Advanced Clean Truck Workgroup Meeting

February 25, 2019
Agenda

- Market segment analysis
- Fleet total cost of ownership
- Infrastructure needs
- Next steps/general discussion
Zero Emission Vehicle (ZEV)
Market Segment Analysis
ZEV Market Segment Analysis

- Initial EMA market segment assessment for 87 truck categories
- Four main categories plus miscellaneous (green, yellow, red designations)
  - Weight
  - Daily range
  - Access to infrastructure
  - Space for batteries, fuel cell and tank placement
  - Other miscellaneous factors
- Overall 1-5 suitability score for each truck segment
- Helps identify vehicle types and uses that are easier to electrify
- Reflects today’s technology
CARB’s Adjustments

• Removed double counting between four main segments and miscellaneous categories
• Revisited weight and range categories
  • No changes for space constraints and infrastructure
  • Truck segment description left unchanged
• Segment suitability scored on a quantitative basis
• Added a fuel cell electric vehicle (FCEV) assessment
• Detailed spreadsheet on website for comment\(^1\)

1: https://ww2.arb.ca.gov/our-work/programs/advanced-clean-truck/act-meetings-workshops
## Truck Segment Spreadsheet

<table>
<thead>
<tr>
<th>Market Segment</th>
<th>Class</th>
<th>Total CA Sales</th>
<th>Battery-Electric Suitability Factors</th>
<th>Loading</th>
<th>Routes/Range</th>
<th>Infrastructure/Charging</th>
<th>Battery Space Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-D Van - Contractor</td>
<td>2B-3</td>
<td>11854</td>
<td></td>
<td>Heavy</td>
<td>50-150 miles per day, High route variability</td>
<td>Some central dispatch, many go with driver in</td>
<td>Constrained</td>
</tr>
<tr>
<td>H-D Van - Shuttle</td>
<td>2B-3</td>
<td>1115</td>
<td></td>
<td>Light</td>
<td>50-300 miles per day, Medium route variability</td>
<td>Centralized, but 24/7 operation</td>
<td>Open</td>
</tr>
<tr>
<td>H-D Van - Refrigerated</td>
<td>2B-3</td>
<td>70</td>
<td></td>
<td>Heavy</td>
<td>200-300 miles per day, Refrigeration reduces range, High route variability</td>
<td>Centralized, at night</td>
<td>Constrained</td>
</tr>
<tr>
<td>Pickup Truck - 4WD Off Road</td>
<td>2B-3</td>
<td>5000</td>
<td></td>
<td>Light to moderate</td>
<td>Variable—except some will have long distance routes.</td>
<td>Variable—off road usage will likely be away from EV grid. Off-highway usage and extended operation will make charging impossible for extended off-road operation</td>
<td>Constrained</td>
</tr>
<tr>
<td>Box Truck - Pickup &amp; Delivery (Fixed Light ≤ 100 Miles per Day)</td>
<td>4-7</td>
<td>3075</td>
<td></td>
<td>Light</td>
<td>Variable ≤ 100 miles per day</td>
<td>Centralized</td>
<td>Open</td>
</tr>
<tr>
<td>Box Truck - Pickup &amp; Delivery (Medium to Heavy Load &gt; 100 Miles per Day)</td>
<td>4-7</td>
<td>1538</td>
<td></td>
<td>Medium to heavy</td>
<td>Variable &gt; 100 miles per day</td>
<td>Centralized or remote</td>
<td>Open</td>
</tr>
<tr>
<td>Box Truck - Pickup &amp; Delivery (Medium to Heavy Load ≥ 200 Miles per Day)</td>
<td>4-7</td>
<td>1530</td>
<td></td>
<td>Medium to heavy</td>
<td>Variable &gt; 200 miles per day</td>
<td>Centralized or remote</td>
<td>Open</td>
</tr>
<tr>
<td>Regional Tractor - Medium Haul</td>
<td>8</td>
<td>400</td>
<td></td>
<td>Variable, up to 80K Gcw</td>
<td>Variable, 100-300 miles per day</td>
<td>Centralized, at night, Multiple shift operations impact charging times</td>
<td>Constrained, short wheelbase</td>
</tr>
<tr>
<td>Port Drayage</td>
<td>8</td>
<td>120</td>
<td></td>
<td>Heavy</td>
<td>Variable, 100-500 miles per day</td>
<td>Variable /Centralized, depending on owner. Multiple shift operations impact charging times</td>
<td>Constrained - short wheelbase</td>
</tr>
<tr>
<td>Refuse, Rear Packer, Residential Service</td>
<td>8</td>
<td>133</td>
<td></td>
<td>Start light, end day at max load</td>
<td>Fixed, 75 miles per day, Occasionally long routes</td>
<td>Centralized, at night</td>
<td>Constrained</td>
</tr>
</tbody>
</table>
Battery Electric Vehicle (BEV) Range

