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A REAL GREEN LAND FORCE: OPTIONS TO DECARBONISE THE CANADIAN FORCES LAND FORCE

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AIM

1. The aim of this service paper is to recommend ideas that will enable the Canadian Army to contribute to Canada's decarbonisation strategy. This paper will focus on the source of energy that the Canadian Army Land Force could adopt and a conceptual approach to future procurement.

INTRODUCTION

2. Canada has signed the Paris Accord Agreement and is prioritising climate change within all departments of the Government. The Prime Minister is clear in his letter to the Defence Minister about his stance on climate change, saying: "I expect you to seek opportunities within your portfolio to support our whole-of-government effort to reduce emissions".[1] Furthermore, National Defense is the department with the largest carbon footprint in Canada, being almost five times higher than its closest competitor department.[2] This means that the Department of National Defence has to do its share to reduce its emissions and work towards decarbonisation. Currently, the Canadian Armed Forces (CAF) Land Force (LF) is dependant on fossil fuels (or diesel) for deployments on operations and training. The fuel is used to power fighting vehicles, support vehicles and even generators that support the electrical demand of a camp. The main advantage of the current construct is that one single type of energy is powering the whole land enterprise. This approach simplifies procurement and logistics for energy requirements.

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[1] Justin Trudeau, *Minister of National Defence Mandate Letter* (Ottawa, CA: ,[2021]).
[2] Carl Myers, "Trends in Greenhouse Gas Emissions by Federal Organization," *Canada's National Observer* (30 Nov, 2020). https://www.nationalobserver.com/2020/11/30/news/national-defence-largest-polluter-federal-government.

3. In order to be able to work towards decarbonisation, the Land Component of the CAF needs to consider how to implement strategies without impeding its capability to conduct operations and training. The procurement of the potential new source of energy needs to be aligned with the capability of the supply chain to maintain a sufficient amount of that energy, to any location required by the CAF.

4. I believe that in order to achieve its carbon footprint goals, the Land Force (LF) needs to focus on two lines of efforts. First, actions that can be taken now, with our current structure and equipment. Second, establishing the framework of equipment acquisition that will enable the LF to be a problem-solver in the 2030 onward acquisition program.

5. This paper will look at options that would allow carbon reduction in the short-term, and will then look at what is being done elsewhere, in order to find interoperable solutions that will allow Canada to work efficiently with its allies. The study will also look at different industry approaches to reduce harmful emissions and will evaluate how the certain components could fit within Canada's requirements.

DISCUSSION

6. In order to reduce the carbon footprint of the current vehicle fleet and camps, the forces need to change its source of energy. In the short-term, options will look at reducing the carbon footprint with the current equipment. For the long-term, two main systems that could replace the diesel engines in the Canadian LF will be evaluated - electric engines and hydrogen power engines.

Short-Term

7. The common thought when talking about decarbonisation is that we need to transition from fossil fuels towards electricity as a source of energy. This is only valid if the electricity is produced without creating more CO_2 emissions. Electricity made from a coal power plant does not solve the decarbonisation problem. In 2022, according to Our World in Data, 15.7% of global energy comes from low carbon sources and 37% of the world's electricity production is also produced from low-carbon sources.[3]. This data shows that electricity is not necessarily green energy because there is no emissions at the site of utilisation. It also suggests that it is not possible today, nor in the near future, to have enough green electricity to meet the current demand and to power our vehicles. The extra demand for electricity to power vehicles will put another strain on the currently overstretched world power grid. Although research shows that an electric car plugged into a coal power plant is slightly less polluting than a gas powered car, the studies do not consider the carbon footprint of the fabrication and disposition of the battery.[4] The electrification of the LF vehicle fleet is therefore not a green solution, until the power grid is green. The Paris Agreement has countries vouching to reduce their carbon emissions, which is the basis to assume that future electricity production will be at a lower carbon emission rate than current electricity production. Knowing that current world electricity is not necessarily green, are there quick fix options to help the Canadian Armed Forces Land Forces reduce its emissions?

