Energy and the Military: Convergence of Security, Economic, and Environmental Decision-Making

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Keywords Energy Technology; Defense Policy; Innovation

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Energy considerations are core to mission delivery of armed forces worldwide. The interaction between military energy issues and non-military energy issues is not often explicitly treated in the literature or media, although in the last decade there has been some increase driven especially by the issues of clean energy. It is recognized that the military has for more than a hundred years taken a leadership role in terms on research and development (R&D) of specific energy technologies – most commonly where they are applicable in theater. More recently that R&D leadership has moved to the energy efficiency of home-country bases, and the development of renewable energy projects for areas as diverse as mini-grids for in-country installations, to alternative fuels for submarines and jets. Nevertheless, the military in most major countries tends to see energy issues as a matter of mission delivery or conversely the denial of enemy energy supply chains as a source of advantage. In this paper we explore the evolving relationship between energy issues and defense planning, and show how these developments have implications for military tactics and strategy and for civil energy policy.

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1. Introduction

1.1 Military Planners Confront an Interconnected Range of Energy Challenges

The famous energy trilemma combines concern for energy economics and affordability with a desire for environmental protection and assured energy security. Addressing all three considerations together has proven to be a difficult challenge for energy policy makers. This paper deals with a separate rather specific policy issue at the interface of defense policy and energy policy. The domain of concern is linked to issues sometimes referred to as "Energy and Security" but to be clear the concern of this paper is not "Energy Security" as conventionally conceived. The concerns addressed in this paper do not relate directly to the availability of energy to serve national economies and societies rather it is the relationship between defense policy (including for technological innovation) and energy supply and use.

The world's militaries have for more than a hundred years taken a leadership role in terms on research and development (R&D) of specific technologies – especially where they are applicable in combat theaters. Over many decades that leadership has involved issues relating to energy supply and use. Recently this interest has not diminished but rather has expanded to bring in stronger consideration of resource efficiency and environmental impacts. In recent years there has been increased emphasis on the efficiency of home-country installations, and the development of unconventional energy projects, including renewables, for areas as diverse as micro-grids for installations, to alternative fuels for major weapons systems such as aircraft and ships. Different countries are approaching the evolving military-energy challenges in different ways and with different emphasis. In this paper we give emphasis to the policies and actions of the United States (US) given its current globally leading role in defense. We also consider some earlier historical British experiences. We also comment on the role of energy considerations in the work of the United Nations, particularly in peace-keeping operations.

When considering the recent position of the US government and military we shall tend to focus on the period 2009-2011. We choose this period because it represents the peak in US defense expenditure (Walker, 2014). As Dinah Walker has commented, US defense expenditure rose sharply after the terrorist attacks of September 11, 2001 to support operations in Afghanistan and Iraq, before (as she explains), "in calendar year 2013, military spending declined from $671 billion to $619 billion, in constant 2011 dollars". With a desire to focus on the most recent data from the period of maximum expenditure we shall frequently make reference to the year 2011."

The drivers for energy decision-making in the non-military sectors of the economy are largely economic. The energy system consists of mostly privately-owned energy assets interacting with public policy and regulatory frameworks to ensure economic competitiveness and social welfare via energy affordability, provide reliable energy services (sometimes elsewhere termed “energy security”) and to achieve environmental goals in areas such as climate change, air pollution, and water quality. Energy security is represented by attempts to reduce the negative economic impacts of supply shocks through efficiency, diversified supplies, and fuel choices. “Environment” is represented by state, federal and international efforts to minimize air, water and waste impacts associated with energy, and to encourage new energy sources with fewer greenhouse gas (GHG) emissions. In military energy decision-making, however, “security” takes on a different meaning more directed at achieving military mission and strategic objectives. The underlying economic, security and environmental drivers of energy decision-making exist, but the military translates and applies these concepts very differently. It might be said that each economic sector has its own unique perspective on energy issues, and while this might be true the relationship of the military to energy issues is special and illuminating. In the domain of defense energy has the potential to be both an enabler of hard power but also, via denial, arguably itself to be a weapon of war.

One of the motivations for this paper has been to make clear that conventional paradigms of energy security (relating to economic prosperity and social harmony) should not be confused with the military-energy nexus (focused on the potential for hard power and willful coercion).

Energy considerations have long been core to mission delivery of armed forces worldwide, for operations in theater, for land, air, and water transport, and for installations and forward operating locations. More recently the topic has again risen in light of issues around clean energy and new challenges facing the military (see e.g. Burke, 2017a; Burke, 2017b; Burke, 2011; CAN, 2017; Lindner, 2017; Conger, 2017; Condliffe, 2017; Gardner, 2017; Pew, 2017; Pew, 2011, Glaser and Kelanic, 2017; McGinn, 2016; Ourenergypolicy.org, 2016; US Navy, n.d; Warrick, 2015) Energy enables nearly everything the military does, and the primary objective is mission assurance and decisive advantage on the battlefield. So “security” is derived through energy powering capable operational major weapons systems and communications infrastructure at the desired levels of performance, range and readiness. But resupplying energy to combat theaters and the battlespace edge is a vulnerability, so security is also derived through minimizing the energy required for vehicles and forward locations. Reducing and diversifying fuel use are also the military’s drivers behind economic considerations. The US Department of Defense (DoD) is the world’s largest user of petroleum and the largest US government user of energy (USDOE, 2017), and within overall constrained budgets volatile energy costs represent a source of a risk to military operations and maintenance. Finally, defense policy makers must choose paths that strengthen environmental performance objectives, which in the US are driven by Departmental and Federal guidelines. Environmental performance also contributes to maintaining DoD’s social license to operate. While that social license might represent an engagement with host communities, it is perhaps more likely to relate to public support back home. One noteworthy example in this regard concerns the use of the defoliant “Agent Orange” in the Vietnam War. Inferred to be a cause of birth defects in Vietnam, it was back in the US that the story resonated as societal alienation with the war grew.

Military decision-making under the confluence of these security, economic and environmental objectives, has over decades coalesced to create a new and adaptive energy policy for the DoD, and hence for the United States. This confluence of objectives will continue to shift the technologies and strategies that will be used to power the warfighter, and which, in time, can be expected to shape civilian technologies.

1.2 Defense and Civilian Energy

Despite our claims for defense exceptionalism, in some scenarios, the military concerns of Defense and Energy can collide with the civilian concerns of Energy Security. One point of contact, of course, relates to energy prices as faced by defense ministries, but the challenges can run deeper than that. For instance, The International Energy Agency was established in November 1974 (Scott, 1994). As Scott explains the origins of the IEA lay in an economic and political crisis in the period 1973-1974. The crisis emerged from the 1973 'Yom Kippur' war and the response of the Organisation of Arab Petroleum Exporting Countries (OAPEC) (Scott, 1994, p. 28). OAPEC was distinct from 'OPEC', a broader body established earlier in 1960, including, for instance, Venezuela and other non-middle eastern states. The industrialised west had become dependent upon petroleum imports from Arab countries and in the face of OAPEC production cuts, prices rose dramatically.

As Scott notes: "*The industrial countries permitted excessive and even wasteful and inefficient use of energy and of oil in particular. Energy conservation measures in those countries were woefully underdeveloped. Their oil production potential was not fully realized, nor was sufficient investment devoted to the development of other energy sources as alternatives to oil. They had yet to devise a workable system for responding to serious disruptions in oil supply; and their organizational arrangements for co-operation could not enable them to cope effectively with the institutional implications of those situations."* (Scott, 1994 p. 11)

The IEA itself is based upon an international treaty: The International Energy Program Agreement of 1974 and amended in 1992 (Scott, 1994 p. 353). The measures included a legally binding oil sharing mechanism and the creation of a strong Secretariat based in Paris. Chapter 6 of the IEP Agreement established a 'framework of consultation with oil companies'.

