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A Value-Focused Approach to Energy Transformation in the United States Department of Defense

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The United States Department of Defense (DoD) has identified its energy requirements as a key vulnerability and in recent years has taken substantial initiatives to improve its energy profile. As part of this process, DoD leaders have issued guidance documents outlining goals and objectives relating to energy. These documents are intended to inform many different decisions at strategic, managerial, and operational levels. They specify a wide range of objectives that overlap only partially, while identical terms appear in many documents, but with inconsistent definitions. In this paper, we review 44 strategic guidance documents and apply a value-focused thinking approach to identify and define explicitly a comprehensive set of common objectives for energy decisions in the DoD. The objectives and associated definitions are intended to facilitate horizontal and vertical communication within the DoD. In addition, the objectives we define suggest possible metrics that may be comparable across services and in some cases may be aggregated across organizational levels.

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1. Introduction

Energy is a critical input for nearly every capability of the United States (U.S.) Department of Defense (DoD). The energy requirements of the DoD are also a critical vulnerability. For more than 65 years, U.S. forces have enjoyed uninterrupted access to fuel. This assurance has come at the cost of constraints on U.S. foreign policy (CNA 2009) and is not guaranteed to continue; the DoD is preparing for anti-access/area-denial that will put the supply chain "fully in play in the battlefield."[1] During World War II, attacks on supply lines were a major element of military strategy on all sides, and access to petroleum was a motivation for conflict (Yergin 1991). Dependence of the world economy on petroleum, instability in oil-producing regions, and the U.S. role in protecting international global commerce on the seas all suggest that energy is likely to drive future missions of the DoD (CNA 2009). In addition, DoD installations have enjoyed nearly uninterrupted access to electrical power in recent years, but their dependence on the "fragile and vulnerable" commercial power grid (DSB 2008, p. 3) is also a vulnerability.

Although DoD's energy consumption is only about 1% of total U.S. energy consumption (Schwartz et al. 2012), without this critical input, DoD's capabilities would largely shut down. Moreover, energy requirements are growing; the newest platforms and weapons systems require substantially more energy than the assets they are replacing (Goudreau 2013). The DoD's "current energy consumption patterns are inconsistent with national strategic goals to build American strength and a stable international order" (Office of the Assistant Secretary of Defense for Operational Energy Plans and Programs 2011, p. 1).

The DoD's energy profile (energy requirements and the means to meet them) is determined by millions of decisions spread throughout the workforce across all of its activities. Energy decisions in DoD range from minute-to-minute choices, such as how fast to drive, to long-range strategic planning of the size of

[1] Sharon Burke, Assistant Secretary of Defense for Operational Energy Plans and Programs, quoted in Defense Tech, *Pentagon Factors Operational Energy into Acquisition*, July 25, 2013. Accessed August 9, 2013, http://defensetech.org/2013/07/25/pentagon-factors-operational-energy-into-acquisition.

the force. Other examples include choosing the type of generator that should power a facility, setting flight training requirements, designing or selecting a new generation of vehicles, and allocating research and development resources.

A 2001 report by the Defense Science Board (DSB) identified decision processes that fail to consider the vulnerabilities associated with energy consumption, including a reduction in capability. Since the DSB (2001) report, and in compliance with guidance from Congress, in particular the 2009 National Defense Authorization Act, DoD leaders have stated on numerous occasions that energy considerations will play a major role in decision making throughout the foreseeable future, and have begun efforts to improve the energy profile of the DoD.

Any large organization faces a challenge in managing many decisions such that the choices made are in alignment with the overall strategy, and thus help the organization achieve its goals. One of the primary approaches that defense and other public organizations use to achieve this alignment is defining strategic objectives and communicating them throughout the organization (Pirnie and Gardiner 1996, Paarlberg and Perry 2007, Casey et al. 2008). The strategic objectives must be defined and measured such that they provide useful guidance for decision makers. We are primarily concerned with ensuring that decision makers within DoD are considering a set of objectives consistent with the preferences of its leaders.

By any measure, the DoD is one of the largest organizations in the world. In seeking to change its energy profile, among its first steps was the issuance of strategic guidance with respect to energy. The Secretary of Defense, leadership in each military service, Congress, and the White House have issued documents outlining energy strategies and policies. Many of these documents provide information about objectives, either explicitly or implicitly, using the terms "goal," "vision," "strategy," "policy," "objective," and even "pillar" to refer to considerations underlying the evaluation of alternatives or motivation to search for new alternatives. In keeping with the decision analysis literature, we use the term *objective*.

The strategic guidance communication has been very successful in bringing attention to energy and activating decisions that improve the DoD's energy profile throughout the organization. However, some challenges remain. It is not always clear what objectives and metrics a decision maker within the DoD should use to guide and justify decisions in which energy is a factor, and it is difficult to ensure that decision makers across different parts of the DoD are consistent in their implementation of the strategies provided by DoD leadership. The purpose of this paper is to develop a comprehensive and clear set of energy-related objectives for decision making within the DoD, consistent with existing strategic guidance. This supports more effective communication about strategic values and can serve as a basis for communicating quantitative information about trade-offs.

We take a value-focused thinking (VFT) approach, using DoD strategic guidance related to energy as our source of information on leadership values. VFT is widely used in the DoD (Parnell 2007) and in other public-sector decision contexts (Keefer et al. 2004) in which a potentially large number of objectives must be considered. VFT has been applied to several areas of defense, including psychological operations (Kerchner et al. 2001), communications networks (Davis et al. 2000), and information operations (Doyle et al. 2000). It has also been applied to homeland security (Keeney and von Winterfeldt 2011).

VFT differs from alternative-focused thinking, which begins by identifying possible alternatives and then determines criteria for evaluation by availability, ease of measurement, and the extent to which they differ among the alternatives. In VFT, on the other hand, the first and most important step in the analysis is to identify and clarify the decision makers' objectives before alternatives are examined. There are several benefits to this approach, including more effective communication among stakeholders, increased focus on the considerations most important to the decision makers, and even the generation of innovative alternatives that were previously unidentified (Keeney 1992, Parnell 2007). However, VFT can still be used in a specific decision context where an existing set of alternatives has been presented (e.g., choosing among platform designs proposed in the early stages of an acquisition process). Examples include Keeney and Sicherman (1983), von Winterfeldt (1987), Merrick et al. (2005), and Feng and Keller (2006). In such cases, measurable attributes associated with the objectives should be defined, allowing the decision makers to use performance on the objectives as a basis for comparing the alternatives.

