FREIGHT EMISSIONS REDUCTION ACTION PLAN

Plan Bay Area 2040

DRAFT SUPPLEMENTAL REPORT

METROPOLITAN TRANSPORTATION COMMISSION

Association of Bay Area Governments

MARCH 2017

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Plan Bay Area 2040

Plan Bay Area 2040:
Freight Emissions Reduction Action Plan

March 2017

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Overview

The Bay Area is home to one of the most busy goods movement operations in the nation, including the fifth-largest container port (Port of Oakland), busy rail lines and terminals, and highways that carry some of the highest volumes of freight traffic in the state. An unintended outcome of this traffic includes increased greenhouse gas emissions that worsen our air pollution and contribute to climate change, sea level rise and negative health impacts. As a result, the region looks to pursue strategies that address freight's impact on climate change while also developing environmental sustainability goals for future efforts that are intertwined with the region's transportation planning efforts.

The Metropolitan Transportation Commission (MTC) has developed this Freight Emission Reduction Action Plan to document and evaluate strategies to reduce emissions from goods movement throughout the region. This plan was developed to meet regional goals and objectives, but also to be consistent with and supportive of major policy initiatives at the state level, such as the California Sustainable Freight Action Plan (CSFAP), released in July 2016, which provides a clear policy foundation for future freight programs in the state and will guide the anticipated update of the state's Freight Mobility Plan[1]. The MTC Freight Emission Reduction Action Plan is guided by many of the same principles.

To develop this plan, MTC is working with its partners including the Bay Area Air Quality Management District (BAAQMD), Port of Oakland, Alameda County Transportation Commission (ACTC) and other key local and state stakeholders and the advocacy community. The Action Plan will inform the region's 2017 update of Plan Bay Area, the long-range regional transportation plan.

The primary objective of this study is to help MTC and its partners develop programs to implement freight emission reduction strategies. Achieving this objective is important to the region for several reasons:

- Strategies to reduce freight emissions will help the region achieve its goals for air quality attainment under both state and federal air quality standards;
- Strategies outlined in this report will also help the region achieve its goals for the reduction of greenhouse gas (GHG) emissions; and
- High levels of freight emissions are often found in specific communities adjacent to freight corridors and activity centers. Strategies examined for this report can provide ways to reduce health impact inequities associated with freight activity.

This Action Plan includes a set of recommendations for MTC and its partners for emissions reductions culminating from a set of technical assessments of zero- and near-zero emission technologies, focusing on applications for goods movement by rail and truck (including cargo-handling truck technologies). The recommendations are designed to help advance zero and near-zero emission freight technologies and applications to a point where they are able to achieve high levels of commercial deployment, including demonstration plans for truck and rail. The Plan also includes discussions of policies and programs MTC and its regional partners can undertake to promote the use of zero-emission technology for freight in the region.

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[1] The Action Plan was prepared in compliance with the June 2014 settlement agreement between the Metropolitan Transportation Commission/Association of Bay Area Governments and the Sierra Club and Communities for a Better Environment.

The implementation of this Action Plan will require funding from a variety of different sources. Funding is available at the federal, state, regional, and local level to support a wide range of actions described in this action plan including technology development and demonstration, purchase incentives and market development programs and infrastructure deployment.

General Strategies for Support of Zero and Near-Zero Emissions Freight Technology

A number of freight emissions reduction strategies were identified as having potential for regional government involvement or leadership. These are:

- **Conduct Technology Demonstration Programs.** As new truck and locomotive technologies enter pre-commercial or early-stage commercial deployment, MTC and its partners can fund or administer demonstration programs that give users an early opportunity to test the technologies in real-world applications. This also benefits technology manufacturers as they fine tune their products for introduction into commercial markets. Two specific demonstration recommendations are included in this Action Plan (one for near-zero emission trucks and one for zero-emission locomotives) but additional demonstrations in different truck and locomotive applications should be pursued.
- **Develop a Sustainable Freight Advisory Committee.** A potential continuation of the task force that supported development of this plan, the proposed committee would work to implement and align plan recommendations with the ARB Sustainable Freight Action Plan and the Regional Goods Movement Plan and review implementation actions and progress.
- **Define Clear Requirements for Zero Emissions Operation.** Vehicles that can operate in either zero-emission mode or near-zero emission mode, such as in the delivery truck demonstration project recommended as part of this plan, can use GPS to target zero emission activities to areas with the highest level of health impact disparities. Zero emissions zones, operating capability, and compliance requirements need to be clearly defined so manufacturers can successfully develop and commercialize a product.
- **Implement Purchase or Incentive Programs.** These programs incentivize users to adopt cleaner technologies. These early adopters influence the growth of the market for new technologies by making it visible to other users that commercial products are entering the marketplace. Purchase incentives reduce or eliminate the incremental cost of new technologies as compared to established technologies during early-stage commercialization before the cost-reduction benefits of mass production are available.
- **Support on-going or proposed regulatory action programs from Air Resources Board (ARB).** A combination of regulation and incentive programs is seen as the best method to advance the development, deployment, and adoption of cleaner technology. In addition to ongoing programs, ARB has proposed to consider a measure to require certain last mile delivery fleets to operate zero-emission trucks starting in 2020.
- **Support development and deployment of electric vehicle charging infrastructure.** Significant and immediate work is needed to evaluate and plan infrastructure requirements for zero-emission heavy duty vehicles. Regional partners can play a key role in bringing together all the fuel suppliers (utilities, private companies) and infrastructure owners (utilities, governments, private companies) to best coordinate this complex area of development.

- **Creating a "Center of Excellence" for Ongoing Efforts.** A Center of Excellence with a visible lead agency or point of contact can illustrate technology, operations, applications, and benefits for reduced emission trucks. Creating a Center of Excellence in the Bay Area provides an opportunity for technology developers, OEMs, truck owners and operators, and government agencies to interact on a regular basis and to gain first-hand experience with the new technologies.

Evaluation of Zero- and Near-zero Technologies, Applications, and Strategies for Truck and Rail

One of the goals of this study was to identify two relatively near-term demonstration opportunities for zero or near-zero emission freight technologies – one for trucks and one for locomotives. In determining what would be good candidate demonstrations, the study considered technologies that were in near commercial stages of development and that could meet the operational requirements for applications that contributed to emissions and/or health impacts that were significant in the Bay Area. Pursuing these demonstration opportunities is one of the strategies recommended in the Action Plan. Selecting the technologies required a technical assessment of the technologies and the applications.

Technologies considered for this assessment must qualify as zero or near-zero emission technologies using criteria defined by the California Air Resource Board (ARB)[2]:

> *"Near-zero emission vehicles must be able to operate for many miles for a period of time while having zero emissions. Outside of that time, there can be emissions (within current standards for clean vehicles)."*

As a first step in this process, a "long list" of technology candidates was reviewed for both truck and rail. Five truck engine/vehicle technologies were selected for initial evaluation. Five freight Intelligent Transportation System (ITS) programs were also reviewed. Four rail zero-emission technologies were selected. Each technology was screened using a "high", "medium" and "low" approach against a number of freight applications in the Bay Area to develop emissions reduction scenarios within a specific context. For example, battery truck technology may be promising in an urban delivery setting, but not suitable for long-haul use. An additional evaluation of the highest rated scenarios for emissions reduction was undertaken to determine the most promising scenarios for both truck and rail.

Truck Demonstration Recommendation

After screening technologies in various applications, technical evaluations were conducted for nine (9) scenarios – a scenario being defined as a technology/application combination:

- Short Haul and Regional Drayage Scenarios
    - Scenario I – Freight Advanced Traveler Information System (FRATIS) and Arterial Smart Corridor (ASC) with Freight Signal Priority (FSP) – This is an advanced intelligent transportation System (ITS) that provides real-time communication among terminals, traffic management centers, and trucks to manage truck activity more efficiently. The FRATIS system can help direct trucks on less congested routes and can link with

[2] There are a number of definitions for the term "near-zero emissions"; for consistency this study defines near-zero as described by the California ARB in 2016.

appointment systems to spread traffic throughout the day. The ASC with FSP component provides real-time information about arterial traffic conditions and dynamically manages signal timing and signal priority to most efficiently route trucks through the arterial network. All of these features improve truck emissions performance while driving, reduce idling, and reduce vehicle miles traveled (VMT) to reduce emissions.
    - Scenario II – Range Extender Electric Vehicles (REEV) with Engine plus Roadway Power – The REEV is a hybrid technology which can operate in full zero emission mode most of the time. The Roadway Power would either be an overhead catenary or in-road power system on certain fixed routes that would be able to provide power to the vehicle to either directly run the motor or to charge batteries. This would extend the fully zero emission operations on those fixed routes. An engine backup would also be available to charge batteries and extend the range of the vehicle for those trucks that are not able to operate on fixed routes at all times. The engine operation would make this a near-zero emission technology.
    - Scenario III – REEV with Fuel Cell – This is similar to Scenario II except there is no roadway power and the engine is replaced with a zero emission fuel cell to charge batteries.
- Long Haul Trucking Scenarios
    - Scenario IV – Platooning and Integrated Corridor Management (ICM) – ICM is a type of ITS technology that manages traffic flow onto the freeways using adaptive ramp metering and provides for advanced traffic management to adjust flows based on traffic conditions during incidents. Truck platoons are systems that allow a group of trucks to travel together in a controlled platoon to reduce the space needed between vehicles (vehicle spacing is controlled electronically) and take advantage of reduced wind drag on vehicles in the platoon to improve energy efficiency (and reduce emissions).
    - Scenario V – Plug-In Electric Hybrid Electric Vehicle – Combining an electric battery driven motor with a low emission diesel engine, while not allowing for much zero-emission operation, would still provide some zero emission operation and reduced emissions over the entire vehicle operating cycle on long-distance hauls.
- Urban Pickup and Delivery Scenarios
    - Scenario VI - ecoDriving, ICM and ASC with FSP – This approach is similar to Scenario I but also adds the ecoDriving technology which monitors driver behavior and signals the driver to make changes that will improve overall fuel economy. This technology is aimed at trucks that do not operate over fixed routes and that may need more range and route flexibility than are available with true zero emission technologies.
    - Scenario VII – REEV with Engine – This is similar to Scenario III but with an engine replacing the fuel cell. The REEV can be built with a battery of sufficient size to allow high zero emission range for the smaller (Class 5/6) trucks that are used for urban pickup and delivery and the engine could be a low emission natural gas engine to further reduce emissions when not operating in full ZE mode.
- Port Facility Scenarios
    - Scenario I – FRATIS with ASC with FSP (already described)
    - Scenario VIII – Battery Electric Vehicle (BEV) or REEV with Fuel Cell – The goal would be to provide a full ZE operation for very short drayage moves or movements within the

terminals or port area. Given the relatively short range envisioned for these vehicles, full ZE operations is more technically feasible than in other applications given the current and near term status of battery technologies.

Table 1 presents the results of the technical evaluations for the most highly rated technology for each of the four different applications. The technologies were evaluated against six different criteria as shown in the table. The Technological Readiness scale is based on a system developed for NASA and rates the technologies based on their stage of development from basic research through prototype demonstration through commercial application. The approach to cost estimates varies from technology to technology and may include the costs of vehicles only or including infrastructure (reflecting the variations in the types of scenarios evaluated).

One of the more important evaluation criteria used in this study was the emissions impacts criterion. The emissions reductions are always provided based on a reduction in emissions for a single truck using the scenario technology compared with a diesel truck meeting current ARB emissions standards for a comparable truck. No attempt was made to estimate potential emissions reductions for a fleet of vehicles and therefore, no estimates of technology market penetration were made. In the case of the ITS technologies, the reductions are generally based on the results of tests of limited applications of the technologies. For example, the U.S. DOT has conducted application demonstrations of the FRATIS concept and measured reductions in VMT for trucks using FRATIS as compared to those that do not in the same application. The reductions in VMT are then used to calculate reductions in emissions assuming the same engine emission characteristics for the trucks both with and without FRATIS, a similar approach was used to estimate reductions in VMT, vehicle delay, and vehicle stops in a demonstration of the ASC technology and a simulation of the FSP technology. The engine emission characteristics are assumed to be the same for the trucks operating with the ITS technologies but the reductions in VMT and improvements in other traffic flow conditions lead to reductions in fuel use and emissions. In the case of the REEV options, the emissions impacts assessments were obtained from grant applications or published materials from manufacturers. In general, these estimates were obtained by estimating daily route miles for a typical truck in the specified application, estimating the all-electric range of the REEV, and then estimating the emissions from the additional VMT that would be necessary from the engine. The engine emissions were estimated based on the specifications of the manufacturers that provide data in their grant applications or published data and standard emissions models to estimate emissions for these engines in their limited operation. Zero emission technologies were assumed to reduce emissions on a per vehicle basis by 100 percent.

The recommended technology for a truck zero-emission demonstration project is an urban delivery application using “Range Extended Electric Vehicle (REEV) with Engine for Medium Heavy Duty (Class 5-6) Trucks.” REEV is a type of plug-in hybrid technology. The REEV is designed to maximize full electric operation (using an electric motor running off a battery pack) as much as possible and uses either a clean burning internal combustion engine or a fuel cell to charge the batteries during operation when additional electricity is needed. Class 5-6 trucks, or “straight trucks” are commonly used for urban delivery in the Bay Area (Illustrated in Figure 1). These designs have been tested in prototype form, and are ready for larger demonstration. The technology is not as route dependent as technology that requires charging infrastructure. Technology options such as geofencing (identifying a defined area and using GPS technology to control the vehicle operations when it is within the defined area) can be used to ensure that maximum zero-emission miles are achieved in areas of concern. Table 1 provides a summary comparison of the highest rated scenario for each type of application. The chosen demonstration scenario is bolded.

While the REEV with Engine and Geofencing for Class 5-6 Urban Pickup and Delivery was selected as the best near-term demonstration application, there were other scenarios that would represent good potential demonstrations as well. The scope of work for this project called for the selection of a single truck demonstration to be identified and the REEV with Engine for Class 5-6 trucks, in addition to comparing favorably on all of the evaluation criteria, also represents a good choice for several other reasons. Class 5-6 Urban Pickup and Delivery trucks are used all over the Bay Area and much of their operations are in residential and commercial areas where population exposure to truck emissions is high. By adding the geofencing feature, this demonstration can also focus emissions reductions on neighborhoods with the highest levels of health risk exposure. These types of trucks are estimated to generate between 12% and 20% of nitrogen oxide, particulate matter, and carbon dioxide emissions of the region.

It is also worth noting why other scenarios that were evaluated were not chosen as the top demonstration opportunity. In general, ITS scenarios were not selected because none could achieve ZE levels for any period of time. While these technologies are important potential contributors to congestion and freight emissions reductions and are included in the Regional Goods Movement Plan, members of the Advisory Committee for this study felt it was more important to demonstrate true ZE or NZE technologies. Long haul scenarios were viewed as the most technologically challenging in which to achieve ZE or NZE operations because of the range limitations associated with ZE operations. The REEV with Fuel Cell and the BEV technologies for short haul regional operations, drayage, or port/facility operations are of significant interest in the Bay Area because of the high levels of diesel emissions around port and major industrial sites, particularly along the I-880 and I-80 corridors in Contra Costa and Alameda Counties. Full zero emission operations of Class 8 trucks, particularly for port drayage, is a critical application for addressing health risks and the Bay Area Air Quality Management District will have funding in 2017 to conduct some demonstrations of ZE trucks in this application. Nonetheless, the study team felt that with limited available funding for demonstrations, much of which is likely to come from state funding sources, it is likely that the lion's share of this funding that is targeted towards port-related demonstrations will be targeted to Southern California with their larger ports and more severe air quality issues than are found in the Bay Area. In light of this, the study team felt that expanding the focus of ZE and NZE demonstrations to include urban pickup and delivery applications as a focus for the Bay Area would allow the region to take advantage of the benefits of the limited demonstrations of port drayage trucks in Northern California, the larger demonstrations in Southern California, and the urban pickup and delivery applications which are a critical part of the region's freight operations.

Figure 1   Examples of Class 6 Straight Trucks

Source: truckinginfo.com (left); Kenworth (right)

Rail Demonstration Recommendation

The recommendation for a rail zero-emission demonstration project is "Yard Switcher Using Dual Mode Battery-Assisted Locomotive" A switcher locomotive is typically smaller than a line-haul locomotive and operates within a rail yard to move rail cars around the yard. A switcher demonstration was proposed as it was determined to be the best choice to focus the health benefits from any emission reductions on the environmentally-disadvantaged neighborhoods of West Oakland or Richmond, will not impact the efficiency of interstate line-haul freight movements, and will provide an opportunity to demonstrate zero-emission technology that can later be reevaluated for more wide scale use. A total of four scenarios were evaluated in this analysis; Table 2 provides a summary comparison of the highest rated scenario for each type of application. The chosen demonstration scenario is bolded.

