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AEPI Report

Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys

Final Technical Report

September 2009

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Resupply of fuel and drinking water for troops in-theater costs lives. The purpose of this study is to develop a methodology for calculating casualty factors for fuel and water resupply convoys in theater operations and to demonstrate the methodology based on historical data from Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF). Casualties calculated include Army soldiers and civilians killed or wounded while transporting fuel or drinking water to consuming units and forward operating bases in theater. Casualty factors developed for the Iraq Theater were also incorporated in the Sustain the Mission Project (SMP) Decision Support Tool. Two case studies [Rapidly Installed Fluid Transfer System (RIFTS) and Thin Film Photovoltaics in Iraq] were conducted to illustrate how the casualty factors could be used in assessments of energy technologies for theater missions. This project provides a step towards analyzing potential casualties related to transporting fuel and water in theaters of operation. However, this study suggests that casualty impacts (and other operational impacts) related to using alternative energy and water technologies to sustain Army missions should be evaluated in Army combat and combat support models over a wide range of theaters and scenarios to better reflect the complex conditions and actions at the tactical and theater levels. That is, Army analysis agencies should evaluate the potential impacts, such as casualties, of different energy technologies in the battle space to include resupply convoys.

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Preface

This report was prepared under contract for the Army Environmental Policy Institute (AEPI) by the National Defense Center for Energy and Environment (NDCEE), operated by Concurrent Technologies Corporation (*CTC*), with additional support from Energy and Security Group (ESG). The views expressed do not necessarily reflect the official policy or position of the Department of Defense, Department of the Army, or the United States Government.

The mission of AEPI is to assist the Army Secretariat in developing forward-looking policies and strategies to address environmental issues that may have significant future impacts on the Army. In the execution of this mission, AEPI is further tasked with identifying and assessing the potential impacts on the Army of emerging environmental issues and trends.

This report discusses the efforts conducted under Contract Number W74V8H-04-D-0005, Task Number 0545, "Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys." The purpose of the task is to develop casualty factors for fuel and water resupply convoys in support of Army planning and analysis requirements.

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Sustain the Mission Project Decision Support – Final Technical Report iii

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Table of Contents

List of Figures

List of Tables

List of Acronyms

AEPI	Army Environmental Policy Institute
APC	Army Petroleum Center
CAA	Center for Army Analysis
CALL	Center for Army Lessons Learned
DoD	Department of Defense
FBCF	Fully Burdened Cost of Fuel
FBCW	Fully Burdened Cost of Water
FY	Fiscal Year
GHG	Greenhouse Gas
HMMWV	High Mobility Multipurpose Wheeled Vehicle
HQDA	Headquarters, Department of the Army
IED	Improvised Explosive Device
KIA	Killed in Action
MRAP	Mine Resistant Ambush Protected
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
PV	Photovoltaic
RIFTS	Rapidly Installed Fluid Transfer System
SBCT	Stryker Brigade Combat Team
SMP	Sustain the Mission Project
TGER	Tactical Garbage Energy Refinery
THEPS	Tactical Hybrid Electric Power Station
USMC	United States Marine Corps
WIA	Wounded in Action

Executive Summary

Resupply of fuel and drinking water for troops in-theater costs lives. The purpose of this study is to develop a methodology for calculating casualty factors for fuel and water resupply convoys in theater operations and to demonstrate the methodology based on historical data from Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF). Casualties calculated include Army soldiers and civilians killed or wounded while transporting fuel or drinking water to consuming units and forward operating bases in theater. Casualty factors developed for the Iraq Theater were also incorporated in the Sustain the Mission Project (SMP) Decision Support Tool. Resupply casualty factors calculated for Iraq and Afghanistan [Fiscal Year (FY) 2007] are shown in the Table below. For example the casualty factor for fuel resupply in Afghanistan is .042; that is .042 casualties for every fuel-related resupply convoy or one casualty for every 24 fuel resupply convoys in Afghanistan. Two case studies [Rapidly Installed Fluid Transfer System (RIFTS) and Thin Film Photovoltaics in Iraq] were conducted to illustrate how the casualty factors could be used in assessments of energy technologies for theater missions.

Theater	**Iraq**		**Afghanistan**	
	Fuel	**Water**	**Fuel**	**Water**
Casualty Factor (Casualties/ Convoy)	**0.026**	**0.016**	**0.042**	**0.034**

This project provides a step towards analyzing potential casualties related to transporting fuel and water in theaters of operation. However, this study suggests that casualty impacts (and other operational impacts) related to using alternative energy and water technologies to sustain Army missions should be evaluated in Army combat and combat support models over a wide range of theaters and scenarios to better reflect the complex conditions and actions at the tactical and theater levels. That is, Army analysis agencies should evaluate the potential impacts, such as casualties, of different energy technologies in the battle space to include resupply convoys.

Sustain the Mission Project:
Casualty Factors for Fuel and Water Resupply Convoys

1 Introduction

1.1 Purpose

The purpose of this project is to develop and demonstrate a methodology to calculate casualty factors for fuel and water resupply convoys in support of Army planning and analysis requirements. Casualties calculated include soldiers and civilians killed or wounded while transporting fuel or drinking water to consuming units and forward operating bases in theater. Casualty factors were derived based on a statistical analysis of historical data from Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF). Casualty factors will be used in the Sustain the Mission Project (SMP) Decision Support Tool as a measure of benefit regarding investments in energy or water technologies that reduce the number of resupply convoys in theaters of operation.

