ARMY ENERGY STRATEGY FOR THE END OF CHEAP OIL

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ABSTRACT

Without ready alternatives to replace ever more costly and scarce oil, we are entering an age of uncertainty and insecurity unlike any other that could include economic stagnation or even reversal. Although the military will always have access to the fuel required for national security missions, the costs will rise substantially in the near future and require the reallocation of resources from other critical mission elements and programs. How close are we to the day when world oil production begins to decline as demand continues to rise? What options currently exist to ease this transition to higher energy costs and to produce new sources of transportation fuels? What are the most important steps that must be taken now to adapt to this certain crisis?

The open and relatively cheap access to energy primarily determines a society's quality of life, particularly the energy of liquid fuels that provide for the increasing transportation needs of all developed and developing economies. Any disruption of access to or substantial increases in the price of energy would have a devastating effect on the economy and way of life in the United States. A recent cable television movie entitled "Oil Storm" dramatically depicted the wide spread chaos, disruption to normal society, and loss of life that would result from the incapacity of the oil supply to satisfy demand and from the resulting sizeable increases in the price of oil.[i] Unlimited access to oil is believed to be an American right and we have already fought major wars in the Middle East partly to ensure continued access to cheap oil. The National Commission on Energy Policy conducted a simulation of oil supply disruptions in June 2005 and concluded that oil cost is highly sensitive to supply, U.S., foreign & military policy are constrained by our oil dependence, and the U.S. is vulnerable to attacks on the oil infrastructure.[ii] The report, "Winning the Oil End Game", by the Rocky Mountain Institute describes how our oil addiction has become a source of weakness. It erodes prosperity by its volative price, creates dangerous new revalries, destabilizes the climate with its emissions, undermines our security, and tarnishes our moral standing in the world.[iii]

The 20th Century will be known as the age of cheap oil, but it is beginning to dawn on many that the 21st Century will not see the same easy access to low-cost oil that fueled the unprecedented technological advances of the last century. We are either at or very near the era when the demand for oil will outstrip the ability of the earth to supply the needs of the global society.[iv] As Kenneth Deffeyes, a geologist and observer of the oil industry over the past several decades has noted, "For the first time since the industrial revolution, the geological supply of an essential resource will not meet the demand."[v]

The nation and the global community need a unique organization to show the way to transform the energy infrastructure and resolve the countless challenges that will end our addiction to oil. The U.S. Army is that unique institution with all the advantages of disciplined organizational leadership and technical knowledge to pilot this essential energy transformation.

1. OIL SUPPLY AND DEMAND

In 1956, M. King Hubbert, an experienced and knowledgeable geologist and analyst of oil production in the United States, predicted that U.S. oil production would peak about 1970 and then continue a slow steady decline into the future. In fact, the year of greatest U.S. oil production was 1970, although the updated theory actually predicted 1976. Since 1976, the production of oil in the U.S. has been in steady decline even though in 2004 the U.S. was still the third largest producer of oil in the world at 8.69 million barrels per day (mbpd) behind Saudi Arabia at 10.37 mpbd and Russia at 9.27 mbpd[vi]. The peaking of U.S. oil production was unexpected by almost all experts at that time, but now provides a compelling model for the analysis of global oil production along with the peaking of oil production in other countries around the globe.

In 1969, Hubbert applied his modeling techniques to global oil production and predicted that total world oil production would peak about the year 2000. With current data, this model indicates that the production peak is either occurring now, or will occur by 2010. The table below shows the current best estimates of the peak world oil production year from a variety of credible sources.

But why are we concerned about the production peak of global oil? First, this does <u>not</u> mean that all oil wells will run dry. Oil will still be plentiful after the peak. In fact, about one-half the total recoverable oil buried in the earth will still be in the ground waiting to be extracted. The problem will be that production will no longer be able to keep pace with the exponential demand for oil, and that is a situation which society has never before had to confront.

