Battery Electric Bus Evaluation Report

Zero-Emission and Onboard Technology,
Program Delivery and Support, Transit

December 2024

SFMTA


Battery Powered
Zero Emission
www.sfmta.com
Stop Back 5 Feet
5004
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Executive Summary

Background

The SFMTA is a leader in low and zero-emission vehicle adoption and is committed to achieving a zero-emission fleet as part of a comprehensive climate strategy. Over 50 percent of the transit fleet, including light rail, cable cars, historic streetcars and electric trolley buses are powered by greenhouse gas-free hydropower generated from Hetch Hetchy. Beyond that, our new electric hybrid buses use 100 percent renewable fuel. This eliminates greenhouse gas emissions and use of petroleum fuel and saves a million gallons of fuel each year. San Francisco's transportation sector generates approximately 44.6% percent of the City's total greenhouse gas emissions, with most coming from the use of private cars and commercial trucks. By contrast, Muni carries a quarter of all trips in the city, but accounts for less than 0.001% of emissions in San Francisco.

The SFMTA has recently amended its Zero-Emission Vehicle (ZEV) policy to allow for the use of all zero emission technologies, including electric trolley buses, and to align with the California Air Resources Board's Innovative Clean Transit regulations, which currently target 2040 for public transit agencies to achieve full zero-emission fleets. Transitioning to a zero-emission fleet is one strategy among a suite of programs to reduce the effects of climate change. But the most effective way to reduce greenhouse gas emissions is to get more people to take Muni, walk or roll instead of driving in personal vehicles.

The SFMTA's Rollout Plan was approved by the SFMTA's Board of Directors in March 2021, and revised in May 2022. The SFMTA revised the the Rollout Plan in 2024 to include an updated procurement schedule, facilities schedule, and Paratransit fleet electrification plan.

In recent years, the SFMTA has worked to change its approach to fleet management by maintaining a consistent average fleet age, changing to performance-based procurements, upholding robust maintenance standards and performing midlife overhauls, and aligning all procurements with the City's sustainability goals.

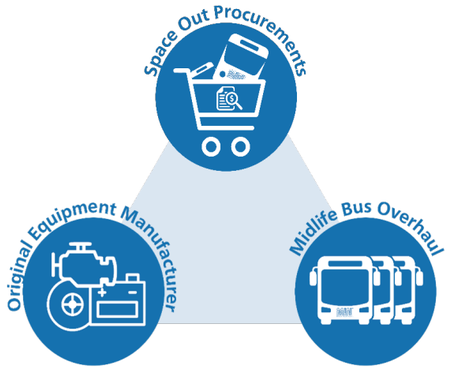

Figure ES 1: SFMTA Approach to Fleet Management

The SFMTA has recently completed a battery electric bus pilot program to evaluate the current state of the commercially available zero emission buses and determine their viability in San Francisco's operating environment. As part of the pilot program, the SFMTA procured 12 Battery Electric Buses (BEBs) from four Original Equipment Manufacturers (OEMs) to determine the future procurement strategy for transitioning to a zero-emission fleet.

Figure ES 2: SFMTA New Battery Powered Zero Emission Decal

The SFMTA procured buses for this pilot program from New Flyer of America Inc. (New Flyer), BYD Coach & Bus LLC (BYD), and Proterra, Inc. (Proterra) through a Request for Proposals (RFP) procurement method. During the procurement, Nova Bus, Inc. (Nova) did not have a suitable battery electric bus to submit for consideration, but buses from Nova were later added to the pilot program by utilizing a Virginia state procurement contract. Gillig did not submit a bid during the RFP procurement.

Evaluation Approach

The SFMTA opted for a holistic approach to evaluating the BEB pilot program, focusing on six key performance categories deemed most relevant to its operation and employing several different scoring metrics. The BEBs were operated in regular revenue service on the SFMTA's most demanding routes, and the manufacturers were compared to each other in terms of performance, reliability, maintainability, operability and the overall procurement and customer experience. Table 3-1utilizes these scoring metrics to compare the performance of the different OEMs. Additionally, a weight factor is used to emphasize the significance of specific areas in relation to the SFMTA's priorities. This comprehensive evaluation aims to provide a nuanced and weighted assessment of OEMs based on a variety of criteria relevant to the SFMTA's considerations.

The evaluation involved two main data types: qualitative and quantitative. Expert judgment and discussions with stakeholders informed all scoring.

The evaluation process lasted over 18 months and included six key categories to assess and identify the best OEMs aligning with SFMTA's priorities:

- Procurement and Customer Experience: The Procurement and Customer Experience category examined the bus acquisition process, evaluating factors such as the manufacturing experience, coordination with OEM teams, and overall customer experience.
- Acceptance: The Acceptance category focused on assessing compliance with SFMTA's quality standards and requirements before the full transfer of ownership.
- Performance: The Performance category assessed the technical aspects of the buses, considering metrics like vehicle range, energy efficiency, performance on grades and passenger capacity to determine operational effectiveness, safety, and overall functionality.
- Operability: The Operability category focused on the driver interface, maneuverability, and ride quality for the SFMTA's operators as well as its riders.
- Maintainability/Reliability: This category evaluated the ease of inspecting, diagnosing, and maintaining buses, as well as keeping the buses operational.
- Financial: The Financial category focused on assessing acquisition costs, including the bus unit price and all other associated costs.

Figure ES 3: SFMTA Approach to evaluation criteria

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Evaluation Findings

In the final technical evaluation, established OEMs such as New Flyer and Nova performed well due to their experience in producing transit buses for decades and their demonstrated history of higher quality customer experience. New Flyer excelled in this evaluation due to their familiarity with the SFMTA, their overall reliability, and their ability to manufacture at scale. Nova exhibited strengths in workmanship and ride quality but presented issues with timely delivery and post-delivery support.

Comparatively, BYD and Proterra need more time to refine their bus manufacturing processes to be on par with their more established counterparts. BYD demonstrated strong battery technology and energy efficiency, but faced significant challenges with coordination, workmanship, acceptance processes, and customer experience. Proterra excelled in bus range and battery capacity, but suffered in the evaluation due to issues with bus reliability, post-delivery support, customer experience, and parts availability.

Buses from all OEMs evaluated during this pilot program were found to meet or exceed our technical requirements and specifications. The SFMTA procured the latest generation buses from each OEM, and the performance of the buses was greatly impacted by technical issues stemming from their infancy. The SFMTA expects the performance of the buses to significantly improve as the OEMs incorporate lessons learned from these early deployments and gain experience manufacturing these vehicles.

Acronyms

Acronym	Description
ADA	Americans with Disabilities Act of 1990
BAFO	Best and Final Offer
BEB	Battery Electric Bus
CAD/AVL	Computer-Aided Dispatch/Automatic Vehicle Location
CARB	California Air Resources Board
DVR	Digital Video Recorder
ESS	Energy Storage System
FTA	Federal Transit Administration
ICT	Innovative Clean Transit
IFB	Invitation for Bids
IVU	Integrated Vehicle Unit
MDBF	Mean Distance Between Failures
OEM	Original Equipment Manufacturer
QA	Quality Assurance
RFP	Request for Proposal
SFMTA	San Francisco Municipal Transportation Agency
ZEV	Zero-Emission Vehicle

Out of the manufacturers evaluated in this pilot program, New Flyer is the only viable option for the SFMTA's future BEB procurement, aligning well with the SFMTA's specific operational needs. Nova Bus cannot be considered for future procurements due to their decision to close their US manufacturing facility and no longer manufacture Buy America-compliant buses. At this time, BYD is not an option for future procurements, as they need to address their bus quality and acceptance process issues and resolve the uncertainties surrounding their ability to participate in federally funded procurements. Proterra cannot be recommended for future procurements due to their declaration of bankruptcy during the pilot evaluation period and their significant restructuring efforts under new ownership, leaving their future in the bus market uncertain.

Lessons Learned

Significant lessons learned from this pilot program include:

- The process of zero-emission bus procurement is comparable to hybrid-electric bus procurement, but BEB infrastructure procurement is significantly more complex and expensive, and this will be the major limitation for fleet electrification. Electric trolley bus infrastructure expansion is similar to BEB infrastructure expansion in complexity and cost.
- There are risks in achieving the electrification goals outlined in the Rollout Plan, including funding shortfalls, prolonged regulatory reviews, PG&E capacity and responsiveness, and other issues. If there is a schedule delay to any one project, the SFMTA may need to delay bus procurements and subsequent project schedules.
- The SFMTA will opt for inverted pantograph chargers to charge its BEB fleet in its yards. Inverted pantograph charging is best suited for the SFMTA's space-constrained environment and will allow for better automation of charging processes.
- The SFMTA encountered no notable difficulties in training their operations and maintenance staff to use and maintain BEBs, as the experience with the SFMTA's existing hybrid-electric buses helped prepare our staff for the transition.
- The SFMTA expects that BEBs will be the preferred zero-emission technology for replacing hybrid-electric buses due to their similarities in design, operation and training, and their versatility in our operating environment.
- BEB technology is rapidly evolving and is a new technology for many transit agencies. The reliability of BEBs is not up to par with existing diesel hybrid and trolley buses due to the infancy of the new technology. However, their reliability is expected to improve over time as they see mass adoption with transit agencies and the manufacturers continue to get better at building quality, reliable BEBs.
- Buses with range significantly exceeding the SFMTA's daily mileage needs are not needed. Surplus battery capacity negatively impacts bus cost and performance, including gradeability.
- The integration of new equipment and systems, such as new CAD/AVL systems, is not ideal for a pilot program and can cause discrepancies in the actual evaluation of the buses.
- Sophisticated yard management and charge management solutions will be important for operating large fleets of BEBs and will reduce the amount of power needed at each facility.
- The industry needs to focus its efforts on bus fire safety, specifically on early detection, fire suppression, and fire prevention systems. Additionally, bus storage facilities need robust design guidelines and standard operating procedures for safely storing large numbers of zero-emission buses.
- The role of BEBs is unknown in the case of providing emergency services during a natural disaster.
- The SFMTA should continue to work with the bus industry and APTA's Bus Manufacturing Task Force to mitigate risks arising from uncertainty in the transit bus market, and should consider procuring buses from multiple OEMs for its future procurement strategy.

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Future Procurement Strategy

The Building Progress Program, a multi-year effort to repair, renovate, and modernize the SFMTA's aging facilities to keep the city moving, is a complex undertaking. The SFMTA is developing the 2024 Facilities Framework Addendum, which provides a roadmap to replace the obsolete yards with a modern, multi-story, efficient bus maintenance and storage garage, equipped to serve the SFMTA's growing fleet as it transitions to a zero-emission fleet. The SFMTA will develop its BEB procurement schedule to align with its facilities timeline as outlined in the SFMTA's 2024 Facilities Framework Addendum. The SFMTA's fleet procurement plan will need to be highly flexible to account for uncertainty involved in delivering facilities projects. As highlighted in the current SFMTA Zero-Emission Vehicle Policy, the SFMTA will continue to procure trolley buses and consider other zero-emission bus technologies to achieve its zero-emission goals. The SFMTA intends to continue to procure hybrid-electric buses for the next several years while working to implement charging infrastructure and facility upgrades.

The FTA has recently shared a "Dear Colleague" letter that includes recommendations directed at sustaining and strengthening the shrinking bus manufacturing industry in the US and addressing escalating costs.

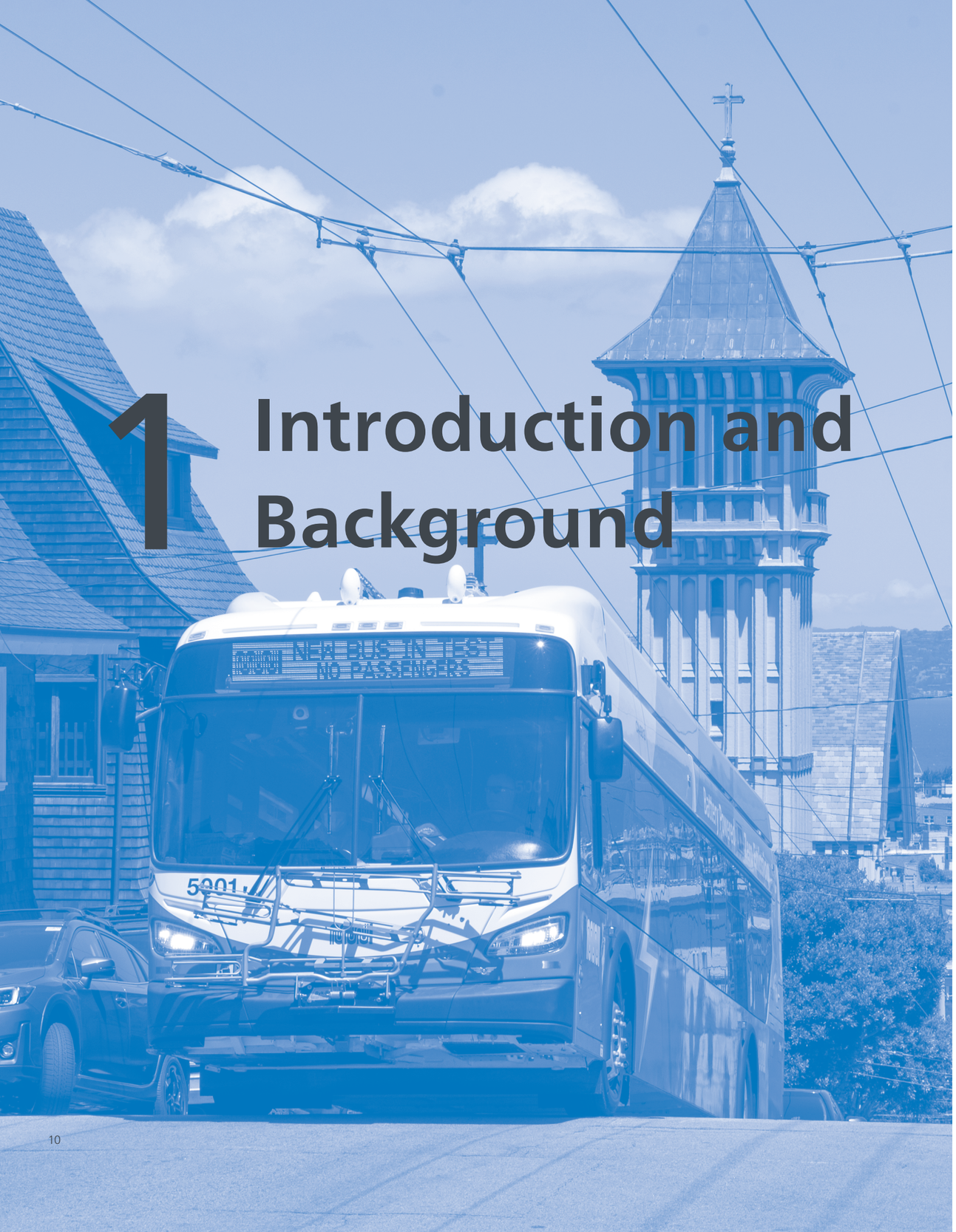
The SFMTA endorses the recommendations in this letter pertaining to stabilizing bus prices and stimulating the transit bus market by increasing competition. BEB technology is still rapidly evolving, and state procurement contracts may be the preferred methodology for the SFMTA for small, nimble procurements for BEBs in the near term.

