ELECTRIFYING BAY AREA: POLICY ANALYSIS AND PRESCRIPTION FOR TRANSITIONING BAY AREA TRANSIT BUSES TO ZERO EMISSION FLEET

Source: Auto.com from the Economic times[1]

Janani Thiagarajan

December 2023

[1] *ChargePoint partners with SFMTA on charging infrastructure for electric buses, Auto News." 2019. ET Auto.* https://auto.economictimes.indiatimes.com/news/industry/chargepoint-partners-with-sfmta-on-charging-infrastructure-for-electric-buses/71444154.

ELECTRIFYING BAY AREA: POLICY ANALYSIS AND PRESCRIPTION FOR TRANSITIONING BAY AREA TRANSIT BUSES TO ZERO EMISSION FLEET

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EXECUTIVE SUMMARY

This report attempts to identify barriers faced by transit agencies in the San Francisco Bay Area during the fleet electrification process and prescribe policies to alleviate these obstacles and improve the uptake of electric buses. With the increasing focus on reducing Greenhouse Gas emissions from the transportation sector, there has been much impetus, particularly in California, to transition existing public transit bus fleets into zero emission vehicles. California Air Resources Board's Innovative Clean Transit regulation, further mandates that this be achieved by 2040. Thus, it is important that the issues concerning fleet electrification be studied and appropriate policies be adopted to facilitate transition to electric buses.

The nine county San Francisco Bay Area is an urbanized region that has an extensive public transportation network covering both high-density developments and suburbs. Nineteen transit agencies govern the public bus transit system and are currently in the process of transitioning their bus fleets to zero emission buses. Staff of these transit agencies were interviewed to get an understanding of their fleet electrification efforts and its associated planning processes. Subsequently, the main barriers to fleet electrification in the Bay Area were identified by analyzing the primary data from these interviews. This revealed that the most prioritized planning issues were (i) Lack of adequate funding for all transit agencies, (ii) Issues with PG&E (the utility provider), (iiii) Dearth of skilled workforce, (iv) lack of standardization in infrastructure, (v) anxiety on the grid capacity and operational resilience and (vi) Lack of a streamlined/consolidated grant application process.

Extensive literature review of reports, research papers and articles, and detailed case studies of successful fleet electrification projects were done to understand the existing policy scenario in the Bay Area and to identify policies that aided electric bus uptake. Initially the proposed policies were categorized as either long term or short term based on the time taken to implement them. These were further refined into two policy packages - the low investment package and high investment package - based on the Non dominated alternatives method of policy analysis. The Low investment package focuses on infrastructure/ operations planning and capacity building and is characterized by low capital and implementation costs. The High investment package focuses on fund procurement for transit agencies or utility companies and, though highly effective, incurs excessive costs.

The Low investment package is the preferred alternative, due to the low investment costs and better implementation feasibility. It addresses key issues including development of a skilled workforce that can help plan and operate electric fleet operations and require preparation for operation resilience during emergencies. It is the more practical approach that focuses on capacity building within transit agencies and enables them to utilize their funding in an effective manner.

1. CHAPTER 1: INTRODUCTION

The transportation sector is a major contributor of Greenhouse Gas (GHG) emissions because of its heavy reliance on fossil fuels. With the advent of battery powered vehicles, which have virtually no tailpipe emissions, there is a global drive to electrify the transportation sector. In the United States, there is much impetus towards electrification of heavy-duty vehicles including buses and trucks as they contribute to air pollution, particularly in disadvantaged and low-income communities. Thus, many transit agencies have been transitioning to electric buses to reduce GHG emissions. This process is termed “fleet electrification” and is defined “as the transition of fleet vehicles from internal combustion engines (ICE) to zero-emission electric vehicles (EV)”[2].

1.1 Relevance

According to the California Air Resources Board (CARB), the transportation sector is responsible for 38 percent of the total GHG emission in California, as of 2020.[3] Public transit, including buses and rail, contributes to a small fraction of these emissions. However, public transit vehicles are heavily reliant on diesel which result in emissions that are far more toxic and potent compared to gasoline.

Of all the public transit modes, buses are the most polluting with carbon emissions of 299 grams (gms) per passenger mile when compared to rail, which emit 177 gms per passenger mile[4]. A 2010 report by the U.S Department of Transportation further finds that the emission levels of an average occupancy bus is higher than that of a 4-person carpool trip or a general non-work trip[5]. A comparison of GHG emissions per passenger mile for different modes (Figure 1.1) indicates that non-electric buses have emissions that are comparable to a single occupancy Private Gasoline Vehicles. Battery Electric buses have very low emissions, even if the electricity is derived from high GHG emitting sources. Thus, reducing GHG emissions of bus fleets is an imperative goal for transit agencies and local governments to achieve carbon neutrality.

In addition to reduced emissions, electric fleets also have added health and economic benefits. “According to the American Health Association’s March 2022 report “Zeroing in on Healthy Air,” the electrification of transportation would save about $72 billion in health-related benefits and avoid more than 6,000 premature deaths by 2050.”[6] This is especially relevant in large urban areas where public transit systems are present in heavily populated areas, which are more susceptible to the negative impacts of tailpipe

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[2] *Driivz. 2022. “What is Fleet Electrification?” Driivz. https://driivz.com/glossary/fleet-electrification/.*

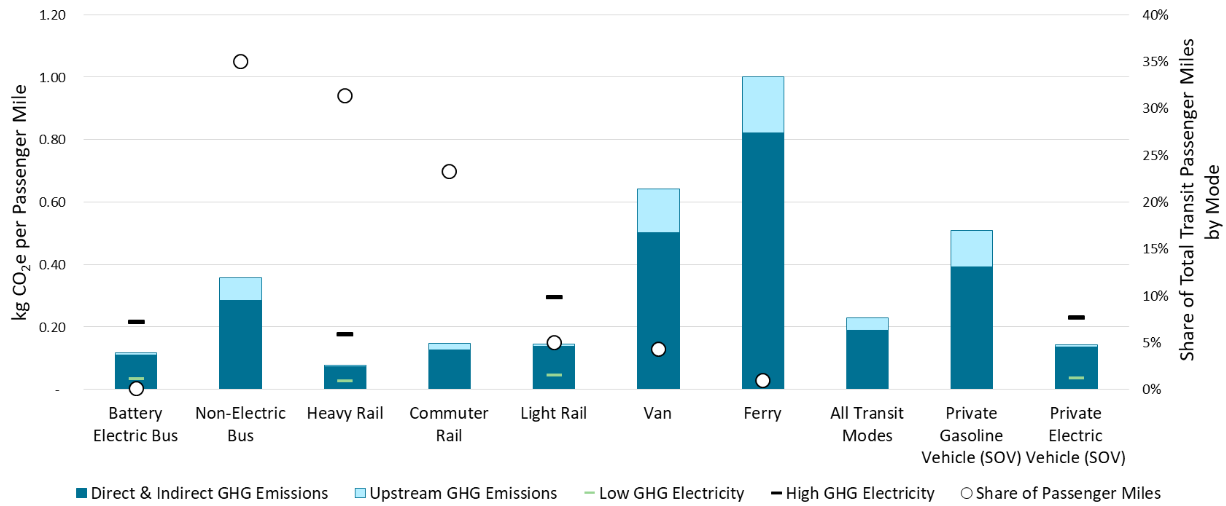
[3] *California Air Resources Board. n.d. “Current California GHG Emission Inventory Data | California Air Resources Board.” California Air Resources Board. Accessed February 9, 2023. https://ww2.arb.ca.gov/ghg-inventory-data.*

[4] *Blumgart, Jake. 2022. Are Trains or Buses Better for the Environment? https://www.governing.com/next/are-trains-or-buses-better-for-the-environment.*

[5] *Hodges, Tina. 2010. “Public Transportation's Role in Reducing Greenhouse Gas Emissions (January 2010).” Federal Transit Administration. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/PublicTransportationsRoleInRespondingToClimateChange2010.pdf.*

[6] *Driivz. 2022. “What is Fleet Electrification?” Driivz. https://driivz.com/glossary/fleet-electrification/.*

emissions. Disadvantaged communities and vulnerable populations including the elderly, children and minorities will be positively impacted from the shift to cleaner vehicles.



** SOV is a single occupancy vehicle. Average private vehicle occupancy for commute trips is 1.18 passengers, for all trips 1.67 passengers (NHTS).*

Source: An Update on Public Transportation's Impacts on Greenhouse Gas Emissions, 2021[7]

Figure 1.1: Average GHG emissions per passenger mile by mode.

Electric buses also have many economic benefits in terms of reduced operating and maintenance costs. When designed properly, electric buses can result in reduced operation cost for transit agencies in the long run due to reliance on renewable energy sources like solar.[8] Though the initial capital cost for electric buses is high, this can be offset by the reduced maintenance /operating cost over time. "It is about 2.5 times cheaper to power vehicles with electricity rather than diesel, and electricity prices are generally much more stable than gasoline or diesel prices." [9] With higher fuel efficiency and lesser moving parts, electric buses incur lesser maintenance costs. With technological advancement and a growing market for electric buses, the initial cost of these buses is expected to go down.

Currently in California, many legislations have been passed, both at the state and federal levels, which encourage transit agencies to shift to zero emission fleets. Specifically the Innovative Clean Transit Rule (2018) requires all transit agencies to purchase zero emission buses by 2029 and transition all of their fleets to zero emission technology by 2040.[10] There are many other policies and legislation, including SB

[7] *"An Update on Public Transportation's Impacts on Greenhouse Gas Emissions." 2021. The National Academies Press. https://nap.nationalacademies.org/catalog/26103/an-update-on-public-transportations-impacts-on-greenhouse-gas-emissions.*

[8] *California Air Resources Board. n.d. "Innovative Clean Transit | California Air Resources Board." California Air Resources Board. Accessed February 12, 2023. https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit/about.*

[9] *Nunno, Richard. 2018. "Fact Sheet | Battery Electric Buses: Benefits Outweigh Costs | White Papers | EESI." Environmental and Energy Study Institute. https://www.eesi.org/papers/view/fact-sheet-electric-buses-benefits-outweigh-costs.*

[10] *California Transit Association. n.d. "Zero-Emission Bus Regulation." California Transit Association. Accessed February 12, 2023. https://caltransit.org/advocacy/key-issues/zero-emission-bus-regulation/.*

372, Clean Truck and Bus Vouchers (HVIP), Medium- and Heavy-Duty Fleet Zero-Emission Vehicle Purchasing Support that are geared to support fleet electrification through the provision of funds and rebates.

Given this context, it is evident that public transit electrification is the need of the hour. Transit agencies in the Bay Area are transitioning to zero emission buses (ZEB) and thus require a favorable policy framework that can enhance and support the uptake of ZEBs.

1.2 Intended Audience

This report is intended to address a diverse array of people. Planners, particularly transportation planners and policy planners working on fleet electrification programs are the priority audience of this report. This will also benefit transportation planners in the Bay Area.

Transit agencies and city governments can draw upon the findings of this report to gain an understanding of the practical difficulties associated with transitioning to zero emission buses and implement policies that address these issues. Transit agencies in the Bay Area will particularly find this report relevant.

Sustainable transportation advocates can utilize this report to better understand the constraints faced by transit agencies in transitioning to zero emission vehicles, propose solutions for increased ZEB uptake and advocate for policies that are geared towards fleet electrification.

With the electrification of public transit being a relatively new phenomenon in urban planning, this report intends to contribute to the existing body of literature on policy planning for fleet electrification, especially in the context of the Bay Area. Thus, academicians and urban planning researchers will find this report useful.

Lastly, this report intends to impart a general understanding of fleet electrification to its readers by introducing basic concepts of electrification and giving an overview of the existing ZEB policy framework in the Bay Area. This is particularly useful in informing the general public about electrification policies and empowering them to support policies that promote electric vehicle uptake.

1.3 Research question and methodology

Research question

This study aims to understand problems incurred by transit agencies during the fleet electrification process and prescribe policy solutions that can facilitate e-bus uptake. It particularly analyzes bus fleet electrification in the context of the Bay Area and attempts to identify the barriers faced by Bay Area transit agencies. Furthermore, it seeks to explore policy practices that can best mitigate these obstacles and improve e-bus uptake.

The study will conclude by proposing a policy recommendation package that can promote fleet electrification in the San Francisco Bay Area. It also aims to inform on the existing condition of fleet electrification in the Bay Area and assist government organizations, including transit agencies, to plan and implement policies that can fast track the fleet electrification process.

Methodology

The first step of this research focused on understanding the fleet electrification process and the current Zero emission bus policy framework in the Bay Area. Firstly, an extensive literature review was conducted to outline the basic components of fleet electrification, barriers to electrification and the current ZEB policy framework. This step is crucial to understand the working of electric fleets and how policies have been formulated over time to facilitate fleet electrification. This would also aid in refining later parts of the research including primary data collection and policy prescription.

This second step of the research involves field design research which will provide a rich description of the existing policy framework and the fleet electrification planning process in the Bay Area. Primary data on current conditions were garnered through interviews with staff in Bay Area transit agencies. This is further supported by case study research of the bus electrification project of Antelope Valley Transit Authority (AVTA) and City of Shenzhen, which offer insights into best practices and policies for transit electrification. This data will be used to identify existing barriers/gaps in the existing policy framework and recognize policies that were particularly useful in promoting electric bus uptake.

The last step involves formulation of policy recommendations to mitigate these shortcomings. These policy alternatives will be further scrutinized based on certain analysis criteria, using a policy analysis matrix, which will aid in distinguishing the most effective policies. These will then be recommended as part of the final policy prescription package.

1.4 Structure of the report

This chapter introduces the research paper and illustrates the relevance of the project topic in the current context of California. It defines the research question and outlines the research methodology adopted.

Chapter 2 delineates the study area, San Francisco Bay Area, provides a description of public transit agencies that operate in the Bay Area, outlines federal and state policies that aid fleet electrification and enlists all relevant stakeholders.

Chapter 3 provides insight into the process of fleet electrification in the United States through extensive review of research papers and project reports. It details the components of the fleet electrification project including the infrastructure, planning and operations. This is followed by outlining the potential barriers for electrification and policies/ best practices that have been adopted globally for achieving fleet electrification.

Chapter 4 discusses and analyzes the data obtained from nine transit agencies in the Bay Area to identify barriers for fleet electrification.

Chapter 5 presents case studies of two successful fleet electrification projects - Antelope Valley Transit Authority (AVTA), California and City of Shenzhen, China. It imparts an understanding on the practical implementation of fleet electrification projects and identifies key policies that facilitated electric vehicle uptake.

Chapter 6 explores policy alternatives and prescribes a policy package that can aid fleet electrification in the Bay Area

Chapter 7 summarizes the findings of the study, its limitations and future research possibilities.

2. CHAPTER 2: BAY AREA CONTEXT

This research intends to formulate policies that can aid with the electrification of public transportation in urban areas. This paper focuses on the nine county San Francisco Bay Area in California primarily because:

I. the region is highly urbanized and has a relatively extensive public transit network compared to other U.S. metropolitan areas;
II. the local governments of the Bay Area are currently in the process of electrifying their existing transportation systems to achieve carbon neutrality; and
III. the urban character of this region, ranging from high density developments in San Francisco to suburban areas in Pleasanton, exhibits different transit characteristics (in terms of average trip numbers, trip length and fleet size) and thus, presents an opportunity to understand the electrification processes and concerns in diverse contexts.

2.1 Study Area

The San Francisco Bay Area region is composed of nine counties: San Francisco, Marin, Contra Costa, Alameda, Santa Clara, San Mateo, Sonoma, Napa, and Solano.[11] (Figure 2.1). This region spans 7000 sq miles with about 101 cities[12] and has a population of 7.77 million people.[13] The region is experiencing substantial growth in population of about 8.6 percent in the last decade which added about six hundred thousand new residents.[14] The Association of Bay Area Governments (ABAG) is the regional planning agency that governs the region with regards to issues of land use, housing and sustainability.[15] The Metropolitan Transportation Commission (MTC) is the regional transportation agency and is responsible for coordinating transportation planning, providing technical assistance and financing projects in the region.[16] It is to be noted that MTC and ABAG, as of 2017, have been consolidated to "promote better collaboration and integration on common goals, and to achieve operating efficiencies."[17]

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[11] *California Climate Adaptation Strategy. n.d. "San Francisco Bay Area Region." California Climate Adaptation Strategy. Accessed February 10, 2023. https://www.climateresilience.ca.gov/regions/sf-bay-area.html.*

[12] *Statista. 2022. "San Francisco Bay Area - GDP 2021." Statista. https://www.statista.com/statistics/183843/gdp-of-the-san-francisco-bay-area/.*

[13] *Li, Roland, and Nami Sumida. 2021. "Census 2020: Bay Area population grew at faster rate than California, with big Asian and Latino gains." San Francisco Chronicle. https://www.sfchronicle.com/bayarea/article/Census-2020-Bay-Area-population-grew-at-faster-16383491.php.*

[14] *ibid*

[15] *Association of Bay Area Governments. n.d. "About ABAG." Association of Bay Area Governments. Accessed February 10, 2023. https://abag.ca.gov/about-abag.*

[16] *Metropolitan Transportation Commission. n.d. "What Is MTC?" Metropolitan Transportation Commission. Accessed February 10, 2023. https://mtc.ca.gov/about-mtc/what-mtc.*

[17] *Metropolitan Transportation Commission. 2017. "ABAG and MTC Staff Join Forces." Metropolitan Transportation Commission. https://mtc.ca.gov/news/abag-and-mtc-staff-join-forces.*

Source: https://www.vectorstock.com/royalty-free-vector/administrative-san-francisco-bay-area-map-vector-27743725

Figure 2.1: Administrative map of San Francisco Bay Area

2.2 Public Transit in Bay Area

The Bay Area is served by multiple transportation modes including rail, road and waterways. The public transit system spans across all these modalities which includes "*heavy rail (BART), light rail (Muni Metro and VTA Light Rail), commuter rail (Caltrain and ACE), diesel and electric buses, cable cars, and ferries*".[18] According to the Plan Bay Area 2050 regional transportation plan, public transit accounts for 13 percent of the commute mode share in the Bay Area which makes it the second most used transportation mode after automobiles.[19]

Public buses are a vital part of the entire public transit network because they provide the first and last mile connectivity to other transportation modes, including BART and Caltrain stations, in the Bay Area. These bus networks are operated by nineteen transit agencies in the Bay Area which are listed in Table 2.1. agencies.

[18] *Metropolitan Transportation Commission. 2021. "Plan Bay Area 2050." Plan Bay Area 2050. https://www.planbayarea.org/sites/default/files/documents/Plan_Bay_Area_2050_October_2021_rev.pdf.*
[19] *ibid*

Table 2.1: List of bus operators in the Bay Area

Transit Agency	Logo
Alameda-Contra Costa Transit District (AC Transit)	
Central Contra Costa Transit Authority (CCCTA), also known as County Connection	
Eastern Contra Costa Transit Authority (ECCTA), also known as Tri Delta Transit	
Fairfield and Suisun Transit (FAST)	
Golden Gate Transit (GG Transit)	
Livermore-Amador Valley Transit Authority (LAVTA), also known as wheels	
Marin Transit	
Napa Valley Transportation Authority (NVTA), known as VINE	
Petaluma Transit	
Rio Vista Delta Breeze	
SamTrans	
Santa Clara Valley Transportation Authority (VTA)	
Santa Rosa CityBus (SR CityBus)	
San Francisco Municipal Transportation Agency (SFMTA), known as Muni	
Sonoma County Transit	
Solano County Transit, known as SolTrans	
Union City Transit	
Vacaville City Coach	
Western Contra Costa Transit Authority, known as WestCAT	

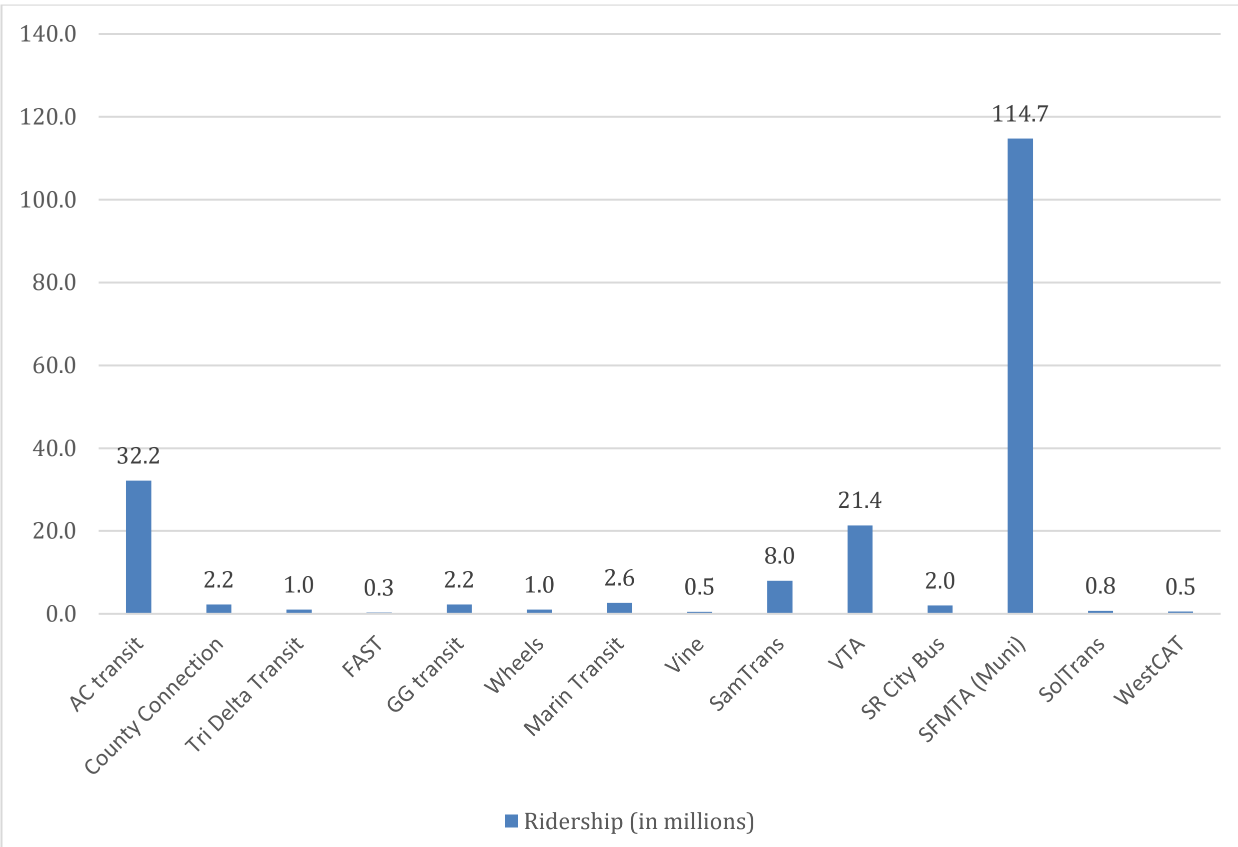
Source: https://www.seamlessbayarea.org/blog/transitagencieslist

Figure 2.2 shows the location of operation of these transit agencies. It is also to be noted that each color patch represents the service area of each transit agency.

