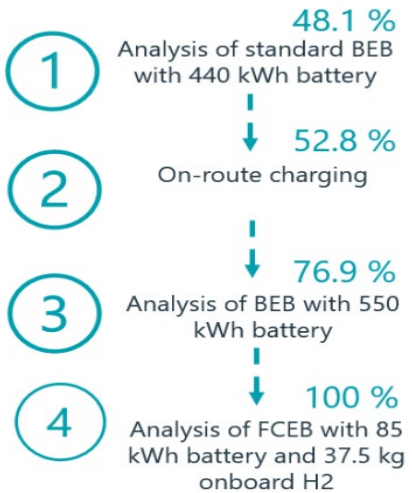
C2E2 Questions on ART Bus Feasibility Study Technical Report

1. What are the estimated usable battery capacity and estimated range for the 588 kWh and 686 kWh buses that the County has just ordered under both summer and extreme winter conditions? Enumeration of all assumptions used and transparency in the calculations for these estimates would be greatly appreciated.

Response: On paper, the usable battery capacity will be between 10% - 90% (80% used). Regarding range, due to challenges which other transit agencies have had in the US market in terms of meeting noted range on paper vs. reality, the manufacturer has not provided a range for the 588kWh and 686kWh buses as same is dependent on many factors from the climate, terrain, charge management solutions, and specifics of where the buses are operated. Based on information from Daimler , their forty-foot eCitaro bus with a 588-kWh battery capacity has a range of about 173 miles and their sixty-foot eCitaro articulated bus with a 686-kWh battery capacity has a range of 137 miles. These general ranges do not account for the weather conditions specific to the region.

2. What are the estimated percentage of route block coverage and route block pairings for both these buses in summer and winter conditions?

Response: The 588 and 686 kWh bus pilot will be used to determine this information for Arlington County. In the interim, the estimated percentages of route block coverage and route block pairings in summer and winter conditions for the 440 and 550 kWh buses are provided as part of the ART ZEB study and can be found in Attachment A of the ART ZEB Study. Although the 588 and 686 kWh bus pilot will be used to determine this information for Arlington County, initial modeling suggests that both the 588 kWh and 686 kWh buses are likely to have higher success rates than the 440 and 550 kWh buses originally modeled. The figure below summarizes the general results of the modeling performed on the 440kWh and 550kWh buses as part of the ART ZEB study



3. Attachment DA of the Technical Report indicates that route block pairings were based on only 55 buses in operation. Excluding 20 percent of the 78 buses in the fleet (about 128 buses) held in reserve for scheduled and unscheduled maintenance, ART should have an additional 711 buses in operation. How are these buses currently used and why were they not included in the route block pairing estimates? If these buses were included based on their current use how would that change the estimated success rate for the buses currently on order?

Response: We are assuming there is an error in the 128 and 711 bus numbers within this question but are happy to discuss. As background, ART currently has 78 buses and 55 buses are used in maximum service based on existing service. At various times, buses are down for scheduled and unscheduled maintenance and inspections. Buses are assigned to blocks daily due to the changing conditions of operations and maintenance; moreover, the same bus cannot be assigned to the same block daily. Buses can be pulled at any time from revenue and non-revenue service due to varying issues from safety and mechanical issues which may occur at any time. Also, buses must undergo maintenance which can impact the availability of buses used in maximum service and as spares. The time which a bus may be down for maintenance can vary based on many things including but not limited to parts availability, software updates, recurring issues, etc. The industry standard is a 20% spare ratio, however this issue is complicated by the fact that the ART fleet still has 16 NABI buses in the fleet that are not supported by the manufacturer for new parts, etc.

4. The technical report only includes estimates for on route charging for the 440 kWh bus. What are the success rates for the 550 kWh, 588 kWh, and 86686 kWh buses with on route charging?

Response: Because Arlington County has no plans for on-route charging during the pilot phase, success rates for larger batteries will continue to remain theoretical. However the projected numbers will be refined by the real world data on battery performance of these buses. On-route charging was not deemed feasible in the early phases based on availability of space, grid capacity and cost issues but may be explored more by the County during the future implementation phases.

For the 440 kWh buses, the success rates for scenarios that included on-route charging were between 5% and 15% higher than scenarios without on-route charging.

5. Why did the study not include midday charging of buses at the AOMF before they go out on their second route block of the day? How would midday charging improve the success rate for the buses on order?

Response: Because ART does not assign buses to individual blocks and does not have set block pairs, the impacts of midday charging are unable to be quantified. This practice enables increased operations flexibility, meaning any functioning bus in the fleet can function on any block pairing. The scenarios that were modeled for the ART ZEB Study assume first-in, first-out methodology for block pairing, where the first bus that returns

to the facility in the morning is the first bus that returns to service in the afternoon. For the purposes of the scenarios that were modeled for the ART ZEB Study, it was assumed that buses that serve afternoon blocks will be fully charged prior to that afternoon block. The implementation of midday charging would therefore not change the success rate for the modeled scenarios.

