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Decarbonizing the Canadian Army

Major Thomas Rivett

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INTRODUCTION

Climate change and the general warming of the planet is poised to remain one of the most difficult and enduring global challenges through the next decades and potentially beyond. The Copenhagen Accord codified a science based response to this issue in 2009, effectively stipulating that atmospheric greenhouse gas (GHG) concentrations need to be kept at a level such that the increase in global temperature due to human activities is kept below two degrees Celsius.[1] Despite this agreement, recent studies have shown that neither G20 countries nor the rest of the world are on track to meet their target emissions rates for 2030,[2] or to meet their commitments to a net-zero emission state by 2050.[3] Current modelling shows that the only way to limit overall warming to two degrees Celsius relies on "rapid and deep and in most cases immediate GHG emission reduction in all sectors."[4]

Given this context, Canada has remained committed to driving change in support of meeting the above goals. The recently released plan on emissions reduction renews targets to cut emissions even further than previously agreed on by 2030 and reconfirms the goal of achieving net-zero emissions by 2050.[5] As an internal department of the Canadian Government, the CAF should expect to be an integral part of these commitments – both to assist in reduction of emissions by 2030 and in the net-zero target for 2050. In addition, given the routinely worsening reports of actual

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[1] United Nations Framework Convention on Climate Change, "Copenhagen Accord" (2009), http://unfccc.int/resource/docs/2009/cop15/eng/l07.pdf.

[2] United Nations Environment Programme, "Emissions Gap Report 2021," 2021, 7, https://wedocs.unep.org/bitstream/handle/20.500.11822/36991/EGR21_ESEN.pdf.

[3] Ibid., 8.

[4] Intergovernmental Panel on Climate Change, "Climate Change 2022 - Mitigation of Climate Change - Summary for Policymakers," 2022, 33, https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf.

[5] Government of Canada, "Delivering Clean Air and a Strong Economy for Canadians" (Vancouver, B.C., March 29, 2022), https://pm.gc.ca/en/news/news-releases/2022/03/29/delivering-clean-air-and-strong-economy-canadians.

global emissions and impacts, it should be expected that targets will be lowered even further and measures to reduce emissions will be increasingly drastic. To that end, significant effort should be put towards devising strategies through which the Canadian Armed Forces (CAF) can reduce its carbon footprint while mitigating or eliminating negative impact on vital force generation and force employment activities.

This paper will serve as an investigation into decarbonization technologies, both current and in development, that could be suitable for military use. It will review present and proposed initiatives of our allies looking for areas of opportunity and partnership, and it will assess strengths, weaknesses, opportunities, and threats to the Canadian Army within this context. Finally, this paper will look to inform a Decarbonization Functional Concept (DCF) for the Canadian Army (CA) across three primary time scales – immediate recommendations, medium-term recommendations that aim at meeting reduced emissions targets for the 2030 timeline, and longer-term recommendations that aim at net-zero carbon emissions.

For background, the total Department of National Defence (DND) fleet produced emissions of 592 kilotonnes (kt) of carbon dioxide equivalent (CO2 eq) in fiscal year 2020/21, the majority of which was produced by aircraft (84%), followed by marine vessels (15%) and land vehicles (1%).[6] Given these proportions it is tempting for the CA to dismiss this issue as primarily of Air Force and Navy concern, however given the joint nature and interdependence of these three domains it is vital that everyone work towards the same goal of reducing all emissions across the department.

[6] Government of Canada, "Government of Canada's Greenhouse Gas Emissions Inventory ," Canada, March 15, 2022, https://www.canada.ca/en/treasury-board-secretariat/services/innovation/greening-government/government-canada-greenhouse-gas-emissions-inventory.html.

Of note, an avenue that will not be explored in depth is that of purchased carbon offsets. At rates available in early 2022, the entire carbon emissions of DND fleets could be offset for an approximate cost of $11M CAD annually.[7] While carbon offsetting is a strategy in heavy use by corporations, it is noted that accurately measuring the offset generated by any specific activity is difficult.[8] Further, carbon offset prices are forecast to rise steadily as the demand grows and standards continue to tighten for acceptable initiatives, so this strategy could quickly become unaffordable for the CAF.[9] Finally, the shell game of carbon inputs/offsets distracts from initiatives that cut emissions at the source, which is a more sustainable strategy that should be pursued by the CAF.

Finally, as implied by Lawrence Freedman in 'The Future of War: A History', which outlines many examples of both accurate prognosticators and false prophets pertaining to the impact of new technology in warfare, "prediction is difficult and likely to be wrong".[10] This paper uses elements of foresight and environment scanning to provide information and initial direction to begin shaping a response to the situation, but a continual re-evaluation will be necessary both as geopolitical conditions change and as technologies advance.[11]

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[7] Cool Effect Org, "Welcome to Carbon Done Correctly," Cool Effect Org, 2022, https://www.cooleffect.org/ Calculated using a quoted price of $14.62 USD/tonne, but rates vary significantly.

[8] Barbara Haya et al., "Managing Uncertainty in Carbon Offsets: Insights from California's Standardized Approach" 20, 20, no. 9 (2020): 1122, doi:10.1080/14693062.2020.1781035.

