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ELECTRIFYING THE NATION'S MASS TRANSIT BUS FLEETS

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Transit authorities are facing new and exciting challenges on the path to electric bus fleets: new infrastructure, technology and operational considerations. To overcome these challenges, transit authorities may need new partners to help develop a comprehensive electrification road map.

Though transitioning a bus fleet from diesel or compressed natural gas (CNG) to electric may sound straightforward, it is anything but. A multitude of new considerations come into play to deploy electric buses, and transit agencies can experience several through small-scale pilot projects as a first step toward full-scale deployment.

The creation of a comprehensive electrification road map can help transit agencies address new considerations through effective means. Proper planning, coupled with staged electric bus infrastructure and new hardware and software rollouts, will allow transit agencies to electrify their fleets within budgetary requirements and without impacting current operations and levels of service.

By understanding the obstacles to overcome and the benefits of an electrification road map, transit agencies can develop a long-term electrification strategy to enable a smooth transition.

DRIVING FORCES BEHIND ELECTRIC BUS ADOPTION

The uptick in electric bus adoption can be attributed to a favorable regulatory environment, an improving total cost of ownership (TCO) model and advancements in electric vehicle (EV) technology. While the TCO model and technology advancements aid adoption, the favorable regulatory environment is leading the charge and will continue to do so in the near term. Consumer demand, while not discussed below, is increasingly impacting fleet electrification decisions and will play a larger, more crucial role in the future.

REGULATIONS

Whether through the availability of federal and state funding or local laws and ordinances targeting emission reductions, much of the adoption of electric buses to date has been driven by regulation. Federal funding through the Federal Transit Administration's (FTA) Low or No-Emission (Low-No) Bus Program provides an avenue for transit agencies to secure funds for electric buses and charging infrastructure. Many transit agencies have piloted their first electric buses through this program.

States such as California are aggressively targeting greenhouse gas (GHG) emissions. Because the transportation sector is a large emitter of GHGs, especially medium- and heavy-duty vehicles, California passed legislation that empowers the state's investor-owned utilities (IOUs) to propose transportation electrification programs to support the state's emission reduction goals.

These potential programs could provide an influx of capital to deploy charging infrastructure, helping overcome an obstacle for adoption. Other states across the country, while not targeting GHGs as aggressively as California, are also turning to their IOUs to lead the way for transportation electrification. Additionally, the $2.7 billion from the Volkswagen Mitigation Trust funds available to states across the U.S. should create an opportunity for transit agencies to explore electric buses.

TOTAL COST OF OWNERSHIP

The TCO drives commercial vehicle procurement decisions, including electric buses. While the TCO of electric buses is typically greater than other bus types, the TCO parity between the two groups is shrinking. In certain regions and for certain applications, the TCO has reached parity, making electric buses a viable option for some transit authorities under certain regulatory or operating conditions.

The California Air Resources Board, through its Advanced Clean Transit Working Group, has published detailed TCO analyses reiterating the competitiveness of electric buses. As manufacturers scale production, the cost of new electric buses will likely trend downward. Maintenance costs for electric buses are already less than those of other types of buses because of fewer moving parts, no need for oil changes and longer-lasting brakes. Operational costs are another hurdle to overcome, albeit not the largest.

Electricity consumption costs are generally less than fueling costs for buses; however, this can be dependent on electric rates, demand charges and consumption. The cost of electric infrastructure installation and facility changes to support electric bus operations can be quite large and should be considered in TCO calculations. These costs are very much dependent on each transit agency's operations but can be offset by the fuel and maintenance savings. Although individually unique, the IOU transportation electrification programs currently implemented could shift the cost burden of charging equipment and electric infrastructure from the transit agency to the electric utility.

TECHNOLOGICAL ADVANCEMENTS

The advancement and availability of EV technology and charging equipment is making it easier for transit agencies to deploy electric buses. On-route pantograph and direct current (DC) fast chargers are becoming more commercially viable, alleviating some charging concerns. This will continue to be the case as manufacturers improve charging technology.