Communicating quantitative information about preferences and trade-offs across levels of the organizational hierarchy would also help in overcoming organizational incentive mismatches and suboptimization problems. By providing insight into the objectives at higher levels of the organization, we improve the ability of individuals and groups within the DoD to make decisions consistent with DoD leadership preferences. Eventually, the effort to systematize communication about objectives could support development of standardized metrics that may be compared throughout the entire organization.

The remainder of the paper is organized as follows: In §2, we describe the source documents and our review process and criteria for identifying objectives. In §3, we present our consolidated set of objectives. In §4, we discuss other findings and compare our objectives to an existing value model used by the U.S. Navy to evaluate installation energy projects. We conclude the paper in §5.

2. Methodology

2.1. Sources

Parnell et al. (1998) refer to the formulation of objectives based on stakeholder-approved documents as the "gold standard" approach to developing multiple-objective value models. We reviewed 44 documents, 38 of them approved by DoD and federal leadership. The complete list is provided in the appendix. All were issued since 2001, and most since 2010. Most of the documents relate specifically to energy policy and strategy, while a few, such as the Quadrennial Defense Review (QDR) (DoD 2010), are more general strategic guidance. The highest level guidance is given by White House and Congressional documents, such as the National Defense Authorization Act. In addition to DoD-level guidance, documents specific to the Army, Navy, Air Force, and Marine Corps are included. Keeney (1988) advises that "a broad range of stakeholder groups should be involved to generate breadth in the suggested objectives." Thus, we also reviewed six documents from other governmental and private nongovernmental organizations.

2.2. Criteria for Identifying Objectives

In this paper, we develop a comprehensive set of energy objectives relevant to the DoD that could help foster clear communication and the development of comparable metrics across the organization. We do not attempt to define a set of objectives specific to a particular decision problem. Rather, our primary purposes are to clarify stakeholder values and to resolve inconsistencies among their stated objectives to the extent possible. We develop a set of objectives that captures many energy-relevant values that stakeholders expressed in a variety of ways, often in different contexts.

Our main criterion for our set of objectives is that it should be comprehensive; i.e., it should include all energy-related considerations deemed important by the leadership as expressed in the document set. However, we also consolidate and remove some identified objectives to ensure that the resulting set of objectives is essential, controllable, and nonredundant. This is necessary to ensure that each objective conveys independent information and to keep the set manageable and meaningful—the desirable properties of a set of objectives as described by Keeney (1992). Several features of our set of objectives may seem counterintuitive. For example, the frequently stated objective to maximize energy efficiency does not appear in our set. This will be discussed thoroughly in §3.

2.3. Types of Objectives

The purpose of this study is to identify a set of objectives that may be used as a basis for communication and for developing metrics for the DoD. At this stage, we did not seek to define objectives that are measurable (precisely defined and quantifiable) and operational (measurable in a practical sense). However, there are widely used measures that are associated with some of the objectives, as discussed in §4.

Following Keeney (1992), we distinguish among three types of objectives:

- Fundamental (ends) objectives—objectives that are inherently important in a decision context; these define why a decision exists and what decision makers are trying to achieve.
- Means objectives—objectives that are pursued because of their "implications for the degree to which [other] (more fundamental) objective[s] can be achieved" (Keeney 1992, p. 34).

- Strategic objectives—objectives that are fundamental to the entire set of stakeholders; they cannot be redefined as means objectives by association with more fundamental objectives of a subset of stakeholders.

Fundamental objectives describe the issues that are of direct concern to stakeholders. Means objectives describe related issues that are relevant primarily because they influence alternatives' performance with respect to one or more of the fundamental objectives. This distinction becomes particularly important in the later stages of a decision analysis; quantitative information about preferences should be elicited using fundamental objectives. Keeney (2002) explains that evaluating trade-offs using means objectives instead of fundamental objectives can lead to flawed decisions.

The distinction between fundamental and means objectives depends on the context of the decision; it is possible that an objective would be considered fundamental at one level of an organization but would be a means objectives from the perspective of a stakeholder either at a higher level of the organizational hierarchy or outside the organization. At higher levels in an organization, decision problems tend to have a broader scope; they consider longer time horizons for both the implementation and impacts of decisions. Accordingly, there may be more decision variables, and their possible ranges are likely to be wider. For example, at the national level (White House and Congress), the overall DoD appropriation for research, development, test, and evaluation is a reasonable decision variable to consider. At the DoD level, the size of a service 10 years in the future is a reasonable decision variable. At the Navy level, the number of aircraft carriers in the fleet is a reasonable decision variable. The scope of alternatives under consideration affects which objectives are fundamental to the given decision problem and which are means to influence those fundamental objectives. In this work, we define as fundamental those objectives that are of direct concern at the Secretary of Defense and Service Secretary levels in the DoD for setting energy policy. We consider objectives that are fundamental at the national level to be strategic objectives for DoD.

3. Results

We specify 12 objectives that the source documents identify as significant to many of the stakeholders. Three are fundamental at the national level and are considered strategic. Three others are fundamental at the DoD level, and the remaining six are means objectives. The objectives appear in Figure 1 and are organized into a fundamental objectives hierarchy followed by a high-level means-ends objectives network. Each of these objectives is included implicitly or explicitly in several of the documents. Each specific DoD energy decision would involve a more detailed means-ends network. There are also objectives stated in source documents that are redundant, as detailed in §3.4. Further discussion of how to operationalize the objectives is in §4. The full details of which documents include which objectives, with specific quotes, are given in a sponsored technical report produced by Whitney et al. (2013, Table A.2) for the Energy System Technology Evaluation Program (though some of the terminology differs). A sample showing three documents and three objectives is provided in Table 1.

