STRATEGIC VULNERABLITIES OF US OFFSHORE WIND ASSETS:

A "NEW" US BORDER REQUIRES A LONG-TERM SECURITY PLAN

By

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ABSTRACT

The United States has set ambitious offshore wind power generation goals in support of its 2015 Paris Agreement commitments. However, climate change and the multi-polar geopolitical landscape will likely translate into significant vulnerabilities, particularly in the Atlantic, which is the focus of this research. Government and the private sector have spent the last twenty years addressing cybersecurity of critical energy infrastructure, but physical risks from extreme weather and/or sabotage have not been adequately considered. The Great Power Competition in the Arctic will bring near-peers close to US waters, and offshore wind distributed throughout the US economic exclusion zone will be attractive targets for hybrid warfare tactics. At present, the US has limited maritime capacity to protect those assets, and the regulatory risk assessment approach focuses on minimizing a wind project's impacts on its surroundings and other activities. The US will need a national, long-term offshore wind security plan to address risks to offshore wind, and federal agencies will need to better incorporate future security into current research, policy, and deployment efforts. Historical case studies from the US Gulf of Mexico, Texas and Ukraine help better understand the baseline for energy assets exposed to extreme weather events and hybrid warfare, and points towards challenges OSW will face in the future. This effort than looks forward at potential OSW vulnerabilities, how a multi-stakeholder body might prioritize those potential vulnerabilities through multi-criteria screening, and the need for both proactive and reactive controls. The analysis also addresses some key government entities that will need to be heavily involved. A framework is then proposed for how a multi-stakeholder process can be conducted, including a gaps analysis for adequately protecting offshore energy assets, and followed by development of a National US OSW Strategy and Roadmap for Long-Term OSW Security. The paper concludes by providing sample recommendations for short-term exercises and data collection projects that will help inform the larger and longer gaps analysis and roadmap process.

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PREFACE

I embarked upon this effort as my capstone project to complete my Masters in Energy Policy and Climate from Johns Hopkins University. As the reader progresses through the subjects to follow, it will quickly become clear that OSW security is a complicated and expansive subject that involves a plethora of agencies, issues, and challenges. Furthermore, the research suggests there is very little, if any, public deliberations to define and address future offshore wind security needs when it comes to kinetic risks. Indeed, the physical vulnerabilities of offshore wind assets are truly a nascent subject that 1) has not yet been tackled by US government or industry, and 2) demands peering into a future, but imminent, world that is warming faster than it likely ever has, and is bringing major geopolitical shifts along with it.

The challenge to explore such a complicated subject was certainly restricted by the time, length and structure constraints set for this one semester capstone course. In turn, this paper does not adequately cover all the relevant issues that I would have liked to address. Nevertheless, this paper reflects my best effort to frame at least some of the larger considerations and challenges in a methodical and thought-provoking manner. Hopefully, the reader will find that this paper is a sufficient primer that lays out a clear picture of why this subject needs attention, and a coherent path forward to begin the important and long security preparations that will be needed.

I extend my deepest gratitude to 1) Dr. Zachary who has been a dependable and steadying force for the Energy Policy and Climate program, including leading a fantastic summer course to study renewable energy projects in Northern Europe; and 2) William

Rogers, for both making the Climate Change and National Security course everything I hoped it would be, and agreeing to be my mentor for this challenging capstone. I would also like to acknowledge my DOE Fellowship mentor within the Hydrogen and Fuel Cell Technologies Office at DOE, Neha Rustagi, whose flexibility and kindness were certainly a blessing during a hectic research semester. Lastly, I would also like to thank all the DOE and Lab personnel from EERE, CESER, WETO, OE and NREL who gave a minute or an hour to explore the subject with me or point me in the right direction.

EXECUTIVE SUMMARY

Climate change is driving a US energy transition and US goals to build-out 30GW of offshore wind (OSW) by 2030, and subsequently adding more in deeper waters, stretching out into the Atlantic as far as the 200-mile EEZ boundary. Achieving these goals will inherently expose vital energy assets to future climate change impacts and geopolitical threats that stakeholders have never had to deal with before. This research points out that extreme weather events of not-previously-seen magnitudes and the Great Power Competition in the warming Arctic present serious threats to OSW power generation.

Using historical case studies for oil & Gas assets in the Gulf, storm impacts on the Texas grid and hybrid warfare attacks on undersea infrastructure abroad, the lessons learned and the US tendency to be reactive instead of proactive point towards OSW challenges to design and execute plans to minimize physical risks, even though impacts on energy, infrastructure and citizens can be extreme when such events happen. There are a variety of nodes or components within OSW systems that can be vulnerable to extreme weather, sabotage, or both. These risks need comprehensive identification, prioritization, and detailed exploration to understand 1) their potential significance to future grid reliability, 2) what adaptive capacities must be developed to minimize such vulnerabilities and maximize OSW resilience, and 3) what cascading impacts could unfold in an OSW disaster scenario.

While the skills, offices and commands exist to conduct this work and develop a comprehensive security plan, it has not begun, at least not to any public or material degree. Yet, the US now has its first commercial OSW farm operating in the Atlantic and another under active construction. DOE, DHS, and DOI must soon engage in active, multistakeholder discussions to 1) conduct a thorough OSW security gaps analysis, and 2) build a National OSW Security Strategy and Roadmap for standing up the resources and capacities required for the 2030s and beyond that is commensurate with our OSW generation goals.

The time to begin is now. An executive steering committee should be convened within the White House Office of Science and Technology Policy to guide the multistakeholder process described within. Concurrently, a variety of near-term actions can be taken within various agency offices and commands to collect data on current science, technologies, capacities, and hurdles that will be invaluable for the larger planning framework to build a National OSW Security Strategy and Roadmap.

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ACRONYMS

ALARP	As Low As Reasonably Practicable
API	American Petroleum Institute
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CEI	Critical Energy Infrastructure
CESER	Cybersecurity, Energy Security and Emergency Response
CISA	Cybersecurity and Infrastructure Security Agency
COP	Construction and Operations Plan
DHS	Department of Homeland Security
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DSCA	Defense Support of Civil Authorities
EERE	Energy Efficiency and Renewable Energy
EEZ	Economic Exclusion Zone
FAA	Federal Aviation Administration
GDO	Grid Deployment Office
GIUK	Greenland-Iceland-United Kingdom
GPC	Great Power Compeition
HSOAC	Homeland Security Operational Analysis Center
NM	Nautical Miles
NOIA	National Oceans Industries Association
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
NSR	Northern Sea Route
NUWC	Naval Undersea Warfare Center
O&G	Oil and Gas
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
OE	Office of Electricity
OSW	Offshore Wind
PRC	People's Republic of China
ROV	Remote Opewrartions Vehicle
RTO	Regional Transmission Operator
UNCLOS	United Nations Convention of the Law of the Sea
USAID	United States Agency for International Development
USCG	United States Coast Guard
USN	United States Navy
WETO	Wind Energy Technologies Office

INTRODUCTION

The United States clean energy transition that will present specific vulnerabilities for deploying clean energy technologies that policymakers, regulators, and utility operators have not adequately considered. While some attention has been given to the strategic vulnerability of clean energy supply chains, particularly regarding critical materials, there has been less attention paid to the strategic vulnerabilities of deployed technologies. To be clear, cyber security vulnerabilities within the critical energy infrastructure (CEI) space have been front and center in funding and attention for two decades now. This paper, instead, addresses the strategic vulnerabilities surrounding direct physical or kinetic risks that will intensify as the energy transition progresses, focusing on Offshore Wind (OSW) in the Atlantic as the main driver for the concerns and forward-looking proposal presented.

With various projections that the planet may surpass 1.5^{o}C permanently in less than a decade, federal agencies, state governments, private industry, and public stakeholders have been focused on technological, economic, financial, and environmental considerations for building out OSW. Throughout the siting, permitting, construction and operation process, the consistent focus is on how we get it done to meet national climate mitigation goals while minimizing impacts to the military, fishing, views etc., through extensive deconflicting processes. Yet, there is little discussion in public view about how we will protect these OSW assets once they are built. The US OSW plans, indeed, are critical climate mitigation but they also expand our geographic energy footprint, adding a "new" border vulnerability that this country has never face before. All involved stakeholders understand and prepare for the reality that we are expanding critical energy assets into potentially contested waters dozens of miles offshore, in the midst of a changing world order (Dalio, 2021).

Energy Resilience and Strategic Risks

The Department of Energy (DOE) defines Energy Resilience as "the ability of the grid, buildings, and communities to withstand and rapidly recover from power outages and continue operating with electricity, heating, cooling, ventilation, and other energy-dependent services" (DOE-EERE, 2024a). Energy Resilience from a military perspective is defined in Title 10 of the U.S. Code:

> *"The ability to avoid, prepare for, minimize, adapt to, and recover from anticipated and unanticipated energy disruptions to ensure energy availability and reliability sufficient to provide for mission assurance and readiness, including mission essential operations related to readiness, and to execute or rapidly reestablish mission essential requirements" (Cornell Law, 2024a).*

These two definitions together highlight the critical importance of energy reliability for basic human security, economic function, and national security, and why the placement of energy assets offshore could carry significant civilian and strategic ramifications. In other words, contrary to various perspectives found in the literature that distributed energy sources improve energy resilience, resilience through offshore distribution could have some severe shortcomings, if physical security is inadequately characterized and addressed. A significant objective identified this paper is to begin the process through which public and private stakeholders evaluate these shortcomings and identify the pathways required to move OSW security forward in a manner to maximize OSW value to US resiliency, while minimizing its potential to do the opposite.

OSW faces two significant strategic risks. The first risk comes from the increased threat of a Great Power Competition (GPC) in the Arctic, which is warming at four times the rate as the rest of the world and could be ice-free by 2050 (Rantanen et al., 2022). As the Arctic warms, the Russian Federation and the People's Republic of China (PRC) both have aspirations to lay claim to the Arctic region's vast natural resources, and that military buildup will bring near-peers closer to U.S. territorial waters than at any point since the Cold War, including areas where OSW is and will be operating. Those assets could be disrupted or attacked in a confrontation with these near peers, and how government and industry stakeholders, including DOE, Department of Defense (DOD), Department of Homeland Security (DHS) and asset owners, prepare for this emerging reality is important.

The second risk comes from the threat of climate change, particularly the increasing severity and intensity of hurricanes that appear insufficiently accounted for in the design and construction of CEI, including OSW farms and transmission. There is growing concern that climate change impacts are accelerating, which could increase such extreme weather risks, and evidence suggests that the US Government (USG), OSW industry, grid operators are not prepared (Hansen, 2023; Mann, 2024). Indeed, the US faces a Catch-22 in that that climate change drives both our mounting need to establish an OSW portfolio AND the risks those assets will likely face. Furthermore, the combination of living in a climate never experienced before by human beings, and novel global changes in geopolitics and balance of power makes evaluating our risks from a classical, historical perspective unrealistic. The US must use foresight to identify potential unforeseen events and failures that could significantly impact US security and resilience (Briggs and Matejova, 2019). The potential ramifications of Russia or another adversary exploiting the impacts of climate change, and climate change compounding the effectiveness of adversary sabotage must both be on the table when planning proactive controls to mitigate risk, as well as integrated disaster planning when proactive measures fail to build a "relentless resilience" (Redick and Jones, Nd).

Climate Security and the Sections to Follow

Climate security is "the study of socioeconomic and political impacts that develop between individuals, communities, and governments because of the effects of climate change, and the political consequences for human, national and global security" (Rogers, 2023).

How the US develops OSW and other offshore energy assets will influence US climate security (see Text Box), and this paper tries to tackle the subject wholistically, albeit superficially, within an overarching temporal construct. In the first section, the Literature Review, we explore how the stage is presently set. This paper takes a look at five essential ingredients contributing to OSW risks: 1) US OSW plans, 2) the GPC underway in the Arctic, 3) adversary Atlantic interests and Arctic spillover, 4) existing authority and military capacity available to protect OSW, and 5) the current US regulatory process and risk management approach for OSW development.

In the Methods section, the paper looks backwards at a few historical case studies to explore how offshore energy assets have been exposed to extreme weather events and sabotage in the US and abroad. The following Analysis section builds off these case studies, applying those lessons learned to OSW combined with some of the inherently limitations that comes with such a nascent industry.

The Results section turns to the future, looking at U.S. government preparedness to tackle OSW security and considering the major agencies likely to be involved in developing a long-term security plan. This section also explores specific nodes or components within a grid-connected wind farm that could be vulnerable to physical risks and shows one method to prioritize those risks. Lastly, it touches upon the potential for these risks to emerge as complex scenarios that are important to consider when developing a comprehensive security approach that includes emergency response.

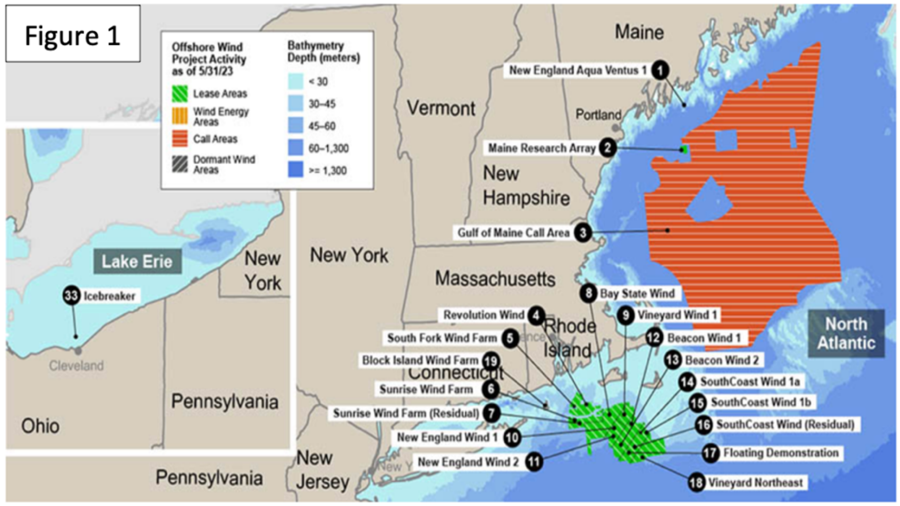
The Discussion section pulls back to a broader view of what this research reveals about US energy security risks in a world where important energy generating assets are distributed out in the ocean. It pushes for all involved stakeholders to take advantage of the opportunity to be proactive and develop an OSW security plan that commensurate with our OSW goals. Lastly, this leads into several Recommendations proposed, which includes a multi-stakeholder framework to inform government and the private sector on the complex issues involved, as well as make some example near-term actions that will help inform the larger, longer planning process.

