NATO supply convoy along Afghan mountain ridge

[*DEPARTMENT OF DEFENSE: RENEWABLE ENERGY & TECH TRANSFER*]

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Executive Summary

The Department of Defense (DoD) has often served as a launching pad for many technologies that have advanced civil society development. These have included societal mainstays such as antibiotics, jet travel, the Internet and GPS. The DoD is in a unique position to have the breadth and depth necessary to acquire emerging technologies from the civilian sector, further research and development and utilize them in real world settings. Through this process DoD channels help establish an economy of scale robust enough that once technology transfers back into the civilian sector and commercialization takes root the starting price point for civilian purchases is approachable. Presently, the DoD is undergoing this process with renewable energy technologies, in both domestic and overseas operations and the benefits to the civilian sector are forthcoming.

Across the DoD there are conservation and renewable energy gains, albeit with bureaucratic hurdles to overcome, in domestic installation operations. The current conflicts in Iraq and Afghanistan, however, have highlighted the security vulnerability and high cost point for the US in acquiring the necessary amount of energy to meet operational requirements at forward operation bases (FOBs). The total energy budget for the DoD (inclusive of domestic and international installations and operations) ebbs and flows around $20 billion. Every $10 increase in price ber barrel (ppb) on the world market equates to an additional annual DoD energy cost of $1.3 billion (Reichart). For a frame of reference to the enormity of this amount one can compare it to the FY 2009 $64 billion budget for the entire Department of Education (Dept).

Though the monetary budget for energy use within the DoD fluctuates around $20 billion, this does not account for the 'fully burdened cost' of fuel. The 'fully burdened cost' increases when human capital in terms of man-hours, casualties and fatalities to secure various LOCs is considered. Most of what travels along combat theater LOCs is fuel and water. Shipments are, on average, 50 percent fuel, 20 percent bottled water and 30 percent other necessary items, including munitions. Securing these LOCs costs service members lives at a rate of one casualty per every 24 fuel convoys in Afghanistan and one casualty for every 39 fuel convoys in Iraq, according to a report done by the Army Environmental Policy Institute (AEPI) in Fiscal Year (FY) 2007 (Eady).

Focus within the DoD has been placed on feasibly implementing various renewable energy technologies at FOBs to reduce this 'fully burdened cost'. To carry out these directives several organizations have emerged. The Secretary of Defense established the office of the Assistant Secretary of Defense for Operational Energy Plans and Programs (Defense) and the US Army recently established the Energy Initiatives Office Task Force (Lopez). The US Marine Corps (USMC) has established an experimental FOB in Afghanistan to actually field test various renewable energy technologies (Moore). These emerging technologies and their implementation have been promising so far. One of the technologies is a multi-fuel capable generator that has built in solar panels adept to harsh climatic conditions and are capable of using diesel fuel, batteries or plugging in additional solar panels (ReGenerator). Improving

tactical vehicle efficiency is an area with ample opportunities. An emerging technology in this sector is called the Oshkosh HEMTT-A3 that is a tactical hybrid truck that utilizes electricity generated from on-board diesel-electric generators to power each of the four axles. Functionality is not lost either – it is capable of hauling 13 tons of cargo while cruising at 65 miles per hour (mph) (Matthews). Another technology, in its infancy but with promising prototypes called the Arroyo 500 which is an air to water generator where moisture is captured from the air and concentrated by a high-temperature desiccant wheel, collected and purified into potable water (Dusenbery).

With a bit of foresight I assess that many of the technological advances carried out by the DoD to reach reduced energy dependence, specifically via renewable energy production and storage options, will provide a feasible, economical and approachable roadmap for large-scale US domestic civil society adaptation. I will detail my findings, analysis and conclusions in the following study.

I: Introduction

The United States (US) Department of Defense (DoD), like many of its international counterparts and predecessors, is charged with attaining and maintaining a military fighting force that is of a higher caliber, and better equipped than its competition, namely other nations (albeit organized and uniformed or nondescript) armies. The US DoD carries this out primarily by developing superior military aircraft, naval warfare equipment, army equipment, weapons arsenal, intelligence collection capabilities and communication systems. Many of these advancements have resulted in benefits for civil society through technology transfer from the DoD to the civilian sector. A couple of these advancements that have become fixtures in society worldwide are Global Positioning System (GPS) navigation and the Internet.