The recommended procurement strategy for the SFMTA is to procure 70-90 buses per year from at least two manufacturers; this will allow the SFMTA to adjust procurements to mitigate risk and account for changes in the transit bus market. This strategy will also help foster competition and diversify the SFMTA's fleet to protect against bus market volatility and supply chain concerns.

The COVID-19 pandemic adversely impacted the financial viability and competitiveness of the US bus manufacturing market. New Flyer and Gillig are currently the only viable US manufacturers for the SFMTA's future BEB procurements. Gillig is a large-scale bus manufacturer, local to the San Francisco Bay Area, which has been successfully manufacturing buses in the US for decades. The SFMTA intends to partner with Gillig on a future procurement of battery electric buses.

Other bus manufacturers may seek to capitalize on the lack of competition in the market and establish a presence in the US. In recent times, European bus manufacturers like Solaris Bus & Coach have shown interest in establishing a presence in North America. The SFMTA plans to partner with Solaris on a future procurement of battery electric buses to increase competition in the US bus market; additionally, Solaris is appealing to the SFMTA as a leading manufacturer of trolley buses in Europe.

To protect the SFMTA's interests and ensure a healthy level of competition in the US bus market, it is in the best interest of the SFMTA to ensure at least two manufacturers are included in its future procurement strategy.



1 Introduction and Background

The San Francisco Municipal Transportation Agency (SFMTA) is a global leader in supporting an environmentally sustainable transportation system, operating the greenest fleet of any city in North America. More than 50 percent of the SFMTA's transit vehicles, including light rail, cable cars, historic streetcars, and electric trolley buses, are powered by 100 percent greenhouse gas-free hydropower generated from Hetch Hetchy.

The transportation sector is San Francisco's largest contributor to the city's overall carbon footprint. As the biggest source of greenhouse gas emissions, it makes up nearly half of all citywide emissions. The pollutants from cars, trucks and other private vehicles account for more than 70 percent of transportation emissions, while public transportation accounts for only 5% of transportation emissions. The SFMTA's transit fleet accounts for less than 2 percent of public transportation emissions, or less than 0.001 percent of the city's overall greenhouse gas emissions. In furtherance of reducing San Francisco's transportation sector emissions, the SFMTA issued a Request for Proposals (RFP) in November 2018 for up to nine 40-foot, low-floor, battery electric buses (BEBs) as part of a BEB pilot program. New Flyer of America Inc. (New Flyer), BYD Coach & Bus LLC (BYD), and Proterra, Inc. (Proterra) responded to the RFP, and SFMTA awarded contracts to all three OEMs in December 2019. Nova Bus, Inc. (Nova) did not have a suitable battery electric bus to submit for consideration at the time of the RFP, but later joined the pilot program in July 2021 through a separate contract awarded by SFMTA based on a Commonwealth of Virginia cooperative procurement agreement. Gillig did not submit a bid during the RFP procurement. In total, the SFMTA procured three buses each from the four Original Equipment Manufacturers (OEMs).

1.1 Pilot Program Goals

The objective of the BEB pilot program was to evaluate the state of the commercially available BEBs and determine their viability in San Francisco's operating environment. The main goals of this program were to utilize the lessons learned during the evaluation to inform the SFMTA's future bus procurement strategy, to determine if BEBs are best suited to replace all routes currently served by hybrid-electric buses, and to determine which buses can be recommended for large-scale bus procurements.

As part of the pilot program, the buses were tested in regular revenue service on some of the SFMTA's most challenging routes and were compared in terms of procurement and customer experience, performance, reliability, maintainability, and operability.

Procurement and Customer Experience

The bus building ability of each OEM was scrutinized to ensure they could provide safe and reliable buses for San Francisco's transit users. The SFMTA evaluated each OEM's customer field service support, customer service, and their ability to facilitate and support future large-scale procurements. The SFMTA also used this pilot program as an opportunity to familiarize the agency with multiple bus OEMs and system providers to increase competition in future bus procurements.

Performance

The overwhelming majority of the SFMTA's service blocks are less than 160 miles in length. The SFMTA established a minimum operating range criteria for the BEBs of at least 160 miles and a minimum gradeability of 21% while operating in 60°F weather and carrying a 52-passenger load. The BEBs also needed to charge using an SAE J1772 CCS Type 1 charger and be able to gain at least 160 miles of range in four hours of charging.

Reliability and Maintainability

The SFMTA sought to determine the reliability and maintainability of the BEBs from each OEM, comparing the miles per service labor hour, miles per chargeable road call, ease of maintenance, quality of manuals and documentation, parts lead times, recalls, and charging reliability.

Operability

The SFMTA sought to ensure that each bus was acceptable for its bus operators and functional in its operating environment. To that end, the pilot program evaluated and compared the driver interface and ride quality of each of the BEBs.

The findings of this pilot program are detailed in this report and have been used to inform the SFMTA's future procurement strategy.

1.2 Zero-Emission Policy and Advocacy

The California Air Resources Board (CARB) adopted the Innovative Clean Transit (ICT) regulation in December of 2018, and it became effective October 1, 2019. The regulation requires all public transit agencies in California to prepare a Zero-Emission Bus Rollout Plan (Rollout Plan) to fully transition to zero-emission buses by 2040. The ICT regulation does not require exclusive use of battery electric buses and accommodates other zero-emission vehicle types including trolleys.

The SFMTA's Rollout Plan was approved by the SFMTA's Board of Directors on March 16, 2021, and revised in May 2022. The SFMTA anticipates revising the Rollout Plan in 2024 to include an updated procurement schedule, facilities schedule, and Paratransit fleet electrification plan.

The SFMTA recently amended its 2018 ZEV Policy to allow the agency to continue its path towards 100% fleet electrification without compromising transit service quality, align with the CARB ICT regulations, allow for the consideration of other zero-emission bus technologies, and align with current facilities plans and timelines for charging infrastructure.

The SFMTA's Facilities Framework presents the framework and actions for transitioning the SFMTA's six bus yards and fleets to support a 100% ZEV operation and help the SFMTA meet the updated ZEV policy goals. This plan will continue to be updated to reflect the SFMTA's best timing estimates, informed by its initial experience with battery electric buses and challenges related to PG&E coordination and funding availability.

1.3 Reduced and Zero-Emission Vehicle Initiatives

SFMTA currently operates a fleet of low-emission hybrid-electric vehicles which run on renewable diesel, and it operates the largest fleet of zero emissions electric trolley vehicles in North America.

In 2019, the SFMTA launched its Green Zone program in which buses turn off their hybrid-electric engines and operate entirely on battery power when the bus enters designated green zone areas (chosen through an environmental justice and equity lens). The SFMTA equipped 68 hybrid-electric buses with higher battery capacities and a GPS-enabled switch, which automatically switches the buses to electric vehicle mode as they enter the green zone areas (geo-fenced areas) throughout the city. In the green zone areas, the hybrid-electric buses operate entirely on battery power, reducing and eliminating SFMTA-generated emissions in some of the city's most environmentally burdened communities.

In 2023, the SFMTA launched its In-Motion Charging (IMC) trolley bus program, which upgraded four of the SFMTA's electric trolley buses with significantly larger onboard battery packs and more advanced battery charging hardware. IMC trolley buses offer the promise of substantially greater off-wire range and faster charging on overhead lines, allowing the buses to operate on routes with partial overhead lines. This advancement significantly increases the versatility of the SFMTA's trolley bus fleet, further contributing to the city's commitment to reducing carbon emissions and improving public transportation.

Figure 1-2: Rooftop Battery Units on the SFMTA's First Battery Electric Bus (New Flyer 5001)

1.4 Fleet Makeup

As of 2024, SFMTA operates a fleet of 856 buses. Table 1 (SFMTA Bus Fleet) shows a breakdown of the SFMTA's bus fleet based on propulsion type and bus length.

Table 1: SFMTA Bus Fleet

Bus Type	32'	40'	60'	Total
Hybrid	30	312	224	**566**
BEB	0	12	0	**12**
Trolley	0	185	93	**278**
Total	**30**	**509**	**317**	**856**

Figure 1-3: 40-foot Diesel Hybrid Bus

Figure 1-4: 40-foot Electric Trolley Bus

1.5 RFP / Procurement Process

1.5.1 Procurement Process for the Pilot Program

On November 21, 2018, the SFMTA issued an RFP for a negotiated procurement of up to nine 40-foot, low floor, BEBs for the SFMTA's BEB pilot program. Under the pilot program, these buses were to be tested for at least 18 months in revenue service to allow the SFMTA to evaluate the available BEBs on the market and test their performance in San Francisco's unique operating environment. All buses would be equipped with ViriCiti on-board vehicle telematics systems which would allow the SFMTA to directly compare the performance of the BEBs from different manufacturers.

New Flyer, BYD, and Proterra responded to the RFP before the deadline on March 20, 2019. Shortly after, the SFMTA's technical and price evaluation panels reviewed the initial proposals. Both panels scored the proposals and found all proposals to be within a competitive range. The SFMTA then negotiated with the three proposers to address technical questions and concerns and arranged for each proposer to deliver a demonstration bus to San Francisco for review by stakeholders.

The SFMTA issued a request for Best and Final Offers (BAFOs) on August 9, 2019, to all three proposers, who responded on August 30, 2019. The SFMTA's technical and price evaluation panels reviewed the BAFOs and found that all three were within a competitive range.

Three contracts were awarded as part of this procurement. Each base contract includes three 40-foot, low floor BEBs, as well as licenses for the ViriCiti vehicle telematics system, operator and maintenance training packages, spare parts, special tools, and all required operating, maintenance, and parts manuals. Each contract includes options to purchase up to three additional coaches over the next five years.

Nova Bus, a leading manufacturer of transit vehicles in North America that delivered more than 12,000 buses to transit operators over the last 20 years, did not respond to SFMTA's RFP in 2018 as its proposed long-range BEB was not available for sale at the time. In March 2019, the Commonwealth of Virginia issued an Invitation for Bids (IFB) for low-floor battery electric transit buses in different lengths (35-foot, 45-foot, 60-foot), and Nova Bus submitted a proposal for 40-foot battery electric buses in response to the IFB on April 15, 2019. The Commonwealth of Virginia's open contract with Nova Bus permitted interstate purchases from public entities, which allowed SFMTA to award its own bus procurement contract to Nova Bus as part of the SFMTA's BEB pilot program. This contract with Nova Bus was similar in scope and provisions to those awarded to New Flyer, BYD, and Proterra during the RFP process, and resulted in a bus configuration that closely matched the other buses delivered through the RFP process. With this, Nova Bus became the last OEM to provide BEBs for the pilot program.

1.5.2 Stakeholder/Public Outreach Feedback

The SFMTA conducted extensive public outreach to industry experts and other transit agency representatives to inform the pilot battery bus design. Within the SFMTA, project staff worked with transit operators and union leadership, vehicle maintenance personnel, and staff from the Accessible Services, Information Technology, and Transit Planning teams. The SFMTA received feedback from stakeholders regarding the low sound levels, new flush mounted and tinted windows, and spacious seating configurations, and incorporated these suggestions in the final vehicle specifications.

The SFMTA opted to use this pilot program to test new technologies prior to their mass adoption within the agency's transit fleet. The SFMTA was able to enhance driver safety with a more protective driver's barrier and updated video surveillance system, upgrade the wheelchair ramp for easier boarding, and improve cyclist safety with exterior mirror turn signals. Other new and improved features in the buses include lightweight seats, an electric bus telematics system, an upgraded ADA-compliant wheelchair ramp, an updated Integrated Vehicle Unit, a passenger information system, plug doors, and backup and rear-door cameras to assist operators. New features present on certain bus models also include rear windows and USB ports on passenger seats

Figure 1-5: Upgraded Wheelchair Ramp

2 OEM Introduction

The following section introduces the four OEMs evaluated as part of this pilot program.

2.1 New Flyer

New Flyer (operating as "New Flyer of America" in the United States) is a Canadian transit bus manufacturer that was founded in 1930 and serves as a subsidiary of the NFI Group. New Flyer has been developing battery electric buses since 2012 and offers a variety of sustainable and zero-emission vehicle options.

New Flyer has a successful history of providing the SFMTA with transit buses and has manufactured a majority of the SFMTA's current rubber tire fleet. New Flyer vehicles presently used by SFMTA include trolley buses and hybrid-electric buses.

