BATTLEFIELD RENEWABLE ENERGY
A Key Joint Force Enabler

U.S. Air Force (Francisco V. Govea II)

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During joint operations or theater campaigns, any joint force commander (JFC), from joint task force to combatant commander, must deal with the enormous amount of energy the combined force needs for subsistence and operations. This situation becomes a limiting factor during all planning and execution across the Joint Operations Concept (JOpsC). To address this problem, many academic and governmental studies and programs focus on the research, development, testing, and procurement of renewable energy sources for the Department of Defense (DOD). However, there have been relatively few studies on the employment of renewable energy throughout the joint environment, especially outside of conventional combat operations.

For the scope of this article, *renewable energy technology* refers to already existing technological solutions that provide the joint force ready solutions to emerging problems and opportunities related to traditional energy consumption. Specifically, *battlefield renewable energy* (BRE) describes systems that generate electrical power through a variety of renewable means—most commonly solar, wind, and biomass conversion. Additionally, these systems must be deployable and sustainable throughout the range of military operations. The application of BRE throughout the JOpsC enables the JFC to decrease reliance on petroleum-based energy logistics and to build usable and sustainable host nation energy capacity.

Current Policies and Directives

U.S. public law, executive policies, and department directives govern the exploration and use of renewable energies. Specifically, two major types of documents provide the policy basis for the joint force to use renewable energy sources as key joint enablers. A series of Presidential orders, culminating with Executive Order 13423, "Strengthening Federal Environmental, Energy, and Transportation Management," directed departments to decrease fossil fuel consumption by 3 percent per year, or 30 percent by 2015 at Federal facilities.[1] While President George W. Bush exempted military operations in this policy, current battlefield trends demonstrate that a reduction of fossil fuel usage directly correlates to mission success.[2] The second series of documents, DOD directives, require Defense facilities, in various capacities, to reduce the use of fossil fuels while maximizing energy conservation and the use of renewable sources to reduce the overall cost of energy consumption throughout DOD. As a study of all these policies pointed out in 2007, there is a disconnect between consumption practices and strategic to operational goals related to the security environment.

Issues and Opportunities

In 2006, the commanding general of Multi-National Force–West (MNF–W) in Iraq described an urgent need to reduce reliance on traditional energy sources to power combat outpost and bases:

More than ever our operating forces rely on the use [of] *electrical power to support critical command and control functions; intelligence, surveillance, and reconnaissance*

Above: Air Force logistics convoy patrol team rolls out at Forward Operating Base Frontenac, Afghanistan

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assets; and life support services. To improve the security posture of the Al-Anbar Province of Iraq, MNF–W requires a renewable and self-sustainable energy solution to support forward operating bases, combat outposts throughout MNF–W's battlespace.[3]

Through analysis, MNF–W determined that most casualties occurred during the movement and delivery of fuel to the various


Backpack that generates power while wearer is walking or running is displayed at military expo

U.S. Navy (John F. Williams)

combat outposts and bases throughout the division's area of operations. This Joint Urgent Operational Need (JUON) asked for a technological solution to power generation in order to reduce the amount of fossil fuel needed at these outposts. MNF–W concluded that if sources of renewable energy production decreased the need for traditional power generation, then fewer convoys would have to drive on long delivery routes, thus reducing the number of attacks and casualties. Additionally, MNF–W argued that the "addition of renewable and self-sustainable energy at the outlying bases will enable the Iraqis to operate independently, lessening the need for Coalition Forces to provide future logistics support."[4] As a result of this JUON, DOD began to increase research and development of BRE technologies for the joint force with the ultimate goal to reduce the need for fossil fuel delivery throughout an area of operations. However, renewable energy need not be limited to a force protection application. This issue creates an opportunity for the JFC to turn this force protection measure into a usable and sustainable source of energy to improve stability in the local security environment.