In the wake of rising energy prices and more acute understanding of the effects of climate change, senior US leadership is shifting policy and recognizing the strategic advantages, from an economic and security standpoint, to arrive at reduced energy dependence. Scientific advances in renewable energy technologies within the civilian sector are being brought into the DoD for further development and application, highlighting the feasibility of moving the DoD towards reduced energy dependence. There are projects underway at stateside DoD facilities and installations moving them towards reduced energy dependence with significant benefits. Overseas, the benefits extend beyond economics given that nearly 70% of logistical shipments to forward operating bases (FOBs), currently in Iraq and Afghanistan, are in the form of liquid fuel (50%) and potable water (20%). These shipments run along vulnerable lines of communications (LOCs), commonly referred to as convoy routes, which are at risk of attack from insurgent forces, often in the form of improvised explosive devices (IEDs) (Eady). If FOBs were able to attain reduced energy dependence the human cost, in addition to the monetary cost, saved would be immeasurable. Currently, the DoD is investing in opportunities to reach reduced energy dependent FOBs with immediate benefits on the battlefield. The FOBs implementing these technologies are also able to provide real-world feedback to the research and development cycle fueling opportunities for future technologies.

II: Historical Perspective

The Internet is debatably the most ubiquitous invention of the current generation. It was born out of a relationship between an academic institution, Massachusetts Institute of Technology (MIT), and the Defense Advanced Research Projects Agency (DARPA) of the DoD. In 1962 J.C.R. Licklider, a Professor at MIT, detailed his vision of a 'Galactic Network' wherein individuals could access data and programs across a global network -- essentially he envisioned the modern day Internet. A few months later he went to work for DARPA as the head of the computer research program. Close to the same time, fellow MIT faculty member Leonard Kleinrock, published a paper and then a book on theories involving packet switching theory. Subsequently, the teams working with these men were able to establish the first ever wide-area computer network in 1965 over a dial-up telephone line between a TX-2 computer in Massachusetts and a Q-32 in California (Leiner).

With this wide-area computer network established prospects were in place to establish the ARPANET, which would connect different nodes across DARPA, both defense and academic. By 1969 four nodes were connected and in 1972 the first public demonstration of the Internet was made at the International Computer Communication Conference (ICCC). ARPANET then expanded, mainly due to the protocol transition from the Network Control Program (NCP) to the currently used Transmission Control Protocol/Internet Protocol (TCP/IP). Over the next decade ARPANET was used as a tool within closed circles of the DoD and academia. In 1985, partially due to the TCP/IP protocol transition, the US National Science Foundation (NSF), acting as one of the leading federal policy directors on use of the Internet, pushed their ARPANET equivalent, NSFNET. They did this to seek non-academic regional partnerships to expand commercial application of the Internet to lower subscription costs. With this initiative commercial Internet for the private sector was set off and by 1990 ARPANET was decommissioned. Commercial equipment of a higher caliber was then brought on line to take over and provide a more robust commercial service. The evolution of the Internet from a specialized tool for DoD research to mass commercial application highlights one innovative tool developed for US competitive leadership that transitioned to a valuable civil society instrument (Leiner).

Another tool employed by civil society on a massive, and now very affordable scale, which originated within the DoD, is GPS navigational technology. With the launch of the first satellite, Sputnik I, in 1957 by the former Soviet Union, scientists found that they were able to track it by the potency of its signal. The US launched its first satellite in 1958 and with each subsequent satellite launch new findings were made as to the strategic benefit of the satellites. By 1964 US submarines were using satellites for their GPS navigational capabilities even though the satellite only conducted one reading on a completely stationary submarine every 30 to 45 minutes. This GPS navigation system was called the TRANSIT and the US Navy decided to develop and launch their own satellite, this one with an atomic clock and an ability to provide geo-locational data while in transit. The accuracy was dodgy at best, and in 1973 the Navy developed a new program called NAVSTAR that provided data from several satellite signals,

instead of only one. When satellites were first launched, government agencies coordinated amongst each other. In 1972 a Canadian company, Telesat, became the first private company to gain operational control of a satellite providing services to the US private commercial market. Shortly thereafter a US home cable network, Home Box Office, provided downlinked cable television and in 1976 Ted Turner kicked off the first 'superstation' by up-linking WTBS out of Atlanta (Kumar).

