



# Operational Energy: Essential Knowledge for Military Officers

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*The US Department of Defense (DoD) defines operational energy as “the energy required for training, moving, and sustaining military forces and weapons platforms for military operations.”<sup>1</sup> Operational energy is essential for almost all forms of combat; as such, “commanding it” will be critical to warfare in the future.*

**OPERATIONAL ENERGY (OE) CAN BE THOUGHT OF AS A** foundation of national defense and an indispensable attribute of military strength. Therefore, military members of all ranks should be educated on every aspect of OE. Over the past 100 years, energy has evolved to power literally every military capability of consequence; since the beginning of World War I, OE has played a decisive role in all major conflicts. In the present day, OE powers almost all forms of communication and sensing; fuels all air, land, sea, and space platforms; energizes all electrical devices; and is itself becoming a primary direct-fire weapon.

Given the importance of OE in combat, it is consequently also an area for adversary forces to target. Access to energy is often considered a “vital national interest,” and has been a *casus belli*: a reason to go to war. Therefore, it is paramount that DoD comprehensively educate officers and enlisted service members about OE throughout their careers. It is important that military leaders understand OE needs and capabilities at the tactical, operational, and strategic levels of conflict. Officers should also realize how OE, in all of its forms within multi-domain warfare, is positioned, maneuvered, and exploited within any given battlespace. With these goals in mind, this paper will discuss why officers should be educated about OE, what they must know about OE at various points in their careers, and to what extent they need to be educated about the different aspects of OE.

## Why Officers Should be Educated about Operational Energy

History is a wonderful educator and can help provide insight into the future. In conventional wars over the past century, OE has played a pivotal role in combat successes and failures alike. Beginning in World War I, for example, petroleum became critical for expanding motorized armies and air forces. At the end of the war, British Foreign Secretary Lord George Curzon declared that “the Allies were carried to victory on a flood of oil.”<sup>2</sup> A French senator similarly stated that “oil—the blood of the earth was the blood of victory.”<sup>3</sup>

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OE powered World War II to an even greater extent, and became a focus for major military battles. At the beginning of the war, the majority of Germany’s oil supply came from Romanian oil fields, which made those fields primary targets for Allied air raids.<sup>4</sup> Beginning in the spring of 1944, the Allies executed the “Oil Plan”—a bombing campaign that systematically targeted elements of German oil production such as oil fields, refineries, and plants that produced synthetic oil.<sup>5</sup> Within months, the campaign had cut Germany’s output of petroleum, oil, and lubricant to less than ten percent of its previous levels, causing major shortages of fuel for the army’s mechanized divisions and the Luftwaffe’s pilot training program.<sup>6</sup> Germany’s Minister for Armaments and War Production Albert Speer described the methodical attacks as “catastrophic” to the German war effort.<sup>7</sup>

Operational energy is an integral aspect of both the direct and indirect methods of warfare, and is a factor throughout all spectrums of conflict. Energy superiority is the ability to fully exploit one’s own energy capabilities while simultaneously preventing the adversary from doing the same. While the United States has enjoyed energy superiority in battle since World War I, the world is evolving, and US energy predominance is being challenged by nations like China. Based on historical conventional warfare, the victor dominates energy capability. Victory in the OE domain occurs when friendly forces have access to efficient, effective, and sustained production of combat power when and where it is required, while the enemy’s combat power production is disrupted, degraded, or destroyed. Attaining OE superiority, therefore, should be a primary goal of the US military. For this reason, we argue that every US military officer should be educated about OE.

Today, the US Secretary of Defense’s Operational Energy–Innovation office focuses on three primary areas of OE development: powering the force, electrifying the battlespace, and commanding energy.<sup>8</sup> Powering the force involves generating and maneuvering OE to all fixed and mobile platforms, while simultaneously reducing vulnerability. Electrifying the battlespace means developing OE into more efficient, effective, and less vulnerable electrical power that can accommodate multiple power sources. No longer can the operations commander simply trust the logisticians to have fossil fuel in place when and where it is needed. In the future, OE decisions will be more complex and will require an immediate understanding of the battlespace before forces maneuver and expend OE. Commanding energy necessitates near-real time OE awareness, in order to exercise command and control (C2) at all levels of conflict—tactical, operational, and strategic. Therefore, it is imperative to require continuing OE education for officers.