Table 1 Selected Summary Comparison of Zero Emission Truck Scenarios

Technology Scenario	Technological Readiness	Capital Cost	O&M Annual Cost	Energy Impacts	Emissions Impacts	Other Factors
Short Haul Regional & Drayage Scenarios						
Scenario III: REEV with Fuel Cell	Medium	Projected high vehicle and infrastructure costs (29% incremental cost or ~$31.5k per truck)	Unknown	Cleaner fuel sources and improved efficiency	100% emissions reduction – fully ZE	Hydrogen infrastructure needs to be developed
Long Haul Scenarios						
Scenario IV: ITS Applications of Platooning and Integrated Corridor Management	Medium - High	Platooning: $250K per freeway DMS ICM: $570K per freeway mile Platooning trucks expected break even period of 7 months	Platooning: $2000 per DMS ICM: $50,000 per mile of freeway	Fuel reductions through more efficient driving	15% to 20% reduction	Trucking Fleets will need to purchase Truck Platooning Systems
Urban Pickup and Delivery						
Scenario VII: REEV with Engine	**Medium - High**	**Current data shows high vehicle costs (potential cost increment of $99.5k per truck)** **Break even period of 5 years or more**	**<30% reduction in O&M costs**	**Shift from petroleum; efficiency gains**	**Approx. 33% reduction**	**Capital Cost challenges**
Port/Facility						
Scenario VIII: Battery Electric or REEV Vehicle with Fuel Cell	Medium	REEV with Fuel Cell is $125,000 and BEV Yard Hostler is $230,000	BEV yard tractor is $0.23/mile (40% reduction)	Cleaner fuel sources and improved efficiency	100% emissions reduction – fully ZE	Need Port or operator to Champion; Hydrogen infra. needs to be developed

Source: Cambridge Systematics, CALSTART

Table 2 Selected Summary Comparison of Zero Emission Rail Scenarios

Technology Scenario	Technological Readiness	Capital Cost	O&M	Energy Impacts	Emissions Impacts
Scenario I: Line Haul rail using Straight-Electric Locomotives with Overhead Catenary	High	High – significant infrastructure costs	Significant Challenges due to captive fleet and need to change to diesel at the edge of the system and catenary system costs.	Electric locomotives twice as efficient as diesel locomotives; electricity more cost-effective than diesel	High reduction potential
Scenario II: Line Haul Rail using Dual-Mode Locomotives with Overhead Catenary	Medium	High – significant infrastructure costs compared to Scenario I with potential offset due to reduced cost of land for location to switch locomotives.	Potentially Significant Challenges due to lack of existing dual-mode freight applications. Reduced operational challenges as compared to Scenario I and catenary system costs.	5 percent energy penalty versus straight-electric; electricity more cost-effective than diesel	High reduction potential
Scenario III: Short line Rail using Dual-Mode Electric Locomotives with Battery Tender	Medium	Medium – fleet costs and moderate infrastructure needed	Moderate Challenges due to power management of battery tenders	9 percent less efficient due to weight penalty; electricity more cost-effective than diesel	Low reduction potential
Scenario IV: Yard Switching using Dual-Mode Electric Locomotives with Battery-assist (Tender) Cars	**Medium**	**Medium – fleet costs and moderate infrastructure needed**	**Moderate Challenges due to power management of battery tenders**	**9 percent less efficient due to weight penalty; electricity more cost-effective than diesel**	**Moderate reduction potential, concentrated in areas with health concerns**

Source: Cambridge Systematics, Inc., TKear Transportation Planning and Management.

Funding Sources

The implementation of this Action Plan will require funding from a variety of different sources and there are a growing number of funding sources at the federal, state, regional, and local level that can support a variety of activities. The uses of funding can be broadly categorized as for research and development (R&D), demonstration of early commercial products, infrastructure deployment, and purchase incentives (grants, loans, or rebates). Funding programs may be targeted directly to users or funding may pass through lower levels of government for the purposes of crafting local programs that are administered by regional or local agencies. Funding for research and development is generally provided by the federal or state energy agencies (the Department of Energy and the California Energy Commission) and goes directly to technology developers. It is less likely that MTC and its regional partners will participate in these types of funding programs, although it is worth noting that the South Coast Air Quality Management District has its own technology advancement program so it is not out of the question for regional agencies to support R&D. In recent years, there has been growing emphasis on purchase incentive programs, especially at the state and local level as California works to meet both clean air standards and greenhouse gas reduction goals that are mandated by state law.

Some of the more significant funding opportunities that should be targeted to support the implementation of the Action Plan were identified as follows:

Funding for Research and Development

The U.S. Department of Energy (DOE) administers funding solicitations to support the development of advanced equipment technologies. This funding typically supports research laboratories, private technology developers, and equipment manufacturers. Similarly, the California Energy Commission's Alternative and Renewable Fuel and Vehicle Technology Program provides funding to develop and deploy alternative and renewable fuels and advanced technologies to help implement the State's climate change policies. These would likely be lower priority funding sources for MTC and regional partners due to the small role this Action Plan contemplates for regional programs in this part of the technology commercialization process. However, if MTC and the BAAQMD do coordinate efforts to develop a zero-emission technology Center of Excellence, they could work with local technology companies to encourage their participation in these federal and state R&D support programs.

Funding for Demonstrations

The state's Low Carbon Transportation Investments and Air Quality Improvement Program has been one of the most significant sources for funding zero and near-zero emission technology demonstration programs including truck and locomotive applications. This program is funded with proceeds from the state's Cap and Trade auction so future funding is somewhat uncertain, dependent on the level of auction activity. The ARB administers the program through a variety of funding solicitations. Sometimes the solicitations target air districts who then administer their own local programs or the solicitations may be open to public and private entities who will be conducting the demonstrations. There have already been solicitations targeted to demonstrating drayage truck technology and other goods movement applications and the BAAQMD has obtained funding for local demonstrations. While future funding levels are uncertain, this is likely to remain one of the most significant funding opportunities for implementing the Bay Area Freight Emission Reduction Program. The CEC also administers a program for Freight Transportation Projects at Seaports that has funded demonstration of medium- and heavy-duty vehicle technologies and ITS technologies.

Infrastructure Development

Funding for infrastructure development and deployment is more limited than funding for other types of activities recommended in this Action Plan and few programs directly target deployment of charging infrastructure. Rather, these sources are primarily intended for ITS infrastructure but have provisions that have been interpreted to apply to charging infrastructure. This is particularly true of the federal FAST Act programs in the Act's Transportation for Tomorrow program. The BAAQMD's Transportation Fund for Clean Air (TCFA) could be used for funding electric vehicle charging infrastructure although the primary use to date has been to fund purchase incentive programs.

Purchase Incentives

There are a growing number of purchase incentive programs at all levels of government. MTC and the BAAQMD should work together to coordinate the region's participation in these programs in order to structure the most wide-ranging and cost-effective programs as zero and near-zero emission freight technologies move into early-stage commercialization. In some cases the role of regional agencies may be to work with eligible government and private incentive recipients to assist them with grant applications to outside agencies, while in other cases MTC and BAAQMD may be applying for funding in order to administer a coordinated regional incentive program. Even in cases where MTC and the BAAQMD are not the provider or administrator of purchase incentive programs, it may be effective to develop a "one-stop-shop" function to reach out to eligible incentive recipients and help them put together the most effective single or combination incentive package for which they may be eligible. A few examples of the more significant purchase incentive funding programs are described below:

- The U.S. Environmental Protection Agency administers the Diesel Emission Reduction Act (DERA) program that has provided funding to the BAAQMD to provide purchase incentive grants for trucks and locomotives.
- The Carl Moyer Memorial Air Quality Standards Attainment Program is a long-standing state program that provides money to the BAAQMD to fund replacement and retrofitting of heavy-duty vehicles and equipment. The BAAQMD can supplement Carl Moyer funding with its own Mobile Source Incentive Fund and the TFCA program described previously.
- The state's Low Carbon Transportation Investments and Air Quality Improvement Program mentioned previously has a component program called the Hybrid and Zero-emission Truck and Bus Voucher Incentive Program that provides purchase incentives at the point of sale.

Next Steps

MTC, in partnership with the BAAQMD, will continue to work with the task force on further development and implementation of these demonstration projects, as well as consideration of emerging technologies and new projects. The task force will also begin to collaborate with private partners to successfully implement the projects. In order to prioritize this effort in upcoming years, MTC has included a freight emissions reduction program in Plan Bay Area 2040's investment strategy, estimating an investment upwards of $300 million in discretionary funding over the next 23 years for this work.

1. Introduction

The Metropolitan Transportation Commission (MTC) has developed the Freight Emission Reduction Action Plan to document and evaluate strategies to reduce emissions from goods movement throughout the region. The result is a plan that identifies the highest priority actions that can be taken to advance zero and near-zero emission freight technologies in the Bay Area. To develop this plan, MTC worked in conjunction with its partners including the Bay Area Air Quality Management District (BAAQMD), Port of Oakland, Alameda County Transportation Commission (ACTC) and other key local and state stakeholders, as well as the advocacy community. The Action Plan will inform the region's 2017 update of Plan Bay Area.

This Action Plan is a set of recommendations for MTC and its partners for emissions reductions culminating from a set of technical assessments for implementing zero- and near-zero emission technologies, focusing on applications for goods movement by rail and truck (including cargo-handling truck technologies)[3]. As a result of this assessment, strategies for reducing goods movement emissions (primarily on the roadway system) through zero- and near-zero emission technology opportunities were developed, including truck and rail zero-emission technology demonstration plans. These are summarized in this document, with the full assessments included as technical appendices. The potential for a zero-emission freight corridor on the I-880 expressway was also evaluated and included in a technical appendix. Additionally, included are discussions of policies and programs that MTC and its regional partners can undertake to promote the use of zero-emission freight technology in the region.

The implementation of this action plan will require funding from a variety of different sources. Funding is available at the federal, state, regional, and local levels to support a wide range of actions described in this action plan including technology development and demonstration, purchase incentives and market development programs and infrastructure deployment. The final section of this document describes existing federal, state, and regional/local funding programs that may be applicable to support different types of recommended actions for this plan.

This document is organized as follows:

- Section 1: Introduction (including an explanation of the objectives of the study and some background on the technology development, demonstration, and commercialization process)
- Section 2: Zero- and Near-Zero Emissions Truck and Rail Technology Technical Assessment Overview
- Section 3: Truck Freight Emissions Reduction Strategies
- Section 4: Truck Freight Emissions Reduction – Demonstration Plan Recommendation
- Section 5: Rail Freight Emissions Reduction – Demonstration Plan Recommendation
- Section 6: Partners, Programs, and Funding Sources
- Appendix I: Zero Emission Truck Technology Evaluation
- Appendix II: Zero Emission Rail Technology Evaluation
- Appendix III: Zero-Emission Corridor on I-880 Feasibility Analysis

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[3] The Action Plan was prepared in compliance with the June 2014 settlement agreement between the Metropolitan Transportation Commission/Association of Bay Area Governments and the Sierra Club and Communities for a Better Environment.

1.1 Objectives

The primary objective of this study is to help MTC and its partners plan, develop and implement the most viable freight emission reduction strategies. Achieving this objective is important to the region for several reasons:

- Strategies to reduce freight emissions will help the region achieve its goals for air quality attainment under both state and federal air quality standards;
- Strategies outlined in this report will also help the region achieve its goals for the reduction of greenhouse gas (GHG) emissions; and
- High levels of freight emissions are often found in specific communities adjacent to freight corridors and activity centers. Strategies examined for this report can provide ways to reduce health impact inequities associated with freight activity.

The last point was discussed extensively in the recently completed San Francisco Bay Area Goods Movement Plan, which laid out general strategies for how to address health impacts from freight activity that would form regional priorities. Work done to support the development of the Regional Goods Movement Plan compiled data from a variety of other sources that shows health risks around the region and drew on analysis conducted by the Bay Area Air Quality Management District that shows adverse health impacts in disadvantaged communities that are nearby freight activity centers and corridors.[4] One of the objectives of this study was to examine certain strategies that could be targeted to communities near freight activity centers. The recommended demonstration of a Range Extender Electric Vehicle (REEV) in Class 5-6 trucks that would use a global positioning system (GPS) and special controls to maximize zero emission operations in particular communities, is an example of this approach to targeting strategies to impacted communities. Other strategies, such as incentive programs for zero emission truck purchases, could also be targeted at fleets that have high levels of activity in communities with high adverse health impacts.

This Freight Emission Reduction Action Plan was developed to meet regional goals and objectives, but also to be consistent with and supportive of major policy initiatives at the state level. In July 2015, Governor Brown issued Executive Order B-32-15 which called for a "more unified approach between State agencies and with stakeholders to improve the efficiency, transition to zero emission technologies, and increase the competitiveness of California's freight transport system."[5] The California Sustainable Freight Action Plan (CSFAP), which was released in July 2016, provides a clear policy foundation for future freight programs in the state and will guide the anticipated update of the state's Freight Mobility Plan. The MTC Freight Emission Reduction Action Plan is guided by many of the same principles set forth in the state's Sustainable Action Plan.

While there are many different technologies and strategies that can reduce freight emissions, the scope of work for this study focused on technologies that are either zero or near-zero local emissions

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[4] Improving Air Quality and Health in Bay Area Communities, Community Air Risk Evaluation Program Retrospective and Path Forward (2004 to 2013), BAAQMD, April 2014.

[5] California Sustainable Freight Action Plan, July 2016.

technologies.[6] The purpose of this study was to conduct technical assessments of different zero and near-zero emissions technologies and to identify one promising demonstration opportunity in a trucking application and one in a rail application. Recommendations were developed for the most promising opportunities identified for each mode for immediate implementation based on technical and operational feasibility today; however as zero-emission research and technology progresses, the recommendations in this document should not supersede the consideration of more progressive/aggressive options, if those options are ready and implementable.

These assessments and other research were compiled into a wide set of actions and recommendations in addition to the two recommended demonstrations that could be taken by MTC and partner agencies to promote the development and deployment of zero and near-zero emissions technologies. Thus, the two demonstration opportunities are a subset of actions that are incorporated in this Action Plan. The rationale behind the two recommended demonstrations is summarized in Section 2 of this report.

1.2 Background on the Technology Development and Commercialization Process

The actions that are included in the Freight Emission Reduction Action Plan are designed to help advance technologies and applications to a point where they are able to achieve high levels of commercial deployment. In order to understand the types of actions that are recommended in this plan, it is useful to have some basic background in the various stages of the technology development and commercialization process. This background helps explain when and how different types of government support can be helpful in accelerating the process.

Technology development and commercialization is typically a private sector endeavor with the government playing a limited, if any, role. However, there are instances in which rapid adoption of a technology can bring significant public benefits, justifying public involvement in order to accelerate technology development and deployment. The development and adoption of zero and near-zero emissions technologies for freight transportation is an example of a case where the public has an interest in helping to accelerate the commercialization process. Public sector roles in this case may include filling the funding gap to pilot or demonstrate newer technologies, creating market demand where little or none exists, supporting infrastructure or new technologies, or other activities. Many of these are described below and in Section 3.

Programs to accelerate the adoption of technology, particularly clean tech systems, are motivated by the government's desire to accelerate the public benefits that come from adopting these technologies. Zero emission vehicles generate no tailpipe emissions, improving air quality relative to diesel or even gasoline vehicles in the areas they operate. Many programs from state, federal, and local agencies work to move technologies with public benefits into the marketplace. The strategies being discussed in this action plan begin with actions that can be applied to technologies at the prototype development stage (what would be roughly TRL 5, see descriptions below) and ending at TRL 9, when the early deployment of production units has begun. The goal is to get the technologies over the "valley of death" where market forces work against the new technology and in favor of incumbent, less beneficial, technologies.

[6] The scope of work also included technology assessment of intelligent transportation systems (ITS). While these technologies can provide operational improvements that could also significantly reduce freight emissions, the technical advisory committee for the study expressed a strong preference to focus the strategy development in this action plan on zero and near-zero technologies.

Once a market for the new technologies is created, private funding takes over and it is hoped the products become widely adopted. Of course, failures do occur and that too is allowed, as the government does not want to be picking winners and losers, but only to support those technologies that have clear public benefits.