The IEA member states are required to maintain strategic petroleum reserves among which the US has the largest. Formally IEA members operate their strategic petroleum reserves autonomously and may use their stocks for national purposes. US emergency draw-downs from its Strategic Petroleum Reserves have historically been coordinated with the IEA (DOE, n.d.). The primary purpose of IEA strategic petroleum reserves is to stabilise global markets in times of turbulence. Coordinated release can meet market demand, in cases of supply disruption and in this way reduce price volatility. Arguably such planning lies within the conventional paradigm of Energy Security. There is however the potential for another dimension to the existence of strategic energy reserves. One can easily imagine conflict scenarios threatening energy supply chains such that military planners might wish to husband strategic reserves and seek to use them to meet military energy needs. That is, strategic reserves might be retained specifically to ensure military access to fuel. Any such desire to retain stocks in the face of system stress would run directly counter to the economist's preference to alleviate supply scarcity in the market.

It would be incorrect to assume that the world of Energy and Defense is a full of change and uncertainty while the civilian concerns of Energy Security are more static and stable, not so very long ago US political rhetoric concerning "Energy Independence" appeared to be merely fanciful and populist. The revolution in natural gas production in North America arising from the hydraulic fracturing of shale gas deposits has in a few years utterly transformed the energy landscape of the United States. The US has gone from being a predicted major importer of liquefied natural gas to a prospective major exporter. The long-term consequences of this shift for the word of Energy and Defense remain to be seen. Two important possibilities are in prospect. First, the potential creation of a free-standing global spot market in natural gas independent of the oil market, and second a shift in the security challenges of the United States in seeking to stabilize that emergent global market alongside an oil market of diminishing direct relevance to US interests.

As regards technological development the historical role of defense related research and development is manifest and seen in many sectors. Civil aviation has been built upon a series of twentieth century military innovations, many forged in conflict. These include: gas turbines (jet engines), radar, cabin pressurization, de-icing, and many more. In space our reliance on satellite-based technologies in communications, geo-positioning and earth observation (e.g. weather forecasting) were all made possible by military developments in rocketry and space-based technologies of nuclear deterrence. In this paper, we posit a looming transformation in energy both military and civilian.

1.3 Structure of the Paper

The remainder of the paper is organized as follows: Section 2 briefly discusses historical energy drivers for the military and the energy impetus included in modern defense planning. Section 3 describes DoD operational and installation energy, and expounds on the evolving confluence of military energy policy. Section 4 provides conclusions and observations. While we will highlight the factors shaping the energy and defense agenda, we exclude from consideration in this paper the ways defense planning will adapt to incorporate climate change impacts (see, for example, DSB, 2011). Climate change impacts can be direct, such as changes to surface shipping routes and military logistics or affecting military installations (DoD, 2015), but could also be indirect, such as increasing regional pressures on natural resources and potentially motivating conflict (DoD, 2015; White House, 2015). We and others will examine aspects of such matters in future work, but at this point we simply concur with Leon Fuerth when he observes;

> *"In the realm of military thinking, it is standard practice to consider worst-case scenarios as a way to avoid settling on insufficiently robust courses of action. Also in military thinking, it is standard to pay serious attention to low-probability, high-damage events (e.g. nuclear war). Where climate change is concerned, however, our thinking tends toward best-case outcomes, for no real reason other than the inconvenience of the possible truth. Planning for climate change needs to shift toward worst-case scenarios, especially because trends in the physical evidence are all pointing in that direction."* (Fuerth, 2013)

2. The Past and Present of Energy's Role in Defense Planning

Historical Linkage of War and Energy

Energy has played a role in every facet of war from troops in garrison and defensive planning to mobilization and attack. The need to deliver adequate and timely energy supplies to military forces—particularly to those in the most forward-deployed locations—has long existed as a strategic vulnerability to the success of military campaigns. Targeting materiel supply channels in an effort to hamstring adversaries' operational strength has often been employed as an effective tactical strategy. In addition, the logistics to deliver a reliable energy supply has been a recurring theme in the story of both successful and unsuccessful military operations (DoD, 2011).

Many of the lessons learned during the world wars of the 20th century are still being appreciated and relearned in today's conflicts. One of the most famous examples of energy influencing military strategy comes from 1911, when Winston Churchill, then First Lord of the Admiralty, converted the British fleet from Welsh coal to foreign oil. The resulting gain in speed and decrease in logistical burden gave the British Royal Navy a critical advantage over the Axis powers (Crowley, 2007). The action proved decisive and enabled the allied power to "float to victory on a sea of oil" (Nemetz, 1979). The policy brought with it further advantage as the less smoky combustion of oil allowed the Royal Navy to avoid producing the tell-tale plume of dark coal smoke that could so easily reveal a fleet's position (Dahl, 2000).

While the shift from coal to oil was a decisive one for Winston Churchill and for the Royal Navy, the history of the First World War further reveals its status as the first major conflict fought, in part for energy. British strategy, reinforced by the Battle of Jutland (May 31st to June 1st 1916), relied on a blockade denying Germany and her allies access to global supply chains including most notably food, but also oil and other industrial resources. Even before the war, there had been a competition for access to Persian Gulf oil with, on the one hand Germany seeking to establish a Berlin to Baghdad railway, and on the other Britain establishing commercial oil operations in the region, among which Anglo-Persian Petroleum was the most prominent (Engdahl, 2007). During the war access to oil became a pressing concern for both sides indeed. According to Paul (2002) Secretary to the British War Cabinet Sir Maurice Hankey went so far as to say about Mesopotamian oil that "Control of these oil supplies becomes a first-class war aim". Following victory, Britain and France initially divided access to all Mesopotamian oil between them, but then the British out-maneuvered France going into the Versailles peace conference and secured exclusive access to Mesopotamian oil via a new League of Nations protectorate called Iraq (Engdahl, 2007, Paul, 2002)).

Throughout the First World War, in parallel to British developments, the shift from coal to oil was also underway in the smaller United States Navy, but running on domestic oil (primarily from Oklahoma, Texas and California) (AOGHS, nd).

As the militaries of the world shifted during the early twentieth century toward oil as the main energy source, energy security and geopolitical positioning became important planning and operational variables. The resulting scramble to secure oil supplies heavily influenced events leading to and throughout WWII. Some of the greatest military strategic decisions in World War II had their roots in a desire to access energy resources. Operation Barbarossa – Nazi Germany's failed invasion of Russia (June-December 1941) is frequently presented as an attempt by Hitler to access Soviet oil resources. Germany captured the Maikop oil field in November 1942, but was overstretched and lacked the equipment to bring the field back into production (Hayward, 2000). The Germans military's perceived need for oil created a two-front war and their failure to take and hold the oil fields spelled disaster at Stalingrad and changed the tide on the eastern front (Yergin, 1991).

In the Asia-Pacific theater, the need for oil and other recourses shaped Japanese military and foreign policy both before and during the war. Much like the surprise attacks in operation Barbarossa, the Japanese surprised the American naval fleet on December 7, 1941 in an attempt to secure oil shipping lanes (Yergin, 1991, Roll, 2013). Previously, at the initiative of US Secretary of State Dean Acheson the US had effectively blocked oil exports to Japan in July 1941 following Japan's invasion of French Indochina which in turn had followed Germany's defeat of France in Europe. Fearing that any mitigating response would prompt conflict Japan decided to act aggressively and near simultaneously attacked Pearl Harbor in the Central Pacific, on Hong Kong and Malaya (Roll, 2013). These attacks were at the heart of a Japanese strategy to secure oil and other natural resources, such as rubber, from South East Asia[1]. Indeed Japan used the term "Southern Resource Area" to describe its sphere of wider influence and its economic hinterland (Mackenzie, 1997), while true vassal states joined the Greater East Asia Co-Prosperity Sphere. As such, Japan's assertion that it was ridding the region of European colonial rule surely had a rather hollow ring.