Toward this end, the 2008 Joint Operating Environment illuminates several "trends that influence the World's security." Among these trends, demographics, energy, globalization, food production, and water scarcity destabilize impoverished regions of the world.[5] One of the most interlinked of these trends, the production and distribution of energy, affects the developing world far more dramatically than the developed world. In fact, the Solar Electric Light Fund (SELF) defines *energy poverty* as "a lack of access to clean and efficient energy systems."[6] Energy poverty increases disease in populations and limits economic growth throughout most of the developing world, driving instability and human disaster.

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The African continent dramatically exemplifies the cause and effect of energy poverty. Africa remains largely devoid of electrical power, yet it produces a significant amount of the world's energy supply. Nigeria, in fact, ranks 12th among nations in world petroleum production,[7] yet lacks the capacity to deliver power to much of its rural population. The majority of its 150 million people remain impoverished and without the means to improve the human condition. In 2001, the U.S. Agency for International Development (USAID) and Department of Energy (DOE), in partnership with the Nigerian Jigawa state government and SELF, demonstrated that sustainable renewable energy provides a solution toward bringing rural Nigeria out of energy poverty. In an unstable environment, renewable energy allowed thousands of Nigerians to improve their living conditions. These projects improved food production, water and electricity generation and distribution, health care, child learning, and microeconomies within Jigawa state. These projects remain locally sustainable with little assistance needed from even the Nigerian government. Clearly, these types of renewable energy applications provide an opportunity for the joint force to partner with other nations' militaries throughout the JOpsC to reduce reliance on traditional energy solutions, while providing sustainable capacity to host nations. To grasp the extent to which BRE applications should support the JOpsC, one first needs a basic understanding of the current state of BRE and the energy requirements of the fielded joint force.

BRE Technologies

In the early 2000s, the Service components began to recognize the value of renewable energy for deployed, off-grid operations (that is, BRE). The first notable joint force application, the aforementioned MNF–W JUON, demonstrated the maturity of particular BRE technologies for forward operating base electrical power generation. Renewable energy technologies such as solar-photovoltaic (PV), wind, and biomass energy conversion can be designed for efficient packaging and are scalable to meet the power generation requirements of remote operating bases of all sizes. However, their inherent advantage over conventional petroleum-fueled systems is that, combined with demand reduction, they greatly reduce and even eliminate the need to provide fuel logistics to remote sites, saving manpower, funds, and most importantly, decreasing the risk to forces delivering supplies over contested lines of communication.

In addition, solar-PV and wind technologies offer significant inherent security features in that they are quiet and have low thermal signatures. Finally, while upfront capital costs are currently higher with renewable technologies, lifecycle costs are already substantially lower than fossil fuel technologies, especially when the fully burdened cost of fuel is included.

Often overlooked outside of the logistics community, it is vitally important to understand the magnitude and character of deployed force power requirements, as well as how particular renewable energy technologies work and their developmental maturity. This is a critical factor for the JFC who seeks to maximize the advantages and synergy achieved with BRE applications on both the battlefield and in the conduct of shaping, stability, and reconstruction operations.

To frame the challenge of powering our forces "off-the-grid," consider the power requirements for both the individual dismounted warrior and our typical forward deployed units. The load carried by a dismounted warfighter ranges from 65 to 95 pounds, with almost half of the weight dedicated to portable power devices and batteries, and recent experience shows "a brigade will consume as much as seven tons of batteries in a 72-hour mission at a cost of $700,000."[8] Maximizing the specific energy, or energy per unit mass, as well as the contribution of renewable energy storage devices is vital to reducing the logistics of supporting portable power devices. At the deployed base level, the fully burdened cost of fuel seriously challenges JFC force protection and logistics functions. As an example, deploying an Army mechanized or airborne division requires approximately 2,300 or 895 diesel generator sets, respectively, which often operate and thus consume fuel 24 hours per day, every day. Interestingly enough, 68 percent of these generators produce 5 kilowatts (kW) or less, which is easily within the demonstrated capability of deployable solar-PV systems.[9] As a second example, power generation systems are the top airlift requirement and make up 16 percent of the total mass (4 million–7 million pounds) of an Air Force Harvest Falcon deployable base, which supports 1 to 3 flying squadrons and 1,100 to 3,300 personnel.[10] The workhorse of this deployed base power generation is the MEP–12, 750kW diesel generator. Each weighs 12.5 tons, takes up the same volume as a tractor-trailer, and costs $165,000 (2005 dollars). It also possesses low fuel efficiency, is noisy, pollutes, and produces an easily targeted heat signature.[11]

