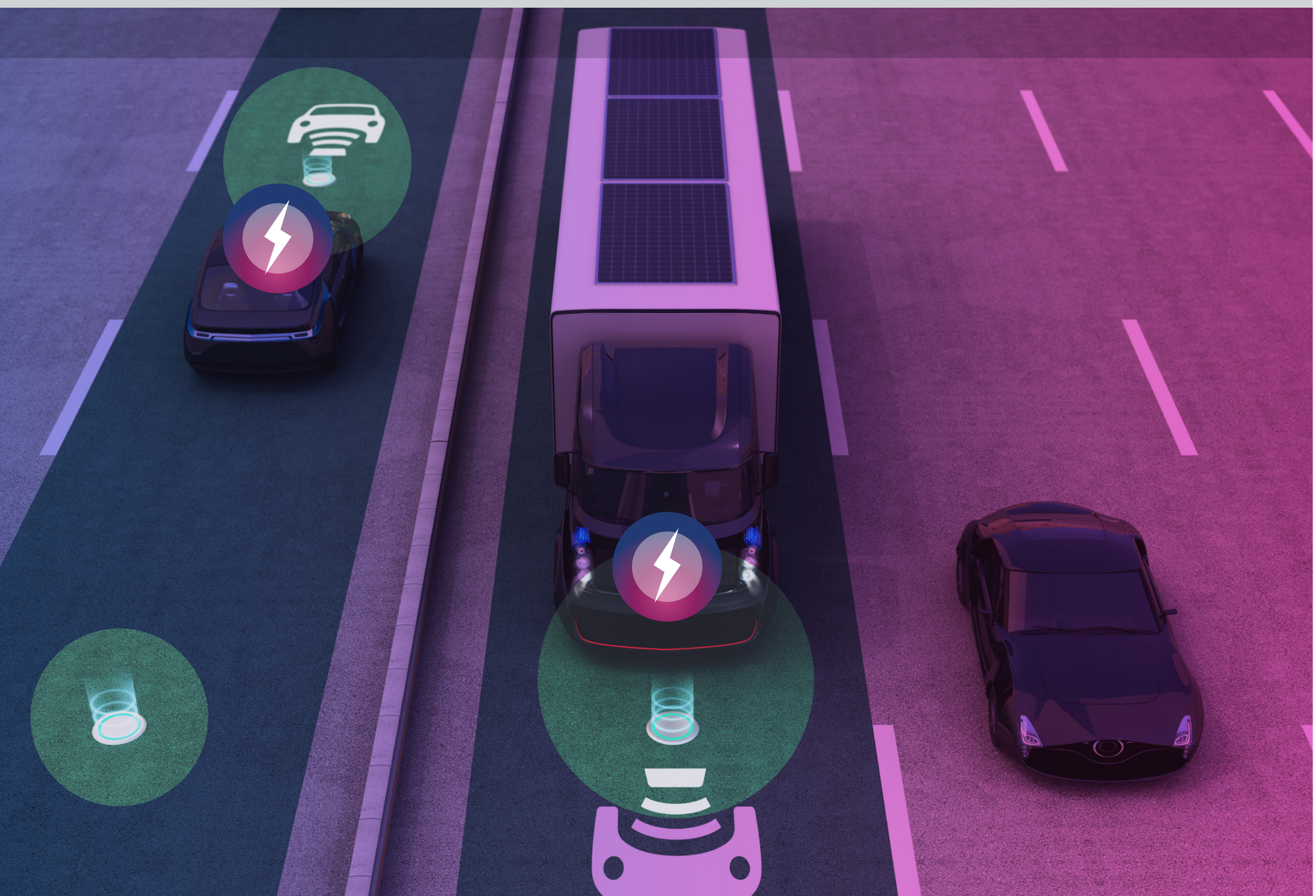
WIRELESS ELECTRIC VEHICLE CHARGING

AUG 2022

WHITE PAPER



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This paper was informed by research conducted in 2020 – 2022 and was co-authored by SANDAG staff. For more information about SANDAG Clean Transportation projects, see the SANDAG website. If you have any questions or comments related this whitepaper, please contact:

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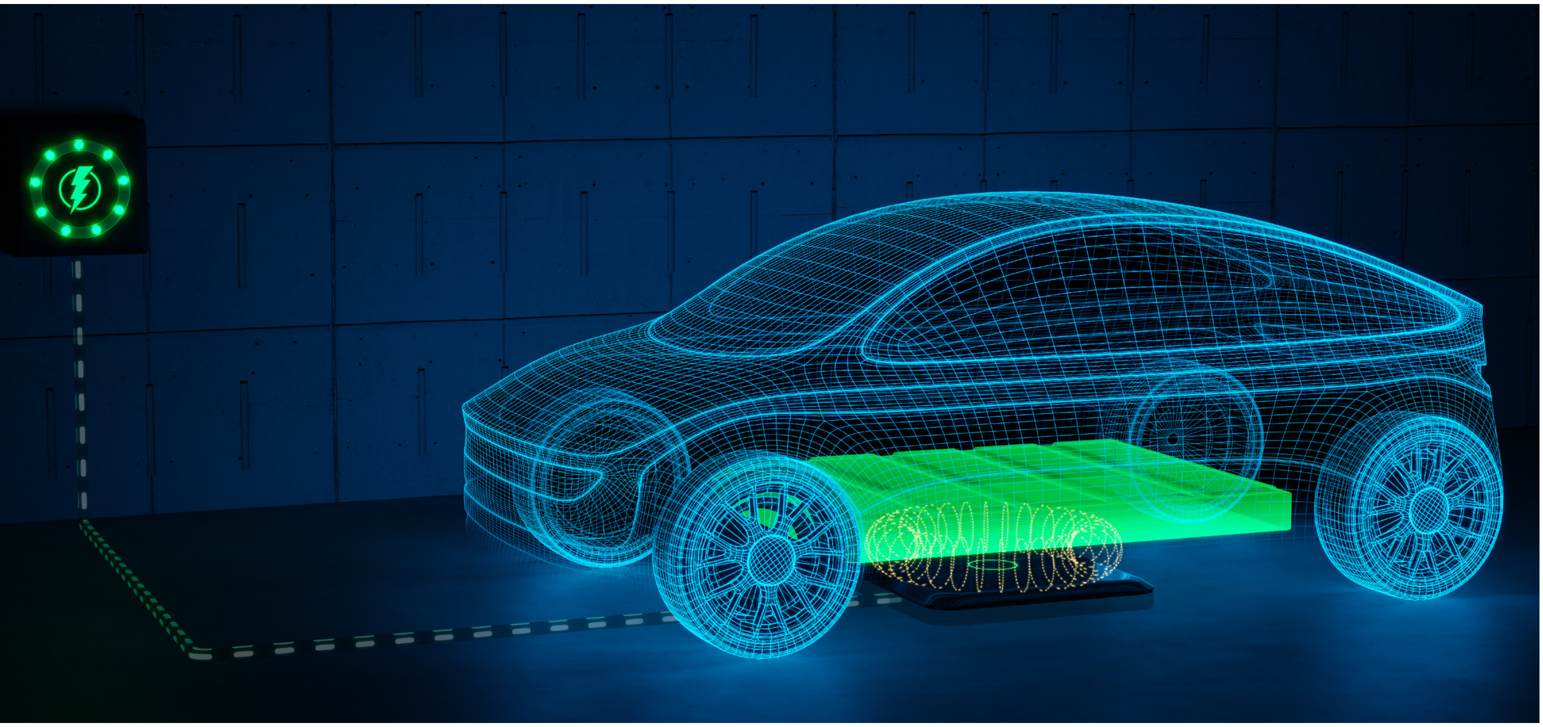