Table 1. Projections of the Peaking of World Oil Production[vii]

Oil Peak Date	Source of Projection	Background & Reference
2005-2006	Deffeyes, K.S.	Oil company geologist (ret)
2006-2007	Bakhitari, A.M.S.	Iranian oil executive
	Simmons, M.R.	Investment banker
After 2007	Skrebowski, C.	Petroleum journal editor
Before 2010	Goodstein, D.	Vice Provost, Cal Tech
Around 2010	Campbell, C.J.	Oil company geologist (ret)
After 2010	World Energy Council	Nongovernmental org.
	Laherrere, J.	Oil company geologist (ret)
2016	EIA nominal case	DOE analysis/information
After 2020	CERA	Energy consultants
2025 or later	Shell	Major oil company
No visible peak	Lynch, M.C.	Energy economist

Why will oil production peak? The production of oil from a single well follows a familiar pattern of increasing production after discovery until approximately half the total available oil in the reservoir remains. At about that point, due to the geophysics of the reservoir, the oil becomes progressively more difficult to remove and the rate of oil extraction gradually declines.[viii]

By analogy, the rate of world oil production is following a production history of the same character as an individual well, or the same history as U.S. oil production from 500,000 wells. It was Hubbert who used the well known logistic curve to model oil production over time as one might model the extraction of any finite natural resource. In essence, this model shows that the rate of production is only a function of the quantity of the finite resource remaining to be extracted.[ix] For example, if there are a finite number of fish in a lake, the rate at which the fish can be caught is a function of the number of fish remaining in the lake. Hubbert's application of the theory clearly shows that the overall rate of global oil production will peak and begin to decrease once half of the producible oil in the earth has been extracted, and the most current data follows his theoretical model remarkably well.[x] As the majority of experts in Table 1 predict, we are either at or within about five years of that peak.

It should be noted that since the vast majority of electrical energy in the U.S. is generated by coal and nuclear power plants, the peaking of oil production should not substantially effect the generation of electrical power. The primary shortage will be liquid energy fuels for transportation, and we are only now beginning to realize the need for increasing conservation as recently demonstrated by the mounting sales of hybrid cars. The one sector of the transportation industry that will probably suffer the most is the airline industry. There are no timely replacements for jet fuel or gas turbine engines currently on the horizon.

1.1 The Great Age of Cheap Oil is About to End

1.1.1. Exponential Change and the demand for oil.

The rate of increasing demand for oil over the past five years has averaged about 1.9 percent per year, which means that today's demand for 81 million barrels of oil per day would double to 160 million by 2040. In light of increasing demand, it is surprising that there are no efforts today by the major oil companies to either increase the carrying capacity of their current tanker fleet or increase the capacity of their refineries. They are undoubtedly aware that their business is based on a finite resource and the production rate of oil is not going to increase much beyond the current global oil production rate.[xi] Although the Saudi Arabian leaders have told the U.S. President that they will increase output over the next decade by 50 to 100 percent to keep pace with demand, most experts do not believe that they can significantly increase their current production rate. As New York Times reporter, Jeff Gerth reported in 2004, "Energy forecasts call for Saudi Arabia to almost double its output in the next decade and after. Oil executives and government officials in the United States and Saudi Arabia, however, say capacity will probably stall near current levels, potentially creating a significant gap in the global energy supply."[xii]

Another way to understand oil peaking is to observe that global oil discoveries have not kept pace with the consumption of oil. Global oil discoveries peaked in the nineteen sixties and since 1980 the world has been consuming oil faster than it is being discovered.[xiii]

1.1.2. The consequences of reaching Hubbert's Peak

What will happen when the oil supply cannot satisfy global demand? First, as we approach the peak there will be wide fluctuations in the price of oil, since demand is not smooth and one would expect many instances of a supply deficit followed by a surplus. In the Oil Shockwave simulation, a supply decrease of only four percent resulted in a price increase of 177 percent.[xiv] We may be seeing the beginning of this phenomenon over the past year. It appears that OPEC can no longer control the price of oil by adjusting production since they are probably already operating near maximum capacity and cannot significantly increase supply to fully satisfy demand. But why must the data on oil supply be sheer speculation? Although one might think that all the data on global oil reserves, current oil production and production capacity would be well known, the Saudi Arabian Oil Company, Aramco, has kept this important data private since the company became solely Saudi owned in 1977 and OPEC made a decision not to publish production data in 1982.[xv] Therefore, the statistics cited by the sources in this paper are based on observations of oil actually produced and the limited information that Aramco and OPEC do provide.

