HUNGER FROM BEYOND

Strengthening Energy Resilience Through Operational Energy: The Case of Taiwan

By

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Abstract

This thesis examines the relationship between energy resilience and deterrence, through the prism of operational energy in military logistics. It highlights the increasing significance of addressing the carbon footprint of global militaries and the growing importance of energy resilience in operational effectiveness. The study focuses on Taiwan as a case study due to its particular strategic position, heavy reliance on energy imports, and favourable environment for military innovation. It argues that energy resilience, specifically operational and installation energy, can contribute to deterrence strategies and act as an additional defence element. The thesis questions whether energy resilience is limited to affluent countries invested in environmentalism or if it can be implemented in resource-constrained countries with particular security threats through appropriate operational and installation energy strategies.

Using a positivist approach, the research employs qualitative methods, including data collection from government institutions, think-tanks, and research organizations, as well as interviews conducted in Taiwan. The thesis is structured into chapters that explore the interconnection between deterrence and resilience, the importance of operational and installation energy in warfare, policy initiatives in the US, NATO, and the European Defense Agency, and Taiwan's approach to energy resilience and operational energy.

The research found that, while Taiwan has taken steps towards energy resilience, energy security is not yet fully embraced by society and the military. The implementation of effective operational energy strategies is hindered by Taiwan's existing defence posture and military build-up.

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Introduction

If the world's militaries were a country, they would be responsible for the fourth highest carbon footprint (Parkinson and Cottrell, 2022). In order to get a hold on climate change, we must therefore also address this very much overlooked area. As a result, there is a growing discourse on green defence across various countries including the U.S., Canada, European states, such as the UK, France, Germany or Italy, and organizations like NATO, and the European Defence Agency. This shift reflects the increasing importance of climate change and environmentalism not only to the public but also to militaries. In response to this trend, countries have been climate proofing their militaries through various measures. These include incorporating climate change into military planning, developing energy-efficient and renewable energy technologies, enhancing infrastructure resilience, and training and equipping personnel to respond to climate-related emergencies.

The war in Ukraine has further highlighted the significance of energy resilience in operational effectiveness. Challenges in fuel logistics, security constraints, supply chain vulnerabilities, and critical infrastructure risks posed by both state and non-state actors, as well as environmental concerns, have underscored the importance of operational and installation energy. Two novel concepts of contemporary military logistics, with energy efficiency and electrification in their core. Although the discourse has been going on for more than a decade, the concept and its technological enablers are very much in their infancy. In recognition of these factors, NATO is currently developing its own Operational Energy Concept (OEC). The OEC will encompass all aspects of energy management, from production and procurement to transportation, storage, distribution, quality control, accountability, data collection, security, and protection. It will also provide guidance on fundamental principles to shape future NATO energy standards.

This paper aims to find out how energy resilience in the form of operational energy can enhance a country's deterrence value. The current literature on the theory of military logistics does not highlight the importance of energy as such, neither does it define it well. It is Kress (2002), who notes that rather than defining it we should think about it as an input in the production system, which is heavily intertwined with economies, where the output is the outcome of the war. Following this logic, the paper analyses the relation between deterrence and resilience through Rhodes (2000), who notes that the primary goal is to deny a quick victory by using resources to build up resilience. One of the most common ways to approach it is through critical infrastructures. This paper looks at energy resilience through the prism of operational energy. The current literature addresses operational energy as a sub-part of green defence, and not really as an emerging concept. Neither do they explain how states might choose to implement it (Clark et al., 2023; Barry et al., 2022; Kõrts, 2023; Patrahau et al., 2010; Smil, 2004). This paper aims to fill the gap in that regard.