• Revisited high mileage or route variability concerns
• EMFAC, Cal-VIUS 2018, VIUS 2002, and other data sources, show most straight trucks average less than 100 miles per day
• During initial deployments, ZEV’s expected to make up a fraction of any one fleet
  • Conventional trucks can cover variable routes or intermittent needs until the technology further develops
Weight and Payload

- AB 2061 (2018) increases the upper weight limit of a zero- or near-zero emission vehicle by 2,000 lb.
  - Eliminates weight concerns for most Class 2B-7 vehicles
  - Reduces concerns for local or regional Class 8 vehicles
- Can also maintain same payload by moving up a weight class
  - Still issue with shifting from Class 6 to 7 due to commercial driver license requirements
FCEV Assessment

• Adjusted BEV assessment with some basic differences
• Range limitation category
  • Changed to green for all segments assuming same range as diesel
• Infrastructure access category
  • Centralized fueling – green
  • Class 2B-3 potential to use retail passenger car fueling – yellow
    • Up to 10 kg hydrogen storage tank
  • Class 4-8 assumed no access to retail fueling - red
CARB Market Assessment Results
California Annual Truck Sales

BEV

10,858
27,457
39,379
34,196

All 4 categories are green
One or two yellow categories
3 to 4 yellow, or one red category
Two or more red categories

FCEV

11,151
27,213
54,000
9,526

One or two yellow categories
3 to 4 yellow, or one red category
Two or more red categories

3 to 4 yellow, or one red category
Truck Segment Results by Weight Class
For Annual California Sales

<table>
<thead>
<tr>
<th>Class</th>
<th>Battery Electric</th>
<th>Fuel Cell Electric</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Score 1</td>
<td>Score 1.1-2</td>
</tr>
<tr>
<td>2B-3</td>
<td>2,353</td>
<td>19,192</td>
</tr>
<tr>
<td>4-7</td>
<td>7,436</td>
<td>6,555</td>
</tr>
<tr>
<td>8</td>
<td>1,069</td>
<td>1,710</td>
</tr>
<tr>
<td>Total</td>
<td>10,858</td>
<td>27,457</td>
</tr>
</tbody>
</table>
ZEV Truck Segment Summary
Reflecting Today’s Market

- Class 4-7: ~70% of sales suitable for electrification
- Class 2B-3 and Class 8 have suitable vehicles for electrification, but currently represent a smaller portion of total sales
  - High pickups sales assumed to be challenging
  - Tractor assessment for regional use requires further study
- Little difference between battery-electric and hydrogen fuel-cell when assuming no public refueling network
- Does not reflect future outlook
Wide Range of ZEV Class 4-7 Vehicles

School Bus
Manufacturers: 3 today, 2 coming
50-150 mi. range

Cutaway Shuttle
Manufacturers: 3 today
100-130 mi. range

Delivery Vans
Manufacturers: 5 today, 2 coming
80-120 mi. range

Cabover Chassis
Manufacturers: 1 today, 2 coming
100-150 mi. range

Conventional Chassis
Manufacturers: 1 today, 2 coming
100-200 mi. range
Several Class 2B-3 and Class 8 Vehicles

Tractor Trailer
Manufacturers: 1 today, 5 coming
150-500 mi. range

Refuse/Straight Trucks
Manufacturers: 2 today, 2 coming
80-130 mi. range

Terminal Trucks
Manufacturers: 3 today
~60-80 miles per charge

Cargo/Passenger Van
Manufacturers: 2 today, 1 coming
50-150 mi. range

Heavy-duty Pickup/Utility
Manufacturers: 1 coming
120-200 mi. range

Image credit: Bollinger Motors
Outlook for the Future

• Several manufacturers targeting categories assessed as more challenging
• Battery density improvements
  • Decrease weight and space constraints, or
  • Enable greater range
• Innovative designs reduce barriers
  • Skate board platforms
  • Composite bodies, e-axles
  • Same or better payload than diesel today
• Fueling/charging network development can address infrastructure concerns

