ENERGY ACADEMIC GROUP
NAVAL POSTGRADUATE SCHOOL

SURGE

ENERGY ACADEMIC GROUP QUARTERLY NEWSLETTER SPRING 2019

Highlights

NATO COHERENT RESILIENCE
ENERGY MANAGEMENT SYSTEM
AIR FORCE ENERGY EFFICIENCY
MICROTURBINE
ENERGY CONSUMPTION

The Naval Postgraduate School's (NPS) Energy Academic Group (EAG) supported the NATO Energy Security Center of Excellence's tabletop exercise (TTX), Coherent Resilience 2018 (CORE18) in Vilnius, Lithuania.

NPS's Energy Academic Group supports NATO Energy Exercise CORE18

From 3 – 7 December 2018, The Naval Postgraduate School's (NPS) Energy Academic Group (EAG) supported the NATO Energy Security Center of Excellence's tabletop exercise (TTX), Coherent Resilience 2018 (CORE18) in Vilnius, Lithuania. In addition to playing an integral role in the development and execution of the TTX, the EAG led the Exercise Evaluation Group.

The TTX focused on Critical Energy Infrastructure Protection/Resilience (CEIP/R) and the collective defense of the Baltic region's fuel supply from hybrid threats. The goals of the event were to identify vulnerabilities in current fuel supply infrastructures (to include electricity, transit, and communications networks), determine military dependence on those infrastructures, and to consider measures to protect them. CORE18 participants included government officials, military personnel, and industry representatives from Estonia, Latvia, Lithuania, and Poland, as well as NATO personnel from across Allied Nations.

CORE18 further highlighted the importance of fully understanding hybrid warfare and the types of campaigns that may be carried out by our adversaries in attempts to create instability, undermine national governance, sow divisiveness within NATO, and—potentially—seize territory. Participants identified the need to develop a strategy that not just responds to hybrid threats, but defeats a hybrid campaign.

To execute its evaluation mission, the EAG assembled an interdisciplinary team of experts that included faculty from the NPS Center for Infrastructure Defense, the Systems Engineering Department, Defense Analysis, the Graduate School of Business and Public Policy, the Center for Civil-Military Relations, personnel from the U.S. Naval Reserves, the U.S. Air Force's Operational Energy Office, and NPS students.

LEARN MORE
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Principal's Thoughts

Dan Nussbaum, Principal, Energy Academic Group

Recently, I spent time in the Pentagon talking with the energy leadership across the services and OSD, and I came away with a common thread: each organization is tackling the issue of "infrastructure resilience". Additionally, I found a robust discussion on "hybrid warfare" and its relationship to infrastructure resilience.

Like most topics, analysis begins with definitions. For example, there are definitions of energy security such as those put out by the National Defense University, but there is not yet a generally accepted definition for either hybrid warfare or infrastructure resilience. We still need to settle this definitional issue.

To that end, I (and others) hosted a two-day workshop at NATO Headquarters entitled Energy Security in the Era of Hybrid Warfare Workshop: Developing a Research Roadmap. The purposes of the workshop were to lay the foundation of an energy security research roadmap, embedded in a hybrid warfare environment, and to develop a roadmap which will be refined and improved over time. The main topics discussed were:

1. **What are the main threats to the civilian infrastructure?**
2. **How do these threats impact force readiness and mission assurance?**
3. **What are the current and future countermeasures?**
4. **Next steps and developing the research roadmap**

This topic is sure to endure, for as the NATO head of infrastructure stressed, we need to ensure that any energy infrastructure is cyber-resilient. I welcome your comments.

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Defense Energy Certificate Awardees

Dr. Dan Nussbaum and the Energy Academic Group congratulate the awardees of the first cohort of the Distributed Learning (DL) Certificate Program in Energy. EAG's DL Energy Certificate program provides those working military and civilian employees of the Department of Defense (DoD) the opportunity to understand the complex issues facing the Operational and Installation Energy segments of DoD.