1.2 Background

Sustainable energy security is a requirement for all Department of Defense (DoD) missions to include operations, installations, the industrial base, and strategic planning. In the Army for example, sustainability policy is promulgated in the *Army Strategy for the Environment: Sustain the Mission, Secure the Future*, which states that a sustainable Army simultaneously meets current as well as future mission requirements worldwide, safeguards human health, improves quality of life, and enhances the natural environment. The priority for sustainable energy security in theaters of operation was articulated in July 2006 when United States Marine Corps (USMC) MG Richard Zilmer, Al-Anbar Province, submitted a Joint Urgent Operational Needs Statement requesting alternative energy solutions. He stated: "By reducing the need for Class III (petroleum) at our outlying bases, we can decrease the frequency of logistics convoys on the road, thereby reducing the danger to our Marines, Soldiers, Sailors and Airmen." MG Zilmer's request was to reduce the amount of fuel needed in order to save lives; in effect, he asked that DoD measure the cost of fuel in blood, not dollars.

In July 2005, Army Environmental Policy Institute (AEPI) sponsored the SMP, which developed and applied an analytic methodology for calculating the fully burdened costs of fuel and water resources to sustain Army missions in theaters of operation and in the training base. It includes the costs of fuel, equipment, personnel, inter and intra-theater transportation, and other costs related to providing energy to a consuming Army unit. The SMP methodology uses Army and DoD databases and processes which enable fully burdened costs of energy and water to be updated as data inputs are updated on a recurring basis. The SMP II project developed a user-friendly decision support tool for cost-benefit analysis of energy and water investments. In the SMP Tool, the value-added of investing in energy or water technologies is measured in terms of factors such as payback, reductions in greenhouse gases (GHG), and most importantly the number of fuel or water resupply convoys (to include ground and air force protection) that would be freed up for other missions as a result of the investment. The value added analysis in the SMP Tool does not account for potential casualties avoided as a result of investment in energy and water technologies that could reduce the number of resupply convoys in theater.

1.3 Report Structure

The remainder of this report is organized into three Sections. Section 2 provides an overview of the methodology developed to estimate Casualty Factors for Fuel and Water Resupply Convoys. Section 3 describes an application of the methodology and the development of casualty factors in the cases of Iraq and Afghanistan. Section 4 provides study conclusions and recommendations.

2 Methodology

This section discusses the methodology and data used to develop the casualty factors. The methodology for calculating fuel and water related convoy casualties is comprised of the steps shown in Figure 1.

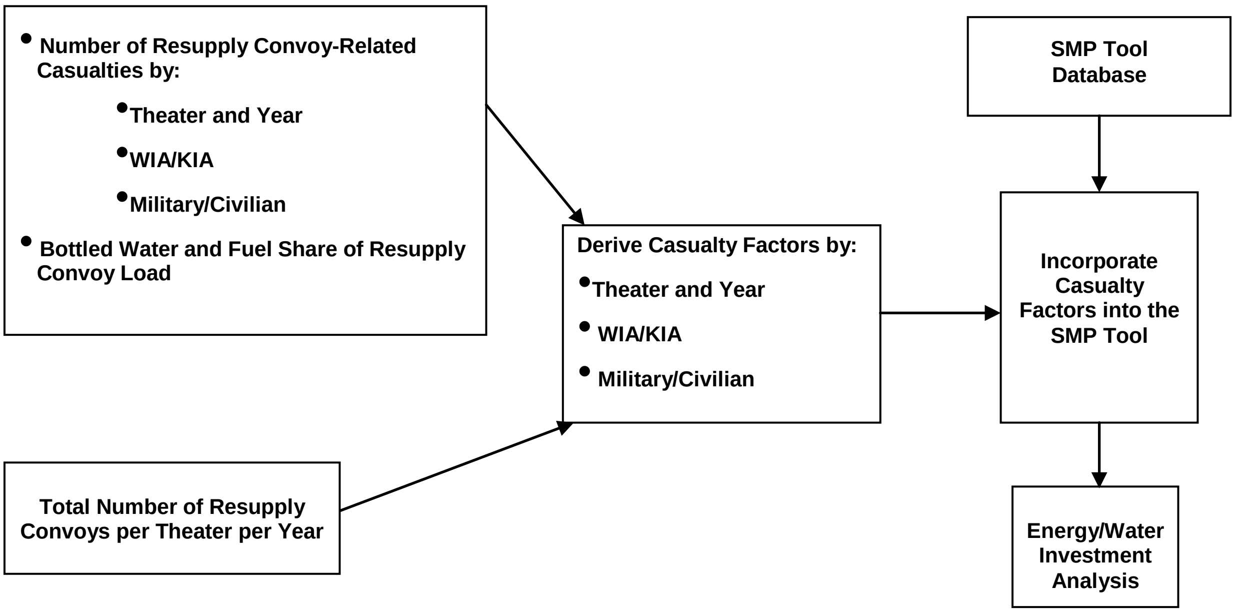
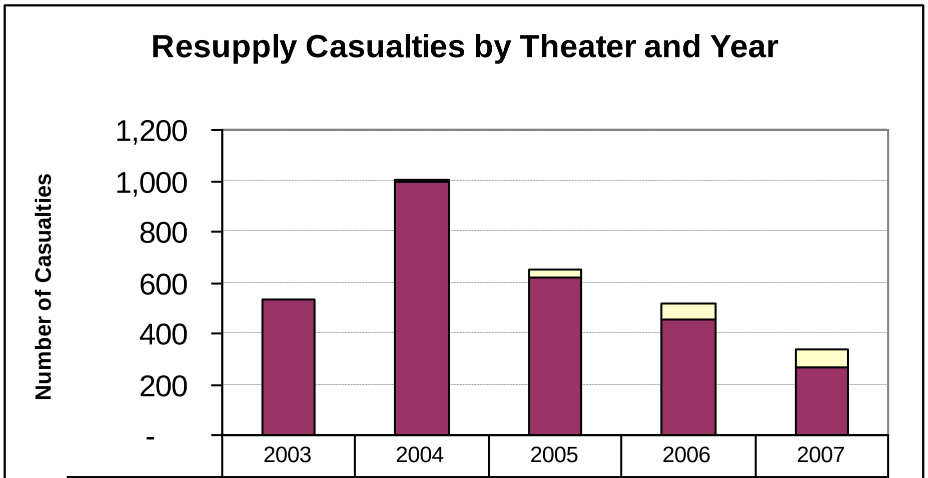


