Zero Emissions 2020

The Clean Air Plan of the San Francisco Municipal Railway

Muni's Goal

Muni has set a course to be the first major transit agency in the world to operate a 100% zero emissions fleet by the year 2020. To achieve this unprecedented goal, Muni has chosen a strategy that capitalizes on its longstanding expertise in electric drive vehicles. For almost 70 years, Muni has continuously operated a network of zero emission cable cars, streetcars, electric trolley buses, and modern light rail vehicles. These electric vehicles not only make Muni the cleanest transit system in California today by CARB standards, they also position Muni to continue its leadership with an all-electric fleet by 2020.

Muni's 2020 zero emission fleet will be comprised of:

Electric Light Rail Vehicles
Electric Trolley Buses
Battery *Electric* Buses
Fuel Cell *Electric* Buses
Cable Cars, Muni's first *Electric* vehicle

Muni's Path to Zero Emissions

To achieve zero emissions by 2020, Muni will expand its electric fleet, replacing conventional diesel buses with the next generation of electric drive bus technologies. Hybrid electric buses and battery electric buses will be Muni's next new bus procurements. Fuel cell electric buses will begin appearing in Muni's fleet in 2016 (or earlier if available) and are anticipated to complete the shift to 100% zero emission vehicles by 2020.

Muni's Clean Air Plan

Muni has a three-part strategy to achieve the lowest possible overall fleet emissions on its way to a 100% zero emission fleet.

1) Maximize the Use of Zero Emission Vehicles (ZEVs)

Muni expansion of the light rail system along major corridors, including the Third Street Light Rail, is part of a long-term effort to shift an increasing number of daily trips to zero emission vehicles. Muni's recent procurement of 273 new electric trolley coaches ensures continued service on Muni's 16 existing electric routes. Muni's Electrification Study, published in December 2002, prioritizes existing non-electric routes for electrification with overhead wires.

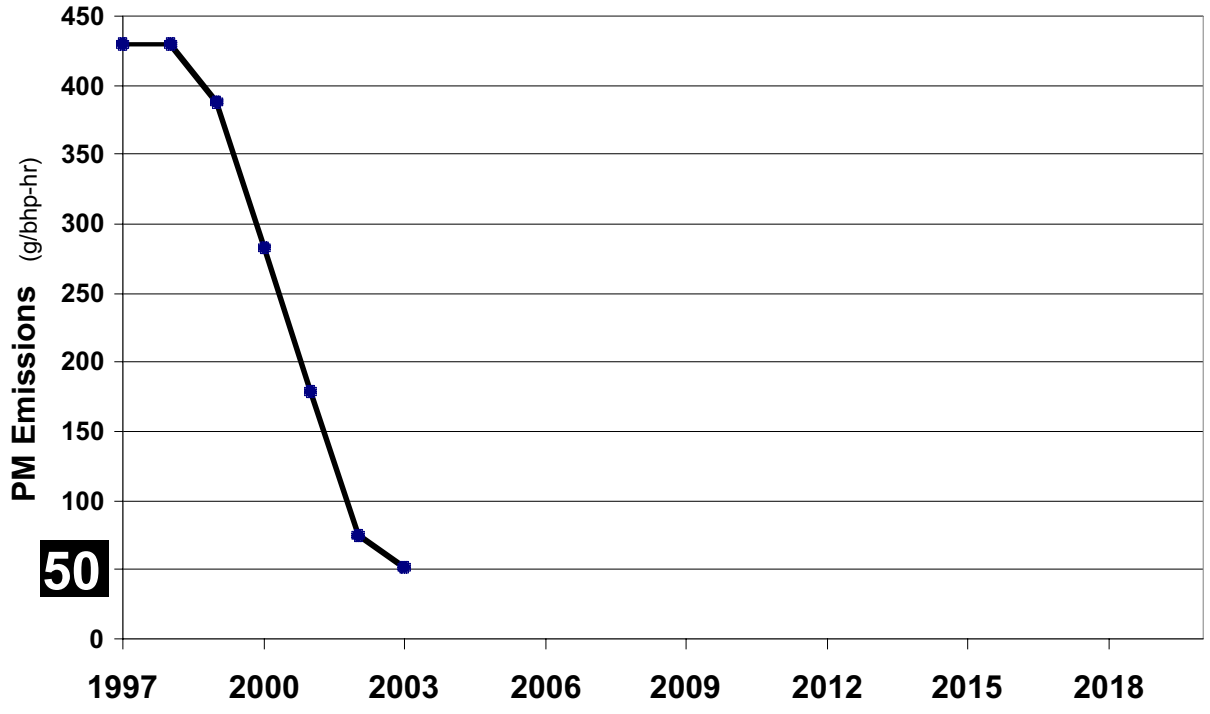
2) Replace Conventional Diesel Buses with Electric Drive Buses

