

2016 DOE Vehicle Technologies Program

Fuel Cell-Battery Electric Hybrid for Utility or Municipal MD or HD Bucket Trucks. Fuel Cell powered Auxiliary Power Module “APM”

Project ID Number: MT020



Abas Goodarzi, Ph.D., PE.
President, US Hybrid Corporation

1. Technical Basis

- a) Project Motivation
- b) Anticipated Benefits

2. Technical Scope/Tasks

- a) Modeling and Simulation
- b) Simulation Results
- c) Summary of Simulation Results
- d) Component Sizing
- e) Operations Analysis
- f) Commercialization

3. Administration

- a) Teaming
- b) Future Work (Phase II)
- c) Milestones

Medium- and heavy-duty (MD/HD) bucket trucks are used daily by line crews employed by utilities, telecommunications companies, and municipalities to repair infrastructure

Bucket Truck Profile

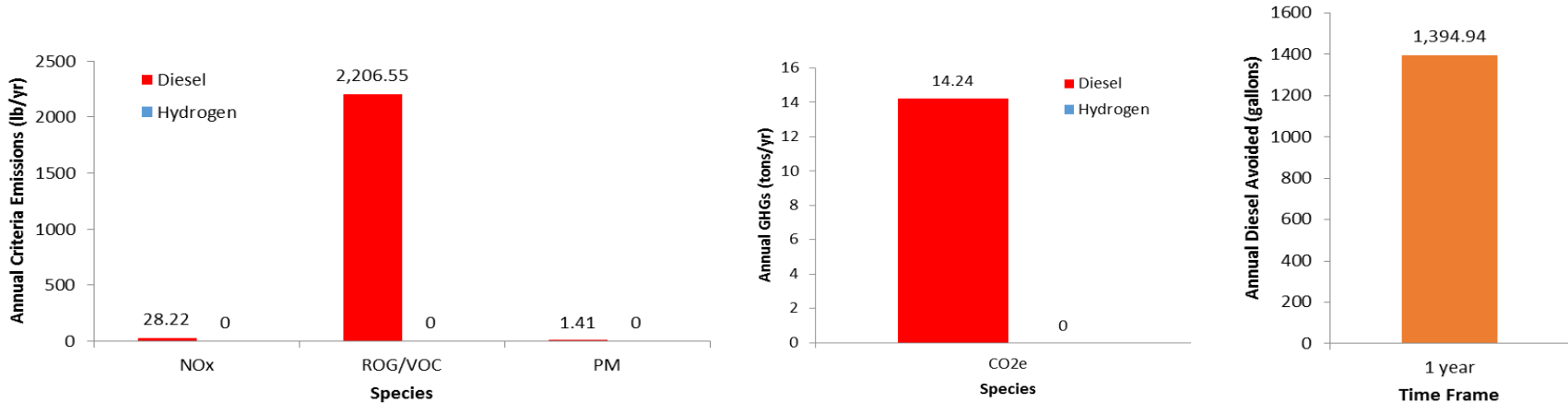
1. Typically diesel
2. Significant idling at the work site to power the hydraulic boom, lights, auxiliary equipment, and cabin heating and cooling, incurring:
 - High fuel costs
 - Diesel exhaust for workers and public
3. Work crews need to use emergency generators to supplement the idling power
4. Noisy operation prevents workers from communicating from ground to boom, resulting in:
 - Safety issues
 - Lowered asset utilization from time of day noise restrictions

More than 23% of the global warming pollution is attributed to MD/HD vehicles¹



¹ "Annual Energy Outlook 2014 (AEO2014)." *U.S. Energy Information Administration (EIA)*. 1 Apr. 2014. Web. <[http://www.eia.gov/forecasts/aeo/pdf/0383\(2014\).pdf](http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf)>.