An obvious response to a decreasing production of cheap oil for transportation is to move to other fossil fuels and to non-conventional oil sources, such as tar sands and shale oil, and an abundance of oil exists in these sources, it is just not cheap oil. The extraction of oil from these sources requires a significant input of energy, so the net energy obtained in considerably less than that of crude oil pumped directly from the ground. As the price of oil makes these sources competitive on the open market, they will surely be produced, but it is uncertain whether this production rate will be able to keep pace with even a reduced demand without a major transformation in our energy sources for transportation.[xvi]

The social and political consequences of the oil peak potentially include the political and economic instability of developing nations. As Thomas Barnett writes in The Pentagon's New Map, "When globalization gets sidetracked by skyrocketing oil prices, it won't be America, or Europe, or even Asia that gets left out of the cold. It will be the Gap, the poorest of the poor, that suffers the most."[xvii] For oil rich nations, oil dollars provide the means to buy off the dissidents and maintain political control, but when oil production and income fall in the near future, the people will demand reform and that will probably not be a peaceful process. As the perceptive observer, Thomas Friedman writes, "Nothing has contributed more to retarding the emergence of a democratic context in places like Venezuela, Nigeria, Saudi Arabia, and Iran than the curse of oil. As long as the monarchs and dictators who run these oil states can get rich by drilling their natural resources--as opposed to drilling the natural talent and energy of their people--they can stay in office for ever."[xviii]

1.2 The Value of an Integrated Army Energy Strategy

1.2.1. The True Cost of Energy Today

The military services maintain huge infrastructures to ensure fuel delivery at the right time and place. Large and small surface trucking organizations, naval fleet tankers and aerial refueling aircraft, along with the associated substantial maintenance and logistics organizations contribute to considerable overhead costs. Increases in fuel efficiency would correspondingly shrink this overhead burden, enabling savings through reductions in logistics requirements far in excess of the investment. These savings accrue largely during peacetime, and represent opportunities to shift financial resources from logistics to operations, or from "tail to tooth", over time.

The Defense Science Board (DSB) published a report in 2001 that showed the true cost of energy for the Army was several times higher than that accounted for in the planning, programming and budgeting process which determines the allocation of resources within the Army and DOD. In their opinion, this is a flawed process since it does not provide incentives for increased fuel efficiency in any Army vehicles or other power generation equipment. This oversight results in a logistics system where, "over 70 percent of the tonnage required to position today's U.S. Army into battle is fuel."[xix] In 2000, the Army directly purchased $200 million of fuel. However, when the cost of 20,000 POL related soldiers in the active force and the 40,000 in the reserve forces are included, the cost increases to $3.4 billion without including the purchase and operating cost of the required fuel handling and distribution equipment.[xx] These real energy costs are never directly included in resource allocation decisions, but are significant costs to the Army and DOD overall given the requirements of the Air Force and Navy to transport the Army.

Consider, for example, the resources required to rapidly transport the Army anywhere in the world and sustain the ground forces once employed. Again, the DSB analysis indicated that for Desert Shield in 1990, if just the Abrams tank had been 50 percent more fuel efficient, the deployment would have taken 20 percent less time.[xxi] Or alternatively, for the same fuel efficient Abrams, substantially less airlift and sealift resources would have been required to deploy the same force in the actual 1990 deployment time.

1.2.2. Consider the value of reducing fuel requirements by ten percent.

The cost of oil energy for the Army is driven more by the transportation weight of the fuel and its associated distribution system for both the initial deployment and for continual resupply than by the actual cost of the oil itself. To achieve the expeditionary and campaign quality goals of the Army Chief, the best force possible must be designed within the constraints of maximum size and cost given the realities of an all volunteer Army and limited funding.

Consider, for example, the Division equipped with the Future Combat System. We can reliably estimate the following force design parameters:

• Initial Deployment. The maximum cargo weight and volume per day that can be devoted to airlift and sealift the ground forces by the U.S. Air Force and the U.S. Navy during the initial deployment is well known. This establishes the rate at which forces can be deployed into the theater. Change the weight and volume of the initially deployed force, and you change the rate at which ground forces can be deployed to any desired location. Reduce the initial supply needs of the force during deployment and you can increase the rate of initial combat force employment.