LITERATURE REVIEW

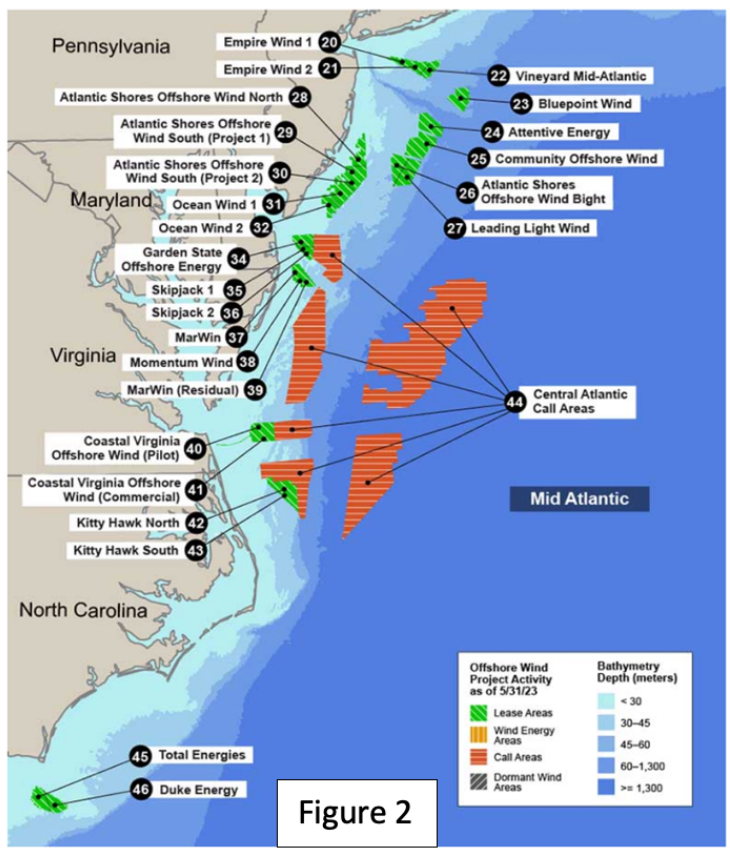
Offshore Wind Powering the Atlantic Coast

Scope of US OSW

Goals - The Biden Administration set an ambitious goal of achieving 30 GW of OSW by 2030, in support of meeting 2015 Paris Agreement commitments (The White House, 2021). Within the US sector-by-sector pathways portion of its Nationally Declared Contribution, the US specifically sets 2035 for achieving 100% carbon pollution-free electricity generation, of which OSW will be a part (USG, Nd). For the Atlantic specifically, the National Renewable Energy Lab (NREL) indicates 45 OSW projects are being considered or developed,



The locations of the current U.S. North Atlantic Coast offshore wind projects being considered or developed as of August 2023. *Map by NREL*



The locations of the current U.S. Mid-Atlantic Coast offshore wind projects being considered or developed as of August 2023. *Map by NREL* stretching from Maine to South Carolina (NREL, 2023). Figure 1 shows the NREL map for North Atlantic projects and Figure 2 shows the Mid-Atlantic plans (NREL, 2023). Modeling indicated that OSW could provide 1-8% (31-256 GW) of the US power generation by 2050, and make-up 20% of the energy servicing the Atlantic Coast regionally, powering the equivalent of over 89 million homes, as well as critical defense and energy infrastructure (Beiter, et al.; 2023; DOI-BOEM, 2023).

The Administration also announced the plan to deploy 15 GW in deeper waters (>60 meters in depth) farther from the US coastline by 2035, utilizing floating foundations (White House, 2022; Paya and Zingeng Du, 2020). In fact, two-thirds of the total potential US OSW resource is in deeper waters, stretching out to or beyond the 200-nautical mile limit of the Exclusive Economic Zone (EEZ) and amounting to 2.8 terrawatts of power generation, as illustrated in Figure 3 (Visconti et al., 2022; DOE-EERE, 2022).

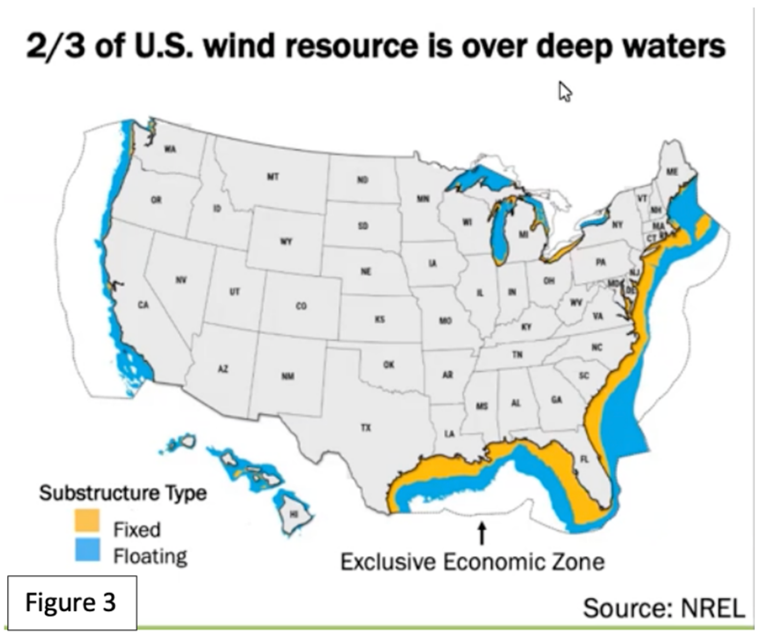
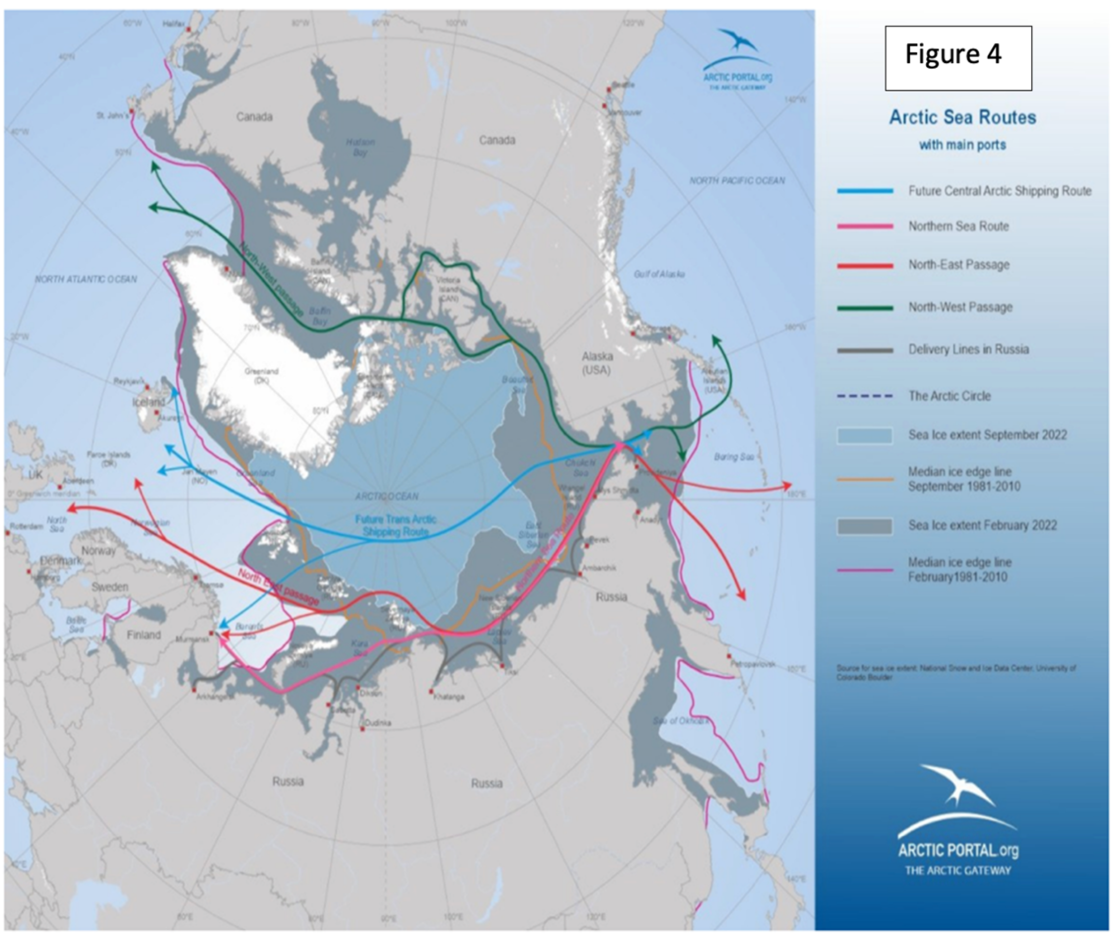


Figure 3

Such US OSW potential and intentions clearly show OSW security will be an issue about real estate. With the emergence of OSW off US seaboards, exercising and protecting US sovereign rights out to 200 nm per the 1982 United Nations Convention of the Law of the Sea (UNCLOS) changes drastically, as vital energy assets are distributed across hundreds of thousands of square miles within the East Coast EEZ (USGS, 2006).

Warming Arctic and the Great Power Competition

Much like building out OSW assets in the Atlantic EEZ is an issue of real estate and security of that real estate, so too is the case with sovereign interests in the Arctic. The riches of oil and gas reserves, critical minerals and fishing are well documented in the literature (EIA, 2012; Desjardins, 2016; Rowe, 2022; Perez, 2020a). Additionally, the trade routes will also be of great interest as the Arctic warming accelerates; see the National Snow and Ice Data Center map of the routes and ice coverage in 2022 (Figure 4, Arctic Portal, 2023).



These direct and valuable interests are creating the GPC among the eight Arctic States, whose EEZ rights butt up against each other via water boundaries (Figure 5, Perez, 2020a). With these Arctic interests and EEZ border issues well known, it is the possibly less known active military expansions by Russia and the PRC that signal a disadvantage for the US and risk to OSW.

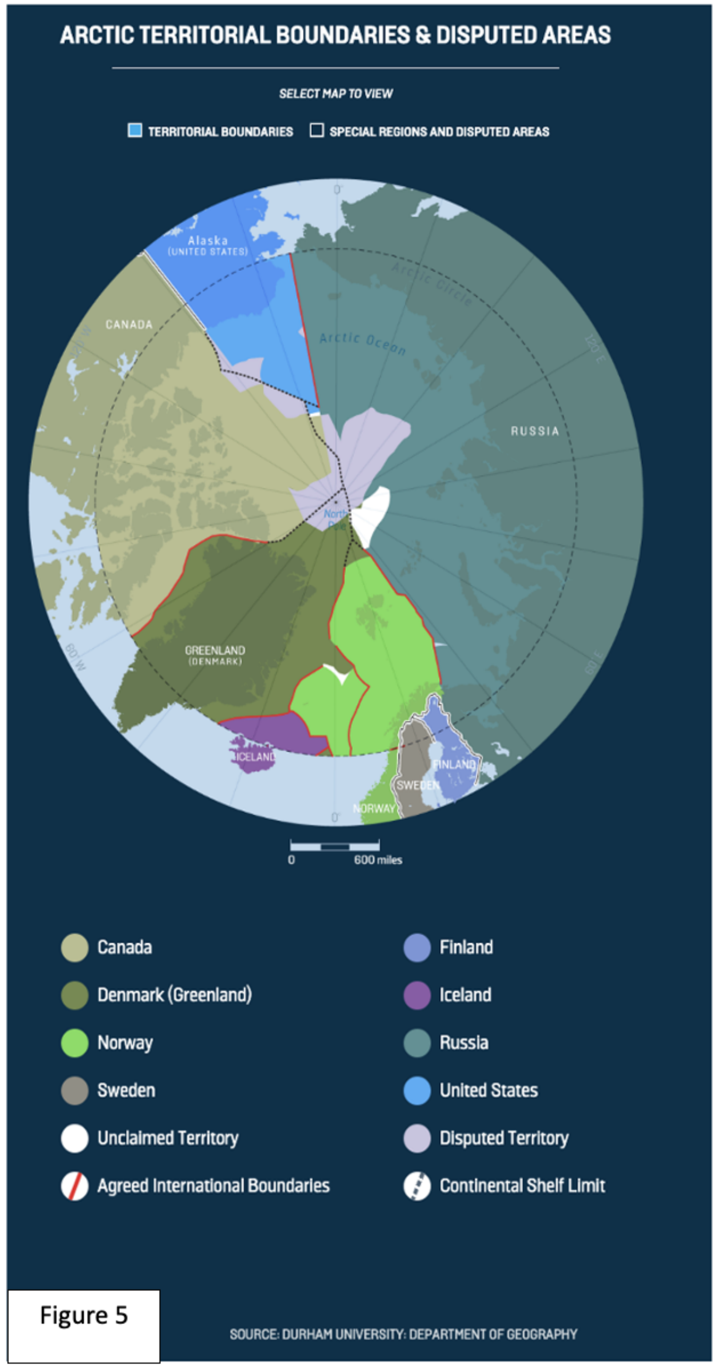


Figure 5

<u>The Adversary Advantage in the Arctic</u> - The US is at a clear disadvantage in the Arctic because Russia dominates both geographic right and force presence. The Russian coastline is approximately 24,000 km in length and makes up 53% of the total Arctic coastline (Perez, 2020a). Its deep interests in the Arctic are rooted in Russia's Arctic resources, which have been estimated to approach $2 trillion and could support its growth for decades (DW, 2023). With the intention to capitalize on

these riches, Russia has reopened tens of Arctic Soviet-era military bases, modernized it Navy and has one of the largest submarine fleets in the world at 58 (NTI, 2023a). In the Northwest part of Russia is its largest Arctic port, Mumansk, which is the headquarters of the Northern Fleet and accommodates half of Russia's nuclear submarine and a fleet of icebreakers (DW, 2023). Recently, Russia designated the Northern Fleet as its own military district (Russia's 5th), with its specific responsibilities being the Arctic, Arctic coastline, and the Northern Sea Route (NSR) (Humpert, 2021). During this period, Putin also approved the NSR Development Plan at the end of 2019. This plan includes "at least 40 new Arctic vessels, including eight nuclear-powered icebreakers and 16 rescue and support ships by 2035," noting some "will be Lider-class ice breakers, allowing them to break through extremely thick Arctic ice and open wide enough shipping lanes for large commercial ships" (Menosky, 2020).

While Russia's focus in rejuvenation of Arctic military infrastructure and capacity, the PRC has been equally active in force projection and economic investment in the Arctic, as well as specifically in Russia. China describes itself as a Near-Arctic State in its Arctic Strategy released in 2018, which identifies the Polar Silk Road as part of its global Belts and Roads Initiative (PRC, 2018). The PRC Arctic intentions include pursuing local economic partnerships, infrastructure development, extractive industries, and emerging maritime shipping corridors (Lanteigne, 2022). China invested $1.4 trillion through foreign direct investment from 2005 to 2017, and over the last five years of that span invested in 281 different projects within Russia, averaging $692 million each (Perez, 2020a). Regarding power projection, China has surpassed the US as having the largest naval fleet and is working diligently to expand its submarine fleet that is rumored to include uncrewed underwater vehicles with torpedo-launching capabilities (McNeil, 2023). As of the beginning of 2023, the US estimated that China had 56 submarines could grow by 10-15 additional subs by the end of the decade (NTI, 2023b). Approximately 40% of China's diesel-electric subs are air-propulsion enabled, which makes them quieter compared to nuclear versions, and are considered quite formidable in chokepoints, coastal areas and near ice-covered areas (NDIA, 2007).

Robert M. Gates, who has served as Director of CIA and Secretary of Defense, stated it bluntly just last year, indicating the US faces "graver threats to its security than it has in decades, perhaps ever," and that "Russia and China are working together against US interests on every continent," while the US is "incapable of mustering the unity and strength necessary to dissuade them"(Gates, 2023). Russia clearly views the Arctic as an extension of its territorial sovereignty, and it's Arctic aspirations combined with increasing Arctic access risks the increase of Russian military adventurism in close coordination with its main ally, the PRC. It is that military adventurism that signals increasing problems for the Atlantic.