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The Wireless Electric Vehicle (EV) Charging Whitepaper documents the current state of wireless charging technology, addresses the challenges to widespread adoption, and highlights opportunities for the San Diego region. To meet federal, state, and regional climate goals, the San Diego Association of Governments (SANDAG) is interested in exploring wireless power transfer, also known as wireless charging and inductive charging, to allow electric vehicles to pick up a charge without stopping to plug in to a traditional EV charging station. There are two forms of wireless charging: static wireless charging, in which an EV can charge while stopped (e.g., while parked), and dynamic wireless charging, which allows an EV to pick up a charge while in motion (e.g., while driving along a wireless-enabled stretch of roadway).

There are numerous policies set at the state level, including clean transportation legislation from the California Air Resources Board and Governor Newsom's Executive Order N-79-20, which establish the need for innovative EV charging technology in the San Diego region. SANDAG is also committed to leading the way for innovation, especially surrounding the deployment of technologies that can better serve the growing population of electric vehicles that are needed to reduce greenhouse gas emissions and improve air quality.

Sourcing battery materials for large-scale fleet electrification mandated by these state regulations presents

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a challenge—with dynamic electric charging, studies suggest that the battery size can be reduced by 90%. There are a number of benefits to smaller battery size; for example, smaller batteries can reduce time needed to fully charge a fleet and also reduce the amount of potential e-waste. Dynamic electric charging can also distribute the load on the electric grid, both in time and space, meaning that the grid does not have to be designed for peak charging only at the times that the fleet is at the charging station.

As a relatively new and emerging transportation technology, there are some challenges associated with the adoption of wireless EV charging. Current demonstrations of wireless power transfer are necessary to enable technology providers and project administrators to scale up the use of wireless charging to adequately serve light-, medium-, and heavy-duty electric vehicles. However, the newness of wireless power transfer means that the cost of wireless EV charging projects can be significant. There are also regulatory challenges related to wireless EV charging, including coordination of land use, right-of-way, permitting, and environmental compliance.

Despite these challenges, wireless EV charging remains a valuable opportunity to support transportation electrification to meet air quality and climate goals. Cost may be a barrier to large-scale wireless power transfer demonstrations in the present, but future funding opportunities are promising given the current trajectory of state and federal grant funding. Additionally, public agencies can leverage innovative partnership models, such as public-private partnerships, to enable further collaboration and co-funding of wireless EV charging projects. Collaborative partnerships also open the region to innovative use cases where wireless power transfer could be used to support the electrification of air, land, or seaport ground equipment, medium- and heavy-duty trucks, transit and school buses, or shuttles. Furthermore, wireless power transfer can support clean transportation equity goals, especially where the burden of air pollution from vehicle emissions is disproportionately high.

Wireless EV charging is a key component in developing the overall network of EV charging infrastructure that will be necessary to support the growing population of zero-emission light-, medium-, and heavy-duty vehicles. To meet long-term state and regional climate goals, the public and private sectors must collaborate in the present to ensure that the feasibility and widespread benefits of wireless power transfer are understood and embraced across the state and nation.

INTRODUCTION

Figure 1: *San Diego Mayor Todd Gloria and other regional leaders speak at an A2Z press event in July 2021 (Source: Mayor Todd Gloria, Twitter)*

The San Diego Association of Governments (SANDAG) is committed to electrifying transportation throughout the San Diego region. The 2021 Regional Plan, adopted by the SANDAG Board of Directors in December 2021, identifies over $2 billion dollars needed to support transportation electrification planning and programs for electric vehicles, including both battery electric and fuel cell vehicles, as well as the infrastructure needed to support EV adoption. As an agency, SANDAG is embracing and engaging with new and emerging technologies that have the potential to benefit our region, including innovative EV charging technologies such as inductive EV charging, also referred to as wireless power transfer (WPT) or wireless charging throughout this paper. This whitepaper[1] supplements the SANDAG April 2021 Emerging Technologies Whitepaper and focuses on the current state of inductive EV charging, the challenges surrounding early-stage adoption, and the opportunities for this technology in the San Diego region. As the region seeks to deploy charging infrastructure to support EV adoption, exploration of innovative stationary (static) and in-motion (dynamic) charging will be needed to support regional and state clean transportation goals.