Source: https://www.seamlessbayarea.org/blog/transitagencieslist

Figure 2.2: Bus Transit operators in Bay Area

Figure 2.3 depicts the total ridership data (including all public transit modes like rail, bus, demand response etc.) for 2022 of the Bay Area Transit agencies. It can be observed that AC Transit, SFMTA (Muni) and VTA are the largest transit operators in the Bay Area that account for the majority of public transit ridership. It is to be noted that due to the unavailability of ridership data for Petaluma transit, Rio Vista Delta Breeze, Union City transit and Vacaville city coach, these agencies are not represented in the chart.



Source: compiled by the author from multiple sources including American Public Transportation Association - Transit Ridership report fourth quarter 2022[20], City of Santa Rosa[21], and Western contra costa transit authority - Short range transit plan[22].

Figure 2.3: 2022 Annual public transit ridership of Transit operators in Bay Area

[20] *American Public Transportation Association. "PUBLIC TRANSPORTATION RIDERSHIP REPORT Fourth Quarter 2022." American Public Transportation Association, 1 March 2023, https://www.apta.com/wp-content/uploads/2022-Q4-Ridership-APTA.pdf. Accessed 15 November 2023.*

[21] *Santa Rosa City Bus. "CityBus General Info." Santa Rosa, CA, https://www.srcity.org/2492/CityBus-General-Info. Accessed 15 November 2023.*

[22] *Western contra costa transit authority. "Short Range Transit Plan." WestCAT, 20 May 2022, https://www.westcat.org/Content/Pdf/SRTP%202023%20Final.pdf. Accessed 15 November 2023.*

2.3 Federal and state policies for Fleet electrification

The United States has pledged to go carbon neutral by 2050 and reducing GHG emissions is a key part of the step towards achieving this goal.[23] The Bipartisan Infrastructure Law, passed in 2021, allocates about $108 billion dollars to modernize public transportation and support the replacement of existing vehicles with low or zero emission ones.[24] The state of California seeks to achieve carbon neutrality by 2045 and achieve 85percent reduction in GHG emissions by then.[25] The California Air Resources Board (CARB) has passed several regulations that aim to reduce air pollution and spur the uptake of zero emission vehicles in the state.

2.3.1 Federal policies

Almost all the federal policies focus on providing grants and funds for fleet electrification. They do not mandate local governments and transit agencies to transition to Zero emission vehicles but simply provide the means to do so. Federal programs also sponsor research in "*the development and deployment of cleaner, more efficient public transit vehicles*" through its Zero Emission Research Opportunity (ZERO) program.[26] However, there are only two main federal programs that focus directly on the electrification of bus fleets. They are

1. Low or no Emission Program [27]

This federal policy provides funding to state/ local governments and transit agencies for procuring zero or low emission buses and associated infrastructure including charging and maintenance facilities. The federal funding share comprises 85percent of the project cost, with the rest being matched by the applicant. Additionally, it also mandates allocation of at least 5percent of the awarded amount towards workforce training and development. As of 2023, the Federal Transit Administration has announced a funding of $1.2 billion for this program.

2. Grants for Buses and bus facilities program[28]

This program also provides funding to state/ local governments, transit agencies and private nonprofit organizations for purchasing low or zero emission buses (particularly fixed route buses) and constructing related infrastructure. This also requires allocation of 5percent of the awarded funds to workforce

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[23] *Parry, Ian. "A New Vision for the US Climate Agenda." International Monetary Fund, 10 March 2021, https://www.imf.org/en/Blogs/Articles/2021/03/10/blog-a-new-vision-for-the-us-climate-agenda. Accessed 17 May 2023.*

[24] *Federal Transit Administration. "Bipartisan Infrastructure Law | FTA." Federal Transit Administration, 14 April 2023, https://www.transit.dot.gov/BIL. Accessed 17 May 2023.*

[25] *Office of Governor. "California Releases World's First Plan to Achieve Net Zero Carbon Pollution | California Governor." Gavin Newsom, 16 November 2022, https://www.gov.ca.gov/2022/11/16/california-releases-worlds-first-plan-to-achieve-net-zero-carbon-pollution/. Accessed 17 May 2023.*

[26] *Federal Transit Administration. 2016. "Zero Emission Research Opportunity (ZERO) | FTA." Federal Transit Administration. https://www.transit.dot.gov/zero-emission-research-opportunity-zero.*

[27] *Federal Transit Administration. n.d. "Low or No Emission Vehicle Program - 5339(c) | FTA." Federal Transit Administration. Accessed May 17, 2023. https://www.transit.dot.gov/lowno.*

[28] *Federal Transit Administration. n.d. "Grants for Buses and Bus Facilities Program | FTA." Federal Transit Administration. Accessed May 17, 2023. https://www.transit.dot.gov/bus-program.*

development. However, under this program the federal share is restricted to 80percent. For 2023, funding of about $469.4 million is available under this program.

It is to be noted that the federal government requires transit agencies to prepare a Zero emission fleet transition plan to avail funding from the Grants for Buses and bus facilities program and the Low or no emission program. The transition plan will provide a roadmap to the fleet electrification which includes assessment of existing infrastructure and workforce skill and development of a fleet management strategy.[29]

2.3.2 State Policies

California state has regulatory policies that require compulsory compliance and incentive programs that encourage transit agencies to move towards zero emission buses. The regulatory policies are particularly instrumental to the adoption of zero emission buses in the Bay Area. Some key policies in California are,

1. Innovative Clean transit:

This program is administered by California Air Resource Board (CARB) and it requires that all transit agencies develop a Zero Emission Bus (ZEB) rollout plan and convert their existing bus fleets into electric fleets by 2040.[30] It also requires that all transit agencies (i) submit a Zero emission Bus roll out plan and (ii) compulsorily purchase only zero emission buses from 2029.[31] Under the program transit agencies are categorized as either large or small based on their fleet size and goals are set accordingly to this classification.

2. Clean Truck and Bus Vouchers (HVIP)[32]

HVIP is also administered by CARB and provides subsidies for the procurement of electric buses and charging infrastructure. The main goal is to make zero emission buses affordable by reducing the high upfront cost. This program is one of the major funding sources for transit agencies and has been quite successful in spurring the uptake of cleaner vehicles. As of 2021, this program has been instrumental in the deployment of more than 7000 clean vehicles and attracting over $2 billion investments into purchase of clean heavy duty vehicles.

3. Bus Replacement Grant[33]

This program provides funds to transit agencies for the purchase of new zero emission vehicles to replace old diesel buses. The funding is variable depending on the type of vehicle being purchased. This program

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[29] *Federal Transit Administration. 2022. "Zero-Emission Fleet Transition Plan | FTA." Federal Transit Administration. https://www.transit.dot.gov/funding/grants/zero-emission-fleet-transition-plan.*

[30] *California Transit Association. n.d. "Zero-Emission Bus Regulation." California Transit Association. Accessed March 27, 2023. https://caltransit.org/advocacy/key-issues/zero-emission-bus-regulation/.*

[31] *California Air Resources Board. n.d. "Innovative Clean Transit | California Air Resources Board." California Air Resources Board. Accessed May 18, 2023. https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit.*

[32] *California Air Resources Board. 2021. "CARB reopens incentives for clean trucks and buses | California Air Resources Board." California Air Resources Board. https://ww2.arb.ca.gov/news/carb-reopens-incentives-clean-trucks-and-buses.*

[33] *US Department of Energy. n.d. "Alternative Fuels Data Center: Bus Replacement Grant." Alternative Fuels Data Center. Accessed May 18, 2023. https://afdc.energy.gov/laws/12513.*

is funded by California's share of proceeds from the Volkswagen Environmental Mitigation Trust and is administered by CARB.

4. Electric Vehicle (EV) Incentives for Medium- and Heavy-Duty Fleets - PG&E[34]

Despite the availability of several funds, it has still been difficult for transit agencies to achieve fleet electrification. This is largely attributed to the lack of charging infrastructure and upgradation of the electric grid to support the electricity needs of zero emission fleets. This program attempts to address these concerns through the provision of both technical expertise and fiscal incentives. Pacific Gas and Energy (PG&E) is the main utility company that provides electricity in the Bay Area region. Under the Electric Vehicle Fleet Program, PG&E provides technical support in the design and construction of the charging infrastructure and rebates for the purchase of charging equipment.

The state of California has many fiscal policies that provide funding to transit agencies for the purchase of zero emission buses and construction of related amenities. Other major sources of funds are (i) Low Carbon Transit Operations Program (LCTOP) (from the Cap-and-trade program) (ii) Transit and Intercity Rail Capital Program (TIRCP) and (iii) Carl Moyer program for transit buses.[35] However policies related to fleet management and workforce development are still in a nascent state and have hampered the transition to electric fleets.

2.4 Stakeholders

The main stakeholders in the fleet electrification process are,

(i) Transit agencies: These are the entities that are responsible for the incorporation, operation, and maintenance of public transit (specifically buses in this case). Most transit agencies in the Bay Area, as outlined in Section 2.2, are public sector enterprises that own transit infrastructure and are tasked with providing/ expanding transit service within their jurisdiction. Though most of them also operate the transit service, a few of them have outsourced operations to private sector companies like First Transit, Transdev, MV transportation etc.

(ii) Utility companies: These are majorly private sector companies that provide electricity to the fleet. They are an important stakeholder because they are responsible for providing fuel, upgradation of electrical infrastructure and maintaining the grid. For this reason, it is quite important that utility companies be involved heavily and early in the fleet electrification process. In the Bay Area, Pacific Gas and Electric company (PG&E) is the main electricity provider. In addition, there are a number of other smaller public electric companies including Silicon Valley Power and Alameda Municipal power and clean energy companies such as Clean Power SF, East Bay Community Energy (EBCE) and MCE Clean Energy. Many

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[34] *Pacific Gas and Energy. n.d. "PG&E fleet program for electric vehicles." PGE. Accessed May 18, 2023. https://www.pge.com/en_US/large-business/solar-and-vehicles/clean-vehicles/ev-fleet-program/ev-fleet-program.page?WT.mc_id=Vanity_evfleet.*

[35] *Listgarten, Sherry. 2019. "Electric Buses: Challenges and Opportunities | A New Shade of Green | Sherry Listgarten | Palo Alto Online |." | Palo Alto Online |. https://www.paloaltoonline.com/blogs/p/2019/09/08/electric-buses-challenges-and-opportunities.*

transit agencies have partnered with clean energy companies to reduce the carbon footprint associated with the fueling of e-buses.

(iii) Government agencies: This includes all planning and governmental entities that aid transit agencies in achieving fleet electrification. In this context, they typically comprise government organizations that provide funding, planning approvals and enforce conformity with legislations. At the federal and state level, the Federal Transit Administration (FTA) and Caltrans are major stakeholders in transit electrification as they provide and administer federal and state funds. In the Bay Area, at the regional level, Metropolitan Transportation Commission (MTC) is the regional transportation planning agency that provides funding and administers state funds to transit agencies. Local governments provide planning approvals, enforce land use regulations and in some cases may even provide infrastructure including land that aids with the electrification process. Lastly there are ancillary authorities including California Air Resources Board (CARB) and air quality districts (Bay Area Air Quality Management District (BAAQMD)) that adopt and enforce legislations that transit agencies need to conform to. Thus, government organizations both stimulate and facilitate implementation of electric fleets in the Bay Area.

(iv) Infrastructure manufacturers: This includes e-bus manufacturers, charging equipment manufacturers and e-bus operation management companies (software developers). Currently the role of e-bus manufacturers is very vital as the market for e-buses is still in its nascent stages. In fact, almost all transit agencies bank on the incentives provided by the bus manufacturers for smooth operation and maintenance of electric fleets. Though most e-bus manufacturers produce charging equipment, there are a few standalone charging companies (ChargePoint, WAVE etc.) that provide charging solutions. Software development companies are also becoming an integral part of fleet electrification as software is necessary for seamless operation and maintenance of electric fleets, especially large ones.

Overall, in an all-electric fleet all three components - the bus, charger, and software - must communicate with one another and work congruently. Hence it is key that all these manufacturers collaborate, communicate and develop compatible products to ensure interoperability and convenience of use. Till such standardization levels are achieved, these private companies will need to be a part of the electric fleet planning process.

(v) End users: The general public and transit riders are important stakeholders with regard to public transit electrification as they are the ultimate consumers. Though at present their role in the fleet electrification process is not prominent, the feedback and opinions of transit riders, transit advocates and the public is bound to influence the fleet electrification process, especially during scaling of e-bus operations. Ultimately e-bus services must cater to the affordability, safety, convenience, and comfort of end users.

3. CHAPTER 3: LITERATURE REVIEW

With growing concerns on carbon footprint and GHG emissions, there is a strong drive to electrify transportation systems worldwide. Public transportation, particularly buses, are heavily reliant on diesel, which generates more particulate matter (PM10 and PM 2.5), NOx and CO2 emissions, and endure longer operating hours per day (about 12-16 hours per day on average.[36] Globally, bus transportation is the backbone of public transportation as they account for 80percent of all public transport passenger journeys.[37] This contributes to air pollution, especially in densely populated urban areas. Thus, transit agencies and governments are phasing out fossil fuel dependent buses and pursuing electrification of existing public transportation systems.

The literature review section attempts to understand how public bus transportation systems undergo electrification in the global and USA context. The answer to this question may be achieved by research into the following three sections,

1. **Components of the fleet electrification**: understanding the role of various components that contribute to electrification such as grid infrastructure, bus types, fleet management etc.
2. **Barriers for electrification**: Identification of barriers (technological, financial, operational institutional and social) that slow down/prevent electrification.
3. **Policies for e-bus adoption**: understanding and documenting various policies/ guidelines that have been used by transit agencies or governments that facilitate electrification.

This section is divided into three parts (i) Components of Fleet electrification (ii) Barriers for electrification and (iii) Policies and best practices. The first part aims to give an understanding of what public transit electrification entails and what its fundamental components include, such as physical infrastructure and planning/operation requirements. The second part deals with potential hurdles that are incurred during the fleet electrification process. The third part outlines various policies and best practices that are adopted globally and in the United States to promote electric bus uptake.

3.1 Components of Fleet Electrification

3.1.1 Infrastructure

There are three main infrastructure components related to an electric fleet are (i) bus configuration, (ii) battery storage system and (iii) charging infrastructure.[38] The bus configuration refers to the characteristics of the bus itself like its physical dimensions, weight, the electric drive system[39] employed,

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[36] *Glotz-Richter, Michael, and Hendrik Koch. 2016. "Electrification of Public Transport in Cities (Horizon 2020 ELIPTIC Project)." sciencedirect.com. https://www.sciencedirect.com/science/article/pii/S2352146516304227.*

[37] *ibid*

[38] *Aamodt, Alana, Karlynn Cory, and Kamyria Coney. 2021. "Electrifying Transit: A Guidebook for Implementing Battery Electric Buses." NREL. https://www.nrel.gov/docs/fy21osti/76932.pdf.*

[39] "*Electric drive system means an electric motor and associated power electronics which provide acceleration torque to the drive wheels sometime during normal vehicle operation*". ("Electric drive system Definition", n.d.)

braking systems and other accessories including cabin heating/cooling and data management systems embedded into the bus. Much research and development is also being done to reduce the overall weight of the bus which will improve energy efficiency of electric buses.

The battery storage system provides the energy for propulsion and is often described by its energy capacity, denoted in kilowatt hours (kWh). Electric buses typically employ either one of the three types of Lithium ion batteries, - (i) lithium iron phosphate (LFP), (ii) lithium titanate (LTO), and (iii) lithium nickel manganese cobalt oxide (NMC) - each of which possesses its own pros and cons.[40] The range[41] Electric buses are largely determined by the capacity, technology and age of the battery, which makes it the most vital component. Furthermore, operating conditions including traffic patterns, average speed, load mass, and air conditioning usage and environmental conditions (hot or cold weather) affect battery performance.[42] Battery storage systems also contribute to a significant portion of the bus cost, given the fact that electric buses do not possess any other moving parts. Thus, larger the batteries, higher the initial capital costs.

Charging facilities are the only stationary component of electric bus infrastructure. Typically, two types of charging methods are employed - (i) Depot charging and (ii) On route charging. Depot charging employs conductive charging technology that uses slow chargers which requires about 6 hours on average to achieve full charge.[43] Generally buses get charged when they are parked at a depot overnight. This is the most widely used charging method due to its low operation and maintenance cost, ease of installation, higher charging efficiency and widespread usage in the Electric bus industry.[44] However this may be unsuitable for large fleets as it requires sizable capital infrastructure costs and longer charging times.

On Route charging is a strategy wherein the buses get charged quickly in short bursts while they are in transit. It may use either conductive or inductive charging technology[45] to achieve this. Buses frequently recharge their batteries at charging facilities that are either placed overhead or underground on the road.[46] This improves the range of electric buses significantly as buses are no longer constrained by the battery capacity. As long as the roads are equipped with chargers, buses can traverse longer routes.

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[40] *Aamodt, Alana, Karlynn Cory, and Kamyria Coney. 2021.*

[41] Range refers to the maximum distance that an electric bus can travel on a single charge of its battery system
For conductive charging, direct contact is used between the connector and the charge inlet (Yilmaz and Krein, 2012). For inductive charging, the power is transferred through magnetic fields and no cables are needed

[42] *Zhou, Boya, Ye Wu, Bin Zhou, Renjie Wang, Wenwei Ke, Shaojun Zhang, and Jiming Hao. 2016. "Real-world performance of battery electric buses and their life-cycle benefits with respect to energy consumption and carbon dioxide emissions." www.sciencedirect.com. https://doi.org/10.1016/j.energy.2015.12.041.*

[43] *Carrilero, Isabel, Manuela González, David Anseán, Juan C. Viera, Joaquín Chacón, and Paulo G. Pereirinha. 2018. "Redesigning European Public Transport: Impact of New Battery Technologies in the Design of Electric Bus Fleets." Transportation Research Procedia 33:195-202. https://doi.org/10.1016/j.trpro.2018.10.092.*

[44] *Xylia, Maria, and Semida Silveira. 2018. "The role of charging technologies in upscaling the use of electric buses in public transport: Experiences from demonstration projects." Transportation Research Part A: Policy and Practice 118 (December): 399-415. https://doi.org/10.1016/j.tra.2018.09.011.*

[45] *For conductive charging, direct contact is used between the connector and the charge inlet. For inductive charging, the power is transferred through magnetic fields and no cables are needed (Xylia and Silveira 2018).*

[46] *ibid*

On Route charging works for all scales of electric bus fleets (large and small) as they do not require a large depot yard and simultaneous charging of all buses. Additional benefits include reduced charging time and battery weight which improves transit reliability and bus energy efficiency (improved mileage).[47] However they are still not widespread due to the high capital and operating costs associated with the charging infrastructure.[48]

Other Allied infrastructure: Charging facilities require many other associated infrastructures in addition to chargers. Any charging system that integrates with the electric grid "*must also be paired with ESS[49]s, grid management control systems (or "smart charging" software systems), grid system upgrades (such as transformer upgrades) and the redesign of facilities to support new energy charging and fueling equipment".*[50] This is specifically applicable in the case of Depot charging wherein buses connect to the electric grid. These infrastructures increase the initial capital cost of bus electrification projects, especially in case of a larger fleet. However, in the case of Inductive charging technology there is minimal allied infrastructure requirement, since charging facilities are placed on public right of way.

3.1.2 Planning and operation

Fleet electrification requires extensive planning before being implemented. Some of the main planning problems are (i) choosing an appropriate battery storage system and charging infrastructure (ii) vehicle scheduling (bus timetable) and (iii) charging scheduling.[51]

The range of electric buses is heavily influenced by the type of battery and charging infrastructure being utilized. Operational parameters including route statistics (road conditions, trip length, average trip speed, traffic conditions etc.), climatic conditions, topography and frequency of charging must be considered while choosing the battery and charging technology. "*The improvement of the Electric Bus battery performance and the design of new recharging strategies have greatly reduced the "Range Anxiety", proving that Electric Bus fleets are an effective mobility solution for daily travel activities*."[52] Thus it is quite important that the right battery be coupled with the appropriate charging infrastructure for electric bus fleets to operate efficiently.

Electric buses require a well-planned vehicle schedule that outlines bus routes, travel time and bus frequencies. Most importantly, this scheduling determines the optimum fleet size that can deliver the required number of trips. Charging schedules optimize "*charging cost based on time-of-use electricity*

[47] *Aamodt, Alana, Karlynn Cory, and Kamyria Coney. 2021. NREL.*

[48] *Xylia, Maria, and Semida Silveira. 2018,*

[49] ESS - Energy Storage Systems - mostly batteries.