Adversary Atlantic Interests and Arctic Spillover

While the Atlantic basin receives less attention due to higher profile activities and conflict elsewhere, the Atlantic is the most heavily traveled basin; its commercial flows outpace the Pacific; it has the densest communications cabling in the world; and it is growing in global importance for both fossil and renewable energy supplies (Brookings, 2024). Thus, it is telling that, in 2016, Russia revamped its national security strategy, which included unfettered maritime access to the Atlantic (Smith and Hendrix, 2017). In support of this objective in 2019, Russian military held exercises in the Greenland-Iceland-United Kingdom (GIUK) Gap, a vital naval chokepoint during periods of war and used by NATO to contain the Soviet Union during the Cold War, which “included ten Russian submarines—eight of which were nuclear-powered—patrolling the GIUK gap, all four of Russia’s naval fleets and 12,000 troops,” and is believed to be the “largest such demonstration since the Cold War” (Figure 6 , Smith and Hendrix, 2017; Tossini, 2023; Perez, 2020b). Once through this chokepoint, Russia has direct access to the portions of the Arctic and Northern Atlantic that are closet to Eastern US and Canada. As cause for concern, some military circles believe the fourth battle for the Atlantic has begun, noting that Russian submarine patrols having increased by 50% over the last decade, and Russia’s current activity in the Atlantic is “at a high level most of the time, [and] at a higher level than we’ve seen in years” (Shinkman, 2023; Foggo III and Fritz, 2016).

Figure 6

Not only with adversarial activity be close to US OSW, but it will also be close to Canadian OSW. Created on Google Earth, Figure 7 shows the locations of various OSW under consideration for Newfoundland, Prince Edwards Island and Nova Scotia, as well as the relatively short distances of planned OSW assets from the tip of Greenland. It is important to remember that Canada's OSW vulnerabilities are US vulnerabilities, and vice versa, because five provinces of Eastern Canada and Northeast US, from New York to Maine, are connected through the grid under the Northeast Power Coordinating Council (NPCC); and, there have been more than one major blackout that has impacted parts of both the Eastern US and Eastern Canada, including one that affected 50 million people in 2003 (D'Hooge, Nd; NPCC, 2022).

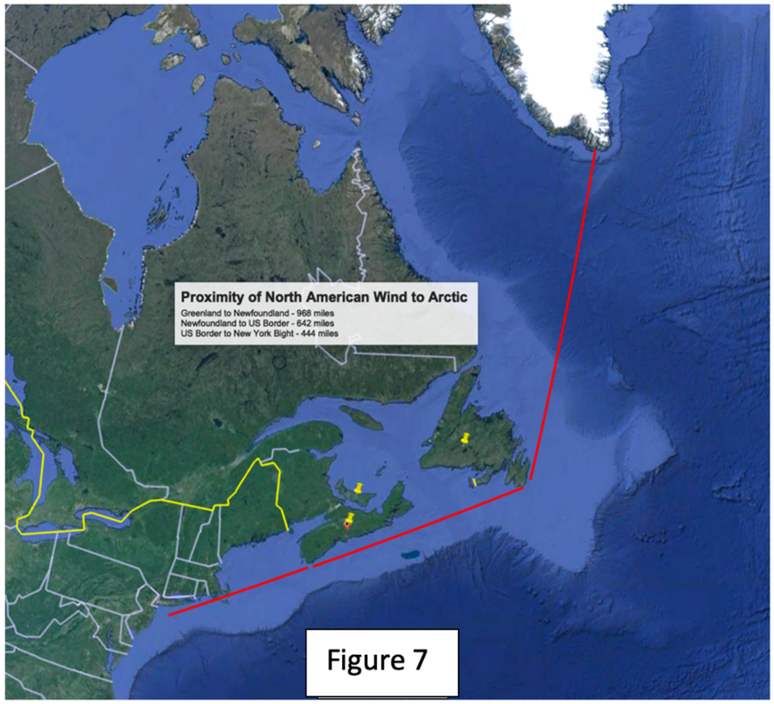


Figure 7

Authority and Military Resources

Any asset that is exposed to a risk is only vulnerable if the adaptive capacity is insufficient to mitigate that risk. In turn, it is important to look at the baseline of our military capabilities within the Atlantic basin. Additionally, it is important to understand who has authority regarding offshore assets.

Basic US and International Law - Based on the United Nations Convention on the Law of the Sea (UNCLOS), the US has sovereign rights to EEZ, which includes to everything within 200 nautical miles off the coast, and these rights include "activities for the economic exploitation and exploration of the zone, such as the production of energy from the water, currents and winds" (NOAA, 2024). There are also Territorial and Contiguous waters out to 12 nm and 24 nm that provide a State with the right to "both prevent and punish infringement of fiscal, immigration, sanitary, and customs laws" (Tufts, 2017).

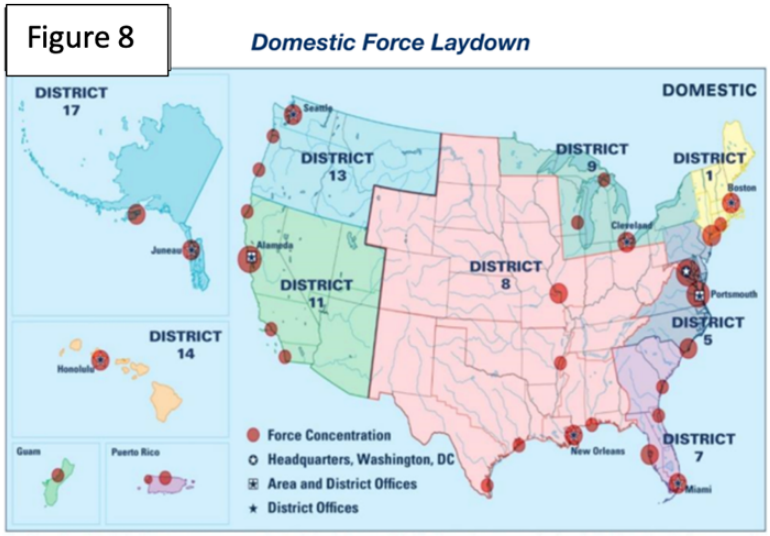
As for US Law, it is the Outer Continental Shelf Lands Act (OCSLA) of 1953 "affirmed that the Federal Government exercised exclusive control over the Outer continental shelf (OCS), defined as all submerged lands beyond the lands reserved to the States up to the edge of the United States' jurisdiction and control" (DOI-BOEM, 2024a). The Submerged Lands Act of the same year gave individual states rights to the natural resources of the submerged land up to 3 nm. Authority over these waters generally falls to the US Coast Guard (USCG) as the lead federal maritime law enforcement agency, which uniquely possesses both the authority and capability to enforce national and international law on the high seas, outer continental shelf, and inward from the EEZ to inland waters (USCG, 2024a).

Table 1

Mission Category	Mission
Safety	Search and rescue
	Marine safety
Security	Ports, waterways, and coastal safety
	Drug interdiction
	Migrant interdiction
	Defense readiness
Stewardship	Aids to navigation and waterway management
	Ice operations
	Living marine resources
	Marine environmental protection
	Other law enforcement

US Coast Guard Capacity and Authority - The Coast Guard has 3 basic roles that involve 11 Missions (Table 1, Tingstad et al., 2018). Executing these

Figure 8



The Coast Guard is divided into two area commands, the Atlantic Area and Pacific Area. The areas are further divided into nine district commands. The Atlantic Area includes five district commands covering the Eastern United States, the Atlantic Ocean, the Great Lakes, and the Gulf of Mexico. The Pacific area includes four district commands covering the Western United States and the Pacific Ocean.

missions within the Atlantic Basis falls to the USCG Atlantic Command and 1st, 5th and 7th Districts that encompass the Eastern Seaboard, as shown in Figure 8 (USCG, 2024b). Worth noting, while the 7th District is responsible for as far north as the North Carolina-South Carolina border, it is responsible for a 1.7 million square mile area that also includes Georgia, Florida, Puerto Rico, and 34 foreign nations and territories (USCG, 2024c). The 1st District has a total of six Cutters, while the 5th District has eight (USCG, 2024d; USCG, 2024e).

Specific to the USCG's involvement with the OSW industry, the recently updated Navigation and Vessel Inspection Circular No. 02-23 provides guidance on its roles and responsibilities through DOI's OSW development on the OCS. This NVIC "identifies the information the Coast Guard will use to evaluate and mitigate the potential impacts of OREI leasing, construction, and operations on the Marine Transportation System (MTS); navigation safety; vessel traffic; traditional uses of waterways; and Coast Guard missions," as well as "provides guidance to members of industry, port safety and security stakeholders, and the public on the Coast Guard's role and responsibilities in the OREI leasing and plan review process" (USCG, 2023).

There are also significant interagency workgroups throughout the siting and permitting process that tackle specific concerns that wind farms may cause for ongoing USCG missions. For instance, as one specific issue, DOE has worked with DOD, DHS, the Federal Aviation Administration (FAA), the National Oceanic and Atmospheric Administration (NOAA), and the Department of Interior's (DOI) Bureau of Ocean Energy Management (DOI-BOEM) since 2014 on the Wind Turbine-Radar Interference Mitigation Working Group (DOE-EERE, 2024b).

While minimizing impacts OSW may have on the USCG is a major focus, this research has been unable to uncover who is addressing the extent to which the OSW will demand protective support from USCG. Furthermore, it is not clear that the USCG has the authority and capacity to protect them. As one example of such ambiguity, consider the USCG's FY2020 report to Congress:

> *OREIs [Offshore Renewable Energy Installations] may be located outside of 12 NM and do not meet the definition of Outer Continental Shelf Facilities under Title 33 CFR § 101.105, which are facilities that explore, develop, or produce oil, natural gas, or mineral resources. Under the current COTP [Captain of the Port] authority, the Coast Guard does not regulate the safety and security risks associated with the construction and operation of OREIs beyond 12 NMs (USCG, 2021).*

US Navy Role – Within DOD, US security and interests in the Atlantic basin are the responsibility of the 2nd Fleet, projecting power, protecting the homeland, and connecting US and allied navies across the Atlantic and the Arctic (USN, 2024a). Its area of responsibility covers millions of square miles of the northern Atlantic up to the

Barents Sea within the Arctic circle and bordering Russian waters (Lagrone, (2018a). The 2nd Fleet had been disbanded in 2011 but, due to the evolving Russian security environment, it was reestablished in 2018 (Lagrone, 2018b). Since then, specific efforts have been underway to improve readiness and response times for heavier Atlantic activity by adversaries, while working around growing capacity limitations, such as maintenance backlogs. For instance, Task Group Greyhound was established in September 2021, following a plan "to take destroyers that have recently completed deployments and are awaiting maintenance availabilities and make them ready for training and operations in the Atlantic" (Shelbourne, 2021). Greyhound was specifically established to hunt submarines and utilizing destroyers coming back from deployment and, thus, provide most ready and most experienced vessels and crews. The goal is for there to be four fully certified and continuously ready destroyers identified in the schedule, permitting two being available at any given time (Shelbourne, 2021). While it is only two ships and the impetus for the move are Russian subs with long-range, land-attack missiles and forthcoming nuclear torpedoes, this Atlantic response capability would likely contribute to OSW risk reduction. Still, growing geopolitical instability will continue to strain such capacity, noting that in 2022 the 2nd Fleet conducted a first-of-its-kind forces surge to the North Atlantic for three months in response to a top US commander's request in the region amid heightened tensions with Russia (Woody, 2022).

Beyond such typical mission expertise, the Navy (as well as other DOD branches) participates in the Defense Support of Civil Authorities (DSCA) mission. A DOD Directive describes it as "Support provided by U.S. Federal military forces, DOD civilians, DOD contract personnel, DOD Component assets, and National Guard forces in response to requests for assistance from civil authorities for domestic emergencies, law enforcement support, and other domestic activities, or from qualifying entities for special event" (CRS, 2023). In 2019, the Navy and Marines used critical naval systems in the Arctic for the first time in support of its DSCA mission (USN, 2019). Such activities will become more prevalent as the Arctic becomes more accessible and one can foresee how the DSCA mission also could become part of a comprehensive security plan for OSW disaster response.

Current Adequacy of U.S. Regulations Governing Offshore Wind

Federal Management and Oversight - US government oversight responsibilities and regulatory authorities pertaining to OSW belong to DOI's BOEM and Bureau of Safety and Environmental Enforcement (BSEE). The latter is charged with "advancing safety, environmental protection and conserving natural resources related to energy

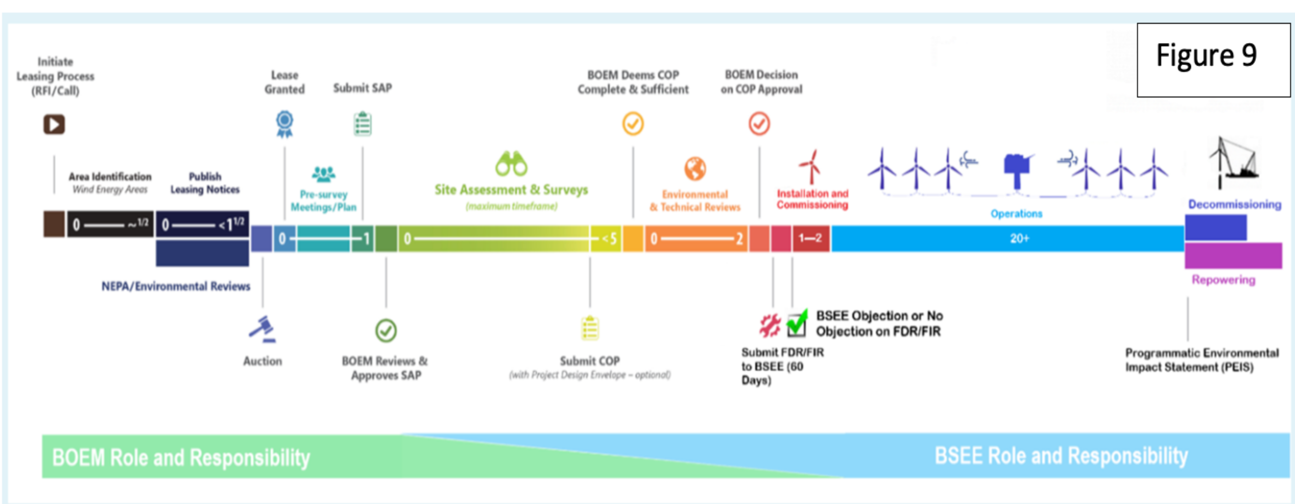


Figure 9

development on the US Outer Continental Shelf (OCS),”and is involved throughout the development process and operations of an OSW asset (Figure 9, DOI-BSEE, 2024).

BOEM is the lead authority in managing the development process, which can

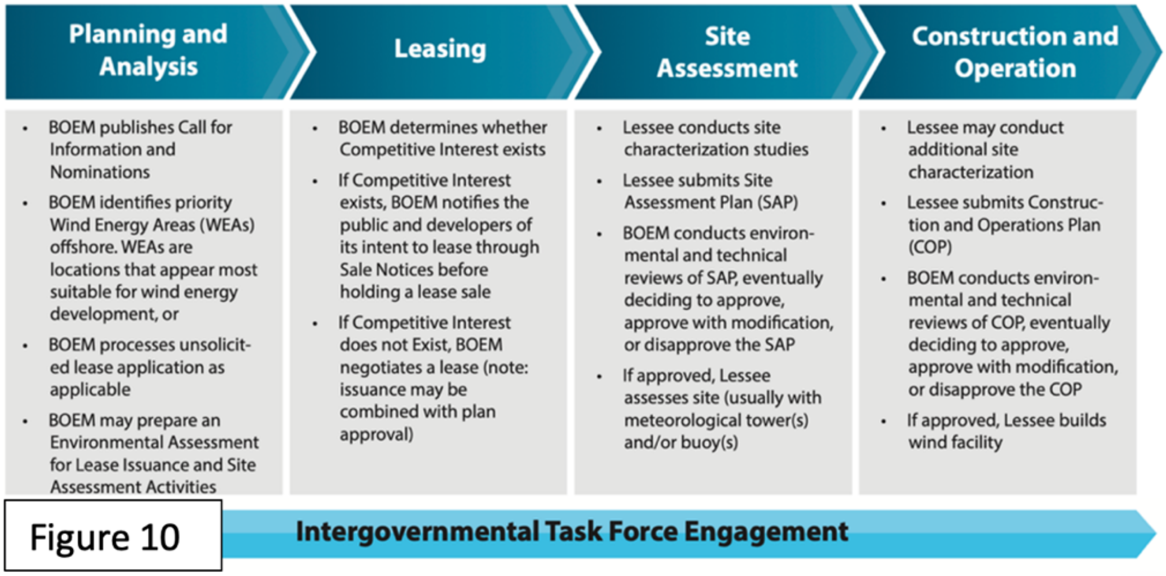


Figure 10

take 6-10 years to reach construction (Figure 10, DOI-BOEM, 2024b). The figure notes the involvement of the Intergovernmental Task Force throughout the process, and this includes an early part of the process where potential lease areas go through a deconflicting process to ensure that any potential windfarm site will not impact a variety of other interests, including military and national security interests. Later, once a WEA is selected and the lease is awarded through auction, the typical lease notes the authority of the BOEM under OSCLA to reserve “the right to suspend the Lessee’s operations in accordance with the national security and defense provisions of section 12 of the Act” (DOI-BOEM, 2014). During the subsequent Construction and Operations Plan development and approval, DOD continues to have a role in various ways, including the Military Aviation and Installation Assurance Siting Clearinghouse that works with industry to overcome national security issues, as well as DOD's Mission Compatibility Evaluation to study any adverse impacts on military operations and readiness and identify mitigation strategies (US Wind, 2023).