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Figure 2: *One of the first electric streetcars in San Francisco, 1903 (Source: SFMTA)*

Policy Considerations

There are a number of statewide mandates driving the need for increased adoption of EVs. Governor Gavin Newsom's Executive Order N-79-20[2] requires 100% of in-state sales of new passenger cars and drayage trucks to be zero-emission vehicles by 2035, thereby creating a large demand for adequate zero-emission vehicle (ZEV) charging and fueling infrastructure. Furthermore, the California Air Resources Board has set a number of regulations which require medium- and heavy-duty vehicles throughout the state to begin transitioning to zero-emission technologies as soon as 2023, such as Innovative Clean Transit,[3] Advanced Clean Trucks,[4] and Advanced Clean Fleets.[5]

Regional Goals and Actions

There are a number of existing efforts in the San Diego region to electrify transportation, meet state climate goals, and improve air quality. As mentioned above, SANDAG's 2021 Regional Plan highlights electric vehicles as one of the methods to reduce transportation-caused greenhouse gas emissions. Similarly, electrification of the transportation sector will help reduce NOx emissions, an Ozone precursor, as well as other localized criteria pollutants and toxic air contaminants that affect the health of San Diego County residents. SANDAG and the Port of San Diego have partnered to develop a Regional Medium- and Heavy-Duty Zero-Emission Vehicle Blueprint which will identify key actions needed to accelerate the transition to zero-emission trucks and buses. Additionally, this effort directly supports the transportation electrification goals and objectives outlined in the Port of San Diego's Maritime Clean Air Strategy.[6]

To help achieve regional EV readiness for all vehicle classes, SANDAG is also a founding member of the Accelerate to Zero Emissions Collaborative (A2Z) (see Appendix A). The A2Z San Diego Regional Gap Analysis[7], published in July 2021, identifies gaps and barriers to zero-emission vehicle infrastructure deployment, especially in Disadvantaged (DAC) and Low-Income Communities (LIC). The report comments on the uncertainty associated with innovative

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technologies; to address this uncertainty, SANDAG conducted a Request for Information process in late 2021 to inform later projects that can prove the feasibility and benefits of wireless charging to promote more widespread adoption of electric vehicles.

These regional efforts are essential to help the San Diego region meet its fair share of statewide goals. However, several barriers, such as EV range limitations, must be addressed to meet statewide zero-emission goals. Innovative technologies like WPT provide promising opportunities to address such barriers.

Technology Considerations

Today, much of the deployed and planned charging infrastructure is focused on light-duty and passenger electric vehicles. Medium- and heavy-duty vehicles contribute up to one quarter of emissions but have unique challenges for electrification. For a required range of several hundred miles, heavy-duty trucks and transit buses require enormous battery capacity, and the battery pack occupies a huge volume, weighing up to 25% of the gross weight of the vehicle. Conversely, smaller battery packs lead to shorter range and time wasted in frequent stops to recharge while en route.

Dynamic electric charging addresses this problem by allowing electric trucks and buses to use a much smaller battery pack that is recharged while the vehicle is traveling on an electrified roadway. Dynamic electric charging on roadways has existed for hundreds of years, such as in the form of conductive charging via overhead lines used to power trolleys.[8] In fact, trolleys and electric buses with long conductive arms that connect to overhead catenaries can be seen in photographs of urban landscapes from the early- and mid-20th century. With the adoption of on-board rechargeable batteries, EVs are no longer dependent on a continuous physical connection to a track or roadway where electric power is deployed. They can venture away from powered roadways as long as there is adequate on-board battery power, thereby decreasing the amount of the roadway that needs to be powered.

Inductive (rather than conductive) wireless power transfer from coils embedded in the roadway is a relatively new technology that is maturing now. Inductive energy transfer occurs between the coils in the roadway and coils mounted somewhere on the vehicle, typically on the undercarriage of the vehicle.

The amount of power transfer is a function of the number of coils on the vehicle; small passenger vehicles can be equipped with one coil, shuttles may be equipped with two, and large transit buses and trucks can be equipped with three or more coils.

WPT has long term potential to be used by a wider range of vehicles in the region. To support the 2021 Regional Plan and accelerate innovation in the region, SANDAG became a member of ASPIRE at Utah State University, a National Science Foundation-funded research institute whose mission is “to improve health and quality of life for everyone by catalyzing sustainable and equitable electrification across the transportation industries.”[9] ASPIRE is interested in innovative technologies and has helped to inform SANDAG’s pursuit of wireless EV charging information.