Figure 1. Overview of Fuel and Water Resupply Convoy Casualty Factor Methodology

The first step of the methodology is to determine the number of resupply convoy-related casualties in theater. For the purposes of this study, a casualty is defined as either military or civilian personnel killed or wounded in either Iraq or Afghanistan in support of OEF or OIF. The historical casualty data used in this study were obtained from the Center for Army Lessons Learned (CALL). Based on their analysis of total casualty data, they were able to provide resupply convoy related casualties in Iraq and Afghanistan from Fiscal Year (FY) 2003 – 2007. The data include both wounded in action (WIA) and killed in action (KIA) for both Army personnel (including Guard and Reserve) and Contractors (and other Civilians). Figure 2 shows the resupply-related casualties by theater and year used in the analysis.



	2003	2004	2005	2006	2007
Afghanistan	5	11	33	64	75
Iraq	531	994	618	452	263

(Source: Center for Army Lessons Learned (CALL))

Figure 2. Resupply Convoy Casualties (FY 2003-2007) in Iraq and Afghanistan

The second step was to determine the proportion of resupply casualties related to fuel and water resupply. According to a Headquarters Department of Army (HQDA) G-4 estimate (from FY08), an average annual load allocation for convoys in theater (for OIF and OEF) is about: 50% fuel; 20% water; and 30% other in terms of volume. These proportions were then used to allocate the resupply casualties to their respective categories.

After determining the number of casualties related to fuel and water resupply, the next step was to estimate the number of convoys by theater, type and year. Data on the total number of resupply convoys in theater are currently not reported in the Army. Therefore, the total number of convoys per year required to move the annual fuel and drinking water consumed in each theater had to be estimated.

Resupply convoys vary significantly in terms of size and composition. Based upon mission scenarios developed by HQDA G4 for the SMP Decision Support Tool, a typical resupply convoy includes 16 supply trucks. For fuel, the average total capacity of the 16 truck convoy is 97,818 gallons per convoy and for drinking water the capacity is 35,200 gallons per convoy. Once the capacity of the convoys (in terms of either 100% fuel or water – that is “full up”) was determined, the total number of convoys needed to transport each commodity by theater and year could then be calculated.

The total amount of fuel sold in-theater was obtained from the Army Petroleum Center (APC), which provided fuel purchases for Iraq and Afghanistan from FY 2003 to FY 2008 (see Figure 3). APC did not begin to disaggregate Iraq and Afghanistan in their fuel purchase data tracking until FY 2007. Therefore, since casualty data was available through FY 2007, casualty factors were derived for Iraq and Afghanistan for only FY 2007. Furthermore, since the current version of the SMP Tool does not contain an Afghanistan scenario, only the casualty factors for Iraq were incorporated in the SMP Tool.