[9] Sarah George, "BNEF: Carbon Offset Prices Set to Increase 50-Fold by 2050," Edie, January 12, 2022, https://www.edie.net/bnef-carbon-offset-prices-set-to-increase-50-fold-by-2050/#:~:text=Prices%20for%20carbon%20offsetting%20could,BloombergNEF%20(BNEF)%20is%20forecasting.

[10] Lawrence Freedman, *The Future of War: A History* (New York: PublicAffairs, 2019).

[11] Canada. Department of National Defence, "B-GL-007-000/JP-007, Canada's Future Army, Vol 1: Methodology, Perspectives and Approaches" (Kingston: Canadian Land Warfare Centre, 2015), https://publications.gc.ca/collections/collection_2017/mdn-dnd/D2-354-1-2015-eng.pdf.

DISCUSSION

Review of Technology

This section will look at developments and challenges across four major categories of emerging technology for potential use in a military context – passenger vehicles, heavy duty vehicles, austere power generation, and individual power generation. First however it will discuss a current limiting factor of energy density as it pertains to batteries compared to fossil fuels.

Energy density (by weight or by volume) measures the amount of energy that can be stored per mass (or volume) of a storage medium. When considering mobile platforms such as vehicles or individually carried equipment, this metric is significant as it dictates how much weight is required to supply the needed power. Traditional fossil fuels have high energy densities – gasoline yields 8,760 Watt-hours per litre (Wh/L) and diesel yields 9,700 Wh/L.[12,13] In comparison to this, the most recently developed battery packs developed by Our Next Energy and tested in the Tesla Model S have an energy density of 416 Wh/L (less than 5% the energy density of diesel fuel).[14] This is a real barrier for increasing the versatility of battery powered devices as there is a continual trade off of capacity against weight. Performance of existing battery technologies continues to be optimized, and alternative methods such as using batteries as structural aspects of vehicles, experimentation with new materials and new methods of energy harvesting from the environment are being pursued, but with

[12] The Physics Factbook, "Energy Density of Gasoline," The Physics Factbook, accessed April 25, 2022, https://hypertextbook.com/facts/2003/ArthurGolnik.shtml.

[13] The Physics Factbook, "Energy Density of Diesel Fuel," The Physics Factbook, accessed April 25, 2022, https://hypertextbook.com/facts/2006/TatyanaNektalova.shtml.

[14] Our Next Energy, "Introducing Gemini 001," Our Next Energy, accessed April 25, 2022, https://one.ai/range/.

many unknowns and uncertain timelines.[15] While there are efficiency increases inherent in electric motors that help offset this disparity, the differential in energy densities still must be reduced significantly.

Within this framework, there are four current types of vehicle technology that the CAF can consider. Hybrid Electric Vehicles (HEVs) contain a gasoline or diesel-powered internal combustion engine (ICE) in combination with batteries and an electric motor. The battery power is provided from the engine and augmented with regenerative braking, so while HEVs deliver better fuel economy when compared to conventional ICE vehicles, they still produce carbon emissions. Offset with this, HEVs are not limited by range as they can revert to their conventional engine when the batteries are depleted.[16]

Plug-in Hybrid Electric Vehicles (PHEVs) operate in a similar manner to HEVs, however generally have larger on-board battery storage and the ability to charge by connecting to a traditional power grid. For short trips with frequent charges, it can operate completely using electrical power, while for longer trips or when depleted it can revert to its ICE and reliance on conventional fuels. Depending on usage this type of vehicle can be more fuel efficient than HEVs.[17]

Electric Vehicles (EVs) or Battery Electric Vehicles (BEVs) do not have an integral ICE and operate completely using stored electrical energy from their battery packs. They do not independently produce any GHG emissions and are recharged from the power grid either via home-based chargers or charging stations.[18] A BEVs

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[15] Chris Hall, "Future Batteries, Coming Soon: Charge in Seconds, Last Months and Power over the Air," Pocket-Lint, March 22, 2021, https://www.pocket-lint.com/gadgets/news/130380-future-batteries-coming-soon-charge-in-seconds-last-months-and-power-over-the-air.

[16] Alternative Fuels Data Center, "Hybrid Electric Vehicles," U.S. Department of Energy, accessed April 25, 2022, https://afdc.energy.gov/vehicles/electric_basics_hev.html.

[17] Alternative Fuels Data Center, "Plug-In Hybrid Electric Vehicles," U.S. Department of Energy, accessed April 25, 2022, https://afdc.energy.gov/vehicles/electric_basics_phev.html.

[18] Alternative Fuels Data Center, "All-Electric Vehicles," U.S. Department of Energy, accessed April 25, 2022, https://afdc.energy.gov/vehicles/electric_basics_ev.html.

range is currently limited to its battery storage capacity or availability of connection to an electrical grid or generating point. An emerging variation on this concept is that of EVs with swappable batteries – empty or low batteries are quickly removed from the vehicle and replaced with full batteries at a ‘swap station’, a process that can take under ten minutes.[19] While early attempts at this process failed, newer attempts at modular and more universal battery swap systems are being developed. China is leading the way in this field with over 1,400 swap stations in operation and plans for 26,000 by 2025.[20]

Fuel Cell Electric Vehicles (FCEVs) operate in the same manner as BEVs but use a hydrogen fuel cell system in place of a battery. Stored hydrogen is converted to electricity through the fuel cell, a process that produces no harmful emissions. Refuelling can be done quickly and consists of refilling or replacing compressed hydrogen tanks.[21] Despite these advantages, the process of first storing, transmitting, then generating electricity in this manner is three times less efficient than the process for BEVs, and at this point most of the hydrogen is itself produced using fossil fuel sources.[22]

Scaling up these technologies to medium- and heavy-duty classes of vehicles has so far proven difficult, but progress is being made. Initial developments of hybrid Class 8 tractor-trailers, hoping to take advantage of fuel efficiencies like passenger HEVs, quickly found that their different operating model of logistics movements of

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[19] Brian Cooley, “A New Take on Swapping Out Electric Car Batteries, From Startup Ample,” CNET, March 12, 2022, https://www.cnet.com/roadshow/news/a-new-take-on-swapping-out-electric-car-batteries-from-startup-ample/.