There are numerous descriptions and models for a new product development cycle, varying by the type of product, the focus of the creators, the level of detail, and myriad other considerations. For the purposes of this report, and for many products with long (multi-year) development cycles, such as heavy duty trucks, an optimal description is the version created by the National Society of Professional Engineers (NSPE). Presented in a document titled "Engineering Stages of New Product Development," the work grew out of the DOE/NIST Energy-Related Inventions Program. It defines six product development steps, along with Objectives and Products (Outcomes) for each step, all with a focus on the engineering tasks involved (See Figure 1.1):

1. Conceptual
2. Technical Feasibility
3. Development
4. Commercial Validation and Production Preparation
5. Full Scale Production
6. Product Support

Figure 1.1 Six Stages of Technology Development and Commercialization

STAGE 1 - CONCEPTUAL

Definition The conceptual stage of engineering development is that period during which a concept is proven **scientifically valid*** or is shown to be potentially valid by the application of a **test-of-principle model(s).**

Objective The objective of this stage is to demonstrate through test or analyses the performance and implementation potential of a concept.

STAGE 2 - TECHNICAL FEASIBILITY

Definition The technical feasibility stage of engineering development is that period during which it is proven possible within the technological state of the art to produce a new product from the concept.

Objective The objective of this stage is to confirm the target performance of the new product through experimentation and/or accepted engineering analysis and to ascertain that there are no technical or economic barriers to implementation that cannot be overcome by development.

STAGE 3 - DEVELOPMENT

Definition The development stage of engineering development is that period during which the needed improvements in materials, processes and design are made and during which the product is tested and proven to be commercially producible.

Objective The objective of this stage is to make the needed improvements in materials, designs and processes and to confirm that the product will perform as specified by constructing and testing **engineering prototypes** or pilot processes.

STAGE 4 - COMMERCIAL VALIDATON AND PRODUCTION PREPARATION

Definition The commercial validation and production preparation stage of engineering development is that period during which a product or process is prepared for introduction into the marketplace.

Objective The objective of this stage is to develop the manufacturing techniques and establish test market validity of the new product.

STAGE 5 - FULL-SCALE PRODUCTION

Definition The full-scale production stage of engineering development is the period during which the manufacturing or process facility is built and full-scale production runs are made.

Objective The objective of the full-scale production stage is to put the new product(s) into commercial production and optimize the manufacturing process consistent with the market demands.

STAGE 6 - PRODUCT SUPPORT

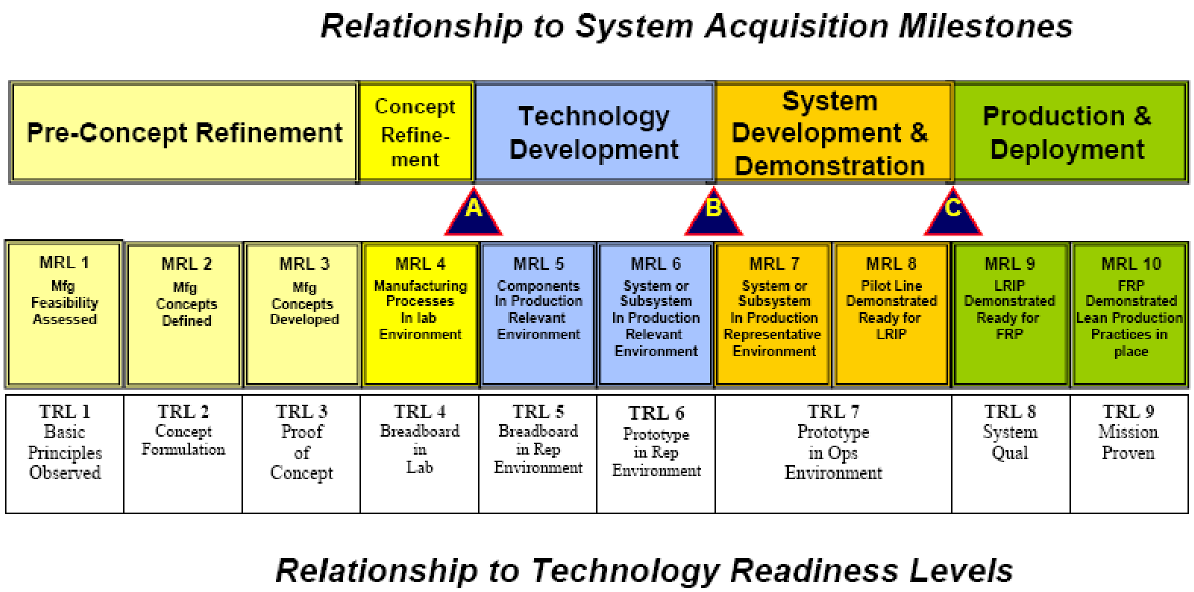
Definition The product support stage of engineering development is the period during which the product or process realizes a useful life.

Objective The objective of this stage of development is to maintain maximum value of the product or process through continued consideration of engineering improvement.

Source: "Engineering Stages of New Product Development" NSPE, undated

A second important model is the TRL/MRL approach, utilizing the systems developed by NASA and the Department of Defense (see Figure 1.2). Most commonly used for systems engineering and weapons acquisition, the model still has great applicability to technology development and commercialization in non-military applications.

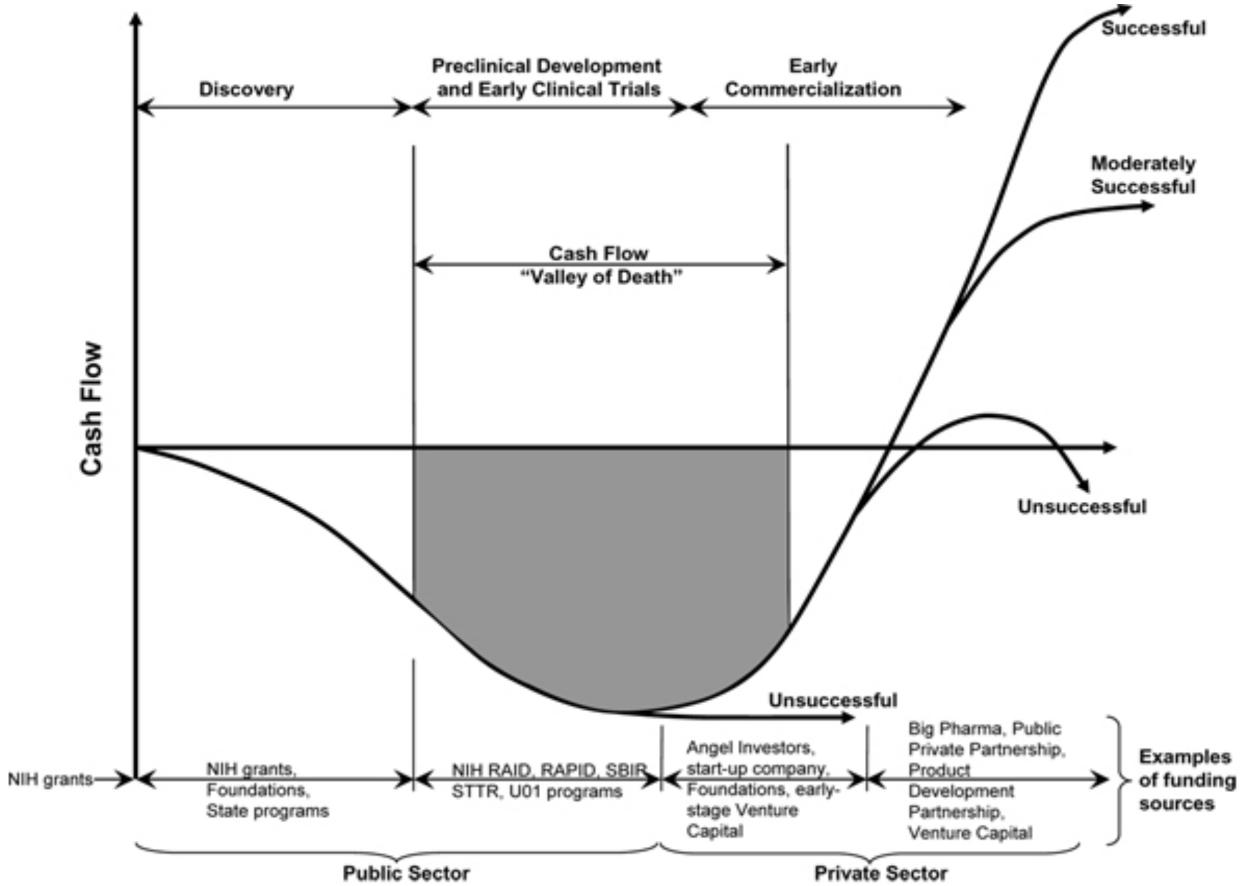
Figure 1.2 Technological Readiness Assessment Model



Source: “Manufacturing Readiness Levels and Manufacturing Readiness Assessments” Jim Moran, US Air Force Manufacturing Technology Division, Wright Patterson AFB, September 2008.

The issue of where/when government support should be provided is a question often asked by those in and around government. Investment in new or languishing technologies by government is nothing new, and the line of demarcation between private and public sector funds is often muddled. In general, however, government investments are usually intended to initiate a market when conventional market forces are not strong enough or moving as quickly as desired. Once a market is established, private sector funding is expected to take over and conventional market forces would apply. A model from the National Institutes of Health (NIH) shows this for the example of drug development, a specific case that has applicability to other forms of technology development. It indicates that generally, public sector funds support technologies up to the early commercialization phases, when private sector funding sources take over. Note, too, that the transition occurs during the highest negative cash-flow for the developer, in the middle of the “valley of death” – a challenging time for technologies moving from early testing into commercialization (see Figure 1.3).

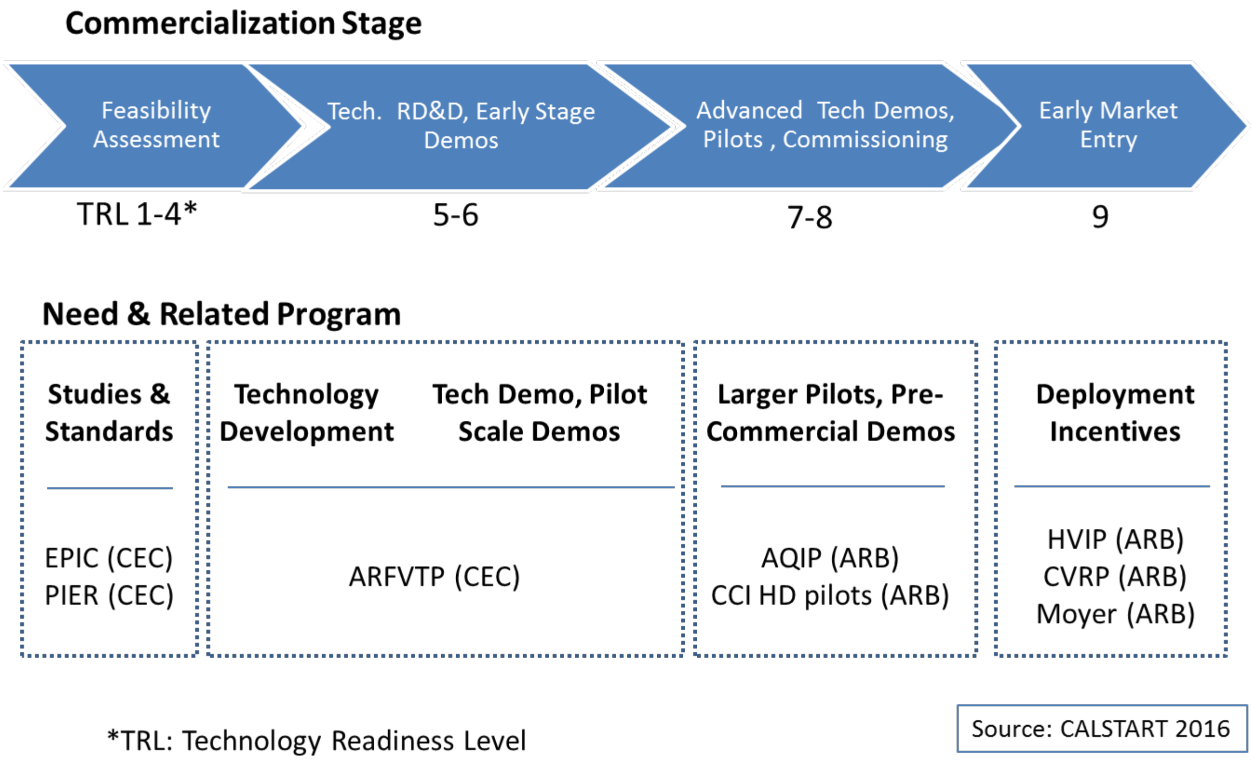
Figure 1.3 National Institutes of Health Technology Development and Commercialization Model



Source: "Writing a Good Commercialization Plan: Suggestions for SBIR/STTR Applicants", National Institutes of Health/ National Institute on Drug Abuse. Undated.

The types of government actions will vary across the different stages until commercialization has begun to take off in private markets; the appropriate actions may include supporting basic and applied research, early demonstrations of prototype products, pilot demonstrations to help give the technology visibility and to help the private sector improve products for commercial applications, purchase incentives to spur early deployment when production volumes are low and prices for the new product are high, regulatory support, and information/technology transfer. Examples of some of the types of actions that can be taken by the public sector and the points in the technology development and commercialization process where they would most logically be applied are presented in Figure 1.4.

Figure 1.4 Stages, Needs, and Programs on the Commercialization and Technological Readiness Scale



2 Zero and Near-Zero Emissions Technical Assessment Overview

As part of the Action Plan development process, a task force comprised of regional stakeholders and advocates, and the selected consultant, Cambridge Systematics, developed technology assessments of truck and rail technology to identify technologies and applications that present the greatest opportunities for local application of sustainable zero and near-zero emission technologies to the Bay Area truck and freight rail network. Technologies considered for this assessment must qualify as zero or near-zero emission technologies using criteria defined by the California Air Resource Board (ARB).[7]

"Near-zero emission vehicles must be able to operate for many miles for a period of time while having zero emissions. Outside of that time, there can be emissions (within current standards for clean vehicles)."[8]

2.1 Technology Assessment Overview

As a first step, a "long list" of technology candidates were reviewed for both truck and rail. Five truck engine/vehicle technologies were selected for initial evaluation. Five freight Intelligent Transportation System (ITS) programs were also reviewed. Four rail zero-emission technologies were selected. Further details about the technology assessments can be found in Appendix I (Truck) and II (Rail).

Each technology was screened against a number of freight applications in the Bay Area to develop emissions reduction scenarios within a specific context. For example, battery truck technology may be promising in an urban delivery setting, but not suitable for long-haul use. Technology strategies for emissions reductions are developed in this section through the application of a two-step process:

1. **Screening of Technologies as Applied to Freight Operations Applications.** Promising technologies meeting the criteria of zero or near-zero emissions described in the previous section were screened to determine which fit best with applications (e.g. urban delivery markets, port operations) in the Bay Area. This screening is conducted to determine where the particular technology strategy can best be applied to realize medium-to-high level of emission reduction benefits.
2. **Development of Scenarios.** Based on the results of the screening of the technologies against the freight operations application categories, the technologies are then grouped into specific combinations that are evaluated for demonstration potential.

2.2 Truck Zero-Emission Technology Application and Scenario Screening

The truck engine/drivetrain technologies included in this assessment are:

- **Plug-In Hybrid Electric Vehicle (PHEV)**
- **Range-Extended Electric Vehicle (REEV) with Engine**
- **Range-Extended Electric Vehicle (REEV) with Fuel Cell**

[7] There are a number of definitions for the term "near-zero emissions"; for consistency this study defines near-zero as described.

[8] California ARB RFP

- **Battery Electric Vehicle (BEV)**
- **Range Extenders: Roadway Power**

The ITS truck technologies included in this assessment are:

- **Freight Advanced Traveler Information System (FRATIS)**
- **Applications for the Environment: Real-Time Information (AERIS) (ecoDriving)**
- **Integrated Corridor Management (ICM)**
- **Arterial Smart Corridors (ASC) with Freight Signal Priority (FSP)**
- **Truck Platooning**

Each of the zero- or near-zero engine/drivetrain technologies and ITS truck technologies were screened against the following four freight operations focus areas:

- **Long-Haul Trucking.** This market segment includes over-the-road truckload freight, less-than truckload freight, and containerized freight, with destinations of 100 miles or more outside of the Bay Area.
- **Urban Pick-up and Delivery** (trucking). This trucking market is primarily focuses, medium duty class 4-7, especially step-in Parcel Trucks (Class 5-6) – with all of these trucks having origins and destinations within the SF Bay Area.
- **Short-Haul Regional and Drayage** (trucking). This trucking market focuses on short haul drayage movements of intermodal containers in and out of the Port of Oakland, within a radius of less than 100 miles from the port.
- **Port/Facility Use** (port specific operational improvement technologies). This category focuses on specialized heavy equipment, such as yard tractors, forklifts, top-picks, and rubber tired gantry cranes (RTGs).

