Trolley Bus System Evaluation
Preliminary Findings

April 2011
Presentation Agenda

1. Background / Purpose of Evaluation
2. Auxiliary Power Unit (APU) Review
3. Environmental Analysis Summary
4. Life Cycle Cost Analysis Summary
5. Preliminary Findings
6. Next Steps
Purpose of the Evaluation

- 2009 transit performance audit required evaluation
- Establish budget plan for fleet replacement (2012-2013 biennial budget)
Evaluation Schedule

Trolley Bus System Evaluation
August 2010-2nd Quarter 2011

Metro develops biennial budget
2nd Quarter-Nov. 2011

Bus procurement contract
advertise/award

Delivery of
100 buses (40-foot)
59 buses (60-foot)
Sept. 2014-2015

2010

2011

2012

2014

2015

Council approves biennial budget
Nov. 2011

Sign bus procurement contract
Sept. 2012

Consultant study

September
2010

March
2011

April
2011

April 27
Public meeting

May
2011

May 6
Public comments due

Initial results

Report finalized

Public Review

Inform 2012-13
Metro budget

June
2011
Metro’s Trolley Bus Network

- 14 routes and 159 trolley buses
- 70 miles of two-way overhead wire
- Carries 20% of Metro’s weekday riders
- One of five trolley systems in USA
  1. Seattle, WA
  2. San Francisco, CA
  3. Dayton, OH
  4. Philadelphia, PA
  5. Boston, MA
Status of Metro’s Trolley Buses

- Buses need to be replaced
- Outdated electrical systems
- Cracked trolley bus frames
- Obsolete parts
## Bus Technologies Eliminated from Further Consideration

<table>
<thead>
<tr>
<th>Technology</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>Less fuel efficient&lt;br&gt;Greater environmental impact than diesel hybrids</td>
</tr>
<tr>
<td>Electric Battery</td>
<td>Not commercially available&lt;br&gt;Reduced travel range</td>
</tr>
<tr>
<td>Compressed Natural Gas</td>
<td>High costs&lt;br&gt;Greater environmental impacts than diesel hybrids</td>
</tr>
<tr>
<td>Hydrogen Fuel Cell</td>
<td>Not commercially available&lt;br&gt;High costs&lt;br&gt;Reduced travel range&lt;br&gt;Reduced reliability</td>
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</tbody>
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Bus Technologies Included in the Evaluation

Diesel Hybrid Bus

- Reworked transmission to travel on steep grades

Electric Trolley Bus

- Added auxiliary power unit (APU) for off-wire travel

Photo by John Perlic
### Electric Trolley Bus Auxiliary Power Unit (APU) Review

<table>
<thead>
<tr>
<th>Measures</th>
<th>Battery APU</th>
<th>Diesel APU</th>
</tr>
</thead>
<tbody>
<tr>
<td>APUs in operation</td>
<td>San Francisco, CA, Dayton, OH, Boston, MA, Vancouver, BC</td>
<td>Philadelphia, PA</td>
</tr>
<tr>
<td>Range (Miles)</td>
<td>Up to 2.5</td>
<td>Up to 150</td>
</tr>
<tr>
<td>Max speed, Level</td>
<td>40 mph</td>
<td>25 mph</td>
</tr>
<tr>
<td>Max grade</td>
<td>As required</td>
<td>6%</td>
</tr>
<tr>
<td>Acceleration</td>
<td>Better</td>
<td>Worse</td>
</tr>
<tr>
<td>Switch from electric power</td>
<td>Faster</td>
<td>Slower</td>
</tr>
<tr>
<td>Fuel required</td>
<td>None</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Environmental Comparative Analysis Summary

<table>
<thead>
<tr>
<th>Category</th>
<th>Diesel Hybrid</th>
<th>Electric Trolley Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Quality / Climate Change</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Justice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Historic Buildings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neighborhood Character</td>
<td></td>
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</tbody>
</table>

**KEY**
- Favors Bus Technology
- Greatly Favors Bus Technology
- Similar Benefit or Impact for both Bus Technologies
Electric Trolley Bus technology costs $3.7 million less than Diesel Hybrid
Traffic

**Diesel Hybrid**

- No travel limitations from trolley wire
- May operate at slower speeds on steep grades
- Low gearing for steep hills limits top speed on level grades

**Electric Trolley Bus**

- Off-wire travel limited by APU range
- Can operate at faster speeds on steep grades
- No speed limitations on level grades
Noise

Diesel Hybrid vs. Electric Trolley Bus

Favors Diesel Hybrid

Favors Electric Trolley Bus

Decibel Scale (dBA)

74 - 80

66 - 75

78 - 84

74 - 80

64 - 70

Diesel Hybrid

Electric Trolley Bus

Garbage Truck

Utility Truck

Passenger Car
Climate Change

Annual Fleet-wide CO₂e Emissions

- Diesel Hybrid: 6,625 Metric Tonnes
- Electric Trolley Bus: 304 Metric Tonnes
Energy

Annual Fleet-wide Energy Consumption (million BTU)