This ongoing involvement elucidates how federal management of wind farm project development consistently focuses on green lighting only the projects with the least impacts to the military, other stakeholders, missions, and environment. While BSEE remains involved throughout the project lifespan, ensuring safe operations and appropriate decommissions, physical security of the asset seems largely absent at this time from the approximate 40-year span of regulatory involvement.

How the Developer Evaluates Risk – To understand how this process plays out at the project level, and as a resident of Maryland, US Wind's Construction and Operations Plan (COP) documents for its Maryland Offshore Wind Project were selected for example reference. US Wind is "majority owned by Renexia SpA, a leader in renewable energy development in Italy and a subsidiary of Toto Holding SpA. Toto Holding SpA has more than 40 years of experience specializing in large construction and infrastructure projects, primarily in the energy, transportation, and aviation sectors" (US Wind, 2024).

Under 30 CFR § 585.626, any developer must include a general description of the operating procedures and systems for both routine operations and "in the case of accidents or emergencies, including those that are natural or man-made" (Cornell, 2024b). US Wind's COP section for non-routine operations regarding major repairs and emergencies is only about eight sentences and does not address specific risks. It does state that "Plans for managing non-routine events will include contracts with vessel service providers, strategic spares inventory or supply agreements, combined with procedures and plans to execute," which would be a valuable component of any future US plan for OSW security (US Wind, 2023).

There is also a Safety Management System that is an appendix to the COP, the guidelines for which are directed by 30 CFR § 285.810. Descriptions required include ensuring the safety of personnel or anyone on or near your facilities, remote monitoring, control, and shut down capabilities, emergency response procedures; fire suppression, testing process and schedule for the safety management system; and personnel training (Cornell, 2024c). While it seems highly unlikely that strategic physical risks would be considered under the remote monitoring discussion in the SMS, this appendix was listed as "confidential" and not publicly available on the BOEM website (DOI-BOEM, 2024c).

As part of trying to understand how an OSW project might address physical risks, this review included Appendix K, Navigation and Military Activities, specifically K-1, Navigational Safety Risk Assessment in accordance with the United States Coast Guard (USCG) Navigation and Vessel Inspection Circular No. 01-19. This appendix conducts a significant review of industry good practices, risk analysis of potential scenarios and potential tools for risk mitigation, with this process illustrated in Figures 11 - 14 taken from Appendix K-1.

First, Good Practices for the industry are shown in Figure 11 (DNV, 2022). The analysis then develops a comprehensive list of scenarios, with the last column within

Figure 11

Design/Plans:

1. Structures distanced from regularly-transited routes (the optimized distance is dependent on the number of and size of passing vessels)
2. Lighting and marking in accordance with internationally recognized practices. Proper marking and lighting of the structures of a wind farm can be used for navigation purposes improving the ability to fix a vessel's position
3. Uniform spacing of offshore structures.
4. Marking of air gap height on the structure and indication of relevant area of hazard on nautical charts.
5. Risk-based determination of cable burial depth.
6. Clear and distinguishable Electronic Navigation Chart symbology for offshore wind boundaries, structures, and export cables
7. Enabling the use of development structures as ATON through implementation of:
   - Lighting coordinated to clearly delineate development boundaries and contiguous developments
   - Sound signals
   - Structure identifiers that are predictable when crossing from one development into another, where applicable.
8. U.S. and/or SOLAS standards regarding construction, safety equipment, and crew for all Project vessels.
9. AIS on all Project vessels.
10. Emergency response planning and exercises
11. Safety zone of 500 m (1,642 ft) around construction vessels during wind farm construction

Activities:

12. Familiarization of commercial fishers and recreational boaters with safe transit through the Lease Area. Vessel safety for shallow draft vessels (i.e., generally vessels with drafts less than 15 m [49.2 ft]) is a potential concern because these vessels are more likely to transit within a wind farm. This is a key human aspect to achieving use of extra caution, employing proper watch, and assessing risk prior to entering or exiting an offshore wind farm.
13. Familiarization of merchant mariners and vessels in international trade with the changes to ATON and navigation hazards in the vicinity of the Lease Area.
14. Timely and effective notices to mariners regarding offshore activity and new hazards.
15. Locking and/or feathering of turbine blades during potential or confirmed emergencies, including icing. (This capability is normally included in offshore wind farm design and control systems.)
16. Dynamic fishery avoidance (likely not applicable to the Project).

Monitoring and post-event activities are not strictly considered risk controls but form an important part of effective risk management. The following monitoring programs been identified by this assessment as good industry practices in the U.S.:

17. Monitoring of export cable location annually for initial years of operation, with potential for reduced frequency of monitoring thereafter.
18. Annual Remotely Operated Vehicle (ROV) surveys around WTG foundations to monitor fishing gear and inform frequency and locations of lost gear removal.

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figure 12 denoting the numbered Good Practices in Figure 11. These scenarios are then measured against Severity and Frequency Indices, as listed in Figure 13. Lastly, the two indices are added together for each scenario, with sums of 10 or greater considered “intolerable,” 4-9 considered “tolerable” and less than 4 considered “acceptable” (DNV, 2022). The outcome of that summation process is exhibited in Figure 14, showing that none of the scenarios stretched into the “intolerable” range.

Thus, it is clear that the developer does take a significant look at maritime risks during development of the COP, which is reviewed and approved by both BOEM and BSEE before final permitting is granted. However, all the scenarios are accident based and the analysis is, logically, focused specifically on incidents and losses associated with this single project. Interestingly, the term “hurricane” is not used in the main volume of the COP and “weather” is not

Figure 12

ID	Scenario	Vessel type(s)	Existing maritime risk controls[23]	Relevant standard U.S. risk controls[24]
1	Collision by a fishing vessel exiting the Project and a commercial vessel transiting the TSS	Cargo/Carrier/Tanker, Cruise ship, ATB	X	1, 3, 6, 13
2		Fishing	X	1, 3, 12
3		Tug and towline	X	1, 3, 6, 13
4	Collision by a tug with a barge and another vessel along the coast, west of the Project, due to increased traffic density.	ATB, Tug and towline	X	1, 3, 13
5	Collision by other vessel types	Pleasure	X	1, 3, 6, 12
6		Passenger	X	1, 3, 6, 12
7	Powered deep draft vessel to structure allision	Cargo/Carrier/Tanker, Cruise ship	X	1, 2, 3, 4, 6, 7, 13
8	Powered shallow draft vessel to structure allision (not including barges)	Fishing	X	2, 3, 4, 7, 12
9		Passenger		
10		Pleasure		
11	Powered tug and barge vessel to structure allision	ATB, Tug and towline	X	1, 2, 3, 4, 6, 7, 13
12	Drift deep draft vessel to structure allision	Cargo/Carrier/Tanker, Cruise ship	X	1, 2
13	Drift shallow draft vessel to structure allision (not including barges)	Fishing	X	2
14		Passenger		
15		Pleasure		
16	Drift tug and barge vessel to structure allision	ATB, Tug and towline	X	1, 2
17	Grounding of a vessel	Cargo/Carrier/Tanker, Cruise ship	X	Not Applicable (Project is distanced from the coastline)
18		ATB,Tug and towline		
19		Fishing		
20		Passenger		
21		Pleasure		
22	Anchor snagging on a Project array cable	Cargo/Carrier/Tanker, Cruise ship	X	1, 5
23		Fishing, Pleasure, Passenger		5
24		ATB,Tug and towline	X	1, 5
25	Anchor snagging on a Project export cable	Cargo/Carrier/Tanker, Cruise ship	X	5, 13, 14
26		Fishing, Pleasure, Passenger		5, 14
27		ATB,Tug and towline	X	5, 13, 14
28	Ice fall/throw strikes a vessel	All		14, 15
29	Strike of a vessel under sail by a turbine blade	Pleasure/sailing	X	4
30	Fishing gear snagged on a Project structure (WTG or OSS foundation)	Fishing		

Figure 13

To assess the need for additional mitigation, the consequences of each scenario are assigned a Severity Index, and the frequency, from MARCS modeling or design criteria, is assigned a Frequency Index. The following index definitions are used, in line with the IMO FSA Guidelines (IMO, 2017).

Severity Index	Definition
1	Spill < 1 tonne
2	Spill 1-10 tonnes
3	Spill 10-100 tonnes
4	Spill 100-1,000 tonnes
5	Spill 1,000-10,000 tonnes
6	Spill >10,000 tonnes

Frequency Index	Description	Definition
1	Insignificant	Likely to occur less than once every 100,000 years of Project operation
2	Extremely remote	Likely to occur once every 10,001 – 100,000 years of Project operation
3	Remote	Likely to occur once every 1,001 – 10,000 years of Project operation
4	Unlikely	Likely to occur once every 101-1,000 years of Project operation
5	Possible	Likely to occur once every 11-100 years of Project operation
6	Reasonably probable	Likely to occur once every 1 - 10 years of Project operation
7	Frequent	Likely to occur more than once per year of Project operation

discussed with regard to asset damage. Security associated with protecting the asset from adversarial interests also is not discussed in the main volume. Even the offshore cameras, which were identified as a potential risk control measure and would provide at least some surface warning of potential intrusion, were rejected because its cost-benefit analysis determined that the costs of such cameras were more than ten times the value of the benefit (DNV, 2022). In other words, that

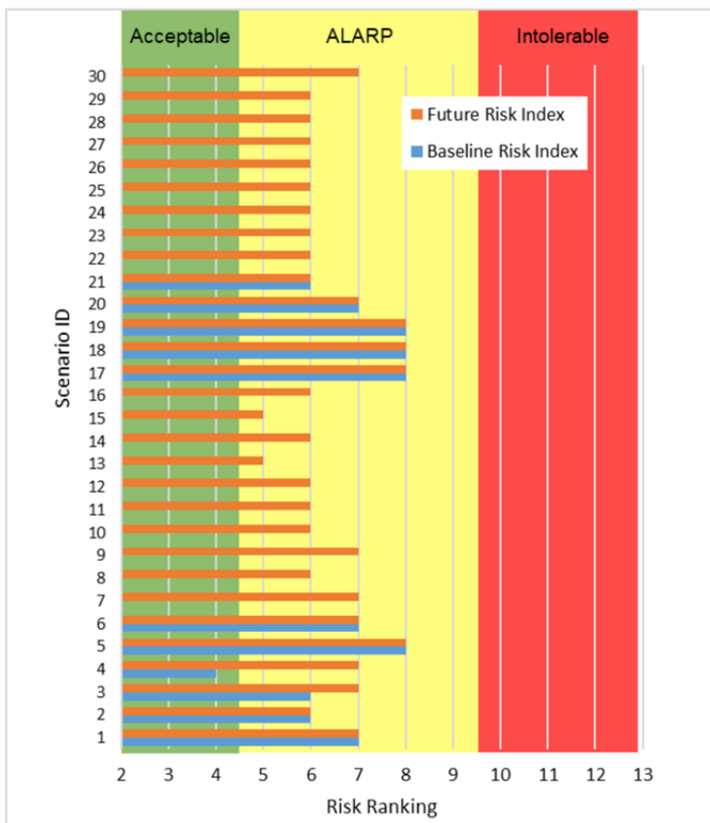


Figure 14

specific mitigation was not considered reasonably practicable in the As Low As Reasonably Practicable (ALARP) risk management approach that weighs a risk against the trouble, time and money needed to control it (HSE, 2024). This simple example shows how costs and benefits are wieghed differently by different stakeholders, and how risk assessment from a project level is vastly different than perspective from a regional grid and human security perspective.

With the Literature Review complete, it is now necessary to turn our focus on what documented threats and impacts to actual US energy. In this context, a few past examples can be used to understand the potential extent of damage and what lessons can be gleaned from them.

METHODS

Case Studies for Evaluating Historical Energy Asset Exposures

The rollout of any new major energy source always has its challenges, setbacks, failures and accidents, and OSW will be no different. In turn, using case studies for learning from other energy infrastructures exposed to extreme weather and hybrid warfare can provide useful insights into some of the challenges that lie ahead. The first is the Gulf of Mexico and its O&G industry for considering hurricane impacts. Second, we can look at the impacts of 2021 Winter Storm Uri in Texas to understand the impacts of losing power generation at times of high load. Lastly, this section reviews how domestic extremism and foreign hybrid warfare can expose the energy system to risks that are hard to defend against.

Hurricanes in the Gulf - The 2005 Hurricane season set single-season records for most storms, most hurricanes, and the highest accumulated cyclone energy index set, as five hurricanes (four major) and two tropical storms made landfall with total damage costs reached $100 billion (Beven et al., 2008). Shortly after, the National Center for Atmospheric Research reported that "global warming accounted for around half of the extra hurricane-fueling warmth in the waters of the tropical North Atlantic in 2005" (Harvard, 2006). Katrina and Rita alone affected the operations on three-fourths of the oil and gas platforms in the Gulf, while destroying 115 and damaging 52 platforms, as well as damaging 457 pipes (Craddock, 2010). The energy unleashed sunk entire platforms and seabed anchors snapped because of wave action (Larino, 2019). Repairs and replacement for everything from rigs to plants required significant investment, noting it was three years before daily oil production reached 88% of pre-hurricane season production and for natural gas to reach 91%. (Craddock, 2010). Unfortunately, the recovery took another significant blow in 2008 when 36% of the Gulf platforms were exposed to hurricane activity, during which "54 of the almost 4000 offshore oil and gas production platforms were destroyed, 35 platforms suffered extensive damage (3 to 6 months to repair), and more than 60 platforms received moderate damage (1 to 3 months to repair)" (Craddock, 2010).

The American Petroleum Institute (API) learned valuable lessons from these experiences embarking on an expansive effort to better prepare for inevitable recurrence. According to the API, scientists determined the Central Gulf was more prone to hurricanes due to the accumulation of warmer currents, and API used updated wind, wave, and current data to reassess designs and operations (API, Nd). API also issued new standards and reaffirmed others covering a variety of topics ranging from the integrity of mooring systems to the use of metocean data for the design and construction of offshore structures (Recommended Practice 2MET of 2014) (API, Nd). Such API improvements made after the 2005-2008 events do indicate industry acknowledgement of increasing risks and the periodic need for improved adaptation measures. As a case and point, the 2014 Recommended Practice 2MET referenced above was updated again, superseded in 2021 by the 2019 edition (Intertek, 2024).