Table 2.1 provides a summary of the screening assessment for truck engine/vehicle drivetrain technologies.

Table 2.1 Screening of Applicable Truck Drivetrain Technologies

Technology / Application	Long Haul Trucking	Urban Pickup and Delivery	Short Haul Regional & Drayage	Port / Facility
Tech 1- PHEV	Low	Med	Low	Med
Tech 2 - REEV w/Engine	Med	High	High	Med
Tech 3 - REEV w/Fuel Cell	Low	Med	High	High
Tech 4 - BEV	Low	Med	Med	High
Tech 5 - Roadway Power	Low	Low	High	Med

Source: Cambridge Systematics, CALSTART

Table 2.2 provides a summary of the screening assessment for ITS technologies.

Table 2.2 Screening of Applicable ITS Technologies

Technology / Application	Long Haul Trucking	Urban Pickup and Delivery	Short Haul Drayage	Port / Facility
FRATIS	Low	Low	High	High
AERIS (ecoDriving)	Low	High	High	N/A
ICM	High	Med	Med	N/A
ASM with FSP	Low	High	Med	N/A
Truck Platooning	High	Low	Med	N/A

Source: Cambridge Systematics, CALSTART

The ratings of High, Med, and Low are qualitative assessments based upon combined analysis from the data discussed above. High is an indication that the technology has strong potential to deliver benefits in the selected application; conversely, low indicates relatively little potential for benefits in fuel economy, emissions, and/or efficiency. N/A means there is no applicability.

An additional screening of the highest rated scenario/technology/ITS combinations for emissions reduction from truck freight undertaken to determine the scenario which would advance to the demonstration recommendation. Table 2.3 presents a brief summary comparison between the technology/application scenarios and highlights those determined to be most suitable for a Bay Area demonstration project. This table summarizes the many factors used to evaluate the options. The current state of readiness for the technologies/applications are summarized by the TRL and CEC Stage in the first column. However, it should be noted that this evaluation did not include creating quantified or weighted metrics for each criteria, as it was determined that sufficient data did not exist to draw definitive conclusions within the scope of this project. Rather, the analyses are based on the technical analyses along with expert opinion from CALSTART and Cambridge Systematics in conjunction with MTC.

The recommendation for a single project to be considered for demonstration and as part of the Action Plan is Urban Delivery - Scenario VII, with particular focus on “straight trucks”. This demonstration recommendation is detailed in Section 4. Further details about the scenario evaluation can be found in Appendix I.

Table 2.3 Summary Comparison between Truck Technology Scenarios

Technology Scenario	Technological Readiness	Capital Cost	O&M Annual Cost	Energy Impacts	Emissions Impacts	Other Factors
Short Haul Regional & Drayage Scenarios						
Scenario I: FRATIS and ASC with FSP	TRL 7	FRATIS: $5000 per truck for large deployments ASC with FSP: $3.5 Million per arterial corridor	FRATIS: $500 per truck ASC with FSP: $5000 per intersection	Fuel reductions through educed trips and more efficient routing	20% to 25% reduction	Need Port of Oakland to Champion

Technology Scenario	Technological Readiness	Capital Cost	O&M Annual Cost	Energy Impacts	Emissions Impacts	Other Factors
Scenario II: REEV with Engine plus Roadway Power	TRL 5.5	Vehicle +50% to +80%, and high infrastructure costs	Similar costs, or unknown	Cleaner fuel sources and improved efficiency	25% or greater reduction	Roadway Power deployment may be a challenge
Scenario III: REEV with Fuel Cell	TRL 6	+29% or more estimated, with additional infrastructure costs	Unknown at this point	Cleaner fuel sources and improved efficiency	100% emissions reduction – fully ZE	Hydrogen infrastructure needs to be developed
Long Haul Scenarios						
Scenario IV: Platooning and ICM	TRL 7	Platooning: $250K per freeway DMS ICM: $570K per freeway mile	Platooning: $2000 per DMS ICM: $50,000 per mile of freeway	Fuel reductions through more efficient driving	15% to 20% reduction	Trucking Fleets will need to purchase Truck Platooning Systems
Scenario V: Hybrid Electric Vehicle	TRL 5	+15% to +20%, potentially less	Neutral given current data	Some improvement	Approx. 15% reduction, potentially more	Challenging ROI for long-haul applications
Urban Pickup and Delivery						
Scenario VI: ecoDriving, ICM & ASC with FSP	TRL 6.5	ecoDriving: $1000 per vehicle ICM: $570K per mile ASC with FSP: $3.5 Million per arterial corridor	ecoDriving: $500 per vehicle ICM: $50,000 per mile of freeway ASC with FSP: $5000 per intersection	Fuel reductions through more efficient driving	15% to 20% reduction	ecoDriving is still in the R&D phase
Scenario VII: REEV with Engine	TRL 7	Current data shows high incremental +200%	Neutral in existing studies	Significant shift from petroleum; efficiency gains	Approx. 33% reduction	Capital Cost challenges
Port/Facility						

Technology Scenario	Technological Readiness	Capital Cost	O&M Annual Cost	Energy Impacts	Emissions Impacts	Other Factors
Scenario I: FRATIS and ASC with FSP	TRL 4	FRATIS: $5000 per truck for large deployments ASC with FSP: $3.5 Million per arterial corridor	FRATIS: $500 per truck ASC with FSP: $5000 per intersection	Fuel reductions through educed trips and more efficient routing	20% to 25% reduction	Need Port of Oakland to Champion
Scenario VIII: Port/Facility using BEV or REEV with Fuel Cell	BEV: TRL 7 Fuel Cell: TRL 6	REEV with Fuel Cell is $125,000 and BEV Yard Hostler is $230,000	BEV yard tractor is $0.23/mile	Cleaner fuel sources and improved efficiency	100% emissions reduction – fully ZE	Need Port or facility operator to Champion Hydrogen infrastructure needs to be developed

Source: Cambridge Systematics, CALSTART

2.3 Rail Zero-Emission Technology Application and Scenario Screening

The four rail technologies assessed are:

- **Straight-Electric Locomotives (Catenary)**
- **Dual-Mode Locomotives (Catenary)**
- **Linear Synchronous Motor (LSM) Technology**
- **Electric Locomotives with Battery-Assist (Tender) Cars**

Each of the four rail technologies were screened against the following applications to develop scenarios.

1. **Line-haul rail:** Line-haul freight rail operations generate a substantial amount of emissions relative to the total rail emissions in the Bay Area. Ideally, Class I railroads need the flexibility to use their locomotives anywhere in their entire system, as they do not plan for a captive fleet that is restricted to a relatively small regional area (the operational impacts of this type of operation is discussed later in this report). However, as the entire system is converted to a new technology, it may be possible to deploy locomotives and infrastructure in a limited area by changing out the locomotive at the edge of the service area. In this case, the "edge" of the system should be in a location where there might be other reasons for a train to stop (for example, at a location at which a crew change typically occurs) and where there is sufficient physical space to change out a locomotive.
   The lines chosen as an example for this study are the UP Martinez Subdivision (from Oakland to Roseville) and the BNSF Stockton Subdivision (from Richmond to Stockton).
2. **Yard Switching:** Yard switching is when locomotives are used in rail yards to build or take apart trains by moving cars between tracks. Switching represents a good potential near-term application for zero emission locomotives for a number of reasons. As noted earlier, the power and tractive effort requirements for a typical switcher are more consistent with the limitations of existing zero and near-zero emission technologies. Additionally, because switchers stay within

a yard there is no issue associated with repositioning locomotives, operations are not affected by the limited range of current battery technology, and the switchers can be kept close to charging locations at all times.
There are a number of major rail yards in the Bay Area (UP's Railport, the OIG intermodal terminal at the Port of Oakland and the BNSF yard in Richmond) that are also local communities with high health risks associated with diesel emissions. A 2008 study by the California Air Resources Board found that switchers were responsible for the largest share of diesel-related health risks associated with the UP Railport and impacts on the West Oakland neighborhood. Similar issues associated with yard emissions are found around the Richmond rail facilities.

3. **Short Line Rail:** A final application scenario that is considered as a potential near-term fit for zero or near-zero emission technology is a true short line application. Because short lines generally operate over short distances, haul smaller trains, and require lower tractive effort from their locomotives, they present an operating environment that could be more suited to the available zero and near-zero emission technologies. An example of a potential short line application would be a scenario involving the Northwestern Pacific (NWP) railroad that operates using track owned by the Sonoma Marin Area Rapid Transit (SMART) system. Because this is a publically owned system and also creates potential for shared electric infrastructure with a passenger system, this application warrants examination.[9]

Table 2.4 provides a summary of the screening assessment for rail technologies.

Table 2.4 Screening of Applicable Rail Technologies

Technology / Application	Line Haul Rail	Yard Switching	Short line Rail
Tech 1 – Straight-Electric Locomotives (Catenary)	High - (Scenario I)	Low	Med
Tech 2 – Dual-Mode Locomotives (Catenary)	High - (Scenario II)	Low	Med
Tech 3 - Electric (Linear Synchronous)	Low	Low	Low
Tech 4 – Hybrid Diesel-Electric Locomotives or Dual-Mode Locomotives with Battery-Assist (Tender) Cars	Med	High - (Scenario IV)	High - (Scenario III)

Source: Cambridge Systematics, T.Kear Transportation Planning and Management

Each of the highest rated freight rail scenarios for emissions reduction was screened to determine the scenario which would advance to the demonstration recommendation. Table 2.5 presents a brief summary comparison between the technology/application scenarios and highlights those determined to be most suitable for a Bay Area demonstration project. This table summarizes the many factors used to evaluate the options. The current state of readiness for the technologies/applications are summarized by the TRL and CEC Stage in the first column. However, it should be noted that this evaluation did not include creating quantified or weighted metrics for each criteria, as it was determined that sufficient data did not exist to draw definitive conclusions within the scope of this project. Rather, the analyses are

[9] It is important to note that this specific scenario has not been discussed with either NWP or SMART and is just offered as an illustrative possibility. There are discussions underway for a similar operation on the California Northern Railroad operating between Shasta County and Vallejo that could provide a near term application similar in many features with the scenario described in this report.

based on the technical analyses along with expert opinion from TKear Transportation Planning and Management and Cambridge Systematics in conjunction with MTC.

Overall, the scenario determined to have the most potential for a demonstration application is Scenario IV – yard switching using dual-mode electric locomotives with battery-assist (tender) cars. This is detailed further in Section 5.0. Although the technology is not as advanced as straight-electric locomotives or catenary systems, the small scale yard implementation allows for the technology to be demonstrated at a lower cost than a line-haul application. Switchers also generate significant emissions impacts on communities neighboring rail terminals/yards, and the potential exists to scale up the demonstration to include further applications of battery-tender technology in the future.

Table 2.5 Summary Comparison between Rail Technology Scenarios

Technology Scenario	Technological Readiness	Capital Cost	O&M	Energy Impacts	Emissions Impacts
Scenario I: Line Haul rail using Straight-Electric Locomotives with Overhead Catenary	TRL 8-9	High – significant infrastructure costs	Significant Challenges due to captive fleet and need to change to diesel at the edge of the system and catenary system costs.	Electric locomotives twice as efficient as diesel locomotives; electricity more cost-effective than diesel	High reduction potential
Scenario II: Line Haul Rail using Dual-Mode Locomotives with Overhead Catenary	TRL 6-7	High –significant infrastructure costs compared to Scenario I with potential offset due to reduced cost of land for location to switch locomotives.	Potentially Significant Challenges due to lack of existing dual-mode freight applications. Reduced operational challenges as compared to Scenario I and catenary system costs.	5 percent energy penalty versus straight-electric; electricity more cost-effective than diesel	High reduction potential
Scenario III: Short line Rail using Dual-Mode Electric Locomotives with Battery Tender	TRL 5-6	Medium – fleet costs and moderate infrastructure needed	Moderate Challenges due to power management of battery tenders	9 percent less efficient due to weight penalty; electricity more cost-effective than diesel	Low reduction potential
Scenario IV: Yard Switching using Dual-Mode Electric Locomotives with Battery-assist (Tender) Cars	TRL 5-6	Medium – fleet costs and moderate infrastructure needed	Moderate Challenges due to power management of battery tenders	9 percent less efficient due to weight penalty; electricity more cost-effective than diesel	Moderate reduction potential, concentrated in areas with health concerns

Source: Cambridge Systematics, Inc., TKear Transportation Planning and Management.

3 Truck Freight Emissions Reduction Strategies

In addition to the demonstration plans outlined in the subsequent sections, there are a number of actions and strategies that can be taken by MTC and partner agencies to promote the development and deployment of zero and near-zero emissions technologies. These recommended actions and strategies are outlined in this section and are intended to provide guidance on the public sector role in creating an environment in which zero and near-zero emission technologies are supported and advanced to commercialization.

3.1 Creating Market Demand for Zero- or Near-Zero Emission Freight Equipment

A sufficient market demand or programs to simulate market demand are necessary in order to interest manufacturers in developing and implementing zero- and near-zero emissions technology. First, MTC and its regional partners should bring together a group of stakeholders to help develop and implement the strategies necessary to create market demand.

3.1.1 Developing a Sustainable Freight Advisory Committee

MTC can encourage the creation of an Advisory Committee for Sustainable Freight, which could be a continuation of the task force meeting regularly on this plan. This would also leverage the work done on the ARB Sustainable Freight Action Plan (CSFP), and the Regional Goods Movement Plan. As an example, the City of Los Angeles and the Port of LA recently created a Sustainable Freight Advisory Committee with the following description:

> *"The charter and goals of Port of Los Angeles Sustainable Freight Advisory Committee is to study and make recommendations to Port of LA executive director Gene Seroka and to LA Mayor Eric Garcetti on strategies that will make continual progress in moving cargo more efficiently, utilizing zero-emission technology everywhere feasible, and near-zero emissions with renewable fuels everywhere else, to reduce emissions from goods movement, while balancing commercial and economic feasibility. The Committee will work to identify opportunities, technologies and resources to increase the percentage of port-related goods movement trips that use zero-emission technologies to at least 15 percent by 2025 and to 25 percent by 2035."*

A similar group could be created for the Bay Area, with priorities set by the stakeholders and partners in the Bay Area. An essential element would be to assemble a wide range of voices on the committee, so the community and environmental groups will be meaningfully engaged.

3.2 Define Clear Requirements for Zero Emissions Operation

One area where the MTC and its regional partners can play a significant role is working with stakeholders to define the needed areas for zero emissions operation. While zero emission operations are not feasible in all applications at present, range-extended electric vehicle (REEV) trucks, as described in the technical assessment, have the ability in the short term to bridge that gap. A REEV applied to Class 5-6 urban delivery vehicles and in certain route configurations could operate much of the time in zero emissions mode. When coupled with a GPS controller technology, the zero emissions operations can also be targeted to areas with the highest levels of health impact disparities. However, in order for this strategy to be most effective, there needs to be clear definitions of the zero emissions zones, and the zero emissions capability required. OEMs and suppliers need to know clear requirements to successfully design a product. However, creating such zones raises several operational issues:

- Would compliance with the zero-emissions freight zone (operating a zero-emission capable truck) be required?
- How would compliance with the zero-emissions freight zone or region be enforced or validated?
- What would the rules be for operating vehicles in the zone – conventional and zero-emissions and near-zero emissions?

3.2.1 Developing Purchase or Incentive Programs

MTC and its regional partners can leverage existing recognition programs, to make visible the effort and expense of adopting cleaner technologies. One leading example is the National Association of Fleet Administrators (NAFA) Sustainable Fleet Accreditation Program[10] (sponsored by the National Association of Fleet Administrators, and CALSTART). Modeled on the LEED Program for buildings (Leadership in Energy and Environmental Design, sponsored by the US Green Building Council), the NAFA program has various levels of accreditation, based on criteria determined by the composition of a fleet and the available technologies. The City of Oakland, Santa Clara County, and Alameda County General Services are all enrolled, and Ventura County, City of Anaheim, and City of Sacramento Fleets have all been accredited. Since programs such as this are implemented by fleets themselves, they can be a powerful approach for countering the "regulation/mandate" aspect of emissions reduction. Bay Area public agencies, such as ports, can be leaders by example and join the programs themselves. Recognition can be as powerful an incentive as money, especially for those companies with Corporate Social Responsibility commitments or programs.

