ZEB Strategy and Rollout Plan

Gold Coast Transit District
ZEB Rollout and Implementation Plan

Final Report

October 2022

Stantec

ZEB Strategy and Rollout Plan

ZEB Rollout Plan and Implementation Strategy

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EXECUTIVE SUMMARY

Gold Coast Transit District (GCTD) is the largest public transportation operator in Ventura County, providing a variety of fixed-route and demand response services to the cities of Ojai, Oxnard, Port Hueneme, Ventura and the unincorporated areas of Ventura County.

With a service area population of 367,260[1] and a fleet of 60 active (4 contingency) standard[2] buses for fixed-route services, GCTD is classified as a small transit agency under the Innovative Clean Transit (ICT) regulation[3]. This regulation by the California Air Resources Board (CARB) mandates that all transit agencies have a goal of gradually transitioning to a zero-emission bus (ZEB) fleet by 2040. Small transit agencies are required to submit a plan to CARB by June 30, 2023 and begin ZEB purchases in 2026. While the ICT regulation is directed primarily at larger, heavy-duty transit buses[4], GCTD has chosen to transition the majority of its fixed route and demand-response service fleet to hydrogen fuel cell electric bus (FCEB) technology. This report provides a strategic transition plan for all revenue and non-revenue vehicles in GCTD's fleet.

This document also serves as the source for GCTD's rollout plan submission to CARB and provides a detailed plan of the technology, needs, and strategies that will help GCTD transition to a ZEB fleet. The previous phases of this project (summarized in this report) laid the foundation for this plan by assessing GCTD's existing conditions and modeling the power and fuel requirements needed to meet GCTD's service through a ZEB fleet. With this information, the initial ZEB fleet was refined through a collaborative optimization process that led to the preferred fleet composition of an entirely FCEB fixed-route fleet, and 90% FCE demand-response van fleet. Because there are no FCE cutaways currently available, portions of the cutaway fleet can be substituted with FCE vans.

With the preferred fleet composition established, the next steps included determining the facility upgrades and modifications—primarily the construction of a hydrogen fueling station and gas leak detection systems—required to support ZEB operations at GCTD's maintenance facility. In addition, a financial ZEB model was developed for comparative purposes against a base case (or business as usual with fossil fuel buses) and developing a phasing or implementation plan. Overall, implementing the ZEB fleet will cost $135M (cumulative capital and operating costs) compared to $105M for business-as-usual (fossil fuel technology) within a 17-year timeframe (through 2040). Stated otherwise, the transition to ZEBs adds incremental capital and operating costs of $30M to GCTD over the 17-year period. The infrastructure requirements are also captured in this plan to accommodate the phased acquisition of FCEBs while still operating and eventually phasing out fossil fuel vehicles.

Based on GCTD's existing fleet replacement schedule and the required ZEB purchase schedule outlined by CARB, this plan recommends that the ZEB procurement begins in 2023 and gradually continues

[1] NTD 2020 service profile
[2] The active fleet consists of 60 buses (40-ft and 35-ft) for revenue service and 4 buses for contingency purposes.
[3] In this document, standard refers to 35-ft and 40-ft buses.
[4] Specifically, the ICT regulation mandates the transition of vehicles with a gross vehicle weight rating (GVWR) of greater than 14,000 lbs.

through 2040 as fossil fuel vehicles reach the end of their useful lives and are retired. This phased approach allows for GCTD to implement a small number of FCEBs and learn from the process and slowly scaling up to reach a ZE revenue vehicle fleet by 2040 and adhering to ICT guidelines and goals. The full phasing and implementation plan is outlined in Table 1. With a full transition to FCEB, GCTD can reduce its fleet-related greenhouse gas emissions by approximately 49% (~5,414 tons annually) due to the residual carbon footprint of hydrogen fuel production and transportation.

Throughout this document, information is provided that corresponds to the required sections of the ICT ZEB Rollout Plan. Taken together, this plan provides a prudent and feasible approach for GCTD to implement ZEBs that meets the agency's vision of providing safe, responsive, convenient, efficient, and environmentally responsible public transportation to the community.

Table 1: ZEB implementation phasing plan, FY2023-2040

Year	Construction – maintenance facility	Fixed-Route ZEB Fleet Procurements	Demand Response ZE Fleet Procurements	Training: operators, maintenance staff, technicians	Training - other	Capital expenses (2022$)	O&M expenses (2022$)	Total expenses (2022$)
FY2023	Construct and install hydrogen fueling equipment for high and low pressure refueling (H35 and H70). Installation of hydrogen gas detection system in maintenance bays and upgrade of ventilation system.	0 35-ft 5 40-ft	6 vans & cutaways	Tier 1 & tier 3 OEM training	Tier 1 OEM training for all other staff	$16,646,000	$5,196,000	$21,842,000
FY2024		0 35-ft 0 40-ft	7 vans & cutaways	Annual refreshers	No activity	$3,448,000	$4,808,000	$8,256,000
FY2025		0 35-ft 0 40-ft	2 vans & cutaways	Annual refreshers	Local fire and emergency response department introduction to new technology	$1,899,000	$4,559,000	$6,458,000
FY2026		0 35-ft 2 40-ft	8 vans & cutaways	Annual refreshers	No activity	$4,821,000	$4,236,000	$9,057,000
FY2027		2 35-ft 0 40-ft	0 vans & cutaways	Annual refreshers	Local fire and emergency response department introduction to new technology	$3,989,000	$3,979,000	$7,968,000
FY2028		0 35-ft 2 40-ft	5 vans & cutaways	Annual refreshers	No activity	$4,824,000	$3,707,000	$8,531,000
FY2029		0 35-ft 5 40-ft	0 vans & cutaways	Annual refreshers	Local fire and emergency response department introduction to new technology	$3,401,000	$3,513,000	$6,914,000
FY2030		0 35-ft 2 40-ft	10 vans & cutaways	Tier 1 & tier 3 OEM training for new staff	Tier 1 OEM training for all other staff	$2,503,000	$3,443,000	$5,946,000
FY2031		0 35-ft 5 40-ft	7 vans & cutaways	Annual refreshers	No activity	$3,805,000	$3,297,000	$7,102,000

Year	Construction – maintenance facility	Fixed-Route ZEB Fleet Procurements	Demand Response ZE Fleet Procurements	Training: operators, maintenance staff, technicians	Training - other	Capital expenses (2022$)	O&M expenses (2022$)	Total expenses (2022$)
FY2032		0 35 -ft 4 40-ft	2 vans & cutaways	Tier 1 & tier 3 OEM training for new staff	Tier 1 OEM training for all other staff	$2,517,000	$3,259,000	$5,776,000
FY2033		0 35-ft 4 40-ft	8 vans & cutaways	Tier 1 & tier 3 OEM training for new staff	Tier 1 OEM training for all other staff	$3,008,000	$3,111,000	$6,119,000
FY2034		0 35-ft 7 40-ft	0 vans & cutaways	Annual refreshers	Local fire and emergency response department training on new technology	$3,628,000	$2,948,000	$6,576,000
FY2035		0 35-ft 6 40-ft	5 vans & cutaways	Annual refreshers	No activity	$3,461,000	$2,787,000	$6,248,000
FY2036		0 35-ft 6 40-ft	0 vans & cutaways	Annual refreshers	Local fire and emergency response department training on new technology	$2,794,000	$2,626,000	$5,420,000
FY2037		0 35-ft 6 40-ft	10 vans & cutaways	Annual refreshers	No activity	$3,568,000	$2,468,000	$6,036,000
FY2038		0 35-ft 6 40-ft	7 vans & cutaways	Tier 1 & tier 3 OEM training for new staff	Tier 1 OEM training for all other staff	$3,133,000	$2,384,000	$5,517,000
FY2039		8 35-ft 0 40-ft	2 vans & cutaways	Annual refreshers	No activity	$3,123,000	$2,252,000	$5,375,000
FY2040		0 35-ft 8 40-ft	8 vans & cutaways	Annual refreshers	Local fire and emergency response department training on new technology	$3,694,000	$2,128,000	$5,822,000

Abbreviations

AHJ	Authorities Having Jurisdiction
AHSC	Affordable Housing and Sustainable Communities Program
APCD	Ventura County Air Pollution Control District
APTA	American Public Transportation Association
BEB	Battery electric bus
BESS	Battery electric storage system
BEV	Business Electric Vehicle
BUILD	Better Utilizing Investments to Leverage Development
CAF	Clean Air Fund
CARB	California Air Resources Board
CCS	Carbon Capture and Storage
CMAQ	Congestion Mitigation and Air Quality Improvement Program
CTTC	California Transit Training Consortium
DGE	Diesel Gallon Equivalent
FCEB	Hydrogen fuel cell electric bus
FHWA	Federal Highway Administration
FTA	Federal Transportation Administration
GHG	Greenhouse gas
HVIP	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Program
ICT	Innovative Clean Transit
LCFS	Low Carbon Fuel Standard
LCTOP	Low Carbon Transit Operations Program
LPP	Local Partnership Program
MPO	Metropolitan Planning Organization
NFPA	National Fire Protection Association

NPV	Net Present Value
NREL	National Renewable Energy Laboratory
NTI	National Transit Institute
OEHHA	Office of Environmental Health Hazard Assessment
PPE	Personal Protective Equipment
PV	Photovoltaic
RAISE	Local and Regional Project Assistance Program
SAC	Stakeholder Advisory Committee
SCAG	Southern California Association of Governments
SCCAB	South Central Coast Air Basin
SCCP	Solutions for Congested Corridors Program
SCE	Southern California Edison
SMR	Steam Methane Reformation
SOC	State of Charge
STEP	Sustainable Transportation Equity Project
STIP	State Transportation Improvement Program
TDA	Transportation Development Act
TIRCP	Transit and Intercity Rail Capital Program
USDOT	United States Department of Transportation
VCTC	Ventura County Transportation Commission
VCREA	Ventura County Regional Energy Alliance
ZE	Zero emission
ZEB	Zero-emission bus

1.0 INTRODUCTION AND BACKGROUND

Gold Coast Transit District (GCTD) provides public fixed-route and paratransit services to western Ventura County, including to the communities of Ojai, Oxnard, Port Hueneme, and Ventura. GCTD is the largest public transportation provider in Ventura County, providing over 3.6 million unlinked passenger trips in 2019[5]. GCTD operates under the mission statement "to provide safe, responsive, convenient, efficient, and environmentally responsible public transportation that serves the diverse needs of our community."

GCTD currently operates a fleet of 64 fixed route and 26 paratransit CNG-powered vehicles fueled by an onsite fueling station in Oxnard. GCTD is part of the Ventura County Air Pollution Control District (APCD), South Central Coast Air Basin (SCCAB), and Southern California Edison (SCE) electric utility territory.

With a service area population of 367,260 and a fleet of 64 fixed route vehicles (60 for revenue service and 4 contingency buses), GCTD is classified as a small transit agency under the Innovative Clean Transit (ICT) mandate and is required to submit a zero-emission bus (ZEB) rollout plan to the California Air Resources Board (CARB) by July 1, 2023[6].

This document serves as the source for GCTD's rollout plan submission to CARB and provides a detailed plan of the technology, needs, and strategies that will help GCTD transition to a ZEB fleet. To develop this rollout plan, several steps have been taken to determine the best ZEB strategy for GCTD. These steps included:

A review of existing conditions to understand characteristics and constraints for GCTD's operations and service area. This included a primer on different ZEB technologies to provide a scan of the market and technologies, including battery-electric buses (BEBs) and hydrogen fuel cell electric buses (FCEBs).

Energy and power modeling to understand performance under different ZE technology options, their viability, and suitability for GCTD's needs. A quantitative and qualitative assessment of modeling results to determine the preferred ZE fleet composition for GCTD.

This report is intended to act as a roadmap to guide GCTD through the ZEB transition to 100% ZEB deployment and implementation by 2040, as well as to fulfill the CARB guidelines as outlined in the ICT mandate. As CARB has reminded transit agencies, the ICT-regulated rollout plan is intended to be a living document that can and should be regularly revisited and updated over time as ZE technologies continue to evolve.

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[5] 2019 NTD agency profile

[6] CARB ICT defined large transit agencies as operating in "an urbanized area with a population of at least 200,000 as last published by the Bureau of Census before December 31, 2017 *and* has at least 100 buses in annual maximum service." Agencies that do not meet this definition are categorized as small transit agencies.

2.0 APPROACH TO ZEB PLANNING

The graphic in Figure 1 provides a high-level schematic of the major steps in this project to derive a recommended fleet mix and implementation plan.

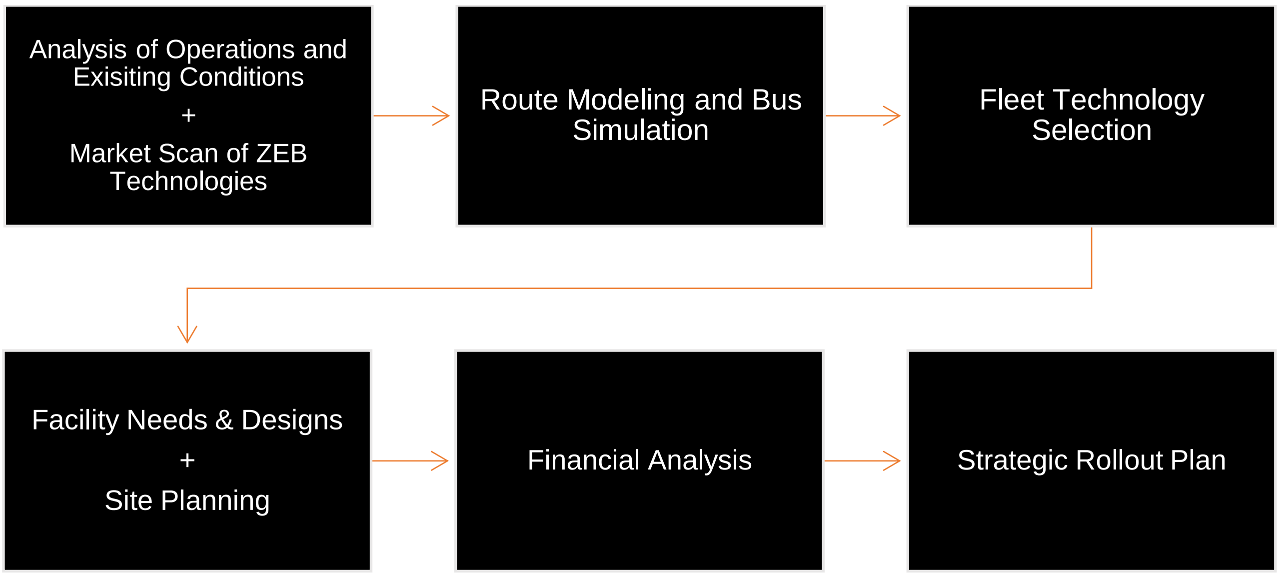


Figure 1: Schematic representation of the steps in the ZEB planning process

The first step involved a review of existing conditions of GCTD to provide a foundation and understanding of GCTD's operations, service, and business processes that would be impacted by a transition to a ZEB fleet. A summary of these findings is provided in Section 3.0. A site visit of the operating base and maintenance facility in Oxnard provided insights into the constraints and opportunities for implementing ZEBs, as well as the condition of the facilities, buildings, and existing service cycle. A market scan was also conducted to analyze the current ZEB technologies, their limitations, and in-development technologies that can help shape GCTD's future ZEB fleet.

Next, we modeled block-level and vehicle-level fuel economies to understand the predicted performance of different ZEB technologies under GCTD's operating parameters for both fixed-route and demand response services. Together with a multicriteria trade-off analysis and in consultation with GCTD staff, Stantec and GCTD determined that the best path forward to a ZE future is with a hydrogen fleet (Section 4.0). The fleet procurement schedule and outlook were designed to account for the ICT Regulation's requirement of annual apportionment of ZEB purchases (Section 5.0).

Stantec designed conceptual site plans (and opinion of probable costs) for the maintenance facility that demonstrates the layout of the yard, the service cycle, buses, hydrogen fueling infrastructure, and other ZEB-related equipment (Sections 6.0 and Section 7.0).

With the site plans and identification of required facility modifications and impacts on capital and operating costs, Stantec developed a financial analysis for the ZEB rollout through 2040 (Section 8.0). Operating and planning considerations (Section 9.0), workforce training (Section 10.0), and potential funding sources (Section 11.0) are also reviewed and discussed.

All steps described here provide GCTD with a ZEB rollout plan and strategy. Throughout this document, reference is made to specific sections that are found in the ICT mandated ZEB Rollout Plan document.

3.0 SUMMARY OF KEY EXISTING CONDITIONS

The Existing Conditions report provided a comprehensive review of GCTD's existing conditions, encompassing operations, facilities, and finances to lay the groundwork for the modeling and understand current (pre-COVID-19) operating conditions[7].

Major findings from the existing conditions report that will affect the ZEB transition include:

- GCTD operates in a relatively compact and flat service area (with the exception of the Ojai area)
- GCTD's current fleet is made up of standard buses (40-ft and 35-ft) for fixed-route services and a combination of cutaways and passenger vans for demand response services (Table 2). Cutaways and vans have fewer ZE alternatives when compared to options available for standard buses. Fixed-route buses are all CNG-powered with an average fleet age of 9.9 years. Cutaways are also CNG-powered and average 4 years old, with passenger vans an average of 4.3 years, fueled by either CNG or unleaded gasoline. All CNG vehicles are fueled onsite at GCTD's operating base and maintenance facility, and unleaded gasoline vans are fueled offsite by the contractor.

Table 2: Current revenue fleet composition

In-Service Year	Quantity	Make	Seating capacity	Fuel type	GCTD retirement year	FTA minimum useful life[8]	Current age[9]	Service type	Summary
2019	5	Nor Cal Van	4/4+2wc	Gas	2027	4 years	2	Demand Response	19 vans for demand response services
2015	6	VPG MV-1	3/3+1wc	CNG	2023	4 years	7	Demand Response	
2016	7	VPG MV-1	3/3+1wc	CNG	2024	4 years	7	Demand Response	
2022	1	Nor Cal Van	4/4+2wc	Battery Electric	2030	4 years	1	Demand Response	
2017	8	Starcraft	14/4+3wc	CNG	2025	4 years	4	Demand Response	8 cutaways for demand response services
2007	13	New Flyer	39	CNG	2021-2024	12-17 years	15	Fixed-Route	60 full-size buses for fixed-route revenue service
2009	9	NABI	30	CNG	2022	12 years	13	Fixed-Route	
2010	8	NABI	30	CNG	2023	12 years	12	Fixed-Route	
2015	8	Gillig	38	CNG	2027	12 years	6	Fixed-Route	
2016	5	Gillig	38	CNG	2028	12 years	5	Fixed-Route	

7 Throughout this report, "current" refers to pre-COVID (2019) conditions unless otherwise stated.
8 https://olga.drpt.virginia.gov/Documents/forms/DRPT%20Asset%20Useful%20Life%20Chart.pdf
9 Current age determined from model year not in-service year

In-Service Year	Quantity	Make	Seating capacity	Fuel type	GCTD retirement year	FTA minimum useful life[8]	Current age[9]	Service type	Summary
2019	5	Gillig	38	CNG	2031	12 years	2	Fixed-Route	
2021	3	Gillig	38	CNG	2033	12 years	1	Fixed-Route	
2022	9	Gillig	38	CNG	2034	12 years	0	Fixed-Route	

- For fixed-route services, a typical service day sees more vehicles in service during the midday period, but hourly vehicle requirements are fairly consistent throughout the day[10]. Hourly vehicle requirements peak at 3-4 pm with 47 vehicles required for service (Figure 2).

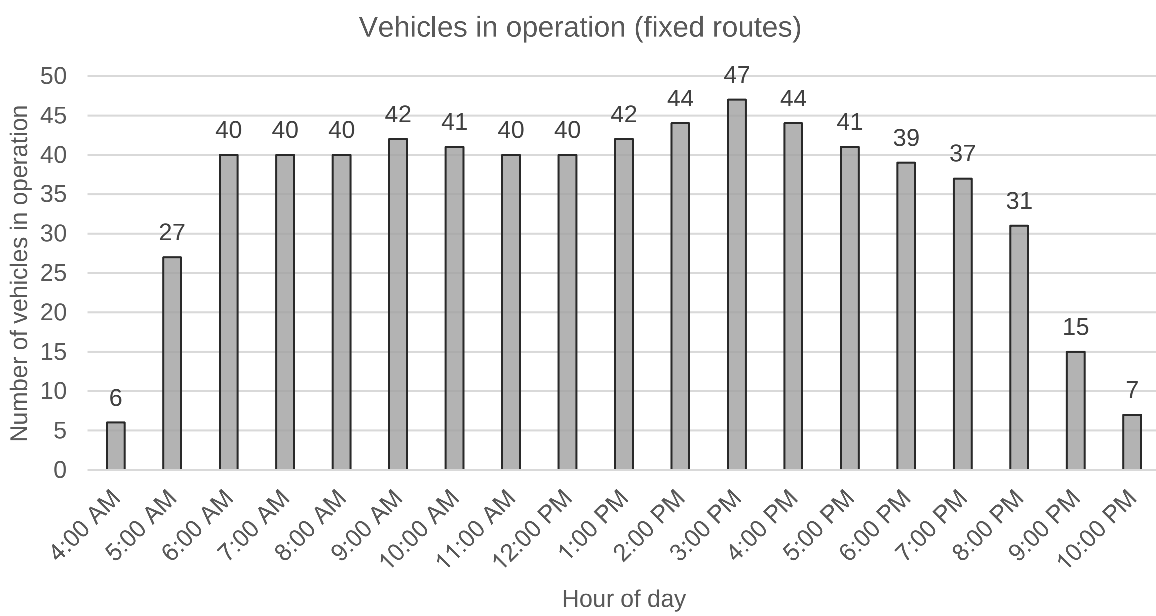


Figure 2: Hourly vehicles in operation (fixed route)

- The ability to analyze GCTD's scheduling and operating practices is crucial for understanding the agency's blocking practices, how long blocks are, and how blocks are assigned to vehicles. This translates to how long vehicles are out in revenue operation and, from a modeling perspective, helps us understand if current blocks can be completed with ZE equivalents. Figure 3 shows that more than half of all blocks have mileages over 100 miles, and the maximum block length is 241 miles.

[10] A representative daily service schedule for a pre-COVID-19 Monday was chosen.

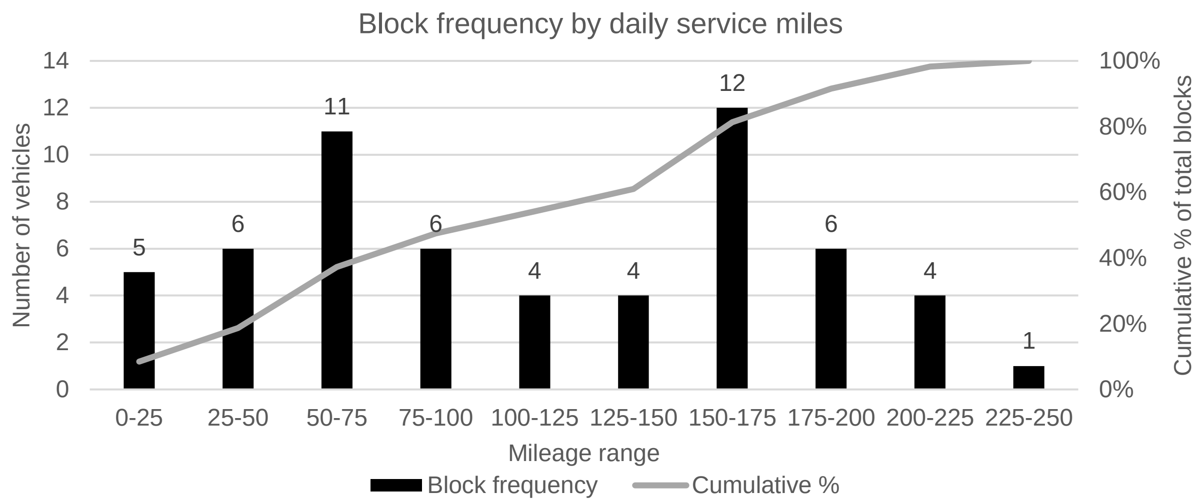


Figure 3: Block frequency by daily service miles

- Seven vehicles (or 13% of vehicles in operation) complete two blocks on an average day. To understand how the daily distance that vehicles are traveling changes, we combine blocks at the vehicle level (Figure 4). This shows that 50% of vehicles travel less than 150 miles in a day, which is a positive sign considering the range limitations of ZEBs.

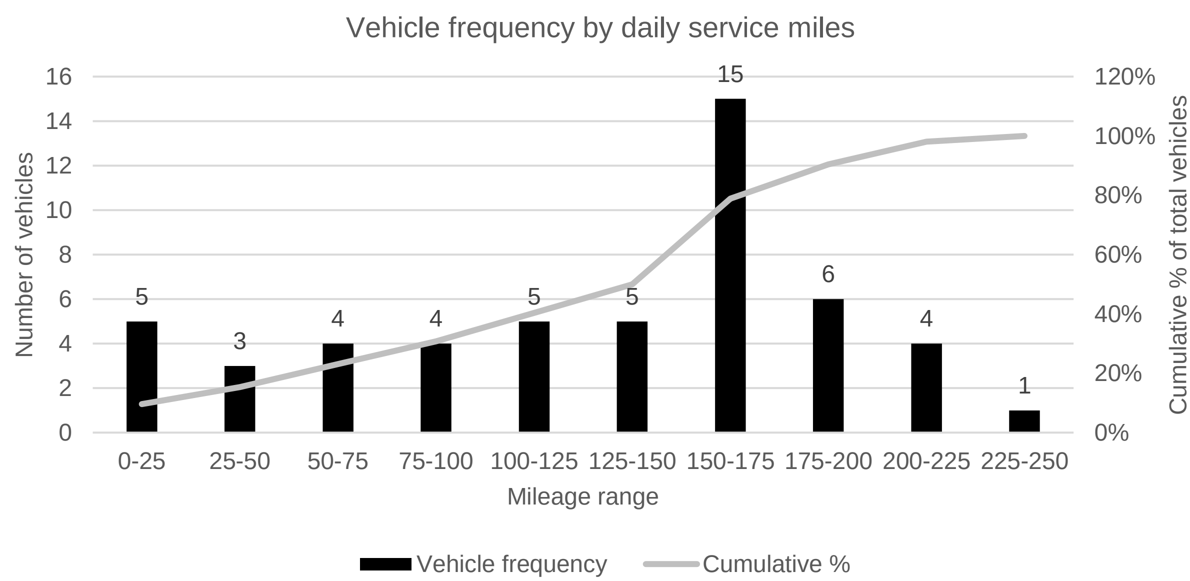
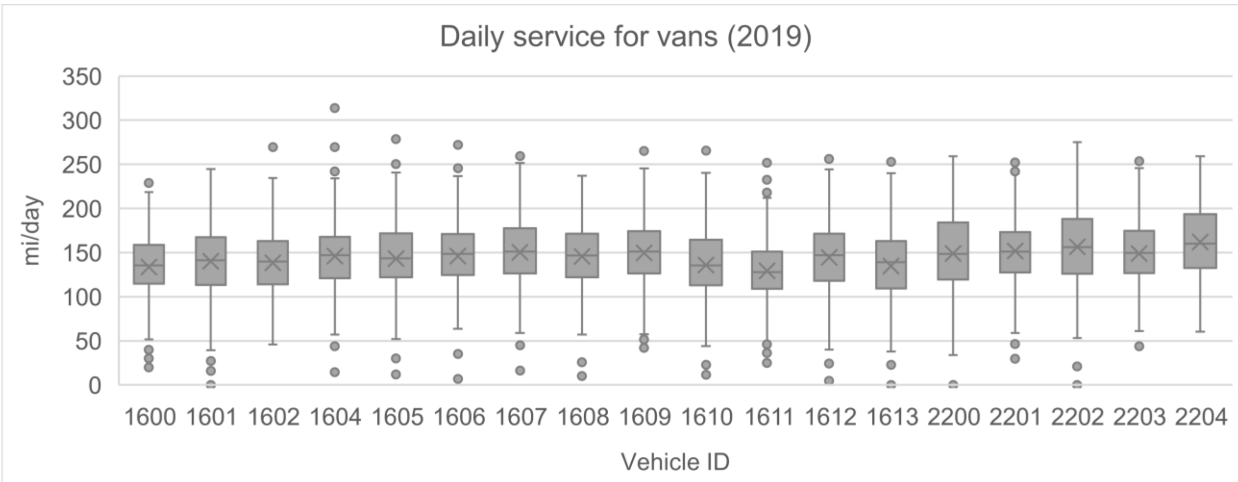


Figure 4: Vehicle frequency by daily service miles

- To understand the variability in daily service for demand response vehicles, an entire year (2019) of data was analyzed. Figure 5 shows that on average, vans (top) travel slightly longer distances than cutaways (bottom), with an average daily service of 144 miles for vans compared to 130 miles for cutaways. However, both vehicles displayed examples where they traveled long distances in a day that exceed ranges of current ZE options for these vehicle types, with vans traveling a maximum of 300 miles in one day and cutaways a maximum of 250 miles.