- Diesel Hybrid: 86,681 million BTUs
- Electric Trolley Bus: 59,710 million BTUs
Environmental Justice: Minority and Low-Income Population Distribution along Electric Trolley Bus Routes

Areas with high concentrations of low-income population

Areas with high concentrations of minority population
Environmental Justice: Impacts to Low-Income and Minority Populations

- Higher impacts from noise and air pollution
- Lower visual impacts with wire removal

- Lower impacts from noise and air pollution
- Higher visual impacts from wires and power supply system
Visual Quality

- Improved visual quality with removal of wires
  (Varies depending on location)

- Impacts from trolley wires
  (Highest in view corridors and residential neighborhoods)
Visual Simulation: Rainier Valley

Before
Visual Simulation: Rainier Valley

After
Visual Simulation: Downtown from Beacon Hill

Before
Visual Simulation: Downtown from Beacon Hill

After
Life-Cycle Cost Model Data

1. Operating environment
   a. Current service
      i. Miles of trolley overhead wire
      ii. Actual annual trolley service miles
      iii. Magnitude and frequency of dieselization
   b. Projected future service
      i. Miles of trolley overhead wire
      ii. Projected annual trolley service miles
      iii. Magnitude and frequency of dieselization
         -Effect of APUs if and when implemented

2. Vehicle
   a. Vehicle types
   b. Vehicle life span
   c. Fleet size
   d. Capital costs
      i. Historic Base Price
         -Escalation
      ii. Current Base Price
      iii. Cost adjustments
         - sales tax
         - additional equipment
         - special tools
         - diagnostic equipment
         - service preparation
         - training & manuals
         - project management
         - inspection
         - contingency
         - salvage value
      iv. Total Capital Cost

3. Operating costs
   a. fuel/electricity
      i. basis for operating cost assumptions
      ii. calculating average fleet operating costs to reflect KC
         Metro trolley service environment
   b. staff labor and overhead

4. Maintenance costs
   a. fueling & servicing
   b. spare parts
   c. tires
   d. routine maintenance
   e. trouble calls
   f. staff labor and overhead

5. Maintenance Facilities
   a. Fueling facility and infrastructure
   b. Efficiencies of work flow, scheduling, spares storage

6. Trolley Overhead (TOH) Wire
   a. Annual maintenance and inspection
      i. Materials and repair
      ii. Cleaning and landscaping
      iii. Utilities and Taxes
   b. Capital Improvements
      i. System Modifications
      ii. Future Rectifier Replacements
      iii. Substation Enclosures
      iv. Contractor Replacement
      v. Substation Batteries and Enclosure
      vi. Substation AC Cubicle
      vii. TAMP: Trolley Overhead Pole And Switch Maintenance
      viii. Influence of TOH lifespan on life cycle cost analysis
   c. Decommissioning
Key Life-Cycle Cost Model Assumptions

- Vehicle useful life (FTA, 2008)
  - Electric Trolley Bus: 15 years
  - Diesel Hybrid: 12 years

- 60 foot vehicle costs
  - Electric Trolley Bus: $1,285,000
  - Diesel Hybrid: $785,000

- Real Discount Rate (King County): 7% future value of today’s dollars

- Annualized cost is calculated over one life-cycle for each vehicle type.

- Differential in fixed guideway grant amount is assumed in the analysis.

- Decommissioning trolley infrastructure: $37 million

- Expanding fuel capacity at base for hybrids: $5 million
Annualized Life-Cycle Cost Summary

Electric Trolley Bus technology costs $3.7 million less than Diesel Hybrid.
Influence of Fixed Guideway Funding on Total Annualized Cost

If FTA fixed guideway funding falls below 31% of current funding, the Diesel Hybrid technology is favored.

![Graph showing the influence of fixed guideway funding on total annualized cost. The graph compares Diesel Hybrid and Electric Trolley Bus costs at 100%, 31%, and 0% funding levels. The Diesel Hybrid cost is shown as $11.8 M at 31% funding, while the Electric Trolley Bus cost is shown as $15.5 M at all funding levels.]
Sensitivity of Major Cost Variables

Base Case

What would be required to make Diesel Hybrid more cost effective?

<table>
<thead>
<tr>
<th>Input</th>
<th>Ability to Switch Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed guideway funding</td>
<td>Reduce to 31% of current level</td>
</tr>
<tr>
<td>Gas price</td>
<td>Not possible</td>
</tr>
<tr>
<td>Electricity price</td>
<td>Increase 20% per year</td>
</tr>
<tr>
<td>Diesel Hybrid life span</td>
<td>Increase from 12 to 17 years</td>
</tr>
<tr>
<td>Electric Trolley Bus purchase price</td>
<td>Increase by 34%</td>
</tr>
<tr>
<td>Diesel Hybrid purchase price</td>
<td>Decrease by 48%</td>
</tr>
</tbody>
</table>
Wrap-up

Built environment elements favor Electric Trolley Bus
Cost elements favor Electric Trolley Bus

Metro preliminary findings favor Electric Trolley Bus
Next Steps

- **April 27**: Public meeting
- **April and May**: Collect public feedback and finalize report
- **June**: Study findings incorporated into Metro’s 2012 – 2013 budget