The range and charging times of electric buses continue to improve much to the benefit of transit agencies. Proterra, an electric bus manufacturer, set a world record when its Catalyst E2 Max bus went over 1,100 miles on a single charge in a controlled environment. While it is unlikely that a transit agency needs an electric bus that can travel over 1,100 miles on a single charge, the announcement highlights the fact that electric bus manufacturers continue to refine the balance between range, charge time and cost.

DRIVING FORWARD

Transit authorities across the U.S. are looking to electrify bus fleets. Some are looking to implement pilot programs while others are ready for full-scale deployment across an entire fleet. The following transit agencies have announced plans to convert to electric fleets:

- **Metro — On July 27, 2017, the Los Angeles County Metropolitan Transportation Authority board voted unanimously to transition its entire bus fleet to electric by 2030. Metro operates a fleet of 2,200 buses and plans to spend $1 billion on new bus purchases over the next 10 years.**
- **New York MTA — In April 2018, New York Metropolitan Transit Authority (MTA) announced plans to convert its public bus system to a zero-emissions, all-electric fleet by 2040. With more than 5,700 buses in its fleet, MTA is already testing 10 all-electric buses and has plans to purchase 60 more by 2019.**
- **King County Metro — On Jan. 10, 2017, King County Metro announced that it would acquire 120 electric buses by 2020 — eight of which were slated to go into service in 2017 and 12 more in 2019. Seventy-three of the electric buses will be purchased from Proterra with the remaining purchased from different manufacturers to test various battery technology.**
- **Foothill Transit — On May 12, 2016, Foothill Transit announced its plan to fully electrify its bus fleet by 2030. Foothill Transit operates a fleet of over 350 buses, of which 17 are electric. Foothill Transit is in the process of deploying another 13 electric buses.**

Hyundai unveiled its new electric bus with a 256-kWh battery that has a range of 180 miles and can be fully charged within an hour. The broad EV industry continues to push for standardization across charging technologies, a goal further perpetuated by trade organizations. This continual advancement and push for standardization will fuel technological advancements within this industry.

PILOT VERSUS FULL-SCALE DEPLOYMENTS

Transit agencies are at various stages of electric bus deployment across the U.S. In California, for instance, some transit authorities are considering full-scale deployment while transit agencies in other parts of the country are more interested in pilot projects. Regardless, transit agencies are looking to expand electric buses in their fleets. This is evident from the year-over-year growth in the number of applicants for the FTA Low-No Bus Program. Whether pilot projects or full-scale deployment, electric buses are here to stay. And transit agencies should develop electrification plans to implement either.

PILOT DEPLOYMENTS

Pilot deployments are a great way for a transit agency to gain experience with electric buses and the associated infrastructure. It provides an opportunity to deploy a limited number of electric buses and charging equipment in a cost-effective manner with limited disruptions to operations. Typically, it is simple to coordinate pilot deployments with local electric utilities, requiring limited, if any, electrical infrastructure upgrades. While the main objective is to learn about electrification, a successful pilot deployment will be informative and scalable to allow a transition to full-scale deployment.

FULL-SCALE DEPLOYMENTS

Full-scale deployment of electric buses across a transit agency is in its infancy. As previously noted, a number of transit agencies are considering or pursuing full-scale deployment. Transitioning an entire fleet means overcoming new challenges. There are different stakeholders such as local electric utilities, new infrastructure requiring detailed engineering and construction, and new operational issues to support bus charging — all of which must be addressed. While there are challenges, all can be overcome through proper planning and analysis.

