Advanced Clean Trucks
Cost Discussion

Workgroup Meeting
December 4, 2018
Sacramento, California
Cost Discussion Goals

- Help us understand cost saving opportunities and find well-suited market segments
  - Costs and emission benefits should be consistent with timeframe for operations in California
- Share data sources we are aware of and receive feedback on them
- Use cost sources to develop total cost of ownership model for rulemaking purposes
  - Advanced Clean Trucks
  - Future fleet rules
Total Cost of Ownership

- Total Cost of Ownership (TCO) is the discounted sum of all costs of a vehicle
- Includes capital costs (vehicle purchase, infrastructure) and operational costs (fuel, maintenance, LCFS credits) as well as other miscellaneous expenses
- TCO depends on how the vehicle is operated – vehicle miles travelled, years of operation, and other factors
Topics for discussion

- Vehicle operations
- Capital costs
  - Vehicle purchase price
  - Residual values
  - Midlife refurbishment
- Operating costs
  - Fuel
  - Low Carbon Fuel Standard
  - Maintenance
- Infrastructure
- Other
Vehicle Operating Assumptions

- **Annual miles**
  - Numerous sources estimate annual or daily miles for vehicle populations including CalHEAT, CARB’s EMFAC, the Vehicle Inventory and Use Survey (VIUS), and the upcoming CalTrans Truck Survey (CalVIUS).

- **Vehicle life**
  - Based on DMV data and other sources, the average lifetime of a truck is 15-25 years.
  - Based on surveys, the typical first life of a vehicle is 8-10 years but varies significantly by truck type, usage, fleet priorities, and other factors.
Mileage Examples

CalHEAT Average VMT by Vehicle Category

EMFAC2017 - 2018MY Daily Miles for Select Categories
Vehicle Prices

- Manufacturer websites and online truck marketplaces
  - Includes TruckPaper.com and CommercialTruckTrader.com
  - Future truck prices influenced by GHG Phase 2 compliance costs
- Zero-emission vehicle prices can be calculated using estimated glider costs and component-level cost estimates
  - Heavy-duty sources include CARB, the International Council on Clean Transportation, Ricardo, University of California, Davis and others
  - Can we use light-duty projections for some vehicles i.e. Class 2B-3?
- Residual values for vehicles
  - Battery-electric
    - A SAE paper estimates BEV battery’s residual value of $20-$100/kWh for BEV batteries
  - Hydrogen fuel cell

Battery Costs

- The cost of the battery is the largest component of battery-electric vehicles
  - Light-duty battery costs have declined dramatically over the last decade
- Cost reductions expected for other EV components
- Today, heavy-duty batteries cost more than light-duty batteries. It is unclear if this trend will continue.
  - Companies may use LD batteries in HD applications

Battery Price History and Projections


CARB, Battery Cost for Heavy-Duty Electric Vehicles, 2016. [Link](https://www.arb.ca.gov/msprog/bus/battery_cost.pdf)

Midlife Costs

- Midlife costs include diesel engine rebuilds, battery replacements, and fuel cell stack refurbishments
- Dependent on vehicle life and usage – more miles means one or more midlife expenses
- Battery replacement
  - Based on battery price curve, battery size, warranty period, and other factors
- Hydrogen fuel cell stack refurbishment
  - Ricardo estimates a refurbishment costs 1/3 of the fuel-cell stack’s cost
Fuel Cost

- Diesel fuel cost – Energy Intelligence Agency’s (EIA) Annual Energy Outlook (AEO) 2018
  - Add in projected 2018 Low Carbon Fuel Standard Amendment costs
- Electricity fuel cost – CARB Battery-Electric Truck and Bus Charging Calculator for initial cost
  - EIA AEO 2018 – models cost increase over time
- Hydrogen fuel cost
  - Production method and volume dependent

Projected Cost of Diesel

![Projected Cost of Diesel Chart]

- EIA Diesel plus 2018 LCFS
- EIA Diesel
Fuel Cost (Cont’d)

[Graph showing the cost of electricity for different years with SDG&E, PG&E, Statewide Average, SCE, SMUD, and LADWP]

**Cost of Hydrogen* (Trillium Estimate)**

<table>
<thead>
<tr>
<th>Buses</th>
<th>kg/day</th>
<th>GH2 Delivery</th>
<th>LH2 Delivery</th>
<th>Onsite SMR</th>
<th>Onsite Electrolysis</th>
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<tbody>
<tr>
<td>5</td>
<td>150</td>
<td>$11+</td>
<td>$12+</td>
<td>$11</td>
<td>$11-$16</td>
</tr>
<tr>
<td>35</td>
<td>1,000</td>
<td>$8+</td>
<td>$7+</td>
<td>$6</td>
<td>$7-$12</td>
</tr>
<tr>
<td>200</td>
<td>6,000</td>
<td>$6+</td>
<td>$4+</td>
<td>$4</td>
<td>$4-$10</td>
</tr>
</tbody>
</table>

*Deduct $6/kg for 5 buses, $1.50/kg for 200 buses for direct CapEx purchase

- Input for electricity graph: 20 vehicle deployment, 19 kW charger, 100 mi./day, 0.96 kWh/mi. 90% charging efficiency, 10PM-6AM charging period, managed charging strategy, 3% local taxes and fees, LADWP - A-2(B), PG&E - CEV-L @ 400kW, SMUD - GS-TOU3, SDG&E - AL-TOU2/EECC-CPP-D, SCE - EV-8
- Note: The graph shows Pacific Gas and Electric’s CEV-L rate and Southern California Edison’s EV-8 rate, both of which are awaiting approval.
Efficiency of Electric Vehicles

- Electric vehicles operate more efficiently at lower speeds compared to diesel.
- Most vocational vehicles operate at low average speeds under 20 mph.