[20] Zeyi Yang, “EV Battery Swapping Was Left for Dead. Now, It’s Being Revived in China.,” Protocol, March 21, 2022, https://www.protocol.com/climate/electric-vehicle-battery-swap-china.

[21] Alternative Fuels Data Center, “Fuel Cell Electric Vehicles ,” U.S. Department of Energy, accessed April 25, 2022, https://afdc.energy.gov/vehicles/fuel_cell.html.

[22] James Morris, “Why Hydrogen Will Never Be The Future Of Electric Cars,” Forbes, July 4, 2020, https://www.forbes.com/sites/jamesmorris/2020/07/04/why-hydrogen-will-never-be-the-future-of-electric-cars/?sh=7b507ec212fa.

heavy cargo did not take advantage of the strengths of a hybrid drivetrain. For the most part, operation of this type of vehicle requires full ICE engagement through long-haul trips, and saw very little engagement of the onboard batteries, negating significant reductions in emissions.[23] BEV heavy transport vehicles, however, are gaining traction within the logistics sector as batteries become lighter and hold higher capacities, and as the charging infrastructure becomes more prevalent through major shipping routes. In 2020 announcements were made by major companies like Daimler, Volvo, Peterbilt, and Cummins that they would be releasing multiple new versions of electric buses, semi-trucks, and other heavy-duty vehicles soon.[24] Task specific heavy-equipment, such as the backhoes, excavators, dozers and graders found on construction sites are also being electrified with major industry names like Caterpillar, Volvo, and Bobcat starting to deliver full BEV versions.[25] The environment of specific duty shifts in areas that generally have accessible power grids for recharging is very well suited to the strengths and efficiencies of full electric vehicles.

Portable off-grid power generation without the use of fossil fuels remains a challenge. Options for renewable power generation including solar, wind, or small hydro-power systems are becoming both more efficient and more affordable, however are still not at the point of being able to replace a deployable tactical quiet generator

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[23] Jim Stinson, “Why Hybrid Diesel Trucks Never Quite Caught On,” Transport Dive, March 23, 2021, https://www.transportdive.com/news/hybrid-diesel-class-8-truck-long-haul/596782/.

[24] M. Moaz Uddin, “The Medium- and Heavy-Duty Electric Vehicle Market: Plugging into the Future Part I,” Great Plains Institute, September 30, 2021, https://betterenergy.org/blog/the-medium-and-heavy-duty-electric-vehicle-market-plugging-into-the-future-part-i/.

[25] Kendall Jones, “Electric Dreams: Will Heavy Construction Equipment Go All-Electric?,” ConstructConnect, February 22, 2019, https://www.constructconnect.com/blog/electric-dreams-will-heavy-construction-equipment-go-electric.

easily or effectively in terms of reliability and output without a significant size and weight increase in equipment required.[26]

Individual level power generation is emerging as a potential new avenue of development. Scientists have developed a small thermoelectric generator that can generate small amounts of electrical power using the heat differential between a person's skin and the ambient temperature.[27] A slightly different design is "capable of converting random mechanical energy directly into electric energy and providing sustainable power source for various wearable electronic devices".[28] While the overall outputs of these systems remains very low (on the level of consistently powering a single LED) it is expected that continued development will increase the output and utility of these systems. It is not likely that these systems will contribute to large scale power generation, but they could offset the need for a significant draw to recharge individual-based electronics systems.

At this point there are significant incentives to continue and increase developments of electric or alternative sources of energy. It is being argued that the world is seeing five waves of innovation that are driving rapid change in this area – increasing renewable energy, changing technology, a shift from competitiveness to sustainability, electrification of mobility, and the electrification of HVAC.[29]

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[26] Energy Saver, "Off-Grid or Stand-Alone Renewable Energy Systems," ENERGY.GOV, accessed April 25, 2022, https://www.energy.gov/energysaver/grid-or-stand-alone-renewable-energy-systems.

[27] Yijie Liu et al., "A Wearable Real-Time Power Supply with a Mg3Bi2-Based Thermoelectric Module," Cell Reports Physical Science 2, 2, no. 5 (2021): no. 5, doi:https://doi.org/10.1016/j.xcrp.2021.100412.

[28] Yao Lu et al., "Wearable Supercapacitor Self-Charged by P(VDF-TrFE) Piezoelectric Separator," Progress in Natural Science: Materials International 30, 30, no. 2 (2020): 174–79, doi:https://doi.org/10.1016/j.pnsc.2020.01.023.