Energy's link to conflict in WWII had as much to do with the denial of resources to the enemy as it did to securing one's own oil supply chains. The stalling of General Patton's Third Army following its campaign across France in August and September 1944 is a telling example of fuel acting as a "tether" to military operations (Decker, 2003). At the time, Patton's army was over 100 miles closer to Berlin than any other Allied army. While Patton had the advantage on the battlefield, he the disadvantage of being tethered to an energy source located hundreds of miles away. Years later, in 1970, the famous war strategist, Sir

[1] As an interesting aside, the oil insecurity affecting the Japanese was the result of a demand of around 30 million barrels per year (Maechling, 2000), in recent years, the US military has been completing fuel shipments into war zones (Iraq and Afghanistan) of around 60-70 Million barrels per month.

Basil Hart, described the delay as the “unforgiving minute” and that the “best chance for a quick finish”, to the war, “was probably lost when the gas was turned off on Patton’s tanks.” (Yergin 1991).

While the skill of logistics forces in providing fuel has grown significantly since World War II, many leaders in the military are mindful of the operational implications of fuel’s logistical requirements. General James N. Mattis has highlighted the enduring criticality of logistics—energy logistics in particular—when he echoed the call of General Patton and entreated the U.S. Department of Defense (DoD) to “unleash us from the tether of fuel” as a result of his experience leading U.S. Marines into Iraq in 2003 (Fenwick, 2009). More recently, a test deployment in 2010 of portable solar-powered generation systems at U.S. Marine forward operating bases in Afghanistan have reduced the bases’ diesel generator usage by more than 90%—virtually eliminating the need for risky and costly fuel convoys to keep these bases supplied with energy (Daniel, 2011).

To summarize: the twentieth century saw energy figure ever more centrally as a driver of conflict, a strategic factor and a tactical consideration in war. The trend extended through the end of the Twentieth Century. For example, the energy intensity of war fighting grew by a factor of 16 and the oil-intensity of the individual soldier rose 2.6% annually from 1970-2010 (Lovins, 2010). This military evolution and decades of technological innovation has, until very recently, done nothing to reduce the mission-criticality of fuel supplies. For this reason, it has become an important area of research, development and defense planning.

Energy and Modern Defense Planning

There is a vast and evolving literature on energy security as seen from the perspective of civilian energy policy-makers the framing of such considerations, and frequently gives emphasis to the concerns of energy economics and involves notions of security of supply and security of demand for those involved in energy-based trade. In this paper we focus on a different set of considerations termed “Energy and Defense”. We invoke the term Energy and Defense for those instances where energy is directly related to armed conflict, the threat of such conflict, or in the clear confines of foreign diplomacy. In the Twentieth Century, this was primarily associated with the global oil sector or the use of fossil fuels for troop movements, although the story of the use of nuclear energy for submarine warfare and naval nuclear deterrence is arguably another fascinating example of defence-energy synergies. The enormous energy density of nuclear fuel made possible the strategic doctrine of Continuous At Sea Deterrence (CASD) in which Ship Submersible Ballistic Nuclear (SSBN) submarines hide in deep blue water awaiting orders from the Commander in Chief to move to launch depth and annihilate the enemy. The nuclear reactor made possible the ultimate second strike nuclear weapons system able to deliver massive retaliation consistent with either counter-force or counter-value goals. Meanwhile ranged against every SSBN force are a set of nuclear powered attack submarines designed to neutralise an enemy deterrent early in a conflict. Arguably this whole defence enterprise was enabled by an energy technological innovation – the controlled nuclear fission reactor.

2.1.1 Geostrategic Risk

The need to secure oil supplies and to maintain the stability of world oil markets has played a major role in shaping U.S. foreign policy and dictating U.S. military strategy and deployment (Crane et al. 2009; Deutch et al. 2006 CFR Task Force report). While DoD's own petroleum demand is a relatively small portion of US petroleum needs, it experiences a unique feedback loop in adding to the energy and defense concerns that arguably have part-motivated U.S. military action in the first place.

2.1.2 Increased Dependence

The international, US-led, operations in Iraq (since 2003) and Afghanistan (since 2001) have illuminated the increased cost and intensity of energy use in modern theaters of conflict. In World War II, the United States consumed about a gallon of fuel per soldier per day, in the 1990-91 Persian Gulf War, about 4 gallons of fuel per soldier was consumed per day. In 2006, the US operations in Iraq and Afghanistan burned about 16 gallons of fuel per soldier on average per day, almost twice as much as the year before (Crowley et al. 2007).

2.2 Energy and Defense - the role of the United Nations

The United Nations (UN) has had a leading role in attempting to mitigate harmful climate change caused by human activities. In Rio di Janeiro Brazil in 1992, the UN created the Framework Convention on Climate Change, which was followed in 1997 in the Japanese city of Kyoto by The Kyoto Protocol. The intention of the Convention (UNFCCC, 1992) was that major developed industrial countries would lead the way in emissions reduction. Developing countries, most notably China, were exempt from any obligation to limit or reduce emissions and the United States, although a signatory to the Convention never ratified the Kyoto Protocol. While one might argue that global emissions are lower than they would have been in the absence of the Convention, the Protocol and UN concern generally, it is clear that this high-profile UN initiative has so far failed to live up to the early expectations of its proponents.

Global environmental protection was not a founding mission of the UN. Conflict prevention motivated and shaped the UN. It was conceived by the Allied Powers in 1942 in the depths of World War II in a *Declaration by United Nations* (UN, 1942). The UN charter reveals an ongoing focus on international peace and security (UN, nd). It is in UN work to support the core function of peace keeping that one can find tangible examples of environmental progress.

2.2.1 UN Peacekeeping

UN Peacekeeping is noteworthy for the explicit policy consideration given to the minimization of negative environmental impacts. While military forces devoted to war fighting must necessarily prioritize narrow military objectives the special focus of peacekeeping operations permits, and arguably even requires, a different balance of priorities in what is fundamentally a military enterprise.

UN peacekeeping operations consist of around 115,000 staff in 16 countries (end of 2012) and represent 55% of the emissions of the entire UN system (UNEP, 2012a). The largest share of emissions for peacekeeping operations is due to air travel (46%), followed by power generation (26%) and road vehicles (15%). Until recently, the decisions regarding the adoption of renewable energy sources and of energy efficiency measures were handled at the single mission level, lacking any general UN-wide policy in the area, despite the potential for cost-savings (UNEP, 2012b, p. 27).

In recent years however the UN started a policy of reduction of its environmental impact in all of its operation, including its energy consumption for the field missions, and to pursue also other environmental goals following the spirit and the indications of the Seventh Millennium Development Goal (MDG7) to ensure environmental sustainability. In fact, since 2009 two new instruments have been adopted: the first is the *Environmental Policy for the UN Field Missions*, adopted by the Department of Peace Keeping Operations DPKO and by the Department of Field Operations DFO, the second is a *Global Field Support Strategy* adopted by the General Assembly (UN, 2010) (UNEP, 2012b). These policies are mandatory and regard many areas of environmental sustainability of peacekeeping operations, including camp management issues like the use of water, wastewater, solid and hazardous waste, wildlife, and energy. The adoption of the new policies is meant to provide minimum environmental standards and operational guidance for all field missions.

In its 2012 report *Greening the Blue Helmets* UNEP affirms that one obstacle to the adoption of energy efficiency and renewable energy technologies in the field is that the field mission's length is often unknown in advance and consequently a future-oriented cost-benefit analysis of renewable technologies becomes difficult (UN, 2012). In many cases the technologies to be deployed are chosen on the base of the initial length of the mission, typically six to twelve months, while the average length of a mission is far longer, typically seven years. Experience from the implementation in UN peacekeeping operation of sustainable energy and energy efficiency measures points to a cost-recovery payback time of one to five years (UN, 2012). The benefits that surely exist are being missed as a result of an excessively short-term mindset in project planning and approvals. Part of the solution must be to allow for time horizons to be considered for cost benefit analysis that exceed the authorisation period of the mission in question at the time of assessment.