MTC and its regional partners can leverage and/or support existing incentive programs. The ongoing **California Heavy Duty Voucher Incentive Project (HVIP)**, funded by ARB, can be given a "Bay Area Plus-Up" that would augment the financial incentive for advanced truck purchases. The San Joaquin Valley Air District implemented a "Plus-Up" program in the past because HVIP voucher distribution under-represented the San Joaquin Valley. The San Joaquin Valley Plus-Up program helped ensure that more zero emission/near-zero emission/hybrid trucks were purchased and driven in the Valley. The SJVAPD discontinued the program when the incremental costs of the new technologies decreased enough to be covered by the new vouchers.

MTC can partner with the BAAQMD, ARB and others to define the vehicles to be specifically incentivized in the Bay Area, and try to identify additional funding for the enhanced incentives. As shown by the San Joaquin Valley program, regional Plus-Up programs are good, but much depends on the overall incentive landscape, what other state or federal incentives are available, and the willingness of the funding agency to cover more than incremental costs in order to drive adoption of new technologies in a particular region. A Plus-Up program could also be narrowly targeted, and apply only to specific types of vehicles that are of interest, and could thus be supportive of a particular pilot demonstration program (such as the Class 5-6 demonstration recommended in this study).

In 2014, MTC provided $2.8 million in grants to local agencies to buy light-duty electric vehicles and support charging infrastructure for these vehicles. Similar programs have been developed in other areas

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[10] website: http://www.nafasustainable.org/

for purchase of zero- or near-zero emission trucks. The State of New York has an ongoing Voucher Incentive Program, which has allocated up to $9 million in grants to off-set the cost of electric trucks and buses, and an additional $10 million to off-set of the costs of other emission-reducing technologies.

MTC is already working on programs to promote consumer adoption of electric light duty vehicles. Through the Climate Initiatives Program, MTC has developed programs designed to spur electric vehicle adoption through incentives, expanding the network of charging stations, and by hosting public test-drive events. In conjunction with the BAAQMD, MTC is aiming to boost the number of elective vehicles in the region to 100,000 or more. These programs could be potentially modified or expanded to include zero-emission truck technology

The ARB is exploring opportunities to further transition its existing incentive portfolio towards one that better aligns with a zero- and near-zero emission future. In fact, their Proposed Fiscal Year 2016-17 Funding Plan very directly states: "many of the same actions are needed to meet GHG, smog forming, and toxic pollutant emission reduction goals – specifically, a transition to zero-emission and near zero-emission technologies and use of the cleanest, lowest carbon fuels and energy across all vehicle and equipment categories. The California Sustainable Freight Action Plan reiterates the need for this transition as it relates to the freight sector. To support this transition, California's first two Cap-and-Trade Auction Proceeds Investment Plans both identify zero-emission passenger transportation and low carbon freight transport as "investment priorities…" Programs that focus on full zero-emission and maximum zero-emission range on near-zero emission technologies are likely to best align with ARB future funding. Because these funds are allocated by the Legislature, and the bills involved (AB 32, AB118, and others) are subject to modification or extension, there is always some uncertainty. The CA Emissions Trading Program (commonly known as Cap & Trade) did not generate the expected revenues this year, adding an additional layer of uncertainty. However, the core objectives for ARB use of the funding are not uncertain. Regional partners should maintain contact with and work with the ARB to align incentive programs aimed at zero-emission trucks, as well as other vehicles.

Support on-going or proposed regulatory action programs from ARB

Ultimately, using both a carrot (incentives) and a stick (regulations) combined is the best method to advance the development, deployment, and adoption of zero-emission and near-zero emission trucks. In addition to regulations, many other approaches can be considered – Cap & Trade programs as the state is running, regional criteria pollutant limits, and fleet specific rules or rules for Ports (a challenging and potentially fractious approach, but sometimes necessary – e.g. the SoCal Clean Truck Program). As part of the Sustainable Freight Action plan, a measure to reduce NOx and greenhouse gas emissions through use of zero-emission technology for last-mile delivery fleets was proposed. The proposal includes considering regulatory action in 2018 to be implemented through the 2020-2050 time period. This proposed measure with anticipated ARB Board consideration in 2018 will require certain fleets that operate last mile delivery trucks to purchase zero-emission trucks starting 2020, with a low fraction initially and ramping up to a higher percentage of the fleet gradually at time of normal replacement.

3.3 Infrastructure and Deployment Support

As mentioned in earlier sections, given its critical role in near and zero-emission truck deployment, significant immediate and continuing work is required to evaluate and plan infrastructure requirements, needs, and locations. This should include development and demonstration projects to validate high-power, multi-vehicle recharging systems. Electric and natural gas utilities and future fuel providers (natural gas and hydrogen) need to be involved in planning how to meet these needs.

Regional partners can play a key role in bringing together all the fuel suppliers (utilities, private companies) and infrastructure owners (utilities, governments, private companies) to best coordinate this complex area of development.

3.3.1 Charging Infrastructure

There are questions surrounding charging or roadway infrastructure to support zero- and near-zero emission vehicles, such as who should own the infrastructure? Who maintains the infrastructure? Who pays for the infrastructure? MTC and its regional partners can play a role in negotiating these questions and guiding the many stakeholders to a good solution. These meetings can discuss different models, such as Tesla model (industry owned) or public sector-owned infrastructure. One option for developing charging infrastructure would be to follow the model developed for light-duty vehicles. In that case, initial investment in infrastructure was made by government but most the maintenance, upkeep and further deployment of these systems has been done by private industry and employers. However, charging infrastructure is different for medium- and heavy-duty vehicles and this may require a different approach than was taken for light-duty infrastructure. For example, power requirements are greater for heavy-duty infrastructure, physical space requirements are greater, and many fleets have/require private fueling/charging facilities, which makes government support problematic.

Regional partners should also be aware of and coordinate, as possible, with potential programs, such as those documented in the California Sustainable Freight Action Plan (CSFAP) related to this topic. Programs and potential implementers documented in the CSFAP include:

- Electric Charging Infrastructure for Parked Trucks – Caltrans
- Electric Charging Infrastructure Incentives – Energy Commission
- Regional Medium- and Heavy-Duty Zero-Emission Vehicle Infrastructure – Energy Commission

MTC and its regional partners can also support the standardization of charging infrastructure by requiring Society of Automotive Engineers (SAE) standards be used in projects. SAE and other industry organizations working on these areas, and preliminary standards need to be supported in order to align different programs and incentives towards a common future.

3.3.2 Deployment Support

Regional partners can play a role in developing programs to educate a workforce that is able to handle new technologies for fuel handling and charging system maintenance, among others. This is also an opportunity for MTC and its regional partners to partner with local educational agencies to train workers and create jobs in the region. This should start with an inventory of existing training programs at community colleges and some private schools throughout the Bay Area. For example, the City College of San Francisco offers a certificate in Hybrid and Electric Vehicle Technology as part of their Automotive Technician training. Other programs that already exist, should be a starting point for collaboration on workforce development.

Regional partners should also be aware of and coordinate with, as possible, potential programs documented in the California Sustainable Freight Action Plan related to this topic. Programs and potential implementers documented in the CSFAP include:

- Regional Workforce Development Initiatives – GO-Biz and the CA Workforce Development Board
- Training Models – GO-Biz and the CA Workforce Development Board
- Community Workforce Agreements – GO-Biz and the CA Workforce Development Board

An additional opportunity is emergency response training for areas that may not be familiar with alternative fuels like hydrogen, which has different characteristics and requires special handling versus diesel fuel or gasoline. The Department of Energy has developed a free online hydrogen safety training resource for emergency responders, with the intention to enable government and private training organizations to develop their own training programs with consistent hydrogen and fuel cell content and standards.[11]

3.4 Creating a "Center of Excellence" for Ongoing Efforts

In order to build a strong regional program for zero- and near-zero emission trucks, the Center of Excellence approach is a possible framework to consider. This Center of Excellence (CoE) is a place (virtual or physical) where technology, operations, applications, and benefits for reduced emission trucks are illustrated. A visible single-point-of-contact is important to get public and private sector buy-in, and show the benefits and challenges of implementation, leading to potential expansion of the region's ZE programs. The CoE creates an opportunity for technology developers, OEMs, truck owners and operators, and government agencies to interact on a regular basis, sharing information, the results of demonstrations and pilots, and to gain first-hand experience with the new technologies. In order to determine if this approach would be effective in the Bay Area, further investigation will be required, but creating a critical mass of technology development and demonstration activity is likely to help accelerate the adoption of ZE/NZE technologies

3.5 Other Ongoing Programs, Policies, and Opportunities for Partnership

Below are some areas and opportunities that should be monitored by MTC and its regional partners and explored for potential partnership opportunities. The technologies are developing rapidly, and new market participants are entering the field. In addition to MTC staff, the use of the technical advisor from the demonstration project can be of help in tracking all the developments and deciding which are worth deeper investigation. Some of the topics below are tangential to the zero-emissions and near-zero emissions work, but will be happening at the same time (specifically Connected and Autonomous Trucks). Others are listings of programs from State agencies or other known upcoming programs.

- MTC and its regional partners can contact the FUSE Corps (http://www.fusecorps.org/), which has defined and recruited for fellowships in areas of benefit to cities and regions. This organization has zero-emission and near-zero emission and Autonomous Vehicle projects in Southern California, and have done projects with San Jose, San Francisco, and Vallejo in the Bay Area. This strategy could prove an effective way to leverage the work of the projects and expand influence.
- The Ports of LA and Long Beach have coordinated to develop a test plan for prototype goods movement equipment – a set of procedures for the two ports to help ensure demonstrations

[11] http://energy.gov/eere/fuelcells/articles/doe-launches-emergency-response-hydrogen-training-resource

need be done just once, and will collect all the data needed to answer questions from either Port leadership. Regional partners could use that document as a model and an equivalent guide for projects in the Bay Area. The guideline could define (based on outcomes from the proposed Class 6 REEV project) a process for all demonstrations in the region, to ensure uniformity and comparability across suppliers and partners.

- Another area where regional partners could create ongoing acceleration of advanced zero-emission and near-zero emission truck commercialization is through the ARB Innovative Technology Regulation (ITR) Program (http://www.arb.ca.gov/msprog/itr/itr.htm). Related to the ARB Sustainable Freight Action Plan, and to the prototype demonstration programs being explored by MTC, ARB is bringing this ITR program proposal to their Board later this year, with the intent of providing a pathway to certification for new technologies which may not fit traditional categories. As the website states, ARB has "…begun development of a proposed ITR to provide certification and aftermarket part approval flexibility for the next generation of innovative medium- and heavy-duty engine and vehicle technologies that California needs to meet its long-term air quality and climate goals." Vehicles such as the Range Extended Class 6 trucks proposed for demonstration are exactly the kinds of technology the ITR is meant to advance. Participation and support for the program from the Bay Area's regional partners would be a big help to accelerating the certification of new truck designs, which do not fit the existing regulatory structure.
- Connected and Autonomous Vehicle technologies are developing rapidly and may pass the deployment of zero- and near-zero emission technology in vehicles. Because of synergies between electrification of the vehicle drivetrain and the ability to add autonomous capabilities, the two areas will likely merge in the near future. There is overlap with current ITS systems and impacts across a number of areas of interest to the regional partners. An entire separate study is justified given the significance of this area of technological development; MTC and its regional partners can and should play a role in the development and deployment of these technologies in combination with zero- and near-zero emissions trucks.

Additional programs or concepts from the California Sustainable Freight Action Plan to monitor include:

- Research Efforts to Support Sustainable Freight Transport System Development – Caltrans, in coordination with the ARB and Energy Commission
- Investments in Advanced Vehicles and Equipment Technology Demonstrations and Deployment, Renewable Fuel Production, and other Freight Technologies – Energy Commission
- Transportation Electrification Planning – Energy Commission
- Regional Zero-Emission Vehicle Readiness Plans – Energy Commission
- Zero-Emission Vehicle Market Forums – Energy Commission
- Advanced Transportation Electrification Technologies – Energy Commission
- Urban Delivery (Bay Area): A combination of strategies to address urban freight congestion and emissions: off-peak delivery, truck parking and charging, collaborative logistics, cargo bicycles, and local workforce development was presented as a pilot program concept in 2016. – ARB Pilot Program Concept

4 Truck Freight Emissions Reduction - Demonstration Plan Recommendation

This section provides guidance for implementation of the demonstration project recommended in the technical assessment portion of this project, a "Range Extended Electric Vehicle (REEV) with Engine for Medium Heavy Duty (Class 5-6) Trucks" used for urban delivery in the Bay Area. The scope of work for this Freight Emission Reduction Action Plan was to identify a recommended demonstration opportunity and steps for how a demonstration could be implemented. The first steps, which include development of a scope of work, schedule, and budget, would result in a much more fleshed out demonstration plan than what was within the scope of work for this study. These recommendations are critical first steps guiding the development of the more detailed demonstration plan.

The demonstration selected as the most viable option in this application is a REEV with Engine – especially using a Low-NOx natural gas engine. This option is better than similar alternatives such as REEV w/ Fuel Cell for urban delivery, as it is less "route-dependent" because it does not require refueling at stations with hydrogen. These designs have been tested in prototype form, and are ready for larger demonstration. Optimization of engine size and battery pack size is one goal that a Bay Area demonstration could provide, working to achieve maximum zero-emission miles when in areas of concern. Operators of the vehicles are readily available and interested. The big players are the best candidates – FedEx, UPS, other large Bay Area users of this type of truck – food delivery, uniform delivery, bakeries, others.

The recommended vehicle type for this demonstration is the "Medium-Heavy Duty" truck segment as described by the ARB. First would be "straight trucks" which refers to the chassis design of a Class 5-6 truck upon which is usually mounted a large box. Similar "straight truck" designs can have work truck bodies, or other kinds of body equipment mounted to the straight chassis. For this demonstration, the target is what is generally known as Box Trucks as shown in Figure 4.1. These vehicles are very common in fleets doing food delivery, goods movement, and general hauling. For urban delivery, these trucks do the majority of the work, as Class 7 or 8 tractor trailers need too much room and are inefficient for frequent stops or smaller loads.

Figure 4.1 Examples of Class 6 Straight Trucks

Source: truckinginfo.com (left); Kenworth (right)

Another category within this segment is the Step-in-Van or Walk-in-Van as shown in Figure 4.2. This design is a common Class 5-6 truck in use for parcel and laundry delivery. It is distinguished by sliding doors and steps up to the driver seat, designed for frequent stops and easy ingress/egress by the driver. As that implies, these vehicles also operate in urban environments and neighborhoods, delivering packages and goods to smaller stores, individual residences, and similar activities.

Figure 4.2 Examples of Walk-in Vans

Source: Morgan Olson

4.1 Class 6 Truck Demonstration Plan Funding and Feasibility Overview

Beginning a new technology demonstration plan often requires participation by both the private and public sector. Typically, demonstrations of prototype and early production advanced trucks involve winning government grant funding, based on a team of technology suppliers, truck OEMs, and demonstration fleet operators responding to a funding announcement. State and Federal grants usually require match funding of up to 50%, which often comes from local agencies, air districts, and in-kind contributions by the team members. Grant requirements vary, as does timing. There is potential to submit unsolicited proposals to some entities such as Ports and Air Districts, for example. Given these complex factors, exact timing for this demonstration is unknown. These factors can be further evaluated as the demonstration plan is translated into action.

The amount of funding available is the limiting parameter in most cases. Early prototypes are costly to build, and usually include some NRE (Non-Recurring Engineering) costs, because the team members have to develop components and system integration which have previously not been done to the level required for road-worthy prototypes. NRE costs are spread across all the vehicles built for the demonstration, so there is benefit to larger deployments. Reviewing recent awards from the CEC and ARB indicate costs per demonstration vehicle are in the range of $325,000 to $675,000 per truck. For the types of trucks recommended here (Class 6) it is reasonable to assume a range of $400,000 to $470,000 as a baseline for estimates. Most demonstrations have been under 10 vehicles, but recent ARB "Pilot" grants are intended to increase the number of trucks, with the recent award being 43 Class 8 demonstration trucks (for $29.6 million in total project costs: $23.7 Million in grant funding, with 25% match additional). Each class 8 truck therefore cost roughly $689,000.