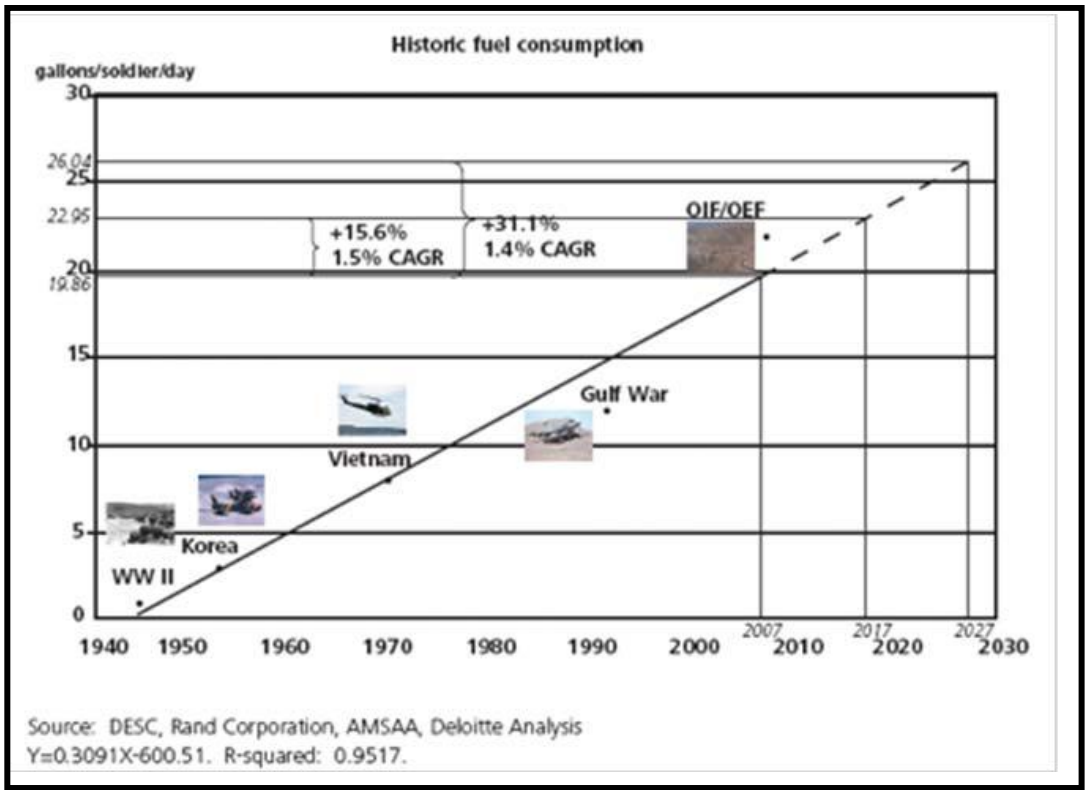
In the coming years satellite technology developed rapidly and parameters to the purpose, maintenance and operation of GPS was detailed in the Presidential Decision Directive. This directive outlined that the Interagency GPS Executive Board (IGEB), composed of members of the Department of Transportation and Defense, would oversee GPS technology to ensure it met civil and military needs. In July 1995 the IGEB determined that GPS technology was robust enough to provide GPS services worldwide, free of charge to direct users. The IGEB dictated it would carry this out through two avenues: 1) Standard Positioning Service (SPS) for general civil use and 2) Precise Positioning Service (PPS), an encoded GPS technology primarily used by the DoD. GPS technology has revolutionized many industries to include the monitoring of weather, natural disasters, environmental concerns, forestry, agriculture and wildlife biology along with sophisticating civil aviation navigation, maritime navigation, telecommunications, ground transportation, surveying and mapping and radio beacons for rescue efforts (Kumar).

Internet and GPS technology have transformed the world and are models of positive DoD technology transfer into the civil society. Both of these advancements were born out civilian innovation and developed further through DoD research and development initiatives and then utilized exclusively within DoD channels. Further, through DoD application the Internet and GPS could be employed at an economy of scale substantial enough to aid price reduction for the common user. Once their transition back into the civilian sector took place, civilian commercialization enabled these technologies to meet their full capacity and capability, capitalizing on these DoD research and development ventures.

III: DoD Energy Use

The DoD has an annual energy budget that, depending on energy prices, ebbs and flows around $20 billion. Every $10 increase in price per barrel (ppb) on the world market equates to an additional annual DoD energy cost of $1.3 billion (Reichart). For a frame of reference to the enormity of this amount one can compare it to the FY 2009 $64 billion budget for the entire Department of Education (Dept). Nationwide, the federal government consumes one percent of annual energy use in the US; of this, the DoD consumes 80 percent, 75 percent of the energy use is operational and 25 percent is consumed amongst the 600,000 plus federal buildings. The most significant consumer of operational energy use within the DoD is the US Air Force (USAF). This is primarily because the airborne mission of the AF requires a vast amount of liquid Jet Propellant (JP)-8 fuel. Beyond aircraft, JP-8 also fuels ships, generators and ground vehicles – it is a necessity in a combat arena (Burke). After aircraft, most liquid fuel is used for non-combat vehicles and generators. Accompanying the technological advancement of the US military came an increasing demand for electricity. Fighter aircraft, communications, computers, Morale

and Welfare Resources (MWR) and dining facilities have attributed to a higher energy demand at FOBs. Historically, fuel has been a showstopper, during World War II Gen Patton was quoted as saying, “My men can eat their belts, but my tanks got to have gas! (Ryan)” He said this after halting his forces because he was unable to acquire the necessary fuel for his tactical vehicles. Fuel demand today, however, has reached a magnitude not yet seen on the battlefield. The following chart, briefed by Tom Morehouse from the DoD at the SERDP/ESTCP Symposium on December 2, 2010, illustrates the growing demand for fuel in a rate of gallons of fuel per soldier per day (Morehouse):



After aircraft fuel consumption, ten percent of the remaining fuel is utilized to carry out lethal ground combat operations. The remaining fuel is used for other ground vehicles and to fuel generators (Goodman). The DoD consumed over five billion gallons of fuel during calendar year 2010 (Burke). For the purposes of this study, I will not be breaking down the monetary fuel price per gallon because of the complex purchasing process for fuel within the DoD along with the varied methods of delivery (sea freight, truck freight, air cargo) and their effect on the monetary cost of per gallon calculations.