Hadassa Baker
Public Works, O&M Division, Fort Riley, KS

Shannon Bergt
US Army Garrison-Detroit Arsenal, Warren, MI

Kevin Centeck
USA TARDEC, Warren, MI

Kristin Cox
IMCOM, Ft Bragg, NC

Maj James Flass (USMC)
MCICOM, Pentagon, DC

Patrick Holmes
IMCOM, Huntsville, AL

Matthew Huffman
NSWC Carderock, West Bethesda, MD

Thomas Jiang
NSWC Carderock, West Bethesda, MD

Brandon Naylor
NPS, Monterey, CA

Carlton Land
Marine Corps Intelligence Activity, Quantico, VA

Louis Levine
NSWC Carderock, West Bethesda, MD

Keshava Prasad
MCBCP, Yuma, AZ

Jeromy Range
MCB Quantico PW, Quantico, VA

Ileana Speer
MCICOM, Pentagon, DC

Gordon Waller
NSWC Carderock, West Bethesda, MD

John Wallingford
DHRA, Seaside, CA

Michael Witmer
IMCOM, FT Riley, KS

Capt Gregory Zerr (USMC)
HQMC, Quantico, VA

STUDENT ENERGY RESEARCH SPOTLIGHT

Implementation of a Microturbine in a Hydrogen Energy Storage and Generation System

By ENS Brianna Kaufmann, USN

The energy needs of the Navy and the Department of Defense demand renewability, reliability, and resilience. Diverse means of energy production, including hydrogen gas combustion, support these requirements. The overarching goal of our previous and current research at the Turbopropulsion Laboratory is to develop a system that produces and stores hydrogen and then combusts the hydrogen in a commercial microturbine to produce electricity. My research focuses on fueling the microturbine with hydrogen. Future research will produce a complete system that uses renewable resources, reliably produces electricity to meet demand, and demonstrates fuel resiliency.

Hydrogen gas combusts in air to produce heat in the same manner as the combustion of gaseous hydrocarbons such as methane (the primary component of natural gas) and propane. However, hydrogen produces more energy per unit mass and produces no carbon emissions. Previous research has developed a renewable method of producing hydrogen using electrolysis. The renewable and reliable production method enables the development of energy resilience with respect to hydrogen-based systems.

The implementation of a commercial microturbine enables the use of a renewable resource in a reliable and resilient system. A system component with the capability to produce energy from hydrogen (in addition to methane and propane) indicates resilience in fuel choices. If the primary fuel is unavailable, secondary fuels fulfill the demand for energy. The challenge: fuel properties differ. I use fluid models to predict some of the challenges associated with hydrogen in addition to experiments with the microturbine. I will recommend modifications and improvements as required to integrate the microturbine into the hydrogen-based system.

Preparing a test run of the microturbine fueled with natural gas.

About the author


ENS Brianna Kaufmann, USN

ENS Brianna Kaufmann is a student of Undersea Warfare and Mechanical Engineering. She graduated from the United States Naval Academy with a degree in Nuclear Engineering in 2018. Upon her graduation from the Naval Postgraduate School, she will report to Naval Nuclear Power Training Command in Charleston, SC to begin Submarine Warfare Officer training.

Contact the MAE research team at **https://www.nps.edu/web/mae/** for more information about this research.

OPERATIONAL ENERGY

The Air Force is Analyzing Operational Efficiency One Airframe at a Time

By Corrie Poland,
Air Force Operational
Energy (SAF/IEN)

Have you ever wondered if the Air Force is flying as efficiently as possible? Well, you're not alone… and there's a task force to find out.

The Energy Analysis Task Force (EATF), led by the Deputy Assistant Secretary of Air Force Operational Energy, has been systematically visiting Air Force bases around the country to observe actual training and mission flights, and speak with flight crews (to include operators and maintainers) about flight operations, practices, and aircraft requirements that have an impact on aviation fuel efficiency. The goal: to identify optimization best practices (and the challenges to implementing them) across each airframe, and produce a report that recommends which initiatives, processes, and technologies could have the greatest benefit to capability and readiness.

