



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

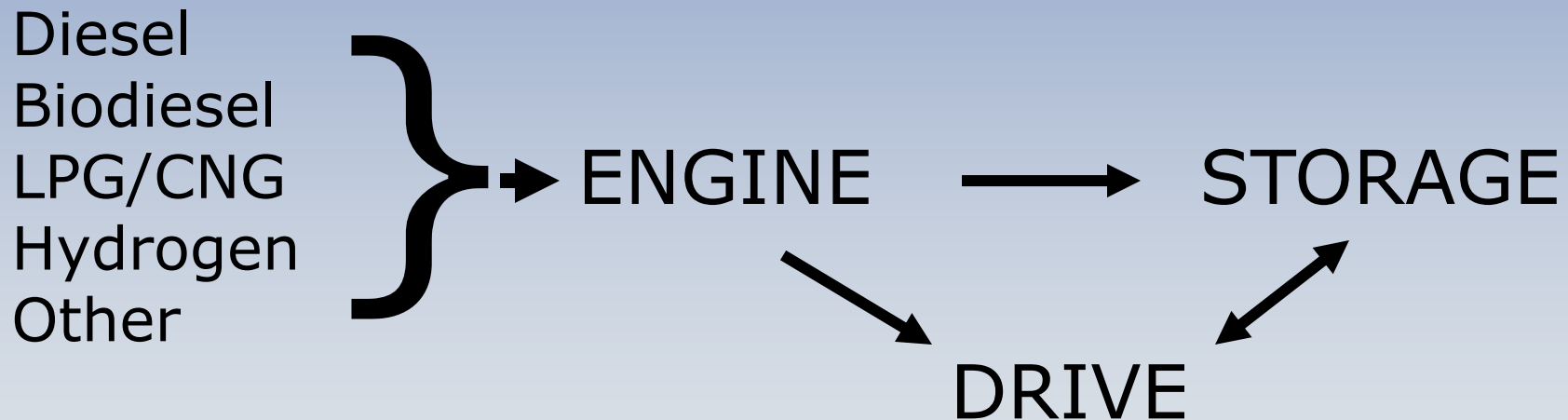


Why is a Diesel Guy at Hydrail?

- Presenting an Economic Analysis:
 - New Technology vs. Established
 - On-board Power vs. External Power
- Similarities between hybrid drive cycle, regardless of energy source

