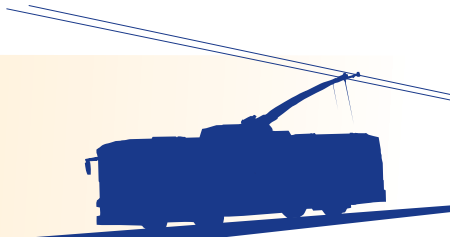
KING COUNTY TROLLEY BUS EVALUATION



MAY 2011

King County
METRO

We'll Get You There

King County Trolley Bus Evaluation

May 2011

Prepared by:

Parametrix

LTK Engineering Services

Contents

Exhibits

Acronyms and Abbreviations

ac	alternating current
ADA	Americans with Disabilities Act
AEO	Annual Energy Outlook
APR	annual percentage rate
APU	auxiliary power unit
ATC	automatic traction control
BRT	bus rapid transit
CAA	Clean Air Act
CE	Categorical Exclusion
CMBC	Coast Mountain Bus Company, Vancouver, B.C.
CNG	compressed natural gas
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalents
CPI	Consumer Price Index
dBA	A-weighted decibel
dc	direct-current
DCE	Documented Categorical Exclusion
EIA	Energy Information Administration
EPU	emergency power unit
ETI	Electric Trolley, Inc.
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GHG	greenhouse gas
HVAC	heating, venting, and air conditioning
hybrid	diesel hybrid
kW	kilowatts
kWh	kilowatt-hours
LNG	liquefied natural gas
Metro	King County Metro
mpg	miles per gallon
mph	miles per hour
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NiCad	nickel cadmium
NiMh	nickel metal hydride
NRHP	National Register of Historic Places
NTD	National Transit Database
NO	nitric oxide
NO_2	nitrogen dioxide
NOx	nitrous oxides
O_3	ozone
O&M	operation and maintenance
OCS	overhead contact system
PSCAA	Puget Sound Clean Air Agency
RTA	Greater Dayton Regional Transit Authority
SAFETEA-LU	Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users
SCL	Seattle City Light
SEPA	State Environmental Policy Act
SEPTA	Southeastern Pennsylvania Transit Authority
SFMTA	San Francisco Metropolitan Transit Authority
TES	traction electrification system
TOH	trolley overhead (system)
U.S.C.	United States Code
VOC	volatile organic compound
WSST	Washington State Sales Tax

Appendices

1. Executive Summary

REPLACING THE TROLLEY BUSES

King County Metro's (Metro) electric trolley bus fleet is scheduled to begin replacement in September 2014. Before purchasing new buses, an in-depth, interdisciplinary evaluation of vehicle options was conducted by Parametrix to determine relative costs, limitations, environmental impacts, and benefits and is summarized in this report. The study evaluated each technology using the current route structure as a base. The findings from this evaluation will inform the technology decision for replacement of the trolley buses.

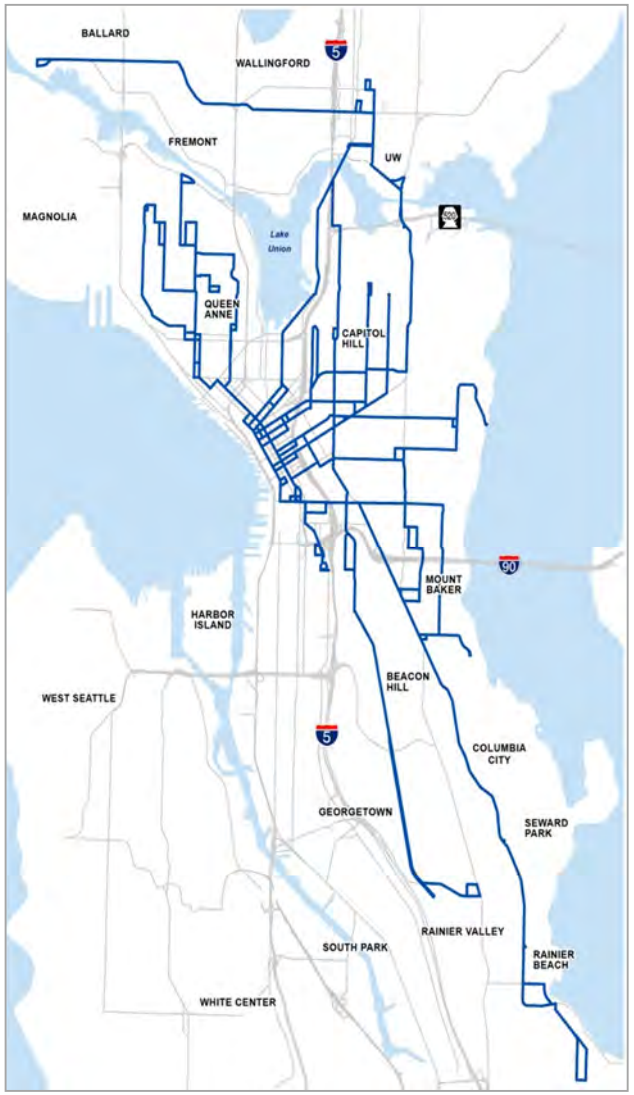
KING COUNTY METRO'S TROLLEY BUS NETWORK

The 14 trolley bus routes carry 20 percent of Metro's weekday riders on 159 trolley buses. The routes have 70 miles of two-way overhead wire. Exhibit 1-1 shows the trolley bus service area in Seattle. Currently, five trolley bus systems are operating in the United States: Seattle, San Francisco, Dayton, Philadelphia, and Boston.

WHY THE TROLLEY BUSES NEED REPLACEMENT

Metro's 159 electric trolley buses are reaching the end of their useful lives. The buses have outdated electrical systems, cracked non-structural overhead frames, and some parts that will be difficult to replace once they fail. There is no longer manufacturer support for the existing propulsion systems.

Exhibit 1-1. Trolley Bus Service Area in Seattle



PROPULSION TECHNOLOGIES EVALUATED

Six propulsion technologies were evaluated as part of the initial screening analysis. Two were selected for further evaluation as follows:

Diesel Hybrid Bus

Diesel hybrid buses are common and currently comprise a growing portion of Metro's fleet. Bus maintenance facilities currently exist to perform necessary maintenance, although additional fueling capacity would be needed to accommodate the increased fleet size.

This technology was selected, but may require modification to the drive train system for travel on the steep hills in Seattle, which would limit the hybrid bus' top speed on level grades.

Electric Trolley Bus

Electric trolley buses have been operating on urban routes in Seattle since the 1940s. The electric power and overhead wire system is in place to support this technology on existing routes. Electric trolley buses operate efficiently on routes with steep grades such as Capitol Hill and Queen Anne.

The electric trolley bus would be equipped with an auxiliary power unit (APU) to increase flexibility by permitting off-wire travel. This study evaluated both diesel and battery APUs—the battery APU was recommended based on performance and cost.

Bus Technologies Eliminated from Further Evaluation

The diesel technology was eliminated from further evaluation because it is less fuel efficient and has a greater environmental impact than diesel hybrid buses.

Electric Battery

The electric battery technology was eliminated because the propulsion system is not commercially available, vehicles have a reduced travel range, and the technology has not been proven to accommodate steep grades on the Seattle trolley routes.

Compressed Natural Gas

The high costs of compressed natural gas (CNG) and the greater environmental impact than diesel hybrid buses were reasons this propulsion technology was eliminated.

Hydrogen Fuel Cell

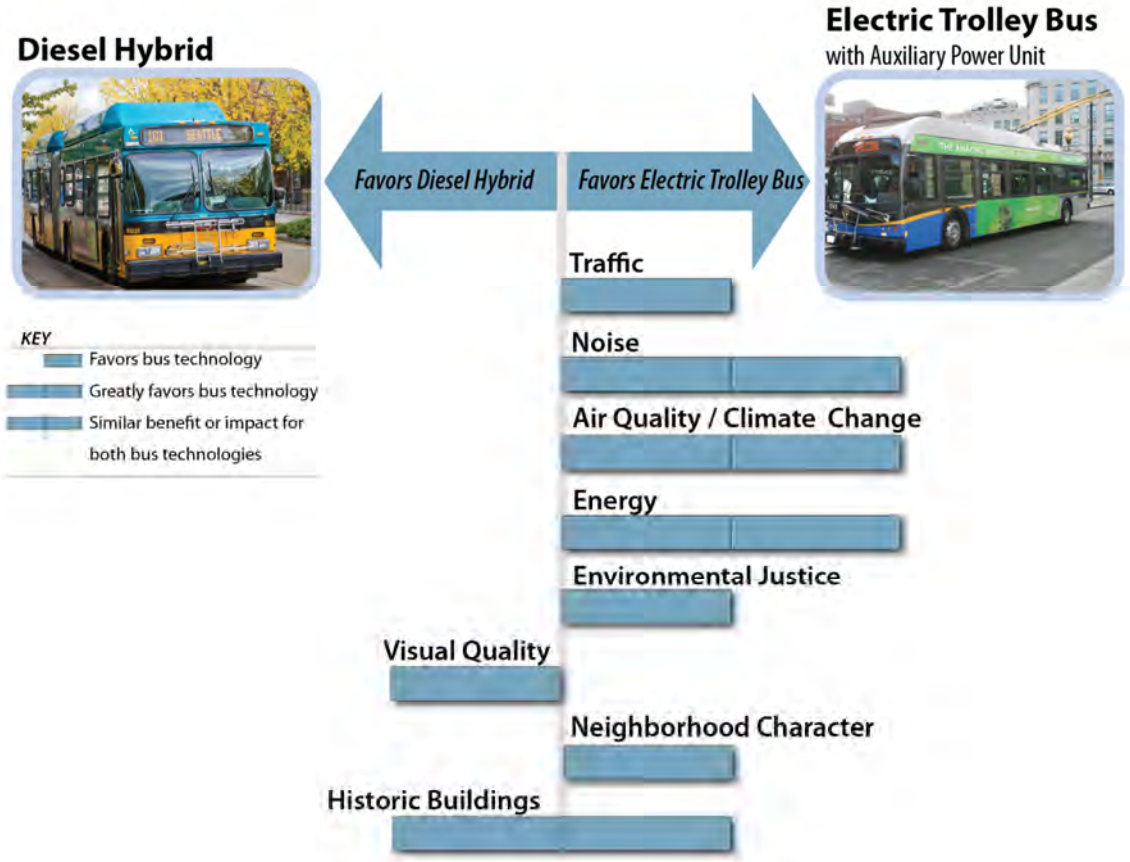
Hydrogen fuel cell propulsion systems were removed from further evaluation because hydrogen fuel is not commercially available, it is expensive, and it has a reduced travel range and reduced reliability.

ENVIRONMENTAL COMPARISON

Environmental components are an important consideration for selecting the appropriate bus technology. After the King County Council selects the preferred fleet replacement option in the 2012 to 2013 biennial budget, Metro staff will conduct a more detailed environmental review if the diesel hybrid technology is selected.

The adjacent chart (Exhibit 1-2) shows why the environmental findings favor the electric trolley bus over the diesel hybrid technology. Electric trolley buses perform better on steep grades (shown in Exhibit 1-2 as a traffic benefit), are quieter, have lower greenhouse gas (GHG) emissions, and consume less energy on a yearly basis.

Exhibit 1-2. Environmental Impacts and Benefits Summary



LIFE-CYCLE COST COMPARISON

A life-cycle cost comparison was prepared to evaluate the full capital and operating costs of each bus technology. Because the estimated life-spans of the electric trolley bus (15 years) and diesel hybrid (12 years) are different, the costs were annualized and discounted to today's dollars to provide a valid comparison. With the current Federal Transit Administration (FTA) funding, the electric trolley bus option annualized life-cycle cost is $11.8 million compared to $15.5 million for the diesel hybrid bus option, or $3.7 million less per year (Exhibit 1-3).

An important component of the cost comparison between diesel hybrid and electric trolley bus is the level of the FTA fixed guideway funding. The level of fixed guideway funding would have to drop to 31 percent of current funding levels before the diesel hybrid bus technology would have a cost advantage (Exhibit 1-4).

Exhibit 1-3. Life-Cycle Cost Analysis Summary

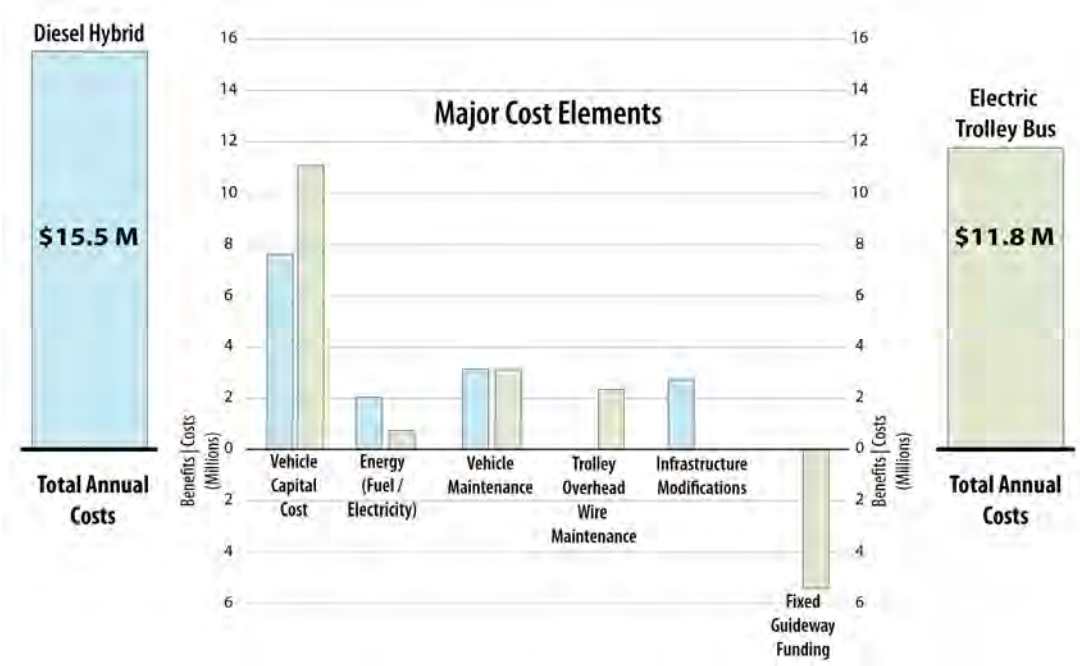
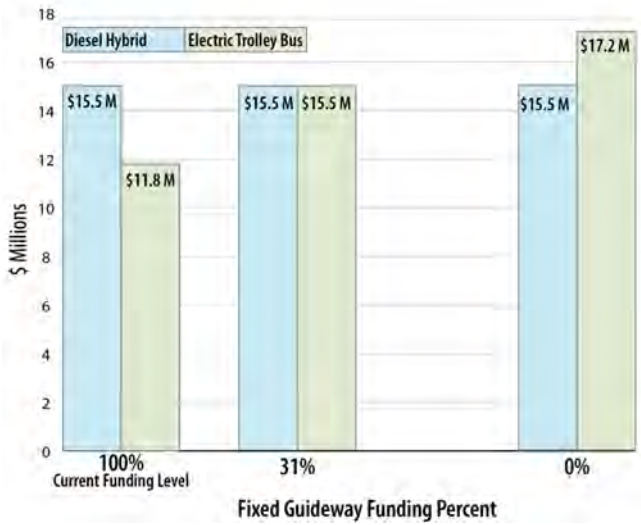


Exhibit 1-4. Fixed Guideway Funding Influence on Life-Cycle Cost



CONCLUSIONS

After considering the environmental and life-cycle cost comparison, this evaluation concludes the electric trolley bus is the preferred technology (Exhibit 1-5) for the following reasons:

- It is more cost-effective to replace the existing fleet with electric trolley buses based on reasonable federal fixed guideway funding scenarios.
- The electric trolley bus generates significantly lower GHG emissions and has a lower total annual energy consumption. Seattle City Light generates 98 percent of Seattle's electricity from non-GHG emitting sources (hydroelectric, nuclear, wind, and biomass).
- The environmental comparison favors the electric trolley bus regarding traffic, noise, air quality/climate change, energy, and environmental justice.

Exhibit 1-5. New Electric Trolley Bus Operating in Vancouver, B.C.

2. Introduction

In 2009, a Transit Performance Audit was conducted by the King County Auditor. The performance audit recommended that King County Metro (Metro) "consider all relevant factors, including costs, when determining an appropriate fleet replacement of the trolley buses." The audit estimated Metro could save on capital and operating costs with hybrid diesel buses instead of electric trolley buses.

REPLACING THE TROLLEY BUSES

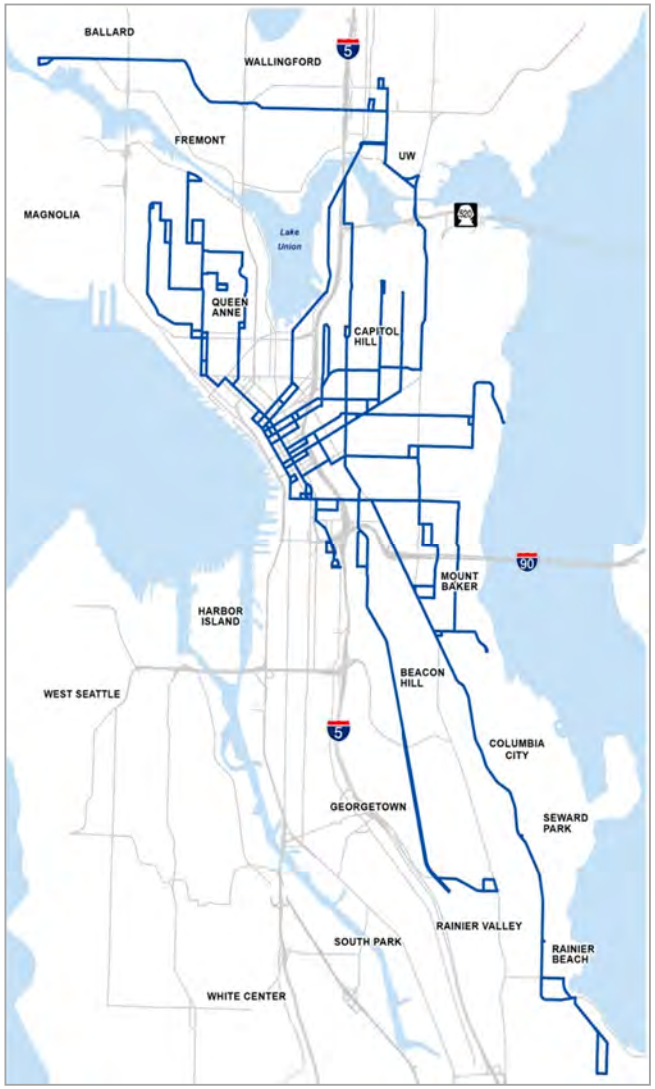
Metro's electric trolley bus fleet is scheduled to begin replacement in September 2014. Before purchasing new buses, an in-depth, interdisciplinary evaluation of vehicle options was conducted to determine relative costs, limitations, and benefits. The study evaluated each technology using the current route structure as a base. The findings from this evaluation will inform the technology decision for replacement of the trolley buses.

KING COUNTY METRO'S TROLLEY BUS NETWORK

The 14 trolley bus routes carry 20 percent of Metro's weekday riders on 159 trolley buses. The routes have 70 miles of two-way overhead wire (Exhibit 2-1). Currently, five trolley bus systems are operating in the United States:

- King County Metro—Seattle, WA
- San Francisco Metropolitan Transit Agency— San Francisco, CA
- Greater Dayton Regional Transit Authority—Dayton, OH
- Southeastern Pennsylvania Transportation Authority—Philadelphia, PA
- Massachusetts Bay Transportation Authority—Boston, MA

Exhibit 2-1. Existing Trolley Bus Service Area in Seattle



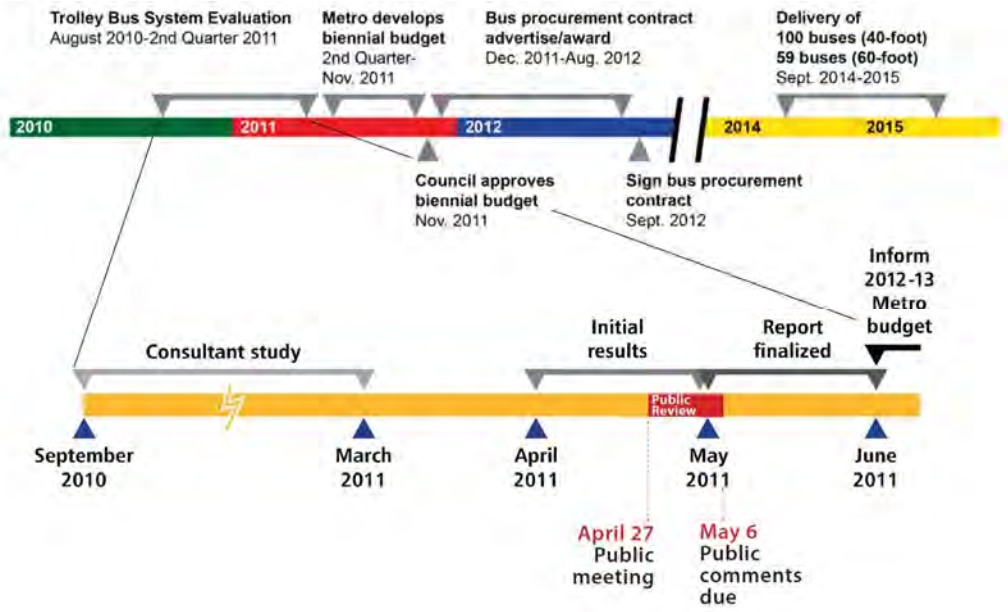
WHY THE TROLLEY BUSES NEED REPLACEMENT

Metro's 159 electric trolley buses are reaching the end of their useful lives. The buses have outdated electrical systems, cracked non-structural overhead frames, and some parts that will be difficult to replace once they fail. There is no longer manufacturer support for the existing propulsion system.

BUS PROCUREMENT AND EVALUATION TIMELINE

The bus procurement and evaluation timeline (Exhibit 2-2) illustrates the schedule for evaluating the trolley bus system (summarized in this report) and the anticipated delivery of the 159 buses needed to replace the existing fleet in 2015.

Exhibit 2-2. Bus Procurement and Evaluation Timeline



PUBLIC AND AGENCY OUTREACH

Beginning in June 2010 and again in April 2011, Metro held two community open houses to solicit comments from the public. In total, Metro contacted over 800 people.

The first public meeting was held to initiate the evaluation process and obtain input on the scope of the evaluation. Input received at the meeting was used to refine the consultant scope of work for the cost and environmental evaluation. The second public meeting was held on April 27, 2011 to present the draft results from the study for the life-cycle cost analysis, environmental comparison, and Metro's preliminary bus technology recommendation.

Key elements of the outreach effort included the distribution of informational materials via mail and email, holding public meetings with presentations, maintaining a project Web site, and informing the media. Metro received 4 letters, 130 emails, and 25 calls; approximately 130 people attended the public meetings (see Appendix A).

Meetings were also held with several Metro divisions and City of Seattle staff to review preliminary findings and results from the evaluation.

BACKGROUND INFORMATION

In 1939, a newly formed Transportation Commission immediately took steps to accelerate a transit system modernization program in Seattle. The program was intended to replace a mixture of streetcar, cable car, and bus lines with a modern 110-mile trolley bus system. The progress was rapid and the first 235 trolley buses were delivered in March 1940.

The trolley bus system slowly declined as the diesel bus began to gain prominence during a period of cheap oil supplies. In 1963, the first major trolley bus lines were discontinued. By 1970, the trolley bus system had been reduced to 32 route miles with only 57 of the 30-year-old trolley buses in operation.

In 1973, the Municipality of Metropolitan Seattle (Metro) inherited the aging trolley bus infrastructure and successfully secured an Urban Mass Transit Administration grant to expand and repair the trolley system.

The electric trolley bus system is an integral part of Metro's transit system. The trolley buses carry over 20 million riders annually and are the cleanest and quietest buses in the transit system.

The current Metro fleet plan projects the existing trolley bus fleet would need replacement during the 2014 to 2016 timeframe. Metro is scheduled to retire their fleet of 159 electric trolley buses beginning in September 2014.

The current system has high fleet procurement costs, high cost of support infrastructure to purchase and install, and high ongoing costs to maintain the bus and system infrastructure. The current electric trolley bus service is less flexible because it is connected to a fixed guideway power supply.

Metro previously examined costs and characteristics of the trolley bus fleet, service area, and infrastructure. A number of cost and environmental elements were found to favor electric trolley buses, and the need for a more detailed understanding of alternative propulsion technologies, environmental costs, and a full life-cycle cost analysis was recommended.

COMPARATIVE INFORMATION OF EXISTING TROLLEY SYSTEM COSTS AND OPERATIONS

This section summarizes the analysis of the most viable technologies for the future trolley bus fleet. This analysis process started with agency and manufacturer interviews, which were undertaken to explore and understand the costs and operating conditions of new electric trolley buses.

Transit Agency Interview Summary

Telephone interviews were conducted with transit agencies in the United States and Canada currently using electric trolley buses. While a number of other transit agencies around the world operate electric trolley buses, the interviews focused on nearby agencies with similar operating conditions and cost structures. The location of available manufacturers and FTA's Buy America policies were reasons to focus on agencies in the United States and Canada.

The following agencies were interviewed for this study:

- San Francisco Metropolitan Transit Authority (SFMTA)
- Coast Mountain Bus Company (CMBC), Vancouver, B.C.
- Greater Dayton Regional Transit Authority (RTA)
- Southeastern Pennsylvania Transportation Authority (SEPTA)

Staff from both vehicle maintenance and transit planning was included in the interviews to provide different information and perspectives on the current and future electric trolley bus operations.

A common list of questions was developed for the interviews by consultants and Metro staff. The list of questions served as a guide to follow during the interviews. Questions were grouped into five categories including general, planning, maintenance, scheduling, and operations (see Appendix B for a copy of the questionnaire).

Exhibit 2-3 provides a summary of the information received from the telephone interviews of the four transit agencies.

Also, CMBC in Vancouver, B.C., provided a demonstration of their new electric trolley bus, which they brought to Seattle. The demonstration occurred in Seattle on December 2010, which allowed Metro staff to examine technology differences between Metro's trolley buses and CMBC's newer buses. Metro and CMBC staff also shared information about vehicle maintenance of trolley buses. As part of the demonstration, the trolley bus was available for viewing by Metro and Seattle Department of Transportation staff, including King County and Seattle elected officials.

Exhibit 2-3. Telephone Interview Summary

	SFMTA – San Francisco, CA	CMBC – Vancouver, B.C.	RTA – Dayton, OH	SEPTA – Philadelphia, PA
Fleet	313 Skoda/ETI • 240 40-foot • 73 60-foot	302 New Flyer • 228 40-foot • 74 60-foot	52 Skoda/ETI, 29 in operation	New Flyer
Fleet Age	• 40-foot—10 years • 60-foot—11–20 years	• 40-foot—4–5 years • 60-foot—2–4 years	12 years	5 years
Replacement Date	Phased replacement from 2014–2024	2007–2009—prior fleet lasted almost 25 years	2016–2018	2007
Wire Length	140 miles	310 miles	122 miles	NE Philadelphia routes only
Trolley Bus Benefits	• Clean air • Infrastructure in place and shared with light rail vehicles and cable cars • City expectations • Clean energy • Good on steep grades • Public support	• Trolleys are part of Vancouver's character • Clean energy • Environmental responsibility		• Environmentally friendly • City of Philadelphia likes trolleys
Trolley Bus Challenges	• Vehicle weight • Visual impacts • Difficulty finding parts • Reliability is poor compared to hybrid diesel buses	• Early maintenance due to new vehicle growing pains • Issues with circuit boards and collector heads • Cold weather operations	• Customer complaints from accident delays • Parts ordering with single supplier	• Trolley infrastructure is old • Capital cost for trolley buses are higher • Electric energy is not clean (coal and nuclear)
Auxiliary Power Unit	• Battery (NiCad) • Range is 2 miles flat at 5 miles per hour (mph) • Used for emergencies and construction detours	• Battery (NiCad) 14-year life • Range—4 km on 6% grade • Used for events and major construction	• Battery (NiCad) • Range—3 miles at 3 mph • Used for accident or construction detours	• Diesel was selected due to flexibility and longer distance potential • 25 mph limit for short distance
Technology Selection	Fleet committee is evaluating overall fleet needs. Decision to continue with electric trolley bus technology has not been made.	• Technology decision was to continue with electric trolley bus technology	• Recent study recommended trolley bus option • Endorsed by RTA Board	Technology decision was to continue with a new fleet of electric trolley buses
Maintenance				
• **Batteries**	$40,000 replacement every 6 years. Some batteries are 10 years old and drained.	$50,000 replacement every 6 years		

3. Bus Technology and Vehicle System Assessment

In early 2010, a Metro and consultant prepared a white paper on the trolley bus replacement options (King County Metro 2009; Booz Allen Hamilton 2010), which narrowed the list of candidate technologies to two vehicle types—diesel hybrid buses and electric trolley buses. Five other technologies were eliminated from consideration, which are briefly discussed below.

ALTERNATIVES ELIMINATED FROM CONSIDERATION

The four technologies eliminated were clean diesel, electric battery, compressed natural gas (CNG), and hydrogen fuel cell.

The diesel technology was eliminated from further evaluation because it is less fuel efficient and has a greater environmental impact than diesel hybrid buses. It does not offer sufficient reduction in emissions to replace the trolley buses as well as achieving clean air goals.

Electric Battery

The electric battery technology was eliminated from consideration for several reasons. While battery buses have been demonstrated in small-scale tests, there are significant limitations for use on Metro's heavily used trolley bus routes. Metro internal assessments and the 2009 audit concurred that battery buses are unlikely as a viable replacement for the current electric trolley bus fleet. Major barriers that Metro has identified include:

- Battery buses have not been proven to withstand heavy duty operating cycles, gross vehicle loads, and steep grades.
- Battery buses are not currently commercially available.
- Sixty-foot articulated electric battery buses have limited availability.

Compressed Natural Gas

The high costs of CNG and the greater environmental impact than diesel hybrid buses were reasons this propulsion technology was eliminated.

Hydrogen Fuel Cell

Hydrogen fuel cells bring the promise of cleaner, quieter, and more efficient operation of transit vehicles (Booz Allen Hamilton 2010). Hydrogen fuel cell technology was eliminated for the following reasons:

- Currently, fuel cell buses cost $2.5 million for a standard 40-foot low floor bus. Sixty-foot articulated fuel cell buses are not currently available; however, a prototype will be

demonstrated soon in Europe for bus rapid transit service.

- In the opinion of several fuel cell bus operators, it is too early to determine if the technology is showing positive progress towards commercialization.
- Fuel cell buses have a limited range compared to diesel buses.
- Overall fuel cost per mile of the hydrogen fuel cell was 2.4 times higher than diesel.