RECOMMENDATION

Implementing a pilot deployment is a necessary and practical approach to fleet electrification. Electrifying an entire fleet is a complex transition that requires appropriate planning to minimize the potential for stranded assets. By electrifying a simple route or even a handful of buses, transit agencies have an opportunity to experience new technology; assess impacts to operations, maintenance, and training; and plan for the future. Engaging an electric bus manufacturer to discuss a pilot project is a good first step for most transit agencies. They have been instrumental in increasing electric bus pilot projects across the U.S. Another option may be to engage local electric utilities. Such utilities are engaging in transportation electrification pilot projects that include port electrification, school or shuttle bus electrification, and consumer vehicle electrification.

HOPPING ON THE LOW-NO BUS

More and more agencies are applying for funds from the FTA Low-No Bus Program. On Sept. 15, 2017, the FTA announced $55 million in grant selections — 51 projects in 39 states to receive funding, up from 20 projects in 13 states in 2016. The funding will purchase Low or No-Emission buses and associated infrastructure. In 2017, all but two of the projects focused on electric buses and associated infrastructure, highlighting the desire by transit agencies across the U.S. to explore fleet electrification.

MOVING FORWARD WITH FULL-SCALE DEPLOYMENT

Part of what makes a full-scale deployment of electric buses difficult is the integrated, detailed analysis necessary to develop a fleet electrification road map. The analysis may seem overwhelming as it covers several areas that cannot be evaluated individually. Given that the transition will occur over multiple years, the plan will need to address maintaining a diverse bus fleet during the transition period, working within the capital budget constraints, and minimizing impact to existing and future operations. A few keys areas should be assessed once the decision has been made to electrify a fleet.

ROUTE AND FLEET ANALYSIS

Bus routes are already well-established within a transit agency's service territory. Routes are added or removed over time based on ridership, urban expansion and future demand. These elements will continue to drive route planning; however, the location, availability or need for charging infrastructure will be a new element for consideration in route planning. Comprehensive route analysis is an important step in building an electrification plan.

Before performing the route analysis, it is important to understand the technical parameters or limitations of the commercially available technology. These parameters are based on a snapshot in time and feed into the route analysis, so potential technological advancements should be considered. Evaluating multiple vendors allows the transit agency's electrification road map to maintain flexibility and minimize the potential of stranded assets. By understanding range and charging capabilities under a variety of environmental conditions and use cases, transit agencies can determine the appropriate fleet to meet their needs.

Once technical parameters are established, the detailed route analysis may be performed to marry the parameters of electric buses with the characteristics and timetables of routes, identifying potential charging windows and determining whether the route can be electrified given the parameters selected. The analysis can also be modified by adjusting the parameters, resulting in multiple solutions. For example, varying battery sizes or charging powers could result in a one-depot-only charging solution or a combination of depot and on-route charging. Or the analysis could determine that multiple on-route chargers are needed or that an additional bus is needed to maintain the desired level of service. Analysis results can also prioritize routes for electrification. For example, a transit agency may elect to prioritize routes that can be electrified by using commercially available electric buses and depot charging while delaying other routes that cannot.

Regardless of the methodology, a transit agency's analysis could result in a fleet of short-, medium- and long-range electric buses with various high-powered chargers, both in the depot and on-route, to align with future ridership demand and mobility.

COORDINATION WITH THE ELECTRIC UTILITY

Understanding electrical limitations depot-only, as well as on the local distribution system, is a must when building an electrification road map. Limitations may not impede a transit agency's ability to move forward with fleet electrification but could impact scalability and timing. Therefore, it's essential to engage the electric utility early and often to navigate this coordination process.

First, agencies should understand the electrical service at their own depots. A fully electrified depot could be a 20- to 30-megawatt (MW) demand customer. While existing infrastructure may be adequate to support a pilot program, electrical infrastructure upgrades may be needed to support a fully electrified fleet charging at the depot. The same applies for local distribution networks. The utility must analyze current and future demand to confirm its local distribution system can meet the agency's needs, and may need to provide a sub-transmission line and substation to the depot. To help, transit agencies must be able to provide details around the timing and number of buses introduced at the depot — an electrification road map can provide these answers.

