Defining an Economic Niche for Hybrid DMUs in Commuter Rail

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Current Commuter Rail Technology Options

- Locomotive-Hauled Coaches – LHC
Current Commuter Rail Technology Options

• Electric Multiple Units – EMU
Current Commuter Rail Technology Options

• Diesel Multiple Units – DMU
Emerging Commuter Rail Technology

- Hybrid Diesel Multiple Units – HDMU
  - Diesel-Electric Propulsion
  - Regenerative Energy Capture
  - Storage
Why is a Diesel Guy at Hydrail?

• Presenting an Economic Analysis:
  • New Technology vs. Established
  • On-board Power vs. External Power

• Similarities between hybrid drive cycle, regardless of energy source
Hybrid Drive Multiple Unit Propulsion Architecture

Diesel
Biodiesel
LPG/CNG
Hydrogen
Other

ENGINE

STORAGE

DRIVE
Energy Transfer Within a DMU

- 2 DMUs
- 10 Mile Route
- 11 Stops
- 60 MPH

236 kWh
41% LF

Energy (kWh)

Time (sec)

Drive

Diesel Engine
Energy Transfer Within an HDMU

- 2 HDMUs
- 10 Mile Route
- 11 Stops
- 60 MPH

161 kWh
26% LF
Potential Fuel Savings of HDMUs

![Graph showing potential fuel savings with Hybrid Drive compared to engine load factor without Hybrid Drive. The graph indicates a positive correlation between the reduction in fuel consumption with Hybrid Drive and the engine load factor without Hybrid Drive.]

- Potential Fuel Savings of 40% with Hybrid Drive.
- Potential Fuel Savings of 30% with Hybrid Drive.
- Potential Fuel Savings of 20% with Hybrid Drive.
- Potential Fuel Savings of 10% with Hybrid Drive.
- Potential Fuel Savings of 0% with Hybrid Drive.

Engine Load Factor without Hybrid Drive

Reduction in Fuel Consumption with Hybrid Drive
Potential Fuel Savings of HDMUs

Graph showing the relationship between the percentage of travel time spent in heavy acceleration and the reduction in fuel consumption with hybrid drive.
## Relative Advantages of Commuter Rail Technologies

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<tr>
<th>Type</th>
<th>Cap</th>
<th>Ops</th>
<th>Maint</th>
<th>Comments</th>
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<tr>
<td>LHC</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Recent Starts</td>
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<tr>
<td>EMU</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Established Services</td>
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<tr>
<td>DMU</td>
<td>Low</td>
<td>Mid</td>
<td>Mid</td>
<td>New Starts and Feeder</td>
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<tr>
<td>HDMU</td>
<td>Mid</td>
<td>Low</td>
<td>High</td>
<td>Potential of Improved Acceleration and Reduced Emissions</td>
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Hypothesis

• Life Cycle Cost Analysis Will Show When HDMU Operational Savings Outweigh Vehicle Capital and Maintenance Penalties

• Combinations of Route Profile, Ridership, and Service Frequency
Life Cycle Cost Analysis

- Capital
- Operations
- Maintenance

\[ LC(t) = \text{Cap} + (O&M)(1 + i)^t \]
Comparison of Technologies Through Life Cycle Costs

Payback:

\[
t = \log \left[ \frac{(Cap_2 - Cap_1) \ln(1+i)}{O & M_1 - O & M_2} \right] + 1
\]

\[
\log(1+i)
\]

Payback

Type 2 Lowest Cost

Type 1 Lowest Cost

Vehicle Type 1

Vehicle Type 2
Capital Costs Unique To Each Technology

- Vehicles
- Traction Electrification System (TES)
- Maintenance Facility Electrification or Fueling Station
- Civil Costs Such as Bridges and Retaining Walls
- Signal Impedance Bonds for EMUs
Fleet Capital Costs

- Vehicle Capital Costs from Recent Contracts and Estimates
  - HDMU Estimated as DMU + $700K
- Trainsets Sized by Ridership and Service Frequency
- Fleet Sized By Travel Times, Turn Times, Service Frequency, and Spares
Sample Capital Costs