Even if the hydrogen fuel is produced from electricity generated from non-carbon sources, the low efficiencies in the electrolysis of water and the compression of hydrogen gas would favor using the electricity directly in a trolley bus.

BUS TECHNOLOGIES SELECTED FOR FURTHER EVALUATION

This section provides an assessment of performance measures for the electric trolley and diesel hybrid technologies. Subsequent sections provide a detailed evaluation of vehicle and system cost (Section 7) and environmental evaluation (Section 8).

Electric Trolley Bus

Electric trolley buses have operated in Seattle for 70 years, since 1940. The present fleet comprises 100 standard 40-foot trolley buses and 59 articulated 60-foot trolley buses.

Electric trolley buses have been operating on urban routes in Seattle since the 1940s. The electric power and overhead wire system is in place to support this technology on existing routes. Electric trolley buses operate efficiently on routes with steep grades such as Capitol Hill and Queen Anne neighborhoods.

The electric trolley bus would be equipped with an auxiliary power unit (APU) to increase its operational flexibility by permitting off-wire travel. Both diesel and battery APUs were evaluated (see Section 6) and the battery APU was recommended.

Trolley Buses in the United States and Canada

The two most recent trolley bus procurements in the United States and Canada were 38 standard units delivered in 2008 to SEPTA in Philadelphia, Pennsylvania, and a larger order delivered to TransLink in Vancouver, B.C., between 2005 and 2009: 188 standard units in 2005 to 2007, and 74 articulated units in 2007 to 2009. Reflecting the small North American market for trolley buses, both procurements were won by New Flyer, integrating Vossloh Kiepe electrical gear into New Flyer's *Excelsior* coachwork. Both sets of vehicles have an APU. A diesel APU was selected by SEPTA, while TransLink chose a NiCad battery APU.

Earlier purchases between 1999 and 2005 saw Skoda electrical equipment being installed in coach bodies by Neoplan (for Boston) and Electric Trolley, Inc. (ETI) (for San Francisco, California and Dayton, Ohio). Any of these firms might be a factor in a future Metro procurement, except for ETI, which is no longer in business.

Other possible suppliers might include Daimler Buses North America and Gillig. During this period, Metro renewed its fleet of 40- and 60-foot trolley buses as follows:

- Purchased 100 new Gillig coach bodies and installed electrical gear refurbished by Alstom that had been salvaged from the 1970s fleet of AM General trolley buses.

- Removed diesel engines and transmissions, and made other modifications to convert fifty-nine 60-foot articulated Breda dual-mode buses to straight electric trolley buses.

Electric Trolley Buses

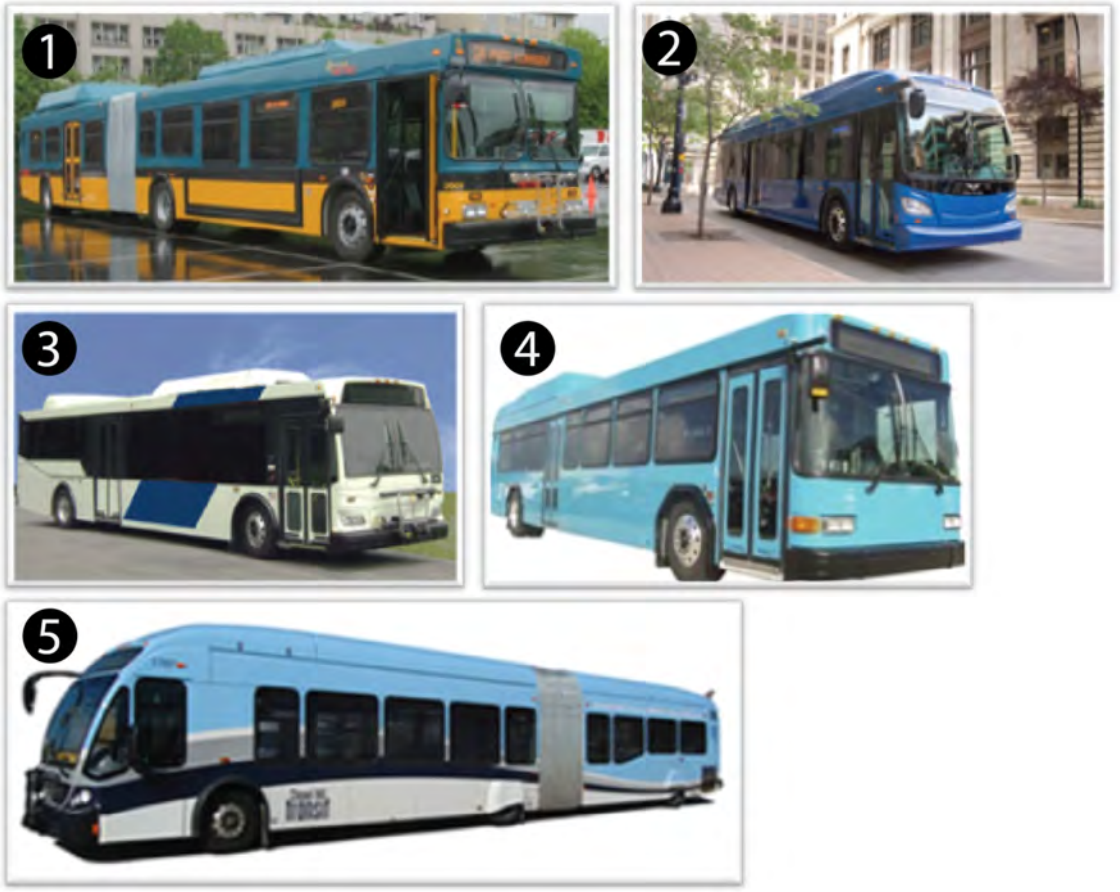
Electric trolley buses, unlike self-contained motor coaches, must be supported by a wayside traction electrification system (TES) consisting of substations feeding an overhead contact system (OCS) of poles, wiring, and associated hardware. Installation and maintenance of the TES represents a cost unique to trolley buses, as compared to motor coaches. Several other characteristics of trolley buses may or may not offset the perceived extra cost and work associated with the TES. Electric trolley bus examples are shown to the right.

Diesel Hybrid Buses

Between 2004 and 2008, Metro purchased 236 articulated diesel hybrid buses from New Flyer of America to replace the Breda dual-power buses operating on tunnel routes. Diesel hybrid buses now comprise a large portion of Metro's fleet. Currently, Metro is planning to procure just over one hundred 60-foot diesel hybrid buses to serve the six lines identified for its RapidRide bus rapid transit (BRT) program.

Bus maintenance facilities currently exist to perform necessary maintenance, although additional fueling capacity would be needed to accommodate the increased fleet size.

Examples of articulated 60-foot diesel hybrid buses (Photos 1 and 5) and standard 40-foot coaches (Photos 2, 3, and 4) are shown to the right.



VEHICLE PERFORMANCE ASSESSMENT

This section evaluates the two vehicle types against four performance measures:

- Vehicle flexibility
- Impact of grades on system operation
- Impact of vehicle weight on roads
- Rider satisfaction

An evaluation of APU technology alternatives is provided in Section 6, Auxiliary Power Unit Evaluation.

Vehicle Flexibility

Vehicles associated with a fixed guideway have less operating flexibility than vehicles that can operate along all public streets. This is a limitation of electric trolley buses as compared to motor coaches. Recent purchases of trolley bus fleets have included APUs to reduce this limitation. This discussion focuses on reducing the trolley bus connection to its contact wires below 100 percent of operating time. Key factors are summarized in Exhibit 3-1.

Exhibit 3-1. Factors Affecting Vehicle Flexibility

Item	Trolley Bus	Hybrid Bus
General Operating Mode	Draws electric power from wire; may have APU	No routing restrictions
Reroute Around Construction	Need adequate APU [a]	Capable as built
Operate in Adverse Weather	Need chains in snow, ice Trolley overhead system may become ice coated	Need chains in snow and ice

[a] Emergency power unit capable of full performance for at least 1 mile.

APUs on trolley buses may enable these vehicles to operate off-wire around construction areas for distances of at least 1 mile on level roads and shorter distances on hills, with distance declining as grades steepen. Lessons learned on peer properties that have been operating trolley buses with APUs include:

Coast Mountain Bus Company (CMBC), Vancouver, Canada

CMBC uses NiCad Battery APUs. To maximize battery life, CMBC uses its APUs for emergencies only, and does not operate off-wire in regular service. Battery life was specified to be 14 years. As of December 2010, with trolley buses ranging from 2 to 6 years in service, no battery replacements have yet been required.

San Francisco Municipal Transportation Agency (SFMTA)

SFMTA uses NiCad battery APUs to bypass obstructions in the street, but continue to use replacement diesel buses for major events and construction. Some batteries are now inoperable and have not been replaced for lack of funding. SFMTA recommends building battery maintenance and replacement costs into life-cycle cost analysis.

Southeastern Pennsylvania Transportation Authority (SEPTA)

SEPTA uses diesel APUs. Operation is limited to an area of one substation power outage, about 2 miles. Multiple outages would require diesel coach substitution over the full route, because trolley bus speed may be limited to 25 mph when running on the APU. Poles lower automatically, but must be raised manually. SEPTA recommends that APU procurement specifications match intended uses and meet all specified requirements.

As outlined in Section 6, Auxiliary Power Unit Evaluation, neither of the above APU systems is deemed desirable for a future Metro trolley bus procurement. Rather, an APU using the present state-of-the-art solution, lithium ion batteries, is recommended.

Even with an APU capable of propelling the vehicle and maintaining its brakes, steering, and other components for 1 mile, trolley buses would need to be replaced by diesel buses in some instances for reasons of range and flexibility. Experience from other transit agencies indicates that it is common to continue substituting diesel or diesel hybrid buses for trolley buses in the case of special events, major ongoing construction, or other situations where APU operation would have to cover a long distance or time period. APUs installed to date typically have some limitations, including reduced vehicle speeds, shortened expected battery life, and the need for operators or other operations staff to reattach poles to wires after using the APU.

For operation in adverse winter weather, Metro places steel shoes on trolley bus poles. Usually just the first bus on each run is so equipped; however, if wire icing conditions warrant, steel shoes may be installed on the first two or three trolley buses to enter service. After that, the trolley buses run frequently enough that ice buildup is not a problem. The 40-foot trolley buses are equipped with ATC (automatic traction control). When it snows, their driven wheels are chained in the same as any other bus.

Because of weight distribution, Metro has not had satisfactory experience with articulated trolley buses in snow and ice. As a result, both the MAN and Breda articulated trolley buses are parked at the first sign of snow.

Impact of Grade on System Operation

A feature of the road system due to Seattle's topography is that a number of streets have steep grades. Short sections of the streets served by trolley buses have grades as steep as 18 to 19 percent (e.g., Queen Anne Avenue, Valley Street to Highland Drive, approximately 1,000 feet in length). Twenty streets used by segments of trolley bus routes have grades of 12 percent to 15 percent. Such grades challenge motor coaches of all types, requiring high-speed operation of the diesel engine to achieve very low running speed, with corresponding wear and tear on engines and transmissions.

Trolley buses, however, have a 1-hour overload capability typical of electric motors, so are well suited to the demands of steeply graded streets. Electric traction motors can be operated above their normal rated capacity for short periods without overheating. Newer diesel hybrid buses may be able to perform similar to trolley buses on steep grades, although the buses have not been field tested on steep routes similar to those in Seattle. Impacts of grade on the system are summarized in Exhibit 3-2.

Exhibit 3-2. Impact of Grade on System

Item	Trolley Bus	Diesel Hybrid Bus
Ability to Operate on Hills	Superior	Inferior, although newer diesel hybrids may be able to perform similar to trolley buses
Maintenance Implications	No change from present	May need more frequent repairs to stressed engine parts and transmissions
Impacts to the System	No change from present	May need more spare buses

Impact of Weight on Road

Vehicle impacts on road surfaces are related primarily to vehicle weight and, in particular, weight per axle. Available information on newer trolley bus and diesel hybrid vehicles suggest that curb weights are similar. The diesel hybrid weight for a standard 40-foot coach is approximately 400 pounds heavier, and the 60-foot coach is approximately 1,700 pounds heavier; however, the diesel hybrid vehicles used for the comparison have air conditioning and the trolley bus vehicles do not, so the difference in weight between the two vehicles is likely to be less than reported in Exhibit 3-3.

Exhibit 3-3. Impact of Weight on Road

Item	Trolley Bus	Diesel Hybrid Bus
Curb Weight of Vehicles:		
Standard 40-foot	31,283 [a]	31,700 [b]
Articulated 60-foot	46,260 [a]	47,980 [b]

Notes:
[a] Weight of current CMBC trolley buses (without air conditioning) from Eric Holmberg, Maintenance Engineering Manager
[b] Weight of existing King County Metro New Flyer diesel hybrid buses—e-mail from Steve Policar

Rider Satisfaction with Vehicle

A transit rider's satisfaction with the vehicle, as opposed to other factors such as service level and reliability, can be assessed in terms of ride quality, noise levels, and exposure to emissions. Seating, ease of access, and other interior design elements can be the same for either vehicle alternative and are excluded from this comparison. Rider satisfaction factors are summarized in Exhibit 3-4.

It is expected that vehicle suspension will be the same for both vehicle alternatives, so the ride quality differences would be limited to passenger experiences of acceleration and braking forces. Acceleration using an electric motor is smoother than a hydraulic transmission. However, hybrid buses accelerate on electric power up to about 15 mph before blended power kicks in; so the difference between alternatives may be slight or even non-existent.

Interior noise may be expected to be lower for the all-electric trolley bus than for the diesel hybrid bus with its engine running. However, new diesel hybrids can achieve relatively low noise levels of 72 dBA (A-weighted decibels or the relative loudness of sounds in air as perceived by the human ear) in the interior and 66 dBA in the exterior (claimed test results from a new diesel hybrid bus manufacturer).

For vehicle emissions and odors, the zero-emission electric trolley bus enjoys a clear advantage over a diesel hybrid bus.

Exhibit 3-4. Rider Satisfaction

Item	Trolley Bus	Hybrid Bus
Ride Quality:		
Suspension	No Difference	No Difference
Acceleration/Braking	No Difference	No Difference
Interior and Exterior Noise	Less – Electric Motors and Solid State Controls	More – Diesel Engine and Transmission
Emissions	None at Vehicle	Gases and Particulates

Permanence—The Fixed Guideway Factor

An important factor affecting rider satisfaction is the degree of confidence that the service will continue operating over the long term. The presence of overhead trolley wire may provide a sense of permanence to system riders.

Compared to motor coach routes, which can be changed easily, rider confidence level is increased when the transit service uses a fixed guideway. Metro's trolley overhead network is considered a fixed guideway system by FTA even though it is not as expensive as a light rail or streetcar line.

CONCLUSIONS

Conclusions from the vehicle and system assessment are summarized below:

Availability: Diesel hybrid buses are offered by the four major North American suppliers, only one of which has supplied electric trolley buses during the past decade.

Flexibility: Diesel hybrid buses offer greater operating flexibility over electric trolley buses, even if electric trolley buses are equipped with APUs.

Road Impacts: Diesel hybrid buses appear to be slightly heavier than trolley buses, by about 1.3 percent for 40-foot buses and 3.7 percent for 60-foot articulated buses.

Rider Satisfaction: Compared to diesel hybrid buses, rider satisfaction is likely to be higher with electric trolley buses, because of their smoother acceleration, lower interior and exterior noise levels, and lack of emissions on the vehicle. Electric trolley bus overhead wire is a form of fixed guideway transit that enhances the transit route's sense of permanence and stability.

Traveling on Steep Grades: Electric trolley buses offer superior grade-climbing capability and performance compared to a conventional diesel hybrid bus. Newer diesel hybrid buses may be able to perform similar to trolley buses on steep grades, although the buses have not been field tested on steep routes similar to those in Seattle.

If the diesel hybrid technology is selected by Metro, the new buses would need to have special gears to travel on routes with steep grades. This would limit Metro's ability to use these buses on other routes because top travel speeds and fuel efficiency on flat grades would be low.

4. Life-Cycle Cost Comparison

INTRODUCTION

A life-cycle cost model was prepared to evaluate and compare the life-cycle costs for the electric trolley and diesel hybrid bus technologies. This model was used to project the relative costs to procure, operate, and maintain these two candidate vehicle technologies over Metro's current electric trolley bus service routes. The objective of the analysis was to determine which vehicle type yielded the lowest life-cycle cost over a single generation.

This section describes the life-cycle cost model. It lists the basic input data, sources, and any assumptions made. Data can generally be traced to Metro experience or that of other agencies operating similar fleets. Because of the uncertainty in predicting some costs, such as future fuel prices, several values were used to test the model for sensitivity to input variations.

LIFE-CYCLE COST MODEL

The annual capital, operating, and maintenance spending for each potential vehicle technology and associated supporting infrastructure was compiled in the model. Costs were tracked by year of expenditure, allowing for the application of various inflation and escalation rates. The total costs associated with one vehicle life cycle were then summed through a net present value calculation. Candidate technologies with different anticipated life spans were compared by dividing the net present value by the life span. The objective of the life-cycle cost analysis was to determine which candidate vehicle technology exhibits the most economical solution over one generation. A vehicle with a high initial capital cost may have lower operation and maintenance (O&M) costs such that the initial cost premium is offset through incremental annual savings.

The focus of the life-cycle cost analysis was to determine the relative cost difference between electric trolley bus and hybrid bus technologies. Costs common to both vehicle types, such as station maintenance, do not differentiate and can be ignored. The model was developed only from costs unique to each candidate vehicle technology. Thus, the modeled costs are relative rather than absolute. The model will correctly indicate the most economical solution; however, the final cost to implement the electric trolley bus or diesel hybrid bus will be greater than estimated within the model because costs common to both vehicle technologies were excluded.

Exhibit 4-1 outlines the life-cycle cost model components for the two candidate technologies. Both include the basic elements of capital, operations, and maintenance. However, the electric trolley bus technology is burdened by the

trolley overhead (TOH) wire and power system while the diesel hybrid technology includes the cost of removing the TOH and modifying the maintenance facilities. The FTA offers significant grants to offset vehicle purchases for both technologies, including fixed guideway operating grants for the electric trolley bus. Costs and specific assumption details are explained in the section below.

Exhibit 4-1. Overview of Life-Cycle Cost Model

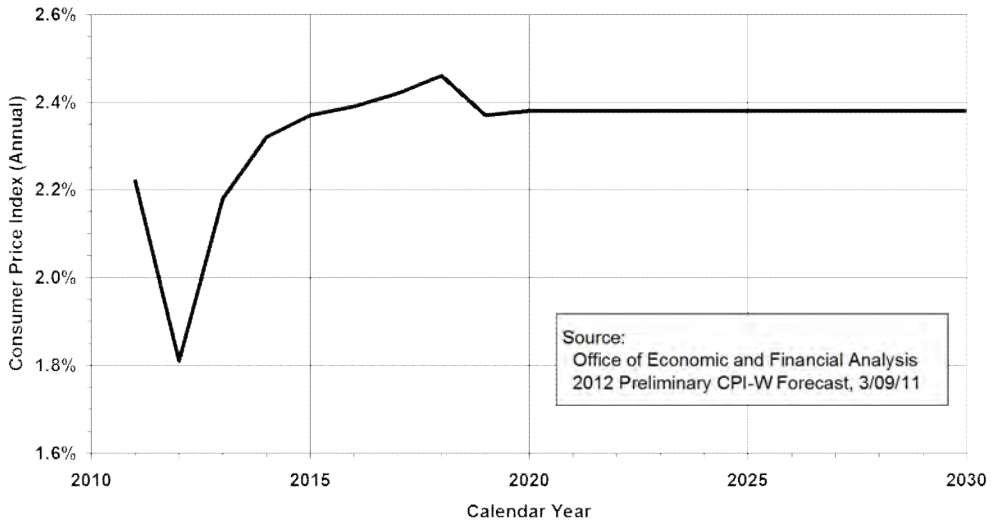
Category	Electric Trolley Bus	Hybrid
Capital	Purchase New Fleet of Electric Trolley Buses	Purchase New Fleet of Diesel Hybrid Buses
	Offsetting Grants	Offsetting Grants
Infrastructure Modifications	Planned Upgrades to TOH	Remove TOH
		Modify Atlantic-Central Base
Operations	Electricity	Fuel
Maintenance	Vehicle Maintenance Costs	Vehicle Maintenance Costs
	TOH Maintenance Costs	
Offsetting Grants	FTA Fixed Guideway Funding	

BASIC ASSUMPTIONS

The basic assumptions of the model focus on the time span of the study, assumed escalation rates, and the general financial climate. Costs were compiled in the reference year 2010, when possible. Historical prices were escalated from their original year of reference to 2010 by assuming 3 percent inflation.

Reference 2010 prices were projected forward at an assumed Consumer Price Index (CPI). All non-diesel fuel prices used a CPI published by the Office of Economic and Financial Analysis in their 2012 Preliminary CPI-W Forecast dated March 9, 2011. Exhibit 4-2 plots the CPI used in this analysis. Fuel cost projections are described in detail in the operating costs section.

Exhibit 4-2. Consumer Price Index Applied to Life-Cycle Cost Analysis



It was assumed that a new bus fleet of either electric trolley buses or diesel hybrid buses would enter into service on the current electric bus routes in 2014. All initial capital costs would be incurred in 2014 with annual O&M costs being charged from 2014 onward.

Metro directed that the assumed life span of the two bus types should reflect FTA precedence, especially considering the high duty cycle associated with the electric trolley bus routes. Thus, the life-cycle cost model assumed that hybrid buses would last 12 years (from 2014 until 2025) and that electric trolley buses would last 15 years (from 2014 until 2028).

As specified by King County Executive Policy, the discount rate was assumed to be 7.0 percent annual percentage rate (APR). The discount rate is used within present value calculations to measure the cost of money considering time, interest, alternative uses, and risks.

SERVICE ENVIRONMENT

The cost estimates assume that the current electric trolley bus fleet and service routes will be maintained, but replaced with a new fleet of either electric trolley buses or diesel hybrid buses.

Fleet Assumptions

The life-cycle cost model maintains the current fleet of 159 buses consisting of one hundred 40-foot units and fifty-nine 60-foot units. It was assumed that a new fleet would be purchased at the beginning of the study and remain in service for one life span. The new fleet was assumed to keep the same nominal seated and total passenger capacity as the current fleet.

The drive trains for both trolley bus and diesel hybrid technologies would be specified to be capable of climbing the relatively steep grades associated with the electric trolley routes. The 40-foot buses were assumed to be single-body units with two side-entry doors and six tires. The 60-foot buses were assumed to be articulated units with three side-entry doors and ten tires.

The current electric trolley buses rely completely on the TOH wire to supply power. The buses cannot operate during a TOH fault or outage, and can never detour away from the TOH to avoid congestion, construction, or accidents.

The life-cycle cost model assumes that the future electric trolley buses will be equipped with moderate-capacity battery APUs to move around short (less than 1 mile) obstructions. (Refer to the Operating Costs section for a discussion of APUs).

The fleet of either electric trolley buses or diesel hybrid buses should benefit from current and near-term future technology improvements. Both bus types should benefit from alternating-current (ac) electric motors as compared to Metro's present direct-current (dc) electric motors. Metro will continue to own and operate a large bus fleet for its other routes. The life-cycle cost model assumes that this fleet exists whether calculating costs for electric trolley buses or diesel hybrid buses. This additional fleet has been assumed to be able to provide, at no cost to the life-cycle cost estimate, the occasional spare or supplemental bus, as needed.

Routes Served

Metro currently operates electric trolley buses on 14 routes in central and north central Seattle. In 2010, these routes accrued a total of 3,688,181 service miles, 62.8 percent on 40-foot buses and 37.2 percent on 60-foot buses. Metro directed that the life-cycle cost model should maintain both these overall miles and the service split between 40-foot and 60-foot buses in the future. This implies that the routes will follow the current operating schedule, hours of service, station stops, and approximate ridership.

Occasionally, special conditions will require the use of diesel-powered buses to replace or supplement electric trolley buses. These events include weekend street construction, TOH maintenance, bus failures, traffic blockages that necessitate rerouting away from the TOH, or special events needing additional capacity.

In 2010, total service substitutions, also known as "route dieselization," accounted for approximately 16.6 percent of all electric trolley bus route service miles.

As described above, Metro has assumed that the future electric trolley buses will be equipped with battery auxiliary power units; dieselization should correspondingly be reduced to one-tenth of current levels, down to 1.7 percent of total electric trolley bus route miles.

For the electric trolley bus analysis, the diesel buses used during route dieselization are assumed to be pulled from the larger Metro fleet. Replacement would be in kind—a 40-foot diesel to replace a 40-foot electric trolley bus and a 60-foot diesel bus to replace a 60-foot electric trolley bus.

Trolley Overhead

Metro maintains approximately 69 miles of two-way TOH wire. The life-cycle cost model assumes that the TOH system will not expand or contract. The current system will merely be kept in a state of good repair for electric trolley bus service or removed for diesel hybrid service. These costs are detailed in the Capital and Operating Costs sections.

CAPITAL COSTS

Capital costs were assumed to be one-time expenses for rolling stock or infrastructure, detailed in the sections below. Each capital cost was assumed to occur as a lump sum payment in the first year of the study.

Rolling Stock

Metro maintains internal cost estimates for fleet replacement, based on firm quotes from candidate bus manufacturers. They provided these cost estimates to the consultant in 2010 dollars and adjusted for their typical procurement specification. The consultant also researched recent industry sales of 40-foot and 60-foot electric trolley buses, and 40-foot and 60-foot diesel hybrid buses. Industry prices, escalated to 2010 dollars and adjusted for Metro-preferred optional equipment, support the Metro internal cost estimates. The Metro estimates were used as current base rolling stock unit capital costs.

The base rolling stock unit capital costs were then adjusted for the following factors:

- Additional Equipment ($8,000 for 40-foot, $12,000 for 60-foot, Fixed)
- Sales Tax (8.9 percent)
- Project Management ($8,100, Fixed)
- Service Preparation and Inspection (2 percent)
- Aftermarket Equipment ($25,700, Fixed)
- Contract Spares (zero percent)
- Training and Manuals ($6,700, Fixed)
- Special Tools and Diagnostic Equipment (0.3 percent)
- Contingency (5 percent)

The additional equipment charge was assumed to cover items such as fare boxes, security cameras, bike racks, disc brakes, electrically-driven accessories, and a third door for passenger entry/exit (60-foot buses only). The aftermarket equipment charge includes items to be installed by Metro such as fare collection smart card readers, radios, WiFi, and the On-Board Systems/Communications Center System project.

A Washington State Sales Tax (WSST) of 9.8 percent was assumed for all items received directly from the bus manufacturer (base bus, additional equipment). Further, it was assumed that 0.9 percent of the bus purchase price was returned to Metro in operating credits by the state. The net WSST was 9.8 minus 0.9 percent, or 8.9 percent.

Other cost adjustment factors were based on experience from past bus procurements. The total rolling stock unit capital cost was calculated from the base rolling stock unit capital cost and additions for taxes and soft costs. Exhibit 4-3 lists the base rolling stock unit capital cost while Exhibit 4-4 shows the total rolling stock unit capital costs.

Exhibit 4-3. Base Rolling Stock Unit Capital Costs

	Unit Cost ($ in millions, 2010)	
Size	Electric Trolley Bus	Hybrid
40 foot	1.031	0.495
60 foot	1.285	0.785

Exhibit 4-4. Total Rolling Stock Unit Capital Costs

	Unit Cost ($ in millions, 2010)	
Size	Electric Trolley Bus	Hybrid
40 foot	1.255	0.629
60 foot	1.557	0.972

FTA Grants

The FTA offers a variety of grants to assist transit agencies purchase new rolling stock. Based on the current FTA programs and formulary grants, Metro is eligible for offsetting grants of up to 83 percent of the total capital costs of electric trolley buses and diesel hybrid buses. Because the total amount of FTA grant funds coming into the region is fixed, the 3 percent higher potential amount for electric trolley buses would not increase the total amount of regional grant funding. Therefore, this difference was excluded from the life-cycle cost analysis.

The FTA capital offset grants were considered as a negative capital cost, occurring coincidently with vehicle purchase to reduce the net cost to Metro. The sensitivity study considered variations in the FTA capital offset grants.

Infrastructure Modification

The Metro electric trolley bus routes and associated maintenance facilities are currently configured for electric trolley bus operations. If electric trolley buses were removed and replaced with diesel hybrid buses, some infrastructure modifications would be required, as detailed below.

Removal of TOH

A TOH wire system, support poles, and associated substations are already installed along the electric trolley bus service routes. If electric trolley buses were replaced with diesel hybrid buses, the TOH would need to be removed at an estimated cost of $37.385 million (2010). This estimate, presented in Exhibit 4-5, does include labor, materials, and mobilization to remove the TOH, soft costs and contingencies, and the salvage value of the wire and land.

Exhibit 4-5. Removal of TOH Construction Cost Estimate

Description		Cost ($ 2010)
Construction Costs		
Remove Metro Only Poles and Eyebolts		1,661,634
Remove Trolley Wire		14,960,285
Traffic Control for Non-Trolley Wire		1,830,000
Remove Substations		363,766
Remove Vaults/Ducts Outside Downtown		5,021,714
Remove Vaults/Ducts Downtown		1,089,400
Mobilization		1,500,000
Construction Costs Total		26,427,000
Soft Costs		
Project Management	5%	1,321,350
Construction Management	15%	3,964,050
Engineering/Design	15%	3,964,050
Environmental Review	1%	264,270
Permits	1%	264,270
Property	2%	528,540
Other: Broken Lease Cost	2%	528,540
Soft Costs Total		10,835,000
Other Costs		
Salvage Wire		(8,456,448)
Land		(2,600,000)
Project Contingency	30%	11,178,600
Other Costs Total		123,000
Rough Order of Magnitude Grand Total		37,385,000

Modification of Atlantic and Central Bases

The Atlantic Base is located adjacent to the electric trolley bus routes and services the current electric trolley bus fleet. However, if the electric trolley buses were replaced with diesel hybrid buses, the Atlantic Base or nearby Central Base would require an additional fueling lane and increased fuel storage capacity.

Together, the Atlantic and Central Bases service 401 diesel-powered buses and 159 electric trolley buses. Metro prefers to schedule fuel deliveries every 3 days. The fuel tanks are sized for fuel delivery every 4 days, providing some contingency for delivery disruptions or unscheduled fuel tank maintenance. Experience has shown that roughly 36,000 gallons of storage capacity are required for every 200 diesel buses. An expansion to 560 diesel buses would require 29,000 gallons of additional storage.

The additional diesel buses at Atlantic Base would require a new fueling and service lane. Assuming each bus requires 3 minutes to fuel and service times 159 additional buses results in 8 hours of additional fuel and service lane

occupancy—an amount only available by adding an additional lane.