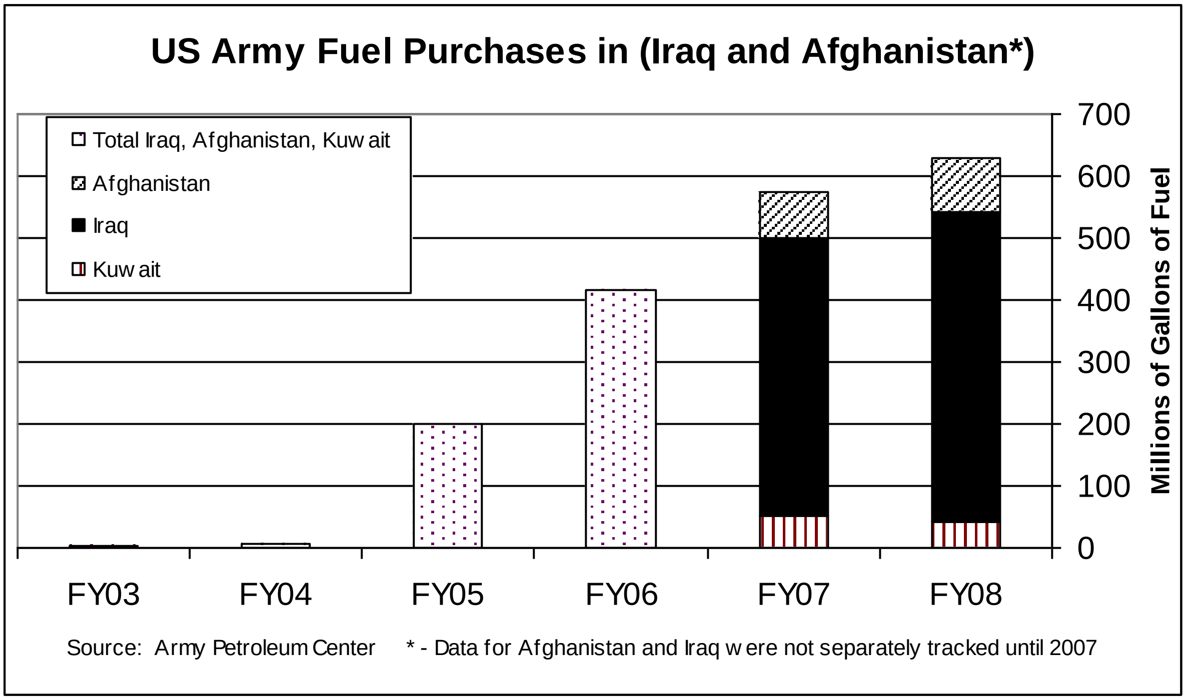


Figure 3. Army Fuel Purchases in Iraq and Afghanistan by Year.

The total amount of drinking water consumed by theater and year was calculated using the following factors provided by HQDA G4. The Army planning factor used for consumption per soldier is 8 liters of drinking water per day. This consumption figure was then annualized and applied to the estimated 150,000 soldiers in Iraq and 20,000 soldiers in Afghanistan (FY 2007) to calculate the amount of drinking water consumed per year.

The total consumption figure for each commodity was then divided by the carrying capacity for each type of convoy to determine the total fuel and water convoys by theater and year. There is not an Afghanistan specific scenario in the SMP tool. To calculate the number of convoys in Afghanistan, we used the Iraq scenarios (16 supply trucks per convoy) as the basis for convoy capacity. The average carrying capacity of the resupply convoy in the Iraq Scenario in conjunction with either the fuel or water commodity consumed in Afghanistan was used to calculate the number of commodity-related resupply convoys in the Afghanistan Theater.

To calculate the average number of fuel-related casualties per convoy, the next step was to divide the fuel related resupply casualties by the total number of fuel-related convoys. To calculate the average number of drinking water-related casualties per convoy, the next step was to divide the drinking water-related resupply casualties by the total number of drinking water-related convoys. Finally, these casualty factors were used in the cost-benefit analysis section of the SMP Tool to calculate the number of casualties that could be avoided by either a fuel or water related investment in Iraq.

3 Analysis and Results

This section is comprised of two parts. The first part presents a numerical representation of how the casualty factors were calculated. The second part shows two specific applications of the casualty factors in an illustrative analysis of two energy investments [RIFTS and Thin Film Photovoltaic (PV)]; and a "what if" analysis of potential casualties avoided from various levels of fuel reduction in theater.

3.1 Casualty Factor Calculation

3.1.1 Calculate the Fuel and Water Related Resupply Casualties in Iraq and Afghanistan for 2007

The total resupply casualties for FY 2007 by theater (263 - total for Iraq and 75 - total for Afghanistan) were allocated to the movement of a commodity using the following percentages: 50% for fuel and 20% for drinking water. Table 1 below shows the values used for the numerator of the casualty factors.

Table 1. Estimated Water and Fuel Resupply Casualties

Iraq-Fuel	132	(50% of 263)
Iraq- Water	53	(20% of 263)
Afghanistan-Fuel	38	(50% of 75)
Afghanistan-Water	15	(20% of 75)

3.1.2 Estimate the Number of Fuel Resupply Convoys in Theater – Iraq

To calculate the number of fuel resupply convoys in Iraq, the following calculations were used:

- 502,110,368: Fuel Transported in Theater (In gallons for FY 2007 from APC)
- 97,818: Average Capacity of 16 Supply Truck Convoy (in gallons from SMP Tool)
- 5,133: Number of Full-up Fuel Convoys Required per Year (502,110,368/97,818 =5,133)

3.1.3 Estimate the Number of Water Resupply Convoys in Theater - Iraq

To calculate the number of water resupply convoys Iraq, the following calculations were used:

- 115,706,460: Water Required in Theater (In gallons – based on 8 liters per soldier per day x number of soldiers [150K soldier estimate from G4])
- 35,200: Average Capacity of 16 Supply Truck Convoy (in gallons from SMP Tool)
- 3,287: Number of Full-up Water Convoys Required per Year

3.1.4 Estimate the Number of Fuel Resupply Convoys in Theater - Afghanistan

To calculate the number of fuel resupply convoys Afghanistan, the following calculations were used:

- 87,731,302: Fuel Transported in Theater (In gallons for FY 2007 from APC)
- 97,818: Average Capacity of 16 Supply Truck Convoy (in gallons from SMP Tool)
- 897: Number of Full-up Fuel Convoys Required per Year