The SFMTA procured New Flyer's Xcelsior Charge XE40 40-ft BEB, equipped with a 525 kWh ESS by Xalt Energy and the Siemens Permanent Electromagnetic Motor (PEM) "2022" motor.

Figure 2-1: BYD Pilot Bus 5004

2.2 BYD

BYD is an advanced battery manufacturer and consumer electronics company originally based in China and has been developing vehicles since 2003. The BYD USA group is headquartered in Los Angeles, CA with its main US manufacturing facility based in Lancaster, CA. BYD has delivered over 65,000 BEBs worldwide and is one of the world's largest battery manufacturers. BYD is currently not eligible for procurement using federal funds due to the National Defense Authorization Act for Fiscal Year 2020, and has recently begun efforts to rebrand their US operations under the name "Ride".

The SFMTA procured BYD's K9MD 40-ft BEB, equipped with a 496 kWh ESS and their dual traction BYD 2912TZA motors.

2.3 Proterra

Proterra was a transit vehicle manufacturer founded in 2004 that designed and manufactured zero-emission electric transit vehicles. In 2023, Proterra announced bankruptcy, and the Proterra battery-manufacturing business was purchased by Volvo Battery Solutions. As of January 2024, the Proterra transit business unit was purchased by Phoenix Motorcars, and Phoenix Motorcars is supporting all existing customers with Proterra buses. For the purposes of this report, "Proterra" is used to refer both to the original company and to Phoenix Motorcars, who continues to offer Proterra-designed battery buses.

The SFMTA procured Proterra's Catalyst E2 Max 40-ft BEB, equipped with a 660 kWh ESS and the DuoPower traction system.

2.4 Nova Bus

Nova Bus (Nova) is a Canadian transit bus manufacturer that was founded in 1993 and is owned by the Volvo Group. Nova started developing battery electric vehicles in 2011 and has since manufactured hundreds of battery-electric vehicles for various North American transit agencies. As of 2023, the Volvo group has announced that Nova will no longer produce Buy America-compliant buses in the US and will instead focus on producing buses for the Canadian market; however, US transit agencies will be free to purchase buses from Nova using state or local funds.

The SFMTA procured Nova's LFSe+ 40-ft BEB, equipped with a 564 kWh ESS by Akasol and the HDS200 motor from BAE Systems.

Figure 2-2: Nova Pilot Bus 5010

3 Evaluation Approach

The SFMTA BEB pilot program staff collected data on the battery buses for a period of at least 18 months. A series of feedback sessions were conducted with various project stakeholders, during which the SFMTA posed interview questions pertaining to six major areas of evaluation. Project stakeholders included staff from maintenance, operations, training, acceptance, accessibility, and planning teams that would be impacted by the outcome of the BEB pilot program. Additionally, the SFMTA collected and reviewed feedback from riders of the BEBs. The SFMTA also held discussions with several North American transit agencies to discuss their experiences with BEBs. Utilizing insights gained from this feedback and expert opinion by the SFMTA BEB pilot program staff, along with telematics and revenue service data from the BEB pilot program, an evaluation matrix was developed to assess and compare the OEMs based on the SFMTA's priorities and requirements. Each evaluation category incorporates metrics to gauge the quality and experience offered by the OEMs in the context of the BEB pilot program.

The views expressed in this report represent the opinion of the SFMTA's project staff and stakeholders and are based on the knowledge available to the SFMTA during the evaluation period.

3.1 Methodology Overview

The BEB evaluation matrix covered six categories of evaluation that were most relevant to SFMTA. The evaluation metrics in each of these categories contain three types of scoring systems: qualitative, quantitative, and ranked.

In the summary table below, these three scoring types are used to compare how each OEM performed relative to a baseline and/or one another. From there, an added weight factor is used to represent the added importance of a metric as it relates to the SFMTA.

Table 3-1: Evaluation Category and Metrics Summary

Evaluation Category	Evaluation Metric	Metric Type	Weight Factor	Primary Data Source
Procurement and Customer Experience	Pilot bus delivery delay days	Ranked	3	SFMTA BEB Revenue Service Data
	Production buses delivery delay days	Ranked	3	SFMTA BEB Revenue Service Data
	Critical deviations from technical specifications	Qualitative	2	OEM Proposals
	Coordination with onboard system suppliers	Qualitative	3	Stakeholder Interviews
	Experience with OEM sales and management	Qualitative	1	Stakeholder Interviews
	Work with resident inspectors	Qualitative	3	Stakeholder Interviews
	Manufacturing ability at scale	Qualitative	5	Stakeholder Interviews
	QA inclusion during production	Qualitative	2	Stakeholder Interviews
	Post-delivery support	Qualitative	5	Stakeholder Interviews
	Workmanship	Qualitative	3	Stakeholder Interviews
	Ease of warranty process and responsiveness	Qualitative	4	Stakeholder Interviews
	Quality of training sessions	Qualitative	4	Stakeholder Interviews
	Long-term viability and risk	Qualitative	3	Stakeholder Interviews

Table 3.1: Evaluation Category and Metrics Summary

Evaluation Category	Evaluation Metric	Metric Type	Weight Factor	Primary Data Source
Procurement and Customer Experience	QA inclusion during production	Qualitative	2	Stakeholder Interviews
	Post-delivery support	Qualitative	5	Stakeholder Interviews
	Workmanship	Qualitative	3	Stakeholder Interviews
	Ease of warranty process and responsiveness	Qualitative	4	Stakeholder Interviews
	Quality of training sessions	Qualitative	4	Stakeholder Interviews
	Long-term viability and risk	Qualitative	3	Stakeholder Interviews
Acceptance	Snag resolution experience	Qualitative	3	Stakeholder Interviews
	Average days between delivery and acceptance	Ranked	3	Acceptance Documentation
Performance	Duty cycle/bus range	Quantitative	3	SFMTA BEB Revenue Service Data
	Energy efficiency	Quantitative	3	SFMTA BEB Revenue Service Data
	Availability	Quantitative	4	SFMTA BEB Revenue Service Data
	Average monthly mileage per bus	Quantitative	5	SFMTA BEB Revenue Service Data
	Curb weight	Ranked	4	Bus Specifications
	Fire detection/suppression	Qualitative	3	Bus Specifications
	Seating layout	Qualitative	1	Stakeholder Interviews
Operability	Driver interface	Qualitative	3	Stakeholder Interviews
	Ride quality	Qualitative	3	Stakeholder Interviews
Maintainability and Reliability	Miles per labor hours booked by SFMTA	Quantitative	3	SFMTA BEB Revenue Service Data
	Mean distance between service interruptions	Quantitative	4	SFMTA BEB Revenue Service Data
	Ease of maintenance	Qualitative	3	Stakeholder Interviews
	Quality of maintenance manuals	Qualitative	2	Stakeholder Interviews
	Parts lead times	Qualitative	5	Stakeholder Interviews
	Recalls (quantity and impact)	Qualitative	4	Stakeholder Interviews
	Interface with charger	Qualitative	3	Stakeholder Interviews
Financial	Bus acquisition costs	Quantitative	3	Price Proposal
	Grants opportunity & funding flexibility	Qualitative	3	Stakeholder Interviews

3.2 Data Type

Each metric was assigned a data type (quantitative, qualitative, or ranked) and scored via a specific scoring rubric based on the data type. Qualitative metrics include variables that cannot directly be compared or require more considerations that are unquantified. Quantitative data are metrics that rely on quantified measurements directly comparable to each other based on the magnitude of the value. The following subsections explain the analysis approach used for each data type.

3.2.1 Qualitative

Qualitative metrics are scored on a range from 1 to 5, with a score of 1 representing poor performance and a score of 5 representing superlative performance. Expert judgment and discussions with project stakeholders were used to validate the assumptions for each metric.

A 1 (or unacceptable) value was assigned if the OEM was deemed to not meet the minimum success criteria for the metric. A 2 (or deficient) value was assigned if the OEM marginally met the minimum success criteria of the metric. A 3 (or average) value was assigned if the OEM met the average success criteria of the metric. A 4 (or good) value was assigned if the OEM exceeded the average success criteria of the metric. A 5 (or excellent) value was assigned if the OEM greatly exceeded the success criteria of the metric.

Table 3.2: Qualitative Data Scoring Method

Qualitative Score	Numerical Score
Excellent	5
Good	4
Average	3
Deficient	2
Unacceptable	1

3.2.2 Quantitative

For the quantitative data, each metric was given a score based on the value differences between the OEMs. The OEM(s) with the best performance in each metric were given a score of 5.

The other OEMs were also given a 5 if the value difference of the metric was less than 10%, a 4 if the difference was within a 10% to 20% range, a 3 if the value difference was within 20% to 30% range, a 2 if the value difference was within 30% to 40% range, and a 1 if the value difference was greater than 40%.

Table 3-3: Quantitative Data Scoring Method

Value Difference	Score
10%	5
20%	4
30%	3
40%	2
>40%	1

3.2.2.1 Ranked

Certain metrics were evaluated by assigning scores corresponding to their rankings from 1 to 4 (first to last), relying on quantitative values. This adjustment aimed to establish a fairer comparison scale for metrics that were considered unjust to evaluate solely using quantitative values and that required more nuance for the comparison. The metrics that were ranked are noted throughout the report in the corresponding sections.

3.3 Weight Factor

It became clear to the SFMTA during feedback sessions that certain evaluation metrics hold greater importance than others for the SFMTA. To accurately model the importance of the evaluation matrix, a weight factor was used to emphasize or minimize the effects of each metric for a more accurate and fair scoring. For the evaluation scoring, a weight factor of 5 signifies a major determining factor while a weight factor of 1 signifies a less significant factor.

3.3.1 Unweighted vs. Weighted Score

The unweighted score is the raw evaluation metric score, only using the quantitative and qualitative scoring methods. The weighted score is obtained by multiplying the unweighted evaluation score by the weight factor, and this weighted score serves to emphasize the significance of the given evaluation metric.

3.4 Evaluation Categories

Six evaluation categories were used to compare the OEMs and evaluate them with respect to the SFMTA's priorities as outlined in Table 3-1.

3.4.1 Procurement and Customer Experience

The Procurement and Customer Experience category evaluates the overall procurement process, including the manufacturing experience, coordination with OEM teams, and the warranty process.

3.4.2 Acceptance

The Acceptance category evaluated the compliance with SFMTA's quality standards and requirements before the full transfer of ownership.

3.4.3 Performance

The Performance category pertains to the technical aspects of the buses, including vehicle range, energy efficiency, and passenger capacity, that determine the operational effectiveness and overall functionality of the buses.

3.4.4 Operability

The Operability category focused on good operability as it directly impacts the efficiency of navigating traffic and diverse road conditions, reducing driver fatigue and enhancing passenger safety.

3.4.5 Maintainability and Reliability

The Maintainability and Reliability category evaluated the ease with which buses can be inspected, diagnosed, and repaired, directly impacting the efficiency of maintenance practices. Additionally, the reliability aspect refers to the consistency and dependability of bus performance.

3.4.6 Financial

The Financial category assessed the acquisition costs for the bus and all associated costs. .

Figure 3-1: SFMTA Buses at Woods Division maintenance bay

4 Procurement and Customer Experience

The following section summarizes the procurement category evaluation and scores for each OEM.

Figure 4-1: BEB Fleet in Woods Division

4.1 Pilot Bus Delivery Delay Days

A A pilot bus is considered the first bus manufactured and delivered by an OEM. The intent of taking delivery of a pilot bus is to conduct training sessions, review the bus design, and perform all necessary testing at the SFMTA site to uncover potential issues that might not be evident during the manufacturing process. Upon receiving approval for the pilot bus design, the OEM is then authorized to commence the production of subsequent buses. Delivery delays for the pilot bus can affect the technical review, acceptance and training efforts, and production schedules.

All the OEMs experienced delays for the pilot bus delivery, mostly related to supply chain shortages and/or plant shutdowns due to the COVID-19 pandemic. Nova had the shortest pilot delivery delay at 140 days, followed by Proterra at 214 days. New Flyer and BYD ranked the worst at 259 and 264 days, respectively.

For this metric, the OEMs were scored based on their rank from first to last dependent on their quantitative values.

Table 4-1: Pilot Bus Delivery Delay Days Evaluation

Evaluation Metric	Quantitative Value (days)				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Pilot Bus Delivery Delay Days	259	264	214	140	3	(2) 6	(1) 3	(3) 9	(4) 12

Source: SFMTA BEB Revenue Service Data

4.2 Production Buses Delivery Delay Days

Production buses are buses manufactured following the approval of the pilot bus design. All modifications, retrofits, and repairs are anticipated to be completed at the OEM facility before the buses are delivered to SFMTA. Being able to meet the production bus delivery is a reflection on the OEM's manufacturing capabilities to meet fleet production schedules and holds a high weight factor.

Many of the OEMs experienced delays for the production buses, except for New Flyer. Most delays were predominantly due to global supply shortages and were not foreseeable by the OEMs.

Proterra experienced minor production delays but did a good job of communicating schedule changes to the SFMTA, allowing the program management team to allocate inspection resources accordingly. BYD had significant issues with adhering to their production schedule and had to be prompted by SFMTA staff to focus their attention on completing the buses.

Nova Bus had significant delivery issues with their production buses due to supply shortages, ESS recalls, and production staffing and capacity issues. Further, Nova did a poor job of communicating these delays to the SFMTA in a timely manner, leading to significant planning and scheduling difficulties for the SFMTA's inspectors.

For this metric, the OEMs were scored based on their rank from first to last dependent on their quantitative values.