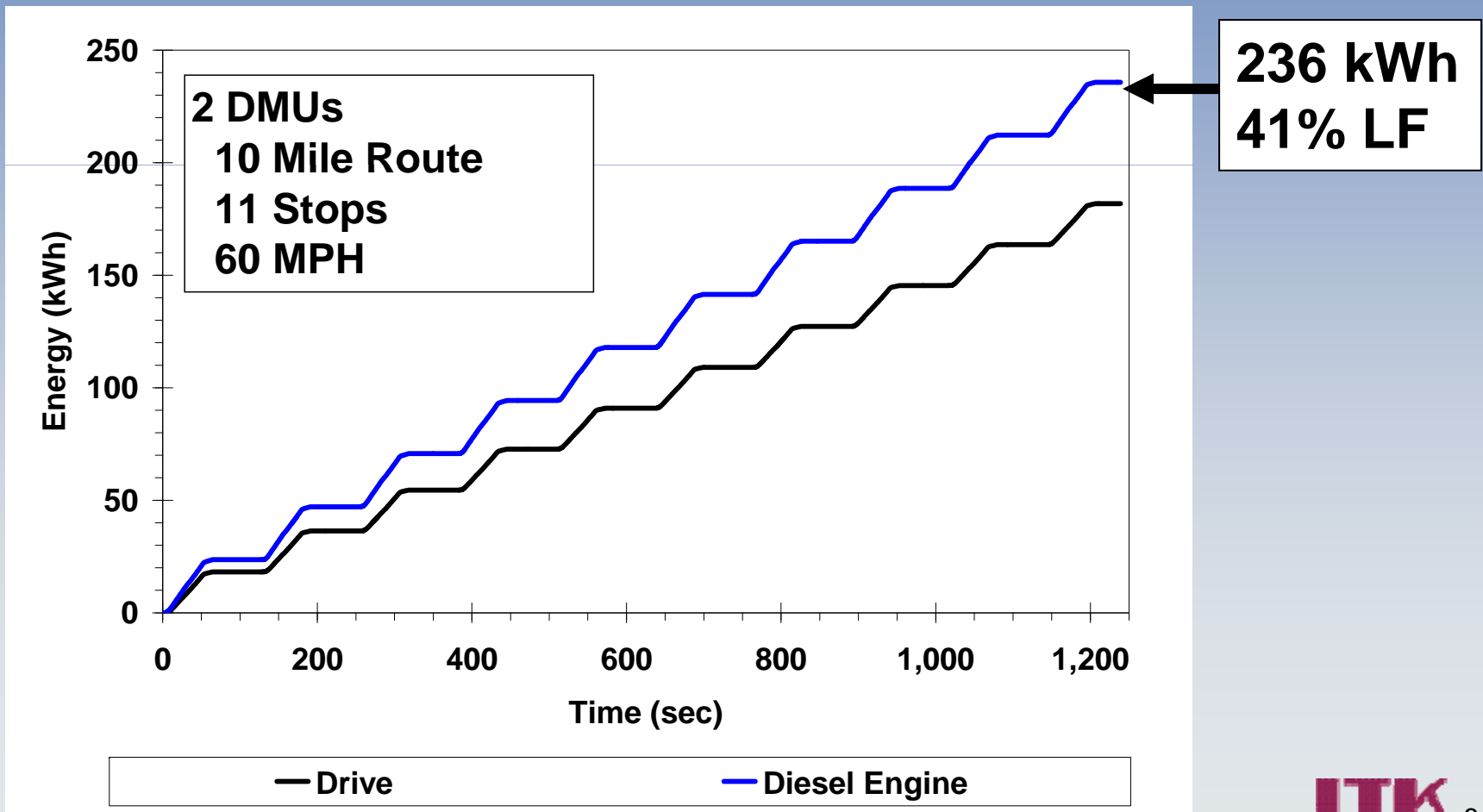


Hybrid Drive Multiple Unit Propulsion Architecture



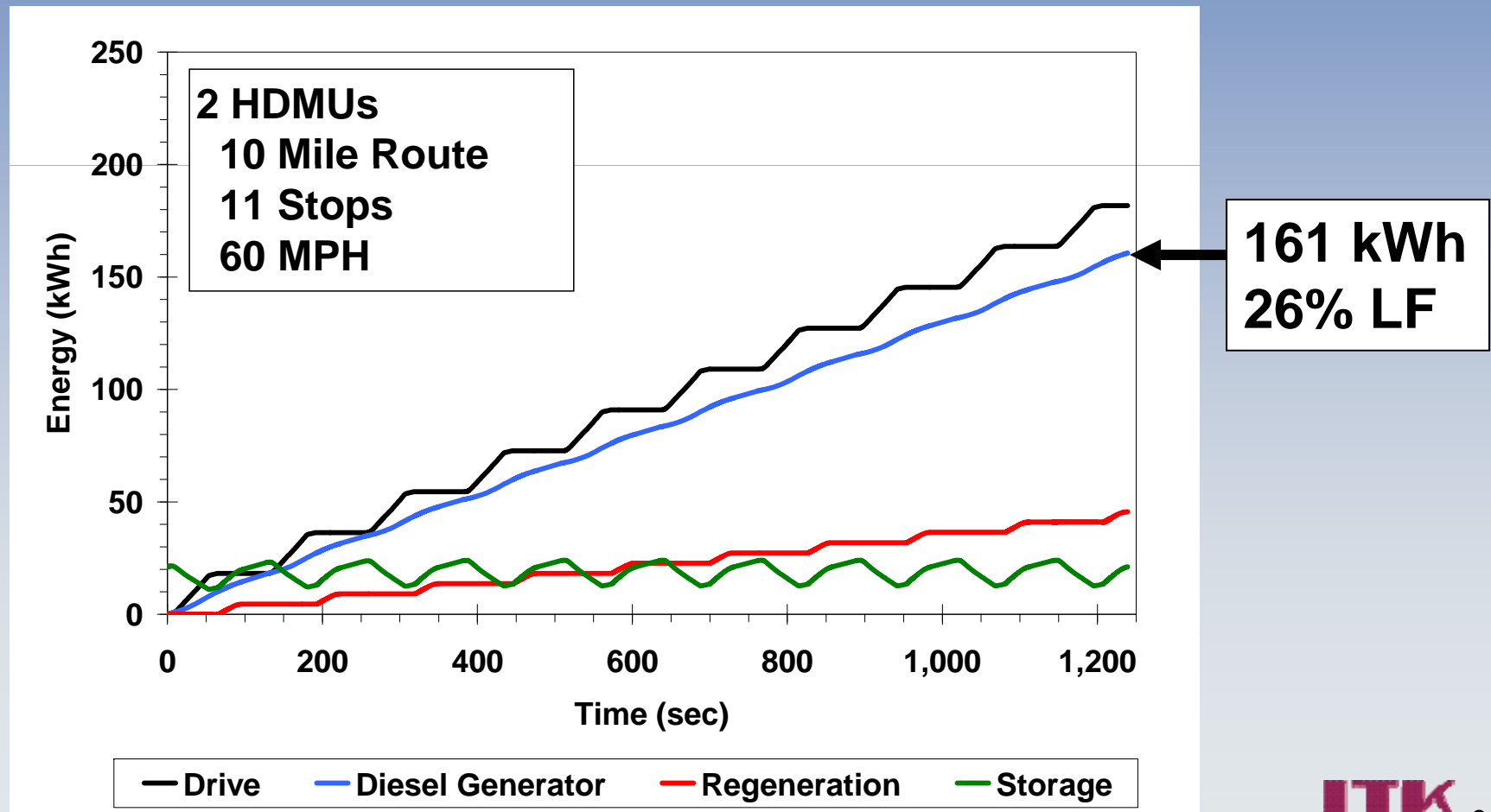


Energy Transfer Within a DMU



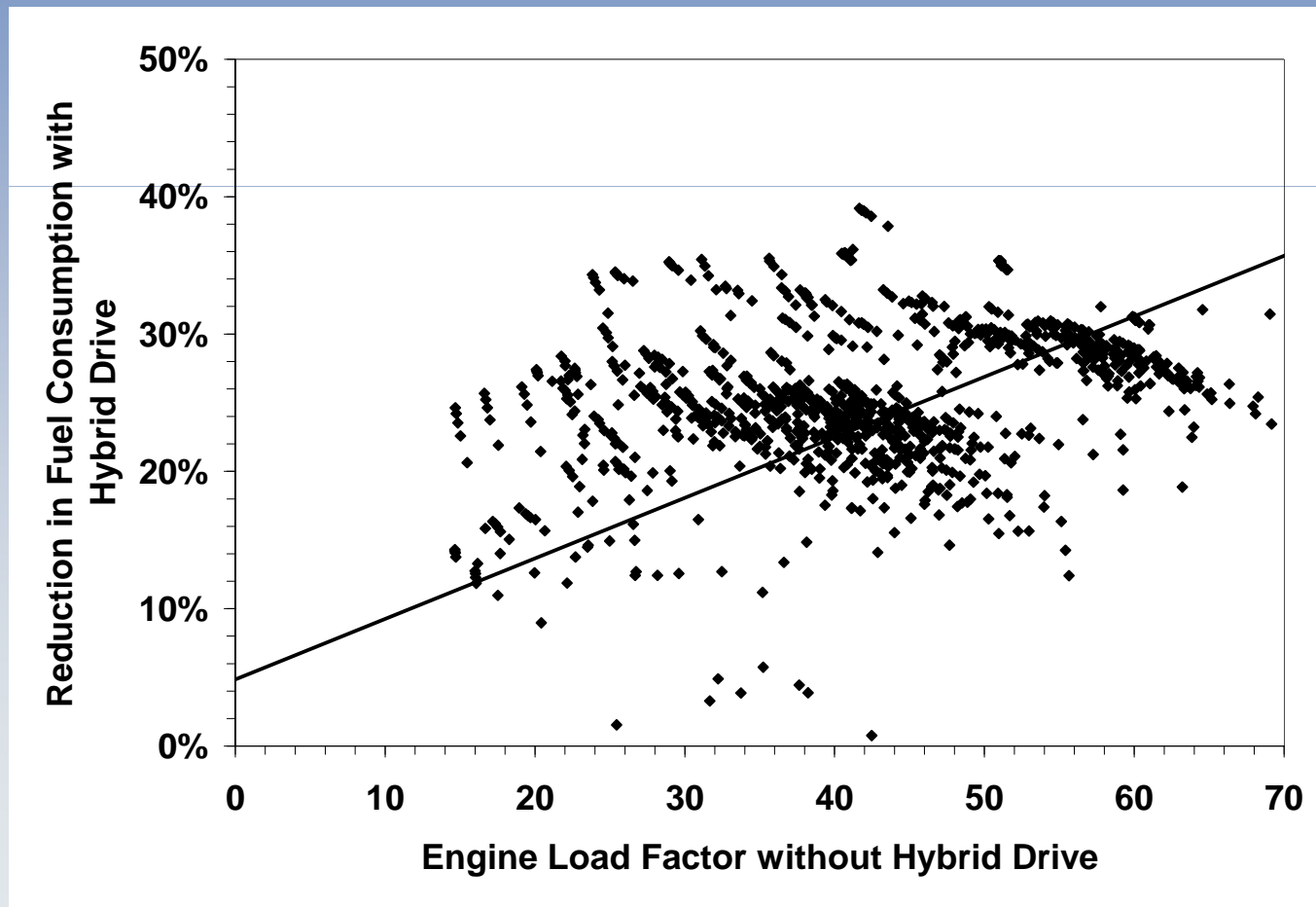


Energy Transfer Within an HDMU



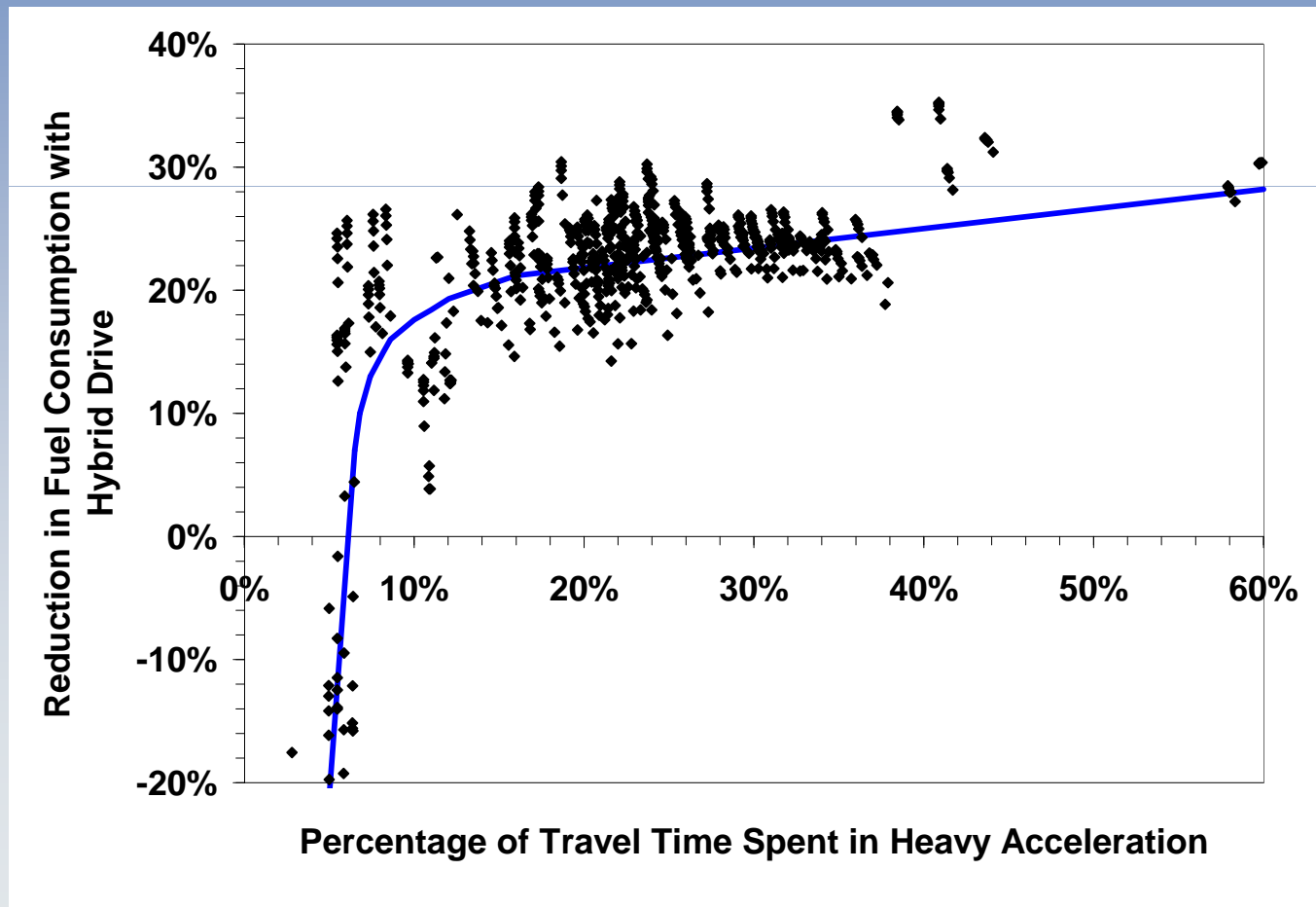


Potential Fuel Savings of HDMUs