[50] *Petrunic, Josipa, Elnaz Abotalebi, and Abhishek Raj. 2020. "Best practices and key considerations for transit electrification and charging infrastructure deployment to deliver predictable,." Canadian Urban Transit Research & Innovation Consortium-CUTRIC. https://cutric-crituc.org/wp-content/uploads/2020/06/Best-Practices-and-Key-Considerations-for-Transit-Electrification-and-Charging-Infrastructure-Deployment-to-Deliver-Predictable_-Reliable_-and-Cost-Effective-Fleet-Systems.pdf.*

[51] *Perumal, Shyam S., Richard M. Lusby, and Jesper Larsen. 2022. "Electric bus planning & scheduling: A review of related problems and methodologies." European Journal of Operational Research 301, no. 2 (September): 395-413. https://doi.org/10.1016/j.ejor.2021.10.058.*

[52] *Carrilero, Isabel, Manuela González, David Anseán, Juan C. Viera, Joaquín Chacón, and Paulo G. Pereirinha. 2018,*

prices and the power load at charging stations".[53] It staggers the charging time slots of buses to prevent overloading the electric grid and assigns charging times during off peak hours when electricity prices are lower. Both these schedules must be planned in conjunction with one another to ensure smooth functioning of electric bus fleets and improve cost recovery.

In addition to the above, workforce and disruption management are an important but overlooked component of electric bus fleets. Bus drivers, technicians and administrative staff contribute to a significant portion of operating expenses and must be optimized through crew scheduling.[54] Transit operations may be hindered due to unforeseen circumstances including infrastructure failure, weather conditions etc. Disruption management refers to the planning and implementation of recovery plans and real time control strategies that reduce the impact of such disruptions.[55]

3.2 Barriers for electrification

Electric vehicles are one of the most effective and practical sustainable transportation technologies that can reduce tailpipe emissions. Public transit electrification is still in its nascent state and there are many challenges that need to be overcome for widespread adoption of electric buses. These barriers may be categorized as (i) Technological (ii) Operational (iii) Financial (iv) Institutional and (v) Social. (Table 3.1)

Table 3.1: Barriers for electric bus adoption

Technological	Operational	Financial	Institutional	Social
• Lack of sufficient information • Range and power limitations of e-buses • Design flaws and lack of standardization • Limitations of charging infrastructure • Lack of understanding on existing infrastructure upgradation • Lack of disposal plan for end-of-life batteries • Limited marketplace	• Lack of fleet operation optimization • Lack of operational data • Limited availability workforce	• High upfront costs for bus procurement and charging infrastructure. • Additional cost for operations planning. • Lack of funding options • Lack of investment for scaling	• Inadequate policies that support electrification • Information dissemination • Negative perception • Involvement of all stakeholders	• Visual impact on urban scape

[53] *Perumal, Shyam S., Richard M. Lusby, and Jesper Larsen. 2022*
[54] ibid
[55] ibid

Source: compiled by author from cited literatures

3.2.1 Technological Barriers

Technological barriers refer to challenges that are associated with electric bus components and their capabilities. The challenges with regards to this are

1. Lack of sufficient information: Being a relatively new technology, electric buses are still evolving in terms of design and engineering. Thus, city governments and transit agencies are unaware of the pros and cons of going electric and lack the knowledge to initiate and operate an electric bus project. The World Resource Institute's (WRI) report states that cities face "*difficulty finding reliable, up-to-date sources of information to produce an accurate cost benefit analysis of the efficacy of adopting e-buses*".[56]

2. Range and power limitations of e buses: As discussed in the previous section, range anxiety is the most common barrier that is cited by operators and transit agencies. In comparison to conventional buses, electric buses need to be recharged every 200-250 km, depending on climatic characteristics and road conditions.[57] Cold weather, hilly terrain, internal space heating/ cooling needs and overcrowding of buses tend to drain the batteries, which consequently affects the range of e-buses. However WRI's report suggests that e-bus performances have been improving over the years as indicated by the improving conventional bus replacement ratios in Shenzhen from 2:1 in 2011 to 1.03:1 in 2016.[58] This is further supported by Pereirinha et al and Carrilero et al. studies that outline the advancements in battery storage systems and notes future possibilities of Zinc, Sodium and solid state lithium based batteries.[59] [60]

3. Design flaws and lack of standardization: E-buses face design issues because their performance is heavily affected by the context of use. For example, e-buses that performed well in China completely failed in Bogota Colombia due to rough road conditions, aggressive driving, requirement for a high bus floor and overcrowding.[61] The technical components of e-buses (batteries, brakes etc.) are not yet standardized which creates challenges in case of repair and maintenance. The Ebussed project under the Interreg Europe programme also confirms this by noting that "*there is some hesitance*

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[56] *World Resources Institute Ross Center. 2019. "BARRIERS TO ADOPTING ELECTRIC BUSES." WRI Ross Center for Sustainable Cities. https://wrirosscities.org/sites/default/files/barriers-to-adopting-electric-buses.pdf.*

[57] *Rodrigues, Alyson L., and Sonia. R. Seixas. 2022. "Battery-electric buses and their implementation barriers: Analysis and prospects for sustainability." Sustainable Energy Technologies and Assessments 51 (June). https://doi.org/10.1016/j.seta.2021.101896.*

[58] *World Resources Institute Ross Center. 2019*

[59] *Pereirinha, Paulo G., Manuela González, Isabel Carrilero, David Anseán, Jorge Alonso, and uan C. Viera. 2018. "Main Trends and Challenges in Road Transportation Electrification." Transportation Research Procedia 33:235 - 242. https://doi.org/10.1016/j.trpro.2018.10.096.*

[60] *Carrilero, Isabel, Manuela González, David Anseán, Juan C. Viera, Joaquín Chacón, and Paulo G. Pereirinha. 2018,*

[61] *World Resources Institute Ross Center. 2019*

toward standardization when the technology is simply the one developed and preferred inside each region."[62]

4. Limitations of charging infrastructure: Chargers require space for installation, be deployed in sufficient numbers and need to be protected from inclement weather and other man-made damages. Being the only stationary component, the availability of charging points largely determine and constrain the range and route of e-buses.[63] There is also a lack of standardization in charging facilities that reduces scalability and compatibility between buses and chargers, increases costs due to reliance on few local/regional suppliers and creates logistical challenges at the global level.[64] Thus electric bus fleets have low route flexibility and e-bus interoperability.

   However, research and development are underway for creating better charging infrastructure that can reduce charging time and incur less costs. Some of these advancements are the advent of inductive charging technology (that curtails physical infrastructure requirements including depots) and fast chargers (that reduce charging time and hence require smaller batteries which reduces upfront costs).

5. Lack of understanding on existing infrastructure upgradation: Integration of Battery Electric buses with the main grid, especially for large scale deployments, can influence the load profile and may cause voltage-drop, harmonic pollution, and energy loss.[65] The WRI report finds that "*planners in Cape Town estimated that the charging infrastructure and new parking schematics may require depots to be up to 30 percent to 40 percent larger to accommodate new e-buses and charging infrastructure*."[66] Thus electrification of bus fleets requires uplifting of existing infrastructure, including electric grid upgradation, smart charging, addition of substations/transformers and expansion of depots.[67]

6. Lack of disposal plan for end-of-life batteries: Batteries are the most cost intensive and energy demanding element of an e-bus. Currently as most of the e-buses in the world have not reached the end of their life, much concern has not been raised over battery disposal. However, research and development are being done on the subject of battery recycling and Li-ion battery recycling facilities are being developed.[68]

7. Limited marketplace: The e-bus marketplace is still in its infancy and there are a limited number of companies that manufacture e-buses within the USA. Electric bus procurement projects are eligible for federal funding only if they comply with the "Buy America" policy. This requires bus contracts

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62 *Tartaglia, Ivo. n.d. "Driver and Barriers to electric bus deployment." Interreg Europe. Accessed March 23, 2023. https://projects2014-2020.interregeurope.eu/fileadmin/user_upload/tx_tevprojects/library/file_1611932796.pdf.*

63 *World Resources Institute Ross Center. 2019*

64 *Assured. 2022. "Clean Bus Report." UITP. https://cms.uitp.org/wp/wp-content/uploads/2022/05/ASSURED-Clean-Bus-report_final2.pdf*

65 *Rodrigues, Alyson L., and Sonia. R. Seixas. 2022*

66 *World Resources Institute Ross Center. 2019*

67 *Pereirinha, Paulo G., Manuela González, Isabel Carrilero, David Anseán, Jorge Alonso, and uan C. Viera. 2018*

68 *ibid*

costing over $150,000 to comply with the requirement that 70percent of the cost of the bus be of domestic origin and its assembly must be completely in the USA.[69] Bus manufacturers are also required to provide a certificate of compliance with Buy America when fulfilling federally funded projects. This limits the "*availability of bus technology used in much larger public transit markets*" and may inflate the cost of buses, leading to slower fleet electrification.[70]

3.2.2 Operational Barriers

1. Lack of fleet operation optimization: Electric bus implementation needs to solve problems associated with charging times, bus range, electric grid congestion, fleet size, battery type and size, charging technology, fleet time schedules and costs. "*Electric bus systems planning, chargers location planning, and charging scheduling appear as main fleet operation research topics*".[71] Mathematical programming models are used to model Electric bus systems to solve these optimization problems.

2. Lack of operational data: In addition to shortage of general information, there is also a dearth of operational data that can help identify and overcome operation constraints. Practical operation data is very essential for transit agencies to design their Electric bus systems. There is insufficient data on topics including range limitations or mileage, charger locations, route planning, impact of local temperatures on battery performance, durability of electric components, cost benefit analysis, safety concerns, risk mitigation and differences over current and next generation technologies.[72] [73] [74]

3. Limited availability of workforce: Electric bus systems are engineered and operated differently as compared to conventional diesel buses, which requires mechanics with different skill sets. For example in the UK, the "*Institute of the Motor Industry — a professional association for those employed in the sector — said roughly 16% of technicians in the U.K. had the relevant qualifications to work on electrified vehicles*." and there is much concern about this skill gap.[75] Mohamed, Ferguson, and Kanaroglou also point out that, both unavailability of skilled workers, and imparting skill training to new/existing technicians are not preferred by transit agencies in Canada as it may raise project costs.[76]

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[69] *Government of Canada. 2021. "The Buy American Act and Buy America Provisions." Trade Commissioner Service. https://www.tradecommissioner.gc.ca/sell2usgov-vendreaugouvusa/procurement-marches/buyamerica.aspx?lang=eng.*

[70] *Congressional Research Service. 2019. "Buy America and the Electric Bus Market." TRID Database. https://trid.trb.org/view/1604436.*

[71] *Manzolli, Jônatas A., João P. Trovão, and Carlos H. Antunes. 2022. "A review of electric bus vehicles research topics – Methods and trends." Renewable and Sustainable Energy Reviews 159 (May). https://doi.org/10.1016/j.rser.2022.112211.*

[72] *Mohamed, Close Moataz, Mark Ferguson, and Pavlos Kanaroglou. 2018. "What hinders adoption of the electric bus in Canadian transit? Perspectives of transit providers." Transportation Research Part D: Transport and Environment 64 (October): 134-149. https://doi.org/10.1016/j.trd.2017.09.019.*

[73] *Morris, Thomas. 2020. "The barriers to electric bus adoption." LinkedIn. https://www.linkedin.com/pulse/barriers-electric-bus-adoption-thomas-morris.*

[74] *World Resources Institute Ross Center. 2019*

[75] *Frangoul, Anmar. 2023. "How a shortage of workers could put the brakes on the shift to EVs." CNBC. https://www.cnbc.com/2023/02/27/how-a-shortage-of-workers-could-put-the-brakes-on-the-shift-to-evs.html.*

[76] *Mohamed, Close Moataz, Mark Ferguson, and Pavlos Kanaroglou. 2018*

3.2.3 Financial Barriers

1. High upfront costs for bus procurement, operation planning and charging infrastructure: Almost all of the studied literature indicates that the initial cost of buses and associated infrastructure is very high when compared to a conventional diesel bus. This may be attributed to (i) the nascent stages of e-bus technology and (ii) lack of an established global marketplace.[77] Electric buses cost almost two to three times as much as their diesel counterparts and their pricing varies based on "*the manufacturer, the specifications of the e-bus, and the location of the transit agency*".[78] Blynn and Attanucci point out in their paper that transit agencies in the USA are forced to buy a lesser number of buses if they opt for e-buses and face "diseconomies of scale" when they want to expand their fleet.[79]

   It is often argued that the initial capital cost invested can be recovered over the life of the e-bus through reduced operating costs. Electric buses incur lower operating costs because (i) they have lower moving parts which reduces maintenance cost, (ii) reduced spending on fuel and (iii) electricity prices are more stable and can be free if sourced from renewable sources like solar.[80] But Blynn and Attanucci also caution that these cost savings are not a given and are sensitive to various parameters including "*1) annual miles driven followed by 2)EIA*[81] *fossil fuel price scenario, 3)average speed, 4) maintenance savings, 5) per kilowatt-hour rate, 6) charging management, and 7) demand charge rate*." [82]

   However, there is much consensus among researchers and transit agencies that e-buses will be available at competitive pricing in the future due to improvement in battery/charging technologies and lower operating costs. A study by the VTT Technical Research Centre of Finland finds that "*If favorable parameter combinations can be reached through careful systems engineering and technological choices, the potential for TCO*[83] *reduction by introducing electric bus systems is considerable*".[84] Similarly a multicriteria decision-making analysis by Theodora Konstantinou and Konstantina Gkritza purports that when compared to other factors like operational reliability, customer experience and acceptance and infrastructure upgradation, Total cost of ownership had the least level of significance as a barrier towards e-bus adoption. Their research indicates that resolving

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77 *World Resources Institute Ross Center. 2019*

78 *ibid*

79 *Blynn, Kelly, and John Attanucci. 2019. "Accelerating Bus Electrification: A Mixed Methods Analysis of Barriers and Drivers to Scaling Transit Fleet Electrification." Transportation Research Record 2673, no. 8 (August): 577-587. https://doi-org.libaccess.sjlibrary.org/10.1177/0361198119842117.*

80 *Horrox, James, and Matthew Casale. 2019. "Electric Buses in America: Lessons from Cities Pioneering Clean Transportation." US PIRG. https://pirg.org/wp-content/uploads/2022/07/US_Electric_bus_scrn-3.pdf.*

81 EIA - Environmental Impact Assessment

82 *Blynn, Kelly, and John Attanucci. 2019.*

83 TCO - Total Cost of Ownership

84 *Pihlatie, Mikko, Samu Kukkonen, Teemu Halmeaho, Veikko Karvonen, and Nils-Olof Nylund. 2019. "Fully electric city buses - The viable option." vttresearch.com. https://www.vttresearch.com/sites/default/files/julkaisut/muut/2014/OA-Fully-Electric.pdf.*

other barriers will lead to a faster growth of the Electric bus market.[85]

2. Lack of funding options and investments for scaling: Transit agencies generally utilize two financing options (i) capital leases and (ii) operating leases. Given the high upfront costs transit agencies depend on grants and subsidies from federal and state governments. But financial regulations prevent transit agencies from opting for operating leases as they appear riskier on paper (operating leases appear as liabilities in the balance sheet).[86] This limits the financing options available to transit operators especially for funding large fleets. But nevertheless, the risks associated with any financing option behooves transit agencies to be conservative and continue with their existing diesel fleets.

   There is also a dearth of investments for scaling e-bus fleets given the risks. Particularly the procurement model adopted by transit agencies requires revision. Currently "*manufacturers supply the electric buses and associated charging equipment and, in many instances, serve as the design-builder for a turnkey solution*".[87] But this procurement model cannot support large scale deployments as design and implementation of charging infrastructure is not a bus manufacturer's core competency. Transit agencies must create a proper plan wherein they call for applications from various suppliers to provide the necessary infrastructure. This would essentially decouple the procurement of buses and other allied infrastructure.

3.2.4 Institutional Barriers

1. Inadequate policies that support electrification: Many countries are yet to adopt policies that necessitate local governments and transit agencies to shift to zero emission buses. However, even in states like California that have enacted pro electrification policies in terms of financial incentives and implementation regulations, there is much to be done with regard to providing planning and operation support.[88]

2. Information dissemination: Generally, there is lack of understanding about the benefits, technology and planning for electric bus systems. Awareness must be raised within potential stakeholders including transit agencies, local governments, utilities companies and the public so as to inform them and address their concerns on electric buses.[89] It is also crucial that other emergency service professionals including security forces, firefighters and first responders be imparted knowledge on the workings of e-bus in event of an accident or fire.[90]

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[85] *Konstantinou, Theodora, and Konstantina Gkritza. 2023. "Examining the barriers to electric truck adoption as a system: A Grey-DEMATEL approach." Transportation Research Interdisciplinary Perspectives 17 (January). https://doi.org/10.1016/j.trip.2022.100746.*

[86] *World Resources Institute Ross Center. 2019*

[87] *Bouslog, Travis. n.d. "Electrifying The Nation's Mass Transit Bus Fleets." Subscribe. Accessed March 24, 2023. https://info.burnsmcd.com/white-paper/electrifying-the-nations-mass-transit-bus-fleets.*

[88] *World Resources Institute Ross Center. 2019*

[89] *Zhang, Yiqian. 2021. "Transitioning towards electric buses: Barriers and opportunities Emerging mobility trends." ICLEI Sustainable Mobility. https://sustainablemobility.iclei.org/transitioning-towards-e-buses-barriers-and-opportunities/.*

[90] *Pereirinha, Paulo G., Manuela González, Isabel Carrilero, David Anseán, Jorge Alonso, and uan C. Viera. 2018*

3. Negative perception: While adopting a new technology transit agencies often come under public scrutiny. Thus, they are wary about attracting negative publicity in case of failure of the e-bus system. They also exhibit “guinea pig” syndrome wherein transit agencies perceive a risk in being the first to implement a new technology and would rather that other operators play the role of “guinea pig”.[91]

4. Involvement of all stakeholders: Electric bus system planning must involve all relevant stakeholders including the transit operator, local governments, utilities companies, the public and e-bus manufacturers. Electrification plans must be refined after receiving input from all these stakeholders to ensure smooth transition to electric buses. Kent Leacock, senior director at Proterra advises that utility companies be consulted in early stages of the project.[92]

3.2.5 Social Barriers

The infrastructure of Electric bus systems needs to be placed in a physical space that can have a potential impact on streetscape and the visual appeal of urban areas. Also the space required for bus depots and charging infrastructure may add to the demand for land in dense urban areas, which may face significant opposition from the public.[93] But most importantly, various studies including UITP’s policy Brief and Konstantinos et al's article, suggest that “*integrating and implementing electric buses in a public transport network is an opportunity for cities to review their mobility strategy and the image of the bus in the city*”[94] and can improve transit image which can have a “*positive effect on riders support towards Battery electric buses*”.[95] Thus bus electrification projects can be used to improve the social imageability of buses, and improve the city fabric by safe and efficient integration of bus transit with the cityscape.

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[91] *Mohamed, Close Moataz, Mark Ferguson, and Pavlos Kanaroglou. 2018*

[92] *Descant, Skip. 2019. “Electric Buses Are Finding their Way Around Adoption Barriers.” Government Technology. https://www.govtech.com/fs/transportation/electric-buses-are-finding-their-way-around-adoption-barriers.html.*

[93] *Tartaglia, Ivo. n.d. “Driver and Barriers to electric bus deployment.” Interreg Europe. Accessed March 23, 2023. https://projects2014-2020.interregeurope.eu/fileadmin/user_upload/tx_tevprojects/library/file_1611932796.pdf.*

[94] *UITP Transport and Urban Life Committee. 2019. “The impact of electric buses on urban life.” UITP. https://www.uitp.org/publications/the-impact-of-electric-buses-on-urban-life/.*

[95] *Konstantinos, Flaris, Gkritza Konstantina, Patrick A. Singleton, Antje R. Graul, and Ziqi Song. 2023. “Riders’ perceptions towards transit bus electrification: Evidence from Salt Lake City, Utah.” Transportation Research Part D 117 (April). https://doi.org/10.1016/j.trd.2023.103642*

3.3 Policies for e-bus adoption

Many global cities have adopted innovative policies for accelerating the uptake of electric bus systems for achieving carbon neutrality. These policies can be majorly classified under three categories (i) Regulatory, (ii) Fiscal and (iii)Technical support and Capacity building. This section will discuss these policy categories in the global and California context to gain an understanding of the policy climate of e-bus adoption in public transit. Electrification policies associated with built environment, commerce, energy management and other transportation modes including cars, rail and water transit are beyond the scope of this project.

3.3.1 Regulatory policies

Regulatory policies are the rules and directives adopted by the government that require compulsory compliance. With regard to electric bus adoption, these are generally in the form of

(i) goal/target achievement: these set targets or goals that need to be achieved within a specific timeframe. For example, California Air Resources Board's (CARB) policy mandates all transit agencies to transition to electric fleets by 2040 and prohibits purchase of diesel or gas-powered buses after 2029.[96]

(ii) regulatory exemptions: that offer relaxations on compliance with existing regulations. For example, AB2622 provides sales and use tax exemptions to zero emission technology transit buses.[97]

In the context of California, CARB's Innovative Transit Regulation (ICT) requires that all transit agencies develop a Zero Emission Bus (ZEB) rollout plan and convert their existing bus fleets into electric fleets by 2040.[98] CARB also requires annual reporting on fleet data and vehicle inventory on a yearly basis so as to keep track of the agency's progress over time.[99] While ICT addresses the demand side, the executive order N-79-20 tackles the supply side by requiring that "*100 % of medium and heavy duty vehicles (including buses) being sold in California be zero emission by 2045*".[100] This order is further supported by CARB's Advanced Clean Fleets Regulation program which aims to achieve the same target.

In addition to the e-buses, many policies have been passed to ensure the availability of associated infrastructure including electric grid upgrades and charging facilities. SB 350 - Clean Energy and Pollution Reduction Act of 2015 - lays down regulations that require both private and public utilities to support transportation electrification and establish efficiency targets for improving electric efficiency of the grid. It also mandates the government "*to ensure efficient and reliable operation of the electrical transmission*

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[96] *Hughes, MacPherson. 2017. "Public Transit Leading in Transition to Clean Technology." American Public Transportation Association. https://www.apta.com/wp-content/uploads/Public_Transit_Leading_In_Transition_To_Clean_Technology.pdf.*

[97] *MacFarlane, Philip. 2022. "California Extends Tax Exemption for Zero-Emissions Trucks and Buses." The California Energy Transition. https://www.californiaenergytransition.com/p/california-extends-tax-exemption.*

[98] *California Transit Association. n.d. "Zero-Emission Bus Regulation." California Transit Association. Accessed March 27, 2023. https://caltransit.org/advocacy/key-issues/zero-emission-bus-regulation/.*

[99] *California Air Resources Board. 2023. "Reporting Tool & Data | California Air Resources Board." California Air Resources Board. https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit/reporting-tool-data.*

[100] *State of California. 2020. "EXECUTIVE DEPARTMENT STATE OF CALIFORNIA." EXECUTIVE DEPARTMENT STATE OF CALIFORNIA. https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf.*

grid”.[101] SB 676 specifically promotes transportation electrification by development of policies that aid infrastructure establishment including deployment of charging infrastructure and most importantly, facilitate development of technologies that promote Electric Vehicle-grid integration.[102] Better vehicle grid integration can aid with meeting the electricity demand and thus optimize grid performance.

