Challenges and Opportunities for New Propulsion Technologies in Commercial Vehicles

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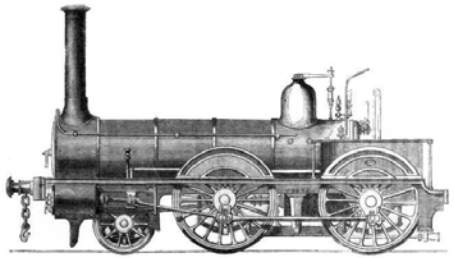
October 4th, 2018

Technology Disruptions

- New technologies periodically improve the movement of freight and people
- Usually these disruptions result from a combination of multiple innovations

SS California 1848



1850's locomotive

1917 Model T

1931 diesel truck

?

3 Major Drivers of Change

Regulations

- Subsidies towards greener technologies
- Greater willingness to invest in infrastructure
- Impact on energy prices through carbon taxes
- Fossil fuel bans

Technology

- Technological breakthroughs overcoming technical barriers
- Increased scale in disruptive technologies reflected in much lower costs
- Accelerated infrastructure pacing via private sector investments

Energy Prices

- Energy prices based on countries' locally-produced natural resources
- New approaches to resources extraction
- Changing demand patterns

Key Drivers for Commercial Vehicle Propulsion Technology Choices

Total Cost of Ownership

- Initial Cost
- Fluid Economy
- Maintenance

Dependability

- Reliability
- Durability

Emissions

- Sociability

Commercial Vehicles and New Propulsion Technologies

Great Opportunity for Application of New Technology

- High Energy Use
- Often predictable routes
- Sometimes controlled environment

Significant Challenges to Adoption of New Technology

- Uptime is critical
- Durability requirements are demanding
- Specialized requirements and low volumes

- LH truck ~ 250MWhr/yr (50x pass car)
- Bus & delivery trucks often have fixed routes
- Forklift and drayage trucks operate in controlled environments

- LH truck: 1 day downtime ~ $1000
- 10% of LH trucks run 250k mi/yr
- City buses often operate 16-20 hr/day
- City bus: 5000 new veh/yr in North America

Technology Requirements for Commercial Vehicles

	Diesel technology			Electric powertrain technology	
	Energy Storage	Refuel time	Life	Energy Storage	Refuel time
	1.6 MWh (100 gal @ 40% eff)	15 min (~5MW usable energy transfer)	1M miles 40k hrs	400-800 kWhr (battery)	1+ hr (@350kW refuel time increases by ~14x)
	0.8 MWh	5-10 min (~5MW usable energy transfer)	40k hrs	400 kWhr (battery)	@350kW refuel time increases by ~14x

Energy transfer for electric commercial vehicles remains a challenge. For a fleet, the challenge is significant.

THE ELECTRICITY IS COMING


20-25
YEARS OF
TRANSITION
Seaco

Phase 1

Sociability need

Capability to use current technology

Suitable drive cycle

Subsidies

High density urban cities
Emissions containment areas
Industrial policy driven cities

Phase 2

Improved technology

Wider local regulations

Some subsidies

Broader charging infrastructure

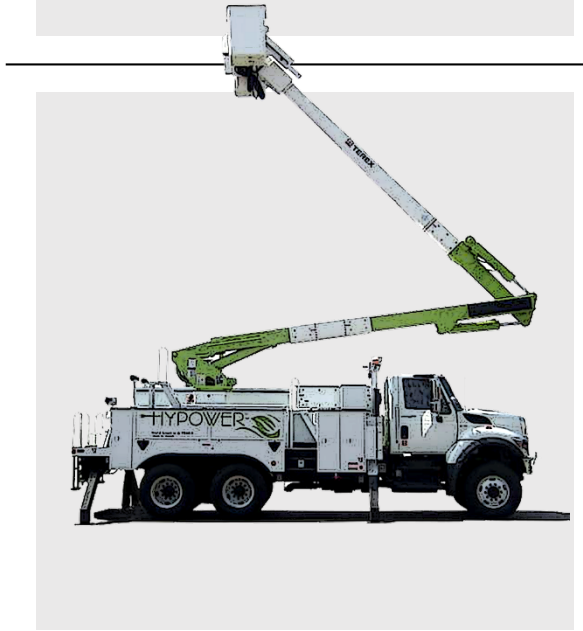
High density urban cities
ULE Zones in US/Western EU

Phase 3

Viable economics

Further technology breakthroughs

Leapfrogging diesel emissions
Traditional commercial vehicles



Powertrain of now

DIESEL

HD Long Haul

Delivers coast to coast
500-600 miles/day
Empty interstates
Steady cruise speeds

Unreliable access
to natural gas

NATURAL GAS

HD Regional Haul

Dedicated route; 200-300 miles/day

Access to economically-priced
natural gas; Incentivized

Refuse Truck

Access to making the fuel cheap
Air quality issues in service area

HYBRID

Utility Truck

Makes repairs at regional/
local sites

During repair work,
vehicle-to-grid power
electronics provides power
through battery/ engine to
keep neighborhood in power

FULLY ELECTRIC

Urban Transit Bus

Densely populated area
Air/noise quality issues

Electricity readily available
in route & at depot

Lowers operation costs; Capital cost
borne by FTA grant process

Diversity of application specific solutions

Electric power plays an increasingly important role, but pace of adoption is uncertain

Pure electric solutions for applications with lower energy requirements, fuel cell for higher energy applications

Autonomous changes missions and business models

Powertrain of the future?

FULLY ELECTRIC

Low Energy

Requirements

Densely populated area
Air/noise quality issues

Electricity readily available in route & at depot

FUEL CELL

High Energy Requirements

200-300+ miles/day

Fast refuel, better energy storage capacity

AUTONOMOUS

Where driver costs high

Hard to predict pace

May impact vehicle design and powertrain design

Q+A