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An Assessment of Vehicle Electrification within the United States Army

Paul Budoff, Gregory Langone, Benjamin West, Noah Lozano, Kyle Kass, Jacob Lueders, Frederick Davidson, and Bret Vanpoppel

Department of Systems Engineering
United States Military Academy
West Point, New York 10996

Corresponding author's Email: pfbudoff@yahoo.com

Author Note: The views expressed herein are those of the authors and do not reflect the position of the United States Military Academy, the Department of the Army, or the Department of Defense.

Abstract: The United States Army is currently undergoing an initiative to modernize its installations and vehicles to reduce logistical demand, mitigate the Army's carbon footprint, and improve the resilience of Army infrastructure. Published in 2022, the Army Climate Strategy provides a timeline for the widespread electrification of both tactical and non-tactical vehicle fleets throughout the next thirty years. The implementation of electric vehicles (EV) in Army tactical and non-tactical operations requires proactive design solutions for energy and logistics systems to maintain capabilities and responsibly manage costs through this transition. The performance requirements and operating environments for the Army can be extreme compared to conventional vehicles. Further, multiple challenges exist that might encumber the use of electrification in the battlefield, including challenging refueling requirements. However, electrifying tactical vehicles presents a number of unique opportunities, including reduced acoustic and thermal signatures. Electrification (full electric or hybridized) also presents a potential pathway to reduce the burden of getting fuel to the battlefield, which has historically been one of the most costly operations after accounting for both the financial burden and the number of casualties associated with defending and operating resilient fuel supply lines. Finally, electrification also presents an opportunity to reduce the environmental impact of Army operations by reducing emissions associated with the vehicle fleet.

This paper responds to three questions that arise in this modernization process. First, a framework for prioritization of which vehicles to replace with EVs was developed by inspecting total cost of ownership and lifecycle carbon footprint. This effort was focused primarily on non-tactical vehicles at select Army installations within the continental United States. Multiple vehicles are considered to replace conventional internal combustion engine vehicles (ICEV); the vehicles under consideration are sourced from the catalogue of available vehicles with the General Services Administration. The lifecycle carbon intensity of different vehicles was compared by leveraging data available through Argonne National Laboratory's GREET model.

Second, a simulation tool is developed to suggest the number, type, and location of chargers to support the EV fleet on an Army installation. The simulation was written using Python and allows the user to observe how vehicle energy reserves, consumption, and charging patterns might impact the capability of a non-tactical vehicle fleet. Subsequently, actionable information can be made available for installations to estimate the design characteristics that will be needed for a network of chargers to meet future demands of an electrified fleet.

Finally, energy production and conversion pathways were inspected for their viability, cost, and carbon footprint to identify the most advantageous paradigms for fueling tactical vehicles. In this task, multiple pathways were considered for delivering sufficient primary energy to the battlefield to fuel necessary generation capacity to recharge electrified tactical vehicles. The pathways include conventional hydrocarbon supply chains (i.e,. JP-8), as well as alternatives such as nuclear and renewables. Hydrogen is also considered in multiple scenarios. The summative response to these three topics expands the base of knowledge informing Army vehicle infrastructure modernization.

It is possible to approximate the charging demands of the EV fleet on an Army Installation using simulation methods. The method developed in this research utilized object-oriented programming written in Python. The input parameters for the model are the specifications of the EV at the installation and usage data of existing ICEV. Different charging arrangements can be tested to evaluate the extent to which they support vehicles to complete existing tasks.

The technology and vehicles needed to transition the U.S. Army to a fully electric, non-tactical vehicle fleet are readily available in the commercial market. The current Army fleet provided a base level of demand as the automotive industry transitions to an EV focused business model. The transition, however, should identify which vehicles are the heaviest used and most carbon efficient to maximize the benefit while minimizing cost.

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The Army's transition from ICEV to BEV vehicles requires life cycle analysis to determine which vehicles of its non-tactical fleet are more advantageous to replace first. LCA is used to find the breakeven mileage between an ICEV and its BEV equivalent. Using Argonne National Laboratory's GREET model, this analysis was conducted on light and medium duty trucks, such as the Ford F-150 and F-550, respectively. For the F-150, its BEV equivalent is the F-150 Lightning; the breakeven mileage is approximately 24,300 miles. The F-550 was compared to Volvo's Class 8 4x2 truck, and the breakeven mileage is around 50,000 miles. These breakeven points are heavily influenced by the weight and utility of the vehicles.

The conversion of energy from one source to another consists of inefficiencies and losses. These were analyzed through the scope of a 200kWh electric HMMWV and a 150kW charger. Calculations determined it would require less hydrocarbon fuel for the same usable energy when combusted through a generator, but a greater quantity when used to produce hydrogen to be run through a fuel cell to charge an EV. Also, to provide enough power to utilize a 150kW charger, over 600 square meters of 460 watt solar panels would be required. A nuclear micro reactor, such as project PELE, would be capable of powering multiple chargers. Each pathway that was analyzed had pros and cons considering environmental impact, complexity and tactical capability.