On-route charging is a little more challenging, as transit agencies need to optimize the location, making sure it is an adequate place for a utility connection, provides enough charge at an opportune time, and easements can be obtained. More coordination is necessary with on-route charging, as the transit agency is usually considering multiple on-route charging locations.

Electricity rates are another important operational cost consideration for electric buses. Transit agencies must understand the local utility rate schedules and types of rates available, which can vary by time of year, time of day and by utility. Some utilities have EV-specific rates, while others do not. Typically, commercial customers are charged in three ways: customer charges, usage charges and demand charges. Demand charges can significantly increase operational costs, especially when utilizing on-route charging. To mitigate demand charges, transit agencies could optimize charging by staggering charging, charging during off-peak hours, or using on-site renewable power or battery storage to meet their needs. In some instances, utilities have even waived demand charges, for a period, to help minimize electricity costs. Regardless, implementing optimized charging to minimize electricity costs should be easier for depot charging in comparison to on-route charging. On-route charging is done out of necessity, limiting the ability to do so. However, it's still important to consider electricity costs based on usage and demand when selecting on-route charging locations.

INTEGRATION OF RENEWABLES AND STORAGE

Many transit agencies have already started to use renewable generation sources by installing solar on the rooftop of their maintenance facilities. With fleet electrification driven by the desire to reduce GHG emissions, it makes sense to increase the use of renewable generation. Storage may become a necessity, depending on how the renewable power supply is sourced, and can provide benefits such as load smoothing and soak up renewable over-generation during peak times.

There are multiple options for sourcing renewable power: on-site generation, off-site generation and green rates through the electric utility. While transit depots come in all shapes and sizes, it's unlikely most have adequate space for on-site generation and storage. A depot for 120 to 150 buses may only be a site of 8 to 12 acres, not nearly large enough for solar-storage combination without costly site layout creativity. Off-site generation or green rates may be more probable because of space constraints, but might be costlier and unable to operate during an outage.

While each situation is unique, finding a middle ground that incorporates both on-site and off-site renewable generation and storage is a probable solution. The on-site renewable generation and storage will allow the transit agency to minimize costs, capitalize on renewable over-generation, and go off-grid during an outage, while the off-site renewable generation will maximize space utilization at the depot. Backup generators can be incorporated into the on-site microgrid to supplement needs during an outage or emergency. Transit agencies must understand the available space as well as the forecasted demand at each depot to determine the best approach for integrating renewables and storage.

IMPACTS TO OPERATIONS, MAINTENANCE AND TRAINING

Intelligent route analysis coupled with the appropriate technology should minimize impacts to route operations, but each situation is unique. Route schedules may be adjusted to provide additional time for charging, whether in the depot or on-route, or additional buses may be added to maintain the same level of service. Transit agencies should be prepared to assign buses to specific routes, especially if a transit agency wants to avoid on-route charging.

Each bus will likely have a unique charging window, requiring a mix of high-powered chargers. This may facilitate the need to assign buses to specific parking spaces in the depot if a transit agency does not install uniform, high-powered chargers. The flow of the depot and available parking should influence the type of chargers installed, whether pedestal- or overhead-mounted. Cord management procedures — a simple but often overlooked challenge — or the use of automated, contact charging also need to be considered. Changes in the order of operations such as fare collection and washing once buses return to the depot may need to occur to accommodate charging. Identifying these operational changes is paramount for complete fleet electrification, but especially for incremental deployment of electric buses to minimize impacts to customers while operating mixed fleets.