The UNEP *Greening the Blue Helmets* report reveals that there have been some successful cases of sustainable energy intervention in UN peacekeeping operations. As an example, in Timor-Leste UNMIT has established an environmental committee that monitors energy use and adopted energy efficiency measures, including staff practices, and the use of solar energy for isolated applications. These practices led to a saving of around 335,000 USD per year. In Lebanon UNIFIL has implemented the UN's 2009 policies: putting in place environmental guidelines and an action plan for the mission, and a complete Environmental Management System (EMS) that manages all environmental related aspects of the mission. The measures adopted include the introduction of efficient transport vehicles, efficient electricity generators and building chillers, and the implementation of solar PV generation. In Darfur UNAMID forces have helped local women with their energy needs and security, escorting them regularly when collecting wood for fuel outside the camp, and also introducing modern cook-stoves reducing the consumption of firewood up to 80%. These measures greatly reduced the risks of assault and violence for the women, particularly during the agricultural cultivation season.

Notwithstanding these cases, UNEP notes also that the new policy guidelines are still to demonstrate sufficient results on the ground, and UNEP further stresses the importance of an initial focus on training, monitoring and reporting activities and of the creation of an Environmental Baseline Studies and of Environmental Impact Assessments for field missions. Furthermore UNEP suggests that a dedicated environmental officer should be appointed to each mission and that this person should report directly to senior level staff.

The extent to which UN concern for environmental impacts in peacekeeping is linked to the role of the organization is attempting to enhance global sustainability and a low-carbon future can be debated, but it seems clear that the desire to be seen to lead by example is underpinning actions by the UN to reduce the harmful environmental impacts of its own activities.

2.2.2 Energy and Defense in a Military Alliance - NATO

The NATO approach to energy issues is taken through an Energy and Defense lens, both for its member countries and of its operations. NATO debated its approach to 'energy security' in 2006, and convened this theme to be of central importance for the alliance and further mandated its member countries to define its role[2] (Shea, 2006) (Gallis, 2007) (Monaghan, 2008) (NATO, 2006, para. 45). One of the consequences of this decision is that, in October 2012, a NATO Energy Security Centre of Excellence was founded in Lithuania

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[2] Article 45 of the NATO Riga declaration in 2006 states that: *"As underscored in NATO's Strategic Concept, Alliance security interests can also be affected by the disruption of the flow of vital resources. We support a coordinated, international effort to assess risks to energy infrastructures and to promote energy infrastructure security. With this in mind, we direct the Council in Permanent Session to consult on the most immediate risks in the field of energy security, in order to define those areas where NATO may add value to safeguard the security interests of the Allies and, upon request, assist national and international efforts."*

(NATO ENSEC COE). The Centre will join the family of the other NATO COE and will provide 1) strategic analysis and research; 2) development of doctrine, standards and procedures; 3) education, training and exercise and 4) consultations (NATO ENSEC COE, 2012). Some work in this area has already started, in particular NATO members are collaborating to exchange smart energy solutions to reduce fossil fuel consumption in their respective militaries, and reduce the threat to the environment (NATO, 2012a).

The problem of fuel consumption and of the security of fuel supplies has particularly affected the biggest NATO operation ever, in Afghanistan. In late 2012 ISAF forces amounted to more than one hundred thousand troops consuming every day more than 1.8 million gallons of fuel (6.8 million litres), 99% of which delivered by truck from abroad. The fuel used to transit through Pakistan but, after an air attack that accidentally killed 24 Pakistani soldiers in 2011, the border was closed by the Pakistan government and NATO forces were forced to shift all the supply of energy to the North, through the so-called Northern Distribution Network (NDN), a rail link of more than 5,000 km starting from Latvia, traversing Russia, Kazakhstan and Uzbekistan until the city of Termez, where trains are offloaded and the fuel is moved to trucks that cross the border to Afghanistan[3]. It should not have come as a surprise when Foreign Policy described this logistic as a “nightmare”. (Trilling, 2011) (Kinaci, 2012) (NATO, 2012b).

It is clear that the long-standing vulnerabilities and difficulties of fuel logistics seen in World War I and World War II are so far undiminished despite enormous progress in military technology. In fact in some aspects, these vulnerabilities have grown as the energy intensity of conflict has increased.

[3] Another route of the NDN bypasses Russia, starting with the Georgian port of Poti, and goods travel through Azerbaijan, the Caspian Sea, Kazakhstan and still reach Afghanistan through the Termez bottleneck in Uzbekistan.

2.3 Positing the Prospect of a Future Revolution in Military Affairs

As in previous conflicts, the U.S. military has used technologies and strategies to adapt to the new challenges experienced in the wars in Afghanistan and Iraq. The rapid increase in use of remotely piloted aircraft (aka "drones") in these theaters signaled a realization of the "revolution in military affairs" that drones represented (see, for example, DoD, 1997; Arquilla and Ronfeldt, 1997; Hundley 1999). A revolution in military affairs, or RMA, "involves a paradigm shift in the nature and conduct of military operations" (Hundley, 1999). The literature cites many past examples of RMAs that have changed warfare, including precision strike munitions, nuclear weapons, the aircraft carrier, radar, and even the English-developed longbow from the thirteenth century. RMAs can be technological, but can also result from the emergence of new strategies, doctrine and decision-making (Hundley, 1999). In this chapter, we argue that the new ways that the military plans for, uses and manages energy could represent a future RMA that could transform DoD acquisitions and operations, and enhances the capabilities of the fighting force. In this way, the military would break free of the risks and difficulties seen in conflicts over at least the last 100 years.

As we have seen, resupplying energy to combat vehicles and the warfighter has long been a vulnerability and area of desired improvements by the military. Throughout the military literature, there has long been a desire of enhancing the ratio of the fighting "tooth" of the military to the supporting "tail" (see, for example, McGrath, 2007; DSB, 2001; DSB, 2008). The size and requirements of the tooth of the fighting force directly affect the size and requirements of the resupplying tail. For example, when combat vehicles and warfighters deploy to theaters, they require additional vehicles and personnel as combat support elements (such as medical, supplies and other needs), and these combat support elements, themselves require resupply from other combat service support elements along the tail. This results in cascading vehicle, personnel and supply requirements from the tooth the tail. In World War II, average fuel demand per soldier was about 1 gallon per day. This has increased to 15 to 20 gallons per solider in Operation Iraqi Freedom and Operation Enduring Freedom (Vane and Roege, 2011). The long-standing challenges of fuel logistics are undiminished and arguably becoming worse. The vulnerability of such supply lines was exploited by Afghan fighters, and contributed to about one U.S. Marine Corps casualty for every fifty convoys in Afghanistan (DoD, 2013 factsheet). A separate estimate (AEPI, 2009) distinguished FY2007 Army solider and civilian casualties by energy and water convoys. In Iraq, the Army study found 1 casualty for every 39 fuel convoys and every 63 water convoys. For, Afghanistan the casualty factors were higher- 1 casualty for every 24 fuel convoys and every 29 water convoys (AEPI, 2009). These casualties incurred during resupply have intensified DoD's efforts to reduce this strategic security vulnerability. Reducing energy and water requirements for the fighting tooth represents a significant and realizable opportunity to shift the fundamental tooth-to-tail ratio in the Armed Services.

Over the past decade, two other factors have shaped military energy decision-making. The first is the increased focus on the costs of military energy. In FY 2011, DoD consumed 890 trillion British thermal units (Btu) of energy, roughly 1% of U.S. energy consumption and 80% of U.S. federal energy consumption (EIA, 2012), at a cost of $19.3 billion (DoD, 2012 AEMR). DoD spent approximately 90 percent of these FY2011 energy costs on petroleum products. In FY2011, DoD consumed roughly 117 million barrels of petroleum (Schwartz et al., 2012), approximately 2% of total U.S. petroleum consumption in 2011 (analysis using EIA 2012). In FY 2011, jet fuel alone accounted for nearly 60% of total DoD energy consumption, while all petroleum-based fuels supplied about 80% (EIA 2012). Despite a 4% decrease in DoD's petroleum consumption between FY 2005 and FY 2011, the agency's petroleum expenditures over the same period rose 381% in real terms due to rising oil prices (Schwartz et al., 2012). While still a relatively small portion of DoD's total spending (2.5% in FY 2011), the $17.3 billion spent on fuel in FY 2011 is large in absolute terms. Since 1990, the DoD's cost of buying fuel has increased faster than health care, personnel and every other major DoD budget category (Schwartz et al., 2012). Additionally, petroleum price volatility has negatively impacted DoD operating budgets and created large unfunded obligations (Schwartz et al., 2012).

