Technical Inquiry

Electromagnetic Harvesting in Relation to Waste-to-Energy

Developed by:

HDIAC
104 Union Valley Rd.
Oak Ridge, TN 37830
HDIAC Contract Number: FA8075-13-D-0001

Technical Inquiry Summary. A request was submitted to HDIAC to research information on electromagnetic harvesting in relation to waste-to-energy within the U.S. Department of Defense (DoD). The information should also include who is conducting this type of work for the DoD.

Background Information: HDIAC processed and analyzed scientific and technical information in internal databases as well as pertinent outside sources to prepare the following summary to the inquiry.

Analysis: Energy harvesters provide a very small amount of power for low-energy electronics. While the input fuel to some large-scale generation costs money (oil, coal, etc.), the energy source for energy harvesters is present as ambient background and is free. For example, temperature gradients exist from the operation of a combustion engine and in urban areas, there is a large amount of electromagnetic energy in the environment because of radio and television broadcasting.

Who's doing What?

The U. S. Air Force Electromagnetics Technology Division at Wright-Patterson Air Force Base, invents new theories, devices, and systems for advanced sensing applications across the entire electromagnetic spectrum. The new technologies are used to improve weapon systems performance, advance national defense capabilities, and satisfy emerging warfighter needs for the Air Force.[1] Within the AFRL, there are several other research groups developing new technologies.

The AFRL/RYHA (Antenna Technology Branch) invents and develops new antenna technologies for the Air Force to improve performance, reduce lifecycle costs, and add dramatic new capabilities to current and future Air Force systems, including electromagnetics, RF metamaterials, and antennas. The AFRL/RYHC (Optoelectronic Technology Branch) develops new semiconductor technologies, including materials and devices, to enhance and support electronic systems for current and future Air Force sensor applications, pushing the frontiers of active and passive electro-optic sensors in the Ultraviolet to long Infra-red orange.[1]

The National Renewable Energy Laboratory (NREL) and the U.S. Navy have worked together to demonstrate new or leading-edge commercial energy technologies whose deployment will support the U.S. Department of Defense (DOD) in meeting its energy efficiency and renewable energy goals while enhancing installation energy security. As part of this joint initiative, a promising waste-to-energy (WTE) technology was selected for demonstration at the Hickam Commissary aboard the Joint Base Pearl Harbor-Hickam (JBPHH), Hawaii. The WTE technology chosen is called high-energy densification waste-to-energy conversion (HEDWEC). HEDWEC technology is the result of

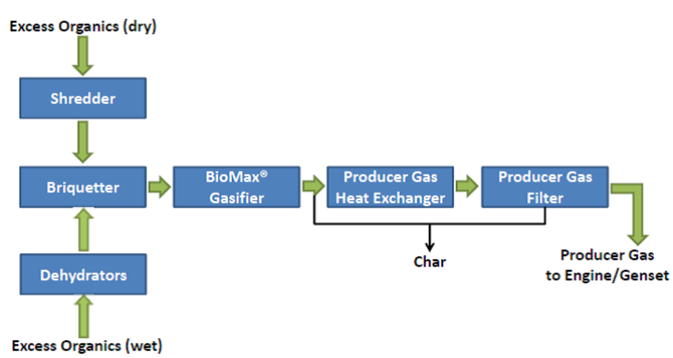

Figure 1. Block diagram of the flow path for materials and gas through HEDWEC.

significant U.S. Army investment in the development of WTE technology for forward operating bases. For example, the high cost of transporting fuel combined with the impractical and hazardous practice of solid waste disposal in burn pits or burn boxes led Natick Soldier Research Development and Engineering Center to initiate a WTE program in 2004. The technology provider, Community Power Corporation (CPC), developed HEDWEC from existing biomass gasification technology called BioMax, which had been successfully operated using biomass feedstock for over 10,000 hours of operating time. Gasification of certain biomass feedstocks is a relatively mature technology, with existing commercial applications around the world. Even more so, WTE using combustion is a mature technology, with hundreds of existing facilities operating around the world. The use of gasification to process municipal solid waste (MSW), however, is a WTE application that is not yet proven in commercial applications.[2]

Another advantage of the Hawaii and Guam energy Improvement Technology Demonstration Project demonstrated the performance of commercially available advanced power strips (APSs) for plug load energy reductions in building A4 at Joint Base Pearl Harbor-Hickam (JBPHH), Hawaii. The entire 100-occupant office building was retrofit with APS devices because building A4 is typical of most of the office space at the base. These power strips automatically cut power to plug loads (devices plugged into electrical outlets) according to an occupant-defined, set schedule. APS energy savings are a function of the power draw of the normally on plug loads, and the duration of time they can be powered down. Only modest energy savings were initially predicted because building A4 occupants had already managed to reduce their building energy consumption by 75% over the previous four years.

