MT017: Medium Duty Parcel Delivery Truck
Thomas Griffin
June 2016
Program Overview

Hydrogen Fuel Cell Extended-Range Battery Electric Vehicles Demonstration

- $3.0 million from Department of Energy
- Integration of fuel cells into 20 battery electric pickup and delivery vehicles, PUDs
  - BP1 – 1 truck
    - Design
    - Integrate & test fuel cell systems
      - Safety
      - Communication
      - Performance
      - Reliability
    - Validate in revenue service
  - BP2 – 19 trucks
    - Integrate hydrogen fuel cell systems
    - Operate in revenue service in Memphis, TN and several locations in CA
## Project Main Objectives

<table>
<thead>
<tr>
<th>DOE Project Objectives</th>
<th>Project Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstrate / deploy hydrogen and fuel cell technologies in real-world environments.</td>
<td>20 parcel delivery trucks will operate one shift 260 days annually for approximately 10 hours per day.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ancillary Objectives</th>
<th>Project Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operate 5,000+ hours</td>
<td>Over approx. 1.92 years, this amounts to approximately 5,000 hours per truck. Total fleet activity is 100,000 hours annually. (Numbers represent minimum.)</td>
</tr>
<tr>
<td>Reduce petroleum consumption</td>
<td>Each diesel truck uses 2,600 gallons per year. The program will reduce diesel consumption by 100,000 gallons over ~1.92 years.</td>
</tr>
<tr>
<td>Reduce emissions</td>
<td>A net of 270 metric tons of CO2 will be prevented.</td>
</tr>
</tbody>
</table>

### Potential Expansion

<table>
<thead>
<tr>
<th>Similar Assets &amp; Duty Cycles (count)</th>
<th>7000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Utilization Range (miles)</td>
<td>20k - 50k</td>
</tr>
<tr>
<td>Approx Annual Fuel Displaced (gal)</td>
<td>14M</td>
</tr>
<tr>
<td>Annual CO2 Avoided (Metric Tons)</td>
<td>69,500</td>
</tr>
</tbody>
</table>
Program Overview

Timeline
• Grant awarded – October 2015
• Kickoff meeting – May 2016
• Project end – October 2019
• Project completion - < 5%

Budget
• DOE – $3.0M
• Partners – $3.367M

Barriers
• Unknown ability to meet safety, performance & reliability needs
• Variable energy requirements
  – Route differences
  – Parasitic losses (HVAC, ancillary systems, effects of temperature)
• EV & FC control systems integration
• Fuel availability

Partners
• U.S. Department of Energy
• FedEx Express – Prime rec
• Plug Power – Fuel cell manufacturer
• Workhorse Group – Truck manufacturer
DOE Goals

- **Office of Energy Efficiency and Renewable Energy**
  - **Fuel Cell Technology Office**
    - Provide clean, safe, secure, affordable and reliable energy
    - Diverse domestic resources, provides energy security, reduces petroleum use, lower GHG emissions and criteria pollutants
Relevance: FedEx Express Strategy

Connect the world responsibly and resourcefully

- **Business case**
  - Reduce fuel use
  - Sustainability
  - Energy independence
  - Lower Total Cost of Ownership

- **Desire for long-range zero emission PUD**

- **Continued need for zero emissions alternative to traditional battery EV**
  - Weight reduction
  - Cost reduction
  - Refueling time reduction

- **Evaluation of Hydrogen Fuel Cells as an On-Board Traction Battery Charger**

*Goal:
Increase FedEx Express vehicle fuel efficiency 30% from a 2005 baseline by 2020

*Progress:
In FY15 we increased efficiency by 4%, cumulatively increasing efficiency by more than 33.5% from a 2005 baseline and surpassing our goal five years early. We believe we can make significant further savings and we are currently working on a new vehicle sustainability goal.

Progress against goals for increased fuel efficiency:
- 30% by 2020
- 33.5% in 2015
Relevance: FedEx Express Fleet Size 71,309

The 2nd Largest Fleet in North America

<table>
<thead>
<tr>
<th>WORLD WIDE VEHICLE COUNT</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk-In</td>
<td>29,610</td>
</tr>
<tr>
<td>GSE (powered)</td>
<td>15,007</td>
</tr>
<tr>
<td>Panel Van</td>
<td>11,440</td>
</tr>
<tr>
<td>Straight</td>
<td>3,572</td>
</tr>
<tr>
<td>Tractor</td>
<td>3,259</td>
</tr>
<tr>
<td>Other</td>
<td>8,421</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALTERNATIVE VEHICLE COUNT</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSE</td>
<td>3,300</td>
</tr>
<tr>
<td>HEV</td>
<td>424</td>
</tr>
<tr>
<td>EV</td>
<td>190</td>
</tr>
<tr>
<td>CNG</td>
<td>57</td>
</tr>
<tr>
<td>LPG</td>
<td>32</td>
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</table>

* Fleet count October 2015
Relevance: FedEx Goals

Vehicle Fuel Economy

2020 Fuel Economy Goal - 30%

% Improvement from FY05

<table>
<thead>
<tr>
<th>Year</th>
<th>FY06</th>
<th>FY07</th>
<th>FY08</th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
<th>FY16</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPG</td>
<td>9.0</td>
<td>9.3</td>
<td>11.8</td>
<td>14.1</td>
<td>15.1</td>
<td>16.9</td>
<td>22.6</td>
<td>27.2</td>
<td>29.9</td>
<td>33.6</td>
<td>46.0</td>
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</table>

