, the Antelope Valley Transit Association (AVTA) leadership set out to become the first transit operator in the United States to have a fully electric local bus fleet. With the range of battery-electric buses (BEBs) limited to between 249 to 354 km, the agency needed to solve the problem of covering routes over 467 km.

Flash forward to August 2021, and AVTA's fully electric 65-bus local fixed-route fleet logged its six millionth mile, just seven years after its first electric bus went into service. Moreover, the agency is able to cover its longest routes with a single battery-electric bus.

How WAVE Works and What WAVE Does

Legacy plug-in and overhead (pantograph) charging systems require time-consuming, hands-on intervention, clutter landscapes, and can be expensive to maintain. The WAVE system has no moving parts and requires no human or mechanical intervention. Within seconds of scheduled stops, the high power needed for meaningful range extension is transferred from ruggedized pads embedded in the roadway, across a five to eight inch air gap, to a receiving pad on the vehicle's undercarriage.

With up to 644 km of range added over 16 hours of route operation, AVTA's BEBs can meet and even exceed the range of diesel buses. Projections have AVTA's investment in WAVE wireless charging saving the agency $1M per year compared to the cost of using just plug-in charging. Today, AVTA operates the largest battery-electric bus fleet in the United States, powered by the largest single high-power wireless (inductive) charging deployment in North America.

BY THE NUMBERS

The Antelope Valley Transit Authority operates the largest battery-electric bus fleet in the U.S. The majority of the fleet is powered by WAVE via the largest high-power wireless charging system in North America.

WIRELESS-ENABLED FLEET

Total service area: 260 km^2

Wireless charging stations:
12 @ 250kW with three more in 2021

Vehicles: 47 BYD wireless-equipped battery-electric buses

RANGE EXTENSION

Longest route covered: 467 km (vs. operating range of 249 km*)

State-of-charge (select routes): Buses end shift with higher SOC than start

Range extension: Double standard operating range in an 8-hour shift*/ Adds over 644 km during 16 hours of operation

WAVE BENEFITS

(JAN. 2019 – OCT. 2021)

Range extension kilometers delivered: **2,712,632**

Power delivered: **3,034 MWh**

Diesel fuel saved: **1,636,030 liters**

Tons of CO_2 saved: **4,658**

Kilograms of $PM_{2.5}$ saved: **11,086**

* standard operating range of a BYD K9

In-Route vs. Depot Charging

The advantages of BEBs over diesel have been well established:

- Environmental benefits from reduced tailpipe emissions
- Lower total cost of ownership (TCO)

Lower TCO results from lower operation and maintenance costs and lower cost per kilometer of electricity vs. diesel fuel.

According to AVTA, the transition from diesel to BEBs has saved $1,649,352 in fuel costs after paying for electricity, and reduced the organization's carbon footprint by more than 13,000 tons of CO_2 and 33 tons of particulate matter.

AVTA Executive Director/CEO Macy Neshati estimates that over 12 years, their electric bus fleet will save approximately $65 million in repair, maintenance, and diesel fuel costs, among other expenses.

While BEBs have a shorter range than diesel buses, two charging strategies can effectively mitigate this:

- Depot charging combined with larger bus batteries and/or using multiple BEB's to cover long routes
- Extending BEB range using in-route charging (recharging through the day)

In-route charging (also referred to as "opportunity" charging) can still require overnight depot charging, but charging throughout the day extends vehicle range beyond the single-charge range of onboard batteries. This allows for smaller, more affordable onboard batteries, which can reduce vehicle cost. Studies have also shown that topping off batteries during the day and avoiding extreme charging from deeply depleted states will extend battery life.

AVTA serves Antelope Valley in northern Los Angeles County, which extends south into the Los Angeles basin and north to Edwards Air Force Base and the Mojave Air and Space Port. With total annual ridership of more than two million commuters, the fixed-route service consists of a network of 13 local transit routes covering 260 km².

To avoid the cost of purchasing multiple BEBs to cover a single route, AVTA chose an in-route charging strategy to augment their depot plug-in chargers. "When you integrate wireless in-route charging into your scheduling and make it a routine part of how you do business," said Neshati, "you can just eliminate the whole concept of range anxiety."