Based on a typical work year of 260 days and an average 3 hours/day spent idling over a typical Hawaiian Electric utility route^{2,3}



- Noise reduction
- Electrified powertrain
 - Reduced operating costs from fuel and maintenance
 - Better packaging
 - Improved handling
 - Electric Power Take-off (ePTO) function with export power

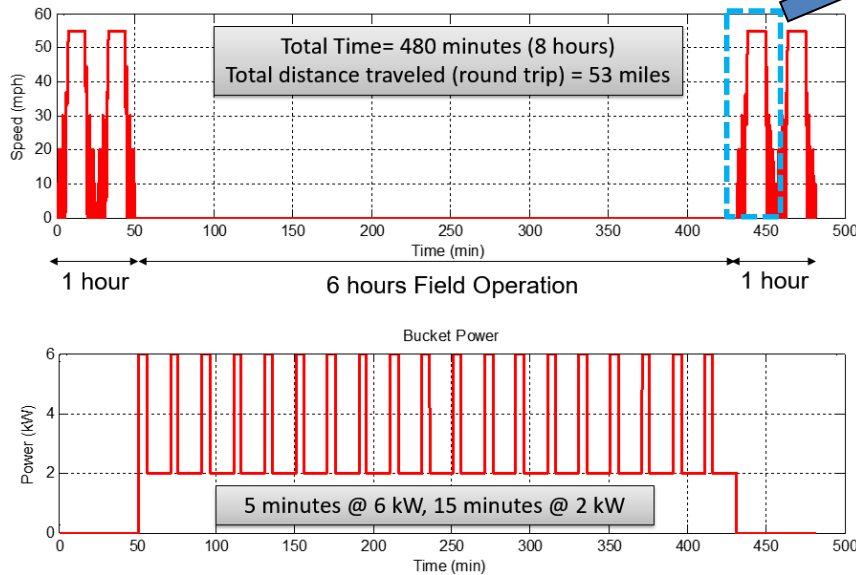
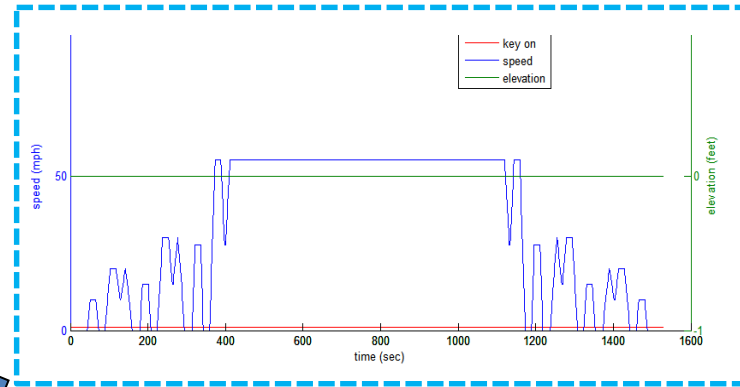
² "Paper No. 06-2567 Estimation of Fuel Use by Idling Commercial Trucks." *Center for Transportation Research Argonne National Laboratory*. 22 Jan. 2006. Web. <<http://www.transportation.anl.gov/pdfs/TA/373.pdf>>.

³ "Heavy-Duty Highway Compression-Ignition Engines And Urban Buses -- Exhaust Emission Standards." *EPA*. Environmental Protection Agency, 6 Mar. 2013. Web. <<http://epa.gov/otaq/standards/heavy-duty/hdci-exhaust.htm>>.

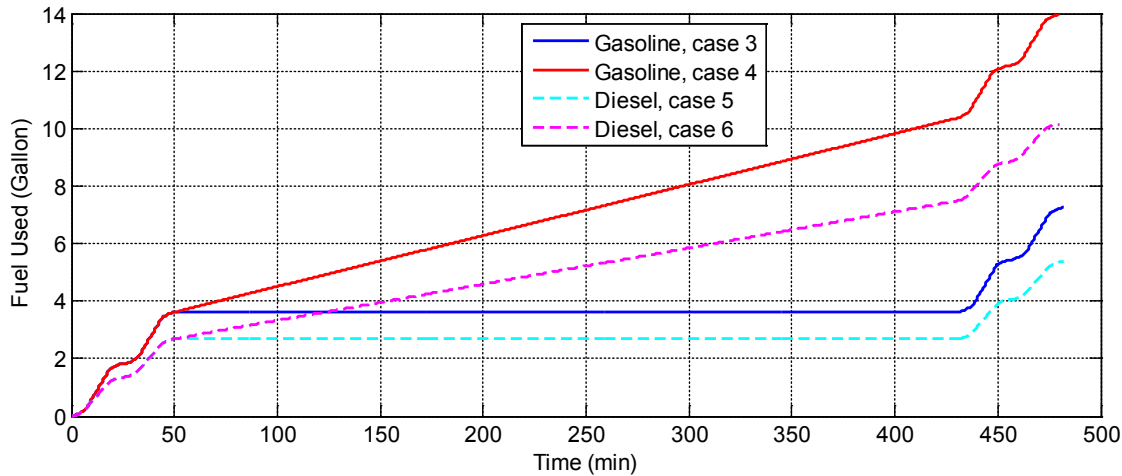
Route, duty cycle, and base vehicle specifications from operating partners