• Resupply. The maximum weight and volume per day that can be devoted to airlift and sealift the resupply needs of the ground forces is generally known. By reducing the weight and volume of the supply needs of the force, resources allocated to transport and distribute the supplies can be reallocated to increase the effectiveness of the combat force.

A reduction in fuel requirements can, therefore, cause a ripple effect throughout the DoD that can ultimately result in a better design of our military forces to significantly increase the ability of the Army to provide the most capable force to the combatant commanders. Using the actual weight and volume data, it would be possible to estimate the sensitivity of ground force effectiveness to a reduction in fuel requirements. The authors believe that this sensitivity is more significant than intuition might presume.

The other factor in designing future force structure is the almost certain knowledge that the cost of liquid petroleum fuels is going to substantially increase; some experts predict a 200% increase in the next five years. Therefore, without a reduction in fuel requirements, more of the resources allocated to the DoD to design our military forces will go into fuel and less into enhancing the mission effectiveness of the force.

1.2.3. Fuel Requirements in Iraq.

In 2004, during periods of heavy equipment movement, it is estimated that the military used over 4 million gallons of fuel per day in Iraq (see Table 1). This estimate is for both U.S. and coalition forces; however the majority of this fuel is used by the U.S. Army. To meet this need, DOD uses in excess of 5,500 trucks to deliver fuel from Kuwait, Turkey and Jordan. In comparison during World War II, on 24 August 1944 during Operation “Red Ball”, Allied Forces used 1.8 Million gallons per day.[xxii]

Table 2. Fuel use per day by fuel type in Iraq, 2004

Fuel Type	Quantity
Kerosene (Jet Aviation)	1.6 million gallons / day
Gasoline	1.6 million gallons / day
Liquid Petroleum Gas	2,600 metric tons / day
Diesel	1 million gallons / day

A rough comparison of the 2004 energy requirements for the 150,000 coalition soldiers in Iraq with about one million soldiers (1,075,681 U.S. Soldiers on 31 August 1944) of the Allied forces in Germany during World War II shows that soldiers today require about 16 times the fuel used per soldier in 1944. This escalating need for more energy has also substantially increased the infrastructure required to supply that level of fuel. When you consider that the coalition forces in Iraq are situated essentially in the middle of the world’s largest fuel station, it means that the same level of fuel supply to an equal number of soldiers in Afghanistan, or other parts of Asia, Africa or South America, would significantly exacerbate the fuel resupply problem.

The increase in military fuel consumption from 1944 until 2005 implies that the annual per soldier energy consumption has doubled every 20 years over this period. This 3.5% annual growth appears modest, but if it continues, the logistical impact on the military would be enormous. At the current rate of increase in fuel consumption, the military could expect to consume 32 times more energy per soldier by 2025 and 64 times more by 2045 than was used in 1944.

Depending on the source, the quantity of fuel consumed per day in Iraq varies considerably, but in a three-month period in 2006, it is estimated the Army consumed 1.3 million gallons per day[xxiii]. The actual amount of fuel consumed is unknown because fuel that is provided free of charge to DoD by Kuwait is not tracked and the units which use it is not clear due to changing accounting procedures and joint operations. It is, however, fairly well established that the average fuel purchase price is around $1.80 per gallon with cost varying slightly depending on fuel source.[xxiv] If we assume the fuel consumption is 1.3 million gallons per day then the approximate fuel purchase cost would be $2.3 million per day.

However, the true cost is much higher. Using the methodology of the Defense Science Board, equipment costs can be approximated between $10 and $40 per gallon or, assuming $10/gal, $13 million per day. Personnel costs can be estimated at 16 times the cost of fuel ($29 per gallon), or approximately $37 million per day. In round numbers, it costs approximately $42 per gallon to move fuel, using more than 5,500 trucks, from DESC distribution centers to tactical distribution points. The true cost of moving fuel, however, is even higher since the fuel must be moved again from tactical distribution points to units who are dispersed throughout the Area of Operations. This could double the cost yet again! Collectively the cost of merely moving fuel by truck is nearly $1.6 billion per month or approximately 23 percent of the estimated total $7 Billion monthly operating cost.