Hybrid electric buses use a small on-board engine to generate electricity for the electric motor. This requires less fuel and produces less emissions than conventional engine-driven buses. Battery electric buses with a 100-mile range are currently being developed for the American transit market. Muni will be the first transit property in the country to consider making significant use of this emerging technology in regular service. Both hybrid electric and battery electric buses will replace conventional diesel buses in Muni's next two bus procurements.

3) Update Remaining Diesel Buses to State-of-the-Art Low-emission Diesel Standards

Muni has reduced Particulate Matter (PM) emissions by 88% from 1997 to 2003. This reduction was achieved with an aggressive bus replacement program that removed 375 old diesel buses from the Muni fleet. By 2007, Muni will reduce PM by 98% from 1997 levels by installing new low-emission engines on older buses and adding PM/NOx reduction devices to all low-emission diesel buses. Lastly, Muni will seek local funding to update its reserve fleet to state-of-the-art low-emission diesel standards.

Muni Reduced PM emissions 88% from 1997 - 2003



Clean Air Plan: 1996 - 2020

Major Goals

2003 88% reduction in PM (Particulate Matter) since 1997

2004 PM/NOx reduction devices installed fleet wide

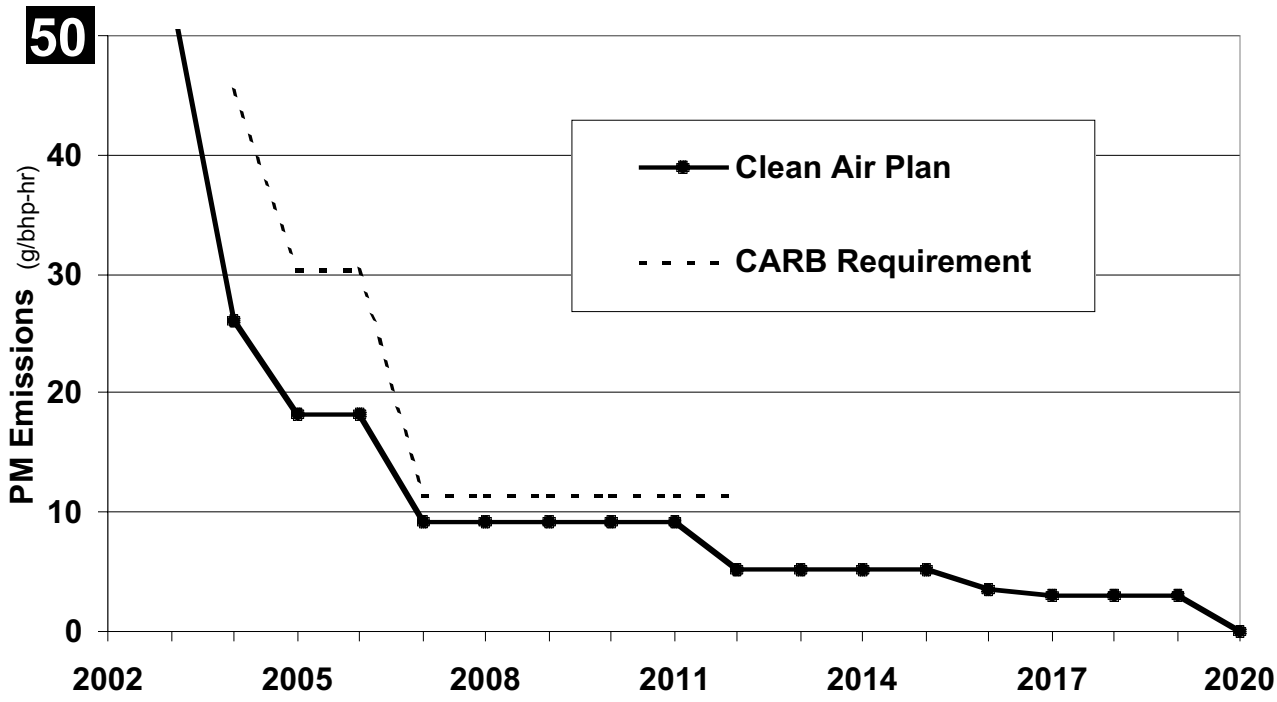
2007 98% reduction in PM since 1997

2012 62% of Muni's vehicles are ZEVs or Hybrids, including 52% of the bus fleet

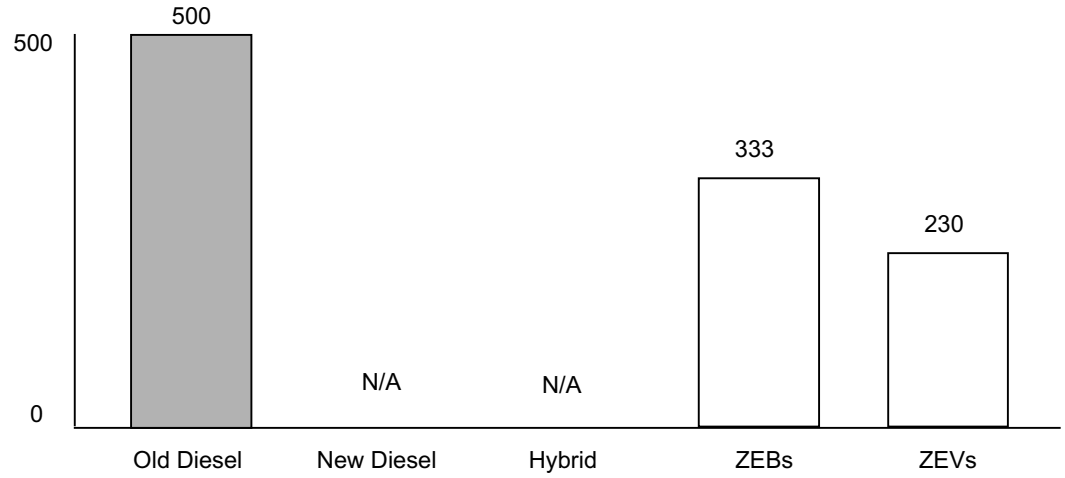
2015 66% of Muni's vehicles are ZEVs or Hybrids, including 57% of the bus fleet

