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DND/CAF Energy Horizons from Historical Data to the Potential Exploitation of Emerging Technologies

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Abstract

This paper reviews the energy portfolio of Department of National Defence (DND) and of the Canadian Armed Forces (CAF) from different perspectives based on recent data analyses of the energy used over several years. Then it shows a projection of the potential impacts on current and future DND/CAF capabilities of selected emerging technologies (nuclear and non-nuclear). When possible, it estimates the potential life-cycle cost savings from the hypothetical adoption of such technologies that minimize operational cost and waste management burden.

Keywords: Energy use, capability, emerging technology, efficiency, energy/power density, waste.

1. Introduction

This paper first objective is to provide sufficient information to appreciate the energy portfolio diversity and magnitude of the DND/CAF. The second objective is to highlight the particular energy challenges due to the fully burdened cost of energy (FBCE) that DND/CAF face here for off-grid installations, and abroad for deployed forces in operational hostile theaters. The third objective is to report on performance claims of emerging technologies and show the potential impact of these technologies on DND/CAF capabilities. Then an estimated order of magnitude of recurring and non-recurring energy cost savings is provided.

2. DND/CAF total energy used

Fuel/energy (~11 PJ[1] per year) used for DND/CAF buildings includes electricity, natural gas, heating fuel oils, propane, kerosene, arctic diesel, cooling water, steam and solar photovoltaic (SPV) [1]. The average over 14 years for heating is around 7.6 PJ with a small downward trend. Electricity for the same period is around 3.4 PJ with a small upward trend. Reference [1] provides details on DND/CAF best estimates of the proportion of energy used by the fleet of each environment (air, maritime and land) out of a total of 12 PJ per year for both domestic and expeditionary operations. Here are the magnitudes of fleet energy used in percentages for the three environments: Canadian Army (CA) 17%, Royal Canadian Navy (RCN) 21% and Royal Canadian Air Force (RCAF) 62%.

For the following charts (Figure 1 and Figure 2), in addition to expeditionary energy used, the total domestic energy includes the fuels used in commercial vehicles and combat equipment (including expeditionary CA energy [1, 2]), the energy used in domestic operations and the total energy used

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[1] 34,121 Tons of Coal Equivalent (TCE) is a petajoule (PJ) which equals one quadrillion (10^{15}) joules.
14.6 PJ is about 4,111 GWhe net, the 2013 electricity production of Point Lepreau CANDU, New Brunswick, Canada.

for buildings. Figure 1 includes all DND/CAF energy usage: aggregated total expeditionary and domestic energy averaged over three fiscal years from 08/09 to 10/11 is 23 PJ or 23,000 TJ. About 52% is for the fleets and the remaining 48% for the buildings/commercial vehicles.

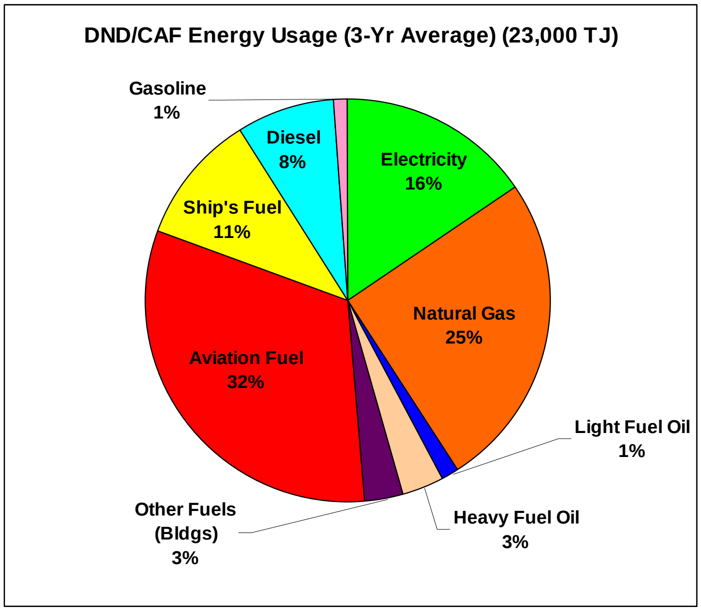


Figure 1 Average annual consumption of domestic and expeditionary energy per type

Figure 2 shows for the same fiscal years the fuel/energy expenditures for domestic utilities and fleets' fuel expenditures that include invoices coming from international operations. These expenditures of the department correspond closely to the 23 PJ of Figure 1.

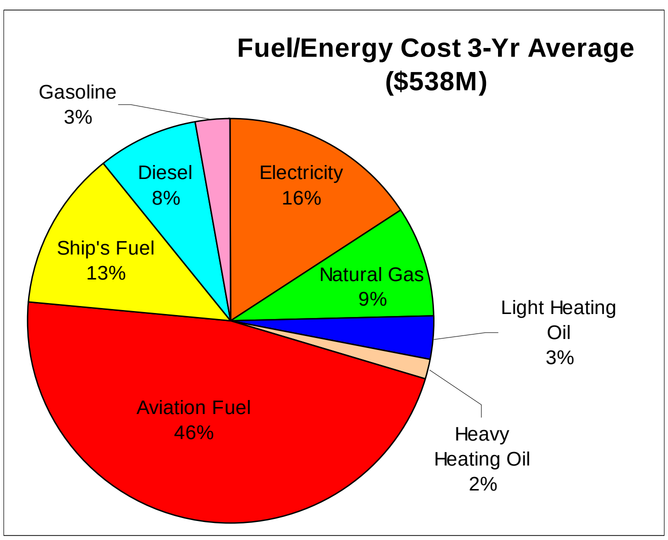


Figure 2 Annual domestic and expeditionary energy cost proportion

From the total cost of $538 million Canadian dollars (CAD), about 70% of the cost is for the fleet and 30% for the buildings. The large difference in percentage between the energy quantities (52%-

48%) and costs (70%-30%) is dominantly driven by the low cost of natural gas in Canada. The aviation fuel represents about 66% of the total fleet fuel cost, which is assumed to be the sum of the following: gasoline (3%), diesel (8%), ship's (13%) and aviation (46%), for a total of 70% of the total fleet fuel cost. This RCAF 66% of the fleet fuel cost correlates closely with the 62% of the fleet energy since aviation fuel is relatively more expensive.