Table 3. Army fuel costs in 2006

Fuel Type	Quantity
Consumption gal/day	1.3 Million
Purchase $/day (consumption x 1.8)	$2.34 million
Trucking $/day (consumption x 10)	$13 million
Personnel $/day (consumption x 29)	$37.7 million
Total fuel $/day	$53 million
Total fuel $/month (daily $ x 30 days)	$1.6 billion

If the total cost of fuel delivery and supporting infrastructure (including equipment, people, facilities and other overhead costs) were known, understood and factored into the cost of fuel, the requirements and acquisition processes would logically be more focused on the true savings of improving platform efficiency. This would create incentives for DoD to integrate fuel efficiency into the acquisition process, thereby cutting battlefield fuel demand and reducing the fuel logistics structure. Clear policy guidance will enable the DoD to achieve the deployability, agility and sustainability required by joint doctrine.

1.3 What are the Options?

In General. As the demand for energy grows exponentially and the era of cheap oil comes to an abrupt end, there are only four broad options for coping with the high cost of energy for transportation.

- **Conservation** – implies that the same quality of life can be maintained just by using energy more efficiently. Hybrid vehicles will still move people to all the places they need to go, but at a substantial reduction in the energy required. Serious conservation efforts can actually go a long way to relieving the pressure on oil demand.
- **Life-Style Change** – Cheap oil has allowed people to commute an hour or more to their work every day. This life-style will quickly become a victim of increasing energy costs. Living close to one's job location as well as both telecommuting and teleconferencing will become the generally accepted means of locating your residence and doing business.
- **Substitution** – With declining oil supply, other energy sources that accomplish the same objectives must be substituted to avoid deprivation. Instead of driving, ride a bicycle; use solar heating to produce hot water and a wind turbine to provide a portion of daily electrical power needs. Increased simulated training for military units without the need for powering actual equipment has already become an accepted but not sufficient means of preparing and maintaining unit readiness.
- **Deprivation** – Some things we may just have to do ***without*:** no Thanksgiving trips to visit relatives, no air-conditioning in the summer, no second car, no actual military flight training in large aircraft. However, at some higher level, deprivation can lead to a significant reduction in the quality of life and social unrest.[xxv]

For the Military. The consequences for the military in general and the Army in particular will be similar to those faced by society as a whole, except that national security issues will not permit liquid fossil fuel deprivation for operational missions. However, training would be curtailed due to cost and public perception at a time when much of the American public would be cutting back their energy consumption. Government imposed rationing of gasoline and diesel fuel to support the military services may become necessary. The first three options listed above must be incorporated into the military's culture as rapidly as possible, because today these are not near the top of any military leader's priority list.

Life style changes include revisions to unit training that place more reliance on simulation, which has been very successful in the Army aviation community, particularly in the area of procedural training. Part of the reason that the American solider requires 16 times the energy of a World War II solider, is the creation of the U.S. standard quality of life in the nations to which the military is deployed. If we adopted the life style of the populace in the deployed nation, not only would energy be conserved, but the U.S. military would live in better harmony with the culture and the people, whose respect and trust they are trying to earn.

The eventual fuel substitution for oil products that society will in all likelihood make for transportation is hydrogen. However, before hydrogen can become a fully operational alternative fuel development efforts should be increased at least tenfold, and the most obvious technology area to be given top priority is increased fuel efficiency. But, this increase in development alone will not be sufficient. Intermediate substitutions for fossil fuels, such as biofuels, must also continue to be studied and implemented in an expeditious manner.

Due to the ripple effect discussed earlier, saving a gallon of fuel in our tactical vehicles results in more than a gallon of fuel saved overall. This savings at the end user is compounded by the savings in the distribution system, not just in terms of fuel required to transport fuel, but also in the people who operate and administer the distribution of fuel from the well to the battlefield. Since it is estimated that 70% of the initial deployment and the resupply weight required by an Army unit is fuel, this cascading effect may be as large as 1.5 gallons saved overall for each gallon saved due to increased fuel efficiency in a tactical vehicle.