Plug load and total building energy consumption were measured both before and during the technology demonstration to derive actual energy savings. One hundred of these power strips were deployed at workstations, print rooms, and break rooms to reduce idle time power consumption, primarily during nights and weekends. APSs allow occupants to conduct business as usual with a minimal investment in learning how to operate the devices. The APS is a commercial, off-the-shelf technology (COTS) at a technology readiness level of 9.

Leading up to the demonstration, NREL assessed building A4’s plug loads and circuits, installed metering at the circuit and plug levels, discussed the APS scheduling features with most occupants, and installed and monitored the APS usage in order to quantify the direct energy savings.
Significant submetering was implemented to measure the energy savings and return on investment for the whole building. Submetering was installed at the panel level to measure receptacle circuit energy consumption. Submetering was also installed at receptacles (plugs) to measure the plug load energy consumption of individual devices and workstations.[3]

In the Spring 2014 edition of the Navy’s Energy and Environmental Magazine, Currents, covers information pertaining to the Secretary of the Navy (SECNAV) energy training events, held on February 11-13, 2014. The SECNAV outlined 5 energy goals to enhance and better enable the DoD’s combat capabilities and to provide greater energy security. Those goals included: increase alternative energy use DON-wide, increase alternative energy ashore, sail a “great green fleet,” reduce non-tectical petroleum use, and energy efficient acquisition.[4]

Personal energy is another area of research being conducted for the DoD. The growing power demands for modern warfare, in which batteries for radios, GPS receivers, computers, and optics, among other devices, compete for rucksack space with water and ammunition, are forcing the U.S. military to rethink how it powers the warfighter. A reliable source of renewable energy could allow for fewer batteries clogging an already heavy rucksack. This would reduce both the numbers and variety of batteries carried, as rechargeable units could do most of the work. The result could be a more resilient force less dependent on complicated logistics and, consequently, engaging in fewer dangerous resupply operations.

Soldiers and Marines are already wasting a lot of energy—not by throwing away half-charged batteries or burning diesel on under-loaded generators but by walking. Around 10 watts (W) of mechanical power is lost in each human leg per step, according Professor Tom Krupenkin of the University of Wisconsin. Much of that power dissipates as heat in shoes, muscles, and joints, and the Marine Corps and Army want to recoup that loss.

Recognizing the greater power, improved testing, and lighter weights making energy harvesting more realistic, an Experimental Forward Operating Base (ExFOB) event was held at Camp Pendleton, CA, in May 2014. The USMC's Expeditionary Energy Office brought together industry and military outfits in both kinetic and non-kinetic energy harvesting to demonstrate their products, causing one vendor to refer to it as a "watershed" event in the sector. Over a hundred Marines tested the devices, and their reviews may influence which, if any, energy harvesting products the Corps pursues.

The Army, which sent representatives from Natick Soldier Research, Engineering, and Development Center (NSRDEC) to the event, is also pursuing an Energy Harvester Suite. Noel Soto, project officer for energy harvesting at NSRDEC, told DoD P&E that the Army's efforts in kinetic energy harvesting were "headed for the dustbin" a few years ago; however, this fall, there will be "on the soldier" events at Fort Benning, GA, to test some of the 15 types of systems the Army is considering.

Both NSRDEC and the USMC are examining kinetic and non-kinetic ways of recharging their critical batteries (such as the Conformal Battery and BB-2590), including wearable solar fabrics and chargers, energy-generating knee pads, and moving backpacks. Though generating less than 100W, these technologies might represent a way to obtain "cheap," burden-free energy in the field. These researchers are also exploring "pack to battery" energy harvesting, personal energy, wearable solar, "power through the knees," and "energetic soles."[6]

Table 1. The Navy's Energy Conservation Team

Who	***Organization***	***What***
CAPT Richard A. Rogers CAPT Ryan B. Scholl	Commander, Naval Air Force U. S. Pacific Fleet	Increasing energy conservation aboard aircraft carriers; Implementing improvements to reduce aviation fuel usage; Launching the Naval Aviation Energy conservation (Air ENCON) program to establish an enterprise-wide program that reduces reliance on petroleum
CDR Bill Partington	Commander, Naval Surface Force, U.S. Pacific Fleet	Executing a multi-purposed approach to reduce surface ship energy consumption while underway (including stern flap and solid state lighting installation); Planning for deployment of the Great Green Fleet in 2016
CDR Brien Dickson	Commander, Submarine Force, U. S. Pacific Fleet	Planning for pier side metering, biofuels for emergency diesel engines, and antifouling coatings on submarine topside surfaces
Mr. Sonjae Whang	Military Sealift Command	Implementing the Energy Management Dashboard which more accurately assesses shipboard energy conservation underway and in port; Execute an energy training program that focuses on improving on-board operating practices for better energy efficiency
CAPT Marc Delao	Navy Expeditionary Combat Command	Implementing the NECC energy strategy including the cost effectiveness and commonality of parts, equipment, systems and procedures, partnering with other Services to support equipment refresh and modernization efforts, and leveraging other DoD and commercial initiatives

