Advanced Clean Transit

May 2015
Mobile Source Control Division
Air Resources Board
Agenda

* Introduction
* The importance of public transit
* Air quality and climate change goals
* Technology assessment
* Costs and funding
* Proposed amendments
* Discussion topics
* Timeline and contacts
Introduction
Transit Fleet Achievements

- Transit Fleet Rule originally adopted in 2000
  - Transit fleet vehicles & urban buses achieved significant PM and NOx emissions reductions
- Diesel fuel path fleets
  - More than 50% of the new purchase are hybrid
  - Zero emission bus demonstration and purchases
    - 12 fuel cell bus demonstration in Bay Area
- Alternative fuel path fleets
  - Converted to natural gas
Zero Emission Bus Technologies Have Matured

- Significant advancements for zero emission buses in the past few years
- Are commercially available
- Costs have come down substantially
- Have reliable performance
- Zero emission buses are operated in California successfully
Many Fleets Operating Zero Emission Buses in California

<table>
<thead>
<tr>
<th>Bus Operator</th>
<th>Technology Type</th>
<th>Total Buses</th>
<th>Operating period (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antelope Valley Transit</td>
<td>Battery</td>
<td>2</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Foothill Transit</td>
<td>Battery</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>LA MTA</td>
<td>Battery</td>
<td>5</td>
<td>--</td>
</tr>
<tr>
<td>San Joaquin RTD*</td>
<td>Battery</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Stanford</td>
<td>Battery</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>SunLine Transit</td>
<td>Fuel Cell</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>UC, Irvine</td>
<td>Fuel Cell</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>ZEBA (AC Transit lead)</td>
<td>Fuel Cell</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>53</strong></td>
<td><strong>--</strong></td>
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</tbody>
</table>

*As of 4/1/2015 five more buses under contract for delivery
Driving Change

- Significant reductions needed to meet air quality and climate goals, and reduce dependence on depletable resources
- Achieving goals will require a transformational change in every sector
  - Zero emission technologies will be necessary where feasible
  - Near-zero emission technologies need to be applied everywhere else
- Transit fleets will play a major role
Transit buses are highly suitable for advanced technologies

- Operate in congested areas where pollution is a problem
- Centrally located and fueled
- Government support

Experiences aid other fleets in deploying heavy-duty zero-emission vehicles

Zero-emission technology in buses can be transferable
Key Step to Zero and Near-Zero Emissions Begins with Transit

* Complete transition to a zero emission bus fleet by 2040 or sooner
* Require near-zero emission technology and fuels for conventional engines during transition
  * Low NOx engines with use of low carbon intensity fuels
* Provide regional flexibility for zero emission bus goals
* Encourage innovative transit beyond buses
The Importance of Public Transit
Transit Systems Provide a Critical Public Service

- Provides safe, reliable, affordable transportation to millions every day
- Transit reduces
  - Roadway congestion
  - Emissions
  - Reliance on petroleum and automobiles
- Supports sustainable communities goals and improves air quality
- Leads technology advancement
Modes of Transportation

- Buses
- Trains
- Ferries
- Trolley
- Other (shuttles, paratransit)
* Urban bus service
  * Short routes with frequent stops in urban centers
  * Typically served by low floor transit bus

* Commuter service
  * Travel between urban centers at peak times
  * Typically served by motor coaches

* Paratransit service
  * Flexible transportation, supplements fixed-route service
Role in Sustainable Communities and Climate Protection

* The Sustainable Communities and Climate Protection Act of 2008 (SB 375)
* Reduce GHG emissions through coordinated transportation and land use planning
* Improve transit system efficiencies while reducing passenger car use
Summary of California Transit Fleet

* Fleet size
  * 9,908 urban buses
  * 1,622 other transit fleet vehicles
* Urban buses by fuel type
  * 5,816 CNG, LNG, LPG
  * 3,084 diesel
  * 667 diesel-electric hybrid
  * 341 all-electric buses

Source: ARB Transit Fleet Rule Reporting database on 03/2015
Air Quality and Climate Goals
Significant technology advancement needed to meet air quality, climate, petroleum reduction, and public health goals:

- 40% reduction in GHG by 2030
- 50% reduction in petroleum use by 2030
- 90% reduction in NOx by 2031
- 80% reduction in GHG by 2050
- Continued reductions in diesel PM and air toxics to protect public health
On-road sector remains a large contributor to statewide emissions