3.1.5 Estimate the Number of Water Resupply Convoys in Theater - Afghanistan

To calculate the number of water resupply convoys in Afghanistan, the following calculations were used:

- 15,427,528: Water Required in Theater (In gallons – based on 8 liters per soldier per day x number of soldiers [20K soldier estimate from G4])
- 35,200: Average Capacity of 16 Supply Truck Convoy (in gallons from SMP Tool)
- 438: Number of Full-up Water Convoys Required per Year

3.1.6 Calculate Casualty Factors

The casualty factors are shown in Table 2 below. For each theater and commodity type, this table illustrates both the numerator (number of casualties) and denominator (number of convoys). For example, in the case of Iraq, there were 132 fuel-resupply related casualties in FY 2007. These casualties occurred over 5,133 convoys during the same time period. The Iraq fuel-related convoy casualty factor is 0.026 (e.g. 132/5,133 = 0.026). This factor means that there are 0.026 casualties for every fuel-related resupply convoy. Conversely this can be interpreted as one casualty for every 38.5 fuel resupply convoys in Iraq.

Table 2. Resupply Casualty Factors

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**

3.2 Demonstration of the Casualty Factors using the SMP Tool Cost-Benefit Analysis Capability

The cost-benefit analysis capability in the Alpha SMP Decision Support Tool allows users to evaluate either a fuel- or water-related investment using fully-burdened costs. Benefit measures include net change in fully burdened cost of fuel (FBCF) or fully burdened cost of water (FBCW); commercial cost avoidance; reductions in logistic and force protection footprint (i.e., fuel supply trucks freed up per year, ground convoy equivalents freed up per year, Apache/C-17 hours freed up per year, gun trucks freed up per year, and reductions in fuel consumption by military/commercial resource); and reductions in GHG emissions due to reductions in fuel consumption both in the convoy and in the Stryker Brigade Combat Team (SBCT). The benefit measures in the SMP have been revised to include resupply casualties avoided. The cost-benefit module in the SMP Tool does not include an assessment of any impacts to combat effectiveness as a result of an energy or water investment.

3.2.1 Rapidly Installed Fluid Transfer System (RIFTS) in Iraq

This case study builds on the previous cost-benefit analysis of energy investment in RIFTS for use in Iraq, as discussed in the AEPI Report, *Sustain the Mission Project: Energy and Water Costing Methodology and Decision Support Tool.* The RIFTS is a flexible conduit pipeline system possessing a throughput bulk petroleum distribution capacity of 850,000 gallons for about 100 miles per day. In this example, RIFTS replaces the first 225 miles of the resupply convoy in the Iraq Base Case Scenario. The key investment inputs for the RIFTS Case Study included in the SMP tool were provided by HQDA G-4 (Office of the Director of Supply). In this case, there is no longer a need for resupply (by convoy) in the first leg of the scenario. The cost-benefit impacts and casualties avoided are related only to this leg.

The first step is to calculate the resupply convoys avoided due to the RIFTS investment. In this case, all of the convoy equivalents avoided occur in the first leg of the resupply trip which is 450 miles roundtrip. The total capacity of a 16 truck full-up fuel convoy on this leg is 128,000 gallons (16 trucks at 8,000 gallons each). The annual fuel consumption of the SBCT in this case is 2,357,589 gallons. This fuel no longer needs to be resupplied by convoy over the first 225 miles of the resupply trip, resulting in 18.4 full-up fuel convoys being avoided (annual SBCT fuel consumption [2,357,589 gallons] divided by 16 truck capacity [128,000 gallons] = 18.4 full-up fuel convoys.)

The second step is to multiply the convoys avoided by the casualty factor for Iraq Fuel (0.026) to derive the casualties avoided for 1 SBCT (0.026*18.4 =0.47)

The potential casualties avoided resulting from this investment are shown in Table 3 below. The table illustrates that the installation of a RIFTS system could result in 0.5 (rounded from .47) fewer casualties per year for an SBCT (over a two year period, one casualty would be avoided through the investment in the RIFTS system.) If this casualty metric were expanded to account for 20 SBCT equivalents (a theater level order of magnitude), the reduction in fuel-related resupply casualties would be 9.4 casualties per year (0.47*20=9.46 casualties avoided per year). The casualties avoided refer only to personnel related to resupply convoys, and does not account for any casualties related to force protection requirements for the RIFTS investment. If RIFTS were installed on a different leg, the number of casualties avoided would change as the fuel truck capacities of the convoy would differ. .

Table 3. RIFTS Cost-Benefit Analysis: Casualties Avoided per SBCT per Year

Force Protection and Logistics Impacts (SBCT Level) - Alternative Metric	Leg 1	Leg 2	Leg 3	Leg 4	Total
Casualty Factor (casualties per convoy equivalent)	0.5	-	-	-	0.5

3.2.2 Application of Stryker Brigade Combat Team (SBCT) Casualty Factor: Thin-Film Photovoltaic (PV) Example in Iraq

In this application, the casualty factors are used to estimate potential casualties avoided by fielding Flexible Thin-Film PV to complement generators in SBCTs. We consider this application in the case of the SMP Iraq Base Case Scenario. Based on input from the Center for Army Analysis (CAA) Study Renewable *Energy Analysis for Strategic Responsiveness 2* (2002); it assumed that the PV complement, will require 75% less fuel required for generators.