Atlantic Base is the recommended location for both fueling and fuel storage expansion. Space constraints at Central Base would be difficult to overcome; eliminating approximately six bus parking spaces in the best case scenario. Fueling and servicing capacity could be added at Atlantic Base east of the 3rd lane facility without any change to base operations. Two additional 12,000-gallon fuel tanks (Metro's preferred size) at Atlantic Base are required to provide the nominal requirement for fuel. The auxiliary tanks (transmission fluid, antifreeze, and oil-based lubricants) are adequate to accommodate the increase in diesel buses. A fuel lane and auxiliary fluids tank expansion project at Central Base in 2003 accommodated the planned expansion to 560 buses assuming that 159 buses would be trolleys.

The addition of a fuel and service lane at the Atlantic Base is estimated to cost $5.228 million (2010) as detailed in Exhibit 4-6.

Exhibit 4-6. Modification of Atlantic Base Construction Cost Estimate

Description		Cost ($ 2010)
Construction Costs		
Add two 12,000-gallon diesel fuel tanks including site preparation, tanks, piping, monitoring, pumps, and site restoration		
Site preparation including relocating utilities		60,000
Tank installation including dead man, sheet piles, backfill, power, fill buckets, manholes, cathodic protection		650,000
Pumps		20,000
Underground piping including containment		25,000
Leak detection		60,000
Concrete lid		25,000
Site restoration		10,000
Add one full-service fuel lane at Atlantic Base including canopy, fuel and other fluid dispensers, DEF dispensing, piping, containment, oil/water capture and separation, fuel management system, communications and bus cleaning vacuum system		
Site preparation including adding and relocating utilities		220,000
Canopy and exterior lighting		120,000
Fluid dispensers and aboveground piping		110,000
Underground piping including containment		140,000
Oil/water capture and separation, waste oil tank		260,000
Fuel management system		60,000
Communications		25,000
Site restoration		120,000
Bus cleaning vacuum		375,000
Construction Costs Subtotal		2,280,000
Contractor use tax on materials, markup, overhead and profit	30%	684,000
Construction Costs Total		2,964,000
Soft Costs		
Engineering	15%	444,600
Project Management	5%	148,200
Construction Inspection	15%	444,600
Permits, Environmental Review		20,000
Subtotal Project Cost		4,021,400
Contingency	30%	1,206,420
Rough Order of Magnitude Grand Total		5,227,820

OPERATING COSTS

Operating costs were assumed to be recurring expenses for rolling stock and infrastructure, detailed in the sections below. Costs were tracked annually over the span of one vehicle life.

Rolling Stock

Rolling stock operating costs typically account for bus operator labor, central dispatch staff and equipment, field supervisors, relief stations, and fuel or energy. However, in a differential cost life-cycle model comparing two technologies following the same nominal route profile and operating schedule, the only significant contributor becomes the fuel or energy.

Electric Trolley Bus

Electric trolley buses were assumed to operate for 98.3 percent of the current trolley system total miles, with 1.7 percent of miles provided by diesel hybrid buses borrowed from the greater Metro fleet. For both electric trolley and diesel hybrid buses, miles were assumed at 62.8 percent on 40-foot buses and 37.2 percent on 60-foot buses.

Metro's power consumption data for the electric trolley buses show that their 40-foot buses average 5.175 kWh/mile while their 60-foot buses average 6.919 kWh/mile. Energy consumption is known to fluctuate seasonally with heating, venting, and air conditioning (HVAC) loads. However, for purposes of the long-term life-cycle cost analysis, an average annual rate was used.

Diesel Hybrid Bus

Diesel hybrid buses were assumed to operate for 99.1 percent of the current trolley system total miles. The hybrids would save approximately 0.9 percent of system total annual miles through more efficient and direct deadheading between the bus base and their entry into service. Miles were assumed at 62.8 percent on 40-foot buses and 37.2 percent on 60-foot buses.

Metro currently operates diesel hybrid buses and this sample can be used to provide a reference fuel consumption rate. However, these hybrids operate on relatively flat routes and typically travel parts of their routes at highway speeds. The electric trolley bus routes have significantly more grades, reduced average and top speeds, and more frequent stops. Some of these route aspects reduce the potential hybrid fuel economy, while others increase the chance for regenerative braking and increase the diesel hybrid fuel economy. LTK estimated the fuel required to travel both the current diesel hybrid bus routes and the electric trolley bus routes. These results were compared to actual Metro data and used to scale the historical diesel hybrid fuel economy to the proposed electric trolley bus duty. The 40-foot diesel hybrid bus is expected to average 4.16 miles per gallon (mpg) while the 60-foot diesel hybrid bus is expected to achieve 2.81 mpg.

Electricity

Seattle City Light (SCL) electricity rates were set on October 1, 2010. Metro has projected their 2011 effective electric trolley bus service rate, accounting for demand, metering, transformer investment, and transformer losses, to be $0.0658/kWh. The life-cycle cost model assumes that this base price increases with CPI over the length of the study.

Diesel Fuel

Metro receives periodic diesel fuel price projections from Linwood Capital, based on market conditions and statistical correlations to the broader petroleum products futures market. Linwood's analysis projects diesel fuel prices for approximately 5 years into the future (2011 through 2015). To acknowledge the variability in future prices, Linwood quotes several price trends based on confidence intervals. The life-cycle cost analysis selected three near-term diesel fuel price estimates:

Low = Projected average price minus one standard deviation, leaving a 15.9 percent chance that actual prices will be below this value. The 2011 reference price was $2.642/gallon.

Middle = 65 percent below probability—a projected price such that there is a 65.0 percent chance that actual prices will be below this value. The 2011 reference price was $3.482/gallon. Metro traditionally bases their annual budgets on this price.

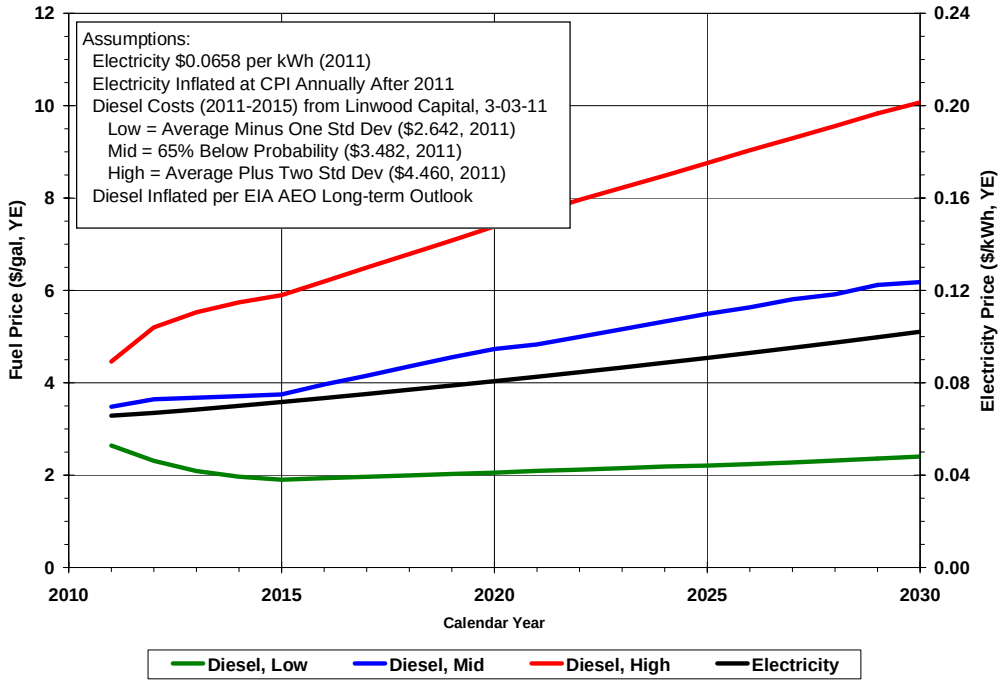
High = Projected average price plus two standard deviations, leaving a 97.7 percent chance that actual prices will be below this value. The 2011 reference price was $4.460/gallon.

The Energy Information Administration (EIA) publishes an Annual Energy Outlook (AEO) that includes long-term projections of petroleum product pricing. The EIA AEO includes low, middle, and high trends. These three estimates were reduced to annual escalation factors.

The life-cycle cost analysis used the Linwood Capital diesel fuel price estimates from 2011 through 2015 and then increased the prices after that to reflect EIA AEO projections. The low, middle, and high price trends were used in the sensitivity analysis.

Exhibit 4-7 shows the year-by-year fuel and energy prices used in the life-cycle cost analysis. Prices are in year of expenditure.

Exhibit 4-7. Projected Fuel and Energy Costs Applied to the Life-Cycle Cost Analysis



FLEET MAINTENANCE COSTS

Maintenance costs were assumed to be recurring expenses for rolling stock and infrastructure, detailed in the sections below. Costs were tracked annually over the span of one vehicle life.

Rolling Stock

Metro tracks the costs of their complete bus maintenance program, including:

- Fueling and Servicing
- Tires
- Routine Maintenance
- Spare Parts
- Trouble Calls
- Staff Labor and Overhead

Fueling and servicing costs were accounted for under Operations and removed from Maintenance.

Metro bus tires are leased and associated labor subcontracted, currently costing $0.009/tire mile (2010). The life-cycle cost model assumed that tire costs escalated from present costs with CPI over the duration of the analysis.

The remaining rolling stock maintenance items were reviewed to identify cost trends over a vehicle's life span. Generational changes within the Metro cost database did not allow for more detailed cost breakdown. This is one case where labor and overhead were included in the life-cycle costs, but only the differential between electric trolley buses and diesel hybrid buses will affect the results.

Electric Trolley Bus

Maintenance costs for the electric trolley bus vary by bus manufacturer and propulsion system technology. Two generations of 40-foot electric trolley buses were fairly consistent in costs among manufacturers and across multiple years of service. Maintenance costs were initially low and increased linearly with age as more significant repairs, overhauls, and unscheduled trouble calls were required. A similar trend was seen in an older generation of 60-foot electric trolley buses, but a significant cost change appeared to occur with the conversion of the Breda electric trolley buses. Initial costs were high because the fleet was small and special problems were worked out in the conversion process. After a few years of service, costs settled down. Other properties were surveyed for electric trolley bus maintenance data for the following reasons:

- Metro historical maintenance data are based on a fleet using electronics 21 to 31 years old. These electronics are too outdated to compare to today's electronic systems.
- New trolleys would use AC motors not DC motors.
- New electronics operate at a higher frequency allowing faster switching. This allows more power using a smaller component and less weight.
- Part of the rehabilitation of the Breda trolley was allocated within the operating budget.
- Breda was not designed as a trolley.
- Data on the existing fleet have gone through several maintenance reporting system changes. Information is lost, converted, or added that was not used before.
- A design problem on the 40-foot electric trolley bus was repaired using money within the operating budget.

CMBC in Vancouver, B.C., operates a fleet of 40-foot and 60-foot electric trolley buses of similar quantity and mixture as

Metro. CMBC replaced all of its electric trolley buses between 2004 and 2007 and recently expanded the fleet. They shared data with Metro that capture the initial annual maintenance costs of a state-of-the-art electric trolley bus fleet. The CMBC maintenance costs were reviewed and scaled up by 15 percent to conservatively account for Seattle cost of living, Metro overhead, and differences in duty cycle between the two services.

The life-cycle cost analysis thus uses annual maintenance costs for electric trolley buses that are based on CMBC initial costs. These maintenance costs increase as the bus ages, following the trend of Metro historical data.

Diesel Hybrid Bus

Historical Metro maintenance data were used to determine the average annual maintenance costs of diesel hybrid buses. Up to two hundred and thirty-five 60-foot diesel hybrid buses have been operated since 2003, giving strong cost references. Only one 40-foot diesel hybrid bus has been operating since 2006. The bus maintenance for the diesel hybrid bus follows the electric trolley bus trend with increasing costs as the bus ages.

Hybrid drive trains should reduce the engine loads with reliance on electric motors and battery packs for starting and stopping. These hybrid-specific parts can require costly repair, refurbishment, and/or replacement as the bus ages.

Metro diesel hybrid bus maintenance costs compared favorably with CMBC and the National Transit Database (NTD). The Metro diesel hybrid maintenance cost data were used in the life-cycle cost analysis, but scaled up slightly to account for the higher duty cycle expected on the electric trolley bus routes as compared to the current diesel hybrid routes.

It is recommended that if diesel hybrid buses are purchased to replace the electric trolley buses, a specific sub-fleet be purchased, more suited to the steep grades, short distance between stops, and lower top speed required of this service. This modification should focus specifically on changing the final drive gear ratio.

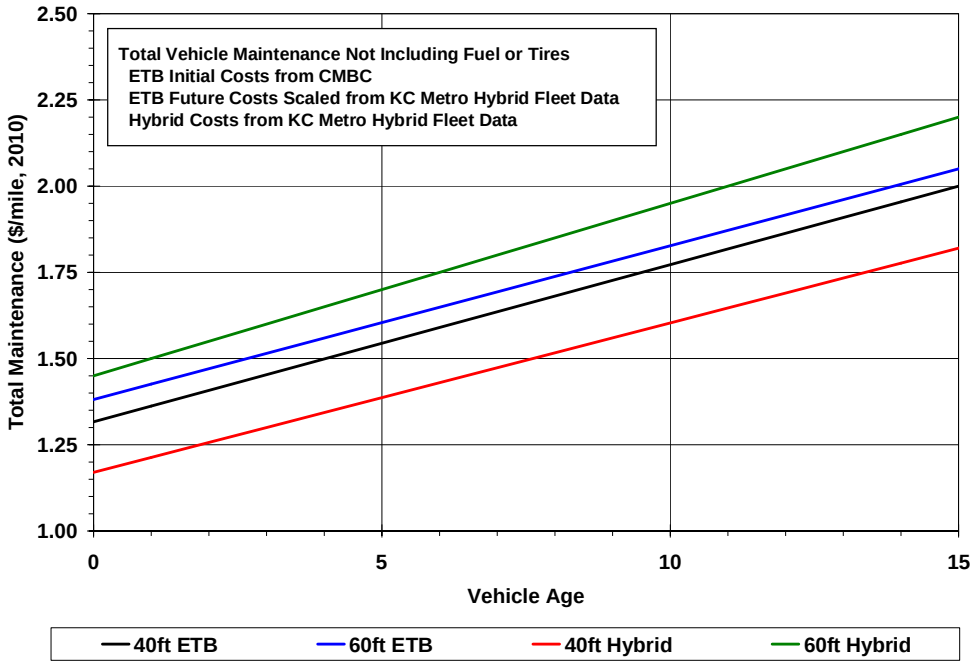
Failure to modify the replacement electric trolley buses could result in:

- More wear on the engine with at least one more rebuild in the life of the bus
- Reduced battery life due to more severe use
- Increased wear on the differential gear set with at least one rebuild in the life of the bus
- Increased brake wear causing more frequent relines

Removing electric trolley buses from the Metro system and replacing them with diesel hybrid buses may allow some consolidation of spare parts, storage, and general efficiencies of work flow. However, as noted, the electric trolley bus replacement hybrids may not be identical to other hybrids within the larger fleet. At this stage of cost estimation, the efficiencies of spares, storage, and work flow is merely noted, but not monetized.

Exhibit 4-8 graphically shows the total vehicle maintenance costs used in the life-cycle cost analysis, not including fuel or tires. Generally, the 40-foot buses cost less per mile to maintain than the 60-foot buses because the shorter units have fewer interior, exterior, and passenger interface features. The 60-foot electric trolley bus costs are close to the 40-foot bus costs, probably reflecting robust drive train elements. The diesel hybrid buses show a larger spread between 40-foot and 60-foot bus costs, possibly indicating that the 60-foot units increase the duty cycle on the diesel engine and battery pack, and inflate associated maintenance.

Exhibit 4-8. Total Maintenance Costs Applied to the Life-Cycle Cost Analysis



TOH SYSTEM MAINTENANCE COSTS

The TOH system requires annual maintenance and inspection. Associated TOH infrastructure requires periodic overhaul, refurbishment, and replacement.

Annual Operation and Maintenance

Metro provided budgetary estimates for the annual O&M costs for the TOH system. Maintenance and inspection costs include:

- Materials and repair
- Cleaning and landscaping
- Utilities and taxes

The dominant operating cost for the TOH is the electricity drawn by the electric trolley bus fleet. These costs were accounted for under rolling stock operating costs. A minor operating cost remains—utility charges to support the TOH substations and stationary equipment. For modeling simplicity, these operating costs were bundled with the maintenance costs to create a simple TOH annual O&M cost.

Capital System Improvements

The TOH has associated infrastructure such as poles, wire, substations, and rectifiers. These elements require periodic overhaul, refurbishment, and replacement. This work can be counted as capital improvements because it extends the life of the components. Metro has scheduled and distributed capital improvements over the next 20+ years, creating an expense distribution resembling an annual expense. For simplicity, the life-cycle cost analysis tracks the TOH capital system improvements in the year of expenditure, just like an annual cost.

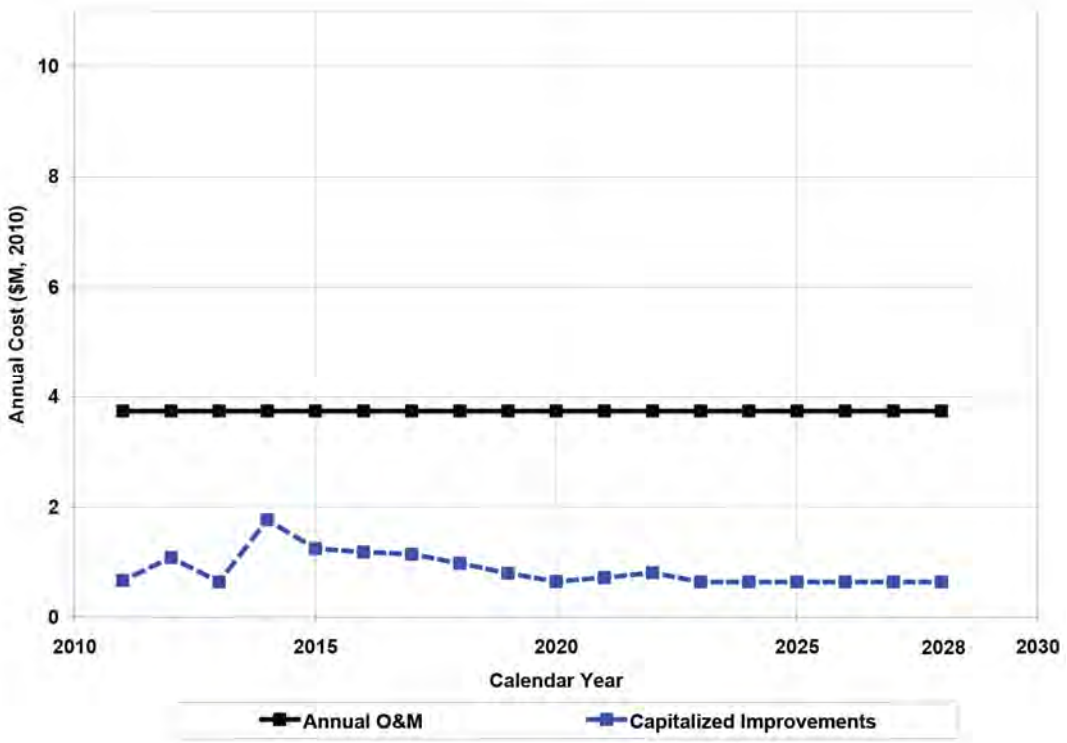
TOH capital system improvements include:

- System modifications
- Future rectifier replacements
- Substation enclosures
- Contractor replacement
- Substation batteries and enclosure
- Substation AC cubicle
- TOH pole and switch maintenance
- Influence of TOH lifespan on life-cycle cost analysis

Major capital system improvements to the TOH system are not anticipated within the 2014 to 2028 time period of the life- cycle cost analysis.

Exhibit 4-9 compares the TOH annual O&M costs to the capitalized improvement costs over the span of the life-cycle cost analysis.

Exhibit 4-9. TOH System Maintenance Costs Applied to the Life-Cycle Cost Analysis



FTA Fixed Guideway Funding

The FTA offers two fixed guideway grant programs through which Metro has historically secured funding for the electric trolley bus system.

The Urbanized Area Assistance Program is a formula grant program also known as Section 5307. The intent is to support the development, maintenance, and improvement of public transportation in areas with a population greater than 50,000. The FTA distributes funds annually based on a population ratio; funds may be used for administrative, operations, and capital costs within the transit program.

The Transit Capital Investment Program, also known as Section 5309, provides capital assistance for three primary activities:

- New fixed guideway systems (New Starts program and Small Starts)
- New and replacement buses and facilities (Bus and Bus Related Facilities program)
- Modernization of existing rail systems (Fixed Guideway Modernization program)

Last year, Metro received $4.336 million (2010) from the Section 5307 grants and $6.609 million (2010) from the Section 5309 grants for a combined total of $10.945 million (2010).

If Metro continues to operate the electric trolley bus service, they may reapply for the 5307 and 5309 grants and could expect to receive approximately the same combined total federal money. However, if Metro discontinues electric trolley buses in favor of diesel hybrid buses, they will no longer be eligible for these grants and lose all associated funding.

The life-cycle cost model assumes the electric trolley bus technology option continues to receive fixed guideway funding at the 2010 levels, but funding levels were significantly varied in the sensitivity analysis.

SENSITIVITY ANALYSIS

The life-cycle cost analysis was based on several significant, uncontrolled assumptions: discount rate, fuel pricing, electricity pricing, FTA grants, and the life spans of the candidate buses. Sensitivity analyses were performed to quantify the effect of these variables on life-cycle costs.

Because of the nature of the life-cycle cost model, it was found that the difference in annualized cost between electric trolley buses and the diesel hybrid buses varied linearly with the relative amount of FTA fixed guideway funding received. To state this another way, it was possible to calculate the FTA fixed guideway funding required to make the two rolling stock choices equally beneficial—funding above this break-even value favored electric trolley buses while funding below this value favored diesel hybrid buses. Thus, the sensitivity analysis could help Metro select a future rolling stock technology based on economic projections as well as confidence in continued federal funding.

As summarized in Exhibit 4-10, the analysis was not sensitive to diesel fuel costs varying between the low, middle, and high projections shown previously in Exhibit 4-7. Even if diesel fuel was free, the cost savings is not high enough to make the diesel hybrid technology more cost effective than electric trolley buses.

Exhibit 4-10. Sensitivity of Major Cost Variables

What would be required to make diesel hybrid buses more cost effective?	
Input	**Ability to Switch Results**
Fixed guideway funding	Reduce to 31% of current level
Diesel fuel price	Not possible
Electricity price	Increase 20% per year
Diesel hybrid life span	Increase from 12 to 17 years
Electric trolley bus purchase price	Increase by 34%
Diesel hybrid purchase price	Decrease by 48%

Electricity was allowed to escalate a few percentage points faster and slower than the CPI, but this also had little influence on the life-cycle cost results.

The real discount rate was varied significantly to test the current investment climate. The total cost of the project changed dramatically with changes in discount rate, but the favored rolling stock technology did not change.

Life-Cycle Cost Model Scenarios Based on Public Input

At the public meetings, information was requested on the results of several scenarios using different input assumptions in the life-cycle model. This type of scenario or sensitivity testing is done to determine which input variables

have the largest influence on the life-cycle cost model results.

Exhibit 4-11 summarizes the results of the scenarios.

Exhibit 4-11. Annualized Cost Comparison ($ millions) Using Different Life-Cycle Cost Model Assumptions

Scenario Name	Electric Trolley Bus Costs	Diesel Hybrid Costs	Differential
Base life-cycle cost model	11.75	15.51	3.76
Discount rate at 5%	14.49	20.38	5.89
Longer life span (electric trolleybus—18 years, and diesel hybrid—15 years)	9.80	12.41	2.61
Longer life span (electric trolleybus—18 years, and diesel hybrid—12 years)	9.80	15.51	5.71

The base case assumes no federal funding for the vehicle capital purchase and the real discount rate at 7 percent. Changing the discount rate assumption alters the magnitude of the result, but not the final outcome favoring the electric trolley bus over the diesel hybrid technology.

Lowering the discount rate from 7 percent in the base model to 5 percent has a moderate impact. The largest impact is on federal fixed guideway grant funding, which is more influential because it is included in each year of the analysis. The discounted annual benefit to electric trolley buses changes from 5.42 million to 8.70 million, increasing the annual cost differential from 3.76 to 5.89 million.

Finally, increasing the vehicle life span from the base case assumption of 12 and 15 years to 15 and 18 years for diesel hybrids and electric trolley buses, respectively, decreases the annual benefit to electric trolley buses from 3.76 to 2.61 million. If the life span for electric trolley buses was increased to 18 years while keeping the diesel hybrid life span at 12 years, the annual benefit to electric trolley buses would increase from 3.76 to 5.71 million.

CONCLUSIONS

A life-cycle cost model was developed to compare two future rolling stock technology alternatives for the current Metro electric trolley bus service routes. The model accurately captured Metro and industry data defining the capital, maintenance, and operating costs of modern electric trolley buses and diesel hybrid buses. The model also highlighted the importance of infrastructure modifications and federal grant money, specifically as follows:

- Electric trolley bus service is not economically favorable without partial fixed guideway funding
- Diesel fuel price forecasts have the greatest influence on life-cycle cost results
- A change in vehicle life span for one or both technologies can significantly alter the magnitude of the cost difference between the two technologies
- Electricity rates, being naturally stabilized by public utility commission oversight, have little influence on the life-cycle cost results
- Lowering the real discount rate can change the total cost of the program, but not the preferred technology

5. Environmental Comparison

This section provides a comparative analysis of environmental effects that would result from replacing the existing trolley bus fleet with a new fleet of diesel hybrid or trolley buses. Metro will review the need for a more detailed environmental review in accordance with the National Environmental Policy Act (NEPA) and the State Environmental Policy Act (SEPA) after determining its preferred fleet replacement option based on this comparative screening analysis. Based on the conclusions of this comparative analysis, it is expected that Metro will prepare a Categorical Exclusion (CE) or Documented Categorical Exclusion (DCE) in coordination with the FTA to comply with NEPA, and a Categorical Exemption or Determination of Non-Significance with an environmental checklist to comply with SEPA.

If Metro chooses to replace the trolley bus fleet with diesel hybrid buses, more detailed environmental analysis may be warranted as a result of additional impacts. Potential environmental effects from each fleet replacement option are summarized in Exhibit 5-1.

Exhibit 5-1. Summary of Potential Comparative Environmental Effects

	Replacement Diesel Hybrid	Replacement Electric Trolley Bus with Auxiliary Power Unit
Traffic Effects		
General Purpose Traffic	Performance of diesel hybrid buses on roadways with steep grades is possible, but engine gearing on the buses would need to be lower, eliminating the flexibility of exchanging these buses with conventional diesel hybrids operating on less steep routes. Newer diesel hybrid buses may be able to perform similar to trolley buses on steep grades, although the buses have not been field tested on steep routes similar to those in Seattle.	Possible advantage due to acceleration and speeds on grades
Bus Speed and Reliability	Relative advantage due to off-wire limitations of trolley bus.	Possible advantage due to acceleration and speeds on grades; relative disadvantage due to occasional off-wire operations, which can be reduced by use of APUs.
Bicycles, Pedestrians, and Parking	No difference	No difference
Noise Effects		
	Higher decibel level	Lower decibel level
Air Quality/Climate Change/Energy Effects		
Air Pollutants	7,075% higher VOCs, 699% higher $PM_{10,}$ 801% higher NOx, and 2,077% CO_2 equivalents relative to trolley buses	Lower VOCs, PM_{10}, NOx, and CO_2 equivalents relative to diesel hybrid buses.
Energy	45% higher Btu consumption relative to trolley buses	Lower British thermal unit consumption relative to diesel hybrid buses.
Environmental Justice Effects		
	Environmental justice communities present along diesel hybrid bus routes would experience relatively higher proximity effects due to increased noise and air pollution but reduced visual/aesthetic effects assuming removal of wires.	Environmental justice communities present along trolley bus routes would experience relatively lower proximity effects due to decreased noise and air pollution effects.
Historic Effects		
	Possible removal of trolley bus wire anchor bolts from historic structures would create the need to go through the Section 106 process. Proximity effects related to noise and air quality are also a disadvantage relative to trolley buses.	Continued visual quality disadvantage relative to diesel hybrid buses because trolley bus wires would remain in place.
Visual Effects		
	Slight relative advantage due to removal of trolley bus wire	Slight relative disadvantage due to continued presence of trolley bus wire
Hazardous Materials		
	No difference	No difference
Stormwater Quality		
	Relative disadvantage due to slight increased risk associated with handling of diesel fuel.	No difference
Neighborhood Character		
	Relative disadvantage due to potential adverse air quality and noise effects. Relative advantage due to beneficial visual effects of removing trolley bus wire.	Relative advantage due to beneficial air quality and noise effects. Relative disadvantage due to continued presence of trolley bus wire.

These potential environmental effects associated with each fleet replacement option are expanded further in the sections below.

In addition to the potential environmental effects described in Exhibit 5-1, if diesel hybrid buses were chosen to replace the trolley bus fleet, maintenance bases currently serving trolley buses would likely need to be modified, and these modifications could necessitate further environmental review.

TRAFFIC

General Purpose Traffic Operation

On roadways shared by buses and general purpose traffic, several characteristics of bus service can affect general purpose traffic operation, especially on one-lane streets where passing is not feasible. These characteristics include service frequency, stop spacing, vehicle length, and vehicle speed and acceleration. For most of these characteristics, the two bus propulsion options would not be substantially different.

Vehicle speed and acceleration is one characteristic that could differ between the two bus propulsion options, especially on steep slopes.

Seattle's natural topography has resulted in several steeply graded streets up to 19 percent. Twenty streets used by segments of trolley bus routes have grades of 12 percent to 15 percent. Other transit agencies have indicated that newer diesel hybrid buses are able to achieve speed and acceleration on steep slopes comparable with trolley buses. However, these operators were discussing experiences with slopes less than 10 percent. Newer diesel hybrid buses may be able to perform similar to trolley buses on steep grades, although the buses have not been field tested on steep routes similar to those in Seattle.

Performance of diesel hybrid buses on slopes steeper than 10 percent is possible, but engine gearing on the buses would need to be lower, eliminating the flexibility of exchanging these buses with conventional diesel hybrids operating on less steep routes. On street segments with grades steeper than 10 percent and relatively full passenger loads, trolley buses would likely be able to accelerate and operate faster than a diesel hybrid bus. This effect would be most pronounced on the route segments shown in Exhibit 5-2.

Exhibit 5-2. Steepest Existing Trolley Bus Route Segments

Street	Grade	Existing Trolley Bus Routes
Queen Anne Avenue North from Prospect Street to Highland Drive	18.5%	2 and 13
James Street from 4th Avenue to 5th Avenue	18.3%	3 and 4

Replacing the trolley bus fleet with diesel hybrid buses would likely present a disadvantage compared to trolley buses, with respect to effects on general purpose traffic operation due to slower acceleration and travel speeds on steep grades.

Bus Speed and Reliability

Bus speed and reliability are affected by a variety of factors, such as general purpose traffic volumes, construction activity, and traffic incidents, as well as vehicle speed and acceleration. The potential effect of acceleration on general purpose traffic operation discussed above applies to bus speed and reliability as well.