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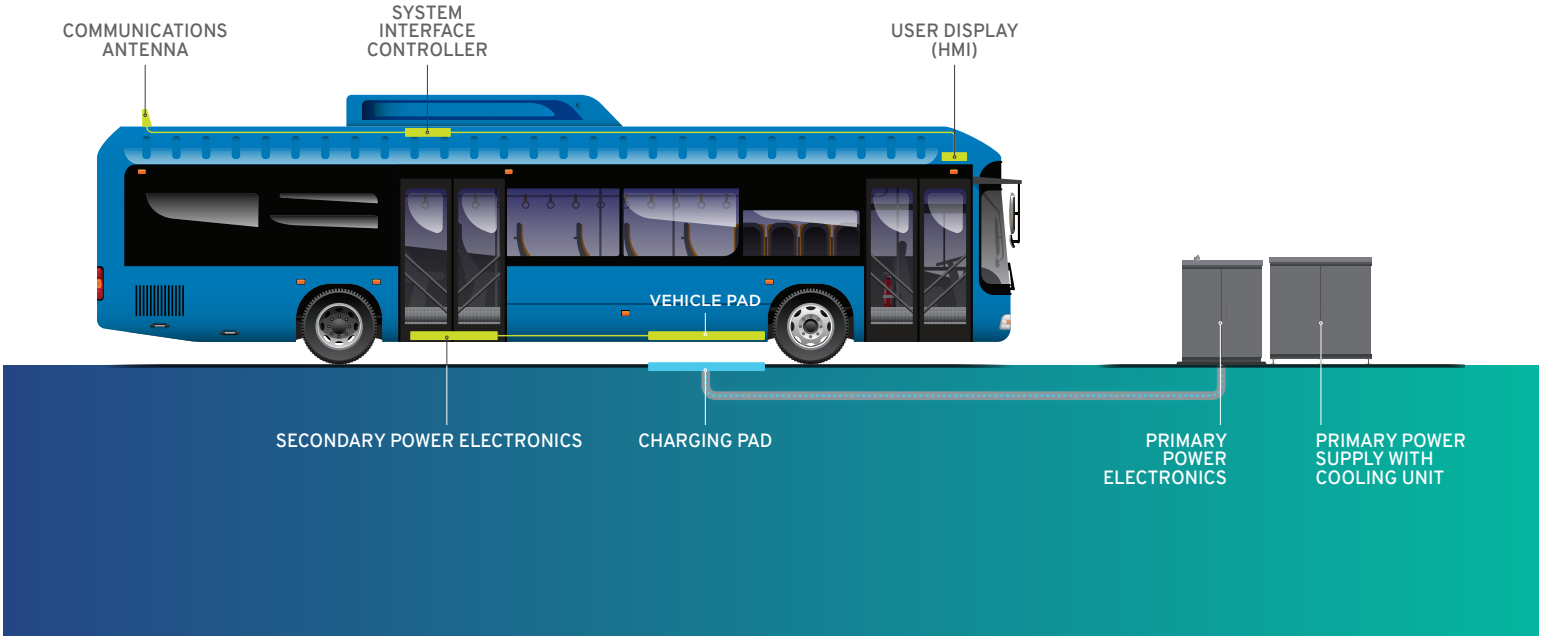
>
> MACY NESHATI | EXECUTIVE DIRECTOR/CEO | AVTA



Making in-route "routine"

SAFETY, RELIABILITY, AND CONVENIENCE

When space and labor at the depot are not constraints, plug-in chargers, ranging between 60kW to 125kW, can work well. However, to maximize the available time during scheduled stops, in-route charging requires higher-power chargers. High-power plug-in chargers are too labor-intensive, cumbersome, and time-consuming to be considered as an in-route option.

"In-route plug-ins were just off the table for us," stated Neshati. "You're not going to get bus operators to get off the bus, go over to the charger, and plug in. That's not the operator's job. It's a different kind of worker, and you can't afford to have them stand there waiting for buses to pull up."

Overhead pantograph charging systems can deliver high power without deploying extra labor in the field. However, the visual impact of pantographs and the space required for pedestal foundations are often subject to local zoning restrictions. Safety, collision damage, maintenance, and vandalism can also be concerns.

"We're huge believers in keeping people off ladders and roofs tops," Neshati said. "Anytime something is 15 feet in the air and requires mechanisms and motors to come down and go back up, things can go wrong and motors can break. Wireless charging technology has no moving parts. You park over it, charge up and pull away. I'll take simplicity and safety over complexity and moving parts."

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MACY NESHATI
EXECUTIVE DIRECTOR/CEO | AVTA

Bus Size	Battery Consump. (kWhr/KM)	Kilometers added in five-minute charge	Kilometers added in ten-minute charge
12-meter*	0.9-1.2	16-23	32-40
18-meter	1.5-1.6	13-16	26-29

* Power delivered can be less than 250kW and is subject to control by the bus battery management system.

At each stop, a small part of the curb is painted to assist the bus operator in aligning the receiver plate under the vehicle with the ground side transmitter embedded in the roadway. Charging begins only after a digital display confirms alignment to the operator and the parking brake is applied.

