New Technology for Commercial Trucking

Technology Assessment Discussion Paper

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This Paper's Objectives

- When a fleet owner considers making some level of investment in alternative fuel vehicles:
  - Provide a project management approach that helps to avoid the high failure rates typical in new technology projects.
  - Stress the point that a functioning, competitive, and thus transparent market for these vehicles does not exist. A mature market has not had time to develop. This factor increases risk and thus potential investors benefit from some alternative project approaches.
  - Show examples of a useful set of tools for evaluating investment risks and rewards.
  - Generate some technical and financial inputs and outputs that are reasonable and apply those to some common vehicle applications.
  - Outline sources of funding designed to reduce risk for private and public entities.

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Alternative Fuel Commercial Vehicles: Characteristics of Successful Projects

- All Electric (AEV), Hybrid Electric (HEV), and/or Alternative Fuel Vehicles (AFV) will have economic advantages over Internal Combustion Engines (ICE).
- Current stage of development for alternative fuel vehicles is characterized by:
  - Rapid technological change for certain components (e.g. batteries, fuel cells, control systems, component interfaces)
  - Most vehicles are 'custom' built to operationally unique specifications.
  - Market place is not yet competitive. Competitive markets ensure pricing transparency.
  - Price premiums can be extraordinary and are being influenced in part by availability of public funds.
  - Many new suppliers. Not all have equivalent engineering skills, funding, and/or product development skills.
- Traditional project management approaches for capital investment projects don't work well for new product development.
  - Dealing with multiple technological 'unknowns'
  - Technology is changing rapidly. This can create multiple changes in scope which leads to frequent budget and schedule overruns.
  - Lack of transparency between buyers and sellers.

Alternative Fuel Commercial Vehicles: Characteristics of Successful Projects - Continued

- Alternative fuel vehicles do not have to be a 'high risk' endeavor. Attractive returns can be generated with modest investment.
- Some of the approaches used for continuous delivery IT projects work well for projects that contain significant unknowns. For technology assessment projects that includes:
  - Deliver complete and useful 'work packages' frequently (about every two weeks). Key project drivers are budget and schedule.
  - Manage to a strict budget and schedule by simplifying work and avoiding multi-tasking.
  - Provide an 'audit trail' without generating extensive project documentation.
  - Choose a vendor carefully. The fleet owner is a participant in an R&D project. Transparency in the absence of a mature marketplace will improve results for all parties.
- A project covering all the items in this paper should take about 8-10 weeks.

The Market for Alternative Fuel Commercial Vehicles

- There will be a significant market for alternative commercial vehicles in 3-10 years. The time-frame will be driven by engineering developments and operational application.
- Alternative technology is not yet mature. A market large enough to have generated a set of design standards or substantial production capacity for most commercial applications doesn't yet exist.
  - Public transit, solid waste, local drayage and yard tractors, and delivery vehicles are being built in increasing quantities in Europe, China and North America.
  - Vehicle battery manufacturing capacity is being added quickly. Battery price per KW has dropped by 70% and will continue that downward trend.
  - Longer-term EVs will be price competitive with ICE. UPS claims that its next acquisition of AEV delivery trucks will be at prices competitive with diesel vehicles.
  - Prices for OEM vehicles are being influenced by public funding. In some cases prices are well above the cost of components and assembly. Public funding is designed, in part, to reward risk takers.

Steps for Evaluating New Technology

- Establish Criteria for Evaluation: What outcomes need to be **accomplished** and **avoided?** Each criteria (outcome) gets valued for importance and scored for effectiveness. Include vendor selection and performance criteria.
- New technology projects tend to get bogged down in ‘scope creep’. Manage the project by managing to a strict budget and schedule. Make each project deliverable a complete ‘product’ in itself.
- Develop a written description of likely range of duty cycles based upon actual fleet operating characteristics.
- Evaluate alternative vehicles and vendors that appear to meet most or all requirements. The fleet owner needs to be thorough but doesn’t have to be in the vehicle engineering business.
- Perform an initial risk analysis of previously identified outcomes to avoid.
- Risk Mitigation Analysis: Nothing new is risk free. Have a written risk mitigation plan.
- Financial Analysis: Discounted cash flow analysis for each of the best scoring alternatives for criteria and risk.
- Develop acquisition and test plan. (Addressed in a subsequent paper)

Evaluation of Alternatives: Establish Criteria for Effectiveness

- Establish Criteria for Evaluating Alternatives.
  - Criteria are the objectives or outcomes that an alternative should be able to achieve or avoid.
  - Each criterion is assigned an ‘importance score’ and an ‘effectiveness score.’
  - Look for large differences in total score.
  - Using a broad scale avoids getting bogged down in score differences that are not meaningful.
  - Examples of ‘Scoring Scale’:
    - “1” Low Importance or Low Score
    - “5” Medium Importance or Score
    - “9” High Importance or Score
  - Combinations of Low Importance (1) and Medium (5) or High Probability of occurrence (9) as well as Low Probability of occurrence (1) risks are only important at the margins.