2020 100% of Muni's fleet are ZEVs

PM Emission Models for Muni Fleet from 2002 - 2012



1996



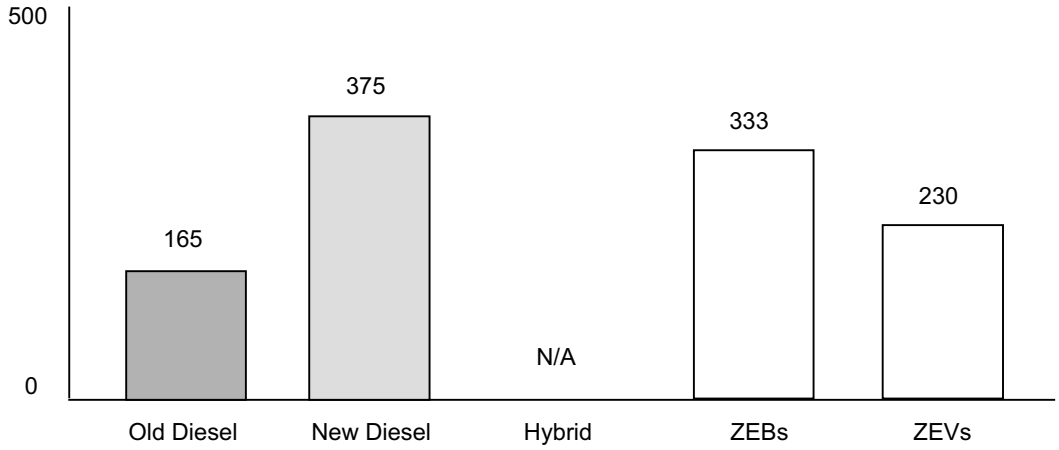
Goals Met 1996 - 2003

- *1996* – Introduced initial Fleet Plan calling for rapid turnover of ALL active pre-1996 motor coaches (455 buses) which would have reduced PM emissions by 98% by the end of 2003 (note: Transportation Authority approved funding for only 80% turnover)
- *1999* – Grew fleet size by 45 buses to meet increased service demands
- *2002* – Converted to Ultra Low Sulfur Diesel fuel ahead of CARB requirements - Muni is the only CCSF department to use this premium diesel fuel (90% less sulfur)
- *2003* – Lowered PM emissions 88% since 1997
- *2003* – Completed Alternative Fuels Pilot Project (AFPP) on CNG and Hybrid-Electric buses – formalized procedures for new technology evaluation and selection
    - Established Hybrid-Electric buses as Muni's preferred technology choice
    - Qualified two technologies still in development – HPDI-LNG (High Pressure Direct Injection Liquefied Natural Gas) and Battery-Electric – as potential future options
- Maintained full compliance with annual CARB, BAAQMD, and EPA emission requirements

Clean Air Plan Status

- 53% of Muni's vehicles are ZEVs, including 38% of the bus fleet
- 57% of Muni passenger trips are on ZEVs. This equals roughly 400,000 passenger trips per weekday (for comparison: BART provides roughly 300,000 passenger trips per weekday)
- Muni has as many ZEBs (330+) as all other transit agencies in the United States combined (and by itself it would be the 4th largest transit bus fleet in California)

2004



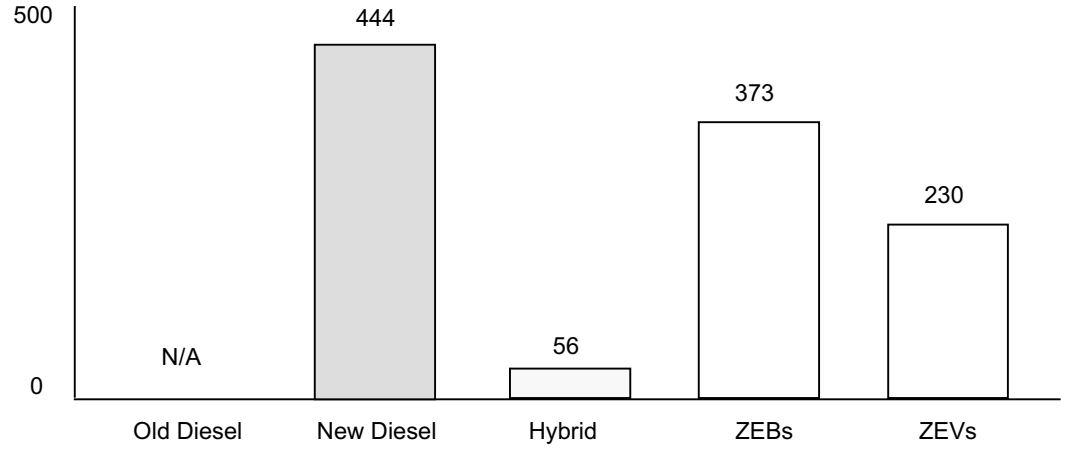
Goals

- Install PM/NOx reduction devices on Muni's 375 low-emission diesel buses by the end of 2004
- Muni has the lowest average bus NOx emissions in California
- Provide regional and statewide leadership as CARB considers changes to its Transit Bus Fleet Rule
- Release RFP for Muni's first Hybrid-Electric bus procurement
- Release RFP for Muni's first Battery-Electric bus procurement (dependent upon manufacturer product advancements)
- Establish a new funding source to address the repowering or replacement of reserve fleet buses to low-emission diesel standards or better
- Investigate the potential use of biodiesel as a near term fuel supplement and as an eventually self-sufficient (Bay Area-produced) fuel supply