Table 4-2: Production Buses Delivery Delay Days Evaluation

Evaluation Metric	Quantitative Value (days)				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Production Buses Delivery Delay Days	0	188	65.5	208	3	(4) 12	(2) 6	(3) 9	(1) 3

Source: SFMTA BEB Revenue Service Data

4.3 Critical Deviations from Technical Specification

During the RFP process, each OEM submitted requests for approval for deviations from requirements laid out in the proposed technical specifications of the RFP package. These requests were negotiated, with the SFMTA eventually approving or rejecting the deviations requests and producing a final technical specifications document.

Deviations from the proposed technical specifications in the RFP package do not necessarily have a negative impact on the operation and functionality of the bus. If the deviations are minor, they are negligible for the purposes of the program evaluation. Deviations from the technical specification that are significant in nature can be problematic to maintenance and operations teams and disruptive to passengers, and therefore are an important determinant in the evaluation.

Most of the OEMs had only minor deviations, but Proterra had notable deviations that were critical, such as the rear step ride height being significantly higher than desired, and the breakover angle being significantly lower than desired. These kinds of deviations may have an impact on daily operations and rider experience if the bus cannot easily accommodate all passengers or traverse certain routes without scraping on the road.

Table 4-3: Critical Deviations from Technical Specification Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Critical Deviations from Technical Specifications	3	3	1	3	2	(3) 6	(3) 6	(1) 2	(3) 6

Source: OEM Proposals

4.4 Coordination with Onboard System Suppliers

The SFMTA introduced their preferred onboard systems suppliers to each of the OEMs to facilitate direct coordination of software and equipment integration for all buses. There are multiple onboard systems on the SFMTA's buses, including fare payment systems, surveillance and Digital Video Recording (DVR) systems, DriveCam, Computer-Aided Dispatch/ Automatic Vehicle Location (CAD/AVL) systems, passenger information systems, and vehicle telematics. These electronic and software systems are critical for safety efforts, daily operations, monitoring of bus metrics, and optimizing passenger experience, and integrating all these systems together on one vehicle is a complex undertaking.

OEMs were instructed to work with these onboard system suppliers to resolve any issues before presenting buses to the SFMTA. New Flyer was able to integrate these systems effectively without any significant issues arising. Nova's implementation of a power shut-off timer for the CAD/AVL and radio systems was problematic, and their DVR wiring was inconsistent with the DVR system supplier's schematics, which had to be fixed after the pilot bus delivery. BYD and Proterra were the least favorable in handling onboard system coordination. BYD had notable issues during commissioning, and even though they were later addressed by onsite technicians, these could have been handled during installation. Proterra had significant issues integrating the passenger information system into the buses, and as of this report the system is still not properly installed on all Proterra buses. There is a medium weight factor applied to this metric since coordination relies somewhat on the performance of the onboard system suppliers.

Table 4-4: Coordination with Onboard System Suppliers Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Coordination with Onboard System Suppliers	4	2	2	3	3	(4) 12	(2) 6	(2) 6	(3) 9

Source: Stakeholder Interviews

Figure 4-2: Clipper 2.0 Passenger Fare Payment System

4.5 Experience with OEM Sales and Management

The SFMTA's experience with each OEM's sales and management teams is a small but noteworthy aspect of the procurement experience, as timely communication and transparency is important throughout the life of the project.

New Flyer had several changes in management during their pilot project, but they communicated these changes clearly and without disruption to the management of the program; therefore, New Flyer did not receive any negative feedback from the SFMTA.

The experience with Nova was mostly satisfactory, with open communication occurring until the abrupt announcement of the company exiting the US market. The least favorable experience was dealing with BYD and Proterra.

BYD was responsive to communication but frequently lacked effective follow-through on project issues. Proterra's sales team provided a mostly pleasant experience and were very responsive, but their customer project management team was the most difficult to work with in terms of bus delivery and acceptance.

Table 4-5: Experience with OEM Sales and Management Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Experience with OEM Sales and Management	4	2	1	3	1	(4) 4	(2) 2	(1) 1	(3) 3

Source: Stakeholder Interviews

Figure 4-3: Maintenance personnel troubleshooting New Flyer bus 5003

4.6 Work with Resident Inspectors

Part of the contractual obligations for each OEM was to work seamlessly with the SFMTA's resident inspectors. The resident inspectors represent the SFMTA at the OEMs' manufacturing facilities and are responsible for monitoring the fabrication of the buses for adherence to the SFMTA's technical requirements.

In addition, the resident inspector provides the approval authorization to release buses for delivery to the SFMTA. Contractually, the resident inspector should be provided a space at each facility to work, and each OEM should provide to the inspector all documentation related to the procurement, including drawings, material standards, spare parts, inspection processes and reports, and bus defect records.

Given the SFMTA's familiarity with New Flyer's inspection process, their work with the SFMTA's resident inspectors was the most favorable of the OEMs, with proper documentation and communication throughout the process. Nova and Proterra provided comparable experiences for this evaluation. Nova's interactions with the resident inspector were middling, highlighting issues with providing a consistent workspace and proper communication with scheduling and delays. Proterra's technicians were quick to volunteer information and assist the SFMTA's resident inspectors, but getting Proterra to commit to the SFMTA's inspection practices was a challenge. BYD struggled to resolve issues in a timely manner or provide accurate schedules and build documents to the resident inspector.

Table 4-6: Work with Resident Inspectors Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Work with Resident Inspectors	4	1	2	2	3	(4) 12	(1) 3	(2) 6	(2) 6

Source: Stakeholder Interviews

4.7 Manufacturing Ability at Scale

An OEM's ability to align their resources, processes, and systems to accommodate a high level of bus production while maintaining quality and efficiency is considered a high determining factor for the evaluation, as the SFMTA may reasonably take delivery of 100 or more buses over a one-year period.

New Flyer scores the highest in this metric, having five facilities in North America that can manufacture more buses than the other OEMs, as well as a long and successful history of delivering large orders of buses to the SFMTA and other large agencies. Nova scored lower in the evaluation, with Nova moving to close their only US manufacturing plant in Plattsburgh.

Nova will retain two manufacturing facilities in Canada, which will be largely focused on meeting the Canadian transit market's needs.

BYD operates a single large facility in the US that produces a wide variety of vehicles, including non-transit vehicles. The SFMTA has expressed concerns about BYD's ability to reliably produce buses at scale at this facility due to its split output.

Proterra was able to produce several buses per week while they operated two US plants early in the pilot program, but the later closure of their City of Industry facility and their declaration of bankruptcy in 2023 results in their low score in this metric.

Table 4-7: Manufacturing Ability at Scale Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Manufacturing Ability at Scale	5	2	1	3	5	(5) 25	(2) 10	(1) 5	(3) 15

Source: Stakeholder Interviews

4.8 QA Inclusion During Production

Quality Assurance (QA) programs help ensure that any defects in the bus are identified and fixed before inspection to deliver an excellent product to the SFMTA. Having a robust QA program does not guarantee a product will arrive without defects, however, and therefore this metric uses a lower weight factor in this evaluation.

Buses from all four OEMs presented to the SFMTA had numerous problems that required correction. New Flyer's QA program was the most effective compared to the other OEMs.

New Flyer also had high familiarity with the SFMTA's practices from previous procurement projects, allowing them to present a higher-quality bus and resolve snags faster.

Nova and Proterra both had robust QA programs, but it was noted that Proterra's QA processes were more difficult for the SFMTA's inspectors to work with. BYD had a reasonable documented QA process, but their buses still exhibited a lot of problems needing correction at the end of the production line and after bus delivery.

Table 4-8: QA Inclusion During Production Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
QA Inclusion During Production	4	2	3	3	2	(4) 8	(2) 4	(3) 6	(3) 6

Source: Stakeholder Interviews

Source: Stakeholder Interviews

4.9 Post-Delivery Support

Buses are frequently delivered to transit agencies with known quality and functional issues that need on-site correction. Additionally, once these buses are deployed into revenue service, issues that may not have been apparent during initial testing often emerge. Fast and responsive post-delivery support becomes a key element in addressing issues promptly and ensuring confidence that the OEM can deliver reliable and efficient services.

New Flyer demonstrated commendable post-delivery support in this pilot program, backed by a field representative near San Francisco who ensured fast and responsive assistance. Similarly, BYD had an on-site representative nearby but had difficulties providing timely vehicle corrections and modifications. Proterra had significant issues with responsiveness due to a lack of availability of support staff, especially post-bankruptcy. Nova had a significant lack of service representatives assigned to the West Coast, impacting localized support and responsiveness.

Table 4-9: Post-delivery Support Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Post-delivery Support	4	3	1	2	5	(4) 20	(3) 15	(1) 5	(2) 10

Source: Stakeholder Interviews

Figure 4-4: Proterra bus 5009 at Woods Division

4.10 Workmanship

A well-crafted bus can significantly influence the passenger experience through superior aesthetics and thoughtful accommodation. Additionally, excellent workmanship simplifies maintenance by reducing quality issues and ensuring consistency in build across the fleet, making issue resolution more efficient and benefiting fleet management.

New Flyer and Nova demonstrated good workmanship upon delivery, with no significant issues reported. Proterra exhibited a moderate level of workmanship. BYD faced numerous significant workmanship challenges that were evident during production, as noted by the resident inspector. The BYD buses required constant on-site attention to address these issues, and this ultimately delayed their deployment to revenue service.

Table 4-10: Workmanship Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Workmanship	4	1	3	4	3	(4) 12	(1) 3	(3) 9	(4) 12

Source: Stakeholder Interviews

Figure 4-5: Twin Peaks, San Francisco

4.11 Ease of Warranty Process and Responsiveness

BEBs are relatively new in the transportation market, and as such there is limited historical information on how OEM warranty programs will cover these buses over their lifetime. Due to this uncertainty, the metric evaluating the ease of the warranty process and an OEM's responsiveness in warranty issues has been assigned an above-average weight factor.

New Flyer stands out as the best of the OEMs for their effective warranty process and responsiveness, not only because they are familiar with SFMTA needs but also due to the effective coordination of warranty efforts with New Flyer service representatives.

BYD and Nova both had acceptable warranty practices, with the SFMTA needing to make relatively minor adjustments to their own warranty practices to accommodate them. Proterra scored the lowest due the difficulties in navigating their warranty system and arranging for reimbursement, and Proterra's lack of manpower to complete warranty work. Proterra has encouraged the SFMTA to complete warranty work internally and seek reimbursement from Proterra afterwards, complicating efforts to keep the buses in service.

Table 4-11: Ease of Warranty Process and Responsiveness Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Ease of Warranty Process and Responsiveness	5	4	1	4	4	(5) 20	(4) 16	(1) 4	(4) 16

Source: Stakeholder Interviews

4.12 Training Program

Quality training should enable the flow of information to be passed from the OEM to SFMTA personnel. Having a robust training program enhances the SFMTA's ability to prepare operators for the vehicles and perform maintenance activities on the new buses upon acceptance, and therefore this metric holds a high weight factor for the evaluation. The SFMTA's maintenance and training teams provided feedback that all OEM training sessions met at least the minimum expectations needed to operate the buses and perform basic troubleshooting work; however, there were notable differences among the OEMs in terms of training program quality.

New Flyer received a high score in this metric for providing a high level of knowledge during training, capably preparing the SFMTA's instructors for training new operators, and providing preventative and corrective maintenance instruction for the SFMTA's maintenance team. They also provided high-quality training videos for an additional fee.

Nova received a high score for their extensive training program offerings, with a hands-on approach that was well-received by SFMTA staff.

Proterra's training staff was experienced but unable to provide dedicated training on key high-level systems like the propulsion system. This shortfall, in conjunction with the fact that many of Proterra's onboard systems are unique, somewhat limited the SFMTA's ability to diagnose Proterra buses and results in Proterra receiving a lower score. BYD scored the lowest, as they offered the least number of training courses at the time of bus delivery and still do not offer training on energy storage and propulsion systems, as their training program is still under development. However, BYD provided reasonably comprehensive diagnostics and troubleshooting training.

Table 4-12: Quality of Training Sessions Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Quality of Training Sessions	4	1	3	4	4	(4) 16	(1) 4	(3) 12	(4) 16

Source: Stakeholder Interviews

4.13 Long-Term Viability and Risk

One of the main goals of the SFMTA's BEB pilot program was to identify buses that are suitable for future large-scale BEB procurements. The SFMTA must be confident in the viability and solvency of an OEM over the long term before committing to placing large orders with them, lest that company suddenly divert or shutter their business amid a concerted procurement effort. To that end, the long-term viability of the OEMs was speculated on by the pilot program staff as part of this evaluation. The speculative nature of this assessment results in the metric receiving only a moderate weight factor.

New Flyer is the largest bus manufacturer in North America, with five production facilities located in the US and Canada. New Flyer has a storied history as a bus manufacturer and does not present much risk of closing in the foreseeable future; as such, it earns a top score in this metric.

BYD is new to the US transit market but carries financial and technical might as one of the largest battery and electric vehicle manufacturers in the world. Due to the recent passage of the National Defense Authorization Act for Fiscal year 2020, there is uncertainty regarding their ability to sell buses to US customers utilizing federal funding, but BYD has indicated to the SFMTA that this issue is being resolved. BYD earns a moderate score in this metric.

Proterra closed one of their two manufacturing facilities in 2023 and, shortly thereafter, filed for Chapter 11 bankruptcy protection. Proterra's assets were divided among three separate entities, with Phoenix Motorcars, a small electric shuttle and fleet vehicle company, taking possession of Proterra's transit bus division. The SFMTA understands that Phoenix Motorcars has committed to support all existing customers with Proterra buses and is working to keep bus production on track, but the uncertain future of the company in the transit market space earns it a low score in this metric.

Nova announced in 2023 that it intends to close its sole US manufacturing facility and focus on the Canadian transit market. Once complete, this move would render Nova unable to produce Buy America-compliant buses, limiting US agencies to procuring Nova buses with only state and local funds. Additionally, US customers may experience a lack of on-site support from Nova Bus due to this decision. The SFMTA expects that Nova will continue to be a major manufacturer in the Canadian transit market.