Example: Establishing Criteria and Scoring Alternatives. Look for Substantial Differences in “Total Scores”.

Commercial Vehicle Alternatives Analysis Selection Criteria Key: Importance and Score - 9 = Very Important, 5 = Somewhat Important, 1 = Low Importance

Alternatives (A higher Score is Better)	Criterion	All-Electric Vehicle: Option "E1"		All-Electric Vehicle: Option "E2"		Hybrid-Electric: Option "H1":	
Criterion	Importance	Score	Total	Score	Total	Score	Total
Capital Cost	5	5	25	5	25	9	45
Financial Stability	9	1	9	9	81	5	45
Operating Flexibility: Geographic	5	1	5	1	5	9	45
Fuel Efficiency	9	9	81	9	81	5	45
Operating Range between Charges	9	5	45	5	45	9	81
Maintenance Cost	5	5	25	9	45	5	25
Battery Life (Charging Cycles)	5	9	45	5	25	9	45
Charging Time	5	9	45	5	25	9	45
Vendor Manufacturing Expertise	9	1	9	9	81	5	45
Vendor Engineering Expertise	5	9	45	5	25	9	45
Choice of Drivetrain Options	5	1	5	5	25	1	5
Use Conventional Trailer w/Airbrake	9	1	9	9	81	9	81
Tare Weight	5	1	5	9	45	5	25
Probability of Meeting Delivery Time Commitments	5	1	5	5	25	5	25
HAZMAT Battery Considerations	5	1	5	5	25	5	25
Total Score			***363***		***639***		***627***

Note: These alternatives are illustrations only and do not represent any particular vehicle builder

Risk is Inherent to Both Doing Something and Nothing

- Risk of an undesirable outcome is always non-zero. Risk can only be minimized and/or mitigated.
- Focus on outcomes that are important and for which a probability of occurrence can be assessed (even if that probability has a low level of precision).
- Examples of Risk and Risk Mitigation:
    - Liability Exposure can be reasonably assessed: Federal law requires a Hazmat response to the breach of a Lithium Ion battery containment structure.
    - The impact of a fleet owner being an "Early" or "Late" entrant into the market may not be meaningful as an individual risk factor.   The 'risk' is dependent upon what competitors and regulators may do at some future point.
    - The exposure associated with a vehicle builder's financial position may be difficult to assess as there are multiple new entrants into the market. Both new and established builders are working with technology that is not yet stable.
    - The risk associated with vendors can be mitigated by a thorough analysis and setting a reasonable budget early in the process.

Example Risk Analysis Format: Risk Factors with low Probability of Occurrence are not Included. A Low Score is Better.

Commercial Vehicle Risk Analysis

Selection Criteria Key: Importance and Score - 9 = Very Important, 5 = Somewhat Important, 1 = Low Importance

(A lower score is better)	Risk	All-Electric Vehicle: Option "E1"		All-Electric Vehicle: Option "E2"		Hybrid-Electric: Option "H1":	
Risk Factors	Significance	Probability	Total	Probability	Total	Probability	Total
Vendor Financial Viability	9	9	81	5	45	5	45
HAZMAT Liability Exposure	9	5	45	9	81	5	45
Technological Obsolescence	9	1	9	5	45	5	45
Parts Availability	9	5	45	5	45	9	81
Charging Station Development Time	5	5	25	9	45	5	25
Substitutability of Parts (Vendor Proprietary Technology)	5	9	45	5	25	9	45
Vendor Ability to Attain Manufacturing Excellence	5	9	45	5	25	9	45
Vendor Ability to Maintain Technology Edge	9	1	9	5	45	5	45
Capital Cost Reductions as Technology Matures	5	9	45	5	25	9	45
Disproportionate Share of Economic Rents Accure to Manufacturer	5	5	25	9	45	1	5
Total Score			***374***		***426***		***426***

Note: This example does not include risk factors with low significance.