[29] Nicolo Rossetto and Jean-Michel Glachant, "Several Innovation Waves Transforming the Electricity Sector," European University Institute, October 25, 2021, https://fsr.eui.eu/several-innovation-waves-transforming-the-electricity-sector/.

Following these rapid shifts will require significant attention and flexibility on the parts of any organization looking to make best use of these new technologies.

Review of Allies Initiatives

The development of military specific equipment, especially in fields of emerging technology, can be extremely time and resource intensive and yield sometimes uncertain results. Fortunately, close working relationships between friendly nations and allies can assist in shortening the timelines of easier development projects, or in sharing the burden of development and investment, such as with the Joint Strike Fighter consortium agreement. This paper will now investigate major initiatives of Canada's allies in the field of decarbonization to assess potential areas of beneficial co-operation.

In February 2022, the U.S. Army published a new Climate Strategy as a roadmap on how the organization will adapt to both reduce GHG emissions and make itself more resilient to natural disasters and extreme weather.[30] This strategy is wide ranging and ambitious, spanning topics including vehicle emissions, deployed power generation, army base power grid management, efficiency of infrastructure, green supply chain development, and increased training in climate literacy. The overall intent of this strategy is to generate an army that is "a resilient and sustainable land force able to operate in all domains with effective mitigation and adaptation measures against the key effects of climate change, consistent with Army modernization efforts".[31]

A key area of desired development for the U.S. Army is to reduce emissions from tactical vehicles, an area that has proven "difficult to decarbonize due to their

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[30] United States Army, *Climate Strategy* (Washington, D.C.: Department of the Army, Office of the Assistant Secretary of the Army for Installations, Energy and Environment, 2022).

[31] Ibid., 16.

large size and need to be able to be refuelled in combat areas where electric charging stations may be unavailable".[32] Despite the challenge, the Army has committed to field hybrid tactical vehicles by 2035 and fully electric tactical vehicles by 2050.[33] A first step in this process is the ongoing testing and implementation of Tactical Vehicle Electrification Kits (TVEKs) – a semi-hybrid conversion kit for existing fleets that increases battery capacity and facilitates an idle-reduction capability. This system allows vehicles to 'run silent', operating most high drain electrical systems within the vehicle without the need for running the engine.[34] While a seemingly minor step, this initial phase is a move to replicate some capabilities of standard HEVs and can help decrease fuel consumption of significant fleets of vehicles.

Industry oriented towards the US Army has also noted this shift in priorities for next generation vehicles. Oshkosh Defence, who was awarded the contract to build the Joint Light Tactical Vehicle (JLTV) in 2015, has recently developed a hybrid version of the same vehicle. The eJLTV contains a diesel engine for normal operation, but also lithium-ion batteries that offer up to 30 minutes of 'silent drive' and 'silent watch' capabilities (comparable to the idle-reduction capability of the TVEK), as well as a 20% improvement on fuel economy.[35] Of note, the recent recompete for this vehicle that is currently underway does not explicitly state a requirement for this

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[32] Nico Portuondo, "Army Details Plans to Hit Net-Zero Carbon Emissions," E&E News, February 8, 2022, https://www.eenews.net/articles/army-details-plans-to-hit-net-zero-carbon-emissions/#:~:text=The%20United%20States%20Army%20released,of%20the%20Army's%20procurements%20by.

[33] U.S. Army, *Climate Strategy*, 10.

[34] Green Car Congress, "DoD to Prototype Commercial Hybrid Conversion Kits for Tactical Vehicles; XL Fleet and Volta Power," Green Car Congress, November 24, 2021, https://www.greencarcongress.com/2021/11/20211124-dod.html.

[35] Andrew Eversden, "Oshkosh Defense Announces First Hybrid Electric JLTV," Breaking Defence, January 25, 2022, https://breakingdefense.com/2022/01/oshkosh-defense-announces-first-hybrid-electric-jltv/.

hybrid technology. Despite the optimism of industry, the U.S. Army is not expecting to field hybrid-drive tactical vehicles until 2035.[36]

A slightly easier vehicle target for the U.S. Army is in non-tactical vehicle fleets, with aims of fielding an 'all-electric *light-duty* non-tactical vehicle fleet by 2027', and an 'all-electric non-tactical vehicle fleet by 2035'.[37] This is being done through a replacement program that mandates new vehicle purchases or leases must select BEVs if possible, HEVs as a secondary option, and ICE vehicles by exception only. It is understood that BEVs frequently require additional charging infrastructure, and to support this the Army is investing in over 470 new charging stations on bases in 2022.[38]

Initiatives are also ongoing to better integrate austere generation of power with vehicle platforms. The vehicle centric microgrid (VCM) project consists of enhancing the power generation capability of existing vehicle platforms and coupling them with smart grid management hardware and software. Existing vehicle platforms (FMTV, MTVR, Stryker, MRAP) can have their conventional transmission modified with a transmission integrated generator (TIG) that can output from 100-160kW, using the diesel engine as the source.[39] While this system does not eliminate or reduce the emissions of the vehicle itself, it significantly reduces the requirement for deployable stand-alone tactical generator sets, reducing fuel consumption and the amount of equipment required. Further, these units provide very efficient power generation, and the smart micro-grid sharing uses the power generated in a much more efficient