Midday charging presents both an opportunity, and a variety of operational challenges, and the success of midday charging can be dependent on weather, delays, or number of passengers served. Midday charging impact on state of charge is also dependent on the amount of time available for a bus to charge, which is difficult to model prior to putting the AOMF in service with actual results with our routes. The fleet transition scenarios described in the ART ZEB Study account for fleet expansion to create the opportunity for ART to replace in-service buses with a low state of charge with fully charged buses to serve afternoon blocks.

6. The report recommended additional study of optimal route block pairing to enhance the success rate. Does ART plan on reviewing how pairings could be managed for a higher success rate?

Response: Yes, ART does plan on reviewing how pairing can be managed for a higher success rate as part of the BEB pilot. ART will use data collected as part of the pilot to examine how to efficiently optimize route block pairings. ART will also be using charge management software that will optimize the charging of the buses on the AOMF site and provide real time status of the battery % charge for operational awareness and deployment decisions.

7. The study imposes a constraint that all buses return with a 20 percent state of charge. How would the success rate change if this constraint was reduced to 15 or 10 percent during the relatively few days of extremely cold temperatures?

Response: The industry best practice of buses returning with no less than a 20% state of charge (SOC) is based on reports that this reserve is crucial for backup during emergencies and unforeseen delays. In addition to this aspect of planning and operational resilience, drawing the battery down to a SOC lower than 20% has impacts on the functional capabilities of a battery and does not contribute to a well-maintained battery. Studies have found that to maintain long-term battery health, the battery of an EV should not be discharged past 20% SOC.[1]

8. As the transition to a ZEB fleet will take up to 12 years, why does the Transportation Bureau think that they have to start replacing from the outset at a ratio of 1:1.5? The study estimates that even under extreme cold the 550 kWh bus could meet 62 percent of the route block pairings (and the buses on order should exceed that success rate), which

[1] https://www.sciencedirect.com/science/article/pii/S2352484719310911

should allow the County to meet the route block requirement for many years at a 1:1 ratio with a mix of CNG and new BEBs.

Response: The route modeling conducted represents a point-in-time analysis based on the current state of BEB technology. As ART continues the transition to ZEB technology, the results of the pilot will inform future route modeling and the eventual decision regarding fleet technology mix to be determined in 2028, the decision year as documented in the ART ZEB Study. Planning for a fleet which requires certain buses to operate on certain blocks and routes can limit operational flexibility and overall resilience. The 1.59 ratio was based on modelling existing ART service, and that 1.59 ratio was reduced to 1.5 based on attempting to optimizing block pairings within the model. The BEB pilot will help ART gather real operating data rather than just theoretical modelling data.

9. How does the County currently manage its fleet as buses approach end of life? Are they used less in daily operations or moved to the reserve fleet? How would this management strategy help mitigate the expected impact of end-of-life battery degradation? Why wouldn't the fleet manager simply place end-of-life buses on shorter routes? Why does the model assume that all buses are simultaneously at the end-of-life when it is a temporary condition that only affects a small number at a time many years in the future?

Response: All buses which are still in revenue service must be able to complete all routes no matter the age of the bus. ART buses which are near the end of their useful life are still used in revenue service. Depending on the operating condition of such buses and availability of other buses, some buses near the end of their useful life may be used less than daily; however, those buses are still used. If any bus, no matter the age, is not in a condition to safely operate, then such bus would be pulled from revenue and non-revenue service. Because buses undergo scheduled and unscheduled maintenance as well as Title VI / equity challenges, buses which are near the end-of-life cannot just be placed on certain routes.

10. The 100% BEB scenario modeled will not occur until 2038. Up until then there will be many CNG buses in the fleet available to handle the longest routes if necessary. Why doesn't the Memorandum more clearly discuss the implications of the availability of CNG buses?

Response: Because of the range limitations of BEBs that are currently available on the market, CNG\RNG buses are being used by transit agencies nationwide to greatly reduce their emissions while maintaining existing operations. In this region, this includes ART, WMATA, Montgomery County's RideOn, and Loudoun County Transit. The ART ZEB Study is designed to be revisited and updated as ZEB technology continues to evolve and has planned for a decision to be made in 2028 regarding the fleet mix beyond that year. It should also be noted that the ART ZEB Study is focused on the long-term goal of zero tailpipe emissions, and therefore a CNG\RNG fleet was not explored beyond the planned interim. Additionally, a fleet in which any bus can operate any block or route is a much more resilient and flexible fleet.