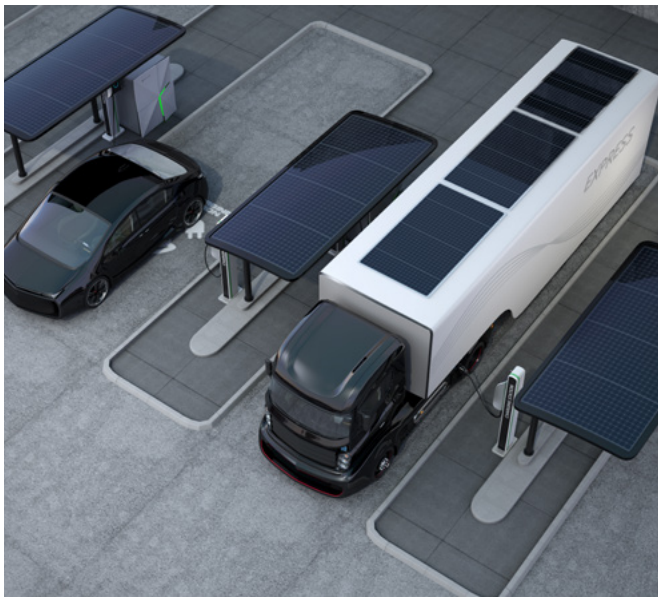
Maintenance programs will also need adjusting, even though electric buses require less maintenance. Maintenance personnel will need training on new procedures, potentially at differing frequencies, and record keeping and reporting must be adapted. Maintenance on new equipment, such as chargers, on-site generation and storage, will require a specialized maintenance program and skill sets or might need to be outsourced. Most importantly, any and all changes to maintenance procedures must be rolled out while simultaneously maintaining existing assets. Bus manufacturers provide adequate support services during pilot implementations, but a strong change management program is beneficial to support complete fleet electrification because each phase will convert a small subset of personnel at a time.

Operators will also require detailed, specialized training on the nuances of driving an electric bus. As with maintenance support services, bus manufacturers provide adequate operator training services during pilot implementations, but a revamped training program is needed for all ongoing operations. New EV fleet monitoring solutions enable vehicle operations to be linked to a specific operator, which can be used to highlight specific training needs of individual operators. Targeted operator training could help an agency maximize vehicle range and minimize electricity costs.

NEW HARDWARE AND SOFTWARE

A smooth transition to an electrified fleet requires the integration of new hardware and software, which is becoming more commercially viable and available. Industry organizations are working to make it more standardized to mitigate concerns of stranded assets. Regardless, transit agencies should use findings from their route analysis to identify the number of and appropriate size of chargers and determine a charging strategy. There are two extremes with combinations in between that a transit agency could utilize. One extreme is a dedicated charger for every bus while the other is optimized charging via a minimum number of chargers.

Depending on the charging strategy, an EV charging software platform may be a critical addition to the transit agency's software suite. Such platforms provide value by enabling visibility into charging operations and allowing a transit agency to perform load management through charge optimization or load smoothing to minimize electricity costs. The platforms can integrate distributed energy resources, such as battery storage or on-site generation, to minimize electricity usage during peak hours. The great news is that once the fleet is completely



transitioned to electric, traditional fueling software tools are no longer needed. The new platforms provide real-time insights into charging operations and the opportunity for predictive analytics.

ESTABLISHING A CAPITAL BUDGET

As with any project, the implementation of the electrification road map must fit within budget constraints. Transitioning to an electric fleet will occur in a multiyear rollout, meaning certain routes or regions of a transit agency's service territory will be electrified at a time. Therefore, a transit agency could build its capital budget around a phased implementation or set an annual budget for electrification and build an implementation plan around it.

Regardless of the methodology, the transit agency must carefully plan its capital expenditures. An electrification road map will help establish a capital budget by identifying an end-state as well as incremental phases along the way that include vehicle and infrastructure costs. To help fund the transition, transit agencies should take advantage of state and federal grants, as well as transportation electrification programs that shift costs of infrastructure installation to their electric utility. While not widespread, electric utilities across the nation have initiated or are exploring transportation electrification programs.