The countries that do address the problem of overreliance on fossil fuel in their militaries are affluent, not under direct threat and are invested in environmentalism. Which brings us to the following question: what about countries that are energy poor, in a vulnerable strategic position, but at the same time have an accommodating environment in terms of research and development? This paper argues that adequate logistics of energy resilience in the form of operational and installation energy can serve as additional elements of deterrence by denial strategies. In other words, the paper wants to see whether green defence is the privilege of a handful of countries, or it can be spread out through the implementation of adequete operational and installation energy strategies. To do this, the paper looks at Taiwan, which is a perfect case study because of various reasons. The island is facing China as its number one security threat, with the possibilities ranging from a blockade to outright invasion to force unification. Secondly, despite huge investments into renewable energy technologies, they import almost

98% of their energy sources (Ritchie & Roser, 2022). Thirdly, there is an accommodating environment for military innovation due to its high-tech manufacturing capabilities and willingness to spend on its army. Finally, it enjoys the support of the United States when it comes to capability procurements.

The thesis will follow a positivist approach, and will utilize qualitative methods to collect and analyse data and interviews as well. For the first half, this research is using publicly available data from government institutions, think-tanks and research institutions alike to get a better understanding of the ongoing developments in military energy logistics. While the second half of the thesis will primarily build upon interviews conducted in Taiwan in April 2023.

In the first chapter the paper elaborates on the two pillars of the main argument, namely the connection between deterrence by denial and resilience, and the logistical thinking of energy. Chapter two then will address the importance of energy in warfare, by explaining operational and installation energy, the main drivers behind them, their core elements and current challenges deriving from technology and systematic limitations. Chapter three will address the growing discourse and policy initiatives of operational and installation energy in the U.S., NATO and in the European Defence Agency to showcase their implementation in a top-tier military, through a military organization and on the multinational level. Finally, chapter four showcases Taiwan's strategic vulnerabilities and chapter five analysis the island's approach to operational and installation energy, and more broadly to energy resilience along the pillars that were identified in chapter two.

Ultimately, this paper found that while Taiwan does certain steps towards energy resilience, energy security is yet to become an issue to society and the military, and the implementation of adequate operational energy strategy is highly limited by its current defence posture and military build-up.

Chapter 1 – Deterrence, Resilience and Logistics

This paper argues that adequate logistics of energy resilience in the form of operational and installation energy can serve as additional elements of deterrence by denial strategies. This is particularly true for small states who are resource poor and are in an extremely vulnerable strategic position. Before talking about the importance of this, the paper situates this phenomenon in the wider literature by explaining two pillars of the argument: the connection between deterrence by denial and resilience; and the discourse on energy in logistical thinking. While it is clear that strengthening critical systems that play a vital role in a country's defence capabilities can thwart an attack and give precious time for the defender and its allies, the importance of *energy* in this, and particularly in logistics, is just starting to get wider attention.

1.1 Deterrence

The aim of deterrence is to prevent the adversary from taking unwanted actions, especially military aggression, to alter the status quo (Schelling, 1980). For it to work, the deterring state must communicate which military actions are unacceptable; and indicate not only its ability but also its willingness to impose high cost on the adversary. If the adversary deems those costs unacceptable and in turn refrains from the intended military action, then the deterrence was successful (Simón, 2020). That said, some potential adversaries are, at least at times, undeterrable. As noted by Rhodes (2000), there are three reasons why this might be. First, if the cost of losing the war is not perceived as high enough, especially when the cost of inaction is higher for the aggressor. Second, the aggressor might know something about the credibility of the deterrer's commitment and capabilities. Thirdly, the aggressor is unable to clearly understand the deterrent threats because of cultural barriers, internal preoccupations or even psychological stress.