Several companies have built small numbers of REEV with Engine trucks in the class 5-7 size. Some have been specifically step-in vans (parcel delivery), others have been work trucks (Utility boom trucks). A critical benefit of this demonstration project will be to build and test vehicles designed for other types of local delivery – straight trucks or box trucks – for food, products, movers, and general work applications. The routes they travel are predominantly urban and suburban, both commercial and residential deliveries. The duty cycles vary depending upon specific applications, but the truck designs can be very similar with important learning to be gathered on software optimization for particular uses. In the Bay Area, the likely routes do include the 880 freeway as many start/end locations are near the airport, and delivery routes within Oakland and San Francisco.

4.2 Recommended Steps for Class 6 Truck Demonstration Implementation

This section provides guidance for implementing a demonstration plan for Class 6 trucks. The demonstration plan can be broken down into several clearly defined steps for implementation, each of which are expanded upon in the following sections:

- Define the scope of the project and obtain partner commitments
- Set a budget and align with potential funding
- Develop proposal documentation including a timeline
- Acquire funding through direct request or grant program(s)
- Implementation
- Dissemination of Outcomes and Building Support

4.2.1 Define Scope and Obtain Partner Commitments

As a first step in developing the demonstration plan, it should be determined who and/or which agencies or companies should be involved in the demonstration plan, and assign roles, including the role of lead implementing agency. Based on the desired project focus and outcomes, the first step should be assembling a team with the capabilities to deliver on the intended goals. Successful demonstrations typically include an administrator role, technology providers and manufacturers, an independent technical expert for general assistance, an entity doing data collection and analysis, and ideally an outreach partner for communicating the program and the outcomes to stakeholders and the general public.

The administrator is the entity that manages the overall project – invoicing and money movement from the funding entities to the partners doing the work, keeping the project on track, ensuring deliverables and timelines are met. This role could potentially be filled by MTC, the Bay Area Air Quality Management District (BAAQMD) or other private or non-profit agencies. Similarly, there are a number of options for fulfilling the role of the technical advisor, but there is a need for a technical expert on the project management team, to provide oversight of technical activities for agencies that do not have the expertise on staff. For example, South Coast Air Quality Management District has some technical experts on staff and they serve as program managers for demonstration projects that the District funds. Other agencies, such as the Ports of Los Angeles and Long Beach have hired consultants to serve in this role and this may be a necessary approach for MTC if it is the lead agency managing the demonstration program. The technical advisor, if it is an outside consultant, is usually a company with expertise in early technology demonstrations, ideally in the clean transportation space. General engineering, traffic planning, or environmental analysis companies can also play this role. The technical advisor is often the first partner hired for the project, as they can provide assistance in finding the right partners and aligning the specific technology to be demonstrated with the goals of the lead agency and the desired program outcomes.

Technology providers and manufacturers are the essential team members. Selection of those partners has to be based on having the technologies and capabilities needed for the desired project. Having a truck OEM involved is the most desirable, as they have both the stability and the competence to best ensure successful outcomes. These OEMs will eventually be the providers of zero- or near-zero-emission trucks. Technology providers are often brought into the demonstration program through a Request for Proposal that may also involve the technology provider teaming with a trucking fleet that will act as the demonstration site. The Request for Proposal should include requirements for cost-sharing or in-kind services to support the demonstration. However, in some cases, the technology provider may be asked to work with the partner agencies to apply for funding and to respond with an Expression of Interest prior to funding having been obtained. Assuming that is the case, the Expression of Interest will need to provide more specific information about the technology to be demonstrated, the trucking firm that will act as the demonstration fleet, and how the technology provider will meet the overall requirements of the demonstration if outside funding for the demonstration can be obtained.

Performance testing, user acceptance testing, and serviceability/maintainability feedback are key components of the demonstration. For a prototype to move forward toward production, these inputs are essential. Overall program objectives can be set by the lead agency, and then adjusted as needed when meeting with program partners. The Technical Advisor can again play a role here, as the entity that conducts the testing and surveys. Working with a provider that has experience in these activities can improve comparisons and repeatability of the testing. These tasks require specific skill sets, and are best handled by experienced entities.

Potential company partners were listed in the technical assessment, with the caveat that the list is by no means exhaustive. The lead agency should reach out to the California Trucking Association or a similar agency to determine the best partners and obtain commitments. The partners that will demonstrate/operate the test vehicles are a critical element for a successful project. Often the partners are called upon to commit funds for charging stations or other capital expenditures, and it is desirable to work with partners that have a track record of following-through on those commitments. Associations like the California Trucking Association (CTA) and the technical advisor can provide input on partners with a positive view toward these kinds of projects.

4.2.2 Set Budget and Align with Funding Opportunities

The lead agency should determine an expected budget and scope, in consultation with agency staff and the project partners. The amount of funding available is the limiting parameter and in many cases, MTC and partner agencies will be applying for funding from state and federal agencies to support a demonstration program that they will manage. Technology suppliers and manufacturers need to have good estimates for costs to develop operational prototypes and maintain them through the demonstration period. Operational costs from the fleets who are demonstrating the prototypes are often considered match funding, to leverage any government grant funds.

Prototype vehicles are costly to build, and usually include some Non-Recurring Engineering (NRE) costs, because the team members have to develop components and system integration which have previously not been done to the level required for road-worthy prototypes. NRE costs are spread across all the vehicles built for the demonstration, so there is benefit to larger deployments. Reviewing recent awards from the California Energy Commission (CEC) and Air Resources Board (ARB) indicate, and as mentioned in Section 4.1 of this document, costs per demonstration vehicle are in the range of $325,000 to $675,000 per truck. For the types of trucks recommended here (Class 6) it is reasonable to assume a range of $400,000 to $470,000 as a baseline for estimates. Most demonstrations have been under 10 vehicles, but recent ARB "Pilot" grants are intended to increase the number of trucks, with the recent award being 43 Class 8 demonstration trucks (for $29.6 million in total project costs: $23.7 Million in grant funding, with 25% match additional). Each class 8 truck therefore cost roughly $689,000.

4.2.3 Develop Proposal Documentation and Timeline

Once a budget and scope is identified and documented, the lead agency should work to develop a demonstration proposal, including a timeline. Even before a particular grant or funding opportunity has been defined, having program documents well written and in place will help demonstrate preparedness and increase the odds of getting funding. Similarly, a realistic timeline, with defined milestones, is an important tool for funding acquisition as well as for program implementation. Having well-defined roles, with proven partners, is the key to successful projects. Due to circumstances beyond MTC's control, including funding availability, etc., it is not currently known when the demonstration project will be made available.

4.2.4 Acquire Funding and Prepare Demonstration

Utilizing the prepared documents, either entering for a known grant opportunity or an unsolicited request to a funding entity is the most effective way to secure the funding required. Most of the funding sources for demonstrations identified later in this Action Plan are Federal and State sources and some have regular solicitations for grants while others will entertain unsolicited proposals. All funders like to see their dollars leveraged, so the budget planning should include a match percentage, up to 50%, with those dollars provided in cash or in-kind services from the project partners. The work done in prior steps, especially developing a proposal and timeline, will pay off here in speeding the process and allowing very fast reaction time when funding opportunities appear. Funding programs are discussed in Section 6.

4.2.5 Demonstration Plan Implementation

Once funding is secured, implementation of the program is straightforward, by following the planning documents created earlier. The project's lead agency for the administrative and technical roles will be the leader in keeping things on track and focusing on outcomes. Clear definitions of roles, tasks, deliverables, and expected outcomes - all things done prior to the implementation – are the most important factors in a successful implementation.

4.2.6 Dissemination of Outcomes and Building Support

During and after the demonstration, it is important for the lead agency to provide information to stakeholders and decision makers regarding the program to build support for future activities. Communicating the program activities and building support for the program, and future programs, is a critical element. Many projects do not allocate sufficient funding for this work, or expect it to happen without professional public relations or marketing assistance. Specific expertise in these areas is important, early in the project, to communicate an ongoing effort that builds upon other efforts, rather than a stand-alone program with no links to the community needs or to other programs.

4.3 Expansion of Class 6 Demonstration Program and Next Steps

Achieving a rapid change in medium/heavy duty truck technology, as well as spurring the adoption of advanced technologies in specific application segments, will require a high degree of focus, cooperation, and consensus among public and private entities.

In the near term, it will require a much higher degree of focused technology development funding and outcome-setting than typically occurs for a single application. Federal, state and regional agencies currently have several funding programs that enable such investments in advanced vehicle technology and alternative fuels to help meet climate change and emissions goals. The activities listed in this report fit in that rubric and are a very important part of the overall effort.

However, having the funds available is only one part of the issue: the various agencies ideally need to agree to follow a clear roadmap for focusing those resources on the specific technologies, vehicle architectures, and fuels that can achieve the outcomes needed. This will require an unprecedented level of agency cooperation. Furthermore, this intensive development process must leverage and include the truck OEMs. This is one of the goals of the Clean Truck Policy and Program Collaborative included in the Regional Goods Movement Plan (produced in partnership with MTC and Alameda County Transportation Commission, among other partners).

In order to support long-term viability of zero- and near-zero emission vehicles, over the next three to five years several priority areas must be supported simultaneously. Field demonstration projects should be targeted at developing and validating the functionality to meet emission performance requirements as well as users' operational needs. At the same time, it will also be critical to encourage development of the new technology's supporting systems, such as electrified auxiliary components, high-power rapid charging, lightweight natural gas and hydrogen storage systems, optimized alternative fuel engines and modular battery packs by working with OEM's and component manufacturers. Furthermore, significant immediate and continuing work is required to evaluate and plan infrastructure requirements, including development and demonstration projects to validate high-power, multi-vehicle recharging systems. Electric and natural gas utilities and future fuel providers (natural gas and hydrogen) need to be involved in planning how to meet these needs. Finally, the public sector should pursue strategies to help build market demand for promising technologies.

Another expansion area for demonstration programs is to "scale up" the proposed Class 6 program to Classes 7 and 8, for regional haul and drayage operations. For the technology suppliers, this is a relatively easy step and one that would expand their potential market. It would further the region's goals to address heavy truck emissions around ports and warehouses. By monitoring the drayage projects in Southern California, regional partners can design a program that would build upon those efforts while leveraging the Bay Area Class 6 demonstration and addressing specific needs in the Bay Area. While demonstrations in other parts of the country can indirectly benefit the Bay Area by providing technology developers and OEMs with valuable experience that is reflected in improved products when fully commercialized, local demonstrations are also important. These local demonstrations give users a change to become familiar and gain comfort with a new technology, thus accelerating the rate at which it is adopted locally. To this end, the BAAQMD will be funding some local demonstration of zero emission drayage trucks with funding provided by ARB.

As mentioned, regional partners can continuously monitor programs happening elsewhere in the state and the nation, and plan follow-on projects to advance the findings of these other programs. Very often there is a need to deploy larger numbers of demonstration vehicles, after a first project has proven the initial five or fewer trucks. Truck manufacturers are especially interested in this step, as it helps them plan for tooling and manufacturing processes that are necessary for full commercial production. The technical advisor from the project team can provide assistance here, if they are focused on clean transportation projects and are monitoring nationwide as a course of business.

For purposes of smart policy making and support of rapid commercialization, it is important to involve OEM truck or chassis makers at the earliest stages of demonstration planning and development. In doing this, the demonstration planners should:

- Recognize the longer lead times and deliberate process they follow to develop and manufacture a product that they believe they can sell and support.
- Structure development programs around the end goal and recognize where in the stage of development a technology product currently lies.
- Structure multi-year efforts to help fund OEMs and suppliers through the development process that leads to a final product.

4.3.1 Commercialization Approaches

Achieving the successful deployment of significant numbers of zero-emission and near-zero emission trucks is not assured and will require a comprehensive approach combining technology development, regulatory requirements, incentives and public sector support for deploying new technologies, and potentially revised business models. Over the next decade, achieving zero-emission and near-zero emission truck market success will necessitate following an aggressive and highly focused commercialization and phase-in plan as outlined in Figure 4.3**.** It will require regional, state and federal government support in providing multi-year funding and the necessary regulatory framework and operational requirements.

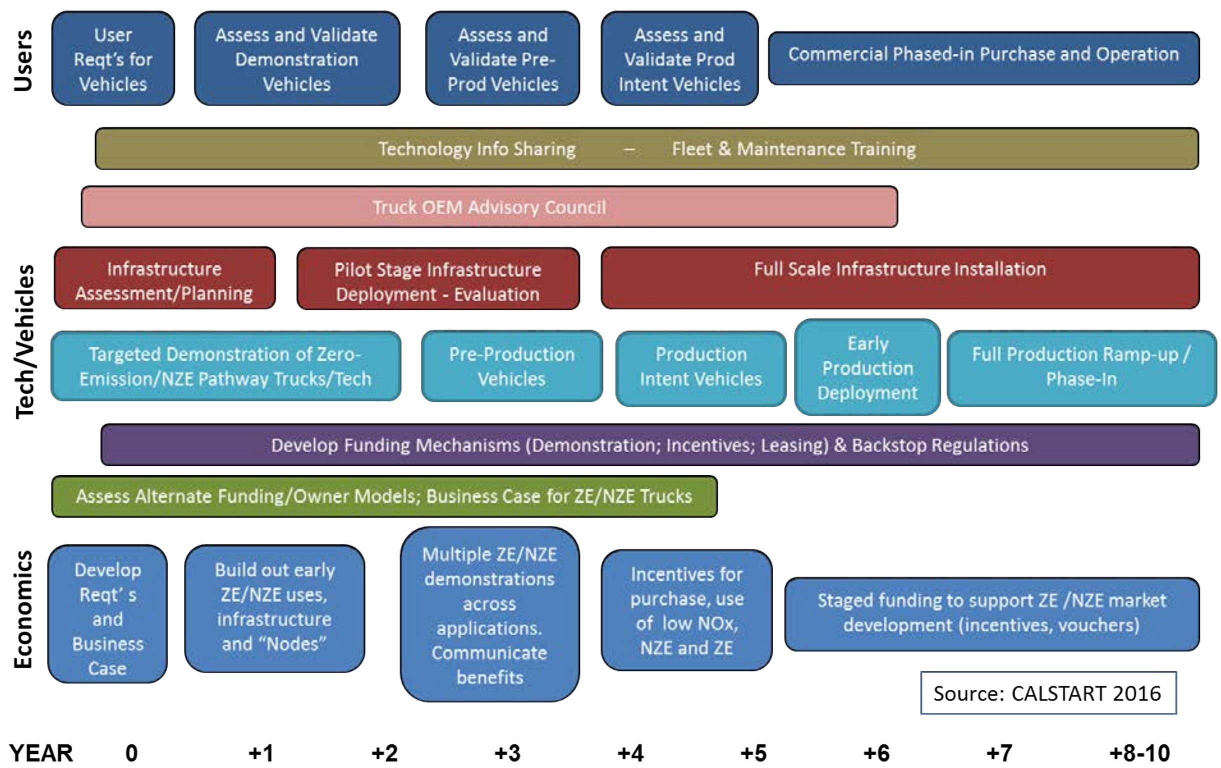
Achieving zero-emission and near-zero emission truck deployment success will also require the involvement of the major truck OEMs. Each has its own current strategy on zero emission-enabling technology based on their product mix, plans for fuel economy, and global market considerations. Full zero-emission technology is not central to the current product plans of any truck OEM[12] – though several have intriguing internal development efforts. In general, the OEMs are not so much skeptical of the feasibility of the technology as they are of the reality of the market for its use. Section 3 describes opportunities for the public sector to play a role in creating and expanding the market for zero-emission technologies to help overcome this gap.

Meeting zero-emission truck deployment needs will not necessarily require every OEM to offer a product. A possible scenario is for one or two OEMs to be active participants, and potentially approach the market via a partner that may provide the zero-emission and near-zero emission technology integration on the OEM truck platform while initial volumes remain low. This approach is already being used with success in the parcel delivery truck (step-in-van) arena, and can reduce the risk to both supplier and OEM.

No matter the scenario, however, truck OEMs need to be active participants in the commercialization process, and potentially be engaged through an OEM Advisory Council. Such a council would directly connect OEMs to the status of the zero-emission truck development (in the Bay Area and beyond) and could assess zero-emission truck requirements, identify gaps and needs based on their business cases, and make suggestions for refined development activities.

[12] One exception is BYD, a Chinese automobile and bus manufacturer that has focused considerable effort on the electric vehicle market, including trucks.