OVERVIEW OF WIRELESS CHARGING TECHNOLOGY

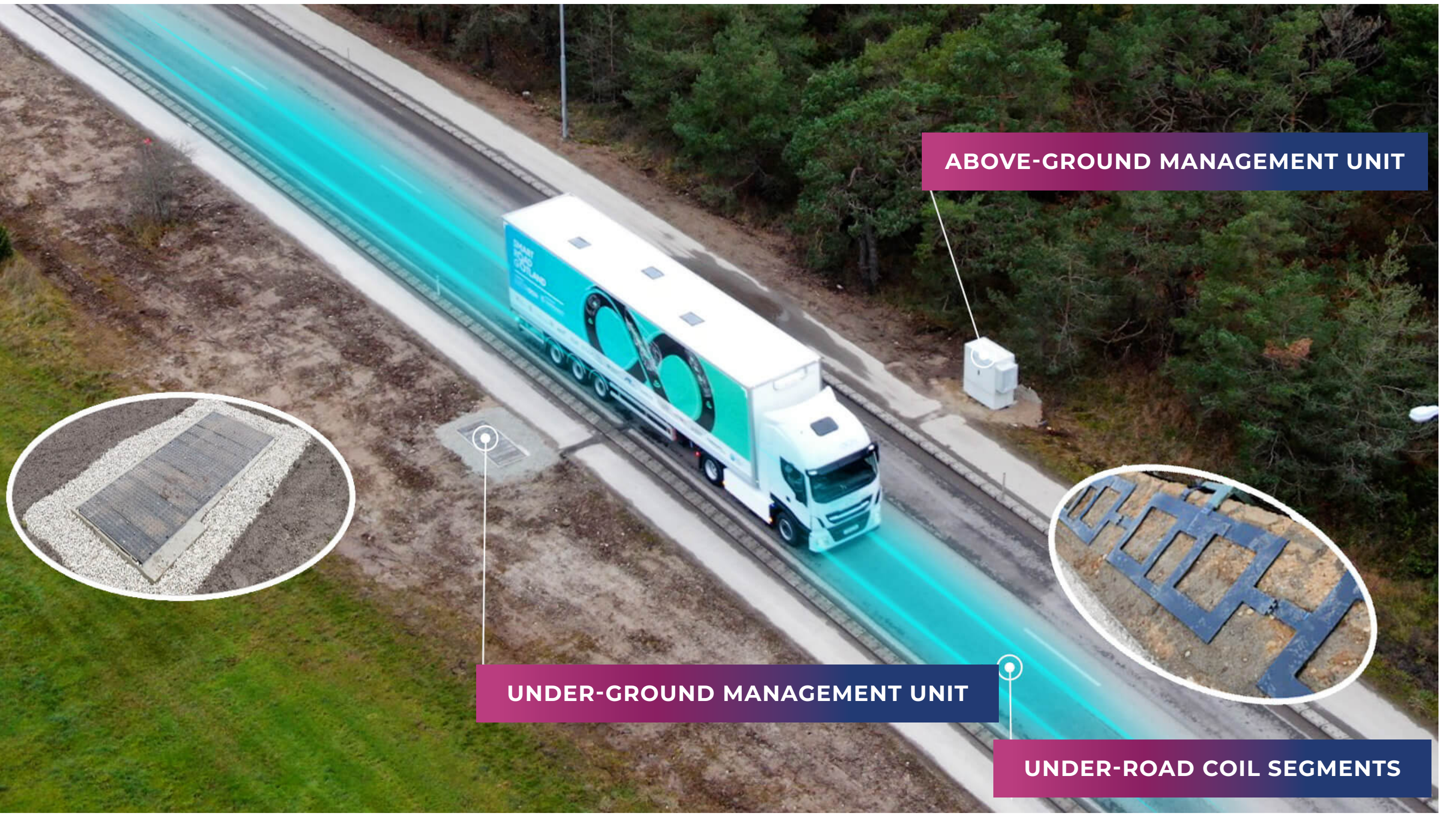

Figure 3*: Wireless charging system components for a heavy-duty truck (Source: Electreon)*

With the adoption of on-board rechargeable batteries, electric vehicles are no longer dependent on a physical connection to a track where electric power is deployed. WPT allows vehicles to pick up a charge, or transfer power, by aligning the vehicle's receiver coil(s) with coils embedded in the ground. This technology can be used in static (stationary), semi-dynamic (slow moving), or dynamic (during normal driving operations) applications to charge a vehicle without plugging in. There are various power levels available to power EVs via wireless charging. Current existing WPT power levels range from low power phone charging applications of around 10 W to high-power, heavy-duty charging applications up to 250 kW.[10] Of course, this technology is continuously evolving and improving: the Oak Ridge National Laboratory reported in 2021 that their scientists plan to develop up to 270kW systems to provide the fastest charging times possible for passenger EVs.[11] Furthermore, the U.S. Department of Energy has sponsored wireless charging projects ranging from 500kW to 1 MW.[12 13]

Ideal early-stage applications of WPT support the replacement of diesel vehicles with EVs to operate on repeatable routes. For example, drayage trucks use repeatable routes, have limited range, and could incorporate both dynamic and static charging in and around communities where deliveries are being made. Similarly, campuses and airports that have high-use shuttles on repeatable routes could benefit from dynamic and static WPT. An important benefit of dynamic wireless charging (i.e., having access to charging along a regularly used route) is that EVs can use smaller batteries while maintaining or increasing the range of that vehicle. Additionally, the smaller battery size allows for decreased gross vehicle weight, which increases the potential to carry more goods or passengers. The use of wireless charging directly supports the transition to zero-emission vehicles to reduce transportation-related greenhouse gas emissions.

In addition to the coils, the overall system includes system controls and management. The charging coils in the roadway are energized only when a receiving coil is detected with verified credentials. This ensures safety, as the embedded coils are never energized unless a verified receiver coil is present. The communication protocol also permits control of the instantaneous power transfer that can be adapted as a function of high-level system-wide energy management, grid load, energy availability and cost, and available battery capacity. Energy transfer can be allowed to flow both ways, as onboard vehicle batteries can provide energy storage and retrieval.

This emerging technology has been proven overseas in demonstration pilots and on public roads and is starting to be rolled out in North America. Several public agencies across the Atlantic, including in Israel,[14] Sweden,[15] Germany,[16] and Italy,[17] have partnered with technology provider ElectReon to deploy a number of dynamic wireless charging pilots (for more information about each pilot, see endnotes). Many pilots are demonstration pilots and are limited to a few kilometers. Most pilots to date are on private demonstration tracks, however, Sweden launched a transit and truck pilot in 2019 on public roads on the island of Gotland and Israel also piloted WTP as part of their public transit system. These pilots have demonstrated that the technology works and that vehicles with repeatable routes will benefit from WPT.

In North America, National Laboratories and academic institutions are researching and exploring WPT and several U.S. states have initiated wireless EV charging pilot projects and are looking to take demonstrations and apply them to real world settings. The Michigan Department of Transportation (MDOT) is leveraging their Central Innovation District[18] and recently selected ElectReon to lead design, evaluation, iteration, testing, and implementation of a pilot program to build a wireless charging system on a one-mile section of public road in Detroit.[19] In Indiana, the state Department of Transportation (DOT) and Purdue University-ASPIRE team are partnered with Magment to pilot magnetizable concrete which will enable wireless EV charging.[20] In late 2020, news broke that the Central Florida Expressway Authority had connected with ASPIRE, and is working on a wireless charging demonstration in a newly-constructed roadway that the project team will be building.[21]

Lastly, In the 2021 Utah Legislative Session, the State of Utah appropriated $5 million to ASPIRE and $15 million to the ASPIRE and Utah Inland Port Authority partnership to develop an early pilot program of wireless charging technology for heavy-duty drayage operations in the Inland Port.[22]