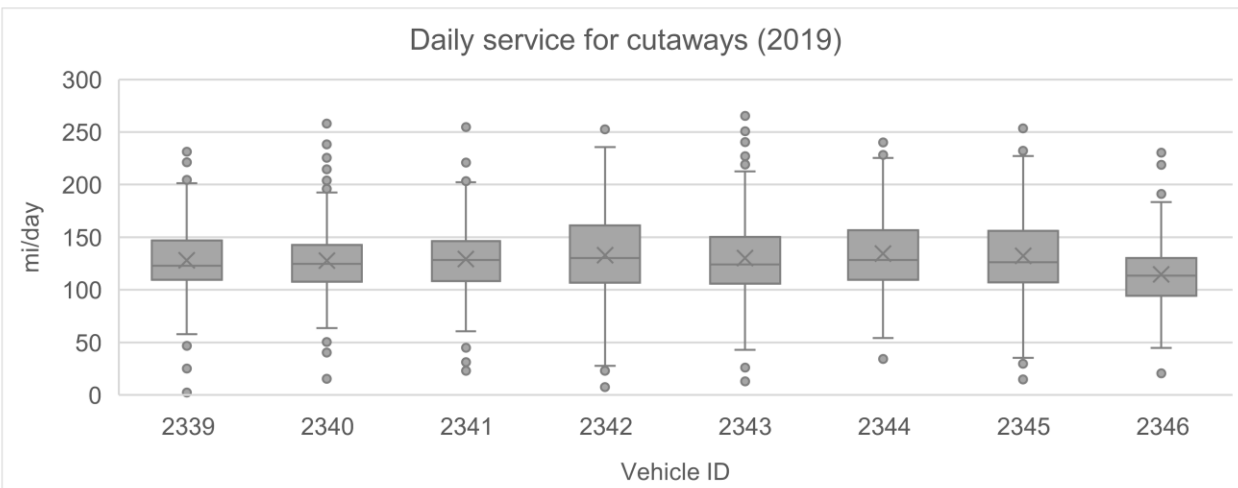


Figure 5: Daily service for demand response vehicles (2019)

- In the modeling, we also took into consideration the service design structure of demand response services, where vehicles can be assigned to a polygon within GCTD's service area, keeping them within a certain geographic area to improve efficiency (Figure 6). Polygon assignment criteria includes vehicle capacity and the number of ambulatory vs. wheelchair spaces available. Some vehicles are left unassigned to polygons to handle trips that cross multiple areas.

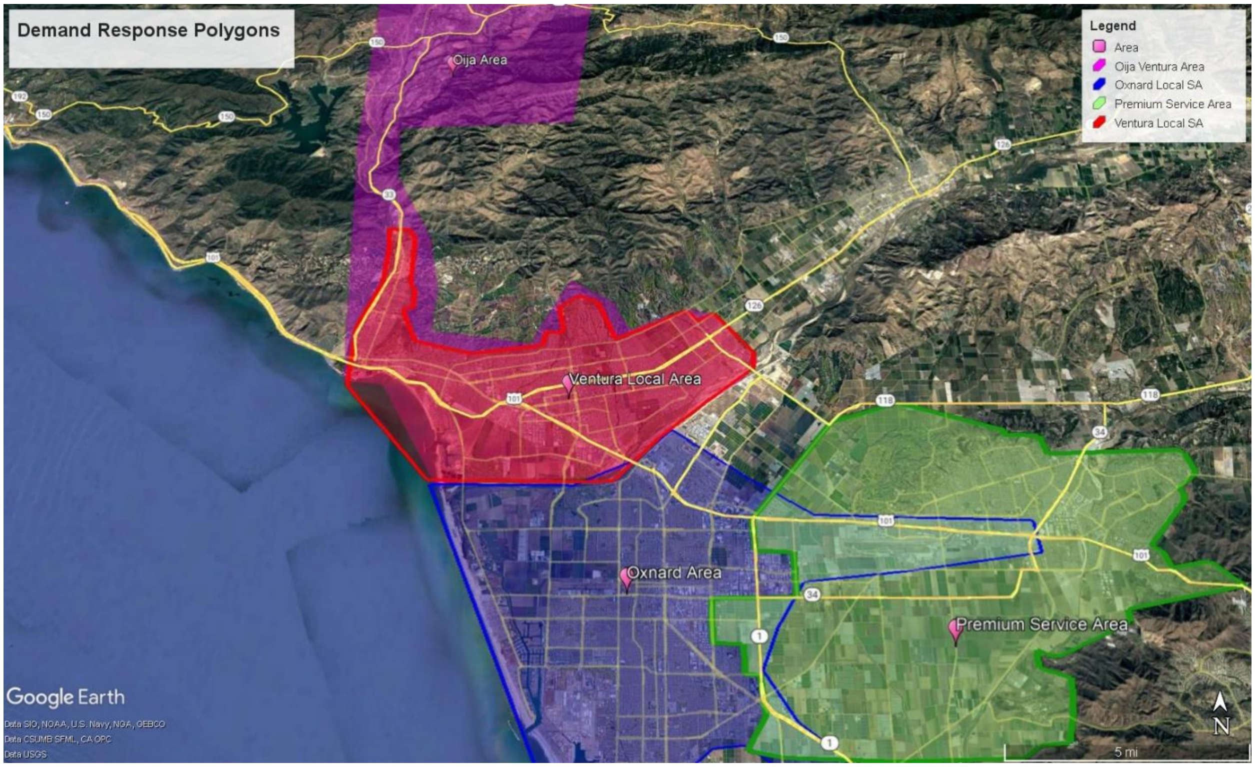


Figure 6: Demand response polygons

- GCTD's operating base and maintenance facility is large, new, and well-maintained with onsite CNG fueling and space for growth in fleet and infrastructure. Transition to either BEBs or FCEBs will be accommodated in the space of the facility, however either technology option will require facility modifications:
    - BEBs will require electrical upgrades and chargers, etc.
    - FCEBs will require new hydrogen storage/fueling infrastructure, gas leak detection, and potentially electrical upgrades.

Overall, GCTD's facility, operations, and service area seem well-suited to a fairly straightforward ZE transition, with factors like a relatively flat and compact service area and new facility without space constraints. Some challenges that may arise are related to how vehicles are scheduled, with many fixed-route vehicles out in operations 12+ hours a day (which could exceed range limitations of ZEBs or limit the ability for midday/opportunity charging), and a demand response fleet made up of vehicles with fewer ZE options that travel long daily distances, and the demand response model is inherently difficult to plan for because daily service miles are dictated by demand and not adherent to a fixed schedule.

4.0 PREFERRED/RECOMMENDED FLEET COMPOSITION

This section provides an overview of the power and energy modeling methodology and presents the results of the modeling to understand the feasibility of transitioning GCTD's operations to different ZE alternatives. Based on the modeling outcomes, we present a discussion of the different ZE fleet solutions and the pros and cons of different fleet compositions which were used to determine the preferred ZEB fleet composition for GCTD's fixed-route and demand response fleets.

4.1 FLEET AND POWER MODELING OVERVIEW

ZEBDecide, Stantec's fleet modeling tool, was used to determine the feasible ZEB composition for GCTD's fleet. The predictive ZEB performance modeling (schematic overview shown in Figure 7) depends on several inputs, such as passenger loads, driving cycles (or duty cycles), topography, vehicle specifications, and ambient conditions subject to the environment in which the agency operates.

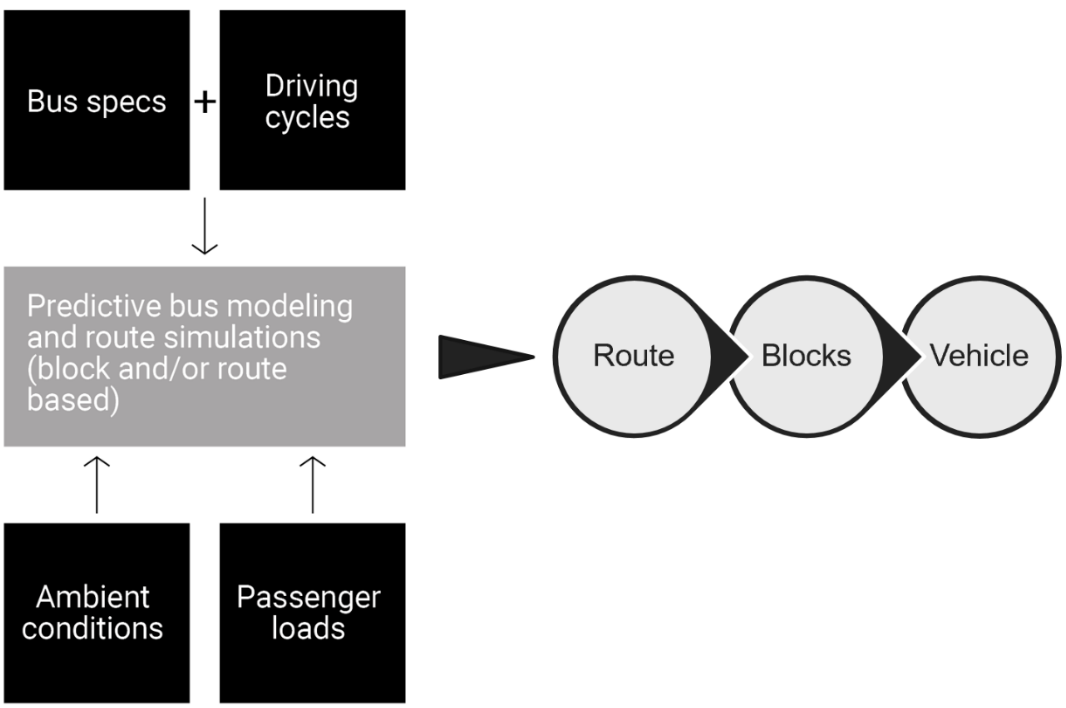


Figure 7: ZEBDecide modeling overview

4.1.1 Modeling Inputs

ZEBDecide's modeling process predicts ZEB drivetrain power requirements specific to given acceleration profiles. The following inputs are included in the model to determine feasibility of different ZEB technologies under GCTD's operating conditions:

Bus/vehicle specifications: the bus specification inputs used in the modeling are shown in Figure 8. For GCTD, the key bus specifications used in the modeling process for each service type are shown in Table 3. Both BEBs and FCEBs were modeled for fixed-route services. As GCTD operates 35-ft and 40-ft models, we specified the appropriate vehicle size (for each route and block) to reflect GCTD scheduling practices.

For demand response services, which are operated with both cutaways and vans, we modeled BEB options for both vehicle types. FCEB options are more limited, and a hydrogen cutaway was not modeled due to a lack of available options currently on the market and being operated by transit agencies at the time of this writing.

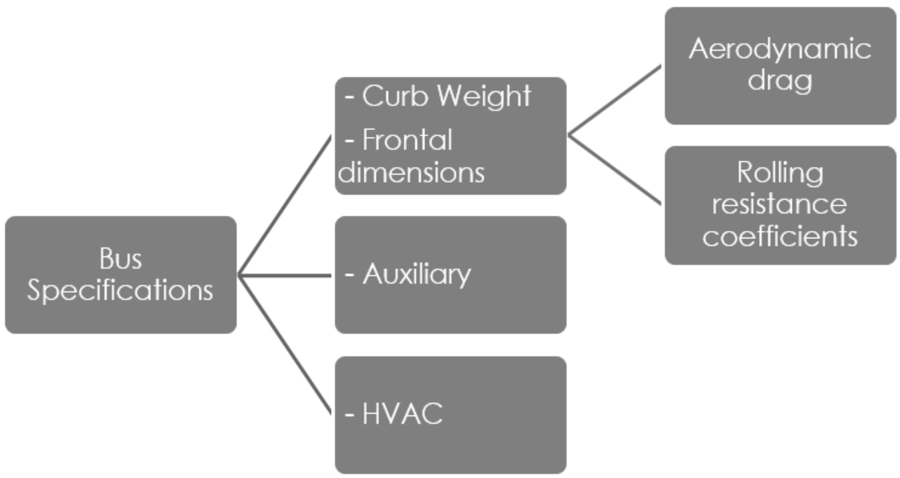


Figure 8: Schematic of the inputs for bus specifications.

Table 3: Vehicle specifications for energy modeling

GCTD service type	Technology type	Vehicle size	Battery (kWh) or tank (kg)	Curb Weight (lbs.)
Fixed route	BEB	35-ft	450 kWh	29,700
		40-ft	525 kWh[11]	45,000
	FCEB	35-ft	35 kg	29,700
		40-ft	37.5 kg	45,000
Demand response	BEB	Cutaway	120 kWh	16,200
		Van (25-ft)	118 kWh	14,330
	FCEB	Van (25-ft)	13 kg	10,360

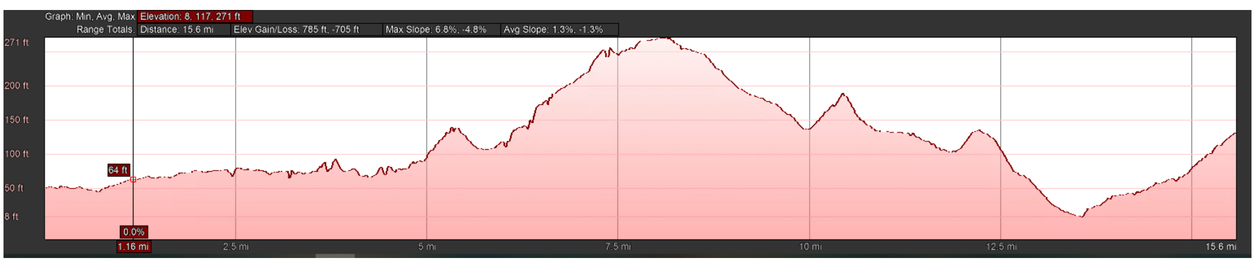
[11] If a block modeled with a 40-ft BEB failed with a 525-kWh battery, blocks were subsequently modeled with a 40-ft BEB with a 660-kWh battery.

Representative driving cycles: also called acceleration profiles or duty cycles, representative driving cycles are speed versus time profiles that are used to simulate vehicle performance and energy use. Cycles were assigned to all routes based on GCTD's operations and observed driving condition and are derived from the National Renewable Energy Laboratory's (NREL) drive cycle database called DriveCAT[12]. The complete assignment of driving cycles to all routes is presented as an appendix in the energy modeling report. For demand response services, the model used the average driving speeds for each individual run instead of assigning representative driving cycles.

Passenger loads: to examine the weight associated impacts of passenger loads experienced by GCTD's fleet, GCTD provided data for each route detailing the passenger load for each route to be modeled. For demand response services, an average of four passengers onboard was assumed for modeling purposes.

Ambient temperature: Stantec developed a correlation between ambient temperature and power requirements from the HVAC system. The power requirement for modeling purposes was set based on an annual low temperature average of 46°F[13].

Topography and elevation: given that portions of GCTD's service area are highly impacted by elevation and topography, it is important to account for the impacts of terrain and elevation on the energy efficiency of ZEBs. Each route alignment was imported into Google Earth to create an elevation profile to understand the total elevation gains/losses seen for each route in the system (see example in Figure 9).



Source: Google Earth

Figure 9: Elevation profile example (Route 6)

The average and maximum grades for each route were similarly determined using these elevation profiles, which were used as the inputs in the topography analysis (Table 4). Modeling for demand response did not directly account for topography. Instead, the model used information about gain and loss in grade from local fixed route to correct fuel economy.

[12] NREL DriveCAT - Chassis Dynamometer Drive Cycles. (2019). National Renewable Energy Laboratory. www.nrel.gov/transportation/drive-cycle-tool
[13] US Climate Data https://www.usclimatedata.com/climate/oxnard/california/united-states/usca0819

Table 4: Elevation analysis for fixed routes[14]

Route	Average slope	Max slope	Weighted average slope
1A/B	0.6%	3.5%	1.1%
3	0.8%	3.5%	0.9%
4A	1.2%	5.4%	2.0%
4B	0.8%	3.9%	1.7%
5	0.9%	4.3%	1.9%
6	1.3%	6.8%	2.6%
8	0.8%	7.5%	2.6%
11	1.4%	11.5%	4.0%
16	1.7%	7.4%	4.4%
17	1.2%	11.1%	1.8%
18A	0.8%	3.4%	1.2%
18C	0.7%	3.6%	0.8%
18E	1.1%	11.7%	1.8%
18F	1.7%	7.5%	2.5%
18G	1.3%	11.9%	2.1%
19	0.5%	2.6%	0.6%
21	1.2%	9.0%	2.7%

4.1.2 Modeling Process

Using the inputs above, predictive power and energy modeling was completed for fixed-route and demand response services. The energy modeling process for fixed-routes first aggregates results at the route level, then at the block level, and is then aggregated at the vehicle assignment level to determine total daily energy consumption per vehicle. This process is described in Figure 10 for fixed routes and Figure 11 for demand response service.

[14] Elevation analysis was not completed for routes missing in GTFS data and was approximated based on data from similar routes.

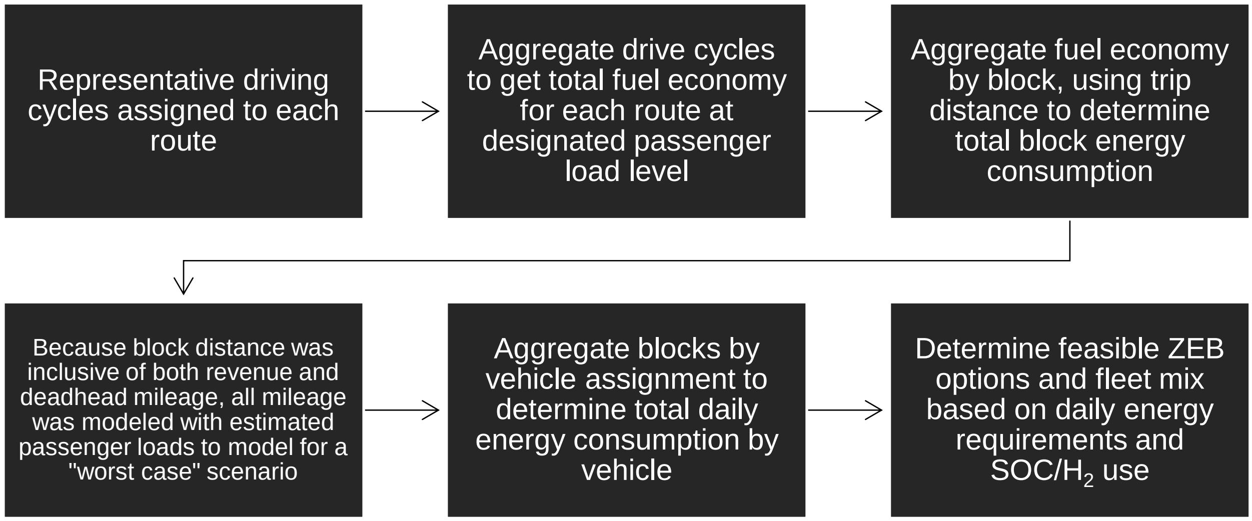


Figure 10: ZEBDecide energy modeling process, fixed routes

The results of the modeling provide insight into:

- Fuel economy and energy requirements
- Operating range

The feasibility of a BEB to complete its assigned service by estimating the state of charge (SOC); the vehicle assignment can be successfully completed with a BEB if it can complete its scheduled service with at least 20% battery SOC remaining.

As mentioned above, modeling for demand response services included all individual runs and vehicle assignments for 2019 and 2020 (1,230 minivan and 900 cutaway vehicle assignments accounting for over 4,800 runs). The energy requirement for each individual trip was aggregated at the vehicle level to calculate the total energy consumed by each vehicle per weekday. A statistical analysis was conducted on the entire dataset to determine the average fuel efficiency and daily energy use per vehicle to evaluate success levels. This process is shown in Figure 11.

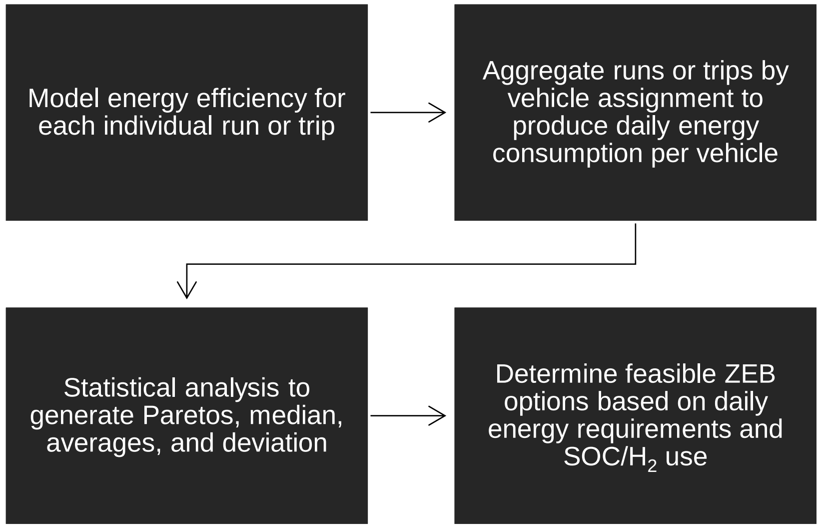


Figure 11: ZEBDecide energy modeling process, demand response

Similar to the fixed-route modeling, the results of the modeling for demand response service provide insights into:

- Average fuel economy
- Probability of energy requirements
- Probability of operating range

The feasibility of different ZEB technologies. For BE cutaways and vans, success is determined through SOC; the vehicle assignment can be successfully completed when BE vehicle can complete its scheduled service with at least 20% battery SOC. For hydrogen vans, if a vehicle consumes less than 95% of its tank capacity, the vehicle assignment is counted as successful.

4.1.3 Modeling Results

BEB Block-level and vehicle-level modeling results for fixed-route services are shown in Figure 12.

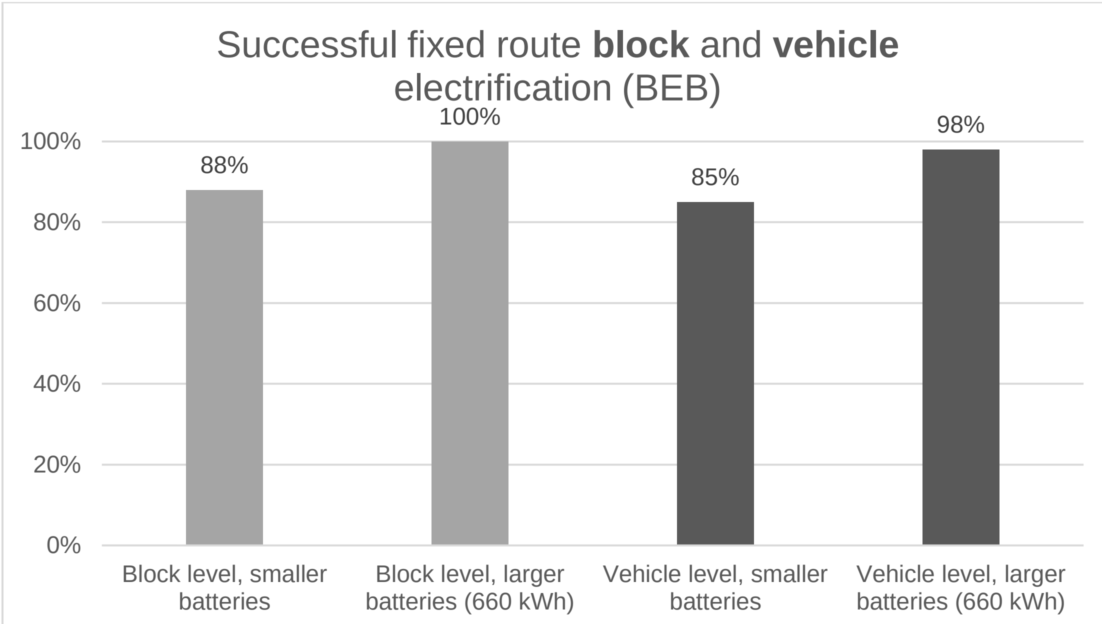


Figure 12: Successful block and vehicle electrification (fixed routes)

The criterion to deem if a block can be successfully served by a BEB is if the SOC of the battery is above 20% after completing all the trips in a block. A block is deemed unsuccessful if the battery SOC drops below 20% after completing the block. These results show that without increasing to a larger battery size, 88% of blocks can be successfully electrified. When unsuccessful blocks were increased to a larger battery size, 100% of blocks can be successfully electrified.

Next, blocks were aggregated at the vehicle-level. These results show that with smaller battery sizes, 85% of daily vehicle assignments can be successfully electrified. When 40-ft vehicles that failed were modeled with a larger battery size, 98% of vehicles can be successfully electrified. This is not 100% because one vehicle assignment that failed is a 35-ft vehicle which does not have an option for a larger battery size.

Table 5 summarizes the average fuel efficiency for each vehicle type.

Table 5: Average fuel efficiency for fixed route BEB modeling results

Vehicle type	Average fuel efficiency (kWh/mi)
40-ft bus (both 525 and 660 kWh, as appropriate)	2.23 kWh/mi
35-ft bus (450 kWh)	2.15 kWh/mi
Overall	2.21 kWh/mi

Next, fixed route service was modeled with FCEBs. These results are shown in Figure 13.

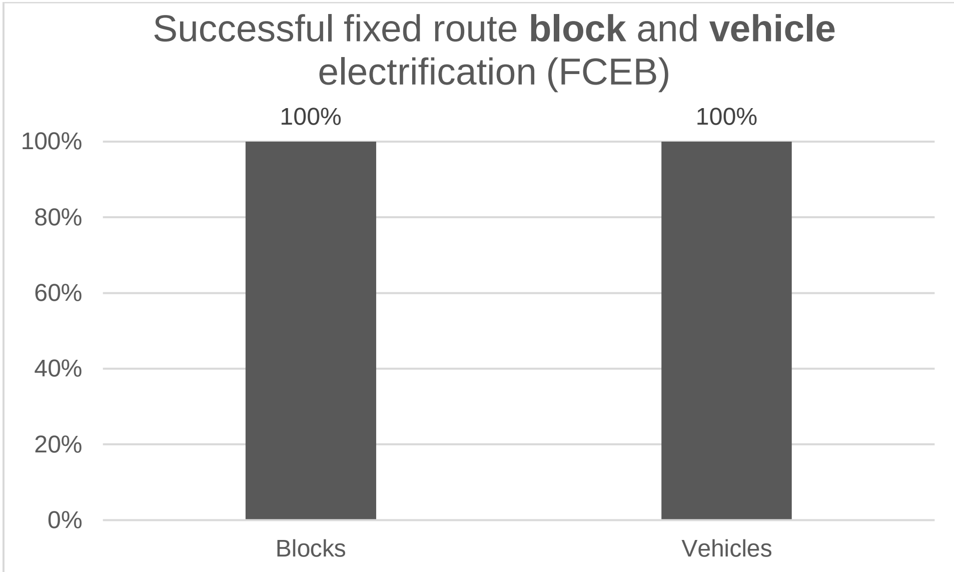


Figure 13: Successful blocks and vehicles that can be served by FCEB equivalents (fixed route)

Figure 13 shows that 100% of GCTD's fixed route service can be successfully completed with FCEBs. Table 6 provides the average fuel efficiency for each vehicle type modeled.

Table 6: Average fuel efficiency for fixed route FCEB modeling results

Vehicle type	Average fuel efficiency (mi/kg)
40-ft bus	7.20 mi/kg
35-ft bus	7.29 mi/kg
Overall	7.22 mi/kg

The same procedure was completed for demand response services. Modeling was based on a sample size of 3,200 total runs, aggregated into 2,060 van assignments and 1,100 cutaway assignments. BE and hydrogen results are first presented for vans in Figure 14 and Figure 15, and BE cutaway results are shown in Figure 16.

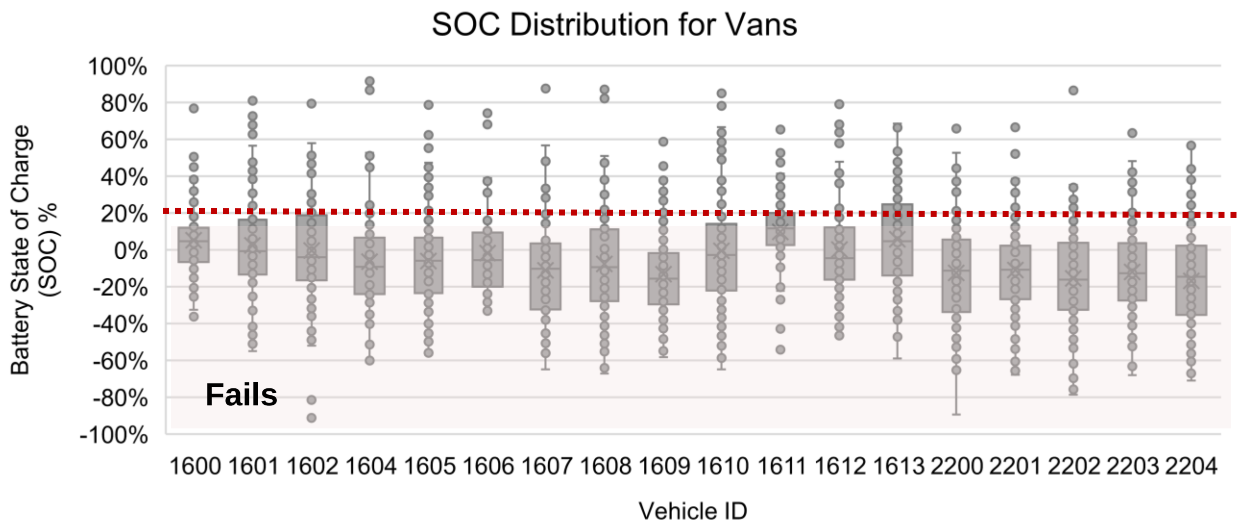


Figure 14: SOC distribution for BE van assignments

Figure 14 shows that when considering a full day of service for each van, 25% of daily vehicle assignments can be completed with BE vans. A sensitivity analysis suggests that with ideal weather and topography, about 60% of vehicle assignments may be successful. The daily mileage for electric vans can range between 135 and 170 mileages with an average fuel efficiency of 0.87 kWh/mi.