3. Total DND/CAF energy cost trends and global perspective

Figure 3 shows that the total energy expenditures for all buildings (green), then the fleets (blue) and then the total of all DND/CAF energy used (red) over 14 years follow persistent upward trends [1]. If it is assumed that these types of trends continue in the future then the fleet energy price (upward trend in blue) will approximately double in a decade. The total CAF fleet energy spending would have increased from approximately 140 million dollars in fiscal year 1998/99 to 800 million dollars in 2030/31, about six times as much if no significant corrective actions are taken. The total DND/CAF energy cost (538 million in 2010-11) follows a similar trend (upward trend in red) from about 240 million to 1,100 million dollars by 2031, which is about five times as much.

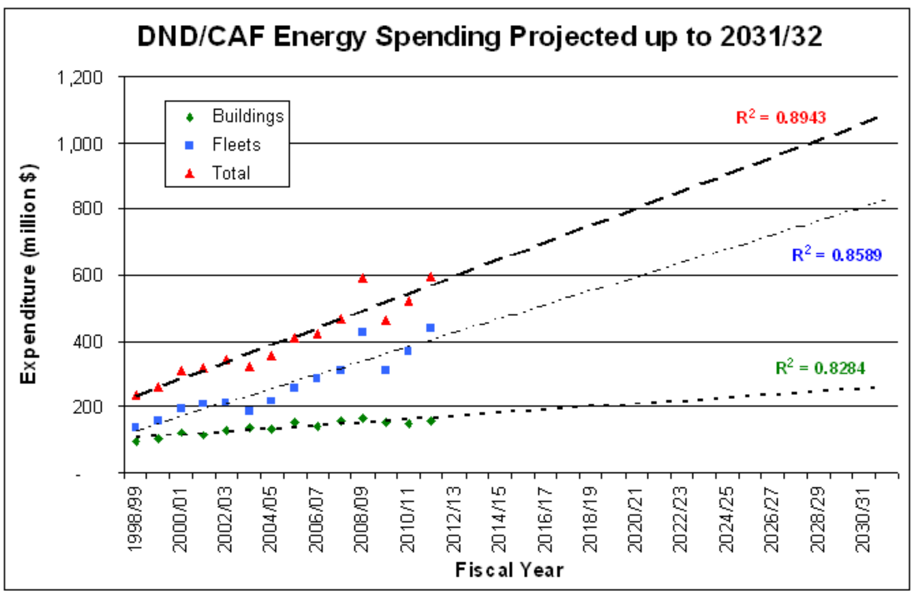


Figure 3 DND/CAF 14-year energy trends and a 20-year projection based on these trends

Currently no additional cost is included in these figures for an eventual carbon tax. In the advent that Canada adds a charge or tax for greenhouse gas (GHG) emissions, this total DND/CAF energy cost trend might be more significant in such future.

The estimate of world energy use in 2008 of ~533 EJ[2] [3] allows to appreciate the order of magnitude of the total energy consumption of primary energy used by Canada in 2008, 12,510 PJ[3] [4, p. 7] or ~13 EJ, i.e., about 2.4%. According to Statistics Canada, the total energy used by all of Government of Canada (GoC) is ~60 PJ (2008, 60,134 TJ [5, p. 5]), which is about ~0.5%. Using the ratio of all combined floor areas (buildings and platforms), the gross floor area, we obtain a

[2] One exajoule (EJ) is equal to one quintillion (10^{18}) joules, 10^3 PJ or 10^6 terajoule (TJ).
[3] http://oee.nrcan.gc.ca/publications/statistics/parliament10-11/chapter1.cfm?attr=0 (Access date: 17 Sept. 2013).

coarse estimate of ~42% or ~25 PJ for the total energy used by DND/CAF out of the ~60 PJ for the whole of GoC while the remainder for other government departments (OGDs) is ~58% or ~35 PJ. Figure 4 illustrates the magnitudes of these energies used from the world perspective up to the DND/CAF total amount of energy used which is about 0.2% of Canada primary energy used in 2008.

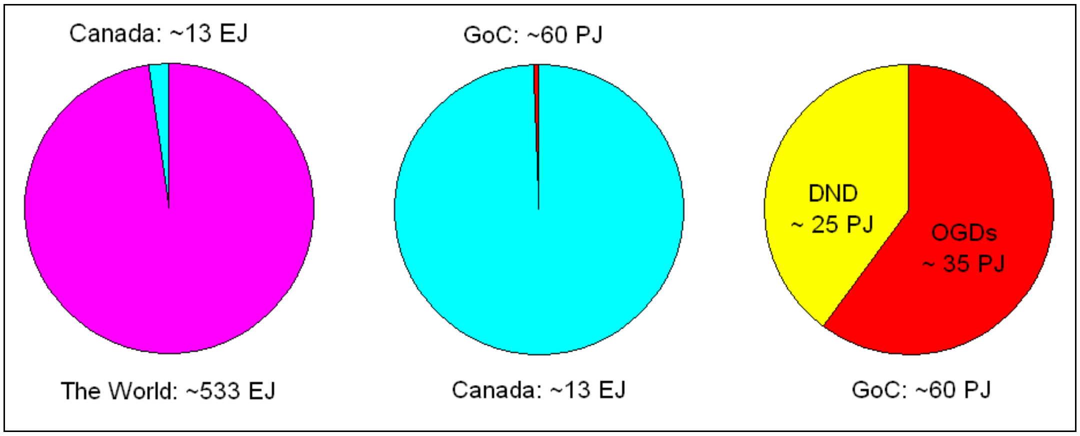


Figure 4 Relative energy consumptions: Canada versus World, the total of all government of Canada (GoC) versus Canada and DND/CAF versus OGDs within GoC

4. Increased electricity demand to power new information technologies

An important trend to consider is the constant increase in data processing and exchange[4] required in modern operations. If this is compounded with cyber warfare and intelligence over telecommunication and Internet, this may translate in substantial energy cost increases as reported in [1]. So it is reasonable to expect that the energy demand from information technologies used by DND/CAF to more than double over the next decade if remediation actions are not initiated soon. According to the Environmental Protection Agency (EPA) executive summary report [6], essentially the best practices scenarios assumed moving in a new facilities or major upgrades[5] to existing ones. But even the improved operation scenario that assumed no significant capital investment offers electricity cost savings in excess of 20% according to this report.