The second other factor affecting military energy decision-making is the requirement for the DoD to improve energy efficiency, use renewable energy, and energy management as directed through several legislative and executive actions. From the National Energy Conservation Policy Act enacted in 1978 to the Energy Independence and Security Act of 2007, the Executive Order 13514 signed in 2009, a bevy of federal mandates have sought to demonstrate the federal government's own leadership in fostering sustainability and reducing greenhouse gas emissions by setting aggressive goals for federal agencies. These goals are aimed at reducing water and energy intensity and petroleum consumption, and at increasing the use of renewable, efficient, and alternative energy technologies. These goals and mandates range from requirements to develop and implement energy and water management strategies; efficiency standards for acquisition of new energy-consuming products, equipment, and vehicles; and percentage targets for the use of renewable energy-generated electricity. Additionally, several of the annual National Defense Authorization Acts (NDAA) that funds the Department of Defense have included language that affects energy use in weapons platforms as well as on installations.

It is clear that the dependence of US military operations of extended and vulnerable fuel supplies is unsustainable at many levels. A Revolution in Military Affairs is needed and can be expected whereby innovative technology in energy supply and use will reduce, or eliminate, the need for extended full supply lines. This technological innovation will be driven by defense policy and military needs and as such will be largely independent of measures to promote energy technology in the civilian sector. The consequences for civilian energy supply and use arising from defense innovation could, however, be significant.

2.4 US Trajectory in Operational Military Energy Decision-Making

In FY 2011, DoD consumed roughly 650 trillion Btu of operational energy, of which the vast majority was supplied from petroleum-based fuels (analysis based on AEMR 2012). Estimates for DoD petroleum expenditures in FY 2011 range from $15-$17 billion (AEMR 2012, CRS 2012). The Air Force consumed the most petroleum (53% in FY 2011), followed by the Department of the Navy (28%), including the Marine Corps, and the Army (18%). All other DoD agencies accounted for the remaining 1% (CRS 2012).

The DoD separates energy consumption along the lines of facility (or installation) and operational energy, since they possess distinct characteristics, priorities, and opportunities. Facility energy is consumed at fixed installations and by non-tactical vehicles (DoD, 2012). Operational energy is defined in law as "the energy required for training, moving, and sustaining military forces and weapons platforms for military operations." (US Code, 2011) Although some ambiguity exists in the delineation between these two categories, DoD's FY 2011[4] energy consumption was roughly 74% operational energy and 26% installation energy (DoD, 2012). The proportion of operational to installation use depends greatly on the current level of military activities. High levels of operational use in recent years reflect U.S. operations in Afghanistan and Iraq (Schwartz et al., 2012).

Bak (2011) identified operational energy processes and levers DoD can influence, including:

- Force Planning Assumptions and Defense Planning Scenarios
- Requirements Development
- Acquisition Programs and Rapid Fielding
- Technology Priorities and Investments
- Culture, Measurement, Education and Billing

Petroleum-based fuels dominate DoD's energy mix. DoD's petroleum consumption (and especially its volume, disproportionately growing cost, and additive effect to geostrategic risks) has been widely discussed as one of the agency's most critical energy issues (see e.g. Defense Task Board reports 2001, 2008, CRS report 2012, Lovins 2010).

The central role of petroleum products in DoD's energy mix is one of the most salient reasons why a large portion of ongoing efforts have focused on reducing DoD's use of petroleum through conservation, increased efficiency, and development and deployment of alternative fuel substitutes and technologies.

[4] U.S. DoD's Fiscal Year 2011 is from October 1, 2010 to September 30, 2012.

The US Defense Logistics Agency - Energy (DLA-E), formerly called the Defense Energy Support Center (DESC)[5], is responsible for supporting the energy needs of DOD's combat operations, which includes the wholesale purchase, storage, and sale of fuels to DoD and other government agencies (DLA-E, 2014).

For operational energy use, the commodity cost of fuels purchased by DoD from DLA-E is often only a fraction of the total costs of energy for operational use. Significant indirect costs can be incurred by the logistical operations needed to transport and protect these fuel supplies from DLA-E supply points to DOE operational theaters, particularly when these theaters are in remote or politically unstable regions of the world. The "fully burdened cost of fuel" (FBCF), as it is called, varies widely depending on the location and distance of the transport operation and, especially, on the amount of force protection needed to guard the fuel supply convoys.[6] Schwartz et al. (CRS, 2012) provide a number of FBCF estimates collected from studies conducted by DoD Armed Forces:

"In 2010, the Marine Corps estimated the fully burdened cost of fuel in Afghanistan at between $9 to $16 per gallon if delivered by land, and between $29 to $31 per gallon if delivered by air. An Army study estimated the fully burdened cost of fuel in Iraq at $9 to $45 per gallon, depending on the type of force protection used to and the delivery distance, while an Air Force study estimated the fully burdened cost of fuel delivered by land at $3 to $5 per gallon and $35 to $40 per gallon for aerial refueling. A 2008 report by the Army Environmental Policy Institute estimated that the fully burdened cost of fuel for a Stryker brigade in Iraq ranged from $14.13 to $17.44 per gallon."

With fully burdened costs at this level we start to see one of the key reasons for the defense arena to be a key driver of technological innovation in energy systems. An economic case for new and initially at least, relatively high cost alternatives can be made much more easily in a defense context than in the lower cost world of civilian energy policy and markets.

Several industry and government reports (see e.g. DTB, 2001; LMI, 2007; etc.) identified a critical need for DoD to develop measures to assess the indirect energy costs of technologies and systems, and to incorporate these measures into operational planning and acquisition processes. In doing so, DoD would be able to compare options on the basis of

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[5] From 2004 through 2008, the cost of DESC purchases from its supply network increased from $5.9 billion to $18.1 billion, a significant jump due almost entirely to increases in fuel prices. Over the same period, DESC sales to its customers increased from $6.9 billion to $18.7 billion. The DoD is overwhelmingly the DESC's largest customer, although the DESC sells a small amount of energy resources to non-DoD governmental agencies, as well as to foreign governments. (Delloite, 2011)

[6] This is quantified in a report completed by the US Army - http://www.aepi.army.mil/docs/whatsnew/SMP_Casualty_Cost_Factors_Final1-09.pdf - in the analysis casualties are measured and projected against fuel use. The study concludes that water and fuel delivery accounted for 10-12% of historic casualties in Iraq and Afghanistan.

their energy performance and efficiency, along with other traditional factors, and make superior strategic acquisition, deployment, and R&D investment decisions.

However, it wasn't until 2007 that a policy memo published by the Office of the Under Secretary of Defense for Acquisitions, Technology, and Logistics (OSD (AT&L)) initiated the incorporation of fully burdened costs of energy considerations into acquisition decisions for three pilot programs. Following that, the Duncan Hunter National Defense Authorization Act (NDAA) for FY 2009, the military budget authorization bill passed by Congress in 2008, required the fully burdened cost of fuel and energy efficiency to be considered in planning, capability requirements development, and acquisitions processes.

With analytical guidance from the Defense Science Board's 2001 report, *More Capable Warfighting Through Reduced Fuel Burden*, the OSD (AT&L) and the Office of Cost Assessment and Program Evaluation (CAPE) (formerly the Office of Program Analysis and Evaluation) have led the way by developing and refining guidelines for a prototype FBCF methodology. These guidelines have been incorporated into the Defense Acquisitions Guidebook, the DoD reference guide of best practices for acquisitions. Within the last few years, the Armed Forces branches have adapted the OSD (AT&L)/CAPE methodology for their own use or developed similar methodologies.