Risk Mitigation: Page 1 of 2

Commercial Vehicle Risk Mitigation	**Risk Mitigation: Importance and Score - 9 = Very Important, 5 = Somewhat Important, 1 = Low Importance**									
(A lower score is better)	Risk	All-Electric Vehicle: Option "E1"			All-Electric Vehicle: Option "E2"			Hybrid-Electric: Option "H1":		
Risk Factors	Significanc	Probability	Total		Probability	Total		Probability	Total	
Vendor Financial Viability	9	9	81	Perform DCF, secure outside expert opinion. Consider 'wait and see'.	5	45	Understand size of vendor commitment in relation to resources.	5	45	Understand size of vendor commitment in relation to resources.
HAZMAT Liability Exposure	9	5	45	Training for Drivers. Get expert opinion	9	81	Ensure vendor testing program is adequate and transparent	5	45	Training for Drivers. Get expert opinion
Technological Obsolescence	9	1	9	Must always be assessing market for potential 'breakout' changes	5	45	Evaluate multiple alternatives.	5	45	Evaluate multiple alternatives.
Parts Availability	9	5	45	Difficult to assess mitigation strategy until final design is proposed	5	45	Difficult to assess mitigation strategy until final design is proposed	9	81	Many parts sourced outside USA.
Charging Station Development Time	5	5	25	Technically does not need charging station. Long range vehicle.	9	45	Likely need to keep equipment in controlled cycles for some time.	5	25	Smaller batteries. Can use mid-capacity charging stations
Total Score	0	***374***			***426***			***426***		

Risk Mitigation: Page 2 of 2

Commercial Vehicle Risk Mitigation	**Risk Mitigation: Importance and Score - 9 = Very Important, 5 = Somewhat Important, 1 = Low Importance**								
(A lower score is better)	Risk	All-Electric Vehicle: Option "E1"			All-Electric Vehicle: Option "E2"			Hybrid-Electric: Optio	
Risk Factors	Significanc	Probability	Total		Probability	Total		Probability	Total
Substitutability of Parts (Vendor Proprietary Technology)	5	9	45	Strategic decision needs to be made of value vs risk. Avoid substantial initial commitment	5	25	Primary risk in motor control system. Evaluate pre-delivery testing.	9	45
Vendor Ability to Attain Manufacturing Excellence	5	9	45	Use outside expertise to evaluate manufacturing plan if needed.	5	25	Publicly held OEM vendor: Info vs. competitors should be available.	9	45
Vendor Ability to Maintain Technology Edge	9	1	9		5	45	Appropriate technical and investment analysis should result in high probability of sufficient economic life	5	45
Capital Cost Reductions as Technology Matures	5	9	45	Negotiate fixed per unit price if possible. Else avoid long-term commitment	5	25	Negotiate fixed per unit price if possible. Else avoid long-term commitment	9	45
Insufficient Proportion of Economic Rents Accrue to Fleet	5	5	25	Avoidance of long-term commitment to single vendor until market matures.	9	45	Avoidance of long-term commitment to single vendor until market matures.	1	5
Total Score	0		***374***			***426***			***426***

Vehicle Duty Cycle is the Key Driver of Fuel Efficiency between ICE and Electric Vehicles

- The efficiency improvements from electric vehicles occur across multiple variables including weight class, vehicle type, and duty cycle.
- The greatest difference (5-7X more efficient) occurs for low speed duty cycles where there are large energy losses from idling, coasting, and short, frequent acceleration.
- The diesel engine narrows that gap to roughly 3.5X (or 1/3 as efficient) when duty cycles are more typical of a longer haul, higher speed, point to point duty cycle.
- The efficiency improvements are consistent whether the data is from controlled test duty cycles or actual 'in use' service.

In Service Testing in a Variety of Applications has Demonstrated the Efficiency of Electric Vehicles.

		Diesel Equivalent MPG		*Fuel*
	Average	*Diesel*	*Battery*	*Efficiency*
Vehicle Type/Duty Cycle	***Speed***	***Engine***	***Electric***	***Ratio***
Class 8: Near Dock	6.6	3.3	18.3	5.5
Class 8: Local Drayage	9.5	3.5	18	5.1
Class 5 Step Van: Parcel Delivery	12.3	9.5	52.3	5.5
Class 5 Van: Parcel Delivery	14	11.7	56.2	4.8
Class 8: Regional Drayage	23.4	4.9	17.9	3.7
Class 8: Cruise Cycle	50.2	5.5	19.2	3.5
Sources				

Performance Evaluation of TransPower All-Electric Class 8 On-Road Truck. Johnson. Kent; Miller, J. Wavne; Xiao, Jiang Yu.
4 In-Use Emissions Testing and Demonstration of Retrofit Technology for Control of On-Road Heavy-Duty Vehicles. Miller, Wayne; Johnson, Kent; Durban, Thomas; Dixit, Poornima.