Though the monetary budget for energy use within the DoD fluctuates around $20 billion, this hardly accounts for the ‘fully burdened cost’ of fuel. The ‘fully burdened cost’ considerably increases when human capital in terms of man-hours, casualties and fatalities to secure various LOCs is considered. Most of what travels along the combat theater LOCs is fuel and water. Headquarters Department of the Army states that annually convoy loads break out to approximately 50 percent fuel, 20 percent bottled water and 30 percent other necessary

items, including munitions (Eady). Another piece of energy consumption that has not been calculated is the energy consumed to transport troops to their various posts in Afghanistan and Iraq.

US Marine Corp (USMC) Major General Richard Zilmer, commander of operations in Al-Anbar province in support of Operation Iraqi Freedom during 2006, demanded the DoD calculate costs of fuel and water in human casualty cost instead of monetary costs after suffering losses of Marines under his command securing LOCs. The Army Environmental Policy Institute (AEPI) was charged with conducting this study. For this study data from Fiscal Year (FY) 2007, in both the Iraq and Afghanistan theaters of US combat operations, was utilized. This paints a somewhat skewed picture for the current situation because it encompasses the height of combat in Iraq and the lull of combat in Afghanistan, which is now reversed. The study is, however, the only study that uses a level of scrutiny and diligence necessary for accurate assessments. Interestingly, and likely due to terrain, channelized routes susceptible to observation and interdiction and predictability of movement, even during this period of time when overall attacks in Afghanistan were lower than Iraq, convoys were at a higher risk in Afghanistan – at a rate of one casualty for every 24 fuel convoys compared to one casualty for every 39 fuel convoys in Iraq. Water resupply convoy routes also suffer casualties; at a rate of one casualty for every 30 water convoys in Afghanistan and one casualty for every 64 water convoys in Iraq (Eady). The chart below details the number of convoys in each respective combat theater, with accompanying casualty information and final causalities per convoy calculations (Eady):

Theater	**Iraq**		**Afghanistan**	
	Fuel	**Water**	**Fuel**	**Water**
FY 2007 Number of Casualties	132	53	38	15
FY 2007 Number of Convoys	5,133	3,287	897	438
Casualty Factor (Casualties/ Convoy)	**0.026**	**0.016**	**0.042**	**0.034**

It is likely that if this study was conducted based off of FY 2010 or 2011 data that the Afghanistan casualty rate would be higher. Not only have combat activities increased, but many of the combat troops, and their fuel needs, from the downsizing of combat forces in Iraq were sent to Afghanistan.

IV: Directives to achieve Reduced Energy Dependence

The severity of continuing a DoD 'business as usual' campaign in regards to fuel consumption has gained much attention. Top brass in the military, lawmakers on Capital Hill and scholars at think tanks and academic institutions have all articulated the importance of this issue. Over the last several years there have been several federal mandates directing future operations to move away from a 'business as usual' scenario. These include:

- 2005 Energy Policy Act
- 2007 Executive Order 13423: Strengthening Federal Environmental, Energy and Transportation Management
- 2007 Energy Independence and Security Act
- 2009 Executive Order 13514: Federal Leadership in Environmental Energy and Economic Performance
- National Defense Authorization Act of 2009
- 2010 Quadrennial Defense Review (QDR)

In addition, each of the armed services has outlined their intents to carry out these directives and have established divisions or offices to oversee progress. Recently, the Secretary of Defense established the office of the Assistant Secretary of Defense for Operational Energy Plans and Programs. This office will oversee operational energy requirements and needs, serving as the focal point to move the DoD operational energy footprint beyond 'business as usual' (Defense).

V: Exclusions from this Study

Another area for discussion that relates to the reduction of fuel demand within the DoD is the effect climate change will have on national security. Whether it is shore-side DoD installation vulnerability, DoD responsive measures to extreme weather events worldwide, the effect of shifting weather patterns on environmental migration or expanding Arctic sea lanes due to melting ice caps, all will have a significant effect on the future missions of the DoD. This forum, while complementary, is distinctly different and I will not focus on these issues. There are a number of studies that highlight these impacts and give notice that the DoD, as a predominant action arm, will have to ensure readiness to react to climate change related events, such as extreme weather events, flooding and sea level rise. These studies point out that the US will have to respond to the stability and security issues surrounding climate change and its tertiary effects, such as environmental migration and lack of access to potable water. They do not, however, give way to a discussion of transfer technology to the civil society. They instead point out the risks of continuing 'business as usual' and at times highlight future technologies to reduce energy dependence for the DoD. I do recommend the following studies, which sufficiently cover the issue of climate change and national security:

- Center for Naval Analysis: National Security and the Threat of Climate Change
- The Strategic Studies Institute: Global Climate Change: National Security
- Center for Naval Analysis: Powering America's Defense

- PEW Project: Reenergizing America's Defense
- Progressive Policy Institute: Cutting the Tether
- Deloitte: Energy Security: America's Best Defense
- RAND Corporation: Alternative Fuels for Military Applications

There are a couple other items that are related to this discussion that will not be directly dealt with in this study due to the limited scope, but are inherently linked. The first item is a jet fuel alternative for military aircraft to the current JP-8 fuel. This is particularly crucial because aircraft operations consume the largest footprint of energy use within the DoD. According to Colonel Jon Ostertag, Headquarters US Air Force (USAF), in his presentation at the March 30-31, 2011 *Defense, National Security and Climate Change* conference in Washington D.C., while the USAF is achieving accomplishments in energy reduction at facilities, one of the main challenges to reduced energy consumption in the USAF is that 'aviation fuel reduction is not mandated (Defense).' Unlike the USMC that has a clear policy directing the force to seek alternative fuels and efficiency (Bases), the USAF leadership is lacking policy guidance in regards to jet fuel reduction and alternative jet fuel options. While all branches have aircraft operations, the USAF has the most aircraft and should be leading the charge for aviation fuel efficiency and jet fuel alternatives, but USAF policy does not direct it. It is unclear why exactly the USAF has not dictated a more stringent policy on jet fuel use, especially considering the service has steep goals for making their buildings more energy efficient. The USMC and Army are leading the charge in these efforts, likely because Soldiers and Marines are most often the securing force on convoys, and these services will be highlighted for their resourcefulness in this study.

The second item of interest is a follow-up study that should be conducted that assesses the monetary and human cost-savings for reducing energy dependence. The assessment should include costs for man-hours to secure access to oil from a geopolitical and physical aspect along with ensuring ease of movement along worldwide sea LOCs. This cost, in addition to the more straightforward calculated cost for drilling and shipment of fossil fuels should be calculated. Further, the full life-cycle analysis payback, human and monetary, for each of the renewable projects must be estimated. Calculating the cost of fuel and its shipment to each individual FOB can do this and then the amount of the actual product less the amount of fuel saved over the lifespan of the product. This report will provide a detailed and technical report in order to conclude with an accurate and reasonable assessment of monetary and human cost-savings.

All of these issues should be addressed in order to have a better understanding of DoD energy use but for the limited scope of this study the focus will remain on FOB energy alternatives and transfer of the technology into the civilian sector.

VI: FOB Energy Alternative Options and Transfer Technology

The DoD is ripe with technological prospects to move towards reduced energy dependence. There are many opportunities to transfigure the energy picture within the DoD, from stateside operations at the more than 600,000 (Defense) DoD buildings and amongst its fleet of domestic vehicles to operations carried out from FOBs in combat operations. To

narrow the scope for this study, however, I will focus only on prospects currently being implemented at FOBs and potential technologies being researched for FOB implementation. This is not intended to be an exhaustive list nor a rank-order of what is assessed to be the most beneficial, instead it is intended to underscore that opportunities exist, are being implemented and that many can be adapted and utilized in our civilian sector.