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Today's state of the art in BRE is anchored in solar-PV technologies, and to a lesser degree in hybrid solar-wind power generation. Solar-PV works by directly converting the sun's light rays into an electric current through the use of semiconducting materials. Until recently, rigid and relatively fragile materials such as silicon were the only choice, making it more challenging to design efficient packaging and combat hardened systems. Now, thin film PV technologies are available that are both flexible and mechanically robust, making them easily integrated into deployable structures such as tents. Flexfilm arrays weigh 90 percent less and are more damage tolerant than conventional glass. In addition, they can be treated with an antiglare coating to reduce reflection from 1 percent to less than 0.1 percent. The primary benefits

Ohio Air National Guard solar collectors reduce fossil fuel use and dependence on foreign energy sources

U.S. Air Force (Beth Holliker)

of a tactical solar-PV system are driven by its lightweight, portable nature:[12]

- high power-to-weight ratios (greater than two times higher than others)
- minimal battery and fuel transport
- high field survivability (silent, camouflaged, low angular or thermal signature)
- targeted energy needs (battery recharging, water purification, personal electronics, transportable energy for command centers, medical and survival kits).

Additional solar-PV advantages include relatively simple operator and maintenance training, and since there are no moving parts, reliability is much higher than for combustion cycle–based systems. Current costs for commercial solar-PV panels of 125 watts or larger are approximately $4.50 per watt, but are projected to drop to ~$1 per watt by 2015 as economies of scale increase supply and higher efficiency technologies mature. Efficiencies are on the order of 6 to 15 percent (up to 30 percent laboratory demonstrated) for peak solar irradiance.[13]

The Army's Tactical Alternating Current System (TACS) and Hybrid TACS (HTACS, which adds a small wind turbine generation capacity) represent the state of the art in solar-PV for tactical battlefield usage, and each "system is supplied with clean, silent power from a lightweight, flexible, and durable solar array. Excess power from the solar array is stored in a battery bank for nighttime or cloudy day use, and backup power is supplied by a generator connected to the system's control unit."[14] TACS components include:[15]

- 2.8 to 3.1 kW solar array
- power management center
- battery bank
- 4 kW AC inverter
- 4 kW backup generator.

The TACS system was designed for 6 amps continuous at 120 VAC (the average load of a typical tactical operations center) with a peaking load demand capability of nearly 60 amps. When the system is operated at its rated output of 6 amps, 120 VAC, average system performance expectations include:[16]

- generator on-time of 5 to 10 percent in sunniest areas and 15 to 20 percent in overcast areas
- silent running 80 to 95 percent of the day
- 10 percent of fuel and maintenance requirements compared to diesel generator alone
- lifecycle cost payback estimated at 1 to 2 years for deployed systems and 8 years for fixed-base support (fully burdened cost of fuel lower for support applications).

For larger deployable systems, Skybuilt Power developed and field-tested a mobile power station named the transportable hybrid electric power station (THEPS), which combines rigid solar panels, a wind turbine, storage batteries, and an augmenting diesel generator to guarantee continuous power during prolonged periods when wind or solar alone do not meet power requirements. THEPS provides, on average, 5 kW of power output depending on the weather conditions.[17] The inclusion of the diesel generator means the warfighter is not entirely freed from fuel logistics; however, even this challenge can be overcome if a system such as THEPS can obtain its diesel fuel via an in-situ resource such as biomass conversion.