Key follow-on questions include how well those design improvements addressed vulnerabilities, and whether the O&G industry modeled the future adequately to protect against yet-to-be-seen level impacts. The National Oceans Industries Association (NOIA) would suggest they are already protected, noting that virtually all the damaged platforms in 2005 were built before 1988 federal design specifications were implemented, a point also made by then-Interior Secretary Gale Norton before Congress (Brannlund et al., 2023; NOIA, Nd). Still, understanding the success of more recent design improvements could be very informative for the OSW industry. Unfortunately, API documents must be purchased and finding an answer to that question for this case study is not feasible. Yet, there is some research that suggests the answer might be a “mixed-bag,” based on a 2023 study from the Journal of Environmental Economics and Management that looked at oil rig resilience investment and production losses following the implementation of the aforementioned 1980s federal resilience regulations. Brannlund et al. concluded that while there is “some evidence that both the intensive and extensive margin production losses from extreme weather events are lower for rigs built after 1980s resilience criteria were introduced, "the estimated benefits are generally less than 20%," and that "adapting for extreme weather through resilience investment provides only partial insurance" (2023). Nevertheless, API learned important lessons from the 2005 and 2008 hurricane seasons and took those lessons to heart, as it recommended more resilient designs to help weather more recent climate impacts that had not been previously considered, even if those design improvements may not adequate for future decades, which remains an open question.

Grid Impacts of Lost Power Generation - US government, businesses, citizens and services all depend on a 24/7 grid, and large impacts to power generation can have extreme impacts. As a case and point, consider Winter Storm Uri that hit Texas in 2021, resulting in a massive electricity generation failure, loss of power to over 4.5 million homes, at least 57 deaths across 25 Texas counties, and over $195 billion in property damage (Energy Institute, 2021). ERCOT lost 50% of its power generation and had to load shed 20 GW, which resulted in significant blackouts (Engblom et al., 2021). Some military installations were able to disconnect from the grid and run on their own power plants, but many others were not so resilient and experienced prolonged electricity and water loss (US House of Representatives, 2021).

The University of Texas at Austin Energy Institute convened an expert panel to conduct an unbiased assessment of the data and events surrounding the blackout. They indicated that the event exceeded prior events with respect to "both the number and capacity of generation unit outages, the maximum load shed (power demand reduction) and number of customers affected, the lowest experienced grid frequency (indicating a high level of grid instability)," among others (Energy Institute, 2021). Some of the factors identified as contributing to these outcomes included demand forecasts for severe storms being too low, high planned generator outages, and inadequate weatherization (Energy Institute, 2021).

Domestic and Foreign Adversarial Sabotage

In 2014, Onyeji et al. wrote in The Electricity Journal about how CEI had become a primate target for attacks of all kinds, starting with the classical physical threat history for CEI (e.g., energy "denial" attacks back in the Iraq-Iran war), and then moving into the subsequent and growing industry risks resulting from cyber-enabled attacks, which broke the Top 10 of Ernst & Young's recurring survey of energy executives for the first time in 2013 (Onyeji et al., 2014). High-profile cyber-attacks around this period included the 2009 Stuxnet virus that damaged Iran nuclear centrifuges, Saudi Aramco attack in 2012, and Russia's use of hackers in 2015 to successfully attack the Ukrainian grid, affecting hundreds of thousands of citizens (Onyeji et al., 2014; Majkut et al., 2022). Importantly, the risks from such growing adversarial hybrid tactics are only increased by the rapid growth of using computing to manage the grid, the internet for industrial control systems and their attendant communication networks, etc. "The average top 25 power company in the US is responsible for maintaining [computerized automated] devices that are dispersed over 125 plants and 94,000 miles of distribution infrastructure" (Sanders et al., 2022). All this has caused governments, energy companies, and IT firms to build-out extensive capacities to defend against and respond to cyber risks throughout the energy system (Sanders et al., 2022).

However, while cybersecurity has exploded, the classical physical or kinetic threats did not go away. Indeed, everything from US extremism to more-widely distributed energy resources are contributing to the growing physical vulnerabilities of the US energy sector. In 2022 alone, there were at least 118 suspicious activities and attacks on US power station or substations in multiple states (Bergengruen, 2023). In one of the more publicized incidents, “intruders breached the gates and opened fire on two Duke Energy substations in Moore County, N.C., in early December, damaging equipment in what local authorities called a “targeted” attack that cut off the power for more than 45,000 people” (Bergengruen, 2023).

While the attacks on energy infrastructure is common during periods of war, the Russian-Ukraine conflict provides insight into the how energy infrastructure is also a focus in more clandestine, grey zone or hybrid warfare, particularly subsea energy infrastructure. the Russian-Ukraine war provides a straightforward example of how distant and subsea energy infrastructure can be targets. In the Fall of 2022, the explosives were used on the Nord Stream 1 and 2 pipelines, releasing large amounts of methane to the air and halting any potential future natural gas shipments from Russia to Germany (Jacobsen and Rasmussen, 2024). Although gas delivery through that system was not active at the time, the attack sent ripples through global security circles, with the Atlantic Magazine calling it “The Most Consequential Act of Sabotage in Modern Times” (Bowden, 2023). Highlighting the valuable plausible deniability of hybrid attacks on undersea infrastructure, the US and Russia suggested the other was responsible, which was followed by a leaked CIA report and other corroborating evidence suggesting Ukraine personnel may well have sabotaged the pipes, using a recreational sailboat rented in Germany (Harris and Mekhennet, 2023). Regardless of the responsible party, it had significant economic impacts on allies, as almost half of the billions invested to construct the pipeline were from German, French and Dutch energy companies (Harris and Mekhennet, 2023). The fact it happened without warning and outside of known areas of direct conflict or confrontation certainly exposed the inherent vulnerability of distant and/or undersea infrastructure and how significant and cascading impacts can be initiated suddenly and without warning.

ANALYSIS

The case studies provide three examples of where critical energy infrastructure, including upstream exploration, transport, generation, and transmission have been disrupted due to extreme weather or sabotage. A comparative analysis of these events and lessons learned can provide OSW regulators and industry valuable information for developing a more proactive approach, designing for a more kinetic future from the start instead of addressing design limitations only after major impacts have occurred.

In the case of O&G, that industry is highly experienced and extremely well-funded, while its activities in US waters generally have been manned, geographically protected from adversarial access (e.g., Gulf of Mexico), and required limited security patrol. Second, the industry has thousands of production points, increasing the likelihood that at least some significant production can remain intact or put back online expeditiously following a severe storm. Third, oil and natural gas extracted from the subsurface must be processed before it enters the market, so at least upstream damage provides a sort of buffer to broader societal function, allowing market compensation in the event of an accident (or malfeasance) in one region. OSW lacks all those helpful attributes. Indeed, the OSW industry has less institutional knowledge built up, the assets are unmanned, and owners will have far less financial, manpower, and vessel resources available to rebuild from major events. As for the grid and customers those assets will serve, loss of several farm assets will be felt immediately and the adequacy of compensating generating assets in future scenarios are far less understood. For these and other reasons, it is critical that OSW regulators and industry incorporate proactive measures to minimize relevant risks, instead of the historical reactive approach illustrated in the Gulf.

As for Winter Storm Uri, the grid fragility and inadequate planning seen serves as a cautionary tale for the Atlantic OSW industry, as well as grid operators, military facilities, and federal and state emergency response agencies. If such an event were to happen off the Mid-Atlantic or Northeast, tens of millions could be impacted, precipitating unprojected impacts, causing serious human security challenges and overwhelming emergency response capacities. ERCOT had experience from 1989 and 2011 extreme weather events and still lacked the resilience needed, while OSW physical vulnerabilities are undoubtedly more difficult to design for and respond to. On the geopolitical front, such grid fragility and highly visible storm impacts on US human and national security make the US energy system a logically attractive target for adversaries. Furthermore, empirical evidence that the US is slow to improve resilience for both civilian and military sectors only enhances that attractiveness, working in the opposite direction of DOD's deterrence through resilience strategy. Thus, how a NERC region could adapt to the extended loss of multiple GW wind farms must be modeled sufficiently, and adequate investment into reducing that risk are paramount. Additionally, how federal, state, and local officials would respond to the specific cascading impacts of lost OSW production at a scale larger than Texas will be required.

Sabotage cases, whether domestic or foreign, raise particularly worrisome considerations given they will be built far out in the EEZ, with inherent distance and subsurface vulnerabilities. Russia has a broad and growing economic interests in a "'blue economy' based on transport and logistics, resource and raw materials, and other opportunities of the seas and oceans," and this helps explain Russian strategic interest in Atlantic access discussed earlier (Druzhinin and Lachininskii, 2021). Furthermore, the GPC in the Arctic (and elsewhere) is influencing the US force planning standard, as the Armed Forces are actively reevaluating "the number and types of simultaneous or overlapping conflicts or other contingencies that the U.S. military should be sized to be able to conduct" (CRS, 2024a). Russia, the PRC, or other adversaries would naturally look to hybrid warfare activities to slow US military force projection capabilities in, and/or response to, areas of high adversarial interests like the Arctic, and these case studies show how effective interruption of power generation can be strategically useful.

Without adequate security planning and capacity, OSW delivers a cheap access point out in the ocean for adversaries to exert leverage and cause damage. A 2024 Congressional Research Report, *Great Power Competition: Implications for Defense—Issues for Congress*, does note USG's recognition of needing to build its capabilities to counter such hybrid warfare activities; however, what is not clear is how the US is considering OSW vulnerabilities in their countermeasures, and whether both proactive and reactive controls are being considered in order to maximize deterrence and minimize impacts (CRS, 2024a).

RESULTS

The historical energy infrastructure case studies permitted a future-focused analysis of potential OSW risks, and that analysis highlighted how such kinetic events may prove very detrimental. It provides ample support to the perspective that comprehensive security planning is vital to avoid destructive and more costly events, and in the best security interests of the United States. To bring such a security framework to fruition, it is important to consider the major federal entities who would have important roles in its development and execution, as well as the types of vulnerabilities and scenarios that all involved stakeholders would likely need to consider. This Results section provides some initial exploration of both topics.

Analysis of U.S. Government Preparedness to Address OSW Vulnerabilities

It will take diverse expertise and bandwidth to turn this single-authored primer into a robust security investigation and plan design that addresses the entire asset chain, from wind technology R&D to deep-sea operational asset monitoring. This need was echoed by the Administration's National Security Memorandum on Critical Infrastructure Security and Resilience, released on April 30, 2024 just days before submission of this paper. The first policy principle and objective listed is Shared Responsibility, stating:

> *Safeguarding critical infrastructure is a responsibility shared by Federal, State, local, Tribal, and territorial entities, and the public or private owners and operators of critical infrastructure (owners and operators). All stakeholders have unique roles to contribute to the national unity of effort. Public-private collaboration is vital to this effort* (The White House, 2024a)

In turn, it is prudent for this primer to take an initial look at the multiple key federal agencies that will guide the effort and their current preparedness to address such risks and impacts.

Department of Energy - Within DOE, it is the Office of Energy Efficiency and Renewable Energy's (EERE) mission to "accelerate the research, development, demonstration, and deployment of technologies and solutions to equitably transition America to net-zero greenhouse gas emissions economy-wide by no later than 2050" (DOE-EERE, 2024c). EEERE's Wind Energy Technologies Office (WETO) executes investment and oversight of wind research, development, demonstration and deployment of wind technologies and innovations, with R&D focusing on the challenges of OSW development and deployment (DOE-EERE, 2024d). EERE's agency-wide, collaborative efforts are exhibited in *Advancing Offshore Wind in the United States: U.S. Department of Energy Strategic Contributions*

Table 2	NOW			FORWARD			CONNECT	TRANSFORM
	Cost Reductions	Domestic Supply Chain Development	Expanded, Just, & Sustainable Deployment	Cost Reductions	Domestic Supply Chain Development	Expanded, Just, & Sustainable Deployment	Transmission Development	Co-Generation Applications
Advanced Materials and Manufacturing Technologies Office	●	●		●	●		●	●
ARPA-E	●			●			●	●
Grid Deployment Office							●	●
Hydrogen and Fuel Cell Technologies Office		●			●			●
Loan Programs Office	●	●	●	●	●	●	●	●
Office of Clean Energy Demonstrations	●			●			●	●
Office of Cybersecurity, Energy Security, and Emergency Response							●	
Office of Economic Impact and Diversity		●	●		●	●	●	●
Office of Electricity							●	●
Office of Manufacturing and Energy Supply Chains	●	●		●	●		●	●
Office of Science	●			●				
Vehicle Technologies Office		●			●			
Water Power Technologies Office	●	●	●		●	●	●	●
State and Community Energy Programs			●			●	●	●
Wind Energy Technologies Office	●	●	●	●	●	●	●	●

Figure H-6. Alignment of DOE office expertise and potential engagement with strategic initiatives
Note: ARPA-E = Advanced Research Projects Agency-Energy

Toward 30 Gigawatts and Beyond, with its Table 2 (above) outlining areas of focus and offices involved (DOE, 2023a). DOE is also working with stakeholders outside the Department on important topics, such as supply chain efforts occurring through the National Offshore Wind Research and Development Consortium, with members spanning DOE, various state entities, developers, and utilities (NOWRDC, 2024; Shields et al., 2023). It is exactly this type of agency-wide and multi-stakeholder efforts, tapping a variety of technology, demonstration, development, and security expertise that will be required to address the diverse OSW physical security needs.

Spearheading DOE-led OSW risks would likely be the Office of Cybersecurity, Energy Security, and Emergency Response (CESER). CESER is a critical office within DOE's Office of Infrastructure and its mission does include evaluating physical risks, such as the domestic substation incidents discussed in the case studies (DOE-CESER, 2023). It is also the home to the Energy Threat Analysis Center (ETAC), which was tasked through the 2021 Infrastructure Investment and Jobs Act to provide operational support to the energy sector to address cyber resilience. While cyber seems to be its initial focus, ETAC's main objectives do suggest that physical risks to OSW would fall squarely within its purview to "strengthen the collective defense, response, and resilience of the U.S. energy sector," "improve the collective understanding of national security risks associated with the energy sector, which are or could be exploited by adversaries," "achieve a deeper understanding of threat actor tactics, capabilities, and activities" (DOE-CESER, 2024a). CESER also has its State, Local, Tribal and Territorial (SLTT) Program through which CESER recognizes SLTT governments "have operational, tactical and policy development roles & responsibilities that can have a wide-reaching impact," and, in turn, supports SLTT efforts in "energy security planning that is risk-based, operationally focused, and cross-jurisdictional and seeks to build SLTT capacity to serve national security interests for cybersecurity, energy security, and emergency response" (DOE-CESER, 2024b). This program would likely serve as a valuable conduit to state, tribal and local governments when developing a comprehensive OSW security plan.

Department of Homeland Security – At least two DHS strategic priorities and mission areas would seem to apply to OSW threats - Counter Terrorism and Prevent Threats, and Secure Cyberspace and Critical Infrastructure. However, a review of DHS's Third Quadrennial Homeland Security Review released in 2023 does not contain any specific discussion regarding offshore energy production and the Atlantic (DHS, 2023) Interestingly, the document does briefly discuss Arctic competition along with Russian and Chinese interests in the Arctic theatre, but it does not discuss spillover risk into US EEZ and the Atlantic basin. The three entities within DHS that would likely be most involved with offshore energy asset protection would be Cybersecurity and Infrastructure Security Agency (CISA), the Homeland Security Operational Analysis Center (HSOAC), and the USCG.