Current trolley bus speed and reliability is restricted by an inability to detour

off-wire to avoid construction activity, traffic incidents, roadway obstructions, special events, and localized electrical outages. Diesel hybrid buses, by contrast, are able to detour as necessary, and are currently used on trolley bus routes when the need for a detour arises. However, according to Metro estimates, new electric trolley buses equipped with APUs would be capable of providing off-wire power for at least a mile. Based on this coverage area, approximately 90 percent of instances requiring detours could be accommodated by trolley buses; however, the remaining 10 percent would still need to be served by diesel hybrid buses.

Compared to electric trolley buses, diesel hybrid buses are expected to reduce bus speed and reliability due to acceleration difficulties on steep grades, but would present an advantage regarding bus reliability due to the unlimited ability to detour around obstructions in the roadway.

Replacement trolley buses equipped with APUs would be at a slight disadvantage relative to diesel hybrid buses due to occasional wire disconnections and off-wire limitations.

Bicycles

Bicycle mobility can be affected by bus operations because both modes generally use the curb lane. However, the service frequency and stop spacing for both replacement options is expected to be the same; therefore, neither option would present advantages with respect to bicycle mobility and safety.

Pedestrians

Pedestrian mobility is generally unaffected by bus operations because the modes use different facilities. However, pedestrian safety can be affected by buses. Because both replacement options would employ the same best management practices to ensure pedestrian safety, neither option would present advantages with respect to pedestrian safety.

Parking

Bus lanes can affect parking availability, but because bus routing changes were not assumed in the analysis, neither option would present advantages with respect to parking availability.

NOISE

Noise tests completed in September 2003, comparing the 60-foot Metro trolley bus and the 60-foot diesel hybrid bus produced the results shown in Exhibit 5-3. Other vehicle types were measured for comparative purposes.

Exhibit 5-3. Sound Testing on Current Fleet Buses and Other On-Street Vehicles (dBA)

Vehicle	At Idle	Accelerating	Driving By
60-foot diesel-hybrid bus	64-66	76-80	74-76
60-foot trolley bus	56	70-75	66-68
Garbage truck		80-84	
Utility truck		76-80	
Passenger car		66-70	

Additional measurements of diesel buses and electric trolley buses on Seattle neighborhood streets confirmed the noise differences shown above. Measurements taken in the Capitol Hill neighborhood of Seattle in October 2003 are listed in Exhibit 5-4. All measurements were taken from the outer edge of the sidewalk (usually adjacent to buildings) with distance from the source ranging from 12 to 25 feet.

Exhibit 5-4. Follow-up Sound Testing on Current Fleet Buses and Other On-Street Vehicles (dBA)

Vehicle	Accelerating	Driving By	Other
Bus (diesel)	82–84	76–79	
Trolley Bus	72–73	66–68	82–84 (air brake)
Large Truck (gas and diesel)		82–86	
Pickup Truck		75–81	
Motorcycle		70–78	

Noise measurements were more recently sampled on the south side of eastbound NE Campus Parkway in the University District on March 7, 2011 for comparison purposes of different environments. All measurements were taken 5 feet from the outer edge of the sidewalk at a height of 5 feet. These measurements are summarized in Exhibit 5-5.

Exhibit 5-5. Second Follow-up Sound Testing on Current Fleets (dBA)

Vehicle	Accelerating	Driving By
Bus (diesel)	76–81	74–80
Bus (hybrid)	76–78	73–79
Trolley Bus	72–75	69–70

The ranges of noise levels generated by each vehicle type differ slightly for each sound testing; however, these variations are expected due to changes in ambient noise levels. Nonetheless, all three sound test samples illustrate a consistent and considerable noise difference between diesel hybrids and electric trolley buses—trolley buses are about 5 decibels quieter compared to diesel hybrids. Therefore, compared to electric trolley buses, diesel hybrid buses would be at a disadvantage with respect to noise levels along existing trolley bus routes.

AIR QUALITY/CLIMATE CHANGE/ENERGY

An air quality analysis was conducted for volatile organic compounds (VOCs), particulate matter larger than 2.5 microns and smaller than 10 microns (PM_{10}), nitrous oxides (NOx), and carbon dioxide (CO_2).

In 2010, the Puget Sound Clean Air Agency (PSCAA) published the Air Toxics Fact Sheet. In this fact sheet, the Puget Sound region was ranked within the top 5 percent of areas nationwide for cancer risk associated with air toxics. Of all the carcinogenic air toxics, particulate matter is the greatest concern (PSCAA 2010). The fact sheet sampled three areas in the Puget Sound region (Duwamish Valley, Beacon Hill, and a Tacoma residential area) and found that diesel particulate matter from buses, trucks, and ships account for 43 percent to 73 percent of the region's carcinogenic particulate matter (PSCAA 2010).

The air pollutants with direct health effects that are the focus of this study include VOCs and PM_{10}. The health risks associated with VOCs primarily relate to respiratory problems, allergic effects, and a variety of acute chronic symptoms; continuous exposure to some VOCs can also cause cancer. PM_{10} reduces general visibility and also causes respiratory problems, such as asthma, lung inflammation, lung cancer, and premature death. Both VOCs and PM_{10} also contribute to overall greenhouse gas emission increases.

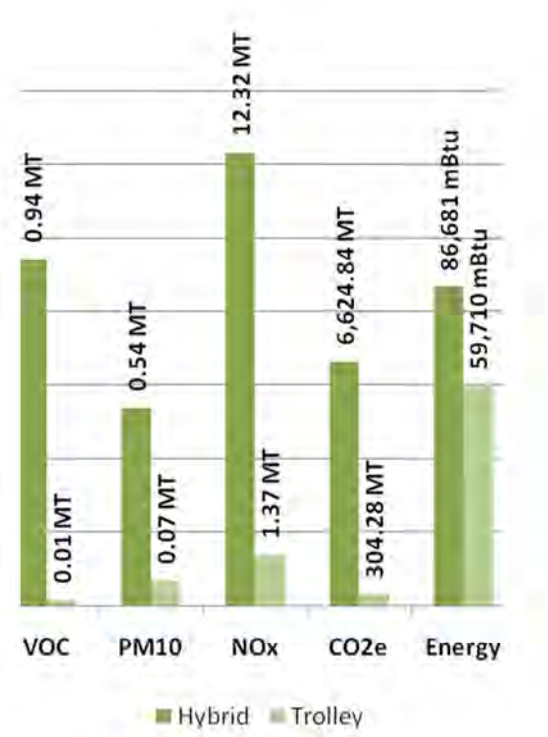
Nitric oxide (NO) and nitrogen dioxide (NO_2) are often collectively referred to as nitrous oxides (NOx). NOx is a pre-cursor of nitric acid vapor and related particles, which can damage lung tissue, cause emphysema and bronchitis, and, in severe cases, cause premature death. When NO_2 reacts with sunlight, oxygen is separated and forms into ozone (O_3),

which is also a GHG. NOx also plays a key role in acid rain.

The exponential increase in CO_2 emissions from humans and its role in the GHG effect and climate change make CO_2 of paramount concern. CO_2 accounts for approximately 95 percent of the total global warming potential from vehicle emissions. To account for the remaining 5 percent, a conversion factor is often applied to CO_2 emissions and the result is expressed in carbon dioxide equivalents (CO_2e).

In addition to air pollutants, the total energy consumption for each vehicle type was also estimated. Air pollutant emissions and energy consumption associated with each fleet replacement option are summarized in Exhibit 5-6.

Exhibit 5-6. Air Quality and Energy Analysis Results



For all four air pollutants, emissions from a diesel hybrid fleet would be several orders of magnitude higher compared to a fleet of electric trolley buses. This is because the electricity used to power the trolley system has been and will continue to be obtained from SCL, which uses coal and natural gas to generate only 2 percent of its electricity and the remaining 98 percent is generated from non-GHG emitting sources (hydroelectric, wind, nuclear, etc.). SCL would need to increase coal and natural gas usage to approximately 50 percent to result in emissions comparable to a diesel hybrid bus fleet.

It is also important to note that the emissions described in Exhibit 5-6 do not represent a fair comparison. Emissions associated with the diesel hybrid bus fleet option do not include emissions associated with extracting, processing, and transporting petroleum; i.e., these emissions do not account for generation emissions and only represent "tail pipe" emissions. Generation emissions for diesel fuel-related production and distribution costs are highly variable and difficult to quantify. Conversely, the trolley bus fleet emission estimates account for both generation and tail pipe emissions.

ENVIRONMENTAL JUSTICE

The concept of "environmental justice" has been discussed publicly for decades. Environmental justice acknowledges that the quality of our environment affects the quality of our lives, and that negative environmental effects should not disproportionately burden low-income or minority populations. Effects associated with transportation projects may include disruptions in community cohesion, restricted commercial access, presence of hazardous material, raised noise levels, increased water and air pollution, and other adverse effects. On February 11, 1994, President Clinton issued Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (Executive Order 12898). In a memorandum accompanying the Executive Order, President Clinton urged federal agencies to incorporate environmental justice principles into planning and programming activities.

NEPA provides a forum for environmental justice analysis and involving minority and low-income populations in the planning and project development process.

Executive Order 12898 lists three major principles of environmental justice:

- Avoid, minimize, or mitigate disproportionately high and adverse human health and environmental effects, including social and economic effects on minority and low-income populations.
- Ensure the full and fair participation by all potentially affected communities in the transportation decision-making process.
- Prevent the denial, reduction, or significant delay in the receipt of benefits by minority and low-income populations.

Title VI of the Civil Rights Act of 1964 requires that "no person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance."

Executive Order 12898 is a renewed focus on the Title VI law with respect to minority populations, and adds emphasis on low-income populations.

In order to determine whether a project would result in disproportionate effects upon low-income and minority communities, the existence of these communities must first be determined. As shown in Exhibit 5-7, the concentration of low-income and minority populations in census tracts containing trolley bus routes is higher than the county-wide concentration. Additionally, the concentration is higher than 26.6 percent minority and 8.3 percent low-income, the thresholds used by Metro in their tri-annual Title VI reporting. Based on these demographics, the existence of low-income and minority communities near trolley bus routes can be confirmed.

Exhibit 5-7. Percent of Minority and Low-income Populations in Census Tracts Containing Trolley Bus Routes Compared to King County Total Population

	King County	Census Tracts containing Trolley Bus Routes
Total Population	1,737,034	274,206
Minority Population	401,797	99,439
Percent of Total	23.1%	36.3%
Population Below Poverty	142,546	38,039
Percent of Total	38,039	13.9%

This screening-level environmental analysis does not make a determination about the possibility of disproportionate environmental effects upon environmental justice communities. It can be noted that trolley bus routes are located in communities classified as low-income and minority, and if the fleet replacement were to result in environmental impacts, an analysis for disproportionality upon low-income and minority communities would need to be performed. Proximity effects on environmental justice communities would be slightly higher with the diesel hybrid bus option compared to the electric trolley bus option due to increased noise and air pollution; however, the magnitude of this impact may not be high enough to be considered a disproportionate effect.

HISTORIC

Replacing the trolley bus fleet with diesel hybrid buses would necessitate removal of trolley bus wires, some of which are anchored to historic structures, as shown in Exhibit 5-8.

Exhibit 5-8. Trolley Bus Wire Anchored to Historic Structures

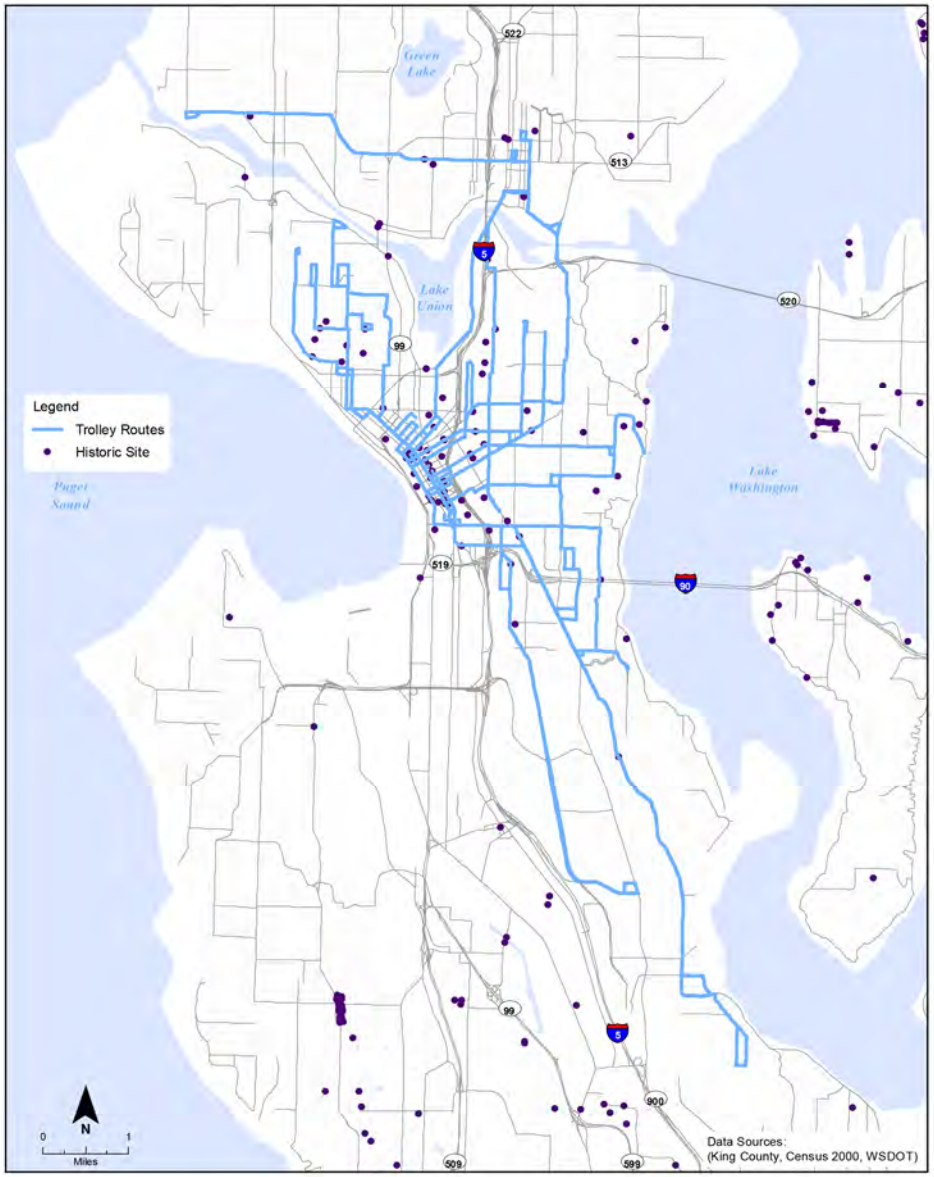
Removal of these anchor bolts would likely require consultation subject to Section 106 of the National Historic Preservation Act (NHPA). Section 106 requires federal agencies to take into account the effects that their federally funded activities and programs have on significant historic properties. "Significant historic properties" are those properties that are included in, or eligible for, the National Register of Historic Places (NRHP). The NRHP is a list of districts, sites, buildings, structures, and objects that are significant in American history, architecture, archaeology, and culture. The NRHP is administered by the National Park Service in conjunction with the State Historic Preservation Office.

Replacing the trolley bus fleet with diesel hybrids would also expose historic structures to additional air quality and noise effects noted above. Exhibit 5-9 shows the concentration of historic sites in proximity to trolley bus routes.

Both bus replacement options could affect historic areaways. Areaways are spaces beneath the sidewalks, located between the building walls and the walls supporting the streets. These are particularly common in Pioneer Square and are found in some other older buildings. Areaways are typically an integral part of a building, either open to the basement or accessible through doorways. Areaways that are located in an NRHP historic district or are attached to an NRHP-listed building are part of the historic resource and are protected. Areaways adjoining an NRHP-eligible building are also eligible.

Use of the curb lane by buses increases the risk of damage to the areaways. Heavier buses increase this risk. Available data suggest the average weight per axle for diesel hybrid buses are somewhat heavier than trolley buses—by about 1.3 percent for standard 40-foot vehicles and by about 3.7 percent for articulated 60-foot vehicles. These relationships were shown earlier in Exhibit 3-3.

Exhibit 5-9. Map of Historic Sites in Proximity to Trolley Bus Routes



VISUAL

The key visual difference between the two bus replacement options is the absence of trolley bus wires if the fleet were replaced by diesel hybrid buses.

The visual simulation for this study illustrates five locations in the trolley bus network, comparing the current view containing trolley bus wires to a simulated view without trolley bus wires.

The five locations are geographically distributed to reflect different neighborhood views throughout the trolley bus service area:

1. Rainier Avenue to the south
2. University of Washington to the north—15th Avenue NE at NE 50th Street
3. Lake Washington to the east at Leschi with a view of Mount Rainier
4. Pike Place Market to the west—Stewart Street at 1st Avenue
5. Downtown from Beacon Hill to the north on 12th Avenue

As shown in the visual simulations, views of distant visual resources such as Lake Washington, Mount Rainier, Elliott Bay, and downtown Seattle, as well as nearby visual resources such as Pike Place Market and the University District can be affected by trolley bus wire. However, as shown in the photo simulations, many of these views would still be affected by other overhead wires and visual barriers such as signs and traffic lights.

Because of the removal of trolley bus wire, replacing the trolley bus fleet with diesel hybrid buses would present a slight advantage with respect to the visual environment.

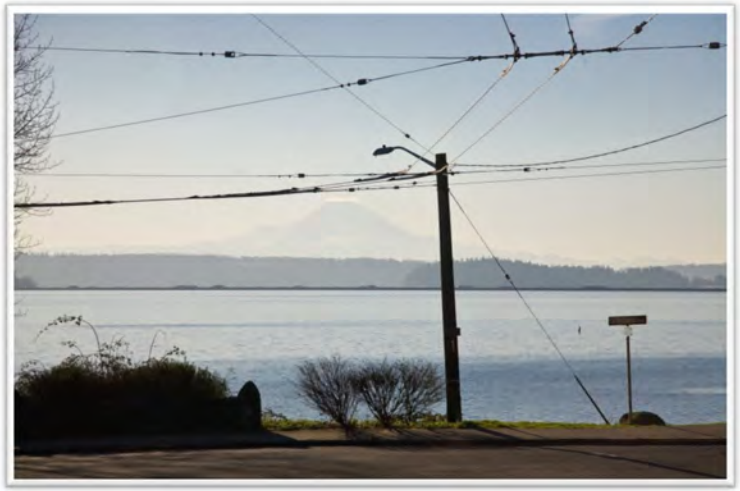
Rainier Avenue

University District 15th Avenue NE at NE 50th Street

Pike Place Market—Stewart Street at 1st Avenue

Downtown from Beacon Hill on 12th Avenue South

Leschi—Lake Washington Boulevard at Madrona Drive



PUBLIC HEALTH

The transportation system can affect public health in many ways. Potential effects on public health due to hazardous materials, noise, air quality, and safety are discussed in their respective sections and are summarized as follows:

- Transportation facilities can increase public exposure to hazardous materials. Neither propulsion option would present advantages with respect to hazardous materials.
- Transportation vehicles can increase public exposure to noise. According to field measurements, diesel hybrid buses can be up to 10 decibels louder than trolley buses, with the most notable difference occurring during acceleration.
- Transportation emissions can affect public exposure to airborne pollutants. Emissions of air toxics would be substantially higher with diesel hybrid buses than with electric trolley buses.
- Transportation networks can affect safety, including personal safety and accessibility-related safety. Neither propulsion option would present advantages with respect to safety.
- In addition, sidewalks, bikeways, and pedestrian-oriented development can affect public health by encouraging physical activity and the general well-being of the population. Both replacement options (and transit services in general) promote dense, pedestrian-oriented development.

HAZARDOUS MATERIALS

Operation and maintenance of either fleet replacement option would involve hazardous materials. Oil-based lubricants, vehicle batteries, parts-cleaning fluids, paints, solvents, and fuels are among the products typically used in the maintenance and operation of transportation vehicles.

For hazardous materials to present a risk to the environment, two components must be present:

- Toxicity or hazard, which creates the potential for a substance to cause an adverse health impact (e.g., cancer)
- Exposure, which creates the potential for humans or environmental receptors to come into contact with the hazardous materials

Although some substances listed above are toxic, their use would be primarily concentrated in maintenance bases, where their exposure to humans would be minimized through the use of best management practices. Therefore, neither propulsion option would present advantages with respect to hazardous materials.

STORMWATER QUALITY

Diesel hybrid buses and electric trolley buses share two common features associated with pollutant loading—rubber tires and brake pads. Research has determined that the resulting operational wear of tires and brake pads releases particles containing zinc and copper that can contribute to stormwater concentrations of these metals. However, diesel hybrid and electric trolley buses, with the ability to brake "regeneratively" via their electric motors, comparatively release fewer brake pad particles. Diesel hybrid buses do have a relative

disadvantage compared to electric trolley buses due to a slight increased risk associated with the handling of diesel fuel.

NEIGHBORHOOD CHARACTER

Neighborhood character is an amalgam of various elements that give neighborhoods their distinct "personality." These elements may include a neighborhood's land use, urban design, visual resources, historic resources, socioeconomics, traffic, air quality, and/or noise. As discussed in this document, diesel particulate matter emissions can result in adverse effects on air quality, which in turn can affect neighborhood character. This section also discusses potential adverse noise effects from diesel hybrid buses as compared to electric trolley buses, as well as potential adverse visual effects of trolley bus wire, which would be removed if the fleet were replaced by diesel hybrid buses.

Of particular interest in neighborhoods currently served by trolley bus routes are potential effects on property values. Research exists demonstrating the positive effect of proximity to light rail transit upon property values (Weinstein and Clower 2003). Less research exists on the effects of bus transit upon property values, though BRT proximity was found to have a positive effect upon nearby property values (Perk and Catala' 2009). The idea of "infrastructure permanence" was found to positively affect property values (Kaplowitz 2005). However, these studies primarily focused on high-capacity transit with permanent stations, so their findings do not directly relate to this study. Research does not exist to support a determination for either propulsion option regarding future value for properties near existing trolley bus routes.

6. Auxiliary Power Unit Evaluation

This section evaluates alternatives for battery or diesel APUs because these technologies could be applied to the next generation trolley bus for Seattle. This review was conducted early in the study process to define the APU power supply for inclusion in the electric trolley bus vehicle evaluation. This section also describes Metro's categories for trolley overhead wire shutdowns.

Trolley buses are mostly dependent on electric power drawn from the overhead contact wire. Power can become unavailable due to a power failure or a street blockage such as an accident or construction project. Trolley buses must wait for power to be restored or replaced by motor coaches during longer routes, or the routes are annulled until power is restored. Metro has historically taken additional measures to mitigate power failures or street blockages, including posting additional power and maintenance staff on site to assist with trolley operation in the area. One or more trolley bus routes operate a diesel bus almost every weekend to accommodate construction projects.

METRO'S AUXILIARY POWER UNIT OPERATING CRITERIA

Based on experience with route closures on the Metro system, minimum operating criteria for an APU are:

- One mile of operation off-wire with a full passenger load
- Making up to five stops
- Ascending an average grade of 8 percent. Peak grade climbing capability should be specified as 19 percent for 100 feet

Metro should consider allowing reduced performance during off-wire operation. Metro may want to consider allowing for a top speed of 20 mph on grades of 10 percent, with a time of 30 seconds to reach 20 mph. The establishment of firm criteria will allow for reviews of cost/time savings and input from manufacturers in terms of tradeoffs for performance, vehicle weight, and cost. There will be a point where diesel APU becomes uneconomical and battery APU replaces it as the method of choice.

More recent trolley buses have been built with off-wire capability allowing the vehicle to be moved "off wire" around blockages. APUs allow greater flexibility for short distances, internal circulation in maintenance yards, and enabling agencies to remove some contact wire from yard and shop areas, as reported by transit agencies in Vancouver, B.C. and Philadelphia, PA. Thus, the benefits of APUs can be both operational and financial.

Because Metro's current trolley bus fleet does not have any backup power; as a result, routes generally use diesel-powered buses to go around construction projects. Approximately 15 percent of the total annual miles on

trolley routes required replacement diesel buses in 2010 (King County Metro 2011).

EXISTING TROLLEY OVERHEAD WIRE SHUTDOWN CATEGORIES

Requests to shut down trolley overhead wire from outside agencies and contractors are not tracked or documented as to how much area (length of roadway) is being blocked or obstructing trolley operations. Also, the duration of construction work obstructions is not recorded. Obstructions that impede trolley operations generally fall into three categories described below:

Category 1: Construction work or equipment in the roadway that affects a single intersection or work that affects an entire city block and adjoining intersections. This is the reason for the majority of requests to allow diesel-powered buses. Examples of construction work include utility work to replace or repair an electrical pole or water/gas line break, pothole repairs or concrete panel replacement, rooftop work requiring a crane to be set out in the street, police or fire responses, and vehicle breakdowns.

Category 1 represents approximately 75 percent of the requests for placing diesel buses on a route. In most cases, these requests could be effectively handled without having replacement diesel buses by an electric trolley that had an alternate propulsion system capable of operating off-wire for up to a mile.

Category 2: Construction work involving longer street sections that are inaccessible for trolley operation. Examples are asphalt surface grinding and resurfacing, parades, demonstrations, or civil unrest.

Category 2 represents about 20 percent of the requests. In most cases, the route would have to be serviced with replacement diesel buses, or where possible, the overhead wire can be moved out beyond the obstructed work area. This often is the solution if the work is in the curb lane only.

Category 3: Long-term construction projects lasting many months or even over a year. Examples include street widening and reconfiguration projects such as the current Mercer Street Project or the Alaskan Way Viaduct project.

Category 3 represents 5 percent of the requests and is handled by permanent reroutes for alteration of service delivery due to the long-term nature and effect on transit service.

DETERMINING APU RANGE

One way to determine the required range of APUs to propel electric trolley buses is to examine the trolley overhead wire breakpoints. These breakpoints are locations along the trolley wire system where Metro can de-energize the wire system (turn off the electricity). Activities such as construction and maintenance could require the overhead wires to be turned off for safety when work is being done on the system. Because the existing electric trolley bus fleet does not have the ability to travel under their own power, diesel buses are used for the routes with de-energized segments. Currently, approximately 90 percent of the trolley overhead breakpoints are less than a mile apart. This distance is important to consider when evaluating the distance electric trolley buses would need APUs to

travel because APUs can have limited travel ranges.

For the purposes of this study, Metro staff estimates APUs must be able to propel trolley buses at least 1 mile.

AUXILIARY POWER UNIT ALTERNATIVES

Two types of power units have been adopted globally and for recent trolley bus fleets in North America:

- Batteries: Vancouver, B.C.; San Francisco, CA; and Dayton, OH (a total of 593 trolley buses)
- Diesel Generators: Philadelphia, PA (38 trolley buses)

Exhibit 6-1 summarizes representative APUs in Vancouver and Philadelphia.

Vossloh Kiepe product brochures indicate a capability for "minor route deviations" (Vancouver) and "route deviations" (Philadelphia), reflecting the ability of the diesel APU to support operation over longer distances than the battery APU. Philadelphia's requirement for the diesel APU was a range of at least 11,000 feet, which was the longest stretch that would lose power with a single substation failure. The APU fuel tank has a 50-gallon capacity, which sustains a range of approximately 150 miles. Though its range is shorter, the battery APU used by CMBC in Vancouver, B.C. is less than half the weight of a comparable diesel generator and provides better speed parameters.

Exhibit 6-1. Representative APUs

Item	Vancouver 60-foot Articulated Bus	Vancouver 40-foot Standard Bus	Philadelphia 40-foot Standard Bus
Type	NiCad Battery	NiCad Battery	Diesel Generator
Rating (amperage hours)	48	32	n/a
Number of Cells	188	188	n/a
Battery Voltage/Generator Rating	225 V	225 V	100 kW
Weight (pounds)	926	705	1,650
Off-Wire Range (miles)	2.5	2.5	[a]
Speed (mph, maximum)	Up to 40	Up to 40	24.9
Grade (%, maximum)	Up to 6%	Up to 6%	[b]

Notes:
[a] Up to 150 miles; limited by 50-gallon capacity of APU fuel tank and consumption of Cummins QSB 4.5 diesel engine.
[b] Unknown; Philadelphia routes are flat to gently rolling.
n/a = Not applicable to this technology.
Source: Information from Vossloh Kiepe for both Vancouver and Philadelphia APUs

Measurable differences between the two APU alternatives may be divided into five categories for purposes of analysis: off-wire operation, impacts on passengers and the public, APU maintenance, maintenance facilities, and life-cycle costs.

Off-Wire Operation

The available data are from the Vancouver and Philadelphia transit agencies which use, respectively, nickel cadmium (NiCad) batteries and a diesel engine generator set.

Off-wire operation is limited by the capability of the APU to provide sufficient power to operate the trolley bus traction and auxiliary systems, with the range limited by the amount of energy stored in the battery or fuel limit of the diesel generator. Existing units have been designed for limited operation.

Vancouver's battery APUs are used for off-wire operation in the storage yard and at one interchange that is out of service, but are not used for off-wire operation in regular service. Diesel buses continue to be substituted for trolley buses for major events and parades.

Battery systems are limited in acceleration and hill-climbing capability by the battery's maximum power capability (kilowatts [kW]) and energy storage capacity (kilowatt-hours [kWh]). Diesel systems are limited in acceleration and hill-climbing capability by the APU's maximum power capability and range, the fuel tank capacity, and thermal ratings for the equipment. Both Vancouver's battery and Philadelphia's diesel units were sized mainly for traction capability. Vancouver's battery APU does not power the air compressor, which limits its range because of the storage capacity of the air system, about 10 brake stops and 10 door cycles (on a future order, presumably, a battery APU could be specified and supplied that would be capable of powering the air compressor and other accessories if desired). The diesel APU in Philadelphia provides traction propulsion, power to the air compressor to charge the air system, and limited heat and air conditioning.

The maximum tractive effort available from the propulsion system will be reduced because of the limited power available from the battery or generator set. This would reduce the top speed, particularly when the vehicle is climbing hills, and the vehicle eventually will "stall out" as the grades become more extreme. The supplier rates Vancouver battery-equipped trolley buses at a top speed of 40 mph, presumably on a level street, and operation up to a 6 percent grade (no speed specified). Although the equipment may be capable of further travel, SEPTA limits diesel emergency operation of the Philadelphia trolley buses to less than 25 mph according to the agreement with environmental regulators.

One of the characteristics of APUs is their adaptability to meet the demands of a system. Rather than having a "one size fits all" application package, such systems are typically provided with energy storage and delivery capabilities to meet the demand. Batteries or capacitors may be arranged in many different series and parallel combinations. Series combinations result in different voltages for the system. Systems with light power demands (a few hundred feet) may use a low-voltage battery pack with a step-up converter to deliver power to the propulsion system. Systems with heavy power demands (such as steep grades)

may use a high-voltage battery pack with two or more packs in parallel to deliver the current required to power up the grade. The expense of the storage media, either battery or capacitor, and the ease of constructing various configurations lead to custom solutions to minimize the initial capital expense while meeting the agency's requirements. Exhibit 6-2 compares the off-wire capabilities of battery and diesel generator APUs.

