Los Angeles County
Metropolitan Transportation
Authority
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REVISED
OPERATIONS, SAFETY, AND CUSTOMER EXPERIENCE COMMITTEE
MAY 18, 2023

SUBJECT: ZERO-EMISSION BUS PROGRAM UPDATE

ACTION: RECEIVE AND FILE

RECOMMENDATION

RECEIVE AND FILE the Progress Report on the Zero Emission Bus (ZEB) Program, including the shift in the program goal of fully transitioning to a zero-emission bus fleet from 2030 to no later than 2035, with a commitment to no longer procure Clean Natural Gas (CNG) buses to accommodate the new program goal.

ISSUE

In 2018, The California Air Resources Board's (CARB) Innovative Clean Transit (ICT) regulation mandated that all transit agencies in the state operate all-zero emission fleets by 2040.

In July 2017, Metro's Board of Directors approved Motion #50 (File 2017-0524) which endorsed a ZEB Strategic Plan (SP) to transition the entire bus fleet to zero-emission by 2030, contingent on envisioned cost and performance equivalence with CNG buses as a result of continued advancements in battery-electric bus (BEB) technology. However, the availability and capacity of sufficient power at each of Metro's bus divisions have been identified as a constraint.

Meanwhile, BEBs' cost and technical parity with CNG buses have not materialized.
Given the current status of the ZEB industry, staff finds that these program challenges (i.e., costs, performance, electrical grid capacity, supply chain and utilities' lead times, and market availability) are exacerbated by trying to achieve a full transition by the 2030 target date.

BACKGROUND

In July 2017, the Metro Board approved Motion #50 (File 2017-0524) by Directors Bonin, Garcetti, Najarian, Hahn, and Solis that endorsed a plan to transition to a ZEB fleet by 2030 (Attachment A). The endorsement was contingent based on two primary factors: continuous advancements in electric bus technology and a drop in prices as the technology develops. This provision stipulates that the ZEB conversion timeline considers the equivalence of ZEBs with Metro's existing compressed natural gas (CNG) buses to ensure that the program is technologically, financially, and operationally

reasonable.

Since the Board's endorsement, Metro has embarked on the most extensive ZEB transition program outside of Asia. To date, Metro has made significant progress in transitioning to ZEB service:

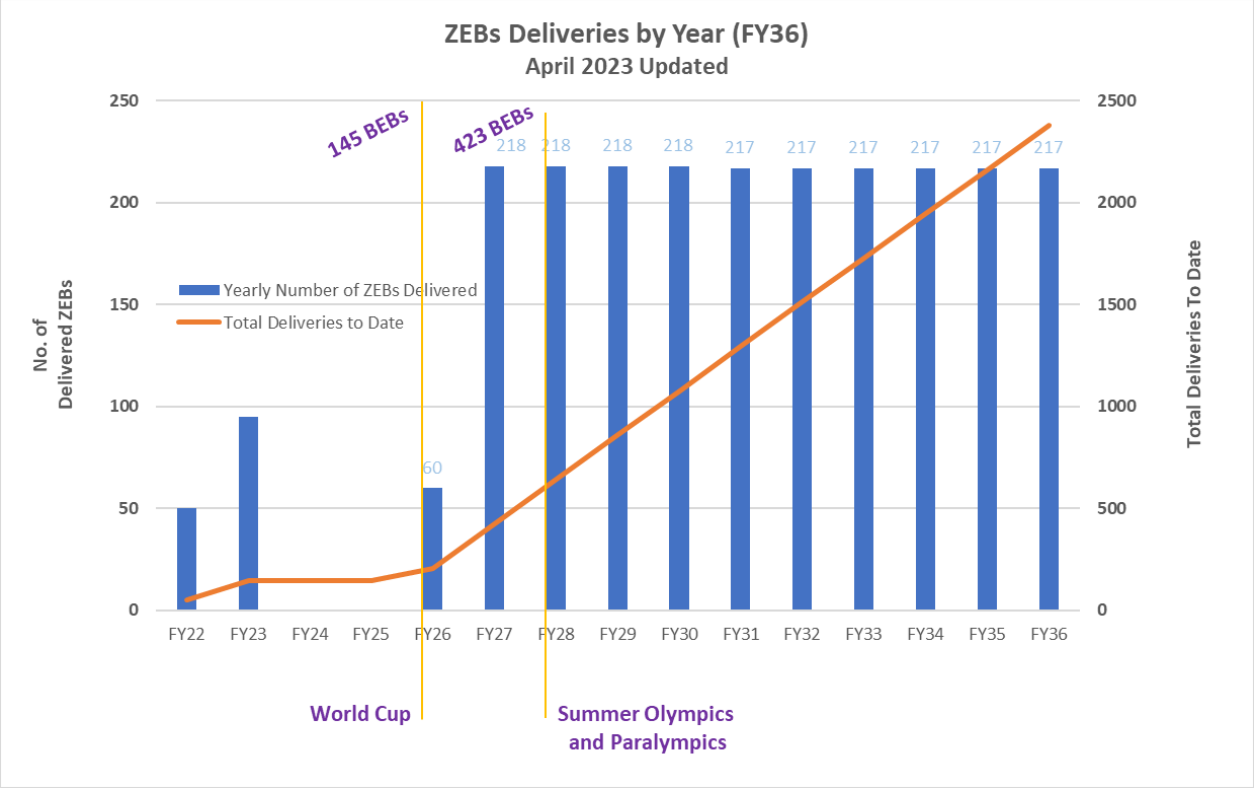
- A total of 145 BEBs have been ordered, one of the most significant BEB procurements to date in CA and among the three largest in the country. Currently, 50 BEBs have been delivered, with the remaining 95 scheduled to be delivered between September 2023 and April 2024; by the end of 2023, Metro will have the most BEBs in active service in the U.S.
- Metro's G (Orange) Line BRT initiated 100% ZE service at the start of 2021. To date, the vehicles have accumulated over 3 million miles of ZE service; the most miles by any public transit agency in the country.
- Conversion of Metro's J (Silver) Line BRT is underway and is anticipated to be completed by mid-2025.
- In ~~December 2022~~ January 2023, the Metro Board authorized the ~~procurement~~ solicitation of ~~an~~ a Request for Proposal (RFP) of 260 additional ~~1,000~~ BEBs and associated charging infrastructure.
- Metro has aggressively pursued all available funding, successfully securing to date $413.1 million in ZEB-related federal and state grant funding, including one of the largest Low-Emission/No-Emission grants in this federal program's history ($104.1 million awarded in 2022).
- Further, Metro has made significant investments in workforce development, developing a manufacturing careers policy and implementing advanced training for operators and maintainers specific to BEB technology.

These aggressive program achievements, combined with significant collaborations with relevant international and national organizations, have incentivized the market to make investments in battery technology, energy management, and motor efficiencies.