The ways in which energy is used in battle, and the kinds of energy that are being used, have changed dramatically over the last fifty years. For example, nations are rapidly developing and beginning to field directed energy weapons, including railguns, lasers, particle beams, and microwave arms. It is likely that these weapons will dominate the battlespace within a few years. Future force concepts envision highly dispersed forces throughout large geographic regions, and these forces will require OE that is immediately available on demand. Without an abundance of ready, secure, and forward-based OE, we argue that future militaries will falter and fail.

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One of the most important reasons to run war games is to be able to estimate the material, personnel, and energy needed for an operation. Napoleon lost significant battles when he ran out of horse feed.<sup>9</sup> Erwin Rommel lost battles in the North African desert when he ran out of fuel for his vehicles.<sup>10</sup> If Napoleon and Rommel had run war energy games, these results might have been different. While the reality of combat and other operations often leads to surprises, an officer need not compound the risks by miscalculating energy needs.

Modern OE encompasses much more than positioning fuel. Warfighting OE is also about managing multiple types of energy sources (e.g., petroleum, solar, hydrogen, nuclear fuel), generation (e.g., generators, convertors,

reactors), distribution (e.g., electrical wires, power beaming), and storage (e.g., batteries, convertors, storage tanks). Warfighting OE includes batteries, weapons (e.g., energy weapons, battery-powered missiles and bombs), weapon platforms (e.g., tanks, planes, ships, satellites), forward-based microgrids, and cyber/communication systems—all the aspects required to accomplish military missions throughout various warfighting domains. Many of the petroleum motors in weapon systems will be replaced by hybrids, and eventually by fully electrical/alternate-fuel engines that are charged from wireless support systems.

OE must be capable of powering deployed platforms and weapon systems that are dispersed to forward operating locations and are thus more vulnerable to enemy attack. Command and control of warfighting OE therefore requires understanding the energy status across the battlespace and directing adjustments, sometimes very quickly. Officers must know how to integrate OE planning and execution at all levels of war, maintaining a near-real time understanding and command of OE throughout all aspects of the battlespace. Officers must ensure that they know how and where to obtain the OE battlespace knowledge they need, so that they can contribute to the effort to develop more advanced OE capabilities.

A focus on OE education and training will have a major impact on OE development, budget, and operations; it will save lives and help to ensure mission success. DoD is the largest single consumer of energy in the world, and about 85 percent of the fuel used by DoD is for OE applications. In regard to combat, one in eight casualties in the Afghan and Iraq Wars happened during fuel movements. If officers of all ranks are trained to understand how OE systems operate, missions might be accomplished with greater safety and efficiency while using less energy or using non-petroleum sources.<sup>11</sup>

## What Officers Must Know About Operational Energy

What do our officers need to know? To begin with, they need to have a foundational understanding of the past, present, and potential future energy resources used in military activities and operations. Officers need to understand the technologies and supply chains, how to think about present and future energy supplies and uses, and how all of these can impact combat operations.