CHALLENGES

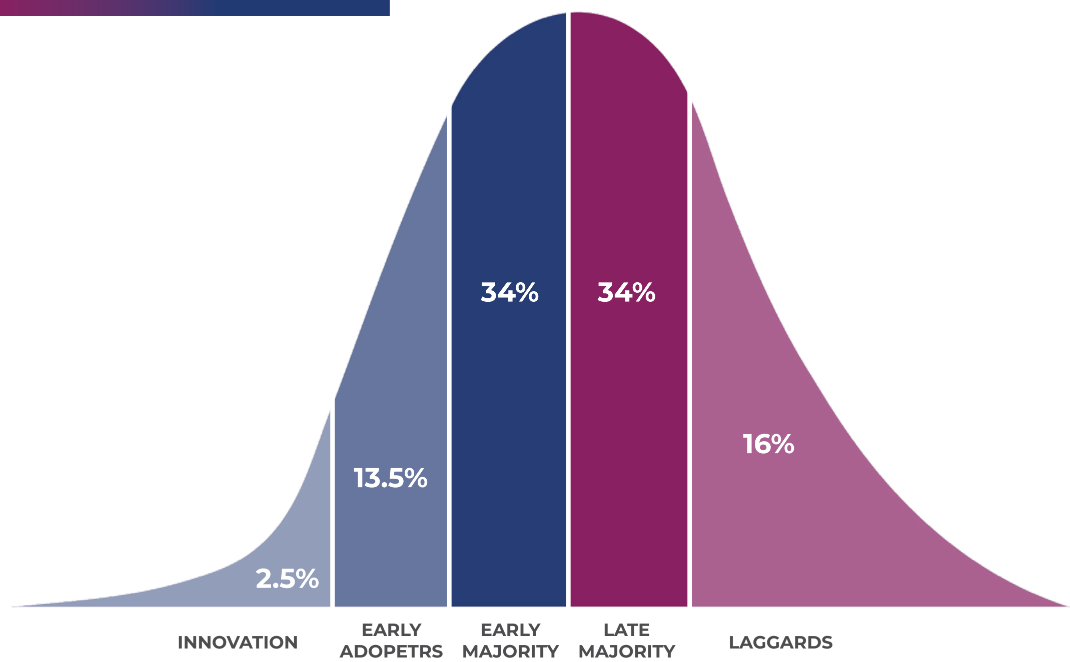

Figure 4: *Diffusion of Innovation Model*

As with many emerging and innovative technologies, there are challenges associated with implementing and commercializing wireless EV charging. Current WPT technology vehicle applications are in the "innovators" stage of the Diffusion of Innovation Model (see Figure 4). SANDAG realizes that widespread transportation electrification and EV adoption must be supported by a variety of entities, both private and public. This section highlights the challenges the San Diego region must address to encourage early adoption and allow the free market to bridge the gap.

As noted in the SANDAG Emerging Technologies Whitepaper, technology adoption has outpaced expectations and continues to do so. The SANDAG 5 Big Moves and the 2021 Regional Plan capitalize on technology adoption to advance a transportation future that is fast, fair, and clean. With WPT in its nascent stages of deployment, SANDAG looks to explore pilots that build off existing demonstrations and support the transition to clean transportation through 2050 and beyond. However, government should not be solely responsible for funding innovative technologies, especially when the use of public funds depends on the technology succeeding.

The scale of a wireless charging network is another key consideration; as more wireless roads are constructed and the availability of WPT becomes more accessible, the value of this technology to users will increase. However, there are many challenges associated with WPT implementation—to establish a larger network of EV drivers and wireless charging users, a "chicken or the egg" paradox can arise. In order to achieve long-term use of WPT in the overall network of EV charging options, current exploration and demonstration of this technology is necessary, despite the challenges that exist in the present. Ultimately, it will be up to public agencies and private industry to collaborate in order to prioritize the deployment of innovative charging technologies to meet regional, state, and national clean transportation goals.

Technology Uncertainty

WPT technology skeptics may cite the inefficient ability to transfer power. Historically, this has been a barrier to wireless charging deployment, but recent demonstrations and lab testing indicate a power transfer efficiency of 90% or better.[23] The speed at which WPT can charge a vehicle in motion depends on rate of speed, length of roadway, and power availability. Current WPT systems are limited by coil and receiver power levels, and battery management units, but national labs and private industry continue to develop systems that can support higher power levels and faster charging speeds.

Asphalt Versus Concrete

Many of the existing wireless roads that have been implemented have been embedded in asphalt. Asphalt is generally less expensive than concrete and has safety benefits including improved vehicle handling in snow and reduced risk of skidding when stopping abruptly. In the United States, and especially in Southern California, many roads are constructed with concrete due to fair climate, high traffic volumes, heavy vehicles, increased resiliency, and environmental benefits.[24] For wireless charging to succeed in North America, WPT transfer technology will have to be demonstrated and successfully integrated in concrete.

Cost and Scale

While there are several existing and planned pilot projects demonstrating the success of wireless charging in Europe and North America, there are still skeptics of the scalability of this technology. One of the leading dynamic WPT technology providers, ElectReon, is currently working with the Swedish government to prove scalability and support Sweden's long-term goals of clean transportation.[25] There are many factors that affect the feasibility of scaling up the deployment of wireless EV charging, but for public agencies and public projects, the cost of wireless charging can be particularly challenging. Technology providers indicated that costs range greatly depending on road conditions, power demand, use case, and local requirements. Additionally, a Request for Proposals released in 2021 by MDOT included a funding amount of $1.9 million, with a 25% match requirement from the selected vendor.[26] This indicates that the expected cost of the MDOT wireless charging pilot is, at minimum, approximately $2.4 million USD for one mile of electrified roadway.

Regulations and Standards

In addition to cost-related challenges, there are regulatory challenges associated with getting wireless EV charging in the ground and operational. Land use coordination and right-of-way (ROW) considerations must be identified and established early on in project development in order to site wireless charging infrastructure in locations that are feasible, effective, and provide value to the region. Use of public ROW, such as on County-, City- or DOT-owned land can benefit the public in terms of accessibility and more widespread benefits. However, public land available for piloting innovative technologies is limited, and there can be restrictions on the type of projects and infrastructure that can be implemented in the public ROW. For example, USC 23 111 restricts vending in Interstate ROW; while exemptions to this were recently clarified in a letter from the Federal Highway Administration (see Opportunities section below), this has been a barrier to widespread EV charging network deployment for some time.

CHALLENGES

Another regulatory challenge is environmental compliance—in California, projects must comply with the California Environmental Quality Act (CEQA). This law requires public agencies to inform decision makers and members of the public of potential environmental impacts of proposed projects, and to reduce environmental impact to the extent feasible.[27] While CEQA is critical to ensure that infrastructure and other capital projects avoid undue environmental impact, the process, which includes a lengthy public comment and response period, can delay the timing of projects, and can potentially add costs to deployment of wireless EV charging. In addition to environmental compliance, there may be other permitting challenges and delays faced by local jurisdictions trying to deploy WPT. Permit streamlining is an issue that currently impacts EV charger installation and is being addressed by the California Governor's Office of Business and Economic Development via Assembly Bills 1236 and 917.[28]

As innovative technologies and their potential applications are explored, the technology itself continues to evolve, which can present both challenges and opportunities. Problems with exclusive technology used in the various types and brands of traditional EV charging stations have already demonstrated the need for early standardization and compatibility discussions. For wireless EV charging, technology standardization can help ensure a seamless, positive experience for EV drivers. The wireless charging industry is working to develop standards for vendors so that the technology is compatible across vehicles, coils, and vendors. Current standards for static wireless charging include SAE J2954 for charging up to 11kW and SAE J2954/2 for charging up to 20kW, and IEC 61980 and IEC 63381 for dynamic wireless charging. There are also standards for the software and communications capabilities of the infrastructure that are currently under development and are necessary for a functional and integrated EV charging system. Best practices from past technology adoption reveals that stakeholders in wireless charging deployment should examine and analyze standardization needs earlier rather than later.