11. Most feasibility studies model a modest annual gain in battery performance of 2-3%. By 2038, that would result in a major improvement in battery performance. Why was this much more realistic scenario not modeled, at least as one of several scenarios? How does it help decision-makers to provide only one unrealistic BEB scenario?

Response: While it is true that the battery performance of BEBs has been improving over the last decade, we do not recommend planning based on assumptions of improvement of BEB technology. Continued improvement in the performance of BEBs (and their batteries specifically) is dependent on a wide range of factors, many of which are unknown. As a result, the feasibility analysis that was performed for ART's ZEB Study represents a conservative estimate of the capabilities of BEB technology in the future. This estimate also takes into account expected battery degradation, which is common for BEBs throughout the lifetime of the bus. Additionally, buses purchased today will continue to be a part of the fleet for at least 12 years (an FTA standard), and the ability to operate any bus in the fleet on any block is helpful for operational flexibility and resilience.

Further, the ART ZEB Study is designed to be a living document that can be adjusted and revisited as technology improves or stagnates. Should the battery performance of BEBs improve to the degree suggested here, then Arlington County will have the ability to reexamine the feasibility of BEB technology to perform their operations. This is reflected in the scenarios presented in the ART ZEB Study, which enable ART to select a preferred ZEB technology in 2028.

12. What is the estimated life cycle cost of a BEB compared with an FCEB?

Response: Generally, the lifecycle costs of BEBs should account for the initial capital cost of a bus alongside the cost of lifetime operations and maintenance, as well as the cost to complete (at least partial) replacement of the battery at some point during the lifetime of the bus. ART anticipates replacing battery packs on BEBs at the mid-lifecycle of a bus, 6 years. At this time, bus battery pack replacements cost approximately $250k per bus. Lifetime operations and maintenance costs, estimated on a per-mile basis, can be found in the ART ZEB Study Final Report. FCEB lifecycle costs should also account for the initial capital cost (which is typically higher than a comparable BEB) alongside the cost of lifetime operations and maintenance FCEBs are also unlikely to require a mid-life battery replacement, as the battery is used for fewer functions than in a BEB.

As an example, Foothill Transit in Arcadia California ran an operating costs projection for a 20-bus fleet of FCEBs over a twelve-year lifecycle. They found that the FCEB lifecycle cost is 21% less—or almost $13M cheaper—than a comparable BEB fleet. To match the service level of 20 fuel cell buses, Foothill Transit would need 34 BEB buses. In addition, the battery-electrical infrastructure investment was 2.5 times more expensive than the hydrogen refueling infrastructure[2].

13. How does lifecycle energy use of a FCEB using green hydrogen compare to a BEB using renewable electricity?

[2] https://www.linkedin.com/pulse/fuel-cell-electric-bus-demand-matches-battery-timothy-sasseen

Response: This information is not yet widely available. There are studies (some published this year) which attempt to compare the overall energy efficiency of either technology, but these analyses are very dependent on regional weather and other conditions which impact operating efficiency. Depending on the conditions, either technology can be more efficient in terms of overall energy use. There are published National Renewable Energy Laboratory (NREL) studies that provide information on the fueling costs and other energy uses, but these costs are subject to regional variability such as electric costs and availability of hydrogen.

14. Is the County exploring available financial incentives for installing a Battery Energy Storage System in lieu of a fossil gas system for backup generation for a BEB fleet?

Response: The County has already completed the design of the backup generation at the ART Operations & Maintenance Facility (AOMF). Three gas generators are planned for the facility to provide for emergency backup generation in the event of an electrical outage. We reviewed this potential but with extended outages, it is essential the backup power source could run for multiple days. Battery storage systems of this size were not deemed feasible due to the size of the units and space constraints on the site and the inability of these units to run for multiple days. Only one generator is being purchased initially for the Transit Bus charging. Technology will continue to be monitored in the future to determine if battery storage could be deployed in the future in lieu of on-site generation.

15. What bus purchases are staff recommending to the Board? When will that recommendation be considered by the Board? What is the community engagement process once the recommendation is made public?

Response: The County has not typically done public engagement on operational items such as bus replacement. Over the 2-½ years of the study there has been outreach and communication with interested stakeholders, commissions and committees and we have a joint meeting scheduled for November 6, 2023 for C2E2, TAC, & TC. Transit Bus replacement decisions have historically been part of the Capital Improvement Program (CIP). The ART ZEB study does have fleet technology transition recommendations that necessitated briefing the County Board in January 2023 prior to submitting for DRPT FY24 grants for bus replacements. This same process is anticipated prior to submitting for FY25 grants in early 2024.