Figure 4.3 Zero-Emission Truck Commercialization Phase-In Plan



Smart, adequate and timely infrastructure development is another one of the keys to the successful deployment of zero-emission trucks. First, and foremost, there need to be sufficient sources and adequate distribution of power and fuel: electricity, hydrogen, and to a lesser extent, natural gas. Refueling and recharging stations have to be included in this plan to assure commercialization for these trucks. Infrastructure development must proceed concurrently with the development and deployment of zero-emission trucks for the introduction of zero-emission and near-zero emission truck operations to be successful. These trucks cannot work without fueling infrastructure, and fueling infrastructure cannot be supported without enough trucks to use it. Additional partners and stakeholders will be needed to participate and assist.

4.3.2 Key Issues Impacting Commercialization

Achieving commercial success is the ultimate goal of all the work around demonstration programs and infrastructure planning; however, it is important to remember that factors such as the future state of the industry and future costs are subject to variability. Fuel prices are notoriously unpredictable, and those often drive benefit-cost evaluations of users who are deciding whether to use a new technology that has a higher up-front cost but promises operating savings over the life of the vehicle. A second factor that must be remembered is the cost for "baseline diesel-powered trucks" will not remain static. The costs for emissions controls will rise in the future, perhaps dramatically, as advanced technology systems are required on diesel engines to meet lower emissions standards. The diesel engine cost increase will have measurable impact on narrowing the gap between zero-emission and near-zero emission trucks compared to conventional diesel trucks. The decline in zero-emission and near-zero emission truck costs are often included, but those too are estimates and faster decreases are possible. The future business case will be better than often estimated, and will help the commercialization process.

To summarize, the core issues that need to be addressed for successful commercialization of zero-emission and near-zero emission freight goods movement vehicles include:

Flexibility

- Vehicles must be able to perform full drive cycle duties, including sufficient range and power (generally equivalent to conventionally-fueled trucks), for the specific truck vocations in which they will be used. Trucks that can only meet the requirements of a very narrow set of truck vocations within the broader array of vocations for which trucks of that size class are used, may be less attractive to owners who are used to using their trucks in a wide range of vocations. Urban delivery trucks are a good example; while the range and duty cycle characteristics of this vocation may be suitable for many local delivery applications, owners of these types of trucks report that they often use them in local delivery service during the day and regional/long haul operations at night. Many truck owners, however, continue to use particular trucks in a narrow range of truck vocations and this vehicle type may have limited re-sale value. Nonetheless, there are pre-commercial versions of zero and near-zero emission trucks that are already moving into commercial applications based on their ability to meet the performance requirements of certain truck vocations and this should be encouraged.

Operations

- Trucks must have the ability to go a minimum distance (at least 20 and up to 50 or more miles) in zero-emission mode and then potentially continue to operate in a reduced emission mode outside the core (urban/environmental justice) regions. For those truck vocations for which existing pre-commercial technologies can meet range requirements, full zero operations should be a required goal.
- Trucks should be able to switch back and forth—between zero-emissions and reduced emissions—several times per day as they enter and exit these zones.
- As noted, this capability implies the need for a fast charging or refueling capability and/or a zero-emission range extender function.

Manufacturability

- To be successful, the manufacturing process would be based on a core, high-volume truck platform of which the zero-emission and near-zero emission version would be a variant. The more common the base truck is to established vehicles, the easier it will be to produce.
- New components (such as batteries, electric drivelines, range-extended electric vehicle (REEV) engines) ideally need the support of a broader market to help reduce costs. This market can come from additional truck applications (such as zero-emission vocational trucks and buses) and from additional markets for zero-emission and near-zero emission trucks in the U.S. and globally.
- OEMs and zero-emission truck component manufacturers need to participate in manufacturing development of zero-emission and near-zero emission trucks, with clear roles, requirements, and expectations.

Infrastructure

- Planning for capacity, distribution, and siting of zero-emission and near-zero emission truck infrastructure needs to start immediately and include the utilities and fuel providers.
- Demonstration evaluations will help identify tradeoffs between speed of refueling, costs of installation and equipment, and the impacts to the power grid and local distribution capacity.

Regulations and Operating Structure

- Given the rapid timing for the rollout of an entirely new category of vehicle, it is unlikely market forces alone will be sufficient motivation. Therefore, regional and state air quality and transportation agencies need to quickly develop a regulatory framework in which zero-emission and near-zero emission trucks will be both required and rewarded.
- Air quality regulations can form a structure for the existence and need for zero-emission and near-zero emission trucks and establish timing requirements. Such rules can then be used as a "backstop" should incentives and use benefits not prove sufficient.
- An operating structure is needed that can create economic benefits for those operating zero-emission and near-zero emission trucks and disincentives for those who do not. Such a structure needs to be in place very soon, ideally within the next two to three years.
- New business models or ownership structures may be needed for the creation of a new zero-emission and near-zero emission economic ecosystem to be successful.

5 Rail Freight Emissions Reduction - Demonstration Plan Recommendations

The "Yard Switcher Using Dual Mode Battery-Assisted Locomotive" was determined as the most feasible scenario for development of a demonstration plan as part of this study through a technological assessment of zero emission locomotive technology. The dual-mode locomotive runs on electric power being supplied by a battery car (also called a "tender") which is connected to the locomotive. A switcher demonstration was proposed as it was determined to be the best choice to focus the health benefits from any emission reductions on the environmentally-disadvantaged neighborhood of West Oakland, will not impact the efficiency of interstate line-haul freight movements, and will provide an opportunity to demonstrate zero- emission technology that can later be reevaluated for more wide scale use.

5.1 Yard Switcher Using Dual Mode Battery-Assisted Locomotive Demonstration Overview

The proposed demonstration would modify an existing AC traction locomotive with a rated power of less than 2,300 horsepower run from electrical power supplied by a battery tender rather than the onboard diesel generators. Working with a switcher locomotive rated below the 1,006 horsepower threshold that is used in regulating locomotives may streamline the demonstration.

- The target operating environment would be BNSF Oakland International Gateway, UP Railport Oakland, and adjacent terminal facilities which are served by the West Oakland Pacific Railroad, LLC (WOPR), a subsidiary of Oakland Global Rail Enterprise, LLC (OGRE). Initial contact has been made with a key member of their team to refine fleet and operation details if this demonstration plan is put into place.
- Though equipment would be acquired through a competitive bid, the target technology is the Rail-Saver™ Battery Tender Car proposed by TransPower. An initial contact has been made with a key member of their team, and he provided related material from proposals that TransPower has previously prepared.

Under this concept, the BTC system will consist of a rail car filled with a large number of batteries, and electrical and data connections to the locomotive enabling the locomotive's traction motors to be powered by the batteries in the BTC, shown in Figure 5.1.

The system is described as incorporating devices enabling the train's braking system and other accessories to be powered by the batteries, which enables the locomotive's diesel engine and generator to be turned off completely, making the train capable of operating in a zero emission mode. The system would also be configured to enable braking energy to be recaptured by the locomotive's traction motors and stored in the BTC batteries during all phases of train operation – providing energy savings as well as significant emissions reductions. In concept, the battery BTC is designed to match the voltage and power output from the diesel generators on the locomotive, allowing that electrical demand to be provided from the batteries by engineering and installing an electrical connection between the diesel generator and the AC inverter. Minimal modification of the locomotive power train and control system would be required and the locomotive's existing transformers, electric motors, and control system would continue to be used.

Figure 5.1 Rail-SaverTM (Artist Concept)

As the next step in development of BTC technology, TransPower would design and build a BTC system at a scale that will achieve a proof-of-concept demonstration and set the stage for subsequent deployment of larger, commercial-scale systems. To make the demonstration project more affordable, a subscale demonstration will provide one-quarter of the capacity of a full-size commercial system. The one-quarter scale battery system in the demonstration project is thus expected to propel a switcher locomotive for a full day's operation.

The BTC design will take into consideration all applicable railroad requirements in terms of operating environment. These will include as a minimum, such aspects as loads for shock and vibration, and electrical safety. These requirements will help define the supporting structure for the battery system inside the BTC, so that it is adequate for operation in a train. TransPower would design the battery system, the battery management system (to perform the battery charging and discharging functions), the supporting structure (for shock and vibration), and any infrastructure aspects (like battery cooling or ventilation), as needed. A DC-DC converter and associated electronics to convert battery voltages to the higher voltages needed by the locomotive, would be incorporated into the design.

High-power chargers would be integrated into the tender cars enabling the BTC to be plugged into the grid with minimal external charging infrastructure, or they could be charged by the diesel generators. TransPower is adapting their battery packs to standard DC fast chargers, which are projected to become available at much higher power levels in the future. A quarter scale system as proposed would likely consist of four parallel battery strings, four 100 Kw charges would produce 400 Kwh to charge the batteries in about eight hours.

5.2 Recommendations for Demonstration Plan Implementation

Implementing a yard switcher demonstration plan includes the following steps:

- MTC should work with its partners to identify appropriate roles for each agency;
- The lead agency would need to reach an agreement with Oakland Global Rail Enterprise, LLC (OGRE) to test the proposed Battery Tender plus Charger (BTC) system in Oakland for 12 months,

or at a substitute rail-yard in the Bay Area if OGRE was not amenable to the proposed demonstration;

- An operation plan needs to be negotiated that specifies who would own the BTC system and associated infrastructure, as well as identify appropriate lease payments (if any);
- To refine costs and schedules, a Request for Information (RFI), including a bid ready set of specifications and/or system objectives, needs to be administered;
- The lead agency would then use results from the RFI to identify required resources and pursue grants and financing to pay for the BTC system demonstration;
- After funds had been identified a request for proposals would need to be conducted by the lead agency, and a vendor selected.

To defray the cost and expand the demonstration program, creation of a public-private partnership, including the modified switcher locomotive, could be created. This could facilitate demonstration of the system in multiple rail yards and potentially on short-line rail roads after the Oakland, California demonstration was completed. Additional potential funding sources are discussed in Section 6.

5.2.1 Technology Attributes to be Measured and Documented

The goals of this demonstration plan would be to document:

- Ton-miles of operation per MWH;
- Battery durability and life-expectancy under real world rail yard applications;
- Operational effectiveness and challenges of the battery tender switchers; and
- Development and certification of locomotive modifications.

5.2.2 Refinement of Demonstration Budget and Schedule

Based on a 2011 proposal to the South Coast Air Quality Management District, a prototype demonstration project could be phased to validate the concept with the initial low MWH capability first, then incorporate additional batteries and demonstrate a higher performance system. The period of performance for such a demonstration project would be about 24 months for design, acquisition, and testing, including 12 months to build the prototype BTC system and 12 months for an initial demonstration. Additional time would be required to negotiate agreements to operate the BTC system and identify grants or other financing for the BTC system.

Table 5.1 lists preliminary estimates from 2011 for developing and building a first BTC prototype. As indicated, two different options are shown – Option A is for a less expensive system with reduced power (1 MW) and energy (1 MWh) capabilities, while option B is for a 3 MW, 6.25 MWh system designed to provide sufficient energy to power large locomotives. The prices shown are not additive – they are two separate options. As indicated, a project to develop the smaller scale Rail-Saver™ system was projected to cost $3.1 million in 2011, while the larger one was estimated to cost $7.4 million in 2011. If a project started off by building the smaller system, the incremental cost to build the larger system afterward would be the difference in costs for the battery subsystem, inverters, and integration labor.

Table 5.1 Estimated Costs for the Yard Switcher Demonstration with Battery-Assist (Tender) Car

Cost Element	Option A: 1 MW, 1 MWh Prototype	Option B: 3 MW, 6.25 MWh Prototype	Estimating Rationale
Battery subsystem (batteries, BMS, wiring, containment	$800,000	$4,062,500	$800/kWh for 1 MWh prototype, declining to $650/kWh for 6.25 MWh
Inverter subsystem	$300,000	$900,000	4 inverters for 1 MWh prototype at $75,000 each. 12 inverters for 6.25 MWh
Accessory subsystem	$100,000	$100,000	Assumed to be 10x the cost of TransPower Class 8 truck accessory subsystem
Rail car	$200,000	$200,000	Extrapolated from on-line pricing data
Miscellaneous integration hardware	$200,000	$200,000	Assumed to be 10x the cost of TransPower Class 8 truck integration hardware
Nonrecurring engineering	$750,000	$750,000	5,000 hours at $150/hour
Integration labor	$750,000	$1,200,000	5,000 hours at $150/hr for 1 MWh prototype, 8,000 hours at $150/hr for 6.25 MWh
TOTAL	**$3,100,000**	**$7,412,500**	

5.2.3 Relationship between Demonstration Plan and Technology Implementation

The phase-in of evermore stringent emission controls for locomotives is mirroring the phase-in period of those technologies for on-road heavy-duty diesel trucks (trucks). In many ways trucks in turn mirrored the technology phase-in of automotive emission controls. It took both cars and trucks about thirty years to obtain a ninety-eight percent reduction in tailpipe emissions of oxides of nitrogen (NOx) and particulate matter (PM) from uncontrolled levels.

- Federal automotive regulations took hold in 1970 and continued to focus on better emission controls through about 2004; after which the majority of reductions have stemmed from increasing market share of hybrid and electric vehicle technologies.
- Federal Regulation of NOx and PM emissions from on-road heavy-duty diesel trucks began in 1985 and a 98% reduction efficiency for both pollutants was achieved with the phase-in of diesel particulate filter (DPF) and selective catalytic reduction (SCR) technologies between 2007 and 2010.

The phase-in of Tier 2 locomotive regulations is roughly comparable to the adoption of robust electronic engine control systems in trucks, and was used to time-align the implementation schedule for increasingly more stringent standards for NOx and PM from locomotives as shown in Figure 4.1[13, 14, 15, 16,]

[13] CARB (2015) EMAFC2014 Volume III Technical Documentation, California Air Resources Board, http://www.arb.ca.gov/msei/downloads/emfac2014/emfac2014-vol3-technical-documentation-052015.pdf.

[17] below. It should be noted that the actual calendar years in which new emission standards were adopted differ for locomotives and trucks (locomotive emission standards have generally lagged truck emission standards by several years) but the relative pace of technology introduction is similar. The grid on the X-axis represents the number of years between implementation of increasingly stringent controls for trucks (using the upper X-axis), and locomotives (using the lower X-axis). The scales for the implementation of the various locomotive and truck emission standards have been aligning to allow the relative pace of emissions reductions to be compared.

Figure 5.2 is intended to show the pace of reductions in emissions standards for locomotives and trucks as similar technologies were applied to locomotive and truck engine emission controls. Both truck and locomotive standards have been met by first implementing robust electronic control of the fuel injection and combustion process, reformulated fuels, reformulated engine oils, and exhaust gas recirculation (EGR). To date, locomotives have not yet implemented after-treatments such as selective catalectic reduction (SCR), and diesel oxidation catalyst (DOC), which was fully phased-in for new on-road diesel trucks between 2007 and 2010. As part of its proposed 2016 Mobile Source Strategy, the California Air Resources Board (CARB) has proposed petitioning EPA to promulgate a “Tier 5” locomotive standard that would require an additional seventy-five percent reduction in NOx and PM[18] relative to Tier 4 emission levels. Figure 4.1 suggests that such a Tier 5 standard might be achievable sometime around 10+ years after the 2015 implementation date for Tier 4 locomotives standards.

Significant market penetration of zero-emission locomotive technologies is unlikely to occur prior to adaptation of exhaust after-treatments (such as SCR and DOC), which are likely on the order of a decade away themselves.

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[14] USEPA (2016) Heavy-Duty Highway Compression-Ignition Engines and Urban Busses: Exhaust Emissions Standards, U.S. Environmental Protection Agency, report number: EPA-420-B-16-018.