The current literature identifies two main forms of deterrence. Deterrence by punishment and deterrence by denial. Punishment threatens with severe penalties, such as nuclear escalation, that are connected to the wider world that not only raise the cost of an attack but would also open new battlefields, thus it removes the illusion of control from the opponent (Mazarr, 2018). Denial, as noted by Mazarr, is confined to the contested territory and "seeks to deter an action by making it infeasible or unlikely to succeed, thus denying a potential aggressor confidence in attaining its objectives" (2018, 2.). Simón (2020) argues that while punishment is often favoured by stronger powers, who are in a position to take the fight to their adversary's territory and defeat them militarily, denial is the frequent choice of the weaker party, who cannot afford escalation. However, the line between the two can be blurry. After all, denial also includes some degree of punishment, while punishment would eventually degrade the adversary's capabilities thus deny its broader strategic objective (Joshi & Mukherjee, 2019). Still, as pointed out by Gallagher, "the credibility of either form of deterrence lies in the mind of the target" (2019, p 33). When it comes to the best choice, Glenn Snyder - one of the foremost experts of deterrence – argued that denial is the more reasonable choice "if the deterrer has strong denial forces" as a "denial response is more likely than a reprisal action to promise a rational means of defense in case deterrence fails" (1961, 15). Huth goes further and notes that "deterrence based on the threat of denial is much more effective than the threat of punishment in a protracted war" (1988, 88). For denial to actually work, argues Gallagher, the "defender needs to understand where the attacker is seeking to strike … [so it] can (…) posture forces and resources (…) to do something about it" (2019, 33). Finally, Rhodes concludes that "(…) the key is to demonstrate a commitment and capability to deny the potential aggressor a quick victory and to convince it that events would escape its control" (2000, 31). After all, in war, time means money, resources and human lives as national economies become ever more intertwined and modern warfare costs more than ever due to state-of-the-art capabilities. Therefore, the longer the war the higher the costs. With this logic, if a state manages to become more *resilient* on the fronts that are most likely to be targeted by the aggressor, thus potentially denying a quick victory, and it manages to communicate this advantage, then it can improve its deterrence by denial.

1.2 Resilience

The term *resilience* can be found in various fields, ranging from psychology (mental health) biology (viruses) and engineering (materials, design). Our understanding of it as part of national security derives from the letter, more precisely from structure design. As noted by Omand, resilience is “the capacity to absorb shocks and to bounce back into functioning shape, or at the least sufficient resilience to prevent stress fractures or even system collapse” (2005, 14). Considering the increasing public and military dependence on certain technologies, with power, telecommunication and the internet being at the heart of all this, it is more important than ever to secure them from both state and non-state threats. This refers to critical infrastructure resilience, which has three important characteristics according to the National Infrastructure Advisory Council (NIAC): (a) robustness, which is the ability to maintain critical functions by absorbing the impact of the crisis or disruption; (b) resourcefulness – to establish and maintain adaptive capacity and flexibility by redirecting resources and assets; and (c) rapid recovery, which is the ability to return to normal functioning capacity as fast and efficiently as possible (2009). When it comes to these critical infrastructure systems (CISs) “our welfare highly depends on their normal and continuous performance” (Mottahedi et al., 2021, 18). Typical examples include energy, water services, communications, transport, food supply chains, health, banking and finance, key government functions, national security and defence-related assets. Lately, more and more countries include “intangible assets, such as supply chains that enable the functioning of physical infrastructure and/or deliver critical services” (OECD, 2008 6). However, as noted by Fjäder, “if the strategic objective is making a nation more resilient, prioritisation is necessary and, in some cases, could produce difficult value choices” (2014, 122). After all, protecting all elements of critical infrastructure against an array of threats is simply impossible. This is why the state must first and foremost establish the objective of their strategy. *Resilience of what and against what?*

Broadly speaking, the infrastructure that must be always available are electricity, health services, water service and national security and defence assets. When it comes to threats, it includes both state and non-state ones. Which means security issues ranging from deliberate kinetic and cyber-attacks to infectious diseases, extreme weather events, natural resource crisis, IT infrastructure breakdowns and even debt crisis. Due to increased digitalization in the industry, cyber-attacks are quickly becoming the number one threats (Roshanaei, 2021). The energy angle of resilience, meaning adequate electricity, heating and transport, is not only important for the public but also for the military, after all "[l]ack of readily available power impacts mission readiness and effectiveness of militaries and other organizations entrusted with national security missions" (Mallery et al., 2022, 1). Which in turn can easily undermine a country's capabilities and morale, thus its deterrence value. However, protecting these assets are not entirely in the state's capacity anymore. After all, most CIs are owned and operated by private entities. This is why "private-public sectors require to develop strong partnerships in information sharing and exchange capabilities" to ensure that electricity supplies are reliable, resilient, and secure (Roshanaei, 2021, 83). No matter how we approach national energy resilience, and the strategy to protect its most vital elements, it is going to be a question of logistics.