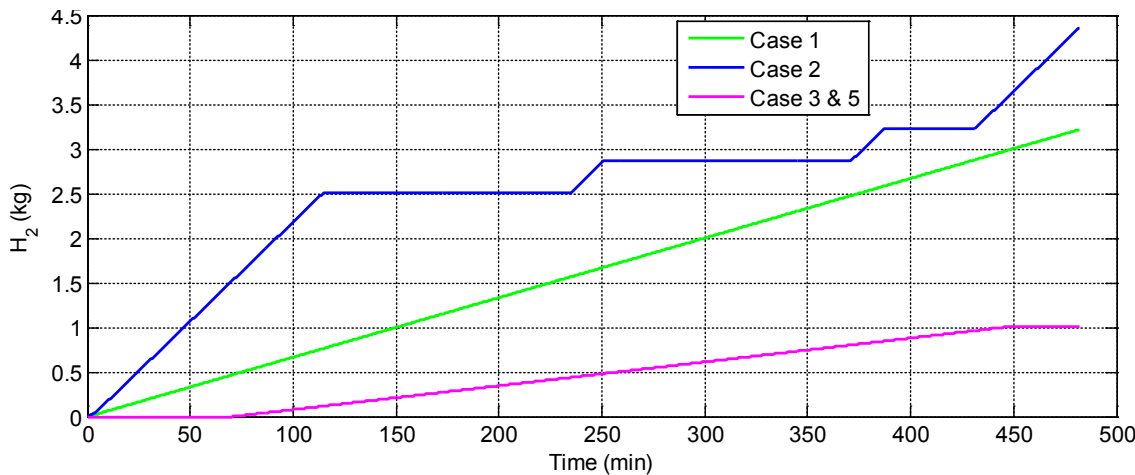
Duty Cycle



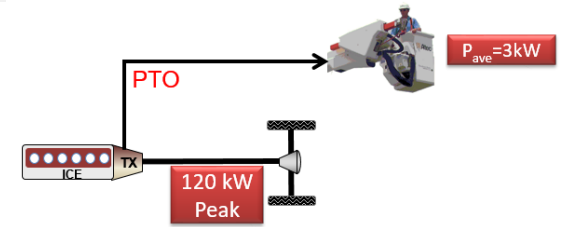
Inputs



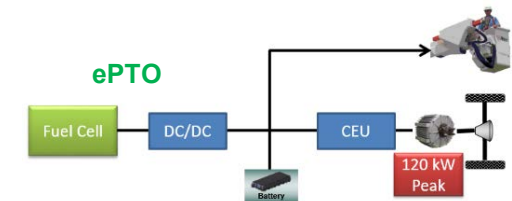
Fuel consumption for gasoline and diesel powertrain systems



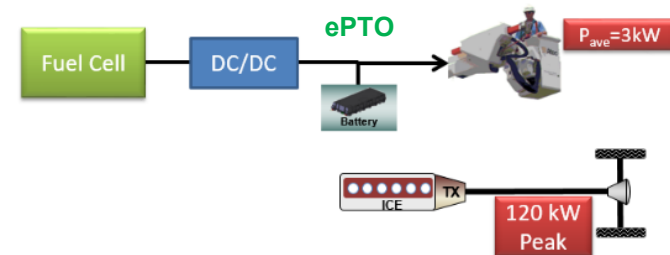
Hydrogen used for fuel cell operated systems



System block diagram for scenarios 4 and 6, Gasoline/Diesel stock powertrain (baseline systems)



System block diagram for scenarios 1 and 2, Fuel Cell Battery (Series Hybrid) Electric for traction and job-site ePTO loads.