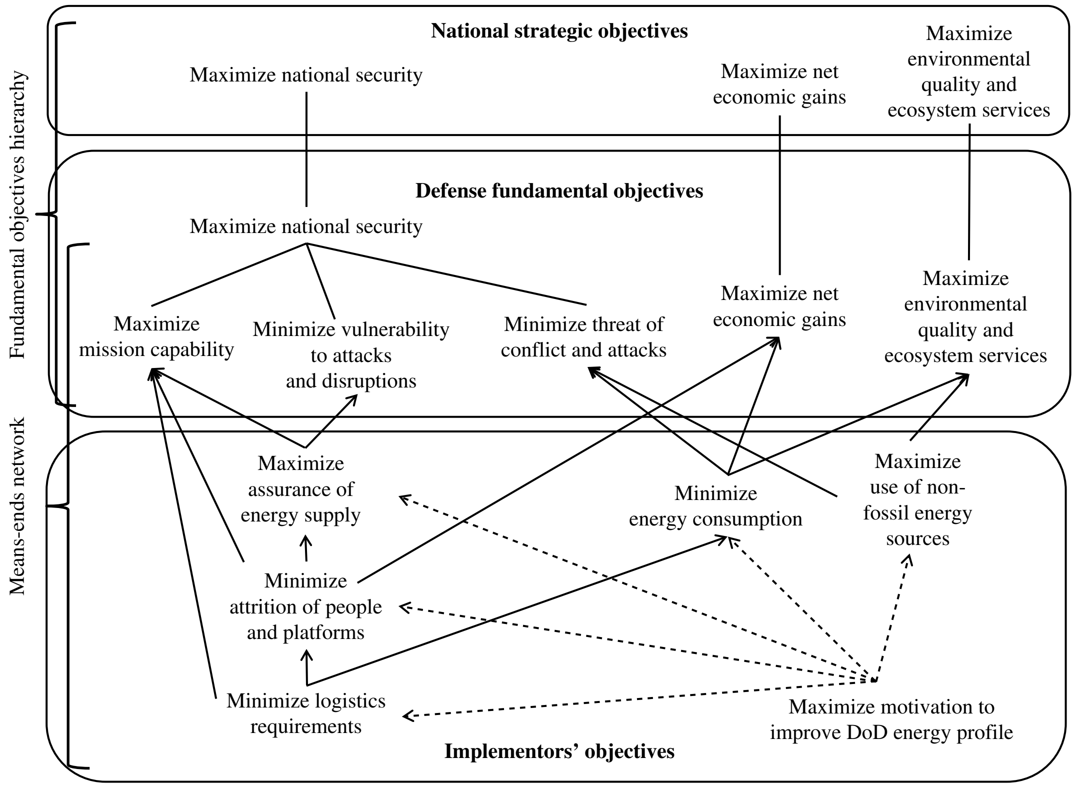
3.1. National Strategic Objectives

Maximize National Security. Security is challenging to define, but it is suggested clearly as an objective in 20 of the 44 reviewed documents and is central to the DoD (2013) mission statement: "The mission of the Department of Defense is to provide the military forces needed to deter war and to protect the security of our country." We treat *national security* as defined by the three lower-level objectives that compose it, as discussed in §3.2.

Maximize Net Economic Gains. In the context of this work, this objective summarizes the impact of the resources expended to provide energy and, ultimately, some type of output. The resources expended are not available for other purposes, which may affect other entities within the DoD, other federal government activities, and the nation as a whole. The economic impacts are usually expressed in terms of the costs of providing energy, but there may also be secondary impacts of energy decisions within the DoD; for example, an innovation within the DoD may lead to the development of a new industry in the private sector.

Maximize Environmental Quality and Ecosystem Services. Environmental quality refers to the health of the natural environment and minimization of exposure and toxicity to humans and damage to animals and

Figure 1 An Objectives Hierarchy and High-Level Means-Ends Network Illustrating the Energy Objectives of Concern at Different Organizational Levels



Note. A dashed line indicates an indirect link; that is, there are likely to be intermediate means objectives in a specific decision situation.

plants. Ecosystem services refer to all resources and support provided by the natural environment, such as food, water, oxygen, and regulation of temperature. A detailed exploration of ecosystem services is provided by Costanza et al. (1997). Greenhouse gas emissions and other pollution are the issues most relevant to energy-related decisions faced by the DoD. This objective captures considerations relevant to the nation as a whole, rather than exclusively to defense.

Table 1 A Small Portion of the Results Documenting the Appearance of Each Objective in the Source Documents

ID	Document	Minimize vulnerability to attacks and disruptions	Minimize threat of conflicts and attacks	Maximize assurance of energy supply
6	Supporting the mission with operational energy	P. 1 "It's about increasing our forces' endurance, being more lethal, and reducing the number of men and women risking their lives for more fuel."		
7	The proposed change strategy to embed energy stewardship into the Army's culture	P. 10 "The challenge is to successfully complete missions while reducing operational and tactical vulnerabilities associated with delivering energy resources."		
8	Department of Defense energy strategy: Teaching an old dog new tricks	P. 20 "U.S. dependence on huge amounts of oil and electricity to power our economy and our military creates much vulnerability."	P. 30 "The DoD needs... an energy strategy that... • Improves national security by decreasing U.S. dependence on foreign oil."	P. 30 "The DoD needs... an energy strategy that... • Ensures access to critical energy requirements."

Note. The complete results are given in Whitney et al. (2013, Table A.2).

3.2. Defense Fundamental Objectives

As indicated in Figure 1, two objectives propagate down from the national strategic objectives with no significant elaboration in definition. *Environmental quality and ecosystem services* are mentioned frequently in DoD documents, but no elaboration beyond the information in the national-level documents is given. The only difference we observe with respect to *net economic gains* is that some types of impacts—those not directly relevant to the DoD—are generally excluded from discussions at this level. The *national security* objective, however, which is the primary purpose of the DoD, may be defined by decomposing it.

Minimize Threat of Conflict and Attacks. DoD stakeholders would like to minimize the likelihood of conflicts anywhere in the world and attacks on U.S. interests arising as a result of reliance on scarce resources controlled by governments of potentially nonfriendly nations. In the reviewed documents and elsewhere within the DoD, there is concern that conflicts may arise over the assurance of access to energy supplies and that maintaining this access imposes constraints on U.S. foreign policy. For example, Ray Mabus, the Secretary of the Navy (SECNAV), testified that “we would be irresponsible if we did not reduce our dependence on foreign oil” (Schwartz et al. 2012, p. 18).

Maximize Mission Capability. *Mission capability* is a broad term for the ability to carry out missions to achieve a desired goal. It includes many different subcapabilities, and in a different type of study, it might be expanded into more specific objectives such as to maximize airlift capacity. Many performance measures used to assess capability, such as endurance, range, speed, and payload are related to *energy consumption*. Not all *mission capability* relates to combat; humanitarian aid and disaster response is a noncombat capability that enhances security. We discuss the challenges of further defining and measuring *mission capability* in §4.