1.3 Theoretical aspects of logistics

Given its huge importance in warfare, the absence of a proper theoretical framework which links logistics to military outcomes is very striking. The concept of logistics is usually attributed to Renatus, Clausewitz and Jomini. Interestingly, after Renatus, the authors do not elaborate in detail on the importance of energy sources, which in pre-20th century military strategy predominantly meant provisions such as food, water and animal feed. Rather they concentrate on weapon supplies.

"Famine makes greater havoc in an army than the enemy, and is more terrible than the sword", wrote Flavius Vegetius Renatus (390 A.D, 31) in his collection of Roman military customs and wisdoms, *De Re Militari*, which influenced many military theorists up until the 18th century. Although the quote might indicate that his scope on logistics is narrow, due to limitations of that era the main concern of the Roman army in terms of war material was indeed provision for soldiers and animals. In his maxims he highlights that "the main and principal point in war is to secure plenty of provisions" (31), the need to do exact calculations about storage and distribution, and to notify provinces in time to prepare provisions and magazines. Renatus even writes about the necessity of war materials being protected from the incoming enemy and the importance of soldiers having wood in winter, water in summer and basics such as wine, vinegar or corn at all times. More than a thousand years later, it is Von Clausewitz who touches upon logistics in his book *On War (Clausewitz et al., 1976)* but does not address it, as such. He argues that:

> "The knowledge and skills involved in the preparations will be concerned with the creation, training and maintenance of the fighting forces. It is *immaterial what label we give them*, but they obviously must include such matters as artillery, fortification, so-called elementary tactics, as well as all the organization and administration of the fighting forces and the like" (131-132).

Like Renatus, he also provides many practicalities. From the dangers of marching with a big army; the need to amass stocks of provisions by purchase, from the state's demesnes, or stored in depots, to the importance of bread being baked and transported by the army. However, he notes that "(…) the importance of the base rests more on the need for replacements of weapons and equipment than on food supplies" (342). That said, he concentrates on leadership as the dominant element of warfare which derives from the fact that Prussia fought short engagements, over limited distances, which influenced his thinking on what was termed as supply, as noted by Prebilič (2006). In contrast, Jomini, the Swiss born strategist who was a general in Napoleon's army, stressed the importance of logistics as a principle of war and even placed it among basic military skills. In his famous work, *The Art of War*, he writes:

> "Logistics is the art of moving armies. It comprises the order and details of marches and camps, and of quartering and supplying troops; in a word, it is the execution of strategical and tactical enterprises" (Jomini in Jomini and Cocroft, 2007, 51).

His understanding derived from military engagements fought at long distances, on a much larger scale and with a highly mobile army, largely based on a magazine-type of supply (Preblič, 2006). Nevertheless, his scope on logistics is rather small, after all, it is much more than just moving armies. Martin Van Creveld, in *Supplying War* (1977), writes extensively about the logistic factors limiting an army's operations between 1805 and 1944. He tries to highlight its crucial importance and expands Jomini's scope, but does not elaborate why conceptually. Rather, he concludes that "most armies seem to have prepared their campaigns as best they could on an ad hoc basis" (332). To sum it up, logistics' definition and relation to strategy and tactics remain a mystery. It's best approached case-by-case, considering factors – or "frictions" as Von Clausewitz put it - that can complicate things in war.