Notions of cost minimization and economic efficiency are attractive to all defense ministries, but acceptance of new more efficient technologies and practices by military personnel rely largely on a different logic. Recent asymmetric conflicts such as Iraq and Afghanistan have relied upon extended and vulnerable supply chains. This combines with the real and perceived isolation of forward operating bases to yield a sense among soldiers that they would prefer any approach that would reduce the need for fuel re-supply. Re-supply risks soldiers' lives and the lives of support workers in ways that would be avoided if more energy efficient systems were deployed. For the soldiers at the front the need for frequent re-supply represents a vulnerability that they would prefer to live without.

The analysis of alternative energy integration in the military found a focus in four areas of development:

- The area of liquid fuels continues to be an area of focus and vast potential. Most of the innovation in the area has involved the air force's implementation of biofuel mixes. While there is skepticism regard the economics of this work, the continued implementation and development of mixed fuel technologies has been ensured by legislation (Wall Street Journal, 2012).

- Away from the front, military installations have received focus for the energy and cost saving potentials of efficiency and renewable energy systems. One estimate found that shifting from reliance on diesel backup generators to advanced microgrids at installations could save the DoD between $8 billion and $20 billion over the next 20 years (Navigant, 2017). The cost savings from these upgrades can be better used to finance the needs at the front.

- The use of small scale systems at the platoon/company level will continue to be developed and utilized as military leaders strive to provide small scale fighting forces independence from their fuel tether.

- The imperative of maintaining power independence in forward operating bases has created demand for innovative systems. The described difficulties of supplying fuel to generators have led to a number of unique efficiency modifications. This system has allowed for the development of more efficient microgrids for electrical power distribution on military bases and installations. These installations combine the smart information technology (IT) and environmental benefits seen in civilian equivalents together with enhanced IT security and with a strong emphasis on reduced fuel needs. Technological leadership in this space comes from US activity.

The growing momentum within DoD and Congress to take action regarding increasingly burdensome fuel logistics led to the establishment in 2010 of a new Assistant Secretary of Defense for Operational Energy Plans and Programs (ASD (OEPP)). The office was charged with developing DoD's first operational energy strategy and providing oversight and guidance to DoD agencies on operational energy. In 2011, the office released the *Operational Energy Strategy: Energy for the Warfighter*, followed by the companion *Operational Energy Strategy: Implementation Plan* in 2012. The report outlined three strategic goals:

- More fight, less fuel: reduce energy demand and increase energy efficiency
- More options, less risk: diversify energy sources and reduce dependence on external energy infrastructure, particularly the U.S. commercial electricity grid
- More capability, less cost: incorporate energy considerations into DoD institutions and processes, particularly for planning and acquisitions

The unique energy perspective of the military is also relevant in how technologies are shared amongst allied forces. Through foreign military sales, joint exercises and international basing, DOD can promote adoption of shared technical standards and directly influence the energy systems used by its allies (Parthemore, Nagl, 2010). The sharing of research and development and the constant push for standardization could lead to the proliferation of energy alternatives to allied countries where the process of military technology pathways to commercial use can take place.

2.5 Energy Decision-Making for Military Installations

In FY 2011, DoD consumed 224 trillion Btu of installation energy at a cost of $4.1 billion (DOD, 2012). Buildings accounted for 95% of consumption, while non-tactical vehicles made up 5% (DOD, 2012). Electricity and natural gas supplied the majority of installation energy (48% and 32%, respectively) (DOD, 2012), which is roughly analogous to the U.S. commercial sector's energy mix of 52% electricity and 38% natural gas in 2011(EIA, 2012) Worldwide, DoD manages more than 500 installations with around 300,000 buildings (AEMR, 2011). The Army consumed the most installation energy (36% in FY 2011), followed by the Air Force (30%), and the Department of the Navy (28%), including the Marine Corps (DOD, 2012). All other DoD agencies accounted for the remaining 6%.

One of Former President Obama's first energy acts was enacting Executive Order 13514 on Federal Sustainability. By signing the act, the President made the government's "goal [to] lower costs, reduce pollution, and shift Federal energy expenses away from oil and towards local, clean energy" (White House, 2010). The US Federal Governments internal goal of 28% reduction in GHG by 2020 has created greater emphasis within departments (DoD/DOE) to reduce fuel use and permitted much energy technology research and development using federal resources. Here there are linkages to long-standing critiques from Europe that while the US tends to avoid political discourse on the themes of industrial strategy or industrial policy perhaps with a sense that such thinking is "un-American". Critical Europeans have argued that such policy is alive and well in the US hidden within vast federal programs with other nominal missions, such as national defense. Such debates have been most visible in the context of political support for the aircraft industry.

Growing global awareness and action toward reducing greenhouse gas (GHG) emissions have led the U.S. federal government to implement several initiatives to reduce federal energy consumption and GHG emissions. These federal mandates have applied to the majority of DoD's vast array of fixed installations in the U.S. and abroad.

Additionally, US DoD concerns about its reliance on commercial networks and infrastructure, particularly the U.S. electricity grid, have provided further impetus for energy innovation at its stationary facilities. Increasingly, fixed installations are directly engaged in operational missions in foreign theaters (for example through the command of unmanned aerial vehicles) as well as serve as local command centers for national relief and recovery efforts and Homeland defense missions. However, these installations rely heavily on a U.S. commercial electricity grid that is increasingly vulnerable to outages due to both accidents and intentional physical or cyber attacks (Samaras and Willis, 2013). Current methods of providing back-up power to installations are highly inefficient, costly, and fragmented (DST 2008).

While DoD’s combat and tactical facilities, vehicles, and systems are largely exempt from these federal regulations, most of the agency’s fixed installations and non-tactical vehicle fleets *do* fall under these regulations. And, in fact, they make up a very large proportion of federal facilities and fleets:

- In FY 2007, the total square footage and energy consumption (1.9 billion gsf and 205 trillion Btu, respectively) of DoD buildings subject to federal energy reduction requirements was more than the square footage and energy consumption of all other agencies combined (1.1 billion gsf and 148 trillion Btu, respectively) (FEMP FY2007 annual report, 2010).
- In FY 2011, DoD fleet vehicles made up 30% of federal fleet vehicles and 24% of federal fleet fuel consumption (GSA Federal Fleet Report 2011).

Key requirements include:

- Produce or procure 25 percent of facility energy consumption by FY2025 (10 USC § 2911)
- Meters capable of recording energy consumption at least hourly and providing data at least daily installed in all federal buildings by October 1, 2012 (EPAct 2005).
- A 30% reduction in energy intensity (energy consumption per gross square foot (gsf)) of federal buildings by FY 2015 using a FY 2003 baseline (EISA 2007, EO 13423).
- A 55% reduction in fossil fuel-generated energy consumption in new federal buildings by 2010, increasing to 100% reduction by 2030, compared to a similar building in FY 2003 (EISA 2007).
- Net zero energy consumption by 2030 for new federal buildings designed in 2020 or later (EO 13514).
- At least 7.5% of federal electricity consumption to be sourced from renewable resources by FY 2013. Renewable energy generated on-site or on other federal or Native American lands can receive double credit (EPAct 2005).

Because of this, the federal mandates have initiated a flurry of activity by DoD component entities to develop and implement renewable energy deployment strategies, build institutional capacity on facility energy management, and strike partnerships with other federal agencies as well as private sector organizations to fund energy research & development projects.

The Deputy Under Secretary of Defense for Installations & Environment (DUSD (I&E)) office is responsible for managing military installation assets and services, including overseeing installation energy management programs and policies. At the request of Congress, the office released in 2005 the *DoD Renewable Energy Assessment Final Report*, which detailed the results of a study conducted to assess the potential to develop renewable energy resources on or near military installations, along with a companion Implementation Plan.

3. Conclusion

Energy has always been a strategic input to warfighting, but typically viewed as a priority of logistics planners. Security, economic and environmental factors have recently elevated energy to be considered as a system-wide strategic lever in the military, which will have lasting and positive results for war-fighting capabilities.