Exhibit 6-2. Comparison of APU Off-Wire Capabilities

	Battery	Diesel	Comments
Range (Miles)	Up to 2.5	Up to 150	Battery limited by air system
Speed, Maximum, Level	40 mph	25 mph	
Maximum Grade	As required	6%	
Acceleration	Better	Worse	
Startup	Faster	Slower	No Engine-Generator ramp up delays with battery APU
Fuel	None	Yes	
Power to Air Compressor	If Required	Yes	

Batteries also have useful lifetimes determined primarily by the number of charge/discharge cycles and the depth of the discharge cycle. Replacement intervals are driven by operational characteristics. Factors that tend to shorten the lives of batteries and must be considered when specifying the system to be procured are: 1) depth of the discharge, and 2) frequency with which the discharge occurs. The specification may require a 10-year lifetime based on the following example; one 80 percent discharge and three 50 percent discharges per week. The number and depth of the discharge needs to be based on operational expectations.
Ultra-capacitors are not subject to the shortened lifetimes exhibited by batteries, but are limited in the amount of energy they can store per unit of installed weight.

IMPACTS ON PASSENGERS AND THE PUBLIC

Attributes of the battery and diesel APUs are as follows:

- Battery APUs are quieter—Interior benefit to passengers; exterior benefit to passengers and the public.
- Battery emergency power units (EPUs) cause less vibration.
- Battery APUs are all electric and have no exhaust emission.
- Battery APUs may or may not be lighter than a genset (depending on the service range), which affects bus impacts on street surfaces.
- Both may cause reduced schedule adherence during APU operation due to limited tractive effort and resulting slower speed. They also require disconnecting the trolley poles to the overhead power supply.
- Current applications of batteries on trolley buses do not provide climate control in passenger space during APU operation; diesel APUs have been used to provide limited heat or air conditioning. It is anticipated Metro would require climate control capabilities. Applications of battery power on light rail vehicles have powered the HVAC system the same as operation on-wire. The requirement for climate control would affect the amount of energy storage required to be provided by the manufacturer.

MAINTENANCE

The battery APU maintenance requirements for the previously described NiCad batteries (Exhibit 6-2) will be similar to those for the electrical control equipment on existing trolley buses. Periodic inspection and testing of the battery and associated electronics would be required. It is assumed that the battery would last 10 years, but it could last for the 15-year life cycle of the electric trolley bus. Metro uses lithium ion batteries in their hybrid fleets that are exceeding the originally assumed life.

The diesel APU would require more maintenance than the battery type to provide quick startup when needed.

MAINTENANCE FACILITIES

Both technologies can provide the capability to operate off-wire in the maintenance yard. It may be possible to retire some portion of the yard/shop TOH system, but additional analysis would be needed to determine if this is cost-effective or desirable. Storage of the buses without a power supply may result in a slow discharge of the batteries over a period of time. Operation in the yard on batteries should not result in a significant depth-of-discharge or result in a significant reduction in their useful life.

The battery APU would require less maintenance work, which implies reduced needs for shop space, tools, equipment, parts, and staffing. Additionally, facilities would not be required for fueling trolley buses equipped with battery APUs.

LIFE-CYCLE COSTS

An estimate of alternative APU life-cycle costs was prepared, with initial investments as quoted via email by Vossloh Kiepe in 2011 U.S. dollars. Values are shown for a standard 40-foot trolley bus with battery APU, and standard 40-foot trolley bus with diesel APUs. It is assumed either of these same units could be applied to an articulated trolley bus for the same cost.

It is assumed that batteries would have a service life of 10 years. To account for this life span, the 2011 battery APU initial costs were inflated to 2021 values. However, a second 10-year battery APU would have 5 years of life remaining at the end of the vehicle's 15-year life, so only half of the replacement cost has been entered in the calculations.

Ongoing operating and maintenance costs are included for both APUs, and diesel fuel for the diesel APU. Life-cycle costs are calculated for a life of 15 years, which is the generally accepted economic lifetime of trolley buses sanctioned by the FTA. Finally, future costs are discounted at 7 percent to 2011 present values.

As shown in Exhibit 6-3, estimated life-cycle costs to equip and operate a single trolley bus are $128,767 for a battery APU and $192,546 for a diesel generator APU, discounted to present value in 2011.

Exhibit 6-3. Estimate of Life-Cycle Costs for Battery EPU and Diesel Generator APU, per Bus

	Item	Battery	Diesel Generator	Comments
	Investment (Capital)			
1	Initial Cost, 2011 U.S. Dollars	$80,000	$95,000	Estimate per recommendation, K. P. Canavan, 02/10/11 email
2	Replace Battery at Year 10 (2021)	$53,750	--	Battery EPU only; 2011 inflated 10 years; 1/2 life remain at 15 years
				Note: Inflation rate for above: 3%/year compounded
	Operations and Maintenance (Ongoing)			
4	Maintenance Hours/Year	9	38	Estimated per TransLink 2005 Study
5	Estimated Maintenance Cost/Hour	$2,354	$9,941	2008 at $239.41/hour, 3 years, 3%/year compounded = $261.61 (Note b)
6	Fuel (Diesel Generator Only)	--	$769	Note [a]
	Life-Cycle Costs			
7	15 Years, Cash Outlay	$169,060	$255,650	Initial + Replacement Investments + Maintenance/Fuel for 15 Years; Not Discounted
8	15 Years, Present value	$128,767	$192,546	Future costs discounted at 7% compounded
	Notes:			
	[a]: Fuel Cost/Year:			
	Mile/Year (3 miles/day)		876	Operation 80% of days in year, based on 20% spares ratio
	Fuel Economy (mpg)		3.00	SEPTA email from L. Hickman, 01/13/11
	Gallons/Year		292	
	$/Gallon		$2.63	$2.6344/gallon in 2011, per Metro study
	Total Cost/Year		$769	
	[b]: Per "Copy of allocation for 2008 ST expenses Print.XLS"			
	Total Maintenance except Tires			$84,299,744
	Total Maintenance Hours			352,117
	Calculated Maintenance Cost/Hour			$239.41
	Sources of Data Used in Analysis			
1	Email 02/10/11 from K. P. Canavan, Vossloh Kiepe Corporation with recommended 2011 U.S. dollars cost allowances for battery and genset EPU/APU			
2	Per above: $80,000 in 2011, inflated 10 years at 3%/yr. compounded, taken at 1/2 result since only 1/2 replacement life used by year 15			
3	Per above: $95,000 in 2011, inflated 12 years at 3%/yr. compounded, taken at 1/4 result, since only 1/4 replacement life used by year 15			
4	Estimated hours per study by TransLink, "EGS v. Battery Technology" 08/24/05			
5	Calculated from Metro, "Copy of allocation for 2008 ST expense Print.XLS" 12/21/2010			
6	Operation assumed per 20% spare ratio implies running 80% of days; consumption per SEPTA email from L. Hickman, 01/13/11; price per G. Prince email 02/09/11.			
7	Previous calculations per comments above			
8	Previous calculations per comments above			

The battery APU life-cycle costs include an initial and mid-life replacement investment of $107,327 (83 percent of life-cycle costs) plus maintenance costs of $21,440 (17 percent of life-cycle costs). For the diesel APU, the split is an initial investment of $95,000 (49 percent of life-cycle costs), $90,542 (47 percent of life-cycle costs) for maintenance, and $7,004 (4 percent) for diesel fuel.

Considering the total trolley bus fleet of 159 units, and assuming no difference in APU costs between standard and articulated vehicles, the estimated fleet life-cycle costs are $20,473,953 for the battery APU alternative, and $30,614,814 for the diesel APU alternative. It costs approximately $10 million more for diesel APUs. The cost difference is mostly due to the higher maintenance and fuel costs.

EMERGING TECHNOLOGIES

New hardware is becoming available that could greatly improve the off-wire performance of a trolley bus, likely within the timeframe of the Metro fleet purchase in 2014 to 2015. These emerging technologies are described below.

- Lithium ion batteries have been developed specifically for transportation and other high power applications. They are being used in many new vehicle applications instead of NiCad or nickel metal hydride (NiMh) batteries because they can provide high power density with very good charge and discharge characteristics. This results in a lighter weight battery that can provide excellent performance. These batteries can store sufficient energy to power both the auxiliary and propulsion systems for extended distances. Although there is currently no known application of lithium batteries on an electric trolley bus, light rail applications in commercial service include the Kawasaki SWIMO vehicle and the Kinki Sharyo LFX-300 vehicle.
- Ultra-capacitors are passive devices that store energy and have fast charge and discharge capabilities. They do not store as much energy as a similarly sized battery, but they can provide a large amount of power for short periods of time to allow the propulsion system to provide a high starting torque and operate the trolley bus for several hundred feet. Ultra-capacitors are used to power trolley buses in service in Shanghai and are being used on light rail vehicles in Mannheim. Ultra-capacitors can also be used in combination with batteries to provide quick powerful accelerations up a grade or to slowly recharge batteries from a quick charge on the capacitors.

Both lithium ion batteries and ultra-capacitors require a power converter to regulate power flow (charge and discharge currents) and monitor the charge level state of the series batteries or capacitors. This function can be integrated into the propulsion or auxiliary power control systems.

Both lithium ion batteries and ultra-capacitors can be used to save energy. They do this by absorbing regenerative brake energy and then by supplying energy during acceleration (and also to power the auxiliary equipment), resulting in a net energy power savings. By being able to supplement the trolley feed during acceleration, the peak current draw from the trolley wires would be reduced.

If a high power lithium ion battery or ultra-capacitor technology APU were used, it would require periodic inspection and review of system fault logs to confirm the state of the battery cells. These systems have monitoring electronics for each cell that can balance the charge on the cells and report data to the propulsion controller for access during maintenance or troubleshooting.

APU TECHNOLOGY RECOMMENDATION

Based on the foregoing analysis, it is recommended that if Metro elects to purchase a new fleet of electric trolley buses, these vehicles should be equipped with a battery APU capable of propelling the vehicle at least 1 mile or more. With recent progress in battery technology, it is further recommended that the APU should be a lithium ion battery, and that the team preparing for procurement should monitor industry developments.

The following five criteria should be evaluated:

- Off-Wire Operation: Though less than diesel APU, a battery APU provides adequate range to meet Metro's 1-mile criterion, and therefore would significantly reduce the number of times per year that trolleys are replaced by diesel buses. Compared to diesel APUs, battery APUs enable higher off-wire operating speed, better acceleration, faster startup, and do not require carrying diesel fuel on the vehicle (Exhibit 6-2).
- Impact on Passengers and the Public: The battery APU is quieter inside and outside, produces less vibration, and has no exhaust emissions. The diesel APU enables charging the air system and limited heat and air conditioning; the battery APU used by the Vancouver buses does not, but this requirement could be incorporated into the specification for a new bus if desired.
- Maintenance: Battery APU maintenance is simple and limited, estimated at about 9 hours annually per unit. Diesel APU maintenance is more frequent and involved, estimated at about 38 hours annually per unit.
- Maintenance Facilities: Either battery or diesel APUs support removal of some overhead wiring in maintenance yards. Lower maintenance effort for battery APU would result in reduced needs for shop space, tools, equipment, parts, and staffing.
- Life-Cycle Costs: For one standard 40-foot trolley bus, battery APU life-cycle costs are estimated at $128,767 per vehicle, versus $192,546 for one diesel APU (Exhibit 6-3). For 159 units, the total difference in life-cycle costs is estimated to be over $10 million more for the diesel APU alternative.

OTHER FINDINGS

The following summarizes the conclusions drawn after evaluating the differences between the two APU alternatives and the emergency units:

- A diesel APU is not expected to be practical for use on the steep grades found in Seattle. A larger generator likely would be needed to provide sufficient power to operate on Seattle's steeper streets, 10 of which have grades of 12 percent or more, including sections over 18 percent on Queen Anne Avenue, Madison Street, and James Street.
- A lithium ion battery APU should be specified to provide additional power and energy for a given weight.
- The APU system output voltage should be increased to allow for full power output from the propulsion system to allow operation on steeper grades (600 volts or higher). The higher voltage can be produced by adding cells to produce a higher battery terminal voltage, or by using a boost chopper with a lower voltage (200 to 400 volts) battery.
- The battery needs to be sized to provide the power needed to operate up the steepest grade with sufficient energy storage capacity to operate the desired distance. If long distance operation is desired, the battery needs to be large enough to power the air compressor and other desired auxiliary loads.
- Ultra-capacitors could be used to store sufficient energy to operate a trolley bus over short distances (several hundred feet). They have the advantage of requiring little maintenance other than inspection and cleaning during their operating life of 10 to 15 years.
- Ultra-capacitors could be combined with a battery or motor generator to provide a power boost during starting to allow for quick acceleration and when starting up a steep grade.

7. Federal Funding Sources

FEDERAL TRANSIT ADMINISTRATION PROGRAMS AND FUNDS

There are several federal funding programs available to provide funding for the acquisition of buses. The primary source of funding to Metro is from the Federal Transit Administration (FTA) formula programs listed below. In addition to the FTA programs below, there are several other Federal Highway Administration (FHWA) competitive grant programs that provide eligible funding for bus acquisition.

URBANIZED AREA FORMULA PROGRAM (SECTION 5307)

The Urbanized Area Formula Funding program (49 U.S.C. 5307) makes federal resources available to urbanized areas and to Governors for transit capital and operating assistance in urbanized areas and for transportation related planning. An urbanized area is an incorporated area with a population of 50,000 or more that is designated as such by the U.S. Department of Commerce, Bureau of the Census.

Eligible activities include the following:

- Planning, engineering design and evaluation of transit projects and other technical transportation-related studies
- Capital investments in bus and bus-related activities such as replacement of buses, overhaul of buses, rebuilding of buses, crime prevention and security equipment and construction of maintenance and passenger facilities
- Capital investments in new and existing fixed guideway systems including rolling stock, overhaul and rebuilding of vehicles, track, signals, communications, and computer hardware and software. All preventive maintenance and some Americans with Disabilities Act (ADA) complimentary paratransit service costs are considered capital costs.

More information on the Urbanized Area Formula Program can be found at: http://www.fta.dot.gov/funding/grants/grants_financing_3561.html.

In FTA Circular 9030.1D, the local matching ratio for the FTA Section 5307 grant program is set at 80 percent federal and 20 percent local. The federal share may exceed 80 percent for certain projects related to ADA, Clean Air Act (CAA), and certain bicycle projects. Related to the purchasing of buses and

vans, a grant recipient may apply for an 83 percent federal share of the total vehicle cost. The 83 percent is a blended figure representing 80 percent of the vehicle and 90 percent of the vehicle-related equipment to be acquired in compliance with the ADA or CAA.

The approval for moving the matching ratio to 83 percent is approved by the FTA after an application for funding obligation has been submitted.

Additional information on matching ratio can be found at: http://www.fta.dot.gov/documents/FTA_Circular_9030_1D_3-31-10.doc in section III.10.b.2.

CLEAN FUELS GRANT PROGRAM (SECTION 5308)

The Clean Fuels Grant Program has a two-fold purpose: first, the program was developed to assist nonattainment and maintenance areas in achieving or maintaining the National Ambient Air Quality Standards for ozone and carbon monoxide; second, the program supports emerging clean fuel and advanced propulsion technologies for transit buses and markets for those technologies.

The Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users (SAFETEA–LU) grants authority to the Secretary to make grants under this section to assist recipients to finance the following eligible projects:

- Purchasing or leasing clean fuel buses, including buses that employ a lightweight composite primary structure and vans for use in revenue service. The purchase or lease of non-revenue vehicles is not an eligible project.
- Constructing or leasing clean fuel bus facilities or electrical recharging facilities and related equipment. Facilities and related equipment for clean diesel buses are not eligible.
- Projects relating to clean fuel, biodiesel, hybrid electric, or zero emissions technology buses that exhibit equivalent or superior emissions reductions to existing clean fuel or hybrid electric technologies.

More information on the Clean Fuels Grant Program can be found at: http://www.fta.dot.gov/funding/grants/grants_financing_3560.html.

FIXED GUIDEWAY MODERNIZATION (SECTION 5309)

The Fixed Guideway Modernization Program (49 U.S.C. 5309) provides capital assistance for three primary activities:

- Modernization of existing rail systems (Fixed Guideway Modernization program).
- New and replacement buses and facilities (Bus and Bus Related Equipment and Facilities program).
- New fixed guideway systems (New Starts program and Small Starts).

Eligible activities are capital projects to modernize or improve existing fixed guideway systems, including purchase and rehabilitation of rolling stock, track, line equipment, structures, signals and communications, power equipment and substations, passenger stations and terminals, security equipment and systems, maintenance facilities and

equipment, operational support equipment including computer hardware and software, system extensions, and preventive maintenance.

More information on the program can be found at: http://www.fta.dot.gov/funding/grants/grants_financing_3558.html.

BUS AND BUS FACILITIES (SECTION 5309, SECTION 5318)

The Bus and Bus Facilities Programs (49 U.S.C. 5309 and 5318) provide capital assistance for three primary activities:

- New and replacement buses and facilities (Bus and Bus Related Equipment and Facilities program).
- Modernization of existing rail systems (Fixed Guideway Modernization program, 49 U.S.C. 5309).
- New fixed guideway systems (New Starts program and Small Starts).

Eligible capital projects include the purchasing of buses for fleet and service expansion, bus maintenance and administrative facilities, transfer facilities, bus malls, transportation centers, intermodal terminals, park-and-ride stations, acquisition of replacement vehicles, bus rebuilds, bus preventive maintenance, passenger amenities such as passenger shelters and bus stop signs, accessory and miscellaneous equipment such as mobile radio units, supervisory vehicles, fare boxes, computers and shop and garage equipment.

More information on the program can be found at: http://www.fta.dot.gov/funding/grants/grants_financing_3557.html.

8. Conclusions

This section summarizes the conclusions when comparing electric trolley buses and the diesel hybrid buses for operating in Seattle.

Life-Cycle Costs

The electric trolley bus technology was found to be $3.7 million less expensive annually than diesel hybrids in the life-cycle cost analysis.

Current FTA fixed guideway grant funding reduces the annual cost for the electric trolley bus technology by $5.4 million dollars.

If the grant funding levels fall below 31 percent of current funding, then diesel hybrid becomes the less expensive alternative.

Other cost variables such as gas price, electricity price, life span, and purchase price were tested. Assuming reasonable variations of these variables, none were found to be significant enough to favor diesel hybrid.

Environmental Screening Evaluation

The environmental comparative analysis favors the electric trolley bus in most categories—traffic, noise, air quality/climate change, energy, environmental justice, and neighborhood character. Visual quality favors the diesel hybrid, and the historic buildings evaluation had similar impacts for both technologies.

Auxiliary Power Unit

If the electric trolley bus is selected as the preferred technology, a battery APU is recommended over a diesel APU. Battery APUs have a shorter range, but can handle the steep grades in Seattle. The switch from overhead trolley wire to a battery APU is significantly faster than diesel.

Vehicle Performance Assessment

The vehicle and system assessment favors the electric trolley bus for traveling on steep grades, lower road impacts, and rider satisfaction. Diesel hybrid buses are favored for their availability and flexibility.

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Appendix A

Public Involvement Report: Trolley Bus System Evaluation

Public Involvement Report

Trolley Bus System Evaluation

King County Department of Transportation
Communications
May 2011

Outreach Summary

Metro's electric trolley fleet is reaching the end of its useful life. The aging trolleys are scheduled to be replaced by September 2014. Before signing a contract for new trolleys in September 2012, Metro conducted an in-depth evaluation of vehicle propulsion technologies to determine the costs, limitations, and benefits associated with the potential options. The findings of this study will enable the county to make an informed decision on the best technology to use going forward.

Beginning in June 2010 and again in April 2011, Metro held two sets of community open houses to solicit comments from the public about the scope and preliminary findings of the evaluation. This report describes key components of Metro's outreach for the Trolley Bus System Evaluation.

Outreach Activities

Metro Community Relations conducted two rounds of outreach, one in summer 2010 and one in spring 2011. Key elements of Metro Transit's outreach included:

- Distribution of informational materials via mail and email
- Public meetings
- Presentations
- Website
- Media

Public Meetings

During the summer 2010 and spring 2011 outreach periods, Metro held two community open houses in Seattle. Approximately 130 people attended these events.

These meetings were publicized via:

- media releases
- postings on Metro Online
- sending information flyers to 34 libraries, community centers, and civic groups in Seattle
- emailing copies to subscribers of the Metro Transit email list
- sending copies to the Employee Transportation Coordinators at worksites of 100 or more employees in Seattle

Presentations

Metro staff offered to present to more than 35 neighborhood and business organizations during the summer 2010 outreach phase. A total of 11 presentations were made based on these organizations' requests:

- Mount Baker Community Club (Summer 2010 and Spring 2011)
- Seattle City Council Transportation Committee (Summer 2010 and Spring 2011)
- Metro Transit Advisory Commission (Summer 2010 and Spring 2011)
- Transportation Choices Coalition (Summer 2010)
- Fremont Neighborhood Council (Summer 2010)

- Uptown Alliance (Summer 2010)
- Seattle Electric Vehicle Association (Summer 2010)
- Squire Park Community Council (Summer 2010)

Media

Metro used a variety of media to publicize the proposed changes:

- News releases
- Tweets to kcmetrobus account with approximately 3,000 followers
- Several months on Metro Online scrolling announcements

Metro's news releases generated coverage in community newspapers, blogs and the Seattle Transit Blog.

Website

The project website went live in May 2010 and was updated on a regular basis with informational materials, frequently asked questions, evaluation process and timeline, and outreach schedule.

Email Updates

Project updates were sent out periodically to an email list of interested community members and stakeholders. This email list contains more than 800 subscribers.

Letters, E-mails, and Phone Calls

Letters

The Local Union No. 77, the Worker Owner Council of Washington State, the Queen Anne Community Council, and Zonda USA wrote letters about the Trolley Bus System Evaluation, which are included in this report. All letters expressed an interest in keeping the trolley buses

E-mails

There were more than 130 e-mails to the project e-mail address. The majority of community members expressed an interest in keeping the trolley buses.

Phone Calls

There were approximately 25 calls received about the evaluation. A number of these callers had questions or requested copies of informational materials.

Public Meetings

Metro held two open houses in Seattle:

- 80 people attended the June 2010 Open House
- 50 people attended the April 2011 Open House

Several people who attended the open houses were interested in preserving the trolley bus system, had questions about off-wire capabilities of trolley buses, and expressed their concerns with hybrid electric-diesel buses.

Comment Log

COMMENT	DATE
Quieter and faster alternatives are always welcome on all of the uphill routes. Motor coaches that are traveling uphill are very slow and incredibly noisy compared to trolley coaches. Some of the trolley routes are outdated though and make people go opposite directions before they can get to their destinations. Many southbound and northbound routes terminate in the middle of nowhere. For example route 14 on Summit, 12 on 19th Ave, and 10 on 15th ave do not go anywhere meaningful northbound. If passengers need to go north they must first ride the opposite direction(south) to downtown through a VERY SLOW PINE STREET or even slower Madison!!! and then transfer to a northbound bus. The region has grown and these routes only get people to downtown. If the wires prohibiting these routes to connect people to the region, then of course get rid of the trolleys and extend them to UW, Montlake freeway station, and other important locations. However routes 3, 4 must stay as trolleys please! Those travel on very steep hills that motor coaches can not do so effectively.	6/15 email
Iconic Seattle are what our transits buses are to our wonderful city. I live and manager one of Capitol Hills old historic apartment buildings on Broadway on Capitol. The trolley buses are so quiet that they only add to the charm of our city and we the people love them because they never wake us up out of our needed sleep; I know my bedroom window is less than 15 feet from the bus stop. I will make you a deal, keep our wonderful trolley styled buses and I will take very good care of the treasure better known as The Capitol Crest Apartments, circa 1905. See the attached photo.	6/14 email
I recently came across the information that King County is kicking off a project to study alternatives to the current electric trolley buses. I am finishing up my masters at the University of Denver and working on a capstone project that relates to this topic. My research project is taking a look at possible regulatory and policy challenges/barriers to the widespread adoption of battery powered electric transit buses. Part of my research involves interviewing potential implementers of this type of bus and understanding the issues that may influence decisions. As you are currently starting a process of evaluating alternatives, it could be of value to me for my project to talk to someone in your organization to get some background on areas of concern and interest in evaluating alternatives. Is there a person I could contact in the transit organization that I may be able to get some detailed information on your electric trolley operation? This may include operations and maintenance costs and other use metrics.	6/15 email
Thank you for contacting us regarding the trolley bus study. The only thing I'd like to contribute at this time is that we'd prefer Metro purchase trolley buses that exceed federal axle-weight restrictions of 24,000 lbs. As we know from the attached report, significant damage is done to arterial pavement by overweight transit buses. While legal, the axle-weight exemption was a consideration for retrofitting buses near the weight limit with wheelchair lifts to comply with the American's with Disabilities Act. That was fine in 1991, but 19 years have passed and new equipment should be compliant. Moreover, it would be of considerable help to communities already struggling with their maintenance backlogs if Metro purchased equipment that did not exacerbate the problem. **SEE ATTACHED MEMO**	6/14 email
I had heard that replacement of green trolleys with polluting diesels was a foregone conclusion, due to initial costs. I certainly hope that any public meeting is more than windowdressing. What a shame if this great hydroelectric city should surrender to demon oil. Shame!	6/14 email
Would like Metro to adhere to new federal law being considered that requires electric/ hybrid vehicles to make noise for purposes of ped safety.	6/16 phone call

I cannot make the public hearings, but want to express my opinion in favor of keeping the electric trolley buses. I own a home on north Queen Anne, immediately in front of a bus stop. I have made several complaints to Metro about the noise and pollution that the diesel buses cause to my home that sits at the bus stop. As a property tax payer, and neighbor to the major bus stop, I can tell you that I am a huge fan of the electric trolley buses. They are clean and quiet and a good symbol for forward thinking Seattle. We made the incorrect decision to rip up the street car tracks years ago. We should not make the same mistake with the electric trolley buses. When gas prices return to $4 or $5 per gallon the decision to keep the electric trolley will be wise. Seattle prides itself on its environmental awareness, and the electric trolleys fit that that vision. Please keep the electric trolley buses and expand them!	6/16 email
Ashley -- I will be out of town for the upcoming public meeting on June 22, but as a resident of Capitol Hill/15th Ave. E. I wanted to lodge my support for finding a viable trolley replacement fleet. The lower emissions and decreased noise are a huge factor for residents amidst the bus routes; and the absence of dependence on fossil fuels should give trolleys a strong 'yes' vote as well. Just wanted to send along in case you are tallying comments leading up to the meeting	6/16 email
This is some text I submitted to Congressman Inslee, someone I know from high school, because it relates to his New Apollo project idea. I also submitted it to Metro, but am not sure if you got it. I am writing neither as an employee of the Bonneville Power Administration, nor as a delegate of the Seattle Electric Vehicle Association (SEVA). But my job at BPA *has* been to promote energy efficiency and renewable energy (RE). This trolleybus topic is not exactly RE, but it is close to my heart. I have a photovoltaic (PV) system on my house and hope to buy a Nissan Leaf all-electric vehicle (EV). Combining PV and EV is an exceptionally good combination. In pursuit of these interests I attend meetings of SEVA. I am on the list to receive a Leaf this year. Few cities have all-electric trolleybuses – San Francisco and Seattle are the main ones, because of the hills. Besides their high torque, they are non-polluting, and quiet. Seattle uses them on weekdays; they use diesels or diesel-hybrids for those runs on weekends, because that is when they do line maintenance and the loads are lighter – and they get complaints regarding noise and pollution. On May 10 the Seattle Times ran an article about this aging KC/Metro electric trolleybus fleet. While a recent audit recommended that KC/M remove their existing overhead wires, KC/M has not yet made that decision. They are looking at several options, included at the end of the Times article. The first option is "Order a trolleybus with supplementary batteries charged through overhead power and regenerative braking so the bus can sometimes detour off-wire." A variation of this option was promoted by a speaker I heard at a recent SEVA meeting. This option preserves the overhead wires (vs. the audit recommendation) while employing enough batteries such that they could be wireless for a few miles (around construction or where wires are bad), just as the M/KC first option states. The supplemental batteries will therefore allow these trolleybuses to be fully utilized, running on weekends as well – a point that the audit did not apparently consider. The trolley wires are an existing, efficient distributed charging network. All other proposals would employ diesel, be loud, and generally increase the carbon footprint. The electric grid can always be fueled by renewable resources, whereas diesel and hydrogen are less so, and they will require a new or more polluting charging system. The following is the SEVA addition to that option: Apparently M/KC has ordered, and is about to take possession of, new Orion VII BAE propulsion **series hybrid** diesel-electric buses to replace some existing articulated coaches. This model's diesel motor runs at a constant speed to continuously charge a battery bank, and is much less polluting than the **parallel hybrids** diesel electric buses now used by M/KC. The proposal I heard is that one or some of these buses should be modified: take out the diesel engine and tank, install a boom/pickup, and add additional batteries such that the buses will have enough power to be off the wire for several miles. Then, when it gets back on the wire, the overhead wires will re-charge the batteries, just as the diesel motor had been doing. In other words, these will become wire-battery **all electric hybrids**. One reason to use this new bus model for a retrofit is that it could then be the standard across the entire new	6/16 email