Natural Resources Canada (NRCan) Office of Energy Efficiency (OEE)[6] reports that a "*data centre is a building space filled with information technology (IT) equipment: servers, storage, networking equipment, but also cooling equipment and power supplies. Data centres consume about 1% of Canada's electricity. One square foot of data centre space can use up to 100 times more electricity than a regular office space. Servers use only around 40% of a data centre's electricity. Another 40% goes to cooling these servers; and another 10% goes to power supplies losses. Conservation measures can dramatically reduce the electricity consumed by data centres.*"

A good example of essential capabilities in future combat theaters is persistent surveillance with sufficient precision for mission effectiveness and force protection. These capabilities would use

[4] Command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) systems must be secure, resilient and deployable.
[5] ENERGY STAR® is the mark of high-efficiency products in Canada.
[6] http://oee.nrcan.gc.ca/equipment/manufacturers/1875 (Access date: 17 Sept. 2013).

extended endurance unmanned aerial vehicles (UAVs) as well as underwater, surface and land unmanned versions[7]. Such capabilities could be classified as energy hungry because their power requirements are moderate while their extended time of operation without the need for logistic support is over several days. In some operational theaters, users would like to extend the autonomy period to weeks without re-fueling or recharging the batteries.

4.1 Electricity demand for new weapon technologies

A US Navy projected 64 MJ railgun may require 16 MW for 6 MA peak at a shooting pace of 6 shots per minute with a maximum range of 350 km. Such railgun would shoot 10 times further than normal ship mounted guns (a definite advantage in combat) and save a lot of money (improving sustainability) for its operation per shot compared to current guns+ammunitions and missiles. Railgun and directed energy weapon (DEW) technologies (these include technologies such as: high energy laser (HEL), radio frequency (RF) DEWs, and relativistic particle beams (RPBs) and high power microwave (HPM)) require usually large and heavy high power sources although technologies advanced made them more deployable. However, such electricity demand still represents a major challenge to accommodate, especially on legacy platforms. Various types of DEWs are currently in deployment phases for air, land and naval platforms with a large variety of electrical energy demands. Figure 5 shows that the pulse power depends on type of targets, use and range.

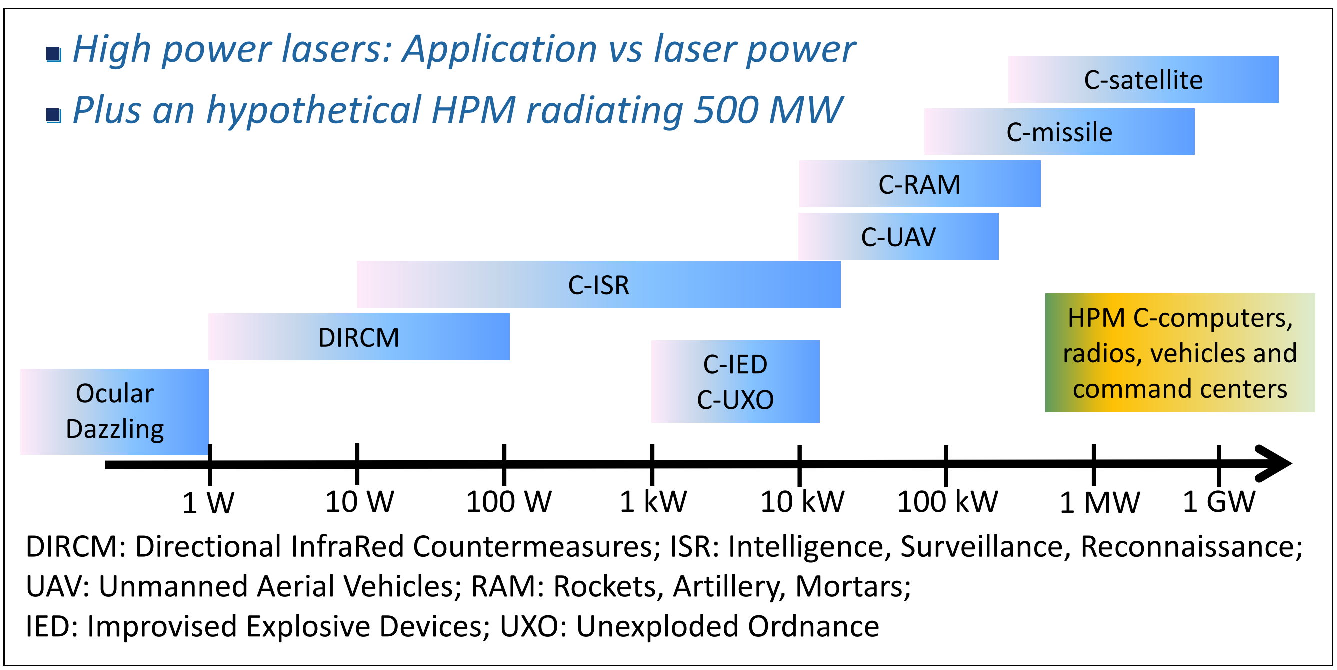


Figure 5 Typical radiating power required for specific counter attack [7]

[7] For example, Tactically Exploited Reconnaissance Node (TERN) in a DARPA program run jointly with Office of Naval Research (ONR): http://www.darpa.mil/Our_Work/TTO/Programs/Tactically_Exploited_Reconnaissance_Node_(TERN).aspx (Access date: 17 Sept. 2013).

For an hypothetical HPM, the authors [8] assume an efficiency similar to radar technologies, i.e., 17% of the input power results in radiating power. They consider that 3.7 GW of input power is required to deliver, at a range of 10 km, a power flux of 10 kW/m^2 on a 30 mrad spot size of 300 m. References [9, 10] provide information on damage level of DEWs.

These technologies are power hungry while persistent surveillance and C4ISR ones are energy hungry.