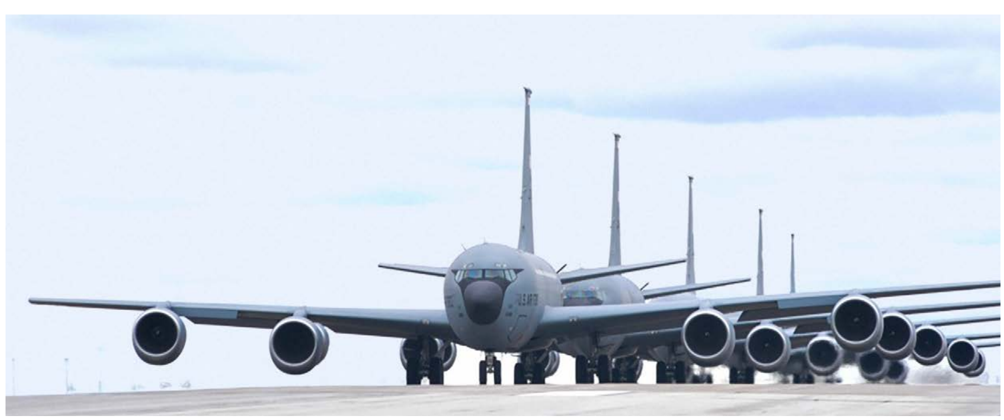
Known as a Line Operations Efficiency Analysis (LOEA), the team starts by targeting one airframe at a time and reviewing applicable publications and in-flight guides for that specific airframe. Then, in coordination with wing leadership, the team visits the aligned bases to conduct in-depth, non-attributional focus groups with aircrews of that airframe.

Led by a team of senior aviators with a breadth of experience across both Air Force and commercial aircraft (many are Reserve Airmen that also fly with commercial airlines), the EATF hopes to gain a better understanding of how crews perceive fuel efficiency efforts, and glean insight about the challenges pilots and maintainers face in their daily operations that may inhibit them from exercising efficiency best practices when the mission allows.

"We understand that the mission comes first—and that the dynamic environment in which we operate does not always allow for the most optimized operations," said Colonel Anthony Brusca, 913th Airlift Group Deputy Commander at Little Rock Air Force Base, and current lead for the EATF. "We're here to figure out where there may be a disconnect between training, policy and operations and where there may be opportunities for setting practical efficiency goals that make the lives of Airmen easier."

Since 2016, the EATF has completed LOEAs on the RC-135 Rivet Joint, E-3 Sentry (otherwise known as AWACS), C-5M Super Galaxy, C-17A Globemaster III, and are currently assessing KC-135 Stratotanker operations.

With the insight gained from these analyses, as well as known industry standards (e.g. best practices for commercial airlines), the team identified a number of processes across airframes that could improve operational efficiency without any capital investment. Examples



of these include better utilization of nearby training ranges, enhanced scheduling efficiency, airspeed and altitude optimization, reduced thrust take-off, reduced engine taxi-in, engine washing, and optimized fuel loads, among others.

For the RC-135, the team estimated a potential savings of $1.5 million in fuel costs annually (2 percent of the total fuel cost for the airframe) if these practices were implemented across the fleet. For the E-3, the potential savings were estimated at $9.5 million annually, or 8 percent of the total fuel cost. The C-5M Super Galaxy LOEA identified approximately $8.2 million in potential annual savings, and the C-17A Globemaster III LOEA identified approximately $43.2 million in potential savings.

While significant, the EATF emphasized that fuel optimization isn't just about saving money. "We're trying to increase capability for the warfighter and make your (Airmen's) lives easier, and if the protocol in place now doesn't make sense—and we can explain why—that's something I want to present to command leadership," explained Brusca to participating Airmen.