Minimize Vulnerability to Attacks and Disruptions. *Vulnerability to attacks and disruptions* refers to the potential to experience attacks or disruptions to energy supply and the magnitude of the impact if they occur. Energy is related to vulnerability at the operational level because the supply chain is a target for adversaries, as discussed earlier, as well as at higher levels, since “[o]ver-reliance on petroleum is a critical strategic vulnerability for the Navy” (Chief of Naval Operations (CNO) 2010, p. 2).

3.3. Means Objectives

At the national and DoD levels, we have defined six strategic or fundamental objectives. However, at lower levels of the organization, it may be difficult for decision makers to directly relate the consequences of their decisions to these objectives. Thus, we identify means objectives that relate to the fundamental objectives and can be used to evaluate operational decisions. Of course, the number of possible means objectives for decisions throughout the entire DoD is enormous; we identify only those that are mentioned frequently in the guidance documents and are applicable to most energy-related decisions. In §4 we present an example of a possible means-ends network for a decision related to energy technology upgrades for Navy and Marine Corps installations.

Maximize Assurance of Energy Supply. *Assurance of energy supply*, in this context, refers to the availability of energy at the time and place it is needed for a given mission. Maximizing *assurance of energy supply* is a good example of an objective that can be considered a means objective for stakeholders at higher levels of the organization but is a fundamental objective for many decision makers at an operational level.

Minimize Attrition of People and Platforms. An argument could be made for treating *attrition of people and platforms* as a particular type of economic impact, but it is also important because lost assets often cannot be replaced immediately and can reduce *assurance of energy supply* in the short term, which decreases *mission capability* and increases *vulnerability to attacks and disruptions*.

Minimize Logistics Requirements. Logistics activities consume resources other than fuel, such as spare parts, and food and water for personnel. Moreover, logistics operations may become a target of attack, and they impose additional organizational and management challenges.

Minimize Energy Consumption. *Energy consumption* is the quantity of fuel, power, or other energy used. Depending on the context of the decision, it may be summarized in an aggregate measure, or categorized by location, purpose, or form (e.g., by fuel type).

Maximize Use of Non-Fossil Energy Sources. This objective refers to the ability to obtain and use energy from sources such as solar, wind, or biofuels, or even nuclear energy. Many of these sources are described as "alternative" or "renewable," because the total global supply is not fixed. The use of sources other than fossil fuels diversifies energy supply and thus reduces *vulnerability to attacks and disruptions* and price volatility, and generally reduces harmful emissions that affect *environmental quality and ecosystem services*. It also reduces dependence on foreign sources, which may affect the threats faced.

Maximize Motivation to Improve DoD Energy Profile. This objective refers to the workforce's awareness of energy issues and incentive to look for alternatives to improve performance with respect to all of the other objectives. Culture change, incentives, and for the Marine Corps, "ethos," were mentioned frequently and prominently in the strategic guidance from every service. *Motivation to improve DoD energy profile* is the quintessential means objective; it influences the achievement of virtually every other objective at the operational level. It creates conditions for easier implementation and sustainment of changes in the energy profile as well as identification of more and better alternatives in the future. It is similar to a *process objective*, as defined by Keeney and von Winterfeldt (2011); in this case, it influences the likelihood of good alternatives being identified and implemented successfully.

3.4. Redundant Objectives

As discussed earlier, the primary criterion for our set of objectives is completeness. However, there are several objectives that were mentioned in many of the documents that are deliberately excluded. We discuss nextthe way our objectives set captures four such excluded objectives.

Energy Security. Many of the documents refer to energy security, usually as an overarching term to capture all issues of concern relative to DoD energy. Roughead et al. (2012, p. viii) expand the definition beyond energy, and go so far as to state that "energy security and national security are increasingly being seen as one and the same." However, the documents define energy security in a number of different ways, and each definition is composed of one or more of the objectives in our set. For example, the Chief of Naval Operations (2010) defines energy security as follows:

> Energy security is having assured access to reliable and sustainable supplies of energy and the ability to protect and deliver sufficient energy to meet operational needs. (p. 4)

This definition is very similar to *assurance of energy supply*. The Army similarly defines energy security, but also mentions renewable sources. The Army Senior Energy Council and Office of the Deputy Assistant Secretary of the Army for Energy and Partnerships (2009) define energy security as

> Preventing loss of access to power and fuel sources (surety), ensuring resilience in energy systems (survivability), accessing alternative and renewable energy sources available on installations (supply), providing adequate power for critical missions (sufficiency), and promoting support for the Army's mission, its community, and the environment (sustainability). (p. 1)

This is simply a list of means objectives, all of which are captured either implicitly or explicitly in §3.3. We do not include energy security in our objectives set, as it is captured by the other objectives.

Efficiency. Efficiency, which we define as the ratio of a desired output to the amount of input used, is an objective mentioned frequently in the documents. It is sometimes unitless, as when both numerator and denominator are in the same units (e.g., the efficiency of a battery). It can also measure the rate of transformation of an input to an output, such as miles traveled per unit of fuel consumed. In either case, if both the output (numerator) and input (denominator) are represented in the set of objectives, including efficiency is redundant. The denominator in energy efficiency measures is captured by the *energy consumption* objective, and the numerator is captured by other desired outputs (primarily *mission capability*). Hence, we do not include efficiency.

Sustainability. Much like energy security, the term sustainability (or sustainable) is used frequently—it appears in about half of the reviewed documents—but is generally not defined. When it is defined, it is composed of objectives that do appear in the set. For example, the DoD Strategic Sustainability Performance Plan (DoD 2012, p. ES-1) states, "The [DoD] vision of sustainability is to maintain the ability to operate into the future without decline—either in the mission or in the natural and man-made systems that support it." This is captured primarily by *mission capability* and its supporting means objectives. The only added consideration is the time dimension; sustainability means that objectives are achieved over time, not just instantaneously. However, in a quantitative value model based on our set of objectives, this could be captured by using an intertemporal value model that includes a time index on each attribute, rather than by adding another objective.