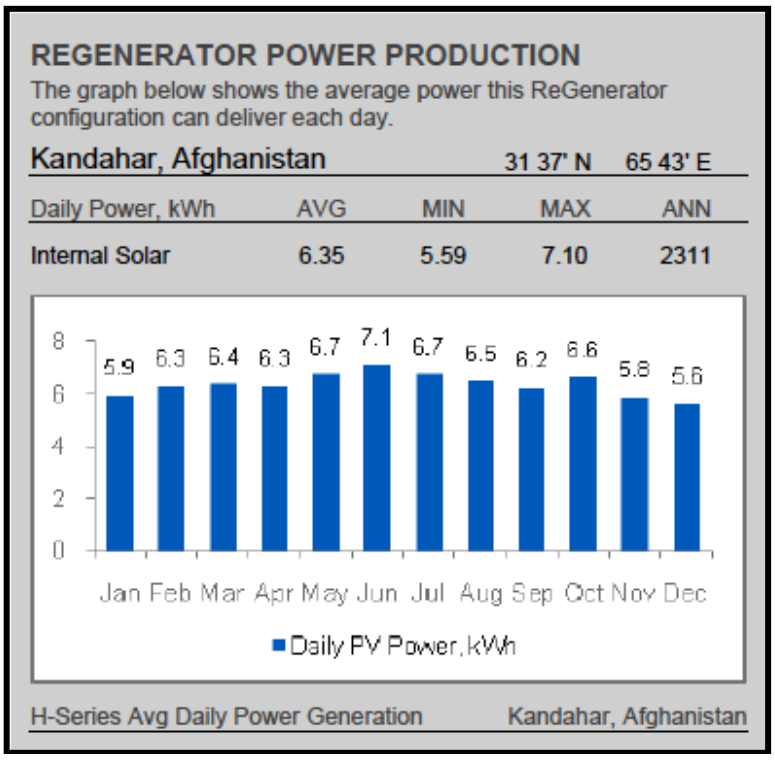
As stated earlier the USMC and Department of the Army are leading the charge for FOB energy transformation, likely because they experience the human cost associated with fuel and water shipments. To further focus the lens of this study, I will discuss three distinct technologies to aid in reduced energy dependence: solar harvesting, tactical vehicle efficiency and water generation/purification. The first two technologies were detailed in a USMC 'Request for Information' (RFI) proposal that assessed what would be most value added to their experimental FOB for reduced energy dependence. An RFI is the process wherein the USMC (this specific one coupled with the Army) solicits private industries to showcase technologies they have available to achieve objectives on the battlefield. For this particular RFI, the USMC established a Marine Energy Assessment Team (MEAT) that conducted field studies (Moore) and divided their findings into two categories. The final technology, water generation/purification, is in response to the high amount of energy used to transport water. In the following I will detail examples of these technologies and provide analysis for appropriate technology transfer opportunities into the civil society sector:

1) Solar Harvesting: Within the last year the USMC has started employing renewable energy generation systems. They have determined solar energy is the most effective renewable energy option at FOBs supporting approximately 150 individuals, or the size of a USMC company. This is primarily because of the minimal infrastructure associated with solar harvesting, in contrast to wind or biomass (specifically Tactical Garbage Energy Refinery) energy generation. In the USMCs RFI they detailed that they need higher concentration solar harvesting tools to meet the 5-kilowatt (kW) continuous base load necessary for a company sized FOB. No reliable estimates were found for the amount of electricity a FOB uses per day but electricity consumption at a state side experimental FOB was approximately 20 kW per hour (ExFOB). The following is an example of a concentrated solar harvesting device already deployed by the USMC and analysis on its potential civilian application:

    a. ReGenerator: This is a trailer mounted, terrain tested, generator capable of taking in diesel, wind, solar and battery energy and outputting a continuous base load of up to 3.6kW solar PV generated electricity. It has 1.2 kW of built-in solar array panels; in addition it has the capacity for 1.2 kW of wind-turbine, additional 2.4kW of solar power, and charge of up to 10kW to the Absorbed Glass Mats (AGM) batteries on-board. It has already been field-tested by the USMC in the Horn of Africa (HOA) and is now being field-tested in Afghanistan. One company sized FOB would require approximately two ReGenerator units to generate all of their electricity needs from solar energy; if they augmented with

diesel, one unit in a hybrid configuration would suffice (Government). The following is a picture of a ReGenerator:

The following chart details the vendor's data in support of their claims that it provides enough solar PV power to meet USMC requirements; the chart outlines the kW per hour generation capacity of one ReGenerator, with only the 1.2 kW internal solar capacities utilized (ReGenerator):



b. Analysis on Technology Transfer to Civil Society: The ReGenerator has the potential for civilian application in the US residential market or in the developing world, whether by humanitarian aide agencies or by villages looking to generate their own energy in areas where an electrical grid is not currently connected.

The US Energy Information Administration (EIA) calculated that average US residences consume approximately 29 kW of electricity per day. Most of the energy consumption is due to energy intensive appliances (End). The current capacity of one ReGenerator would not be sufficient to supply the necessary energy for an entire house. It is, however, a viable launching point to develop more capable systems that could become an onsite residential energy generator.

In the developing world I assess this technology would develop similarly to cell phone technology where technology leapfrogging occurred, in part due to the robust infrastructure necessary for landline telephones. Cell phone companies captured the market by installing less costly cell phone towers and now cell phones are ubiquitous in the developing world. ReGenerator technology could work the same way and the hindrance that not being connected to the main electrical grid could become less of an issue. Electricity would enable developing countries to conduct business in non-daylight hours, refrigeration and other food activities and enhanced education opportunities.