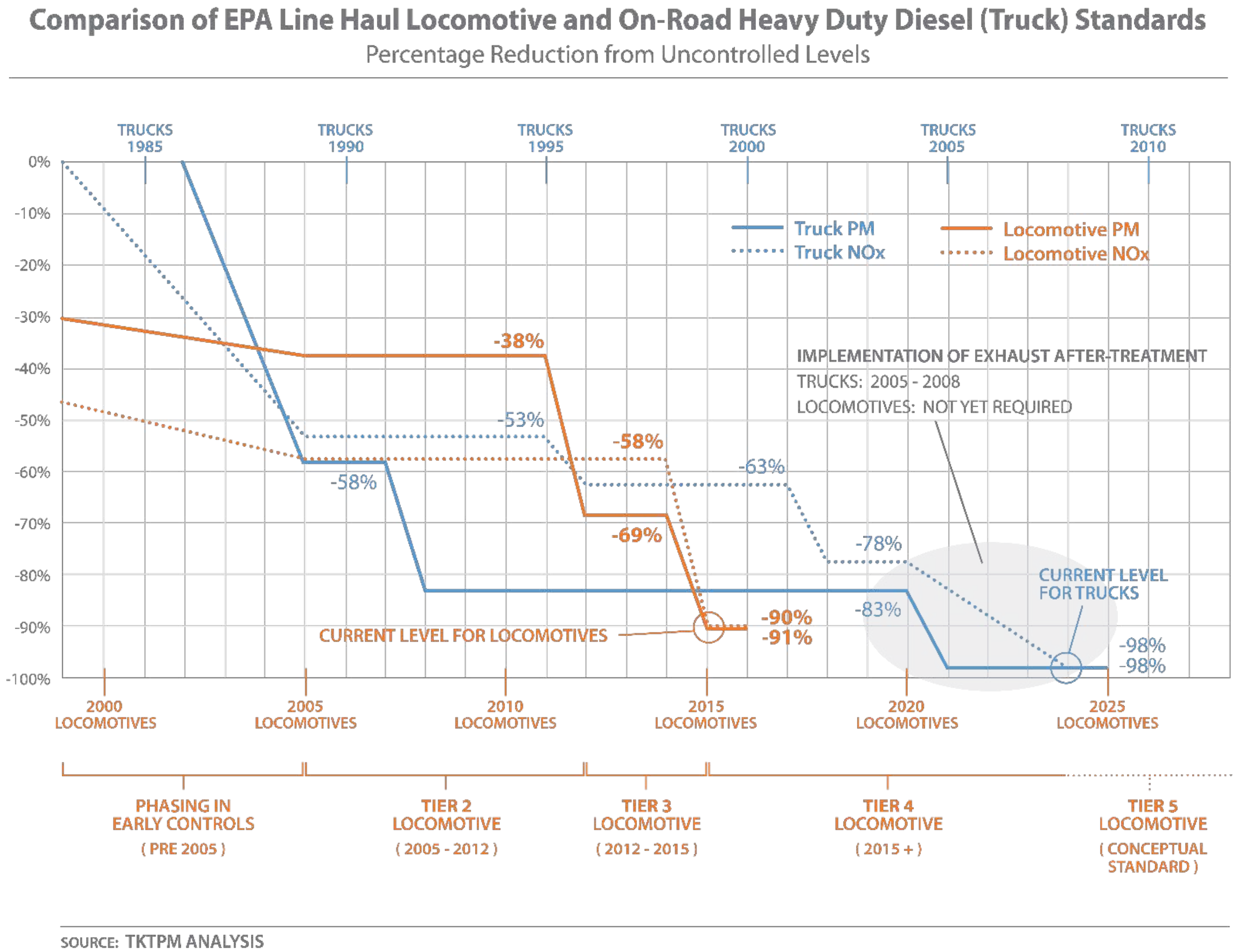
[15] USEPA (2009) Technical Highlights: Emission Factors for Locomotives, U.S. Environmental Protection Agency, report number: EPA-420_F_09_025.

[16] CARB (2009) Technical Options to Achieve Additional Emission and Risk Reductions from California Locomotives and Railyards, California Air Resources Board, www.arb.ca.gov/railyard/ted/083109tedr.pdf.

[17] CARB (2008) Proposed Regulation for In-Use On-Road Diesel Vehicles, Appendix G: Emissions Inventory Method and Results, California Air Resources Board, www.arb.ca.gov/regact/2008/truckbus08/appg.pdf.

[18] CARB (2016) Draft Technology Assessment” Freight Locomotives, California Air Resources Board, www.arb.ca.gov/msprog/tech/techreport/freight_locomotives_tech_report.pdf.

Figure 5.2 Comparison of Line Haul Locomotive and On-Road Heavy Duty Diesel Emission Standards



5.3 Expansion of Demonstration Program and Next Steps

Once the dual-mode locomotive is successfully demonstrated in the yard switching environment, there are potential opportunities to build off of this demonstration plan to facilitate use of zero-emission rail technology in other yards and on short-line or short-haul rail in the Bay Area. Although adoption of zero-emission technology for line-haul rail operations will require more efforts at the national level and coordination with the private sector than MTC and its regional partners are able to accomplish, there are opportunities to build upon the yard switcher demonstration in a way that supports regional and state goals and contributes to the development of this technology.

As part of its rail planning process, the State of California is developing potential future scenarios for the rail infrastructure in the state, ultimately identifying areas of opportunity for new approaches, and links between existing freight and passenger service and high speed rail. Although there is some discussion that over 20 years the region will electrify, this will occur first on lines that are run by agencies that own their own track, in areas with low levels of freight traffic, such as the Caltrain corridor, which is schedule to complete switch to electric operation by 2021. Successful electrification and demonstration of electric locomotives by Caltrain may spur electrification efforts on rail lines with much heavier and significant freight service such as the Capitol Corridor.

Although most plans for electrified systems rely on catenary, operational obstacles such as double-stack intermodal service will limit the use of overhead catenary systems on certain corridors. And if corridors in the Bay Area or any region were to electrify in a way that impacted the way that long distance freight is carried, this will increase the inefficiencies in the national freight rail network, a potential future that is strongly unsupported by the Class 1 rail operators, and unlikely to come to pass. More likely, these parties would support efforts to move towards Tier 5 locomotives, rather than electrification of the system.

However, an alternative option for electrification is use of battery tender cars. This option does not require the investment in or challenges of an overhead catenary system. The experience with battery tenders in the switching yard could support deployment of battery tender electrification of passenger of freight rail of key corridors in the region, supporting potential state or regional goals of electrification, without the constraints of a catenary system. With this in mind, if the switcher demonstration is successful and progress is made on power management and safety of battery tender technology, MTC and its regional partners can play an active role in finding the next opportunity for demonstration of the technology on a line with low power needs, such as the Capitol Corridor commuter rail or a shortline.

It is important to also note the existing BAAQMD and ARB programs to facilitate the adoption of Tier 4 locomotives by short-line and switcher operators, and that these programs are currently working to replace older switcher locomotives with the Tier 4 technology. As locomotives have a relatively long replacement cycle, it is unlikely that owners and operators will be interested in replacing new Tier 4 locomotives with electrified alternatives in the short-term. Therefore, it is important to effectively coordinate programs aimed at reducing emissions from locomotives in the region. As Tier 4 (and Tier 5) locomotives are more widely adopted, the incremental emissions difference between the locomotive standard and zero-emission locomotives becomes smaller. MTC and its regional partners should examine the differences and the benefits of promoting zero-emission locomotives, versus encouraging faster adoption of the Tier 4 standard to determine which approach is the most effective and efficient way to reduce locomotive emissions.

6 Funding Sources

The implementation of this Action Plan will require funding from a variety of different sources. Funding is available at the federal, state, regional, and local level to support a wide range of actions described in this action plan including technology development and demonstration, purchase incentives and market development programs, and infrastructure deployment. In reviewing funding opportunities, it is important to keep the following characteristics of different sources in mind:

- A number of programs that have been available over the last decade that are beginning to wind down. Those that were focused on freight and trucking often funded alternative fuel applications. Now that zero- and near-zero emission truck technologies are beginning to move closer to commercial application, it makes sense to renew some of the programs that have allocated all of their original funding. This could include funding sources such as the California Prop 1B funding that was available and used to help transition trucks to cleaner alternative fuels but had limited application to zero-emission vehicles because of the stage of development these technologies had achieved when the funding was available.
- Some programs, particularly those that support charging infrastructure deployment, that are designed for light-duty applications and do not fit the needs of trucking fleets.
- Some programs are available in other parts of California are not currently available in the Bay Area. These include certain voucher programs that build on incentives offered through the California Air Resources Board (ARB) and technology advancement programs. It is worth considering these in the future but they will require new local funding sources.

The following sections describe existing federal, state, and regional/local funding programs and their applicability to support different types of recommended actions for this plan.

6.1 Federal Funding

- The US Environmental Protection Agency (EPA) administers grant funding to reduce emissions through its Diesel Emission Reduction Act (DERA) program. Recent funding cycles have prioritized projects that reduce emissions from equipment involved in freight movement. The intent of the DERA programs is to fund retrofit, repowering, or replacement of older diesel engines with lower emission engines. There are various eligibility criteria for different types of diesel applications but replacement of diesel trucks with electric trucks meets eligibility criteria. The National Grants program will award $26 million in 2016. Eligible applicants include regional, state, local or tribal agencies/consortia or port authorities with jurisdiction over transportation or air quality, including air districts, Metropolitan Planning Organizations (MPO), and municipalities. States also receive an allocation of grants to provide loans, grants, or rebates. In 2015, California received $418,650. Recently, as part of the 2016 EPA solicitation, the Bay Area Air Quality Management District was tentatively awarded $1,420,263 for the replacement of three switcher locomotives with Tier 4 engines.
- The US Department of Energy (DOE) administers funding solicitations to support the development of advanced equipment technologies. These projects can help move technologies through the research & development phase and into commercialization and deployment.
- The Fixing America's Surface Transportation (FAST) Act provides new funding for ITS projects such as vehicle-to-vehicle and vehicle-to-infrastructure technology as well as infrastructure maintenance systems, alternative charging systems, and information sharing systems that could

involve a freight component. The bill also explicitly makes ITS-related projects eligible for funding under several formula programs including the National Highway Freight Program (NHFP) and Fostering Advancements in Shipping and Transportation for the Long-term Achievement of National Efficiencies (FASTLANE) Program. These new programs are included in Section VI of the bill called the “Transportation for Tomorrow Act of 2015.” One new funding program in this Section is the Advanced Transportation and Congestion Management Technologies Deployment Program. This competitive grant program will focus on the development of pilot projects and model deployment sites for the installation and operation of advanced transportation technology.

6.2 California State Funding

- Proposition 1B – $1 billion bond program to ARB to reduce freight air pollution, and the associated health effects, on impacted communities along California’s trade corridors. The program, locally administered by the Bay Area Air Quality Management District, has funded shore power and truck upgrades (retrofits and replacements) in the Bay Area, and is currently in the final cycle of funding. In addition to trucks and shore-power, project opportunities also exist for cargo-handling equipment, transportation refrigeration units, and locomotives. Zero-emission and near-zero emission trucks that are market ready have been eligible for grants under this program as long as they are certified by ARB and meet other eligibility criteria. Grants are available for eligible Class 6-8 trucks. BAAQMD anticipates a final solicitation late in 2016, after which the program will be discontinued unless a new source of funding is made available.
- The Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program) provides grant funding for cleaner-than-required engines and equipment. The program is authorized at $69 million per year statewide and is funded by Department of Motor Vehicles smog abatement and tire fees. These funds are allocated annually to local air districts to award to projects in their regions. Historically, this has provided $7-$10 million per year to the BAAQMD to distribute to eligible projects in the Bay Area. The Carl Moyer Program provides grants to upgrade or replace heavy-duty vehicles and equipment, school buses, agricultural equipment, marine vessels, and locomotives. This program cannot be used to demonstrate new technologies. .
- ARB’s Low Carbon Transportation Investments and Air Quality Improvement Program projects provide incentives to reduce greenhouse gas emissions, criteria pollutants, and toxic air contaminants through the development and deployment of advanced technology and clean transportation. California Cap-and-Trade auction proceeds support Low Carbon Transportation investments. Per statute, these funds must further the purposes of Assembly Bill 32 (AB 32; Núñez, Chapter 488, Statutes of 2006) with a priority for benefitting disadvantaged communities. The current freight-related Low Carbon Transportation and Air Quality Improvement Program Projects include Advanced Technology Demonstration Projects, Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project, Zero-Emission Truck and Bus Pilot Projects, and Truck Loan Assistance Program.
    - During 2015 and 2016, ARB conducted two solicitations under the Advanced Technology Demonstration Projects program. These focused on demonstration of full zero-emission drayage trucks and demonstration of a multi-source facility program that could significantly reduce emissions from multiple sources located at the same facility. A total of $25 million each was allocated to these programs. Future solicitations will continue

this approach to technology demonstration but will likely focus on other applications. The Zero-Emission Truck and Bus Pilot Projects program was also a demonstration solicitation with a focus on projects that will benefit disadvantaged communities. It is expected that a similar program will continue in the future.
    - The Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project provides purchase incentives at the point of sale to simplify and speed the process of providing incentives to purchasers of eligible equipment. Manufacturers must submit applications to the program to be included in the list of eligible equipment. Vouchers range between $20,000 and $110,000 per truck depending on the size of truck, the equipment, and whether the truck is garaged in a disadvantaged community.
- The Low Carbon Transportation Investments and Air Quality Improvement Program is funded out of the 60% of Cap and Trade auction proceeds that are permanently designated for specific programs by the legislature. The remaining 40% of auction proceeds are allocated by the legislature based on annual priorities. There has been some discussion in the legislature about the possibility of creating a targeted goods movement program that is funded on an ongoing basis out of a portion of the 40% unallocated Cap and Trade funds. The specific uses of these funds have not been determined and no legislation to create this set-aside has been approved at this time.
- The Alternative and Renewable Fuel and Vehicle Technology Program authorizes the Energy Commission to develop and deploy alternative and renewable fuels and advanced transportation technologies to help implement the State's climate change policies. The Energy Commission has an annual program budget of approximately $100 million to support projects around the State.
- CEC funding for Freight Transportation Projects at Seaports. Eligible projects have included those that: 1) demonstrate freight transportation projects (FTP) for medium- and heavy-duty (MHD) vehicle technologies; 2) demonstrate intelligent transportation systems and technologies (ITS); and 3) deployment of natural gas vehicles (NGV). More information at: http://www.energy.ca.gov/contracts/GFO-15-604/.
- The California Alternative Energy and Advanced Transportation Financing Authority, in the State Treasurer's Office, works collaboratively with public and private partners to provide innovative and effective financing solutions for California's industries. It assists in increasing the development and deployment of renewable energy sources, energy efficiency, and advanced transportation and manufacturing technologies to reduce air pollution, conserve energy, and promote economic development and jobs.
- The California Pollution Control Financing Authority, in the State Treasurer's Office, provides low-cost innovative financing to California businesses (including freight sector businesses) for qualifying projects that control pollution and improve water supply. The California Pollution Control Financing Authority also partners with State agencies to achieve the State's environmental policy objectives by administering high-impact financing programs designed to assist regulated entities and other stakeholders with accessing private capital.
- The California Infrastructure and Economic Development Bank uses its Infrastructure State Revolving Fund program to provide financial assistance to public agencies and non-profit corporations for a wide variety of infrastructure and economic development projects. Recently, Assembly Bill 1533 (Chapter 383, Statutes of 2015) amended the Infrastructure State Revolving Fund program by expanding project criteria to include goods movement-related projects.

6.3 Bay Area Regional Funding

- The Bay Area Air Quality Management District collects a $6 per vehicle registration fee that it administers through its Transportation Fund for Clean Air (TFCA) and Mobile Source Incentive Fund (MSIF) programs for projects that reduce emissions from primarily mobile sources. Through the MSIF program, the Air District provides grants to public and private sector entities for projects that are eligible for the Carl Moyer Program, vehicle scrappage and agricultural assistance programs, and for projects to reduce pollution from school busses. The TFCA program funds cost-effective projects that reduce on-road motor vehicle emissions within the BAAQMD's jurisdiction. Sixty percent of TFCA funds are awarded through the Air District's TFCA Regional Fund program. The remaining forty percent of these revenues are distributed to the designated County Program Manager in each of the nine Bay Area counties for emission reduction projects. TFCA funding has been used for vehicle-based projects, and trip reduction projects and must be related to on-road sources. These funds could be used for electric vehicle charging infrastructure.
- Congestion Mitigation and Air Quality (CMAQ) funds – MTC has access to discretionary CMAQ funds that are programmed to our region for the purpose of reducing congestion or improving air quality, and, more recently, have been (at least partially) focused on assisting MTC in meeting the region's GHG emission reduction goals enacted per Senate Bill 375. Since SB 375 mandates focus on passenger vehicles and light trucks, the amount of funds available for freight projects may be limited. However, funds may be available in the future to include a new a focus on the zero- and near-zero emission technologies that have been identified in this study as having high potential.
- Alameda CTC Measure BB Transportation Expenditure Plan – A number of Bay Area counties have passed sales tax measures to fund a variety of transportation improvements. Alameda CTC developed a Transportation Expenditure Plan (TEP) to guide investments supported by the County's Measure BB Sales Tax. Included with the TEP are $77.4 million (over the life of the measure) to fund Technology Development and Innovation projects. While these are primarily intended to support advanced technology applications such as new ITS programs (some of which could include the ITS technologies described in this study). It is also possible that some of this funding might be available for zero- and near-zero goods movement projects but given the amount of funding available, it might be difficult to come up with projects that would have a significant impact.