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[36] U.S. Army, *Climate Strategy*, 11.
[37] Ibid., 6.
[38] Ibid., 8.
[39] Joseph K. Heuvers, "Vehicle Centric Microgrid Development," Vehicle Electrification Forum (U.S. Army Combat Capabilities Development Command, May 30, 2019), https://jteg.ncms.org/wp-content/uploads/2020/06/07-Vehicle-Centric-Microgrid-Development-Dist-A.pdf.

manner than existing deployable equipment. U.S. Army project staff predict that in the future between ten and twenty percent of tactical vehicles will have VCM capability.[40]

At the highest end of technological development and disruptive innovation, the U.S. Army Deputy Chief of Staff, G-4, conducted a study into the use of mobile nuclear power plants (MNPPs) for ground operations in 2018. This study recognized the key roles that a large amount of reliable power in austere environments will hold in resolving future conflicts, including "to enable air and missile defense capabilities, long-range precision fires, a future electrified force, and other modernization priorities."[41] It also noted that approximately half of U.S. casualties over a nine year period during Operation IRAQI FREEDOM and Operation ENDURING FREEDOM were caused during attacks on land based sustainment convoy missions, and that part of the nexus of this study was to mitigate that risk by reducing the quantity of land based convoys required by minimizing the need to transport fuel overland. In terms of energy density, uranium far outstrips gasoline or diesel fuel, however that calculus is complicated by the more elaborate system required to produce electricity via nuclear fission, so an output per mass figure is somewhat misleading. Nuclear is also considered a clean and sustainable energy source by the U.S government as it does not result in GHG emissions.[42] Despite this certification, there is significant resistance to the development and use of MPRRs, with critics citing concerns with high costs,

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[40] David Vergun, "DOD Demonstrates Mobile Microgrid Technology," DOD News, July 6, 2021, https://www.army.mil/article/248221/dod_demonstrates_mobile_microgrid_technology.

[41] Juan A. Vitali et al., "Study on the Use of Mobile Nuclear Power Plants for Ground Operations," Deputy Chief of Staff, G-4, October 26, 2018, 1.3, https://apps.dtic.mil/sti/pdfs/AD1087358.pdf.

[42] Office of Nuclear Energy, "3 Reasons Why Nuclear Is Clean and Sustainable," ENERGY.GOV, March 31, 2021, https://www.energy.gov/ne/articles/3-reasons-why-nuclear-clean-and-sustainable#:~:text=Nuclear%20is%20a%20zero%2Demission,byproducts%20emitted%20by%20fossil%20fuels.

vulnerability to enemy missile attacks, concern of increased proliferation of radioactive fuel or waste that could be used in terror attacks, and the lack of a real justification for these reactors.[43] Despite these concerns, the U.S. DOD recently granted approval for a MNPP prototype to be built and tested at the Idaho National Laboratory.[44]

The U.K. Ministry of Defence (MoD) also released their Climate Change and Sustainability Strategic Approach in 2021, defining three epochs of activities.[45] The first epoch (2021-25) is seen as foundation setting through increased understanding of the issues, database building and baselining, and target establishment. The second epoch (2026-35) will build on those initiatives to significantly reduce emissions and to maximize use of emerging technologies. The third epoch (2036-2050) is focused on harnessing novel technologies. Of specific note, this strategy emphasizes the desire to "build a coalition of militaries working to achieve commitments on adaptation, resilience, and mitigation".[46] The U.K. Army has prototyped hybrid versions of the Foxhound Light Protected Patrol Vehicle, the Jackal High Mobility Weapons Platform, and MAN SV 6T logistics vehicle to "inform modernisation of the Army using the commercial technology currently available".[47] These prototype vehicles are showing positive results with increased cross-country performance, the ability to conduct neutral turns, and integral power generation allowing either 'run silent'

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[43] Alan J. Kuperman, "Proposed U.S. Army Mobile Nuclear Reactors: Costs and Risks Outweigh Benefits," Nuclear Proliferation Prevention Project (Austin, Tx: University of Texas at Austin, April 22, 2021), https://sites.utexas.edu/nppp/files/2021/04/Army-Reactor-Report-NPPP-2021-April.pdf.

[44] Keith Ridler, "US Military OKs Prototype Mobile Nuclear Reactor in Idaho," Abc News, April 21, 2022, https://abcnews.go.com/Technology/wireStory/us-military-oks-prototype-mobile-nuclear-reactor-idaho-84224272.

[45] Ministry of Defence, "Climate Change and Sustainability Strategic Approach" (Ministry of Defence, March 30, 2021), 20, https://www.gov.uk/government/publications/ministry-of-defence-climate-change-and-sustainability-strategic-approach.

[46] Ibid., 23.

[47] Ministry of Defence, "Army Hybrid Vehicles Power Forward," July 21, 2021, https://www.army.mod.uk/news-and-events/news/2021/07/army-hybrid-vehicles-power-forward/.

capability or the potential to power nearby infrastructure. Investing in these types of vehicles are a potential avenue for the U.K. to achieve its 2nd epoch goals of significantly reduced emissions. In terms of reaching net-zero emissions for army tactical vehicles, General Mark Carleton-Smith, CGS British Army, noted in 2021 that he "think(s) we're, industrially, still some way away from completely living without carbon engines in our principal war-fighting equipment. There's considerable battery and propulsion requirements that have not yet been solved".[48]

Strengths, Weaknesses, Opportunities, Threats

"Unleash us from the tether of fuel."

