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MANAGEMENT, OPERATIONS AND ENGINEERING CONSULTING

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ELECTRIC TROLLEYBUSES FOR THE LACMTA'S BUS SYSTEM

PREPARED FOR THE ADVANCED TRANSIT VEHICLE CONSORTIUM UNDER CONTRACT NO. OP 3320661

EXECUTIVE SUMMARY

California Air Resources Board (CARB) Adopted Urban Bus Transit Rule for 2010 Emission Standards requires that MTA, starting in 2010, set aside 15% of all bus purchases to acquire Zero Emission Vehicles (ZEVs). Currently, none of the buses in the MTA's inventory can be classified as ZEV, nor there are any transit buses [defined as propelled by an internal combustion engine (ICE) powered by either diesel or alternate fuels] available on the market that can be classified as ZEV. The California emission standards are well ahead of those for the rest of the United States and the manufacturers will not develop suitable vehicles on their own unless incentivized by large customers such as LACMTA. Failure to meet the 2010 Emission Standards will result in regulatory punitive fines and potentially litigation.

It is important to note here that this is not the first time that the subject of incorporating electric trolleybuses into the MTA's bus system comes before the MTA Board of Directors. In the 1992 30-Year Integrated Transportation Plan, electric trolleybuses were the preferred solution to meet CARB air regulations. The Plan provided for 18 routes, 300 miles of overhead wires and 400 peak electric trolleybuses by 2004 to be increased to 1,100 peak electric trolleybuses by 2010. Eventually, the Board voted to terminate the project.

After reviewing the various technologies that might qualify as zero emissions under CARB rule, the report focuses on electric trolleybuses as the technology of choice. The history, the current applications as well as the engineering and the economics of the trolleybuses are all covered to some depth. A strategic proposal for introduction of electric trolleybuses to the MTA's bus system is outlined.

The report recommends that MTA will:

- Formally add electric trolleybuses to its long- and short-range plans as the primary (but not exclusive) option to meet the 2010 CARB's emission standards.
- Formalize the electric trolleybus feasibility study to include potential routes identification and project costs.
- Enter into formal, preliminary negotiations with LADWP and other electric power suppliers to form public-public and/or public-private partnerships.

INTRODUCTION

California Air Resources Board (CARB) Adopted Urban Bus Transit Rule for 2010 Emission Standards requires that MTA, starting in 2010, set aside 15% of all bus purchases to acquire Zero Emission Vehicles (ZEVs). Currently, none of the buses in the MTA's inventory can be classified as ZEV, nor there are any transit buses [defined as propelled by an internal combustion engine (ICE) powered by either diesel or alternate fuels] available on the market that can be classified as ZEV. The California emission standards are well ahead of those for the rest of the United States and the manufacturers will not develop suitable vehicles on their own unless incentivized by large customers such as LACMTA. Failure to meet the 2010 Emission Standards will result in regulatory punitive fines and potentially litigation.

This report will look first at the potential ZEV technologies and assess their technological, commercial and economic maturity and feasibility. Then, we will describe the electric trolleybuses, will review their history and current applications. Third, we will review the known advantages and disadvantages of the electric trolleybuses.

In the second half of this report, in order to enable the readers of the report to pass personal judgment on the potential advantages for MTA to invest into the electric trolleybus system, we will cover to some depth the engineering and economics of the electric trolleybuses.

We will conclude this report with a strategic proposal for the implementation of the electric trolleybuses in the MTA's bus system.

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Directors. In the 1992 30-Year Integrated Transportation Plan, electric trolleybuses were the preferred solution to meet CARB air regulations. The Plan provided for 18 routes, 300 miles of overhead wires and 400 peak electric trolleybuses by 2004 to be increased to 1,100 peak electric trolleybuses by 2010. Eventually, the Board voted to terminate the project. Appendix A will review the history of the project and compare it with the current proposal.

POTENTIAL ZERO EMISSIONS VEHICLE TECHNOLOGIES

Although the CARB regulation addresses specifically only the requirement for zero emissions at the street level, there are other attributes such as reduced noise level, reduced release of “green house” gases that might contribute to the global warming, and lowest possible emissions into the environment as a whole that are desirable from the society and communities point-of-view and must be incorporated in the new vehicle design.

Adopting the above view leads one to operate vehicles using electric power motive, i.e. with electricity supplied by large, fixed power stations operating under stable conditions and offering significant environmental advantages over large numbers of individually powered ICEs using fossil fuels and operating under continually varying conditions. There are several technologies that result in "electric vehicles/buses".