Regulatory exemptions have been granted to zero emission bus projects in California. AB 784 provides partial sales and use tax relief on the purchase or lease of eligible[103] zero emission transit buses to transit agencies or government organizations, until Jan 1, 2024.[104] However this bill does not allow for exemption under local sales and use tax law and applies for electric vehicles that are approved under the HVIP program. The deadline for this bill has been extended to Jan 1, 2026, by the passage of AB 2622. Similarly, SB 288 provides statutory exemptions for sustainable transportation projects, including charging infrastructure for zero-emission transit buses, from the California Environmental Quality Act, until December 31st, 2022.[105] However SB 922, passed in 2022, extends this deadline until January 1, 2030.

Additional policies include stringent regulations on fuels and standardization of e-bus charging. The Low Carbon Fuel standards promote the use of cleaner transportation fuels that have lower GHG emissions and decrease dependency on fossil fuels. These strict regulations are intended to move the market towards cleaner vehicles including electric vehicles. SAE international, a professional association for engineers, has also developed various electric charging standards for depot charging and high-power wireless charging that are adopted in North America.[106]

Other countries like China, India, Canada, Chile and European nations have also adopted a multitude of policies to support zero emission bus uptake. China offered four-year pilot programs wherein “*cities received support for research, development and demonstration of fuel cell electric vehicles*.”[107] Shenzhen city’s “National Electric Vehicle Industry Base” requires the city to invest in “Shenzhen’s new energy bus operation monitoring system standard” that helps with the collection of real time operational data.[108]

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[101] *California Energy Commission. n.d. “Clean Energy and Pollution Reduction Act - SB 350 - Clean Energy and Pollution Reduction Act - SB 350.” California Energy Commission. Accessed March 27, 2023. https://www.energy.ca.gov/rules-and-regulations/energy-suppliers-reporting/clean-energy-and-pollution-reduction-act-sb-350.*

[102] *State of California. 2019. “SB-676 Transportation electrification: electric vehicles: grid integration.” https://leginfo.legislature.ca.gov/. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB676*

[103] Electric buses that are approved by the HVIP program are considered to be eligible for exemption under this Bill

[104] *State of California. 2019. “Assembly Bill 784.” California Legislative Information. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201920200AB784.*

[105] *California Air Resources Board. n.d. “2020 - Senate Bill 288 (Wiener, Scott), California Environmental Quality Act: Exemptions for Transit and Alternative Transportation Projects (Chaptered) | California Air Resources Board.” California Air Resources Board. Accessed March 27, 2023. https://ww2.arb.ca.gov/2020-senate-bill-288-wiener-scott-california-environmental-quality-act-exemptions-transit-and.*

[106] *Jeffers, Matthew, Kenneth Kelly, Timothy Lipman, Andre Fernandes Tomon Avelino, Caley Johnson, Mengming Li, Matthew Post, and Yimin Zhang. 2022. “Comprehensive Review of California's Innovative Clean Transit Regulation: Phase I Summary Report.” NREL. https://www.nrel.gov/docs/fy23osti/83232.pdf.*

[107] *International Energy Agency. 2022. “Global Electric Vehicle Outlook 2022.” www.iea.org. https://iea.blob.core.windows.net/assets/ad8fb04c-4f75-42fc-973a-6e54c8a4449a/GlobalElectricVehicleOutlook2022.pdf.*

[108] *Ministry of Housing and Urban Affairs and Rocky mountain Institute. 2019. “Electric Mobility: Policy Workbook.” RMI. https://rmi.org/wp-content/uploads/2019/07/rmi-electric-mobility.pdf.*

3.3.2 Fiscal policies

Financial tools including subsidies, grants and procurement programs have helped facilitate the uptake of electric bus systems by transit agencies. Both the federal government and California state provide a variety of fiscal incentives to transit agencies for procurement of electric buses. Federal programs, such as the Low or No Emission Grants and Bus and bus facilities grants, are intended to help private transit operators and state or local governments to procure funds for the capital improvement of transit facilities which includes transition to zero emission vehicles.[109] Other similar sources of federal funding are Capital Investment Grants (CIG), Better Utilizing Investments to Leverage Development (BUILD) Grants and the Volkswagen Clean Air Act Civil Settlement fund. Often each of these grants will have different financing structures and may require compliance with certain expenditure regulations. For example, the Buses and bus facilities grants have a funding formula of 80-20 wherein 80 percent of the project cost will be funded by the federal government and the rest by the transit operator. It also requires that 5 percent of the project funds be used for workforce training.

In California, CARB funds the Low Emission Truck and Bus Vouchers (HVIP), provides subsidies for the procurement of electric buses and charging infrastructure. This helps offset the high initial cost of e-buses and incentivizes transit operators to electrify their fleets. Currently, SB 372 requires CARB to support medium and heavy duty zero emission vehicle uptake by providing financial and resource assistance. The Medium- and Heavy-Duty Fleet Zero-Emission Vehicle Purchasing Support is being developed by CARB to meet the provisions of the bills.[110] The Low Carbon Fuel Standard (LCFS) program provides credit for creation of zero emission vehicle infrastructure, usage of low carbon fuels and implementation of projects that sequester and capture carbon.[111] These credits can be applied for future low emission projects including e-bus adoption, thus reducing initial project costs.

There are financial incentives that are targeted towards lowering operation costs too. SB 1000 "*requires California Public Utilities Commission to explore more targeted rate design strategies for commercial electric vehicle (EV) customers and fleets and to deploy charging stations where there is existing excess grid capacity*"[112] Pacific Gas and Electric Company (PG&E) offers incentives for fleet electrification which includes charger rebates (up to 50 percent), infrastructure incentives and Time of Use (TOU) rate plans that help cut down cost of fuel.[113] In addition to this they also provide on-site planning, construction and maintenance of electrical grid upgrades.

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109 *Hughes, MacPherson. 2017.*

110 *California Air Resources Board. n.d. "Medium- and Heavy-Duty Fleet Zero-Emission Vehicle Purchasing Support." California Air Resources Board. Accessed March 28, 2023.* https://ww2.arb.ca.gov/our-work/programs/medium-and-heavy-duty-fleet-zero-emission-vehicle-purchasing-support/about.

111 *US Gain. 2020. "Understanding the California Low Carbon Fuel Standard (LCFS)." U.S. Gain.* https://www.usgain.com/resources/education-center/understanding-the-california-low-carbon-fuel-standard-lcfs/.

112 *Jeffers, Matthew, Kenneth Kelly, Timothy Lipman, Andre Fernandes Tomon Avelino, Caley Johnson, Mengming Li, Matthew Post, and Yimin Zhang. 2022*

113 *PG & E. n.d. "EV Fleet Program for public-transit fleets." PGE. Accessed March 28, 2023.* https://www.pge.com/en_US/large-business/solar-and-vehicles/clean-vehicles/ev-fleet-program/transit-fleets.page

In the global context many innovative financing mechanisms have been utilized to stimulate electrification of public transit fleets. For example, China has used debt financing tools including green bonds and concessional loans (with lower interest rates) to procure more than 500 buses.[114] Leasing of buses and infrastructure is another approach that can be used to reduce the high upfront cost. This also has the added advantage of mitigating the risk associated with owning the asset. Leasing reduces the "*financial burden for the operator and transfers technology and/or credit risk onto the third party*."[115] In the United States Proterra, the bus manufacturing company, provides battery leases which can significantly reduce project costs as batteries contribute to the largest share of the cost.

3.3.3 Technical support and Capacity building

Workforce and fleet operations planning is a significant barrier for fleet electrification. Workforce training is particularly required for operating e-buses due to the novelty of the technology and for safety reasons. Electric Vehicle Infrastructure Training Program (EVTIP) is a certification program developed by collaboration of various stakeholders of the electric vehicle industry including manufacturers, utility companies and educational institutions. This program provides training to electricians to enable them to work on electric vehicles.[116] AB 841 further requires that "*25 percent of installation crew members of any State-funded electric vehicle charging infrastructure be certified*" under EVTIP.[117]

California Energy Commission and CARB offer grants to fund workforce training and development that support Zero emission Vehicles, infrastructure, and technologies in California.[118] Alameda County Transit agency has its own workforce training (for drivers, mechanics and other technicians) and data (cost and performance data) management systems that have significantly aided in the incorporation of electric buses into its existing fleet.[119] Similarly Suzhou city in China employs big data and intelligent network connection to improve technology monitoring, coordination management and travel service technology of new energy buses.[120] Technical support is also given through the development of pilot programs in various cities of China.

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114 *Moon, Christopher, Anne Maassen, Xiangyi Li, and Sebastian Castellanos. 2019. "Financing Electric and Hybrid-Electric Buses." World Resources Institute. https://www.wri.org/research/financing-electric-and-hybrid-electric-buses*

115 *ibid*

116 *EVITP. 2019. "Training." EVITP. https://evitp.org/training/.*

117 *CARB. n.d. "2020 - Assembly Bill 841 (Ting, Philip), Electric Vehicle Infrastructure Training Program and Energy Efficiency Programs (Chaptered) | California Air Resources Board." California Air Resources Board. Accessed March 28, 2023. https://ww2.arb.ca.gov/2020-assembly-bill-841-ting-philip-electric-vehicle-infrastructure-training-program-and-energy*

118 *Jeffers, Matthew, Kenneth Kelly, Timothy Lipman, Andre Fernandes Tomon Avelino, Caley Johnson, Mengming Li, Matthew Post, and Yimin Zhang. 2022*

119 *AC Transit. 2022. "Zero Emission Transit Bus Technology Analysis." AC Transit. https://www.actransit.org/sites/default/files/2023-01/0430-22%20Report-ZEBTA%20v4_FNL_012423.pdf*

120 *Zhang, Tianshu, Madan B. Regmi, and Ganesh Raj Joshi. 2020. "UNITED NATIONS CENTRE FOR REGIONAL DEVELOPMENT Ministry of the Environment, Government of Japan United Nations Economic and Soci." Sustainable Development Goals. https://sdgs.un.org/sites/default/files/2020-12/UNCRD_13th%20EST%20Forum_Backgroung%20paper_Plenary%20Session%203-%282%29.pdf.*

3.4 Conclusion

An analysis of the literature has revealed that the police framework with regard to electrification of public transit is still in its nascent stage and is undergoing transformation rapidly. Current policies aim to address barriers that prevent the uptake of electric vehicles. Some of the technological and financial challenges including lack of knowledge, high upfront cost, infrastructure upgradation, limited workforce, lack of standardization and financial incentives have been successfully addressed by the current policy framework. However, there is much to be done in areas concerning fleet operation optimization, collection and management of operation data, scaling of e-bus fleets and addressing social and visual impacts of electric infrastructure.

Latest studies have indicated that uptake of electric buses in public transit fleets are least sensitive to initial costs and most sensitive to operational parameters including bus technology, infrastructure upgradation, fleet planning and workforce training. The California energy commission report on California E-Bus to Grid Integration Project outlines the importance of operation efficiency using the case of Antelope Valley Transit Agency's fleet electrification project. It recommends operation improvement including technological upgrade of the electric grid and training of e-bus operators.

Even though there is abundant research into the technological, engineering, and operational aspects of electric buses, there are still gaps in literature pertaining to large scale fleet planning and social impacts of electric bus systems. Currently transit agencies are adopting piecemeal plans that are limited to their jurisdictions and there is very limited research on coordinated planning efforts for fleet electrification. Transit agencies are also heavily reliant on federal and state grants and seldom employ other financial mechanisms. The visual and social implications of electric bus systems must also be investigated so as to ensure smooth integration with the urban environment.

There is also a need for a comprehensive policy framework that can address operational barriers and focus on implementation of electric bus projects. Policies that support fleet operations by aiding agencies with fleet planning and requiring publication of operational data can be crucial for the adoption of electric buses. In addition to bus and charging time schedules, operation planning needs to address issues of risk management so as to ensure safe and efficient functioning of the transit system in case of system failure or unforeseen emergencies.

My research seeks to explore and address some of these policy gaps in fleet electrification, specifically in the context of the Bay Area. It also aims to gauge the performance of existing policies and understand their shortcomings, if any, in achieving their objectives. Thus overall, this research project will provide a comprehensive assessment of current electrification policies and propose new policies for addressing the gaps identified from literature review analysis.

4. CHAPTER 4: BAY AREA TRANSIT AGENCIES: TRANSITION TO BATTERY ELECTRIC BUSES (BEBs)

Currently all Bay Area transit agencies are working towards achieving complete electrification so as to comply with CARB's ICT regulation. Different transit agencies are at different stages of electrification depending on the type of zero emission technology they have selected, the scale of their transit fleets and their ability to access funds. This chapter aims to understand the fleet electrification efforts and the planning processes undertaken by transit agencies in the Bay Area.

4.1 Data Collection Method

Both primary and secondary data collection methods were employed to obtain information on the fleet electrification process undertaken by Bay Area transit agencies. CARB's ICT regulation mandates the preparation of a **"zero emission bus roll out plan**" by all transit agencies. This was an important source of secondary data that outlined the planning process, inventory of existing infrastructure, challenges (both existing and future) that needed to be overcome, funding sources and workforce development agendas of transit agencies. Seven bus roll out plans were reviewed for this project. It is also to be noted that not all transit agencies have published their bus roll out plans.

In addition to the bus rollout plans, **interviews of staff** were conducted virtually through zoom. This primary data collection was important because (i) many transit agencies had not published their bus roll out plan which rendered no data on their electrification plan and (ii) a firsthand interview can give insights into practical difficulties incurred and more nuanced descriptions of the planning process.

Of the nineteen Bay Area transit agencies, only nine agencies agreed to be interviewed and recorded. They are (i) Union City transit, (ii) Marin Transit, (iii) Livermore Amador Valley Transit Authority (LAVTA)[121], (iv) Napa Valley Transportation Authority (NVTA), (v) Alameda-Contra Costa Transit District (AC Transit), (vi) Santa Clara Valley Transportation Authority (VTA), (vii) Santa Rosa CityBus (SR CityBus), (viii) San Francisco Municipal Transportation Agency (SFMTA) and (ix) Eastern Contra Costa Transit Authority (ECCTA). This proved to be a good sample in that it consisted of large, small, and medium sized transit agencies with fleet sizes ranging from eighty to nine hundred. This gave insights into the opportunities and difficulties incurred while transitioning both large and small fleet sizes.

4.2 Data Analysis

The data collected from the interviews of nine transit agencies are condensed into a single table as shown in Table 4.1. It is to be noted that the fleet size mentioned in the table refers only to the fleet size of Fixed Route Services and excludes paratransit, emergency vehicles and dial a ride services. Refer to Appendix B for more details on fund sources.

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[121] *It is to be noted that LAVTA is planning on going with hydrogen fuel cell technology for its fleet and not electric. However they were interviewed to understand barriers associated with transition of their fleet to zero emission buses including funding availability and other bureaucratic barriers.*

Table 4.1: Data Analysis of Primary Data collected from interviews[122]

Transit Agency	Key components of ZEB transition	Opportunities	Difficulties
City of Union City (Fleet Size*: 17, 0% electric)	(i) Partnered with Gillig and Center for Transportation and Environment (CTE), a private consultant, to apply for Low No grant and vet the Bus rollout plan required by ICT. (ii) Partnered with East Bay Community Energy (EBCE) to provide green electricity, design and install the charging facility. (iii) PG&E's grid is used for electric transmission (iv) Employment of "**Charging as a service**" wherein the transit agency pays EBCE a fee for maintaining the charging infrastructure and incurs the cost of electricity used. (10 years lease with EBCE) (v) fund sources: TIRCP, TDA, LCTOP, Low No Emission Vehicle program, AB 664 funds, funds from Alameda County Transportation Commission (Alameda CTC), regional measures and local measures (sales tax) (vi) Workforce development is provided by OEM, National Training Institute, CTE and other contractor training. (vii) End of bus life: buses are auctioned off, no federal/state policy for this	(i) smaller fleet size (ii) average trip route length is less and on flat terrain which reduces range anxiety (iii) trip routes avoid freeways and are mostly on stop-and-go traffic that benefits from regenerative braking (iv) buses with overhead rails are being ordered so to future proof the buses for on route charging in the future (v) installation of renewable energy sources on site (vi) local community and bus drivers prefer BEBs due to less noise and easier operability	(i) High price of BEBs and delays in bus manufacturing and delivery (ii) Less number of potential bus vendors: Federal policy requires local labor component in the buses to be 70% which reduces the options of bus vendors (iii) Increase in federal policy requirements over time including Buy America policy (iv) infrastructure concerns: only select chargers could be used due to limited software interface with the buses, battery drained by associated bus functions including AC, wheelchair operations etc. (v) PG&E is sunsetting their EV fleet program on Dec 31st, 2024, that provides rebate on electricity pricing (vi) PG&E takes a long time to install service lines from street to meter and often impose several requirements (vii) Less staff to manage grants and their reporting requirements (viii) workforce development funding only accounts for upskilling of existing workers. It doesn't account for attrition and retraining new staff. State policies don't fund upskilling

[122] *This table has been compiled from primary data gathered from interviews and secondary data sourced from the respective transit Agency's ICT Bus rollout plan*
** Fleet Size refers only to the fleet size of fixed route services and excludes Paratransit, Dial a ride services and other emergency services*

Transit Agency	Key components of ZEB transition	Opportunities	Difficulties
Marin Transit (Fleet Size: 81, 7% electric)	(i) Marin Transit does not own transit facilities or employ operation staff (mechanics/ drivers) as they lease land or operate from Golden Gate Transit's land and operations are provided through private contractors. (ii) They own all transit vehicles, charging equipment and have recently purchased a paratransit facility and a small parking facility that has four chargers capable of charging 20 BEBs. (iii) The planning approach is conservative and have not invested money in studies as technology is evolving and there are many unknowns (iv) During the transition of the entire fleet, some routes have longer lengths which may either need to be supplemented by opportunity charging or have fuel cell buses operating these routes. (v) workforce development: rely on OEM training, AC Transit's training program and charging manufacturer's training program. (vi) funding sources: TIRCP, TDA, SB 125, LCTOP, Low No Program and other local measures using sales tax (particularly for land purchase)	(i) medium feet size (ii) PG&E's fleet ready program provides free electrical installation up to the facility's meter and also cheaper electricity rate (iii) Electric Vehicle industry is evolving and moving towards standardization (iv) Availability of adequate funds (v) local government is cooperative (vi) Buy America policy not a problem for larger buses	(i) Range limitations of BEBs and long lead times for parts availability for buses (ii) ensure current service during electrification (iii) lack of land ownership: Marin Transit does not own land currently for the installation of charging infrastructure. Also land supply is limited in Marin county. (iv) funding for buses is contingent on land ownership that can host charging equipment. (v) longer project timeline as more time is required to first buy land followed by installation and purchase of charging infrastructure and buses. This can also result in expiration of certain funds. (vi) PG&E's impose high demand charges which makes electricity rate costlier than diesel and (vii) Facility development/upgrade has CEQA review (viii) lack of a consolidated funding mechanism - expensive to have more staff on grant management

Transit Agency	Key components of ZEB transition	Opportunities	Difficulties
Eastern Contra Costa Transit Authority (ECCTA) (Fleet Size: 62, 10% electric)	(i) ECCTA owns capital infrastructure including depots, buses and allied infrastructure. But it contracts its operations to First Transit, a private company. (ii) The ICT Bus rollout plan was done by the agency (iii) They plan to have a mix of both hydrogen fuel cell buses (50%) and BEBs (50%) equally as of 2023. This may change depending on future developments. (iv) their existing depot will house a hydrogen fueling station and electric chargers (charging capacity up to 4 vehicles). Land was purchased to develop a depot that would host additional charging infrastructure. (v) Workforce training is provided by OEM (vi) Funding sources: FTA - Transit capital priorities program, Urbanized Area Formula grant (5307 program), Bus and bus facilities grant, State: TDA, STA, LCTOP, Regional measures	(i) medium fleet size (ii) electric buses were bought from a state contract with Washington state which reduced the purchase price of BEBs (iii) No issue with Buy America regulations (iv) Due to high risks associated with hydrogen fueling infrastructure and fuel cell buses, the approval process (environmental, zoning and safety clearance) takes longer when compared to electric bus infrastructure.	(i) Range anxiety and longer charging times for BEBs (ii) PG&E is taking a long time (over 2 years) to upgrade their transformer at the existing facility. (iii) High cost of infrastructure upgradation and bus prices (iv) All grants require some percent of the project cost to be borne by the transit agency. ECCTA encountered difficulty in obtaining their share of the project cost due to high costs of fleet electrification. (v) standardization issues where earlier Proterra and BYD bus chargers are incompatible with their recent Gillig e- bus purchase (vi) grant processes can be made smoother (vii) Loss of operation funds: TDA and STA funding that were earlier used for operations are now being diverted to purchase capital infrastructure