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While the current state of the art focuses largely on solar-PV technologies, deployable biomass conversion has been demonstrated under field conditions. Biomass conversion, also known as a biorefinery, mimics the digestion process. As demonstrated in a particular 3-year, $850,000 Army development program, the process begins with taking organic waste such as food leftovers, plastics, and papers and mixing it with water and enzymes to metabolize the organics into ethanol. Waste that does not get converted in this manner is dried and burned to produce a mixed gas of light hydrocarbons, carbon dioxide, and hydrogen. The ethanol and composite gas are then combined 9:1 with conventional or biodiesel and combusted to directly generate electricity.[18]

The appeal of biomass conversion becomes obvious when one considers that each soldier in the field produces an average of 4 to 6 pounds of trash daily. Currently, field practice is to establish "burn pits" to prevent the accumulation of this waste and to address the attendant sanitation and disease risks. A transportable biorefinery the size of a semitrailer can process the daily waste produced by 500 soldiers and generate 60 kW, enough for a large mess tent or three homes. As an added advantage, the excess thermal energy produced during the combustion process can be used to heat water for camp use.

Chief of naval research leads interagency panel on energy innovations and Federal collaboration opportunities

U.S. Navy (John F. Williams)

It is easy to see that the American way of war is energy intensive. Just as renewable energy is an invaluable tool for the JFC to address battlefield requirements, it follows that BRE can also be an indispensable tool for providing shaping, stability, and reconstruction for our security partners, particularly those in the developing world who live the reality of energy poverty.

Applying BRE across the JOpsC

The JFC benefits twofold through the employment of renewable energy technologies: on the battlefield via reduced sustainment requirements for his own operating forces, and also as an effective tool to be employed for security cooperation, stability, and reconstruction activities. Since access to reliable and relatively inexpensive energy is a requirement for healthy living and the basis for a decent quality of life, the ability to employ renewable energy generation capabilities is a critical way to contribute to security and stability.

The idea of utilizing renewable energy sources fits neatly within the JOpsC set forth by the Capstone Concept for Joint Operations (CCJO). The employment of this technology on the battlefield to sustain ourselves, and its use to help build host nation or partner nation capacity to sustain themselves, can contribute greatly to the JFC's ability not only to accomplish his tactical missions, but also to enhance reliable energy capacity throughout an entire area of operations across the range of military operations.

Reducing reliance on nondomestic energy sources and increasing the deployment and use of renewable energy technologies enable the achievements of stated goals or enhance the desired capabilities discussed in many, if not all, of the Joint Operating Concepts (JOCs) and CCJO. The CCJO "proposes that future joint force commanders will combine and subsequently adapt some combination of four basic categories of military activity—combat, security, engagement, and relief and reconstruction—in accordance with the unique requirements of each operational situation."[19] Along with the idea of sustaining the force during all phases across the range of military operations, as addressed in the MNF–W JUON, it is important to understand the other dimension of introducing renewable energy as a viable security cooperation tool to assist nations in building reliable energy capacity and also possibly setting conditions for potential operations in a particular country or region.

There are currently six approved JOCs:

- Major Combat Operations (MCO)
- Homeland Defense and Civil Support
- Military Support to Stabilization, Security, Transition, and Reconstruction Operations (SSTRO)
- Deterrence Operations (DO)
- Irregular Warfare
- Cooperative Security and Engagement.

Although somewhat different in focus, each JOC shares common themes and discusses many issues that the introduction of renewable energy technologies can help address, relieve, contribute to, or solve.