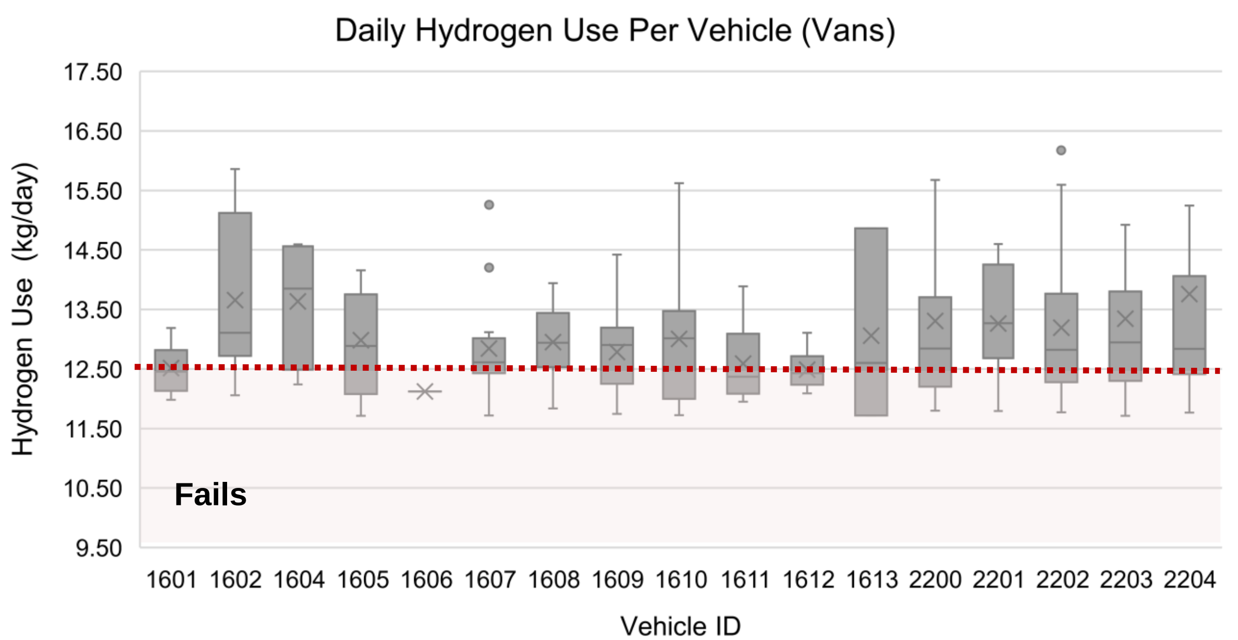


Figure 15: Daily hydrogen use per van

Figure 15 shows that with hydrogen vans, around 90% of daily vehicle assignments can be completed successfully. The daily mileage for hydrogen vans ranges between 210 and 250 miles with an average fuel efficiency of 17 mi/kg[15].

Finally, demand response services completed by cutaways was modeled with BE cutaways. No hydrogen FCE option was modeled due to lack of hydrogen FCE cutaway options.

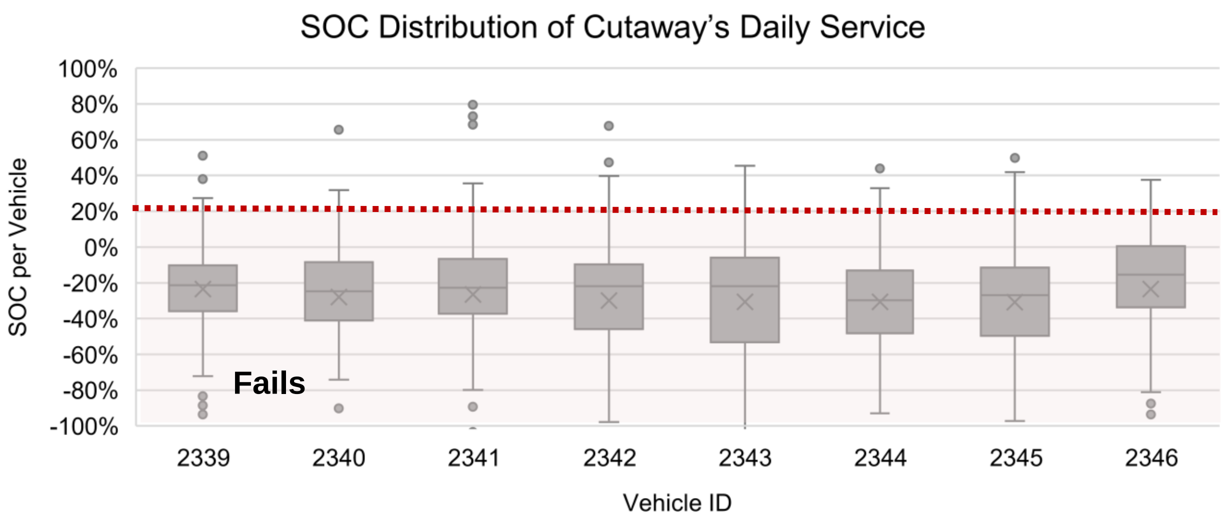


Figure 16: SOC distribution for BE cutaways

Figure 16 shows that only 10% of daily service schedules completed by cutaways can be successfully completed with BE equivalents. A sensitivity analysis suggests that with the ideal weather and topography, 50% of vehicle assignments may be successful. The daily mileage for an electric cutaway ranges between 105 and 135 miles, with an average fuel efficiency of 1.13 kWh/mi. Table 7 summarizes that daily mileage ranges and average fuel efficiency for all demand response modeling results.

Table 7: Average fuel efficiency and daily mileage ranges for demand response vehicles

Vehicle type	Average fuel efficiency	Daily mileage range
BE van	0.87 kWh/mi	135-170
FCE van	17 mi/kg	210-250
BE cutaway	1.13 kWh/mi	105-135

[15] Note that Altoona testing has not been completed for hydrogen vans and not enough public data is available to validate the expected hydrogen efficiency.

4.2 SUMMARY AND FLEET RECOMMENDATIONS

In summary, the fixed-route service modeling results show that both BEB and FCEB options could be feasible for GCTD's operations. One hundred percent of service can be successfully transitioned to FCEBs without changing anything about GCTD's current scheduling, blocking, or operations. The majority of GCTD's fixed-route service can be successfully transitioned to BEBs, but 7 40-ft vehicles would require a larger battery (660 kWh), and one 35-ft vehicle is unsuccessful and would either require midday/opportunity charging between blocks or reblocking to be successful with BEBs.

Demand response services are less successful as ZE operations, with only 25% of daily service assignments for vans able to be successfully converted to BE vans. This jumps to about 90% for hydrogen vans, but it is important to note that no hydrogen vans have undergone Altoona testing yet.

Vehicle options are more limited for cutaways, with only BE options available. Modeling suggests that 10% of daily assigned cutaway service can be successfully completed with BE cutaways.

Following the modeling results, a variety of potential solutions were developed for each service type to weigh the pros and cons of different solutions across different areas of interest, including financial, facility, and operational considerations. Following the development of the preliminary solutions, Stantec met with GCTD staff to workshop the feasibility of the different solutions and come to a preferred fleet concept that best fits the needs of GCTD. The recommended ZE approach is summarized in Table 8.

Table 8: Recommended fleet summary

Vehicle type	Tank size	Quantity	Notes
35-ft. buses	35 kg	17	All blocks and vehicle assignments successful under the modeling conditions.
40-ft buses	37.5 kg	44	All blocks and vehicle assignments were successful under the modeling conditions.
Cutaways	N/A; CARB exemption	N/A; CARB exemption	N/A; CARB exemption. No hydrogen cutaway currently available. Depending on passenger capacity needs, GCTD could explore substituting a portion of the cutaway fleet with FCE vans. For the purposes of the ZEB Plan, cutaways are assumed to be replaced with passenger vans.
Vans	13 kg	18	Around 90% of the daily service assigned to vans can be converted to FCE. Vehicles need to refuel at the main facility with the fixed-route vehicles.

5.0 FLEET PROCUREMENT SCHEDULE/OUTLOOK

GCTD has specified a fleet replacement schedule for their current fleet (fixed-route and paratransit services) as summarized in Table 9. This proposed replacement schedule developed in June 2022 provides the basis for the ZEB phasing strategy[16].

Table 9: GCTD fleet replacement schedule, March 2021 Fleet Management Plan

Year	Vehicle Make	Service	Useful Life	Size	No. Vehicles
2021	New Flyer 2006	Fixed route	12-yrs	40’	3
2022	New Flyer 2006	Fixed route	12-yrs	40’	9
2023	New Flyer NZ 2006	Fixed route	17-yrs	40'	13
	MV-1	Demand Response	7-yrs	Van	6
2024	MV-1	Demand Response	7-yrs	Van	7
2026	NABI 2008	Fixed route	12-yrs	35'	9
	Star Craft 2017	Demand Response	7-yrs	Cutaway	8
2027	NABI 2009	Fixed route	12-yrs	35'	8
2028	Gillig 2015	Fixed route	12-yrs	40'	8
	Ford Vans 2019	Demand Response	7-yrs	Van	5
2029	Gillig 2016	Fixed route	12-yrs	40'	5
2031	Gillig 2019	Fixed route	12-yrs	40'	5
2033	Planned Gillig 2021	Fixed route	12-yrs	40'	3

Based on the bus modeling, route simulations, and further analysis by the Stantec team, it was determined that a FCEB fleet is preferred to maintain the current fixed route service levels and a combination of zero-emission vehicles (both battery-electric [at least for a short time until hydrogen vehicles are more widely available] and hydrogen) will be used to replace the current CNG/gasoline paratransit vehicles. The phasing plan for GCTD to ZE vehicles considers the following:

- The same level of fixed-route service will be provided as pre-pandemic conditions by using hydrogen 35-ft and 40-ft buses; as the fleet expands, service levels will be increased as well.
- Seven 35-ft buses will be replaced by 7 40-ft buses, as specified by GCTD.
- The fixed-route fleet size will be expanded from 61 to a total of 69 buses in 2040, by gradually expanding the fleet starting in 2030

[16] Funding availability and changes to revenue service may require updates or changes to this proposed plan.

- The demand response fleet size will be expanded from 27 to a total of 32 vehicles in 2040, by expanding the fleet starting in 2025
- All demand response vehicle purchases starting in 2023 will prioritize available zero-emission vehicle options. Battery-electric, hydrogen fuel cell or hybrid vehicles will be acquired depending on the refueling infrastructure abilities and market availability to achieve reliable ADA / demand response service to the communities GCTD serves.
- The same spare ratio will be maintained.

Figure 17 displays a graph with the proportion of the fleet by vehicle type over time as the transition from carbon-emitting vehicles to ZEVs proceeds.

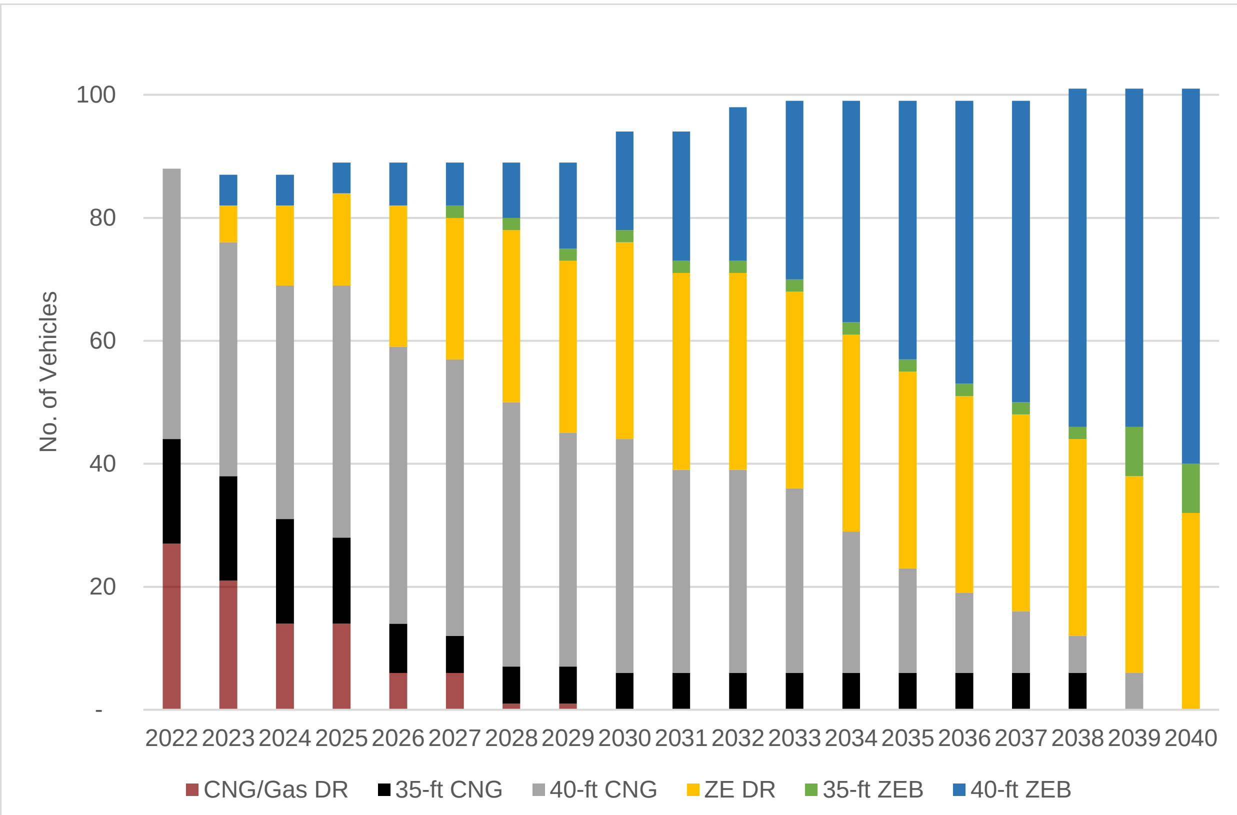


Figure 17: GCTD fleet composition through 2040 by vehicle type and technology

Table 10 displays the recommended fleet acquisition schedule for 35-ft and 40-ft vehicles. This plan was developed by accounting for fossil fuel vehicle retirement and the ICT purchase requirement. While the acquisition schedule assumes the first purchase for hydrogen vehicles in 2023, the purchase of these ZE vehicles can be postponed if funding for the hydrogen refueling infrastructure is not available. Table 11 provides an annual fleet plan for the demand response fleet.

Table 10: 2023 – 2040 Fleet Forecast for 35-ft and 40-ft Vehicles

			2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
35-ft	CNG	Replace			-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-
	CNG	Expansion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	CNG	Retire		-	(3)	(6)	(8)			-		-	-		-	-	-	-	(6)	-
	Total 35-ft CNG		**17**	**17**	**14**	**8**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**-**	**-**
	ZEB	Replace		-	-	-	2	-	-	-	-	-	-		-	-	-	-	8	-
	ZEB	Expansion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	ZEB	Retire	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(2)	-
	Total 35-ft ZEB		**-**	**-**	**-**	**-**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**8**	**8**
40-ft	CNG	Replace	4	4	3	4	-	6	-	-	-	-	-	-	-	-	-	-	-	-
	CNG	Expansion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	CNG	Retire	(10)	(4)	-	-		(8)	(5)		(5)		(3)	(7)	(6)	(4)	(3)	(4)	-	(6)
	Total 35-ft CNG		**38**	**38**	**41**	**45**	**45**	**43**	**38**	**38**	**33**	**33**	**30**	**23**	**17**	**13**	**10**	**6**	**6**	**-**
	ZEB	Replace	5	-	-	2	-	2	5	-	5	-	3	7	6	6	6	4	-	8
	ZEB	Expansion	-	-	-	-	-	-	-	2	-	4	1	-	-	-	-	2	-	-
	ZEB	Retire	-	-	-	-	-	-	-	-	-	-	-	-	-	(2)	(3)	-	-	(2)
	Total 40-ft ZEB		**5**	**5**	**5**	**7**	**7**	**9**	**14**	**16**	**21**	**25**	**29**	**36**	**42**	**46**	**49**	**55**	**55**	**61**
Total Fleet Size			**60**	**60**	**60**	**60**	**60**	**60**	**60**	**62**	**62**	**66**	**67**	**67**	**67**	**67**	**67**	**69**	**69**	**69**

Table 11: 2023 – 2040 Fleet Forecast for Demand Response Vehicles

		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
CNG/Gas	Replace	-	-			-	-	-	-	-	-	-	-	-	-	-	-	-	-
CNG/Gas	Expansion	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CNG/Gas	Retire	(6)	(7)		(8)	-	(5)		(1)					-	-	-	-	-	-
Total CNG/Gas Demand-Response		**21**	**14**	**14**	**6**	**6**	**1**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
ZE	Replace	6	7	-	8	-	5	-	7	7	2	8	-	5	-	10	7	2	8
ZE	Expansion	-	-	2		-	-	-	3	-	-	-	-	-	-	-	-	-	-
ZE	Retire	-	-	-	-	-	-	-	(6)	(7)	(2)	(8)	-	(5)	-	(10)	(7)	(2)	(8)
Total ZE Demand-Response		**6**	**13**	**15**	**23**	**23**	**28**	**28**	**32**	**32**	**32**	**32**	**32**	**32**	**32**	**32**	**32**	**32**	**32**

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Total Fleet Size	27	27	29	29	29	29	29	32	32	32	32	32	32	32	32	32	32	32

6.0 HYDROGEN FUEL DEMAND AND SUPPLY

6.1 HYDROGEN DEMAND

After determining a hydrogen-fueled fleet as the best fit for GCTD, the next step was to determine the estimated daily hydrogen demand to fuel the future fleet as well as the best method of supplying hydrogen to the facility. Table 12 summarizes estimated hydrogen demand needed at the facility. This includes demand from GCTD's fleet as well as the demand for the Ventura County Transportation Commission (VCTC). VCTC is a partner transit agency providing commuter services in Ventura County that could, at a future time, refuel FCEBs of its own at GCTD's shared facility.

Table 12: Daily hydrogen demand

Agency	Item Description	40-ft and 35-ft Buses	Cutaways and Vans
GCTD	Total vehicles in fleet	64	27
	No. of active vehicles	60 (4 contingency)	26
	Average H2 demand per vehicles (kg/day/vehicle)	15.5	8.5
	H2 demand for all active vehicles (kg/day/fleet)	885	180
	Total GCTD Fleet Hydrogen Demand (kg/day)	1,065	
VCTC	Total VCTC Fleet Hydrogen Demand (kg/day)	1,335	
Total Estimated Fleet Hydrogen Demand (kg/day)		**2,400**	
Monthly Estimated Hydrogen Demand (kg/month)		**72,000**	

Two possible methods for providing hydrogen to the new hydrogen facility were assessed Option 1: Trucked-in liquified hydrogen and Option 2: On-site production of gaseous hydrogen derived from water electrolysis using onsite solar PV power generation, supplemented by electricity from the grid. Option 1 is the most feasible and least costly of the two options and for the near-term implementation of FCEBs, GCTD should deploy Option 1, similar to most other transit agencies in California[17]. At a later time when GCTD's fleet is entirely hydrogen vehicles, GCTD could explore deploying the hydrolysis concept in Option 2 as a way to generate on-site hydrogen, increasing its resiliency. A deeper discussion on the two options can be found in Appendix A: Memo—Infrastructure Options for Different Hydrogen Fueling Arrangements. Note that the values in Table 12 do not include projected consumption by public-access users, which is estimated at about 60 kg per day.

[17] OCTA has recently commissioned hydrogen fueling facility based on trucked-in liquid, and other agencies including Foothill Transit, Santa Clarita Transit and Victor Valley Transit Authority are planning similar systems.

For the purposes of the rollout plan, the remainder of the analysis, recommendations, and strategies are based on the assumption that GCTD will deploy equipment necessary for on-site storage of liquid hydrogen, conversion to gaseous hydrogen, and dispensation of gaseous hydrogen. More information about the equipment required can be found in Section 7.1.

6.2 HYDROGEN SUPPLY

Not all hydrogen is created equal, in fact, hydrogen has several pathways to be generated and this includes different carbon intensity levels. Figure 18 provides an overview of the different hydrogen classifications based on the generation source. Gray, blue, and green hydrogen have different levels of carbon emissions, with green being the ultimate goal because it is carbon neutral.

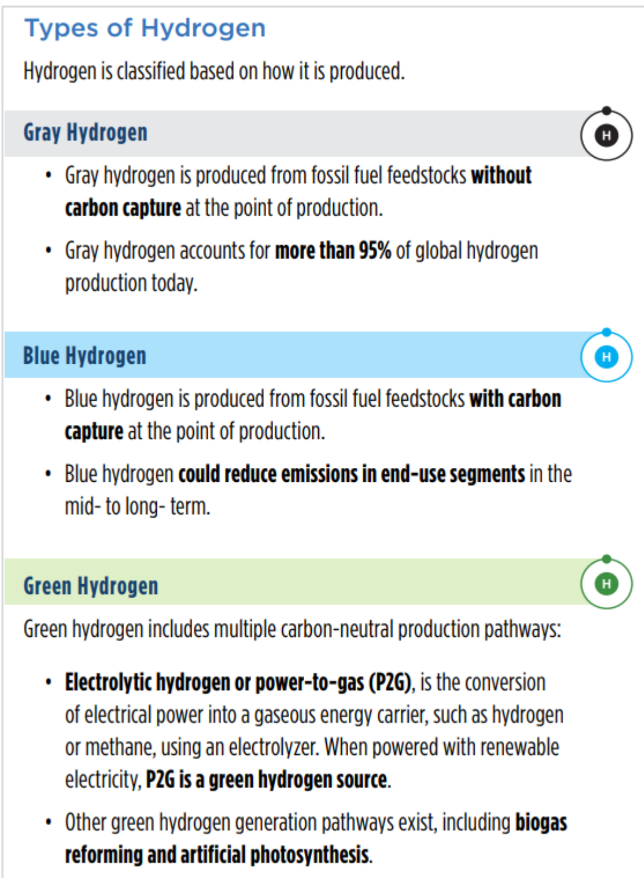


Figure 18: Types of hydrogen based on generation source[18]

Today, 37%-44% of hydrogen used in transportation is renewable, but 95% of all hydrogen produced in the United States is made by industrial-scale natural gas reformation (gray hydrogen). This process is called fossil fuel reforming or steam methane reforming (SMR). The process takes natural gas (NG) and

[18] https://www.energy.ca.gov/sites/default/files/2021-06/CEC_Hydrogen_Fact_Sheet_June_2021_ADA.pdf

steam to generate a product stream of carbon dioxide (CO_2) and hydrogen (H_2). Greenhouse gas emissions can be avoided completely if the CO_2 produced in SMR is captured and stored (blue hydrogen) in a process known as carbon capture and storage (CCS).

In the short-term, GCTD will likely receive its hydrogen from the Sacramento area that is currently produced via SMR with a mixed of biogas to account for 33% renewable green hydrogen. But as sustainable renewable energy generation advances in the United States, it is anticipated low to zero carbon hydrogen production will become more commonplace. For example, the City of Lancaster will host and co-own a green hydrogen production facility with SGH2, which will be able to produce up to 11,000 kilograms of green hydrogen per day. SGH2 anticipates breaking ground in Q1 2021, start-up and commissioning in Q4 2022, and full operations in Q1 2023[19]. Additionally, Plug Power recently announced it will build the largest green hydrogen production plant on the West Coast. The state-of-the-art production facility in Fresno County in the Central Valley of California will be powered by renewable energy. Once completed, it will produce 30 metric tons of green hydrogen daily and serve customers up and down the West Coast. The facility will use a new 300 MW zero-carbon solar farm to power 120 MW of Plug Power's state-of-the-art PEM electrolyzers, and the project includes construction of a new tertiary wastewater treatment plant in the city of Mendota that will provide recycled water for the people of Mendota and supply the full needs of the plant. The plant will break ground in early 2023 and complete commissioning in early 2024[20].

[19] https://www.sgh2energy.com/worlds-largest-green-hydrogen-project-to-launch-in-california
[20] https://www.globenewswire.com/news-release/2021/09/20/2299650/9619/en/Plug-Power-to-Build-Largest-Green-Hydrogen-Production-Facility-on-the-West-Coast.html

7.0 MAINTENANCE FACILITY INFRASTRUCTURE MODIFICATIONS

This section outlines the proposed facility modifications for FCEB implementation to GCTD's bus operations and maintenance facility. The final master plan has been developed proposing the addition of hydrogen fueling dispensers at the existing Fuel Building with a new hydrogen equipment yard to the northeast of the Fuel Building. Fortunately, the facility has sufficient space opportunity for the new fueling infrastructure and equipment, avoiding the reduction in parking stalls while maximizing yard flexibility by taking space from the existing storm water retention swale for the new equipment yard.

The existing service cycle can be maintained and is not required to be changed for FCEB implementation since the facility currently uses CNG fueling which is nearly identical in operation to hydrogen fueling.

The ample and spacious nature of the property will allow for simple phasing of construction with little to no impact on current operations. GCTD will need to work closely with a contractor to implement the proposed modifications to the facility but the impacts to operations will be temporary in nature and should be limited to the north of the bus parking area and the north end of the Fuel Building. Considering the facility has multiple fuel/service lanes, it should be assumed that sufficient opportunity exists to temporarily remove certain portions of the facility from GCTD's use for limited periods of time. In summary, there does not appear to be any significant constraints to the physical property that would create noteworthy cost increases to the implementation of the proposed hydrogen fueling improvements.

7.1 PROPOSED FUELING FACILITY MODIFICATIONS

The following summarizes the proposed improvements for the hydrogen fueling system (Figure 19):

- A new hydrogen fueling system designed to dispense 2,463 kg of hydrogen per day (90-bus capacity). This about 26.7 kg per FCEB per day and captures usage by both the GCTD and VCTC fleets (as described in Table 12). Quantities of each component are one unless noted otherwise (see Figure 20 for details).
    - 18,000 gallon liquified hydrogen tank
    - Reciprocating LH2 pump for H35 fueling (qty: 3)
    - High pressure GH2 compressor for H70 fueling
    - Hydrogen vaporizer (qty: 2)
    - Superheater vaporizer
    - GH2 priority valve panel
    - High-pressure GH2 storage vessel for H35 fuel (qty: 6)
    - High-pressure GH2 storage vessel for H70 fuel (qty: 2)
    - Pre-dispensing chiller (qty: 2)
    - GH2 H35 dispenser (qty: 2)

    - GH2 H70 dispenser with chiller
    - Air compressor system
    - Main electrical service panelboard
    - Motor starter panelboard for pumps (qty: 2)
    - System control panel
    - Electrical transformer (as required)
- New hydrogen equipment yard site improvements:
    - Perimeter security fencing to separate from other areas. Fencing to include lockable vehicle and pedestrian access gates.
    - Bollards along the vehicle traffic facing sides of the yard.
    - Equipment pads/foundations as required and pavement between all portions of the equipment yard to allow for access and maintenance activities.
    - Site retaining walls and associated foundations for equipment yard – required because of significant grading/slopes into the adjacent stormwater swale (similar to existing CNG equipment yard).
    - New site lighting and security cameras in equipment yard as required.
    - Modifications to existing storm water swale to account for capacity lost by the new equipment yard displacement. Modifications will include regrading of portions of swale and modified or new planting in those areas impacted.
- Modifications to the Fuel Building's service lanes includes the extension of service lane striping, new equipment pads for GH2 dispensers, and new bollards.
- Electrical system improvements and modifications:
    - A new transformer and panelboard to provide adequate power to the new hydrogen equipment.
    - Connection of new panelboard to existing electrical room at Fuel Building to the southwest. Power supply for hydrogen fueling equipment assumed to be backed-up by existing generator via electrical connection to the existing switchgear in the Fuel Building.
    - Associated equipment pads, fencing and bollards.
    - CMU fire barrier wall perimeter around new electrical equipment and panels.
- Pavement replacement/repair for trenching associated with electrical distribution for Area A where new electrical service and switchboard will be allocated.
- Demolition of existing north trash enclosure and replacement with a new trash enclosure to the west, outside of vehicle circulation areas and access to CNG equipment yard.
- Gas detection system modifications at Fuel Building and Maintenance Building, see narrative below.

Full site plan details can be found in Appendix B: Site Plans.