- General James Mattis, Operation IRAQI FREEDOM

The biggest strength of the Canadian Army is, as it always has been, the dedication, enthusiasm, commitment, and ingenuity of its people – whether they are military members, public servants, or contracted personnel. The institution can reap huge benefits from assigning a direction and defining performance targets, then enabling subordinate commanders and subordinates while 'demand[ing] the aggressive use of initiative at every level' through a mission command approach.[49] Canadian Army personnel are astute at solving problems at all levels, but must be properly informed, engaged, and empowered to do so.

In contrast to this, a weakness inherent within the organization in the context of green energy are the extreme performance conditions required of Army equipment. Army vehicles usually have significant electronics suites on-board that consume high

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[48] Aaron Mahta, "UK Army Chief Talks Green Energy, Countering Russia and Digital Modernization," Defense News, May 24, 2021, https://www.defensenews.com/interviews/2021/05/24/uk-army-chief-talks-green-energy-countering-russia-and-digital-modernization/.

[49] Canada. National Defence, "CFJP 01 - Canadian Military Doctrine" (Ottawa, ON: National Defence, 2009), 4–3, https://publications.gc.ca/collections/collection_2010/forces/D2-252-2009-eng.pdf.

levels of power themselves. They have unpredictable use schedules, which vary considerably depending on the nature of the operation or training they are undertaking. Perhaps most daunting, Army tactical vehicles are often required to be operated in austere areas with no ready access to an electrical grid for extended periods of time, or in locations where the power available is provided via fossil fuel generation. Throughout all these conditions, there is no real acceptance of any amount of vehicle downtime for charging purposes or altering vehicle routes or timings to find a charging station. In the implementation of alternative fuel vehicles, it is vital that these capabilities are not lost or downgraded. Especially in the context of the Canadian Army, the ability to operate independently off-grid for extended periods of time must be retained. As the U.K. climate strategy is doing, the Canadian Army must be prepared to identify where there are emissions that cannot be cut at the current time due to the lack of a technologically viable solution that will maintain an operational capability.[50]

In counterpoint to these concerns are the existing limitations imposed on conventional ICE Army vehicles through their reliance on a steady and significant supply of fuel. To quantify this, the U.K. MoD reports that "…a UK Army division can consume approximately 800,000 litres of diesel per day during high-intensity warfighting…."[51] Logistics planners, understanding the direct operational impact of fuel shortages, have necessarily become skilled at meeting this requirement, but it comes at a significant cost. Planners for Operation IRAQI FREEDOM recognized that the fuel required for a rapid advance across Kuwait would be significant. This

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[50] Julia Powell and Dave Perry, *Greening British Defence*, Podcast (Canadian Global Affairs Institute, 2021).

[51] Major Alistair Beard and Dr Sarah Ashbridge, "Greening Defence: The British Army's Bet on Electrification," Royal United Services Institute, March 23, 2022, https://rusi.org/explore-our-research/publications/commentary/greening-defence-british-armys-bet-electrification.

spawned exhaustive fuel support planning, employed 7 fuel truck reserve companies, and led to the establishment of fuel farms through the JOA.[52] On top of this, this particular issue was simplified by Kuwait being able to locally provide most of the fuel, and by existing infrastructure being well established, and the mission still required extensive logistics to conduct properly. Demand was significant – V Corps averaged 402,000 gallons of fuel per day for the first week of April 2003, while 3rd ID averaged 153,000 gallons of fuel per day.[53] Fuel in this case was recognized as a very real limiting factor, one that could significantly reduce operational options if not properly managed. Lengthening or completely removing this 'tether' of fuel dependency is an opportunity to increase freedom of manoeuvre and flexibility in tactical army vehicles.

A further weakness of existing equipment is the almost complete decoupling of vehicle systems and camp infrastructure assets. Current vehicle fleets can produce small amounts of A/C power through converters, but they are generally intended to only power vehicle integrated equipment. Portable generators are used with their own bespoke wiring systems to provide austere camps with general electrical service. On top of this, heating systems and kitchen cooking equipment are generally completely independent, and carbon emitting fuel based. This plethora of systems to independently generate power is wasteful in that there is a requirement to bring enough equipment to satisfy all these separate needs, it is inefficient in terms of a wide variety of systems being managed by individuals, and it is generally using comparatively inefficient gas burning appliances rather than their electric counterparts. The Camp Sustain project is pursuing some of these goals, including

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[52] Eric Peltz et al., "Sustainment of Army in Operation Freedom" (Santa Monica, CA: RAND Corporation, 2005), 12, https://www.rand.org/content/dam/rand/pubs/monographs/2006/RAND_MG344.pdf.

[53] Ibid., 14–15.

delivering more efficient generators, deployable renewable energy systems, smart power management, and camp energy storage.[54]

There are opportunities for real change within this context. Canada overall produces a very high percentage of electricity from low-carbon sources, including hydropower, nuclear, and wind power – 83% in 2021.[55] This compares to 55% for the U.K., 53% for Germany, and 40% for the U.S. The consequence of this is that the transition of energy source from fossil fuel to an electricity-based system within Canada comes with a very high percentage of reduction of secondary emissions as well because most electricity is produced cleanly.