Weight. Weight is another objective that appears in several documents. For example, the United States Marine Corps Expeditionary Energy Office (2011, p. 17), explicitly calls it an objective: "The objective is to allow Marines to travel lighter—with less—and move faster by reducing size and amount of equipment and dependence on bulk supplies." The Navy includes weight as well; the CNO (2010, p. 8) states, "To provide operational advantages that resonate across sea, air, and land, the Navy will 'lighten the load,' physically and in terms of power consumption, through weight-reducing advances to airframes, vehicles, and weapon casings, energy efficient technologies, or changes to policy." As described, weight is a means objective supporting the reduction of *energy consumption* and *logistics requirements*. Weight is a central component of *logistics requirements*, and is often relatively easy to measure. Although we exclude it from our set of broader objectives, it is a good candidate for use as a measurable attribute in many specific operational decision contexts.

4. Discussion

Measuring Objectives. To compare specific alternatives in energy-related decisions, it is important to be able to quantify each alternative's achievement of the relevant objectives. Quantitative measures are vital in allowing decision makers to think coherently about trade-offs among objectives, which are often competing. Stakeholders are often willing to make statements about the relative importance of various objectives, such as "cost and effectiveness are equally important." However, without a clear understanding of the measurement scales and the ranges within which trade-offs are being considered, such statements are meaningless. An unambiguous trade-off statement requires specific measurement scales and ranges. For example, the following statement is clear and can be used to compare desirability of alternative performance levels quantitatively: a $10 M life-cycle cost differential is "equally important" to a 5-knot differential in top speed.

Quantitative measures are especially important in large organizations such as the DoD that include many distributed decision makers. It is clear that if one DoD decision maker chooses to spend $50,000 to reduce annual consumption of diesel fuel by 5,000 gallons, and another DoD decision maker declines to spend $20,000 to reduce annual consumption of diesel fuel by 5,000 gallons, preferences of senior leadership have not been applied properly to both decisions. It is extremely difficult to ensure that trade-offs are evaluated consistently across decision makers without quantitative guidance. In this example, there could be organization-wide guidance specifying the maximum amount of money to be spent per unit of reduction in annual consumption of diesel fuel. One of the drawbacks of purely qualitative guidance is that it can be interpreted very differently by various decision makers within the organization; qualitative guidance should be viewed as an important first step in defining organizational preferences.

Natural Measures. The means objectives suggest a few natural measures that are reasonably straightforward to measure, and in some cases are comparable across different parts of the organization. *Energy consumption* may be the simplest to measure, as discussed earlier, in units of energy (such as kilowatt-hours) or fuel consumption. The importance of *energy consumption* may therefore differ based on where it occurs—for example, reducing *energy consumption* in a forward-deployed environment may be more valuable than the same reduction at an installation in the United States. Measures of *energy consumption* may need to be split by type and location.

Assurance of energy supply also suggests a natural measure: the probability that mission demand is met over a certain period under given circumstances, or equivalently, one minus the probability of failing to meet the demand. Assurance measures are specific to a mission, and while the nominal units may be the same, they are not equivalent across decision contexts, because the importance of the missions and the consequences of failure may differ substantially. *Assurance of energy supply* will therefore often need to be defined relative to a given geographic, temporal, or mission scope.

Attrition of people and platforms can be measured in natural units, either aggregating or separating loss of lives and loss of assets. However, the challenge with respect to this objective is prediction. For example, in retrospect, it is straightforward to estimate attrition to the logistics convoys supplying fuel to NATO forces in Afghanistan (Eady et al. 2009). When decisions are made regarding acquisition of fuel-consuming assets and deployment of troops, however, estimating attrition or its relationship with these alternatives is extremely challenging. It is possible that a given attrition measure (e.g., lives lost) may be comparable across decision contexts, and equivalent in terms of organizational preferences. This would imply similar trade-offs with respect to other objectives. For example, if stakeholders believe it is worth 60,000 barrels of F-76 (a type of diesel fuel) *energy consumption* to save one statistical life in a particular decision context, that same information about preferences between these two objectives would likely apply elsewhere.

Measuring Mission Capability. The term *mission capability*, or often simply *capability*, is often used in DoD as a desirable quantity to maximize, but it is rarely defined precisely, and therefore it is difficult to measure. Air Force Policy Directive 90-16 (2011, p. 8) defines capability as "[t]he combined capacity of personnel, materiel, equipment, and information in measured quantities, under specified conditions, that, acting together in a prescribed set of activities can be used to achieve a desired output." In other words, capability is defined within the context of a detailed scenario, which specifies an operation or mission. Sometimes, with an appropriate modifier, the term capability refers to a very specific function; for example, "UNREP capability" describes a logistics vessel's ability to replenish another vessel while underway. Capability is also used to refer to much more complex functions, such as "long-range strike capability" and "space capability" (DoD 2010).

DoD capabilities are grouped into nine top-level Joint Capability Areas (JCAs), with further hierarchical elaboration (DoD 2011). Within the relatively narrow context of installation energy, Samaras and Willis (2013) proposed a capabilities-based planning framework for evaluating DoD installation energy assurance alternatives, and identified 45 relevant JCAs at the second through fifth hierarchical levels. Disaggregating capability even to a single level would dwarf the remainder of the hierarchy, whereas only a small portion of the additional detail would be relevant for any given energy decision context. Therefore, we do not elaborate further on measures of *mission capability*. Rather, we identify other objectives that need to be evaluated so their impact on performance with respect to capability and preference trade-offs may be evaluated in specific analyses. For example, the USMC uses the Marine Air-Ground Task Force Power and Energy Model (MPEM) that relates fuel consumption to the number of vehicles that can operate, within a given constraint.

Targets. In some cases, the strategic guidance expresses energy objectives as binary targets. For example, the SECNAV (2009) introduced five energy targets for the Department of the Navy (DON), briefly:

1. Contracts: include energy evaluation factors in contracts.
2. Green Strike Group: in 2012, sail a strike group on nuclear and biofuel power only, and in 2016, deploy a fleet including aircraft flying on only biofuels.
3. Consumption: reduce petroleum use by 50%.
4. Alternative sources: half of shore-based energy produced on-installation and from non-fossil-fuel sources by 2020.
5. Alternative sources: half of all DON energy derived from non-fossil-fuel sources by 2020.

Targets are generally specified with respect to an objective, often one that is a means objective at the high level, but a fundamental objective at lower levels. Targets can be expressed in terms of multiple objectives; the SECNAV's Target 4 includes both the source of energy (*use of non-fossil energy sources*) and the location at which the energy is generated (related to *assurance of energy supply*). Targets 2–5 are consistent with our set of objectives. In particular, Targets 2, 4, and 5 focus on maximizing *use of non-fossil energy sources*, and Target 3 addresses a combination of minimizing *energy consumption* and maximizing *use of non-fossil energy sources*. Target 1 is an initiative that the SECNAV believes will support the pursuit of the objectives by encouraging consideration of them in a particular class of decisions.