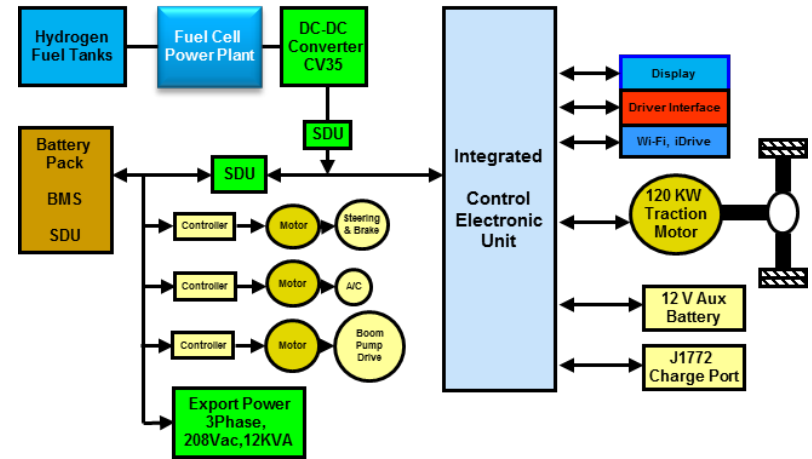


Proposed Configuration:
System block diagram for scenarios 3 and 5, Gasoline/Diesel stock powertrain for traction and Fuel Cell APU for job-site ePTO loads

CONFIGURATION 1:

Fuel Cell Powertrain

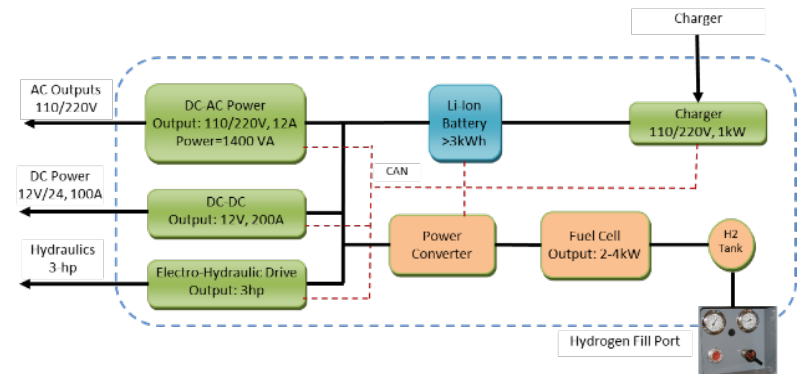
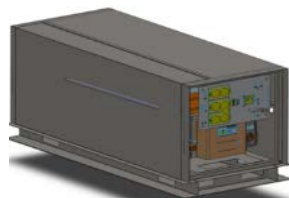
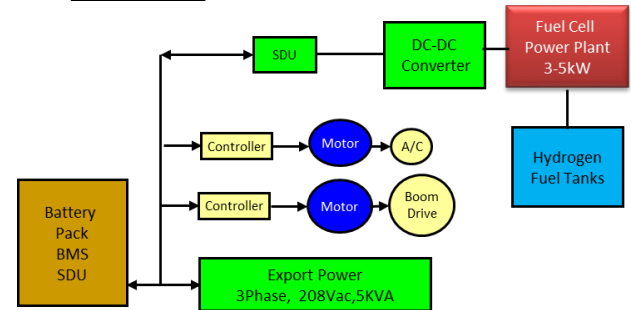
- FC power plant
- Battery and Drivetrain, Power Electronics
 - Energy
 - Power, Torque, Speed
- Electro-hydraulic system
- H2 Storage System
- ePTO
- Vehicle and ePTO Control



CONFIGURATION 2 (Proposed):

Fuel Cell Powered Accessories

- APM FC power plant & Power Electronics
- H2 Storage System
- Battery
- Electro-hydraulic drive system
- ePTO
- APM Controls and optimization