A further opportunity for the Canadian Army at this point is an unprecedented level of global support and actual pressure to take strides towards reducing carbon emissions. The global shift from ICE powered vehicles to hybrid or electric vehicles is accelerating, and with this acceleration comes significantly more investment as industry commits to and competes in this domain. With an anticipated $500B USD expected to be invested into EV development by the auto industry by 2030, improvements in range, storage capacities and efficiencies are expected to continue.[56] While early hybrid or electric vehicles relied on the owner's desire to reduce GHG emissions as a selling point to offset the additional cost, at this point many use cases for personal transportation have the cost of purchasing and operating a hybrid or electric vehicle as very comparable to an ICE vehicle.[57] Beyond the commercial

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[54] Government of Canada, "Camp Sustain," Government of Canada, January 9, 2020, http://dgpaapp.forces.gc.ca/en/defence-capabilities-blueprint/project-details.asp?id=1471.

[55] Hannah Ritchie, Max Roser, and Pablo Rosado, "Canada: Energy Country Profile ," Our World In Data, 2020, https://ourworldindata.org/energy/country/canada.

[56] Robinson Meyer, "Electric Cars Have Hit an Inflection Point," The Atlantic, September 28, 2021, https://www.theatlantic.com/newsletters/archive/2021/09/electric-cars-have-hit-inflection-point/620233/.

[57] Mike Winters, "Here's Whether It's Actually Cheaper to Switch to an Electric Vehicle or Not—and How the Costs Break Down," December 29, 2021, https://www.cnbc.com/2021/12/29/electric-vehicles-are-becoming-more-affordable-amid-spiking-gas-prices.html.

development of technology, militaries across the world are tackling the same problem sets – heavy duty cycles, off-grid usage, austere power generation – with new focus and dedication. From this massive parallel effort two factors emerge for the CA. First, the opportunity for collaboration and cooperation with allied and friendly nations is enormous with significant payoffs. Not only could this speed development of needed technologies, but it would also strengthen ties economically and diplomatically. Further, cooperative development would increase levels of interoperability with these allied countries in future operations across the globe, a challenge that NATO has identified as "essential to ensur[ing] NATO's force effectiveness".[58]

The second factor from the preceding point is that other nations competing on the world stage are also developing their own solutions to these issues, in a manner that can be considered a "green energy arms race".[59] Unequal distribution of renewable resources (good sources for hydro, wind or solar power, and location of rare earth minerals) could replace the current fossil fuel oriented geopolitical situation, and technological advances in energy storage and efficiency could confer significant advantages to the countries that control them.[60] China specifically produces "more than 70 per cent of all solar photovoltaic panels, half of the world's electric vehicles and a third of its wind power", controls many of the minerals required for production of these items, and produces the most batteries globally.[61]

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[58] James Derleth, "Enhancing Interoperability: The Foundation for Effective NATO Operations," NATO Review, June 16, 2015, https://www.nato.int/docu/review/articles/2015/06/16/enhancing-interoperability-the-foundation-for-effective-nato-operations/index.html.

[59] Paddy Ryan, "The Green Energy Arms Race Is Underway," DefenceNews, August 9, 2021, https://www.defensenews.com/opinion/commentary/2021/08/09/the-green-energy-arms-race-is-underway/#:~:text=Energy%20is%20woven%20into%20the,the%20West%20to%20its%20knees.

[60] Alexander V. Mirtchev, *The Prologue - The Alternative Energy Megatrend in the Age of Great Power Competition* (New York: Post Hill Press, 2021).

[61] Leslie Hook and Henry Sanderson, "How the Race for Renewable Energy Is Reshaping Global Politics," Financial Times Magazine (Financial Times, February 4, 2021), https://www.ft.com/content/a37d0ddf-8fb1-4b47-9fba-7ebde29fc510.

Falling behind the curve of development and implementation of cleaner and alternative energy equipment today is a real threat to the Army's ability to survive in a future operating environment where access to fuels could be limited or use of carbon emitting equipment restricted for various reasons.

Further threatening the Canadian Army's ability to adapt to a new paradigm of decarbonization is the length of time it takes to develop, contract, integrate, and field new equipment. Army tactical and support vehicle fleets have lifespans measured in decades. Because of this, replacing existing fleets when they reach the end of service life is an inherently drawn-out strategy, but replacing vehicles before they reach the end of their service life is seen as a poor use of public funding. The timeline of project approval and contract award further exacerbates this issue, especially within areas of developing technology as changes literally occur within the timespan of the project. While speeding project and procurement timelines is out of the scope of this project, the CA must factor this in to its climate strategy or risk falling behind allies and competitors alike.

Decarbonization Functional Concept

Recommendations for a DFC plan are included here in three timeframes. Immediate actions are intended to create and publicly state intentions, set ambitious but achievable targets, and start influencing long term initiatives. Medium-term recommendations are aimed at the goal of reducing emissions ahead of 2030 through increased efficiencies and increasing use of hybrid and renewable technologies. Longer-term recommendations are aimed at positioning the Army for net-zero emissions by 2050.