Battery Electric Parcel Delivery Truck Testing and Demonstration. California Energy Commission. Gallo, Jean-Baptiste, Jasna
Tomic. (CalHEAT). 2013

Economic Analysis Examples

- Three examples of after tax DCF are included for: (1) Class 8 yard tractor, (2) Class 8 OTR tractor, (3) Class 4/5 local delivery van.
- The yard tractor and delivery van use assumptions from fleet owner analyses or publicly available test data. The OTR tractor uses information provided by OEM vehicle and component manufacturers.
- The examples are a single scenario from a DCF model.
- The actual project output includes multiple scenarios representing the most likely outcomes based upon a reasonable range of technical inputs and quantified risk factors.
- Each fleet owner establishes their risk adjusted cost of capital and acceptable financial return boundaries.

Investment Example: Class 8 Yard Tractor

- The following example is from an actual distribution center project which had duty cycle characteristics similar to ports and intermodal yards.
- All electric yard tractors have been used at ports and intermodal facilities for about five years.
- Characteristics of yard operation duty cycles tend to make the electric tractor an attractive investment
  - ICE uses much more energy than an electric motor during frequent idling and acceleration.
  - AEV can use regenerative braking which reduces air brake system maintenance
- The duty cycle is sixteen hours per day, six days/week. Daily short haul OTR shuttles are required.
- The IRR is 38% and does not include public funding.
- The maximum EV price premium over an ICE that generates a 15% IRR is about $100,000 given the assumptions about the duty cycle. Duty cycle inputs were gathered from the ICE vehicle with the aid of inexpensive instrumentation.

Inputs: Class 8 Yard Tractor

Propulsion Technology Alternatives: Cash Flows

Note: A positive number is a net cash inflow, a negative number is a net outflow

Base Case: Class 8 Yard Tractor, Investment Case: All Electric Tractor

	Base	Investment	Difference		Base	Investment	Difference
Vehicle Capital Cost	$ (107,000)	$ (167,000)	$ (60,000)	Cost of Electricity per Operating Day	$ -	$ 72.07	
Number of Vehicles	6	6	-	Total Diesel/Gasoline Cost/Year	$ 44,520	$ -	$ 44,520
Vehicle Investment Total	$ (642,000)	$ (1,002,000)	$ (360,000)	Total Electricity Cost/Year	$ -	$ 21,622	$ (21,622)
Charging Infrastructure Investment per Station	$ -	$ (2,000)	$ (2,000)	Number of Days in Service at 100 Availability	300	300	
Charging Infrastructure Number of Stations	0	6	6	Availability Percent	99.3%	98.0%	
Investment M&R Tools/Infrastructure	0	$ (5,000)	$ (5,000)	Incremental Price Margin Per Day	0	0	
Mechanic Training Initial Investment	$ -	$ (5,000)	$ (5,000)	Number of Battery Charging Cycles	0	300	
Maintenance Cost per Vehicle Per Year	$ 10,000	$ 8,000	$ 12,000	Battery Charging Cycle Life	0	2500	
Annual Maintenance Cost Charging Station	$ -	$ 250	$ (250)	Battery Size KW	0	960	
Miles or Hours per Vehicle Day	16	16		Battery Cost per KW	0	100	
Equivalent Diesel Fuel Consumption Per Hour or Mile	3.5	0		Expected batter life (years)	0	8.33	
Electricity KW per MI or Hour of Operation	0	35		Total New Battery Cost/Unit	0	$ (96,000)	
Cost per Gallon of Diesel/Gasoline	$ 2.65	$ 2.65		Residual Value	$ 192,600	$ 300,600	$ 108,000
Cost per KWH electricity	$ -	$ 0.117		Federal/State purchase grant/unit	$ -	$ -	
Vendor Markup on Charging Services as % of KWH Cost	0	10%		Federal/State Tax Credit per Unit Acquired	$ -	$ -	
Total Diesel/Gasoline Cost per Day	$ 148.40	$ -	$ 148.40	EPA Grant	$ -	$ -	