fleet – whether diesel-electric or all electric – which will help with operations and maintenance, spare parts, and driver familiarity (like all Southwest Airline planes being 737s). Any diesel motor components that are taken out could be used as parts for non-altered diesel-electric hybrid buses. This should help equalize the maintenance differential between trolleys and other coaches. The proposal was to do this work locally, either by the transit mechanics or by fledgling EV company personnel. This would be a good conjunction with Seattle's role as a test city for the Leaf/Volt marketing of all electric passenger vehicles. Seattle could become famous an all-electric vehicle city. An all-electric hybrid relies on the local power company, so any pollution produced is managed at the plant, rather than generated throughout the city. The buses, as mobile electric storage units, could be programmed to feed back onto the electric grid as a way to shave Seattle City Light daytime peaks in a Smart Grid application. The Puget Sound area could become a center for excellence in this field. Now KC/M is at a critical juncture, and there is an opportunity to influence future direction and upcoming purchases of buses and/or trolleys.	
Keep them!!! I live on a trolley bus line and the thought of having diesel buses going by daily is enough to make me move.	6/17 email
I would just like add my voice, to the many, that wish to keep the trolly busses rolling in Seattle. You can be sure that failure to do so, is guaranteed to become an election issue.	6/17 email
I'm writing to strongly urge King County Metro to **replace current electric trolley buses with new, state-of-the-art electric trolley buses.** European cities have demonstrated the economic value proposition of electric trolleys vs. diesel when fuel costs are high. It would be a huge mistake to replace electric trolley buses with diesel when all evidence points to the ever-increasing cost of fossil fuels in the country. In addition, a U.S. carbon tax is inevitable, adding to the relative cost of diesel and hybrid operation. Hydroelectric rates have shown remarkable stability. However, the most important factor is environmental. It is inconceivable that any public agency would choose to replace a lower carbon technology with one that is both higher carbon and that causes the kinds of catastrophic environmental disasters as we've seen in the Gulf of Mexico, Kuwait, Alaska, the Amazon Basin and everywhere fossil fuels are extracted. Hydroelectric dams, while not perfect, are much preferable sources of energy in the Northwest.	6/17 email
What year(s) were the 1978 AMG trolley coaches replaced by the Gillig-bodied vehicles? And what year(s) were the Breda's converted to straight trolleys and put into service to replace the MAN artic units? The FAQ on the trolley study web page doesn't include such details. My interest is more for my own enlightenment, although occasionally work conversations stray into this field. (Linda responded 6/18)	6/17 email
According to http://metro.kingcounty.gov/up/projects/trolleyevaluation.html "A trolley cannot operate if it is not connected to the overhead power. Unlike a hybrid bus, a trolley has no on-board energy storage system. So, when a trolley is braking or going downhill, the extra energy that is developed is dissipated through resistors. Some energy can be put back into the power lines, but only if there is another trolley on the line that needs the energy." It should be noted that those two limitations only apply to the equipment that Metro currently owns. All other systems operating in North America have "off wire" capability. I don't know about the regenerative braking though.	6/17 email
Hello: As someone who has resided on Capitol Hill for over 35 years (on 15th Avenue East where the trolleys are prevalent), I would urge **strong support** to keep them: namely, the lack of pollution and noise compared to other mechanized vehicles should be considered. Thank you for this opportunity to express my opinion.	6/17 email
As a native Seattleite, I must adamantly oppose any consideration to replace electric trolley buses. With oil gushing into the Gulf of Mexico, perhaps as much as 60,000 barrels a day, with our dependence on foreign oil at an all time high, and climate change a major environmental issue, it is extremely short sighted and unconscionable that King County Metro would even consider the	6/17 email

idea. And finally, electric trolleys are a part of Seattle and it's unthinkable that they may be replaced. Please pass this email on to whomever it may make a difference.	
Hello. I was shocked to learn that Metro is considering getting rid of trolley buses and purchasing diesel buses. The trolley buses are great and I wish that all the buses in the city were trolley buses. They are very quiet and pleasant to ride in. The gas powered buses and noisy and are constantly belching pollution into the city. Diesel buses release more particulate matter into the air, causing smog. Why, in the era of global warming, would Metro decide to go from a cleaner technology to a dirtier one? Why, in the era of disastrous oil spills, would Metro decide to go from hydroelectricity to fossil fuels. Truly shocking. I hope you don't decide to go through with it. The more I think of it, the more upset I get.	6/19 email
i appreciate the lack of pollution from the **trolley** buses. One of the things i love about Wallingford as an urban village is the lack of bus noise and air pollution. BUT - I prefer the safety of having a backup system like that provided by a **hybrid.**	6/19 email
I am operator #117, out of 1762 full-time operators this shake-up. I have picked a trolley route to operate for 23 out of my 28 years of service. Tomorrow I will again pick trolleys. Trolleys are part of what separates Seattle from other cities, I see it in the tourists eyes everyday. Trolley's are part of the "Soul of the City" Please don't allow an auditors report to kill our soul. Don't let history repeat itself. In 1963 Seattle Transit eliminated these routes-15, northend & West Seattle 18, northend & West Seattle 5, 6. 16, 7 northend (today's 73 to 85th & 71 to 65th) & Rainier, 8 (today's 30 to 55th & 35th), and the 21. Along with the 11 in 1965. And the 3,4 on Queen Anne & Jefferson Park & Montlake in 1970. Trolley's may cost more but they last more than twice as long as diesel coaches. Our system would become more economical if it were expanded, not reduced or eliminated. Costs could also be reduced by having more turnbacks at key locations. When the system was reduced in 1963, Seattle Transit kept virtually all the downtown wire for a system that in the end was running about 50 trolleys, down from 307. What is the price of good health? What is the price of noise? Stand at Bellevue & Pine and note the difference in noise a trolley makes climbing the grade. It's not even one of our steepest grades. If diesel or hybrid or anything else tried to carry the loads the trolleys do, on the steepest grades, on a regular WEEKDAY bases it would end up costing much more in the long run.	6/19 email
Dear Ashley - I read this blog/article is the Seattle Times: http://www.seattlepi.com/transportation/421887_trolley17.html - and am added my vote to those who say "Please keep Seattle quiet cleaner cable trollies - and no to diesel buses" I take the Route #1, 2, 13 everyday and the #1 goes by where I live on West Olympic Place. I am certainly not in favor of us going backwards to more fossil fuel burning vehicles in this day & age of climate change, BP disasters - plus the noise factor is a big concern for me, too.	6/19 email
At first, when I heard you were getting rid of Trolleys, I figured, "OK, they're getting rid of those ancient 60 foot MAN trolleys (I can remember riding the diesel ones when they were still in service!), good!" But I saw a picture of one of the new Gillig trolleys on your web page, and I'm confused. I can see getting rid of the old 60ft MAN trolleys, they're from 1986! I can even see getting rid of those LemonBredas, they're from 1990-1991. But to get rid of those new Gillig Phantom trolleys that are only ~8 yrs old seems Ridiculous!! Am I missing something here? And what is your top idea for replacing the trolleys? My first idea would be hybrids- I like the technology, and if they're built right, and if you have sufficient power for the weight of the bus(Important!), I don't see a downside...the ones we have seem to be working well so far in their current roles...they're not fast as a good old regular diesel NewFlyer(2300-~2550 series), but they're not bad....I'd like to see any new hybrids that we get have the same acceleration & speed as the regular diesels...if possible...	6/20 email
The trolley bus system is a mode with almost a century of service in the tough job of carrying riders around cities all over the world. Unlike diesel-powered motor buses, when trolley buses do their work they make no smoke and little noise, pleasing their	6/20 email

riders, nearby pedestrians, and residents along the routes. The region's electricity supply has low cost and can be expected to stay low, while the price of diesel oil is rising and hard to predict for the future. Their initial success after World War I came from economy - cheaper than streetcar routes to install, and cheaper to operate and maintain than gasoline-powered stick-shift buses. The streetcar is no longer in the transit mainstream; diesel engines and modern automatic transmissions have reduced operating costs of motor buses. Today there is a modest cost disadvantage to operating trolleybuses. The vehicles cost more than motor buses, mainly because they are made in lower volumes, but they last somewhat longer. The electrification infrastructure requires a team of maintenance workers. Do the advantages make the extra cost worth while? I would vote YES. Some trolley routes in Seattle operate on hills up to 20% grade; by using electricity from the power grid trolleys climb them quietly and effortlessly. Descending, speed is controlled by the motors without wearing out brake components, and energy can be returned to the grid. In the 1970s when the electrification was renewed, the replacement motor buses required extra maintenance due to operation on these steep routes. Seattle is unusual in North America and Europe by not having any auxiliary power source on its trolleybuses. Vancouver and San Francisco have batteries onboard; most European systems use a small diesel generator, which can (slowly) accelerate the bus to around 30 mph on level ground. Metro considered adding battery auxiliary power to the 1979 fleet and modified an old trolley to try the concept. Analysis of the cost of maintaining the extra equipment on the fleet vs. savings from fewer trouble calls showed negative net savings, and the idea was dropped. That question could be revisited. After 28 years working in public transit (Pittsburgh, Seattle and New Jersey, now retired) I am a great supporter of trolleybuses. In my opinion, Seattle would be wise to stick with a system that uses our hydropower to move thousands quietly and odorlessly, contributing to a livable urban environment. I'd urge the county council to take a trip to Vancouver BC and ride the new trolleys there.	
Just voicing an opinion on electric vs. diesel buses. I think that, despite the extra costs, we should replace the aging fleet of electric trolley buses with new all-electric buses. There are a number of reasons that this is a good idea, and most of them have to do with the quality of life, both for bus riders, and for others. . environmental impact is less . buses are quieter . buses do not emit bad smelling exhaust . diesel fuel costs may increase significantly during the lifespan of the new bus fleet	6/21 email
Would you please add me to any "public involvement" email distribution list you might develop on the topic of the electric trolleybus fleet replacement?; Replace our fleet of electric trolley buses! In fact, increase their usage!! Just considering purchase and maintenance monetary costs in the replacement decision is being short sighted. In addition, one needs to consider air pollution and noise. It is such a pleasure to be in and around electric trolleys. No pollution. Very little noise. Especially in densely populated areas this is a real plus. I'd be willing to pay an electric trolley premium fare, if need be.	
Thanks. If you keep me updated, I can keep the City Neighborhood Council, the Sierra Club, and others updated on how it's going.; How are things going for the planned review of last year's audit on the electric trolleys? Also, here's another question to consider: What studies have been done that compare electric trolley ridership with diesel bus ridership on the same or comparable routes? Or of rider satisfaction, particularly with respect to smoother, quieter, and cleaner rides? I'm told that Carl Natvig at Municipal Transportation Agency in San Francisco might have some data.	2/22 email
Thanks for the follow-up. What does it take to get a copy of the Sept 2010 "scope, schedule and work plan" ? Please support Electric Trolley Buses. It is important that King County continue to LEAD THE WAY towards clean transportation	6/22 open house

which does not destroy the planet our children and grandchildren need to live on! Electric Trolley Buses will help us "weather the storm" during the coming next oil crises as China and India's fuel consumption continues to grow exponentially. To get rid of the Electric Trolley Buses would be to head backwards in time when we should be moving forward. Getting rid of the Electric Trolley Buses would be "pennies wise and pounds foolish!"	
It has been my experience over the last 60 years or so that the trolley buses handle hills better in the snow than do motor buses. I would hate to see us give them up.	6/22 open house
If something must be eliminated, please consider doing away with the ride free area. This should placate some of the suburban interests, save Metro some fare revenue and simplify things for everyone. The ETBs do more good for Seattle and the system than the RFA which makes everything more confusing, especially for "choice" riders!	6/22 open house
Center Park is a 136-unit apartment complex owned by Seattle Housing that is occupied by people with various disabilities. Many of it's residents use routes 4 and 7 which use 40 or 60-foot trolley coaches. Many of these same residents have mobility impairments, meaning a lift or ramp is required for them to get on or off the bus. At the current time the bus zone at 26th and Waler (the "layover" zone for route 4) has no curbing, making it extremely difficult for many people to get on or off, especially if they are using a manual chair. The zone to Rainier and Walker is fully useable however. Please look into putting curbing at zone at 76th and Walker. Thanks!	6/22 open house
The steep streets of Seattle requires them. The availability of hydro power favors their use. If we are serious about increasing urban density and reducing Co2 footprint the quieter, cleaner trolleys are the way to go. What is the value of infrastructure already in place in today's dollars? It is likely to dwarf any savings achieved by switching to diesel. The outdated fleet represents deferred decisions to keep it current and calls for stepping up to the plate.	6/22 open house
The trolley bus is smoother and quieter then the diesel bus is . The trolley bus doesn't jerk, the diesel bus does. Trolleys can get faster up hills. Trolley should be replaced with another trolley system. The diesels and hybrids are really loud all the time except when they are stopped. You know where trolleys are going because they are on a fixed guide way.	6/22 open house
Consider air pollution and noise!	6/22 open house
We live on Queen Anne and a bus stops right in front of our house. It the bus #1, a trolley. We love the trolley connections to QA! On weekends when we are served by diesel buses, the noise and fumes are very intrusive and unpleasant. You would be doing a huge dis-service to our neighborhood's livability and character if you replaced the trolleys with diesel - not to mention their historic value and their contribution to carbon reduction.	6/22 open house
I am strongly in favor of keeping the electric trolley system because it isn't based on petroleum which is going to get more expensive and degrades our environment; it allows us to use our hydro electric power through our access to Seattle City Light; It is quiet; it operates well on hills; over time trolley buses are competitive economically; to shift from electric powered trolleys to diesel symbolically gives the wrong message.	6/22 open house
I would like to see Metro better educate the public about the possible new technologies, so that riders understand our choice is between state-of-the-art trolleys vs. state-of-the-art hybrids, and NOT old trolleys without air conditioning and which can't leave the wires vs. new buses that have air conditioning, nice seats, and don't break down as often. Would like to make sure that this study compares performance of technologies e.g. ability to climb hills, noise levels, and in adverse weather conditions.	6/22 open house
There is no question we should purchase electric trolley buses and it seems a ridiculous waste of taxpayer dollars in these cash-strapped times to spend $850,000 on a study. The benefits which include better hill "climbing" gas emmissions reduction, sound, etc. and the reduction in reliance upon oil and money for increased diesel costs is a no-brainer and better for our environment and	6/22 open house

is more fiscally responsible (In fact - beyond this discussion, I know, it is ridiculous to hear the steel railed street cars with theur built in inflexibility but that's another thing. Thank you.	
I'd like to hear that the polls/townhall meetings done earlier this year by SDOT/City of Seattle have been forwarded onto King County as part of this trolley decision process.	6/22 open house
Every time Metro puts an appeal for funds on the ballot, I vote "yes". Without dependable bus system, I can't have a life; so I have voted "yes" (as have my senior neighbors) on every ballot measure which promised better transportation. We kept our part of the bargain' now Metro should keep it's word and give us state-of-the-industry , high-tech, dependable buses! Let Vancouver be Vancouver and Seattle be Seattle. Put away your state-of-the-industry, high-tech cars for a year and submit your life, health, errands and social connections to a bus system where power failures and breakdowns leave you stranded miles from home, in every kind of weather. Then add 20, 30, 40 years to your age, add crutches, a can or walker and ask yourself whether you are good stewards of Seattle's transportation needs. Keep one trolley line for those who can afford to court the antique and picturesque. For active, employed or volunteering people who have appointments and commitments, GIVE SEATTLE THE BEST $ CAN BUY!	6/22 open house
I live in Center Park Apartment building which is full of people with differing (dis-) abilities, including deaf and blind and wheelchairs. The one thing that so far everyone in my building agrees on is that we all like the low floor buses better than the high floor buses. We all find it harder to get on a high floor bus. Someday soon the present coaches use by "C.P." which is a separate contract with Metro that predates the Access vans will have to be replaced.	6/22 open house
Consider buying 15-25% more articulated trolleys for complete and total electrification of route 36, ending the current half-diesel-half trolley policy. Seattle NEEDS electric trolley buses.	6/22 open house
Consider putting an emergency loop on route 44 near the vicinity	6/22 open house
Service Suggestion: One problem with using a bus is that groceries are difficult to maneuver. I'd like to see carts that can be used to and from bus stops to the grocery store and to the residence for an extra fee. This would include having a locker on the bus for two or three standard bags. There would be stalls at bus stops where carts could be locked in place until pick-up. Grocery shopping is one of the most difficult things to do without a car, if not the most that is non-emergent.	6/22 open house
I went to trollybus Twin #627 Seattle Downtown 12/1977. To AM 6 trolleybus 1979 See 1983-2003 AMG Trolleybus Seattle Gillig Trolleybus and MAN articulated trolleybus 1987. Brade 2003-NOW Trolleybus articulated.	6/22 open house
I currently live on a trolley line. The trolley currently is fairly quiet and non-polluting. If the decision is made to go with diesel, I would rather not have the service in my neighborhood. Whatever alternative is chosen (if not trolley (electric)) the system should be carefully evaluated for air pollution and noise. Whenever the trolley line is replaced with diesel due to construction issues somewhere on the electric line it is very noisy and smelly and impacts quality of life in the residential neighborhood (I am on the #3 route)	6/22 open house
Encapsulation of comments received at June 22 Open House, Station 1: - Would the removal of trolleys affect City Light revenue? - Will you include analysis on greenhouse gases? - Are you considering supercapacitor-type technology? - Need more information on scope, want to comment on scope; on web? - Hybrid, all-electric appropriation/grant, 600K vs 1.2M comment/question - City vs. County concern; look at Vancouver BC's recent trolley purchase	6/22 open house

- Opposed to trolleys; wants best, most efficient system; supports study; look seriously at hybrids - To what extent are we using existing studies such as Vancouver? - What methodology are we using to predict future energy costs? - Trolley drivers have a history of trolley experience; trolleys are very reliable/tough in city/hill conditions; how much weight will maintenance staff's opinion have? Evaluate non-trolley buses on trolley routes, real-life conditions.	
I am unable to make it to tonight's meeting due to childcare responsibilities, but I would like to make a comment. It seems to me that to switch to diesel at this time would be short-sighted (I realize that current budgets make people short-sighted, but let's fight the good fight!!). Even though the new diesel buses are very clean in terms of emissions, they are noisier and even biodiesel is mostly fossil fuel—the problems with which we're seeing every day in the Gulf of Mexico and beyond. Electricity, on the other hand, can be sourced from a number of clean options. Let's keep King County moving toward a clean energy future!	6/22 email
I just saw a note online about the meeting tonight about the trolley study. Unfortunately I already have plans and since I just found out about it I can't change my plans or I would be at the meeting. It said on Metro's website that I could direct comments about the study to you so here it is. I only have one comment and that is to make sure the environmental impacts are included in the study. Specifically the CO2 emissions and the reduced noise should be compared to other buses as part of the study.	6/22 email
I had planed to attend however I have to drive to Portland today and can't make it. I live on the #12 trolley route and have lived here for 35 years.When the city transit system was merged with the almost non existent Metropolitan Transit system we were assured that the city would be able to keep our electric trolley's . Electric trolleys last a lot longer then diesel busses because of a lot less vibration . They are quite and clean. The 1940's trolley's lasted well over 40 years and the only reason the latest trolleys are warring out is we cheeped out and used the electric motors from the AMC trolley's which preceded them. I intend to lobby the Mayor and the city council to keep the trolley's. I am not fond of the County Council making decisions about a Seattle issue. I have informed the county exec that I am not happy with the frequent motorization of the trolley's on weekends with busses with crappy cheep caterpillar engines. They are noisy, and dirty.	6/22 email
The mere fact that this discussion and debate is even taking place is total insanity. Did anyone in Seattle ever hear of the Gulf of Mexico and the ongoing oil spill disaster? Does Seattle have network TV news that allows its citizens and public officials to see what is going on in the world? I guess the King County officials all have their heads in the sand. It would seem that they're in denial or reality hasn't quite set in yet in the Pacific Northwest. The whole debate is a "no brainer" and is actually embarrassing to even be having. Hello King County !! Millions of gallons of oil continue to pour uncontrolled into the Gulf of Mexico. President Obama continues to push the country away from the use of oil and to explore other means of "clean" energy. You guys are fortunate to already have in place what the rest of North America needs and will spend billions to achieve. And here you are, thinking of ways to scrap it and replace it with oil burning Diesel buses. There's something wrong with this picture. Am I dreaming this? Will I suddenly wake up and find out that it was a horrible nightmare? We certainly don't need to find more ways to consume and burn oil in this country. I'm beginning to wonder if the King County officials, who would even entertain the thought of scrapping an electric trolley coach network powered by a clean hydro-electric power source, ever went beyond the third grade. Wake up Seattle.....you've got a wonderful, valuable asset, that you should be proud of and boast of to the world. I'm wondering if this debate is just a "make work" project for unemployed consultants? Or do the King County officials own lots of oil stock? What other reasonable explanation could there be? And it should be noted that while Hybrid Diesel buses might consume somewhat less fuel that a straight Diesel bus, the oil still has to be extracted out of the ground, refined and transported to the location where it will be used. This is costly and actually consumes even more oil and causes even more pollution. And Hybrid Diesel buses must haul around a heavy supply of fuel in their fuel tanks. Electric trolley coaches just draw the power they need from the trolley wires	6/22 email

without carrying around their fuel supply or a heavy engine and power plant. In addition, electric trolley coaches have far less moving parts to maintain and wear out and usually last three times as long as Diesel buses, Hybrid or otherwise. Thank you for allowing me to vent.....	
I saw that you were the contact person for Metro regarding the electric buses. I live at 1547 16th Avenue East where the number 10 runs behind my house on Grandview on Capitol Hill. I will not be able to attend, but would like to have these be replaced with new electric buses. The 10 uses the diesels on weekends and the difference between the two is quite significant.	6/22 email
I attended the community meeting today and wanted to put my questions in writing: 1. Are the potential impacts to the overhead system including the substations and/or vaults being assessed as part of the evaluation for each propulsion system being considered? 2. Is the cost of dismantling the overhead system including the substations and/or vaults or the potential of leaving the overhead, substations and/or vaults in place but mothballing them being included in the evaluation? 3. Are there any impacts from changing, mothballing or closing the overhead, substations and/or vaults to the transit tunnel operation? If so, are these potential impacts being included in the evaluation? 4. I am wondering what the demographics and income level of the trolley service routes are in comparison to the suburban routes. 5. Did the county audit differentiate between the current maintenance costs per platform hour and per platform mile for the trolley coaches and the diesel, hybrid fleet due to the difference in age of the vehicles and the costs covered under warranty? 6. Councilman Phillips mentioned that the current trolley service level is in place through 2011 and that decisions need to be made for 2012. Is this evaluation part of what will be considered in the discussion of how much service the County Council wishes to cut in the City of Seattle?	6/22 email
I have been following the Trolley Bus System Evaluation fairly closely, including attending the meeting downtown yesterday. These are my comments: As both a daily trolley route rider and a resident living directly on the trolley route I have a great deal of experience with the system. The trolley routes are quieter and more comfortable, whether you are riding the route or are near a passing bus. For some reason on the weekends the route that goes by my house (49) switches to diesel coaches. On those days it is noticeably louder on our street. If reduced noise and more comfortable rides were the only benefits of the trolley system I would fully support changing to another, more cost-effective technology. However, the long-term benefits of the electrified trolley system far outweigh any short-term cost savings from switching to diesel. First, the environmental damage created by an electrified system is far less than diesel. This cannot easily be monetized, but should be a primary consideration. Second, the assumption that fuel prices will only increase over the next 20 years at the same rates they have for the previous 20 is near-sighted and illogical. Look at what happened just 2 short years ago! What are the long-term costs if fuel is $4, $6, $10 or even $20 a gallon? I'd wager the electrified system becomes more cost-effective over the long-term very quickly as fuel prices drastically escalate, which they are sure to. Third, even if fuel prices don't escalate dramatically over the life of the next fleet of coaches, having an electrified system helps us to reduce our dependence on foreign nations for our energy needs. We produce our electricity relatively near where it is used. This is another thing that can't easily be monetized, but should be considered highly relevant. Fourth, it seems that due to the relatively fewer parts in an electric coach, the long term maintenance needs would be less. While I understand the need to save money, I find this whole process to be a waste of public time and money. Of course we should continue using the electrified trolley system, in fact, we should be expanding it. The possibility of switching more of our public transit to fossil fuels is ridiculous, especially in light of current environmental problems being caused by our thirst for oil. Please share my comments with whoever is making these decisions.	6/23 email

It has been my experience over the last 60 years or so that the trolley buses handle hills better in the snow than do motor buses. I would hate to see us give them up.	6/18 email
It was great meeting you yesterday. Thanks so much for your great presentation! The meeting with city council's transportation committee was very informative and in a very enjoyable location. Please let me know if there is anything we can do to help with your study or the open house sessions. We'd be more than happy to support you with arranging for a trolley bus demonstration in Seattle or to welcome you or any of your colleagues here in Vancouver. On a side note: we have a team specialized in designing substitute trolley components if parts become obsolete. Please let us know or feel free to pass on my contact details if we can support you with sourcing battery chargers or other items.	6/17 email
While I appreciate the effort Metro has put in to inform us riders of the trade-offs between trolleys and diesels, I'm a bit concerned about the information on this page: http://metro.kingcounty.gov/up/projects/trolleyevaluation.html This page compares the current fleet of diesels against the current fleet of trolleys. However, if the decision is whether to replace the aging trolley fleet with new trolleys or new diesels, analyzing the status quo is somewhat beside the point. Specifically: A trolley cannot operate if it is not connected to the overhead power. Unlike a hybrid bus, a trolley has no on-board energy storage system. So, when a trolley is braking or going downhill, the extra energy that is developed is dissipated through resistors. Some energy can be put back into the power lines, but only if there is another trolley on the line that needs the energy. While this is true of the current fleet, Seattle has the only electric bus fleet that cannot operate (for at least short distances) off the wires. Other cities have battery backups to get past dead wires, blockages, or other buses, and for regenerative braking; other cities have combination diesel + wired buses which can run on wires where available, and diesel when not available. Perhaps it's too early in the process to have a list of replacement models, which presumably have different features & engineering trade-offs (and prices), but because this information is presented as something that's an inherent limitation of wired buses, this could cause confusion.	6/24 email
I'd like to put in a good word on behalf of the electric trolleys in the Metro fleet, and strongly encourage you to replace them with electric trolleys. I get excellent use out of Rts. 14, 43, and 49. In fact, I live next to the Rt. 14 terminus. The next closest practical bus is Rt. 49 (also electric!), and I have to walk up a big hill to get there. I won't dispute you if you honestly think it will save a few bucks to replace the electric trolleys with diesel hybrids, but consider the environmental savings of using trolleys that run on clean hydroelectric energy. Consider the severity of our dependency on oil for transportation. Consider the odds that oil prices will increase in the future. Consider the elegance of quiet, charming electric trolleys--especially in residential neighborhoods. And consider the city that Metro serves, and the will of the people who live in it. Our fares keep going up anyway; you might as well raise them a bit faster and give us the trolleys. In fact, if anything, we should be building more electric trolley lines--not retiring the current ones. Rt. 8 should become electric, for instance. Some people have said that they think the placement of the existing electric routes is inefficient. I don't know about Rts. 13 and 36, but all the others seem pretty well placed--especially Rts. 14, 43, 44, and 49.	6/24 email
Sorry, I was out of town during your recent open house on this subject. This would be my comments: Replacing clean green non-polluting trolley buses with dirty diesel buses would represent a HUGE step backwards in the wrong direction. On the contrary we need to be moving towards MORE electric trolley buses in the future, to fight global warming, fight the air pollution that is making our citizens sick, to fight rising fuel prices, and to stop sending hard-earned Washington State Tax Dollars to support terrorism in the Middle East. Please continue and expand the number of electric trolley buses in the Metro Fleet!	6/25 email
I really hope that Seattle can keep its electric trolley bus system. They are SO MUCH!!!! quieter than the hybrid busses they were replaced with in the tunnels downtown. I'm sure if we looked we could find more efficient, maybe even battery electric that could	6/25 email

replace or augment them. I always feel good when I ride in those because it's about the greenest way to go to travel any good distance.	
Thank you for clear and well-publicized information regarding the trolley study. I wanted to offer a voice of support for trolleys, and also wished to make clear the necessity for the study to have fact-based, current estimates for maintenance and procurement costs. There are three points that I feel are particularly crucial, and I'm sure the study is already aware of them, but feel compelled to reiterate-1. Maintenance for new ETB's would be dramatically less than current maintenance on Bredas, and motors from '79; 2. Off-wire capability would reduce current backup/scheduling costs significantly; 3. Ensure getting competitive prices for new coaches, to keep the capital cost comparison fair. In essence, this means pricing and examining the performance of new trolley buses, rather than the current ones. There is also the issue of taking into consideration the non-financial benefits of ETBs, like noise reduction and hill-climbing ability. The "green" argument will also likely hold a lot of traction, especially given the current level of political awareness on the subject.	6/25 email
The position of Uptown Alliance on possible Metro Transit service hours cuts has been that any reduction in service hours is the worst outcome for our urban center and for Seattle's Center City neighborhoods. Under the current 20:40:40 division of Sales Tax revenues Seattle would have difficulties building the service hours back to current levels over future years - especially given the share of new population that Seattle is committed to receive. Here are some scoping comments for the Trolley Bus System Evaluation Study: - Utilize independent consultant to define likely scenarios for diesel fuel costs and Seattle-generated electric power costs within the lifetime of buses purchased in 2014. - Define the trade-off for Seattle transit services: How many service hours for Seattle would be retained, if the trolley bus system were replaced by another mode of transit? - Utilize independent consultant to determine potential for loss of Federal grant status, if the Seattle electric trolley bus system is replaced by diesel hybrid buses. - Define the Federal grant dollars lost to Seattle City Light, if the greenhouse gas-free Seattle electric trolley bus system is replaced by diesel buses. - Define the loss in Federal grant dollars now given to Metro Transit for maintenance of the electric overhead wires. - Define the loss in property values due to increased noise and air pollution from diesel buses vs. electric trolley buses. - Define dollar amount of loss of sales from City Light to King County resulting from trolley bus service replacement and how that dollar loss to City Light would impact Seattle electric rate payers.	6/25 email
Nice to meet you at the Friday Forum. In thinking about what event we have coming up in South Lake Union, I'm not sure if there's a good fit for getting a lot of public feedback on the trolley system evaluation. I can tell you many in SLU use the 3/4 trolley routes to get up to the top of Queen Anne, and the 70 to get to Eastlake. (Also I know expansion is not part of your evaluation, but as I mentioned I've heard people wish that the 8 going up Denny Way to Capitol Hill was a smoother ride.) As I mentioned the SLU chamber and community council are beginning to update our transportation plan due to the huge changes in our neighborhood (many more residents, Amazon, Mercer, SR-99 north portal, etc) so we'd love to be on your contact list!	6/26 email
Keep the trolley buses. They are one of the unique things about Seattle. In fact, expand the system, much cheaper than laying tracks. The tracked trolley from international district to capitol hill should have been done with trolley buses. Diesel hybrid buses still emit fumes when going up-hill, not acceptable. Some times it costs a little more to do the right thing. Also, with oil gushing in the Gulf of Mexico, we should be thinking of non-petroleum transportation. Since we get electricity from hydro power, the trolley	6/26 email