Partnerships and Funding

Another challenge is the political aspect of regional project development. Partnerships with local governments, utilities, and non-governmental organizations are necessary to ensure projects support shared climate and equity goals and provide public benefit to the region. Therefore, the success of a wireless charging pilot project is largely dependent on the interest and capacity of these stakeholders and public perception.

Similarly, private industry partners such as original equipment manufacturers (OEMs), including both wireless charging technology providers and vehicle manufacturers, are critical to successful project delivery. Many providers of emerging technologies, such as WPT, are new companies or startups lacking access to the amount of capital that larger, more mature companies have available. Thus, smaller technology providers rely on grants and public funding in the early stages of wireless charging commercialization, and sometimes prefer to join projects that are already fully funded, placing additional responsibility on public agencies to secure enough funding and identify shovel-ready opportunities.

OPPORTUNITIES

Figure 5*: Public electrified road in Sweden (Source: Smartroad Gotland)*

While there are several challenges that wireless EV charging technology faces, many of these challenges are also opportunities for government and private industry to showcase partnerships and innovative applications to accelerate the commercialization of WPT.

Innovative Use Cases

Potential applications for use of WPT in the San Diego region vary but are often focused on medium- and heavy-duty EVs. For instance, wireless charging pilot projects could serve repeated routes used by goods movement trucks and airport shuttles, school or transit buses, or cargo equipment like forklifts, terminal tractors, and cargo vans. There are several use cases that are suitable for deploying a WPT pilot project. For example, tribal use cases such as repeated shuttle routes can integrate wireless charging. One benefit of piloting WPT on tribal lands is that they are sovereign nations and have reduced regulatory challenges. Other potential use cases include San Diego's portside and border communities, which are impacted by air pollution emissions and have goods movement use cases that may be suitable to deploy a wireless in-road charging project. This would not only demonstrate WPT's feasibility and benefits, but also help to meet climate, public health, and equity goals by bringing air quality benefits to these areas.

OPPORTUNITIES

Goods Movement Opportunities

In October 2021, the Port of San Diego (Port) adopted the Maritime Clean Air Strategy[29] (MCAS), which highlights several ambitious goals:

- 100% of trucks serving the Port's maritime cargo terminals to be zero-emissions by 2030
- An interim goal of 40% of the Port's annual truck trips serving the Ports maritime cargo terminals to be zero-emissions by June 2026
- 100% cargo handling equipment to be zero-emissions by 2030

The MCAS was adopted with a strong public health and environmental justice focus. Additionally, the San Diego County Air Pollution Control District adopted a complementary document, the Portside Environmental Justice Neighborhoods Community Emissions Reduction Program (CERP) in July 2021. The CERP includes emission inventory data, air pollutant monitoring, and strategies to reduce emissions and exposure to air pollutants in portside communities. The CERP lists 11 goals, several of which are focused on reducing greenhouse gas emissions from medium- and heavy-duty trucks; the CERP also supports technologies that can reduce diesel emissions.

In spring of 2022, the Port of San Diego released its draft Port Transition Plan that identifies a pathway to reaching 40% of the Port's annual cargo truck trips being zero-emissions by June 2026. In order to reach these goals, opportunity charging is needed to alleviate limitations surrounding electric truck battery capacity and mileage.

SANDAG is also currently working on two complementary goods movement projects: the Sustainable Freight Implementation Strategy and a Regional Medium- and Heavy-duty Zero Emission Vehicle Blueprint. Focused on goods movement operations throughout the regional freight network, these projects will result in an implementation plan that will guide sustainable freight investments in the San Diego and Imperial Counties over the next 30 years. SANDAG staff from the Sustainable Freight Strategy and the Blueprint are working together to ensure consistency and collaboration between these projects to meet state and regional goals—demonstrating dynamic wireless charging near or within the portside community would help meet these ambitious goals.

Airport Shuttle Opportunities

In 2019 the California Air Resources Board passed the Zero-Emission Airport Shuttle Regulation[30] which requires airport shuttle operators to transition to 100% zero-emission vehicle technologies by 2035. Airport shuttle operators must begin adding zero-emission shuttles to their fleets in 2027. San Diego International Airport has multiple shuttle services that will be, or are currently being, transitioned to zero-emission.

The San Diego County Regional Airport Authority (Airport Authority) owns and operates San Diego International Airport and has started its transition and is operating about half of its total fleet with electric shuttles and buses electric shuttles and buses. The shuttles run about 20 hours per day and on average travel anywhere from 2 to 4.5 miles one way or 4 to 9 miles roundtrip, per loop. The shuttles have 129KW batteries with an advertised range of 125 miles, but due to weather, air conditioning needs, and driving performance, the actual range is usually less. Logistically, if a bus begins the day with a full charge, it can last through a full shift if charged during the driver's lunch break. If the driver makes sure to charge during the additional ten-minute breaks