76 Round Trips per Day
23 Miles, 8 Stops, Up to 79 MPH

Capital Costs Unique to Technology ($M, 2009)

Rolling Stock  Facilities  TES  Signals

2-Car Consists  4-Car Consists  6-Car Consists
Operating Costs

• Non-Energy
  • On-Board Staffing
  • Labor Burdened for Indirect Costs

• Energy
  • Route Travel Modeling, Service Plan
  • Electric Power: $0.095 per kWh
  • Diesel Fuel: $3.00 per gallon
Maintenance Costs

- Rolling Stock
  - Daily Maintenance and Inspection
  - Programmed Life Cycle Maintenance (LCM)
  - Running Repair and Corrective Maintenance
  - Heavy Repair
  - Mid-Life Overhaul
  - Assumed 30 Year Life
Maintenance Costs

- Traction Electrification System (TES)
  - Traction Power Substations
  - Autotransformers
  - Overhead Contact System (OCS)
Sample O&M Costs

76 Round Trips per Day
23 Miles, 8 Stops, Up to 79 MPH

Annual O&M Cost ($M, 2009)

Operations, Non-Energy
Operations, Energy
Maintenance, Rolling Stock
Maintenance, TES
Capital and O&M Cost Differences

The image contains a scatter plot graph comparing Initial Capital Cost Premium ($M, 2009) vs Annual O&M Cost Premium ($M, 2009) for different route lengths (10 Mile, 23 Mile, 40 Mile) and carriage consist sizes (2-Car Consists, 4-Car Consists, 6-Car Consists).

The graph includes data points for EMU vs DMU, and it shows the cost differences for various combinations of route lengths and carriage consist sizes.
Can EMUs be a Smart Investment?

-ROI

+ROI

76 Round Trips per Day

EMU vs DMU

Initial Capital Cost Premium ($M, 2009)

Annual O&M Cost Premium ($M, 2009)

2-Car Consists
4-Car Consists
6-Car Consists
HDMU as an Investment

![Graph showing HDMU vs DMU with data points for 2-Car Consists, 4-Car Consists, and 6-Car Consists. The graph compares Annual O&M Cost Premium ($M, 2009) against Initial Capital Cost Premium ($M, 2009).](image)
Payback on Short Route, High Utility

Technology Cost Comparison
Lowest Life Cycle Cost by Year of Service
76 Round Trips per Day
10 Miles, 11 Stops, 60 MPH

Cars per Train
- DMU
- HDMU
- EMU
Short Route, Moderate Utility

Technology Cost Comparison
Lowest Life Cycle Cost by Year of Service
24 Round Trips per Day
10 Miles, 11 Stops, 60 MPH

Cars per Train

- DMU
- HDMU
- EMU
Payback on Moderate Route

Technology Cost Comparison
Lowest Life Cycle Cost by Year of Service
76 Round Trips per Day
23 Miles, 8 Stops, Up to 79 MPH
Payback on Long Route

Technology Cost Comparison

Lowest Life Cycle Cost by Year of Service
76 Round Trips per Day
40 Miles, 9 Stops, Up to 70 MPH

Cars per Train

- Blue: DMU
- Red: HDMU
- Light Gray: EMU
EMU Target Service

- Short Routes
- High Vehicle Utility
- Significant Time Accelerating
  - Moderately Spaced Stations
  - High Track Speed
DMU Target Service

- Long Routes
- Low Vehicle Utility
- Short Consists
- Minimal Time Accelerating
  - Widely Spaced Stations
  - Moderate Track Speed
  - Minimal Engine Transients
HDMU Target Service

- Short Routes (≤ 20 Miles)
- Moderate Vehicle Utility
- Short Consists (≤ 2 Vehicles)
- Significant Time Accelerating
  - Closely Spaced Stations (< 2 Miles)
  - Moderate Track Speed
  - Significant Tractive Effort Transients
Questions?