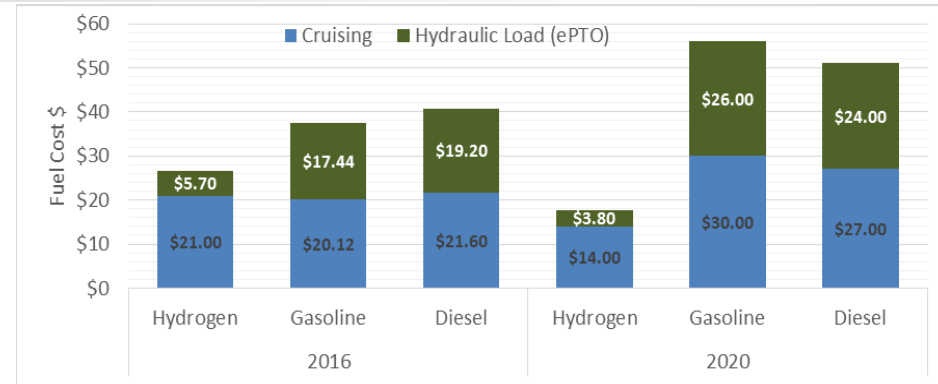
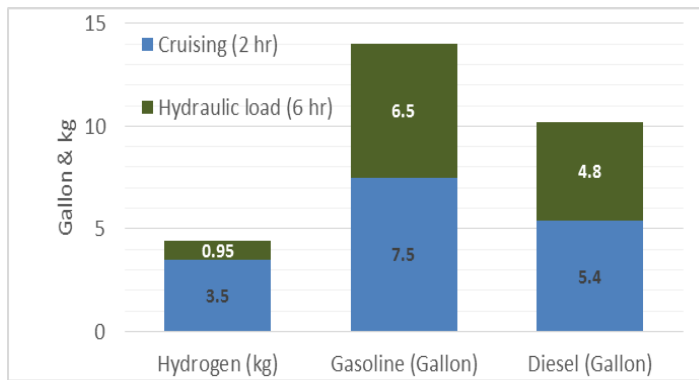


Figure: Daily fuel usage and cost (base vehicle and proposed APM)

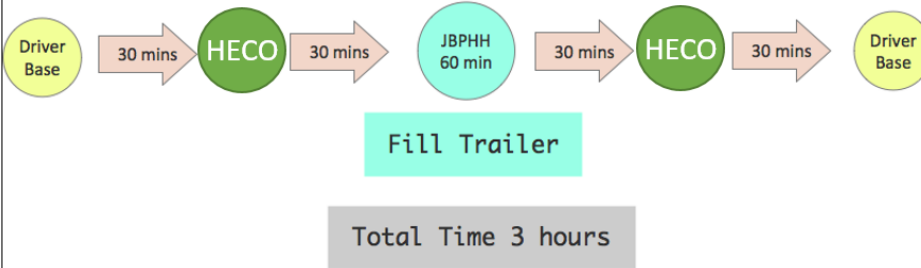
Case	Propulsion System (Traction)	Boom/Bucket Power (ePTO)	Fuel Cell Power (kW)	Battery (kWh)
1	Fuel Cell Powertrain Series Hybrid Electric	Fuel Cell Series Hybrid Electric	7.5	60
2	Fuel Cell Powertrain Series Hybrid Electric	Battery	25	30
3	Stock- Gasoline Engine	Fuel Cell	3	5
4	Stock- Gasoline Engine	Main Engine	-	-
5	Stock- Diesel Engine	Fuel Cell	3	5
6	Stock- Diesel Engine	Main Engine	-	-

Total daily fuel cost for six simulation scenarios

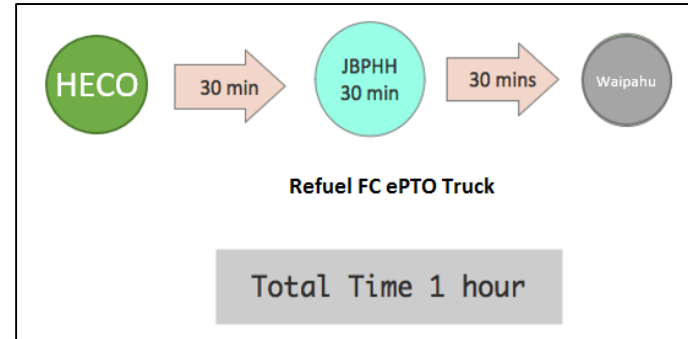
fuel used for Hydraulic	daily operation	annual operation	Diesel fuel saved per truck	No of trucks in the fleet	Annual Diesel fuel saved in the fleet	Emission (Ton)				
						gallon/hr	hours	days	gallon	HC+Nox
0.9	6	260	1404	8,300	11,653,200	207	9,447	5.8	9,661	123,081