OPPORTUNITIES

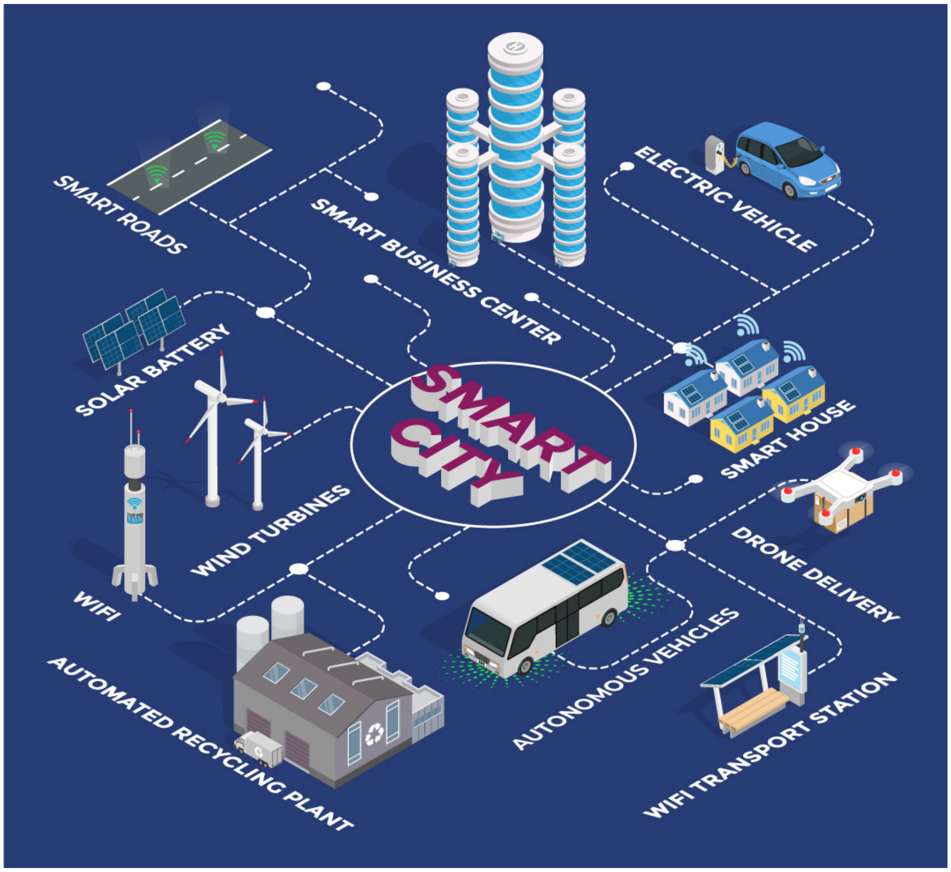

Figure 6: *Smart City Infrastructure with V2X Integration*

the bus may have enough charge to make it longer.

Currently the Airport Authority has over 30 electric shuttles and buses and is charging the fleet around the clock because there are currently only 10 chargers to support the fleet. This includes lots of opportunity charging during breaks, lunches, and other downtime throughout the day. The Airport Authority currently has two full time employees whose essential job responsibility is efficiently connecting and rotating vehicles for charging. This will likely continue even when the Airport Authority moves to a new facility by the end of calendar year 2022 that will offer far greater charger capacity. Frequently, the porter will have to connect and reconnect the charging cables a few times to initiate the 'handshake'. This costs time/money/efficiency. In addition, at least one of the bus types need to be backed in to charge, which is an inherently dangerous practice. Repetitive utilization of the chargers and charging cables many times over each day will inevitably lead to degradation of the equipment and need for replacement.

A wireless charging system made up of static and dynamic charging opportunities could help San Diego International Airport meet its ZEV goals, address the charging challenges noted above, and serve as a regional proving ground for wireless charging technology.

To maximize the climate and air quality benefits of wireless charging, there is an opportunity to connect wireless charging infrastructure to renewable sources of energy and battery storage. This will also increase clean sources of power to the grid, allow for the integration of charging demand management practices, and add additional clean energy to the power supply. Early coordination with the local utility can support use of best practices for clean energy use and energy demand management from the start of project development and help utilities across the state better understand grid impacts of WPT technology.

OPPORTUNITIES

Partnerships

To implement many of the innovative projects in the Regional Plan, SANDAG is developing a Public-Private Partnership (P3) program to facilitate innovative partnerships and alternative delivery methods. P3s are long-term agreements between a public agency and private sector partner(s) that use an integrated approach to develop, finance, and deliver projects that may otherwise be too costly, risky, or complex for a public agency to deliver through traditional methods. Pursuing a partnership with the private sector could offer a unique opportunity to leverage existing public infrastructure to accelerate the design, construction, and delivery of EV charging, test new technologies, and explore alternative business or operational models to help scale and sustain EV charging operations region-wide.

SANDAG is interested in developing public-private partnerships to address the challenges of early-stage adoption of WPT. These partnerships should leverage existing state and regional efforts to make impactful reductions in greenhouse gas (GHG) emissions and air pollution, leverage existing funding, prepare the region to receive future funding, and integrate a suite of intelligent transportation system technologies to holistically approach WPT. The wireless charging pilot project should consider a variety of factors to ensure greatest possible benefit to the region, including but not limited to: repeatability of the route; GHG emissions and air pollution reduction potential; political and physical feasibility; and equity. Furthermore, a wireless charging pilot project could integrate economic development components, such as workforce development, to support partnership opportunities in early market adoption.

For example, several wireless providers are considering a Charging as a Service (CaaS) business model, which support revenue generation as a means to help recoup some of the investment needed to install wireless charging infrastructure. A CaaS model could have the technology provider cover upfront costs, including infrastructure and operational costs, and then provide the charging as a paid service to customers via a monthly subscription or pay-as-you-go.[31] While this requires integrating some form of payment method into the wireless charging system, this feature could be built into the communications and software capabilities of the system, and can make the overall project more feasible and enticing to public and private entities.

Existing Legislation and Funding Opportunities

The high cost of wireless EV charging infrastructure can be a challenge when deploying projects in the region. However, there are numerous economic and financial opportunities that can be leveraged to ease the cost burden on public agencies and help entice additional public and private investment. Project teams can pursue grant funding opportunities at the state and federal levels to supplement any public and private investment available for wireless EV charging projects.

At the state level, the California Energy Commission (CEC) releases grants under its Clean Transportation Program that support a variety of EV-related topics.[32] The CEC Electric Program Investment Charge (EPIC) Program[33] was established to help meet the state's climate goals as new clean energy solutions are developed and commercialized to decarbonize the electricity sector. The EPIC Program invests more than $130 million annually to support research focused on a number of initiatives including advancing clean transportation.

OPPORTUNITIES

The CEC Best Fit program funds projects to demonstrate innovative EV charging solutions for light-, medium-, and heavy-duty vehicles, and seeks to accelerate the successful commercial deployment of these solutions. Another complementary grant opportunity is the CEC's Vehicle-to-Building Technologies (GFO-21-303), released in October 2021, which indicates a state-level interest in innovative and emerging technologies.[34]

At the federal level, President Biden's Infrastructure Investment and Jobs Act (IIJA), passed in November 2021, includes $7.5 billion for electric vehicle chargers and outlines goals for zero-emission technology adoption.[35] Recently, U.S. Representative Brenda L. Lawrence (MI-14) introduced H.R. 6546, the Wireless Electric Vehicle (EV) Charging Grant Program Act of 2022,[36] which would create a $50 million grant program in the U.S. Department of Transportation for small-scale wireless EV charging projects, and included language highlighting the benefits of wireless charging to increase EV accessibility for disabled drivers. This bill is endorsed by MDOT, the Electrification Coalition, ASPIRE, The Ray, and Accelerator for America Action. Clearly, there is increasing interest in the public sector, at all scales, in wireless EV charging, which will help get projects implemented in the San Diego region and across the United States.