1. Vehicles drawing electricity from energy stored in batteries. If developments in storage battery technology produce batteries that can compete in terms of size, weight, cost, ease of recharging and efficiency, with say, a tank for diesel fuel, then all vehicles could be electric, with all the environmental advantages that would bring.

   But this is very unlikely to happen in the foreseeable future. Figure 1 shows that both gasoline (CNG and diesel fuels have similar specific energy and specific power) and hydrogen have a higher specific energy than the rest of the electrical storage devices. An advantage of the high specific energy of liquid or gaseous fuels is to provide the vehicles with long-range capabilities. Conversely, the high specific power can provide the peak power requirements.

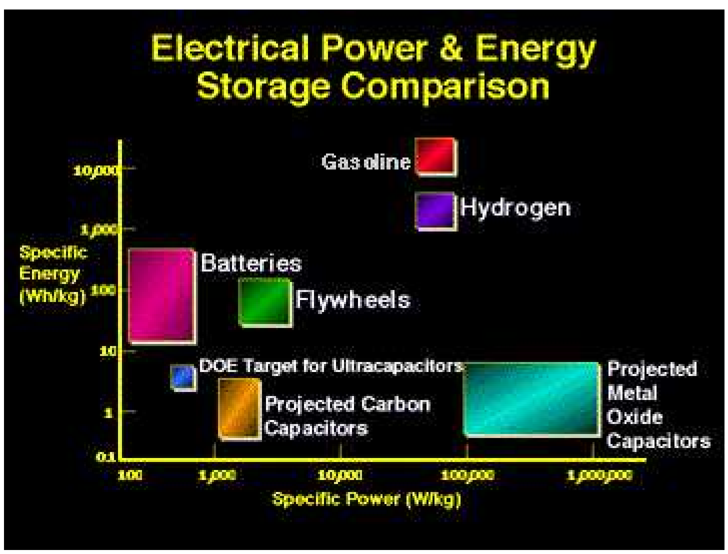


Figure 1- : Plot of energy versus power for various fuels and energy storage devices.

2. Fuel cells represent a halfway house between storage batteries and fuel burning engines. A fuel cell takes in hydrogen plus oxygen from the air and combines the two, producing electricity plus water as the byproduct. If supplied with hydrogen, the fuel cell can be viewed as a storage battery, but a not very efficient and a very expensive one. There are problems of distributing the hydrogen to and storing it on vehicles. In Figure 1, fuel cells are about half-way between the liquid hydrogen and batteries(~ 2,000 Wh/kg specific energy and ~ 5,000 W/kg specific power).

3. Vehicles generating electricity on-board. If the fuel cell is supplied with a hydrocarbon fuel e.g. gasoline, natural gas or diesel fuel, hydrogen can be made from the fuel [by on board 'reforming'], but this system produces much the same range of byproducts as an internal combustion engine.

   The prospect that on-board fuel cells will provide efficient, clean, cheap, safe power in moving vehicles is very new and very experimental. The prospects for larger and stationary fuel cells, fed [via a reformer] with natural gas, probably as part of combined heat and power schemes are very much better. Such fuel cells may provide much clean cheap electricity for electric vehicles. Fuel cells supplied with hydrogen produced by renewable sources, hold the promise of pollution free power, would require massive new infrastructures.

4. Vehicles receiving electric power via an energy conductor system. Where vehicles operate a fixed route at sufficient frequency, it is both practicable and economic to provide an energy conductor system. Thus in many railway, and virtually all light systems, electric propulsion via an energy conductor, a conductor rail or trolleybus overhead wire' is the norm.

   As is the case with light rail, objections have occasionally been voiced about the visual intrusiveness of overhead wires. Considering that the diesel bus generates 41 different substances listed as air contaminant emissions, and these are released directly into the streets where pedestrians, transport users and people in other vehicles breathe them in and given that the trolleybus eliminates these hazardous emissions, overhead wires may be seen as a symbol for clean air. They also present a sign of service permanence appreciated by passengers.

   The overall technology evaluation matrix indicating the alternative technological paths and the configurations to be evaluated is shown in Appendix B.

WHAT ARE ELECTRIC TROLLEYBUSES?