Inputs Common to Base and Investment Case		
Discount Rate	15%	Notes: Each tractor requires 160Kw battery. Total for 6 tractors is 960Kw.
Marginal Tax Rate	26%	
Vehicle Sales Tax Rate	6%	
Depreciation Life	6	MACRS 5-Year depreciation formula used in this example
Replacement Battery Depreciation	3	
Residual Value Difference	0%	

Financial Analysis: Discounted Cash Flows Class 8 Yard Tractor

Alternative Propulsion: Investment vs Base Case with MACRS Depreciation

All Values are expressed as difference between Investment and Base Case

Class 8 AEV Tractor	Year										
	0	1	2	3	4	5	6	7	8	9	Total
Incremental Vehicle Investment Acquisition	($360,000)	$0	$0	$0	$0	$0	$0	$0	$0	$0	**($360,000)**
Charging Station Invest	($12,000)	$0	$0	$0	$0	$0	$0	$0	$0	$0	**($12,000)**
M&R Investment (Tools, infrastructure)	($5,000)	$0	$0	$0	$0	$0	$0	$0	$0	$0	**($5,000)**
Battery Investment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
Capital Investment Summary	($377,000)	$0	$0	$0	$0	$0	$0	$0	$0	$0	**($377,000)**
Total Depreciation	($9,300)	($14,880)	($8,928)	($5,357)	($5,357)	($2,678)	$0	$0	$0	$0	**($46,500)**
Federal/State Incentives	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
Total Mantenance Savings	$0	$0	$72,000	$72,000	$72,000	$72,000	$0	$0	$0	$0	**$288,000**
Energy Savings	$68,695	$137,390	$137,390	$137,390	$137,390	$137,390	$0	$0	$0	$0	**$755,647**
Other Costs	($2,750)	($2,750)	($250)	($250)	($250)	($250)	$0	$0	$0	$0	**($6,500)**
Residual Value	$0	$0	$0	$0	$0	$108,000	$0	$0	$0	$0	**$108,000**
Net Pre-Tax Cash Inflows (Expensed)	$65,945	$134,640	$209,140	$209,140	$209,140	$317,140	$0	$0	$0	$0	**$1,145,147**
Pre-Tax Cash Outflows (Capitalized)	($377,000)	$0	$0	$0	$0	$0	$0	$0	$0	$0	**($377,000)**
Net Pre-Tax Cash (Including Fed/State/Local Incentives	($311,055)	$134,640	$209,140	$209,140	$209,140	$317,140	$0	$0	$0	$0	**$768,147**
Cash Tax Impact from Depreciation	$2,418	$3,869	$2,321	$1,393	$1,393	$696	$0	$0	$0	$0	**$12,090**
Income Taxes on Cash Flows	$0	($35,007)	($54,377)	($54,377)	($54,377)	($82,457)	$0	$0	$0	$0	**($280,593)**
After Tax Cash Flows	($308,637)	$103,503	$157,085	$156,157	$156,157	$235,380	$0	$0	$0	$0	**$499,645**
NPV: After Tax Cash Flows	$209,129	15% Discount Rate									
IRR: After Tax Cash Flows	38%	Note: Depreciation is calculated for each capital expense separately. The calculations are hidden to reduce clutter.									

Image Copyright by Thor Truck

Investment Example: Class 8 OTR Tractor

- There is no long-term operating and testing history on Class 8 tractor for long-haul truckload service. Class 8 vehicles are being used in intermodal and inter-city service for services under about 100 miles.
- Some of the concepts being developed include both the tractor and trailer. Any trailer could be used, but the dedicated trailer has certain advantages in aerodynamics and braking.
  - Historically this approach has been avoided due to the requirement to maximize tractor productivity; especially in general freight service.
  - At some level of operating efficiency a dedicated trailer makes sense. Whether that level can be attained at a sufficiently low capital cost is speculative at this point.
- This example is for a Class 8 tractor only. No trailer is included.
- *The IRR in this Class 8 example is 24%.* The fuel efficiency advantage for the AEV is lower than that established by the California Air Resources Board updated 2018 study.
  - The California study uses ICE fuel consumption factors that are consistent with other comprehensive studies of diesel truck fuel consumption. The study also uses consistent duty cycles.
  - This sample analysis uses values more consistent with ICE and AEV manufacturer claims for new vehicles.
- Individual Fleet Owners' analysis will likely differ from manufacturer stats; but will be directionally consistent.