Transit Agency	Key components of ZEB transition	Opportunities	Difficulties
Napa Valley Transportation Authority (NVTA) (Fleet Size: 45, 15% electric)	(i) NVTA owns the capital infrastructure including depots and buses but has outsourced their operations to a private company, Transdev. (ii) procured their first five BYD e-buses in 2016. Partnered with CTE to help develop e-bus specifications, manage production and do quality assurance and certifications at the BYD facility. (iii) chargers (with warranties) were purchased from ChargePoint. However, ChargePoint does not offer any workforce training for the charging equipment. (iv) Currently working to incorporate smart charging for optimizing charging and operations (scheduling) (v) Workforce development: rely only on OEM training, for chargers there is no training available, (vi) reliance on other state's (Washington or Virginia) list to procure e-buses as California's bus list is restricted to one manufacturer currently. (vii) Estimation of project cost was a learning curve as there was no guidance (like a bus price list) for costs related to charging infrastructure (viii) Funding Sources: RAISE grant from USDOT, FTA's Low No Emission Vehicles grant, Bus and Bus facilities grant, Urbanized area formula grant, STA, LCTOP, TIRCP, HVIP, AHSC, funds from MTC and Regional measures (bridge tolls)	(i) smaller fleet size (ii) smaller transit agencies are working together to create e-bus training programs in the Bay Area. (iii) reduced e-bus prices through wholesale purchase through other state's list (iv) CEQA exemption for charger installation in depot (v) MTC aids small transit agencies with bus procurement and is currently working on a regional zero emission bus plan (vi) no pinch points on local approvals for yard upgradation/ charger installation	(i) Range anxiety, longer charging times and poor build quality of e-buses (ii) Inadequate funding given high costs of infrastructure (ii) Long project time due to (a) supply chain issues for e-buses, its parts and electrical upgrade equipment like switchgear and (b) delays caused by PG&E for yard upgradation (iv) Service area has power cuts due to frequent wildfire, high temperatures and safety power shut offs which hampers (a) fueling and (ii) interrupts communication between bus and chargers (v) Lack of training programs for upskilling: Transdev (which has non-unionized labor), is ineligible for AC transit's training program and local community colleges do not support e-bus mechanics program (vi) Lack of policies for end-of-life disposal and plans for emergency situations (disasters) (vii) Lack of feedback from grant providers on grant applications (especially when they are rejected) and addition of requirements to the application (vi) Lack of ChargePoint approved service providers in within close proximity of Napa Valley (vii) Unable to outsource charging as most grants require proof of land ownership for fund procurement (viii) Buy America policy eliminated BYD as a vendor

Transit Agency	Key components of ZEB transition	Opportunities	Difficulties
Santa Rosa City Bus (Fleet Size: 28, 14% electric)	(i) Planned to employ electric buses as they had access to clean electricity sourced from renewable sources (ii) Partnered with Sonoma Clean Power - an aggregator- to develop an electrification plan for fleets of Santa Rosa City bus, Mendocino transit, Sonoma County transit and Petaluma transit. (iii) application for PG&E's EV fleet program was done in 2019 followed by a charging facilities plan. The final construction of electrical infrastructure and energizing the chargers took another 2-3 years. (iv) The internal capital improvement project team designed and built the charging infrastructure (iv) vehicles were procured through state DGS contract which provided competitive pricing and allowed the state to purchase on behalf of transit agencies (v) additional leases on bus batteries were purchased which allowed for battery replacements as the bus warranty was limited to exchange of batteries only to a few years after bus purchase. (vi) Telematics and charge management solution from Valence that would optimize fleet operations. This was required due to increasing number of BEBs in the fleet. (vii) Workforce development: offered by OEM for drivers, garage and charging infrastructure staff (viii) funding: FTA, TIRCP, LCTOP, HVIP, 5307, 5339, AHSC, 5310, TDA, local sales tax	(i) Access to renewable energy sources gave an edge to Santa Rosa city bus in winning competitive grants (ii) small fleet with short trip lengths (170 miles per day) eased range anxiety and fleet scheduling of BEBs (iii) PG&Es EV Fleet program provided electrical infrastructure upgrades (iv) Location within suburbs made land available and existing yard was large enough so that it could cater to the current charging needs (iv) procurement through state provided competitive rates	(i) procurement of funds and high cost of electric fleets (ii) Working with PG&E took a long time (iii) Chargers and switch gears arrived late due to supply chain issues. Thus, alignment of charging infrastructure and bus procurement schedules was tough. (iv) Experienced battery issues and other bus amenities problems with Proterra which were ultimately resolved. (v) planning for grid and bus operation resiliency (including battery backup options, generators etc.) is overlooked (vi) Standardization for charging infrastructure is needed (vii) charging infrastructure is idle for most parts of the day and is not being utilized to its full capacity. (viii) General apprehension on the capability of the grid to meet the electrical demand in the future (ix) Currently, Santa Rosa City Bus has a strong grants management team, but the process can be streamlined. (x) Availability of grants/funds when the entire bus fleet requires replacement after their useful life

Transit Agency	Key components of ZEB transition	Opportunities	Difficulties
Livermore Amador Valley Transit (LAVTA) (Fleet Size: 62, 0% electric)	(i) The reason for going with hydrogen technology was due to (i) political motivation as the city council wanted to be early adopters of this technology, (ii) a rail line project - Valley Link- that is expected to come in the Livermore area is hydrogen based. LAVTA can share hydrogen supply with this project and (iii) there is no range anxiety associated with fuel cell buses. (ii) There are plans to source fuel cell buses from Gillig as they have a manufacturing plant in Livermore (iii) California State is working to get funds from the Department of Energy to set up a hydrogen fuel supply chain in the state. They have formed a group called Arches which comprises stakeholders from government, private sector, and communities to promote clean hydrogen supply. (iv) LAVTA intends to open their hydrogen fueling facility to the public/ other transit agencies in the initial days as they will not utilize the full capacity of the fueling facility. This can bring in revenue. (v) Have been successful with getting state grants but not so much with federal grants (vi) Hired private consultants to help with grant applications. LAVTA used their own funds for this. (vii) Workforce development: mechanics have to be upskilled, but no driver training is required (viii) funding: LCTOP, TIRCP, Bus and bus facilities,	(i) medium fleet size (ii) proposal of hydrogen fuel-based Valley link rail project (iii) proximity to bus manufacturer	(i) High cost of hydrogen technology (fueling infrastructure, bus costs and fuel costs (ii) Very few vendors can actually design and build a hydrogen fueling station. (iii) Only one bus manufacturer, New Flyer, currently produces hydrogen fuel cell buses. This can increase the supply time. (iv) Uncertainties on whether (i) there will be clean hydrogen fuel supply chain in Northern California and (ii) Gillig will manufacture fuel cell buses (v) Grant application process takes long and often results in project cost inflation (vi) Competitive grants implies that a few agencies will lose out to others (vii) Lack of funds to meet the local match requirement for most grants (viii) Bureaucratic processes associated with grants favors grants that look good on paper but may fail practically. (ix) Unsuccessful with grant applications as there was no clear vision on future service expansion

Transit Agency	Key components of ZEB transition	Opportunities	Difficulties
San Francisco Metropolitan Transportation Authority (Fleet Size: 900, 30% electric)	(i) Of the total 900 buses, 274 are trolley buses that run on overhead wires and 12 are BEBs (ii) Hired a consultant to do the roll out plan. They had an elaborate planning process consisting of (a) facility assessment study, (b) technology assessment study and (c) a pilot program to test e-buses from various manufacturers. (iii) BEBs were preferred over hydrogen fuel cell due to smaller land requirements for e-bus charging, cheaper electricity rate and safety risks linked to hydrogen fueling. (iv) Planning process included schedule, scope, funding, staffing and organizational change (v) Bus manufacturers will be finalized based on (a) ability to build buses on scale, (b) performance of product, (c) customer service, (d) software market support and (e) ability to build quality buses. (vi) Currently have direct plug-in charging but overhead pantograph chargers is the future due to limited space (vii) Yet to figure out operation management including smart charging and yard management (viii) Workforce development: Existing mechanics and electricians are able to service bus and charging equipment as SFMTA had electric trolley buses and diesel electric hybrid buses, which are similar to BEBs. (ix) Funding: Appendix B (over 25 funding sources)	(i) Cheaper electricity rates (ii) as a large transit agency, SFMTA had the resources to conduct detailed studies and engage in a well thought out planning process (iii) SFMTA had already started to work on going emission free much ahead of CARB's regulation in 2018 which gave them a head start (iv) experience of current staff from working on electric trolley buses and diesel hybrid buses (v) ability to partner with startup companies that can optimize operations though software	(i) lack of adequate funding, especially given the high costs of upgrading of old facilities, installation of charging infrastructure and increasing construction costs (ii) Lack of land within San Francisco for new facilities (iii) PG&E application process takes very long (5 years from date to filing to actually receiving power) (iv) Redundant paperwork and lack of guidance from PG&E: PG&E requires a detailed plan of the charging facility with location of charging equipment, switch gears etc. to even start a discussion with SFMTA. (v) PG&E has no incentives to work with transit agencies as transit agencies pay low electricity rates. (vi) Upgradation of facilities triggers code compliance which further delays the project timeline as old facilities must be brought up to code. (vii) supply chain issues have increased bus delivery time from one to two years and long lead times on PG&E equipment including switch gears and transformers (viii) With many bus manufacturers going out of business, there is inadequate e-bus supply (ix) need yard management, driver training and novel project delivery methods (as opposed to traditional design and build models that take longer) (x) Compliance with CARB's timeline is a challenge given the large fleet size of SFMTA

Transit Agency	Key components of ZEB transition	Opportunities	Difficulties
Santa Clara Valley Transportation Authority (VTA) (Fleet Size: 440, 0% electric)	(i) VTA's planning process consisted of (i) understanding their existing service (trip lengths) and (ii) selection of the appropriate zero emission technology. (ii) BEBs were selected because (a) it could service the short service blocks (<150 miles), (b) for the short term (next 5 years) it was cheaper than fuel cell technology, (c) could test out with the purchase of only a few buses and chargers as hydrogen fueling station catered to a minimum demand of 50 buses and were more costly. (iii) There are plans to upgrade Cerone bus yard that can charge up to 34 buses with pantograph chargers and supported by a micro grid. VTA is also considering on route chargers and electrification of Chaboya yard. (iv) Have employed about three Charging Management Systems (CMS) to optimize charging and bus operations. But all of them have failed and currently charging is being done manually in the yard. (v) The 8 Proterra e-buses that were purchased are currently not in service due to many issues. (vi) Workforce development: had a Joint workforce investment program for diesel buses, which is now being transitioned to ZEBs, apprenticeship program with Mission College to provide training, (vii) funds: Appendix B	(i) PG&E's EV fleet program provides rebate on electricity and capacity expansion of yard (ii) looking towards privatization models wherein yard development may be outsourced to private company and charging infrastructure opened out to the public for extra revenue (iii) cooperative local government (iv) most of the operations including fleet scheduling, facilities planning etc. are handled in house	(i) Lack of funding to cater to the needs of all fleet electrification projects given high costs of BEB projects (ii) Limited number of e-bus manufacturers-long order times (iii) Land supply is limited and expensive in Santa Clara (iv) Not optimistic about achieving fleet transition without having to do service cuts (v) PG&E may not have the capacity to meet electrical demand and is spending more resources on wildfire prevention, which limits its resources for grid upgradation (vi) PG&E require at least 5-7 years notice for any capacity expansion at depots, which is a long time (vii) Lack of interoperability between the softwares of bus and charger manufacturers. This has made it very difficult to have a CMS that can effectively communicate with the buses. (viii) Grants come with several requirements including terms that require start of project within 6-12 months of award and proof of existing infrastructure to support BEBs. These terms do not take into consideration practical concerns like delays or lack of funds to procure infrastructure. (ix) Mechanics are reluctant to work on BEBs due to frequent breakdown and inability to transition to computerized system (x) Drivers pursue aggressive driving (which drains the battery) to get off early from their shift (xi) Inter departmental coordination is vital

Transit Agency	Key components of ZEB transition	Opportunities	Difficulties
Alameda Contra Costa Transit District (AC Transit) (Fleet Size: 637, 4.3% electric)	(i) In 2017 a consultant was hired to understand service demand of AC transit and estimate electricity needs. (ii) Conducted extensive studies by partnering with other organizations including Precourt and CTE to study various ZEB technology and select the appropriate mix for its service. Also did pilot projects before scaling. (iii) Adopted a combination of fuel cells and BEBs with the former being the larger share (70%) in the long run. (iv) Preference for hydrogen technology is due to limited range of BEBs, longer charging times and presence of existing fueling infrastructure. (v) Developed a Facilities Utilization Plan that outlined infrastructural needs, financial & funding strategies and an implementation plan. (vi) Implementation of "Information Technology Infrastructure and Data Analytics Platform" to optimize operations and maintenance (vii) Involvement of stakeholders (PG&E etc.) from start (ix) Plans to implement micro grids to be self-sufficient. (x) Workforce development: OEM provided training and AC transit's own training program (xi) funds: Appendix B	(i) AC transit had planned to transition to zero emission buses in 2017- The Clean Corridors Plan - before the ICT mandate (ii) part of PG&E's EV fleet program (iii) reduced bus pricing due to State Cooperative Purchasing Agreements (iv) Good grant writers at AC transit (v) partnering with worker unions	(i) BEBs have range anxiety and longer charge times (ii) scaling challenges: scaling to large number of BEBs requires planning for additional infrastructure including smart charging/ charging management solutions and replacing plug in charging with other technologies like overhead charging to maximize space efficiency at depots (iii) Evolving nature of the zero-emission bus industry (iv) PG&E is not equipped to meet the energy demands of transit agencies (v) infrastructure delivery must be aligned with bus delivery for maximum efficiency (vi) lack of coordination between various state departments, local governments, and transit agencies to collaborate on achieving zero emission fleets (vii) long approval times for large projects (vi) lack of end-of-life recycling program

The analysis of the data in the above table was done by **looking for common grievances and concerns** amidst the transit agencies that hindered their transition to a completely electric fleet. Some of the barriers cited by all nine transit agencies were high project costs, inadequate technology, long wait times associated with the utility provider, supply chain issues that increased equipment/bus delivery times, and lack of an end-of-life disposal policy. However, it was also apparent that larger transit agencies (with fleet sizes over 100 buses) had other issues which smaller transit agencies did not incur.

Large transit agencies like SFMTA, VTA and AC transit face scaling issues, larger power demand, larger trip lengths, lack of land and the need to incorporate a telematics/Charging management system into their operations. These issues are currently not faced by smaller agencies who have just started out with a few BEBS and have managed most of the operations through traditional methods. On the other hand, small transit agencies grapple with problems of inadequate funds, lack of access to technical resources, smaller workforce, and reliance on state or Metropolitan Transportation Commission (MTC) for bus procurements.

But in the context of fleet electrification, there have also been some factors that have contributed to increased BEB uptake. From the interviews it is very clear that CARB's ICT mandate is the primary reason for all transit agencies to go electric. This has stimulated most transit agencies to reduce their carbon footprint and has mandated them to achieve this goal by 2040. Other policies including PG&E's EV fleet program, state lists for bus purchase, exemptions from environmental regulations (CEQA and NEPA) for transit electrification projects and OEM provided workforce training have supported uptake of BEBs.

5.3 Inferences

Table 4.2 summarizes the barriers and assets associated with fleet electrification. They have been listed in descending order of priority and policy solutions will be proposed for mitigating the most pressing issues.

The most prioritized issues are those that have been mentioned by at least five of the nine transit agencies interviewed. These are (i) Lack of adequate funding for all transit agencies, (ii) Issues with PG&E, (iiii) Supply chain issues and (iv) Lack of a streamlined/consolidated grant application process. The next most frequent concern of transit agencies was the electric bus technology which is characterized by range anxiety, long charging times and operational complexity, which requires elaborate planning and novel project delivery methods. There are also issues of standardization wherein products from different manufacturers, both hardware (chargers) and software (Charging Management Systems), are incompatible with one another. This problem is currently exacerbated by the fact that many e-bus companies are out of business or moving out from the US market, which makes their products redundant as they have difficulty working with equipment from other manufacturers.

Other concerns that are more specific to small transit agencies are lack of access to workforce development programs for their private operators and general anxiety on the resiliency of the grid and e-bus operations during emergency situations like disasters or lack of power. Larger transit agencies have offset these concerns by developing their own training programs and installing other power sources on their site. Conversely large transit agencies grapple with scaling, unavailability of land and local bureaucratic processes that delay projects.

Table 4.2: Fleet Electrification in Bay Area: Barriers and Assets

Priority	Barriers	Assets
HIGH ↑ LOW	1. Financial burden caused by **lack of adequate funding** and high costs of buses and infrastructure upgradation. 2. **PG&E issues** include long wait times for capacity upgradation, their ability to meet electricity demand for bus fleets, sunsetting of the EV Fleet program in 2024 and lack of cooperation. 3. **Supply chain issues** causing delayed procurement of buses and allied infrastructure including electrical upgrades. 4. **Lack of a streamlined/ consolidated grant application process** that reduces processing time and paperwork. 5. **Technological issues** of BEBs including range anxiety, longer charging times and operation complexity 6. **Increasing requirements associated with grant funding** including Buy America Policy 7. **Lack of interoperability between products** (both hardware and software) of different manufacturers 8. **Lack of land within Bay Area** to host charging facilities. 9. **Project delays due to local planning regulations** including planning approvals, code compliance, environmental compliance (for large projects) etc. 10. **Anxiety about grid resiliency and operational resilience** during natural disasters, power shut offs etc. 11. **Lack of policies for end-of-life disposal** of e-buses 12. **Lack of workforce development programs**, particularly for private operators. 13. **Higher issues associated with poor design and build of BEBs.** 14. **Difficulty in scaling e-bus operations**	• ICT regulation mandate • OEM provided workforce training. • State/ MTC provided wholesale contracts for bus purchase. • PG&E's EV Fleet program • Hardware standardization for charging equipment • CEQA and NEPA exemptions for small scale projects • Cooperation from local governments

5. CHAPTER 5: FLEET ELECTRIFICATION CASE STUDIES

This chapter aims to understand the best practices associated with fleet electrification by analyzing case studies of AVTA and the city of Shenzhen. In both these cases, the transit agencies were able to completely transition to 100% electric fleets and became a model for the rest of the world. These diverse cases were selected so as to gain an understanding of (i) both the global and North American fleet electrification policies and (ii) the working of a variegated fleet scale, both of which will aid in the prescription of appropriate policies in the case of Bay Area.

5.1 Case Study: Antelope Valley Transit Authority (AVTA), California

Antelope Valley Transit Authority became the first transit agency in North America to achieve 100 percent public transit fleet electrification in 2022. This included transition of all services including fixed routes, commuter routes and dial a ride services. This section aims to illustrate the process of fleet electrification through data garnered from secondary data sources and an interview with AVTA's staff.

Context: AVTA provides public transit services to Lancaster city, Palmdale city and other unincorporated areas of northern Los Angeles County in California. This area is largely characterized by flat lands and is known to experience heavy swings in temperature, with very hot summers and cold winters. They serve a population of 475,000 residents and have a service area of about 1200 square miles.[123] The fixed route transit service is operated and maintained by MV transportation, a private company that provides transportation services.[124] Its service area is well connected with other transit networks in Southern California including Los Angeles Metro, Metrolink, LADOT Transit Services, Amtrak etc through the TRANSporter program.[125]

The agency's first attempt at renewable power sources was initiated in 2004 through the installation of solar panels in their bus parking facility to generate electricity on site. This project was expanded in 2009 due to the cost savings generated by this project. In 2012 the benefit of having access to electricity on site prompted the board to shift to diesel hybrid buses. Subsequently, over the years, AVTA's board passed resolutions that facilitated the execution of a pilot program with two battery electric buses in 2014 and the adoption of complete fleet electrification in 2016.[126]

But this transition had much to do with the politics of the city and the larger federal and state policies prevalent during the time. During that time, the City of Lancaster had completed their Climate Action Plan and had a vested interest in becoming sustainable and developing green businesses. Thus, given the availability of land and the climate goals, the city's mayor was looking to attract the bus manufacturer,

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[123] *Antelope Valley Transit Authority. n.d. "About AVTA - Lancaster." Antelope Valley Transit Authority. Accessed September 29, 2023. https://www.avta.com/about-avta.php.*

[124] *Ibid*

[125] *Antelope Valley Transit Authority. "TRANSporter Brochure -2022 april.cdr." Antelope Valley Transit Authority, https://www.avta.com/userfiles/files/TRANSporter%20Brochure%20-2022%20april.pdf. Accessed 15 November 2023.*

[126] *Antelope Valley Transit Authority. n.d. "AVTA's Journey to Electrification." Antelope Valley Transit Authority. Accessed October 2, 2023. https://www.avta.com/avtas-journey-to-electrification-1.php.*

BYD, to set up a plant in Lancaster. This was expected to bring in economic and environmental benefits due to their ability to provide a green transportation solution to the city's public transit. The city board thus took a resolution supporting public transit electrification and Los Angeles County supervisor, Michael D. Antonovich provided grant funding to AVTA to start a pilot project with two e-buses. Given the success of the pilot project, AVTA's board undertook the resolution to go 100percent electric by 2018. This required that all diesel buses at the end of their useful life be mandatorily replaced with e-buses.

The federal and state policies in the late 2010s had started to encourage reduction of carbon emissions from the transportation sector including the public transit systems. The federal and state government provided funds to transit agencies for transitioning their existing diesel fleets to zero emission vehicles. AVTA availed much of these funds to procure e-buses and their associated infrastructure including charging equipment and softwares.

Fleet planning: AVTA operates "*13 local transit routes, six commuter routes, and three supplemental school routes for the local high schools*".[127] Currently they have an all-electric fleet consisting of 62 zero emission buses, 8 battery electric support vehicles and 24 battery electric commuter coaches. This is supported by two transfer centers, one each in Lancaster and Palmdale and on route inductive charging infrastructure at 13 locations within the service area.[128]

Being a smaller transit agency with a fleet size of 85 buses, it was relatively easy for AVTA to scale their fleet electrification. Their planning process was more of a "learn as you go" approach wherein infrastructure was added or upgraded depending on the need. They did not have a concrete planning document that guided their steps. They started out with a pilot project consisting of two buses and its associated charging equipment. After this proved to be successful, they went on to procure new e-buses by applying to various grants. Supporting infrastructure requirements including additional charging equipment, utility upgradation, e-bus management software systems and installation of onsite solar panels, were procured later on as they were necessary for the smooth operation of the buses.

In order to manage the entire bus fleet, AVTA has a bus management system which comprises two sections - (i) HAMS (Health Alert Management System) & (ii) ELMS (Electrical Load Management System). The former tracks data on the state of the bus including real time location and maintenance status while the latter tracks the charge component including state of charge and optimal scheduling of charge time for each bus that optimizes bus charging during off peak hours when electricity prices are low. The management system's goal was to achieve a diesel bus to e-bus replacement ratio of 1:1 by enhancing bus operations and reducing charging costs.