Clean Air Plan Status

- Maintain full compliance with annual CARB, BAAQMD, and EPA emission requirements – including higher January 2004 PM standards
- Revise Clean Air Plan to be the framework for 98% PM reduction by 2007, and strategic incorporation of new technologies positioning Muni to be an early adopter of fuel cell buses

2007



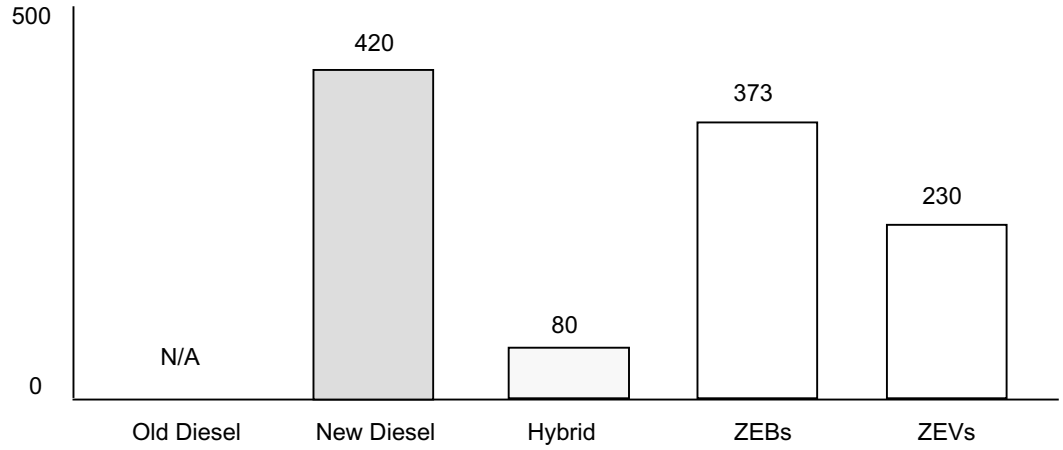
Goals

- PM emissions lowered 98% since 1997
- Muni has the lowest average bus PM emissions in California
- 60% of Muni's vehicles are ZEVs or Hybrid-Electric, including 49% of the bus fleet
- Manage bus procurement and retirement so that the oldest buses in Muni's fleet are low-emission diesel (1999 or newer) with PM/NOx devices installed

Clean Air Plan Actions

- Complete 40' Hybrid-Electric bus procurement (56 buses)
- Enter final stages of a 30' Battery-Electric procurement (40 buses) – Hybrid-Electric buses if battery-powered buses are not available
- Complete the installation of low-emission diesel engines in the remaining 1989 40' buses (all 45 in reserve fleet) and 1991 60' buses (24). (See *Reserve Fleet Funding* under *Other Projects* later in this document.)
- Remain in full compliance with all CARB, BAAQMD, and EPA emission requirements – including higher 2007 PM standards