Bordley and Kirkwood (2004) discuss assessment of preferences in situations where attributes are defined in this way and stakeholders do not care about the degree to which a target is missed or exceeded. However, we are skeptical that these binary targets truly capture the SECNAV's preferences. Rather, targets are a policy tool often used by managers at a high level in an organization to improve motivation of decision makers at lower levels and to focus their attention on important objectives (Casey et al. 2008). The SECNAV's targets have been effective in this respect. When a decision maker is trying to help the organization meet these targets, however, there is no guidance about how other considerations should be balanced against the specific objectives included in the targets. For example, if running a fleet on biofuels requires reducing the maximum speed of some of the vessels, or if it requires maintaining a longer supply chain, is that choice consistent with the SECNAV's preferences?

An additional challenge for decision makers relying on these targets is that most individual decisions will have very little impact on whether a target is met. This makes it even more difficult to use the targets to assess the relative value of improved performance on each objective. The set of targets gives some insight into the objectives the SECNAV would like to pursue, but a helpful further step would be to provide guidelines about what sorts of trade-offs between objectives are appropriate.

Differences Across Services. In addition to the differences across organizational levels discussed earlier, there are noticeable differences in the frequency with which objectives appear in documents from each of the military services. Figure 2 shows the percentage of documents from each service that included each objective. Although this is by no means a rigorous measure of the services' priorities, it does provide some interesting qualitative information. The Air Force appears to be more explicitly concerned about *cost* than the other services are. *Motivation to improve DoD energy profile* also appears in every Air Force document. The Marines focus on expeditionary sustainability, which emphasizes decreasing *energy consumption*; they are less concerned with *vulnerability to attacks and disruptions* and *assurance of energy supply*. The Air Force and Navy both focus heavily on maximizing *use of non-fossil energy sources*; nearly all of their documents include this objective.

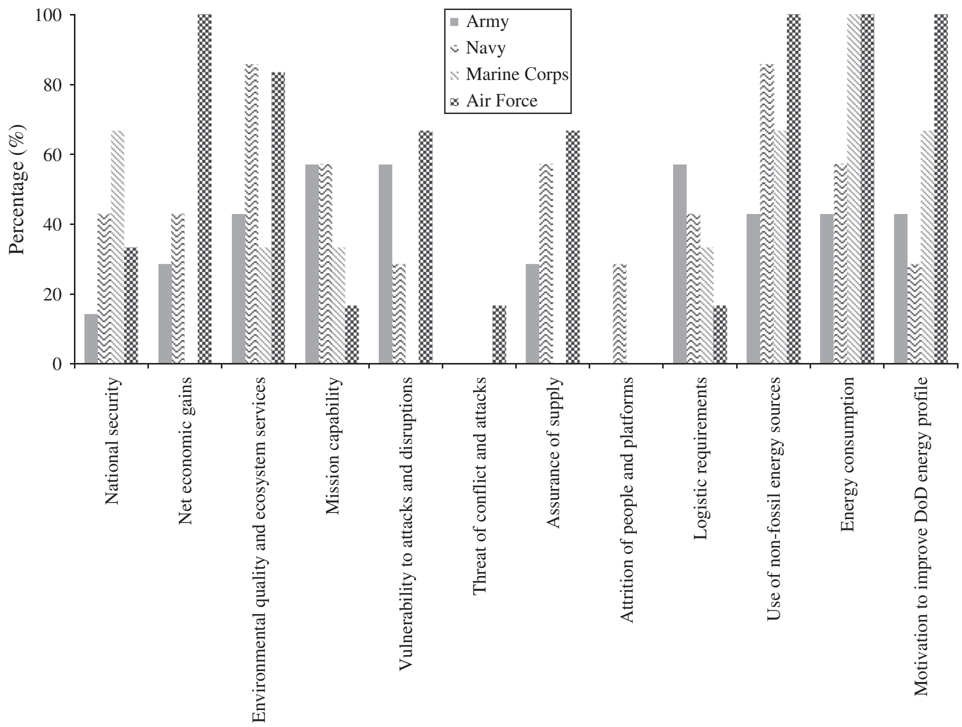
Example: Energy Return on Investment (eROI) Tool. As part of its implementation of the National Defense Authorization Act (2009) for fiscal year 2010 for shore energy management, the CNO issued OPNAVINST 4100.5E (Department of the Navy 2012), which specifically requires prioritizing energy proposals "solely based on eROI criteria" (p. 7). The eROI criteria are defined, and a summary measure of eROI is calculated, using a spreadsheet-based tool that takes data for each proposed project and uses a multiattribute function to calculate an eROI value, as well as to report summary scores in subcategories. The eROI tool is therefore highly influential in determining the project selection decisions for installation energy management. Figure 3, reproduced from Naval Facilities Engineering Command (NAVFAC 2012), shows the eROI objectives hierarchy that formed the basis for the tool.

Table 2 describes how our five bottom-level fundamental objectives are addressed (or not addressed) by the eROI value model. Many of the means objectives we identify are captured in the eROI hierarchy. *Energy consumption* is stated explicitly, *assurance of energy supply* is phrased as "reliable energy" (and measured by outage exposure), and *motivation to improve DoD energy profile* is arguably addressed by some of the metrics supporting the "develop enabling infrastructure" objective. *Use of non-fossil energy sources* is related to the "energy flexibility" and "tech adoption" metrics.

However, several of the fundamental objectives are not fully captured and therefore the eROI objectives set violates Keeney's (1992) completeness criterion. Bond et al. (2008) found that individuals can typically identify only about half of their own objectives. It is possible that this result would apply to group objectives generation processes to some extent as well, and may explain why the fundamental objectives to *minimize threat of conflict and attacks* and *minimize vulnerability to attacks and disruptions* are not explicitly included. Whereas some of the eROI metrics have means relationships to these objectives, as noted in Table 2, the structure of the qualitative value model (Figure 3) would make it difficult to capture the value contributions of, for example, reduction in fossil fuel consumption on national security threats.