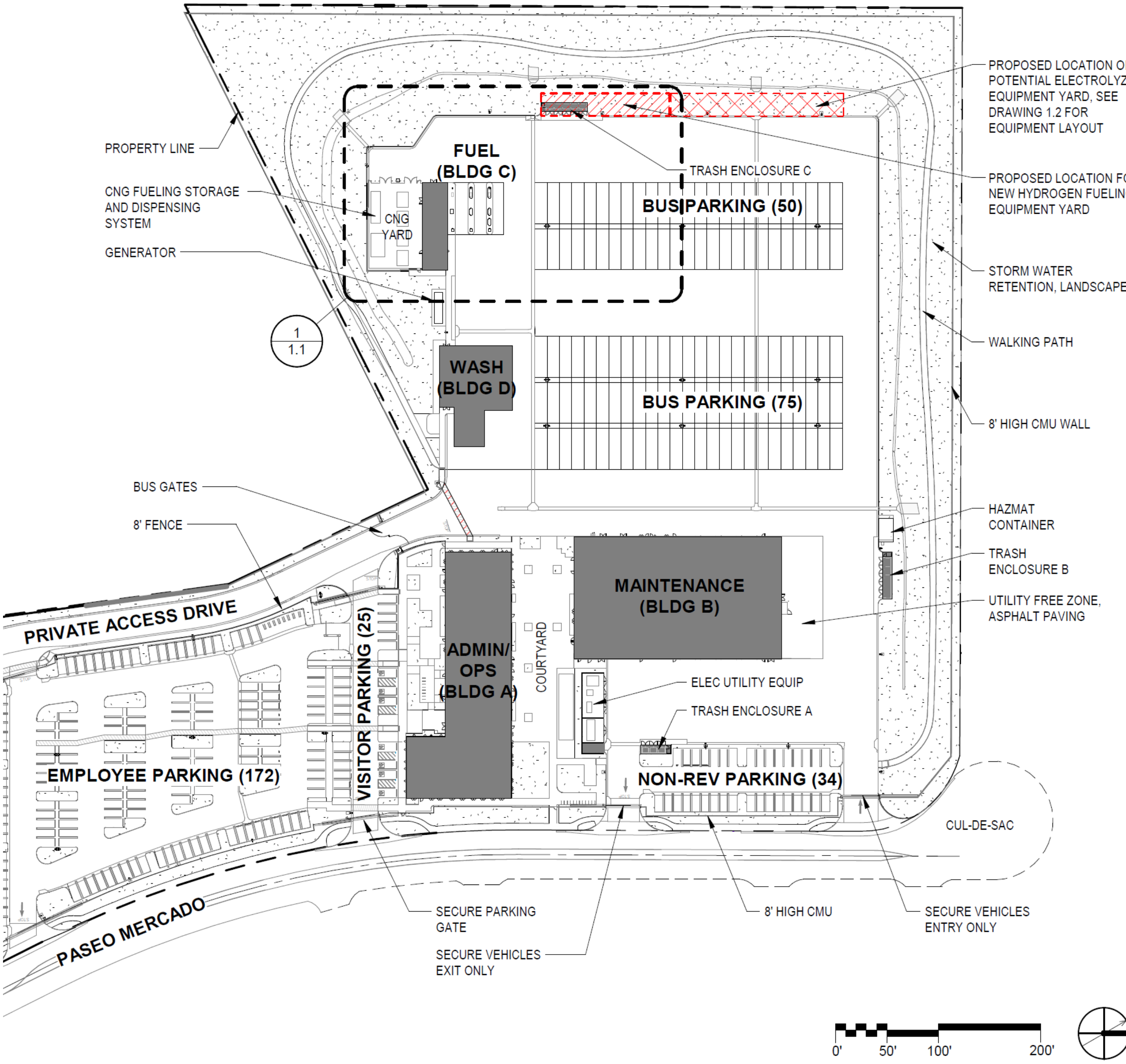
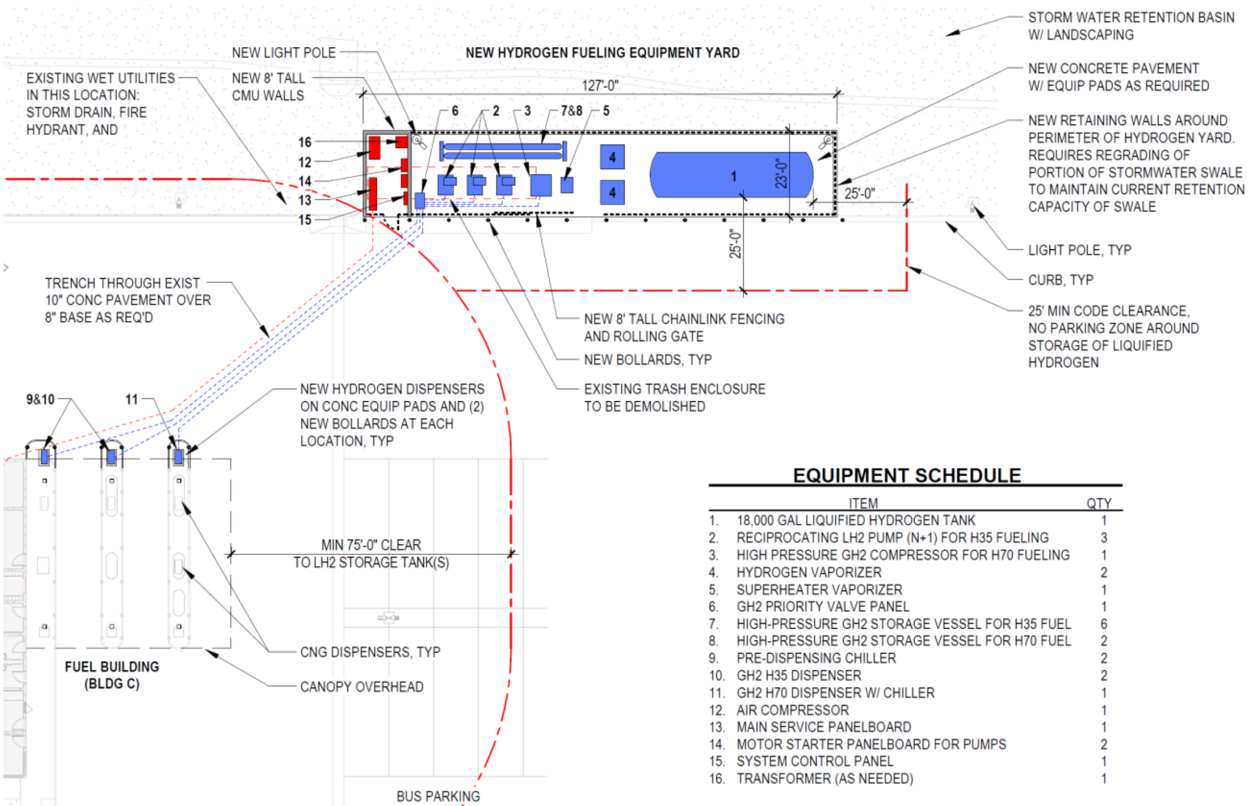


Figure 19: GCTD Site Plan



EQUIPMENT SCHEDULE

	ITEM	QTY
1.	18,000 GAL LIQUIFIED HYDROGEN TANK	1
2.	RECIPROCATING LH2 PUMP (N+1) FOR H35 FUELING	3
3.	HIGH PRESSURE GH2 COMPRESSOR FOR H70 FUELING	1
4.	HYDROGEN VAPORIZER	2
5.	SUPERHEATER VAPORIZER	1
6.	GH2 PRIORITY VALVE PANEL	1
7.	HIGH-PRESSURE GH2 STORAGE VESSEL FOR H35 FUEL	6
8.	HIGH-PRESSURE GH2 STORAGE VESSEL FOR H70 FUEL	2
9.	PRE-DISPENSING CHILLER	2
10.	GH2 H35 DISPENSER	2
11.	GH2 H70 DISPENSER W/ CHILLER	1
12.	AIR COMPRESSOR	1
13.	MAIN SERVICE PANELBOARD	1
14.	MOTOR STARTER PANELBOARD FOR PUMPS	2
15.	SYSTEM CONTROL PANEL	1
16.	TRANSFORMER (AS NEEDED)	1

Figure 20: GCTD ZEB Site Conceptual Master Plan

7.2 FIRE PROTECTION CONSIDERATIONS

With the implementation of FCEBs, fire protection and life-safety concerns can be significant. The primary code dictating the implementation of hydrogen fueling systems in National Fire Protection Association (NFPA) 2 – Hydrogen Technologies Code. However, since the GCTD facility is relatively new and was also designed to serve CNG vehicles, many of the requirements for hydrogen fueling can already be met with little to no changes to the existing facilities.

The need for enhanced fire protection systems has not been specifically assessed as a part of this study and should be discussed with the local fire marshal and the local building officials to ensure all stakeholders in the approval process understand the proposed systems. Fire truck access to the site and hydrant access is already well defined but will need to be reviewed and approved by the pertinent AHJs prior to implementation of any facility improvements.

In summary, it is assumed that no fire protection system modifications are required for FCEB implementation, but further analysis may be required.

7.3 GAS DETECTION SYSTEM MODIFICATIONS

The Maintenance Building is equipped with a modern methane leak-detection system that uses infrared sensors mounted along the ceiling above the bays (methane is lighter than air), and also has carbon monoxide sensors located at personnel height (carbon monoxide is neutrally buoyant in air).

If FCEBs are deployed, new catalytic-bead sensors to detect hydrogen-gas leaks would be required, since infrared sensors cannot detect hydrogen gas. This system will need separate alarm lights that are distinct from the methane-leak alarms, as required by NFPA 72 (fire-alarm code). However, the modern site controller at the existing system can accept the new catalytic-bead sensors and can also drive the new and distinct alarms. This will allow a common control interface for all gas-leak sensing and will also reduce overall clutter and cost.

The existing ventilation system that makes the maintenance garage safe for CNG vehicles is assumed to provide at least five air-changes per hour and equipped with explosion- proof and spark-resistance fans. Accordingly, the ventilation system is adequate and compatible for hydrogen vehicles as well.

7.4 BACKUP PLANNING AND RESILIENCY

Planning for resiliency and redundancy is necessary not only to support operations or evacuations during emergencies or other disruptions, but also to ensure if the bus facility loses power, FCEBs can still be operated. This is particularly important given the propensity of black outs in California, especially as the adoption of EVs increases along with the demand on the electrical grid throughout the state.

Currently, GCTD's facility is equipped with a backup diesel generator for the CNG fueling infrastructure to ensure CNG compression and fueling can continue in case of a power outage. Stantec estimates that the current generator for the CNG fueling infrastructure is sufficient to support the operation of the hydrogen fueling infrastructure. As such, no additional backup generator is required, and the generator should be connected to serve the hydrogen fueling compound when it is built.

While the above is most pragmatic and direct solution for redundancy and backup, GCTD has also previously explored solar photovoltaic (PV) equipment to generate off-the-grid electricity to power the CNG equipment to reduce reliance on SCE derived electricity. The analysis by ENGIE demonstrated that by installing solar PV panels[21] above the employee and guest parking and using a stationary battery[22] (Figure 21) the project cost would be approximately $2.8 million but could result in a total net savings of $6 million over 25 years. Given the similar electrical loads for the proposed hydrogen fueling infrastructure and the CNG fueling infrastructure (Figure 22), GCTD could explore using this ENGIE solar and storage model to reduce electricity costs related to the hydrogen fueling facility, while also storing energy in case of a power outage.

[21] ENGIE analysis, estimated 514 kWdc / 890,000 kWh-yr generation.
[22] ENGIE analysis, storage system of 232 kW / 928 kWh.

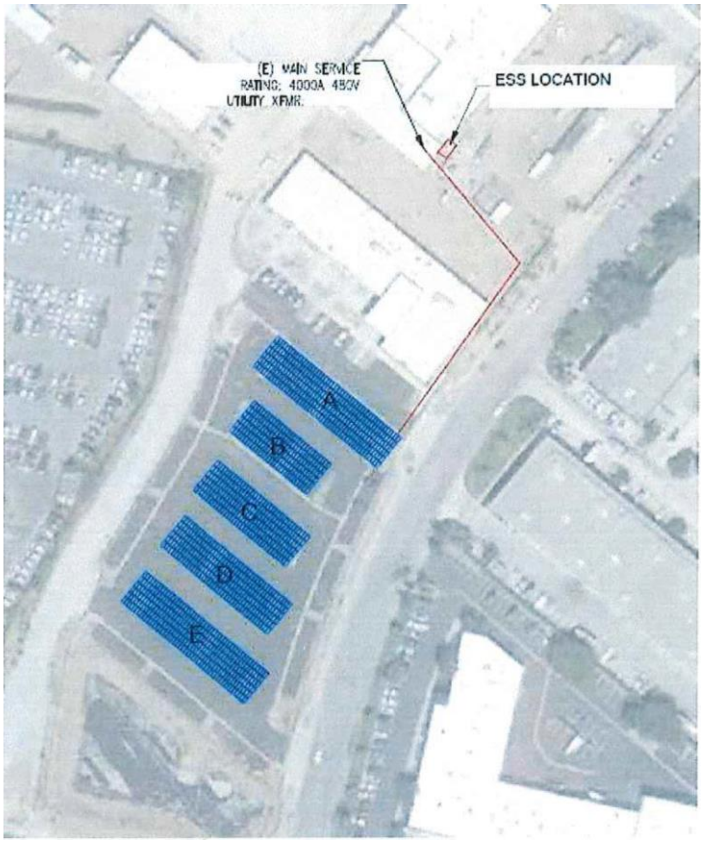


Figure 21: Proposed Solar PV system analyzed by ENGIE over employee and guest parking (Source: ENGIE)

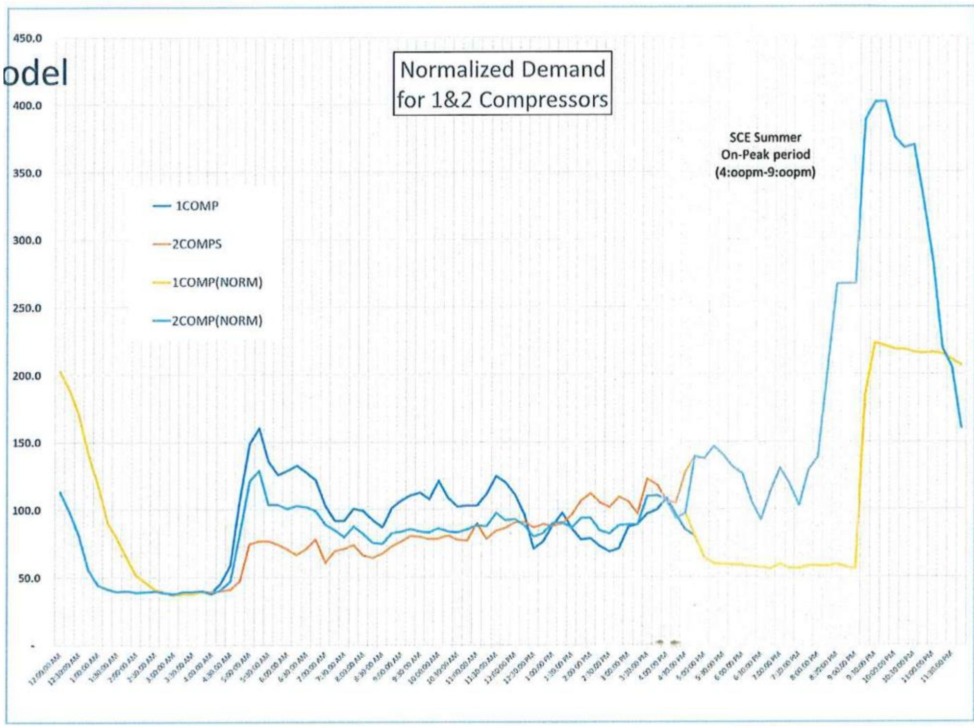


Figure 22: Normalized Demand model to offset CNG compressors with Solar PV and a battery storage system performed by ENGIE (Source: ENGIE)

While the power demand for compressors and other equipment to store trucked-in liquid hydrogen and dispense gaseous hydrogen is on the order of ~129 kW, Stantec's analysis of on-site production using hydrolysis revealed potentially 1.25 MW of power required just to offset 22% of the total hydrogen demand—the rest of the hydrogen would need to be delivered via a tube truck. For this scenario, it would be prudent for GCTD to further investigate the opportunities to curb grid demand by deploying solar PV assets; more information can be found in Appendix A: Memo—Infrastructure Options for Different Hydrogen Fueling Arrangements.

While the onsite generators and potential solar and battery system would be ideal solutions for on-site resiliency, GCTD also needs to consider the resiliency of its hydrogen supply. Different hydrogen suppliers will incorporate into their contract contingency plans if there is a disruption to 1) the generation site or 2) the distribution paths (e.g., the truck cannot make it to its destination). Each disruption would have different mitigation measures such as deploying a new truck to make the delivery on the same day or allow GCTD to purchase hydrogen from a different supplier at the contracted cost. Each situation would be unique and GCTD would need to incorporate mitigation strategies into their supply contract.

7.5 FACILITY AND INFRASTRUCTURE MODIFICATIONS CONCLUSION

Table 13 summarizes the minimum facility and infrastructure requirements for FCEB implementation at the agency's operations and maintenance facility.

Table 13: Infrastructure modification summary

Division Name	Address	Main Function(s)	Type(s) of Infrastructure	Service Capacity	Needs Upgrade (Yes/No)
GCTD Operations and Maintenance Facility	1901 Auto Center Dr, Oxnard, CA 93036	Operations, Maintenance, Training, Fueling	New FCEB fueling equipment, additional electrical improvements,	40-60 – 40-ft buses 8-17 – 35 ft-buses 25-30 – demand response vehicles (note, these vehicles will be fueled at the 1901 Auto Center Dr, but stored at the paratransit operations center)	Yes

Table 14 provides a breakdown by cost category for the proposed site modifications as discussed throughout Section 7.0 to transition to hydrogen as an alternative fuel. Nearly 90% of the cost—$5.42 million—is related to the hydrogen equipment, including the storage tank and related equipment, leak detection for safety, and construction hard costs to build the hydrogen fuel yard. In addition to the construction and equipment costs, soft costs related to market factors, design contingency, insurance and contractor fees bring the total estimated cost of the project to $8.97 million. The full cost estimate is found in Appendix C: Cost Estimates.

Table 14: Cost estimate for hydrogen fueling infrastructure

Cost Category	Total Estimated Cost ($)	Percent of Estimated Cost
Existing conditions (demolition, protection work etc.)	$20,143	0.35%
Hydrogen fueling equipment (tank, vaporizers, dispensers, etc.)	$4,771,010	81.83%
Electrical (power hook ups, disconnect switch, etc.)	$74,815	1.28%
Communications upgrades	$30,600	0.52%
Hydrogen leak detection system	$335,759	5.76%
Earthwork (grading)	$17,000	0.29%
Exterior improvements (CMU retaining wall, bollards, fence, etc.)	$315,703	5.41%
Utilities (yard lighting, fuel piping, ductbank, etc.)	$265,393	4.55%
Subtotal	$5,830,423	100%
General conditions/ general requirements	$728,803	
Estimate/ design contingency	$1,311,845	
Market factor	$393,554	

Cost Category	Total Estimated Cost ($)	Percent of Estimated Cost
Subtotal	$8,264,625	
Bonds & Insurance	$165,292	
Contractor’s fee	$537,201	
Grand total	**$8,967,118**	

8.0 FINANCIAL EVALUATION AND IMPACTS

The financial evaluation for GCTD's ZEB rollout plan consisted of the modeling of a Base Case (assuming continued use of CNG and gasoline vehicles or 'business-as-usual') and a ZEB Rollout scenario (assuming a transition to 100% ZEB operations and the phasing out of diesel/gasoline vehicles), and a comparison between the two scenarios to quantify the financial impacts of the transition and of ZEB operations. Stantec's cost estimator, Jacobus & Yuang, Inc., provided a detailed cost estimate of materials, soft costs, constructions, and other line items related to facility modifications for the ZEB case (more information in Section 7.5).

The main assumptions for the cost modeling are:

- Financial modeling was completed in real 2022 dollars (2022$).
- A 7% discount rate was applied for all calculations, as per USDOT guidance.
- The chief source of information regarding fleet planning is the GCTD Fleet Management Plan, dated March 2021. This document contains a fleet plan through 2031. Stantec worked with GCTD staff to revise the fleet management plan for the purposes of the ZEB rollout plan to account for fleet expansion for potential service improvements and other operational growth, as well as to extend the plan through 2040, as required by the ICT regulation; the proposed fleet plan is shown in Table 9. Furthermore, for the paratransit and demand-response fleet, the fleet management plan provides an indication of replacement and fleet size, but not of vehicle type, as more study is needed to determine the appropriate vehicle size dependent upon passenger demand. For simplicity, we assumed for the ZEB Case that paratransit and demand-response vehicles would be FCE passenger vans; future revisions to the fleet plan may be required as determined by GCTD staff and will impact the cost assumptions here.
- Annual average vehicle mileage is as follows for each vehicle type[23]:
    - 43,115 miles for 40-ft vehicles
    - 41,297 miles for 35-ft vehicles
    - 39,093 miles for CNG cutaways and ZE paratransit vehicles
    - 10,606 miles for gas vans
- Average fuel economy as follows (based on GCTD information for existing fleet and Stantec vehicle modeling for the ZE vehicles):
    - 2.82 miles per diesel gallon equivalent (DGE) for 40-ft and 35-ft vehicles

[23] Based on 2019 NTD reported statistics.

  - 6.45 miles per DGE for CNG cutaways
  - 11.95 miles per gasoline gallon for gas vans
  - 7.20 miles per kg of hydrogen for 40-ft FCEBs
  - 7.29 miles per kg of hydrogen for 35-ft FCEBs
  - 17.00 miles per kg of hydrogen for FCE paratransit vehicles

- The ZEB case included the operation of CNG and gasoline vehicles (as well as ZE vehicles) during the transition period until fossil fuel vehicles are phased out.
- The model was completed using a consistent format for both the Base Case and the ZEB Rollout to facilitate clear comparison between the two. The modeling was developed on an annual basis from 2023 through to 2040.

More details about the assumptions and inputs for both base case and ZEB case can be found in Appendix D: Financial Modeling Inputs and Assumptions.

8.1 BASE CASE APPROACH

Stantec developed the forecast for the Base Case (business-as-usual) scenario, assuming that the existing fleet of CNG and gasoline vehicles is maintained and renewed through to 2040. This model is inclusive of all scheduled fleet replacements required during the 2040 project horizon. It should be noted that this Base Case would be non-compliant with the ICT regulatory requirements as it deploys fossil fuel vehicles and is thus used only for illustrative purposes to determine the financial impacts of a ZEB rollout.

The Base Case fleet sees a gradual reduction in the total number of 35-ft buses and a gradual increase in 40-ft buses, thus resulting in larger vehicles for the fixed-route bus fleet over the 2040 project horizon. Moreover, for the demand response fleet, the total fleet size in the Base Case will grow but no new cutaways are assumed in this model; new demand-response vehicles are assumed to be passenger vans using gasoline. GCTD will need to conduct further analysis to right-size the paratransit fleet, as mentioned in the Fleet Management Plan.

Capital expenses modeled consist of fleet acquisition based on GCTD's Fleet Management Plan, the FY2020-22 Capital Project Plan – Funded Projects, and the FY2021-22 Budget Book for inputs related to replacement quantities and estimated purchase costs.

Vehicle maintenance costs were derived from NTD 2019 data based largely on salaries, tires and other materials; costs were developed as a cost per mile for fixed-route services and demand responses services.

Fuel costs are based on invoicing from Clean Energy from June 2022 for CNG fuel and GCTD information for gasoline fuel.

8.2 ZEB CASE APPROACH

The ZEB Case foresees a gradual transition to 100% ZE revenue vehicle operations by 2040 in alignment with ICT regulations. The transition follows the fleet replacement schedule presented previously in Table 9, based on GCTD's Fleet Replacement Plan but modified to account for gradual fleet growth (similar to the total fleet size as in the Base Case).

The last purchase of a CNG bus for fixed-route service would be in 2028, and the last purchase of a non-ZEB demand-response vehicle would in 2022. The assumed life cycle for the ZEB vehicles were the same as the current life cycles for non-ZEB vehicles—12 years for full size buses, and 8 years for demand-response vehicles. For demand-response vehicles, given the immaturity of the small vehicle market particularly for FCE vehicles, the modeling captured a generic 'demand response ZE' based on quotes and specifications from an OEM that has developed a FCE passenger van based on a Ford Transit Van chassis.[24] As GCTD transitions its non-fixed-route fleet to ZEBs, GCTD will likely need to revisit and refresh the assumptions in this cost model to better account for updated vehicle specifications.

Capital expenses modeled consist of fleet acquisition, extended vehicle warranties, and fuel cell replacements at a vehicle's mid-life but only for large, fixed-route vehicles (based on OEM information).

Vehicle maintenance costs for FCE vehicles were generated based on GCTD's current costs for its fossil fuel fleet based on literature from comparative FCEB and CNG operations for two California transit agencies. The findings in these reports demonstrated that on a per mile basis, vehicle maintenance costs were comparable between CNG buses and FCEBs.[25] The lack of data on maintenance costs, particularly for costs outside of any OEM warranty, makes maintenance costs difficult to forecast.

Fuel costs were based on industry reports that indicate that the price per kg of hydrogen will decrease in the future as the supply chain matures along with investments from private and public actors. The cost assumed here is the cost of the commodity as delivered liquid hydrogen.

Infrastructure costs for the ZEB case are related to facility modifications to accommodate FCEBs and hydrogen fueling infrastructure. The related infrastructure is detailed in Section 7.0.

8.3 COMPARISON AND OUTCOMES

The cost comparison of net present value (NPV) between the CNG/gasoline Base Case and the ZEB Case transition scenario is presented in Table 15 incorporating both capital (orange) and operating (blue) expenses. The ZEB Case has a total NPV of $134,963,000 versus $105,294,000 for the Base Case, a difference of $29,669,000 or 28% increase in NPV over the base case. The financial assessment below does not consider any rebates, grants, credits, or other alternative funding mechanisms. Therefore, there may be several opportunities to offset the difference in the price between the two scenarios.

[24] GCTD is currently exploring procuring battery-electric vans for paratransit/on-demand service as a short-term strategy to provide ZE operations in the interim while the FCE market matures for paratransit/on-demand. The modeling in this report does not consider this potential short-term fleet strategy.
[25] https://www.nrel.gov/docs/fy21osti/78078.pdf, https://www.nrel.gov/docs/fy21osti/78250.pdf

Table 15: Cost Comparison 2023-2040

	Base Case	ZEB Case	Cost difference (ZEB – Base)
Fleet Acquisition	$45,200,000	$65,425,000	$20,225,000
Fleet Refurbishment	$—	$457,000	$457,000
Infrastructure	$—	$8,380,000	$8,380,000
Fleet Maintenance	$49,098,000	$48,829,000	$(269,000)
Fuel/Hydrogen	$10,996,000	$11,872,000	$876,000
Total	$105,294,000	$134,963,000	$29,669,000

Figure 23 displays the breakdown of total costs by category—the largest difference between the two scenarios is the capital expenses related to fleet procurement and hydrogen infrastructure deployment.

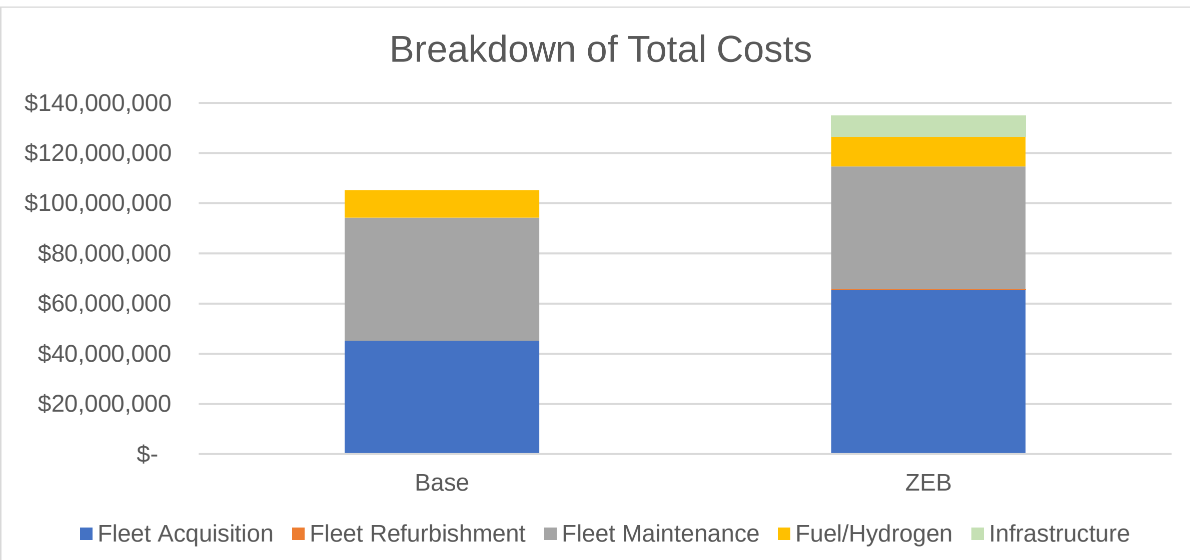


Figure 23: Breakdown of Cost Categories for the Base Case and ZEB Case

The procurement of ZEBs represents $20.2 million more in expenses due to the higher purchase price of FCEBs compared to fossil fuel vehicles. The conversion and upgrades to the facility to install the hydrogen fueling infrastructure and related equipment represents another added cost of over $8 million.

Capital costs associated with vehicle overhauls are related to fuel cell stack replacements or refurbishments at the midlife of a vehicle; for the Base Case, no heavy midlife refurbishments are conducted by GCTD. Notably, we assumed comparable useful life spans for both fossil fuel and ZE vehicles. Given that no agency has operated a modern FCEB in the United States continuously for over 10 years, it is unclear if an FCEB can operate longer than 12 years, but a recent report looking at the price parity of fossil fuel buses and FCEBs assumed a 14-year life span.[26] Operating the FCEBs for a

[26] https://www2.deloitte.com/content/dam/Deloitte/fr/Documents/fusions-acquisitions/fueling-the-future-of-mobility-fuel-cell.pdf

longer timespan can help spread out the steep capital costs over a longer timeframe and represents an opportunity for lower overall costs, although the impacts to fuel economy are currently unknown.

Related to operating costs, given the operating range parity of CNG vehicles and FCEBs, minimal changes to planning and scheduling is envisaged, and the servicing cycle will be similar too. Maintenance costs on a per mile basis of recent FCEBs at Sun Line and OCTA in Southern California have demonstrated relative cost parity with CNG buses. Initially, as maintenance technicians get trained to work on FCEBs, the learning curve will likely result in a greater maintenance cost for FCEBs over CNG vehicles; work under warranty can also help mitigate costs. Over time, as GCTD staff become more proficient with the FCEB technology, it is likely that maintenance costs will come down, particularly as FCEBs having fewer moving components than fossil fuel vehicles reducing the number of parts that can malfunction and that need to be periodically maintained.