There are many ways to generate electricity, including solar photovoltaics, concentrated solar power, spaced-based solar, wind power, tidal and wave power, biomass, geothermal,

## Energy Concepts

It is important for military officers and civilian specialists in defense science and technology, and in acquisition and sustainment to study the energy ontology, because it provides a framework for understanding the energy process and supply chain. The following is a partial glossary of important energy concepts:

**Sources:** basic elements that “contain” energy (petroleum, coal, sunlight, etc.)

**Power Generation/Conversion:** converting sources to useable energy

**Transmission/Distribution:** making energy available to users

**Storage:** methods to store energy for later use

**Energy Management:** awareness, command, and control of energy

**Tools and Analytics:** methods to improve current systems and develop new capabilities

**Platforms:** mobile vehicles of all domains (land vehicles, aircraft, ships, satellites, etc.)

**Weaponry (specifically military):** includes energy weapons

**Education and Training:** career-long learning for all military personnel

coal, natural gas, oil, and nuclear power, among others.<sup>12</sup> To run operations effectively, officers need to know how the various energy systems they rely on work, including their supply chains, and what needs to be done when systems fail or when the supply chain is interrupted. Some training in both large and small electricity grids, microgrids, and battery and storage systems will help all officers understand how these systems function, and how to restore essential electrical systems in times of conflict and war.

## Markets and Supply Chains

Most ships, vehicles, and aircraft used by the US military are fueled by oil-based products. The volatility of prices for



petroleum and refined products creates its own set of risks. Therefore, an understanding of energy markets is vital for officers, especially those involved in logistics, planning, and intelligence. Such understanding will enable them both to estimate their budgets and needs, and to appreciate the risks involved with relying on specific markets for energy, energy storage, and more. Diversity of sources can be key to saving lives and mission success. By gaining a better understanding of energy markets, officers will better understand the impact of new technologies, new entrants into the markets, the competitive or contestable nature of the markets, energy substitutes and complements, and how energy markets may be interlinked. Furthermore, since much of the infrastructure required by solar, wind, and other renewable technologies typically comes from overseas suppliers, it is important for officers to understand how tariffs, quotas, trade disputes, and trade agreements may affect the military's ability to acquire those technologies affordably, reliably, sustainably, and on time.

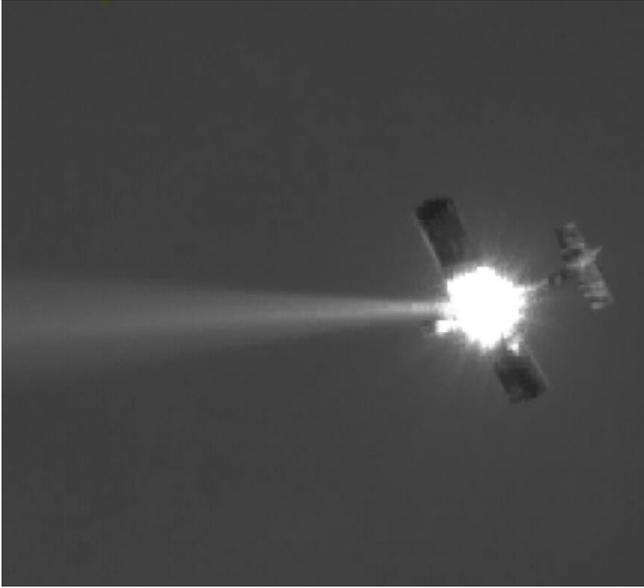
The supply chains for fuels are directly linked to electricity markets. The supply chains for natural gas and coal in the United States are mostly domestic. Global supply chains for fossil fuels, including coal, natural gas, and petroleum, often have important geopolitical ramifications. When fuel is needed for military activities outside of the home country, then a deep understanding of the local, regional, and global markets for the fuels and technologies that will be required in the area of operations is crucial, as well as an understanding of the rules that apply at each level. Oil markets are mostly global, but there may be local, regional, and national rules that can apply at times. Although natural gas

markets are usually regional, the distribution of natural gas is often local, with local rules and regulations that officers should understand.

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Electricity markets can be some of the most regulated energy markets, usually under the control of public utility commissions or their equivalents. There are also, however, electricity markets that have been unbundled, so that generation, transmission, and distribution are the responsibility of separate entities. Understanding local electricity auction markets also helps with “hedging,” whenever that is allowed. In the context of this paper, hedging is defined as a way to acquire energy for distribution that minimizes customers' vulnerability to the high volatility of the wholesale energy market.