Lastly, on April 22, 2021, the Federal Highway Administration (FHWA) issued a letter to the FHWA Division Offices who work with State DOTs to clarify acceptable uses for Interstate right-of-way (ROW). The letter provided guidance on pressing public needs related to climate change, equitable communications access, and energy reliability. Two of the allowable utilizations are EV charging and renewable energy generation in FHWA ROW. USC 23 111 limits vending or sales in the ROW along the Interstate System; however, this letter explained that EV charging and renewable energy generation could be allowed if accommodated as a utility (in California EV charging is not considered a utility) under 23 CFR Part 645 or as an approval as an alternative use of the highway ROW under 23 CFR Part 710. SANDAG views the intent of this letter as a recommendation that FHWA and State DOTs allow for EV charging on highways, at rest stops, and other FHWA ROW.

Complementary Technologies

Wireless charging can embrace other smart infrastructure elements that are being supported at both the state and federal levels. For example, WPT technology and how it interfaces with payment, software, and other smart infrastructure could be included in strategic Intelligent Transportation Systems planning efforts to ensure public agencies are considering standardized approaches to wireless charging, and other innovative charging methods, in long-range planning. Wireless charging infrastructure can also utilize vehicle-to-everything (V2X) communications technology, a concept which envisions electric vehicles having a more involved relationship with their environment. For instance, vehicle-to-grid (V2G) connections would allow for power transfer between vehicles and the electrical grid to balance demand and supply of energy. Similarly, there are a number of other V2X connections that can be leveraged for maximum efficiency, such as vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-network (V2N) connections. Thus, there is significant opportunity with not only the hardware needed to implement wireless EV charging, but also the related software and communications technology.

CONCLUSION

Wireless EV charging, while still emerging in North America, has the potential to revolutionize the electric vehicle industry, support public electric vehicle adoption, and help meet climate and air pollution goals. As a relatively new and emerging technology, there will be some expected and unexpected challenges associated with the adoption of wireless EV charging. Some questions surrounding the implementation of wireless EV charging remain; for example, how much power will be needed to electrify a roadway, and how will the number of vehicles serviced by the roadway affect electricity need? Continued research and real-world demonstrations of WPT in the San Diego region will help to answer these questions and further advance this innovative EV charging technology to support a clean transportation future. Demonstrations of wireless power transfer that build off past demonstrations are necessary to enable technology providers and project administrators to learn how to plan for and implement wireless charging at scale to adequately serve light-, medium-, and heavy-duty EVs.

SANDAG seeks to be a leader of innovation by exploring applications of WPT in the San Diego region.

Source: Getty Images

Near-term actions for the agency include establishing regional partnerships and identifying potential funding sources. Desired applications for a wireless charging demonstration/pilot would showcase feasibility of normal business operations that use repeatable routes, drastically reduce GHG and air pollution, and benefit underserved or historically underrepresented communities. SANDAG would also like to use public-private partnerships to reduce government risk, support private industry commercialization of the WPT technology, and position the team to be able to nimbly apply for grants and funding opportunities as they arise.

LIST OF ACRONYMS

A2Z	Accelerate to Zero Emissions Collaboration
CaaS	Charging as a Service
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CERP	Community Emissions Reduction Plan
DAC	Disadvantaged Community
DOT	Department of Transportation
EPIC	Electric Program Investment Charge
EV	Electric vehicle
FHWA	Federal Highway Administration
GFO	Grant funding opportunity
GHG	Greenhouse gas
IEC	International Electrotechnical Commission
kW	Kilowatt
LIC	Low-Income Community
MCAS	Maritime Clean Air Strategy
MDOT	Michigan Department of Transportation
OEM	Original Equipment Manufacturer
P3	Public private partnership
ROW	Right-of-way
SAE	Society of Automotive Engineers
SANDAG	San Diego Association of Governments
USC	United States Code
V2G	Vehicle-to-grid
V2I	Vehicle-to-infrastructure
V2N	Vehicle-to-network
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-everything
WPT	Wireless power transfer
ZEV	Zero-emission vehicle

APPENDIX A: SANDAG TRANSPORTATION ELECTRIFICATION PROJECTS

SANDAG has been working towards regional transportation electrification for several years. In addition to projects that are currently underway, many others have already been completed and have guided the region towards EV readiness, paving the way for innovative charging technologies such as WPT to be considered.

CURRENT PROJECTS	
Accelerate to Zero Emissions (A2Z)	A2Z is a collaborative comprised of regional stakeholders in support of transportation electrification in the San Diego region. The A2Z Gap Analysis, published in July 2021, identified barriers to EV adoption, and will be followed by an EV Strategy (forthcoming) to overcome these barriers and support widespread EV technology deployment in the region.
California Electric Vehicle Infrastructure Project (CALeVIP): **San Diego County Incentive Project**	CALeVIP is a California Energy Commission (CEC) program that provides incentives for light-duty EV charging infrastructure. SANDAG and the Air Pollution Control District partnered to bring the CEC program to San Diego, incentivizing the construction of Level 2 and DC Fast Chargers around the region.
Medium- and Heavy-Duty Zero-Emission Vehicle Blueprint (**MD/HD ZEV Blueprint**)	SANDAG and the Port of San Diego were awarded a California DOT Planning Grant and are currently working on a MD/HD ZEV Blueprint to plan for the charging infrastructure that will be needed to electrify medium- and heavy-duty fleets throughout the region.
Regional EV Charger Management Strategy (**REVCMS**)	SANDAG and the North County Transit District (NCTD) were awarded a Caltrans Planning Grant to research and develop a comprehensive public EV charger management strategy that will help local jurisdictions streamline their method(s) of public EV charger management and maintenance.
PAST PROJECTS	
Emerging Technologies Whitepaper	This whitepaper was last updated in April 2021 to better reflect current research and transportation-related trends. The whitepaper covers a variety of innovative topics, including clean transportation and electric vehicle charging technologies.

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