Potential Fuel Savings of HDMUs





Relative Advantages of Commuter Rail Technologies

Type	Cap	Ops	Maint	Comments
LHC	Low	High	Low	Recent Starts
EMU	High	Low	High	Established Services
DMU	Low	Mid	Mid	New Starts and Feeder
HDMU	Mid	Low	High	Potential of Improved Acceleration and Reduced Emissions



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



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Life Cycle Cost Analysis

- Capital
- Operations
- Maintenance
- Inflation
- Time

$$LC(t) = \text{Cap} + (\text{O\&M})(1 + i)^t$$

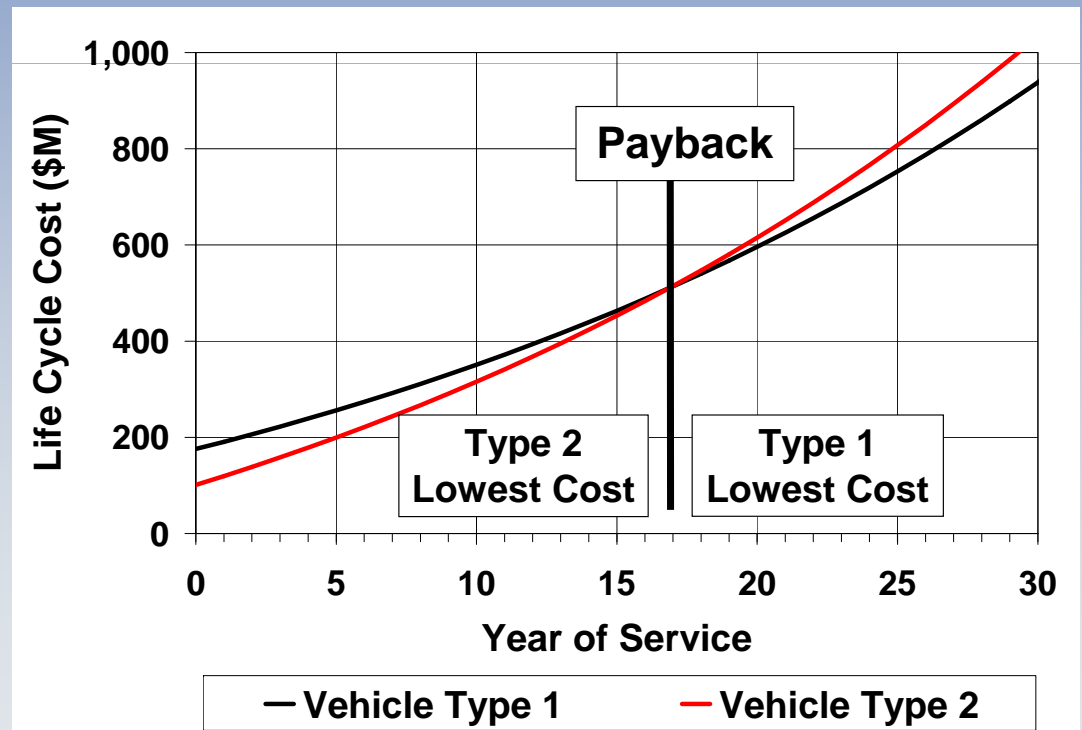
$$\log \left[\frac{(Cap_2 - Cap_1) \ln(1+i)}{O \& M_1 - O \& M_2} + 1 \right] \\ \log(1+i)$$