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[3] "Electricity Mix," last modified Jan, accessed 18 Jan, 2022, https://ourworldindata.org/electricity-mix.
[4] Anrica Deb, "Why Electric Cars are Only as Clean as their Power Supply," *The Guardian*, no. Climate crisis (09 Dec, 2016). https://www.theguardian.com/environment/2016/dec/08/electric-car-emissions-climate-change.

8. The easiest way not to produce greenhouse gases is to avoid the use of fossil fuels. Fossil fuel is currently being used for both operations and training. From these two tasks, only training has the option to transition from using it. The use of Rehearsals Of Concepts (ROC) drills and simulations are the best approach to minimise the use of fuel in training. Looking at a tactical application, the Royal Canadian Engineers are using simulators to train heavy equipment operators, which is one way to considerably reduce the fossil fuel consumption in a training environment. Another way the Canadian Forces College currently uses virtual training to reach training objectives, without the use of troops on the ground, is through war gaming. This approach achieves specific training objectives by targeting learning goals with specific games. Although not perfect, the games are able to emphasize certain aspects of warfare and give the senior officer students an appreciation for different consideration when planning operations. Therefore, the use of simulators in most training exercises to reduce the physical movement of troops in vehicles is one way to cut emissions and costs. This option does come at a price though - which would be the potential impact on the quality of the training. This will need to be evaluated by commanders at each level, to balance CO_2 emissions and training requirements.

9. It is also important to consider fossil fuel alternatives when trying to reduce emissions in operations. The most common one is biodiesel, which will power a diesel engine without any modifications. A study from the Department of Mechanical Engineering Science from the University of Johannesburg concludes that the life-cycle of soy biodiesel, compared to the one of fossil fuel diesel, reduces the emission of CO_2 by

78%.[5] This option does not require any change to the current fleet and equipment. It also does not create emissions through having to build a new fleet. In the short-term, it is not only viable, but it is cheap and shows results rapidly. One of the main advantages of biodiesel is that it is possible to use diesel fuel if biodiesel is not available in a certain location.

Long-Term

10. According to a Swiss study following NATO's carbon footprint reduction objectives, Power to Hydrogen (P2H) is a viable solution for NATO countries.[6] The study looks at the German, US and Japanese military efforts to pursue a hydrogen-based solution to carbon reduction for their land forces. It mentions that there is a requirement for a "comprehensive life cycle assessment (LCA)"[7] of the implementation of a hydrogen solution. This assessment is critical, as hydrogen fuel, used in *fuel cells*, is a green energy, as it produces water as a by-product while producing electricity. Japan and Germany are both looking at developing a sustainable supply chain for hydrogen in the medium future.[8] They plan on importing a significant portion of this hydrogen. This means that other countries will be producing the hydrogen to meet this demand. As the supply chain for hydrogen grows, the transportation will become cheaper and enable deployed forces to access this energy source at an affordable price, without having a negative impact on the environment.

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[5] Noor A. Ahmed, "Overview of Biodiesel Combustion in Mitigating the Adverse Impacts of Engine Emissions on the Sustainable Human–Environment Scenario," *Sustainability* 13, no. 10 (2021), 5465. doi:http://dx.doi.org/10.3390/su13105465. https://www.proquest.com/scholarly-journals/overview-biodiesel-combustion-mitigating-adverse/docview/2533036377/se-2., 11.
[6] Andrzej Sobon et al., "Prospects for the use of Hydrogen in the Armed Forces," *V2,* 29 Oct, 2021, 3.
[7] Ibid.
[8] Ibid, 9.

