

Alternative Energy Solutions for the US Army

by *Tony Bui*

Tony Bui is the Materials Engineer, Power Sources, at the US Army's Communications-Electronics Research, Development and Engineering Center at Fort Monmouth. Here, he describes the approaches that CERDEC is taking to provide the US Army with alternative energy solutions to deliver more power for less weight and bulk.

The US Army is exploring ways to reduce fuel consumption and dependency because of the rising fuel costs and security risks associated with delivering fuel. It is estimated that the total cost of fuel when transportation and delivery costs to the theatre are factored in is about \$400 per gallon. The US Army Communications-Electronics Research, Development and Engineering Center (CERDEC) Army Power Division, headquartered at Fort Monmouth, New Jersey, is developing safe, technically innovative and cost-effective solutions to meet the warfighter's portable and mobile power and energy needs for today and for all future platforms: land, air and sea. Our goal is to provide soldier power and soldier system power that delivers more power with less weight and size. Photovoltaics, fuel cell systems and advanced battery chemistries are technologies that offer viable alternative energy solutions.

Photovoltaic Technology

Photovoltaic technology is ideal for providing continuous power to sustain and complete the mission. By harvesting energy from the sun, solar panels collect the energy necessary for the warfighters to operate their equipment effectively in areas where a constant power supply is



AMI-developed Solid Oxide Fuel Cell. This is a 25W system that utilises propane cylinders

unavailable. The Rucksack Enhanced Portable Power System (REPPS) is a state-of-the-art lightweight, portable power system that utilises a flexible solar panel capable of recharging batteries and/or acting as a continuous power source. The solar panel features anti-glare/anti-glint coating to eliminate solar reflections. In addition to the solar panel, the REPPS kit contains a series of adapters that provide system power or battery recharging capability from AC, military standard batteries and DC power sources. The entire system weighs approximately 10 lbs (4.5 kg). Applications currently in use range from recharging BB-2590 and other military standard batteries, powering notebook computers and providing continuous power for unattended ground sensors and surveillance cameras.

Due to the high cost of procurement and low solar panel efficiency, the technology is not readily available for wider Army use. Existing flexible photovoltaic technologies that have been evaluated by CERDEC have demonstrated 35 watts per kilogram (W/kg), 15W/m² (roughly 9% efficient), but \$15 per watt is considered too costly. Enabling technologies including novel photovoltaic chemistries, substrates, production processes and coating techniques that show potential to yield flexible photovoltaic systems capable of 100W/kg, 50W/m² (30% efficiency) and \$5 per watt will be considered as most beneficial. A reduction in photovoltaic product size, weight and cost could translate into a significantly increased user acceptance by the US Army in the near term. Over the long term, a reduction in operational weight and life-cycle cost could be realised over current tactical power generation systems. With the advent of solar photovoltaic systems, an energy-independent warfighter will enable reduced logistics and improved readiness in future US Army operations.

We are envisioning the next generation of photovoltaic systems to use wind power generation as part of a hybrid system for larger-power demand applications. The concept combines wind generation and solar harvesting components to collect energy and store it in a battery bank for future use. Embedded AC/DC outputs would allow military devices to connect to the system for power. Applications that can benefit from this type of system are re-transmission sites, battery charging, command posts and communication equipment.

Fuel Cells

Fuel cells are an emerging alternative energy solution we are developing that will provide reduced fuel consumption



UltraCell-developed Reformed Methanol Fuel Cell (RMFC). This is a 25W system that utilises cartridges packaged with MeOH/H₂O fuel mixture

and extended power capabilities on the battlefield. Similar to the operation of a battery, the gaseous or liquid fuel operates on an external power generation source allowing extended and continuous runtimes with low weight and volume. For portable applications, two fuel cell systems are under development. First, a 25W Reformed Methanol Fuel Cell system that operates on packaged MeOH/H₂O fuel mixture. For 72-hour missions, this fuel cell can achieve energy densities of 360 Whr/kg, which is higher than current technologies. Weight savings over batteries become apparent after 24 hours, causing fuel cell systems to become attractive for multi-day missions.

The second system developed is a Solid Oxide Fuel cell. This system is a 25W system that operates on commercial propane cylinders. Cylinders are attached to the fuel cell via a tethered fuel cable which contains a fuel regulator and sulphur trap. This fuel cell is capable of producing 460Whr/kg energy density for a 72-hour mission. The portable fuel cell systems weigh 3–5lbs and utilise disposable fuel cartridges. Applications include dismantled soldier radios, notebook computers, sensors and small consumer electronics. The benefits of the fuel cell are portability, continuous power, lighter weights than batteries for extended missions, potential to reduce life-cycle costs and the use of a renewable energy source.

The fuel cell systems are still under heavy development. Presently, it is considered an 80% solution because it is not a fully developed product. The general problems with fuel cell systems are the initial start-up time before the system can operate, poor reliability due to many mechanical components and high procurement costs. Additionally, the 25W fuel cell system is unable to deliver high peak and high power demands. However, CERDEC is seeking solutions to resolve these issues. Therefore, only select applications such as communications, battery charging, sensors and surveillance and ruggedised notebooks are applicable. We are also doing research in the 250-300W fuel cell range as

a means to provide power to recharge batteries or power portable equipment in Tactical Operations Centers.

Battery Chemistries

Another area where we are also focusing our research is advanced battery chemistries. There is still tremendous energy density that needs to be explored. The energy density of batteries has risen continuously over the last three to four decades. Energy densities of primary, or disposable, batteries have risen from 25-50Whr/kg in the 1950s to 300-400Whr/kg today, with much higher power capabilities and wider operating temperature ranges. Energy densities of secondary, or rechargeable, batteries have risen from 25Whr/kg to 150-200Whr/kg over the same period.

The next generation of primary batteries that is under development is Lithium Carbon Monofluoride (LiCFx). This chemistry is capable of delivering twice the energy at 400Whr, which is two to three times as much energy (175Whr/kg) and half the weight (2.2lbs) as Lithium Sulphur Dioxide (LiSO₂). An energy improvement of more than 60% over LiSO₂ has been achieved on the cell level. The difficulty is translating the results at the cell level and maintaining the same energy improvements at the battery level. Although LiCFx provides greater energy density, its limitations are apparent at higher current draws. Operating at more than 2A, the battery cells overheats, therefore rendering it inoperable. Strategies to alleviate the overheating and improve the operating current range include using aluminum cans, utilising phase changing materials for packaging and blending the cathode chemistry with Lithium Manganese Dioxide (LiMnO₂).

Ultimately, LiCFx is our enabling technology towards the highest specific energy chemistry, Lithium Air (Li-Air). Li-Air chemistry is still in early development and won't reach a level of maturity for testing and fielding for at least another three to five years. The practical improvements would have substantially more energy density than any existing battery technology and alternative solution currently available.

Summary

Over the past few years we have introduced a wide range of state-of-the-art technologies to meet the warfighter's power demands: wind power generation, photovoltaics, batteries, battery adapters/connectors and chargers, fuel cells, generators, power supplies, inverters, environmental control units and auxiliary power units. We will continue to investigate and provide power solutions from intelligent power management and distributions systems, advanced battery chemistries and alternative energy solutions. These advancements in portable power provide the warfighter with additional portable power options while reducing their logistics footprint. Our technologies ensure that the warfighters maintain their global technological superiority in the areas of mobility, sustainability, survivability and deployability. ■