Rather than combining multiple low-power pads designed for smaller vehicles, WAVE's ground side transmitter uses a single, ruggedized pad purpose-built for high-power, heavy-duty wireless charging. The single pad design not only allows for a large alignment window but better overall power transfer efficiency. The system is unaffected by snow, ice, moisture, and heat, and is nearly as invisible as it is indestructible. Free of moving parts, connectors, or cables means there is nothing to break or freeze.

WIRELESS VS. PANTOGRAPH + PLUG-IN

- No extra charging labor required
- Free of visually-detracting cabling, ground, and overhead clutter
- Fewer zoning and maintenance concerns

Matching the Range of Diesel Buses

AVTA has deployed 12 WAVE 250kW chargers over the 260 km². Of the 65 BYD battery-electric buses AVTA has in operation, 47 were equipped for wireless charging in nearby Lancaster, California, where the buses were manufactured.

"I think the biggest concern for everybody was range anxiety," said James Holtz, Regional Manager for BYD, which partnered with WAVE to manufacture the 47 AVTA buses enabled with wireless charging capabilities. "Providing a flexible solution like WAVE helps us to overcome some objections presented by our customers."

With the majority of AVTA routes exceeding the typical range of a BEB, every second of a scheduled stop offered AVTA an opportunity to add meaningful kilometers to vehicle range. Free from human contact and mechanical movement, a WAVE 250kW charger can add up to 40 km of range to a 12 meter bus in just 10 minutes.

"Our bus operators know the pads are out there and they've really learned how to use them," Neshati continued. "For us, range anxiety is becoming a thing of the past."

RANGE EXTENSION

- Range extension between 206-322 km per 8-hour shift
- Matches the range of diesel buses

Flexibility

Decentralizing charging not only provides operational continuity against power outages but offers the flexibility to adapt to unforeseen changes. Having wireless charging deployed in the field allows route length or operational hours to be extended without buses having to return to the depot to be charged.

"Let's say you decide you want to take your service to 24 hours a day, but you don't really have a depot availability," explained Neshati. "With wireless charging, that's not an issue. It adds a tremendous amount of flexibility and makes your system a lot more dynamic."

COLD WEATHER INSURANCE

Whereas pantograph chargers can be challenged by extreme cold and snow, wireless offers tangible benefits. "The range of a 290 km bus can drop down to 225 km because of the snow and the cold," said Neshati. "WAVE ensures we get that extra boost we need out there to complete the route successfully."

FLEXIBILITY

- Labor-free, trouble-free decentralized charging
- Protects against cold weather range loss
- Unaffected by snow and ice range loss

Total Cost of Ownership

$12M SAVINGS PROJECTED OVER 12 YEARS

Had wireless in-route charging not been available, battery-depleted BEBs would have to be swapped in the field with charged ones. This would have required AVTA to purchase an additional 20-37 buses.

Fast, hands-free wireless charging not only saved millions on additional bus purchases but lowered labor and maintenance costs related to daily BEB switch-outs and a larger plug-in footprint in the depot.

TOTAL COST OF OWNERSHIP

- AVTA's investment in WAVE is projected to save $1M/year over 12 years
- 23% fewer buses (65 vs. 102) because of in-route range extension
- Reduced labor and maintenance associated with BEB switch outs and larger plug-in footprint

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JAMES HOLTZ/REGIONAL MANAGER/BYD

Conclusion

With over 2.1 million kilometers of hands-free, low-maintenance range extension delivered, the success at AVTA shows that the speed, power, safety, and convenience of WAVE wireless charging is the most advanced way to enable battery-electric buses to match the range of their diesel counterparts.

The low-maintenance system is cost-effective and has years of field-tested performance. Hands-free and requiring no human or mechanical movement, WAVE wireless charging is proven to eliminate the range anxiety that is often a barrier to commercial fleet operators adoption of EVs.

The warrantied solution offers interoperability among different vehicle sizes and manufacturers. Applications are also available for port, industrial, and off-road electric vehicles.

SUMMARY OF WIRELESS BENEFITS

- Safe, no-contact high-power charging
- The most convenient way to extend electric bus range
- Enables 1:1 diesel-to-BEB replacement
- Free of visually detracting cabling, ground and overhead clutter
- Lower projected TCO than legacy charging
- Allows for smaller onboard batteries
- Higher cold-weather resiliency vs. legacy in-route charging solutions

INTEGRATE WITH TOP BUS MANUFACTURERS

WAVE partners with global electric vehicle manufactures to bring wireless power to battery-electric buses, medium and heavy-duty electric vehicles. Vehicles can be equipped at the time they are built or retrofitted for wireless even after they are in service.

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