In Academe

A study from the University of Birmingham, UK, presents an overview on the state of the art of Tyre Pressure Monitoring System related technologies. This includes examining the latest pressure sensing methods and comparing different types of pressure transducers, particularly their power consumption and measuring range. Having the aim of this research to investigate possible means to obtain a tyre condition monitoring system (TCMS) powered by energy harvesting, various approaches of energy harvesting techniques were evaluated to determine which approach is the most applicable for generating energy within the pneumatic tyre domain and under rolling tyre dynamic conditions. The article starts with an historical review of pneumatic tyre development and demonstrates the reasons and explains the need for using a tyre condition monitoring system. Following this, different tyre pressure measurement approaches are compared in order to determine what type of pressure sensor is best to consider in the research proposal plan. Then possible energy harvesting means inside land vehicle pneumatic tyres are reviewed. Following this, state of the art battery-less tyre pressure monitoring systems developed by individual researchers or by world leading tyre manufacturers are presented. Finally conclusions are drawn based on the reviewed documents cited in this article and a research proposal plan is presented.[5]

Ambient energy can in many situations not only augment battery life in autonomous devices, but enable the whole functionality of such devices. Harvesting of ambient energy in any available form is hence very desirable. From available sources of ambient energy, solar and vibration energy are now prevalent forms of harvested energy. Several transduction mechanisms exist for transformation of mechanical energy of ambient vibrations into electric energy. Electromagnetic Transduction seems to be proper mechanism for harsh conditions thanks to its simplicity and robustness. [7]

Conclusion

Energy harvesting devices converting ambient energy into electrical energy have attracted much interest in both the military and commercial sectors. Some systems convert motion, such as that of ocean waves, into electricity to be used by oceanographic monitoring sensors for autonomous operation. Future applications may include high power output devices (or arrays of such devices) deployed at remote locations to serve as reliable power stations for large systems. Another application is in wearable electronics, where energy harvesting devices can power or recharge cellphones, mobile computers, radio communication equipment, etc. All of these devices must be sufficiently robust to endure long-term exposure to hostile environments and have a broad range of dynamic sensitivity to exploit the entire spectrum of wave motions.

References

1. U.S. Air Force Fact Sheet AFRL/RYH Electromagnetics Technology Division. http://www.wpafb.af.mil/library/factsheets/factsheet_print.asp?fsID=6302&page=1
2. Davis, J., Gelman, R., Tomberline, G. and Bain, R. (2014). National Renewable Energy laboratory (NREL). Naval Facilities Engineering Command (NAVFAC). Waste-to-Energy: Hawaii and Guam Energy Improvement Technology Demonstration Project. http://www.nrel.gov/docs/fy14osti/60868.pdf
3. Sheppy, M. Metzger, I., Cutler, D., Holland, G. and Hanada, A. (2014). National Renewable Energy laboratory (NREL). Naval Facilities Engineering Command (NAVFAC). Reducing Plug Loads in Office Spaces. Hawaii and Guam Energy Improvement Technology Demonstration Project. http://www.nrel.gov/docs/fy14osti/60382.pdf
4. The Navy's Energy and Environmental Magazine, Currents. Spring 2014. http://greenfleet.dodlive.mil/currents-magazine/currents-magazine-2014/currents-spring-2014/
5. Kubba, A. E. & Jiang, K. (2014). A Comprehensive Study on Technologies for Tyre Monitoring Systems and Possible Energy Solutions. *Sensors, 14:* 10306-10345, 11 June 2014. Doi: 10.3390/s140610306
6. Jagels, G. (2014). Recharging the Force. *DoD Power & Energy Magazine,* Fall 2014. http://tacticaldefensemedia.com/blog/2014/09/19/recharging-the-force/
7. Cottone, F. NiPS Energy Harvesting Summer School, 1-5 August 2011. Introduction to Vibration Energy Harvesting. http://www.nipslab.org/files/file/nips%20summer%20school%202011/Cottone%20Introduction%20to%20vibration%20harvesting.pdf.

Kline, Robert and Walker, Richard Clark. Waste Recovery and material handling Process to Replace the traditional Trash Transfer Station and Landfill by Extracting Reusable Material and Energy from joined Refuse Streams to Include; Office Waste, Dry Waste, Wet Garbage and the Special Hazardous Material Handling of Biological, Chemical, and Nuclear Waste. U.S. Patent Application Publication. US 2005/0080520 A1. April 14, 2005. http://www.google.com/patents/US20050080520

Pew Charitable Trusts, Research and Analysis. Power Surge: Energy Security and the Department of Defense. http://www.pewtrusts.org/en/research-and-analysis/reports/2014/01/16/power-surge-energy-security-and-the-department-of-defense

Opportunistic Energy Harvesting for Submarine Wireless Sensors. KCF Technologies, Inc. 2011. https://www.sbir.gov/sbirsearch/detail/6485

Energy Horizons. United States Air Force Energy S&T Vision, 2011-2026. http://www.defenseinnovationmarketplace.mil/resources/EnergyHorizonsFINAL.pdf