4.2 Electricity end use growing faster than fuel direct use

According to Richard G. Newell and Stuart Iler as stated in "The Global Energy Outlook" [11, p. 46] "*In terms of end-use energy consumption, electricity is growing much faster than direct use of fuels.*" Similarly, future DND/CAF electricity demand from new technologies, such as C4ISR and weapon systems, is expected to increase at a faster pace than the direct use of fuel especially for the fleets and off-grid installations. This is the most critical point that DND/CAF must address to insure sustainable capabilities to fulfill their mandate here and abroad.

5. Tools for addressing holistically the DND/CAF energy demand domain challenges

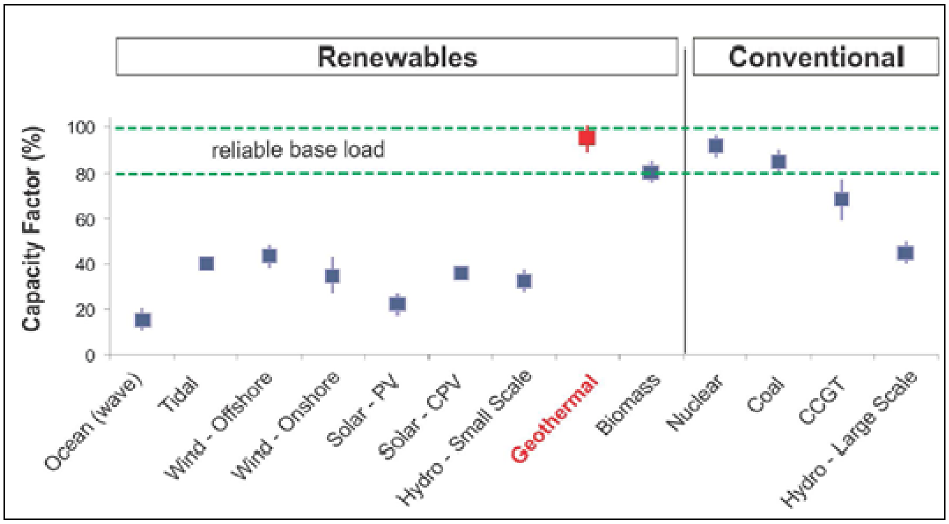
Here are some energy considerations essential to ensure energy technologies fitting to DND/CAF capabilities, especially when they drive operational effectiveness, provide CAF advantage over opposing forces and reduce risk to our combatants [1]:

1. Capacity factor, i.e., actual energy output over a period of time against generation potential.
2. Energy conversion efficiency, i.e., the ability to convert the maximum amount of source energy toward the desired work, function or amenity.
3. Power density versus energy density (acceleration versus range), i.e., the ability to achieve varying load profiles (demands) over time.
4. Volumetric versus gravimetric energy density or power density (size versus weight), i.e., the ability to meet the physical constraints imposed by the intended application.

5.1 Capacity factor

Capacity factor (net) could be defined as the ratio of the net electricity generated, for the time considered, to the energy that could have been generated at continuous full-power operation during the same period[8]. A similar definition can be applied for thermal systems and electrical-thermal systems [12]. Figure 6 shows typical capacity factors used by NRCan [13] to show the advantages of enhanced geothermal technologies for electricity generation and district heating in Canada.

[8] http://www.nrc.gov/reading-rm/basic-ref/glossary/capacity-factor-net.html (Access date: 17 Sept. 2013).



PV = photovoltaics; CPV = concentrated photovoltaics; CCGT = combined-cycle gas turbine.

Figure 6 Typical capacity factors of different power generation technologies

5.2 Energy conversion efficiency

Energy conversion efficiency needs to be maximised in order to reduce undesirable loss and expenses while providing energy for a capability or a desired work. Most of the time an energy conversion or transformation is required to accomplish the desired work. Energy conversion efficiency (η) is the ratio between the useful output of an energy conversion device and the input, in energy terms. The useful output could be electrical, mechanical, or thermal.

$$\eta = \frac{E_{out}}{E_{in}} \tag{1}$$

Table 1 shows the high efficiency of electric motors and generators compared to internal combustion (IC) engines. Also worth observing is the energy conversion combination ($\eta \approx 63\%$) of fuel cell devices with electric motors and batteries which surpasses the traditional gasoline combustion engine ($\eta \leq 30\%$) or the more energy efficient diesel engine ($\eta \leq 50\%$). However, for off-grid operations the traditional IC engine has the advantage of a transportable and storable fuel. In the case of newer technologies, fuel cell technologies could offer similar advantages, with the addition of being more energy efficient than using IC engines.

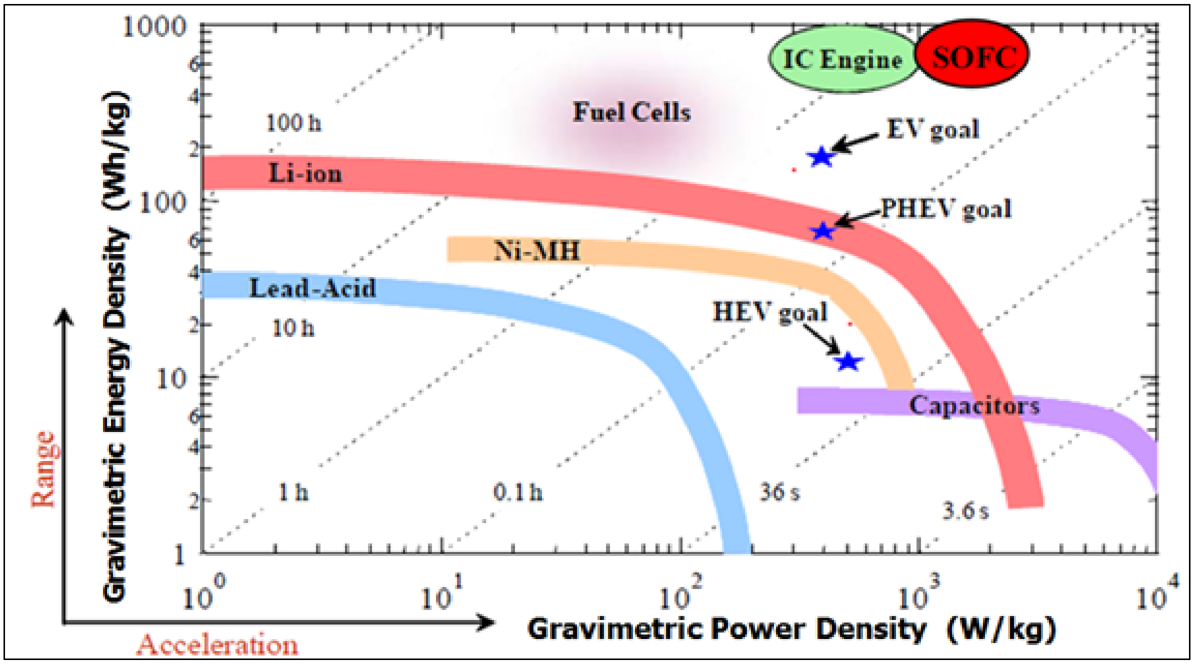
Table 1**:** Efficiency of selected energy conversion devices