Even though each electricity market, whether domestic or abroad, has its own peculiarities, it is important for acquisition officers to understand what a market is, how markets behave (including during times of stress), how stable and controlled prices may remain over time, and the people with whom to communicate and negotiate. While the US Defense Logistics Agency (DLA) is currently the DoD agency charged with addressing many of these issues (petroleum acquisition, transportation, and storage) for the US military, senior leaders outside of DLA may be



The use of a high-energy laser aboard the Mobile Active Targeting Resource for Integrated Experiments (MATRIX) as it negates a UAS, 2010.

making strategic energy decisions in the future, as energy sources and energy generation become more diverse.

Transmission and distribution systems are different parts of the process of moving energy from where it is produced to where it is used. Electricity is sent from the generating source at a very high voltage over heavy transmission pylons and similar structures; it is stepped down in voltage when it transfers into a distribution system that carries it to its destination. Natural gas usually moves from a storage facility through high volume pipelines that cover long distances before connecting with the distribution pipelines that carry the gas to houses and other end users. Oil transmission pipelines known as trunk lines carry crude and refined products, including jet fuel, diesel, and gasoline, over long distances. These products are then distributed to various customers at various terminal points. Officers should be able to understand and map out these systems in the localities where forces are stationed, in order to identify potential points of failure and the places that may need extra protection. This information could be an important form of intelligence when planning an operation.

## Energy Storage

Energy storage is an important aspect of supply chains that can have a direct effect on OE supplies. Energy storage comes in the form of batteries, pumped hydro, flywheels, chemical reactions, or heat storage (e.g., molten salts). Energy storage systems can be used for routine storage;

they can also be backup sources for vital and life-saving energy in times of stress when no other sources are available. Energy storage can tide over forward operating bases (FOBs) when fuel deliveries are interrupted, or when other methods of producing needed energy are not available. Without proper energy storage, energy systems could at times become unstable, or even unworkable. Determining the optimum way for soldiers and others to carry batteries and recharge them could mean the difference not only between victory and defeat, but also between life and death. Batteries and other storage options are also important for communications at all levels, from the individual to the battlefield. When an electricity grid goes down, an officer needs to know that there is a backup source of energy to tide the operation over until new supplies can be produced onsite or be transported in.

## Platforms

Officers need to understand platform energy—the energy systems that are powering the ship, aircraft, or transport vehicle they are using. Miscalculations at the tactical and even strategic levels can happen, with the potential for mission failure in the near term, and service and national failure in the longer term. Lives can be lost due to such miscalculations.

## Energy Weapons

As the energy weapons currently under development are fielded, they will pull heavily on the energy supplies of an operation. In some instances, they can be connected directly to platform energy: on an energy-integrated ship, for example, the energy used for such weapons will come from the same source as the power that runs the ship. Therefore, an officer on that ship needs to understand the tradeoff between having enough energy available to fire the directed weapon and to power and maneuver the ship.

## Safety

Officers should also understand the safety issues related to fuels, electricity, and nuclear power, when these apply, and how to train their personnel in safe-use practices. For example, one of the hazards of high-voltage electricity systems is electric arc, when electricity jumps long distances. This can cause injury or death, and can damage platforms and other equipment. An officer dealing with the possibility of an electric arc needs to understand, at a minimum, proper grounding. Whether on an FOB, an aircraft, or a ship, the implementation of appropriate controls and procedures for handling power supplies is critical.

## When preparing for any type of operation, whether on the battlefield or in training environments, officers need to know their energy requirements.

When preparing for any type of operation, whether on the battlefield or in training environments, officers need to know their energy requirements, energy use, energy safety issues, available energy storage, and the energy supply chains to sustain the operation. Energy must be an integral part of military C2, either as an independent system or as part of a comprehensive C2 system.