bus question is a no brainer, KEEP THE TROLLEY BUS SYSTEM!	
I attended the Transportation Choices open house yesterday and I wanted to thank you for inviting public comment. I don't think I adequately expressed my dissatisfaction with the proposed study's scope and overall objective. The wire network in Seattle represents a tremendous capital investment that we already own and it would be appalling to dismantle even if the study shows Metro could save a few bucks in the short term on new buses. Perhaps it would be more diplomatic of me to say, of course studying all options is a good idea but, I really don't see this as a good idea. I recognize the tremendously difficult fiscal pressures Metro is facing but that is precisely why I feel a study of this nature is particularly dangerous right now. In this climate, the only type of change in policy this study will be used for is one that will help the budget: a short term, fiscally appealing choice of switching to diesel at the expense of creating a long term plan to make a great, clean transit system (if you are serious about hydrogen and natural gas you could implement them anywhere, why start with replacing all of these core routes with unproven technology?). The potential for electric buses is huge but as Metro has stated, this study will not give the slightest thought for how th electric bus system could eventually be expanded and improved. Not a thought to what our transit system should look like in 2100, let alone 2050. I personally think Metro should be studying the myriad ways to maximize this capital investment in new ETBs. The city of Seattle would bend over backwards to help improve the routes and infrastructure. Federal dollars will flow for forward looking capital projects that can actually promise (and have a proven track record) of redusing fossil fuel consumption. Most people in Seattle do not even realize that they have an option to avoid fossil fuel consumption right now in the ETB network. My hope is Metro will decide not just to buy new low floor ETBs with auxiliary power for improved operational performance, but will simultaneously brand the ETB system to let people know that we don't have to wait on the Chevy Volt to ride a clean energy vehicle. We have a great system here and now, a basis for a clean network that can serve far more people than rail at a fraction of the cost.	6/26 email
Please do not under any circumstances remove electric buses from service or seek any other means of propulsion. It would be a great crime to the people to subject them to the cancer causing pollution, and nuisance noise. The electric infrastructure is less costly to maintain mechanically (less moving parts and engine corrosion), and saves money on fuel costs. Also, the cost of fuel is more predictable over time, and produced locally. All-electric transportation is the ideal that the city needs to be moving towards, for reasons of health, property values, and cost savings. Every petrol chemical burning city vehicle needs to be phased out of service at the end of its operational life due to rising oil and gas costs, the attrition of citizen's lungs, harm to the environment, and overall public health. New buses must be electric only. No transportation vehicle that employs a polluting and expensive chemical reaction will be acceptable in the future. The older pure electric surface rail system had the following benefits. (enhanced commerce / happy people / high property values) 1) higher throughput from point A to B 2) higher average speed per commuter trip 3) no pollution 4) predictability of transportation cost This is the ideal that we must restore, the perfect system which once made Seattle a "crown jewel" of America. This is the way that we need to go in the future, stating with total electrification. Overhead wires are not even necessary, electricity can be transferred from cables burried under the pavement. Mass transit systems around the world can do this already, the technology is roughly as old as alternating current. This will also be cheaper than stringing wires, but even that is less costly than gasoline or hybrid. Hybrids have far more mechanical parts and cost more, it does not make sense to even involve a corroding, maintenance intensive internal combustion system. No hybreds, yes to electric. All electric only is the path to success. Conclusion: Purchase	6/26 email

only electric buses (no hybrids) while moving toward restoring the pure electric system, and surface rail utopia. Save lungs, save money, rise property values, speed up commutes, boost commerce in one fell swoop. A very sound and wise investment that will only pay back more as time progresses.	
I attended the open house regarding the trolley bus system evaluation. As a result of my discussions with several Metro employees, I request that Metro consider the following factors in conducting the Electric Trolley Evaluation: In order to create objective real-world data to compare the true costs and performance of electric trolleys vs. diesel hybrids, Metro should immediately place diesel hybrid coaches onto each of the electric trolley routes 7-days per week for the duration of the study. This is not a request to replace all service, but 1-2 coaches on each route should be operated by diesel hybrid buses for the duration of the study. While Metro has not had 40-foot hybrid coaches, these are now being delivered, and there certainly are 60-foot hybrid coaches available which today operate non-tunnel routes. It is important that these coaches be evaluated on a long-term basis over six or more months so that the impact of operating heavy passenger loads with frequent stops and steep hills can be effectively evaluated. This evaluation should result in real-world objective data about whether the diesel hybrids can maintain the same schedules, what the real fuel consumption is, what the real maintenance costs are, and what is the dispatch reliability and miles between service calls. Previous studies have compared the diesel hybrids vs. diesel non-hybrids, and on routes with different characteristics, including higher average speeds, more freeway driving, and less hills. We need to know how the diesel hybrids will perform on the trolley routes before making the difficult and expensive to reverse decision to shut down trolley system. In order to fully evaluate how modern, low-floor electric trolley buses will perform, Metro should seek to make arrangements with Vancouver to borrow some of Vancouver's new low-floor electric trolleys and demonstrate them here in Seattle. This would give some indication of operating performance and rider acceptance. In considering any input from riders and the experience of hybrid buses, these riders should be exposed to modern low-floor electric trolleys, and they should not be mistakenly put in the position of comparing riding in 20-year-old Breda high-floor coaches or 12-year-old Gillig high-floor coaches with new low-floor diesel hybrids. It is my understanding that no real firm price quotations were developed for new electric trolley buses, and that the figure of $1.2 million that's been mentioned was an estimate made some years ago – and that there is no documentation of that estimate. Further, I understand that Orion, who produced the new 40-foot series hybrid buses would be interested in bidding on any new electric trolley buses, and that 160 units is enough buses to get good economy-of-scale pricing, particularly if there is commonality with a series hybrid design. As part of the evaluation, Metro should seek to get the best possible price indications from three qualified firms in order to get an accurate figure for the cost of new electric trolley buses. The differences between a series hybrid and an electric trolley bus should be relatively minor and it is very difficult to imagine that there would be a 2X cost differential. In fact, eliminating the diesel motor could result in a cost reduction while the rest of the system might be similar, aside from the trolley poles and any power conversion. In addition, to have an apples to apples comparison, it is important that prices for both diesel hybrids and new electric trolleys reflect the current economic and competitive environment, where prices for both have likely come down substantially since 2007. Thus current actual price indications should be sought. Metro should not use the maintenance costs of either the converted Bredas or retrofitted Gilligs in evaluating the maintenance costs of new electric trolley buses. The Bredas are 20-year old buses that were overweight and had an exceptional number of problems. The Gilligs are operating with 1970's electronics and electrical equipment which are exceptionally difficult to repair. While it does demonstrate the greater lifetime of electrical vehicles, it does not give the correct data to use to compare the maintenance costs of new electric vehicles. There may not be much institutional knowledge of how new electric trolleys perform since no new trolleys have been purchased since the 1980's. Perhaps data from either San Francisco or Vancouver can be used. It appeared to me from talking to both Metro operators and Metro maintenance staff, that many Metro employees think the ETBs are a viable and preferred vehicle	6/27 email

within Seattle, and don't want to see them go. I would encourage the evaluation to solicit employee input from the employees who operate and maintain the vehicles as to their reasons for wanting to keep them. My requests above are in addition to the factors that I already understand to be part of the evaluation, such as fuel costs, noise and emission considerations, etc. I did not hear that these five factors would be part of the evaluation. If Seattle chooses diesel hybrids, and dismantles the overhead power lines, it is likely an irreversible decision. Thus it is important to get the complete facts. In the last five years, I believe that Boston, Dayton, Philadelphia, San Francisco, and Vancouver have all purchased new electric trolleys. Thus, they did not choose to close their systems, and there are also many trolley systems continuing to operate in Europe and Asia. If the economics of electric trolley buses were dramatically inferior to diesel buses, we would see more abandonments. Therefore, we should see proof based on real data that there is to be a meaningful savings before losing the Seattle electric trolley system.	
Just last evening I became aware of proposed plans to replace electric trolleys with diesel veihicles. This is very disturbing to me on so many levels, and my comments reflect my strong preference for ELECTRIC vehicles, and for NON- ARTICULATED vehicles. We are facing fossil fuel price increases. Seattle already has horrible rush hour air quality. (I'm pretty healthy, but had to resort to inhalers at times at the 9th and Jefferson stop and after several minutes in older articulated busses. The articulated vehicles seem dangerous in Seattle weather and on Seattle hills, and passengers (especially near the accordian folds) are treated to exhaust seeping into the vehicles, especially on the older vehicles. Purchasing imported vehicles is not a good idea in this economy. Seattle's weather is too unpredictable, and the terrain too hilly for articulated vehicles. With the economy as poor at it is now, this may actually be the best time to negotiate for better prices for an electric transport system, and to invest in the long-range cost saving of having both a better transport system and better air quality in Seattle.	6/27 email
Ashely, I just wanted to add my two cents. I really like using the electric trolley buses in the Seattle area. This is for two reasons. The first is that they are not burning diesel thus reducing emissions and dependence on oil products. The second is that most of electricity in the north west is hydro powered and is thus non-polluting. Thanks for listening, Jaime.	6/27 email
Can you please keep me in the loop on any updates concerning the trolley bus evaluation program? My company has supplied the electrical systems of the new trolley buses here in Vancouver and some of the key components of your vehicles. Hence please let us know if there is anything we can do to help! Fantastic web site by the way! I really love the trolley bus video featuring Mike.	7/5 email
I would like to make the following comments with regard to the scope of the upcoming evaluation of the trolley system: 1. I believe the scope of the evaluation should be comprehensive and inclusive of all possible options. One of those options, it seems to me, would be an expansion of the current trolley system. Would there be any efficiencies gained with this option?? What would the effect be on the area's carbon footprint? 2. Hopefully included in the scope of the study will be health impacts of diesel vehicles from engine emissions and particulate matter. The Puget Sound Clean Air Agency is acutely aware of the effects of particulate matter on air quality. 3. City and County's carbon footprint, which should include idling time at bus stops and intersections. 4. Costs incurred in repairs and engine longevity to run diesel buses up steep hills such as the QA Counterbalance. 5. Appropriateness of running large, articulated diesel buses along narrow, winding neighborhood streets. 6. Noise level and its impact in neighborhoods as well as downtown. Thank you for your consideration of the above suggestions.	7/4 email
Please find attached a letter detailing our suggestions for subjects to be analyzed in King County Metro's Trolley Bus System Evaluation process. Please feel free to call or write if questions should arise.	7/7 letter
Please find attached our letter detailing our suggestions for the subjects to be analyzed in King County Metro's Trolley Bus	7/7 email

System evaluation process. If you should have any questions, please feel free to contact me.	
Hi! You are listed as the contact person for the trolley bus debate. I couldn't make it any of the open houses--are you the right person to send in comments? Will they count as much as if I had been able to attend? I would like to say--as a homeowner, taxpayer, and resident who lives on one of the affected bus line--PLEASE buy more trolley buses!! Do NOT switch to diesel buses! They are polluting and loud and I do not see why you would even consider switching to them. I think the entire city should be on the trolley buses--get RID of ALL the diesel buses. Seattle has a huge problem with only looking at what something costs now--in the short term and then getting screwed later in the long term and looking around wondering what went wrong. PLEASE try and think long term! Diesel is polluting, loud, and more costly in the long term. Please try and think of the future and not just about the next year.	7/19 email
You are being asked to decide whether to follow the recommendation of the Performance Audit of Transit that King County consider replacing the current electric trolley bus fleet with diesel hybrid transit vehicles. This may be a very reasonable step to take in terms of performance and cost. However, in material that I have seen there has not been a clear evaluation of potential health consequences of the decision. There are abundant data on the contribution of diesel vehicles to increased particulates in the air. But to my knowledge, this has not been quantified as related to this community and to this decision. I have not seen data showing what would be the potential health effects of a new diesel fleet of buses on metro citizens with chronic cardiopulmonary disease and on healthy citizens as well. I ask that you include specific data on potential health consequences, where they are available, or conduct a formal health impact assessment if data are not available, so that this can be a part of the discussion of the pros and cons of either position you are considering. Although I am a member of the Queen Anne Community Council and the Magnolia/Queen Anne District Council, I offer these comments as a private citizen and not as a representative of any group.	7/15 email
My friend, the pedestrian advocate Jon Morgan, said Metro is considering discontinuing electric buses. With the city pushing its citizens to find alternatives to fossil fuel-based transportation, this seems unwise. From my apartment in Fremont, I can see a billboard from CityU that promotes Seattle's innovation in using electric buses. The message is that the water in the canal is used to power city buses. That may not be entirely accurate, but it clearly views Seattle's use of electric buses as positive and progressive.	7/17 email
Metro needs to consider rising oil/diesel prices as well as ~$11m a year it gets from the feds for fixed guideways in determining whether diesels or ETBs are cheaper. We want cheaper, quieter, and cleaner transit. Your study must account for non-monetary benefits of ETBs like noise and greenhouse emissions. The hybrid buses barely emit less than diesels. You should work with Seattle AND suburbs to expand the ETB network. We want low-floor buses w/ multiple doors, GPS, verbal and visual route and stop announcements, real-time arrival info, and off-board pymt.	7/26 FNC Mtg.
Will this study address Federal EPA requirements for reduced particulate emissions and for reduced carbon emission that King County is already in violation of> Will said limits impact federal funding?	7/26 FNC Mtg.
I am a professional Resource Conservation Manager, and find it curious that your office has not been forthcoming with the financial analysis behind your apparent decision to abandon the electric trolley bus infrastructure in favor of new hybrid buses that are not grid-enabled. Please provide a copy of that analysis.	8/28 email
I read the Trolley Bus System Evaluation page recently included on your Website and in particular clicked through each of the frequently asked questions and answers. The penultimate question "How are the trolley buses different than (sic) diesel or hybrid buses?" (the 'than' should presumably read 'from'), to which the answer given was as follows: *"A Metro trolley bus draws power from the overhead electrified wires, and that power is used to drive a large electric motor. The trolleys connect to the wire via a pole on the roof that is topped by an insulated shoe. The pressure from the spring-loaded pole*	8/28 email

keeps the shoe pushed up against the overhead wire, providing the connection that powers the bus and allowing the trolley to maneuver through turns and around corners. *A Metro trolley cannot operate if it is not connected to the overhead power. Unlike a Metro hybrid bus, a Metro trolley has no on-board energy storage system. So, when a trolley is braking or going downhill, the extra energy that is developed is dissipated through resistors. Some energy can be put back into the power lines, but only if there is another trolley on the line that needs the energy.* *With hybrid buses, the engine is coupled to a generator and the generated energy powers the motor. When more power is generated than is needed to operate the bus, the extra energy goes into a battery pack for later use. When the bus is coasting downhill or braking, that energy is turned into electricity and also stored into the battery pack on the roof of the bus. Stored energy in the batteries assists in the acceleration of the bus during starts, reducing the load on the diesel engine."* May I point out the following errors and omissions?: 1 (second sentence) The trolleys connect to the wires by means of two poles on the roof each of which is topped by an insulated shoe. 2 (third sentence) The pressure from the spring-loaded* poles keeps the shoes pushed up against the overhead wires, providing the connections that power the bus which enable it to manoeuvre between three adjacent traffic lanes, through turns and around corners. (*Modern systems use air or hydraulic cylinder pressure instead of springs so that the trolley poles can be lowered and raised from the driver's cab enabling re-wiring to be effected automatically). 3 (second paragraph) Although existing obsolescent Metro trolley buses can only operate if they are connected to the overhead power wires, modern systems in other North American and worldwide Cities have small engines, battery packs or capacitors which can provide emergency traction, the last two storing braking or coasting energy. Lineside gyroscopes can also be used to store surplus power when the trolley bus motors are acting as generators to permit braking, returning the saved power to the wires when needed. Apart from the final stop, trolley buses do not use up brake pads so reducing the amount of environmentally unfriendly waste and maintenance time and cost. 4 (final paragraph, first sentence) With hybrid buses, the engine (powered by diesel or other hydrocarbon fuel and emitting noise, vibration, exhaust gases and particulates) is coupled to a generator and the generated energy powers the motor. I feel that the suggested amendments provide a far more balanced and accurate picture for the general public and avoid the bias in the response as it stands.	
Thank you for the update. I am copying those leaders in our community focused on the extreme importance of this issue – "The Quiet, Green, Electric Bus Initiative". Unfortunately it appears the notice of the below public hearings, unless they are for 2011, we are hearing of them after the fact. The many concerned community representatives - experts in this field, I am in communication, in the future would appreciate hearing about these opportunities for input in advance. Until now the County's presentations appear to be biased to remove Trolleys. This is very disappointing despite the: * "Quiet" interests of the neighborhoods; * "Green" value and the message of a community commitment to long lasting environmental benefits. A "green" message expressed in through expanding a spiderweb of the overhead distribution of energy that can come from any number of green fuels for creating electricity, e.g. biogas, solar, wind, etc. * "Electric Bus Initiative" opportunity to lead in electric vehicle development. PACCAR and Metro both have a rich history of innovation demonstrated in saving costs through adapting series hybrid vehicle technologies and generating local family wage jobs.	8/28 email

I would encourage the County to give far greater attention to the above benefits and others in support of preserving the Quiet – Green – Electric Bus.	
Thanks for keeping me in the update. I've been tracking this study fairly closely and do not see a place for citizen input. There seem to be only public presentations, not public hearings where citizen input is sought, heard, and becomes part of the evaluation. I do recognize that at the end of Metro's presentations to the public some time is left for Q&A, but this does not have the formality, or weight, of public testimony at a hearing. Perhaps this study does not have a "citizen participation" piece, and our chance to weigh in on the decision will come later when the County Council reviews, considers, and votes on the study's recommendations??? Clarification of the process would be appreciated as many of us in Queen Anne (on trolley bus lines 1, 2, 3, 4, and 13) are eager to have a voice in the decision. (Our neighborhood council sent a letter several months ago in support of keeping the trolleys that serve QA, but we do not know where it landed—in other words, who received it and was it entered as a part of the study.) Another question we have is whether environmental impacts of each option are analyzed in the evaluation. Finally, am I correct in assuming that the evaluation will contain recommendations for the County Council and the Council will decide which option to pursue, or is it Metro's decision?	8/28 email
The Metro customer comment form does not work for me. As a result I have the following comments to you. Re the TROLLEY EVALUATION, WHAT IS THE PROJECTED COST PER MILE FOR EACH OPTION? What value is put on the visual mess of the trolley wires around the city? What other technologies show promise? What is the cost of each per mile. How much money did we save with the electric trolley? Better than if we went with diesel? Or did it cost more and we had all those wires all over the city? THE BOTTOM LINE TODAY IS WHAT DOES IT COST? That should be your most important question. I did see some cost considerations on future repairs etc. but you should go to the bottom line. WE UNDERSTAND COST PER MILE.	9/3 email
I am sending you a copy of the recent news article from Wellington, New Zealand where it has been announced that for the next several months their Electric Trolley Buses which are only a couple of years old will be operating on battery power in the Central Area while overhead wires are renewed. This is nothing short of a miracle because just a few years ago Wellington was on the road to substituting diesel buses for its Electric Trolley Buses. Wellington's trolley buses go through some hilly terrain like Seattle's so trolley buses are well suited for their topography. As the article points out, Electric Trolley Buses equipped with battery capability are the best kind of "green vehicle" that one can have in an environment concerned about Global Warming. I hope that these recent developments in Wellington, NZ will provide a guiding light to the retention of Electric Trolley Buses in Seattle that will have off wire capabilities. **Wellington's trolley buses to run on batteries for two months** August 31, 2010Business, Politics, PressRelease0 comments Report from aktnz.co.nz Wellington's inner city trolley buses will have to run on battery power for over two months – with people stationed around the city employed just to take the bus poles up and down. This is because work on the overhead network will begin in the central city from Thursday week so trolley buses can use the re-	9/8 email

arranged Golden Mile bus route under construction in Willis and Manners streets. By day, road building and footpath changes will continue to create a single two-way public transport spine through the city. By night, linesmen in cherry pickers will work above the street, installing new overhead wires and equipment. New dark grey poles, that the trolley bus wires will be attached to, have already been installed in places along the new route and new overhead equipment is about to arrive from Switzerland. Installation and reconstruction work will take nearly three months, starting at the intersection of Willis and Mercer streets. But the problem is that from late September, the power to a section of the central city trolley bus network will have to be disconnected. Transfield Services, the company doing this work, can't work on a live network and will have to remove parts of the old network to construct the new one. This will mean changes for some buses and bus users at all times for just over two months. Greater Wellington Public Transport Manager Wayne Hastie says from late September there will be a temporary route operating in one direction via Wakefield and Taranaki streets and in others, buses will run on battery power for a short distance. That's when people will be stationed at different locations around town to take the bus poles down and put them back up as quickly as possible to minimise delays. The old trolley buses could only operate on the wires, but the new buses are capable of running on battery power. The battery back-up system is primarily designed for emergency use but in preparation for this work Go Wellington has conducted trials and say trolley bus services can be maintained while the work is carried out. Wellington City Council Infrastructure Director Stavros Michael says the changes are an important part of the Golden Mile project and the most significant to be made to the overhead network for almost 30 years. ***"With the growing awareness of climate change and the need for sustainable forms of transport, new trolley bus networks are being upgraded, constructed and proposed around the world all the time," he says. "We've not only retained our system – the only one in Australasia – but Greater Wellington, Go Wellington and the Government have invested in it in recent years by replacing all the old trolley buses with new, more reliable models.***	
The following comments were received during a presentation given at the Mont Baker Community Club: • Lack of public meetings being held in Capitol Hill about the trolley evaluation. A woman was in attendance who lived in that area and felt that it was a major oversight that we had not met with Capitol Hill groups. I explained about our mailing list and that we are giving presentations upon request. She felt that we should have been seeking out and setting up more formal opportunities and that we haven't been letting people know enough about the outreach meetings in general. • Noise and environment are key factors for the neighborhood. Several people noted that they really don't like it when there are diesels on the weekends. • Concerns about Metro analysis making the trolley buses look expensive. • Concerns that hybrid buses still aren't very good for the environment. People noted that they still have low m.p.g. and even though they have less emissions they prefer trolleys which are the cleanest. • Concerns that we are not doing enough public outreach until we have results, so how is the public really being heard? (This was based on the slide that shows "public review" next March) • Desire to see Metro include an analysis option using the existing Orion buses outfitted with trolley poles and modified BAE propulsion. Commenter thought this would be much cheaper because the parts could be shared with a larger fleet. This comment came from Chuck Lare, who has contacted the County Exec's office and who I have had several	9/13 MBC mtg.

conversations with. This is a concept that Vehicle Maintenance staff had at one point, and sought a grant to explore. We did not get that grant and aren't seeking another. I've referred Chuck to VM at this point but we may hear more about this.	
The following comments were received during a presentation given at Seattle Electric Vehicle Club: • Critiques of the assumptions used by the audit report, and concerns that all the assumptions were not clearly spelled out. • Life cycles of trolley buses are longer than hybrids. Is Metro going to look at European life cycles and/or how are we defining the life cycle of the trolley buses? • Concern about why Metro isn't looking at replacing the propulsion in the 40-foot buses but keeping the shell of the buses (e.g. the opposite of what waas done in the early 2000s on those buses). • Concerns about a lack of public review of the technical assumptions. If the public doesn't get to see the report until next March, how will they be able to provide feedback about the assumptions used? • Another inquiry about whether the evaluation will included Orion/BAE modified bus. (see above, comment was from Chuck Lare who was in attendance both nights). • A little discussion of battery technologies and general agreement with the exclusion of battery buses from this test. There were one or two strong dissenters who felt that batteries could be developed.	9/14 SEV mtg
In looking at the reference web pages, I was unable to find any links or specific references to any of the analyses which are mentioned. In general, these pages appear not to provide, directly or indirectly, any specific detailed information. For example, the 2nd reference states "Metro completed the work plan, scope, and schedule for the Trolley Bus System Evaluation in August 2010," but does not provide a link to any document and does not identify even the form or format of this "completed" effort. **Where can I find a copy of this completed effort?** A second example: The 2nd reference states "Metro identified and did preliminary evaluations of a range of propulsion technologies for replacing the trolley bus fleet," but again does not provide any way for the reader to obtain a copy of these preliminary evaluations. **Where can I find a copy of these preliminary evaluations?** The 2nd reference also states "Metro reviewed these technologies to determine their feasibility for a large fleet purchase in 2012."**Where can I find a copy of that review?** Finally, a colleague noted to me that one vehicle configuration apparently not considered was an electric-electric hybrid that would use the electrified wires but also have on-board batteries (just as the diesel hybrid would) that would enable regeneration (e.g., from braking). **Why was an electric-electric hybrid not considered?** Thank you very much. I look forward to hearing from you in the near future.	9/19 email
While going through some potential projects on other transit agency's web sites, I noticed that Massachusetts Bay Transportation Authority is currently requesting bids on a project to "Repair and Rebuild the Propulsion System Circuit Boards used on Board its Electric Trolley Bus Fleet".	9/24 email

The request for bids is located here: http://www.mbta.com/business_center/bidding_solicitations/materials_manageme nt/invitation_for_bids/ About 1/3 of the way down the page of bid requests. I've heard that King County Metro has been considering various alternatives to what to do that the trolley bus fleet is needing some overhaul. It might be useful to consider examining MBTA's request for bids, and see if they are similar systems. If so, then perhaps King County Metro could request that they be added to the bid as a potential option. If it becomes necessary to exercise the option to rebuild some of the trolley bus electrical panels, then the option to have it done by the same contractor could then be exercised. Of course, if the needs of the two vehicle fleets are radically different then that would not work, but then all that would be necessary would be to not exercise the option.	
The Queen Anne Community Council represents stakeholders in the Queen Anne Planning Area. The Queen Anne Urban Village on Queen Anne Hill, the Uptown Urban Center, and Seattle Pacific University re served by King County Metro Transit electric trolley bus routes 1, 2, 3, 4, and 13; important transit links to Downtown Seattle and beyond. Our neighborhoods have been well served by the electric trolley buses since the conversion from the streetcar system in 1941/1942. At the time of Metro Transit's formation an agreement was put in place between the City of Seattle and Metro to continue the electric transit service. Now we understand that the quiet running, zero-emissions trolley bus fleet of 159 vehicles is under consideration to be eliminated. Under this proposal, diesel hybrid transit vehicles would serve the electrified routes within the City of Seattle. The recent "Performance Audit of Transit: Technical Report A" suggested that Metro could save $8.7 million annually by buying diesel-electric hybrid buses to replace all the electric trolley buses, which are due for replacement around 2013. We believe that this audit did not adequately consider many factors and we understand that Metro is now in the process of arranging an expert review of the audit, tasked with evaluating these factors more thoroughly. Metro has described these factors as "operating environment (steep slopes), volatility of diesel prices, federal fixed guideway capital and operating reimbursements, advances in battery and trolley vehicle technology and of course societal benefits of the trolley's zero emission, low noise operation." The audit appears to have been built on a "cost analysis form current experience of new low floor hybrid coaches running partly on freeways" and not at all on typical Seattle trolley bus routes which are hill, with closely spaced stops, heavy rider ship, and requiring frequent lift deployments. The audit did not compare Metro's current trolley bus vehicles with the new trolleys used in Vancouver, BC, which are "low-floor vehicles with wider aisles and doors, regenerative braking and off-wire capability. $3.1 million of the audit's $8.7 million in savings came from scheduling efficiencies due to off-wire capability. New generation trolley uses would eliminate a big portion of the claimed savings. More realistic routing eliminates another portion. Queen Anners know that the number of breakdowns for diesel transit vehicles on our steep hill routes is much greater that the number of electric trolley bus breakdowns. If the trolley bus fleet serving fourteen Seattle routes were eliminated, Metro would lose $10 million annually in federal grant money contributing to fixed guideway (trolley wires) overhead costs. The audit noted environmental and noise benefits of clean-fuel electric engines but make no attempt to quantify these. Recent studies have estimated the health impacts of diesel vehicles from engine emissions and particulate matter. The escalating costs of climate change produced by green house gas emissions are a factor to be considered. As Seattle taxpayers we must note that City Light provides the electric power for the trolley bus routes, power that comes for 100% carbon neutral sources. Noise from diesel engines is another livability impact in the densely populated Uptown Urban Center and the Queen Anne Avenue North corridor. It is reasonable to expect a dramatic rise in diesel prices within 5 to 10 years as crude oil supple declines: a development that would encourage the extension of some	2/13 letter

electric trolley bus routes – not their conversion to diesel hybrid transit vehicles. The Queen Anne Community Council recommends a careful study of the benefits of beginning replacement of the current trolley bus fleet around 2013 with state of the art 100% electric trolley buses. Please consider this letter as the first notice of our continuing work to ensure the continuation of the zero emission, quiet, dependable electric trolley bus system in Seattle.	
Thank you for your work assessing the feasibilty of maintaining the Trolley Bus System. I am writing because I believe the benefits of the Trolley Bus System are clear and overwhelming and want to encourage you to consider the full range of these benefits. As we try to create communities that are livable and climate-neutral, the diesel bus represents less and less of a realistic long term option. Dismantling the trolley system would be a drastic step backward at a time where we have set aggressive goals for reducing global warming. It is almost impossible to envision meeting our County goal for climate change if even our small bus system is exclusively diesel. Trolley buses are also vastly superior for creating livable neighborhoods. I live on the 43 and 48 routes and can tell from inside my house whether a bus is diesel or trolley based on the rattle of my window (ie the diesel is disgustingly loud). There is also a substantial equity issue since it would disproportionally impact lower-income urban residents who already get the bad end of the stick under the 40/40/20 funding rule which ensures that they subsidize suburban and rural routes. Secondly, I would also ask that King County refrain from using the term "diesel electric" in describing the diesel buses with regenerative braking. This term is confusing to people because it indicates that it gets part of its energy from an electric source while the energy is 100% diesel gas. Obviously, we should be encourage more efficient diesel buses by embracing hybrid technology wherever feasible, but we should be clear in our terms. I think diesel hybrid would be an appropriate term as people understand the concept.	10/28 email
Please send me notices of project updates, meetings, and so forth on the trolley fleet evaluation process.	1/11 email
I was trying to find info on the results if the trolleybus evaluation, which I believe is set to be completed this month. Is there an update site or any additional information?	3/28 email
Ashley, per our conversation SFMTA is undergoing a trolley coach evaluation similar to King County. I think it would be very valuable to SFMTA to use the data compiled by King County as a starting point in their study. SFMTA would appreciate it if you could provide any preliminary information or findings from your study. Jacobs is currently under contract to SFMTA to provide as-needed engineering support for their rubber tired fleet. It is my intention to share any preliminary King County data and information within the SFMTA staff level discussions only. We are just starting our project discussions so it is not intended to share any of our information with the SFMTA Board or the public at this time.	3/28 email
Ashley, thank you for the update!	3/30 email
Ashley, This is great news—thanks! Queen Anne	3/30 email
Thanks for the update on the trolleybus study. I will read it with great personal interest (I went to work for Seattle Metro [not King County then] in 1977 on the Trolleybus Rehabilitation and Expansion Project, doing community outreach). One close corollary issue is the routing of the trolleybus network. The system today follows all of the through-route connections originally established in 1978. Given all the changes in inner-city transit usage over the years, it is past time to re-evaluate the network to see if better routings and through-routes can be established. Such a follow-on study could very easily have an effect on the number of 40' and 60' coaches in the new fleet. All trolleybuses on	3/30 email