Energy conversion device	**Energy conversion**	**Typical efficiency**[9]
Electric heater	Electricity to thermal	~100%[10]
High-efficiency gas furnace	Chemical to thermal	~98%
Large electric generator	Mechanical to electricity	>95%
High-efficiency electric motor	Electricity to mechanical	>90%
Battery	Chemical to electricity	>90%
Water turbine	Potential-kinetic to mechanical	>90%
Permanent-magnet alternator	Mechanical to electricity	60-90%
Fuel cell	Chemical to electricity	Up to 85%
Large diesel engine generator[11]	Chemical to electricity	≥60%
Diesel engine (car/truck/ship)	Chemical to mechanical	30-50%
Gas turbine, jet engine	Chemical to mechanical	Up to 40%[12]
Solar cell	Sun radiation to electricity	10%, up to 40%
Light-emitting diode (LED)	Electricity to light	Up to 35%
Thermophotovoltaic (TPV)	Heat-infrared to electricity	8-30%
Firearm (.300 Hawk ammunition)	Potential to kinetic	~30%
Gasoline engine (car/truck)	Thermal to mechanical	10-30%
Fluorescent lamp	Electricity to light	20%
Incandescent lamp	Electricity to light	5%

5.3 Power density versus energy density

A Ragone plot helps visualizing the energy-power density of candidate sources for a specific application energy and power demand. Figure 7 compares selected batteries chemistries with other technologies. It shows that most batteries deliver more energy when operating at low power over longer period, while due to their chemistry and heat loss they deliver less energy at high power over shorter period. In addition, Figure 7 shows that energy drives the vehicle range while power drives the acceleration. YASA-750 delivers a power density of 6 kW/kg[13]. Another example is Siemens' unique weight-to-performance ratio of 5 kW/kg for aircraft[14]. Nanotechnologies enhanced conductors and materials can improve these by more than 20%.

[9] Information sources include http://en.wikipedia.org/wiki/Energy_conversion_efficiency (Access date: 17 Sept. 2013).
[10] Using a thermopump, this could be increased by a factor of three using a ground-water loop.
[11] http://arpa-e.energy.gov/?q=arpa-e-events/small-scale-distributed-generation-workshop (Access date: 17 Sept. 2013).
[12] This needs to be adjusted by the propulsive efficiency η_p for specific jet parameters.
[13] http://www.yasamotors.com/products/yasa-750/
[14] http://www.siemens.com/press/en/feature/2015/corporate/2015-03-electromotor.php?content%5B%5D=Corp



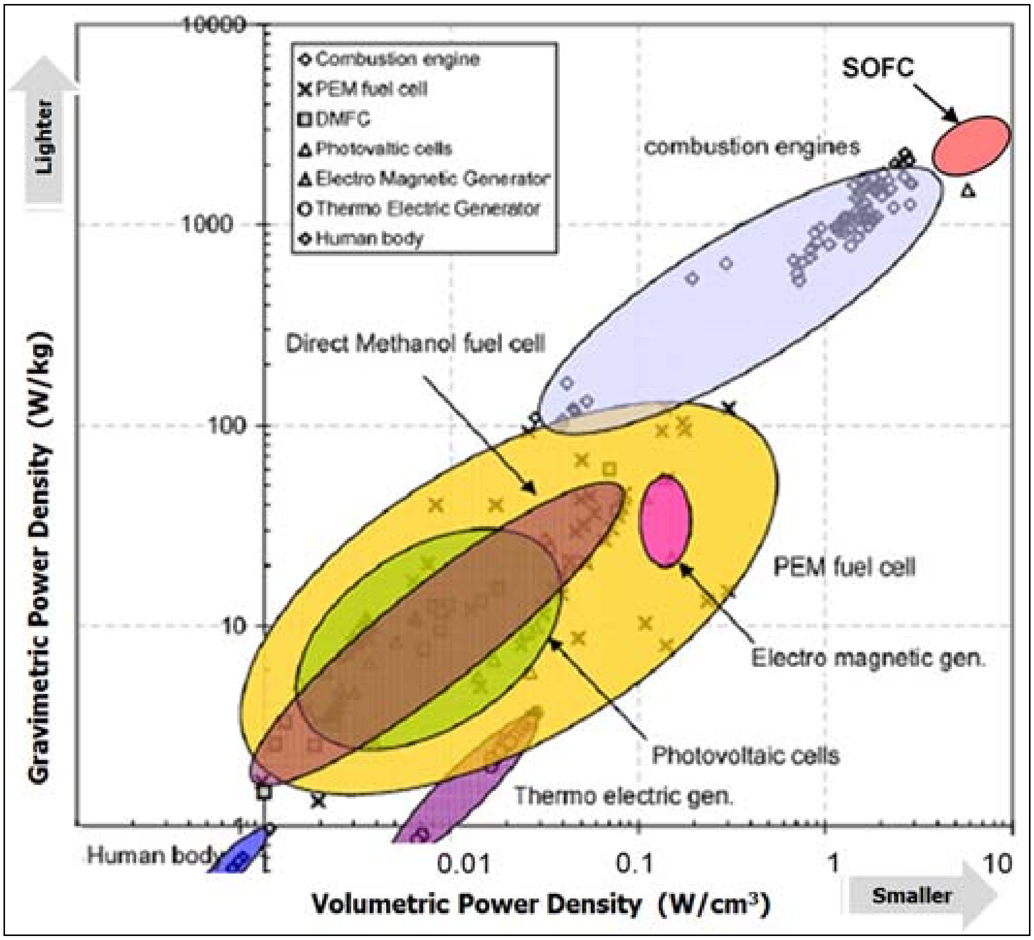
Legend: solid oxide fuel cell (SOFC); internal combustion (IC) engine; nickel–metal hydride battery (Ni-MH); hybrid-electric vehicles (HEV); electric vehicles (EV); and plug-in hybrid-electric vehicles (PHEV).