However, with the fluidity of military operations, many Airmen contributing to the focus groups agreed the efficiency standards recommended by the Air Force are not always possible, or realistic in theater, based on current operations. Several participants cited difficulties with ineffective software and fuel gauges, aging equipment, and greater mission demands than manpower available as reasons why fuel efficient methods were not always utilized.

One KC-135 instructor pilot, a major participating in the focus group stated, "There's this assumption that we can operate how the airlines operate—but that's typically not the case. We're working in a much more dynamic environment."

"At the end of the day, we can't delay mission effectiveness," said another captain participating in the LOEA, an instructor pilot for the KC-135. "We need to find a better balance between the needs of the crew, and the bureaucracy of the Air Force. Updating our guidelines regularly based on practical metrics and creating incentives for fuel efficient operations is a good place to start."

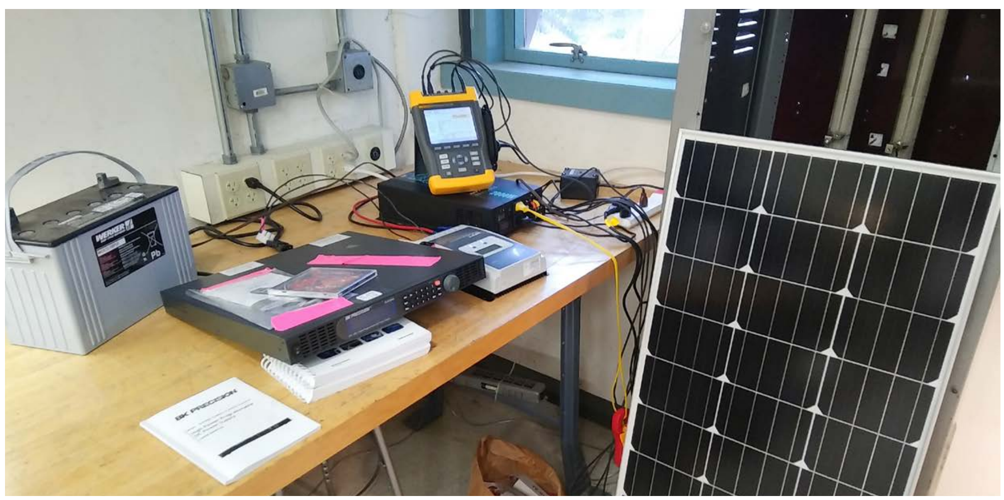
Through the LOEA reports, the EATF is looking to do just that. Although fuel efficiency efforts can often be a sensitive topic among pilots and maintainers, the team is looking for a middle ground where Airmen are able to maintain (and even increase) operational effectiveness, while also optimizing fuel use.

LEARN MORE

For more information on energy optimization efforts in the Air Force, visit: **http://safie.hq.af.mil/OpEnergy**

ENERGY RESEARCH

Hastily-Formed Microgrid Project Transitions to Student Learning Tool



Hastily-Formed Microgrid project (HFM) utilizes commerical-off-shelf (COTS) components.

The NEPTUNE-sponsored Hastily-Formed Microgrid project (HFM) is taking on new life as a testbed for student projects and experiments for microgrid technology. The HFM was originally designed to demonstrate the potential for military, humanitarian, and disaster relief forces to construct flexible low cost micro-grids using readily available commercial-off-the-shelf (COTS) components. The system consisted of 1200w of solar generation and 4800wh of battery storage built into a rugged rolling cart that could be easily transported for demonstrations or to serve as a mobile power source. This system is now being used by the Power Systems Integration Lab at the Naval Postgraduate School as a platform for students to conduct experiments and learn more about micro-grid technologies. Planned experiments include integrating new software solutions for power management and exploring ways to improve battery cycle life. A follow-on project is in the works to build a larger grid-tied microgrid into a standard shipping container to serve as a template for building larger, more capable systems using COTS components. The lessons learned from these projects will hopefully help pave the way for wider adoption of affordable and rapidly deployable microgrid systems.

