Electrification of Transportation - Keshav Sondhi

October 2010
Who killed the Electric Car?

• Late 19th - early 20th century EVs were common

Oliver Parker Fritchle
Lincoln NE - NYC
31 October 1908 - 28 November 1908

100 Mile Fritchle Battery circa 1908
Who killed the Electric Car?

- Amongst other factors, ironically, the invention of the electric starter motor resulted in the first demise of the EVs in the early 20th century.
FedEx Electrification

- **History** – (alternative/cleaner power sources)
  - Battery Electric Vehicles
  - Bio-fuels
  - CNG
  - Fuel Cell
  - Hybrid Electric vehicles
  - LPG

- Electric Vehicles
  - 1992 Lead Acid Battery Electric Vehicle (BEVs)
  - 2000 – Ni-MH Hybrid Electric Vehicles
  - 2006 – Li-ion BEVs
Timeline

2000
FedEx Express & Environmental Defense
begin working together to develop low emission HEV (E700)

2004
FedEx receives
EPA Clean Air
Excellence Award &
Harvard JFK School of Govt
Roy Family Award

2005
FedEx receives
CALSTART
Blue Sky Award

2006
18 Pre-Production
FCCC/Eaton
Hybrids deployed:
- Tampa
- Sacramento
- New York City
- Washington, DC

75 FCCC/Eaton
Hybrids deployed:
- Portland
- San Francisco
- Denver
- Chicago
- Ann Arbor
- Toronto
- Washington, DC
- Memphis
- Sacramento
- New York City

2 Isuzu Hybrids
deployed in
Japan

2007
Agreement w/Azure
For 20 gasoline
Hybrids

Agreement w/hveco
For 10 Daily Hybrids
1 Isuzu hybrid (Japan)

2009
Hybrids deployed:
92 W700 Repowered W700s
10 MODEC all-electric

Agreement for 51 Azure
gasoline hybrids

2010
Hybrids and
EVs deployed:
- 2 Hino Hybrids
  (Hong Kong)
- 5 EVs (Paris)
- 4 EVs
  (Los Angeles)
- 10 M2 Hybrids
  (USA)

Development & testing of pre-production units
Hybrids in Commercial Fleets

FedEx worked with the Environmental Defense Fund in 2000 to engineer the first hybrid trucks — and to share what we learned with other companies. By 2005, we had 18 hybrid trucks on the road. A year later, the technology we helped to develop had spread through the entire transportation industry. By the end of 2010, there will be 1,745 hybrid delivery trucks on the road in the U.S., used by a wide variety of companies.
**Fleet Optimization**

- **Optimized fleet**
  - Place the right vehicle for the mission on the route
    - Right vehicle for the route (payload, cubic capacity)
    - Right technology for the route (power source)

FedEx EV at a delivery depot

Fleet distribution by load requirement and periodic utilization (miles/day)

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**EV Initiatives**

October 2010
Fuel Economy Improvement

- **Optimized fleet**
  - Right vehicle
  - Right technology

FedEx' efforts in improving fuel economy of conventional fleet in the last few years (14.1%)
BEV Advantages

- Electric Vehicle Advantages:
  - Zero local tailpipe emissions
  - Reduced reliance on petroleum
  - Torque curves - Simplicity
    - ICE vs
    - EV
  - Operating costs: 1/4th of a regular diesel powered vehicles
Environmental Benefits

Reduction in Carbon footprint by using an EV is a function of:
- Electricity generation source
- Replaced ‘conventional’ vehicle
Component Interchangeability

Nissan Leaf*  Navistar eStar

<table>
<thead>
<tr>
<th>Performance</th>
<th>Nissan Leaf</th>
<th>Navistar eStar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving range</td>
<td>100 miles</td>
<td>100 miles</td>
</tr>
<tr>
<td>Max speed (km/h)</td>
<td>85 mph</td>
<td>50 mph</td>
</tr>
</tbody>
</table>

**Motor**

| Type | AC motor | DC Permanent Magnet |
| Max power (kW) | 80kW | 70kW |
| Max torque (Nm) | 280Nm | 300Nm |

**Battery**

| Type | Laminated lithium-ion battery | Laminated lithium-ion battery |
| Total capacity (kWh) | 24kWh | 80kWh |
| Battery layout | Under seat & floor | Within frame under cargo area |

**Charging**

| Quick charger DC 50kW (0 to 80%) | Less than 30 min | -NA- |
| AC200V charger | Less than 8 hrs | Less than 8 hrs |

Larger scale commonality of components between electric cars and electric trucks should further enable cost reduction for trucks through economies of scale.

BEV Challenges

- **Electric Vehicle Challenges:**
  - Cost
    - Battery - cost, warranty and longevity
  - Reliability
  - Battery size/weight
  - Grid/Utility readiness
    - Infrastructure
    - Reliability
Battery Cost and Life

- **Battery Cost Curve**
  - DOE Chart

DOE expects battery costs to halve in next 3 years

Battery warranties are improving
Battery Weight and Size

- **EV truck batteries**
  - Could be 1,000+ kg in mass
  - Heavier vehicle frame required for the added mass
  - Reduced payload or higher GVW for same payload as conventional vehicles
    - May affect driver’s license requirements

*Photo: General Motors – Volt Battery – Source Autoblog

*Photo: Nissan – Leaf Battery – Source Autoblog*
Grid readiness – Supply and Infrastructure
- Street side transformers 50kW powering 4/5 households
- EV loads of up-to 10kW each
- 100 Vehicle metro stations Could create MW level requirements
- Reliability – We will be the fueling station
January 2010 SAE finalizes J1772 - First two levels of charging
- AC Level 1: 120 V, 1 phase, up to 16 A
- AC Level 2: 240 V, 1 phase, up to 80 A
- DC Fast Charger Level 3 being worked on
FedEx Electrification

- **Changing Landscape**
  - 4 years ago:
    - Modec
    - Smith
  - Now - Several other global mainstream manufacturers
    - Navistar (Modec)
    - Freightliner Custom Chassis
    - Mercedes
    - Iveco
    - Renault

Mass produced Mitsubishi iMiev
Location of FedEx Alternate Drive-train Vehicles

348 HEV & EV units in service with over 7 million miles of service to date

- London – 10 Modec (testing)
- Italy, Fr. & Ger. – 10 Ivec (testing)
- Tokyo – 6 Isuzu (testing)
- Paris – 5 Modec (testing)
- Hong Kong – 2 Hino (testing)

Cities with HEV & EV units in service:
- Ann Arbor 2
- Toronto 5
- Portland 15
- Sacramento 9
- San Francisco 28
- Los Angeles Metro 91
- New York City 143
- Wash. DC 3
- Tampa 3
- San Diego 7
- Memphis 3
- Denver 4
- Chicago 2
- London – 10 Modec (testing)
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FedEx Express Alternate Drivetrain Family

- FCCC/Eaton W700
- Modec/eStar Electric
- Ford/Azure W700
- Isuzu Hybrid
- Hino Hybrid
- Iveco Hybrid

19 October 2010

EV Initiatives