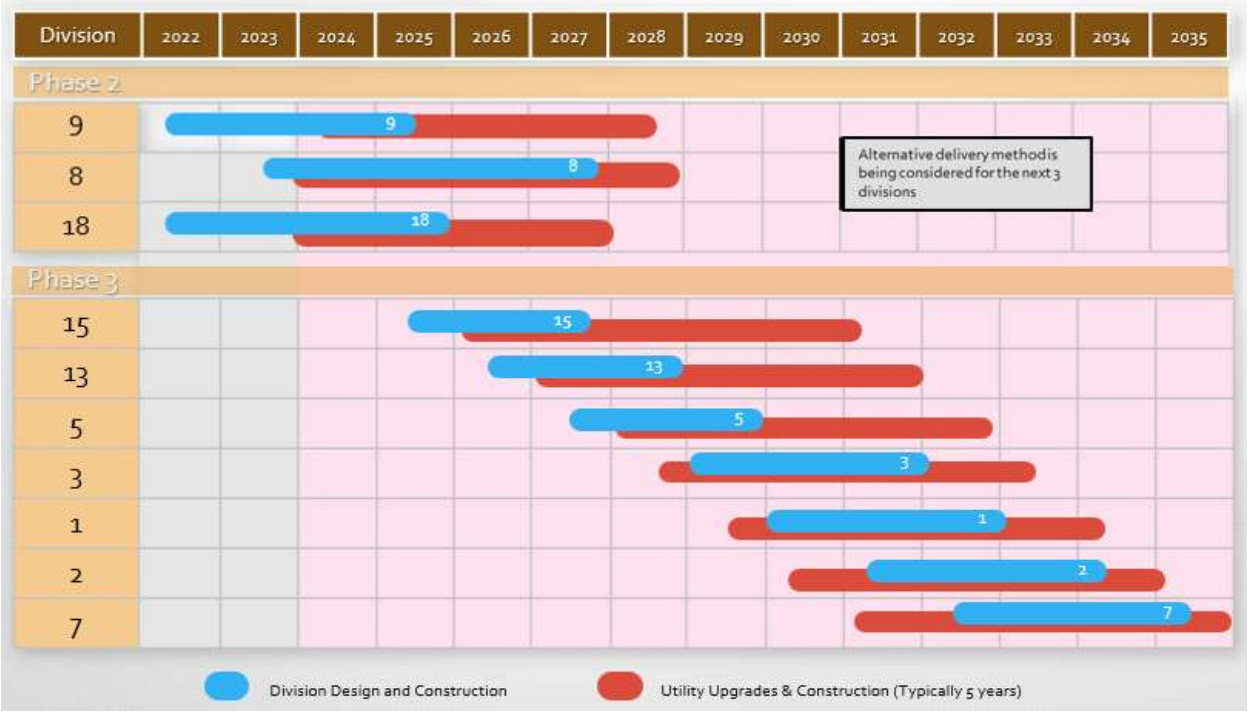
DISCUSSION

Despite the significant progress made to date, staff has found that the ZEB industry is still evolving and not sufficiently mature to allow for full implementation by 2030 without risk to service. Key issues include cost, grid capacity, performance (reliability, maintainability, and operability), early obsolescence, utility lead times, and supply chain issues.

Shifting the program implementation from 2030 to no later than 2035 will help mitigate these challenges and will not impact compliance with CARB's ICT regulations or hinder supporting the planned major regional events, such as the World Cup in 2026 and the Olympic & Paralympic Games in 2028. By the first half of 2026, 145 buses, or 8% of Metro's bus fleet, will be converted to BEB operation. By 2026, three of Metro's bus divisions (8, 9, and 18) will be fully electrified for BEB operation. Further, by 2028, Metro will have accepted and placed into revenue service 423 BEBs. These buses will be designated for lines in the most critical parts of Metro's Westside and Central bus service to support these globally important 2026 and 2028 events. The chart below outlines the number of vehicles that will be delivered per year to meet the full transition goal no later than 2035.



It is critical that the facilities phasing schedule aligns with the BEB deliveries to support the bus division charging needs. Metro cannot afford to simultaneously begin the work to fully electrify multiple bus divisions at once due to operational constraints such as service requirements, space, and storage limitations, construction activities, BEB deployment, etc. The ZEB Master Plan's phased approach (bus divisions that are independent and have fewer constraints and operational impact versus dependent bus divisions) allows staff to plan the work with minimal impact to operations. The chart below outlines the no later than 2035 facilities phasing approach.



ZEBs have not achieved CNG Parity

To date, ZEBs, whether BEBs or fuel cell electric buses (FCEBs), have not achieved parity with CNG buses, either in terms of performance or cost. More importantly, there are concerns that the electric grid is currently unable to support full BEB operation when regional demand is high and that electric utilities' lead times to provide upgrades can be lengthy. For FCEBs, the market is even more nascent - there are only two bus original equipment manufacturers (OEMs) and three hydrogen fuel cell suppliers, and the cost of both buses and hydrogen fuel are even higher than for BEBs, up to 30% higher for buses and more than four times that of electricity for the cost of hydrogen.