The primary immediate recommendation is that the CA establish a Climate Strategy itself, reflecting the overarching goals of the recently published 2030

Emissions Reduction Plan and the DND/CAF Defence Energy and Environment Strategy (DEES) 2020-2023, but expanding on internal steps to reach them.[62,63] The existing plans provide high level targets for the government overall, however the Emissions Reduction Plan has very little specific guidance for DND or the CAF, and the DEES has very little specific direction for the Canadian Army as a whole outside of increasing the efficiency of soldier equipment and deployable power solutions. Discussion of vehicle fleets focuses on 'commercial light-duty vehicle fleets' without commitments on tactical vehicles, support vehicles, or other heavy-duty vehicle fleets. There is a need as an organization to translate the high-level targets that are being established by the government into smaller attainable goals and a create a roadmap to achieve these goals. The establishment of this plan cannot jump directly to decarbonization – the technology needed to do that without reducing operational capabilities of the CA does not currently exist, but there is potential for it to exist in time to meet 2050 net-zero emissions goals. The CA must position itself within the CAF and the Government of Canada to continually take incremental steps towards this goal, while allowing flexibility to adapt to changing technologies as they are developed.

An Army specific Climate Strategy advertising intent and including small but measurable short-term goals will have multiple galvanizing effects. First, it will act as an 'Army Commander's Intent' for how the CA is going to navigate the coming technological disruption. Armed with this intent, soldiers of all rank levels will be

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[62] Environment and Climate Change Canada, "2030 Emissions Reduction Plan" (Government of Canada, 2022), https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/emissions-reduction-2030.html.

[63] National Defence / Canadian Armed Forces, "Defence Energy and Environment Strategy 2020-2023" (National Defence / Canadian Armed Forces, 2020), https://www.canada.ca/content/dam/dnd-mdn/images/dees2020/2020-23%20Defence%20Energy%20and%20Environment%20Strategy_EN%20-%20Signed.pdf.

better informed and better enabled to take the initiative at their own level but along the organization's axis of advance. Second, it will inform the direction of projects across all levels to begin seriously incorporating more efficient, renewable, or interconnected systems from inception. Finally, the document would be a signal to industry that the Canadian Army is looking to shift meaningfully into the alternative energy realm, which could spur increased research and development of local options to compete for contracts.

Further immediate actions should include a re-evaluation of ongoing major projects currently in Identification, Options Analysis, or Definition phases. As these projects are going to deliver major equipment over the coming 5-10 years that would then be expected to last 10-20 further years, these are targets of opportunity to have quick and significant impacts on the Army of 2030. Vehicle project requirements should be modified to include at a minimum an equivalent to the Tactical Vehicle Electrification Kits (TVEKs) being assessed by the U.S., or at best to include a degree of hybridization to provide some battery manoeuvrability for silent-drive and silent-watch capabilities. Specifically, the Logistics Vehicle Modernization (LVM) Project which currently has a Request for Proposal out to qualified suppliers should be amended to include these types of equipment integrally.[64] As these vehicles are expected to be in service through the next decades, their use case needs to be nested within the context of decarbonization that we expect to see in the 2030-2040 timeframe.

In the medium term, the DFC should have two focus points – generating reduced emissions to assist in meeting targets for 2030 and driving change within the

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[64] Government of Canada, "Logistics Vehicle Modernization Project," Government of Canada, April 4, 2022, https://www.canada.ca/en/department-national-defence/services/procurement/logistics-vehicle-modernization-project.html.

organization and supporting industry. With the current technological state of BEVs, it is not possible to replicate our current capabilities with fully electric vehicles. What *is* possible in this medium term is an increased fuel efficiency and reduced emissions across lighter tactical and support vehicle fleets through the use of hybrid technologies. Given the life-cycle stage of current Army fleets, modification of existing vehicles such as the LAV 6, TAPV, and MSVS should be studied through methods like the TVEKs mentioned above or more extensively such as the modifications recently tested on light tactical vehicles by the U.K. to increase performance, integrate power generation (meshing with the Camp Sustain project equipment), and run silent capabilities. Developing these solutions for Canadian equipment with local industry would signal intentions to pursue this technology, would begin familiarizing Army soldiers and technicians with this type of equipment, and would stimulate the local economy in a more sustainable direction. This is also a significant opportunity to collaborate with the U.K. given their recent work in this field.

Finally, and as stated earlier, a long-term net-zero goal for GHG emissions by 2050 within the Army is not possible with today's technology without the use of carbon offsets or a degradation in capability, neither of which are recommended. Despite this, the stated intention that the Army will pursue avenues towards net-zero carbon emission operations must be captured as a long-term goal. This will align capability development projects and initiatives towards a distant goal and will signal to industry that development of ever more efficient and extended range EVs, or alternate energy generation solutions, are of a high value to the organization.

CONCLUSION

This paper reviewed existing and developing technologies that could be applied to the CA and investigated initiatives of allied forces along this avenue. It assessed strengths, weaknesses, opportunities, and threats to the CA within this domain, and provided initial recommendations for the creation of an Army Climate Strategy and the basis for a Decarbonization Functional Concept.

Decarbonization will challenge many industries and organizations moving forward, but perhaps none more so than national armed forces with their no-fail, any environment, heavy-duty usage requirements. Despite this, there are many opportunities present for those willing to drive forward with the developing changes. There are also many emerging risks due to inaction or unwillingness to change with the times. While prediction of emerging technology is never straightforward, the Canadian Army must take action to begin grasping this issue and must, by all means possible, avoid being forced into a reactive stance on this issue when solutions have such long implementation times.

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