A trolleybus is an electrically propelled bus. Unlike a light rail, which uses rails as a return circuit and operates with a single overhead conductor wire, a trolleybus requires two overhead wires. Two swiveling current collectors allow a trolleybus to operate up to about fifteen feet either side of the wires. These collectors are spring loaded to press upward against the wires. Contact with between pole and wire is by a grooved shoe containing a carbon insert that slides along the wire. Modern collectors have pneumatic equipment for the lowering and lifting.

The trolleybus has been in existence as a method of public transportation for some 70 odd years and was at various times during that era a major mode of transport in many cities in Europe, Asia and the North and South America.

A recent survey estimated there are still about 340 trolleybus systems operating throughout the world and that between 1990 and 2000, there have been 37 new systems opened, and 29 systems closed.

Regrettably, many people are only familiar with the rather basic and austere type of trolleybus favored by Russian and Chinese operators, which do not offer the comforts and appeal of more modern transit buses.

In several cities new trolleybuses are being introduced which offer at least the same facilities and comfort standard as transit buses, but with the added benefits of a much smoother and quieter ride. Figure 2 shows some of the new, modern trolleybus designs.

Despite the numerous development advances being made with internal combustion engine technology, alternate fuels, and exhaust after treatment devices, transit buses will always continue to emit polluting exhaust fumes. These advances, and improved fuel standards will certainly reduce the total quantity of pollutants from any given number of vehicles, but within the dense urban corridors of Los Angeles is this acceptable? It must be remembered that with buses stationary at bus stops, and traffic lights, the air conditioning load, battery charging load, and transmission drag on an ICE engine, there will still be significant exhaust fumes emitted, which will adversely affect the environment within these corridors. The only currently available alternative which will not pollute at street level, is the trolleybus. Considerable advances in trolleybus technology, such as much less obtrusive overhead, ac traction equipment and solid state sub-stations further enhance an already reliable system. Where tested (Vancouver), passengers prefer to ride on trolleybuses and there is evidence (San Francisco, Seattle) of 10-15% increases in usage where trolleybuses have been installed.

Greenwich, Greater London, UK

Lausanne, Switzerland


Budapest, Hungary

Figure 2- Trolleybuses in service. Notice how unintrusive the overhead wires are in an urban environment.

While this report strongly advocates the introduction of trolleybuses in Los Angeles, it is under no illusion that they will replace transit buses entirely. Clearly the economies of trolleybuses preclude their use in areas where bus frequencies and ridership are low.

ELECTRIC TROLLEYBUSES-ADVANTAGES AND DISADVANTAGES

The advantages of electric trolleybuses are as follows :

1. To the passengers:

    - Zero pollution emissions in the streets
    - Lowest possible noise levels
    - Powerful but smooth acceleration and braking
    - Sense of permanence of service
    - Best ride quality

2. To the public generally**:**

    - Lowest possible emissions into the environment as a whole
    - Lowest possible consumption of non renewable resources
    - Lowest possible release of greenhouse gases like CO_2

3. To the operator:

- High mechanical reliability and efficiency
- Long service life
- No idling motor losses
- Greater acceleration and hill climbing performance
- Lower power costs
- Lower maintenance costs

Tables 1 through 3 clearly show some of the advantages provided by the utilization of the electric trolleybuses.

TABLE 1-COMPARATIVE TOXIC AIR CONTAMINANTS
(based on CBD duty cycle) (in g/km)

	PM	NO_x	CO
Diesel Bus	1.3-3.5	22.0-38.0	10.0-30.0
Clean Diesel Bus	0.1-0.35	10.8-21.0	3.1-24.3
CNG Bus	0.016-0.051	3.6-13.0	5.6-6.0
Diesel-Electric Hybrid Bus	0-0.2	6.6-8.6	0.08-2.5
CNG-Electric Hybrid Bus	0	0.25	0.12
Trolleybus	0	0	0

TABLE 2- TOTAL GREENHOUSE GAS EMISSIONS*
(based on NYC duty cycle)

	Approximate Greenhouse Gas Emissions (in g/km of CO_2 equivalent)
Diesel Bus	3,975
Clean Diesel Bus	4,975
CNG Bus	5,200
Diesel-Electric Hybrid Bus	3,750
CNG-Electric Hybrid Bus	5,000
Trolleybus	0

* Includes CO_2, NO_X, CH_4, NMCH, and CO)

TABLE 3- NOISE LEVELS (based on the Seattle, WA experience)

	Noise Level , in dbA
Hearing Loss	90
Diesel Bus	80-90
CNG Bus	75-80
Fuel Cell	70
Trolleybus	50-60
Quiet street	60

It would be unrealistic to believe that there are no adverse factors associated with a trolleybus system.