Inputs: Class 8 OTR Tractor

Propulsion Technology Alternatives: Cash Flows

Note: A positive number is a net cash inflow, a negative number is a net outflow

Base Case: Class 8 Tractor, Investment Case: All Electric Tractor

	Base	***Investment***	***Difference***
Vehicle Capital Cost	$ (125,000)	$ (180,000)	$ (55,000)
Number of Vehicles	1	1	-
Vehicle Investment Total	$ (125,000)	$ (180,000)	$ (55,000)
Charging Infrastructure Investment per Station	$ -	$ (6,000)	$ (6,000)
Charging Infrastructure Number of Stations	0	1	1
Investment M&R Tools/Infrastructure	0	$ (2,000)	$ (2,000)
Mechanic Training Initial Investment	$ -	$ (2,000)	$ (2,000)
Maintenance Cost per Vehicle Per Year	$ 20,000	$ 20,000	$ -
Annual Maintenance Cost Charging Station	$ -	$ 250	$ (250)
Miles or Hours per Vehicle Day	9	9	
Equivalent Diesel Fuel Consumption Per Hour or Mile	6.25	0	
Electricity KW per MI or Hour of Operation	0	90	
Cost per Gallon of Diesel/Gasoline	$ 3.04	$ 3.04	
Cost per KWH electricity	$ -	$ 0.117	
Vendor Markup on Charging Services as % of KWH Cost	0	10%	
Total Diesel/Gasoline Cost per Day	$ 171.00	$ -	$ 171.00

	Base	***Investment***	***Difference***
Cost of Electricity per Operating Day	$ -	$ 104.25	
Total Diesel/Gasoline Cost/Year	$ 51,300	$ -	$ 51,300
Total Electricity Cost/Year	$ -	$ 31,274	$ (31,274)
Number of Days in Service at 100 Availability	300	300	
Availability Percent	99.3%	98.0%	
Incremental Price Margin Per Day	0	0	
Number of Battery Charging Cycles	0	300	
Battery Charging Cycle Life	0	2500	
Battery Size KW	0	640	
Battery Cost per KW	0	100	
Expected batter life (years)	0	8.33	
Total New Battery Cost/Unit	0	$ (64,000)	
Residual Value	$ 50,000	$ 72,000	$ 22,000
Federal/State purchase grant/unit	$ -	$ -	
Federal/State Tax Credit per Unit Acquired	$ -	$ -	
EPA Grant	$ -	$ -	

Inputs Common to Base and Investment Case		
Discount Rate	15%	
Marginal Tax Rate	26%	
Vehicle Sales Tax Rate	6%	
Depreciation Life	6	MACRS 5-Year depreciation formula used in this example
Replacement Battery Depreciation	3	
Residual Value Difference	0%	

Financial Analysis: Discounted Cash Flows Class 8 OTR Tractor

Alternative Propulsion: Investment vs Base Case with MACRS Depreciation

All Values are expressed as difference between Investment and Base Case

Class 8 AEV Tractor	Year										
	0	1	2	3	4	5	6	7	8	9	Total
Incremental Vehicle Investment Acquisition	($55,000)	$0	$0	$0	$0	$0	$0	$0	$0	$0	**($55,000)**
Charging Station Invest	($6,000)	$0	$0	$0	$0	$0	$0	$0	$0	$0	**($6,000)**
M&R Investment (Tools, infrastructure)	($2,000)	$0	$0	$0	$0	$0	$0	$0	$0	$0	**($2,000)**
Battery Investment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
Capital Investment Summary	($63,000)	$0	$0	$0	$0	$0	$0	$0	$0	$0	**($63,000)**
Total Depreciation	($9,300)	($14,880)	($8,928)	($5,357)	($5,357)	($2,678)	$0	$0	$0	$0	**($46,500)**
Federal/State Incentives	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
Total Mantenance Savings	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
Energy Savings	$10,013	$20,026	$20,026	$20,026	$20,026	$20,026	$0	$0	$0	$0	**$110,142**
Other Costs	($1,250)	($1,250)	($250)	($250)	($250)	($250)	$0	$0	$0	$0	**($3,500)**
Residual Value	$0	$0	$0	$0	$0	$22,000	$0	$0	$0	$0	**$22,000**
Net Pre-Tax Cash Inflows (Expensed)	$8,763	$18,776	$19,776	$19,776	$19,776	$41,776	$0	$0	$0	$0	**$128,642**
Pre-Tax Cash Outflows (Capitalized)	($63,000)	$0	$0	$0	$0	$0	$0	$0	$0	$0	**($63,000)**
Net Pre-Tax Cash (Including Fed/State/Local Incentives	($54,237)	$18,776	$19,776	$19,776	$19,776	$41,776	$0	$0	$0	$0	**$65,642**
Cash Tax Impact from Depreciation	$2,418	$3,869	$2,321	$1,393	$1,393	$696	$0	$0	$0	$0	**$12,090**
Income Taxes on Cash Flows	$0	($4,882)	($5,142)	($5,142)	($5,142)	($10,862)	$0	$0	$0	$0	**($31,169)**
After Tax Cash Flows	($51,819)	$17,763	$16,955	$16,027	$16,027	$31,611	$0	$0	$0	$0	**$46,564**
NPV: After Tax Cash Flows	$11,865	15% Discount Rate									
IRR: After Tax Cash Flows	24%	Note: Depreciation is calculated for each capital expense separately. The calculations are hidden to reduce clutter.									