1.4 Essence of modern logistics

Henry Eccles, a founding father of logistics thinking, understood this concept on two different but very much intertwined levels. "In military, terms, it is the creation and sustained support of combat forces and weapons. Its objective is maximum sustained combat effectiveness. Logistical activities involve the direction and coordination of those technical and functional activities which in summation create or support the military forces" (1981, 23). Eccles also saw the link between logistics and grand strategy and highlighted the importance of economic factors that can determine the limits and direction of strategy. As a consequence, he thought of logistics as "a bridge between the economic system of the nation and the combat forces" (41). A prime example is President Franklin D. Roosevelt's grand strategy, which elevated the U.S. industrial might that created the "Arsenal of Democracy" and turned the U.S into the logistics foundation for the allies to fight Nazi Germany and its allies (Gropman, 1997). As Herman noted in *Freedom's Forge* (2012), this not only required him to rally popular support for his vision but also to muster leading figures at the forefront of such businesses as Chevrolet, Ford, General Motors and others. So, in totality, logistics, as argued by Proenca and Duarte (2005, 645), "accounts for all activities in war that are pre-conditional to the use of the fighting forces". To provide better focus, Johnson (1993), for instance, divides logistics into three levels: strategic, operational and tactical. He explains that the operational level, which is where the success of war is determined, is the link between the strategic goal and the tactical battle. And that the successful execution of operational art, which is the effective usage of war resources (soldiers, materials, time), is determined by the resources provided by a system of logistics. According to the *U.S. Army Field Manual on Operations* (1993, 5), the first level of logistics thinking "focuses on mobilisation, acquisition, force projection, and strategic mobility; it provides the linkage between the nation's economic base (people, resources and industry) and its military forces". The operational logistics level "(…) has as its primary focus reception, distribution and management of material movements, terrain, personnel and health services. It includes those support activities required to sustain the force in campaigns and major operations". And finally, tactical logistics which "is the synchronization of combat service support activities required to sustain soldiers and their weapon systems and has as its focus the essential elements of support for tactical units and systems (manning, arming, fuelling, fixing, moving and sustaining)".

From the above-mentioned descriptions and definitions, it is clear that logistics is a complex mix of rules, processes and physical entities, best understood as a system, governed by mostly abstract principles, with energy being adamant on all three levels. Consequentially, argues Moshe Kress (2002), drawing analogies between war and general production systems might be a better way to grasp its essence. The author notes that the principle component of this system "is the processing or the physical transformation of inputs into outputs" (5). In this equation the output is the outcome of the war and the inputs are combat means (manpower and weapon systems) and combat resources (consumables like fuel, food, water and services such as maintenance, medical, recovery and transportation). To conclude, Kress defines logistics as:

"A discipline that encompasses the resources that are needed to keep the means of the military process (operation) going in order to achieve its desired outputs (objectives). Logistics includes planning, managing, treating and controlling these resources" (7).

Just like with actors responsible for critical infrastructure systems, the logistics landscape also became more diverse. Whether it is service contacts in World War II, maintenance specialists in Vietnam or base security personnel in Afghanistan, over the last decades, the process of acquiring and procuring services, logistics, and technology became reliant on various private sector entities, particularly private military security contractors, or PMSCs (Tkach, 2017). As noted by Tkach, "International actors, particularly the United States, are increasingly reliant on PMSCs in conflict environments to deliver military services (i.e. intelligence and physical security) and government and social services (i.e. water purification, construction, and electricity)" (2019, 291). He also notes that this U.S. military model is being adopted more frequently by other countries in the hope of increasing operational effectiveness. On the rapidly changing front of acquisition, private equity firms have become significant financial players in the defence industry of the United States. Not to mention that the Pentagon is seeing Silicon Valley newcomers and established technology companies, such as Amazon and Microsoft, emerge as major providers of autonomous and cyber services at a fast pace (Mahoney et al., 2022).