1. High capital cost

An equivalent trolleybus will cost about 30% more than the ICE equivalent. However, the normal working life of trolleybus will be 20 years, as against 14 for an ICE bus. It can therefore be seen that the annual depreciation is only 9% more than for a CNG bus.

The installation of the power supply and overhead wiring network is undoubtedly capital intensive, when compared to normal buses. However, provided the network is intensively used, and can remain in use for a prolonged period, then its costs can be amortized over many years.

2. Running costs

The cost of maintaining a modern trolleybus is certainly lower than for a diesel and in San Francisco the difference amounts to about 68:100 for trolleybus/diesel bus or, approximately 56% of that for a CNG bus.

The maintenance cost of the overhead wiring and substations is an extra burden, which must be carried by the trolleybus operator. However, even taking this into account, the total maintenance costs of the trolleybus system, and vehicles should be at least 20% less than for diesel/CNG buses, based on experience elsewhere.
The comparative fuel costs are very similar.

3. Inflexibility

It is often perceived that trolleybuses can only run in procession, and on fixed routes. However, while this was once true, the use of modern, remotely controlled overhead switches mean that it is easily possible for overtaking maneuvers to take place, as well as segregated use of bus stops.

Another often quoted “problem” is the difficulty of re-routing trolleybuses to go through new development areas, etc. Again this does not apply to most of the main urban bus routes, which have remained basically unchanged for many years. Where a major road construction/repair is unavoidable, there is always adequate notice, which gives the trolleybus operator sufficient opportunity to modify the overhead network. As a last resort, trolleybuses could be moved for short distances under the auxiliary power mode to meet a temporary disruption.

4. Visual intrusion of overhead wiring

It is impossible to make overhead wiring for trolleybuses completely invisible, but with good design, and use of high quality components, its visual impact can be reduced. Sacramento has introduced an innovative overhead wire masking scheme using specially trimmed trees along the routes. In fact, in the average Los Angeles urban environment, it is likely to be unnoticeable to most people. How often is the light rail overhead wiring considered to be a visual monstrosity.

Great simplification could occur if street light poles could also carry the trolleybus wiring. This would just require a higher quality lighting standard, at minimal extra cost. Where possible suspension wires should be fixed to buildings, which will reduce the number of poles required.

ELECTRIC TROLLEYBUSES-ENGINEERING

Much of the engineering of trolleybuses is similar to internal combustion engine buses. Modern North American and European trolleybus designs are usually derived from proven internal combustion engine bus designs- see Figure 3. Trolleybus electrical equipment is very flexible, consisting mainly of modules connected by flexible cables that need no special consideration for accessibility, cooling, or noise and vibration. Trolleybuses, therefore, present easier design challenges compared to ICE systems.

Figure 3- Common subassembly for ICE bus and trolleybus.

Although trolleybus suspension, steering and mechanical braking are the same as ICE buses, trolleybuses provide the opportunity to use the motor(s) as effective electric brakes, dramatically reducing the wear and tear on mechanical braking components and tires.

The energy generated by electric braking is either dissipated in resistors on the vehicle, or fed back into the overhead line, a system known as regenerative braking. Depending on the type of route and pattern of service, energy savings from regenerative braking can be substantial - up to one third less energy consumption.

Many trolleybuses operate without any source of power other than the overhead wires. In modern traffic situations, some ability to operate from the overhead wires may be considered essential. Modern battery systems or auxiliary small [ICE] generator systems permit operation at 10 to 20 mph, for considerable distances, independently of overhead wires.

Instead of a diesel engine and transmission, a trolleybus usually has a single electric motor, similar in size to an internal combustion engine bus automatic gearbox, connected directly to the driving axle. There is no gearbox or clutch, and all gearing is done in the axle, which has a higher reduction ratio to cope with faster running trolleybus motors.

Recent developments have permitted driving axle designs with an AC motor per wheel, or within the wheel, eliminating differentials and half shafts, permitting further simplification and greater flexibility in overall layout and facilitating low floors. Such designs are just entering service.