2) Tactical Vehicle Efficiency: The majority of missions in combat theaters take place with a Family of Medium Tactical Vehicles (FMTVs); there are 14 varieties, the most common being the Light Medium Tactical Vehicle (LMTV) (Liao). Nearly all missions, regardless of objective, take place with personal electronics such as laptops, jammers, radios and communication equipment. Even when a group of Marines has reached their mission destination and are stationary, they do not turn off their vehicles because of the associated risk of not being able to move swiftly and immediately. These tactical vehicles generally have an energy generation capacity and are able to recharge the electronics brought onto the mission. This uses more energy and idling engines charging personal electronics is inefficient thus presenting an opportunity for change (ExFOB). A major technological improvement for tactical vehicle efficiency is as follows:

    a. Oshkosh HEMTT-A3: This heavy expanded mobility tactical hybrid truck utilizes electricity to power motors for each of the four axles; there is an on-board diesel-electric generator that produces electricity. The vendor states that fuel savings are in excess of 20 percent and that maintenance and brake costs are reduced. Each of the motors that drive the axles act as generators to produce electricity when not pushing the vehicle, such as coasting or braking. The vehicle also does not utilize batteries; instead they use an ultracapacitor electrostatic device, about the size of a soda can. These ultracapacitors allow the electricity generated at each of the axles to be quickly generated and quickly expended for acceleration purposes. Also, stated by the vendor, they can be recharged and expended over a million times (not field tested to verify this claim) -- far more than battery storage devices. Given that there is not a traditional engine also allows for reconfiguration of the truck set-up and opens up space for a 40 percent larger cab, and reduces 3,000 pounds off the weight of the truck. From a tactical perspective it also reduces noise and vibrations, enabling a more stealth posture. Functionality is not lost – it is capable of hauling 13 tons of cargo cruising at a speed of 65 miles per hour (mph). One of the most

advantageous perspectives of this hybrid-truck technology is the flexibility the on-board generator provides; it has the capacity to provide 100 kW of military grade power for field hospitals, communication systems, or whatever the mission dictates (Matthews). The following is a picture of the HEMTT-3:

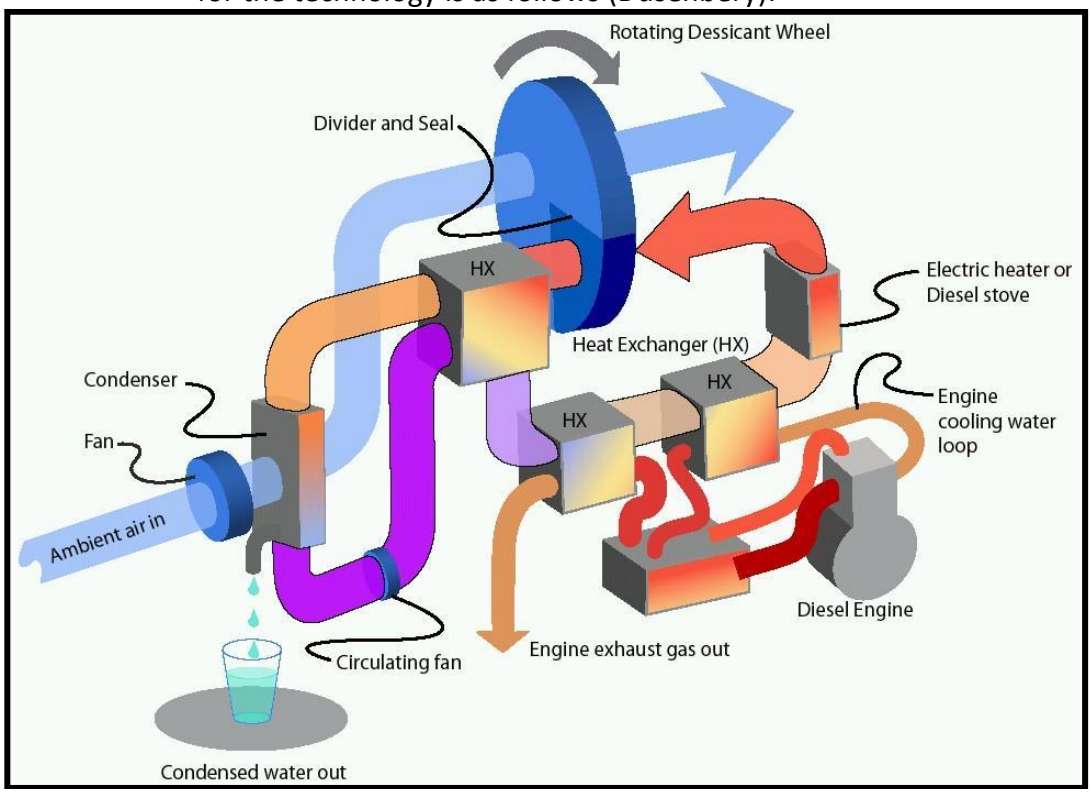
b. Analysis on Technology Transfer to Civil Society: There are approximately 8,542,163 total roadway line miles in the US where the majority of commodities travel (RITA). The hybrid technology in place in the HEMTT-A3 illustrates the capacity for heavy hauling of commodities by hybrid trucks, the feasibility of which has been a subject of debate. Rail transportation is the most efficient way to transport goods (Comparative) but without a dedicated federal funding source (UTCM) the railroad infrastructure is not in place in the US to support the majority of shipment of goods. To date there are no large-scale projects on the docket to expand rail service enabling it to be the primary means to transport goods across the US. This may be the inlet where HEMTT-A3 technology can transfer into civil society and provide a more sustainable way to transport goods.