Chapter 2 – Energy and War

The previous chapter served as an overview of the pillars of the main argument. It highlighted that deterrence by denial should be the ideal choice for small countries with strong denial forces, especially in case of a protracted warfare. By denying a quick victory from the aggressor, the deterrer not only forces the attacker to keep spending war materials but also takes away the illusion of control. Best way to do this is to identify vulnerabilities that might be potentially targeted and use resources to make those more resilient, ideally as vocally as possible. This paper focuses on the energy angle of resilience, which generally means critical energy infrastructure protection (CIEP), but the paper mostly deals with the energy resilience of military operations. As noted above, this is best understood as an input in the Kressian way of logistics, meaning combat resources such as energy (electricity, fuel etc.), water and food. In this chapter, the paper explains novel approaches to energy in warfare, the main drivers behind them and the technological and systematic challenges that severely limits these notions.

2. 1 Energy concepts in the military

Reliable and secure energy sources have been important factors in human development in terms of technology and living standards alike. The same is true for warfare which requires an immense amount of energy and the ability to mobilize it efficiently. Humanity came a long way from powering warfare only by human and animal muscle. In the last two centuries the emergence of high explosives, jet propulsion, rocket engines and the usage of oil and oil related fuels became vital to military operations (Smil, 2004). As highlighted by Smil, while a simple arrow produced 20 J of kinetic energy, a Second World War rocket had 18 x 10 on the sixth J of energy. As the implementation of new technologies and energy sources created bigger and more destructive armies, with huge energy needs, the importance of logistics grew accordingly. It is no surprise then, that at the end of the First World War, Lord George Curzon declared that “the Allies were carried to victory on a flood of oil” and that it became an even more important strategic enabler and a strategic vulnerability by the Second World War (Engdahl, 2004, 34). Although the energy needs behind manufacturing military capabilities is beyond the scope of this paper, it is worth taking into consideration the following example: While a trebuchet, a powerful siege engine used as artillery in the 13th century, was made of timber, ropes, lead, a large iron bar, hide and pig grease (Reference.com, 2020), a modern artillery weapon requires very different components in a much larger scale. It not only needs a vast amount of high-quality steel but a great variety of critical raw materials such as aluminium, natural graphite, beryllium, chromium, copper, nickel, tantalum, vanadium and eight others. As the same report noted, the defence sector makes use of a selection of 40 raw materials that is deemed critical across air, sea and land domains. All subjected to considerable supply security risks, as they have to be mined, processed, refined, manufactured into special components and of course transported before being assembled into a weapon (Girardi et al., 2023). Let alone the ammunition. Suffice to say, these steps can be quite energy intensive.

Since the 1990s and the advent of modern warfare, the use of energy in military operations became even more important. As noted by Clark et al., "The expansion and development of high-tech equipment and vehicles has increased the energy demands of the military, as enormous quantities of fossil fuels are required to operate the planes, ships, tanks, helicopters, and vehicles of the armed forces" (2010, 38). For instance, in FY 2017 alone, the Department of Defense of the U.S. consumed over 85 million barrels of fuel, which cost $8.2 billion, and while 70% of this was used for *operational energy* (OE) related issues, the rest went for *installation energy* (IE), for fixed installations and non-tactical vehicles (Greenley, 2019). The Office of the Assistant Secretary of Defense for Sustainment of the U.S. defines OE as the energy "required for training, moving, and sustaining military forces and weapons platforms for military operations. The term includes energy used by tactical power systems, generators and weapons platforms" (Office of the Assistant Secretary of Defense for Sustainment, 2022).

Compared to “old” OE, modern OE requires much more than positioning fuel. As noted by Carpenter at al., warfighting OE also encompasses the management of multiple types of energy sources (e.g., hydrogen, solar, wind, nuclear etc), generation (e.g., generators, reactors etc), distribution (e.g., electric grids, power beaming) and storage (e.g., batteries, convertors etc). The authors highlight, that logistics officers must understand energy markets, tariffs, quotas, trade disputes and agreements to properly estimate their budgets while simultaneously being aware of the risks involved (2022).