Image Credit: Workhorse Group, Rivian
Vehicle Total Cost of Ownership (TCO)

- Diesel, BEV, and FCEV in 2018, 2024, and 2030
  - Class 3 passenger van
  - Class 6 walk-in stepvan
  - Class 8 regional day cab tractor
- Draft discussion document for comment on methodology and key assumptions
Total Cost of Ownership Analysis

• Vehicle capital costs
  • Vehicle price
  • Taxes
  • Financing costs
• Fuel costs
  • Dispensed fuel cost
  • LCFS credit revenue
• Other expenses
  • Maintenance cost
  • Midlife costs
  • Vehicle registration
  • Residual values at the end of analysis period
• Charging infrastructure costs
Vehicle Mileage and Analysis Period

- 12 year economic life assumed for all vehicles
- Lower bound on how long a vehicle stays in operation
- From DMV and EMFAC, most vehicles can last 20+ years
- Annual Miles – Based on EMFAC and a CALHeat report
  - Passenger van – 15,000 miles/yr
  - Stepvan – 24,000 miles/yr
  - Regional Tractor – 54,000 miles/yr
- Daily miles – assuming 300 days of operation

EMFAC 2017. https://www.arb.ca.gov/msei/categories.htm#emfac2017
Vehicle Capital Cost

- Diesel truck prices
  - Manufacturer websites and online truck marketplaces for new and used
- Zero emission truck prices
  - Diesel glider plus component cost estimate
  - Battery costs
    - Bloomberg light-duty battery cost projections with a five-year delay
    - Suggestion from last workgroup meeting
  - BEV Component costs\(^1\)
  - FCEV component costs\(^2\)
  - Retail price assumes 10% profit margin
- Taxes and financing costs included

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2. Ricardo, “Economic models for Truck TCO and Hydrogen Refueling Stations”
Example – Stepvan Purchase Price
Fuel Costs and Efficiency

• Fuel Cost
  • Diesel – Energy Information Administration - Annual Energy Outlook 2018 with higher cost of Low Carbon Fuel Standard (LCFS)
  • Electricity – CARB Battery-electric Truck and Bus Charging Calculator
  • Hydrogen – Email from Trillium

• Fuel Economy/Efficiency
  • Diesel truck – GHG Phase 2 calculated fuel economy
  • BEV – in-use data from available studies
  • FCEV – Class 2B-3 – 2.5x more efficient than diesel, Class 4-8 – 1.9x more efficient than diesel
  • Diesel fuel economy decreases significantly in urban operation and not modeled for van or tractor (plan to include in future updates)
Electricity Costs

- Assumes 20 vehicles charged overnight in yard
- Determined with the Battery-electric Truck and Bus Charging Calculator
  - Energy charges
  - Demand charges
  - Fixed fees
  - 90% charging efficiency

<table>
<thead>
<tr>
<th></th>
<th>Passenger van ($/kWh)</th>
<th>Delivery van ($/kWh)</th>
<th>Regional tractor ($/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LADWP</td>
<td>$0.10</td>
<td>$0.10</td>
<td>$0.10</td>
</tr>
<tr>
<td>PG&amp;E</td>
<td>$0.15</td>
<td>$0.14</td>
<td>$0.13</td>
</tr>
<tr>
<td>SMUD</td>
<td>$0.14</td>
<td>$0.11</td>
<td>$0.11</td>
</tr>
<tr>
<td>SDG&amp;E</td>
<td>$0.21</td>
<td>$0.20</td>
<td>$0.19</td>
</tr>
<tr>
<td>SCE</td>
<td>$0.13</td>
<td>$0.12</td>
<td>$0.11</td>
</tr>
<tr>
<td>Statewide Average</td>
<td>$0.14</td>
<td>$0.13</td>
<td>$0.12</td>
</tr>
</tbody>
</table>

Battery Electric Truck and Bus Charging Calculator, 2018. [https://ww2.arb.ca.gov/resources/documents/battery-electric-truck-and-bus-charging-cost-calculator](https://ww2.arb.ca.gov/resources/documents/battery-electric-truck-and-bus-charging-cost-calculator)
Fuel Cost and LCFS Revenue