LEARN MORE

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ENERGY RESEARCH

Energy Consumption and Soldier Performance—A Modeling and Simulation Perspective

CPT Jeremiah Sasala, U.S. Army, and Dr. Curtis Blais, NPS MOVES Institute

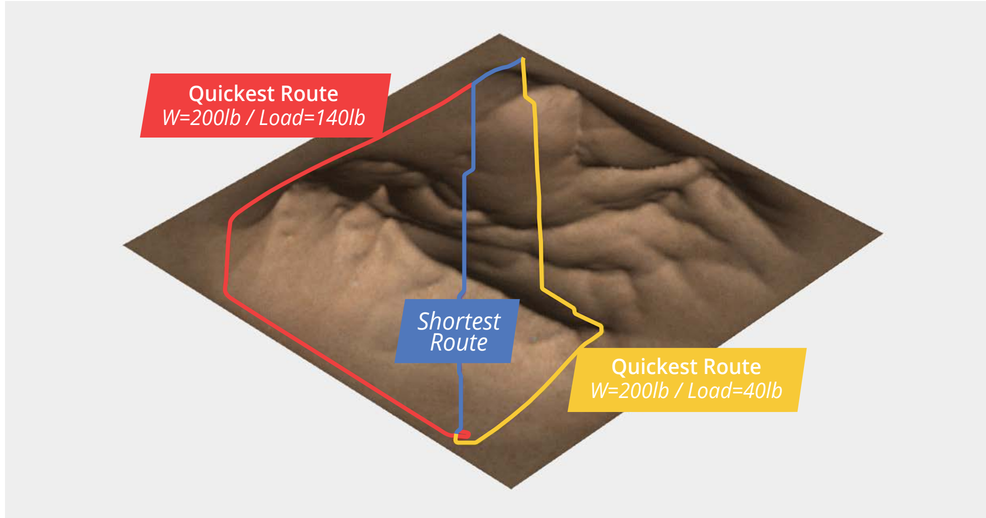

Figure 1. Effects of Load on Route Selection (Sasala, 2018)

Vehicles, electronics, and other equipment are not the only things on the battlefield that use energy. Arguably, they are not even the most important things on the battlefield that use energy! Human energy consumption and replenishment affect diverse aspects of combat effectiveness—from attentiveness to decision-making to skill performance—and are critical considerations in the conduct of warfare. With this in mind, modeling and simulation can provide valuable insight into the relationship between energy consumption and soldier performance

The rate of human energy consumption is largely a function of load, body weight, movement speed, and terrain (Pandolf et al., 1976). Given these several factors, it might seem like an obvious suggestion to simply reduce the load that soldiers must carry. This approach, however, does not match reality on the modern battlefield. As technology advances and better, lighter materials become available, soldiers do not enjoy lighter loads: in fact, the reverse is true, and loads only tend to increase (J. J. Knapik, Reynolds, & Harman, 2004). An increase in load means an increase in energy. A benefit of modeling and simulation is showing interactions among multiple factors. For example, given a standardized level of energy consumption, it is possible to solve for speed with respect to a variety of circumstances (Sasala, 2018).

At this point, simulations can provide an in-depth investigation into the relationships between load, speed, terrain, and energy; all of this can be done rapidly and without subjecting soldiers to harsh conditions or the risk of injury. Figure 1 shows the results of just such a simulation: using an A* search algorithm, this simulation reveals the quickest route over three-dimensional terrain for differing load amounts (Sasala, 2018). Overall, energy is critical to understanding human limitations and allows simulations to further explore battlefield performance and aspects of individual soldier readiness.

LEARN MORE
Contact Dr. Curtis Blais at **clblais@nps.edu**

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2. Pandolf, K. B., Givoni, B., and Goldman, R. F. (1976). Predicting energy expenditure with loads while standing or walking very slowly. USARIEM-M-3/77). Army Research Institute of Environmental Medicine, Natick, MA.
3. Sasala, Jeremiah (2018). Individual soldier loads and the effects on combat performance. Master's Thesis. Naval Postgraduate School.