Policy changes. The conclusions and recommendations of the 2001 Defense Science Board Report[xxvi] are even more important in 2005. Presently, the real cost of fuel in the Army is invisible to decision makers and, therefore, fuel conservation measures have no apparent value in the decision making process. To change its culture, the U.S. military must first account for the true cost of energy in the planning, programming and budgeting process. The leadership must then provide guidance with tangible motivations for increasing energy efficiency and set aggressive but realistic goals for unit and installation commanders that provides for the sharing of energy savings. An unpublished study of the processes and goals instituted by private industry to reduce their energy needs demonstrates that a serious approach to energy conservation has produced substantial savings in a wide range of industries.[xxvii]

However, the most important national security reason for the reduction of energy use is to decrease the weight requirements for the deployment and resupply of Army Units. The Army desires to be an expeditionary and campaign quality force, and its ability to attain these goals resides to a great extent with the ease of deployment and the logistics requirements to maintain that force in a remote area of the world. Therefore, the requirements process must be stimulated to acquire equipment and vehicles that include fuel efficiency constraints on the design process to optimize not only weapon system performance, but also the ability to achieve the expeditionary and campaign quality strategic Army goals. The design tradeoffs necessary to realize these competing goals in a complex system of systems context can probably only be accomplished through the use of high fidelity war-game and security operations simulations that include the fully integrated logistical support processes that accounts for the entire system of systems life cycle costs.

In the interim, cultural change must begin. Developers of new weapon systems must make design decisions within the integrated context of Corps, Division and Brigade Combat Teams. A weapon system can no longer be designed without regard to every aspect of the environment in which it will operate. The role of energy efficiency in the design process must be viewed through the design tradeoffs in the size, quantity and cost of the Navy and Air Force fleets necessary for deployment of the expeditionary force in the desired time and then for logistically maintaining the deployed units during an extended campaign.

Technology Changes. Many opportunities exist in the Science & Technology base to improve fuel efficiency and reduce the logistics burden. Propulsion and power generation systems as well as new materials to reduce the weight of armored protection are obviously the first technology to consider. However, no single technology offers a solution across a broad range of platforms. High efficiency hybrid propulsion systems are the place to begin and should ultimately lead to efficient electric drives. Further increases in fuel efficiency will result from the reduced weight of materials that can still provide the desired armor protection and these materials are rapidly becoming easier to design and manufacture. Advanced engine technologies such as OPEC,[xxviii] variable displacement engines, waste heat utilization, advanced lubricants, advanced control systems, light weight materials, advanced batteries and low temperature combustion should all be considered.

Fuel cells, although they currently have had a poor track record of development and performance, are of particular interest since they have the potential for double the energy efficiency of current power systems. The initiation of a hydrogen fuel cell demonstration pilot program by the Army would provide an opportunity to become a unique laboratory for the nation to learn how to make the move to a substitute fuel.

Although renewable energy sources will not be able to provide for all of society's or an expeditionary Army's energy needs, they will be important contributors to an overall strategy for energy production. Renewable energy sources are primarily solar and wind, but also include wave, tidal and ocean thermal inclination methods. Photovoltaic solar power could be a valuable energy source for forces in the field, particularly to reduce the significant battery supply problem. Only a ten percent reduction in liquid fuels means a greater than ten percent reduction in fuel distribution requirements for deployed military forces.

As witnessed in Iraq, the generation of electrical power for forward operating bases in remote locations will continue to place a heavy demand on fuel resupply when the local power generation system is neither adequate nor reliable. An attractive potential option for deployed power generation is a small self contained portable nuclear power plant of about 5 megawatts possibly based on the Navy carrier sized nuclear power systems. The electric generator fuel resupply problem is eliminated, although protection of the reactor from insurgent attack will need to be carefully considered.

Now is the time to start integrating energy costs and changes into weapons systems design as today's designs will remain fielded for decades.

Cultural Changes. Cultural changes have a very large role in resolving energy problems. These changes are needed to insure the integration of societal concerns into a comprehensive solution.

For example, the metering and billing of electricity and fuel at military quarters is a technique that could modify behavior. Most military installations' facilities and quarters are not metered and most occupants of those quarters view energy as a "free" benefit. Energy meters must be used to bill occupants for extravagant energy use exceeding a fixed allowance. The resident could elect to reduce energy consumption below a fixed level and be paid for the difference, or pay for energy used beyond the allowance Army regulation AR 210-50 specifically states the Army will apply new techniques while designing, building, modernizing and operating housing facilities and that it will determine where excessive energy consumption occurs.[xxix] AR 210-50 even states that family housing occupants may be charged for excess energy consumption or have their rights to quarters terminated. Additionally, new quarters built within the last 10 years either have meters or bases for meters already installed, but have not been used. Without an effective energy metering program, the effectiveness of an energy management program cannot be assessed. Although technically feasible with policies in place, this approach would require a shift in the way Army leadership views residential as well as institutional energy consumption and the soldier's benefit to "free" energy.