For the purpose of the 'What if" analyses we use a total of 20 SBCT equivalents in theater to derive a theater-wide casualty avoidance value. Additionally, we assume that the systems will be in Iraq for 5 years. The total SBCT electricity generating capacity for each SBCT is 609 kW using 38,189 gallons of fuel per year. A 75% reduction in this fuel requirement yields an annual reduction of 28,642 gallons per SBCT per year. The total fuel consumption of each SBCT is 2,357,589 gallons per year.

The reduction in generator fuel accounts for a 1.2% reduction in annual fuel consumption or resupply for each SBCT (28,641/2,357,589 = 1.2%). The 1.2% reduction in fuel resupply was input into the SMP fuel investment module under the *Impact of investment on SBCT fuel consumption* section. The results below were generated using the Iraq fuel Base Case modified to increase the number of SBCT equivalents to 20.

The initial step is to calculate the convoy equivalents avoided. As illustrated in Table 4 below, the first calculation is to develop the number of full-up fuel convoy equivalents for each leg before the PV investment. As above, the annual SBCT fuel consumption before the investment (Column A) is divided by the total capacity for each leg (Column B) to calculate the full-up fuel convoy equivalents required for each leg (Column C). This process is repeated for each leg using the fuel consumption after the PV investment, which in this case reduces the annual amount of fuel required by 1.2%. (Columns D-F). The full-up convoy equivalents required after the investment are the subtracted from those required before the investment (Column F- Column C = Column G)

Table 4. Photovoltaics Investment: Convoy Equivalent Calculation Steps.

	[A] SBCT Annual Fuel Consumption BEFORE Investment (gals)	[B] Full-Up Fuel Convoy Capacity (gals)	[C] Total # of convoys at full-up fuel capacity needed to supply 1 SBCT per year	[D] SBCT Annual Fuel Consumption AFTER Investment (gals)	[E] Full-Up Fuel Convoy Capacity (gals)	[F] Total # of convoys at full-up convoys needed to supply 1 SBCT per year	[G] Full-up Convoy Equivalents Avoided per SBCT per year [C-F]
Leg 1	2,357,589	128,000	18.4	2,328,947	128,000	18.2	0.2
Leg 2	2,357,589	80,000	29.5	2,328,947	80,000	29.1	0.4
Leg 3	2,357,589	80,000	29.5	2,328,947	80,000	29.1	0.4
Leg 4	2,357,589	40,000	58.9	2,328,947	40,000	58.2	0.7

The next step is to multiply the convoys avoided by the casualty factor for Iraq Fuel (0.026) for each leg to derive the casualties avoided for 1 SBCT. For example, in the first leg, the 0.2 convoy equivalents avoided is multiplied by 0.026 (0.026*0.2 =0.0052) The casualties avoided for 1 SBCT (.0052) was then multiplied by 20 to account for the total casualties avoided based on 20 SBCT equivalents (e.g. 0.0052 * 20 = 0.104 for the first leg of this example). Finally, this was multiplied by 5 to account for the total casualties avoided based on 20 SBCT equivalents over 5 years. (0.104*5 years = 0.6 the results for the entire resupply trip are shown in Table 5 below – that is, approximately 4 casualties would be avoided over 5 years for theater level of PV investment.

Table 5. Photovoltaics Investment: Fuel-Related Casualties Avoided from a 75% Reduction in Generator Fuel Consumption (20 SBCT equivalents over 5 years)

Force Protection and Logistics Impacts (SBCT Level) Alternative Metric	Leg 1	Leg 2	Leg 3	Leg 4	Total
Casualty Factor (casualties per convoy equivalent)	0.6	0.9	0.9	1.8	4.2

3.2.3 Application of Stryker Brigade Combat Team (SBCT) Casualty Factor: Generic Fuel-Reduction Investment

The PV analysis above shows the impact of a particular technology that could reduce fuel use in an SBCT. There are a variety of technologies that DoD is evaluating to reduce fuel consumption in operational units and forward operating bases. Examples include energy investments such as the Tactical Garbage Energy Refinery (TGER—a transportable system that can convert waste products generated at military sites into fuel and electric power), the Tactical Hybrid Electric Power Station (THEPS—a system that utilizes wind, sun, a diesel generator, and storage batteries to provide reliable power), fuel cells, micro-hydro systems, and exterior insulation of temporary structures. DoD is also evaluating technologies to reduce the number of convoys transporting drinking water such as Expeditionary Water Bottling Plants and Water-from-Air Systems. To illustrate the casualty impact reduction from a variety of fuel reduction alternatives, Figure 4 below shows the potential casualties avoided by a 10-50% reduction in fuel use by 20 SBCTs over a 5 and 10 year period.