Consider the following passages from the JOCs to illustrate some of these common themes:

The U.S. economy and military forces will have and use technological superiority that provides a competitive edge that also creates vulnerabilities that adversaries might exploit. Planners must address U.S. vulnerabilities, identify ways of eliminating them where feasible, and compensate for them when necessary.[20]

battlefield renewable energy may have the indirect effect of building trust with the local populace by not overburdening any existing system and possibly even building energy capacity in that area

This reference from the DO JOC highlights the need to identify and reduce vulnerabilities that enemies might exploit. This not only applies to the national strategic need to reduce the reliance on foreign sources for our energy needs but also implies the need to reduce opportunities for an enemy to attack and interdict supply lines. By steadily institutionalizing the use of renewable energy technologies in the continental United States and deploying BRE technologies overseas, we take significant steps in minimizing our strategic, operational, and tactical vulnerabilities.

Next, from the MCO JOC, we read, "Innovative methods for replenishing widely distributed combat forces with critical fuel, water, and munitions receive emphasis including the development of alternative sources for bulky commodities."[21] This passage recognizes the fact that the very nature of future combat operations presents unique challenges to the resupply and logistic considerations for widely distributed forces across expansive areas of operation. It directly ties initiatives such as the MNF–W JUON to the requirement to develop, deploy, and utilize new methods and technologies to help sustain the force and reduce the logistic tail, thus contributing to increased force protection. Also, by the very nature of distributed operations, the use of BRE helps sustain forces in the field and may have the indirect effect of building confidence and trust with the local populace by not overburdening any existing system and possibly even augmenting or building energy capacity in that particular area.

The Earthquake in Haiti

Although tragic, the recent earthquake in Haiti presents an opportunity to utilize some of the technologies discussed in this article. The mass devastation from the earthquake compounded an already stressed economic condition in a country that had an unreliable infrastructure at the onset. Moreover, the lack of major road arteries to reach outlying communities added to the complexity of efforts. From the start, gasoline was in high demand and extremely short supply. Electric power generation capability was stressed, impeding basic services and medical response. Some of these renewable technologies may be just what is required to help Haiti not only recover, but also grow a power infrastructure in both the major population centers and hard-to-reach outlying communities. Understanding that the requirement to meet immediate survival and health needs is the first phase of relief operations, we should plan in subsequent phases to introduce renewable energy sources to comprehensively build a lasting capability for nations such as Haiti. These capabilities should become routine planning considerations in all operations ranging from humanitarian assistance/disaster relief to security cooperation activities to major combat operations.

The next two passages out of the SSTRO JOC highlight the applicability of introducing these technologies in realms other than major combat operations, such as security cooperation: "Operational capabilities focus on capabilities associated with accomplishing a desired end state [i.e., major mission element] within a SSTR operation, e.g., delivering supplies of food and medicine, rebuilding a power generation and distribution system."[22] Moreover, in "many of the major urban areas, the government's inability to provide the basic public services heightens the potential for chaos and civil unrest. Critical infrastructure most likely will be austere—water and sewer services in disrepair; limited or compromised electrical service; and inadequate educational opportunities and medical care."[23]

The current state of affairs in Nigeria provides an excellent scenario for how the use of these technologies in security cooperation could positively shape the theater strategic environment. As previously noted, this energy-impoverished nation could be a major benefactor of expanded cooperation activities modeled after the approach taken by organizations such as SELF. As a key strategic partner in Africa, Nigeria needs to be a stable nation that can provide for the basic needs of its entire citizenry. Although the deployment of renewable energy will not alone solve the ongoing ethno-religious issues in the northern states, this technology could immediately assist in the southern portions of the country. However, even in the north, most of the tensions center on the fact that the government is seen as an ineffective provider of basic human services. Building sustainable, reliable energy solutions via security cooperation programs could serve to reduce those underlying tensions and help build confidence in the national government.