## When to Educate Officers About Operational Energy

In recent years, DoD has begun to reinforce the importance of OE throughout the armed services. In 2012, Congress directed DoD to stand up an organization, Operational Energy Innovation, to manage the Operational Energy Capability Improvement Fund, which guides strategic and operational energy development and transformation across the services.<sup>13</sup> In its *2016 Operational Energy Strategy*, DoD emphasized three objectives “to ensure the consistent delivery of energy to the warfighter:”<sup>14</sup>

- “Increase future warfighting capability by including energy as a factor throughout future force development.
- Identify and reduce logistical and operational risks from operational energy vulnerabilities.
- Enhance the mission effectiveness of the current force through updated equipment and improvements in training, exercises, and operations.”<sup>15</sup>

While implementation of these objectives requires the efforts of the Office of the Secretary of Defense, Defense Agencies, Joint Staff, combatant commands, and the military departments, the DoD must also use a holistic approach to education and training. Officers should be exposed to OE issues early in their careers and updated often, with a focus on information relevant to each officer’s rank and position. Officers must first be educated about OE at a tactical, introductory level. Then, as they progress through their careers, they will need to learn more operationally focused aspects of OE and, eventually, strategic OE, as it impacts the overarching planning and management of the forces.

It is very important that an officer understand the energy support that is available for operations and training. In the

United States, DLA-Energy is the major logistical support for DoD energy needs, working with the private sector and others to ensure there is enough energy available for DoD requirements. Officers need to know how DLA-Energy works and how to make use of its system; therefore, a visit with DLA-Energy should be required for all officers who are involved in the logistics and planning of major operations.

Given the importance of energy in operations, energy education should be part of the fitness reports for officers involved with energy logistics. These reports should also have markers for how well an officer plans, uses, and develops OE in his or her areas of responsibility.

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### Basic OE Education: Officer Training/Candidate School and the Service Academies

At the beginning of their careers, officers should begin to learn OE concepts and their impact on current tactical operations through Officer Candidate School or the service academies. OE education might be accomplished through an overview course that does the following: (1) introduces officers to the multi-disciplinary considerations of energy; (2) shows how mastering these OE issues provides strategic, operational, and tactical advantages over opponents; and (3) illustrates how failure to master OE presents an opportunity for enemy exploitation and friendly mission failure. The following key educational areas should be included:

- basic energy ontology and how it functions,
- energy superiority,
- energy sources and generation for tactical platforms and weapon systems,
- exploiting and maneuvering energy,
- basic OE resourcing and logistics.

### Intermediate OE Education: Functional Career Courses and Intermediate Service Schools (ISS)

More tailored and detailed OE education should be integrated into the functional career courses (e.g., Supply Corps School) and ISS, particularly as it relates to operational warfare. Functional schools must teach about OE and its supply chains relevant to their areas of specialization. ISS

and senior military education schools offer a tremendous opportunity for OE education. Many of these programs take 10 months or longer to complete, and educate students in operational warfare and strategy. At this intermediate level, the following areas should be included:

- joint/coalition operational/theater OE planning and execution,
- operational C2 systems and OE components,
- wargaming and field exercising that includes OE,
- advanced near- to mid-term energy systems and how to operationalize them,
- adversary energy systems and how to interdict them.

### Senior OE Education: Senior Service Academies

Flag officers and senior executive service candidates complete leadership courses upon selection. In addition, the vast majority attend a senior service school. As part of this education, these senior leaders should be introduced to the strategic-level aspects of OE and how these issues impact planning, operations, and management of the forces. Senior leaders need to have a solid understanding of the strengths, weaknesses, opportunities, and threats presented by OE, in order not only to command operational forces, but also to help advance military OE. Key energy areas that senior-level education should address include the following:

- national OE leadership and development,
- national energy resourcing and strategic stockpiles,
- future OE systems, economics, and funding,
- global energy C2 systems.