11. Hydrogen is not found in nature as a fuel (it does represent a negligible percentage of the atmosphere, but not enough to warrant capture from air), it needs to be created, thus cannot be a source by itself. Hydrogen "can be produced with low-carbon emissions through water electrolysis, or by combining natural gas reforming and coal gasification processes with carbon capture and storage (CCS) technology."[9] Although an option, this low-carbon production is not the norm. Currently, 95% of the hydrogen produced in the United States comes from the burning of natural gas, which even if not as bad as other fossil fuels, still emits CO_2 in the atmosphere.[10] Furthermore, whilst used as a fuel cell, hydrogen produces electricity with low efficiency. For example, if the energy required for electrolysis is calculated, the hydrogen fuel cell technology to power a vehicle yields an efficiency of just 18% to 46%, depending on the method used.[11] While other methods of electricity storage have efficiency ranging from 42% to 85%, using different methods and batteries.[12] In an effort to keep the process as friendly to the environment as possible, some research focuses on conducting the electrolysis with a low current and using salt water, or even sewage water.[13] This research, combined with

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[9] Akito Ozawa and Yuki Kudoh, "Assessing Uncertainties of Life-Cycle CO_2 Emissions using Hydrogen Energy for Power Generation," *Energies* 14, no. 21 (2021), 6943. doi:http://dx.doi.org/10.3390/en14216943. https://www.proquest.com/scholarly-journals/assessing-uncertainties-life-cycle-co-sub-2/docview/2596033344/se-2.

[10] "Climate Change and Sustainability Strategic Approach," Ministry of Defence Climate Change and Sustainability, , accessed 11 Jan, 2022, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/973707/20210326_Climate_Change_Sust_Strategy_v1.pdf.

[11] Tom DiChristoopher, "Hydrogen Technology Faces Efficiency Disadvantage in Power Storage Race," *S&P Global Market Intelligence* (24 Jun, 2021). https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/hydrogen-technology-faces-efficiency-disadvantage-in-power-storage-race-65162028.

[12] Ibid.

[13] Sun Fu et al., "Energy-Saving Hydrogen Production by Chlorine-Free Hybrid Seawater Splitting Coupling Hydrazine Degradation," *Nature Communications* 12, no. 1 (2021). doi:http://dx.doi.org/10.1038/s41467-021-24529-3. https://www.proquest.com/scholarly-journals/energy-saving-hydrogen-production-chlorine-free/docview/2549013066/se-2., 2.

NATO's prediction of future green electricity, suggests that, in the long-term, there is potential for hydrogen to be a real sustainable clean source of energy.

12. Despite this, hydrogen is still considered one of the most important green energy sources for the future, why? The answer comes with its capacity to be stored, and its energy to weight ratio. The weight here is the key element, as battery weight is the main factor that prevents transport truck companies from having electric tractors.[14] Once produced, hydrogen, liquid, or in gas form, does not lose power and does not have an expiry date. When compared to fossil fuels, once again, hydrogen outperforms fuels, as hydrogen energy is 120 MJ/kg, where gasoline energy is 47 MJ/kg and coal is 25 MJ/kg.[15] So, even if the production of hydrogen is energy intensive, it has potential to be green and carries a lot more energy than its current competitors for equal weight. Another of the major downside of hydrogen is its potential for explosion. This needs to be taken in consideration in its use for fighting vehicles.

13. A vehicle powered by hydrogen fuel cells, is in fact an electric car with hydrogen fuel cells used as batteries to create the required electricity. The other way that hydrogen can be used is by mixing it with current fuel to improve combustion, therefore getting more power from a certain quantity of fossil fuel.[16] In this case, the hydrogen is not a green energy per se, but reduces emissions by improving the efficiencies of an engine. This second option is not discussed much in literature for uses for the militaries, as it

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[14] Antti Lajunen et al., "Overview of Powertrain Electrification and Future Scenarios for Non-Road Mobile Machinery," *Energies* 11, no. 5 (2018), 1184. doi:http://dx.doi.org/10.3390/en11051184. https://www.proquest.com/scholarly-journals/overview-powertrain-electrification-future/docview/2108543538/se-2., 5.