With more e-buses being in operation the agency decided to install on route chargers to solve the issue of range anxiety. Wireless Advanced Vehicle Electrification (WAVE) company provided these wireless

[127] *Antelope Valley Transit Authority. n.d. "About Our Fleet." Antelope Valley Transit Authority. Accessed October 2, 2023. https://www.avta.com/about-our-fleet.php.*

[128] *Antelope Valley Transit Authority. n.d. "About AVTA - Lancaster." Antelope Valley Transit Authority. Accessed September 29, 2023. https://www.avta.com/about-avta.php.*

inductive charging systems that could "*add as much as 133 miles of range on a typical 8-hour shift*".[129] This system consisted of wireless charging apparatus on the bus and a charging pad on the ground, placed in transfer stations and metro link stations. The buses would get charged when they moved onto the charging pads. Another software was added to manage this on route charging and bus routing.

Infrastructure procurement: AVTA worked hand in hand with their vendors and providers during the procurement of the buses. They were one of the first transit agencies to get 60 feet articulated buses and 40 feet commuter buses and put them into service. The strong communication with the bus manufacturers proved to be mutually beneficial in that the transit agencies could be involved in the design of the buses during production and the bus manufacturer got firsthand data on bus configurations that worked practically. This enabled the scaling of the pilot to complete fleet electrification. Also, BYD provided warranty for the full lifetime of their buses, which eased maintenance costs and provided quality assurance.

Following the purchase of buses, much investment was made to develop infrastructure that supported these buses. This included land development, upgradation of utilities and workforce training. Due to the availability of land in AVTA's service area, charging facilities - both depot and on route charging - could be developed with ease. The planning departments of the City of Lancaster and City of Palmdale also processed permits in a timely manner and did not present problems to acquisition of easement rights. This was also because the city's elected officials sat on the board of AVTA and had a commitment to fleet electrification.

Southern California Edison and City of Lancaster's Lancaster choice energy were the two main utility providers in the region. Southern California Edison is the main utility provider and is responsible for the electricity grid. This company is highly supportive of electrification and provides incentives to fleet electrification including special rates for fleet charging, rebates, and faster processing of electrical infrastructure upgrades. Lancaster's choice energy is a relatively smaller operator but is unique in that they provide green energy to their providers. AVTA had established good working relationships with both these providers and involved them in the planning process.

Both federal and state grants were used to fund the procurement of buses, infrastructure and other allied services including workforce development and operation costs. AVTA received $24.4 million from Transit and Intercity Rail Capital Program (TIRCP) and $3.5 million from Los Angeles County Metropolitan Transportation Authority (LA Metro) to fund their first stage of fleet conversion. This funded the purchase of thirteen 60 feet articulated buses, 16 commuter buses, a few 40 feet buses and their associated charging infrastructure. At this time BYD was the only bus manufacturer who could provide both these bus types and AVTA preferred to source from only one vendor. Federal funds were also availed because the use of federal funds for capital projects also enabled AVTA to get federal operating money and preventive maintenance funds. But later on additional requirements were imposed by the federal

[129] *Mass Transit. 2019. "WAVE supports Antelope Valley Transit Authority to be the first fully electric fleet powered by wireless chargers." Mass Transit. https://www.masstransitmag.com/bus/vehicles/hybrid-hydrogen-electric-vehicles/press-release/21091577/wave-inc-wave-supports-antelope-valley-transit-authority-to-be-the-first-fully-electric-fleet-powered-by-wireless-chargers.*

government including Buy America requirements and Altoona test standards. BYD's commuter buses were running into issues with the Altoona testing which extended the bus procurement timeline. In order to avoid expiration of federal funds, AVTA switched to Motor Coach Industries (MCI) buses who met all the federal requirements.

With the passage of the ICT regulations by CARB, several other federal funding sources including Federal Transit Administration's (FTA) formula funds, Low -No program and BUILD grant and state funding sources including Heavy Duty Vehicle incentive program, Low Carbon Transit Operations program, Volkswagen Mitigation funds and State of Good Repair (SGR), were available. Additionally, local air districts and cities passed measures to raise funds through sales tax and AVTA invested its own capital reserve. Overall, with a total funding of $104 million, AVTA was able to completely transition to zero emission buses.[130]

Workforce development: Staff development was considered holistically, and budgets were created for development of staff in finance (personnel for grant application, accounting etc.), operations (drivers, software management team and support staff) and maintenance (mechanics) departments. Also, the low attrition rate of employees and retention of staff from the beginning of the electrification process till its completion has preserved valuable knowledge within the organization. Thus, no additional costs were incurred for recruiting and training new staff.

BYD offered technical training to AVTA personnel and provided onsite maintenance staff to AVTA. Their proximity to the transit agency made mechanics readily available in case of need and the bus purchase contract also specified the requirement of at least two BYD mechanics on site at AVTA at all times. The same terms were extended by MCI for the commuter buses. Thus, financial planning and manufacturer support aided with upskilling of AVTA's workforce.

Disposal: Currently the two pilot buses from 2014, having completed its life cycle, have been replaced by new buses. The first batch of buses that were purchased are nearing their end of life and need to be replaced in 2027. Mostly the shells of the buses are auctioned off while the battery is repurposed for other uses. However, currently, there are no specific federal or state government policies that direct the disposal of these buses.

Lessons: The main benefit of fleet electrification for AVTA have been in terms of reduced operating costs and zero emissions to within their service area. Additionally Low Carbon Fuel Standard (LCFS) credits can be applied towards electric buses which can significantly reduce operation costs. AVTA also had some inherent advantages including a perennial access to solar energy, availability of land, small fleet size, a finite service area with little variation in trip lengths and the advantage of having a head start on electrification before other transit agencies. Certain state policies like CEQA exemption, elimination of state sales tax on buses and availability of funding for zero emission transit infrastructure were also conducive to the transition to e-buses.

Nevertheless, there are many issues that need to be addressed through larger policy frameworks. Despite the availability of federal and state funds, they may still be short when compared to the actual cost of

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130 *Antelope Valley Transit Authority. n.d. "AVTA's Journey to Electrification." Antelope Valley Transit Authority. Accessed October 2, 2023. https://www.avta.com/avtas-journey-to-electrification-1.php.*

transitioning fleets across all transit agencies. Given that most of these grants are competitive in nature, smaller transit agencies, unless they start early, tend to lose funds to larger agencies who have more manpower, technical expertise, capital and lobbying power. Ancillary industries including utilities, renewable energy and emergency services sector need to be upgraded to facilitate the e-bus industry. Due to this shortage of funds, transit agencies often refer to CARB's ICT regulation as an "unfunded mandate" that provides neither money nor manpower.

Though the e-bus industry is moving towards standardization, there is still much to be done to promote seamless experience between different bus manufacturers, charging companies and software developers. For example, during the initial days, AVTA procured BYD buses that operated on AC charging. But currently the entire bus manufacturing sector has moved to DC fast charging which renders the older buses and chargers obsolete. Thus, AVTA had to replace their entire infrastructure which proved to be highly capital intensive.

Lastly, with the availability of a number of funding opportunities transit agencies often require dedicated personnel simply to manage the grant application process and reporting requirements. While this might be more convenient for larger transit agencies, smaller transit agencies with smaller staff are often overwhelmed by this. Given that almost all grants require the same project details including bus/charger specifications, workforce development plans and operation management plans, a streamlined process can reduce processing time and create a more seamless experience for funding recipients.

5.2 Case Study: City of Shenzhen, China

City of Shenzhen is located in Southeast China and is the first city in the world to have 100 percent electric public transit which includes bus and taxi fleets. By 2017 Shenzhen achieved complete electrification of its public transit bus fleet consisting of 16,359 electric buses, one of the largest public transit fleets in the world.[131] This fleet is supported by an urban infrastructure comprising 510 bus charging stations and 5100 charge points.[132] This is managed by three different operators namely, (i) Shenzhen Bus Group (SZBG), (ii) Eastern Bus Company (EBC) and (iii) Western Bus Company (WBC).

Many factors contributed to the successful electrification of the public transit system ranging from national policies to local collaborations between stakeholders. This section however aims to explore the context and decision making at various levels of the fleet electrification process that made such a feat possible using the case of the Shenzhen Bus Group.

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131 *The World Bank. 2021. "Electrification of Public Transport: A Case Study of Shenzhen Bus Group." https://openknowledge.worldbank.org/. https://openknowledge.worldbank.org/server/api/core/bitstreams/e0837a35-a2db-582d-a730-16a8e692cc1a/content.*

132 *Murdie, Meghan. 2022. "China: Shenzhen's shift to an electric mobility system." https://knowledge-hub.circle-lab.com. https://knowledge-hub.circle-lab.com/wctd/article/22912?n=China-Shenzhen%E2%80%99s-shift-to-an-electric-mobility-system.*

Context: The city of Shenzhen experienced poor air quality, 20 percent of which was attributed to vehicle emissions.[133] In 2009 the city was chosen as one of the 13 electric vehicles pilot cities and received immense support from the national government to de-dieselize its transportation sector. The city's designation as a Special Economic Zone allowed the local government flexibility in its economic spending which facilitated the funding of electric fleets and their associated infrastructure. Also, its flat terrain and sub-tropical climate was particularly conducive to the operation of Battery Electric Buses (BEBs) as it minimized fuel loss and improved operation efficiency of BEBs.[134]

The political context of Shenzhen was particularly important in shaping the policies of its fleet electrification process. At the national level, the initiation of the New Energy Vehicle (NEV) policy aimed to "*reduce reliance on oil, strengthen national automotive industries and improve air quality*".[135] These national policies trickled down to the local and regional governments, who were in turn empowered to take up clean energy vehicles. Additionally, the promotion of local tax paying automotive industries and improved air quality aligned with the interests of the municipal government.

At the local level, the municipal government set up the Shenzhen Energy Conservation and New Energy Vehicle Demonstration and Promotion Leading Group (SNEVLG) in 2009. This was composed of representatives from the Shenzhen Development and Reform Commission (SDRC), Shenzhen Transportation Commission (STC), Shenzhen Finance Bureau (SFB) and the Shenzhen Urban Planning, Land and Resources Commission (SUPLRC), mayor's office and other district offices.[136] This collaboration between various departments streamlined bureaucratic processes, promoted inter department communication and facilitated formulation and adoption of mutually beneficial policies. For example, the SDRC was solely responsible for the distribution of both local and national subsidies to local EV manufacturers, transit operators and charging operators which made it a single window system. The STC and SUPLRC worked in tandem such that the routes approved by the STC are made feasible by the provision of adequate infrastructure (land for charging station or maintenance depot) by the SUPLRC.

Also, the city of Shenzhen has a local policy that limits the registration of private cars per year at 100,000.[137] This has pushed a significant portion of the population towards public transit. Thus, the physical, political, and economic context of Shenzhen played a vital role in not only its transition to electric vehicles but its continued operational success.

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[133] *Global Infrastructure Hub. 2021. "Shenzhen e-Mobility System." Global Infrastructure Hub. https://www.gihub.org/innovative-funding-and-financing/case-studies/shenzhen-e-mobility-system/.*

[134] *The World Bank. 2021. "Electrification of Public Transport: A Case Study of Shenzhen Bus Group." https://openknowledge.worldbank.org/. https://openknowledge.worldbank.org/server/api/core/bitstreams/e0837a35-a2db-582d-a730-16a8e692cc1a/content.*

[135] *ibid*

[136] *ibid*

[137] *ibid*

Fleet Planning: As of 2009 the SZBG operated 5998 buses, which is roughly a third of the total bus fleet in the city of Shenzhen. It operates 319 routes with an average route length of 21.73 km and the annual travel distance per bus is about 61,000 km. Given these extensive operational parameters much effort was put into the fleet transition process.

In the initial stages several pilots were done to gauge the feasibility of BEBS in the existing routes of SZBG. In 2009, the first pilot was done using 10 hybrid vehicles but later on this was deemed infeasible and the city took to the employment of 100percent electric buses.[138] This was "*followed by small pilots from 2012-2015, and a large-scale electrification from 2016-2017*".[139] This process of scaling was done efficiently through the establishment of a Technology R&D department, which mainly focused on (i) selection of the appropriate bus and charging technology, (ii) assignment of buses to appropriate routes, and (iii) collecting and analyzing operational data.

The main parameters that influenced the selection of the bus technology were route length, route topography, availability of land along the routes (for charging stations), daily ridership and operational flexibility.[140] SZBG zeroed on buses with large battery capacity that could support long haul routes akin to their existing routes on a single charge. BYD's K8 bus which was "*10.5-meters long with a theoretical 250km battery range, featured by 2 hour direct current fast charging or (or 4-5 hour alternating-current slow charging)*" fit this requirement and formed the bulk of the fleet.[141]

But it is to be noted that there were malfunctions in the beginning of the scaling and at least two electric buses were required to replace a single diesel bus (electric bus to diesel bus replacement ratio of 2:1) in this stage. But over time, collaborations with the bus manufacturer and constant operational monitoring, the fleet technology and operations were adjusted and optimized. This resulted in a nearly 1:1 electric bus to diesel bus replacement ratio by 2019.[142]

By 2019, SZBG had access to 1707 charging terminals (majority of which were DC fast chargers) at 104 stations, mainly in their terminals and depots. However, the charging infrastructure was constructed and operated by other companies (both private and public).[143] "*The number of charging terminals, charging plugs, and power of the charging terminals were decided based on the land availability at the location of*

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138 *Mobility Innovators Podcast. 2022. "E02: Lessons from Electrification of Public Transport in Shenzhen, China | Joe Ma." YouTube. https://www.youtube.com/watch?v=d7HA7EXRY88.*

139 *Berlin, Annika, Xiuli Zhang, and Yang Chen. 2020. "Electrification of Public Transport : A Case Study of the Shenzhen Bus Group." Case Study: Electric buses in Shenzhen, China. https://iea.blob.core.windows.net/assets/db408b53-276c-47d6-8b05-52e53b1208e1/e-bus-case-study-Shenzhen.pdf.*

140 *The World Bank. 2021. "Electrification of Public Transport: A Case Study of Shenzhen Bus Group." https://openknowledge.worldbank.org/. https://openknowledge.worldbank.org/server/api/core/bitstreams/e0837a35-a2db-582d-a730-16a8e692cc1a/content.*

141 *Berlin, Annika, Xiuli Zhang, and Yang Chen. 2020. "Electrification of Public Transport : A Case Study of the Shenzhen Bus Group." Case Study: Electric buses in Shenzhen, China. https://iea.blob.core.windows.net/assets/db408b53-276c-47d6-8b05-52e53b1208e1/e-bus-case-study-Shenzhen.pdf.*

142 *The World Bank. 2021. "Electrification of Public Transport: A Case Study of Shenzhen Bus Group." https://openknowledge.worldbank.org/. https://openknowledge.worldbank.org/server/api/core/bitstreams/e0837a35-a2db-582d-a730-16a8e692cc1a/content.*

143 *Berlin, Annika, Xiuli Zhang, and Yang Chen. 2020. "Electrification of Public Transport : A Case Study of the Shenzhen Bus Group." Case Study: Electric buses in Shenzhen, China. https://iea.blob.core.windows.net/assets/db408b53-276c-47d6-8b05-52e53b1208e1/e-bus-case-study-Shenzhen.pdf.*

the charging station, number of buses to be served, space requirements, speed of charging terminals, grid capability, and other factors".[144] The lack of land in the densely populated city of Shenzhen also propelled the adoption of DC fast chargers over slower AC chargers.

The design of charging stations also evolved over time to maximize the charger to bus ratio. Initially every charging terminal served a single bus (ratio of 1:1). But in 2016, SZBG piloted the "network charging concept" wherein four buses could be plugged into a single charging station for simultaneous charging (ratio of 1:4).[145] Though this resulted in longer charge times per bus, as each bus would charge at one fourth the total power, it reduced the labor costs incurred in having a worker move the bus after its charging time. However, with the more advanced bus management systems, software-based charging systems have been used to optimize power to each charging terminal for achieving maximum operational efficiency.[146]

Procurement of buses and infrastructure: The political impetus at both the national and city level supported the manufacture of e-buses, batteries and charging facilities through the provision of financial subsidies. "*The combination of purchase subsidies from national and local government together contributed more than 60 percent of the total procurement cost of electric buses from 2015 to 2017*."[147] Operational costs for the charging operators and the bus company was also subsidized by the local government. The Shenzhen municipal government subsidized up to 30percent of the upfront cost of charging infrastructure, provided wholesale electricity tariff rates to the charging operators and regulated service fees of charging operators (to protect bus companies from being overcharged).[148] This environment enabled the procurement of e-buses. Figure 5.1 explains this financial leasing model.

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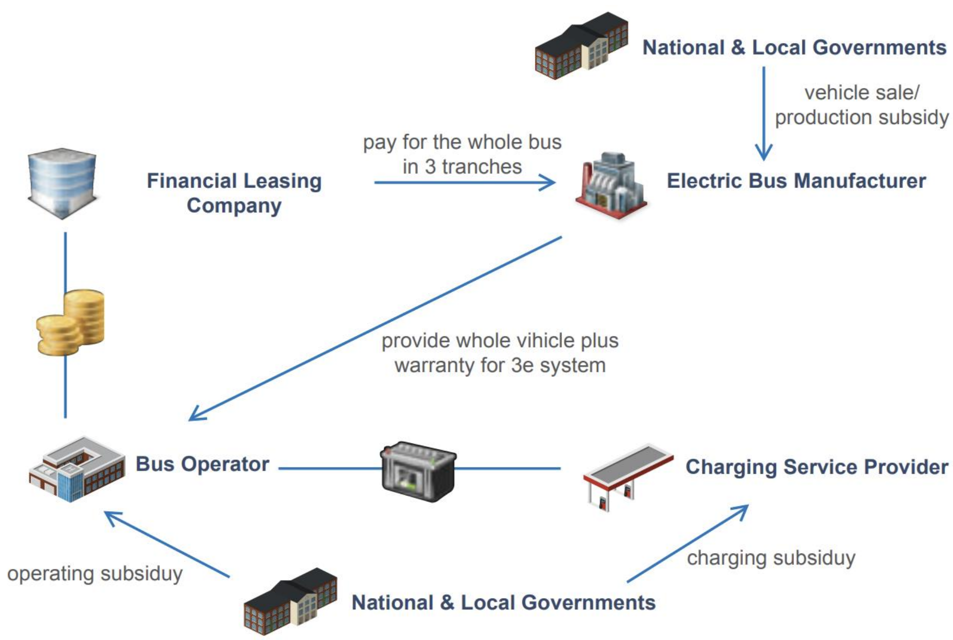
144 *The World Bank. 2021. "Electrification of Public Transport: A Case Study of Shenzhen Bus Group." https://openknowledge.worldbank.org/. https://openknowledge.worldbank.org/server/api/core/bitstreams/e0837a35-a2db-582d-a730-16a8e692cc1a/content.*

145 *Berlin, Annika, Xiuli Zhang, and Yang Chen. 2020. "Electrification of Public Transport : A Case Study of the Shenzhen Bus Group." Case Study: Electric buses in Shenzhen, China. https://iea.blob.core.windows.net/assets/db408b53-276c-47d6-8b05-52e53b1208e1/e-bus-case-study-Shenzhen.pdf.*

146 *Mobility Innovators Podcast. 2022. "E02: Lessons from Electrification of Public Transport in Shenzhen, China | Joe Ma." YouTube. https://www.youtube.com/watch?v=d7HA7EXRY88.*

147 *The World Bank. 2021. "Electrification of Public Transport: A Case Study of Shenzhen Bus Group." https://openknowledge.worldbank.org/. https://openknowledge.worldbank.org/server/api/core/bitstreams/e0837a35-a2db-582d-a730-16a8e692cc1a/content.*

148 *Wang, Zhe, Qiyu Liu, Dave Mullaney, and Ross McLane. 2020. "PUTTING ELECTRIC LOGISTICS VEHICLES TO WORK IN SHENZHEN." https://rmi.org/. https://rmi.org/wp-content/uploads/dlm_uploads/2020/10/RMI_Charging-Volume_Putting-Electric-Logistics-Vehicles-To-Work_2020.pdf.*



Source:https://openknowledge.worldbank.org/server/api/core/bitstreams/e0837a35-a2db-582d-a730-16a8e692cc1a/content

Figure 5.1: Financial Leasing Model

Despite the availability of these subsidies the SZBG procured all its capital infrastructure through financial leasing instead of buying/owning. They leased their buses from a financial agency (Bank of Communications) and charging stations from charging facility providers (Potvin and Winline). This proved to be greatly advantageous to SZBG because this model reduced the upfront cost and shifted both the financial and operational risks to third parties. In terms of finance, SZBG only had to pay the lease fee for the buses, electricity fee for charging and service charges if any. In case of operations, the battery life and maintenance of the bus was completely guaranteed by the bus manufacturer and finance agency.[149]

The proximity of BYD's e-bus manufacturing plant to Shenzhen further reduced overhead costs and allowed for customized buses as per the requirement of SZBG. These customizations included added safety standards for fire, adherence to universal accessibility standards, requirement for higher battery efficiency and implementation of smart devices for operational monitoring.[150]

Operations management (including charging management): The operational management of electric buses is very different from that of diesel buses. Due to additional constraints like bus range and longer charging time (as opposed to the fueling time for a diesel bus), electric buses require advanced management systems that can synchronize charging, bus routing and bus scheduling. The ability of SZBG

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[149] *Zhang, Qihang. 2019. "Analysis of "Shenzhen Model" for New Energy Vehicle Promotion in Public Transportation." https://iopscience.iop.org/. https://iopscience.iop.org/article/10.1088/1755-1315/295/5/052048/pdf.*

[150] *The World Bank. 2021. "Electrification of Public Transport: A Case Study of Shenzhen Bus Group." https://openknowledge.worldbank.org/. https://openknowledge.worldbank.org/server/api/core/bitstreams/e0837a35-a2db-582d-a730-16a8e692cc1a/content.*

to efficiently design and implement operations management particularly aided in scaling their e-bus operations.