2.2 Drivers

The reasons behind the gradual shift towards more diversification in the military in terms of energy is best explained in the 2016 Operational Energy Strategy of the U.S. (Department of Defense, 2016). On the one hand, the document highlighted the importance of renewables on the battlefield, especially in those security environments where logistics may be constrained. Prime examples are Iraq and Afghanistan. As pointed out by Roege (2015), 70% of ground logistics during the campaigns was about the movement of energy and water, which eventually led to serious investments in efficient shelters, alternative fuels, microgrid systems and renewable energy sources to cut fuel consumption. This is also important because transportation routes offer easy targets to adversaries. In 2009, over 3,000 American troops and civilian contractors were either killed or injured while safeguarding convoys, with 80% of these convoys carrying fuel (Patrahau et al., 2023). As a solution, the U.S. Army ordered Advanced Medium Mobile Power Systems (AMMPS) to Afghanistan in 2012 to shorten supply chains and decrease the chances of an attack, which eventually led to a 21% cut in fuel consumption (Jones-Bonbrest, 2012).

On the other hand, the document (Department of Defense, 2016) also pointed out the growing threat of hybrid warfare and the vulnerability of supply chains, including critical infrastructures. This clearly materialized in an attack against Saudi Arabia, when Iran used 18 drones and three missiles which knocked out 5% of global oil production and resulted in a 20% spike in crude oil prices (Reuters Staff, 2019). Another more unconventional example is when the supply of batteries for defence equipment was disrupted not because of issues with the physical battery supply chain, but due to a shortage of cardboard packaging caused by increased online shopping during Covid (Wilding, 2023).

Sukhodolia and Walzer (2022) highlight the need for critical infrastructure protection measures (CIP), which include: shift from reactive policy to preventative policy (deter, mitigate and effectively respond); coordinated system between critical infrastructure stakeholder (public-private included); and a clear definition of CIP system functions. This is supported by Migli (2020), who adds that most U.S. military bases are overly reliant on civilian grids that are vulnerable to both external (cyber-attack, drones etc) and internal factors (sabotage, extreme weather events). He also concludes that shifting the military to renewables in both fielded equipment and in grids on military installations, after separating it from the civilian one, will strengthen it against not only near-peer and non-state actors, but also against resource shortages. One way to ensure CIP is through microgrids that "(…) offer protection from power disruptions, whether natural or man-made, through the utilization of distributed energy resources (DERs) independent of the utility grid. Military installations, especially those in remote areas, are similarly dependent on supply chain networks (SCNs) to ensure continuity of operations" (Anuat et al., 2021, 1). As noted by Patrahau et al., "(…) hydro-powered microgrids in a military setting are more reliable than those powered by wind or solar power, because water is highly controllable and the amount required to run the grids is so minimal that hydropower is still obtainable in drought-stricken regions, e.g., through the use of grey water" (2023, 4).

Last but not least, is the environmental factor. As climate change became a burning issue for states, and most of them made pledges to reach carbon neutrality by 2050, countries had to face the carbon footprint of their armies. A study found that even in peace time the continuous consumption of fossil fuels by militaries allows carbon dioxide to accumulate and produce toxic waste (Isiksal, 2021). So much so that a recent paper highlighted that if the world's militaries were a country, they would be responsible for the fourth highest carbon footprint (Parkinson and Cottrell, 2022). As the same study points out, this could be mitigated by the implementation of renewables and alternative energy sources into military capabilities (2022). The environmental devastation of war is clearly highlighted in a very recent paper, which looked at the Ukraine war (Rawtani, 2022). The study mentioned both short-term impacts (water pollution, higher greenhouse gas emission, soil erosion etc) and long-term ones such as chronic respiratory ailments, permanent change in soil fertility or huge biodiversity loss (2022). In fact, war can have such long-term consequences as heavy-metal pollution induced irreversible loss in plankton communities from WW2 era (Siano et al, 2021).