[15] Sobon, "Prospects for the use of Hydrogen in the Armed Forces,"

[16] Ozawa, "Assessing Uncertainties of Life-Cycle CO_2 Emissions using Hydrogen Energy for Power Generation," , 6943

creates a requirement for two types of fuel for each engine, thus increases the complexity of the logistic chain and renders engines more complex.

14. Vehicles powered by hydrogen fuel cells would prevent the military from having to choose between electric and hydrogen as a power source in the future. It is only required to ensure modularity of the equipment. Electric Engines are costly to produce and require CO_2 emissions in order to be produced. However, these engines are more than environmentally friendly, they have "more precise actuator control, reduced need for maintenance, and flexibility in powertrain design."[17] These factors would help the LF be more efficient on the field, as reduced maintenance and simplicity of engines would facilitate the supply and support for the units.

15. Electric vehicles also have the option to be modular. With research and development, an electric engine could work on either a fuel cell or from a battery. The modularity option would mean that a transport truck with an electric engine should be able to have a set of batteries inserted, or a set of hydrogen fuel cells. This will prevent commitment to one source of energy and potentially missing future opportunities to switch from a source of energy to another. It also helps to adapt to the green sources of energy available in the environment that the equipment is required to operate in. In short, an electric vehicle that can run from battery or fuel cells, with less maintenance requirements than the current fleet, would be the perfect fit for the future of the Land Force in Canada.

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[17] Lajunen, "Overview of Powertrain Electrification and Future Scenarios for Non-Road Mobile Machinery," , 1184, 6.

16. Electricity is not an easy source of power to find when deploying to an area that has just been hit by a disaster or an area that needs combat forces to stay safe. What if there could be other sources of energy that could work for the military? For example, the World Economic Forum discusses more options to create clean energy and more green hydrogen from nuclear waste.[18] This means that Canada could work with companies on research and development towards new green sources of energy. This will give options to be more efficient in the future.

CONCLUSION

17. Although a good start, *mission accomplished* cannot be called once the land force has changed its fuel source to a green renewable source, as the whole life cycle of the equipment purchased needs to be looked at, to allow for decarbonisation.

18. From my perspective, one of the best success examples in the Canadian military Land Force procurement is the Pallet Loading System (PLS). This system is modular and is useful for transportation of goods, sea containers, is compatible with US transport vehicles and can be used for domestic operations or in combat zone as close support. In the same manner, modularity of an electric fleet in the future, could enable the forces to have vehicles that can be modulated to take electricity from different types of batteries. This modularity could allow for transition from hydrogen to batteries when there are risks of explosion when using hydrogen fuel. As the years go by, the fleet will stay relevant as the power systems will be able to be changed without the requirement of a new fleet. The

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[18] Franklin Servan-Schreiber, "Destroying Nuclear Waste to Create Clean Energy? it can be Done," *World Economic Forum* (. https://www.weforum.org/agenda/2018/11/destroying-nuclear-waste-to-create-clean-energy-it-can-be-done/.

modularity of the new equipment and its resilience to change will dictate if the LF will be part of the solution or part of the problem when it comes to decarbonisation.

19. There are good options for the CAF to work with the government towards decarbonisation. The next step should be to conduct analysis on the efficiency of each of the recommendations before implementation.

RECOMMENDATIONS

20. The following recommendations for the Land Force are based on the previous study:

Short-Term

- Increase virtual training;
- Use of War gaming tool and Table top exercises;
- Transition from fossil fuel diesel for the Land Force to biodiesel;

Long-Term

- Modularisation of the procurement plan to avoid having to change vehicles when transition of fuel is required;
- Use of green hydrogen as fuel;
- Use of high efficiency batteries interchangeably with hydrogen fuel cells as required by the environment and from what logistic elements can get to the theater of operation.
- Work with and/or within industry on Research and Development to stay up to date with new sources of energy and the potential of new coming, as per the potential of re-use of nuclear waste in low power, self-sufficient generators.

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