Route 36, for example, are 40-footers, even though this is the second or third busiest route in the city and warrants all-artic service just like the 7 and 43 and 44.	
Thank God! Great news!!	4/6 email
While I am not a Seattle resident, I am a resident of King County. I urge you to keep trolley bus lines for a number of reasons. First, they are a commitment to service. The lines may seem symbolic, but they have real meaning that a given route will be serviced. That translates into people choosing to locate along the lines and real investment by developers and businesses. They also serve as a historic reminder to the former streetcar lines. A loss of these buses would be a loss of our history. Given new information coming to light via Vancouver, BC, trolley buses are cheaper to operate in the long-term over buses served by non-electrical lines. Moreover, with the increase of gas, running normal or hybrid buses will continue to become more expensive to operate into the future. The trolley buses run cleaner, which is particularly important in Seattle. Bicyclists and pedestrians are everywhere and adding diesel emissions to our air is really crappy for those who are exposed. It's unhealthy. It's also in contravention of our goals to reduce emissions in accordance with city, county, and state goals. Please do not remove trolley buses. This would be an even graver mistake than replacing the original streetcar lines with the buses in the first place. I fully understand that Metro is in a crunch. I don't want to see service hours reduced. But, it comes to that and putting outlays for new trolley buses, I'm willing to accept the short-term consequences of reduced service hours for the longer-term of new trolley buses and the preservation of their routes.	4/8 email
Congratulations J I am confident that your transit facility has made a fundamentally sound decision in keeping your Trolley system active. I I thank you for keeping me on your list of persons interested in your Trolley future. I was delaying my response in hopes I could convince our Executive Director Mark Donaghy to attend your open house. The outcome was not what I was hoping for but the news you delivered was!	4/8 email
I am writing to express my very strong view that King County should retain its electric trolley buses. I live on a hill next to a stop for Route #2. One of the reasons I purchased my home there 22 years ago is because this trolley provides me with convenient service to downtown Seattle. But on Sundays, when the system for some reason runs diesel buses, the noise and pollution are unpleasant. To imagine this kind of service seven days a week has me upset, to say the least; I'm happy that the initial recommendation is to stay with the trolleys.	4/16 email
Thanks for the notice. Unfortunately, I have a conflict on that day. As you know I am a serious supporter of trolleys vs. hybrid or diesel buses. My only wish is that new trolleys be able to run “off-wire” for a mile or more. If they can’t, then the off-wire capability will only be of modest importance. Short off-wire capabilities may permit very short reroutes around an obstruction (a traffic accident, etc), but they will not address Metro’s ever increasing tendency to de-energize whole trolley wire sections on weekends because of road construction. So, while I’m an enthusiastic supporter of electric trolley buses, addressing Metro’s deficiencies in managing weekend construction events on City streets is more important. It’s the weekend TOH de-energizations, not the occasional site specific obstruction, that’s the key to reducing costs to the environment, Metro’s fuel costs, and neighborhood noise and fumes disturbances.	4/18 email
I am aware that fuel costs are now only a very small part of the overall costs. However, people like me who study the global energy situation, anticipate radical change over the next generation. World oil production is now maxed out and as it goes into decline (expected by 2015) the costs will accelerate. There is virtually no chance that oil prices will be the less than the CPI by 2030 (my estimate of $20 to $40 a gallon by 2030 is in current dollars). The indirect costs (vehicles and infrastructure) will also	4/18 email

see a very substantial rise. All this will affect individuals even more, so I expect a big decline in SOV commuting miles. In turn, this will increase the demand for transit and for various forms of ride sharing, biking, walking, etc. , and shorter trips generally. Well paying jobs will become much harder to come by. I realize that all this is not that easy to factor into an electric trolley study, since it has not yet been factored into higher level planning. I would recommend that the 'low' fuel price match the CPI. Even this would mask the real inflation because the oil price will become the primary driver of inflation, which is already starting to happen.	
Would it be possible to get an electronic copy of the initial evaluation report. As chair of the TRB ETB Committee, I would like to forward a copy to committee members. Thanks for your help.	4/21 email
I visited Seattle back in 1976 when the 'old' fleet of trolleys were in service. I was shown around by Mike Voris & met Wayne Hom. Since then I have followed the progress of Seattle trolleybuses with enthusiasm but was horrified when the study last year suggested getting rid of them. Seattle, like San Francisco, having extremely steep hills is ideal for trolleybuses. They are pollution-free, silent, clean have fast acceleration. If you pedestrianised Downtown streets and had pavement restaurants you could still have transit if trolleybuses are retained but certainly not diesels blowing fumes onto your food. Trolleybus wires give an air of permanence to any potential transit rider. Now that you have a light rail line, trolleybuses are an ideal complement for it. Seattle has shown the way forward in American transit with the lrt.Continue the process with the bus fleet please. Stay electric Seattle!! CLEAN, SILENT, FAST TROLLEYBUSES! With very best wishes to Seattle Metro from 'Across the Pond'	4/23 email
Continue advocating for trolley buses and expanding the system in local Seattle Neighborhoods. Loss of federal funding will impact Metro across the board. Metro should work with Seattle City Light for special reduced rates. Trolley buses have better acceleration uphills quieter, smoother ride.	4/27 open house
Choosing the electric trolley system over the diesel hybrid system seems to be a wise choice. The long-term benefits outweigh the short-term higher costs. The analysis appears to be thorough and rigorous enough. I appreciate the simple and complete presentation of the findings.	4/27 open house
Consider buying more articulated trolleys to completely electrify the 36.	4/27 open house
For two decades the future of electric trolleys has been undetermined, and in the meantime Metro has been reticent to make permanent investments in the trolley fleet or infrastructure- and all expansion has been on hold (for example, rather than replacing artic trolleys, Metro instead extended the life of the most expensive and unreliable fleet in it's history – making current Metro trolley operating costs even higher which makes this study's conclusions stronger still.) I hope Metro will now put this issue in it's past, move on, and make capital investments consistent with a commitment to maintain a permanent trolley operation. It's time to accept victory and end the permanent study of trolleys.	4/27 open house
Thank you for holding the trolley bus open house although I am "technology-agnostic" I do favor a sustainable, cost-effective ETB replacement – and it sounds like new ETB's are the answer. I hope Transit is exploring other options for saving additional money such as eliminating the Ride Free Area, which would likely reduce the loss of revenue due to fare expansion.	4/27 open house
We need to preserve our trolley route, the new Roling (?) stock on the Powers (?) looks good. Trolleys accelerate quicker making better use of Roling stock. Trolleys are clean and quiet. The sooner the better for new Trolley Roling stock. Visually the overhead is okay. There is rumor that Metro is considering taking the trolleys out. Tourist arrive in Seattle to see our trolley system on the #8 much of the route on South of MLK and E Madison is not much grade however on Madison and Denny it is very steep. Trolley on steep paths a P.U. on not much grade diesel buses waste fuel when loading and unloading and stuck in traffic. Low floor mobility devices can move more quickly.	4/27 open house
I'm very pleased that the worth of the trolleys seem to be appreciated.	4/27 open

	house
The trolley bus overhead wiring maintenance costs can be significantly reduced by simplifying the wiring infrastructure. By using modern technology battery APU's to maximize battery operation, maintenance base wiring can be eliminated as well as complex wiring such as Broadway and Madison.	4/27 open house
A). Center Park Apartments there is no curb for #4. There is no way possible to use lift or ramp. A). Our Fauntleroy Ferry terminal facility for #54 is bound.	4/27 open house
Route #4 zone at 26th & Walker – what will be done to make this usable with low-floor vehicles? This zone is near Center Park and is used by a Large number of lift users, many of whom have difficulty getting on or off a low-floor bus, due to a lack of a curb at this location. I have mentioned this several times, byt have not gotten much of a response. How about an answer?	4/27 open house
sorry I am out of town during these hearings but I want to go on record as saying simply. I ride the trolleybuses and light rail but will drive rather than use a bus or see them on my routes. certainly the ETB is the future of the system and should be expanded not abandoned, I've ridden the new ones in Vancouver and in Philadelphia and they are great, and the off wire capability overcomes the only major drawback.	4/27 email
Unfortunately I can't attend the meeting tonight. Yes, replace the trolley busses with more electric trolleys. They are quiet and effective, and a hallmark of our city's transit network. Glad to see the study. One major issue with diesel is air quality. As the city becomes more dense, the quality of life experience is heavily impacted by noise and air pollution. Will the new busses have loading similar to streetcars? Finding busses with those features would be a plus as we modernize our transit system. I am a 40 year Capitol Hill Resident and property owner, and very active in the neighborhood.	4/27 email
Hi Ashley, I wanted to thank you and all the other Metro folks for both this new report which is much more comprehensive and thus a huge improvement over the earlier audit, and for holding these public events and presenting, taking comments, answering questions, etc. It is noticed and appreciated.	4/28 email
I just wanted to let you know how pleased and relieved I am that it is likely that Metro will opt for new trolleys over diesel replacements. A regular bus rider who lives on First Hill, I find the trolleys are more comfortable to ride and vastly more pleasant to walk down the street with.	5/2 email
I am a resident of Seattle, and am writing to express my support for buying new trolley buses. I also request that the county include options in the contract for many more trolleys than the 159 to maintain the current levels. The trolley buses are a very visible way Seattle demonstrates its commitment to environmental friendly transit, and I am strongly in favor of increasing the number of trolley routes in Seattle over the next decade, starting with the #8, 11 and 48. Thank you for all the work you do!	5/2 email
Very informative presentation. Thank you! I endorse the continuation of the electric system/replacing with new electric trolley	5/2 MBC mtg.
Congratulations on doing best practice research! Finding a solution to using diesel to go around construction, etc. is fabulous. I want the electric trolley to NOT go up and down McLellan hill to transit center. I want a small bus that goes throughout the entire neighborhood to collect riders for light rail. Yippee electric over diesel! GOOD JOB! We would like to have the bueses move out of the intersection when they go off the cables.	5/2 MBC mtg.
We absolutely want the electric trolleys to continue! We don't need more diesel fumes.	5/2 MBC mtg.
Go Go Go Electric Trolley Buses!	5/2 MBC mtg.
I tried to call you this morning, but your phone (published on the Trolley Bus Evaluation) is no longer in service! I was at the	5/3 email

Mount Baker Clubhouse meeting last night regarding the electric trolleys. In a few words, I love them! Quiet, and no exhaust. I remember as a child with my father driving behind a diesel bus, and my father just cursing the powers that be that eliminated the trolleys. Of course, the exhaust then went directly into the car of anyone driving just behind it! What I want to tell you is an idea that came to me last night. My boyfriend's chair in the living room looks directly at the intersection of Hanford and Mt Rainier Dr and Hunter Blvd. He sees the trolleys get off the wires repeatedly, and all the work that goes into getting the bus back on the tracks. I suggested at the meeting using the "batteries" of course, not understanding how they worked. The idea is to have a line painted (green, pink?) on the asphalt to guide the new drivers on the correct course to get around this turn. It certainly would have to be engineered, but what a savings it would have in the long run. Far fewer trips for that van to rescue the buses in distress! This could also be used on other turns that cause trouble for the drivers. Noel Peterson was saying every time there is a new driver, there are problems, and she is inevitably late to work because of this. Please forward this idea to who ever could implement this. I look forward to your comments about this also!	
I just wanted to send a note of thanks and share my appreciation at the outcome of the trolley evaluation. Frankly, I and many of my colleagues are absolutely thrilled at the outcome, for many of the reasons outlined in the study. I'm glad that innovative and unique methods of public transport continue to be used in Seattle. When will we know if the Council has approved this in their next budget? Would it be helpful to email them, or no? Thanks again for all your hard work on keeping Metro the excellent system that it is.	5/4 email
I am a regular rider on Metro buses, and would like to express my great preference for electric trolleys over diesel. I think the Environmental Comparison page in your Trolley Bus System Evaluation report accurately reflects my views. Please keep the trolleys. They provide a great benefit to both Metro riders and neighborhood residents.	5/6 email

QUEEN ANNE COMMUNITY COUNCIL
1818 1ST AVENUE W
SEATTLE, WA 98119

February 13,2010

Hon. Tom Rasmussen
Chair, Seattle City Council Transportation Committee
600 Fourth Avenue
PO Box 34025
Seattle, WA 98104

Re: King County "Performance Audit of Transit: Technical Report A, Page 46: "Transit and the council should consider all relevant factors, including costs, when determining an appropriate...fleet replacement for the trolley buses." (Last page of Chapter 4 of the audit, which begins on page 39)

Dear Councilman Rasmussen

The Queen Anne Community Council represents stakeholders in the Queen Anne Planning Area. The Queen Anne Urban Village on Queen Anne Hill, the Uptown Urban Center, and Seattle Pacific University re served by King County Metro Transit electric trolley bus routes 1, 2, 3, 4, and 13; important transit links to Downtown Seattle and beyond.

Our neighborhoods have been well served by the electric trolley buses since the conversion from the streetcar system in 1941/1942. At the time of Metro Transit's formation an agreement was put in place between the City of Seattle and Metro to continue the electric transit service. Now we understand that the quiet running, zero-emissions trolley bus fleet of 159 vehicles is under consideration to be eliminated. Under this proposal, diesel hybrid transit vehicles would serve the electrified routes within the City of Seattle.

The recent "Performance Audit of Transit: Technical Report A" suggested that Metro could save $8.7 million annually by buying diesel-electric hybrid buses to replace all the electric trolley buses, which are due for replacement around 2013. We believe that this audit did not adequately consider many factors and we understand that Metro is now in the process of arranging an expert review of the audit, tasked with evaluating these factors more thoroughly..

Metro has described these factors as "operating environment (steep slopes), volatility of diesel prices, federal fixed guideway capital and operating reimbursements, advances in battery and trolley vehicle technology and of course societal benefits of the trolley's zero emission, low noise operation."

The audit appears to have been built on a "cost analysis form current experience of new low floor hybrid coaches running partly on freeways" and not at all on typical Seattle trolley bus routes which are hill, with closely spaced stops, heavy rider ship, and requiring frequent lift deployments. The audit did not compare Metro's current trolley bus vehicles with the new trolleys used in Vancouver, BC, which are "low-floor vehicles with wider aisles and doors, regenerative braking and off-wire capability.

$3.1 million of the audit's $8.7 million in savings came from scheduling efficiencies due to off-wire capability. New generation trolley uses would eliminate a big portion of the claimed savings. More realistic routing eliminates another portion.

Queen Anners know that the number of breakdowns for diesel transit vehicles on our steep hill routes is much greater that the number of electric trolley bus breakdowns.

If the trolley bus fleet serving fourteen Seattle routes were eliminated, Metro would lose $10 million annually in federal grant money contributing to fixed guideway (trolley wires) overhead costs.

The audit noted environmental and noise benefits of clean-fuel electric engines but make no attempt to quantify these. Recent studies have estimated the health impacts of diesel vehicles from engine emissions and particulate matter. The escalating costs of climate change produced by green house gas emissions are a factor to be considered.

As Seattle taxpayers we must note that City Light provides the electric power for the trolley bus routes, power that comes for 100% carbon neutral sources.

Noise from diesel engines is another livability impact in the densely populated Uptown Urban Center and the Queen Anne Avenue North corridor.

It is reasonable to expect a dramatic rise in diesel prices within 5 to 10 years as crude oil supple declines: a development that would encourage the extension of some electric trolley bus routes – not their conversion to diesel hybrid transit vehicles.

The Queen Anne Community Council recommends a careful study of the benefits of beginning replacement of the current trolley bus fleet around 2013 with state of the art 100% electric trolley buses.

Please consider this letter as the first notice of our continuing work to ensure the continuation of the zero emission, quiet, dependable electric trolley bus system in Seattle.

Sincerely

Ellen Monrad
Chair, QACC

Worker Owner Council of Washington State

2800 First Ave. #254, Seattle WA 98121
206-239-2742

July 2, 2010

Christina O' Claire
Senior Transportation Planner, Service Development
King County Metro Transit

Re: Scoping Comments for Trolley Bus System Evaluation process

As promised, please find below our request that certain subjects be analyzed as part of the Trolley Bus System Evaluation process you are now undertaking. We hope these comments reach you in time to be considered for inclusion in your study.

Transmission Line removal replacement

1) Analyze the cost of removal of the existing system of Transmission cables and substations.

2) Analyze the present cost of replacing the same system in the event it were destroyed following a conversion to diesel buses and later needed to he re-built.

3) Project the future cost of the rebuilding the transmission system at different time intervals, for example at 2024, 2034, 2044.

Vehicle Alternatives

1) Define and analyze the feasibility and unit cost of an alternative that includes the purchase of a fleet of mass-manufactured series hybrid diesel bus (such as the new Orion buses that the County is currently receiving to replace existing diesel buses) that are or have been modified to operate with no diesel engine, with batteries installed for off-wire use, and trolley poles installed for normal operation with existing wire system.

2) Analyze the cost, service and operations impacts afforded by selection of an all-electric or hybrid diesel vehicle that can operate seven days per week, on flexible routes. Deduct this cost from cost of existing system that requires switch to diesel busses on weekends.

3) Analyze the capital cost, operations, maintenance, training cost and performance impacts of running a bus fleet that utilizes a common bus type with some units equipped with bybrid diesel power trains and otbers all-electric trolleys witb batteries installed for off-wire use.

4) Analyze and compare the possible sources of Federal or State funding available for each vehicle type analyzed (all-electric trolley, diesel -hybrid, diesel.)

5) Analyze cost of operating diesel hybrid buses on the actual routes using actual passenger loading dnring peak-time operation for all routes that are currently served by electric trolleys and compare to the cost of continuing to serve those routes with electric trolleys.

6) Analyze the operations and capital cost savings and performance benefits realized from the comparatively long life of electric motors and transmissions versus the comparatively limited life of diesel motors and transmissions.

7) Analyze the cost of operation of each vehicle alternative at incremental diesel fuel price points.

8) Analyze the cost of operation of each vehicle alternative at incremental prospective carbon-tax cost levels.

9) Consider alternative replacement schemes involving tbe existing trolley fleet that could augment a purchase of new electric trolley vehicles with possible modification or replacement of propulsion systems on existing but more recently purchased trolley bodies with new electric motors. Analyze the capital cost impact of such schemes versus those of alternatives that replace the entire fleet at once.

10) Analyze the future opportunity for an electric trolley to receive free electricity from the new 2010 legislation, SB6658, community solar projects. See, the Wallingford Solar Initiative, (WSI, www.wallingfordsolarinitiative.org) is working to install photovoltaic collectors systems in Seattle while providing free electricity. WSI is currently developing that opportunity for the City of Seattle's Park and Recreation Department at Gas Works Park. This offer of free electricity through community solar projects may be extended to King County's trolley substations and other County facilities.

Air Pollution and Compliance-Related Impacts:

1) Estimate the impact on regional emission levels for each EPA-regulated and measured air pollution component of a conversion of the existing electric trolley system to a hybrid diesel bus system.

2) Identify each present and known future air-pollution-compliance threshold for each regulated pollution component and measure the impact of projected additional pollution produced by adoption of a hybrid diesel trolley replacement alternative on the region's ability to comply with those present and known future standards.

3) Analyze the opportunity cost of lost economic development, lost highway funds or other resulting Federal penalties or constraints placed upon the Seattle, Tacoma Everett region in the event that the region should exceed applicable EPA air pollution standards.

4) Analyze the comparative carbon emissions of each vehicle alternative and the consequential prospective impact of those emission levels on achievement of existing goals for greenhouse gas reduction.

Impacts to other governments/agencies

1) Analyze the fiscal impacts to the City of Seattle in the event that Metro were terminate its existing power purchases now made for trolleys operations.

2) Estimate the economic cost to dislocated workers and to the State, City, Federal and County governments in the event of a decision to terminate the electric trolley system.

Thank you for the opportunity to make these suggestions. We hope these proposed scoping comments assist you in your study. Please feel free to contact me if questions should arise.

Sincerely,

Doug Kilgore
Executive Director
Worker Owner Council or Washington State

Cc: Larry Phillips
Tom Rasmussen
Richard Conlin
Don Guillot
Joe Simpson
Tim Trohimovich

DON GUILLOT
Business Manager - Financial Secretary

RICK JOHNSON, President
DAVID HUMLICEK, Vice President
DAVID WHEELER, Recording Secretary

LOCAL UNION No. 77

International Brotherhood of Electrical Workers

IBEW LOCAL UNION 77
WASHINGTON
N. IDAHO
N.W. MONTANA

321 - 16TH AVENUE SOUTH, SEATTLE, WASHINGTON 98144 • MAILING ADDRESS: P.O. BOX 12129, SEATTLE, WA 98102
OFFICE: (206) 323-4505 • FAX: (206) 323-0186 • CONSTRUCTION DISPATCH: (206) 323-0585

July 7, 2010

Via US Mail and E-Mail

Christina O' Claire
Senior Transportation Planner, Service Development
King County Metro Transit
King Street Center
201 S. Jackson Street, Room 426
Seattle, WA. 98104

Re: Scoping Comments for Trolley Bus System Evaluation process

Dear Ms. O' Clare:

Please find below our request that certain subjects be analyzed as part of the Trolley Bus System Evaluation process you are now undertaking. We hope these comments reach you in time to be considered for inclusion in your study.

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3) Project the future cost of the rebuilding the transmission system at different time intervals, for example at 2024, 2034, 2044.

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3) Analyze the capital cost, operations, maintenance, training cost and performance impacts of running a bus fleet that utilizes a common bus type with some units equipped with hybrid diesel power trains and others all-electric trolleys with batteries installed for off-wire use.

4) Analyze and compare the possible sources of Federal or State funding available for each vehicle type analyzed (all-electric trolley, diesel -hybrid, diesel.)

5) Analyze cost of operating diesel hybrid buses on the actual routes using actual passenger loading during peak-time operation for all routes that are currently served by electric trolleys and compare to the cost of continuing to serve those routes with electric trolleys.

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2) Estimate the economic cost to dislocated workers and to the State, City, Federal, and County governments in the event of a decision to terminate the electric trolley system.

Thank you for the opportunity to make these suggestions. We hope these proposed scoping comments assist you in your study. Please feel free to contact me if questions should arise.

Sincerely,

Don Guillot, Business Manager/Financial Secretary

DG/km opeiu8 afl-cio

cc: Larry Phillips
Tom Rasmussen
Richard Conlin
Tim Trohimovich
Doug Kilgore
Joe Simpson

Zonda USA

[redacted]

10 May 2011

Ms. Christina O'Claire and Ms. Ashley DeForest
King County Metro
516 Third Avenue
Seattle, WA 98104

Dear Ms. O'Claire and Ms. DeForest;

Having reviewed the Trolley Bus System Evaluation published by King County Metro, I am submitting the following feedback as solicited at the King County Metro Website.
Unfortunately, your evaluation was based on a faulty assumption and therefore may have come to an inaccurate conclusion. Specifically, you removed Electric Battery Buses from the evaluation because you assumed they are not commercially available and they have a reduced travel range.

This is inaccurate. My company currently produces electric battery transit buses with a 300 mile driving range on a single charge (when fully laden). We are not only in commercial production; the vehicle is in use in transit fleets right now. Recharging takes less than 6 hours at 320 volts at the recharging station; less time if 500 volts are used. Each recharging takes 25 kWh, making the operating cost less than 5 cents of electrical energy per mile driven. Our vehicles also carry more passenger amenities than the current trolley fleet in use in Seattle. I would further like to make the following points:

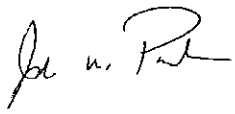
- We can deliver electric buses in 90-120 days of order.
- We can finance 80%-100% of the order, plus finance additional aspects of the conversion, to include removal of overhead wires, new maintenance facilities, etc.
- The cost of each electrical bus is about $400,000, or one third of the electrical trolleys you currently intend to buy, and about half of the diesel hybrids that were considered in your study. This is even less than a CNG transit bus.

I was also quite frankly shocked to see that King County Metro was spending $4.7M to buy "one or two" battery powered buses that go only 15 miles before recharge (vice 300) for fleet evaluation under a federal program. This amount would buy 10 of our electric buses which have already proven viable in BRT fleet use. Furthermore, we can deliver now and not in 2 years as stated in the press release. I realize that this study may be the result of some inside political deal, but clearly that money might now be better spent elsewhere.

Just so you know that we are not rookies at transportation: our company is a very large industrial group and one of the largest bus manufacturers in the world. Our products and brand value are very high. Our electric buses have been tried, tested and are in use in some very large transit fleets now, and we are just introducing them to the US. Orders for these buses are such that we built a one million square foot assembly facility just for electric buses, and that is in addition to the 6 other bus manufacturing plants we already have in service. We make more conventionally fueled buses than any US or European manufacturer: over 15,000 per year. The battery technology is so advanced that only we have it and we built a factory just to make the vanadium lithium iron phosphate batteries for the buses. Our other 5 groups make automotive tooling, paint and industrial coatings and equipment, steel construction, R&D, and business and financing. One of our six groups is on the Hong Kong big board, but the entire group is privately held.

To give you an idea of the strength of our company: we have the capacity to finance, build, deliver and put all 159 electric buses, and the associated training and infrastructure, into service before the end of this year. We could also do the same for the rest of the transit system. We do not want or need any US government funding or assistance to do this.

I realize that you are in the final stages of your budget report, but I hope you will take the time to talk and meet with me. I am certain we can save King County Metro and the taxpayers of King County a great deal of money, reduce the budget pressure within your organization, and at the same time deliver a superior bus product to your riders.



Joseph W Parker
President
Zonda USA

Appendix B

Interview Questions for Manufacturers and
Other Transit Agencies

Interview Questions

REPLACING THE TROLLEY BUSES

Metro's electric trolley bus fleet is scheduled to begin replacement in September 2014. Before purchasing new buses, an in-depth, interdisciplinary evaluation of vehicle options was

Common Questions (Agencies)

1. What was your role in determining the selection of the current propulsion system (trolley)?
2. Did your agency seriously consider any other technologies? If so
    a. What were they (hybrid, diesel, etc)?
    b. What factors did you consider compare between technologies?
3. What were some of the major influences on your decision?
4. Do you have any documents or supporting materials for your decision that you could share?
5. Describe any environmental impact issues that influenced the decision (air quality, noise, social, traffic)

COMMON QUESTIONS (MANUFACTURERS)

1. Briefly describe your expertise and experience with hybrid and trolley buses.
2. Describe the current bus options and technologies that your company provides. (e.g. batteries, materials, bus sizes). (no need to get into details like A/C or seat configuration that would be customized by Metro)
3. Would there be need for development of any new technology or components for your company to contribute to the development of a trolley bus? If so, what would be the cost?
4. Could you describe cost implications for battery technologies that would allow various distances of off-wire operation for a trolley bus (e.g. ½ mile, 1 mile, 2 mile)?
5. Do you have any documents or supporting materials for your hybrid or trolley buses that you could share?

PLANNING

1. Describe the general characteristics of your trolley system:
    a. Number and types of routes (i.e. in-city, suburban, rail feeder, express)
    b. Ridership
    c. Operating environment (i.e. terrain, speeds, stop-and-go)
    d. Routing patterns (i.e. through-routes)
2. Were there any policy issues associated with replacement alternatives? (e.g. energy plans, emissions targets, interlocal agreements)
3. Has your agency made an effort to quantify public benefit of reduced noise and emission free nature of trolley operations?
4. What is the decision-making process for determining when buses operate off-wire? Are there any times when off-wire activity is scheduled, such as for base deadheads, terminal to terminal movements, or in service?

5. Have you done any comparison of the costs and benefits of dieselization versus the battery replacement cost that would be incurred with greater off-wire running?
6. Has the ability to run off wire presented a tension between planning staff and maintenance staff? (e.g. with maintenance staff wanting to use off-wire less to save batteries and planning staff wanting to use it more for flexibility)
7. Is there organized support for or against electric trolley buses in your community? Has there been any public tension between areas served by trolley buses and those served by other areas, in relation to potential cost differences? (e.g. suburbs against trolley buses due to higher cost per hour/mile)
8. Have you done any recent conversion of routes from diesel to trolley, or trolley to diesel? If so:
    a. What type of feedback did you receive from the public?
    b. Can you share any public information materials you may have assembled?
    c. What were the characteristics of the routes: headways, terrain, ridership
9. Have you recently added or are you planning to add new trolley overhead? If so:
    a. What is the public response to the wire extensions?

SCHEDULING

1. What is the decision process for determining when buses operate off-wire? Are there any times when off-wire activity is scheduled, such as for base deadheads, terminal to terminal movements, or in service?
2. Do you have experience with mixing trolley and diesel service on the same routes? If yes, are there noticeable differences in running times on the two modes?
3. What are the platform to in-service and layover to in-service ratios of your trolley routes? Is there a difference in the platform to in-service ratio and layover to in-service ratios between trolleys and similar diesel services (similar in miles per hour, operating environment)?
4. Are there significant differences in operating staff who operate trolley buses versus other buses? Is there a pay difference that would lend itself to more senior staff?

MAINTENANCE

1. Describe the equipment/technology your trolleybus routes are currently running.
2. How long has your trolley fleet group been in service?
3. What is the Gross Vehicle Rated Weight of the total vehicle and each axle?
4. Are you experiencing any ongoing maintenance issues or concerns?
5. What are the trouble calls per mile for your trolley fleet?
6. Who is the manufacturer and model of the trolley pole retrievers are you using?
7. What maintenance/repair costs and labor hours are you spending on your trolley pole system?

Backup Propulsion

1. What type of backup propulsion do you use?
    a. If motor/generator, answer questions 2 - 11
    b. If battery, answer questions 12 - 19.
2. What is the process and time needed to switch between trolley mode and motor/generator mode?
    a. What is the process and time needed to switch back to trolley mode?
3. How much does the motor/generator system weigh?
4. What is the maximum KVA output of the motor/generator?
5. What EPA emission regulations and testing do you need to perform on the motor/generator system?
    a. If there is an emission certification, how often must it be performed?
    b. What process is involved in emission certification?
6. Does the motor/generator system's mounting location cause you to lose seating capacity? What is the seating capacity?
7. What is the noise level in decibels of the motor/generator when operating at maximum capacity?
8. How fast can the vehicle travel when it is in motor/generator mode on level ground?
    a. How far can the vehicle travel when in motor/generator mode?
    b. What is the maximum grade the vehicle can travel when fully loaded and in motor/generator mode?
9. What types of maintenance are needed on the motor/generator system?
10. What common failures have you experienced with the motor/generator system?
11. What are the maintenance/repair costs and labor hours for the motor/generator system?
12. Do you find a need to add fuel stabilizers or other additives to the fuel for the motor/generator to keep alga from growing in the tank?
13. How often and for how long is the vehicle operated in motor/generator mode?
14. What battery type (chemistry) are you using? (i.e. Lithium, Lead, Nickel)
15. How much does the battery pack weigh?
16. How are the batteries cooled?
17. What is the process and time needed to switch from trolley mode to battery mode?
18. What is the process and time needed to switch back to trolley mode?
19. Does the battery location cause you to lose seating capacity? What is the seating capacity?
20. How fast can the vehicle travel when it is in battery mode on level ground?
    a. How far can the vehicle travel when in battery mode?
    b. What is the maximum grade the vehicle can travel when fully loaded and in battery mode?

21. What was the predicted battery life before a need for battery replacement when you first purchased the vehicles?
    a. Has actual battery life expectancy increased or decreased based on your actual service conditions?
22. What is the estimated cost of replacing the batteries?
    a. What is the amount of labor time needed to replace the batteries?
23. How often and for how long is the vehicle operated in battery mode?
24. (Translink only) Are there cold weather operating issues with the battery propulsion systems?

OPERATIONS

1. How long (distance and time) are buses running offline and supplemented by diesel service? (Reliability question for Operations)
2. Have there been issues with buses exhausting battery power before regaining access to recharge areas, such as the overhead wire system?
3. What is the anticipated life-cycle of your trolleybus vehicle?