Comparison of Technologies Through Life Cycle Costs

Payback:

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





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

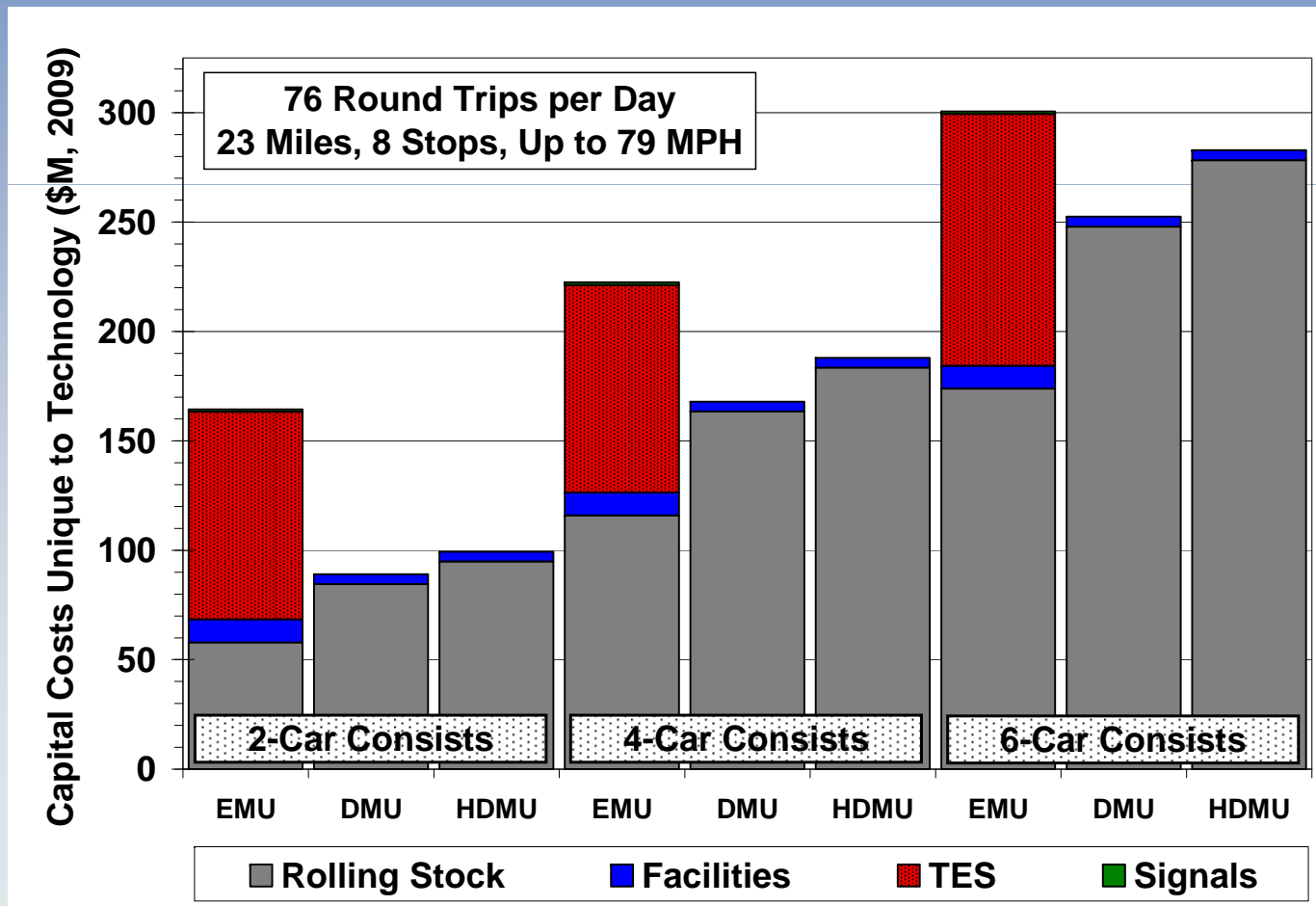


Fleet Capital Costs

- 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





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

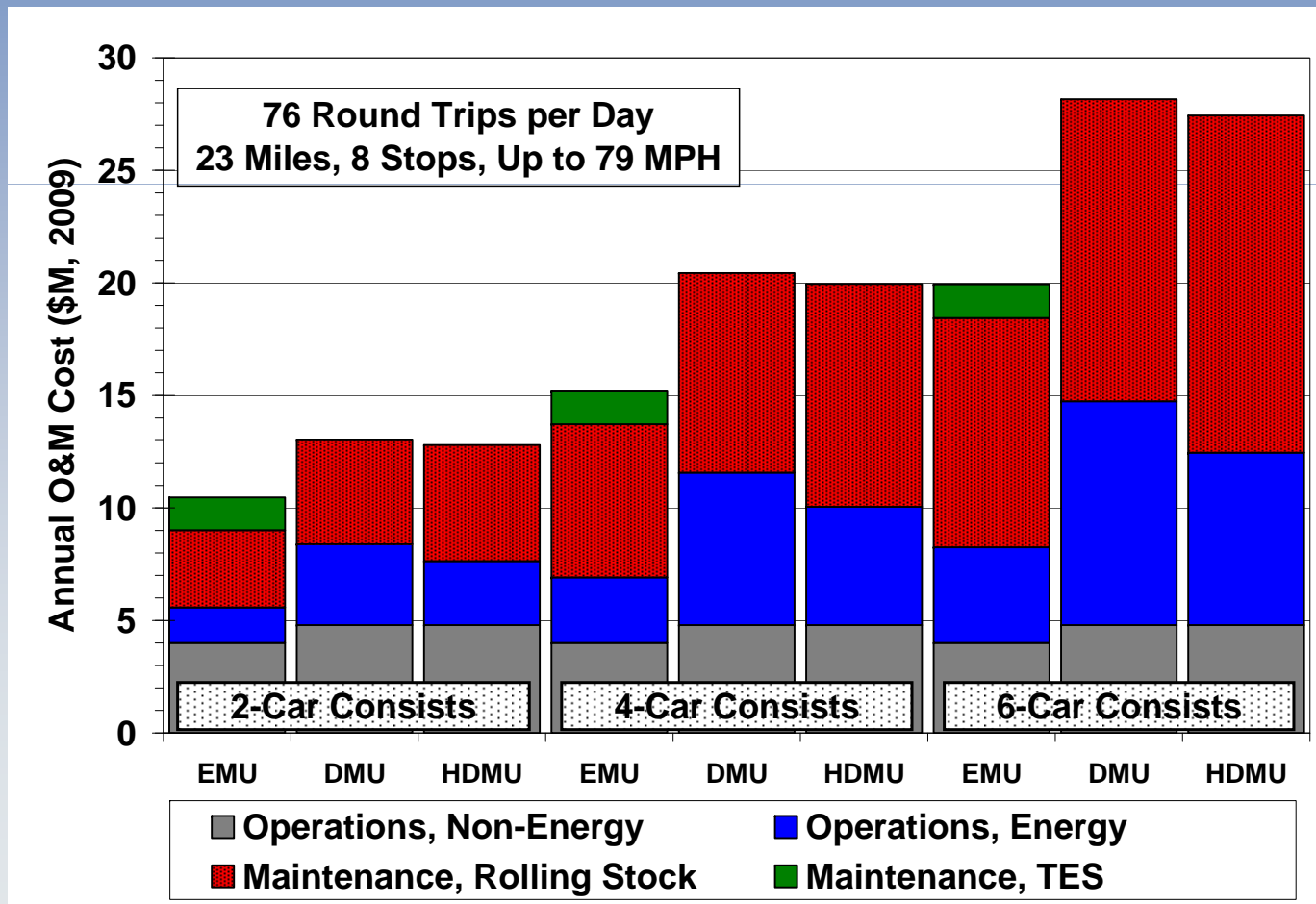


Maintenance Costs

- Traction Electrification System (TES)
 - Traction Power Substations
 - Autotransformers
 - Overhead Contact System (OCS)