Each issue is discussed further below.

Utility Infrastructure Challenges

- Grid capacity. Studies have shown that the entirety of the California electrical grid is undersized and not ready to support a large-scale adoption of ZE vehicles. Additionally, more refined surveys of the divisions have revealed that the available grid capacity to serve some of its divisions may be less than the assumed minimum of five megawatts. These challenges will require added efforts in the planning and design processes to mitigate and may result in schedule impacts.
- Long lead times for grid upgrades. According to interviews with relevant staff of the electric utilities serving Metro's bus divisions, the project time that the utilities need to perform service studies, develop engineering and design documents, and add the necessary construction contractor time is a minimum of four years for each division. Five years is more realistic, according to these discussions. Furthermore, should substation or transmission infrastructure

upgrades be needed, the project time could be seven years.

- Market availability. Supply chain issues and constraints are currently impacting the timelines to deliver ZEBs and their supporting infrastructure. These issues are worse for FCEBs than for BEBs, as the market is still not mature enough to support Metro's goals. Only two OEMs produce FCEBs, and only four percent (4%) of all ZEBs (procured or in operation) are FCEBs.

ZEB Performance

ZEBs also have not reached parity with CNG buses regarding performance. The following are the areas of note:

- Range. Current BEBs have an operable range of 150-160 miles (dependent on a myriad of factors, such as HVAC energy usage, operator efficiency, elevations, speeds, etc.). Currently, 64% of Metro's approximate 1,800 service blocks are within 150 miles, with 14 service blocks exceeding 300 miles. More importantly, 27% of the service blocks in Metro's route network cannot be completed with current BEB technology, and would require more buses and bus network restructuring or implementation of a wider network of "opportunity" (i.e., on-route) chargers at strategic locations throughout the County. Moreover, recent range growth from the industry remains consistent at approximately 2% to 5% per year, therefore a conservative estimate of BEB's range improvement with a reliable 300-mile will not be available until 2035, at the earliest. (Recent years have seen range improvements of up to 20% annually, though such growth has been inconsistent.)
- Reliability. The industry is still learning how to integrate new technologies into existing systems. Metro continues to experience integration issues between new and existing battery systems and interfaces between the bus charging rails and pantographs, leading to premature failures of components, such as belt drives and bearings. For instance, Metro had experienced premature bearing failures on our BEB fleet on the G Line where Metro is the first transit application of its kind with no service proven history which led to a fleet defect and fleet wide bearing replacement. Recent reports suggest that this continues to be an industry-wide problem and not unique to Metro's operation. Extending the transition period will allow technology to mature, improving fleet availability and reducing the time and resources required to maintain the fleet in a State of Good Repair.
- Maintainability. While the industry has focused primarily on ensuring ZEBs can perform as CNG counterparts, less effort has been made to develop diagnostic information and tools for on-site technicians to expeditiously investigate and repair failures. Because the technology is relatively new and rapidly evolving, agencies are resigned to rely on OEMs' suppliers remotely located subject matter experts to investigate and mitigate failures, leading to longer out of service times. Staff has taken steps to request that OEMs' suppliers provide US based engineering and technical support. Staff has made some progress with Siemens and ABB for our existing charging equipment. Metro has taken on additional consulting staff to address these issues and recently received a $5 million training grant for workforce development. The recent LoNo grant from the Federal Government can also be used to improve operator and maintenance staff training. Metro's work to establish a Center for Transportation Excellence for advanced transportation technology is also designed to address these issues by incentivizing suppliers to locate their technical staff in Southern California.