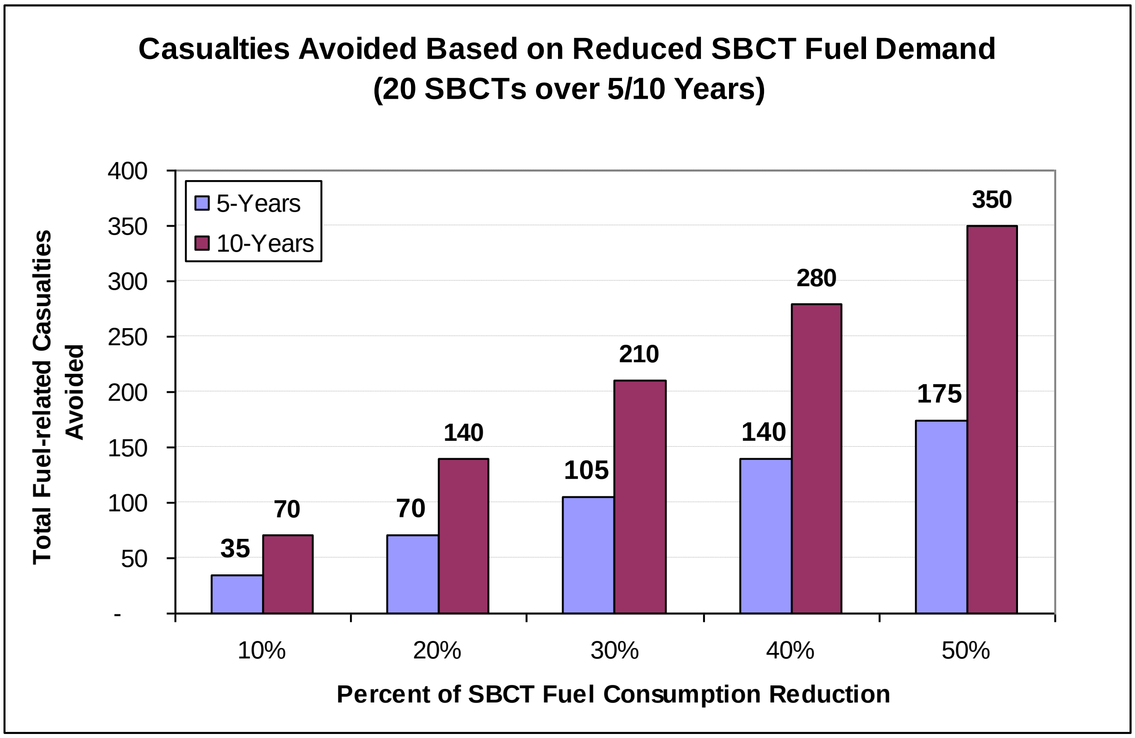


Figure 4. Casualties Avoided based on Varying Reduction in SBCT Fuel consumption.

For example, in Figure 4 above, a 20 percent reduction in fuel consumption by 20 SBCT equivalents over a five year period could lead to a reduction of 70 fuel-related resupply casualties. Similarly a 40-percent reduction could result in 140 fewer fuel-related resupply casualties.

4 Conclusions

Resupply casualties have been significant in Iraq and Afghanistan. According to CALL, they have historically accounted for about 10-12% of total Army casualties – the majority related to fuel and water transport. Since 2004, resupply casualties have been decreasing in Iraq and increasing in Afghanistan. Energy and water technologies are emerging that can substantively reduce the need for resupply convoys in theater; and therefore potentially reduce casualties without sacrificing operational effectiveness. The casualty factors derived in this study have been incorporated into the SMP Decision Support Tool as defaults and can be used to assess casualty (and other impacts) related to using alternative energy and water technologies to sustain Army missions.

This project calculated the human costs of resupplying Army units with fuel and drinking water in theaters of operation – that is “casualty factors.” Resupplying troops in theater with fuel and water is a mission in which personnel vulnerability can be reduced through increased use of energy efficiency, renewable energy and on-site water production in theaters of operations.

5 Recommendations

The Army recognizes the life and equipment savings potential associated with reduced fossil fuel and water convoys for forward and remote operating bases/units per resupply period. In particular, the Army’s challenge is to increase the energy efficiency of weapons and support systems while maintaining combat and operational performance. These goals need to be accomplished without increasing weapons system vulnerability or decreasing firepower or logistical sustainability. For example, a lighter system usually means a more deployable and mobile system for strategic and tactical responsiveness and agility. A lighter system also usually means a more fuel efficient system, which means greater range and less fuel convoys. Greater range contributes to operational mission effectiveness and logistics sustainability; fewer fuel convoys reduce vulnerability, while providing cost and fuel savings, and free-up military resources for other missions. Conversely, a heavier weapon or support system usually means increased armor protection and less vulnerability improving operational mission effectiveness while saving lives at the front lines.

The case of the Mine Resistant Ambush Protected (MRAP) vehicle—the MRAP is a heavier, more formidable system, but fuel inefficient requiring more fuel convoys— is a good example of the issue of tradeoff between vulnerability and fuel efficiency. High Mobility Multipurpose Wheeled Vehicles (HMMWVs), which are particularly susceptible to improvised explosive device (IED) attacks, have been replaced by MRAPs in many cases. In the short term this is an excellent force protection solution to the IED problem; however, the MRAP consumes significantly more fuel than the traditional (and up-armored) HMMWV and therefore requires more fuel resupply convoys. The complexity and scope of these types of issues and tradeoffs is beyond the scope of the methodology and capability presented in this report. These hardware decisions require the application of large scale combat and combat support models used by the Army's analytical agencies such as the Center for Army Analysis.