Investment Example: HEV Delivery Truck

- U.S. market for Class 3-5 trucks: 380,000 per year or about one-half of the Class 3-8 vehicle total.
- Hybrid/Electric vehicle for this analysis is a ‘walk-in’ similar to those used by UPS, FedEx, and numerous local delivery fleets.
- The Input data for the HEV was taken from *several studies* of this type of vehicle in operation between 2008 and 2017.
- The duty cycle is a ‘typical’ city delivery application: 80 miles per day for roughly 7.5 hours operating time and includes multiple stops; often within the same block.
- The HEV vehicle will travel 70 miles on a full battery charge and includes a 2 cylinder gas engine that starts recharging the battery when 50% depleted.
- Includes regenerative braking which provides battery charge assist and reduces brake pad application.
- The base case vehicle is a similar weight van with a 6 cylinder diesel engine.
- The IRR for this example is 26% and does not include government funding assistance which was provided to the fleet owner.

Cash Flow Analysis Inputs: Class 4 Delivery Vehicles

Propulsion Technology Alternatives: Cash Flows

Note: A positive number is a net cash inflow, a negative number is a net outflow

Base Case: Class 4 Delivery Truck with 6 CYL Diesel ICE, Investment Case: Hybrid Electric with 2 CYL Gas ICE

	Base	***Investment***	***Difference***		***Base***	***Investment***	***Difference***
Vehicle Capital Cost	$ (60,000)	$ (75,000)	$ (15,000)	Cost of Electricity per Operating Day	$ -	$ 3.51	
Number of Vehicles	1	1	-	Total Diesel/Gasoline Cost/Year	$ 6,549	$ 1,310	$ 5,240
Vehicle Investment Total	$ (60,000)	$ (75,000)	$ (15,000)	Total Electricity Cost/Year	$ -	$ 965	$ (965)
Charging Infrastructure Investment per Station	$ -	$ (1,700)	$ (1,700)	Number of Days in Service at 100% Availability	275	275	
Charging Infrastructure Number of Stations	0	1	1	Availability Percent	99.3%	98.0%	
Investment M&R Tools/Infrastructure	0	$ (2,000)	$ (2,000)	Incremental Price Margin Per Day	0	0	
Mechanic Training Initial Investment	$ -	$ (2,000)	$ (2,000)	Number of Battery Charging Cycles	0	500	
Maintenance Cost per Vehicle Per Year	$ 3,340	$ 3,077	$ 264	Battery Charging Cycle Life	0	4000	
Annual Maintenance Cost Charging Station	$ -	$ 250	$ (250)	Battery Size KW	0	60	
Miles or Hours per Vehicle Day	80	80		Battery Cost per KW	0	100	
Equivalent Diesel Fuel Consumption Per Hour or Mile	0.10	0.02		Expected batter life (years)	0	8.00	
Electricity KW per MI or Hour of Operation	0	0.375		Total New Battery Cost/Unit	0	$ (6,000)	
Cost per Gallon of Diesel/Gasoline	$ 3.04	$ 3.04		Residual Value	$ -	$ -	$ -
Cost per KWH electricity	$ -	$ 0.117		Federal/State purchase grant/unit	$ -	$ -	
Vendor Markup on Charging Services as % of KWH Cost	0	0%		Federal/State Tax Credit per Unit Acquired	$ -	$ -	
Total Diesel/Gasoline Cost per Day	$ 23.82	$ 4.76	$ 19.05	EPA Grant	$ -	$ -	

Inputs Common to Base and Investment Case	
Discount Rate	15%
Marginal Tax Rate	26%
Vehicle Sales Tax Rate	6%
Depreciation Life (Straight Line)	6
Replacement Battery Depreciation	3
Residual Value	0%