CHANGES TO THE DEPOT

It's safe to say that the bus depot of tomorrow will look different from the depot of today. Renewable generation, energy storage and chargers will shape the depot of tomorrow. Maintenance facilities, such as engine and transmission overhaul facilities, will be repurposed. Traditional fueling facilities will be eliminated altogether. To add to the complexity, modifications will need to be implemented over a five- or 10-year period, all while maintaining service operations.

Determining charging needs and a charging strategy will help inform the number of chargers needed, allowing an agency to assess potential reductions in yard space or impacts to bus flow. Because depots are typically located in industrial areas with limited room for expansion, a transit agency will need to optimize its depot space.

Some agencies will have the luxury of building a new depot, but those that don't will need to be creative with their space as they look to incorporate high-powered chargers, renewable generation, energy storage, backup generation or a distribution substation at their depots. One appealing option for transit agencies may be to construct a building shell overtop their existing depot. This shell could provide a way to elevate charging equipment, eliminating the potential for operators to drive into it, minimizing implementation costs as wire and conduit are installed overhead rather than underground, and providing space for more on-site solar.

Designing and installing the infrastructure is not necessarily a complex task; however, doing so while trying to implement the plan over several years and maintaining minimal impacts to operations and services can make it quite complicated. An electrification road map can help a transit agency mitigate unforeseen issues, as the road map breaks the implementation into multiple phases.

OBSTACLES TO OVERCOME

While transit agencies can implement pilot deployments fairly easily today, barriers still exist for full-scale deployment.

First, transit agencies must realize the importance of developing an electrification road map. Transitioning to an all-electric fleet is complex and very different from traditional transit planning and operations. Finding the right partner to help may require transit agencies to look outside their traditional consultants. A consultant that can pair traditional transit and capital planning with electric grid and rate analysis, renewables integration, and route analysis — and possesses the technical knowledge and experience to implement various types of charging hardware and software technology — will be key to developing the electrification road map.

Second, transit agencies must overcome the cost hurdle to develop the electrification road map. An overall transition requires a significant investment from the transit agency — new buses, new chargers, new software, upgraded depots and modified processes, to name a few. To plan for these changes without investing in an electrification road map would be misguided. It may be expensive given the

multitude of variables that must be iteratively evaluated, but this road map should minimize the risks of stranded assets, minimize costs and result in a smoother transition.

Finally, transit agencies must decouple the procurement of charging equipment and electrical infrastructure from electric buses. This model works well for small pilot programs, as manufacturers supply the electric buses and associated charging equipment and, in many instances, serve as the design-builder for a turnkey solution.

However, as transit agencies transition to full-scale deployments, the procurement model appears to be a barrier. Providing turnkey solutions is not a bus manufacturer's core competency. More importantly, this deployment model has the potential to either lead to stranded assets or lock in a transit agency to a particular vendor. Transit agencies would benefit by developing a comprehensive electrification road map prior to turning to bus manufacturers or purchasing electric buses, associated charging and electrical infrastructure.

The road map would feed into multiple request for proposal opportunities, separating the procurement of electric buses from the procurement of charging and infrastructure upgrades.

While transit agencies have been some of the first large, centralized fleet operators to explore fleet electrification, they are no longer alone. More and more fleets are beginning to evaluate electrification, such as local delivery or commercial automobile fleets. This will lead to continued technological advancements and more widely distributed experience with electrifying depots that will surely benefit all.

DEVELOPING A COMPREHENSIVE PLAN

Before a transit agency can begin building a comprehensive electrification road map, it must recognize the challenges that require specialized assistance from an external consultant. A consultant can develop a pilot project that separates the procurement of electric buses from the required infrastructure, captures appropriate data to run the program properly, and monitors and analyzes the results to develop a comprehensive electrification plan.

Consultant services may be costly, but it's a drop in the bucket compared to the cost of transitioning an entire fleet. Armed with a well-developed electrification road map, transit agencies can convert fleets in an efficient, cost-effective manner.

BIOGRAPHY

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