Fuel Economy

- Diesel – can be derived from GHG Phase 2 standards
- Battery-electric – based on in-use data
  - Passenger van – 0.56 kWh/mi.
  - Delivery van – 0.7 to 1.0 kWh/mi.
  - Cutaway shuttle – 1.0 kWh/mi.
  - Day cab tractor – 2.1 kWh/mi
  - Refuse truck – 2.5 to 3.0 kWh/mi.
- Hydrogen fuel-cell – Apply Low Carbon Fuel Standard Energy Economy Ratios to diesel fuel economy
  - Class 1-3 – hydrogen fuel-cell is 2.5 times more efficient than diesel
  - Class 4-8 – hydrogen fuel-cell is 1.9 times more efficient than diesel
- BE and HFC fuel economy will improve over time like diesel
The Low Carbon Fuel Standard (LCFS) program requires fuel producers to lower the carbon intensity (CI) of their fuel or purchase credits from low-CI fuel producers.

- Electricity and hydrogen can generate revenue

- LCFS credits for hydrogen will vary based on production method
  - Renewable versus fossil sources, electrolysis vs steam methane reformation
  - $0.30/kg to $2.60/kg in 2018
BEV Fuel Cost Saving Opportunities

**Airport Shuttle**
Ev: 0.56 kWh/mi. Diesel: 22 mpg

**Package Delivery**
Ev: 1.04 kWh/mi. Diesel: 10 mpg

**Local Drayage**
Ev: 2.1 kWh/mi. Diesel: 3.5 mpg

<table>
<thead>
<tr>
<th>Vs Diesel</th>
<th>15%</th>
<th>35%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>With LCFS</td>
<td>45%</td>
<td>75%*</td>
<td>80%*</td>
</tr>
</tbody>
</table>

Data from [CARB Paper](#). Assuming $3.00/gal., $0.17/kWh plus a 15% charging loss, LCFS Credits at $100
Maintenance

- The maintenance cost reflects the cost of labor and parts for routine maintenance, preventative maintenance, and fixing broken components.

- Diesel-powered maintenance costs
  - Passenger Van - $0.17/mi. – Average of California Energy Commission and Access LA sources
  - Delivery Van - $0.22/mi. – National Renewable Energy Laboratory
  - Cutaway Shuttle - $0.29/mi - Access LA
  - Short-haul Tractor - $0.19/mi. – American Truck Research Institute Report
  - Refuse truck - $0.80/mi. – M. J. Bradley and Associates
Maintenance (Cont’d)

- Data suggests a battery-electric vehicle’s maintenance is 25% lower than diesel
  - Limited truck sources exist, data comes from light-duty and buses

- Limited data suggests hydrogen fuel-cells have similar maintenance to diesel vehicles
  - Ballard estimates a fuel cell bus costs the same as a battery-electric bus plus $0.20/mi. for maintaining the fuel cell stack. This puts it in-line with a diesel bus.

- Data shows that maintenance costs start lower and increase over the life of the vehicle
Infrastructure

- Electric and hydrogen vehicles new additional infrastructure to operate

- Charging Infrastructure
  - Pacific Gas and Electric and Southern California Edison estimated per-vehicle costs:
    - Light trucks: $3,500-$5,000 for the charger, $12,300-$20,300 for site upgrades
    - Heavy trucks: $15,000 for the charger, $14,200-$29,100 for site upgrades
  - Early truck and bus deployments suggest that Class 8 vehicles may have higher infrastructure costs - $50,000 per charger, $55,000 for site upgrades

- Hydrogen infrastructure - the Trillium hydrogen fuel costs projections include infrastructure costs
How should infrastructure be included in a vehicle TCO analysis?

- Large upfront cost to install infrastructure should be reflected.
- For an initial rollout, infrastructure will be rolled out concurrently with vehicles, meaning costs will be tied to vehicles.
- Infrastructure lasts multiple vehicle lifetimes, costs generally should be amortized over the total life of infrastructure.
- Small deployments need minimal to no site upgrades.
- Utilities have programs to pay for infrastructure upgrades today (SB 350).
- Infrastructure upgrades not necessary if public refueling/recharging exists.
Other

- **Discount Rate**
  - Regulations typically assume a discount rate of 2.5%-5%

- **Taxes**
  - Sales tax – Varies across the state from at least 7.25% to 10.25% in some cities
  - Federal Excise Tax – 12% tax on purchase of Class 8 trucks

- **Financing**
  - Most private vehicles financed, most public vehicles purchased outright
  - What interest rate and period to assume?

- **Registration Fees**
  - Diesel and ZE vehicles have significantly different fee structures, can be modelled separately
  - ZE vehicles may pay slightly less

- **Other costs to consider?**
Contact Information

- Please send any information, feedback, data sources, etc. to:

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