Cash Flow Outputs: HEV Delivery Vehicle

Alternative Propulsion: Investment vs Base Case with MACRS Depreciation

All Values are expressed as difference between Investment and Base Case

Class 4 HEV	Year 0	1	2	3	4	5	6	7	8	9	Total
Incremental Vehicle Investment Acquisition	($15,000)	$0	$0	$0	$0	$0	$0	$0	$0	$0	**($15,000)**
Charging Station Invest	($1,700)	$0	$0	$0	$0	$0	$0	$0	$0	$0	**($1,700)**
M&R Investment (Tools, infrastructure)	($2,000)	$0	$0	$0	$0	$0	$0	$0	$0	$0	**($2,000)**
Battery Investment	$0	$0	$0	$0	$0	$0	$0	$0	($6,000)	$0	**($6,000)**
Capital Investment Summary	($18,700)	$0	$0	$0	$0	$0	$0	$0	($6,000)	$0	**($24,700)**
Total Depreciation	($9,300)	($14,880)	($8,928)	($5,357)	($5,357)	($2,678)	$0	$0	($1,200)	($1,920)	**($49,620)**
Federal/State Incentives	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
Total Mantenance Savings	$0	$0	$264	$264	$264	$264	$264	$264	$264	$264	**$2,110**
Energy Savings	$2,137	$4,274	$4,274	$4,274	$4,274	$4,274	$4,274	$4,274	$4,274	$4,274	**$40,606**
Other Costs	($1,250)	($1,250)	($250)	($250)	($250)	($250)	($250)	($250)	($250)	($250)	**($4,500)**
Residual Value	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
Net Pre-Tax Cash Inflows (Expensed)	$887	$3,024	$4,288	$4,288	$4,288	$4,288	$4,288	$4,288	$4,288	$4,288	**$38,215**
Pre-Tax Cash Outflows (Capitalized)	($18,700)	$0	$0	$0	$0	$0	$0	$0	($6,000)	$0	**($24,700)**
Net Pre-Tax Cash (Including Fed/State/Local Incentives	($17,813)	$3,024	$4,288	$4,288	$4,288	$4,288	$4,288	$4,288	($1,712)	$4,288	**$13,515**
Cash Tax Impact from Depreciation	$2,418	$3,869	$2,321	$1,393	$1,393	$696	$0	$0	$312	$499	**$12,901**
Income Taxes on Cash Flows	$0	($786)	($1,115)	($1,115)	($1,115)	($1,115)	($1,115)	($1,115)	$0	($1,115)	**($8,590)**
After Tax Cash Flows	($15,395)	$6,107	$5,494	$4,566	$4,566	$3,869	$3,173	$3,173	($1,400)	$3,672	**$17,826**
NPV: After Tax Cash Flows	$4,757	15% Discount Rate									
IRR: After Tax Cash Flows	26%										

Note: Depreciation is calculated for each capital expense separately. The calculations are hidden to reduce clutter.

Federal/State/Regional Investment Incentives

- There may be substantial incentives for purchasing alternative fuel vehicles.
- Those incentives are in the form of purchase grants, rebates and vouchers, tax credits, and tax exemptions.
- Some incentives require that vehicles be put in service for an agreed time frame and geographic location.
- Agencies that provide grants tend to reward early applicants that are willing to take the risk.
- Purchase grants typically require an application. Thorough, high quality submissions get the money. There are people that have specific skills in grant application.
- Agencies that provide grants and incentives include: US DOT, EPA, regional organizations, and some large cities.
- Every state received a portion of the initial $2.7B VW Settlement Agreement. The VW funding is for EVs and EV infrastructure and is available to both private and public entities.

Careful Operations, Equipment, and Financial Planning will Result in a High Probability of Attractive Returns with a Modest Initial Investment in EVs

- Electric motors are highly reliable, relatively simple, and are inherently more efficient than diesel and gasoline engines.
- Battery technology is not yet mature and some manufacturers exhibit varying ranges of quality. Range and charging infrastructure is limited and will be for years.
- Battery technology is improving rapidly and costs are declining. The weight penalties associated with some EV options will be gone soon.
- Over time, competitive factors will decrease the cost savings and relatively profitability of EVs for both manufacturers and fleet owners; especially ‘for hire’ carriers.
- Almost every innovation since deregulation (e.g., the 53x102 trailer, digital communications) has been widely and quickly adopted by competitors.
- Appropriate investment timing will materially influence the outcome.