3) Water Generation/Purification: As stated earlier approximately 20 percent of shipments into Iraq and Afghanistan are water. The amount of actual fuel used to transport water is unclear because of the various vehicles used to haul it. Within the DoD the US Army Tank Automotive Research, Development and Engineering Center (TARDEC) center has the responsibility to reduce the amount of water used in combat operations (Duisenberg). It is estimated that Soldiers and Marines require approximately 50 gallons per day (god) of water, for both hygiene and consumption (Moore). Technology exists currently to purify fresh water or desalinate salt water but palatability is lacking. It has been preferred by military leadership since 1991 to ship in 'lakes of bottled water' for general consumption (Dusenbery).

Along with palatability is the underlying issue of relying access to water in combat areas. Availability is often in question, especially in Iraq and Afghanistan, and the ultimate military edge is to not have such a vital resource be a potential target for attack.

A significant technological advance that would aide in avoiding this vulnerability is as follows:

a. Arroyo 500 by FLIR Systems, Inc: This is one commercial name given to a technology that the US Army TARDEC is researching where in concept moisture is captured from the air and concentrated by a high-temperature desiccant wheel, collected and purified producing potable water (Arroyo). The schematic for the technology is as follows (Dusenbery):



The vendor advertises that the Arroyo 500 can produce up to 500 gallons of potable water per day, even in desert conditions (Arroyo). Initial Army TARDEC testing validates these claims, although it should be noted that this device has not been deployed and out of the three emerging technologies outlined in this study, this one is still in its infancy. Currently, it is fueled by JP-8 fuel and with a full tank can run 22 hours. Efficiency of production is one gallon of fuel to five gallons of water (Dusenbery). This is a major limiting factor and to become a value-added alternative it should incorporate renewable energy fuel generators. Design engineers should redesign it so solar panel arrays supply the necessary energy to run the air to water generation process.

b. Analysis on Technology Transfer to Civil Society: The potential for the transfer of technology from military application to the civil society for air to water generation is life changing in parts of the developing world where access to potable water is close to non-existent. A solar powered air to water generating system would transform the lives of individuals in the developing world where

there is no running water in their home and finding potable water is a daily chore. Like the ReGenerator, if a village located in an area not easily accessible to potable water were able to purchase one of these devices they would experience infinite value. The time and health benefits gained by not having to search for potable water and worry about people getting sick would provide the opportunity to focus efforts on something else, such as economic or educational projects that aide in attaining a higher standard of living.

VI: Conclusions

The DoD has long served as a catalytic force for innovation and advancement of technologies that are now mainstays in civil society. The Internet and GPS are indisputably influential and were able to achieve a large enough economy of scale, in part because of DoD application, that when transfer into the civil society occurred the entering price point was cost competitive. As the DoD, through their acquisitional relationship with private industry, continues to develop and expand their renewable energy backbone they will maintain their role of having the breadth and depth sufficient to act as the transitioning agency for broad scale application of these forward-thinking technologies.

Already many vendors engineering the technologies mentioned are exploring their future residential and business markets. It is unclear how they will be rolled out for commercial application but perhaps one day, at homes across America, renewable energy generation systems with concentrated solar harvesting capabilities, will sit next to air conditioning units outside supplying all necessary energy for individual homes. Further, given the funding lapse for expansion of a rail in the US to meet logistical routes necessary for the transfer of commodities, the development of diesel-electric hybrid trucks that are capable of heavy hauling may become a logistical imperative, with rising oil prices, to maintain the movement of goods currently experienced in the US economy. With tales of looming water wars, air to water generators may be worth their weight in gold, especially in arid regions of the world that already experience hardships due to lack of access to potable water.

In the wake of the current economic crisis, recession and the ongoing political partisan budget crisis within the US, many congressmen are hesitant to support funding measures for research and development initiatives that can be debated by constituents as to their necessity or legitimacy. The research, development and large-scale economy of scale application that is necessary for renewable energy technologies to become cost competitive on a vast level can occur through technology transfer from the DoD into the civil sector. The transfer will likely occur after wide-scale deployment of devices such as the ReGenerator or Arroyo 500. When thousands of these devices are bought and the factory manufacturing is established and streamlined the price will reduce to a cost competitive level. To establish a superior military posture the US must, as Lt Gen James Mattis stated, 'release itself [ourselves] from the tether of fuel' that hinders operations, maneuverability and makes forces particularly vulnerable to attack (Energy). If the US military can release themselves from this tether resulting in a tactical military edge while developing tools that will help achieve reduced energy dependence, the

scenario is completely win-win. In essence, foresight to see the potential for technology transfer into various arenas serves as an additional source of hope to achieve reduced energy dependence.

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