Finally, it may be necessary to reconsider the very essence of how priorities are set and resources allocated for the end of the era of cheap, accessible energy via oil. W. Wayt Gibbs in a Scientific American article entitled, "How Should We Set Priorities?" contended that society uses essentially two kinds of imperfect social mechanisms, governments and markets, to set rational priorities and consistently adhere to them.[xxx] Maybe in the U.S. military, it is time to consider some variation on the use of markets to motivate the achievement of expeditionary and campaign quality goals. The creation of markets to reduce power plant sulfur dioxide emissions, regulate fisheries, control the release of carbon into the atmosphere, and restore wetlands, among others, has met with some success over the past decade. The Army leadership might consider establishing a market in the energy needed to train, deploy, and sustain brigades. Every item of equipment within the unit would be provided an energy budget, which could be sold or traded by equipment builders and the services to most efficiently reduce the overall energy requirements of the total force. It is not easy to create an efficient and effective market, but new ideas are vitally needed.

2. CONCLUSIONS

The era of cheap, available oil is coming rapidly to an end and demand will begin to outstrip supply driving the price of liquid fuels to rise steeply over the next decade. There will be significant consequences resulting from inadequate oil supply and rising prices:

- Economic recession and decreased quality of life especially in developing countries.
- Political unrest as the quality of life is diminished.

Difficult societal and cultural changes that occur as priorities are reordered will further exacerbate a growing dissatisfaction with government.

Increasing energy efficiency within the DoD can have substantial value well beyond what current analyses would conclude due to a flawed energy accounting process. It would provide a more effective expeditionary and campaign quality Army for the same cost.

The options for reducing the impact of rising oil prices are several at this point, but with the rapidly increasing cost of liquid fuels, not much time exists to develop and implement these options.

For the military to operate effectively in the coming age of very expensive liquid fuels, changes to our culture, policies and technology are essential.

3. RECOMMENDATIONS

1. Military leaders must understand the approaching end to cheap, abundant oil and its impact on our organization; the vital need to change the ways we use energy in the military and in society. We must start the effort to change the culture by mandating energy efficiency in all of our requirements and by highlighting the crucial importance of energy efficiency for leaders, Soldiers and civil servants at all levels.
2. Solutions can only come from a comprehensive systems view of energy. Account for the total cost of energy in force and equipment design decisions in terms of the Soldiers, equipment and training necessary to distribute the fuel at all levels in the supply chain. The savings are larger than a cursory review might indicate and can result in a distinctly more effective expeditionary and campaign capable military force. Decision makers at the highest levels must be made aware of the design tradeoffs involving energy in the acquisition of military systems and we recommend that investment decisions be based on the true cost of delivered fuel and on warfighting and environmental benefits.
3. Require a comprehensive integrated design process to be able to make systems of systems, life cycle design tradeoffs. This might involve the extensive use of high quality simulations in the force and equipment design process to permit tradeoff analyses to be conducted in a life cycle and systems of systems context.
4. Develop techniques to motivate the reduction of fuel needs throughout the DoD. The creation of energy markets involving contractors within the military acquisition community might have value to reduce energy needs as in integral part of the design and acquisition process.
5. Ensure at least 10% of RDT&E funding is specifically targeted at fuel efficiency improvements. Analyze this allocation of research funding within the systems of systems design process to improve the design knowledge of the proper apportionment of research funding. Integrated Product Teams for Power and Energy should take the lead for determining metrics.
6. Empower the Power & Energy Integrated Product

Team of RDE Command to coordinate with the Department of Energy, the Department of Transportation and other organizations to develop a comprehensive "Future Energy Alternatives for Transportation" project that would use the Army to pilot the wide-ranging changes that society will have to make to accommodate the end of the era of cheap energy for transportation.

7. Explicitly include fuel efficiency in requirements and acquisition processes. Establish an energy budget just as all current systems include weight, size and cost budgets.

8. Establish clear goals for installations to reduce per capita energy consumption by sharing cost savings.

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