In this paper, we have sought to argue that there is a very long history of energy/defense interactions and these interactions apply in policy, strategy and tactics. Furthermore, defense innovation has long led to civilian technological improvements in many technological areas (such as perhaps most notably in aerospace) we are now on the cusp of a possible similar technological transfer in the domain of energy technology. Defense can lead the way for economic reasons as well as a result of more direct military concerns. For example, for war-fighting in recent decades the US military has faced an extremely high fully burdened cost of fuel. Those very high costs favour moves to innovative approaches far earlier than would be seen in civilian contexts where prices and costs of traditional and established options are far lower. We recommend such questions for further research. The authors see these pressures in the defense context only growing further favouring defense-led innovation. Alongside these developments, the issue of anthropogenic climate change has become a major international concern. While this paper does not directly concern itself with the impacts of a changing global climate on international relations and potential conflict there are clear points of interaction between this paper and that literature. This paper sees how climate change policies are affecting not only civilian innovation but also policy and decision making in defense contexts (nationally and inter-governmentally, such as in UN peacekeeping).

Military and defense innovations are now showing positive developments in the environmental area. Whether the changing nature of energy supply and use in military planning and tactics represents a revolution in military affairs remains an unanswered question, but we see the potential for a major shift emerging from the military arena where it may even achieve the status of a Revolution in Military Affairs.

In closing, we observe that there is an unhelpful separation, organizationally and socially, between experts involved in civilian energy policy and innovation and their colleagues concerned for military strategy and planning. We suggest that those concerned for civilian energy technology and policy should do more to consider innovations and potential innovations emerging from the defense sector. The advantages lie not just in looking at the present and the past, but also (where possible) into the future. We further suggest that there is a growing opportunity for a reverse flow (civilian to military) in energy innovation especially as one considers the greening of military operations. These opportunities for mutually beneficial exchange have considerable potential.

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References

AOGHS, American Oil and Gas Historical Society, no date, http://aoghs.org/offshore-exploration/petroleum-and-sea-power/

Army Environmental Policy Institute (AEPI), 2009. Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys, Final Technical Report. September 2009.

Arquilla, John and David Ronfeldt. In Athena's Camp: Preparing for Conflict in the Information Age. Santa Monica, CA: RAND Corporation, 1997. http://www.rand.org/pubs/monograph_reports/MR880.

Blair, Bruce; Yali, Chen and Hag, Eric. (2006) The Oil Weapon: Myth of China's Vulnerability. World Security Institute. China Security, Summer 2006, pp.32 - 63

Burke, S. (2017a). The Pentagon's Fuel Fiefdom. New America, Washington, DC, USA.

Burke, S. (2017b). Mattis on Military Enetrgy Security. New America, Washington, DC, USA.

Burke, S (2011). Energy for the War Fighter. Harvard University Center for the Environment. Cambridge, USA.

Centre for Defense Enterprise - MOD-UK. (2012). Energy Efficiency and Optimisation for Defense Call release, 2012(1), 1–6. Retrieved from http://www.innovateuk.org/_assets/energy_efficiency_call_brief.pdf

Centre for Defense Enterprise - Ministry of Defense UK. (2012). Energy Efficiency and Optimisation for Defense, (c). Retrieved from http://www.science.mod.uk/controls/getpdf.pdf?713

CNA. 2017. Advanced Energy and US National Security. Washington, DC, USA.

Clark, Ryan (2010). Chinese Energy Security: The Myth of the PLAN'S Frontline Status. Retrieved from: pdfwww.strategicstudiesinstitute.army.mil/pdffiles/pub1012.pdf

Condliffe, J. 2017. The Department of Defense Wants to Double Down on Renewables. MIT Technology Review.

Conger, J. 2017. The Military Value of the Defense Department's Energy Efforts. Defense One.

Crowley, Thomas D. ; Corrie, Tanya D. ; Diamond, David B. ; Funk, Stuart D. ; Hansen, Wilhelm A. ; Stenhoff, Andrea D. ; Swift, Daniel C. (2007). Transforming the Way DOD Looks at Energy. An Approach to Establishing an Energy Strategy. Logistics Management Inst (LMI)

Daniel, L. (2011, 09 05). Marines prove energy efficiencies in Afghanistan. American Forces Press Service . Retrieved from http://www.defense.gov/news/newsarticle.aspx?id=63841Department of Energy, USA, Strategic Petroleum Reserve – Profile, DOE website, no date, http://fossil.energy.gov/programs/reserves/spr/

Dahl, E.J. 'Naval innovation: from coal to oil,' Joint Force Quarterly, Winter, 2000 http://www.dtic.mil/doctrine/jfq/jfq-27.pdf

Defense Logistics Agency – Energy (DLA-E) (2014). Defense Logistics Agency – Energy Factbook. U.S. Department of Defense. http://www.dla.mil/Portals/104/Documents/Energy/Publications/E_Fiscal2014FactBookLowResolution_150911.pdf

Department of Defense (DoD). 1997. Report of the Quadrennial Defense Review. William S. Cohen, Secretary of Defense. U.S. Department of Defense. May 1997. http://www.dod.mil/pubs/qdr

Department of Defense (DOD) (2011) Energy for the Warfighter: The operational Energy Strategy. Assistant Secretary of Defense, Operational Energy Plans and Programs. http://energy.defense.gov/OES_report_to_congress.pdf

Department of Defense (DoD). 2012. Annual Energy Management Report, Fiscal Year 2011. U.S. Department of Defense, http://www.acq.osd.mil/ie/energy/library/FY.2011.AEMR.PDF

Department of Defense (DoD). 2013. Annual Energy Management Report, Fiscal Year 2012. U.S. Department of Defense, http://www.acq.osd.mil/ie/energy/energymgmt_report/FY%202012%20AEMR.pdf

Department of Defense (DoD). 2013. Operational Energy by the Numbers. U.S. Department of Defense, http://energy.defense.gov/Blog/tabid/2569/Article/4866/operational-energy-by-the-numbers.aspx. September 30, 2013 [SEARCH AND REPLACE FOR FACTSHEET]

Department of Defense (DoD). 2015, *National Security Implications of Climate-Related Risks and a Changing Climate* https://climateandsecurity.files.wordpress.com/2014/01/15_07_24-dod_gcc_congressional-report-on-national-security-implications-of-climate-change.pdf 23 July 2015

DOE (2016). Comprensive Annual Energy Data and Sustainability Performance, U.S. Department of Energy. http://ctsedwweb.ee.doe.gov/Annual/Report/TotalSiteDeliveredEnergyUseInAllEndUseSectorsByFederalAgencyBillionBtu.aspx

Defense Science Board (DSB), 2008. "More Capable Warfighting Through Reduced Fuel Burden. May, 2001

DSB, 2008. "More Fight – Less Fuel". Report of the Defense Science Board Task Force on DoD Energy Strategy. February 2008.

DSB, 2011. "Trends and Implications of Climate Change for National and International Security". October, 2011.

EIA, 2012. US Energy Information Administration, Annual Energy Review 2011, released September 2012, various extracts available at: http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0111 or http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0113 and http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0103 for total US consumption.

Engdahl, E.F. "Oil and the origins of the 'War to make the world safe for Democracy'", 22 June, 2007 http://www.oilgeopolitics.net/History/Oil_and_the_Origins_of_World_W/oil_and_the_origins_of_world_w.HTM#_edn13

Fuerth, L. "National Security, Energy, Climate Change: New Paradigm; New Strategy; New Governance" in "Energy and Security, Strategies for a World in Transition (Second Edition)" Editors: Kalicki, J.H. and Goldwyn, D.L. Woodrow Wilson Center Press, Washington D.C. and Johns Hopkins University Press, Baltimore, Maryland USA (2013)

Gallis, P. (2007). NATO and Energy Security. CRS Report for Congress.

Gardner, T. 2017. US military marches forward on green energy, despite Trump. Reuters.

Glaser, C and Kelanic, R. Getting out of the Gulf. Foreign Affairs.

Guanqun, W. (2011, 03 31). Full text: China's national defense in 2010 . Xinhua News. Retrieved from http://news.xinhuanet.com/english2010/china/2011-03/31/c_13806851.htm

Hayward, Joel. (2000). Too Little, Too Late: An Analysis of Hitler's Failure in August 1942 to Damage Soviet Oil Production. The Journal of Military History. Ed 64. The Society for Military History.