Table 4-13: Long-Term Viability and Risk Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Long-term viability and risk	5	3	1	1	3	(5) 15	(3) 9	(1) 3	(1) 3

Source: Stakeholder Interviews

5 Acceptance

The following section summarizes the acceptance category evaluation and scores for each OEM.

5.1 Snag Resolution Experience

Snags are defects identified during the production and acceptance phases that need resolution before the bus is eligible for full acceptance by the SFMTA. An OEM's ability to resolve snags in a timely and effective manner without requiring constant oversight is a desirable trait and receives a moderate weight factor in this evaluation.

New Flyer and Nova stood out with high scores in this metric, indicating that these OEMs were both collaborative and proactive in addressing their snags. Proterra was not as cooperative with the SFMTA in their snag resolution efforts, but their overall performance was acceptable. BYD received the lowest score in this metric, as the experience with BYD's management team was the least favorable of the OEMs and the resolution of their open issues took a considerable amount of time.

Table 5-1: Snag Resolution Experience

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Snag Resolution Experience	4	1	2	4	3	(4) 12	(1) 3	(2) 6	(4) 12

Source: Stakeholder Interviews

Figure 5-1: New Flyer bus 5001 during testing in San Francisco

5.2 Average Days Between Delivery and Acceptance

The timeframe between the buses' arrival at the SFMTA and their acceptance is an important factor in this evaluation. In this period, each OEM is tasked with promptly addressing any outstanding items identified during the acceptance phase or during the SFMTA's post-delivery inspection.

Proterra scored the highest in this metric despite having a high number of snags on vehicle delivery, as they were able to resolve all issues in a timely manner. Nova came in second, reflecting their proactive and collaborating approach to bus acceptance tasks. New Flyer came in third, even though they had the least number of snags on vehicle delivery. BYD scored the lowest, facing many challenges getting their buses ready for acceptance, particularly on issues requiring engineering support and relying on overseas suppliers.

Table 5-2: Average days between Delivery and Acceptance

Evaluation Metric	Quantitative Score (days)				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Average Days between Delivery and Acceptance	116	164	77	90	3	(2) 6	(1) 3	(4) 12	(3) 9

Source: Acceptance Documentation

6 Performance

The following section summarizes the performance category evaluation and scores for each OEM.

6.1 Duty Cycle/Bus Range

Buses from all OEMs met or exceeded the range requirement of 160 miles of range on a full battery charge, but there were notable differences in bus range between the buses that merited consideration in this evaluation.

Proterra received the highest score in this metric as their buses had the largest battery packs and could travel over 230 miles in the SFMTA's environment. Buses from BYD, New Flyer, and Nova all had similar ranges that were above the minimum range requirement, so they scored similarly. This metric has a moderate weight factor, as longer range is generally a desirable feature but is not essential for use in the SFMTA's operating environment.

Table 6-1: Duty Cycle/Bus Range Evaluation

Evaluation Metric	Quantitative Value (miles)				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Duty Cycle/Bus Range	204	200	232	190	3	(4) 12	(4) 12	(5) 15	(4) 12

Source: SFMTA BEB Revenue Service Data

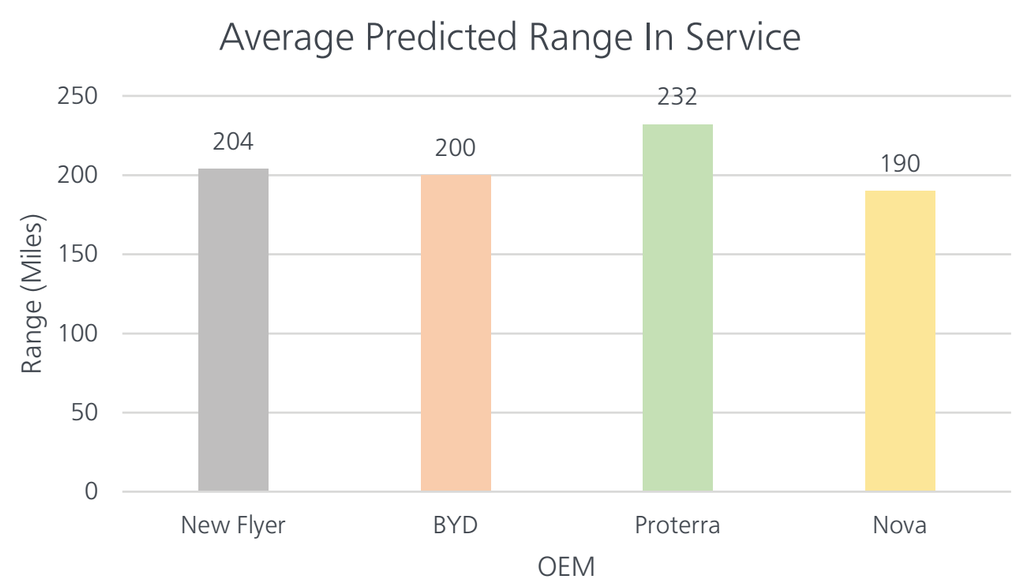


Figure 6-1: BEB Pilot Program Data for Average Predicted Range

Figure 6-2: New Flyer bus 5002 operating in revenue service

6.2 Energy Efficiency

Energy efficiency refers to how effectively the energy stored in a bus's battery is used for propulsion. This metric is significant as it directly impacts operational costs, range, and charge time. Buses with better energy efficiency can drive further distances on a single charge, reducing operational downtime and total charge time.

A quantitative approach was used to score this metric, with the efficiency figures encompassing all energy usage data from the time the buses were in revenue service. BYD, Nova and New Flyer all scored highly in this metric, with BYD being the most efficient based on predictive range and regularly recovering 36% of its power back through regenerative braking. Proterra scored the lowest with a 10% lower overall efficiency than BYD. The differences in efficiency between the buses are likely attributable to differences in overall bus weight, regenerative braking configuration, and power consumption of onboard auxiliary systems, and there is a possibility that these buses could see efficiency improvements with refinements to these factors.

Table 6-2: Energy Efficiency Evaluation

Evaluation Metric	Quantitative Value (kWh/mi)				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Energy Efficiency	2.59	2.39	2.63	2.55	3	(5) 15	(5) 15	(4) 12	(5) 15

Source: SFMTA BEB Revenue Service Data

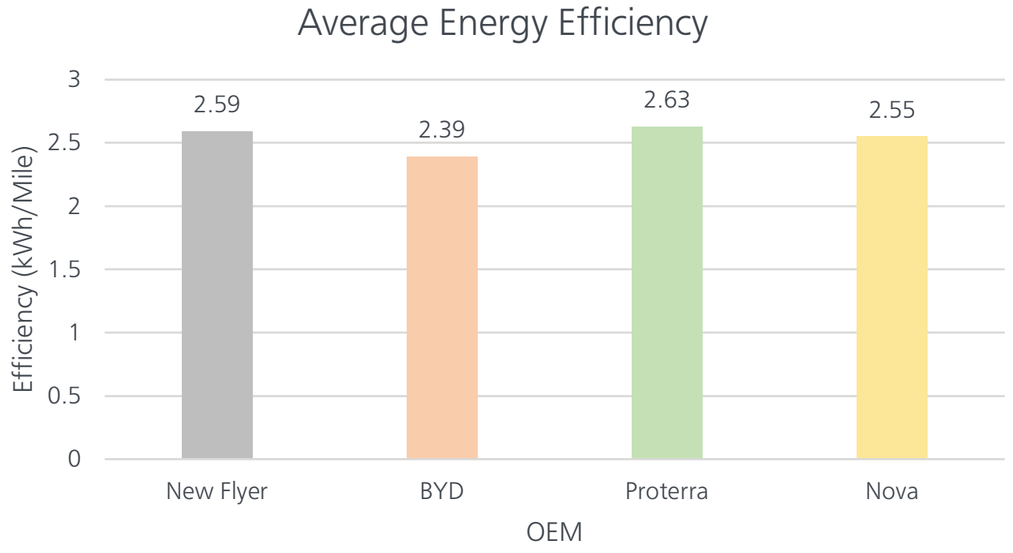


Figure 6-3: BEB Pilot Program Data for Average Energy Consumption

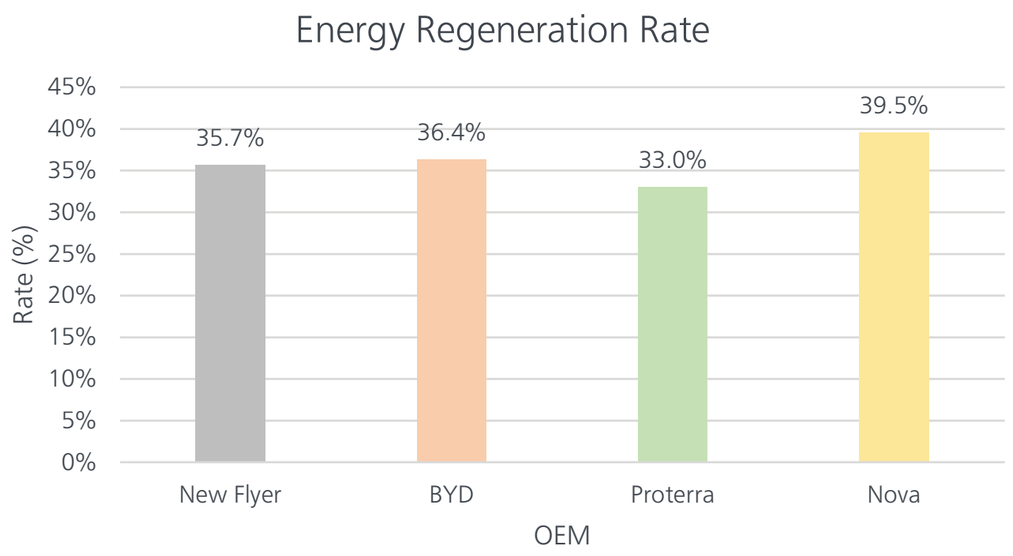


Figure 6-4: BEB Pilot Program Data for Average Energy Recovery

Figure 6-5: Charging Station at Marin Facility

6.3 Availability

BBus availability is an important metric for determining how often a vehicle is ready for operator use. Buses should be available as frequently as possible for revenue service, and not be held up for unscheduled repairs, maintenance, or other bus issues. This metric is reliant on ease of maintenance, warranty support, OEM responsiveness, parts lead times, and other factors.

New Flyer exhibited 67% availability, ranking the best of the OEMs, with Nova following at 60%. Proterra and BYD ranked lower with 51% and 50% availability, respectively. The availability was greatly impacted by various factors such as integration of new technologies, lack of on-site support, recalls, charger issues, availability of parts, and the steep learning curve associated with maintaining and troubleshooting new buses from four different manufacturers. In addition, the majority of the pilot buses were transported off-site to perform lengthy repair or rework campaigns, further extending their time out of service.

Table 6-3: Availability Evaluation

Evaluation Metric	Quantitative Value (%)				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Availability	67%	50%	51%	60%	4	(5) 20	(3) 12	(3) 12	(4) 16

Source: SFMTA BEB Revenue Service Data

6.4 Average Monthly Mileage Per Bus

The pilot program BEBs are intended to be used in regular revenue service like a conventional hybrid-electric bus, operating on the same routes, under the same conditions, and with similar duty cycles. This metric evaluates the average monthly mileage per bus to illustrate how frequently and effectively the buses provided service during the pilot program. The metric has been assigned a high weight factor to reflect the importance of meeting service requirements.

New Flyer buses saw the most usage, primarily due to the SFMTA's operations team's familiarity and preference with these buses and the higher level of availability that these buses exhibited. In contrast, the other OEMs saw similarly lower average monthly mileage per bus, ranging from 576 to 661. New Flyer received the top score in this metric, with all other OEMs receiving low scores.

Table 6-4: Average Monthly Mileage Per Bus Evaluation

Evaluation Metric	Quantitative Value (miles)				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Average Monthly Mileage Per Bus	1267	621	576	661	5	(5) 25	(1) 5	(1) 5	(1) 5

Source: SFMTA Battery Electric Vehicle Stats

6.5 Curb Weight

For BEBs, a lower curb weight is a generally positive trait which translates to more efficient battery usage, resulting in extended driving range and improved sustainability. Moreover, a lower curb weight can also result in increased performance, making vehicles easier to navigate through San Francisco's streets, and in increased passenger capacity.

New Flyer scored the highest in this metric with a curb weight of 35440 lbs., BYD second with 36473 lbs., Proterra third with 36810 lbs., and Nova last with the heaviest weight of 37880 lbs.

For this metric, the OEMs were scored based on their rank from first to last based on their quantitative values. This metric is heavily reliant on bus configuration, as the buses with greater battery capacities tended to weigh more, but body design also affected the curb weight of the buses.

BEBs are heavier than their corresponding hybrid-electric bus equivalents, as the large battery packs add a substantial amount of weight to each bus. As batteries become more energy dense and more efficiently integrated into bus designs, BEBs are expected to become lighter and more competitive with hybrid-electric buses.

Table 6-5: Curb Weight

Evaluation Metric	Quantitative Value (lbs.)				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Curb Weight	35440	36473	36810	37880	4	(4) 16	(3) 12	(2) 8	(1) 4

Source: Bus Specifications

Figure 6-6: Loaded Bus During Testing

6.6 Fire Detection and Suppression

An effective fire suppression and detection system is essential for ensuring the safety of both the vehicle and its occupants. By promptly detecting and suppressing fires, these systems prevent harm to passengers, ensure the safety of the driver, protect maintenance staff and first responders, and protect the SFMTA's capital investments.

BYD received the highest score in this metric as the only OEM with an active fire suppression system in the battery modules and a notable record of extensive testing to ensure battery safety. All other OEM buses are equipped with active fire detection and suppression systems in their high-voltage compartments, but they lack any ability to suppress thermal events occurring in their lithium-ion battery packs.