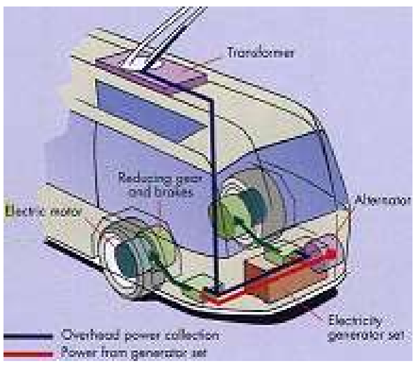


Figure 4-Trolleybus electrical equipment

The latest control technology for trolleybuses use alternating current [AC] motors, controlled by inverters that create variable voltage and frequency AC for the motors, from the DC overhead line supply. The supply voltage is between 600v and lately, 750v.

AC motors and control systems have many advantages over traditional DC systems, including greater reliability, less maintenance, greater efficiency, sophisticated control over acceleration and ‘jerk’ rates. The efficiency advantages should be substantial - up to one third less power consumption than DC systems. Maintenance and reliability advantages should also be substantial - at least ten times more reliable than previous generation installations

There have been considerable improvements in detail design, for example the automatic lowering of poles in the event of de-wirement or under the direct control of the driver without the driver having to leave the driving seat. And also ways of automatic re-wiring, in conjunction with special overhead fitments.

Advances in materials science and better understanding of motion dynamics have led to considerable improvements in overhead wire design. Modern suspension systems can cope easily with vehicle speeds of up to 50 mph while being lighter in construction and less visually obtrusive. Together with the latest development in electronic power feeder systems, these advances have reduced costs, improved efficiency and freed the trolleybus from having to take junctions and crossings any more slowly than other traffic.

Modern light rail systems, operated on right of way corridors, are a much more environmentally friendly alternative to ICE buses. But with effective traffic management to give buses sufficient priority, electric trolleybuses would give the public a similar travelling experience to modern light rail, and at a fraction of the capital cost. Features associated with light rail such as reliable, congestion free operation, smooth, fume free ride, level boarding from raised platforms, real time information systems, etc., are all possible with modern trolleybuses.

ELECTRIC TROLLEYBUSES-ECONOMICS

Electric trolley vehicles, with their lighter infrastructure, are inherently cheaper to construct than equivalent light rail systems, with a carrying capacity that approaches parity. The recent expansion of light rail systems has a beneficial effect for trolleybuses, as much of the electrical equipment is the same and standardization will see lower costs. Compared to ICE buses, which also share components with trolleybuses, much depends on recent integration developments and sizeable production runs.

Generally the maintenance costs of a trolleybus have been shown to be far below those of an ICE bus, because there is so much less that needs any kind of frequent attention. And electric braking dramatically reduces maintenance required on mechanical brakes - not a small item of expense on an ICE bus used on stop-start services.

Supplied with power from modern efficient, clean, green generating plant, trolleybus energy costs should be less than CNG. On intensive urban services, a trolleybus system should be able to finance its overhead power supply infrastructure from maintenance and energy cost savings.

Compared with light rail infrastructure [wires and rails] trolleybus infrastructure [wires] can be put in at around 10% of the cost and disruption associated with light rail.

Tables 4 through 6 back these arguments.

TABLE 4- OPERATING COSTS (BASED ON FTA's NATIONAL DATABASE)

MODE	VEHICLE REVENUE HOUR	PER BOARDING
BUS	$101.59TO $102.79	$1.47 TO $3.33
TROLLEYBUS	$84.44 TO $101.78	$1.31 TO $1.68

TABLE 5- CAPITAL COST*

MODE	CONSTRUCTION DIFFERENTIAL	OVERHEAD WIRES	POWER SUBSTATIONS	VEHICLES DIFFERENTIAL
BUS	0	0	0	0
TROLLEYBUS	0	$0.6 MILLION/ MILE	$0.7 MILLION/ MILE	$132,000 EACH

*SOURCES OF DATA: DATA: a) PRIVATE COMMUNICATIONS WITH TROLLEYBUS OPERATORS IN SEATTLE,WA; SAN FRANCISCO, CA; DAYTON, OH;BOSTON, MA; PHILADELPHIA,PA; AND VANCOUVER,BC; b) FTA'S NATIONAL DATABASE; c) APTA'S 2001 PUBLIC TRANSPORTATION FACT BOOK; d)SAN FERNANDO VALLEY EAST-WEST TRANSIT CORRIDOR, FINAL ENVIRONMENTAL IMPACT REPORT, 2002.