The military fights as it trains. Therefore, integrating realistic OE considerations and challenges into war games and tabletop exercises (TTXs) will provide critical education for officers at all levels. In fact, if realistic OE is not incorporated into war games and TTXs, officers' understanding of OE will be inadequate. Therefore, it is imperative that energy become a primary aspect of all military exercises, whenever possible and appropriate.

## Conclusion

Energy education in DoD should take place across all levels and for the long term. As some enemies and competitors of the United States, including China, rapidly increase their use and understanding of OE, DoD needs to ensure that the US military can maintain its lead in OE development and deployment. In addition to educating all military personnel, it is important to develop a corps of "energy officers" who are constantly testing the energy pulse of their area of responsibilities, and who are also looking to the future energy challenges near and far. There is no place for complacency in a quickly changing OE world.

The military services use doctrine to establish baselines for education, training, and operations. However, the US military currently lacks a comprehensive energy doctrine;

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the limited energy doctrine that does exist focuses solely on liquid fossil fuels.<sup>16</sup> In future warfare, "strategic" OE will be optimized by doctrine, planning, and strategy. Thus, developing an overall energy doctrine is an important first step in the process of improving energy education for officers.

OE is a physical force, powering microgrids and platforms and functioning as a weapon itself. New and developing forms of warfare demand that energy be operationalized, with its full capabilities available from forward operating locations. Many weapon systems will likely evolve from their current engines to hybrids, and then to fully electrical engines that are charged from power-beaming systems. DoD is currently working with numerous universities and civilian labs to maximize efficiencies and take advantage of assets across the enterprise and research spectrum. Developments from DoD often spill over into the US civilian sectors, while the civilian sector supplies energy and technology for the DoD in turn. As a matter of total investment, the civilian industrial energy sector dwarfs that of DoD. Therefore, joint military/industry OE development and investment will be necessary in order for DoD to realize the best economies of scale. These are some of the many reasons why officers must be educated about OE early, often, and in ways that are relevant to their jobs throughout the course of their careers.

Sun Tzu noted that "in all fighting, the direct method may be used for joining battle, but indirect methods will be

needed in order to secure victory . . . these two in combination give rise to an endless series of maneuvers.”<sup>17</sup> Today, OE is an integral aspect of both the direct and indirect methods of engagement and throughout all spectrums of conflict. Since the beginning of the twentieth century, the United States has had “energy superiority,” but this is being challenged today. Maintaining this superiority should be a primary goal of the US military, and educating officers in OE is an essential part of attaining that goal.

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8. Paul Carpenter is a member of the Operational Energy—Innovation office and helped develop and implement the Secretary’s plan.
9. See Robert Burnham, “Why did Napoleon Fail in Russia in 1812?,” The Waterloo Association, n.d.: [https://www.napoleon-series.org/faq/c\\_russia.html](https://www.napoleon-series.org/faq/c_russia.html)
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11. The information in this paragraph comes from the Office of the Secretary of Defense, Operational Energy Innovation Briefing, 15 December 2020.
12. With the proper safeguards, small modular reactors have considerable potential as a source of operational energy. Several countries are developing some version of these. See the International Atomic Energy Agency’s webpage on this topic for more information: <https://www.iaea.org/topics/small-modular-reactors>
13. “Operational Energy Capability Improvement Fund,” Department of Defense Research and Engineering Enterprise: <https://rt.cto.mil/ddre-rt/dd-rtl/oe-i/ocif/>
14. Department of Defense, *2016 Operational Energy Strategy* (Washington, DC: Office of the Assistant Secretary of Defense for Energy, Installations and Environment, Department of Defense, 2016), 6: <https://www.acq.osd.mil/eie/Downloads/OE/2016%20DoD%20Operational%20Energy%20Strategy%20WEBc.pdf>
15. Ibid., 6.
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### NOTES

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7. Ibid.; RuthAnne Darling and Paul Mason Carpenter, “Energy: An Essential Element for Winning Future Wars—Operational Energy Part 1,” Surge (Fall 2020): 6: <https://nps.edu/web/eag/future-wars>