Figure 7 Balance between gravimetric energy and power densities (range versus acceleration) [15]

5.4 Volumetric versus gravimetric energy or power density

An important aspect of energy sources is their suitability to an application in terms of volume and weight. Volumetric versus gravimetric energy or power density is critical to applications such as dismounted combatant systems and air platforms where there are requirements to meet the physical constraints imposed by the intended application (size or form factor, and weight). Figure 8, adapted from [14], shows that an increase in gravimetric power density could result in a lighter device, while an increase in volumetric power density could result in a smaller device.

[15] This illustration is based on various sources including product data sheets as reported in http://bestar.lbl.gov/venkat/files/batteries-for-vehicles.pdf (Access date: 17 Sept. 2013) by Dr Venkat Srinivasan of the Lawrence Berkeley National Lab. Then the solid oxide fuel cell (SOFC) was added in the file provided by Dr Eric Wachsman (www.energy.umd.edu). Finally it was further updated here for the purpose of this paper with the selected axis labels.



Legend: proton exchange membrane (PEM) fuel cell; and solid oxide fuel cell (SOFC).

Figure 8 Selected energy sources illustrating size and weight at play[16]

6. Applying the selected energy considerations to platform demands

For example, a fuel cell usually requires using a battery-supercapacitor energy storage device in order to increase its maximum power capacity much above what it could deliver as shown by Figure 7. Fuel cells provide better energy densities than most energy storage technologies but offer less power densities than supercapacitor energy storage technologies.

For a more persistent surveillance using low cost UAV platforms one may assume that such UAV will not be equipped with weapons, sophisticated stealth capabilities or electronic countermeasures. For such UAVs the energy requirements will be dictated by the mission profile, distance to the area to conduct surveillance, type of propulsion, period of time required, type of sensor suite required for the desired surveillance and probability of detecting wanted objects or opposing force actions (e.g., identifying hostile activities such as deploying IEDs along a route). The total energy and power will be the sum of the requirements for the sensor suite demand and the propulsion demand for the UAV with its sensor, communication and other payloads such as the navigation system.

[16] Figure 8 is based on the material provided by Dr Eric Wachsman (www.energy.umd.edu) and also published in Wachsman and Lee [14]. Authorization to use the material confirmed by email: Wachsman-Labbé 18 July 2013.

6.1 Examples of operational energy costs

Another aspect is the fully burden cost of energy in a theatre of operations where opposing forces disrupt fuel supply chain or in a difficult to access location such as CFS Alert. A recent energy audit of CFS Alert reveals that the cost of fuel is about five times as much as the bulk price negotiated across Canada for the CAF. The fuel at CFS Alert needs to be airlifted out of the US Base Thule in Greenland. For operations in the Middle East, fuel delivered by convoys is often disrupted by opposing forces. Here are some DoD examples of FBCE costs:[17] "*The Defense Logistics Agency buys military fuel for $2.82 per gallon. But that same fuel can cost $13 if it's shipped by ground to a forward-deployed location, during peacetime. If it's transferred in-flight from a refueling airplane to another aircraft, the gas is $42. If troops are in hostile areas, prices can range from $100 to $600 for "in theater" delivery. The Army estimated fuel can cost up to $400 a gallon if the only way to ship it is via helicopters.*" For the purpose of this paper, it is assumed that the lower bound multiplying factor due to FBCE during CAF operations in hostile areas is 40 times for land and air platforms. A factor of 4 could be used for naval platforms.

7. Technology wild cards

A 'wild card' is an unpredictable or unforeseeable factor that occurs outside of the normal rules and expectations. Examples of technology wild cards may include a) progress in technologies to produce new hydrocarbons with less GHG impacts at lower price than $50 a barrel, b) technologies to produce mechanical work and electricity with much less fuel, and c) others with substantial paradigm changes with much higher energy and power density with minimal waste and environmental impacts, such as a new nuclear technology with minimal harmful radiation, no dangerous wastes and little undesirable environmental impact.

In this paper disruptive technologies are defined as follows [15]: "*What makes a technology 'game changing', 'revolutionary', 'disruptive' or a 'killer application' is that it both offers capabilities that were not available – and were in many ways unimaginable – a generation earlier and in so doing provokes deep questions whose answers are not readily available. These kinds … of questions encompass not only what is possible, but also what is proper, in everything from doctrine and staffing to law and ethics. Such technologies – be they fire, the printing press, gunpowder, the steam engine or the computer – are rare but truly consequential.*"

There are a variety of emerging energy technologies claimed by several organizations and individuals to be able to produce at very low cost, high volume, high energy density and power density above what is currently known with no major environmental negative impacts. Figure 9 positions the level of some of these energy claims under the label of 'new nuclear technologies'.

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[17] http://www.nationaldefensemagazine.org/archive/2010/April/Pages/HowMuchforaGallonofGas.aspx (Access date: 7 April 2015).