- Operability. BEBs are not as user-friendly to operate as Metro's legacy fleet. As such, operators of BEBs need to be more intentional with driving. For example, operators will need to consider regenerative braking, HVAC usage, and buses' state of charge. Additional training and experience are needed to ensure the operators follow the correct procedures to avoid creating fault conditions.
- Obsolescence. As technology advances, parts, models, and other seemingly new equipment are rapidly becoming replaced - and in some cases, obsolete - as vendors continue to evolve their models and respond to market needs. Vendors have less incentive to support earlier technology than their newest offerings. This has been the case with some higher voltage chargers that Metro has deployed to serve the buses on the Metro G Line.

ZEB Costs

Meanwhile, BEBs' cost and technical parity with CNG buses have not materialized. For example, per current contract prices from the States of California and Washington, the cost of a BEB 40-footer is almost double that of a CNG 40-foot bus. For 60-footers, the cost differential is 70.1%. ZEBs are more expensive than CNG buses, and the new infrastructure required to support ZEBs requires a large initial capital investment. The following are the areas of note:

- Capital Costs
  - ZEBs continue to have a premium over CNG buses depending on vehicle size and recent pricing trends. This differential has not dropped as fast as originally expected.
  - The capital costs for installing BEB charging infrastructure at the depots and on-route charging are approximately $600 million to $800 million higher than the periodic cost of replacing CNG infrastructure.
- Operating Costs
  - Costs to maintain and operate ZEBs are still being evaluated. From initial deployments, savings in maintenance costs have only now begun to be realized in some agencies. However, energy costs have not remained stable.
  - Costs to maintain and operate charging infrastructure can be higher than conventional CNG storage and fueling infrastructure, although many agencies are mitigating cost increases through external vendor contracts and extended warranties on the charging equipment, covered under capital expenditures.
  - Costs associated with charge management are still being developed; however, these costs will also be new costs over that of the CNG legacy fleet.

Adding an additional five years to Metro's ZEB program transition will help mitigate the challenges summarized above. It will also provide Metro with additional time to seek and gather funding for the ZEB transition program. The following summarizes some of the specific ways in which a no later than 2035 program horizon can help mitigate the adverse impacts of these challenges.

2035-Related Utility/Grid Upgrade Benefits

- Grid capacity. To meet the requirements of the CARB ICT (Innovative Clean Transit) regulation

regionally and statewide, as well as other municipal and state policies that are committed to ZE transitions, electric utilities will continue fortifying and enhancing the grid's capacity. It is thus expected that the grid will be more built out in 2035 than in 2030 - thus, improving reliability of the grid and reducing the probability of Metro service interruptions. For example, California's Independent System Operator recently approved a 10-year transmission plan involving 23 projects estimated to cost almost $3 billion in total for system expansions and upgrades necessary to keep pace with the state's mandated transition to renewable energy resources by 2045.

- Long lead times for grid upgrades. As utilities become more experienced with supporting large scale ZE fleets, it is expected that their efficiency and project delivery methods will improve. This should help reduce timelines for Metro over-time.
- Market availability. Both the BEB and FCEB markets continue to expand over time. With more state and federal legislation to encourage ZE adoption (and more funding), and as the COVID-19 pandemic recedes into the past with more time, it is expected that some of the chokepoints with delivery will be eased. An additional five years of transition should help reduce costs and optimize the transition timeline further.

2035-Related Performance-Related Benefits

Considering that battery capacity and efficiency have steadily improved, it is safe to say that BEBs will be much closer to the BEB-for-CNG bus parity in 2035 than in 2030. The additional five years will also provide Metro with more time to train operators and maintenance staff, allow for the technology to further mature, and allow Metro to continue to monitor the market to take advantage of the latest offerings, newest vendors, and other benefits that come with fully transitioning at a later stage.

Additionally, based on current state of technology and anticipated availability of ZEBs and charging infrastructure, Metro does not intend to procure additional CNG buses, with the 2035 target date. If there are issues impacting availability of either BEBs or Charging Infrastructure, there are options that can be exercised. Those options include procurement of Hydrogen Electric Buses, installation of temporary charging infrastructure, and, if needed, extending the life of our CNG buses.

