New Power, Lightweight Materials, and Sustainable Design Tools for Small Arms Systems

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Introduction

Lightening operational and logistical loads for individual warfighters and meeting increasing portable power needs, continue to challenge weapon system developers. Programmatic requirements now exist that require consideration of energy, environment, and sustainability in the Systems Engineering (SE) process, which can add additional challenges to the development process, if not integrated properly.

Building on over two decades of research and technology transfer, the Expeditionary Capabilities Consortium (ECC) is a partnership with Kansas State University, M2 Technologies, and CABEM Technologies that performs research to develop new technologies for the Marine Corps and the Department of Defense. One focus area of keen interest is power systems. Research with nanomaterials to reduce the size and weight of lithium ion batteries; beta-voltaic cells with boride semiconductors for small, extremely long-lived portable power; and methods for producing hydrogen fuel using water and sunlight at forward bases, may provide dramatic reductions in weight, size, and re-supply requirements for power.

Because performance, mobility, and reliability are all key variables for warfighters with respect to portable electronic devices (e.g., night vision goggles), especially in precarious field conditions, evaluating and improving the underlying sources of equipment power is vital going forward. The ECC is conducting a preliminary sustainability evaluation of beta-voltaic power cell technology compared to disposable and rechargeable “double-A” (AA) batteries. Interdisciplinary professionals are conducting the evaluation, using the Environmental Knowledge and Assessment Tool (EKAT) and other life cycle assessment software, and data from previous battery technology analyses. This preliminary assessment of a conceptual beta-voltaic battery, compared to current battery technologies, will allow for comparative up-front materials screening and comprehensive assessment of potential risks throughout life-cycle stages .

The objectives of this evaluation are three fold: 1) investigate the life cycle impacts of various battery products and power systems; 2) utilize findings and results for improving the design of emerging technologies; and 3) develop effective frameworks and pragmatic indicators to facilitate the advancement of sustainable (military) products and processes.

EKAT

The Environmental Knowledge and Assessment Tool (www.ekat-tool.com) is a versatile and user-friendly web-based tool designed by ECC member partners for the U.S. Marine Corps to identify, evaluate, and mitigate potential environmental and safety-related issues, and is used in Programmatic Environmental, Safety and Occupational Health Evaluation (PESHE) development.

Conceptual AA Beta-Voltaic Battery

The development of beta-voltaic batteries could lead to creating new power sources having several advantages over currently existing counterparts, including improved energy density, efficiency, and much longer product lifetimes.

The scientific theory behind radioisotope batteries is similar to that of solar cells, except that energy is provided via beta particles from a radioactive source, rather than from photons from the sun.

Alternating layers of the radioisotope beta source and semiconductor materials would be present within the battery shell. The primary near term niches for such technology would likely be military or space applications, where a longer-life (even decades) and smaller-sized power source would be required.

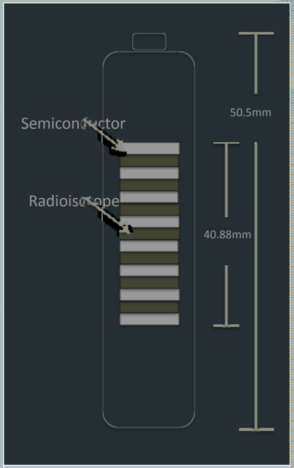

Figure 1 - AA configured beta voltaic battery.

Thin layers of beta particle emitting material (µm-range) with effective semiconductors.

Program and Regulatory Drivers

In an effort to meet energy security goals and measure the true price of crucial resources, senior military officials with the Joint Requirements Oversight Council have approved the Energy Key Performance Parameter (KPP) policy, and are working to incorporate methods to calculate the Fully Burdened Cost of Fuel (FBCF) into acquisitions programs. These metrics are being integrated into technology procurement.

Beyond the ESOH requirements detailed in DoDI 5000.02 *Operation of the Defense Acquisition System*, Executive Orders 13423 (*Strengthening Federal Environmental, Energy, and Transportation Management*) and 13514 (*Federal Leadership in Environmental Energy, and Economic Performance*) incorporate rules and set goals for energy efficiency, acquisition, renewable energy, toxics reductions, recycling, sustainable buildings, electronics stewardship, fleets, and water conservation. These EOs also prioritize reducing greenhouse gases and require development of sustainability plans.

Conducting Battery Sustainability Evaluations

With increased tactical demands involving portable wireless devices, leaner and greener power is needed. Three categories of AA batteries that could potentially be used in mission and training operations are being analyzed to better understand environmental and sustainability aspects. Both off-the-shelf, primary (non-rechargeable alkaline) and secondary rechargeable cells (including lithium ion), along with innovative (beta-voltaic) cells were identified as reference products for lifecycle analysis. These technologies are being comparatively reviewed in a conceptual use scenario in terms of equivalent functional units, resource demands, toxic and hazardous materials, multimedia impacts, recycling, cost, and other sustainability considerations.

Previous life cycle assessments that compared non-rechargeable alkaline and rechargeable nickel cadmium (NiCd) battery technologies found that material use, energy use, and emissions are lower for rechargeable batteries.[1]

Comparing nickel-metal hydride (NiMH) and NiCd rechargeable battery technologies, both battery types have roughly the same level of performance. However, the negative health impacts of cadmium, as compared to the metal hydride batteries, is the reason why rechargeable NiMH use is encouraged over NiCd .[2]

In order for the sustainability assessment to be conducted on next generation technologies, assumptions were made that material abundance, equivalent regulatory restrictions, and sufficient radioisotope shielding and sealing are possible.[3] The validity of these assumptions will be examined throughout the course of the evaluation.

The results of this study will be presented in terms of attributes that lead to the minimum number and weight of battery units needed to successfully perform missions, with the minimum re-supply burden, financial cost, and environmental/health impact. Lessons learned will be applied to SE processes, larger scale energy systems, and where appropriate, integrated into installation- and community level-sustainability initiatives.

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