Lastly, the use of hydrogen as an alternative fuel is a large cost driver compared to CNG. At the moment, even with rising fossil fuel prices due to inflation and volatility worldwide, the unit price of CNG procured by GCTD is very favorable especially compared to hydrogen fuel. The model assumed an eventual decrease of hydrogen fuel to $4 per kg based on market and industry forecasts. Even with adjustments for future fuel prices from the US Energy Information Administration, the cost of CNG fuel in the Base Case is less than for hydrogen fuel in the ZEB Case. GCTD should explore other avenues to lower the cost of hydrogen fuel, including fuel credits and potentially generating hydrogen on-site (which is described as a possible long-term strategy and detailed in Appendix A: Memo—Infrastructure Options for Different Hydrogen Fueling Arrangements).

Figure 24 shows the year-to-year comparison between the Base Case and the ZEB Case. The higher costs for the FCEB scenario occur each year, with the largest single year being the first year due to the procurement of not only FCEBs, but the large investment required for the hydrogen fueling infrastructure as well.

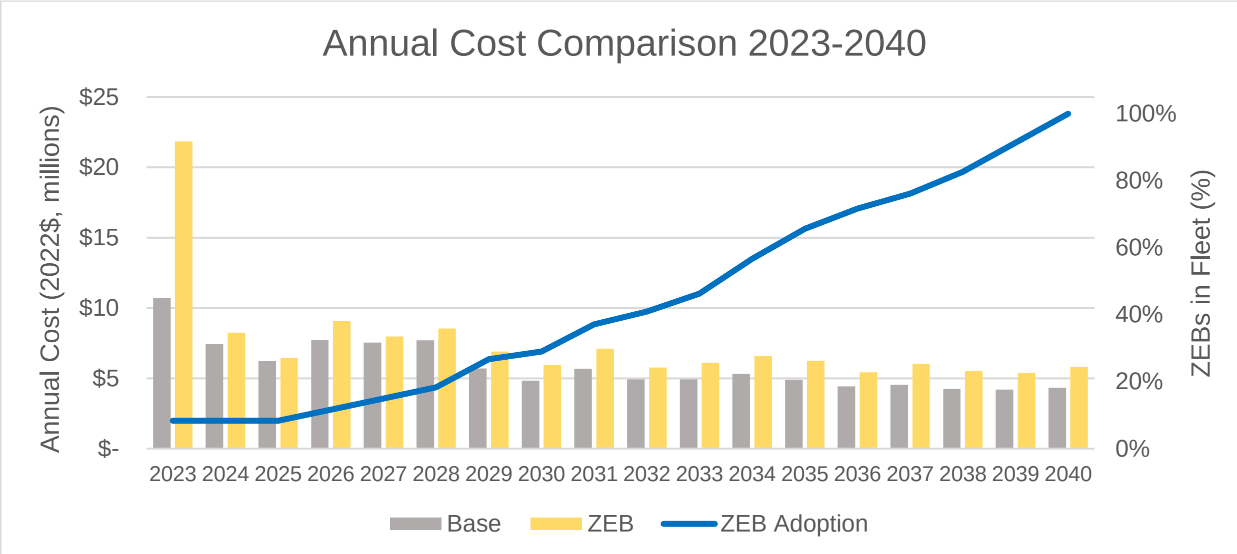


Figure 24: Annual Total Cost Comparison

8.4 SENSITIVITY ANALYSES

Notably, this financial analysis includes judgments and assumptions about future prices and assets costs. To ensure the results are robust, we conducted several sensitivity analyses to understand the potential impacts of inflation and price swings of different cost drivers for fleet and operations.

8.4.1 Inflation Testing

First, the impacts of three levels of inflation were considered on the cost of ownership analysis. For this analysis, year-over-year inflation was considered as follows:

- 3% for low inflation
- 5% for moderate inflation
- 7% for aggressive inflation

The summary results for the different levels of inflation tested are shown in Table 16.

Table 16: Inflation Sensitivity analysis and impact on NPV

	3% inflation		5% inflation		7% inflation	
	Base Case	**ZEB Case**	**Base Case**	**ZEB Case**	**Base Case**	**ZEB Case**
Fleet Acquisition	$58,688,000	$85,765,000	$70,546,000	$103,730,000	$85,429,000	$126,338,000
Fleet Refurbishment	$--	$677,000	$--	$879,000	$-	$1,140,000
Infrastructure/ Facility Mods	$--	$8,632,000	$--	$8,800,000	$--	$8,967,000
Fleet Maintenance	$62,902,000	$62,543,000	$74,825,000	$74,386,000	$89,576,000	$89,040,000
Fuel	$14,335,000	$15,654,000	$17,238,000	$18,985,000	$20,852,000	$23,165,000
Total	**$135,925,000**	**$173,271,000**	**$162,609,000**	**$206,780,000**	**$195,857,000**	**$248,650,000**

The graph in Figure 25 compares the NPV of both the Base Case and ZEB Case under the different inflation scenarios tested. The analysis demonstrates that the NPV of the ZEB Case can range from $173 million to $249 million depending on the rate of inflation.

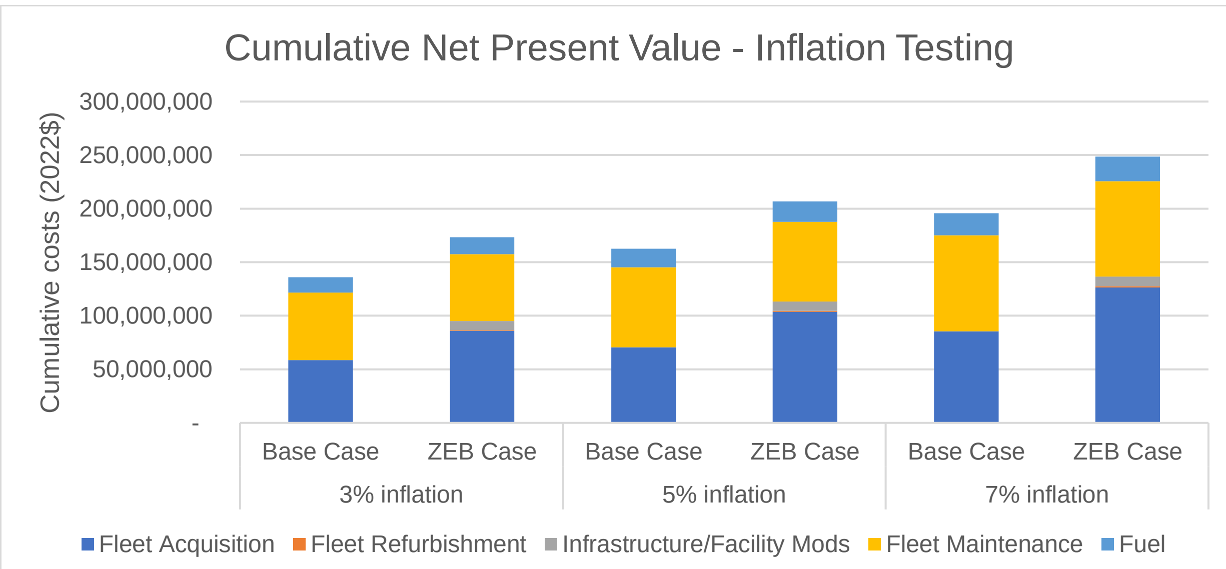


Figure 25: Cumulative NPV at different inflation rates

8.4.2 Item Sensitivity

Beyond the impacts of inflation on capital and operating expenses, we wanted to test the impacts that swings in specific cost assumptions could have on the cost of ownership for the Base Case compared to the ZEB Case. Note that the calculations below include the 7% discount rate to derive NPV, but do not include inflation for simplicity of comparison with the results in Section 8.3.

As discussed in Section 8.3, there are a range of different predictions and forecasts for ZEB capital and operating costs. The largest cost driver, other than the hydrogen fueling station, is the purchase price of an FCEB, which is currently about double the cost of a CNG equivalent. As such, we tested the impact of a much lower FCEB purchase price—ramping down from 90% of the purchase price of a CNG bus in 2026, to 50% of the purchase prices of a CNG bus in 2030 through 2040.[27] With this assumption, the total NPV of the ZEB Case is $114 million compared to $105 million for the Base Case, or about 9% more compared to the Base Case, demonstrating the significant impact that bus purchase prices will have on the total ZEB rollout budget.

Next, we tested a potential increase in the price of CNG fuel of 50%. The volatility of CNG could be a significant expense into the future and thus no longer be such a deeply discounted commodity. A 50% swing in CNG could result in a cost increase in the Base Case of $3 million; however, because CNG is a fuel in both the Base Case and the ZEB Case (while fossil fuel buses are phased out), the cost difference between the two scenarios is still about 26%, similar to the baseline analysis in Section 8.3. Thus, CNG cost swings have a minor impact in the total potential cost savings of a transition to FCEBs. Fuel-related cost savings as such would need to come from reductions in the cost of hydrogen fuel.

Another potential way to translate FCEB operations into cost savings is through maintenance cost savings due to reduced labor for maintenance work. To account for potential cost savings through reduced maintenance labor, we tested a 40% decrease in FCEBs maintenance cost per mile. A 40% decrease in maintenance labor for FCEBs decreases the NPV of the ZEB Case by $8.6 million, resulting in the ZEB Case being 20% greater than the Base Case. So, while cost savings can arise from maintenance savings, it is not as significant as the impact of cheaper FCEB purchase prices.

Table 17 summarizes the results of the sensitivity testing on the NPV of the Base Case and ZEB Case.

Table 17: Sensitivity analysis and impact on NPV

	Base Case	Base Case Diff	ZEB Case	ZEB Case Diff	ZEB vs. Base
Baseline	$105,294,000	NA	$134,963,000	NA	28%
FCEB purchase price **-50%** swing	$105,294,000	$--	$114,323,000	$(20,640,000)	9%
CNG fuel **+50%** swing	$108,348,000	$3,054,000	$136,863,000	$1,900,000	26%
FCEB maintenance **-40%** swing	$105,294,000	$--	$126,347,000	$(8,616,000)	20%

Overall, the sensitivity analysis demonstrates that changes in capital expenses for bus purchase price has the biggest impact on NPV. If FCEB prices come down in the future, the total budget required for the transition will be significantly closer to the business-as-usual scenario. Further, GCTD will continue to use competitive and formula funding sources to reduce the expenses of capital acquisitions, such as the recent application to the federal Low-No funding program for a hydrogen fueling station.

[27] https://www2.deloitte.com/content/dam/Deloitte/fr/Documents/fusions-acquisitions/fueling-the-future-of-mobility-fuel-cell.pdf

9.0 OPERATIONAL AND PLANNING CONSIDERATIONS

This section provides guidance and strategies for various operational and planning requirements when implementing FCEBs.

9.1 OPERATOR NEEDS

As FCEBs have different components and controls than conventional buses, FCEB bus performance also differs. Operations staff should also be briefed on expected range and limitations of FCEBs (such as variability in energy consumption from HVAC under different weather conditions) as well as expected refueling times and procedures. Interaction at the depot should be similar to what is done with the CNG fleet, which is fueled as part of the service line process.

The presence of hydrogen gas and the safety issues that relate to this must be addressed as well as any differences to gauges and instrumentation. An overview of the technology should be included. An additional increment of time beyond just the vehicle layout and driving characteristics needs to be added to training sessions to address the technology and unique safety considerations. Additional training time for different start-up and shut-down procedures and proper procedures regarding what to do if there is a failure on route should be accounted for as well.

Finally, ZEBs are much quieter than conventional fuel buses. Operators should be aware of this and that pedestrians or people around the bus may not be aware of its presence or that it is approaching. CARB has also stated that due to the vehicle’s lack of noise, some operators forget to turn off the bus after parking. Operator training should include a process for ensuring that this happens as well.

9.2 PLANNING, SCHEDULING, AND RUNCUTTING

FCEBs come closest to matching the current diesel bus range and APTA White Book Guidelines for heavy duty bus ranges (280-360 miles). GCTD can launch FCEBs first on routes/blocks with shorter daily distances to get a feel for them in terms of range and handling—placing them on routes that remain relatively close to the facility would be a pragmatic strategy at first. Non-revenue tests should be conducted to understand actual driving range and fuel economy, particularly as a function of route operating conditions, ambient temperature, passenger loads, and driver behavior.

9.3 MAINTENANCE NEEDS

The elimination of the internal combustion engine and powertrain will reduce operating maintenance costs in labor, material, and outsourcing. However, maintenance staff will still need to be trained on safety, scheduled maintenance, diagnostics, and repair of multiple systems that may be new to them. While a smaller high voltage battery installation is present and will require inspection and eventual changeout, the inspection and possible replacement of hydrogen fuel cell apparatus may be necessary. Tanks will have the same ruggedness as CNG products and should fulfill in excess of the heavy-duty bus 12-year service design life cycle.

According to FCEB OEMs, FCEB technicians should receive training on:

- Hydrogen systems, including fuel cell engine
- Hydrogen fuel system
- Hydrogen detection and fire suppression systems
- Hydrogen cooling system package

9.4 REFUELING CYCLE

Fueling a FCEB is very similar to fueling a traditional CNG bus. Attaching a dispenser nozzle to the vehicle and fueling for ~8-12 minutes will yield a full tank. The hydrogen nozzle is completely sealed to the bus while refueling due to the high-pressure delivery method (above 350 bars). The operation of the nozzle and the pump are virtually the same but specific training needs to be provided to staff for safety reasons.

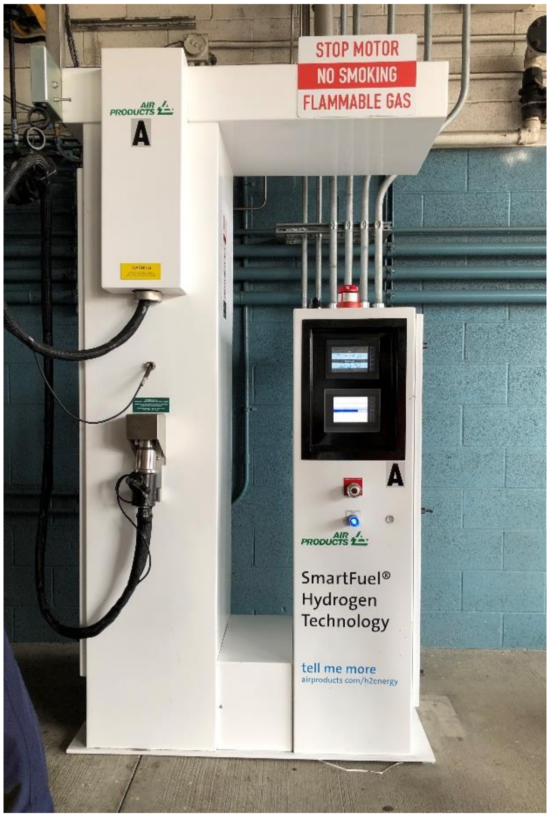


Figure 26: Hydrogen fueling dispenser at OCTA for heavy-duty transit buses

Overall, the concept design for the hydrogen fueling station is for two low-pressure dispensers (H35) in the current fueling lanes for 35-ft and 40-ft FCEBs to create a seamless transition to ZEBs by maintaining the current practices around servicing and fueling procedures for GCTD. Additionally, the design considers one high-pressure dispenser (H70) to refuel vans and cutaways. The pressure difference between H35 and H70 dictates how much hydrogen can be stored in the tanks and is limited by the design specifications of each vehicle. While a van or cutaway could refuel at H35, they would only get half the tank fill capacity. However, a 35-ft or 40-ft bus is unable to fill using a H70 dispenser. Based on the design of the hydrogen infrastructure and the forecasted demand for hydrogen, we estimate that a delivery of hydrogen fuel would be required every 2-3 days to replenish the storage tank.

10.0 WORKFORCE TRAINING

Transitioning to zero-emission vehicles presents complexities for all areas of transit operations including scheduling, maintenance, and yard operations. GCTD has specified a fleet replacement schedule for their current fleet (fixed route and paratransit services) and aims to transition to a 100% ZEB fleet by 2040. To ensure a qualified workforce is ready to support ZEB deployment it will be essential to provide effective training and align workforce development with the fleet transition timeline. This is summarized in Figure 27 below.

Year	ZEB Fleet Totals	Training
2023-2024	35-ft ZEB total: 0 40-ft ZEB total: 5 ZE DR total: 13	Tier 1: All employees Tier 3: facility and maintenance mechanics
2025-2026	35-ft ZEB total: 0 40-ft ZEB total: 7 ZE DR total: 23	Refresher training
2027-2028	35-ft ZEB total: 2 40-ft ZEB total: 9 ZE DR total: 28	Refresher training
2029-2030	35-ft ZEB total: 2 40-ft ZEB total: 16 ZE DR total: 32	Tier 1 & 3: new employees Refresher training: existing employees
2031-2032	35-ft ZEB total: 2 40-ft ZEB total: 25 ZE DR total: 32	Tier 1 & 3: new employees Refresher training: existing employees
2033-2034	35-ft ZEB total: 2 40-ft ZEB total: 36 ZE DR total: 32	Tier 1 & 3: new employees Refresher training: existing employees
2035-2036	35-ft ZEB total: 2 40-ft ZEB total: 46 ZE DR total: 32	Refresher training
2037-2038	35-ft ZEB total: 2 40-ft ZEB total: 55 ZE DR total: 32	Tier 1 & 3: new employees Refresher training: existing employees
2039-2040	35-ft ZEB total: 8 40-ft ZEB total: 61 ZE DR total: 32	Refresher training

Figure 27: GCTD training timeline

10.1 CURRENT PLANS

GCTD is committed to training existing employees to retain staff and develop a qualified ZEB staff and has already implemented training opportunities. For example, GCTD worked with the SEIU Mechanical

Unit to create a mentorship program that allows less experienced mechanics to learn from experienced mechanics. In addition, bus repair and electrical training is provided via the California Transit Training Consortium (CTTC), which includes high-level ZEB bus safety and operations. Mechanics also receive training on GCTD's non-revenue electric vehicles[28].

To facilitate a successful transition to a 100% ZE fleet, GCTD identified their primary training needs, which include[29]:

- Operational and safety training
- Technical training on fuel cell operations
- Technical training on battery-electric drive systems
- Tools, PPE, and equipment training
- Operational safety training on hydrogen fueling stations

Acquiring the following tools and safety materials was also identified as a top priority to ensure successful in-house ZEB maintenance and management[30]:

- Operational training module
- High voltage interface box
- Portable leak tester
- Virtual training module
- High voltage insulated tools
- Insulated PPE
- Electrical safety hooks
- Arc flash clothing

Taking these needs into consideration, GCTD developed a plan for initial training. Within one month of receiving the first vehicles, all GCTD mechanics, workers, specialists, bus operators, and office staff will attend the one-day OEM Tier 1 training. Within six weeks, facility and maintenance mechanics will receive Tier 3 training. Tier 1 and Tier 3 courses are summarized in Table 18.

Table 18: OEM tier 1 & tier 3 training

Tier	Course
Tier 1	Fuel cell 101
	Fuel cell system basics
	Hydrogen safety
	Servicing basics and schedule
	Preventative maintenance
Tier 3	Introduction to system schematics
	Corrective maintenance
	Diagnostics
	Basic and advanced troubleshooting

[28] GCTD FTA ZE Fleet Transition Plan, pg. 13
[29] GCTD FTA ZE Fleet Transition Plan, pg. 14-15
[30] GCTD FTA ZE Fleet Transition Plan, pg. 15

Tier	Course
	Integration basics
	Remote data analysis

GCTD also created a framework of potential training methods and strategies to bolster their workforce development and successfully transition to a 100% ZEB fleet, summarized in Table 19 below.

Table 19: Potential training methods

Plan	Description
Train-the-trainer	Small numbers of staff are trained, and subsequently train colleagues. This maintains institutional knowledge while reducing the need for external training.
Vendor training from New Flyer and fueling vendor	OEM training provides critical, equipment-specific operations and maintenance information. Prior to implementing ZEB technology, GCTD staff will work with the OEMs to ensure all employees complete necessary training.
Retraining & refresher training	Entry level, intermediate, and advanced continuous learning opportunities will be offered to all GCTD staff.
ZEB training from other transit agencies	GCTD plans to leverage the experience of agencies who were early ZEB adopters, such as the ZEB University program offered by AC Transit.
National Transit Institute (NTI) training	NTI offers zero-emissions courses such as ZEB management and benchmarking and performance.
Local partnerships and collaborations	GCTD works with local schools to showcase potential careers in bus and facilities management to students.
Professional associations	Associations such as the Zero Emission Bus Resource Alliance offer opportunities for sharing and lessons learned across transit agencies.

10.2 FUNDING

GCTD plans to use $764,990 of FY2022 Low-No Grant funding (if awarded) to fund the initial steps of workforce development.[31] Training and budget details are summarized in Table 20.

Table 20: FY2022 Low-No training funding

Training Resource/Strategy	FY2022 Low-No Budget
Bus OEM operator, maintenance, first responder training	$84,490
Operational and safety training for operators, service workers, and other staff	$50,000
Technical training for mechanics on hydrogen fuel cell operations and battery systems	$100,000
Regional Consortium (specific OEM training, specialized training modules for continuing education, hosting training seminars for regional providers, specialized training on hydrogen fuel station maintenance)	$480,500

[31] GCTD FTA ZE Fleet Transition Plan, pg. 16

Training Resource/Strategy	FY2022 Low-No Budget
Operational and safety training for facility mechanics, building maintenance workers, and building mechanics	$50,000
Total	**$764,990**

10.3 ADDITIONAL CONSIDERATIONS

In addition to the plan outlined above, OEM recommendations from the California statewide contract procurement for ZEBs can provide general guidance for training and workforce development (Table 21).

With a focus on safety, it is highly recommended that all local fire and emergency response departments be given training as the layout, componentry, safety devices, and other features on the new technology. This should reoccur every few years. The specific frequency can be dependent on agency discretion.

First-responder training is also recommended due to the nature of the new technology, particularly fire and emergency personnel. Additionally, training for staff involved in related functions like facility maintenance, tow truck providers, and utility service works might be necessary.

Although not specifically training, dry runs on each route should be done with the ZEBs to validate range and identify opportunities for coasting and adjustment to the vehicle's acceleration profile. In turn, changes in timing points may be necessary or beneficial for all parties. This should be done with planning staff on board and schedules should be adjusted as appropriate. In tandem, based on having several vehicle types particularly during transition, dispatching training and instructions to staff on parking routines will be necessary.

Table 21: OEM recommendations from the California ZEB contract procurement

Training Type	Course	Sessions	Session Hours
Operator	Drive training	4	4
	Overall vehicle/system orientation	20	2
Maintenance/Technician	Preventative maintenance	4	8
	Electrical/electronic	6	8
	Multiplex	4	3x8 days
	HVAC	4	4
	Brakes	4	4
	Energy storage system, lithium-ion battery and energy management hardware and software training	6	8
	Electric drive/transmission	6	8
	H2 system – fuel cell engine	6	8

Training Type	Course	Sessions	Session Hours
	H2 fuel system	4	8
	H2 detection and fire suppression systems	4	8
	H2 cooling system package	6	4

11.0 POTENTIAL FUNDING SOURCES

As a cost driver for transit agencies, funding the ZE transition will require external financial aid. Due to the long timeframe over which buses will be procured and infrastructure will be constructed, it is imperative that GCTD constantly monitors existing funding and financing opportunities and is aware of when new sources are created. Below are major current programs available for ZEB transition (Table 22).

Table 22: Grants and potential funding options for ZEB transition

Type	Agency	Fund/Grant/Program	Description	Applicability & Details
Federal	Federal Transportation Administration (FTA)	Low or No Emission Program (Low-No Program) (5339(c))	Low-No provides competitive funding for the procurement of low or no emission vehicles, including the leasing or purchasing of vehicles and related supporting infrastructure. This has been an annual program under the FAST Act since FY2016 and is a subprogram of the Section 5339 Grants for Bus and Bus Facilities. There is a stipulation for a 20% local match.	In FY2021 the FTA awarded $180 million to 49 projects for the Low-No program.[32] In FY2021, Golden Empire Transit District received $3 million to construct a permanent hydrogen fueling station to support its electric bus operations.[33] $1.1 billion has been announced for FY2022 projects.[34] GCTD applied for a Low-No grant in FY2022.
		Buses and Bus Facilities Program (5339(a) formula, 5339(b) competitive)	Grants applicable to rehab buses, purchase new buses, and invest and renovate related equipment and facilities for low or no emission vehicles or facilities. A 20% local match is required.	FY2021 5339 funding totaled $409 million in grants to 70 projects in 39 states. $372 million has been announced for FY2022 grants. [35]
		Urbanized Area Formula Grants (5307)	5307 grant funding makes federal resources available to urbanized areas for transit capital and operating assistance. Eligible activities include capital investments in bus and bus-related activities such as replacement, overhaul and rebuilding of buses. The federal share is not to exceed 80% of the net project cost for capital expenditures. The federal share may be 90% of the cost of vehicle-related equipment attributable to compliance with the Clean Air Act.	Typically, the MPO or another lead public agency is the direct recipient of these funds and distributes these to local transit agencies based on TIP allocation. Agencies can allocate these funds for the purchase of ZEBs.

[32] https://www.transit.dot.gov/funding/grants/fiscal-year-2021-low-or-no-emission-low-no-bus-program-projects
[33] https://www.transit.dot.gov/funding/grants/fiscal-year-2021-low-or-no-emission-low-no-bus-program-projects
[34] https://www.transit.dot.gov/lowno#:~:text=On%20March%207%2C%202022%2C%20FTA,improve%20air%20quality%20and%20combat
[35] https://www.transit.dot.gov/bus-program

Type	Agency	Fund/Grant/Program	Description	Applicability & Details
	Federal Highway Administration (FHWA)	Congestion Mitigation and Air Quality Improvement Program (CMAQ)	The Congestion Mitigation and Air Quality Improvement (CMAQ) Program provides funds to states for transportation projects designed to reduce traffic congestion and improve air quality, particularly in areas of the country that do not attain national air quality standards.	Projects that reduce criteria air pollutants regulated from transportation-related sources, including ZEBs.
	United States Department of Transportation (USDOT)	Local and Regional Project Assistance Program (RAISE)	Previously known as BUILD and TIGER, RAISE is a discretionary grant program aimed to support investment in infrastructure. RAISE funding supports planning and capital investments in roads, bridges, transit, rail, ports, and intermodal transportation. A local match is required.[36]	FY2020 provided $1 billion in BUILD grants to 70 projects with a stipulation requiring 50% of funding for projects in rural areas. In FY2022, $2.28 billion in funding was announced for the RAISE Grant Program. [37]
State	California Air Resources Board (CARB)	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Program (HVIP)	Voucher program created in 2009 aimed at reducing the purchase cost of zero-emission vehicles. A transit agency would decide on a vehicle, contact the vendor directly, and then the vendor would apply for the voucher.	$430 million in funding for the FY21-22 year was announced in March 2022.[38] Hydrogen fuel cell vehicles are eligible for HVIP but must not have plug-in capacity.[39]
		Carl Moyer Memorial Air Quality Standards Attainment Program	The Carl Moyer Program provides funding to help procure low-emission vehicles and equipment. It is implemented as a partnership between CARB and local air districts.	Transit buses are eligible for up to $80,000 funding.

36 https://www.transportation.gov/RAISEgrants/about
37 https://www.transportation.gov/sites/dot.gov/files/2022-04/RAISE_2022_NOFO_AMENDMENT_1.pdf
38 https://californiahvip.org/funding/
39 https://californiahvip.org/wp-content/uploads/2022/03/HVIP-FY21-22-Implementation-Manual-03.15.22.pdf

Type	Agency	Fund/Grant/Program	Description	Applicability & Details
		Volkswagen Environmental Mitigation Trust Funding	VW's settlement provides nearly $130 million for zero-emission transit, school, and shuttle bus replacements.	Transit may be eligible for up to $65 million. Applications are open for transit agencies and are processed on a first come, first serve basis. Maximum: $400,000 per FCEB and maximum of $3,250,000 total funding per agency.[40]
		Sustainable Transportation Equity Project (STEP)	STEP was a pilot that took a community-based approach to overcoming barriers to clean transportation. The future of STEP is currently being determined by CARB and stakeholder groups through the FY22-23 Funding Plan and Three-Year Plan for Clean Transportation Incentives.[41]	There are two different grant types: Planning and Capacity Building Grants (up to $1.75 million for multiple grantees) and Implementation Grants (up to $17.75 million for between one and three grantees). Lead applicants must be a CBO, federally-recognized tribe, or local government representing a public transit agency. Award amounts ranged from $184,000 to a maximum of over $7 million.[42]
	California Transportation Commission (CTC)	SB1 Local Partnership Program (LPP)	The Local Partnership Program provides funding to counties, cities, districts and regional transportation agencies to improve aging infrastructure, road conditions, active transportation, transit and rail, and health and safety benefits. Funds are distributed through competitive and formulaic components.[43]	To be eligible, counties, cities, districts, and regional transportation agencies must have approved fees or taxes dedicated solely to transportation improvements. $200 million is available annually. In Ventura County, a transportation sales tax measure may be placed on voter ballots for the November 2022 election. If passed, the LPP will be a potential future funding option. [44]
		Solutions for Congested Corridors Program (SCCP)	The SCCP includes programs with both formula and competitive funds. Funding is available to projects that make specific performance improvements and are a part of a multimodal comprehensive corridor plan designed to reduce congestion in highly traveled corridors by providing more transportation choices for residents, commuters, and visitors.	Improvements to transit facilities are eligible projects. Cycle 2 funding of $500 million covers two years (FY2022 and FY2023). To submit a SCCP application, the applicant needs to know exactly what sources will be funding the project and when the funds will be used, as well as which project phase they will be used for. Total estimated funding: $500,000,000 for FY22-23[45]

[40] http://vwbusmoney.valleyair.org/documents/FAQ.pdf
[41] https://ww2.arb.ca.gov/lcti-step
[42] https://ww2.arb.ca.gov/news/grant-awards-announced-new-195-million-pilot-funding-equitable-clean-transportation-options
[43] https://catc.ca.gov/programs/sb1/local-partnership-program
[44] https://www.vcstar.com/story/news/local/2021/10/22/group-proposing-transit-sales-tax-measure-countys-2022-ballot/5988391001/
[45] https://www.grants.ca.gov/grants/solutions-for-congested-corridors-program/

Type	Agency	Fund/Grant/Program	Description	Applicability & Details
	California Department of Transportation (Caltrans)	SB1 State of Good Repair	SGR funds are formula funds eligible for transit maintenance, rehabs, and capital programs. Agencies receive yearly SB1 SGR funding through their MPO, based on population and farebox revenues.	Agencies can decide to devote its portion of SB 1 funds to ZEB transition.
		Low Carbon Transit Operations Program (LCTOP)	The LCTOP provides capital assistance to transit agencies in order to reduce greenhouse gas emissions and improve mobility. 5% and 10% of the annual Cap and Trade auction proceeds fund this program.	Many agencies are already recipients of these funds and can use these funds to purchase ZEBs and related equipment.
		Transit and Intercity Rail Capital Program (TIRCP)	The TIRCP was created to fund capital improvements that reduce emissions of greenhouse gases, vehicle miles traveled, and congestion through modernization of California's intercity, commuter, and rail, bus, and ferry transit systems.[46]	The five cycles of TIRCP funding have awarded $6.6 billion in funding to nearly 100 projects throughout California. In 2022, the Humboldt Transit Authority (HTA) received $38,743,000 to procure 11 hydrogen fuel cell buses, design a hydrogen fueling station, and design and construct an intermodal transit and housing center.[47]
		State Transportation Improvement Program (STIP)	The STIP is a five-year plan for future allocations of certain state transportation funds including state highway, active transportation, intercity rail, and transit improvements. The STIP is updated biennially in even-numbered years. [48]	ZEB procurement could compete for STIP funding. The 2022 STIP was adopted in March 2022 and included $796 million in available funding. [49] Funding is distributed via a formula for a variety of projects.