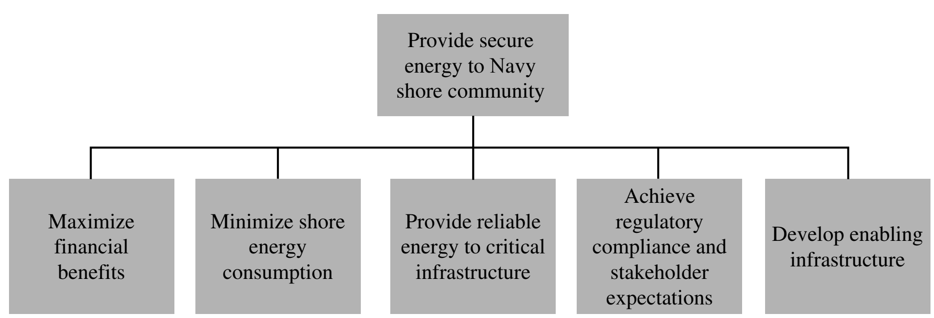
In addition, the set of eROI objectives violates both decomposability and nonredundancy, identified by

Figure 2 The Percentage of Source Documents from Each Service That Include Each of the Twelve Objectives



Keeney (1992) as desirable properties of an objectives set. Using a separate objective (fourth objective in Figure 3) to capture the value of meeting mandates that relate to consumption and financial benefits creates the possibility of double-counting the value associated with some impacts. For example, efficient lighting

Figure 3 The Objectives Hierarchy Used as the Basis for the eROI Spreadsheet



Metric	Financial net present value (NPV)	Utilities	Scoring scale • MDI • Outage exposure • Incremental backup	Scoring scale • Mandates • Public perception • Quality of service	Scoring scale • Data improvement • Energy flexibility • Tech adoption
Measure	Dollars	MBTU	Scaling questions	Scaling questions	Scaling questions
Weight (%)	39	9	26%	13	13

Notes. Reproduced from NAVFAC (2012). MDI stands for Mission Dependency Index. MBTU stands for Million British Thermal Units.

Table 2 **A Comparison Between the DoD Fundamental Objectives Identified in §3.2 and the Objectives and Metrics Used in the eROI Value Model Shown in Figure 3**

Figure 1 fundamental objective	Related eROI objectives	Comments
Maximize mission capability	Provide reliable energy to shore infrastructure	*Assurance* is a means objective supporting capability; it is not clear whether the eROI objective captures all benefits of on-site power generation.
Minimize vulnerability to attacks and disruptions	Provide reliable energy to shore infrastructure	*Assurance* is a means objective; eROI metrics do not reflect cause of outage (environmental or adversarial).
Minimize threat of conflicts and attacks	Minimize shore energy consumption	*Consumption* is a means objective; there is no indication that the eROI value model captures impact of reduced consumption on threats.
Maximize net economic gains	Maximize financial benefits, minimize shore energy consumption	The eROI model considers only direct cost savings, not broader economic impacts.
Maximize environmental quality and ecosystem services	Minimize shore energy consumption, develop enabling infrastructure	*Consumption* is a means objective; enabling infrastructure is clearly not fundamental; the metrics supporting enabling infrastructure may not capture all contributions to environmental impacts.

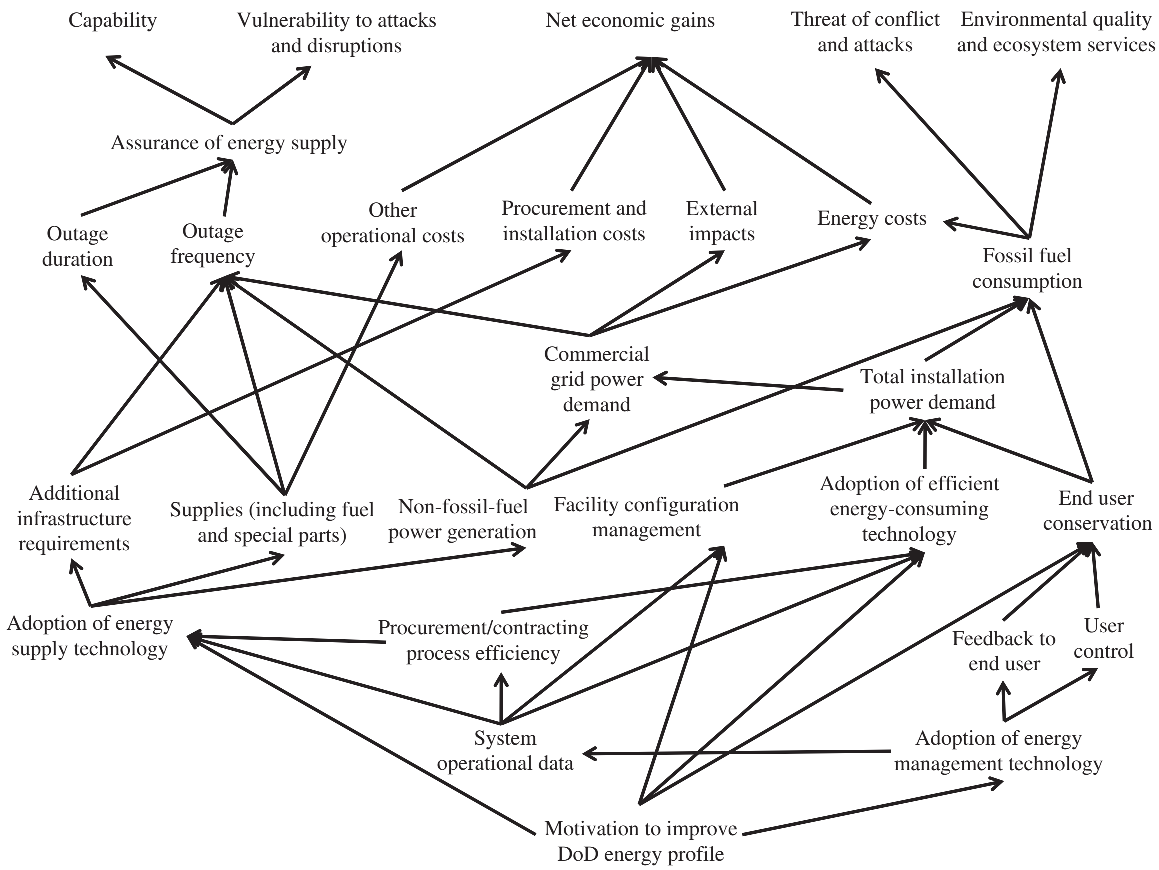
and photovoltaic projects contribute to financial cost savings and reducing installation energy consumption. They also contribute to meeting SECNAV targets and executive and legislative mandates, such as the requirement of Executive Order 13514 (2009) for new federal buildings to achieve "net-zero" (on-site power generation exceeds total requirement) by 2030. Because the mandates were motivated by the same strategic objectives of *national security*, *net economic gains*, and *environmental quality and ecosystem services*, the design of the eROI tool appears to double-credit some project impacts. VFT principles suggest that removing the fourth eROI objective, and creating one or more new objectives (if needed) to capture any aspects of higher-level preferences conveyed in the mandates that are not already covered by other objectives, would lead to a better quantitative value model.