2012: MUNI'S 100-Year Anniversary – 75 Years of Continuous ZEB Operation



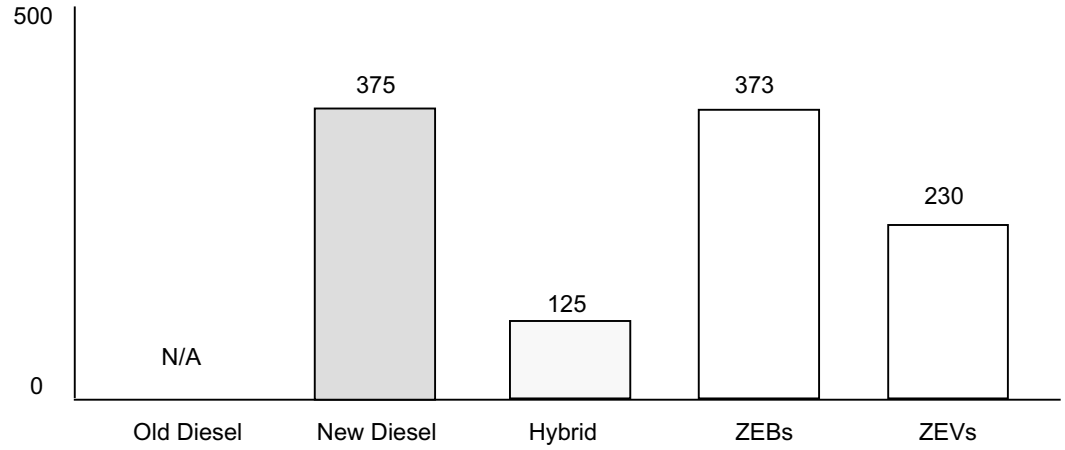
Goals

- 62% of Muni's vehicles are ZEVs or Hybrid-Electrics, including 52% of the bus fleet
- The Islais Creek ZEB maintenance facility is completed and in full operation? (2008)

Clean Air Plan Actions

- Aggressively pursue the purchase of 24 60' ZEBs for this year's replacement buses. (Note that while the bus industry is moving forward by introducing ZEB technologies as the eventual replacement for conventional bus engines, it is anticipated that ZEBs may still be cost prohibitive or otherwise not available for large procurements of 60' buses in the 2010-12 timeframe. If ZEBs are not available for this application, this procurement will be Hybrid-Electric).
- Aggressively pursue the purchase of 45 40' ZEBs for 2013. While the 60' buses in 2012 will likely be Hybrid-Electric, there is a better chance that ZEB technologies will be an option for large purchases of relatively lighter 40' buses.

2015



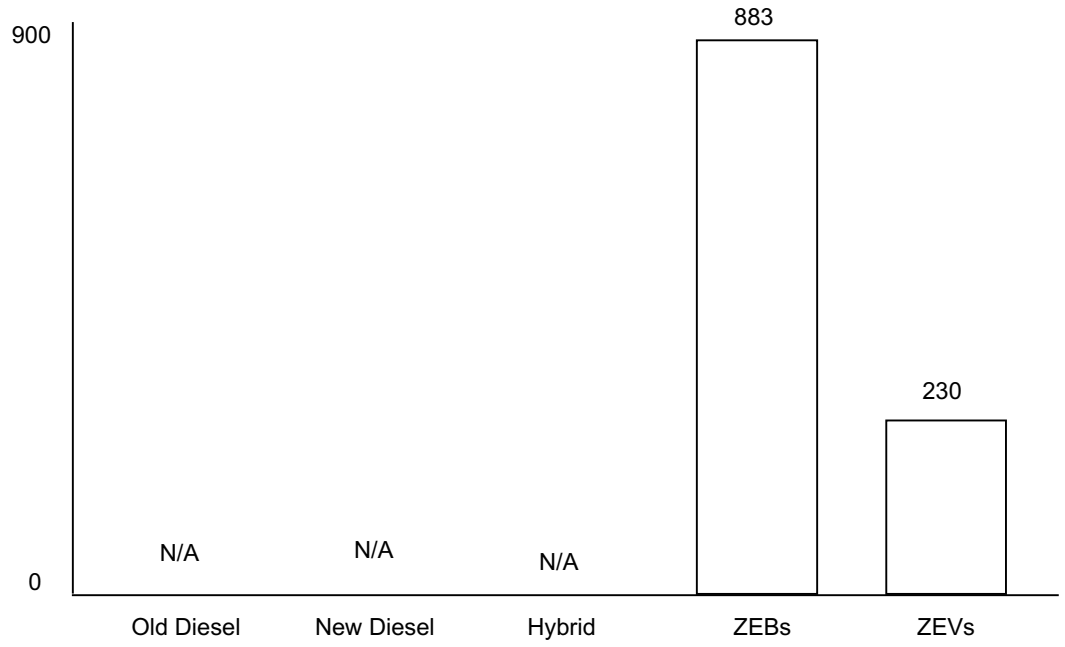
Goal

- 66% of Muni's vehicles are ZEVs or Hybrid-Electrics, including 57% of the bus fleet