Hundley, Richard. Past Revolutions, Future Transformations: What Can the History of Revolutions in Military Affairs Tell Us About Transforming the U.S. Military?. Santa Monica, CA: RAND Corporation, 1999. http://www.rand.org/pubs/monograph_reports/MR1029.

Kinaci, M. (2012). Energy Security: Tough Lessons of Afghanistan - ACT. Retrieved November 14, 2012, from http://www.act.nato.int/transformer-2012-01/article-7

Lindner, D. 2017. Air Force Develops New, Deployable, Energy Systems. US DOD. USA

MacKenzie, Curtis M. (1997). Japan's 'Operational Hawaii': An Operational Design Case Study. Naval War College. Retrieved from http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA328108 :

McGrath, John J. *The other end of the spear: The tooth-to-tail ratio (T3R) in modern military operations*. ARMY COMMAND AND GENERAL STAFF COLL FORT LEAVENWORTH KS COMBAT STUDIES INST, 2007. http://www.cgsc.edu/carl/download/csipubs/mcgrath_op23.pdf

McGinn, D. 2016. FROM THE GREAT WHITE FLEET TO THE GREAT GREEN FLEET - A CONVERSATION WITH ADMIRAL DENNIS MCGINN ON THE U.S. NAVY'S GREEN FUTURE (9/12/16). Columbia Center for Global Energy Policy.

Maj Jeffrey W. Decker, "Logistics and Patton's Third Army: Lessons for Today's Logisticians," Air & Space Power Journal, March 20, 2003, in Chronicles Online Journal, accessed February 13, 2006.

Monaghan, A. (2008). Energy Security: NATO's Limited, Complementary Role. … Division-NATO Defense College, Rome-No, (36), 1–12. Retrieved from https://transnet.act.nato.int/WISE/FSE/FuturesPap/NDUReport/file/_WFS/NATO RP 36 EN.pdf

NATO. (2006). NATO Riga Summit Declaration. Retrieved November 15, 2012, from http://www.nato.int/docu/pr/2006/p06-150e.htm

NATO. (2012a). NATO - News: NATO seminar highlights smart energy projects, 05-Mar.-2012. Retrieved November 15, 2012, from http://www.nato.int/cps/en/SID-69477654-8333BFE2/natolive/news_84927.htm

NATO. (2012b). International Security Assistance Force International (ISAF) Contributing Nations, (october). Retrieved from http://www.nato.int/isaf/docu/epub/pdf/placemat.pdf

NATO ENSEC COE. (2012). Concept of the NATO Centre of Excellence for Energy Security. Retrieved from http://enseccoe.org/projects/publications?download=10:concept-of-the-nato-centre-of-excellence-for-energy-security

Navigant. (2017). Military Microgrids. Navigant Research. https://www.navigantresearch.com/research/military-microgrids

Nemetz, P. N. (1979). Energy policy, the global challenge. Montreal: Institute for Research on Public Policy .

Ourenergypolicy.org. 2016. Should the Pentagon re-think its energy strategy. http://www.theenergycollective.com/billsquadron-2/2382135/should-the-pentagon-rethink-its-energy-strategy?platform=hootsuite

Parthemore C. and Nagl J. (2010) *Fueling the Future Force: Preparing the Department of Defense for a Post-Petroleum Era*, Center for a New American Security, 24 Sep 2010

Paul, J.A. Global Policy Forum, *Great Power Conflict over Iraqi Oil: The World War I Era*, October 2002, available at http://globalpolicy.org/component/content/article/185-general/40479-great-power-conflict-over-iraqi-oil-the-world-war-i-era.html accessed 6 November 2017.

Pew, 2011. Clean Energy Innovation and Americas Armed Forces. Pew Trusts, DC, USA.

Pew. 2017. Power Begins at Home. Event, January 12, 2017. Washington DC. http://www.pewtrusts.org/en/about/events/2017/power-begins-at-home

Roll D.L. *Oil Led to Pearl Harbor*, The Globalist, 12 May 2013, available at:salon.com/2013/12/05/oil_led_to_pearl_harbor/ accessed 6 November 2017.

Samaras, C., Willis, H.H. (2013). Capabilities-Based Planning for Energy Security at Department of Defense Installations, Santa Monica, CA: RAND Corporation, RR-162-RC, 2013.

Scott R, The History of the International Energy Agency, Volume 1 the first twenty years 1974-1994, 1994, available at: http://www.iea.org/Textbase/nppdf/free/1-ieahistory.pdf

Schwartz, Moshe, Blakely, Katherine, and Ronald O'Rourke, 2012. Department of Defense Energy Initiatives: Background and Issues for Congress, Congressional Research Service, R42558.

Shea, J. (2006). Energy security: NATO's potential role. Retrieved November 15, 2012, from http://www.nato.int/docu/review/2006/issue3/english/special1.html

Soder, K. (2009). Multilateral Peace Operations: Personnel, 2008. SIPRI Fact Sheet, (July), 2–5. Retrieved from http://books.sipri.org/files/FS/SIPRIFS0907P.pdf

Tracy, Ryan. (November 29, 2012).The Wall Street Journal. Retrieved from: http://online.wsj.com/article/SB10001424127887323751104578149423431835586.html

Trilling, D. (2011). Northern Distribution Nightmare. Foreign Policy, December. Retrieved from http://www.foreignpolicy.com/articles/2011/12/06/afghanistan_resupply_nato_ndn

UK Ministry of Defense. (2011a). United Kingdom Defense statistics 2011, (September). Retrieved from http://www.dasa.mod.uk/modintranet/UKDS/UKDS2011/pdf/ukds.pdf

UK Ministry of Defense. (2011b). Sustainable Development Strategy - A sub strategy of the strategy of defense. 2011 – 2030. Retrieved from http://www.mod.uk/NR/rdonlyres/F6A0B684-3F48-4D1D-9D06-7E2650C8F721/0/20110527SDStrategyPUBLISHED.pdf

UK Ministry of Defense. (2012). Greening Government Commitments Annual Report 2011-12. Retrieved from http://www.mod.uk/NR/rdonlyres/CEE79C80-305E-4D4E-93DB-7D7ED435A27C/0/mod_ggc_annual_rpt_2011_12.pdf

US Navy, nd. Energy, Environment, and climate change. http://greenfleet.dodlive.mil/energy/repo-3/

UN (1942) United Nations Declaration, available at: http://www.un.org/en/sections/history-united-nations-charter/1942-declaration-united-nations/index.html

UN (no date) United Nations Charter (full text), available at: http://www.un.org/en/sections/un-charter/un-charter-full-text/index.html

UN (2012) Greening the Blue Helmets, United Nations Environment Programme, available at: http://staging.unep.org/disastersandconflicts/Introduction/EnvironmentalCooperationforPeacebuilding/GreeningtheBlueHelmetsReport/tabid/101797/Default.aspx

UNFCCC (1992) United Nations Framework Convention on Climate Change available at: https://unfccc.int/resource/docs/convkp/conveng.pdf

U.S. Code (2011) Title 10 Subtitle A Part IV Chapter 173 Subchapter III § 2924, December 31, 2011, available at: https://www.law.cornell.edu/uscode/text/10/2924

Vane, Michael A., and Paul E. Roege. *The Army's Operational Energy Challenge*. ASSOCIATION OF THE UNITED STATES ARMY ARLINGTON VA, 2011. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA543153

Walker D. "Trends in U.S. Military Spending", Council on Foreign Relations, July 15, 2014, available at: https://www.cfr.org/report/trends-us-military-spending

Warrick, J. 2015. Pentagon bets heavily on sun, wind with major energy projects. Washington Post.

White House (May 2015) *Findings from Select Federal Reports: The National Security Implications Of A Changing Climate*, https://obamawhitehouse.archives.gov/sites/default/files/docs/National_Security_Implications_of_Changing_Climate_Final_051915.pdf