CISA's broad role regarding critical infrastructure is to "provide guidance to support state, local, and industry partners in identifying the critical infrastructure sectors and the essential workers needed to maintain the services and functions Americans depend on daily" (DHS-CISA, 2024a). The generation of electricity is included in the National Critical Functions Set released in 2019 and Energy is one of 16 sectors identified as Critical Infrastructure (DHS-CISA, 2019). The 2015 Energy Sector-Specific Plan notes that "collaboration is vital due to the urgency of the potential threats to the Energy Sector, including multiple, coordinated physical attacks and electromagnetic pulse (EMP) events," and this document specifically addresses extreme weather events, risks to oil and gas, and physical attacks on the grid, such as large power transformers. However, the document does not specifically address risks to the wind industry, onshore or offshore (DHS-CISA, 2015). Additionally, review of the Energy Sector Working Groups identified on CISA's website did not reveal any OSW planning. However, the Securing

Energy Infrastructure Executive Task Force, a joint effort with DOE's CESER, was listed and, while it appeared to be cyber focused as of now, it could play a future role in comprehensive OSW security (DHS-CISA, 2024b).

HSOAC is a federally funded research and development center under DHS's Science and Technology Office and has "expertise in the complexities of meshing military and civilian organizational structures and cultures," with "expert forecasting capability…examining mission risk analysis for capability gaps, assessing threat, vulnerability, and risks from national and international trends with U.S. security implications" (DHS-HSOAC, 2024). With focus areas that include 1) Preparedness, Response and Recovery, 2) Organizational and Operational Studies, and 3) Regulatory, Doctrine and Policy, HSOAC would be well position to provide the analytical rigor and timely analysis required to evaluate long-term risks to OSW and the capacities required across the Homeland Security Enterprise to protect them. (DHS-HSOAC, 2024).

As for the USCG, a review of its strategic plans reveals at least an evolving awareness for the Atlantic and OSW. The 2018 USCG Strategic Plan did not mention the Atlantic or offshore energy (USCG, 2018). However, in the 2022 Plan, USCG specifically addresses changing operational domains within the security environment, identifying "Emerging uses of the maritime environment – including offshore energy production, unmanned vessel and aerial systems employment, and commercial space activities — are rapidly expanding, challenging existing regulatory and operational frameworks" (USCG, 2022). However, that is the only time the Strategic Plan mentions offshore energy, so it is unclear how the recognition of emerging maritime environment feeds into active USCG preparedness. This particularly matters because it seems likely that the USCG is where the "marine rubber will meet the marine road" for OSW security, and the OSW's novel mission impact on the US military as it relates to needed CEI asset protection cannot be overstated. Suppose one analyzes the 11 USCG missions previously listed in Table 1. In that case, one might take the liberty to describe them as "quasi- transient" in nature, meaning that risk to specific US citizens from such threats, such as drug smuggling or port safety, are always possible. Still, actual exposures to these threats are not constant, and the impacts from exposures are not immediate, except for a few isolated cases (e.g., Baltimore's Francis Scott Key Bridge). For example, workers or nearby residents' exposure to potential physical security risk in a port only occurs when a ship or truck is arriving or departing. In contrast, OSW is going to be quite different in that the US will have dozens of wind farms tens or hundreds of miles off the coast, and those critical assets will be feeding a 24/7 grid most of the time. And, if an event does take place that suddenly removes that power generation, there could be potentially significant, wide-spread impacts to US businesses and citizens immediately.

Department of Interior – BOEM and BSEE were discussed in the Literature Review, but they mentioned here to highlight their regulatory authority when it comes to OSW. Additionally, BSEE is taking some proactive interest in evaluating offshore energy asset cybersecurity as it pertains to O&G sites (Slighe, ND) In turn, DOI would have an important role within the OSW security framework, particularly regarding any asset security responsibilities that may eventually fall to the developer/owner. For instance, US Wind plans to employ ROVs at least once in the first 2 years for "inspection of the underwater portions of the foundation, including cable protection and cable entry, cathodic protection, and scour systems," with subsequent inspections occurring every 4-5 years. (US Wind, 2023). While such infrequent use is of little to no application to regular monitoring, it is conceivable that a US OSW security plan could include requirements and standardization of more frequent use of such risk mitigation technologies, whereby BOEM requires them in COPs, and annual BSEE security reviews/inspections include such protocols. Such standardization approaches align with the third policy principle and objective in the Administration's Critical Infrastructure and Resilience Memorandum, which states: "Federal, State, local, Tribal, and territorial regulatory and oversight entities have a responsibility to prioritize establishing and implementing minimum requirements for risk management, including those requirements that address sector-specific and cross-sector risks" (The White House, 2024a).

Identification of Potentially Vulnerable OSW Components and Risks

USAID's Climate Resilient Development Frame provides a 5-step straightforward approach addressing Scope, Assessment, Design, Implementation, and Evaluation (USAID, 2016). The Literature Review already laid out the Scope of planned OSW energy and its importance, and the Design, Implementation and Evaluation would be addressed in the long-term OSW Security Action Plan for which this research is hopefully a primer. The second step of conducting a vulnerability assessment is explored here.

Vulnerability of a nation, a sector or an asset involves the interaction of three factors: "*exposure* to stressors, *sensitivity* to those stressors, and *adaptive capacity* to manage stressors" (USAID, 2016). Potential points or nodes sensitive to that climatic or adversarial risks may include: 1) the turbine blades, 2) the nacelle, 3) foundation (e.g., monopile, jacket, etc), 4) the offshore collector-transformer, 5) the cabling that delivers power (and communications) to shore, and 6) onshore substations. A thorough review of such risk exposure would be conducted in the multi-stakeholder framework described in the Recommendations, but several examples and concerns are raised in the following paragraphs to explore how identifying and prioritizing risks for further consideration could be conducted.

Turbines - Currently, utility-scale wind farms use upwind turbines that generate power by facing the wind, utilizing a yaw and a weathervane to constantly monitor and turn the turbine to maintain its wind-facing orientation (DOE-EERE, 2018). Extreme weather risks to the turbine include the potential for the large, rigid blades to break and/or strike the nacelle. To reduce such risk, the blades are designed to "lock and feather" when winds are too strong, locking the blades from turning the rotor, and feathering the blades to minimize surface area harnessing the wind (DOE-EERE, 2018). During these periods, the yaw continues to turn the nacelle to face the wind (DOE-EERE, 2017).

Rose et al. questioned the limits of the yaw to maintain least-damaging position, noting that at least some turbines do not contain backup power for yaw motors and, additionally, there have been documented cases where hurricane winds have changed direction 66% faster than a turbine can yaw (Rose et al., 2012). To reduce such risks, Ingeteam Power Technology offers a Yaw Backup Power Supply, but the prevalence of use in US OSW COPs would need to be studied to quantify industry adaptative capacity better when conducting a full vulnerability assessment (Ingeteam, Nd). Such an example does raise an important question regarding the need for US standardization for certain OSW design aspects tied to physical security.

Foundations – There is some historical evidence that the hurricanes could pose a risk for OSW foundations. Rose et al. calculated that 46% of offshore towers could buckle in a Category 3 hurricane, and that 9 of the 14 Atlantic states have been hit by a storm of that intensity or higher over the last 170 years (2012). This is just one, decade-old modeling study, but it serves as an example of how industry and USG must consider each point or node within the wind farm design for sensitivities to exposures. And within the foundation space alone, there are not just monopiles but also jacket, twisted jacket, tension-leg floating platform, semi-submersible platform, and spar-buoy designs (Keene, 2021). Certainly, there are hardened design lessons from the O&G industry, as well as European companies with decades of experience and working on cutting edge floating designs (Mercado, 2021). All such considerations need careful review in understanding OSW vulnerabilities.

Beyond this more basic hurricane consideration, the unquantifiable future risk from ever-stronger storms will need to be considered, as there is mounting evidence that Atlantic hurricanes are strengthening as a result of GHG warming, aerosol reductions, and/or ocean circulation changes (Handwerk, 2023). Whether the number of hurricanes will increase is still being debated, but one recent study suggested a large increase in Atlantic hurricane frequency as a result of steering flows pushing tracks more westward, taking them through more climatologically favorable environment (e.g., reduced wind shear) (Balaguru et al., 2023). Another recent research paper discussed their increasing strength, suggesting that the Saffir–Simpson hurricane wind scale is now inadequate for conveying wind risk and highlighting that five storms in the past decade would be classified as a Category 6, if the scale was extended to better classify storms with sustained winds exceeding 192 mph (Wehner and Kossin, 2024). The 1^{o}C of warming already experienced by tropical oceans increases hurricane wind speed by 12% and this results in a 40% increase in destructive potential, and we appear to be on track to double that increase (Mann, 2024).

Substations - Whether an offshore or onshore substation is utilized for an OSW project depends on several factors include size of project, distance from shore, and whether connection to the grid is at collection voltage (Wind Energy Facts, Nd). With the size and distance of planned US OSW farms, inclusion of an offshore substation will be far more common. A modern offshore station is massive, taking up a 400 sq meter area and standing over 20 meters in height, with an example of such provided in Figure 15 (Froese, 2016).

Hurricanes, particularly offshore hurricanes where they are strongest, present both wind and wave risks. In the case study reviewed, entire oil rig platforms were sunk as a result of the 2005 hurricane season, and as a result of those events, API raised its 100-year wave crest height to 91 feet as part of its design standards upgrades (Larino, 2019). The adequacy of such asset height planning and future storm strength is questioned in a BSEE study that noted that 91-foot wave height was documented in the Gulf for Hurricane Ivan in 2004 and that it is suspected that wave crests reached 130 feet (DOI-BSEE, 2009). Any potential for such wave action in the Atlantic combined with sustained winds approaching 200 mph is clearly a potentially significant risk.

Alstom's GIS substations were installed on a platform at the Baltic Sea 2 offshore wind site. The platform was placed on a pre-installed jacket and brought out to the installation site where water depths reached 44 meters. The buoyant and self-erecting platform design enabled a high degree of flexibility and independency from crane ships for the transport and installation of the substation. The closed platform layout protects the electrical components from offshore conditions. (Credit: Alstom)

Figure 15

Regarding onshore substations, they can fall prey to hurricanes in similar ways to all coastal infrastructure involving wind and flooding. For instance, Superstorm Sandy resulted in a "storm tide" (high tide plus storm surge) that reached 14 feet above Mean Lower Low Water mark (40% higher than the previous record) and knocked out five major transmission substations (NYC, NDa; NYC, NDb). Another potential future factor is a recent study released in September providing the "strongest, most definitive evidence yet" that the Gulf Stream is weakening (Turner, 2023). The slowing of the Gulf Stream could result in heat buildup along the coast and strengthen storms, as was the case with Super Storm Sandy (University of Maryland, 2016). Additionally, the sweeping action of the Gulf Stream keeps water levels along the shore up to 5 feet lower than farther out in the ocean, so any significant slowing of the Gulf Stream may well accelerate coastal sea level rise and result in higher storm tides (Turner, 2023).

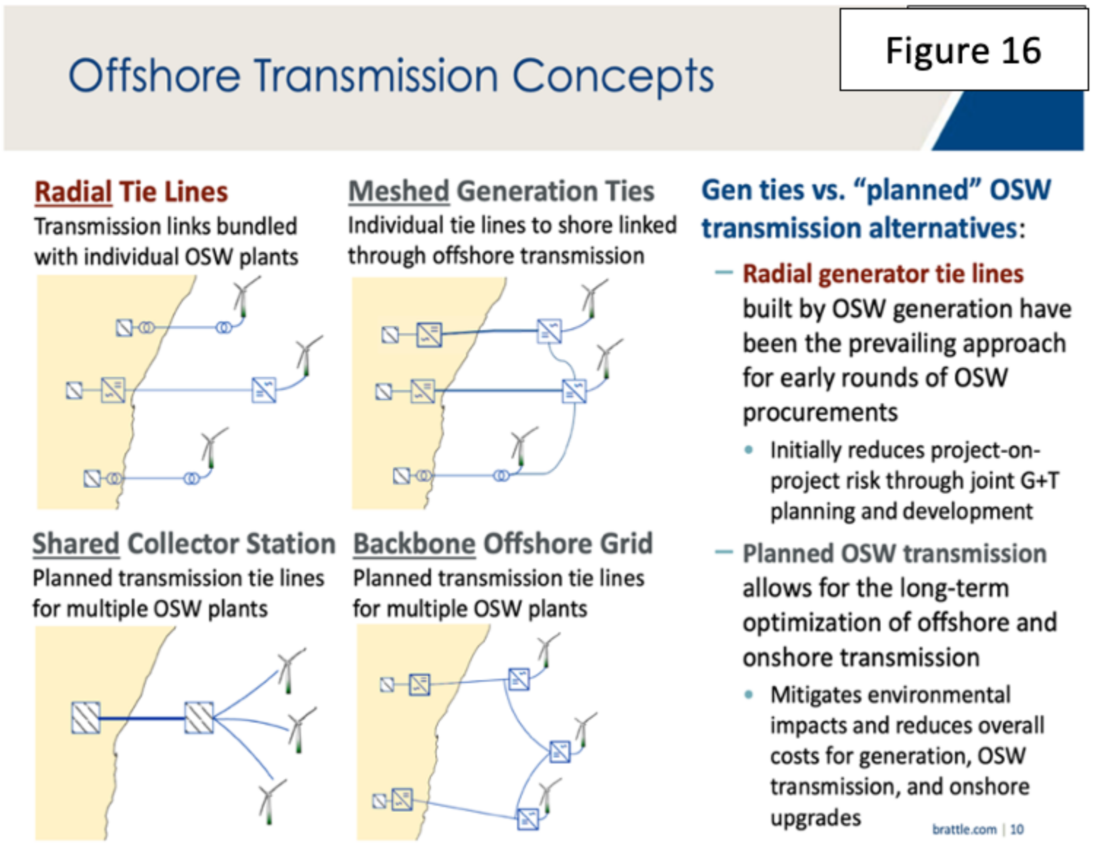
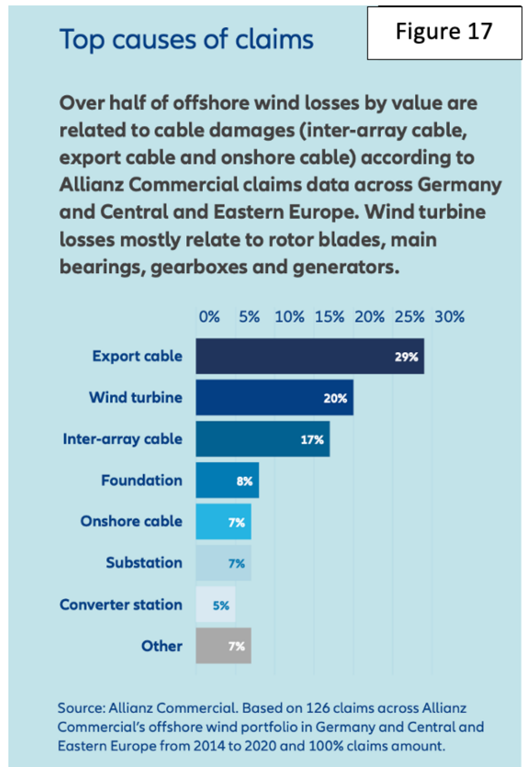


Figure 16

Power Cabling - Storms have been known to damage critical subsea fiberoptic cables, and landing areas can also be damaged by sea level rise and wave action. (Judge, 2023). Certainly, cabling associated with OSW is similarly vulnerable, but lacks the redundancy usually available for undersea communication cables. As illustrated in Figure 16, damage to a single cable can remove one or several GW sized wind farm from the grid depending on whether US OSW development progresses in a single-project radial approach, or more towards an intraregional or interregional grid approach incorporating a meshed or backbone design (Pfeifenberger, 2021). This is particularly problematic since Allianz, the world's largest insurance company, reported that 53% of losses by value in their European portfolio was due to cable damage or loss (Figure 17, Allianz, 2023). The 2nd largest insurance company, AXA, reports that 80% of OSW claims are related to cabling (Klimczak, 2023).