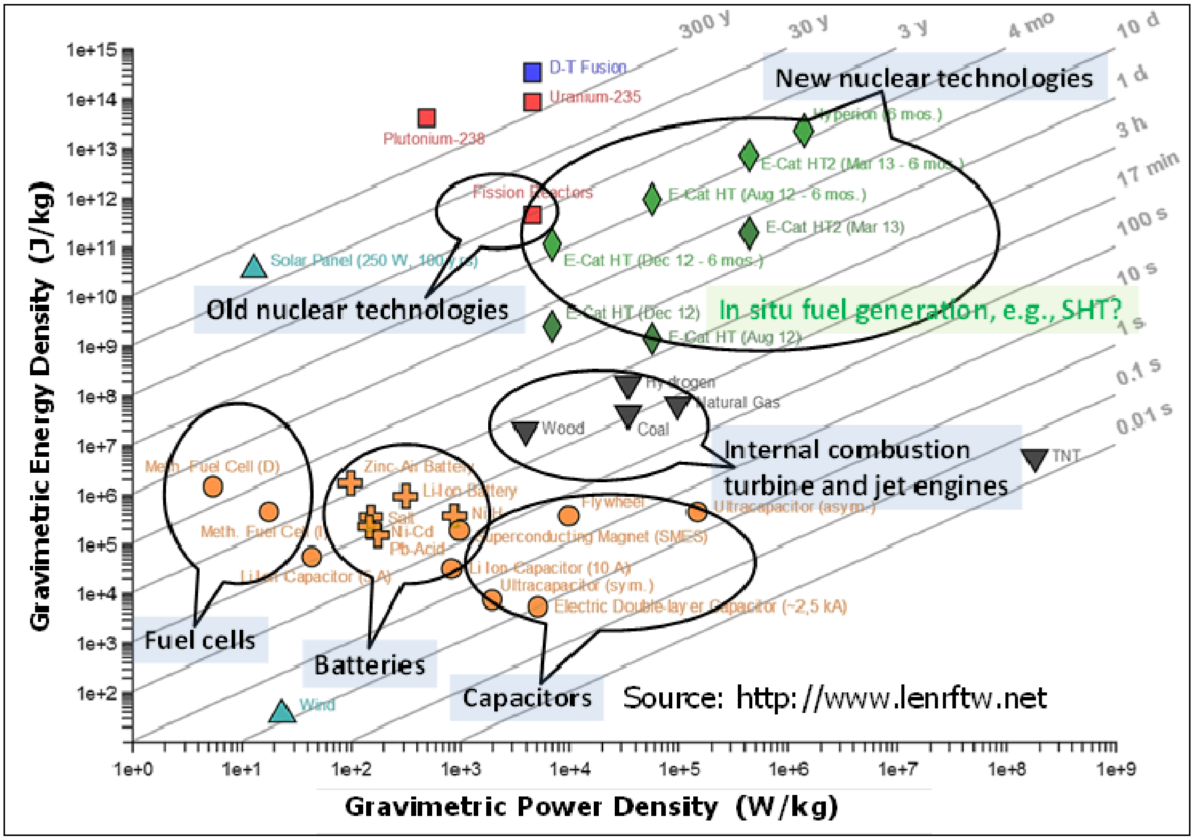

Figure 9 Notional Ragone chart modified to show selected categories of energy sources[18]

Such emerging technology is considered disruptive. According to a United Kingdom MOD report, "*Global Strategic Trends - Out to 2040*" [16], not only trends drive the future situation but shocks like: the 2007-8 financial crisis, the 9/11 terrorist attacks and the collapse of the Berlin Wall.

"*Strategic shocks have a cascade effect, leading to multiple, apparently unconnected and unforeseen changes. They transform the strategic context, changing behaviour and activity across the board. For example, the 2007 financial crisis began with US sub-prime debt… the future cannot be predicted in detail or with certainty. However, they will inevitably influence defence and security in some way, providing a strong argument for versatile and adaptable defence institutions, equipment and personnel to deal with the unexpected challenges they will present.*"

This MOD report selected five credible strategic shocks and the third one is about a new energy source, more efficient than anything available currently.[19] "*New Energy Source. A novel, efficient form of energy generation could be developed that rapidly lowers demand for hydrocarbons. For example, the development of commercially available cold fusion reactors could result in the rapid economic marginalisation of oil-rich states. This loss of status and income in undiversified economies could lead to state-failure and provide opportunities for extremist groups to rise in influence.*"

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[18] More details about the data and methods used in developing this Ragone chart are available at: http://www.lenrftw.net/comparing_energy_sources.html (Access date: 14 May 2014).
[19] https://www.gov.uk/government/publications/dcdc-global-strategic-trends-programme-global-strategic-trends-out-to-2040 (Access date: 14 May 2014).

DRDC report [1, p. 41] provides a summary of energy disruptive technologies that could deliver several orders of magnitude greater energy density than current fossil fuels. One of them was given different names (see Atomic Energy of Canada Limited (AECL) report [17]) over the years from the coined label 'cold fusion' then to Low Energy Nuclear Reactions (LENR), Chemically Assisted Nuclear Reactions (CANR), Lattice Assisted Nuclear Reactions (LANR), Condensed Matter Nuclear Science (CMNS) and Lattice Enabled Nuclear Reactions. For this paper the term LENR is used. Recently this emerging disruptive technology, LENR, has been identified as one of the technology to be considered by the technology watch of TTCP MAR TP-8 Power and Energy, Materials and Systems. It is included in a recent NATO report [18].

The Preface of the 25 February 2015 Current Science, Special Section: Low Energy Nuclear Reactions provides an overview of the 34 selected papers covering this subject [19]. These papers cover findings, studies and theories about radioactive nuclear waste remediation/recycling, transmutation, hydrogen, exothermal reactions, experimental systems, etc.

During a 2015 interview [20], Dr. Michael McKubre of the Stanford Research Institute (SRI) said that he tested, under a DARPA contract, between 12 and 15 LENR technologies for the United States government [21, 22, 23, 24]. Also McKubre claimed that his team was able to replicate at least five of those technologies so far. Furthermore an advanced LENR device, Andrea Rossi's Energy Catalyzer High Temperature (E-Cat HT), was evaluated by different groups of experts [25]. In 2014 E-Cat HT tests were run and partly funded by the Swedish energy research consortium, Elforsk [26]. Based on the Elforsk report, Professor Alexander Parkhomov published in December 2014 a report in which he claimed to have replicated Andrea Rossi's E-Cat HT technology. Parkhomov's paper detailing his replication was originally published in Russian but several English translation versions can be found on the Internet [27].