Annual fuel saving and emission reduction for a fleet of 8,300 bucket trucks

Option #1



Option #2



Near Term Infrastructure



Operations and Productivity Gains

- ePTO availability
- Productivity Gains
 - Noise Reductions
 - Energy savings
 - Petroleum Reductions
 - Emissions Reductions

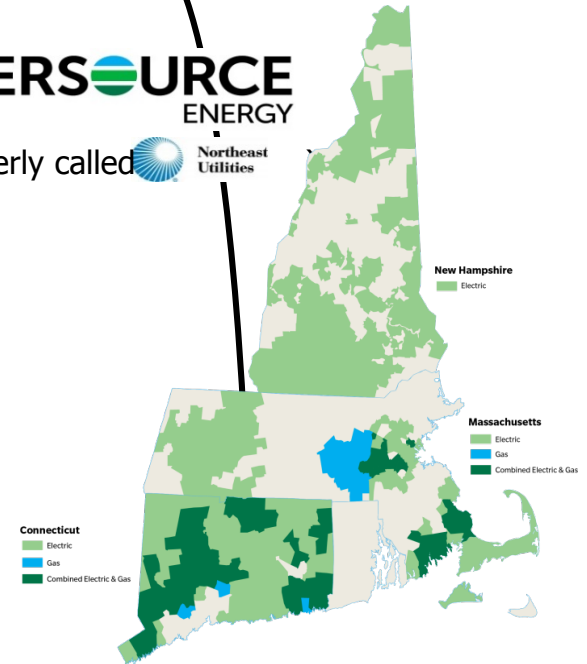
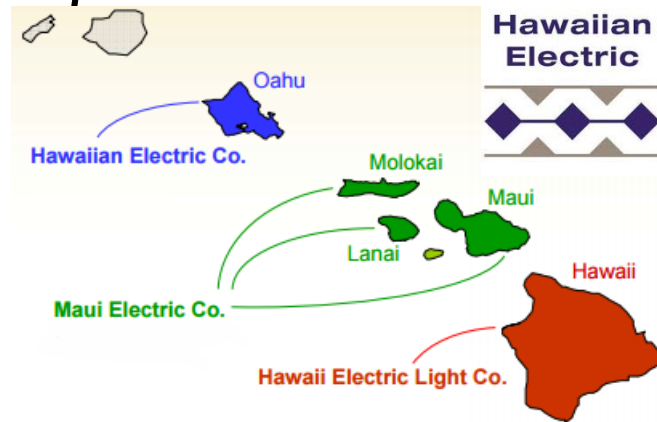
Technology Developer



Commercial Partner



Demonstration Region

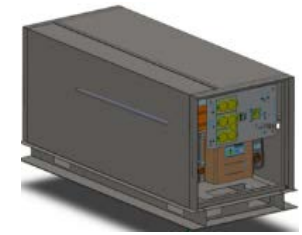


http://mydocs.epri.com/docs/publicmeetingmaterials/1104/4ANZGWRJTYQ/E236208_04_S.Seu_Energy_Storage_Briefing_4-5-2011.pdf
<https://www.eversource.com/Content/images/default-source/Content-Images/service-territory-map.png?sfvrsn=0>