As we learned from the case studies, energy infrastructure can easily become an attractive target. OSW substations could present a valuable target for hybrid warfare because sabotage at one substation could knock out power supply from one or more farms depending on design. However, such an effort could be more prone to satellite detection and/or much more difficult to retain strategic plausible deniability by blaming it on storms or currents. In turn, power cabling seems to be the most vulnerable component for domestic terrorism or hybrid warfare, noting Russia has shown specific interest in undersea undersee infrastructure. For instance, Russia has developed specialized subs and associated tools through its Main Directorate of Deep Sea Research, which is responsible for surveillance of and sabotage against critical maritime infrastructure, and has been suspected as the culprit in multiple underwater cable and pipeline events (Gronholt-pedersen and Fouche, 2022; Atlamazoglou, 2023).

Figure 17



Sabotaging a cable that provides OSW power to some portion of East Coast would permit an adversary to achieve significant US impact, given the East Coast is home to over one-third of US population, noting 100 million citizens live within the PJM, New York ISO and ISO New England alone as well as important political, military and financial hubs, including Washington DC and New York City (PJM, 2024b; ISO New England, 2024; USCB, 2024). Furthermore, as with a variety of gray zone warfare activities, damaging a power cable, particularly during a storm, would allow any adversary to retain plausible deniability avoiding direct, all-out conflict while still achieving strategic impacts.

The examples above show just some of the OSW components and considerations in conducting a vulnerability analysis. Through further research and multistakeholder collaboration, a working group could compile a comprehensive table outlining OSW Component, Impact Type and Method of Impact for potential OSW risks from a grid resilience perspective, which is quite different than the more project-focused, cost-benefit analysis conducted within the wind farm development and COP process covered in the Literature Review. While not comprehensive, Table 3 provides as an example of my own selections.

Table 3

OWS Component	Impact Type	Method of Impact
Turbine Blade	Extreme weather	Hurricane
Offshore Power Collector	Extreme weather	Hurricane
Offshore Power Collector	Acciddent	Adrift ship
Offshore Power Collector	Sabotage	Domestic projectile
Onshore Substation	Extreme weather	Hurricane, storm surge, sea level rise
Onshore Substation	Sabotage	Domestic projectile
Offshore Power Cables within Single Windfarm	Sabotage	Explosive or cutting device
Transmission Lines	Sabotage	Explosive or cutting device
Fiberoptic Communication Cable	Sabotage	Explosive or cutting device

Prioritization of Potential Risks – Compiling such a list then allows an informed body to apply a Multi-Criteria Screening (MCS) approach to help prioritize the different risks for more through assessment, return period, extent of impact, bandwidth to address, etc. This prioritization process can be done through ranking (e.g., 1, 2, 3 etc.) or rating (e.g., low, medium, high) of each identified component threat, and xamples of factors that could be considered is developing scoring parameters are listed and used in Table 4. Scoring parameters can be based on modeling, available literature, professional judgment and other methods (Peterson, 2023).

Table 4			Frequency of Event	Likelihood of Event	Event Causes *Partial* or *Complete* Loss of Power from Wind Farm	Timeframe Required for Completing Repairs	Total
OWS Component	**Impact Type**	**Method of Impact**	1= 1-5 yrs; 2=10 yr; 3=20+ yr	1=high; 2=medium; 3=low	1=Complete; 2=Partial	1=2+yrs; 2=1-2 yrs; 3=6-12 mo; 4=0-6 mo	
Turbine	Extreme weather	Hurricane	2	1	2	2	**7**
Offshore Power Substation/Collector	Extreme weather	Hurricane	3	2	1	1	**7**
	Accident	Adrift ship	3	3	1	1	**8**
	Sabotage	Domestic projectile	3	3	1	1	**8**
Onshore Substation	Extreme weather	Hurricane, storm surge, sea level rise	2	1	1	4	**8**
	Sabotage	Domestic projectile	3	2	1	4	**10**
Offshore Power Cables within Single Windfarm	Sabotage	Explosive or cutting device	3	3	2	3	**11**
Transmission Lines	Sabotage	Explosive or cutting device	2	1	1	2	**6**
Fiberoptic Communication Cable	Sabotage	Explosive or cutting device	Same as Transmission line, as fiberoptic is run with the power line connecting the farm to shore				**6**

In this sample exercise, the lowest numbers reflected the highest priority risks, including transmission line sabotage, and hurricane damage to turbines and offshore transformers. The lowest risks of concern were the highest totals, namely sabotage of onshore substations and array cables within a single wind farm. The ranking could then be used to group the different risks into High, Medium and Low priorities, as shown in Table 5.

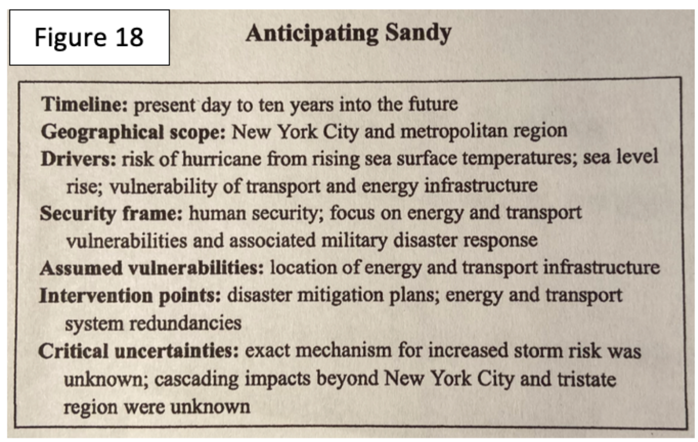
Table 5

OWS Component	Impact Type	Method of Impact	Priority Groups based on Ranking Exercise
Turbine Blade	Extreme weather	Hurricane	High
Offshore Power Collector	Extreme weather	Hurricane	High
	Acciddent	Adrift ship	Medium
	Sabotage	Domestic projectile	Medium
Onshore Substation	Extreme weather	Hurricane, storm surge, sea level rise	Medium
	Sabotage	Domestic projectile	low
Offshore Power Cables within Single Windfarm	Sabotage	Explosive or cutting device	Low
Transmission Lines	Sabotage	Explosive or cutting device	High
Fiberoptic Communication Cable	Sabotage	Explosive or cutting device	High

Again, this is just a sample exercise and not all points of vulnerability are included. For instance, specific domestic terrorism risk to power cables at coastal landing locations could be significant but was not included here. If this screening would be conducted in depth and for US planning purposes, it would require significant time investment with diverse expertise and stakeholder participation because each potential vulnerability is complicated.

Complex Scenarios – At some point after initial screening and prioritization of individual potential risks, more complex risk scenarios will have to be considered in developing a comprehensive security plan that includes emergency response. Valuable Foresight work was conducted by Chad M. Briggs and Miriam Matejova in *Disaster Security*: Using Intelligence and *Military Planning for Energy and Environmental Risks*. Briggs and Matejova led multi-year, preparedness and contingency planning activities with DOE and later through the US Air Force's Minerva Initiative (2019). They discuss how by the nature of these complex energy and environmental systems, compound disasters (i.e., multiple sequential disaster events) can occur, result in potentially cumulative cascading impacts, and how "due to the complexity and considerable uncertainty associated with such events, the effects of compound disasters are not yet fully accounted for in contingency planning" (Briggs and Matejova, 2019). Their efforts ended up being prescient, as they developed a scenario for New York two years before Superstorm Sandy struck (Figure 18, Briggs and Matejova, 2019).

Figure 18



Anticipating Sandy

Timeline: present day to ten years into the future
Geographical scope: New York City and metropolitan region
Drivers: risk of hurricane from rising sea surface temperatures; sea level rise; vulnerability of transport and energy infrastructure
Security frame: human security; focus on energy and transport vulnerabilities and associated military disaster response
Assumed vulnerabilities: location of energy and transport infrastructure
Intervention points: disaster mitigation plans; energy and transport system redundancies
Critical uncertainties: exact mechanism for increased storm risk was unknown; cascading impacts beyond New York City and tristate region were unknown

Their work will need to be expanded for OSW because of significant geopolitical changes since that book was published. Threats to OSW from the Arctic GPC and hybrid warfare risks must be integrated to fully define the potential scenarios the US will face with offshore energy assets. By simple example, consider a CAT 6 scenario hitting New York during a severe heatwave. What would be the additional cascading impacts if an OSW sabotage action was carried out on a major, subsea power cable during the recovery? What if a separate sabotage event was carried out against New England OSW generation while New York is dealing with the climate-driven OSW emergency, suddenly impacting adjacent regional power grids?

These are the types of complex scenarios the US could well face and that a national OSW security plan must address, including making sure modeling is adequate, which it was not in the Winter Storm Uri case study. Noteworthy in this regard is the fact that PJM's energy demand projections for over the next ten years do not consider climate change impacts, although there apparently are plans to do so in the future (PJM, 2023). Reinforcing such importance, a 2021 study leveraged machine learning and climate model projections to quantify potential future household air conditioning use, something critical during extreme heatwaves. At 1.5^{o}C increase in global mean temperature, they modeled a 5%-8.5% increase across the US with an increase of 11%-15% under a 2^{o}C scenario and suggested that at "some states will face supply inadequacies of up to 75 million 'household-days' (i.e., nearly half a month for every current household) without air conditioning in a 2^{o}C warmer world (Obringer, et al., 2022).

DISCUSSION

The purpose of this research was to examine 1) the projected growth and importance of the US OSW industry, 2) the resulting physical vulnerabilities these offshore energy assets will be exposed to because of extreme weather and GPC-driven, hybrid warfare, and 3) the energy and climate security risks for which US government and the private sector will need to plan. The literature review revealed that OSW could contribute as much as 20% of the East Coast energy mix in the decades ahead, while the buildout will occur within a multi-polar world and GPC that will increase adversary presence and interests to both the Arctic itself and the North Atlantic. It also elucidated that our current military capacity is not built to monitor and protect critical energy infrastructure distributed widely within the EEZ, and the development process is simply not focused on external physical risks to these assets.

The selected case studies clearly showed that physical or kinetic events have caused significant damage to various parts of the US and Ally energy supply chains and that these can have major impacts on energy production, the grid, and civilian human security and military operations. Furthermore, there is some significant evidence that sectors and states alike tend to consider the physical security of energy infrastructure from a mostly a reactive position, designing for situations and occurrences that either have already taken place or, at best, are easily predicted, as long as it passes a less-than precautionary and project-centric cost-benefit analysis. This is no longer acceptable because climate change is making the quantification of risk less possible, and the growing global instability makes remaining reactive dangerous.

Cybersecurity and energy transition have both ramped up significantly over the last two decades, but it is the opinion of this author that physical vulnerabilities of energy assets as a hybrid warfare target have never gone away and are becoming more attractive again. Furthermore, as we electrify everything in a warming climate, attacks on energy infrastructure likely will become more effective while recovery will become more difficult.

Multiple agencies within the federal government should take the opportunity we currently have to change the national mindset and build a culture of proactive energy asset security for OSW within the missions of each major agency that will have a role in reaching our OSW goals. For instance, while DOE's focus on research, funding, modeling and liftoff of OSW, physical security of those assets must be woven through each of those stages and efforts. If they are not doing so internally now, DHS and USCG must review their missions and capacities to deal with 24/7 power generating capacities far out into the EEZ. DOI and developers must consider their shared responsibilities, as outlined in the April 30th National Security Memorandum on Critical Infrastructure Security and Resilience, and the potential need for greater standardization in wind farm development as it pertains to kinetic risks.

It will take decades to standup a national OSW energy security program capable of dealing with evolving and unpredictable climate and geopolitical threats. A diverse set of OSW stakeholders will need to vastly expand the sample risks, prioritization and scenarios explored in the Results section, considering "all threats and hazards, likelihood, vulnerabilities, and consequences, including shocks and stressors — as well as the scope and scale of dependencies within and across critical infrastructure sectors, immediate and long-term consequences, and cascading effects" (The White House, 2024b). To kickstart such consideration, the following Recommendations provide a proposed framework for informing stakeholders regarding OSW vulnerabilities, as well as a sampling of near-term actions that can be undertaken to inform the larger, longer collaborative process.

RECOMMENDATIONS

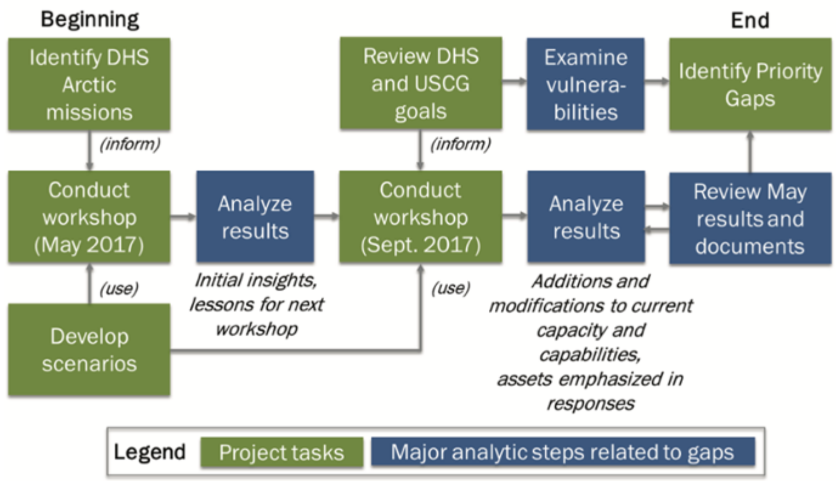
Framework for informing policymakers, regulators, and industry on offshore wind vulnerabilities

With national plans for and significant public and private investments into developing OSW, a multistep, multi-stakeholder approach is needed that culminates with an OSW Security Roadmap that outlines goals and objectives for what that security looks like five years from now, ten years from now, and twenty years from now. The following is one potential approach achieving such a goal.

Executive Steering Committee – Given OSW security is a nascent subject, the first step is to establish an Executive Steering Committee (ESC) consisting of four to six individuals who can review the issues and suggestions presented in this primer, evaluate its merits, identify key issues not yet considered, and suggest the best offices and personnel within each agency to include in the next steps. The ESC should sit within the White House given climate change and OSW are all important administration goals, and security issues surrounding OSW could be a sensitive national security and political subject. Specifically, the White House Office Science and Technology Policy (OSTP) could oversee the effort, since its responsibilities include Climate and Environment, Technology, and National Security. OSTP's National Security team seems well aligned for this subject, noting it works to "reduce catastrophic risks at the intersection of technology and global security, spanning nuclear, biological, cyber, and autonomous technologies, associated risks of war, pandemics, and large-scale disasters, as well as emergent risks in space, ocean, and polar domains" (The White House, 2024b). As for leadership representatives on the ESC, members might include DHS' Science and Technology Directorate, USCG and CISA, DOE's EERE and CESER, DOI's Office of Land and Mineral Management, US Navy's Office of Naval Intelligence and Naval Surface Warfare Center, and DOD's Office of the Secretary of Defense. Given their extensive USG experience, the ESC would also have valuable insight into the form the next steps should take, such as whether there is an existing forum or task force that could be tapped, whether a single agency is most appropriate to lead the effort, whether the ESC would benefit from including an industry representative at this early stage, etc. Under OSTP oversight, co-chair representatives from DHS' HSOAC and DOE's ETAC could utilize the direction and feedback from the ESC to convene the next step in developing an OSW security strategy forum.