- 46% of total NOx emissions in CA
- 33% Heavy duty
- 13% Light duty

**2014 Statewide NOx Emissions**

- On-Road Heavy duty: 33%
- On-Road Light duty: 13%
- Marine: 15%
- Off-road equipment: 6%
- Trains: 14%
- Aircraft: 13%
- Stationary: 13%
- Areawide: 2%

![Pie chart showing distribution of NOx emissions by sector in 2014](chart.png)
* On-road sector contributes to 30% of total GHG emissions in CA
Planning efforts focus on
- Achieving climate change emissions reduction targets
- Meeting ozone air quality standards
- Technology development, deployment, and incentives

Zero emission technologies will be needed everywhere feasible and near zero emission everywhere else as technology matures

Zero emission buses are a key part of strategy
Existing Zero Emission Bus Requirements on Hold

* Zero emission bus purchase requirement on hold pending technology review
  * Resolution 09-49; (January 2010 mailout, MSC #10-04)

* Technology assessment conclusions
  * Over the past 5 years technology has matured
  * Costs have come down substantially
  * Both battery and fuel cell electric buses ready for transit applications

More information on the technical assessments can be found at:
Bus Technology and Fuel Options

* Zero emission technologies
  * Battery electric buses
  * Fuel cell electric buses
* Other advanced technologies
  * Hybrid buses
  * Low NOx engines
* Renewable fuels
Battery Electric Buses

* Commercially available
  * Battery lease options
  * 4 manufacturers, 8 models
* Multiple charging options
  * Slow charging with \( \sim 160-190 \) mile range
  * Fast charging for unlimited range on shorter routes
* Higher upfront cost compared to conventional diesel vehicles
* Total cost of ownership is similar to conventional diesel vehicles after federal funds utilized
### Commercially Available Battery Electric Buses

<table>
<thead>
<tr>
<th>Technology</th>
<th>Manufacturer</th>
<th>Bus Type</th>
<th>Charge/Fuel Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery</td>
<td>BYD</td>
<td>30’</td>
<td>2-4 hours</td>
</tr>
<tr>
<td>Battery</td>
<td>BYD</td>
<td>35’</td>
<td>2-4 hours</td>
</tr>
<tr>
<td>Battery</td>
<td>BYD</td>
<td>*40’</td>
<td>2-4 hours</td>
</tr>
<tr>
<td>Battery</td>
<td>BYD</td>
<td>60’ Articulated</td>
<td>2-3 hours</td>
</tr>
<tr>
<td>Battery</td>
<td>Proterra</td>
<td>*35’</td>
<td>Fast Charge (&lt;10 min.)  Slow Charge (90 min.)</td>
</tr>
<tr>
<td>Battery</td>
<td>Proterra</td>
<td>*40’</td>
<td>Fast Charge (&lt;10 min.)  Slow Charge (90 min.)</td>
</tr>
<tr>
<td>Battery</td>
<td>Nova</td>
<td>40’</td>
<td>Fast Charge (6 min.)</td>
</tr>
<tr>
<td>Battery</td>
<td>New Flyer</td>
<td>40’</td>
<td>Slow Charge 96 min.  Fast charge 4-6 min.</td>
</tr>
</tbody>
</table>

* Completed Altoona testing
Battery Electric Buses Currently Operating in California

<table>
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<tr>
<th>Bus Operator</th>
<th>Total Active Buses</th>
<th>Operating Period (years)</th>
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<td>Stanford</td>
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<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>37</strong></td>
<td><strong>--</strong></td>
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</tbody>
</table>

*As of 4/1/2015 five more buses under contract for delivery
Fuel Cell Electric Buses

- Early commercialization
  - Capital costs substantially higher than conventional and battery electric buses
    - Expect further cost reductions over time
  - Two manufacturers
- Performance, durability and availability similar to conventional buses
- Hydrogen fueling 4-6 minutes
- Range of ~300 miles
- Operational flexibility same as conventional buses
### Fuel Cell Electric Buses

<table>
<thead>
<tr>
<th>Technology</th>
<th>Manufacturer</th>
<th>Bus Type</th>
<th>Fuel Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Cell</td>
<td>New Flyer</td>
<td>40’</td>
<td>4-6 min.</td>
</tr>
<tr>
<td>Fuel Cell</td>
<td>New Flyer</td>
<td>60’</td>
<td>4-6 min.</td>
</tr>
<tr>
<td>Fuel Cell</td>
<td>El Dorado National</td>
<td>41’</td>
<td>4-6 min.</td>
</tr>
</tbody>
</table>
## Fuel Cell Electric Buses Operating in California