Clean Air Plan Actions

- Muni is in pre-production phase for 2016-17 procurement of 206 40' ZEBs
- Muni is in pre-production phase for 2016-17 procurement of 124 60' ZEBs

2020



Goals

- 100% of Muni's bus fleet are ZEBs
- Muni becomes the first multi-mode transit agency in the world to have all passenger trips 100% zero emission

Clean Air Plan Actions

- Repower the oldest buses in the fleet (45 2006 40' Hybrid-Electrics) with ZEB technology in order to completely phase out the remaining emissions producing buses (5% of the bus fleet).
- The 2012 and 2013 purchases (45 40' buses; 24 60' buses), if Hybrid-Electric, are upgraded with ZEB technology in place of mid-life engine rebuilds.

Summary of Current Projects

Background on Bus Technologies

Hybrid-Electric buses have been chosen as Muni's preferred "next-step" bus technology because:

1) They build on Muni's existing competency in electric drive systems
2) They position Muni to be an early adopter of zero-emission fuel cell technology

Battery-Electric buses could soon be available in a commercial application suitable to Muni's 30' bus needs. Vehicle range is presently the limiting factor for this technology when applied to 40' and 60' transit bus applications (heavier buses, longer runs).

LNG (Liquefied Natural Gas) in a compression-ignition application (HPDI-LNG) has also been identified as a suitable technology; however no manufacturer is currently developing an engine that matches Muni's operating specifications. If available in the short term, the procurement of natural gas buses could serve as a useful "stop-gap" measure allowing Muni to replace it's oldest unreliable buses. However, in future procurement cycles, natural gas buses would need to be phased out as quickly as possible in favor of electric drive buses (Hybrid-Electrics, Battery-Electrics, and fuel cells) if Muni is to continue to make significant reductions in emissions.

CNG (Compressed Natural Gas) buses failed Muni's AFPP testing and are not being considered for the Muni fleet. Poor reliability and performance were shown to be significant concerns in San Francisco tests. These inherent limitations of spark-ignited engines are unlikely to be addressed by any near-term technology refinements. This conclusion is supported by the engine manufacturers. Muni's two-year experience with CNG buses helped to identify operational safety concerns throughout the City that will need to be addressed prior to wide use of large fuel cell (hydrogen) vehicles. Muni also gained valuable knowledge regarding lighter-than-air gas fueling, storage, and facility requirements – all of which will aid future fuel cell implementation.

Major Projects

40' Hybrid-Electric Bus Procurement

Muni's 1988/89 40' diesel buses have been the top priority for replacement since the original replacement plan was not fully approved by the Transportation Authority in early 2001. Muni intends to replace these remaining buses with its first Hybrid-Electric bus procurement. The procurement process depends on:

1) CARB rules changes necessary to allow Muni's preferred form of Hybrid-Electric technology to be purchased in California

2) Industry response and availability of production capacity

3) Funding for the incremental cost of Hybrids over conventional diesel buses

Note that the procurement process will include a significant and thorough production prototype phase to ensure the success of this emerging technology. Buses from this procurement would be expected to begin arriving at Muni in 2006.

30’ Bus Procurement

Forty (40) 30’ buses are 1990 diesels. Funds are being programmed from regional sources that will allow Muni to begin a procurement process to replace these buses starting in 2004. This 30’ procurement could be the nation’s first application of battery-powered buses with a major transit agency. Alternatively, this procurement may be Muni’s second Hybrid-Electric bus procurement. Buses from this procurement would be expected to begin arriving at Muni in 2006-2007.