New Flyer scored the lowest in this metric, as in 2022 a New Flyer BEB in Connecticut suffered a fire that originated in one of the buses battery packs. New Flyer demonstrated a swift response by initiating discussions with its engineering team and addressing the issue promptly, showcasing a commitment to resolving safety concerns, but the event prompted the grounding of all New Flyer BEBs in the SFMTA's fleet for a short time.

Table 6-6: Fire Detection/Suppression Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Fire Detection and Suppression	2	4	3	3	3	(2) 6	(4) 12	(3) 9	(3) 9

Source: Stakeholder Interviews

6.7 Seating Layout and Overall Configuration

A bus's seating layout, overall configuration, and accessibility are critical for passenger comfort, operational efficiency, and maintenance effectiveness. A well-designed layout helps ensure smooth passenger flow and a positive transit experience.

Proterra earned a low score in this metric, as the clearance between aisle-facing seats on Proterra's upper deck was uncomfortably tight due to the design and placement of the wheel wells and seating provisions. Layouts on New Flyer, BYD, and Nova were deemed acceptable, with New Flyer receiving the top score due to its overall preferential configuration and accessibility for maintenance personnel.

Figure 6-7: BYD bus 5004 Seating

Table 6-7: Seating Layout and Overall Configuration Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Seating Layout and Overall Configuration	5	3	2	3	1	(5) 5	(3) 3	(2) 2	(3) 3

Source: Stakeholder Interviews

Figure 6-8: BYD bus 5004 Seating and interior

7 Operability

The following section summarizes the operability category evaluation and scores for each OEM.

7.1 Driver Interface

The driver interface is comprised of controls, displays, and instruments which allow interaction with the bus. A well-designed interface helps improve bus operation, minimize distractions, and reduce driver fatigue to ensure safety of the bus and the occupants.

New Flyer scores highly in this metric due to their consistent and accommodating driver interface, which presents minimal differences in the driving set-up compared to that of SFMTA's existing buses. Nova relies on prominent use of symbols in the driver interface, which some operators find non-intuitive, but otherwise presented an acceptable driver interface. BYD faces challenges with operators needing more practice during start up, as the air tank must reach a specific air pressure level for the motor to start, and the buses would show messages on startup that confused unfamiliar operators, occasionally causing delays. Furthermore, the gap in the operator barrier allowing riders to touch the drivers raises safety concerns, but BYD is reportedly resolving this issue.

Proterra's driver area was determined to be less suitable for larger operators, and operators consistently noted issues with steering wheel adjustment, glare, and visibility.

Figure 7-1: New Flyer bus 5001 Driver's Area

Table 7-1: Driver Interface Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Driver Interface	4	2	1	3	3	(4) 12	(2) 6	(1) 3	(3) 9

Source: Stakeholder Interviews

7.2 Ride Quality

Ride quality refers to the perception of comfort, smoothness, and acoustics experienced by passengers and operators during transit. Good ride quality serves to minimize driver fatigue and enhance operator and passenger satisfaction. This metric is influenced by factors like overall build quality and the suspension system, and it receives a moderate weight factor in this evaluation.

New Flyer claims the top score for ride quality, demonstrating smooth operation during acceleration and braking and low levels of rattling and vibration. The buses also exhibited excellent performance on hills, despite New Flyer quoting traction motor performance figures that slightly trailed their competitors. Nova also exhibited low noise and smooth operation while in operation.

BYD offered a mostly smooth ride and low noise level but faced challenges with uphill terrain. BYD buses also earned a reputation early in the program for having harsh braking, but this was resolved with tweaks to the regenerative braking system.

Proterra was observed to have the worst vibration issues and be among the noisiest of the buses. Operators noted dissatisfaction with operator controls, doors being slow, and low overall propulsion and braking performance.

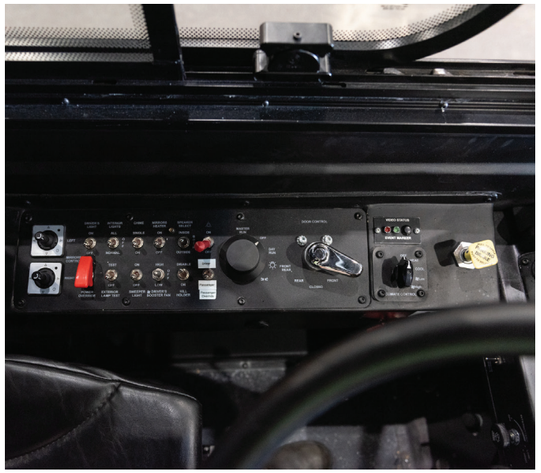


Figure 7-2: BYD bus 5004 Operator Side Panel Controls

Table 7 2: Ride Quality Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Ride Quality	5	3	2	4	3	(5) 15	(3) 9	(2) 6	(4) 12

Source: Stakeholder Interviews

Figure 7-3: BYD bus 5004 operating in revenue service

8 Maintainability and Reliability

The following section summarizes the maintainability and reliability category evaluation and scores for each OEM.

8.1 Miles Per Labor Hours Booked by SFMTA

This metric assesses the amount of service a bus can provide for a given amount of labor time invested in maintenance and repairs. This metric provides insights into the productivity and effectiveness of the maintenance processes for a given fleet. A higher miles per labor hour figure typically indicates that buses are covering more distance while requiring less time for maintenance activities, which can be indicative of an effective and well-maintained fleet.

New Flyer scored the highest in this metric with 80 miles per labor hour. Nova came in second with 78 miles per labor hour; however, the data for Nova only represents the performance of the prototype bus, as only the prototype bus had been entered into revenue service at the time of this report.

Proterra scored relatively well with 64 miles per labor hour, reflecting an efficient preventative maintenance program and decent reliability. BYD scored the lowest at 35 miles per labor hour due to difficulties with maintenance and the more frequent and critical issues found on the BYD buses.

As a new technology, BEBs are still undergoing refinement to address potential operational challenges and enhance overall performance. The SFMTA also used this BEB pilot program to test out new onboard systems, further presenting challenges with keeping vehicles in service. Therefore, it is important to note that these BEBs may not initially match the same level of reliability as the existing hybrid-electric buses in the SFMTA fleet. Additionally, maintenance staff will need specialized training to deal with the intricacies of electric propulsion systems, battery management, and other unique systems.

Figure 8-1: New Flyer bus 5001 on Lifts

Table 8-1: Miles Per Labor Hours Booked by SFMTA Evaluation

Evaluation Metric	Quantitative Value (miles)				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Miles Per Labor Hour Booked by SFMTA	80	35	64	78	3	(5) 15	(1) 3	(4) 12	(5) 15

Source: SFMTA BEB Revenue Service Data

8.2 Mean Distance Between Service Interruptions

Mean distance between service interruptions (MDBSI) is a critical metric as it directly reflects the reliability and operational efficiency of buses. This metric measures the average distance a bus can be expected to travel in service before experiencing a mechanical or system failure that results in a service interruption. A higher MDBSI indicates that buses can cover more miles before encountering issues, resulting in reduced downtime and increased availability for service.

All OEMs demonstrated a generally similar MDBSI performance. New Flyer recorded 619 miles, Proterra reached 512 miles, BYD achieved 462 miles, and Nova Bus achieved 455 miles, indicating comparable overall reliability. Nova was excluded from this metric due to having only one bus in service during the evaluation period and having been in revenue service for a shorter time than the other OEMs.

Table 8-2: Miles Per Chargeable Road Call Evaluation

Evaluation Metric	Quantitative Value (miles)				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Mean Distance Between Service Interruptions	619	462	512	N/A[1]	4	(5) 20	(3) 12	(4) 16	N/A[1]

Source: SFMTA BEB Revenue Service Data

1. Nova was excluded from this metric due to limited data set.

8.3 Ease of Maintenance

Minimizing maintenance downtime is crucial for adhering to schedules and ensuring reliable services. Streamlining the maintenance process reduces repair time and resources, contributing to a more responsive transit operation.

New Flyer performs well in this metric because their manuals and preventive maintenance practices are well documented and easily followed. In addition, the SFMTA's maintenance staff is familiar with New Flyer vehicles which helps New Flyer in this metric. This familiarity largely streamlines maintenance processes and contributes to a higher ease of maintenance. BYD and Proterra both scored low, reflecting the difficulties that maintenance staff had with keeping the vehicles maintained. Nova scored higher than BYD and Proterra, indicating a relatively higher ease in comparison.

Table 8-3: Ease of Maintenance Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Ease of Maintenance	4	2	1	3	3	(4) 12	(2) 6	(1) 3	(3) 9

Figure 8-2 Technician Performing Preventative Maintenance

8.4 Quality of Maintenance Manuals

High-quality manuals serve as comprehensive guides for technicians, streamlining troubleshooting, reducing downtime, and ensuring standardized practices. The SFMTA prefers manuals that clearly present information and procedures using terms and practices they are familiar with but can acclimate to most manuals if they are sufficiently thorough; therefore, this metric is assigned a low weight factor.

The SFMTA desires that OEMs submit a draft or generic maintenance manual initially and subsequently refine and finalize it after their designs have been finalized and buses have been delivered. This approach allows the OEMs to incorporate feedback and concerns, and tailor the manual to the specific needs of their vehicles. Only New Flyer and Proterra provided manuals ahead of bus delivery per SFMTA requirements.

New Flyer received the top score in this metric for their excellent manuals. The overall quality of manuals submitted by Nova and Proterra was good, and BYD's submissions were of significantly lower quality, containing incorrect wiring diagrams that required field corrections. Manuals presented by both Proterra and BYD were not always clear and concise, having checklists rather than the preferred convention of maintenance interval schedules.

Table 8-4: Quality of Maintenance Manuals Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Quality of Maintenance Manuals	4	1	3	3	2	(4) 8	(1) 2	(3) 6	(3) 6

8.5 Parts Lead Times

Timely parts deliveries are crucial to ensuring efficient maintenance and minimizing downtime in a bus fleet. A streamlined supply chain is vital to reducing parts lead times and keeping buses in service.

New Flyer stood out with the best parts availability and was able to leverage their parts department to get buses back into service quickly. BYD's parts availability was generally good but occasionally varied due to unpredictability in their supply chain, and some parts that were shipped from China to the US had particularly long lead times. Nova faced challenges with parts for their buses, notably BAE Gen 2 components and the recalled Akasol battery replacement parts. Proterra had significant issues with parts lead times, particularly for battery and propulsion system components, and one bus has been out of service for more than 9 months due to their inability to provide replacement parts. This situation has been further complicated by the company's bankruptcy, affecting deliveries of all manners of parts and supplies.

OEMs were generally transparent about part shortages, mainly attributing them to COVID-related supply chain disruptions (or bankruptcy proceedings, in the case of Proterra). The varying parts lead times underscore the importance of a reliable and transparent supply chain for maintaining a BEB fleet.

Table 8-5: Parts Lead Times Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Parts Lead Times	4	3	1	3	5	(4) 20	(3) 15	(1) 5	(3) 15

Source: Stakeholder Interviews

8.6 Recalls (quantity and impact)

The quantity and impact of bus recalls are critical, directly affecting public safety and reliability. Recalls signify potential safety concerns or defects in bus components, and the frequency and severity of these recalls may indirectly correlate with the overall reliability and quality of the bus.

New Flyer issued a recall in 2023 for its BEBs due to a defect that is thought to have caused a lithium-ion battery fire in Connecticut, prompting the SFMTA to ground their New Flyer BEBs temporarily. While New Flyer was prompt in engaging in investigations and resolutions, the recall impact is significant and is one of the most severe observed among the OEMs during the pilot period, resulting in New Flyer's low score in this metric. Proterra similarly received a low ranking due to a high number of recalls, including with their power steering system, wiper motors, and propulsion system. BYD had no significant recalls during the pilot program. Nova had moderate recall impacts and scored accordingly.

Table 8-6: Recalls (quantity and impact) Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Recalls (quantity and impact)	1	4	1	2	4	(1) 4	(4) 16	(1) 4	(2) 8

Source: Stakeholder Interviews

8.7 Charging Experience

Buses seamlessly integrating with bus charging systems is vital for transitioning to a BEB fleet, as it aids operational efficiency by maintaining consistent charging connections and reliably achieving desired state of charge levels. Maintaining a stable connection requires the buses and chargers to interact effectively. The interface between buses and chargers will play a crucial role in optimizing the charging infrastructure in the future, facilitating a smooth transition during the shift from conventional buses to BEBs.

New Flyer scored low in this metric due to their buses presenting numerous challenges in maintaining charging sessions, often requiring multiple charging attempts for a successful connection. New Flyer's buses also periodically exhibited issues with charge ports failing or locking charging plugs into place. BYD experienced occasional issues with charging, notably with their low voltage batteries draining while the buses were charging but managed to promptly address their issues. Nova also faced issues with low voltage batteries draining during bus charging but has not yet managed to resolve this problem. Proterra experienced minimal issues with their charging sessions, demonstrating their reliable charging interface technology.

Table 8-7: Charging Experience Evaluation

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Parts Lead Times	4	3	1	3	5	(4) 20	(3) 15	(1) 5	(3) 15

Source: Stakeholder Interviews

Figure 8-3: Charging Station at Woods Facility

9 Financial

The following section summarizes the financial category evaluation and scores for each OEM.

9.1 Bus Acquisition Costs

Comparing the costs of the BEBs tested in the pilot program highlights notable differences in pricing structures. BYD's buses were the least expensive at $873,300 per bus. New Flyer's buses cost $1,183,884 per bus, and Nova's buses cost $1,312,591 per bus. Proterra's buses were the most expensive at $1,407,624 per bus.