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<th>Bus Operator</th>
<th>Total Active Buses</th>
<th>Operating Period (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SunLine Transit</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>UC Irvine</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>ZEBA (AC Transit lead)</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17</strong></td>
<td><strong>--</strong></td>
</tr>
</tbody>
</table>
Conventional Hybrid Buses

* About 50 percent of current diesel purchases
* Reduces GHG emissions with improved fuel efficiency
* Support supply chain for zero emission drivetrain and components
* Hybrids certified to same emission standards as conventional diesel and natural gas vehicles
Low NOx Engines

- Expected to be available for CNG buses in 2016-2017
  - Certified to ARB optional low NOx standards
  - Likely to be 90% lower NOx than existing engines
- Expect limited impact on bus cost
Renewable Fuels

- Renewable fuels are commonly available
  - Renewable natural gas
  - Renewable diesel
  - Biodiesel
- Power to gas from renewables

Low Carbon Fuel Standard:
http://www.arb.ca.gov/fuels/lcfs/lcfs.htm
Emissions Comparison

* GHG emissions compared with a well-to-wheel analysis where the emissions associated with the vehicle use and fuel consumed
  * Regardless of where the activity occurs
* NOx emissions compared by engine certification standard
  * Reflects regional exposure where engine exhaust occurs
  * In-use comparison varies by a number of factors
Urban Bus GHG Emission Comparison

Low Carbon Fuel Standard Carbon Intensity as of April 28, 2015

All LCFS carbon intensity are draft proposed and subject to change until LCFS readoption in 2015.
Engine Certification Standards for NOx Emissions

- Diesel (2010-Present): 0.20 g/bhp-hr
- CNG (2010-Present): 0.20 g/bhp-hr
- 50% Lower NOx: 0.10 g/bhp-hr
- 90% Lower NOx: 0.02 g/bhp-hr
- Battery Electric: 0.00 g/bhp-hr
- Fuel Cell Electric: 0.00 g/bhp-hr

NOx Emissions (g/bhp-hr)
Costs and Funding
**Normal Transit Funding Sources**

* Federal Transportation Agency (FTA)
  * 80% of capital funding for buses (Section 5307)
  * Funds distributed by MPO/RTPA
  * Funding requirements for buses: Buy America, Altoona tested and have a 12 year minimum service life
  * Must maintain minimum spare ratio

* Operation and maintenance funded mainly through local funds
  * Ticket fares, sales tax, property taxes, bridge tolls, etc.
## Bus Capital Cost Comparison

<table>
<thead>
<tr>
<th>Technology</th>
<th>Purchase Price</th>
<th>Estimated FTA Section 5307 Funding</th>
<th>Transit Agency Cost Share</th>
<th>Incremental Cost to Transit Agencies above Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>$485,000</td>
<td>$398,000</td>
<td>$87,300</td>
<td>---</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>$525,000</td>
<td>$431,000</td>
<td>$95,000</td>
<td>$7,000</td>
</tr>
<tr>
<td>Diesel Hybrid</td>
<td>$758,000</td>
<td>$622,000</td>
<td>$136,000</td>
<td>$49,000</td>
</tr>
<tr>
<td>Battery Electric</td>
<td>$800,000</td>
<td>$656,000</td>
<td>$144,000</td>
<td>$57,000</td>
</tr>
<tr>
<td>Fuel Cell Electric*</td>
<td>$1,300,000</td>
<td>$1,066,000</td>
<td>$234,000</td>
<td>$147,000</td>
</tr>
</tbody>
</table>
Incremental Cost Example: Battery Electric Buses

<table>
<thead>
<tr>
<th></th>
<th>Diesel</th>
<th>CNG</th>
<th>Battery Electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus Cost</td>
<td>$485,000</td>
<td>$525,000</td>
<td>$800,000</td>
</tr>
<tr>
<td>Charger and Installation</td>
<td>0</td>
<td>0</td>
<td>$40,000</td>
</tr>
<tr>
<td>FTA Formula Funds</td>
<td>-$398,000</td>
<td>-$431,000</td>
<td>-$656,000</td>
</tr>
<tr>
<td>HVIP</td>
<td>0</td>
<td>0</td>
<td>-$110,000</td>
</tr>
<tr>
<td>Net Transit Agency Cost</td>
<td>$87,000</td>
<td>$94,000</td>
<td>$74,000</td>
</tr>
</tbody>
</table>