[46] https://calsta.ca.gov/subject-areas/transit-intercity-rail-capital-prog
[47] https://calsta.ca.gov/-/media/calsta-media/documents/tircp---program-of-projects-as-of-july-2022---cycle-5-only-a11y.pdf
[48] https://catc.ca.gov/programs/state-transportation-improvement-program
[49] https://catc.ca.gov/-/media/ctc-media/documents/programs/stip/2022-stip/2022-adopted-stip-32522.pdf

Type	Agency	Fund/Grant/Program	Description	Applicability & Details
		Transportation Development Act (Mills-Alquist-Deddeh Act (SB 325))	The TDA law provides funding to improve existing public transportation services and encourage regional transportation coordination. There are two funding sources: the Local Transportation Fund (LTF) and the State Transit Assistance (STA) fund.[50]	Funding opportunities include transportation program activities, pedestrian and bike facilities, community transit services, public transportation, and bus and rail projects.
	California Energy Commission	Clean Transportation Program (Alternative and Renewable Fuel and Vehicle Technology Program)	The California Energy Commission's Clean Transportation Program provides funding to support innovation and acceleration of development and deployment of zero-emission fuel technologies. A local match is often required.	The Clean Transportation Program provides up to $100 million annually for a variety of renewable and alternative fuel transportation projects throughout the state, including specific projects for heavy-duty public transit buses. In 2021, between $4 million and $6 million were awarded to the following transit agencies to assist with zero-emission transit fleet infrastructure deployment: Anaheim Transportation Network ($5 million), LADOT ($6 million), Sunline Transit ($5 million), and North County Transit District ($4 million)
	Department of Housing and Community Development	Affordable Housing and Sustainable Communities Program	The AHSC Program funds land use, housing, and transportation projects to support development that reduces GHG emissions. The program provides both grants and loans that reduce GHG emissions and benefit disadvantaged communities through increasing accessibility via low-carbon transportation. $405 million in available funds was announced in 2021.[51] The maximum award amount is not to exceed $30 million per project, with a minimum award of at least $1 million.[52]	Sustainable transportation infrastructure projects, transportation-related amenities, and program costs (including transit ridership) are eligible activities. Agencies can use program funds for assistance in construction or modification of infrastructure for ZEB conversion as well as new vehicle purchases.
Local	Ventura County Air Pollution Control District	Clean Air Fund (CAF)	The CAF provides financial support for projects that reduce emissions of greenhouse gases and the global warming impact of carbon emissions via mitigation. [53]	Approximately $25,000 is available for project funding each year on January 1st. Projects are reviewed and recommended based on their ability to reduce air pollution in Ventura County. [54]

[50] https://dot.ca.gov/programs/rail-and-mass-transportation/transportation-development-act
[51] https://www.hcd.ca.gov/grants-funding/active-funding/ahsc/docs/final_ahsc_nofa_round_6.pdf
[52] https://www.hcd.ca.gov/affordable-housing-and-sustainable-communities#:~:text=Communities%20Program%20(AHSC)-,Affordable%20Housing%20and%20Sustainable%20Communities%20Program%20(AHSC),(%22GHG%22)%20emissions.
[53] http://www.vcapcd.org/pubs/Incentive-Programs/What-is-the-Clean-Air-Fund-Program.pdf
[54] http://www.vcapcd.org/pubs/Incentive-Programs/What-is-the-Clean-Air-Fund-Program.pdf

Type	Agency	Fund/Grant/Program	Description	Applicability & Details
	Ventura County Regional Energy Alliance (VCREA)	EV Ready Communities Challenge Grant: Ventura County EV Blueprint	VCREA and Community Environmental Council (CEC) are creating a plan for electrifying transportation in Ventura County. The second phase of funding that will go towards EV charging installations in Ventura County if approved. [55]	
Other		Low Carbon Fuel Standard (LCFS credits)	LCFS credits are not necessary funding to be applied for; rather, they are offset credits that are traded (through a broker) to reduce operating costs.	Once ZEBs are acquired and operating, agencies can collect LCFS and 'sell' them to reduce operating costs of ZEBs. Both hydrogen and electricity used as fuels are eligible for LCFS credits. Credit prices range, but average credit price between 2016 and 2019 was between $65 and $200 per credit, with an average of $10,000 per vehicle.
		Transportation Development Credits	Although they are not funds for projects, Transportation Development Credits, also called "Toll Credits", satisfy the federal government requirement to match federal funds.[56]	Toll credits provide a credit toward a project's local share for certain expenditures with toll revenues. FHWA oversees the toll credits within each state.[57]

[55] https://www.vcenergy.org/electric-vehicle-blueprint/
[56] https://dot.ca.gov/-/media/dot-media/programs/rail-mass-transportation/documents/f0010121-toll-credit-fact-sheet.pdf
[57] https://dot.ca.gov/-/media/dot-media/programs/rail-mass-transportation/documents/f0009899-2-toll-credits-fact-sheet-a11y.pdf

12.0 SERVICE IN DISADVANTAGED COMMUNITIES

CARB defines Section F of the rollout plan as “Providing Service in Disadvantaged Communities” based on disadvantaged communities as identified by CalEnviroScreen, an online mapping tool developed by the Office of Environmental Health Hazard Assessment (OEHHA). The tool identifies (at the census tract level) the state’s most pollution-burdened and vulnerable communities based on geographic, socioeconomic, public health, and environmental hazard criteria.

ICT provisions require that transit agencies describe how they are planning to deploy ZEBs in disadvantaged communities by outlining the location of the disadvantaged community (census tract) where the ZEB will be deployed, how many ZEBs, and in what year the ZEBs will be deployed.

Figure 28 shows that there are eight census tracts that are classified as ‘disadvantaged communities’ according to CalEnviroScreen 4.0, and Table 23 details the routes that operate within or touch these census tracts.

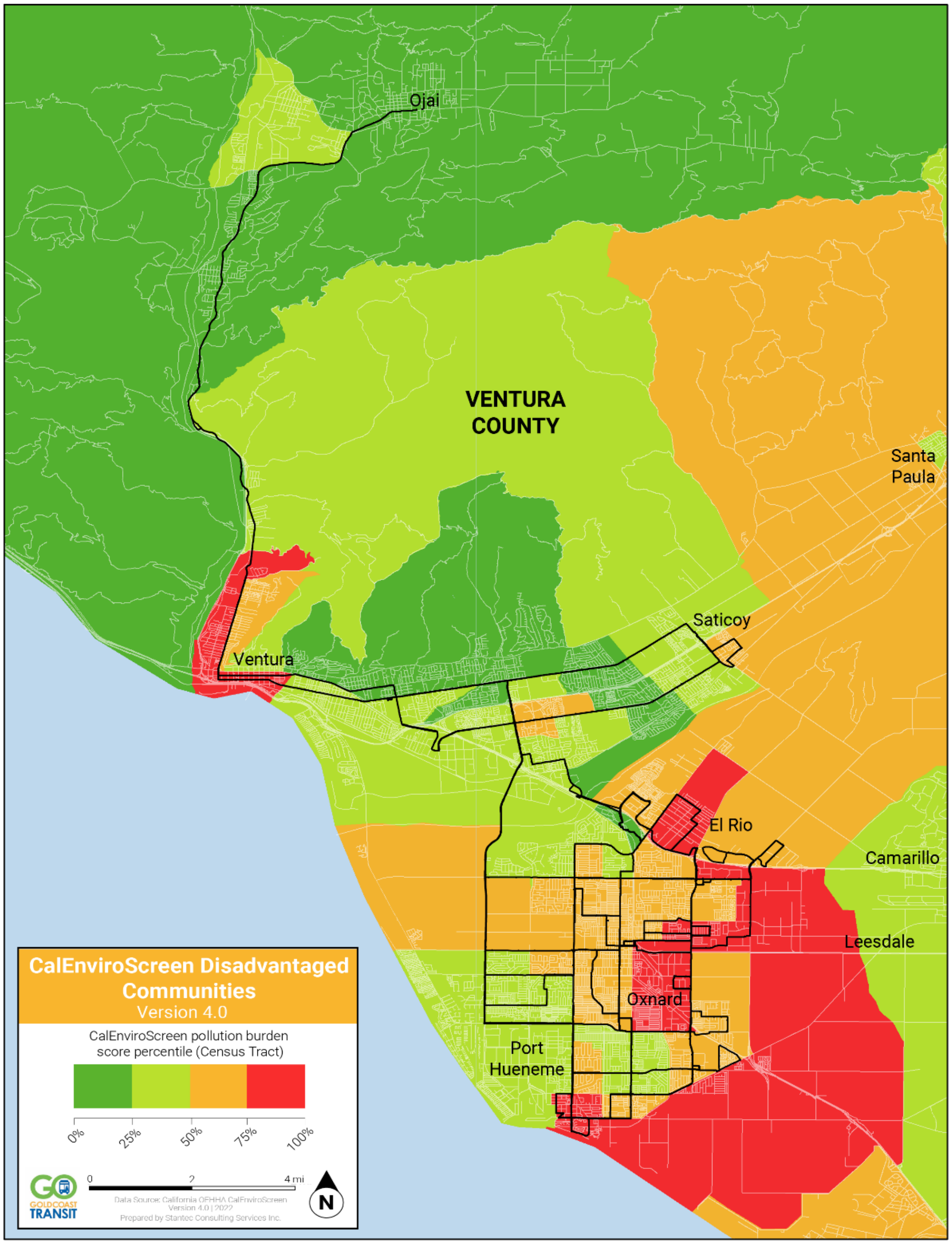


Figure 28: CalEnviroScreen disadvantaged communities in GCTD service area

Table 23: Disadvantaged communities - census tracts and routes

Census Tract ID	Community	Route(s)
6111004902	Oxnard	2, 4A, 4B, 15, 17, 19
6111009100	Oxnard	2, 4A, 4B, 8, 17, 19
6111004400	Port Hueneme	1A, 1B, 23
6111003900	Oxnard	3, 7, 8
6111002300	Ventura	6, 16
6111002400	Ventura	6, 16
6111005003	El Rio	15, 17
6111004715	Oxnard	7

While census tracts that are considered disadvantaged are dispersed throughout the service area, there is a concentration in Oxnard (affecting routes 2, 3, 4A, 4B, 7, 8, 17, and 19). Disadvantaged communities are also seen in Ventura (affecting routes 6 and 16) and Port Hueneme (affecting routes 1A, 1B, and 23), and El Rio (affecting routes 15 and 17).

To make the biggest positive impact on disadvantaged communities in the service area, GCTD can prioritize ZEB deployment along route 17, as this route touches three different disadvantaged communities. However, GCTD can achieve this goal by deploying ZEBs first on any routes except routes 5, 10, 11, and 21, as these routes do not touch or run through any CalEnviroScreen-defined disadvantaged communities.

13.0 GHG IMPACTS

Based on the ZEBDecide modeling of greenhouse gas (GHG) emissions, GCTD's CNG/gasoline fleet emits ~6,300 tons of GHGs per year. Upstream GHGs related to CNG and gasoline production add another ~4,800 tons of GHGs per year for a total carbon footprint of over 11,100 tons per year (Table 24).[58]

By operating ZEBs, GCTD will be able to completely eliminate tailpipe GHGs and other harmful emissions, providing a clean, quiet ride for operators and passengers, while also eliminating emissions linked to respiratory diseases from the neighborhoods GCTD serves. Nonetheless, the current production of hydrogen does result in GHG emissions and is not a completely 'carbon-free' process. Residual GHGs resulting from the carbon-intensity of generating hydrogen through a process that is 33% green (carbon neutral) and the remainder via SMR, based on GCTD's projected hydrogen demand, can emit about 5,700 tons of GHGs per year (Table 25). Overall, however, this reduces GCTD's fleet-related GHG footprint by nearly 50% (Table 25).

Table 24: Annual Emission in Tons of CO_2 per year for the GCTD fleet by service type

	Zero Emissions		CNG/Gasoline		
	Fixed Route Fleet	**Demand Response Fleet**	**Fixed Route Fleet**	**CNG Demand Response Fleet**	**Gasoline Demand Response Fleet**
Fleet tailpipe emissions (ton CO_2/year)	-	-	5,627	394	284
Upstream emissions (ton CO_2/year)	4,960	732	3,510	246	1,044
Total Ton CO_2/year	**4,960**	**732**	**9,137**	**640**	**1,329**
Total Ton CO_2/year	**5,692**		**11,105**		

[58] All GHG calculations are presented in tons (not metric tons) of CO_2 equivalent, which is calculated using the short-term 20-year global warming potential of CO_2, methane, black carbon, and particulate matter.

Table 25: Summary of Annual Emissions for the GCTD fleet

	Fleet Emissions (Ton CO_2/year)
FCEBs fleet	5,692
CNG/Gasoline Fleet	11,105
Difference	**5,414**
	49%

As presented in Figure 29, implementing a ZEB fleet will eliminate emissions equivalent to removing 1,167 passenger vehicles per year or reducing emissions from 682 households in a year[59].

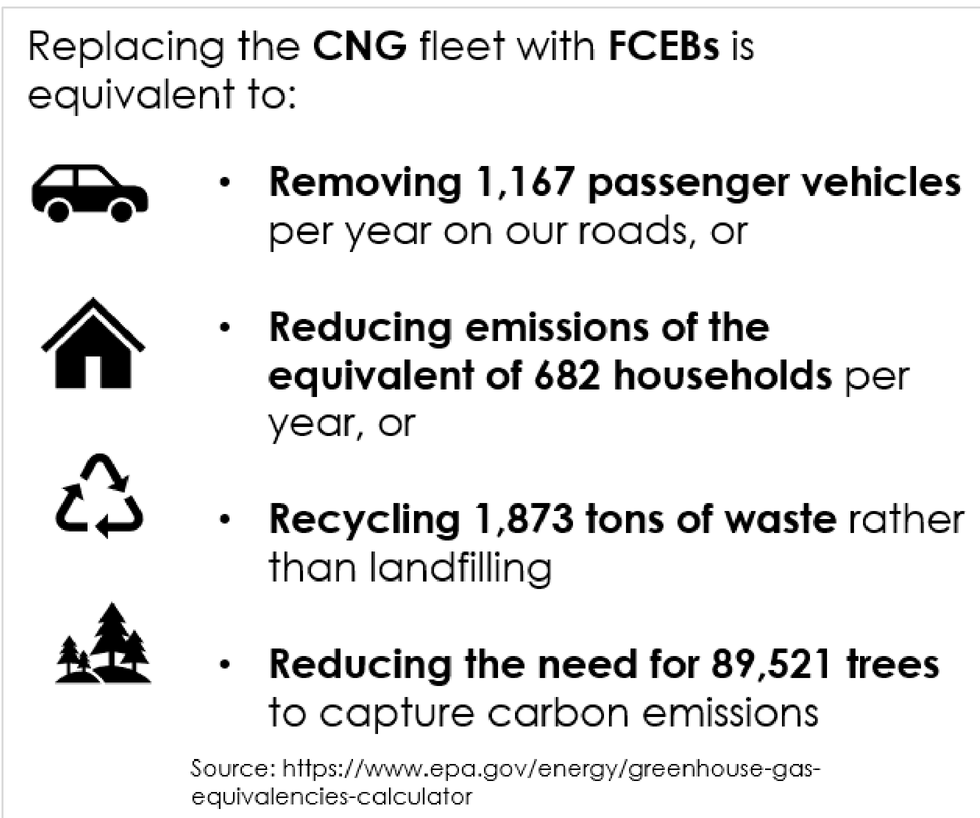


Figure 29: Equivalent benefits of implementing a FCEB fleet at GCTD.

[59] https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

14.0 OTHER TRANSITION ITEMS

14.1 JOINT ZEB GROUP AND ASSESSMENT OF MULTI-OPERATOR VEHICLE PROCUREMENT

According to ICT regulation, transit agencies can pool resources when acquiring ZEB infrastructure if they:

- Share infrastructure
- Share the same MPO, transportation planning agency, or Air District
- Are located within the same Air Basin

The Southern California Association of Governments (SCAG) is the MPO for Ventura County and provides regional transportation funding and planning for Ventura County, Los Angeles County, Orange County, Imperial County, Riverside County, and San Bernardino County. GCTD's service area is located within the Ventura County APCD and South-Central Coast Air Basin. Table 26 lists the agencies that operate fixed route transit services within Ventura County. These agencies also are within the same air basin and air district. While GCTD could theoretically partner with any transit agency in the SCAG region, the list was limited to Ventura County due to geographic proximity and service area overlaps that could make a joint group feasible and beneficial.

Table 26: Other bus transit agencies in Ventura County

Agency	Total revenue vehicles[60]	ZEB Choice	Notes
Gold Coast Transit District	***87***	***Hydrogen***	
Ventura County Transportation Commission[61]	51	TBD	ZEB plan currently underway.
Simi Valley Transit	21	BEB	2019 SRTP notes BEBs are the likely technology option, but a full ZEB study is recommended.
Camarillo Area Transit	19	TBD	
Thousand Oaks Transit[62]	38	TBD	No ZEB plan yet, but SCAG's 2021 FTIP noted the purchase of electric vehicles by Thousand Oaks transit to replace existing buses.
Moorpark City Transit	5	TBD	

[60] Based on NTD 2020 data.
[61] Includes both Valley Express Bus and VCTC Intercity.
[62] Also includes Kanan Shuttle and ECTA InterCity Dial-A-Ride.

Agency	Total revenue vehicles[60]	ZEB Choice	Notes
Ojai Trolley	6	BEB	ZEB plan currently underway.

While GCTD could potentially partner with any of these transit agencies to form a joint ZEB group, it would make the most sense to partner with other agencies moving forward with hydrogen as their ZEB technology choice to potentially share in the costs associated with hydrogen fueling infrastructure. As the majority of the other agencies operating in the county are small municipal agencies utilizing vehicle types with fewer hydrogen options, such as cutaways and trolleys, it might not be realistic to partner with other agencies for this reason. Nonetheless, GCTD and Ojai Trolley Service have formed a strategic partnership to collaborate with the ZEB transition in that they

Regardless of whether it makes sense to explore formation of a joint ZEB group or not, GCTD should remain in constant communication with other Ventura County agencies to understand how the agencies can work together to leverage resources and coordinate efforts on a regional level.

Another recommended strategy is developing a multi-operator vehicle procurement group. That is, GCTD could join with any of the agencies outlined above to produce common specifications for ZEBs, thus potentially driving down the purchase costs of ZEBs. Leveraging joint procurement through the CalACT/MBTA purchasing cooperative is a prudent approach, as the Cooperative offers a variety of ADA compliant vehicles like vans and cutaways; currently, ZE options are limited, however. Most judiciously, GCTD and other operators may wish to encourage OEMs to develop vehicles with longer ranges and more hydrogen options, especially vehicle types like cutaways and vans.

14.2 CONSIDERATIONS FOR PARTNERSHIPS

As other transit partners in the region are developing their own ZEB plans and rollout strategies, there are opportunities for partnership that can benefit all parties and help to facilitate seamless regional ZEB infrastructure. With this in mind, GCTD's hydrogen fueling station was designed to serve regional partners. For example, VCTC Intercity vehicles that travel through western Ventura County would be able to refuel at GCTD's hydrogen fueling station. VCTC is currently in the process of developing its own ZEB plan, and this opportunity will be explored in greater detail as that plan progresses. GCTD can also explore more ways to collaborate with its regional transit partners, such as exploring joint grant opportunities for ZEB vehicles and infrastructure.

14.3 CHANGE MANAGEMENT

Because the ZEB transition and implementation is an agencywide endeavor that also includes the need to actively consider utilities as a stakeholder and partner, an agencywide approach to the rollout is required. Additionally, the union representing the bus operators and maintenance technicians should also be included due to the large role they will play in the success of the ZEB transition and implementation. Thus, it is prudent for GCTD to form a steering committee or task force composed of staff from each major functional department and union representation to help ensure the impact of ZEBs are considered for each. Using the rollout plan as a guide, the task force can develop action items, performance indicators, and risk assessments. The task force should also name a leader who acts as a champion for the ZEB conversion within the agency and to external stakeholders. Communication will be critical during the transition to ensure customers are made aware of potential disruptions and changes to bus operations. ZEB conversion also offers an excellent marketing opportunity for GCTD to promote its climate commitments.

15.0 PHASING AND IMPLEMENTATION

Table 27 provides an overview of the phasing plan for GCTD's ZEB rollout strategy. Note that expenses are in the year of cost incurred. See Table 9 for more details regarding the fleet replacement schedule.

Table 27: ZEB implementation phasing plan, FY2023-2040

Year	Construction – maintenance facility	Fixed-Route ZEB Fleet Procurements	Demand Response ZE Fleet Procurements	Training: operators, maintenance staff, technicians	Training - other	Capital expenses (2022$)	O&M expenses (2022$)	Total expenses (2022$)
FY2023	Construct and install hydrogen fueling equipment for high and low pressure refueling (H35 and H70). Installation of hydrogen gas detection system in maintenance bays and upgrade of ventilation system.	0 35-ft 5 40-ft	6 vans & cutaways	Tier 1 & tier 3 OEM training	Tier 1 OEM training for all other staff	$16,646,000	$5,196,000	$21,842,000
FY2024		0 35-ft 0 40-ft	7 vans & cutaways	Annual refreshers	No activity	$3,448,000	$4,808,000	$8,256,000
FY2025		0 35-ft 0 40-ft	2 vans & cutaways	Annual refreshers	Local fire and emergency response department introduction to new technology	$1,899,000	$4,559,000	$6,458,000
FY2026		0 35-ft 2 40-ft	8 vans & cutaways	Annual refreshers	No activity	$4,821,000	$4,236,000	$9,057,000
FY2027		2 35-ft 0 40-ft	0 vans & cutaways	Annual refreshers	Local fire and emergency response department introduction to new technology	$3,989,000	$3,979,000	$7,968,000
FY2028		0 35-ft 2 40-ft	5 vans & cutaways	Annual refreshers	No activity	$4,824,000	$3,707,000	$8,531,000
FY2029		0 35-ft 5 40-ft	0 vans & cutaways	Annual refreshers	Local fire and emergency response department introduction to new technology	$3,401,000	$3,513,000	$6,914,000

Year	Construction – maintenance facility	Fixed-Route ZEB Fleet Procurements	Demand Response ZE Fleet Procurements	Training: operators, maintenance staff, technicians	Training - other	Capital expenses (2022$)	O&M expenses (2022$)	Total expenses (2022$)
FY2030		0 35-ft 2 40-ft	10 vans & cutaways	Tier 1 & tier 3 OEM training for new staff	Tier 1 OEM training for all other staff	$2,503,000	$3,443,000	$5,946,000
FY2031		0 35-ft 5 40-ft	7 vans & cutaways	Annual refreshers	No activity	$3,805,000	$3,297,000	$7,102,000
FY2032		0 35 -ft 4 40-ft	2 vans & cutaways	Tier 1 & tier 3 OEM training for new staff	Tier 1 OEM training for all other staff	$2,517,000	$3,259,000	$5,776,000
FY2033		0 35-ft 4 40-ft	8 vans & cutaways	Tier 1 & tier 3 OEM training for new staff	Tier 1 OEM training for all other staff	$3,008,000	$3,111,000	$6,119,000
FY2034		0 35-ft 7 40-ft	0 vans & cutaways	Annual refreshers	Local fire and emergency response department training on new technology	$3,628,000	$2,948,000	$6,576,000
FY2035		0 35-ft 6 40-ft	5 vans & cutaways	Annual refreshers	No activity	$3,461,000	$2,787,000	$6,248,000
FY2036		0 35-ft 6 40-ft	0 vans & cutaways	Annual refreshers	Local fire and emergency response department training on new technology	$2,794,000	$2,626,000	$5,420,000
FY2037		0 35-ft 6 40-ft	10 vans & cutaways	Annual refreshers	No activity	$3,568,000	$2,468,000	$6,036,000
FY2038		0 35-ft 6 40-ft	7 vans & cutaways	Tier 1 & tier 3 OEM training for new staff	Tier 1 OEM training for all other staff	$3,133,000	$2,384,000	$5,517,000
FY2039		8 35-ft 0 40-ft	2 vans & cutaways	Annual refreshers	No activity	$3,123,000	$2,252,000	$5,375,000
FY2040		0 35-ft 8 40-ft	8 vans & cutaways	Annual refreshers	Local fire and emergency response department training on new technology	$3,694,000	$2,128,000	$5,822,000

APPENDIX A: MEMO—INFRASTRUCTURE OPTIONS FOR DIFFERENT HYDROGEN FUELING ARRANGEMENTS

Stantec

Memo

To:	James Beck	From:	Reb Guthrie
	Gold Coast Transit District		Faye Farahmand
			Analy Castillo
			David Verbich
			Los Angeles
Project/File:	GCTD ZEB Rollout Plan	Date:	May 26, 2022
	2073016250		

Reference: Infrastructure options for supplying and generating hydrogen fuel to a new hydrogen bus-fueling facility at the GCTD Facility

1 Background

As Gold Coast Transit District (GCTD) plans a transition from a compressed natural gas (CNG) bus fleet to a fleet of hydrogen fuel cell-electric buses (FCEBs), the appropriate mode of providing the hydrogen fuel to the GCTD facility and its full FCEB fleet needs to be established.

The approach deployed at peer agencies with similar fleet sizes is to use liquid hydrogen (LH2) that is trucked to the site and stored in an aboveground cryogenic tank, and is the approach recommended and assumed to be baseline for the purpose of this memorandum. Another possible approach to supply hydrogen for use by the FCEBs is by producing the needed hydrogen on-site using water electrolysis. However, given the greater level of complexity, space requirements, maintenance requirements, extensive utility interconnects and concerns about system reliability that are associated with on-site hydrogen production via electrolysis, a hybrid approach is considered here (i.e., trucked LH2 supplemented by a portion of onsite electrolysis) as a comparison to the baseline.

Therefore, this report will analyze two possible scenarios for providing hydrogen to GCTD’s new hydrogen facility, which are summarized as follows:

1. Trucked-in liquified hydrogen (LH2 Only)
2. Trucked-in liquified hydrogen at same capacity as in scenario 1 with supplemental (25%-35%) onsite hydrogen generation via electrolysis (LH2 + Electrolysis)

The assessment of both models will be sized to accommodate GCTD’s eventual full FCEB fleet of 87 FCEBs, potential fueling from buses operated by the Ventura County Transportation Commission (VCTC), as well as a small portion for future public fueling of light-duty hydrogen vehicles, since it would be in the County’s interest to maximize the use of its investment in infrastructure.

The LH2 + Electrolysis scenario has the benefits of improving resiliency of hydrogen-commodity supply and partially protecting against supply interruptions, as well as possibly reducing hydrogen-commodity costs. However, since the underlying LH2-based system would be sized and configured to meet 100% of the GCTD's and VCTC's hydrogen needs, any issues related to reliability of the supplemental electrolysis system would not weaken the underlying capacity or overall ability of the core hydrogen-fueling system to meet both agencies' needs. Further, the limited nature of the onsite production capacity in relation to the total daily demand would proportionally reduce the concerns for space and utility (electrical power) that would be needed if the full (100%) facility demand were otherwise to be provided by the onsite generation system. Additionally, the high electrical power requirements for a '100%' on-site electrolysis could only be fractionally met by photovoltaic power and associated PV battery-storage system planned for the GCTD facility. Conversely, the more modest power needs of an electrolysis system that is only supplemental in nature will allow the capacity of the PV system be more proportionally matched to the electrolysis-generated power load.

Stantec conducted bus predictive modeling for the fleet of 86 vehicles and estimates the hydrogen demand for the GCTD's fleet. The hydrogen demand for the VCTC vehicles, if this fleet where transition to hydrogen vehicles, was calculated at 1,338 kg per day for VCTC commuter fleet[1]. Furthermore, a capacity of 60 kg/day was assumed for public fueling if GCTD decides to open its station to the public. A summary of the total hydrogen demand for the site is presented in the Table 1 below; the total estimated hydrogen fuel demand at GCTD's facility will be about 2,463 kg/day.