Notably, Proterra's higher cost is influenced by its sizable Energy Storage System (ESS), with a capacity of 660 kWh (66-164 kWh greater than the other OEMs). This substantial ESS configuration, while contributing to a higher overall cost, was neither required nor needed by the SFMTA for the purposes of the BEB pilot program, but Proterra did not offer another ESS configuration that would have comfortably met the range requirements of the pilot program.

Table 9-1: Bus Acquisition Costs Evaluation

Evaluation Metric	Quantitative Value ($)				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Bus Acquisition Costs	$1,183,884	$873,300	$1,407,624	$1,312,591	3	(2) 6	(5) 15	(1) 3	(1) 3

Source: SFMTA BEB Pilot Program Contract

Figure 9-1: BEB Fleet in Woods Division

9.2 Grant Opportunities and Contracts

For a transit agency that uses federal funds for bus procurements, the ability to purchase buses from an OEM using those federal funds is paramount to that OEM's viability in future large-scale procurements. Additionally, transit agencies benefit from being able to utilize state cooperative purchasing agreements as convenient tools of bus procurement. This metric assesses the ease in obtaining federal funding for each OEM and utilizing state cooperative purchasing agreements and is assigned a moderate weight factor.

New Flyer and Proterra produce Buy America-compliant buses for the US transit market, and these buses are eligible for federal funding and grant opportunities. However, it is unclear if Proterra's acquisition by Phoenix Motorcars will limit an agency's ability to purchase their buses in the near-term under existing state cooperative purchasing agreements.

BYD also produces Buy America-compliant buses, but there is currently concern about their ability to sell buses to US customers due to the National Defense Authorization Act for Fiscal Year 2020, a law that restricts the use of federal funding for buses from transit manufacturers linked to China. BYD is in the process of restructuring their transit business to regain their buses' eligibility for federal funding. The SFMTA anticipates that BYD will be able to enter into new state cooperative purchasing agreements after restructuring.

Nova announced in 2023 the pending closure of their only US manufacturing facility, following the company's stated goal of focusing their efforts on the Canadian transit market. With the closure of their US facility, Nova will have no obvious pathway to producing Buy America-compliant buses, preventing US agencies from using federal funding for Nova buses without receiving a waiver from the FTA.

Table 9 2: Grant Opportunities and Contracts

Evaluation Metric	Qualitative Score				Weight Factor	(Un) Weighted Score			
	New Flyer	BYD	Proterra	Nova		New Flyer	BYD	Proterra	Nova
Grant Opportunities and Contracts	4	3	4	1	3	(4) 12	(3) 9	(4) 12	(1) 3

Source: Stakeholder Interviews

Figure 9-2: New Flyer bus 5002 operating in revenue service

10 Evaluation Findings

Figure10-1: San Francisco Commute

In the pursuit of transitioning to a zero-emission fleet, the SFMTA embarked on a pilot program aimed at comparing BEBs from four leading OEMs: New Flyer, BYD, Proterra, and Nova Bus. This comprehensive report meticulously evaluated these OEMs across a variety of critical aspects, including procurement and customer experience, acceptance, performance, operability, maintainability and reliability, and financial considerations. The findings are presented below.

10.1 Scoring Results

The final scores, reflecting their performance in all evaluation categories, can be found below in Table 10-1. New Flyer, Proterra, and BYD were evaluated out of a total possible score of 517. Nova was not scored in one metric (Mean Distance Between Service Interruptions) due to the limited data available during the pilot program, and their score is evaluated out of a total possible score of 497.

Table 10-1: Scoring Matrix by Category

Evaluation Category	New Flyer	BYD	Proterra	Nova
Procurement and Customer Experience	153	78	74	114
Acceptance	18	6	18	21
Performance	99	71	63	64
Operability	27	15	9	21
Maintainability and Reliability	82	67	65	59
Financial	18	24	15	6
Weighted OEM Score	397	257	240	285
OEM Score (%)	76.79%	49.71%	46.42%	57.34%

Source: Stakeholder Interviews

10.2 Discussion of Results

10.2.1 New Flyer

New Flyer demonstrated a strong showing in this pilot program, excelling in procurement, manufacturing ability at scale, and manufacturing efficiency. New Flyer's abilities in production, aligning resources to ensure timely deliveries, and effective coordination position them as a leader in manufacturing. New Flyer stood out as the only OEM to meet their delivery schedule for their production buses. Moreover, New Flyer's post-delivery support, ease of warranty process, and responsiveness contributed to its overall favorable standing, and resulted in their buses delivering more service than any other OEM.

New Flyer had a less-favorable showing in two areas of this evaluation. Their recall stemming from a battery fire posed a significant concern, despite the company demonstrating responsiveness in developing a swift resolution. Notable charging interoperability issues further reduces their overall score. New Flyer is working to iron out these problems, and their commitment to addressing these issues gives the SFMTA confidence that they will not impact future procurements.

New Flyer was the overall highest performing OEM in this pilot program and is a viable option for the SFMTA's future large-scale BEB procurements. The SFMTA's familiarity with their existing New Flyer bus fleet aided the overall score of New Flyer's BEBs; however, New Flyer performed well even without considering the SFMTA's prior experience and familiarity.

10.2.2 Nova

A late addition to the pilot program, Nova exhibited notable strengths in workmanship, performance, acceptance, and ride quality. Their warranty and training programs also demonstrated promise, and while there isn't as much service data available for Nova than the other OEMs, Nova appears to offer good reliability.

Nova had significant delays on their production buses, and these delays were not properly communicated to the SFMTA, impacting inspection efforts. Nova scored poorly in post-delivery support as they took a long time to resolve issues found on the buses, and their bus was the heaviest out of the OEMs.

Nova had a strong showing in the pilot program, and most of their issues could be rectified by allocating more resources to support their field service teams and improving communication on production-related issues. However, due to Nova's decision to abruptly close their US production facility and focus on the Canadian market, the SFMTA cannot consider Nova Bus as a viable option for future procurements as their future buses will not be able to meet Buy America requirements, and Nova Bus will have a lack of field service support in the US.

10.2.3 BYD

BYD showcased notable strengths in battery technology, energy efficiency, and their proactive approach to safety with their active fire suppression system. BYD also did a respectable job in other aspects of the evaluation, including overall bus performance and warranty experience, and they offered a significantly less expensive bus than their competitors. However, challenges in coordinating with resident inspectors and providing timely responses to issues during commissioning significantly impacted their performance in the pilot program. Issues in management, coordination, training, and workmanship were significant drawbacks, compromising the overall reliability and availability of BYD buses. The SFMTA expressed concerns about BYD's ability to produce at scale at their sole US manufacturing facility, which also produces a variety of vehicles for non-transit applications, and questions about purchasing BYD buses with federal funding remain a significant unknown at this time.

The SFMTA believes that BYD is not a viable option for future procurement needs. BYD is currently not eligible for procurement using federal funds due to the National Defense Authorization Act for Fiscal Year 2020. Additionally, BYD exhibits significant deficiencies in their bus manufacturing processes, training offerings, and acceptance experience.

Figure 10-2: Golden Gate Bridge

10.2.4 Proterra

Proterra excelled in terms of bus range, battery capacity, and charging experience. Proterra's buses performed well in service; however, they saw limited revenue service due to lack of parts and timely field service support.

All OEMs exceeded the 160 miles range requirement of the pilot program, and the SFMTA determined during testing that bigger battery capacity and longer range, the major standout features of the Proterra bus, are not critical advantages in the SFMTA's use case. Proterra performed poorly in a variety of evaluation areas including post-delivery and warranty support, driver interface, ride quality, and parts lead times. Proterra's shortcomings were further compounded by their declaration of bankruptcy and acquisition by Phoenix Motorcars, and their future in the transit industry does not appear promising. Overall, Proterra ranks last in this evaluation, and the SFMTA does not recommend Proterra for future BEB procurements.

10.3 Lessons Learned

10.3.1 Charging Infrastructure Complexity and Cost

BEBs are notably more expensive than hybrid-electric buses, but otherwise the process of BEB procurement is comparable to hybrid-electric bus procurement, using similar procurement tools and operating under similar time frames. However, the SFMTA found during the pilot program that BEB infrastructure procurement is significantly more complex and expensive, and this will be the major limitation on the agency's ability to achieve its electrification goals.

Transitioning all our aging facilities for BEB readiness is a complex process that relies on precise project delivery timing, sequencing, and logistical planning to minimize disruption to service, operations, and maintenance. In addition, the SFMTA will have to request more power for each of the SFMTA's bus yards, necessitating utility upgrades at each facility. Facility capital projects have long lead times, requiring 3 to 5 years for retrofits, and 6-10 years for full rebuild projects.

The SFMTA projects that transitioning facilities to accommodate BEBs will be an expensive endeavor, requiring facility retrofits, code compliance upgrades, utility work required by PG&E, and the cost to completely rebuild 100-year-old facilities in poor condition like Potrero and Presidio Yards, in which e-bus infrastructure is just one component.

Many of the SFMTA's bus yards are old and have seismic and other safety needs. The SFMTA cannot simply retrofit a facility for BEBs if it needs to be completely rebuilt. Additionally, to maintain Muni service during the transition, the SFMTA can only rebuild one yard at a time, so these facilities projects must be carefully sequenced to limit impacts to transit operations.

10.3.2 Zero-Emission Transition Risks

The SFMTA's zero-emission transition strategy is a developing process that is being updated regularly due to the unknowns, complexities, changes, and challenges that may occur during the transition to a zero-emission fleet. Updates may be necessary due to factors such as advancements in bus technology, changes in building and bus regulations, shifts in transit demands and needs, funding, and adjustments in project delivery timelines. In particular, the conversion and reconstruction of bus yards are large-scale, expensive, and complex undertakings. To facilitate the SFMTA's transition to a zero-emission bus fleet, a planned sequence of projects has been established. This ambitious timeline faces several risks, including funding shortfalls, prolonged regulatory review and approvals, and other potential factors. Most notably, new electrical service and any associated grid improvements needed to fuel a BEB fleet are solely dependent upon external utility partners (SFPUC and PG&E).

Any delay in one facilities project could cause a ripple effect, delaying bus procurements and subsequent project timelines, ultimately delaying the SFMTA's zero-emission transition.

10.3.3 Charging Strategy

In preparation for the BEB pilot program, the SFMTA purchased Express Plus plug-in chargers from ChargePoint in August 2019. The SFMTA was the first in the US to procure and deploy ChargePoint's Express Depot charging system with the capability to charge concurrently (ie. "parallel charging"). This helped future-proof the system by giving the SFMTA the option to add additional dispensers while utilizing the same charging cabinets, which was later demonstrated with the purchase of three additional dispensers to accommodate the Nova BEBs.

Upon the arrival of each pilot BEB from the four OEMs, every bus had interoperability issues with the SFMTA's chargers. After several charger software revisions from ChargePoint in coordination with the BEB OEMs, buses from all four OEMs were able to successfully complete the handshake protocol and establish a charging session as well as complete the charging session without any premature interruptions.

The SFMTA has decided to specify SAE J3105 inverted pantograph charger dispensers as opposed to the SAE J1772 plug-in dispensers for all future full scale yard electrification projects to save floor space as well as help automate the logistics for connecting and disconnecting chargers to and from BEBs. Some SAE J1772 plug-in dispensers may be installed in maintenance bays to allow for charging if necessary while buses are undergoing maintenance activities.

The charging experience with plug-in charger dispensers in the pilot program informed the SFMTA of the complexities of the logistics for plugging in and unplugging chargers, the floor space requirements, coordination between the charger manufacturer and the installation contractor, and coordination between the charger manufacturer and the BEB OEMs.

10.3.4 Zero-Emission Workforce Development

One topic of particular interest to the SFMTA at the onset of the pilot program was the amount of training needed for operations and maintenance staff to use and maintain BEBs, particularly for staff familiar with hybrid-electric vehicles. The SFMTA found over the course of the pilot program evaluation period that only minimal retraining was needed to familiarize staff with the new BEBs, and that the SFMTA's prior experience with trolley buses and hybrid-electric buses helped prepare staff for some of the intricacies of working with battery electric vehicles.

The SFMTA's operators needed introductory training on the specifics of the controls and interfaces for each new pilot vehicle, but there were few problems operating the buses in revenue service once familiarity was established and operators gained experience. Likewise, maintenance staff required training to familiarize themselves with the new propulsion and multiplexing systems, doors, and other major systems, but did not have issues applying general troubleshooting and high-voltage safety practices to the new vehicles. Generally, the SFMTA has observed that a purely electric propulsion system is analogous in design and function to a series hybrid-electric propulsion system without internal combustion elements; manufacturers like BAE and Allison are working on streamlining and standardizing their propulsion system offerings to share many components between their BEB and hybrid-electric systems, further increasing their similarity.

The SFMTA has a storied history of employing low-emission and zero-emission vehicles, and procuring BEBs to replace hybrid-electric buses is the next logical step for the SFMTA in their zero-emission transition. Of the zero-emission technologies available today, BEBs are the most similar in design and operation to our existing hybrid-electric bus fleet, require the least amount of operator and maintenance training, offer the greatest versatility in our operating environment, and are available from the largest number of bus OEMs.

10.3.5 Rapidly Evolving Technology

The SFMTA launched its BEB pilot program with the understanding that it would be evaluating technologies that are new to the SFMTA, and in some cases new to the industry at large. The BEB pilot program gave the SFMTA an opportunity to gain valuable experience with different bus OEMs, suppliers, and technologies.

As part of the pilot program, the SFMTA was an early adopter of the latest-generation models from BYD (K9MD), Nova (LFSe+), and New Flyer (XE40). The SFMTA has experienced many teething issues with the buses, as they have not had the time needed in service for the buses and technology to fully mature. Overall, the reliability of the BEBs is not up to par with existing diesel hybrid and trolley buses. The SFMTA helped identify many bugs with the vehicles and has worked with the OEMs to enhance the performance and reliability of the vehicles. One of the major lessons from the pilot is that the performance of the buses will continue to improve as the OEMs deploy updates, and future generations of buses will benefit from the lessons learned in this pilot program.