*Assume standard overnight charging
*Does not include $17,000 in annual fuel savings for battery electric
*Does not include maintenance bay upgrades and training

1Hybrid and Zero Emission Truck and Bus Voucher Incentive Project
Cost Analysis

- Analysis period 2018 to 2040
- Total cost of ownership comparison
  - Bus, fueling and maintenance facility infrastructure
  - Fuel and maintenance costs
- Cost analysis at transit fleet level
  - Normal replacement practices
  - Projection of likely actions with rule
- Information on type(s) of buses that can serve needs
- Annual mileage, fuel use, cost of fuel or electricity
Option to lease the high value components can reduce up-front cost similar to a conventional bus

- Reduce the incremental capital cost and offset with operating and maintenance cost savings
- FTA confirmed federal funds could be used for lease

Manufacturers also offering extended warranty options for batteries (no mid-life cost)

- Up to life of bus (12 years)
Proposed Amendments
Zero Emission Bus Targets

- Beginning January 1, 2018
- Low initial targets allow fleets to prepare and become familiar with technologies
- Requirements will increase over time, with goal to achieve full zero emission fleet by 2040
- Base requirements on percentage of bus purchases
  - Potentially higher initial credit for fuel cell electric buses
  - Potentially additional time for smaller transit fleets
    - Need to establish appropriate size threshold
2040 Zero Emission Bus Goal Requires Action Now

More Than One Way to Reach Zero Emission Goal

<table>
<thead>
<tr>
<th>Year</th>
<th>Percent of Fleet</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>0%</td>
</tr>
<tr>
<td>2020</td>
<td>10%</td>
</tr>
<tr>
<td>2025</td>
<td>20%</td>
</tr>
<tr>
<td>2030</td>
<td>30%</td>
</tr>
<tr>
<td>2035</td>
<td>40%</td>
</tr>
<tr>
<td>2040</td>
<td>50%</td>
</tr>
</tbody>
</table>

Scenario 1
Scenario 2
Scenario 3
Scenario 4
Minimize Emissions from Conventional Fleet

* Beginning January 1, 2017
* Purchase best available technology at time of replacement
* Purchase renewable diesel or CNG for entire fleet at time of fuel contract
* Need to discuss role of hybrid electric buses
  * Potential for zero emission miles
* All transit fleet vehicles must have PM filters
Regional Flexibility Options

- Option for transit fleets to pool bus purchases
  - Meet same total zero emission bus milestone
  - Allows for flexibility for vehicle and infrastructure deployment
Innovative Transit Beyond Buses

- Opportunity for transit fleets and regional planning agencies to transform passenger transportation with creative methods and new technologies
  - Result in additional GHG reduction
  - Beyond buses and conventional technologies

- Provide additional flexibility in zero emission bus requirements

- Potential to be recognized in meeting regional Sustainable Communities Strategies (SB375)
Areas Staff is Working On

* Incentives alignment with federal formula funding
* Role for hybrids (including plug-ins)
* Economic analysis data and assumptions
* Axle weight
Bus purchases prohibited if exceeding axle weight limits
- California: 20,500 lbs./axle
- Federal: 24,000 lbs./axle

Bus axle weight limits commonly exceeded when at capacity

Higher axle weights result in greater road wear

National study identified pros and cons of potential options
- American Public Transportation Association

Continuing to monitor outcome

Discussion Topics
* How to phase-in requirements for zero emission bus purchases in a manner that is consistent with existing purchase patterns?
* How existing funding programs could be improved to provide more certainty about available funding and funding levels?
* Should smaller transit fleets be given more time to phase-in zero emission buses?
Discussion Topics (2)

- How to encourage deployments of fuel cell buses to bring them into broader commercialization?
- How should conventional and plug-in hybrid (PHEV) buses be included in the strategy?
- What are the approaches to build innovative transit beyond buses?
Timeline

* Summer 2015: Public workshops
* September 2015: Update to Board on progress
* Winter 2015: Public workshops
* Spring 2016: Board hearing
Contacts

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  * peter.christensen@arb.ca.gov
  * (916) 322-1520