TABLE 6- CAPITAL COST COMPARISON

PROJECT TYPE	NO. OF PROJECTS	COST RANGE PER MILE (ADJUSTED TO FY 2001)
LRT*	18	$12.4 MILLIONS TO $118.8 MILLIONS
TROLLEYBUS**	Unk	$0.3 MILLION TO $ 7.0 MILLIONS

* BASED ON GAO-010984 (SEPTEMBER 2001) REPORT

** BASED ON RTP (PARIS, FRANCE TRANSIT AGENCY)- FTA's PARIS TRIP REPORT- ISSUED BY CALSTART (2002)

*** SPECIFIC ITEMS CONSIDERED:

a) SIGNALS; COMMUNICATIONS;ELECTRICAL POWER SYSTEM; OVERHEAD WIRES
b) RAIL, TIES, TRACK BALAST
c) MAINTENANCE FACILITY
d) VEHICLES

With effective traffic management to give buses sufficient priority, electric trolleybuses could give the traveling public much the same experience as light rail, but at a fraction of the capital cost.

For trolleybuses there are two possible financial structures: one is for MTA to invest in both wiring and vehicles. Another is long-term, say 20 to 50 years, arrangement where a power distribution company to pay for the wiring and its maintenance and the MTA to pay for the vehicles and their operations.. The second structure could be fully commercial if the MTA were charged full "absorption costs" of the wiring over the life of the arrangement.

Commercial finance should not be a problem with a long term arrangement. In effect, the successful power distributor (that might be asked to pay a license for monopoly rights) would be able to forecast cash flows over life of the arrangement quite accurately. All the foregoing is predicated on the project being economically sensible in the first place

ELECTRIC TROLLEYBUSES FOR LOS ANGELES COUNTY- A STRATEGIC PROPOSAL

We envision a system that will reach 300 peak trolleybuses (15% of 2000 peak buses), operating on very high density routes. The routes should be selected on criteria based on the highest possible daily boardings, the largest number of vehicle required, and the shortest possible routes. These criteria will ensure that MTA will need to open the minimum number of trolleybus routes and will keep the capital expenses for wiring and sub-stations to an absolute minimum. The vehicles should be 60 feet, articulated with multiple, wide doors for fast passengers loading and unloading. In addition the vehicles must have secondary power source to enable limited off-wire travel. No specially constructed, dedicated maintenance facilities will be required. Trolleybuses and buses will share those facilities.

We suggest public-public and public-private partnerships with LADWP and other electric power suppliers to build and maintain wiring and sub-stations. The partnerships should be broadly similar to those entered by MTA for the construction and operation of the CNG refueling stations.

MTA will fund the purchase of the vehicles through the usual bus acquisitions Federal, state and local funds. The same will be true for the operating funds. The partnering utilities will have no difficulty in getting funding for a project that can normally guarantee a monopoly based cashflow for 20+ years.

RECOMMENDATION

We recommend that MTA will:

- Formally add electric trolleybuses to its long- and short-range plans as the primary (but not exclusive) option to meet the 2010 CARB’s emission standards.
- Formalize the electric trolleybus feasibility study to include potential routes identification and project costs.

- Enter into formal, preliminary negotiations with LADWP and Edison Electric to form public-public and public-private partnerships.

APPENDIX A

The RTD Board of Directors approved the implementation of the ElectricTrolley Bus (ETB) program on June 11, 1992. Subsequently, on July 21,1992, the LACTC approved partial funding for ETB with authorization to do environmental work for twelve-lines and construct two prototype segments. The 30-Year Plan included Phase I, a twelve-line project, estimated at $1.1 billion as an unfunded program. The only funds approved for ETB were $8 million for environmental work and feasibility study and $50 million to complete the design and construction of two short segments on MTA Line 30/31 and Long Beach Line 40.

In June, 1993, the FTA approved MTA Lines 40 and 45 for a Turnkey Demonstration Project. The designation was not accompanied with any commitment of federal funds. On October 25, 1993, the Long Beach Transit Board declined further participation in the ETB project unless funding was provided for their entire four line system.