Most OEMs are starting to offer large capacity ESS to help with BEB range. The SFMTA does not need a bus with excessive ESS capacity that exceeds the SFMTA's daily mileage requirement. Based on the pilot evaluation, the SFMTA will need an ESS capacity between 525 kWh and 600 kWh to comfortably meet daily service needs. Specifying an appropriately sized ESS capacity will improve energy efficiency by reducing the overall weight of the BEB.

The pilot program allowed different BEB OEMs the opportunity to familiarize and integrate with the SFMTA's preferred third-party and subsystem suppliers, procurement practices, and technical specifications. As a result, all manufacturers are comfortable in participating in the SFMTA's future large-scale procurements.

The SFMTA will continue to monitor the transit market for developments in zero-emission technology and may adjust their zero-emission transition plans accordingly.

10.3.6 Integration of New Systems and Sub-suppliers

SFMTA used the pilot evaluation opportunity to test many new features and systems such as new plug-style doors, updated CAD/AVL systems, back-up cameras, new bike racks, USB charging ports, ADA-compliant wheelchair ramps, flush windows, and other software enhancements. The inclusion of these features impacted the availability of these buses in revenue service and harmed the SFMTA's ability to collect revenue service data for the pilot evaluation. A major takeaway from this experience is to limit introduction of new systems and features to focus on the main objective of the program.

The SFMTA's current CAD/AVL supplier for all its modes of transportation is Conduent. The SFMTA used this opportunity to test and validate Conduent's latest Integrated Vehicle Unit (IVU) 4000 on-board system as opposed to equipping the BEBs in the pilot with the obsolete IVU-3100 model. Conduent is still working to address software and programming bugs with its latest IVU-4000 to get it ready for large-scale procurement and deployment.

The SFMTA also incorporated plug-style doors from two different suppliers to improve safety and customer experience for its ridership. The plug-style doors open outward and away from the bus as opposed to the SFMTA's existing slide-glide style doors that open inward and present potential pinch-point hazards if riders ignore warnings and stand in the "Do Not Stand" floor areas.

The integration of the new door system introduced many challenges when the SFMTA first deployed the buses in revenue service; however, the new door has been a success, and the SFMTA is planning to incorporate the plug-style door for its future procurement of buses.

10.3.7 Yard Management and Smart Charging

It is recommended that the SFMTA modernize their operational procedures and practices, moving away from outdated, manual processes towards a more efficient and automated approach, and implement a charge management system to assist in their transition to a zero-emission fleet.

Existing operations and practices will have to change for BEB operations as BEBs require consideration for charging time and range restrictions. The SFMTA has identified a need to invest in Yard Management and Smart Charging technology to successfully transition to a fully zero emission fleet while operating a mixed propulsion fleet for the foreseeable future.

The practice of providing 150 kW of concurrent charging capacity for each BEB at a bus yard is not feasible for large-scale BEB operation and would result in large infrastructure costs and high peak utility demands. Smart Charging technology will be required to reduce the amount of power needed at each facility. Smart Charging technology will ensure BEB charging loads and schedules are optimal to minimize the demand on the grid, improving resilience and reducing infrastructure and energy costs.

The SFMTA does not have effective real-time visibility of the buses in the yard and currently uses a handwritten map, which is generated early each morning, to dispatch and manage the buses in the yards. Yard Management technology, which will accurately locate buses in each bus yard and allow for more intelligent bus dispatching, will be required due to the increased complexity of integrating the operations of a mixed fleet of BEBs and hybrid-electric buses. This technology will allow SFMTA to automate the bus dispatch function and intelligently assign buses to service blocks based on numerous factors including as bus SOC, mileage needs, battery health and climate.

Together, Yard Management and Smart Charging technology will integrate operations planning, dispatch, yard management, and charge management system functions into a single dashboard to manage bus fleets of all propulsion types more efficiently. Key benefits will include transitioning from an archaic manual approach to scheduling, bus management, dispatching, work orders, charging, and battery health to a real-time based data that helps staff be more efficient at their jobs, while mitigating risks around BEB limitations to ensure reliable service delivery to transit customers.

10.3.8 Safety

As the SFMTA shifts from hybrid-electric buses to an entirely zero-emission fleet, it's critical to implement stringent safety protocols to minimize fire risks. This was especially evident during the BEB pilot program, when several OEMs experienced bus-related fires at other agencies.

The SFMTA hired a third-party consultant to conduct an evaluation of the fire risk of the BEB fleet. The SFMTA held interviews with all internal stakeholders involved, as well as the San Francisco Fire Department (SFFD) to discuss the latest fire safety protocols and preventative measures. The evaluation concluded that only minimal adjustments were necessary for the SFMTA to operate its BEB pilot fleet at a high level of safety; however, the industry needs more work to understand the risks involved with operating BEBs in an indoor facility. The SFMTA will partner with third party consultants, the SFFD, and industry experts to further develop fire prevention, mitigation protocols, fire codes and standards, and standard operating procedures as it relates to fire safety.

10.3.9 Resiliency

The SFMTA's fleet plays a role in city and regional emergency response, potentially requiring long-distance travel that is not supported by battery-electric buses. Last year's wildfires and associated power outages placed new urgency on the need for a contingency fleet not reliant on the electrical grid.

The increased frequency of fires and natural disasters, especially in areas with exposed power distribution grids, pose a significant risk to zero emission vehicles, highlighting the importance of readiness and resilience. The role of BEBs is unknown in the case of providing emergency services in the event of a natural disaster or otherwise resulting in a prolonged power outage. The SFMTA plans to request dual feeds from PG&E at each of its facilities to provide redundancy. In addition, it is recommended that the SFMTA install microgrids in the form of on-site battery storage systems, photovoltaic systems, vehicle to grid integration systems, and emergency back-up generators to provide sufficient power to charge 20% of its entire bus fleet. In the near term, the SFMTA intends to continue to procure hybrid-electric buses as it electrifies its bus yards, and these should contribute to the SFMTA's resiliency in the event of a natural disaster.

10.3.10 Transit Bus Market

During the period of evaluation, ENC, Proterra, and Nova declared bankruptcy or announced plans to exit the US market. Due to the unpredictability of the transit bus market and the lack of competition among bus manufacturers, it is in the SFMTA's best interest to engage in business with multiple bus manufacturers for future procurements. The SFMTA cannot rely on a single manufacturer to provide transit buses, as this would result in higher costs, increased dependency on the manufacturer, and greater vulnerability to production delays.

It is recommended that the SFMTA continue to look to partner with multiple viable bus manufacturers, and the SFMTA should continue to work with the bus industry and APTA's Bus Manufacturing Task Force to mitigate risks arising from uncertainty in the transit bus market.

The SFMTA has also become aware of the possibility of other manufacturers entering the US market in the near future. Solaris, a leading zero-emission bus manufacturer in Europe, has announced their desire to establish a presence in the North American transit market to produce BEBs, fuel cell buses, and electric trolley buses. The SFMTA has a strong interest in establishing partnerships with any viable zero-emission bus manufacturer, particularly if they can produce electric trolley buses for the US market.

Figure 10-3: BYD bus 5004 operating in revenue service

Figure 10-4: Nova bus 5010 parading during pride month

10.4 Future Procurement Strategy

The selection of OEMs for future BEB procurements demanded a thorough understanding of the SFMTA's priorities, operational demands, and specific challenges. Considering the strengths and weaknesses of all OEMs, New Flyer and Nova are viable for the SFMTA's future BEB procurements, demonstrating well-rounded performance across various metrics in the evaluation and aligning well with the SFMTA's specific needs. The SFMTA also desires to procure and evaluate BEBs from Gillig, and European manufacturers such as Solaris Bus & Coach in the near term to increase competition and ensure the SFMTA has multiple options for its future procurement strategy.

The recommended procurement strategy for the SFMTA is to procure 70-90 buses per year from multiple OEMs using state procurement contracts; this will allow the SFMTA to rapidly adjust procurements to account for possible delays in facilities and infrastructure projects. The SFMTA determined that the most preferred method for all its future bus procurements is to utilize available state procurement contracts. This method is efficient in both time and cost as statewide contracts leverage the states' collective buying power to negotiate and establish fair base bus prices, help minimize risk, and streamline the procurement process.

For the most part, the BEB procurement process is largely similar to previous traditional hybrid-electric bus procurements deployed in the past, and minimal operator and maintenance staff retraining would be needed to transition from hybrid-electric buses to BEBs. However, the BEB infrastructure procurement process is significantly more complex and expensive and will be the major limitation for fleet electrification; chargers and infrastructure need to be in place before BEBs can be delivered to a bus yard.

The SFMTA's BEB procurement schedule will need to align with its facilities timeline as outlined in the SFMTA's 2024 Facilities Framework Addendum. Due to complexities with implementing charging infrastructure and facility upgrades, the SFMTA will need to procure hybrid-electric buses in limited quantities for the foreseeable future. As highlighted in the current SFMTA Zero-Emission Vehicle Policy, the SFMTA will continue to procure trolley buses and consider other zero-emission bus technologies.

Appendices

1. Evaluation Matrix

Evaluation Category	Evaluation Metric	Metric Type	Weight Factor (1-5)	OEM Raw Scores				OEM Unweighted Rating (1-5)				OEM Weighted Rating			
				New Flyer	BYD	Proterra	Nova	New Flyer	BYD	Proterra	Nova	New Flyer	BYD	Proterra	Nova
Procurement and Customer Experience	Pilot bus delivery delay days	Ranked	3	259	264	214	140	2	1	3	4	6	3	9	12
	Production buses delivery delay days	Ranked	3	0	188	65.5	208	4	2	3	1	12	6	9	3
	Critical deviations from technical specifications	Qualitative	2	3	3	1	3	3	3	1	3	6	6	2	6
	Coordination with onboard system suppliers	Qualitative	3	4	2	2	3	4	2	2	3	12	6	6	9
	Experience with OEM sales and management	Qualitative	1	4	2	1	3	4	2	1	3	4	2	1	3
	Work with resident inspectors	Qualitative	3	4	1	2	2	4	1	2	2	12	3	6	6
	Manufacturing ability at scale	Qualitative	5	5	2	1	3	5	2	1	3	25	10	5	15
	QA inclusion during production	Qualitative	2	4	2	3	3	4	2	3	3	8	4	6	6
	Post-delivery support	Qualitative	5	4	3	1	2	4	3	1	2	20	15	5	10
	Workmanship	Qualitative	3	4	1	3	4	4	1	3	4	12	3	9	12
	Ease of warranty process and responsiveness	Qualitative	4	5	4	1	4	5	4	1	4	20	16	4	16
	Quality of training sessions	Qualitative	4	4	1	3	4	4	1	3	4	16	4	12	16
	Long-term viability and risk	Qualitative	3	5	3	1	1	5	3	1	1	15	9	3	3
											Procurement and Customer Experience Total (199 Points)	**153**	**78**	**74**	**114**
Acceptance	Snag resolution experience	Qualitative	3	4	1	2	4	4	1	2	4	12	3	6	12
	Average days between delivery and acceptance	Ranked	3	116	164	77	90	2	1	4	3	6	3	12	9
											Acceptance Total (27 Points)	**18**	**6**	**18**	**21**
Performance	Duty cycle/bus range (miles)	Quantitative	3	204	200	232	190	4	4	5	4	12	12	15	12
	Energy efficiency (kWh/mile)	Quantitative	3	2.59	2.39	2.63	2.55	5	5	4	5	15	15	12	15
	Availability	Quantitative	4	67%	50%	51%	60%	5	3	3	4	20	12	12	16
	Average monthly mileage per bus (miles)	Quantitative	5	1267	621	576	661	5	1	1	1	25	5	5	5
	Curb weight (lbs)	Ranked	4	35440	36473	36810	37880	4	3	2	1	16	12	8	4
	Fire detection and suppression	Qualitative	3	2	4	3	3	2	4	3	3	6	12	9	9
	Seating layout and overall configuration	Qualitative	1	5	3	2	3	5	3	2	3	5	3	2	3
											Performance Total (111 Points)	**99**	**71**	**63**	**64**
Operability	Driver interface	Qualitative	3	4	2	1	3	4	2	1	3	12	6	3	9
	Ride quality	Qualitative	3	5	3	2	4	5	3	2	4	15	9	6	12
											Operability Total (30 Points)	**27**	**15**	**9**	**21**
Maintainability and Reliability	Miles per labor hours booked by SFMTA (miles)	Quantitative	3	80	35	64	78	5	1	4	5	15	3	12	15
	Mean distance between service interruptions (miles)	Quantitative	4	619	462	512	N/A	5	3	4	N/A	20	12	16	N/A
	Ease of maintenance	Qualitative	3	4	2	1	3	4	2	1	3	12	6	3	9
	Quality of maintenance manuals	Qualitative	2	4	1	3	3	4	1	3	3	8	2	6	6
	Parts lead times	Qualitative	5	4	3	1	3	4	3	1	3	20	15	5	15
	Recalls (quantity and impact)	Qualitative	4	1	4	1	2	1	4	1	2	4	16	4	8
	Charging experience	Qualitative	3	1	3	5	2	1	3	5	2	3	9	15	6
											Maintainability and Reliability Total (120 Points)	**82**	**63**	**61**	**59**
Financial	Bus acquisition costs ($USD)	Quantitative	3	$ 1,183,884.00	$ 873,300.00	$ 1,407,624.00	$ 1,312,591.00	2	5	1	1	6	15	3	3
	Grants opportunities and contracts	Qualitative	3	4	3	4	1	4	3	4	1	12	9	12	3
											Financial Total (30 Points)	**18**	**24**	**15**	**6**
											Weighted OEM Score	**397**	**257**	**240**	**285**

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