Many of these JOCs discuss the need for forward presence, persistent engagement, security cooperation, and capacity-building as means to contribute to security and stability. Most of these concepts, while citing the fact that lack of resources and useable energy can be a source of destabilization, do not address the option of deploying renewable technologies, either through military engagement programs such as security assistance means, exercise-related construction funds, or other means, such as National Defense Authorization Act (NDAA) 1207 funds or in cooperation with nongovernmental organizations (NGOs) via USAID. The Shaping Operations JOC currently in development is expected to describe the long-term, integrated joint force actions taken before or during crisis to build partnership capacity, influence nonpartners and potential adversaries, and mitigate the underlying causes of conflict and extremism.[24] This document may be an ideal place to discuss the JFC ability not only to reduce the logistic tail and positively impact partner nations' already strained infrastructure but also to contribute significantly to the development of sustainable energy capacity.

Advocacy for Policy Change

The 2007 *Transforming the Way DoD Looks at Energy* study devotes an entire chapter to the recommended way ahead for policy change.[25] To summarize the recommendations, a comprehensive change in culture must be achieved for renewable energy solutions to reach the joint force. This culture change should not focus solely on deploying renewable technologies for our forces but should also encompass military engagement programs such as security assistance, exercise-related construction funds, and NDAA 1207 funds. Interagency cooperation, particularly with the Department of State, USAID, and DOE, must be fostered. Change begins from the top down through all the strategic planning conducted by DOD and ends through the Planning, Programming, Budgeting, and Execution (PPBE) process. Strategic leadership becomes the key throughout this process to ensure the right amount of emphasis remains on delivering

U.S. Air Force (Thomas Cook)

British Viking combat vehicles refuel after conducting convoy through Helmand Province, Afghanistan renewable energy solutions to the joint force. The current Quadrennial Defense Review (QDR) provides the best opportunity for this complete transformation to occur and must address energy reliance throughout all the JOCs.

A bottom-up approach from the combatant command's review of priority requirements should also address renewable energy. Requirements must migrate from the JUON to the programmed requirement process—most notably the input into the integrated priority list. Once there, the Joint Capabilities Area managers, as well as the J7 and J8 staffs at the combatant command and Joint Staff levels, must begin to advocate for renewable energy to be included in the strategic planning system. Once introduced into the Joint Capabilities Integration and Development System and Joint Requirements Oversight Council processes, the requirements must be introduced and advocated through the Chairman's Risk Assessment and the CCJO. These strategic documents inform the QDR and PPBE systems. Each combatant command deputy commander would be a natural advocate for these requirements.

Moreover, as these requirements and concepts emerge in DOD strategic documents, Congress should ensure the renewable energy requirements reach the budgetary cycles of the NDAA. These planning and budgetary systems allow further advocacy in the private sector as joint commanders begin to implement renewable energy solutions throughout the joint operating environment.

Recommendations

BRE provides the JFC deployable, sustainable electrical power generation through a variety of renewable means—most commonly solar, wind, and biomass conversion. The application of BRE throughout the JOpsC gives the JFC a cross-spectrum force enabler by decreasing reliance on petroleum-based energy logistics. On the one end, BRE enhances force protection and increases the tactical flexibility of forward operating units, a capability already delivered to Iraq in response to the 2006 MNF–W JUON. At the other end, BRE can provide the JFC operating in the developing world a powerful tool for shaping the area of operations, directly through security cooperation and indirectly through coordinated support to interagency and NGO efforts to provide renewable energy systems for local population development.

In the event of conflict or disaster, the JFC can directly provide BRE systems, technology, and expertise to the affected region to address basic population needs and promote postconflict stability and reconstruction. Then, once conditions permit, BRE can become the basis for transitioning the host nation's energy infrastructure to one that is usable, sustainable, and distributed, thus building the host nation energy capacity in a manner that ensures the basic needs and aspirations of its people are met.