Another technology [1, p. 43] that can put DND/CAF capabilities on steroids includes the possibility reported under 'in situ fuel production'. The high rates of hydrogen production as claimed by Solar Hydrogen Trends (SHT) were confirmed by third party measurements (209 kL/h for 415 Wh, that generating hydrogen at an equivalent of 626 kWh, or at 1500 times the input energy used) [28]. The size and weight of tested SHT devices were small although larger than E-Cat HT ones. The E-Cat HT and SHT devices are under the label 'New nuclear technologies' in Figure 9. Once these high-energy density devices are adapted to defence platforms, they will provide enough energy to power adapted defence platforms for extended periods much beyond what is currently possible, including powering emerging DEWs and railguns.

Most recent results from the independent E-Cat HT trials [26] showed exceptional energy densities. When including internal plus external components, the volumetric energy density observed was 36,000 MJ/L and the gravimetric energy density was 13,000 MJ/kg. In comparison, the energy densities of gasoline are 32.4 MJ/L and 44.4 MJ/kg respectively. So the E-Cat HT is 1,111 times more volumetric energy dense and 293 times more gravimetric energy dense than gasoline.

The E-Cat HT fuel weight of the charge was 1 g [26]. According to the Elforsk report, it delivered the following thermal energy density and power density: $1.6\ 10^6$ Wh/kg or $5.8\ 10^6$ MJ/kg, and $2.1\ 10^6$ W/kg. These results place the E-Cat HT beyond any conventional source of energy.

Based on information available so far about high-energy density technologies, one can project their potential impacts on defence and security (D&S) capabilities in terms of advantages and threats to

Canada, i.e., advantages in terms of multiplying DND/CAF capabilities and threats if malevolent groups use such advantages against our nation and our allies. This paper only focused on comparing existing platform autonomy using germane energy sources (batteries or fuels and associated energy conversion technologies) with what is possible according to a selected high-energy density technology, the E-Cat HT. The following results are intentionally limited to unclassified sources of military platform specifications.

8. Applying the identified energy technologies to unclassified military platform performance

Using the conservative results for the E-Cat HT, one can project the order of magnitude of the multiplying factors of performance for a variety of military capabilities as follows:

Table 2: Examples of capabilities and related potential multiplication factors

Platform	Typical performance	Projected performance based on energy density
MQ-1 Predator	Range: 740 km Loiter: 14 hours	For air platforms the gravimetric factor should be dominant: x 293.
Sikorsky CH-124 Sea King	Range: 1,000 km Maximum flying time: 3h 45 minutes	
CP-140 Aurora Long-Range Patrol Aircraft	Range: 9,266 km at 648 km/h Flight time: 14.5 h	
Buffalo Mine Protected Vehicle	Range: 480 km Fuel capacity: 322 L	For a land platform, ship and submarine the volumetric factor should be dominant: x 1,000.
M1 Abrams	Range: 426 km Fuel capacity: 1,900 L	
Halifax-class frigate	Range: 17,600 km Maximum time at 28 km/h: 14 days	

Similar gains in D&S capabilities for defence infrastructure and off-grid installations are expected, e.g., CFS Alert used an average of 1.8 10^6 L of JP-8 per year (2007-2010), that is 62 10^{12} J. A 1-MW E-Cat plant generates 32 10^{12} J per year, so two plants could fulfill CFS Alert energy demand.

8.1 In addition to capability improvements, what could be the recurrent cost saving?

If the assumed cost of a 1-MW E-Cat plant[20] is $1.5 million USD and the Canadian currency conversion is around 0.8, then each plant costs about $1.875 million CAD and delivers 31.6 TJ per year. Heating for all of DND/CAF is 7.6 PJ so it requires 240.8 plants. The investment cost for heating with these plants is $75.3 million so that over 10 years a potential return on investment could be $300 million.

[20] http://www.e-catworld.com/2014/12/16/the-impact-of-oil-prices-on-lenr/ (Access date: 16 April 2015).

Assuming an energy conversion efficiency of heat to electricity of 30%, as from a thermoacoustic generator, then the DND/CAF electricity demand could be fulfilled by 359 units. The $86 million for electricity cost could be used to amortize the cost of the 359 units required with a potential return on investment of $186 million over 10 years. Note that the operation cost is assumed to be similar to the existing systems. We don't know if the cost for operating the new installations is lesser or higher. Using SHT could be more efficient with a fuel cell but not enough information is available to prepare a similar potential return on investment at the time of writing this paper. However, using SHT could offer an advantageous alternative for the fleets.

CFS Alert used an average of 1.8 ML of JP-8 per year at an average cost of $5.45/L (2007-2010) that is 62 TJ at a cost of $9.81 million per year. Only two 1-MW E-Cat plants are required to fulfil the demand. So the initial cost of the two plants could be paid in the first year with a surplus of $6 million. For the subsequent years the recurring saving for the energy at CFS Alert could exceed $9 million per year.

When such environmentally friendly energy technologies will power most DND/CAF capabilities, decennial savings in excess of several billions dollars would become achievable.

9. Conclusion

DND/CAF energy recurring expense represents a substantial portion (4%) of its budget. The $538 million for energy is more than the total department S&T investment. The discussed emerging technologies provide amazing potential improvements to DND/CAF capabilities while at the same time making operations and missions more sustainable.

Eventually, technology like LENR will facilitate the integration and persistent exploitation of new information technologies and weapons such as railguns and DEWs on legacy and future platforms. Such capabilities were either not achievable or sustainable using legacy energy technologies.

It is expected that Canadian multidisciplinary teams with relevant know-how would investigate the plausibility of claims made about LENR while DRDC conducts operational research studies and system analyses to estimate which legacy capabilities would most benefit from such advanced energy technologies. The time has come to investigate the impact of a variety of advanced energy technologies on Canadian Defense and Security, and Canadian Armed Forces capabilities [29].

In addition, such energy technologies would provide opportunities to produce clean water and better living conditions to people in places around the world affected by climate changes or already under extreme harsh living conditions. Improved living conditions are likely to reduce regional conflicts and wars. The advent of low-cost environment-friendly transportable energy sources/systems would improve Canada resources exploitation and transformation thus stimulating its economy.

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