Currently, there are no major transit bus manufacturers producing a battery bus; Muni’s ability to pursue battery buses will depend on manufacturer product offerings available in 2004. Several propulsion system and minor bus manufacturers are in the process of prototyping battery-powered buses in a 30’ transit bus configuration. Muni hopes to be able to establish a working prototype project based on one of these small efforts, and encourage a major bus manufacturer to invest in this technology for applications in San Francisco and other U.S. cities. The intention is to directly base the 30’ bus procurement on successful prototype development.

60’ Articulated Repower

Twenty-four (24) 1991 diesel buses are to be repowered to modern low-emission diesel standards by the end of 2005. These buses will meet the same emission standards as any of Muni’s 2003 state-of-the-art low-emission diesel buses. This repower will extend the useful life of these buses by seven years (through 2012).

Cleaire Device Retrofit

All of Muni’s modern low-emission diesel buses (including repowers) can be retrofit with combined PM and NOx devices to further reduce emissions. 375 buses are scheduled for retrofit by the end of 2004. Buses that are repowered after this time will be retrofit as part of the repower process.

Other Ongoing Projects

Reserve Fleet Funding

Muni is working to find funding resources to address emissions from the reserve fleet. Regular funding sources are not available to apply to the reserve fleet, but local funding and a spending plan is being considered. While funding to replace the reserve fleet with new buses may be beyond reach, minimal funding to repower or replace reserve buses with low-emission diesels would greatly improve emissions from this portion of the Muni fleet.

CARB

Muni is working closely with CARB to stay informed of proposed changes to the Transit Bus Fleet Rule. These changes are essential to Muni’s progress on the pending Hybrid-Electric bus procurement.

LNG

Muni continues to monitor the progress of the Cummins-Westport compression ignition (HPDI) LNG engine – which is based on the 11-liter ISM engine that Muni already uses in 375 buses. Unfortunately, their development plans for this engine have been put on hold due to a lack of research and development resources. Plans for a similar engine, the larger 15-liter ISX used by San Francisco's NORCAL Waste Systems, have also met with significant development delays within the last year.

Biodiesel and Alternative Fuel Investigations

Diesel engines were originally designed to be fueled with peanut oil. Similarly, biodiesel offers the potential for Muni to fuel its diesel bus fleet with locally recycled restaurant waste oils, uniformly processed, and residing in Muni's existing underground fuel storage tanks. Biodiesel can be mixed with conventional diesel (at 20% or B20 - for example), or it can be used in its pure form (B100). While potential is great, issues related to increased NOx emissions, availability, cost, performance, and vehicle compatibility remain. Despite these concerns, the City of Berkeley has already decided to fuel its entire diesel fleet with B100. Note that CARB will have to approve this fuel before Muni could legally adopt it. Muni will continue to work closely with Berkeley and other municipalities as they explore this fuel. Synthetic diesel and diesel emulsion are also alternatives to ultra low sulfur diesel that are being investigated.

California Fuel Cell Partnership

The CaFCP is a collaboration of vehicle manufacturers, energy providers, fuel cell technology companies, and government agencies. In addition to testing the fuel cell vehicles, the partnership is examining fuel infrastructure issues and beginning to prepare the California market for this new technology.

To gain insight into the viability and timing of fuel cell technology, Muni participates in many CaFCP events and demonstration projects. AC Transit is a member of the CaFCP, and together with Golden Gate Transit, VTA, and SamTrans, they will be formally evaluating six (6) fuel cell buses beginning in 2005. Unlike these agencies, Muni is not required by law to demonstrate fuel cell buses (due to the fact that Muni already operates over 330 ZEBs), however, Muni intends to be an active participant in these evaluations in order to better inform future procurement decisions. This may include performance and range testing in San Francisco, in addition to regular project debriefings.

Islais Creek Maintenance Facility

Muni has completed construction plans for a new maintenance facility focused on electric drive vehicles and lighter-than-air fuels. Lighter-than-air fuels require specific safety accommodations including non-spark electrical fixtures, gas detection devices, and custom ceiling design/ventilation, all of which have been incorporated into the Islais Creek design since project inception. The new facility, scheduled for completion in 2008, will position Muni to be an early adopter of fuel cell buses and interim bridge technologies using electric drives and lighter-than-air fuels.