The means-ends relationships among objectives shown in Figure 1 clarify the mechanisms by which means objectives and possible metrics support the strategic objectives. Understanding these relationships would support developing value models that better reflect strategic guidance. The eROI spreadsheet reveals some features that appear inconsistent with the strategic guidance, and could be made more consistent by a more careful consideration of the means-ends relationships. For example, the eROI spreadsheet includes the financial cost and greenhouse gas emissions associated with *energy consumption*. However, as shown in Figure 1, *minimize threat of conflict and attacks* is also one of the fundamental objectives supported by the *energy consumption* objective (and, we would argue, a very important one), but it is not captured in the eROI tool. By missing the contribution of consumption to threats, it by extension misses consumption's impact on *national security*.

In the eROI spreadsheet, *mission capability* is measured in terms of assurance, specifically the critical facilities supported and the ability to provide required energy during a supply disruption. However, it is not clear that it captures the potential of installation energy projects to reduce the frequency or likelihood of outages. The eROI spreadsheet credits a project that generates electrical power on-site as part of the objective to "achieve regulatory compliance and stakeholder expectations." Given that weights are assessed for the five top-level objectives, it is not clear that the value of on-site power generation in reducing the likelihood of disruption (and hence increasing *assurance of energy supply*) is captured.

The implementation of strategic guidance in the eROI spreadsheet illustrates some of the potential problems that can arise when measuring value with a quantitative tool based on a set of objectives whose interrelationships are not modeled carefully. Figure 4 shows a means-ends network based on VFT principles. The network excludes some means objectives that are not substantially influenced by decisions in this context, such as *attrition*. It includes more detailed means objectives that are directly relevant to installation energy technology and may be forecast or estimated based on knowledge about the technology under consideration, such as "Commercial grid power demand" and "Feedback to

Figure 4 **An Example Means-Ends Network for Energy Technology Adoption Decisions at DON Installations**



end user." This network illustrates how the DoD fundamental objectives can be pursued in installation energy decisions.

5. Conclusion

Decisions relating to energy within the DoD will have significant consequences in both the short and long term. There is a wealth of published DoD guidance regarding energy, but a lack of precision and consistency limits its practical usefulness in analyzing energy decisions. A value-focused thinking approach can help provide structure to decisions at all levels of the organization by identifying objectives, illustrating connections between fundamental and means objectives, suggesting possible ways of quantifying objectives, and providing a basis for evaluating specific trade-offs among competing objectives. The eROI tool shows some of the challenges and inconsistencies that can arise when developing a quantitative value model based on an objectives structure that does not follow VFT principles. Achieving the benefits of VFT is vital to ensuring that future energy decisions are consistent with the higher-level preferences of the organization and the nation.

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Appendix
Table A.1 lists the 44 documents reviewed in this work. Full citation information, quotes, and additional details about the documents are included in a technical report created by Whitney et al. (2013). The majority of the documents are available online to the public.

Table A.1 A List of Recent Documents Relevant to DoD Energy Policy Included in This Analysis

ID	Document	Source
1	Sustain the mission. Secure the future. The Army strategy for the environment	Army
2	Army energy security implementation strategy	Army
3	Energy security: Army priority and national imperative	Army
4	Use of the Army's strategic management system (SMS) to track Army energy security implementation strategy (AESIS) performance	Army
5	Army energy enterprise	Army
6	Supporting the mission with operational energy	Army
7	The proposed change strategy to embed energy stewardship into the Army's culture	Army
8	Department of defense energy strategy: Teaching an old dog new tricks	Brookings
9	Fueling the "balance": A defense energy strategy primer	Brookings
10	Energy Policy Act of 2005	Congress
11	Duncan Hunter National Defense Authorization Act for FY 2009	Congress
12	National Defense Authorization Act for FY 2013	Congress
13	Department of defense energy initiatives: Background and issues for congress	Congressional Research Service
14	More capable warfighting through reduced fuel burden	DoD
15	More fight—Less fuel	DoD
16	Report to Congress on energy security initiatives	DoD
17	Quadrennial defense review report	DoD
18	Energy for the warfighter: Operational energy strategy	DoD
19	The national military strategy of the United States of America	DoD
20	Operational energy strategy: Implementation plan	DoD
21	Sustaining U.S. global leadership: Priorities for 21st century defense	DoD
22	Energy Independence and Security Act of 2007: Major provisions of interest to federal energy managers	Federal Energy Management Program
23	Transforming the way DoD looks at energy: An approach to establishing an energy strategy	Logistics Management Institute
24	Naval energy: A strategic approach	Navy
25	The department of the Navy's energy goals	Navy
26	A Navy energy vision for the 21st century	Navy
27	Energy evaluation factors in the acquisition process	Navy
28	Department of the Navy (DON) objectives for FY 2012 and beyond	Navy
29	Shore energy management (OPNAV instruction 4100.5E)	Navy
30	Energy program for security and independence	Navy
31	Reenergizing America's defense: How the armed forces are stepping forward to combat climate change and improve the U.S. energy posture	Pew
32	Air Force energy program policy memorandum	Air Force
33	Air Force acquisition and technology energy plan	Air Force
34	Air Force aviation operations energy plan	Air Force
35	Air Force energy plan	Air Force
36	Air Force infrastructure energy plan	Air Force
37	U.S. Air Force energy strategic plan	Air Force
38	35th Commandant of the Marine Corps commandant's planning guidance	Marine Corps
39	Marine Corps vision and strategy 2025: Implementation planning guidance	Marine Corps
40	USMC expeditionary energy strategy and implementation plan: Bases to battlefield	Marine Corps
41	Executive Order no. 13423	White House
42	Executive Order no. 13514	White House
43	National security strategy	White House
44	Blueprint for a secure energy future	White House

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