- Analysis based on LCFS at $125/credit
  - Actual LCFS value higher credit at ~$190 today
- Electricity cost for depot charging eliminated
- Assumes hydrogen near parity with diesel by 2024 with low volume
Fuel Cost and LCFS Revenue

- Analysis based on LCFS at $125/credit
  - Actual LCFS value higher than $125/credit at ~$190 today
- Electricity cost for depot charging eliminated
- Assumes hydrogen near parity with diesel by 2024 with lower volume

2024 Operating Cost per Mile Comparison

<table>
<thead>
<tr>
<th></th>
<th>Passenger Van</th>
<th>Stepvan</th>
<th>Regional Tractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.20</td>
</tr>
<tr>
<td>Battery - electric</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.30</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>$0.30</td>
<td>$0.30</td>
<td>$0.45</td>
</tr>
</tbody>
</table>

LCFS credit offsets electricity cost

Total Cost per Mile
Other Costs

- Maintenance
  - Diesel – based on in-use data
  - BEV – 25% maintenance reduction
  - FCEV – same as diesel
- Residual value at end of operating life
  - Diesel – For sale price by truck age using TruckPaper
  - BEV – Assumes 50% of diesel
  - FCEV – Assumes 25% of diesel
Other Costs (Continued)

• Registration fees
  • Fee structure different for diesel and ZEV
  • ZEVs generally pay less

• Midlife costs
  • Diesel – no rebuild assumed due to lower mileage assumptions
  • BEV – no battery replacement for passenger van or delivery van, assumed to be necessary for regional haul tractor
  • FCEV – stack refurbishment included for all vehicles
Infrastructure Costs

• Diesel and hydrogen infrastructure costs factored into fuel costs
• BEV: Overnight depot charger installed cost
  • 19 kW charger costs based on PG&E and SCE SB350 applications
  • 100 kW charger based on transit bus data
• Costs spread over a 20 year period

<table>
<thead>
<tr>
<th></th>
<th>Passenger van</th>
<th>Stepvan</th>
<th>Regional tractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charger info.</td>
<td>19 kW AC</td>
<td>19 kW AC</td>
<td>100 kW DC</td>
</tr>
<tr>
<td>Charger Cost</td>
<td>$5,000</td>
<td>$5,000</td>
<td>$50,000</td>
</tr>
<tr>
<td>Infrastructure Upgrade</td>
<td>$20,000</td>
<td>$20,000</td>
<td>$55,000</td>
</tr>
</tbody>
</table>
Passenger Van TCO

Assumptions: 50 mi x 300 days x 12 years, retail diesel, overnight depot charge, retail H₂ price declining with volume, $25,000 total EV infrastructure costs spread over 20 years
Stepvan TCO

Assumptions: 80 mi x 300 days x 12 years, retail diesel, overnight depot charge, retail H₂ price declining with volume, $25,000 total EV infrastructure costs spread over 20 years
Regional Tractor TCO

Assumptions: 180 mi x 300 days x 12 years, retail diesel, overnight depot charge, retail H₂ price declining with volume, $105,000 total EV infrastructure costs spread over 20 years
BEV TCO vs Diesel Improves with Higher Daily Miles

Note: Assumes no changes in electricity costs and fuel economies
TCO Summary

• By 2024, BEVs likely to have TCO parity with diesel in a wide range of applications
  • Vehicles need to be placed where suitable
  • Better TCO opportunity for higher mileage/fuel use operations
  • LCFS credits likely to offset most electricity costs
  • Higher capital costs (vehicle/infrastructure) still an issue
• By 2030, hydrogen may approach TCO parity with diesel
  • Dependent on hydrogen station throughput and placement
  • May happen quicker if costs decline faster than assumed
  • Higher vehicle capital costs still an issue
Infrastructure Needs
Infrastructure Support

• Challenges to address
  • Planning, availability, and lead time
  • Access to refueling and standardization
  • Cost and scalability
• California has committed to support transportation electrification in medium- and heavy-duty
  • Southern California Edison – $343 million
  • Pacific Gas and Electric - $236 million
  • San Diego Gas and Electric - $151 million (pending)
Projected Infrastructure and Needs

- CPUC approved infrastructure plans exceed rule requirements
  - Innovative Clean Transit
  - AB739 – State fleet purchases
  - Zero Emission Airport Shuttle (proposed)
Infrastructure Discussion

- California utility programs (SB 350)
- Hydrogen production and station buildout