Table 1: GCTD's Hydrogen demand

Agency	**Item Description**	**40-ft and 35-ft Buses**	**Cutaways and Vans**
GCTD	Total vehicles in fleet	64 (4 contingency)	27
	No. of active vehicles	60	26
	Avg. H2 demand per vehicle (kg/day/vehicle)	15.5	8.5
	Total H2 demand for active vehicles (kg/day/fleet)	885	180
	Total GCTD Fleet Hydrogen Demand (kg/day/fleet)	1,065	
VCTC	Total VCTC Fleet Hydrogen Demand (kg/day/fleet)	1,338	
Public	Public Fueling (6 kg / fill x 10 fills / day)	60	
Total Facility Hydrogen Demand (kg/day/fleet)		**2,463**	

[1] Based on high level assumptions using VCTC mileage data.

2 Option 1 – Trucked-In Liquified Hydrogen

2.1 Summary Description

LH2 will be delivered to the facility in loads of roughly 8,000-12,000 gallons, pending sizes of delivery tankers and then will be stored in a horizontal 18,000-gallon (4,822 kg[2]) cryogenic storage tank. Assuming 90% usable tank capacity (16,200 gallons or 4,340 kg) and a facility demand of 2,463 kg per day, the tank capacity will last 1.8 days, which equates to about four hydrogen fuel deliveries per week. Note that if two 12,000-gallon tank is used instead, the usable capacity would be 21,600 gallons or 5,787 kg, which would last up to 2.5 days, which would increase the reserve days until empty to 2.5 days.

The liquid will be fed from the tank to the high-pressure reciprocating cryogenic pumps at high pressure (450+ bar). The system will have four total reciprocating pumps with any two running and one acting as a rotating spare for large vehicle refueling at lower pressure—350 bar (also known as H35)—plus the fourth pump dedicated to refueling at higher pressure—700 bar (also known as H70)—that will be used for smaller vehicles like vans, cutaways or other light-duty vehicles. The buses and dispenser nozzles will both be equipped with high-flow nozzles that will allow fill rates of up to 7.2 kg/minute (when available from buffer contribution), but the nominal or rated flow will be 3.9 kg/minute, based on LH2-pump discharge.

The pump discharge would then be routed to ambient-air vaporizers or heat exchangers, where the high-pressure liquid will be warmed to atmospheric temperature. The high-pressure gaseous hydrogen (GH2) is then routed to a priority-valve panel that will automatically direct the GH2 to either the hydrogen dispensers or to an array of high-pressure GH2 buffer-storage vessels that will accumulate pump discharge during the brief period between bus fills at the dispensers. Once there is no demand at the dispensers and the buffer vessels are full, the pumps will automatically turn off.

Two dispensers will provide 'H35' (350 bar or 5,076 PSI[3]) GH2 to the buses and one dispenser will provide 'H70' (700 bar or 10,000 PSI) to cutaways and vans. The dispensers will be located in the existing service lanes and will be connected to the existing terminals in their respective lanes.

Lastly, prior to dispensing, the hydrogen gas is chilled to compensate for the heat of compression that occurs in the onboard storage cylinders during filling. Some dispensers include a chiller function, while other configurations rely on an external pre-chiller.

[2] One gallon of liquid hydrogen equals 0.2679 kg.

[3] 1 bar is equal to 1 atmosphere of pressure at mean sea level or 14.504 PSI.

2.2 Equipment Requirements

An equipment compound for liquified hydrogen-based system includes the following main components:

- 18,000-gal (4,822 kg) LH2 storage tank configured horizontally (Note: Vertical tanks are available and are more space efficient, but they are more costly due to added structural bracing required. Additionally, the footers supporting the tank would need to be substantially deeper and larger, further increasing costs. Vertical tanks may be considered at a future point). Approximate dimensions: 43-ft. long x 11-ft. diameter
- (3) reciprocating LH2 pumps for H35 (any two operating with the other configured as a rotating spare)
- (1) reciprocating LH2 pump for H70
- (3) ambient-air heat-exchanger towers (also called dispensing vaporizers) for warming LH2 from pump discharge
- Warming vaporizer for generating transfer pressure at delivery truck
- (6) cylindrical high-pressure storage vessels for H35 (two stacks of three vessels)
- (2) cylindrical high-pressure storage vessels for H70 (two stacks' vessels)
- Priority valve panel
- 480V electrical power-distribution panelboard and programmable logic control (PLC) panel sized for approximately 400A (each of the running pump motors will draw about 90A, with the remaining loads being modest)
- Air compressor system
- Main service panelboard
- Motor-starter panelboard for powering four pumps
- System control panel

2.3 Space Requirements

The area needed to accommodate the main equipment—including the equipment listed above and accounting for a demising wall around the electrical equipment—is about 3,200-3,600 square feet. Depending on nature of other demising walls around the perimeter of the compound, setbacks of up to 40 ft. from the equipment to property lines and buildings may be required. Also, no vehicle parking is allowed within 25 ft. of the compound.

2.4 Utility Requirements

Given the low amount of electrical energy needed to operate the baseline LH2-only facility, it is likely that all of the power needs for the system could be met by the existing power system. Assuming a total running load of 175 HP (about 129 kW) with a nightly operating window of 8 hours, the station would have a demand of about 129 kW and a daily energy usage of about 132 kWh.

Aside from Internet connectivity—either via cellular modem or via GCTD's IP data network—no other utility connections are required.

2.5 Key Considerations

- Possible requirement to enter into long-term LH2-supply agreements (as preferred or required by some industrial-gas vendors). However, this may be less of a limitation in the future with an expanding network of liquid hydrogen producers and distributors including Plug Power and the emergence of Chart Industries as a new hydrogen liquefier/supplier.
- Supply resiliency, as supply disruptions as have been experienced at some light-duty hydrogen-fueling stations in California. Simply put, if the delivery truck fails to arrive on time, the supply chain and facility operation are interrupted. This is expected to improve in the near- and medium-term future as hydrogen production (including 'green' hydrogen with low carbon intensity) is expected to improve.
- The cost of LH2 commodity delivered to the site (currently estimated at $7.50-$8.50/kg) will likely be higher than if produced onsite, though LH2-commodity prices are expected to gradually fall over time (some industry projections suggest the cost could fall below $5/kg). However, this price uncertainty can be complex since an increased production is generally expected to reduce cost, demand will also rise some, so the ultimate relationship between the two forces is unclear.
- Product boiloff[4] occurs at about 0.5% to 1% of consumption. While is technically possible to capture and compress this gas, it would require a dedicated compressor that would likely cost as much to amortize and maintain as the boiloff hydrogen, and thus is not recommended.

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[4] Hydrogen boiloff gas (BOG) is produced when a small percentage of the cryogenic liquid unavoidably heats up and reach its boiling point (above -420°F) after a prolonged period of time in the storage tanks, or when transported over long distances.

2.6 Key Benefits

- The energy required to pump and dispense is relatively low (less than 0.5 kWh/kg).
- The area required for a given flow capacity is considerably less than that of comparable systems using on-site GH2 production.
- Regional production of LH2 in California will greatly improve resiliency and should result in lower commodity costs, though the actual degree of cost reduction will be determined per market conditions.
- A reciprocating LH2 pump system requires minimal need for on-site high-pressure storage vessels. Only six total vessels configured as three banks of storage are needed, roughly similar to that of a comparable CNG-fueling system.
- The ‘warm end’ (connected to the drive motor and belt) of the reciprocating cryogenic pump has a long-life expectancy and the ‘cold end’ (cylinder and piston) part of pump is easily replaceable in about two hours. Cold-end spares can be maintained on-site or elsewhere locally.
- The ambient-heat exchangers needed to warm the cryogenic hydrogen up to above -20°F for storage are simple, solid-state devices with no moving parts. The periodic nature of bus fueling allows for the heat exchanges to defrost daily (they often accumulate a thick frost layer due to contact with ambient humidity), so redundancy is not required.
- Relatively speaking, the entire system is simple, compact and easy to maintain.
- The system is expandable with the addition of more pumps, heat exchangers and dispensers if the FCEB fleet grows and demand grows.

2.7 Equipment Costs

The preliminary cost estimate (in 2022$) in *Table 2* for Option 1 is based on the direct costs for primary equipment required for the system. However, the bottom line of this estimate does include additional capex costs for construction, site materials, piping, wiring, and foundations, as well as escalations and contractor markups. This amount should also include costs for dispensing equipment, which are assumed to be uniform across the two options considered in this memo and therefore are not otherwise listed in the below table.

Table 2: Equipment costs for system using trucked-in liquified hydrogen

Item	Qty.	$ Unit ROM	$ Extended
Liquified 18,000-gal hydrogen tank	1	$1,100,000.00	$1,100,000.00
Reciprocating LH2 pumps for H35	3	$180,000.00	$540,000.00
Reciprocating LH2 pump for H70	1	$198,000.00	$198,000.00
Hydrogen vaporizers for H35	2	$110,000.00	$220,000.00
Hydrogen vaporizers for H70	1	$125,000.00	$125,000.00
Hydrogen vaporizer for pressure building	1	$90,000.00	$90,000.00
Priority valve panel	1	$100,000.00	$100,000.00
High pressure GH2 storage vessels	8	$40,000.00	$320,000.00
Air compressor system	1	$9,000.00	$9,000.00
Main service AC Power panelboard	1	$50,000.00	$50,000.00
Duplex motor starter panelboard (pumps)	2	$50,000.00	$100,000.00
System control panel	1	$60,000.00	$60,000.00
Total (equipment only without markups)			**$2,912,000.00**
Total CAPEX (with markups and site construction; see appendix for backup)			**$7,429,309.00**

3 Option 2 – LH2 Plus Augmentation with On-site Hydrogen Production via Electrolysis

3.1 Summary Description

The addition of an on-site augmentation system for hydrogen production via electrolysis will have four principal elements to be added to the baseline system as follows: one electrolyzer package (with integrated DC-power inverter), one high-pressure GH2 compressor to compress the GH2 produced by the electrolyzer, a high-pressure GH2 storage array, and a large power-feeder upgrade needed to power the electrolyzer. Two secondary components will be a water supply with deionizer and a suction-buffer vessel between the discharge of the electrolyzer and the compressor inlet, as needed to even out variations of output and suction rates of the electrolyzer and compressor respectively.

The GH2-storage array and compressors are to be sized as needed to sequester GH2 output from electrolyzer during the approximately 16 hours that it will be producing GH2 but when no FCEB will be fueled. The storage array should be somewhat oversized so that it can be sure to accommodate and absorb all of the hydrogen produced by the electrolyzer, such as if the start of FCEB fueling is delayed during a given evening.

The priority-valve panel specified in the baseline system would need inlets for contribution of pre-compressed GH2 that is stored in the '16-hour' array referenced above, as well as the direct-compressor discharge coming from the electrolyzer output during the 8-hour fueling window.

3.2 Equipment & Area Requirements

A summary description of the added equipment needed for electrolysis-augmentation subsystem is provided below:

a. Electrolyzer package
   - Reference Nel model MC250
   - GH2 output: 531 kg / 24 hrs (hourly: 246 m^3, 9,353 SCF or 22.1 kg; = 156 SCFM)
   - Output pressure: 435 PSIG
   - Input electrical power: 1.25 MW
   - Input electrical energy: 50.4 kWh / kg (26,762 kWh / 24 hrs)
   - Input water: 4.25 gal / kg (2,257 gal / 24 hrs)

b. Hydrogen gas compressor skid
   - Reference PDC model 500b or similar
   - 6,000 PSI discharge pressure, sized to match electrolyzer output of ~ 156 SCFM (note that one unit is adequate to meet the functional requirement for flow; a second unit may be considered as a rotating backup)
   - Hybrid trunk-piston compressor driving multi-stage diaphragm compression units
   - Approx. 75 HP electric-motor drive

c. Storage-vessel array
   - 32 total vessels, arranged in 8 sets of 4 (stacked) vessels
   - 14,600 SCF capacity per vessel
   - Gross capacity of 467,200 SCF (assumes usable or working volume of about 33%)

d. AC power upgrade feeder for 1,600 A at 480 V circuit needed to power 1.25 MW electrolyzer and 75 HP GH2 compressor skid

e. Secondary equipment:
   - Intermediate buffer vessel—approximately 1,000-gal (water) capacity, 750 PSI MAWP
   - Water deionizer / purification system

f. Solar PV array
   - Module DC Nameplate 1,740 kW (approximately 3,222 modules assumed to be ground mounted)
   - Inverter AC Nameplate 1,460 kW
   - Annual Production of 2.612 GWh (average)
   - 1,501 kWh/kWp

3.3 Space Requirements

The additional area needed to accommodate the equipment listed above is about 35’ x 100’ (an additional 3,500 square feet to the 3,600 square feet for the LH2 equipment). The code offsets referenced in the description of the baseline system apply similarly to the electrolysis-augmentation subsystem as well.

The full solar PV array was assumed to be allocated in the vacant land adjacent to the GCTD facility and will approximately take a footprint of 96,000 square feet (2 acres of land).

3.4 Utility Requirements

As described above, the added utility requirements are about 1,600A of 480V 3-phase electrical service. While the intent is to use PV power for this system as much as possible, the station should have 100% utility power available to ensure maximum operational capability and reliability. Additionally, a domestic water-supply line of 1” will be needed and a commercial-grade water deionizer will also be required. Since electrolysis system requires deionized water, it will generate industrial waste that may require coordination with the County for disposal.

Additionally, the system requires network connection for transfer of data and communication for control and monitoring.

3.5 Key Considerations

- Added capital cost.
- Larger area requirement, requiring about 3,500 square feet more area vs.LH2 only.
- Expenses for the added electrical power capacity to the site to produce hydrogen via electrolysis
- Low GH2-discharge pressure (for compressor inlet) at ~ 0 PSIG for alkali systems, though PEM systems (as assumed in this analysis) have a skid-discharge pressure of just over 400 PSIG.
- Dependence on purified water and need for deionizing (or reverse osmosis) systems. The actual demand for water may be 1.5 to 2x the process water demand. The local water impurities and the local ground water (EPA) requirements will dictate the actual water cost.
- High maintenance labor and cost for compressors and electrolyzer system (due to the complex electrolyzer, GH2 compressor skid and storage vessels with many relief valves etc.).

3.6 Key Benefits

- The most attractive benefit of an electrolysis-based hydrogen system is the potential ability to power the system with a portion of renewably sourced electrical energy, such as from solar. However, in practice, owner-operated renewable electrical power generation currently has limitations, including space and cost effectiveness.
- Added resiliency of hydrogen-commodity supply. The 531 kg provided per day from the electrolyzer is about 22% of the 2,463 kg of total daily hydrogen demand. While far short of the full daily demand, it is a meaningful contribution and can allow deployment of at least some high-priority dispatches and otherwise provide a bridge for any delayed LH2 deliveries to the baseline station.
- The commodity cost for the hydrogen produced by the electrolyzer-based subsystem is expected to be lower than the cost of delivered LH2 (pending detailed analysis of electric power costs and determination of operating costs associated with the PV and battery-storage system).
- GCTD would likely enjoy some benefit through positive marketing and messaging from being able to advertise on-site and 'green' GH2 production (to the extent that on-site PV or green-purchased electricity are used).

3.7 Equipment Costs

The preliminary cost estimate (in 2022 dollars) in Table 3 for Option 2 is based on the direct costs for primary equipment required for the system. However, the bottom line of this estimate does include additional capex costs for construction, site materials, piping, wiring, and foundations, as well as escalations and contractor markups. This amount should also include costs for dispensing equipment, which are assumed to be uniform across the two options and therefore are not otherwise listed in the below table.

Table 3: Equipment costs LH2+ onsite electrolysis

Item	Qty.	$ Unit ROM	$ Extended
Liquified 18,000-gal hydrogen tank	1	$1,100,000.00	$1,100,000.00
Reciprocating LH2 pumps for H35	3	$180,000.00	$540,000.00
Reciprocating LH2 pump for H70	1	$198,000.00	$198,000.00
Hydrogen vaporizers for H35	2	$110,000.00	$220,000.00
Hydrogen vaporizers for H70	1	$125,000.00	$125,000.00
Hydrogen vaporizer for pressure building	1	$90,000.00	$90,000.00
Priority valve panel	1	$100,000.00	$100,000.00
High pressure GH2 storage vessels	8	$40,000.00	$320,000.00
Air compressor system	1	$9,000.00	$9,000.00
Duplex motor starter panelboard (pumps)	2	$50,000.00	$100,000.00
System control panel	1	$60,000.00	$60,000.00
Electrolyzer Package	1	$975,000.00	$975,000.00
Hydrogen gas compressor Skid	1	$375,000.00	$375,000.00
Storage-vessel array (32 vessels)	32	$40,000.00	$1,280,000.00
AC Power upgrade feeder for 1,600A	1	$100,000.00	$100,000.00
Intermediate buffer vessel	1	$60,000.00	$60,000.00
Water service & deionizer/purification	1	$10,000.00	$10,000.00
PV system (KW)	1	$4,000,000.00	$4,000,000.00
Total (equipment only without markups)			**$9,662,000.00**
Total CAPEX (with markups and site construction; see appendix for backup)			**$24,650,406.02**

4 Life Cycle Cost Analysis and Comparison

Data and calculations indicating the quantity of hydrogen fuel needed per day and per month are provided in Table 4 below. Notes and assumptions are: 1) Spare FCEB have no hydrogen demand. 2) The average demand may be greater if a significant number of coach buses are implemented. 3) Usage assumes no reduced consumption for weekend days.

Table 4: Fleet data and hydrogen demand

Agency	Item Description	40-ft and 35-ft Buses	Cutaways and Vans
GCTD	Total vehicles in fleet	64	27
	No. of active vehicles	60	26
	Avg. H2 demand per vehicle (kg/day/vehicle)	15.5	8.5
	Total H2 demand for active vehicles (kg/day/fleet)	885	180
	Total GCTD Fleet Hydrogen Demand (kg/day/fleet)	1,065	
VCTC	Total VCTC Fleet Hydrogen Demand (kg/day/fleet)	1,338	
Public	Public Fueling (6 kg / fill x 10 fills / day)	60	
Total Facility Hydrogen Demand (kg/day/fleet)		**2,463**	

Data and calculations for the quantities of input utilities and commodities on a unit basis are provided in Table 5. Notes and assumptions are: 1) SCE (Southern California Edison) tariff has multiple demand and energy rates and are approximated here as a single rate. 2) Costs are good faith estimates and may vary. 3) Costs include maintenance of associated hydrogen-gas compressors required for these systems. 4) This does not include 50¢ per gallon Federal tax credit for liquid hydrogen, which has expired but may be reinstated (https://afdc.energy.gov/laws/319).

It was assumed that all energy needed to run the electrolyzer will be provided by an on-site solar PV energy. Any surplus generation of solar PV energy was assumed to be wasted since future opportunities to sell back to the grid are becoming less and less encouraged by the utilities. Furthermore, for the basis of this analysis, the cost of PV electricity to power the electrolyzer was assumed to be only accounted by the capital investment of the PV panels.

Table 5: Input costs for utilities, commodities, and maintenance[5]

Description	Cost
Water ($/Gal)	$0.005
Power Demand chargers ($/kW)	$14.50
Electric Energy from Gid ($/kWh)	$0.12
Electric Energy from Solar PV ($/kWh)	$0.00
Liquid Hydrogen Commodity ($/kg)	$7.50
Liquid Hydrogen-Facility Maintenance ($/kg)	$0.50
Electrolysis-Facility Maintenance ($/kg)	$2.32

Data and calculations indicating the quantities of input utilities and commodities as required to produce hydrogen fuel on a per-kg basis for each of the two options are provided in Table 6.

Table 6: Utility consumption per unit of hydrogen[6]

	Consumption per kg Hydrogen (*x*/kg)		
Utility	**Unit**	**Option 1 LH2**	**Option 2 LH2 + Electrolysis**
Water	Gal/kg	0	5.24
Energy from Grid (kWh)	kWh/kg	0.32	0.32
Energy from Solar PV (kWh)	kWh/kg	N/A	50.4
LH2 Commodity by truck	kg	1	0.78
Maintenance Allowance	$/kg	0.50	2.32

Data and calculations indicating the quantities of utility commodities consumed for each of the two options on a monthly basis are provided in Table 7.

[5] Based on current hydrogen prices for transit agencies in Southern California.
[6] The energy generation of solar PV onsite would only allow for approx. 22% of onsite hydrogen generation, the rest would be procured via tub trucks of liquid hydrogen delivery (LH2).

Table 7: Utility consumption per month

Utility	Monthly Utility Consumption		
	Unit	**Option 1 LH2**	**Option 2 LH2 + Electrolysis**
Water	Gal/Month	0	85,213
Energy from Grid (kWh)	kWh/Month	23,911	18,650
Energy from Solar PV (kWh)	kWh/Month	0	819,292
Power Demand	kW	91	1,250

Data and calculations indicating the quantities of utility commodities consumed for each of the three options on an annual basis are provided in Table 8.

Table 8: Utility consumption per year

Utility	Yearly Utility Consumption		
	Unit	**Option 1 LH2**	**Option 2 LH2 + Electrolysis**
Water	Gal/Year	0	2,556,387
Energy from Grid (kWh)	MWh/Year	717,324	560
Energy from Solar PV (kWh)	MWh/Year	0	24,579
Power Demand	kW	91	1,250

Data and calculations indicating the operating expenses (Opex) for each of the two options are provided in Table 9. Notes and assumptions are: 1) The operating costs are assumed to extend for 12 years, as needed to match the minimum asset life of bus rolling stock per FTA requirements. 2) the 12-year costs are straight extrapolation of current-year maintenance costs and are not discounted per time value of money.

Reference: Infrastructure Options for Supplying and Generating Hydrogen Fuel

Table 9: Operating costs

Opex Estimates			
Utility or Commodity	**Unit**	**Option 1 LH2**	**Option 2 LH2 + Electrolysis**
Water	$/month	$0	$426
Power Chargers (kW)	$/month	$1,320	$18,125
Energy from Grid (kWh)	$/month	$2,869	$2,238
Energy from Solar PV (kWh)	$/month	$0	$0
LH2 Commodity	$/month	$554,175	$432,257
Maintenance Allowance	$/month	$36,945	$66,531
Solar PV Maintenance Cost	$/month	$0	$3,333
Total Unit Operating Cost	**$/kg**	**$8**	**$7**
Monthly Operating Cost	**$/month**	**$595,309**	**$522,910**
Lifetime Operating Cost	**$/12 Yrs.**	**$85,724,467**	**$75,298,969**

Data and calculations indicating the combined costs for equipment costs (Capex), Opex and combined life cycle cost analysis (LCA) for each of the two options are provided in Table 10. Notes and assumptions are: 1) These costs are per the totals in the body of the report respectively, 2) as indicated in Table 9, the operating costs do not reflect any discounting for the time value of money, 3) 12 years reflects the minimum operating duration for a bus purchased with FTA funding.

Table 10: Summary costs for Capex, Opex, and Lifecycle Cost Estimates

Summary Capex, Opex and Life Cycle Cost Estimates			
Item	**Unit**	**Option 1 LH2**	**Option 2 LH2 + Electrolysis**
Equipment Capex	$	$7,429,309	$24,650,406
Lifetime Operating Cost (simple)	$/12 Yrs.	$85,724,467	$75,298,969
Lifecycle Cost	**$**	**$93,153,776**	**$99,949,375**

5 Summary and discussion

In summary, Option 2 (LH2 + on-site electrolysis) has a higher cost of $6.8 million over a 12-year lifetime when compared to using trucked-in LH2, a 7% increase. Furthermore, an additional 36,000 square foot of area is required to accommodate the electrolysis equipment that may be a challenge to implement at the current GCTD facility. Lastly, a sensitivity analysis was conducted and determined that a unit price greater than **$10.50 per kg**[7] for the hydrogen commodity to be paid at delivery would be the breaking point to make Option 2 with on-site electrolysis economically viable and preferrable over a purely trucked-in LH2 solution.

Additionally, GCTD must consider the feasibility of increasing the current power capacity at their facility in coordination with SCE since an upgrade to at least 1.5 MW would be required for electrolysis. For the purposes of this analysis, it was assumed that no cost would be passed on to GCTD for the utility upgrade to a 1.5-MW capacity. However, up to half a million dollars could be the price increase if SCE passes on the capital upgrade costs to GCTD. Additionally, the lead time for installation could be on the order to 10 to 18 months. Moreover, the large quantities of water needed (as well as the need to deionize the water) may be a significant expense and limiting factor given the trends of increasing draughts throughout Southern California.

Lastly, for the purposes of this analysis, the allocation of the solar PV system was assumed to be located in the empty lots in the vicinity of GCTD's facilities, but the cost of land or leasing fees were not considered here. The feasibility of having approximately 2 acres of land to install solar panels can prove to be a heavy constraint in the implementation of Option 2.

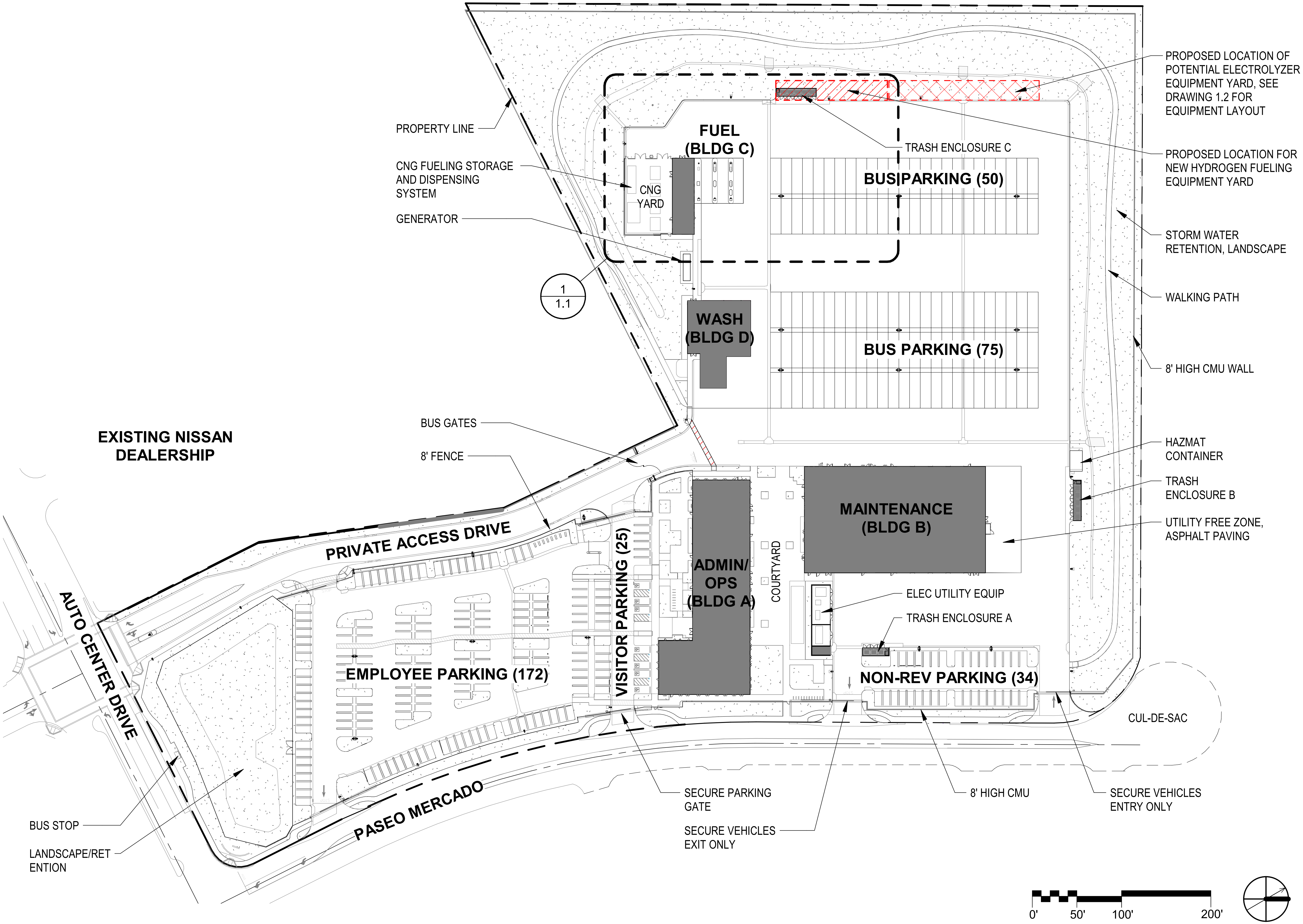
Yours sincerely,

STANTEC CONSULTING SERVICES INC.

[7] Assumption used for current assessment was $7.50 per kg of hydrogen based on current prices for transit agencies in Southern California.

APPENDIX B: SITE PLANS

See attached documents for site plans, including hydrogen fueling equipment yard (drawing 1.1) and conceptual design for hydrogen electrolysis equipment (drawing 1.2).