2035-Related Cost Benefits

- Capital Costs
    - Annual program costs will be reduced with a no later than 2035 program completion horizon. Although overall program costs may increase with an annual escalation of an additional five years, on an annual basis, program costs will be reduced by almost 40% with the no later than 2035 program extension. Please refer to the Financial Impact section for additional details.
    - With advancements in technologies, there will be less need to introduce mitigations to address the performance challenges noted above. As one example, as bus range increases, there will be less need to introduce opportunity charging, resulting in considerable capital cost savings. As noted in the financial table below, the precise number of the difference in chargers needed is being modeled at the time of this report, but it is expected to show substantial savings compared with the 2030 transition

schedule's cost estimates.
    - As vendors and OEMs become more efficient over time with their production, the capital costs of infrastructure are expected to decrease. This is already being realized with the downward trend of the cost of batteries per kilowatt hour.
- Operating Costs
    - As the region transitions to more renewable sources of electricity, long-term power costs are expected to attain parity or even become less expensive than natural gas, thereby lowering fuel/charging costs. A five-year extension of Metro's ZEB transition horizon makes these projections more attainable.

Advanced Transit Vehicle Consortium (ATVC)

The information above was presented at the Advanced Transit Vehicle Consortium (ATVC) at its March 2023 meeting to solicit feedback from ATVC board members on the recommendation to move the full transition to 2035. The board members engaged staff in discussions around battery technology, specifically increased range and reduced degradation, limitation of the utility companies in providing sufficient electricity in line with the conversion schedule, temporary charging, charge management, hydrogen fuels and redundancy, as well as the reduction in annual cost. At the conclusion of the discussion amongst all board members, there was an appreciation for the need to extend the timeline for full conversion from 2030 to 2035.

Transportation Electrification Partnerships

Metro is active in our efforts to collaborate and lead nationally and internationally. These efforts include but are not limited to the following: staff actively outreaches to other municipalities about potential partnerships and is active in coalitions such as the Zero Emission Bus Resource Alliance (ZEBRA), APTA ZEB Fleet Committee, and UITP Bus Committee to share lessons learned. Staff take advantage of these partnerships by applying lessons learned from others' experiences and apply those to reduce risk to our own projects. Further, additional industry leadership activities have included European fact-finding tours, attending and presenting at industry technical conferences, i.e., APTA, CTA, UITP, etc. The work on the Center of Excellence will incentivize industry investment in LA County as well. The benefits of these partnerships provide Metro with the latest market and technical trends, collaboration among agencies and suppliers on standards, codes etc., and potential funding opportunities. Lastly, Metro's Office of Strategic Innovation (OSI) is also evaluating potential public private partnerships.

Other Considerations

Continuing to implement the transition program associated with a 2030 program schedule was considered, but not recommended due to the factors associated above, as well as the likely opportunities to take advantage of the expected advances in technology.

Extending the program transition even further, to beyond 2035 and possibly to the 2040 state-mandated regulatory deadline was also considered. However, this alternative is not recommended as

costs associated with the program are also expected to escalate, and the need for operating the legacy CNG fleet past its design life would substantially increase operating costs, risk service, and supply chain issues as suppliers begin to exit the transit bus market for CNG issues and exacerbate environmental and equity impacts associated with continuing to operate the aging CNG fleet.

DETERMINATION OF SAFETY IMPACT

Up to an additional five years would allow Metro to incorporate additional safety systems and features that will help improve both passenger and pedestrian safety. Some of the safety enhancements that may be included on new buses: improved ADA securement provisions and self-leveling ADA boarding ramps, improved vehicle monitoring, pedestrian warning systems, curbside cornering lights, operator safety barriers and video monitors, real-time video security system accessibility, collision avoidance sensors, and improved passenger door sensors. Anticipated additional technologies include early warning and improved detection and mitigation associated with battery thermal events, as well as new battery designs that are expected to virtually eliminate such events altogether. These innovative designs are expected to be propagated in the vehicle industries in the late 2020s through early 2030s. Accordingly, a transition program goal to no later than 2035 would allow Metro to take advantage of these developments.