Multi-Stakeholder Gaps Analysis – In 2018, the RAND Corporation, which operates the HSOAC for DHS, released *Identifying Potential Gaps in U.S. Coast Guard Arctic Capabilities*. Within the Gaps Report for the Arctic, RAND used a multi-workshop model (Figure 19) looking at USCG missions and utilizing Arctic scenarios to generate discussion among a variety of subject experts. This process identified three broad gaps involving 1) *communication*, 2) limited capacity and capability to *monitor* threats and hazards, and 3) scarcity of available assets and infrastructure for *response*. A fourth, separate gap identified was DHS and USCG difficulties in addressing persistent Arctic challenges and the importance of improving abilities to identify needs and risks (Tingstad, et al., 2018).

Figure 19 Summary of Research Approach



Both the process by which RAND conducted these Arctic workshops, as well as the broad categories of potential gaps identified will serve useful in bringing the right people together and identifying the broad needs for OWS security.

Another useful aspect of the RAND report was the qualitative vulnerability assessment they conducted for each gap on each of the USCG's eleven missions by the 2030s, if these gaps are not closed. The results of this assessment are shown in Table 6 (Tingstad, et al., 2018). It highlights USCG Security missions and raises the significant question as to whether OSW security falls within an existing mission, if a 12th mission must be lobbied for in order to garner the policy and financial support needed to achieve the objectives. Second, it highlights the "critical" importance closing the gaps for both "Response" and "Needs and Risks" by the 2030s, as a similar timeline certainly applies to OSW (Tingstad, et al., 2018).

As for what stakeholders should be included in such a larger stakeholder group, the spectrum of parties that could eventually touch the process is very broad. Some

Table 6. Level of Vulnerability Associated with Not Closing Possible Capability Gaps by the 2030s

Mission Category	Mission	Communications	Awareness	Response	Needs and Risks
Safety	Search and rescue	**Critical**	**Critical**	**Critical**	**Critical**
	Marine safety	**Critical**	**Critical**	**Critical**	**Critical**
Security	Ports, waterways, and coastal safety	Important	Important	**Critical**	**Critical**
	Drug interdiction	Potential	Potential	Potential	Important
	Migrant interdiction	Potential	Potential	Potential	Important
	Defense readiness	Important	Potential	Important	Important
Stewardship	Aids to navigation and waterway management	Important	Important	Important	Important
	Ice operations	**Critical**	**Critical**	Important	**Critical**
	Living marine resources	Important	Important	Important	Important
	Marine environmental protection	Important	**Critical**	**Critical**	**Critical**
	Other law enforcement	Potential	Potential	Potential	Important

significant effort will need to be made to home in on what entities will be participants, what entities should be presenters/resources for the process, and whether certain entities will likely contribute to the process in the future but are not critical for the initial framing and gap analysis efforts. The experience of the ESC, the HSOAC, and the ETAC will be critical in making such an assessment, but Table 7 provides a jumpstart for such discussion. Such a participant list will put the right knowledge in the room to build out the full spectrum of considerations for understanding OSW security, ranging from wind turbine design and future "CAT 6" Atlantic hurricanes to emergency response to address energy and human security impacts resulting from a loss of multiple, GW-sized OSW farms.

Agency/Stakeholder Group	Office/Entity	Expertise & Potential Role in Security Chain
Energy	CESER	Security and Resilience of US Energy Sector
	WETO	Energy Generation Technology R&D and deployment
	OE	Grid Technologies and Planning
	GDO	Transmission
	HFTO	Storage technologies, Green H2
	WPTO	Energy Generation Technology
National Labs	NREL	Renewable Energy Research, Development and Deployment
	PNNL	Grid Modernization; Threat Analysis
Homeland Security	USCG	Primary authority within EEZ
	CISA	Homeland Infrastructure Security
	HSOAC	Gap Analysis and Vulnerability
Defense	Navy	Atlantic Basin Defense
Interior	BOEM	Permitting, Deconflicting
	BSEE	OCS Security; Safety and Operations Inspections
Commerce	NOAA	Climate Modeling and Projections
Industry	Ocenatic Network	Offshore Wind and Ocean Renewables Industries
	OEMs	Engineering Design
	Developers	South Fork Wind (operational); Revolution Wind (under construction)
States	New York, Rhode Island, etc.	Workforce, Supply Chain, State Energy Security Plan, Disaster Response
Grid Operators	PJM	Wholesale Market, Grid Reliability, Load Planning

Table 7

National Strategy and Roadmap – Once a multi-stakeholder body dives into OSW scenarios and potential broad gaps are identified, this or a different group should turn its focus towards a national strategy and roadmap for OSW asset security. DOE and the Hydrogen Fuel Cell and Technologies Office produced such a document in 2023 for the future hydrogen economy, developing a “comprehensive national framework for facilitating large-scale production, processing, delivery, storage, and use of clean hydrogen to help meet bold decarbonization goals across virtually all sectors of the economy" (DOE, 2023b). A similar structure could be followed for OSW security, laying out key strategies and guiding principles for establishing robust OSW security capabilities. Three key OSW security strategies could be:

- ⇒ *Strategy 1 – Align OSW Research, Deployment, Grid Integration, Protection and Emergency Response Necessary to include Minimizing Future Vulnerability to Physical Risks.*
- ⇒ *Strategy 2 - Develop a Public-Private Partnership to Identify, Plan for, and Execute Respective Responsibilities, Capacities and Technologies for Monitoring and Protecting OSW Assets.*
- ⇒ *Strategy 3 – Identify and Address All Legal, Policy and Funding Needs and Constraints for Executing a National OSW Security Strategy and Roadmap.*

Guiding Principles of OSW Security are provided in Table 8.

1.	Maximize Deterrence through Resilience of for offshore assets	5.	Enable affordability and versatility of capacity and technologies
2.	Catalyze technology development and scale-up to meet security goals	6.	Advance energy justice within security planning
3.	Ensure domestic supply chain for OSW deployment and protection meets timelines for energy asset deployment.	7.	Foster DEIA because energy security is an American right
4.	Approach wholistically, including both preventative and responsive approaches	8.	Ensure OSW security enhances quality job opportunities

Table 8

One other useful Roadmap for reference in the proposed process is EERE's Roadmap for Wind Cybersecurity (2020). It sets out a 5-part vision that identifies 1) challenges, 2) strategies, 3) short-term milestones, 4) mid-term milestones, and 5) long-term milestones (DOE-EERE, 2020). Of particular interest and applicability to a physical security roadmap for OSW are the main strategies from this roadmap involving the need to develop the culture, identify risks and protect, detect events, and the need for timely respond and recover capabilities (Table 9, DOE-EERE, 2020).

Table 9				
Strategies	**<u>Develop Wind Cyber-Culture</u>:** Promote cybersecurity culture among wind energy community, encouraging cybersecurity information sharing including cyber threats, Indicators of Compromise (IOC), vulnerabilities, cyber incidents, attack patterns, lessons learned, and best practices; facilitate and support a cooperative environment for the exchange of information, ideas, and collaborative efforts among wind energy stakeholders	**<u>Identify and Protect</u>:** Develop an organizational understanding to manage cybersecurity risk to wind assets, data, and grid infrastructure; develop and implement appropriate cyber-safeguards to ensure delivery of wind energy	**<u>Detect</u>:** Develop and implement appropriate detection technologies to identify malicious or unintentional cybersecurity events impacting wind technologies or networks	**<u>Respond and Recover</u>:** Encourage development and implementation of appropriate activities to take timely and effective action to mitigate cybersecurity incidents; execute plans for resilience and restore wind energy capabilities or services

Recommendations for Near-Term Actions

While the above process will take considerable time, there are a variety of actions that could get underway now, or soon, at the individual office or command level, which would add valuable data and insights to the longer, multi-stakeholder effort. The example recommendations provided are, by no means, comprehensive. They are provided to show the breadth of topics needing attention and help kickstart such explorations. The same is true for the few useful questions posed with some of the recommendations.

<u>*Security Lens Review of Current/Recently Completed National Lab Projects*</u> - The Atlantic Offshore Wind Transmission Study report released in March 2024 was part of DOE's efforts to understand and facilitate the transmission of OSW electricity. Providing a multiregional transmission perspective, the study considers "environmental, ocean co-

use, and other siting considerations into defining potential offshore transmission routes" (DOE-EERE, 2024e). While the document references other reports brought to the attention of the research team, such as the Federal Communications Commission's work on communication cables and undersea cabling routing and landing, physical security of OSW power cabling is not addressed. Furthermore, PNNL utilizes its Electrical Grid Resilience and Assessment System to consider transmission tower damage and OSW turbine shutdown during Superstorm Sandy, but physical damage to OSW assets or the cascading impacts that might cause are not considered. DOE and other funding agencies should consider conducting a review of critical work by NREL, PNNL, and other labs from a future strategic physical risk security perspective, evaluating if such considerations alter any findings, conclusions, or recommendations, and/or if there are useful next steps on for security utilizing such recently completed research.

Model and Integrate OSW Emergency Response Needs into Projected Supply Chains and the Just-in-Time Economic Model – The supply chain is certainly one hurdle for OSW, noting a recent quote from an industry expert, " we're trying to build an industry for which we have no supply chain," and that "our demand has outstripped not only the U.S. supply chain but the global supply chain" (Richards, 2024). Efforts by DOE and states like New York, include strong efforts to build-out domestic supply chains and workforces, in order to stand up the industry (NYS, 2024). But, when it comes to OSW security, supply chain planning will need to consider availability of vessels, components, and workforce capacity in the immediate aftermath of a damaging event(s). A kinetic lens should be applied to whether back-up power at the wind farm is adequate to keep essential systems functional during prolonged loss of power, as well as how protection of the wind farm is managed (e.g., remotely activated locking and feathering of blades) if communications and remote control is lost (DOI-BOEM, 2021; DNV GL, 2021). Other issues to be considered would also include authority to expedite response and financial incentives or support to maintain emergency repair readiness.

Establish Appropriate International Channel and Working Group to Learn from Allies – The EU, UK and NATO are confronted with many operational OSW assets, and due to the war and Russian naval activities, they are now facing the difficult challenge of addressing OSW security in a reactive manner. EU governments will need to address everything from technology tools, to capacity, to financing, working with asset owners to try and find common ground on responsibilities (Gronholt-pedersen and Abnett, 2023). While there likely will be some differences between the EU approach and what US OSW Security will entail, it would be highly beneficial for US stakeholders to participate in their process, providing our support and input in exchange for learning from their challenges and expediting our learning curve.

Utilize Currently Operational OSW Assets as Pilot Projects to Test and Understand USCG Authority, Requirements and Capacities to Protect the Asset – The first turbine of Vineyard Wind I (806 MW when completed) provided energy to the Massachusetts grid in January and the 130-MW South Fork Wind Project opened in March off Long Island (Mahe, 2024; Associated Press, 2024). Construction has begun on the 704-MW Revolution Wind project (32 miles southeast of the Connecticut coast), which will split delivered power between Rhode Island and Connecticut (State of Rhode Island, 2023; Revolution Wind, 2024). USCG District 1 should use such opportunities to for its Operations and Resource Planning, Prevention, and Response Divisions, taking on temporary and periodic exercise scenarios of different time lengths to monitor and protect those assets under the pretense of pending hurricane and nearby Russian activity. Such a pilot program would help elucidate what vessel, manpower and technology needs are important for the District to address various vulnerabilities as those assets multiply. Such identified needs could then be crosschecked with existing USCG programs, such as Cutter Procurement, to determine if existing USCG plans will meet the projected needs (CRS, 2024b).

Utilize Currently Operational OSW Assets as Pilot Projects to Test and Understand US Navy 2nd Fleet Capacity to Protect the Asset and Respond to a Heightened Concern - The 2nd Fleet is based in Norfolk, but Vineyard Wind, South Fork Wind and Revolution Wind could provide the 2nd Fleet an opportunity conduct response exercises as well. Additionally, the Newport Undersea Warfare Center (NUWC) is near Southfork Wind and is a major research, development, test and evaluation, engineering, and fleet support center for submarine warfare systems and many other systems associated with the undersea battlespace (USN, 2024b). A useful exercise could involve mock intelligence indicating that a Russian sub, known to have been surveying undersea cables off Canada, is leaving the Arctic and headed down the East Coast withing the US EEZ and towards these OSW assets. Would the 2nd Fleet respond to monitor and protect both OSW assets? Would that response be different if the 2nd Fleet has to surge to the

European North Atlantic again? What role is there for NUWC in current or future security planning?

Conduct a Preliminary Desktop Assessment as to What Extent Potential Climate Change Impacts Are Being Considered Across the Lifespan of an OSW Asset – Various modeling discussed within do not consider climate change or focused on past storms as benchmarks. Yet, it seems clear that hurricanes are going to come up the Atlantic with growing intensity, with even this year possibly providing a preview of what the future might look like (Skinner, 2024). Furthermore, there is some research, as well as empirical climate evidence, that suggests the mid-latitudes will become more favorable to hurricanes, and that places like New York, Boston and New England area could be exposed to more frequent hurricanes (Studholme et al., 2022; Casey, 2023). An appropriate lab should start to investigate issues to inform potential future standardizations, such OSW design consideration of IPCC scenarios (e.g.SSP-2.6 vs. SSP-7.0), industry OEM standards for turbines and foundation design, engineering references for on and offshore substation elevation above sea level, and grid reliability planning by RTOs and NERC. A comprehensive baseline understanding of what each stakeholder does and does not consider regarding future climate change impacts will be vital for understanding potential vulnerability gaps and building a roadmap for proactive and response planning.

Conduct Desktop Assessment of known Technologies Designed for or Utilized in Civilian or Military Sectors that could Contribute to Long-Term Planning – In 2022, BSEE released a guide on current state of remote technology for conducting remote activities such as monitoring, inspection, testing, maintenance, repairs and replacements on offshore wind farm components and subsystems above and below the water line, and it is clear that such technology will play a critical role in building a robust, multi-layered, strategic protective capacity as well (DOI-BSEE, 2022). For instance, companies like MARTAC have developed unmanned surface vehicles, ROVs or autonomous underwater vehicles are used in such activities as pipeline maintenance (MARTAC, 2024). Thus, these technologies are well positioned to supplement responsibilities and capacities of project owners and US military alike for OSW security (Monaghan et al., 2023). Additionally, there are sonar-based hydroacoustic sensors used by certain countries to detect subs near coastlines, and it has been reported that China is working on methods to detect low-frequency electro-magnetic signals and tiny bubbles from passing submarines (TRTWorld, 2023; USNA, Nd). These types of patrol and detection technologies will all be enhanced by AI and automation technology (Monaghan et al., 2023). Thus, to support the gaps analysis and roadmap process, preliminary security technology opportunities need to be compiled, assessing what technologies are currently on the market, the TRL stages of tools under development, which technologies lend themselves to developer/owner deployment versus defense contractor/military utilization, etc.

CONCLUSION

The Royal United Services Institute, the world's oldest and the UK's leading defense and security thinktank, held a webinar in 2023 about nations facing a "Polycrisis" of climate change, energy security and instability (RUSI, 2023). Without using the term, the Administration's April 30th National Security Memorandum on Critical Infrastructure Security and Resilience points to the same central reality: we are in the midst of a generational energy infrastructure investment, climate impacts will strain our assets and systems, and we have entered "an era [emphasis added] of strategic competition with nation-state actors who target American critical infrastructure and tolerate or enable malicious actions conducted by non-state actors" (The White House, 2024a). Such national security messages from both sides of the Atlantic in undeniable; the energy security risks we will face could not be clearer and those risks will be long-lasting. Mirroring this Administration's push to build an OSW industry, DOE, DHS, and other stakeholders must plan for energy adaptation in this new world, and security is a core component. The physical security of OSW needs to be woven into every facet of the OSW industry and it will need to become a USG-wide mission and culture. We have time and opportunity to do it right, but we must start.

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