To date, the joint force has not recognized the overall value that BRE brings to the fight, and thus DOD has not systemically embedded it into its consciousness and culture. Therefore, we advocate a twofold approach to this transformation. It begins from the top down, with strategic leadership ensuring emphasis remains on delivering renewable energy solutions to the joint force through all the strategic planning conducted by DOD. From the bottom up, the combatant command's review of priority requirements should also address renewable energy. The approach to this review should migrate from the urgent needs approach to the programmed requirement process—most notably the input into the integrated priority list—and from there should merge with the top-down transformation by having the combatant commander and/or deputy advocate for renewable energy be included in the strategic planning system. Only a sustained effort from both sides will bring about the transformation needed.

The American way of war is too energy intensive to justify sustaining it with Industrial Age technologies and approaches. The multifaceted nature of 21st-century warfare rewards stability through shaping the environment, addressing human needs, and preventing the seeds of conflict. Renewable energy is the critical enabler to succeed in these missions. **JFQ**

NOTES

[1] George W. Bush, Executive Order 13423, "Strengthening Federal Environmental, Energy, and Transportation Management," *Federal Register* 72, no. 17 (January 26, 2007).

[2] Defense Science Board (DSB), *"More Fight—Less Fuel": Report of the Defense Science Board Task Force on DOD Energy Strategy* (Washington, DC: Department of Defense, February 2008), available at <www.acq.osd.mil/dsb/reports/ADA477619.pdf>.

[3] Multi-National Force–West (MNF–W), "Joint Staff Rapid Validation and Resourcing Request," in *Renewable Energy System*, ed. Robert B. Neller (Washington, DC: Department of Defense, July 25, 2006).

[4] Ibid.

[5] U.S. Joint Forces Command (USJFCOM), *The Joint Operating Environment* (Suffolk, VA: USJFCOM Center for Joint Futures, November 25, 2008), 10–23.

[6] Solar Electric Light Fund (SELF) is a nonprofit, nongovernmental organization committed to "provide solar power and wireless communications to a quarter of the world's population living in energy poverty." See *SELF Vision, 2009*, available at <www.self.org/vision2.shtml>.

[7] According to the Energy Information Administration, Nigeria's average daily production in 2007 was 2.35 million barrels, making it the largest producer on the African continent.

[8] Theodore Motyka, "Hydrogen Storage Solutions in Support of DoD Warfighter Portable Power Applications," The *WSTIAC Quarterly* 9, no. 1 (2009), 83–87.

[9] Scot P. Albright, *Transportable and Hybrid Transportable AC Systems, Final Technical Report* (Tucson: Global Solar Energy, 2005), 6.

[10] Miriam Keith, *BEAR Base Solar Power System, Final Technical Presentation* (Wright-Patterson Air Force Base, OH: Air Force Research Laboratory, 2005), 3.

[11] Ibid., 4.

[12] Albright, foreword.

[13] Keith, 8.

[14] Albright, foreword.

[15] Ibid., 7–8.

[16] Ibid., 8–9.

[17] Breanne Wagner, "Battlefield Energy," *National Defense Magazine*, April 2007, 32–33.

[18] Michael Behar, "Junk In, Power Out," *Popular Science*, May 2005, 44.

[19] The Joint Chiefs of Staff (JCS), *Capstone Concept for Joint Operations 3.0* (Washington, DC: JCS, 2009).

[20] JCS, *Deterrence Operations Joint Operating Concept 2.0* (Washington, DC: JCS, 2006), 4.

[21] JCS, *Major Combat Operations Joint Operating Concept 2.0* (Washington, DC: JCS, 2006), 28.

[22] JCS, *Military Support to Stabilization, Security, Transition and Reconstruction Joint Operating Concept 2.0* (Washington, DC: JCS, 2006), viii.

[23] Ibid., 15.

[24] JCS, *Irregular Warfare Joint Operating Concept 1.0* (Washington, DC: JCS, 2007), 15.

[25] Thomas D. Crowley et al., *Transforming the Way DOD Looks at Energy: An Approach to Establishing an Energy Strategy, Report FT602T1* (McLean, VA: LMI Government Consulting, April 2007), 4–1 to 4–11.