Defense Energy Seminar Series

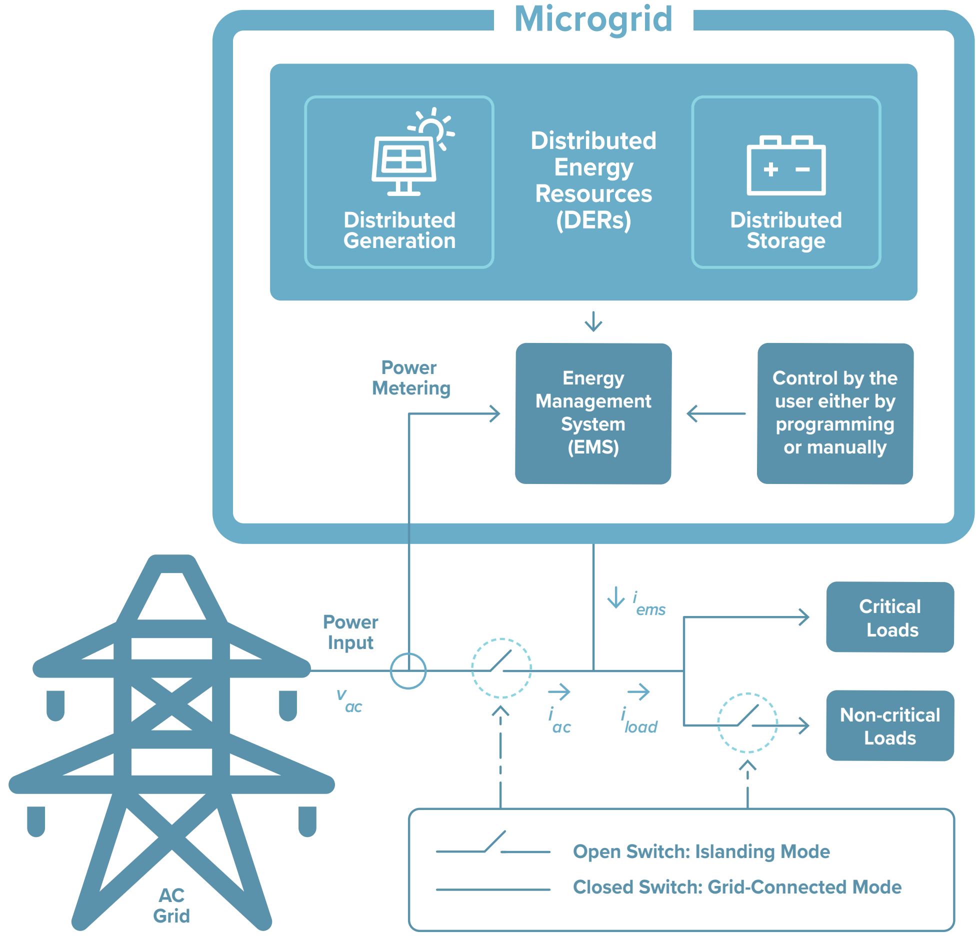
NPS's academic programs in Defense Energy are supplemented by a seminar series which provides a forum for leading voices within the field, practitioners, and other Defense Energy influencers. These professionals give presentations, engage in brown bag discussions, and facilitate informal gatherings that encourage Defense Energy faculty and students to discourse over current issues in Defense Energy, supplementing classroom teaching with practical, professional experiences. The Defense Energy Seminars Series is a permanent part of NPS's Defense Energy program, and a key to its real-world relevance.

LEARN MORE
Please see the Calendar of Events in this issue of ***Surge*** or visit **nps.edu/web/eag/seminars** for upcoming and archived seminars.