The main measures undertaken by SZBG were "*refining the operational plan and scheduling for each line, optimizing charging arrangement, and the use of intelligent bus dispatch and management systems*".[151] Bus operations were constantly monitored and optimized to meet the changing passenger demand. The passenger demand fluctuates based on time of day, day of week and development of other transit modes like metro. Optimization solutions were in terms of routing adjustment, fleet and charging scheduling that aimed to meet transit demand and lower charging costs by charging during off peak hours. There were also emergency response plans which optimized operations based on emergency situations like accidents, natural events, lack of electricity etc.

SZBG employed an intelligent e-bus management system to achieve all the above goals. This system integrated (i) e-bus data, including its real time location, charge levels, maintenance status and driver schedules and (ii) charging terminal data, including real time data of charging terminals. The availability of this crucial data improved operation management by allowing for coordination between multiple functions, thus creating a seamless workflow.

Workforce development: With the advent of new technology, there is also a need to upgrade the existing workforce. For an electric fleet, skilled operation managers, charging terminal operators, bus technicians and drivers are required. SZBG had assessed their workforce requirement, developed staff standards, and implemented plans to upskill their existing labor force. "*They developed a step-by-step staff transformation plan—training, re-assignment, incentives, talent attribution and compensation—for each team in each maintenance and repair workshop, considering the difficulty of transformation based on specialty, age, and experience."*[152] The bus manufacturer BYD also provided (i) warranty services which included regular repair and maintenance and (ii) free training to SZBG's workforce. Additionally, to encourage future supply of e-bus technicians, SZBG sponsored the training programs in vocational schools and offered incentives to technicians who pursued national level certifications.[153]

Fleet operators were required to constantly monitor bus operations by keeping track of real time operations data provided by the integrated e-bus management system. They were also tasked with scheduling of routes and optimizing routes for operational efficiency. Drivers had to undergo an extensive training program which included (i) knowledge training, (ii) Test driving requirement (minimum 50 kilometers of driving) and (iii) Online resources for continuous learning.[154] In this case, since the operations of charging facilities were outsourced to private contractors, training of charging terminal operators fell under their purview.

151 *ibid*

152 *ibid*

153 *ibid*

154 *ibid*

End-of-life disposal: The policy regulations in China require the e-bus manufacturer to recycle the battery after the lifecycle of an e-bus is complete. Thus, SZBG returns (not sell) the batteries to BYD. Depending on the residual capacity of these batteries, either they are reused in other applications or simply recycled for the valuable metals in them. The rest of the bus parts are "*sent for scrappage and metal recycling*".[155]

5.3 Findings from Case Studies

A review of the above case studies indicates several common policies and planning processes undertaken by government and transit agencies to electrify their fleet. These policies stem from the need to address the main impediments to electrification including (i) procurement of funding to plan and implement e-buses, (ii) upgradation of existing electrical infrastructure, (iii) reducing maintenance and operation costs, (iv) workforce development and (v) planning efficient e-bus operations. The following are some of the main policies that enabled successful transition to e-buses,

1. **Government subsidies/ grants** which provided funding for bus operators/ transit agencies to procure infrastructure.
2. **Strong governmental policies** that mandated transition to electric vehicles
3. **Starting out with pilot projects** to understand the workings of e-bus operations before full transition to e-buses.
4. **Planning coordination, cooperation and communication with stakeholders** including bus manufacturers, utility companies and local governments.
5. **Awareness and implementation of appropriate technology** including bus management softwares, upgraded charging technology and safety mechanisms, which can optimize e-bus operation management and maintenance.
6. **Upskilling of existing workforce** through various innovative mechanisms including manufacturer sponsored training and fostering of e-bus related study programs in educational institutions.

[155] *ibid*

6. CHAPTER 6: ANALYSIS OF POLICY ALTERNATIVES

This chapter aims to identify and prescribe policies that can counteract the obstacles highlighted in the previous chapter and come up with policy alternatives within the scope of the urban planning realm. Each of the policy alternatives are compared with one another by analyzing their performance on the basis of certain parameters. Finally, a policy package is prescribed based on the results of this analysis.

6.1 Policy Analysis Criteria

In an effort to hone in on a specific policy, all policy alternatives were compared on the basis of their performance in each of the following criteria:

Effectiveness - The effectiveness criteria refers to the ability of the policy alternative to address the central problem.[156] Effectiveness in this context is measured by the reduction in share of Diesel buses in the fixed route fleets.

Equity: Equity involves determining how alternatives may affect different groups of people in terms of cost and benefit.[157] In this context it refers to the impact of the alternatives on equitable distribution of resources to all transit agencies. The end transit users are not the primary consumers in this case.

Cost - Costs usually refer to the direct costs of administering a program or policy which includes both capital and operational cost.[158]

Political feasibility: Political feasibility generally refers to the chances that policies or programs will receive sufficient support from key "stakeholders".[159] In this case the key stakeholders are utility companies, bus manufacturers, transit agencies and local/state/federal government.

Implementation Feasibility: Implementation feasibility refers to various barriers that might prevent it from being executed as intended.[160] In this context it refers to the administrative capacity and organizational process required for policy implementation.

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[156] *Meltzer, Rachel, and Alex Schwartz. Policy Analysis as Problem solving : A flexible and evidence based Framework. Routledge, 2019.*

[157] *Ibid*

[158] *Ibid*

[159] *Ibid*

[160] *Ibid*

6.2 Policy Alternatives

The policy alternatives were formulated with the objective of alleviating the barriers identified in Chapter 4. These were derived after a careful study of best practices, case studies and research papers in the context of the United States and the world. The policy alternatives were categorized as long-term policies and short-term policies based on the scale of implementation, cost, execution time and impact time. While long term policies require larger investments, lengthy implementation timeline and improves e-bus uptake for a longer time, short term policies facilitate quick e-bus uptake, incur less costs and can be executed faster. It is to be noted that the inherent character of the proposed policy alternatives is such that they can be phased out or modified at any time which provides added flexibility.

6.2.1 Long Term Alternatives

1. <u>Increased Transit Funding</u>

This policy aims to enhance funding by increasing the apportionment of state and federal funds for zero emission transit projects. Currently the funding demand for zero emission transit projects outweighs the total funding itself. As one interviewee pointed out, FTA's Low and No Emission grant program disbursed $1.7 billion towards zero emission transit which is only 20percent of the total funding demand of $8.7 billion (the cost of all projects submitted by 495 agencies in the United States).[161] Also with most grants being competitive (wherein only select projects get funding), many transit agencies, particularly smaller ones, are seldom awarded funds.[162]

Increased funding will help grow the nascent e-bus market and will allow transit agencies to take the risk of investing in zero emission technology.[163] The American Public Transportation Association (APTA)'s research also indicates that guaranteed transit funding encourages innovation, supports US manufacturing, delivers projects faster and at less cost and improves the state of good repair.[164] Also in the case study of Shenzhen, it was evident that the purchase of e-buses and its associated infrastructure was heavily subsidized by the national government, which eventually resulted in implementation of e-buses into public transit fleets. Thus, with increased investments in fleet electrification projects, especially during the nascent stages, transit agencies can adopt e-buses more quickly.

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161 *Sourced from the author's Interview with a Bay area transit agency*

162 *ibid*

163 *St.John, Jeff. 2023. "The US' billion-dollar EV bus program can't keep up with demand." Canary Media*

164 *Kline, Sarah. n.d. "The Benefits of Reliable Federal Funding for Public Transportation." American Public Transportation Association. Accessed October 29, 2023. https://www.apta.com/wp-content/uploads/Resources/resources/reportsandpublications/Documents/APTA-Benefits-Reliable-Funding.pdf.*

2. Creation of Technology and Project Delivery Cell

"*Well-defined goals for procurement and performance can provide a solid basis for planning BEB operation, but thorough analysis is needed to produce successful BEB deployment that satisfies the needs of the transit agency and the public*." [165] However, one of the key barriers to implementation of fleet electrification projects in the Bay Area was the deficiency in planning, knowledge and project management skills required for fleet electrification.

In the context of the Bay Area, most large transit agencies, despite undertaking the efforts to hone in on appropriate technology, are still behind with respect to project delivery and management. Smaller transit agencies, which have very few e-buses in their fleets, are still using traditional methods of scheduling, route design and operation to manage their e-bus fleet, which is unsustainable in the case of complete fleet electrification. It is also to be noted that most transit agencies have outsourced project planning works to private consultants, which reduces the knowledge assets within the agency. In the case study of Shenzhen, these issues were addressed through the creation of a technology cell that would assess existing conditions of service areas, select the appropriate zero emission technology, and manage fleet operations.

It is highly recommended that transit agencies "*maximize electric bus adoption targets based on local conditions and to develop a responsible strategy for implementation*."[166] This policy would require all transit agencies to set up a Technology and Project Delivery Cell that would be responsible for planning, implementation, and management of fleet electrification projects. It would also be tasked with the management of fleet operations (given that operation of e-bus fleets requires dedicated and skilled personnel) and replacement of buses after the end of their useful life. Additionally, the incorporation of such a team will reduce reliance on private consultants and third-party operators by imparting technical knowledge to transit agencies. With the evolving nature of zero emission technology, the role of the Technology and Project Delivery cell will be significant for the foreseeable future.

3. Data Communication Standardization

For electric bus fleets to be successful, all components of an electric fleet "*need to be able to seamlessly communicate with one another, and in particular a central charge management software has to be able to map and manage all of these components.*" [167] However, many Bay Area transit agencies have reported on data communication issues between products of different manufacturers (say between a Proterra bus, Charge point Charger and the charge management software) due to software incompatibility. The issue arises because bus manufacturers have their own softwares preinstalled in the buses which limits access of bus data to fleet operators.

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165 *Aamodt, Alana, Karlynn Cory, and Kamyria Coney. 2021. "Electrifying Transit: A Guidebook for Implementing Battery Electric Buses." NREL. https://www.nrel.gov/docs/fy21osti/76932.pdf.*

166 *Li, Xiangyi, Camron Gorguinpour, Ryan Sclar, and Sebastian Castellanos. 2019. "How to Enable Electric Bus Adoption in Cities Worldwide." World Resources Institute. https://www.wri.org/research/how-enable-electric-bus-adoption-cities-worldwide*.

167 *Krause, Stefan. 2023. "Standard interfaces for charging e-buses." CarMedialab. https://www.carmedialab.com/wp-content/uploads/2023/03/Whitepaper_standard_interfaces_e-buses.pdf.*

This policy proposes to develop data communication standards which will improve interoperability and provide seamless communication between various components of an electric fleet, including charging stations, buses, and the charge management system. In an effort to standardize data communication, the Association of Public Transportation in Germany has proposed VDV 238, a data communication standard for electric buses in 2023. [168] This new standardization is expected to improve data security, transparency, interoperability, ease of use, efficiency of fleet operations and enables fleet operators to source products from different manufacturers.[169] [170]

Furthermore, the creation of these standards is also beneficial in the long run as they can improve Vehicle to Grid Integration (VGI)[171], a crucial step that ensures stability of the grid. The California Energy Commission's report "California E-Bus to Grid Integration Project", indicates the lack of communication between Antelope Valley Transportation Authority's (AVTA) BYD buses and the charge management system and thus recommends development of VGI specifications and requires OEMs to "*standardize charging protocols… and other protocols to enable remote monitoring, controls, and dispatch signaling*".[172]

6.2.2 Short Term Alternatives

1. <u>Incentive to PG&E</u>

This policy calls for government incentives to PG&E to (i) reduce electricity rates for public transit fleets, (ii) aid with grid upgradation, and (iii) improve application processing time for fleet electrification projects. Under PG&E's current Electric Vehicle fleet program, "*fleets can significantly reduce energy costs by 25% to 50% compared to traditional commercial electricity rates*".[173] This is evidenced by the fact that commercial electricity rates are 25-26 cents per kWh while the public bus fleet tariff is only 8 cents per kWh.[174] Thus subsidized electricity pricing can greatly reduce operating costs for transit agencies and improve e-bus uptake.

With ICT mandate the electrification of all public transit fleets in California, investment in grid upgradation will enable the grid to service additional e-buses. This will facilitate quicker adoption of electric buses by transit agencies and alleviate concerns about grid capacity. The Department of Energy has launched the Building a Better Grid Initiative in 2022 which aims to "*catalyze the nationwide development of new and*

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168 *Schabert, Alexander. 2022. "What is VDV 238 and how will it impact your electric fleet operation?" ChargePoint.* *https://www.chargepoint.com/en-gb/blog/what-vdv-238-and-how-it-will-impact-your-electric-fleet-operation.*

169 *ibid*

170 *Krause, S. 2023. "Easier and faster access to bus data thanks to VDV 238." CarMedialab.* *https://www.carmedialab.com/en/easier-and-faster-access-to-bus-data-thanks-to-vdv-238/.*

171 *Vehicle-grid integration (VGI) refers to technologies, policies, and strategies for electric vehicle (EV) charging which alter the time, power level, or location of the charging (or discharging) in a manner that benefits the grid while still meeting drivers' mobility needs Source: Vehicle-Grid Integration Program | California Energy Commission.*

172 *California Energy Commission. 2021. "California E-Bus to Grid Integration Project." California Energy Commission.* *https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2021-014.pdf.*

173 *"EV Fleet Program Saves on Energy Costs for PG&E Business Customers." 2020. Advanced Clean Tech News.* *https://www.act-news.com/news/save-on-energy-costs-with-pges-business-ev-rates/.*

174 *Sourced from the author's Interview with a Bay area transit agency*

upgraded high-capacity electric transmission lines and support investments to modernize the flexibility and resilience of the distribution system to create a more resilient electric grid." [175] This provides billions of dollars of funds through programs including Transmission Facilitation Program ($2.5 billion), Grid Resilience Formula Grants ($2.3 billion), Grid Resilience and Innovation Partnerships program ($10.5 billion) etc.[176] Similar grants can be extended to utility providers in California.

Currently the time taken for PG&E to process electrical upgradation projects ranges anywhere between 2-5 years. Incentives including tax rebates or credits upon prioritization of electrical upgradation work for public transit fleets can incentivize PG&E to process these applications faster. A "fast track process" can also be formulated wherein small-scale projects that do not require large upgradation works can be processed through a different system. For example, the Environmental Protection Agency's (EPA) Re-Powering America's Land Initiative, incorporates a streamlined interconnection review (fast tracking) process that expedites review of projects 5 MW or less in capacity, resulting in time reduction of eight or more weeks. [177]

2. <u>Operations Resilience Plan</u>

Operations resilience plan aids in understanding the risks associated with electrification and adopting ways to mitigate them, to ensure smooth fleet operation. Some of the main risks associated with fleet electrification are lack of electricity, accident repairs/maintenance/accident management, cyber security, natural hazards, and fire risks. [178] Some of the main goals of resilience planning are (i) planning for grid resilience, (ii) protection of critical assets including vehicle, power sources etc., (iii) incorporation of operational flexibility, (iv) improving fleet efficiency, (v) collaboration with critical stakeholders so as to provide flexibility during emergencies, (vi) integration of fleet planning into agency resilience efforts and (vii) incorporating fleet fuel diversification. [179]

Integration of operation resilience plan improves the uptake of e-bus into public transit fleets by reducing anxiety on operations during times of emergencies. Some of the measures that have been adopted by transit agencies as part of their resilience planning are incorporation of microgrids, development of independent power sources in depots through installation of solar panels, generators etc., implement electric vehicles with bidirectional charging[180] capability, forecasting and modeling of emergency events, coordination with other agency fleets, logistical planning and inclusion of CNG or gasoline vehicles in the

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[175] *US Department of Energy. n.d. "Building a Better Grid Initiative." Department of Energy. Accessed October 30, 2023. https://www.energy.gov/gdo/building-better-grid-initiative.*

[176] *ibid*

[177] *Environmental Protection Agency. 2019. "Interconnection: Plugging RE-powering Sites Into the Electric Grid." Environmental Protection Agency. https://www.epa.gov/sites/default/files/2019-10/documents/interconnection_plugging_re_powering_sites_into_the_electric_grid_oct2019_508.pdf.*

[178] *Weber, Jaeson A., and Vanessa V. Mathews. 2023. "Electrical Vehicles (EV) and Operational Resilience | BCI." Business Continuity Institute. https://www.thebci.org/news/bcaw-2023-electrical-vehicles-ev-and-operational-resilience.html.*

[179] *National Renewable Energy Laboratory, Mark Singer, Cabell Hodge, Federal Energy Management Program, and Ashley Pennington. 2021. "Federal Fleet Resilience Planning." NREL. https://www.nrel.gov/docs/fy21osti/77721.pdf.*

[180] *Bidirectional charging is when an electric vehicle can send electricity back to the grid (referred to as vehicle to grid charging) so as to provide back up power to buildings or specific loads to improve resilience of the grid. Source: Bidirectional Charging and Electric Vehicles for Mobile Storage | Department of Energy*

fleet.[181] An example of this is the pilot project in Beverly, Massachusetts, electric school buses "*helped the local utility, National Grid, meet peak loads over the course of 30 events in the summer of 2021*"[182] Similarly the Metropolitan Transportation Authority (MTA) of New York city had conducted extensive resiliency modeling after hurricane Sandy, protected existing electric charging infrastructure and incorporated diesel buses into the fleet to achieve operation flexibility during the calamity. [183]

3. Workforce Training Program

Inadequate and lack of skilled workforce causes poor operation efficiency due to lack of personnel to operate/maintain the buses, inefficient driving practices and poor maintenance of charging stations. This seriously affects the reliability of electrified fleets and behooves transit agencies to either slow e-bus uptake and continue relying on diesel/CNG buses. However, "investing in proper training programs is essential for a smooth transition and optimal operation of electric commercial fleets".[184]

This policy recommends the incorporation of a region-wide workforce development program that can impart skilled education and training on electric bus fleet infrastructure maintenance and operation to all existing workforce of transit agencies. It is to be noted that this policy (i) requires the establishment of a proper curriculum/framework for training programs, (ii) would seek to establish vital collaborations with colleges in the Bay Area so to ensure future supply of workforce and (iii) would not discriminate between unionized and non-unionized workers.

There are many examples of workforce development initiatives by state and local governments. The "*Washington State legislature passed legislation in 2019 directing the WSU Energy Program to establish and administer a technical assistance and education program for public agencies on the use of alternative fuels and vehicles*."[185] This resulted in the creation of the Green Transportation program that "*provides education and assistance about alternative fuels and vehicles to all public agencies in the state, including cities, counties, tribes, transit agencies, ports, school districts, colleges and universities*."

San Francisco's Electric Vehicle Ready Community Blueprint lists imparting workforce training as an important strategy to improve electric vehicles uptake. It seeks to achieve this by assessing the supply and demand gap in electric vehicle workforce, collaborating with the City College of San Francisco's

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181 *Hance, Amy. 2023. "Resiliency in a Zero-Emission World." CALACT. https://calact.org/wp-content/uploads/2023/04/Resiliency-in-a-Zero-Emission-World-Amy-Hance.pdf.*

182 *Brower, Michael. 2023. "Electric Vehicles and the Case for Resilience." Clean Energy Group. https://www.cleanegroup.org/electric-vehicles-and-the-case-for-resilience/.*

183 *Tessler, Maya E., and Elizabeth J. Traut. 2022. "Hurricane resiliency methods for the New York City electric bus fleet." Transportation Research Part D: Transport and Environment 105 (March). https://doi.org/10.1016/j.trd.2022.103255.*

184 *Zamanov, Nick. 2023. "Adoption of Electric Vehicles in Commercial Fleets: An Analysis of Benefits and Challenges - News." Cyberswitching. https://cyberswitching.com/adoption-electric-vehicles-commercial-fleets/.*

185 *Washington Green Transportation Program, Stacey Waterman-Hoey, and Alan Hardcastle. 2021. "Initial Research Review for Workforce Development Phase 1." WSU Energy Program. https://www.energy.wsu.edu/documents/SumRecApp_web.pdf.*

Automotive Technology program, recruiting students to enroll in the program and disseminating information on associated job opportunities.[186]

4. Streamlined Grant Application

With the push towards zero emission fleets both the federal and state government have initiated several grants and initiatives to fund fleet electrification projects. These grants are administered by various government departments and agencies, each of which have their own separate applications with disparate requirements and reporting procedures. Thus, a transit agency applying for these grants must submit multiple proposals for the same project based on the requirements of the administering agency, which creates duplication of work and unnecessary paperwork that costs time and money. This is particularly hindersome for small and medium transit agencies who don't have a dedicated grants management team.

The goal of this policy is to create a streamlined grant application process that creates an electronic single window system for application and reporting. This will entail development of data standards[187], combining multiple applications into a single form[188], standardization of application[189], technical assistance and financial support[190], create communication platforms including publication of procedures and requirements[191] and opportunities for feedback/ Q & A[192]. This will also enhance data collection, enable easier project tracking/management, and facilitate dissemination of funding information to the general public.

The Streamlining Federal Grants Act of 2023 that "*would help streamline the administration of grant programs across the federal government*" through development of data standards for application and reporting was recently approved.[193] It was passed to ensure that government agencies and other organizations in non-urban communities could access federal grant programs by removing complications from the application and reporting process. Currently California has passed AB 972 bill that has incorporated the Local Assistance and Grant Program Streamlining Workgroup that would aim to "*centralize local assistance and develop a coordinated system to manage available state and federal*

[186] *Department of the Environment City and County of San Francisco. 2019. "San Francisco's Electric Vehicle Ready Community Blueprint." SF Environment. https://sfenvironment.org/sites/default/files/editor-uploads/transportation_vehicle/san_francisco_ev_blueprint.pdf.*

[187] *The National Grants Partnership. 2005. "Accelerating Grants Streamlining." National Academies. https://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga_055948.pdf.*

[188] *Orrantia, Leslie. 2022. "Streamlined grant procedures can make competitive funding fairer." State Smart Transportation Initiative. https://ssti.us/2022/08/09/streamlined-grant-procedures-can-make-competitive-funding-fairer/.*

[189] *ibid*

[190] *ibid*

[191] *ibid*

[192] *USDR Grants Team. 2023. "Streamlining the Federal Grant Process to Empower Small Communities." Medium. Streamlining the Federal Grant Process to Empower Small Communities | by U.S. Digital Response.*

[193] *Homeland security and governmental affairs. 2023. "Peters, Cornyn and Lankford Introduce Bipartisan to Bill Help Improve the Federal Grant Application Process - Committee on Homeland Security & Governmental Affairs." Senate Committee on Homeland Security and Governmental Affairs. Peters, Cornyn and Lankford Introduce Bipartisan to Bill Help Improve the Federal Grant Application Process - Committee on Homeland Security & Governmental Affairs.*

funding to deliver the maximum number of projects as efficiently as possible".[194] This working group is also required to develop a report comprising its findings and recommendations by 2026.[195]

6.3 Analysis of Alternatives

In order to arrive at a specific policy, the policy alternatives were compared with one another using the Non dominated Alternative Method of policy analysis. This method involves measuring the performance[196] of each alternative on each criterion and then ranking them. Then the final policies were derived through the elimination of the dominated alternatives. A matrix which links the criteria and alternative was created to understand the performance of each alternative with respect to each other across a selected criterion and identify the strengths and weaknesses of the options.[197] Table 6.1 and 6.2 depict the matrix.