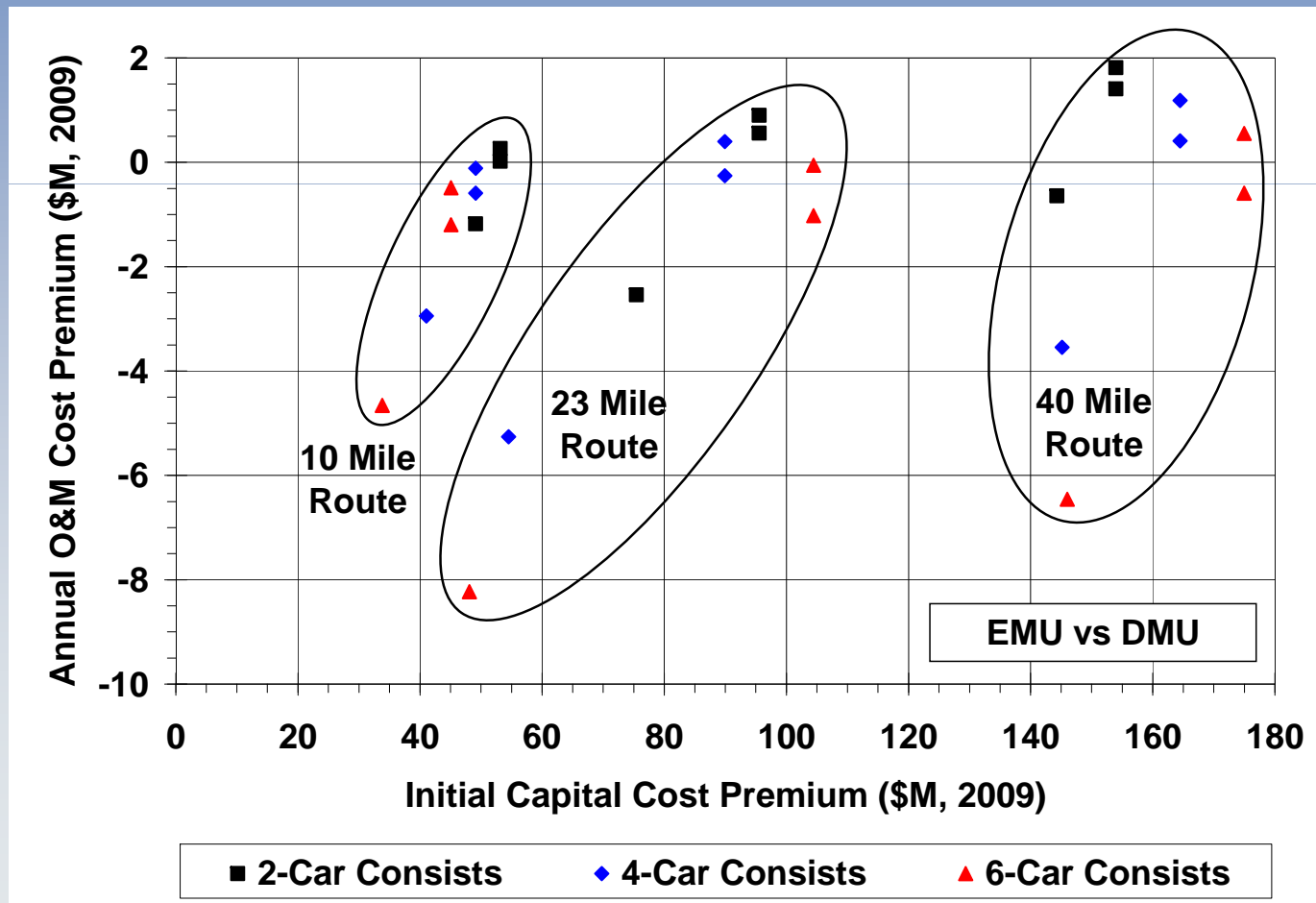


Sample O&M Costs



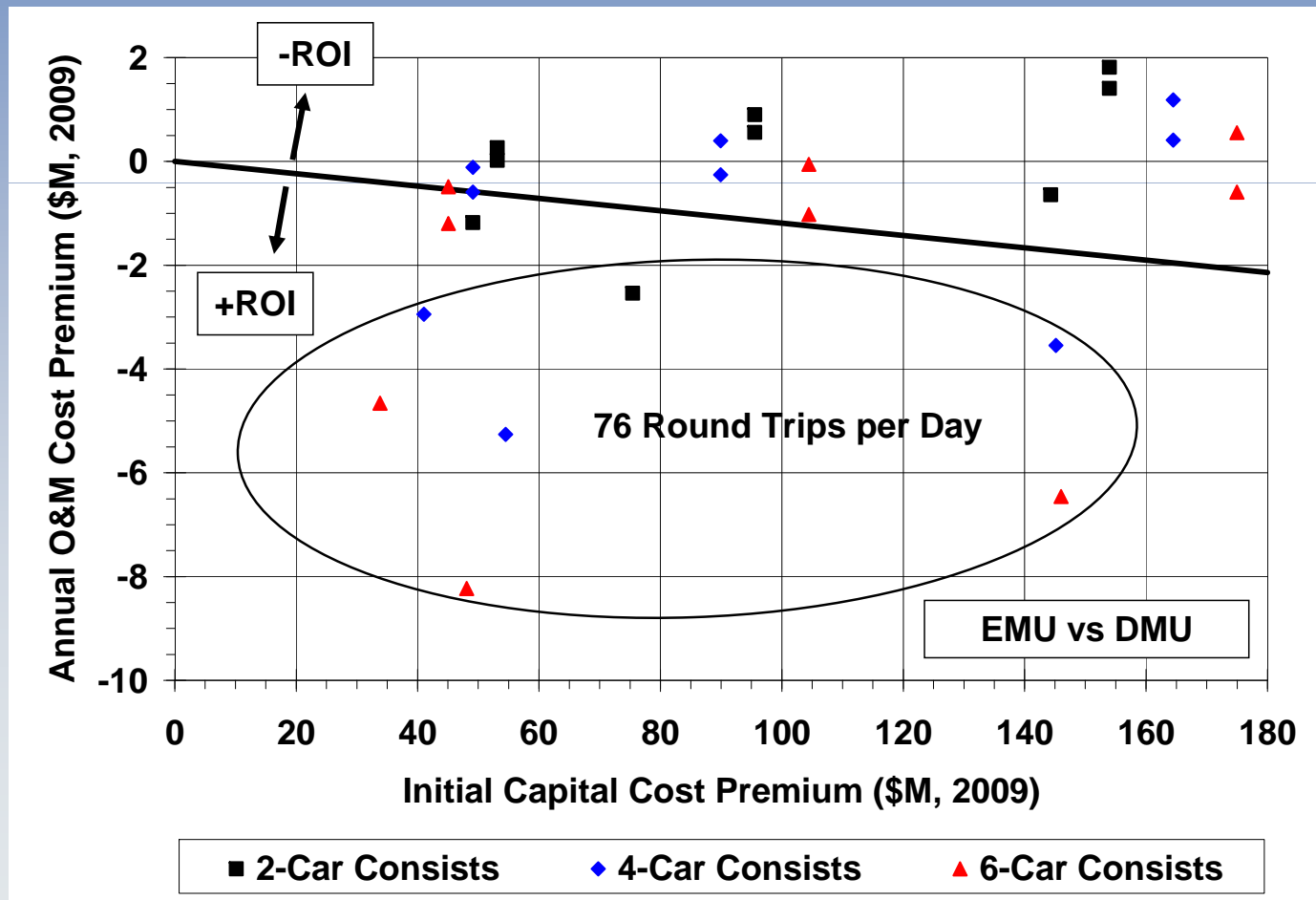


Capital and O&M Cost Differences



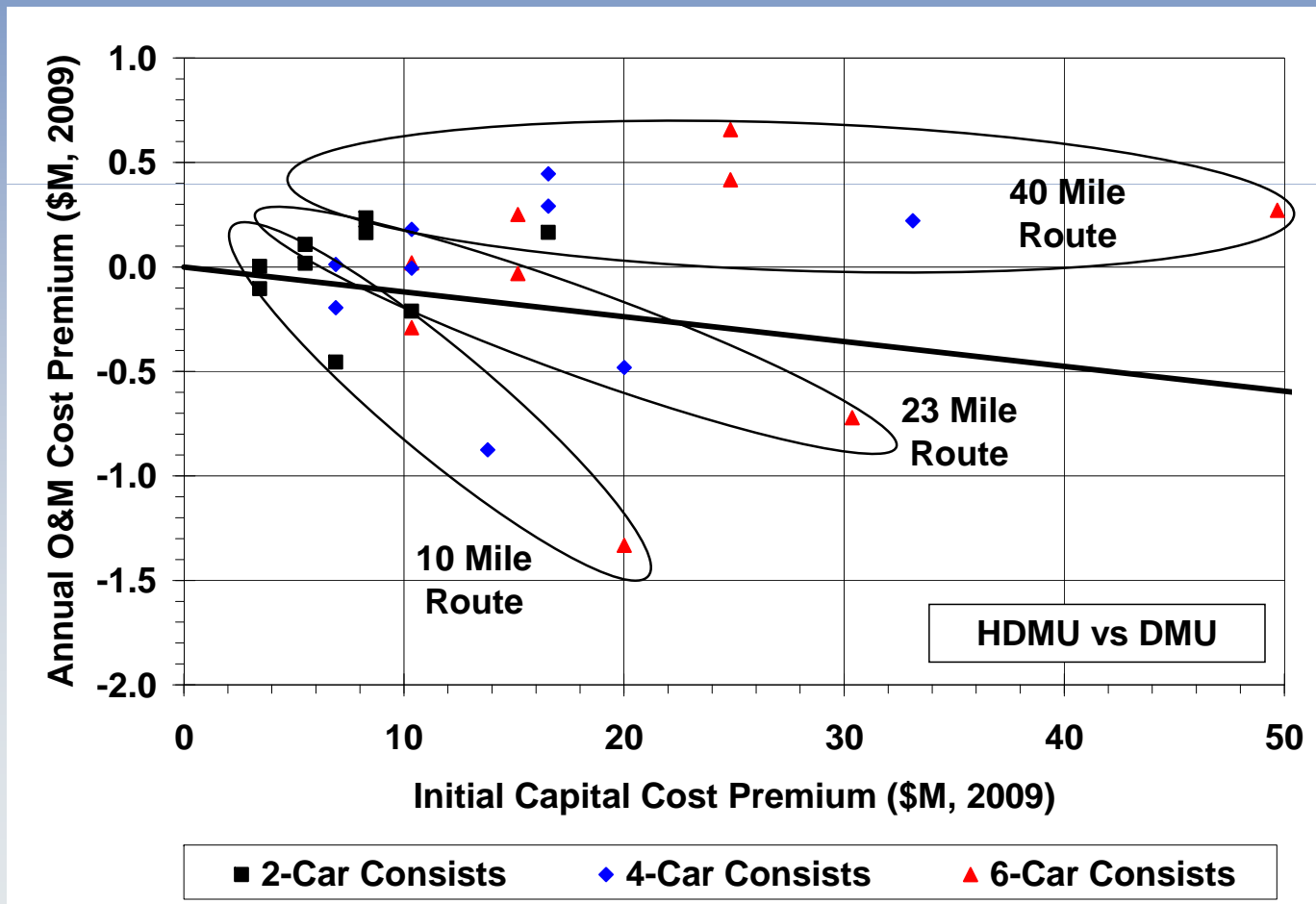


Can EMUs be a Smart Investment?