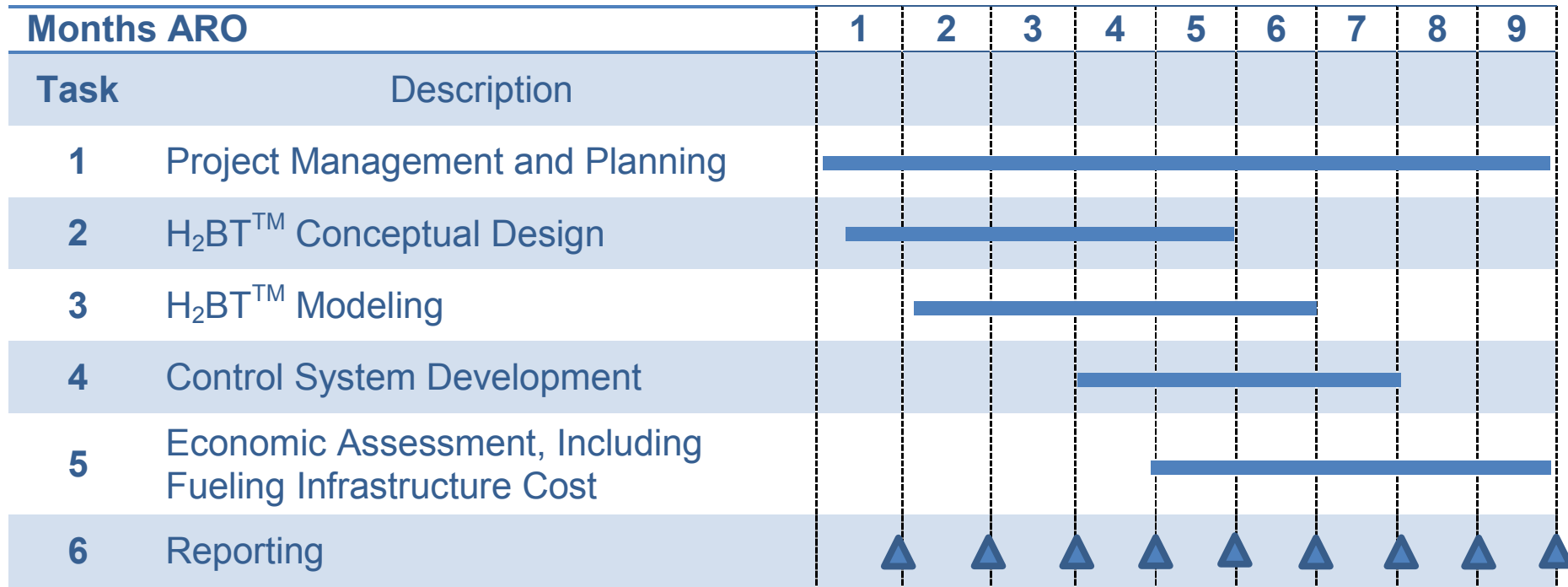
TOTAL INTEGRATED SOLUTION

- OEM drive
- Export power
- FC powered ePTO



- US Hybrid to purchase the Truck
- US Hybrid to integrate Fuel Cell powered ePTO with AC and DC export power and hydraulic drive.
- The powered rolling chassis to be delivered to HECO
- US Hybrid and ALTEC engineers to tune the hydraulics and actuator
- US Hybrid and HECO/ALTEC to tune the operation
- Truck to be released to HECO for 200 hrs. Demonstration.
- US Hybrid to collect data during operation and provide performance and energy analysis

Fuel Cell powered Auxiliary Power Module "APM" For Utility or Municipal MD or HD Bucket Trucks.



1. For Phase II of the project, the best ROI, GHG reduction and fuel savings per \$ investment, fueling infrastructure, user benefits and commercially viable alternative is buckets truck configuration 3 (Gasoline engine powertrain with fuel cell ePTO) for Medium Duty and bucket trucks configuration 5 (Diesel engine powertrain with fuel cell powered ePTO) for Heavy Duty .
2. For a fleet of 8,300 bucket trucks, the total diesel fuel saving is over 11 million gallon of diesel and this results in approximately 9,700 ton reduction in emission and 123,000 ton reduction in GHG.
3. Based on the initial technical and economic analysis and performance data, the fuel cell-powered, ePTO is a viable product with a focused niche markets, where eliminating emissions or the operating noise is critical, due to its higher capital cost. Eventually, economies of scale and fueling infrastructure growth will reduce the cost, so the fuel cell powered bucket truck will provide a lower lifetime operating cost while reducing emissions and allowing full utilization of renewable energy for transportation.
4. The bucket truck with fuel cell ePTO commercial data sheet that outlines the final design selection, component sizing, and specifications that resulted from the simulation and design work is attached in Appendix B.
5. It is anticipated that multiple patents for application and technology will be filed during Phase II commercialization. No patents have yet been filed.