Stantec

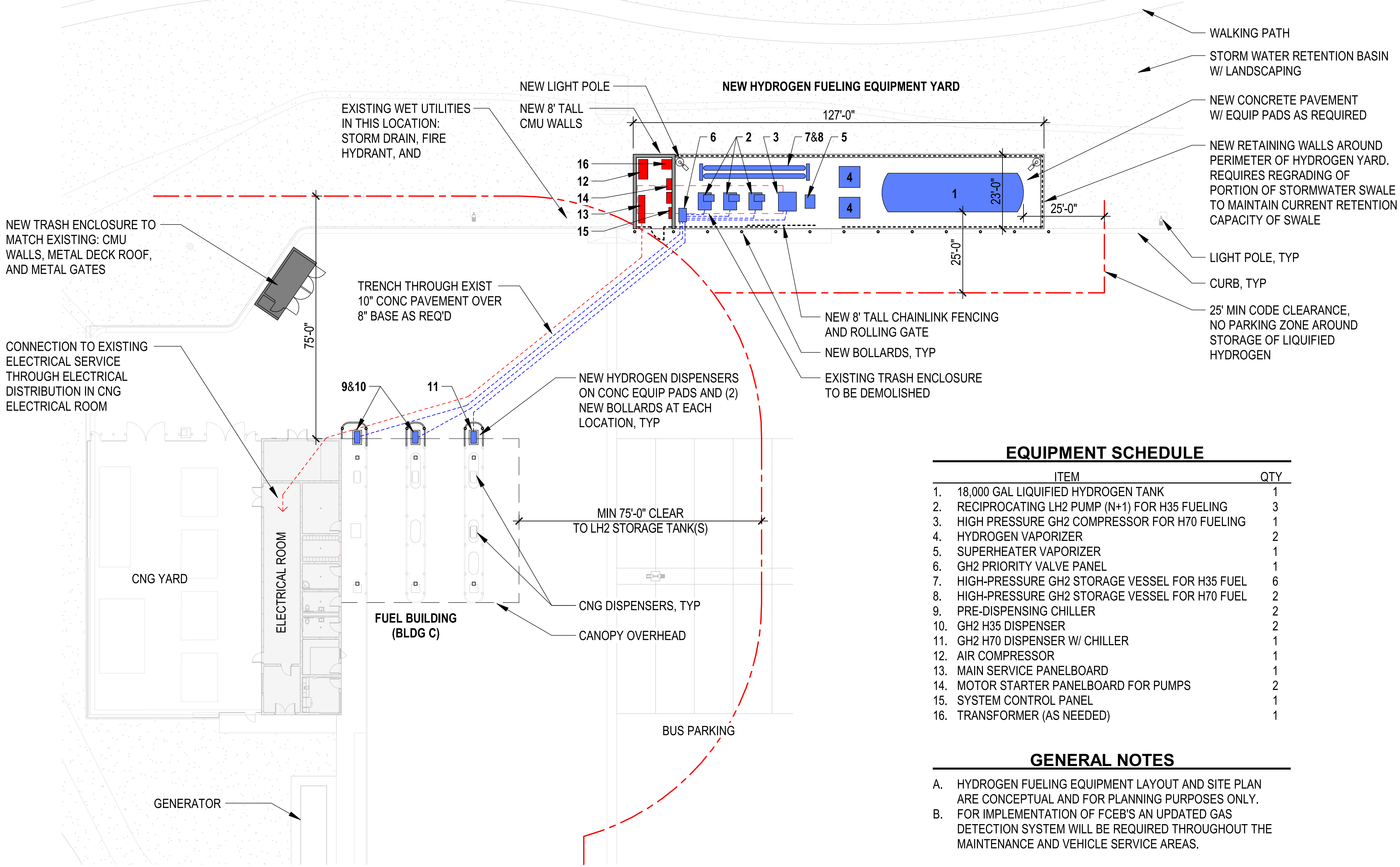
Stantec Proj No: 2073016250

GOLD COAST TRANSIT DISTRICT
OPERATIONS & MAINTENANCE FACILITY

ZERO-EMISSIONS BUS MASTER PLAN
EXISTING SITE PLAN

DATE:
07/21/22

DWG:
1.0



EQUIPMENT SCHEDULE

	ITEM	QTY
1.	18,000 GAL LIQUIFIED HYDROGEN TANK	1
2.	RECIPROCATING LH2 PUMP (N+1) FOR H35 FUELING	3
3.	HIGH PRESSURE GH2 COMPRESSOR FOR H70 FUELING	1
4.	HYDROGEN VAPORIZER	2
5.	SUPERHEATER VAPORIZER	1
6.	GH2 PRIORITY VALVE PANEL	1
7.	HIGH-PRESSURE GH2 STORAGE VESSEL FOR H35 FUEL	6
8.	HIGH-PRESSURE GH2 STORAGE VESSEL FOR H70 FUEL	2
9.	PRE-DISPENSING CHILLER	2
10.	GH2 H35 DISPENSER	2
11.	GH2 H70 DISPENSER W/ CHILLER	1
12.	AIR COMPRESSOR	1
13.	MAIN SERVICE PANELBOARD	1
14.	MOTOR STARTER PANELBOARD FOR PUMPS	2
15.	SYSTEM CONTROL PANEL	1
16.	TRANSFORMER (AS NEEDED)	1

GENERAL NOTES

A. HYDROGEN FUELING EQUIPMENT LAYOUT AND SITE PLAN ARE CONCEPTUAL AND FOR PLANNING PURPOSES ONLY.
B. FOR IMPLEMENTATION OF FCEB'S AN UPDATED GAS DETECTION SYSTEM WILL BE REQUIRED THROUGHOUT THE MAINTENANCE AND VEHICLE SERVICE AREAS.

0' 15' 30' 60'

Stantec

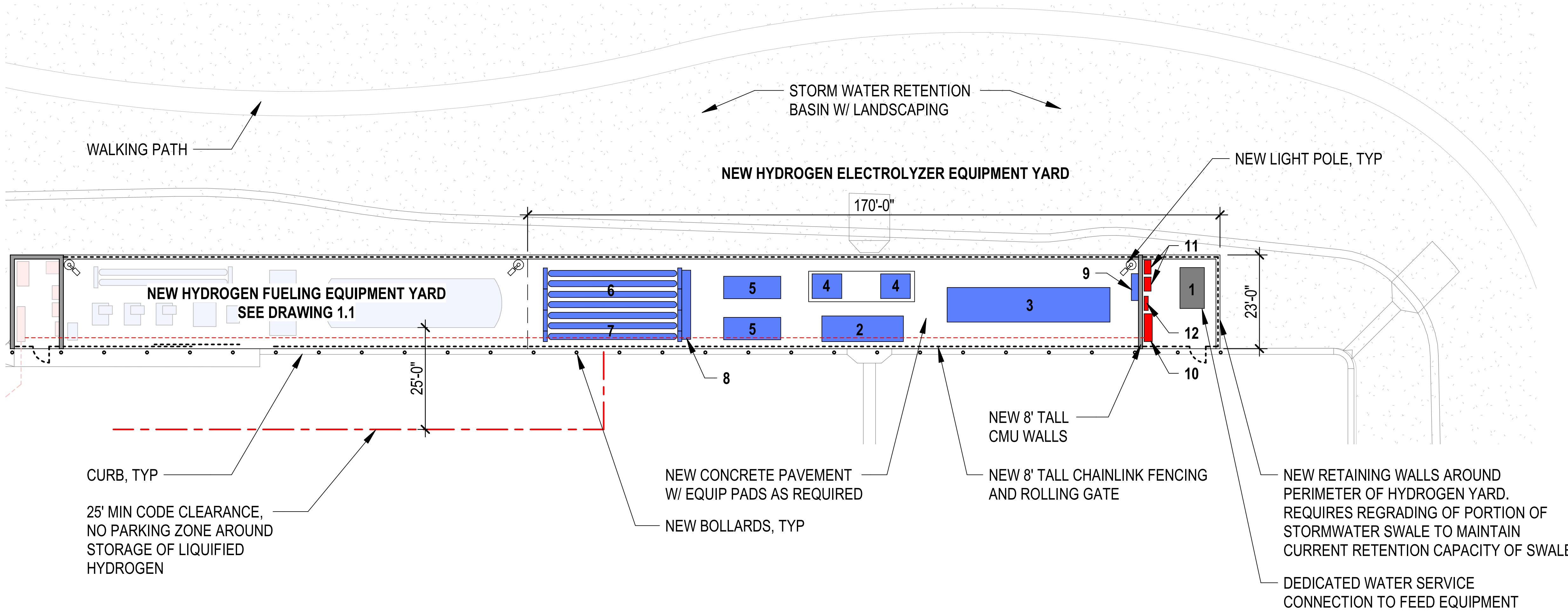
Stantec Proj No: 2073016250

GOLD COAST TRANSIT DISTRICT
OPERATIONS & MAINTENANCE FACILITY

ZERO-EMISSIONS BUS MASTER PLAN
ENLARGED SITE PLAN

DATE: 07/21/22

DWG: 1.1

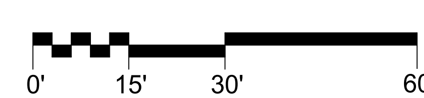


EQUIPMENT SCHEDULE

	ITEM	QTY
1.	WATER DE-IONIZER	1
2.	ELECTRICAL POWER SUPPLY	1
3.	ELECTROLYZER SKID	1
4.	HYDROGEN COMPRESSOR FOR H35 FUELING	2
5.	HYDROGEN COMPRESSOR FOR H70 FUELING	2
6.	BUFFER VESSEL FOR H35 FUEL (STACK OF 6)	36
7.	BUFFER VESSEL FOR H70 FUEL (STACK OF 6)	6
8.	PRIORITY VALVE PANEL	1
9.	NITROGEN CYLINDERS	1
10.	MAIN SERVICE PANELBOARD	1
11.	MOTOR STARTER PANELBOARD FOR PUMPS	2
12.	SYSTEM CONTROL PANEL	1

GENERAL NOTES

A. HYDROGEN FUELING EQUIPMENT LAYOUT AND SITE PLAN ARE CONCEPTUAL AND FOR PLANNING PURPOSES ONLY.
B. FOR IMPLEMENTATION OF FCEB'S AN UPDATED GAS DETECTION SYSTEM WILL BE REQUIRED THROUGHOUT THE MAINTENANCE AND VEHICLE SERVICE AREAS.



Stantec

Stantec Proj No:
2073016250

GOLD COAST TRANSIT DISTRICT
OPERATIONS & MAINTENANCE FACILITY

ZERO-EMISSIONS BUS MASTER PLAN
POTENTIAL ELECTROLYZER EQUIPMENT LAYOUT

DATE:
07/21/22

DWG:
1.2

APPENDIX C: COST ESTIMATES

Please see attached cost estimates.

GOLD COAST TRANSIT DISTRICT MAINTENANCE & OPERATIONS FACILITY

ZERO EMISSIONS BUS MASTER PLAN

ROUGH-ORDER-OF-MAGNITUDE OPINION OF PROBABLE COST

JYI #: C2616A-R2

June 16, 2022
Revised: June 24, 2022

PREPARED FOR:

STANTEC

BY:

JACOBUS & YUANG, INC.
355 North Lantana Street, #220
Camarillo, CA 93010
Tel (213) 688-1341 or (805) 339-9434

PROJECT: GOLD COAST TRANSIT DISTRICT MAINTENANCE & OPERATIONS FACILITY - ZERO EMISSIONS BUS MASTER PLAN	**JYI #: C2616A-R2**
LOCATION: OXNARD, CA	**DATE: 16-Jun-22**
CLIENT: STANTEC	**REVISED: 24-Jun-22**
DESCRIPTION: R.O.M. OPINION OF PROBABLE COST - SUMMARY	

ITEM NO.	DESCRIPTION	EST QTY	UNIT	UNIT COST	TOTAL COST
	SUMMARY OF ESTIMATE				**$**
	HYDROGEN FUELING	3,000	SF	2,989.04	8,967,118
	ADD INFLATIONARY ESCALATION	10.7%			957,567
	R.O.M. TOTAL OF OPINION OF PROBABLE CONSTRUCTION COST W/ PRORATES + ESCALATION	**3,000**	**SF**	**3,308.23**	**9,924,684**

ESCALATION CALCULATION

BASE MONTH	Jun-22
CONSTRUCTION START MONTH	Jun-23
CONSTRUCTION DURATION (MONTHS)	6
MID POINT OF CONSTRUCTION	Sep-23
% ANNUAL ESCALATION	8.50%
ALLOWANCE FOR ESCALATION (TO MIDPOINT OF CONSTRUCTION)	10.7%

NOTES:

SPECIFIC INCLUSIONS

1 PREVAILING WAGE RATES IN THE AREA OF THE PROJECT
2 EQUIPMENT PADS
3 EQUIPMENT YARD
4 ALLOWANCE FOR EQUIPMENT POWER
5 ALLOWANCE FOR COMMUNICATIONS INTERPHASE WITH HYDROGEN
6 PAVEMENT REPAIR PER TRENCHWORK

SPECIFIC EXCLUSIONS

1 ASBESTOS OR HAZARDOUS MATERIAL ABATEMENT
2 PROJECT SOFT COSTS & CONSTRUCTION CONTINGENCY
3 NEW PRIMARY POWER SERVICE AND ELECTRICAL UTILITY SERVICE FEES
4 CABLINGS AND CONNECTIONS FOR PRIMARY POWER SERVICE CONDUIT
5 EMERGENCY GENERATOR UPGRADES
6 GASEOUS CLEAN AGENT EXTINGUISHING SYSTEM TO ELECTRICAL ROOM

GENERAL NOTES

1 ESTIMATE ASSUMES THAT ALL COMPONENTS WILL BE BID AS A SINGLE BID PACKAGE
2 ESTIMATE ASSUMES WORK TO BE DURING NORMAL WORKING HOURS
3 ESTIMATE ASSUMES BID COVERAGE FROM AT LEAST 4-5 RESPONSIVE BIDDERS
4 ESTIMATE IS BASED ON CONCEPTUAL DESIGN DRAWINGS PREPARED BY STANTEC, DATED 06/02/2022, RECEIVED 06/02/2022.

PROJECT: GOLD COAST TRANSIT DISTRICT MAINTENANCE & OPERATIONS FACILITY - ZERO EMISSIONS BUS MASTER PLAN		**JYI #:**	**C2616A-R2**
LOCATION: OXNARD, CA		**DATE:**	**16-Jun-22**
CLIENT: STANTEC		**REVISED:**	**24-Jun-22**
DESCRIPTION: R.O.M. OPINION OF PROBABLE COST - SUMMARY			

DEFINITIONS

OPINION OF COST

An Opinion of Cost is prepared from a survey of the quantities of work-items prepared from written or drawn information provided at the Conceptual stage of design.

Historical costs, information provided by contractors and suppliers, plus judgmental evaluation by the Estimator are used as appropriate as the basis for pricing.

Allowances as appropriate will be included for items of work which are not indicated on the design documents, provided that the Estimator is made aware of them, or which in the judgement of the Estimator are required for completion of the work.

JYI cannot, however, be responsible for inclusion of items or work of which we have not been informed.

BID

An offer to enter a contract to perform work for a fixed sum, to be completed within a limited period of time.

SPECIAL NOTE - MARKET CONDITIONS

In the current market conditions for construction, our experience shows the following results on competitive bids, as a differential from JYI final es

Number of bids
1............
2-3..........
4-5..........
6-7..........
8 or more....
Accordingly, it is extremely important to ensure that a minimum of 4-5 valid bids are received

PROJECT: GOLD COAST TRANSIT DISTRICT MAINTENANCE & OPERATIONS FACILITY - ZERO EMISSIONS BUS MASTER PLAN		**JYI #:**	**C2616A-R2**
LOCATION: OXNARD, CA		**DATE:**	**16-Jun-22**
CLIENT: STANTEC		**REVISED:**	**24-Jun-22**
DESCRIPTION: R.O.M. OPINION OF PROBABLE COST		**HYDROGEN YARD AREA:**	**3,000**

ITEM NO.	DESCRIPTION	EST QTY	UNIT	UNIT COST	TOTAL COST
	SUMMARY OF ESTIMATE				**$**
1	GENERAL REQUIREMENTS				See Prorates
2	EXISTING CONDITIONS	0.35%		6.71	20,143
11	EQUIPMENT	81.83%		1,590.34	4,771,010
26	ELECTRICAL	1.28%		24.94	74,815
27	COMMUNICATIONS	0.52%		10.20	30,600
28	ELECTRONIC SAFETY & SECURITY	5.76%		111.92	335,759
31	EARTHWORK	0.29%		5.67	17,000
32	EXTERIOR IMPROVEMENTS	5.41%		105.23	315,703
33	UTILITIES	4.55%		88.46	265,393
	SUBTOTAL	**100.00%**		**1,943.47**	**5,830,423**
	GENERAL CONDITIONS/ GENERAL REQUIREMENTS	12.50%		242.93	728,803
	ESTIMATE/ DESIGN CONTINGENCY	20.00%		437.28	1,311,845
	MARKET FACTOR	5.00%		131.18	393,554
	SUBTOTAL			**2,754.87**	**8,264,625**
	BONDS & INSURANCE	2.00%		55.10	165,292
	CONTRACTOR'S FEE	6.50%		179.07	537,201
	R.O.M. OPINION OF PROBABLE COST W/OUT ESCALATION			**2,989.04**	**8,967,118**

PROJECT: GOLD COAST TRANSIT DISTRICT MAINTENANCE & OPERATIONS FACILITY - ZERO EMISSIONS BUS MASTER PLAN		**JYI #:**	**C2616A-R2**
LOCATION: OXNARD, CA		**DATE:**	**16-Jun-22**
CLIENT: STANTEC		**REVISED:**	**24-Jun-22**
DESCRIPTION: R.O.M. OPINION OF PROBABLE COST		**HYDROGEN YARD AREA:**	**3,000**

ITEM NO.	DESCRIPTION	EST QTY	UNIT	UNIT COST	TOTAL COST
1	**GENERAL REQUIREMENTS**				**$**
	SEE PERCENTAGE ALLOWANCE				
	SUBTOTAL				
2	**EXISTING CONDITIONS**				**$**
	SITE DEMOLITION (HAULING INCLUDED)				
	DEMOLISH EX. TRASH ENCLOSURE & BUILD NEW, W/ CMU WALLS, METAL GATE - OVERALL 10'X20'	200	SF	17.25	3,450
	DEMOLISH CURB & PATCH ALONG EDGE OF EX. PAVING & NEW HYDROGEN YARD - SAY 3' WIDE	126	LF	100.50	12,663
	MISC. SITE DEMO & PROTECTION WORK	1	LS	4,030.00	4,030
	SUBTOTAL				**20,143**
11	**EQUIPMENT**				**$**
	HYDROGEN FUEL EQUIPMENT & RELATED				
	18,000 GALLON LH2 TANK	1	EA	840,000	840,000
	RECIPROCATING LIQUID-HYDROGEN PUMP (N+1)	3	EA	190,000	570,000
	HIGH PRESSURE GASEOUS-HYDROGEN COMPRESSOR	2	EA	220,000	440,000
	DISPENSER VAPORIZER	2	EA	70,000	140,000
	OFFLOAD VAPORIZER	1	EA	40,000	40,000
	PRIORITY VALVE PANEL	1	EA	90,000	90,000
	HIGH-PRESSURE GH2 STORAGE VESSEL FOR H35 FUEL	6	EA	39,000	234,000
	HIGH-PRESSURE GH2 STORAGE VESSEL FOR H70 FUEL	2	EA	42,000	84,000
	PRE-DISPENSING CHILLER	2	EA	20,000	40,000
	GH2 H35 DISPENSER	2	EA	60,000	120,000
	GH2 H70 DISPENSER W/ CHILLER1 EA	1	EA	85,000	85,000
	AIR COMPRESSOR SYSTEM	1	EA	9,000	9,000
	FLAME-DETECTION SYSTEM	1	EA	60,000	60,000
	MAIN SERVICE PANELBOARD	1	EA	25,000	25,000
	TRIPLEX MOTOR STARTER PANELBOARD	1	EA	65,000	65,000
	SYSTEM CONTROL PANEL/PLC W/ PROGRAMMING	1	EA	60,000	60,000
	TRANSFORMER (ALLOWANCE)	1	EA	25,000	25,000
	ALLOWANCE FOR FREIGHT, TAXES & INSTALLATION OF HYDROGEN FUELING EQUIPMENT	50%		2,927,000	1,463,500
	ELEC PANELS AND CONTROLS, ALLOWANCE	1	LS	146,350.00	146,350
	INTRA HYDROGEN EQUIPMENT PIPING, VALVES & SPECIALTIES - ALLOWANCE	1	LS	234,160.00	234,160
	FUEL PIPING FROM HYDROGEN YARD TO FUEL CANOPY HYDROGEN DISPENSERS - ALLOWANCE (SAME TRENCH AS ELECTRICAL FEEDERS)				SEE DIV 32
	CUT & PATCH EX PAVING/FLOORING FOR PIPE TRENCH				SEE DIV 33
	SUBTOTAL				**4,771,010**
26	**ELECTRICAL**				**$**
	PRIMARY POWER SERVICE				
	ASSUME NOT REQUIRED				
	MAIN POWER SYSTEM - NORMAL				
	RSG POWER FEEDER FROM U/G DUCTBANK TO INTERIOR ELECTRICAL ROOM + C & P	75	LF	269.00	20,175

PROJECT: GOLD COAST TRANSIT DISTRICT MAINTENANCE & OPERATIONS FACILITY - ZERO EMISSIONS BUS MASTER PLAN		**JYI #:**	**C2616A-R2**
LOCATION: OXNARD, CA		**DATE:**	**16-Jun-22**
CLIENT: STANTEC		**REVISED:**	**24-Jun-22**
DESCRIPTION: R.O.M. OPINION OF PROBABLE COST		**HYDROGEN YARD AREA:**	**3,000**

ITEM NO.	DESCRIPTION	EST QTY	UNIT	UNIT COST	TOTAL COST
	POWER CONNECTION TO EXISTING ELECTRICAL SERVICE IN ELECTRICAL ROOM	1	LS	10,000.00	10,000
	HYDROGEN EQUIPMENT NORMAL POWER HOOKUP, INCLUDING DISCONNECT SWITCHING				
	RECIPROCATING LH2 PUMP (N+1)	3	EA	1,115.00	3,345
	HIGH PRESSURE GH2 COMPRESSOR	1	EA	1,275.00	1,275
	HYDROGEN VAPORIZER	2	EA	1,015.00	2,030
	SUPERHEATER VAPORIZER	1	EA	1,275.00	1,275
	GH2 PRIORITY VALVE PANEL	1	EA	450.00	450
	GH2 H35 DISPENSER	2	EA	1,015.00	2,030
	GH2 H70 DISPENSER W/ CHILLER	1	EA	1,275.00	1,275
	AIR COMPRESSOR SYSTEM	1	EA	1,275.00	1,275
	MAIN SERVICE PANELBOARD	1	EA	625.00	625
	MOTOR STARTER PANELBOARD FOR PUMPS	2	EA	500.00	1,000
	SYSTEM CONTROL PANEL	1	EA	500.00	500
	TRANSFORMER (AS NEEDED)	1	EA	1,000.00	1,000
	EMERGENCY POWER				
	ALLOW FOR EMERGENCY GENERATOR CIRCUITRY REWORK FOR HYDROGEN EQUIPMENT	1	LS	25,000.00	25,000
	MISCELLANEOUS				
	MISC./ TESTING/COMMISSIONING	1	LS	3,560.00	3,560
	SUBTOTAL				**74,815**
27	**COMMUNICATIONS**				**$**
	ALLOWANCE FOR COMMUNICATIONS UPGRADE FOR HYDROGEN INSTALLATION	3,000	SF	10.20	30,600
	SUBTOTAL				**30,600**
28	**ELECTRONIC SAFETY & SECURITY**				**$**
	GAS/HYDROGEN DETECTION SYSTEM INCLUDING AUDIBLE & VISIBLE ALARMS - MAINTENANCE & BUS WASH BUILDINGS	29,925	SF	11.22	335,759
	SUBTOTAL				**335,759**
31	**EARTHWORK**				**$**
	GRADE, LEVEL & COMPACT FOR EQ. YARD, SAY AV .3' D, 128' X 24'	340	CY	50.00	17,000
	SUBTOTAL				**17,000**
32	**EXTERIOR IMPROVEMENTS**				**$**
	EQUIPMENT PADS & THE LIKE				
	FUEL ISLAND EXPANSION & CURB / EQUIPMENT PADS	162	SF	50.00	8,100
	FUEL EQUIPMENT YARD PAVING + 60% EQUIPMENT PAD THICKENING	3,000	SF	22.20	66,600
	MISC. HYDROGEN YARD PADS	1	LS	3,735.00	3,735
	EQUIPMENT ANCHORAGE				
	EQUIPMENT ANCHORAGE - HYDROGEN COMPONENTS	12	EA	750.00	9,000
	SITE MISCELLANEOUS				
	PIPE BOLLARDS, PAINTED, AT FUEL ISLAND EXTENSION	6	EA	1,250.00	7,500
	PIPE BOLLARDS, PAINTED, AT HYDROGEN YARD	15	EA	1,250.00	18,750
	ROLLING GATE, 20' L X 8' H, MANUAL	1	EA	4,800.00	4,800
	PEDESTRIAN GATE, 3' X 8'	1	EA	840.00	840

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DESCRIPTION: R.O.M. OPINION OF PROBABLE COST		**HYDROGEN YARD AREA:**	**3,000**

ITEM NO.	DESCRIPTION	EST QTY	UNIT	UNIT COST	TOTAL COST
	CHAIN LINK FENCE, 8' H	126	LF	68.00	8,568
	8" CMU RETAINING WALL, 8' H PLUS FOUNDATION	171	LF	846.67	144,780
	ALLOWANCE FOR ADDITIONAL SECURITY CAMERAS TIED TO EX. CONTROL ROOM	4	EA	7,000.00	28,000
	MISC. SITE IMPROVEMENTS ALLOWANCE	1	LS	15,030.00	15,030
	SUBTOTAL				**315,703**
33	**UTILITIES**				**$**
	YARD LIGHTING				
	NEW LIGHT POLE AND FEEDERS TO EQ. YARD	2	EA	4,200.00	8,400
	CUTTING & PATCHING FOR TRENCHING				
	1-PIPE TRENCH, 1'-6"W INCLUDING C & P 10" CONC. SLAB	113	LF	179.67	20,302
	3-4 PIPE TRENCH, 4'-6"W INCLUDING C & P 10" CONC. SLAB	88	LF	245.67	21,619
	FUEL PIPING				
	FUEL PIPING FROM HYDROGEN YARD TO FUEL CANOPY HYDROGEN DISPENSERS - ALLOWANCE (SAME TRENCH AS ELECTRICAL FEEDERS)	352	LF	196.875	69,300
	POWER FEEDERS AND DUCTBANK				
	DUCTBANK ENCASED NORMAL POWER FEEDER FROM HYDROGEN YARD TO ELECTRICAL ROOM	176	LF	320.81	56,463
	DUCTBANK ENCASED POWER FEEDER TO HYDROGEN DISPENSERS	332	LF	269.00	89,309
	SUBTOTAL				**265,393**

APPENDIX D: FINANCIAL MODELING INPUTS AND ASSUMPTIONS

Table 28 presents a description as well as the sources for the cost inputs (in 2022$) of the Base Case and the ZEB Case.

Table 28: Summary of cost inputs

Main Category	Item	Description	Inputs for Base Case	Inputs for ZEB Case	Sources and comments
Capital					
Fleet acquisition	Bus purchase price	Purchase price of a bus/vehicle inclusive of options and taxes and extended warranty	CNG 40-ft: $600,000 CNG 35-ft: $552,000 CNG Cutaway: $130,000 Gas passenger van: $77,000	FCEB 40-ft: $1,100,000 FCEB 35-ft: $1,012,000 FCE Passenger van: $220,000	Base Case: industry values and GCTD FY2021-22 Budget Book ZEB Case: industry values CalDGS, and MBTA/CalACT Values are in 2022$ and adjusted over time based on price trendlines from CARB
Fleet refurbishment	Mid-life rehabs	Any heavy mid-life work needed to achieve the useful life minimum benchmark	N/A; GCTD does not perform any heavy mid-life work on its CNG fleet	$30,000 per 40-ft and 35-ft FCEB at 6 years for fuel cell stack replacement	Base Case: GCTD ZEB Case: OEM information; smaller vehicles with shorter lifespan are not assumed to require a fuel cell stack replacement
Infrastructure and Facility Modifications	Infrastructure Modification Costs	Includes equipment, installation, testing, civil and electrical work, as well as contractor's fees and escalation factors. Includes backup	N/A	$8,967,000	Engineer's cost estimate

Main Category	Item	Description	Inputs for Base Case	Inputs for ZEB Case	Sources and comments
		generator for hydrogen fueling equipment.			
Operating and Maintenance					
Operating	Vehicle fuel	Cost of fuel commodity for revenue vehicles	CNG: $0.64 per diesel gallon equivalent Gasoline: $6.00 per gallon	Hydrogen: $6.00 per kg	Base Case: GCTD ZEB Case: Industry reports Trendlines for projected CNG and gasoline costs were obtained from the US Energy Information Agency for the Pacific region and applied to CNG and gasoline costs through 2040.[63] For hydrogen fuel costs, industry research indicates that overtime, the cost will decrease from $6.00 per kg to $4.00; the model accounted for decreases in price over time.
Maintenance	Vehicle maintenance costs	Maintenance costs (per mile) inclusive of labor and parts for scheduled and unscheduled maintenance	Fixed-route buses: $1.48 per mile Demand response vehicles: $0.89 per mile	Fixed-route buses: $1.48 per mile Demand response vehicles: $0.89 per mile	Base Case: NTD 2019 Operating Expenses Detailed sheet, adjusted to 2022$ ZEB Case: Based on industry research demonstrating comparative

[63] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2022&region=1-9&cases=ref2022&start=2020&end=2050&f=A&linechart=ref2022-d011222a.3-3-AEO2022.1-9&map=ref2022-d011222a.26-3-AEO2022.1-9&ctype=map&sid=ref2022-d011222a.26-3-AEO2022.1-9&sourcekey=0

Main Category	Item	Description	Inputs for Base Case	Inputs for ZEB Case	Sources and comments
					maintenance costs per mile for two Southern California agencies operating CNGs and FCEBs[64]

[64] https://www.nrel.gov/docs/fy21osti/78078.pdf, https://www.nrel.gov/docs/fy21osti/78250.pdf