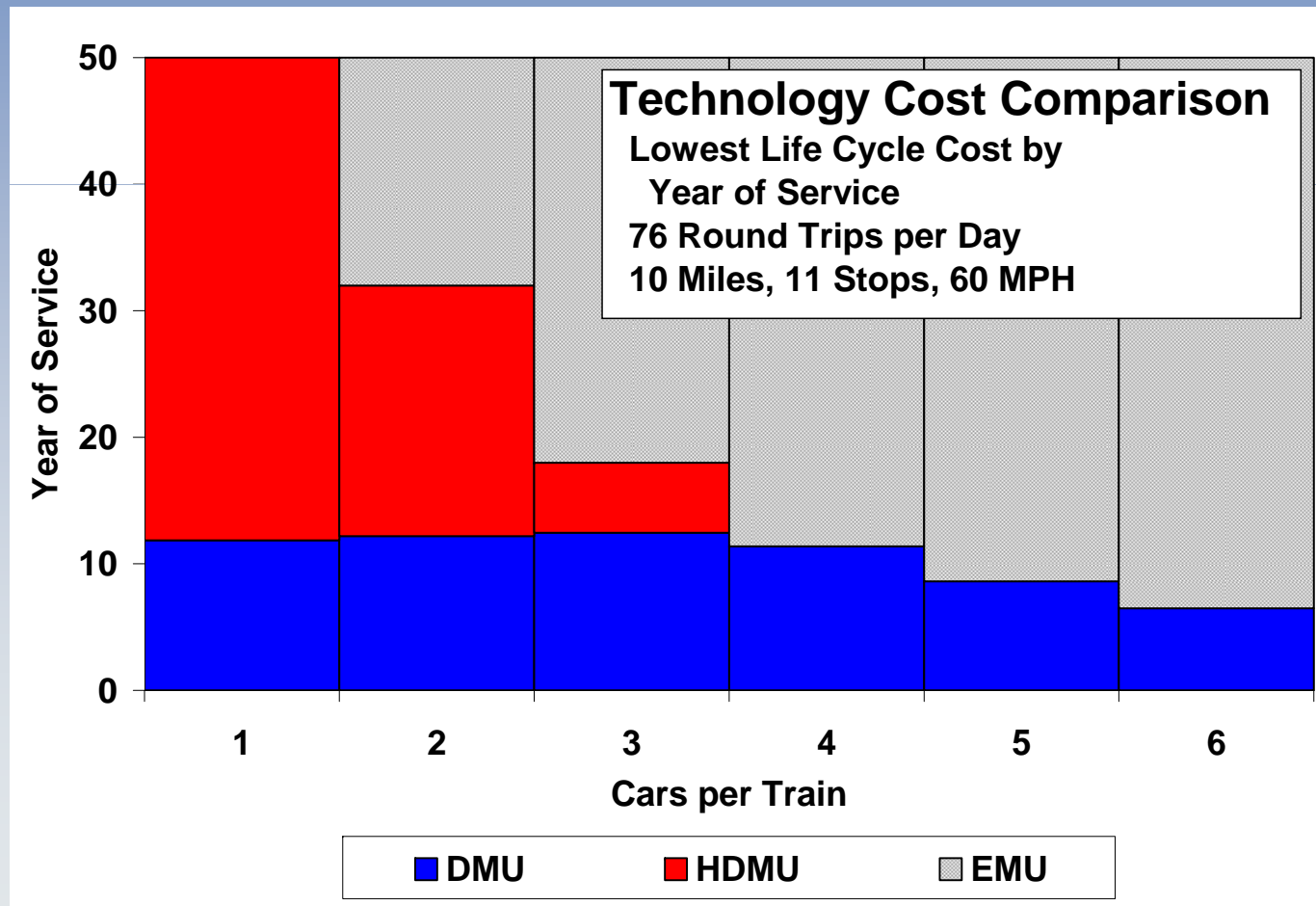


HDMU as an Investment



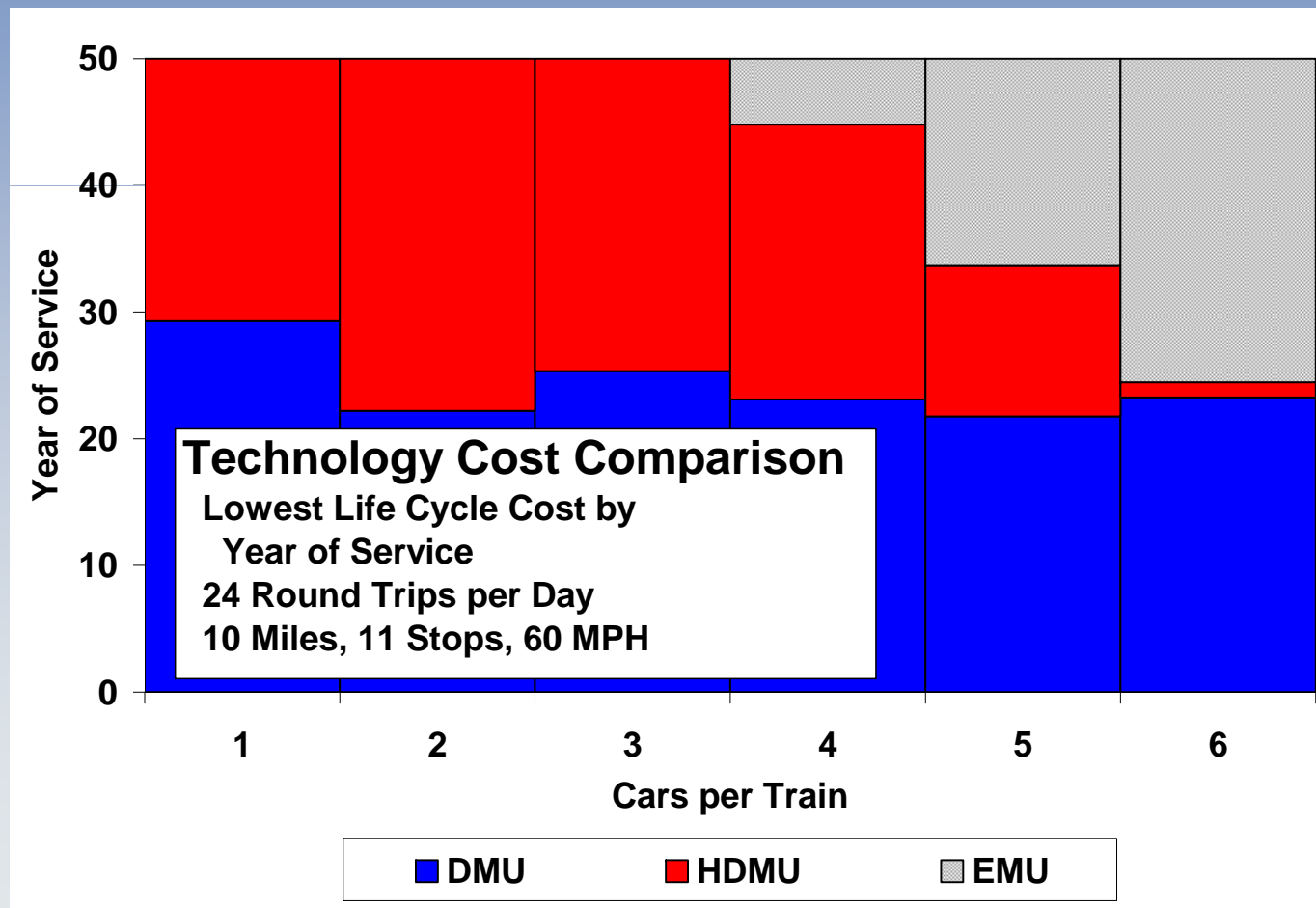


Payback on Short Route, High Utility



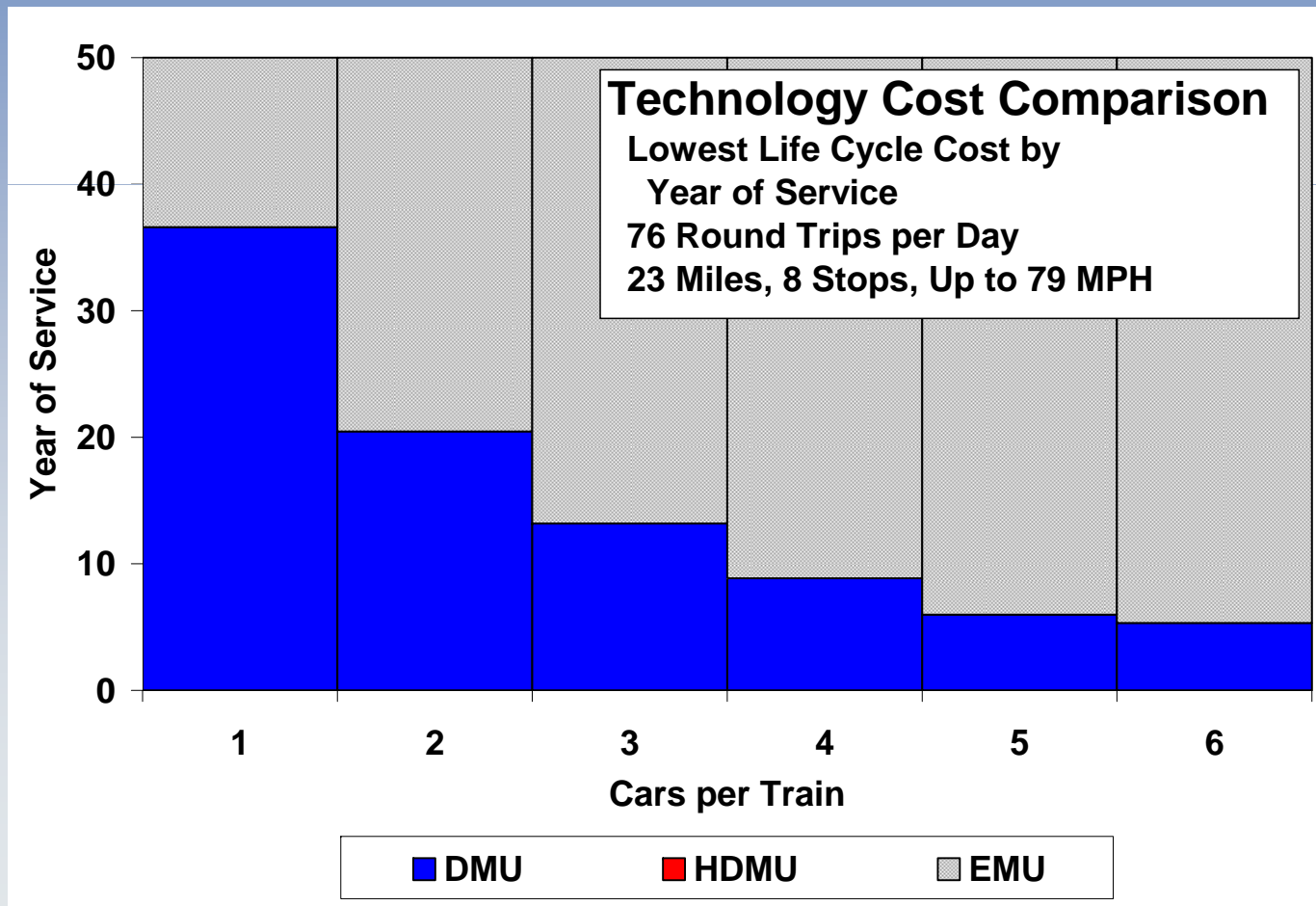


Short Route, Moderate Utility



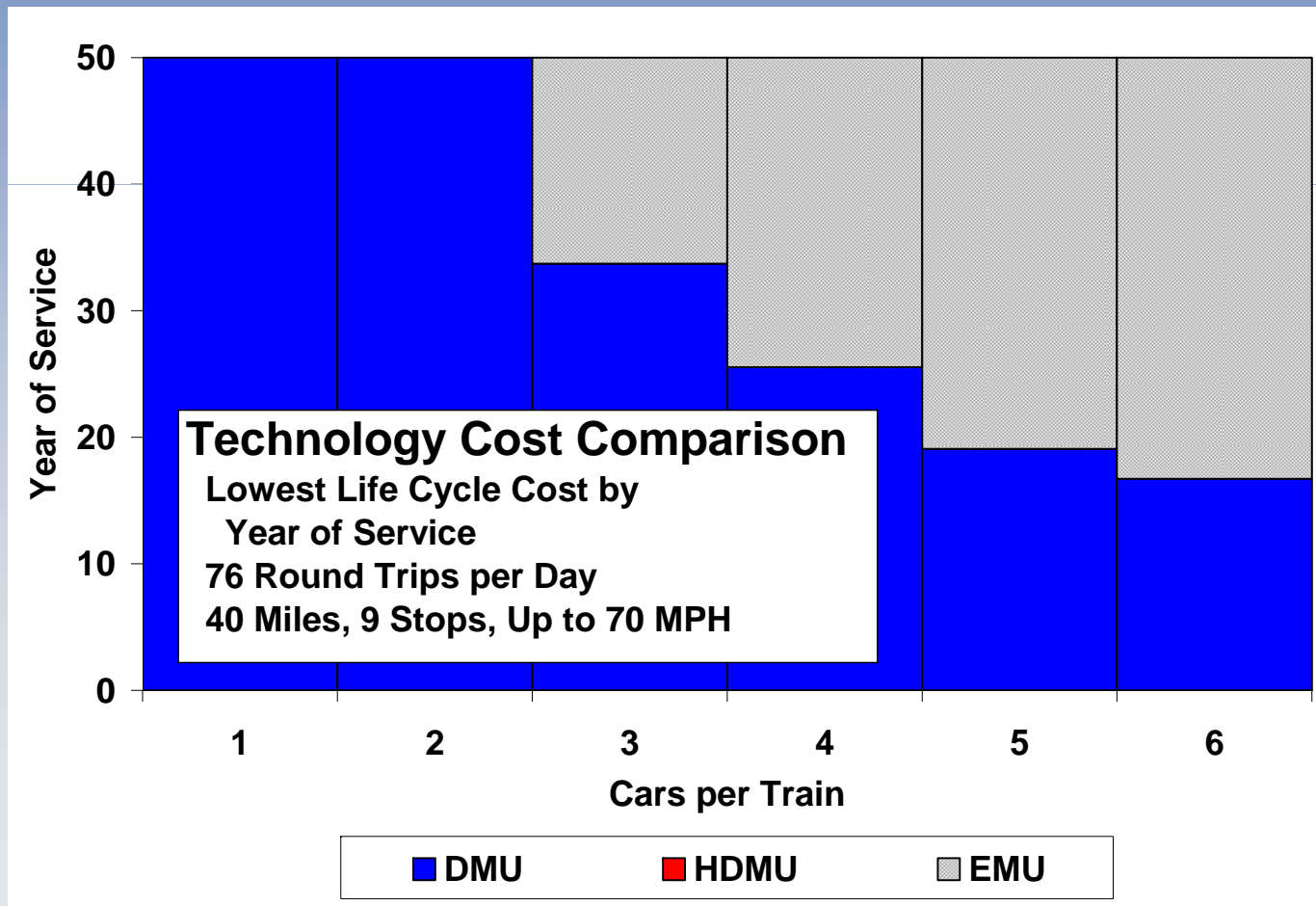


Payback on Moderate Route





Payback on Long Route





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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



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Questions?