FINANCIAL IMPACT

The table below notes that extending the transition horizon to up to another five years may result in an estimated additional capital cost of $203 million in year of expenditure dollars, the increase is primarily the result of additional cost escalation. However, as noted above, the estimated capital increases may be offset by the reduced need to purchase, maintain, and operate charging infrastructure. As one example, it was originally estimated that approximately 190 opportunity chargers would be needed at a cost of approximately $155 million. With added range, it may be possible to reduce the number of chargers by 70% or more, reducing the capital costs by $119 million or more bringing the total capital cost more in line with the 2030 goal, while simultaneously reducing the annual cost of the program by almost 40%. It should be noted that these expenditures come directly from State of Good Repair (SGR) funds which are operations funding.

Program Capital Expenditures (YOE millions)	**2030 Goal**	**2035 Goal**
Vehicle Purchases	$3,131.97	$3,303.76
Modifications & Contingency	$368.23	$389.60
Charging Infrastructure	$836.21	$872.84
Total Capital Costs	**$4,336.41**	**$4,566.21**
Savings due to Range Efficiency	*$0.00*	*$119.00*
Net Total Capital Costs	**$4,336.41**	**$4,447.21**
Average Annual Capital Costs	**$542.05**	**$342.09**

Impact to Budget
As noted above, the estimated Total Capital Costs is $4.3 billion in the 2030 scenario. For a no later than 2035 scenario, the estimated Total Capital Costs of the BEB program is $4.6 billion. However, the no later than 2035 case's Average Annual Capital Costs is $200 million less per year when that cost is spread over five additional years.

EQUITY PLATFORM

No changes in equity-associated impacts are expected to the previously submitted board reports associated with the ZEB transition program. BEBs will operate on routes restructured through the NextGen transit service plan. The service area of the corridors is vast-147 square miles-encompassing 2.2 million people in 650,000 households and 750,000 employees. Therefore, the corridors contain approximately 21 percent of the County's population and approximately 20 percent of the County's employment.

The Project Service Corridors include significant populations identified as disadvantaged or low-income communities as defined by Senate Bill 535 (SB 535) and Assembly Bill 1550 (AB 1550). There is great overlap between these areas and areas that Metro defines as Equity Focus Communities. The improvements are targeted to benefit communities with some of the greatest mobility needs in Los Angeles County. The Project's service corridors are composed of 88 percent in Low-Income Communities as identified by AB 1550 (Figure 1), 73 percent disadvantaged Communities as identified by SB 535 (Figure 2), and 61% Equity Focus Communities as defined by Metro's EFC (Equity Focus Communities) definition (Figure 3). The investment brings benefits to the community beyond the transit riders themselves: quieter exterior and interior noise not only attracts riders but provides a benefit to the community as well. Program implementation considers equity needs, along with sufficient space, utility placement, readiness and other factors when prioritizing ZEB fleet conversion.

IMPLEMENTATION OF STRATEGIC PLAN GOALS

These recommendations support Goal #3, Enhance communities and lives through mobility and access to opportunity, and Goal #4 Transform LA County through regional collaboration and national leadership.

NEXT STEPS

A. Staff will update the ZEB Master Plan and program schedules in accordance with the new transition goal and provide updates on an annual basis.
B. Staff will continue to proceed with a competitively negotiated solicitation for acquiring new BEBs and supporting Charging Infrastructure.
C. Once bids have been received, Staff will return to the Board to award the contract and establish a LOP for the procurement.

ATTACHMENTS

Attachment A - Motion #2017-0524 by Directors Bonin, Garcetti, Najarian, Hahn, and Solis
Attachment B - Equity Platform - Figures 1 - 3
Attachment C - Table 1 - Power Requirements Per Division

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