Casualty impacts (and other operational impacts) related to using alternative energy and water technologies to sustain Army missions should be evaluated in Army combat and combat support models over a wide range of theaters and scenarios to better reflect complex strategy, tactics, and conditions at the tactical and theater levels. More specifically, Army analysis agencies should evaluate the potential impacts, such as casualties, of different energy technologies in the battle space to include resupply convoys. Casualty factors related to deploying alternative energy systems (and alternative water systems) should be derived from combat modeling and analysis, like other systems evaluated within the Army analysis community.

Appendix A
SMP Tool Default Scenarios and Assumptions

Fuel

Theater of Operations
Base Case (Iraq)

1. The consuming unit is a Stryker Brigade Combat Team (SBCT) comprised of 3,972 soldiers
2. Soldier and contractor costs are fully-loaded
3. 1.7% of SBCT (68 soldiers within Distribution Company of the Brigade Support Battalion (BSB)) provides fuel support to SBCT
4. One Sustainment Brigade (480 soldiers) provides theater logistics support to 10 Brigade Combat Teams (or equivalent); 5% of Sustainment Brigade personnel (24 soldiers) provide theater logistics fuel support to the SBCT
5. 10% of fuel support equipment in Sustainment Brigade supports SBCT
6. Fuel support equipment in SBCT and Sustainment Brigade deploy from Ft Lewis to Iraq (one-way)
7. Fuel Consumption for SBCT (2.5 mil gallon per year, 6,850 gal per day)
8. Fuel Re-supply Distances and Convoy Characteristics

Re-supply Trip Legs	Capacity of Fuel Trucks	Type of Supply Truck Personnel	% of Trip Protected by Air	Miles (roundtrip)	Type of Gun Truck
Leg 1: Kuwait to Cedar II	8,000 gallons	100% contractor	20%	450	HMMWV [M1114]
Leg 2: Cedar II to Expeditionary Sustainment Command (ESC)	5,000 gallons	50% contractor 50% military	40%	500	HMMWV [M1114]
Leg 3: ESC to BSB	5,000 gallons	50% contractor 50% military	40%	100	MRAP
Leg 4: BSB to Consuming Unit	2,500 gallons	100% military	40%	50	MRAP

9. Fuel re-supply every other day (182 trips per year)
10. Ground convoy consists of 20 vehicles:
    a. 16 supply trucks
    b. 4 gun trucks; (4 soldiers per truck)
    c. 1 gunman per fuel truck
    d. Percent of convoy cost applied to SBCT varies by leg
       Example for Leg 1:
       - 8000 gal x 16 trucks = 128,000 gal capacity
       - Daily fuel consumption for SBCT is 6,850 gal/day x 2 days = 13,700 gallons per trip
       - 13,700 gal/128,000 gal = 10.7% of Leg 1 cost to be allocated to SBCT
11. Air support to convoy includes 2 Apaches (AH-64D), 2 soldiers per Apache
12. Average speed of the convoy is 35MPH
13. SBCT relocates once within theater per year – distance is 200 miles.

Drinking Water

Theater of Operations

Base Case (Iraq)

1. The consuming unit is a Stryker Brigade Combat Team (SBCT) comprised of 3,972 soldiers
2. Soldier and contractor costs are fully-loaded
3. 1.7% of SBCT (68 soldiers within Distribution Company of the Brigade Support Battalion) provides water support to SBCT
4. One Sustainment Brigade (480 soldiers) provides theater logistics support to 10 Brigade Combat Teams (or equivalent); 5% of Sustainment Brigade personnel (24 soldiers) provide theater logistics water support to the SBCT
5. 10% of water support equipment in Sustainment Brigade supports SBCT
6. Water support equipment in SBCT and Sustainment Brigade deploy from Ft Lewis to Iraq (one-way)
7. Drinking water consumption for SBCT – 31,776 liters per day at 8 liters consumed per day
8. Water Re-supply Distances and Convoy Characteristics

Re-supply Trip Legs	Capacity of Water Trucks	Type of Supply Truck Personnel	% of Trip Protected by Air	Miles (roundtrip)	Type of Gun Truck
Leg 1: Anaconda/ESC to BSB	8,400 1 liter bottles on palettes	50% contractor 50% military	40%	100	MRAP
Leg 2: BSB to Consuming Unit	8,400 1 liter bottles on palettes	100% military	40%	50	MRAP

9. Water re-supply every other day (182 trips per year)
10. Ground convoy consists of 20 vehicles:
    a. 16 supply trucks
    b. 4 gun trucks; (4 soldiers per truck)
    c. 1 gunman per water truck
    d. Percent of convoy cost applied to SBCT varies by leg (similar to fuel)
11. Air support to convoy includes 2 Apaches (AH-64D), 2 soldiers per Apache
12. Average speed of the convoy is 35MPH
13. SBCT relocates once within theater per year – distance is 200 miles
14. Bottled drinking water is supplied by a commercial plant in theater (Anaconda); continuous operation of plant at peak load, 18 hours/day, 365 days/year
15. Army supports commercial bottling plant with:
    - Two 2MW diesel generators and fuel (17 year economic life)
    - 2 water pumps
    - 7 MPs to protect bottling plant
    - Construction of 7 new wells (3 year life)
16. Each soldier consumes 8 liters of drinking water per day