STUDENT ENERGY RESEARCH SPOTLIGHT

Implementation of Active and Reactive Power Flow

By LT Kanavaros Dimitrios



Microgrid is a synthesized term originating from the Greek word mikros, which means small, and grid. The synthesized word indicates that a microgrid is a miniature of the main grid, and its main purpose is to operate autonomously and to increase the reliability of the power system in a naval installation. Two types of power are flowing from the utility to the microgrid and vice-versa: 1) active power, which is the real power that can be transformed from electric to non-electric by the loads; and 2) reactive power, which doesn't do real work but is required by electric motors. The presence of the latter category lessens the energy efficiency of our installation, reduces the real energy, and increases the cost of the electricity for the consumer.

One way to compensate for the reactive power and to simultaneously control the active power is usage of a highly developed electronic system called the energy management system (EMS). The EMS manages the distributed energy resources (DERs) in a microgrid, such as solar panels and batteries, to ensure that electricity is available to an installation when the main grid is off (e.g. blackout). The EMS operates the microgrid in grid-connected mode, or in islanding mode.

In our research, four different methods of EMS control have been examined in order to regulate the active and reactive power flow from the source in a single-phase microgrid when it operates in grid-connected mode. Experimental measurements validate the simulated results, and as a consequence three of those different kinds of controls have accomplished the maximum desired efficiency. This means that the microgrid can compensate for reactive power, and simultaneously manage the active power. This contributes to the reduction of the cost of the electricity and to the delivery of the maximum available power to the consumer.

LT Kanavaros Dimitrios

About the author

LT Dimitrios Kanavaros is a Greek naval officer and a student in the Electrical Engineering Department of the Naval Postgraduate School. Contact Dr. Giovanna Oriti at **goriti@nps.edu** for more information about this research.

Calendar of Events

APR

April 5, 2019
Defense Energy Seminar: Novel Polymer Electrolytes for Batteries
Naval Postgraduate School

April 9–11, 2019
Naval Research Working Group
Vilnius, Lithuania

April 12, 2019
Defense Energy Seminar: DoE Collaboration with DoD; Projects & Opportunities
Naval Postgraduate School

April 15–19, 2019
Regional Energy Security Symposium Caucasus
Tbilisi, Georgia

April 19, 2019
Defense Energy Seminar: Optimizing the U.S. Air Force through 21st Century Tools and Technologies
Naval Postgraduate School

April 26, 2019
Defense Energy Seminar: Concentrated Thermal Power
Naval Postgraduate School

MAY

May 3, 2019
Defense Energy Seminar: Energy as a Weapon in a New Generation of Warfare and Its Influence on National Defense Capability—Overview of the Ukrainian Case
Naval Postgraduate School

May 10, 2019
Microgrid Projects at Naval Base Ventura County
Naval Postgraduate School

May 14–16, 2019
EAG Support to NATO Energy Security Center of Excellence TTX
Vilnius, Lithuania

May 20–24, 2019
Energy Efficiency in Military Operations Short Course
Naval Postgraduate School

Interested in Energy-Related Thesis Research?

Over the past five years, NPS and the EAG supported a plethora of student thesis research in the area of energy. A compilation of abstracts on student thesis and other research is available on the EAG website: **www.nps.edu/energy.** The EAG's extensive resources, intellectual capital, and connections with multi-disciplinary faculty and energy professionals provide students enhanced support for energy-related research. If interested in energy research, please reach out to the EAG team!

ENERGY ACADEMIC GROUP
NAVAL POSTGRADUATE SCHOOL

Connect with the Energy Academic Group

The Energy Academic Group is located in Quarters D, Bldg 281 on the NPS campus in Monterey, California. A wide range of NPS faculty are affiliated with the energy program, actively participate in energy graduate education, energy executive education, and energy research. For questions, please contact one of the principal EAG faculty members:

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Contribute to an issue of *Surge*

If you would like to contribute an article or have your research/work published in the *Surge* newsletter, please contact Jack Templeton via email at jctemple1@nps.edu or phone 919.696.1398.

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