142 Million Gallons Saved Since FY05
1.4 Million Metric Tons of CO2 Reduced

FY15 Efficiency Gains and Cost Savings

<table>
<thead>
<tr>
<th>Environmental objective</th>
<th>FedEx initiative</th>
<th>FY15 cost savings</th>
<th>FY15 emissions avoided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce aircraft emission intensity 30% from a 2005 baseline by 2020</td>
<td>Aircraft fleet modernization, FedEx® Fuel Sense operational improvements</td>
<td>$296 million</td>
<td>1.15 million metric tons of CO2 avoided</td>
</tr>
<tr>
<td>Increase FedEx Express vehicle fuel efficiency 30% from a 2005 baseline by 2020</td>
<td>Fuel-efficient driving, vehicle technology improvements and alternative fuel usage</td>
<td>$65 million</td>
<td>215,000 metric tons of CO2 avoided</td>
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</tbody>
</table>

REPLACE
Optimize routing and driving habits to reduce mileage and fuel use

REVOLUTIONIZE
Identify and invest in future technologies such as alternative fuel, hybrid-electric and electric vehicles

REPLACE
Upgrade vehicles to more efficient ones wherever possible

FedEx Express
Relevance: Mileage Management

Right Vehicle
Right Route
Mileage Bands – Miles Per Year

- HYBRID: 15,000 – 30,000
- COMPOSITE BODY REACH: 10,000 – 40,000
- EXISTING W700: UP TO 20,000
- SPRINTERS TYPE: 10,000 – 50,000
- EV: UP TO 16,000
- eREV: > 16,000

PAYLOAD – STOPS – VOLUME

RANGE – SPEED – TIME

Right Technology
Right Duty Cycle
### Approach/Milestones

<table>
<thead>
<tr>
<th>Task Title</th>
<th>Task or Milestone Completion Date</th>
<th>Original Planned</th>
<th>Revised Planned</th>
<th>Actual Completed</th>
<th>Current % Complete (0-100)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Budget Period 1 Demonstration</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Task 1: Program Management (3+ years)</td>
<td>Completed Quarterly and Final Reports</td>
<td>Quarterly and 10/1/19</td>
<td>Quarterly and 10/1/19</td>
<td></td>
<td>12.5</td>
</tr>
<tr>
<td>Task 4: First Unit Integration (8 weeks)</td>
<td>Integrated Truck Performs per Stated Specifications</td>
<td>4/1/2016</td>
<td>10/31/2016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 5: First Unit Validation (4-8 weeks)</td>
<td>Evaluation Document of First Unit Performance</td>
<td>6/1/2016</td>
<td>1/31/2016</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Budget Period 1 Go/No-Go Decision Point</strong></td>
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<tr>
<td>Task 1 (continued): Program Management (3+ years)</td>
<td>Completed Quarterly and Final Reports</td>
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</tr>
<tr>
<td>Task 6: Remaining Fleet Builds (8 weeks)</td>
<td>FC Systems Pass Factory Acceptance Testing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 7: Remaining Fleet Integration (8 weeks)</td>
<td>Integrated Trucks pass FAT</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Task 8: Full Deployment (4 weeks)</td>
<td>Trucks Deployed and Operating in PUD Application</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Task 9: Continued Deployment (152 weeks)</td>
<td>Deployment Exceeds 5000 hours in PUD application</td>
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</table>
Accomplishments

• Identified replacement EV OEM
  – Already has experience with range extension
• Technical kick-off meeting among program partners at manufacturing facility
• Program kick-off meeting among program partners at Memphis Superhub
• Analysis of worst case drive cycle (150 mile total route length with 60 mile stem length at beginning and end)
• Preliminary mechanical layout of batteries, fuel cell, converter H2 storage
• Planning in process for dyno testing
Accomplishments

Usage profile simulation to confirm right sizing
Includes drive cycle, parasitic losses, regenerative braking

Baseline Electric Vehicle

Fuel Cell Extended Range Electric Vehicle
Accomplishments

Preliminary mechanical layout of batteries, fuel cell, converter H2 storage
Accomplishments

• Identified replacement EV OEM
  – New EV subrecipient has experience with range extension
• Technical kick-off meeting among program partners at manufacturing facility to discuss component requirements and placement
• Program kick-off meeting among program partners at Memphis Headquarters
• Analysis of 150 mile drive cycle with up to 60 mile stem length at beginning and end
• Planning in process for dyno testing
  – Variable payloads
  – Temperature effects
  – Parasitic loads
Future Work

Budget Period 1

• Safety Planning
• First Fuel Cell Unit Build
• First Unit Integration
• Verify Optimization Analysis
  – Dyno Testing
  – Durability Testing
• First Unit Validation
Project Phase BP2

Budget Period 2
- Fuel system design
- Safety planning

Optimization modeling
- Battery capacity (kW-hr)
- Fuel Cell Power (kW)
- Hydrogen Tank capacity (kg H₂)

Safety Planning
- Communications and Control Strategies
- Leak detection and fuel isolation or purging

Integration of fuel cell into first truck
- Performance testing
- Shock and vibration testing

Commissioning
- Place into revenue service
- Validation
- Prepare for BP2
Collaborations

U.S. Department of Energy
Project Sponsor

Federal Express
Prime Recipient

Subrecipients

NREL
Vehicle and Fuel Cell Data Collection

PLUG POWER
Fuel Cell Manufacturer

WORKHORSE
EV chassis and Powertrain Manufacturer

MORGAN OLSON
Truck Body Manufacturer

Vehicle Safety Regulations

NATIONAL RENEWABLE ENERGY LABORATORY

Hydrogen Safety Advisors

TRANSPORTATION.GOV
U.S. Department of Transportation

Pacific Northwest National Laboratory
Thank You

- FedEx Low Emission
  Hybrid Electric

- FedEx Zero Emission
  All Electric

- FedEx solutions for a
  more sustainable world

- FedEx Extended Range Electric

- FedEx Fuel Sense