6.3.1 Non-Dominated Alternatives method

Long-term and short-term policy alternatives were compared against the criteria of Effectiveness, Equity, Cost, Political feasibility, and Implementation feasibility. For the long-term policy solutions, the alternative "Increased transit funding" ranked the highest in effectiveness and implementation feasibility as provision of funding has been the most preferred solution for stimulating the uptake of new technologies. However, it performs poorly in parameters of equity, cost and political feasibility. However, there is much evidence, as indicated in Section 6.2.1, that increased funding leads to increased e-bus uptake as it empowers transit agencies to purchase the necessary infrastructure. Also, over 70 percent of the interviewed transit agencies suggested lack of funding as a barrier towards fleet electrification. Thus, this option is retained for consideration.

"Creation of Technology and Project Delivery Cell" is the more balanced option given that it performs exceptionally with respect to cost and averagely on all other criteria. The main reason for its average performance on most criteria is because it appears to be beneficial to transit agencies with larger or medium fleet size. It is also the only alternative that requires extensive cooperation from transit agencies as it directly affects their administrative structure, and its success depends entirely on their commitment to its implementation. But it is to be noted that it will be instrumental in the long run for sustaining e-bus operations.

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194 *"AB972 | California 2023-2024 | Local Assistance and Grant Program Streamlining Workgroup." n.d. TrackBill. Accessed October 31, 2023. https://trackbill.com/bill/california-assembly-bill-972-local-assistance-and-grant-program-streamlining-workgroup/2367590/.*

195 *"Bill Text: CA AB972 | 2023-2024 | Regular Session | Amended." n.d. LegiScan. Accessed October 31, 2023. Bill Text: CA AB972 | 2023-2024 | Regular Session | Amended | LegiScan.*

196 *Performance of alternatives with respect to the criteria is represented qualitatively through the designation of ratings such as "High", "Medium" and "Low" and then ranking them.*

197 *Meltzer, Rachel, and Alex Schwartz. Policy Analysis as Problem solving : A flexible and evidence based Framework. Routledge, 2019.*

Table 6.1: Long term Policy Alternatives

ANALYSIS CRITERIA	LONG TERM POLICY ALTERNATIVES		
	Increased Transit Funding	**Creation of Technology and Project Delivery Cell**	**Data Communication Standardization**
Effectiveness	High (1st): This alternative will increase funding for transit and enable transit agencies to purchase infrastructure and operate BEBs.	Medium (2nd): this will aid every transit agency to plan for their service area by selecting the appropriate zero emission vehicle technology and project delivery mechanism. This increases the rate of success of the transit system.	Low (3rd): this will improve uptake of e-buses and reduce anxiety on technology by increasing the interoperability between manufacturers. However, this is time consuming and requires consensus amidst stakeholders.
Equity	Low (3rd): All transit agencies will benefit from increased funding. But due to the political influence of large transit agencies, they tend to get a larger share of funds compared to small/medium transit agencies.	Medium (2nd): This allows for informed decision making in all transit agencies. But it may become redundant over time for small transit agencies as small fleets do not require elaborate bus procurement/ fleet replacement schedules and operations planning.	High (1st): this policy affects all transit agencies equitably and improves e-bus uptake uniformly across the board, irrespective of transit agency's scale.
Cost	High (3rd): Increasing funding for fleet electrification for all transit agencies is very expensive, due to the high cost of these projects. However, given the low operation and maintenance costs of e-buses there will be long term cost savings	Low (1st): This alternative requires the least cost. However, there are some operational cost incurred for employee salaries, office space and procurement of other work infrastructure. This creates additional jobs.	Medium (2nd): Creation of standardization guidelines require research & development and replacement/modification of existing infrastructure which will incur significant costs. However, these are one-time costs and are not recurring.

Political Feasibility	Low (3rd): This will receive maximum push back from policy makers as it requires increased apportionment in federal/state budgets to public transit (often a result of cutting funds for other projects including highways). This is highly dependent on the political climate at the state and federal level.	Medium (2nd): This option will receive pushback from small transit agencies (as they might not realize long term benefits from this) and private consultants like CTE, WSP etc. (who may lose business).	High (1st): This alternative will receive least resistance from all relevant stakeholders. Additionally, this will boost the economy through job creation, increased consumption, reduce operational/ compatibility issues and lower time spent on repair/maintenance.
Implementation Feasibility	High (1st): This does not require setting up of a new administrative framework or high level of coordination between government agencies. It is easy to implement as the framework for providing funds already exists at local, region, state and federal level	Medium (2nd): This requires an increase in administrative capacity and significant organizational changes to be incorporated within the transit agency, which will take time and additional regulatory frameworks. The technology cell also cannot be a standalone entity and must be integrated with the existing planning/ transportation department.	Low (3rd): This alternative needs extensive collaboration and coordination between a diverse array of stakeholders followed by formulation of procedures /guidelines. This increases organizational complexity and needs constant monitoring for successful implementation.

The "Data communication Standardization" alternative performs well with regard to equity and political feasibility as it benefits all stakeholders with very little opposition. However, it performs very poorly on effectiveness and implementation feasibility due to the time taking and collaborative nature of the policy. The smaller transit agencies are not particularly affected by the lack of interoperability within their electric infrastructure which reduces the effectiveness of e-bus uptake. It lacks implementation feasibility as it requires extensive communication, cooperation, and consensus between a diverse array of stakeholders including bus and charging infrastructure manufacturers, the utility company, professional associations, quality control departments and other governmental agencies. Thus, this alternative appears unfavorable and has been discounted from further consideration.

In the case of short-term policy alternatives, Incentive to PG&E is the most effective and equitable alternative with the only drawback being politically unfavorable. Utility companies are important stakeholders and need to be involved in the fleet electrification process early on for assessment of electric demand and effective infrastructure planning.[198] The results of the primary data collection also indicate that fleet electrification projects are delayed in lieu of PG&E, which makes incentivization of PG&E a much needed policy for improving e-bus uptake in the short term.

Operations Resilience Plan, despite high implementation feasibility performs moderately in all other categories. The primary reason for its poor effectiveness is because transit agencies have either already implemented it into their fleet planning or are not subject to frequent emergency situations like power shut offs or natural hazards (wildfire). This alternative is politically favorable as it prevents damage and would sustain transit operations during critical times. Also, this complements the long-term policy alternative of "development of technical and project delivery cell" as both policies aim to bring about efficient electric fleet planning.

Workforce training programs policy performs moderately in all criteria and is a relatively balanced strategy in comparison to other alternatives. It is politically favorable and is quite effective in stimulating e-bus uptake by transit agencies. It is also equitable as all relevant stakeholders including transit agencies, utility companies, manufacturers, and the general public benefit from the development of training programs. Cost recovery is also possible in the long run through fees or training charges. Additional advantages of this policy include an increase in job opportunities, development of knowledge capital and skilled labor force, and enhanced economic productivity.

Streamlined grant application strategy is the most cost-efficient policy but performs below average on all other criteria. This strategy is beneficial mostly to small transit agencies and is not viewed as an immediate concern. The general opinion is to hire more staff for grant management rather than go through an entire overhaul of the grant system.[199] Furthermore the fund administration departments including state or federal agencies have to lead the implementation and engage in retraining their staff in the new system. Given that this is a high-risk low reward alternative, it has been discounted from further consideration.

[198] *Womble, Joseph, Lori Bird, and Patti McConville. 2023. "How the US Can Electrify Its Public Fleets, from City Buses to Garbage Trucks." World Resources Institute. https://www.wri.org/insights/us-public-fleet-electrification.*

[199] *Sourced from the author's Interview with a Bay area transit agency*

Table 6.2: Short term Policy Alternatives

ANALYSIS CRITERIA	SHORT TERM POLICY ALTERNATIVES			
	Incentives to PG&E	Operations resilience plan	Workforce training program	Streamlined grant application
Effectiveness	High (1st): Incentivizing PG&E to provide cheaper electricity and upgrade their grid will reduce cost/ time and improve reliability of fleet electrification projects. This has been successful in Shenzhen.	Low (4th): Effectiveness of operations resilience plan is most evident during emergency times. Given this limited duration of its application, it might not be as effective as other options.	Medium(2nd): Development of region wide workforce training programs will increase supply of skilled workforce. This will motivate transit agencies to electrify their fleets.	Medium (3rd): Streamlining of grant applications increases time/ cost savings and eases the application process. This allows transit agencies to effectively apply for more grants and cut operational costs, resulting in increased funding for e-bus projects.
Equity	High(1st): This benefits all transit agencies. Smaller transit agencies with limited operation funding, will particularly benefit from reduced electricity prices.	Low (4th): This is more beneficial to smaller transit agencies that rely extensively on PG&E and incur frequent emergencies. Transit agencies that already have backup plans might not benefit from this.	Medium(2nd): These programs will benefit all agencies. However, depending on how the programs are formulated non-unionized workforce might be excluded.	Medium(3rd): All transit agencies will realize the benefits of streamlined application process. However, this may reduce jobs (in the grants management section) due to efficient automation processes.
Cost	High (4th): Provision of incentives to PG&E will cost the government a lot of money. However, PG&E will	Medium(2nd): This option will incur costs for plan development and purchase of backup infrastructure. But	Medium (3rd): Training programs require higher upfront costs and incur operating costs. However, they	Low (1st): Capital and operational costs for this policy is the least. Also, this will result in cost and time savings over time.

	benefit in the long run through increased revenue.	these are one-time costs and incur minimal expenditure.	can earn revenue through fees or registration charges.	
Political Feasibility	Low (4th): This requires rebates, funding, or incentives to be given to PG&E, a private company, which might garner opposition from politicians, certain citizen groups and other utility companies.	Medium (2nd): As this is a safety measure incorporated into the planning process, it will garner support from most stakeholders. Only transit agencies might be inconvenienced as this adds to compliance requirements.	High (1st): These programs will have high support from all stakeholders as it will result in job creation and enhance the e-bus economy.	Medium (3rd): Though this is viewed positively by transit agencies, it requires support from state and federal governments who administer grants. They may oppose it given that it is a change from their status quo.
Implementation Feasibility	Medium (2nd): Implementation of incentive programs requires creation of new processes, guidelines, and dedicated personnel to administer them.	High (1st): This does not require any additional framework or resources to implement, given that transit agencies already have a skilled workforce and infrastructure.	Low (4th): Workforce training programs need resources/ infrastructure to set up and skilled staff to administer them. Also, they need to comply with safety and labor regulations.	Medium (3rd): It requires overhaul of the current application system and implementation of a new one. This will incur a lot of work during the initial planning stages and needs staff to undergo training for effective program administration.

6.4 Policy Prescription and Implementation

6.4.1 Policy Prescription

Based on the analysis in the previous sections, the policy prescription comprises two packages - Low Investment and High Investment - based on the investment required for implementation. Additionally, each package is composed of one long-term and one/two short-term alternative to achieve a balance between immediate and long ranged objectives. The Low investment package comprises alternatives that require low capital investment, generate revenue for transit agencies and are easier to administer and monitor. Contrastingly High Investment packages, though highly effective and favorable to stakeholders, incurs high capital costs with much slower cost recovery making them relatively riskier. These packages are presented in Table 6.3.

Table 6.3: Policy Packages

TYPE	LOW INVESTMENT PACKAGE	HIGH INVESTMENT PACKAGE
Long term	Creation of Technology and project delivery cell	Increase transit funding
Short Term	Workforce training program	Incentives to PG&E
	Operations resilience plan	

In the case of the Low Investment Package, all the policies are **focused on infrastructure/ operations planning and capacity building**. "*The path to successful fleet electrification requires careful planning and analysis that not only prepares for immediate EV needs but also future needs*".[200] While the long-term policies are crucial to the initial project planning and building of infrastructure, the short-term policies are key to efficient fleet operation. It is to be noted that both these policies complement each other and ensure sustainability of the electric fleet. This package also has cost recovery mechanisms including reduced operation costs (by virtue of improved operational efficiency, reliance on site power sources etc.) and training fees.

For the High Investment package, the focus is more towards **fund procurement for transit agencies or utility companies** to empower them to provide better services. This package addresses the two main obstacles cited by Bay Area transit agencies. It assumes that through the provision of funding, transit agencies shall have the resources to purchase and plan for fleet electrification and utility companies will be motivated to prioritize transit projects. Thus, for this package to be truly successful every transit agency must have the knowledge and capacity to make the right investment decisions for their project.

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[200] *Blackwell, Joseph. 2023. "The importance of developing a framework for fleet electrification." Leidos. https://www.leidos.com/insights/importance-developing-framework-fleet-electrification.*

6.4.2 Policy Implementation

Low investment package: For the creation of the technology and project delivery cell, the onus is on the transit agency to build the appropriate administrative framework that can accommodate this unit. Also skilled staff must be either recruited or designated from the existing workforce to this unit. However, the operations resilience plan will be a product of the technology and project delivery cell and will not incur any additional staffing or administrative needs. But implementation of the plan requires collaboration with other stakeholders including PG&E.

In the case of the workforce training program, planning and implementation would mainly be spearheaded by the regional transportation authority, Metropolitan Transportation Commission (MTC) in the Bay Area. MTC has to bring various stakeholders (transit agencies, operational workforce, electric infrastructure manufacturing industries, education institutions, utilities) together and formulate an appropriate region wide training program that could impart skills to existing workforce and help create future supply of skilled labor.

High Investment Package: This package requires financial planning wherein the increase of funding to transit agencies (generally through increasing the apportionment for transit in the state budget) is phased in a strategic and sustainable manner without adversely affecting other transportation investments. The regional, state, or federal body must administer these funds efficiently and grant recipients must be accountable for the use of these public funds.

Incentives to PG&E must be formulated, provided, and administered by state departments (CARB, California Energy Commission or Caltrans). They must clearly outline the procedure for application and conditions of eligibility for utility companies to qualify for these incentives. This also requires the setting up of an electronic application system wherein utilities companies can submit their program proposal.

7. CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 Findings

California has committed to becoming carbon neutral by 2045 and transition to zero emission public transit fleets is the first step towards achieving this goal. Though most Bay Area transit agencies have managed to electrify at least a small portion of their existing fleet, there are many potential barriers that would undermine their ability to scale and operate their electric fleets. Additionally, there are other practical difficulties incurred while executing fleet electrification projects. Thus, it is essential that appropriate policies be implemented to mitigate these obstacles and ensure seamless transition to electric fleets.

Chapter 4 of this study highlights the key barriers faced by Bay Area Transit agencies for fleet electrification. Of this, the issues that were most frequently cited were (i) lack of adequate funding, (ii) poor cooperation from utility provider, PG&E, (iii) lack of interoperability between various infrastructure components, (iv) lack of a streamlined grant application process, (v) anxiety on grid and operational resilience and (vi) dearth of workforce development programs. Thus, the above issues were prioritized, and policies formulated to address them.

The best practices and case studies analyzed in Chapter 3 and 5 were instrumental in shaping the policy solutions for increasing e-bus uptake in the Bay Area. The planning processes and fiscal/regulatory policies implemented in the case studies were proven to be successful and were relevant to the context of the San Francisco Bay Area. These include (i) government incentives through increased funding, tax rebates etc., (ii) incorporation of a dedicated technology and operation planning unit, (iii) incorporation of innovative workforce development programs, (iv) planning for emergency situations and (v) extensive cooperation with diverse stakeholders.

7.2 Recommendations

Based on the above findings, two policy prescription packages were proposed - (i) low investment package and (ii) high investment package. While the former was focused on addressing planning (infrastructure and operation planning) and capacity building issues, the latter aimed to alleviate the funding constraint for transit agencies and utility company, PG&E. In the context of Bay Area, the low investment package is the recommended policy prescription package for the following reasons:

1. Most transit agencies in the Bay Area need proper infrastructure and operations planning teams to design, implement and operate electric fleets. Even large transit agencies have currently outsourced the planning aspects to consultants, which may not be beneficial or cost effective in the long run.
2. OEM provided training is only for a limited period after bus purchase. After this time, transit agencies need to be able to access training programs to train new staff or update their existing ones given the evolving nature of technology.
3. The Bay Area faces several hazards including wildfires, earthquakes, and frequent power shutoffs. Transit operations must be resilient to these conditions and thus would be greatly benefitted by the

operations resilience plan. Additionally given the opportunities of renewable energy sources in the Bay Area, these resilience plans can be expanded to include grid resilience.

4. Low investment package has opportunities for cost recovery.
5. With the increased funding provided in the high investment package, there is no guarantee that this will mean efficient utilization of funds, especially given the capacity constraints experienced by transit agencies.

Thus, it is necessary that capacity limitations of transit agencies be addressed first to ensure efficient planning of fleet electrification projects. This also optimizes cost and has the potential to alleviate associated issues that are vital to long term sustainability of an electrified public transit fleet.

7.3 Study Limitations

The study attempted to capture all facets of fleet electrification in the Bay Area but faced certain limitations pertaining to data collection and policy solutions. Firstly, only select transit agencies in the San Francisco Bay Area were interviewed. Also input from other stakeholders including PG&E, infrastructure manufacturers, private consultants and the operations workforce were not garnered. This may have resulted in the failure to capture perspectives and obstacles encountered by these groups.

The policy recommendations are solely based on the backdrop of the San Francisco Bay Area and thus may not be applicable in other contexts. It is also to be noted that though there were other obstacles including supply chain issues and limited technological capability of electric buses, they were not addressed in the policy prescription packages as they represented issues beyond the scope of urban planning.

7.4 Future Research

There is much scope for future research in public fleet electrification, particularly on agendas of operations optimization, security features, end of life battery disposals and increasing development in the field of autonomous vehicles. Currently most operation optimizations are done only for a particular transit agency’s fleet and infrastructure upgradation is limited within its service area. However, with the growth of mega regions, optimization of public fleet operations and infrastructure planning at the regional level might be a necessity in the future.

Electric bus fleets are essentially managed by softwares and thus face cyber security issues including exposure to hacking and stealth of proprietary/ sensitive data. This can result in security risks to transit riders, disruption of services and cause financial losses to transit agencies. Also, electric fleets are more predisposed to being replaced with autonomous vehicles that can render the current workforce redundant. Much research is required to be done with regard to cyber security protection and the role of autonomous vehicles in public transit fleets.

Lastly, there are no effective policies or proven technologies that can effectively recycle an e-bus’s battery after its end of life. Current practices aim to give second life to these batteries by employing them in micro grids or other uses. Significant research and development are required for effective recycling of e-bus batteries as this directly affects the sustainability of electric fleets.

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APPENDIX A: Transit agency: Interview Questionnaire

Questionnaire for Interview

Name of the agency: _________________________________

1. What is the total fleet size of buses operated by the agency? What percentage of it (approximately) is electric currently?

2. Has the agency prepared a Zero emission bus roll out plan as mandated by the Innovative Clean Transit (ICT) regulation? If yes, please provide a link to the document.

3. How is the planning done for transition to ZEB? Enlist the main stages of the planning process.

4. Who are the main stakeholders that are involved in the planning process?

5. What are the main obstacles for conversion to ZEBs? (For e.g., lack of funding, technical expertise, limitation of technology, scaling etc.).

6. Enlist the key policies at the Federal, state and regional levels that facilitate transition to ZEBs. (For example, the federal Low or No emission program, the state's Low Carbon Transit Operations program (LCTOP) etc.)

7. Are there specific issues that are currently not addressed by existing policies? (For example, lack of policy for workforce development or imparting technical expertise required for the planning and implementation of ZEB fleets).

APPENDIX B: Funding Sources availed by Transit agencies to purchase zero emission bus infrastructure in the Bay Area

FUNDING SOURCES	TRANSIT AGENCY								
	Union City	Marin transit	ECCTA	NVTA	SR City Bus	LAVTA	SFMTA	VTA	AC Transit
FTA Formula funds (5307)	✓	✓	✓	✓	✓	✓	✓	✓	✓
FTA Low No Emission Program	✓	✓	✓	✓			✓	✓	✓
FTA bus and bus facilities program (5339)		✓	✓	✓	✓	✓	✓	✓	✓
Congestion Mitigation and Air Quality Improvement Program (CMAQ)			✓	✓	✓		✓	✓	
CAP & Trade - Low Carbon Transit Operations Program (LCTOP)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cap & Trade- Affordable Housing & Sustainable Communities (AHSC)		✓		✓				✓	✓
Cap & Trade - Transit & Intercity Rail Capital Program (TIRCP)	✓	✓		✓	✓	✓	✓	✓	✓
SB1 Local Partnership Program					✓	✓		✓	✓
SB1 State of Good Repair (SGR)				✓	✓	✓		✓	✓
State Transit Assistance (STA)			✓	✓		✓			
Transportation Development Act (TDA)	✓	✓	✓		✓		✓		
Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)		✓	✓	✓	✓	✓	✓		

Volkswagen Environmental Mitigation Trust fund							✓	✓	
Solution for Congested Corridor Programs (SCCP)							✓		
Carl Moyer Program (CARB, BAAQMD)							✓	✓	✓
Low Carbon Fuel Standard (LCFS)		✓	✓					✓	
California Energy Commission’s Clean Transportation Program		✓							
Transportation Fund for Clean Air (BAAQMD’s TFCA)		✓			✓				✓
Local funds (tolls, sales tax, parking fees etc.)	✓	✓	✓	✓	✓	✓	✓	✓	
Regional Measures	✓		✓	✓	✓	✓	✓		✓