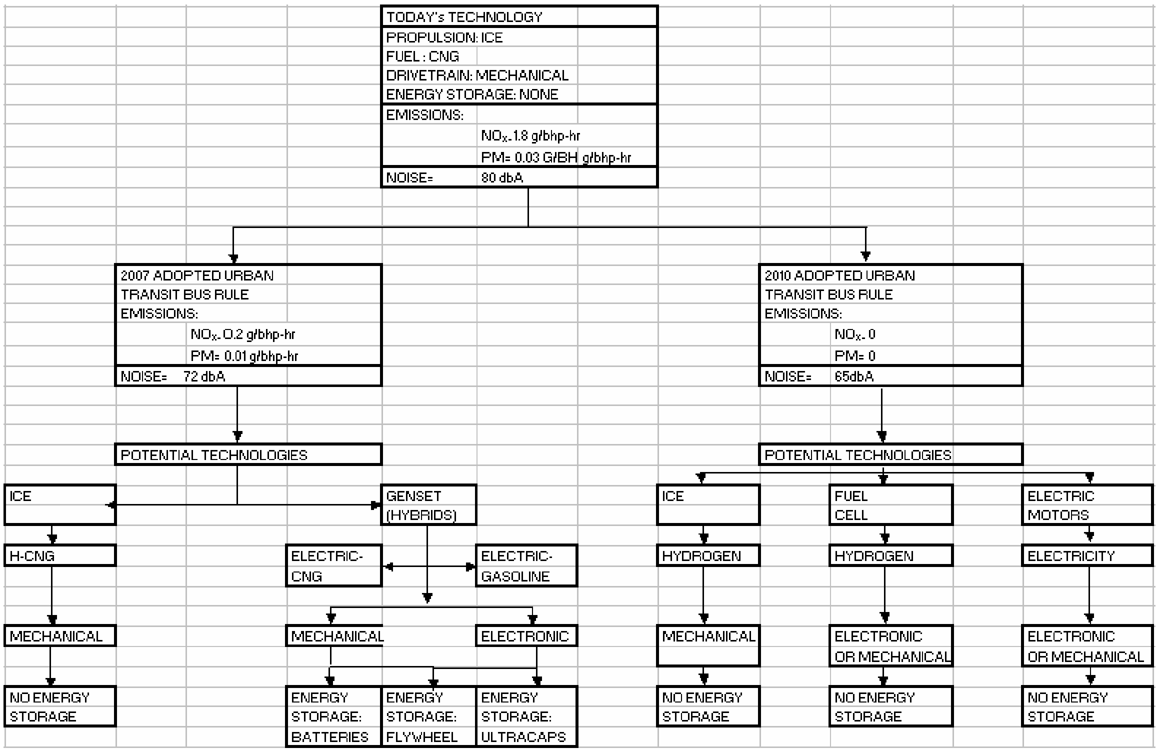
On December 15, 1993 the MTA Board considered recommendation from workshop regarding ElectricTrolley Bus (ETB) Program.

Director Braude made a motion to reaffirm commitment to the ETB program. Several Board members questioned the cost of the project and whether it was the appropriate decision given the realistic development in technology. Public speakers were both in favor and against the ETB project.

Director Wilson made a substitute motion to suspend activities and reprogram available funds. This motion was approved on a Roll Call vote. The vote was 8 to 4 in favor, with one Director absent.

On May 24, 1994 $36,975,000 of the funds allocated to Project 29244, Electric Trolley Bus (ETB) were deobligated and programmed for other projects.

Appendix B


TODAY's TECHNOLOGY
PROPULSION: ICE
FUEL : CNG
DRIVETRAIN: MECHANICAL
ENERGY STORAGE: NONE
EMISSIONS:
NOx- 1.8 g/bhp-hr
PM= 0.03 G/BH g/bhp-hr
NOISE= 80 dbA
2007 ADOPTED URBAN TRANSIT BUS RULE
EMISSIONS:
NOx- 0.2 g/bhp-hr
PM= 0.01 g/bhp-hr
NOISE= 72 dbA
2010 ADOPTED URBAN TRANSIT BUS RULE
EMISSIONS:
NOx- 0
PM= 0
NOISE= 65dbA
POTENTIAL TECHNOLOGIES
POTENTIAL TECHNOLOGIES
ICE
GENSET (HYBRIDS)
H-CNG
ELECTRIC-CNG
ELECTRIC-GASOLINE
MECHANICAL
MECHANICAL
ELECTRONIC
NO ENERGY STORAGE
ENERGY STORAGE: BATTERIES
ENERGY STORAGE: FLYWHEEL
ENERGY STORAGE: ULTRACAPS
ICE
FUEL CELL
ELECTRIC MOTORS
HYDROGEN
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