2.3 Pillars of operational energy

Although the discourse on OE has been going on for more than a decade, its technological enablers, just as the concept itself, are very much in their infancy. That said, the most significant keywords when it comes to operation energy, which is also the main source of energy consumption and emissions, are: fuel efficiency and electrification (Kõrts, 2023). By looking at examples given to challenges mentioned above, we can concur that there are three pillars of both OE and IE: (a) diversification of energy sources (renewables, alternative fuels, hybrid power systems); (b) improved energy efficiency (improved grid systems, smart grids); and (c) implementation of energy resilience and climate plans into military planning (microgrids, advanced energy storage systems, climate resilience training and preparedness). Furthermore, as energy can only be understood as a system, these pillars should not be separated entirely, rather they should be looked at as a whole.

2.4 Challenges ahead

Decarbonizing armed forces without disarming them, just like with our economies and core industries, is a considerable challenge. Without a doubt, it is going to require the defence sector to grapple with some uncomfortable compromises. As noted by Barry, Fetzek and Emmett (2022), the majority of military carbon footprint derives from vehicles and platform systems consuming petroleum to function. While converting land vehicles is already underway in the civilian sector, the same will be much harder with maritime, air and space forces which use inherently larger platforms.

First of all, these technologies have to pass the "SWaP challenge" – size, weight and power – to be adopted in the military. As Mansfield at al. (2021) pointed out there are no current fuel source meeting U.S. Amy requirements. The study focused on energy density (the amount of energy stored in a system per unit of volume), conversion and mass and volume requirements, to see how they compare to fuels used in the present. The paper found that no alternative fuel source has as much energy, by weight, as diesel or gasoline. The authors concluded that one would need at least four to 10 times that of gas and diesel in terms of size or volume to generate the same amount of electricity. Not to mention, that it must be carried on the battlefield as well. The same goes for full-electric vehicles, as current batteries are heavy, take a long time to charge and only offer a limited range (Mansfield at al., 6). Consequently, the easiest short-term win is simply to alter installation energy, thus reducing the emission of military infrastructures. Although as more capabilities will be dependent on electricity the more pressure the grid will experience. As a result, military bases must be equipped with proper energy-storage facilities to withstand the increasing demand. Especially if directed-energy weapons, advanced electronic-warfare systems, electromagnetic rail guns and radiated-energy systems will be integrated on them (Barry at al., 2022). This is also supported by Kõrts (2023) who adds that "Electrification is likely to be critical to the integration of emerging war-fighting capabilities such as high-power communications, high-power jamming, vehicle-centric microgrids and directed-energy weapons" (99).

When it comes to military organization the picture is even more complicated. As noted by Juljius Grubliauskas (Atlantic Council, 2020), after asserting that expanding distributed energy resources and increasing interconnectivity can improve security and reduce logistical burdens, for NATO the "(…) energy transition is an adaptation and interoperability challenge". After all, the existing legacy system establishes a path dependence that requires new energy applications to undergo sufficient modifications to ensure compatibility and interoperability with the current system, while avoiding changes to the broader support and infrastructure mechanisms (Soni, 2020).

Last but not least, it is clear that while renewable energy use in the military aligns with sustainable development goals, the primary objective of the military remains national security, creating a conflict between enhancing environmental performance and fulfilling its mission (Chang et al., 2023). This is supported by Saritas and Burmaoglu, who highlight that "Currently, the key measures of military power are lethality and impact, which are far from reflecting the efficiency, sustainability, and greater responsibility for human life and environment" (2016, 342).

Chapter 3 – Pursuing Green Defence

The push behind green defence which derives from (a) efficient operability in constrained security environments; (b) vulnerability of supply-chains and critical infrastructures and (c) environmental concerns, is a completely justifiable cause. That said, as it requires huge amount of capital and brain for military related research and development (R&D), stable status-quo and political incentive as well, there are only a handful of countries who have been particularly vocal about the need to "green" their armies. This section is only looking at the U.S., NATO and the EU, to demonstrate changes in a top-tier military; through a military organization and on the multinational level. It shows that besides a growing discourse on the importance of energy resilience in military operations, there are also trend determining policy initiatives in the making.

3.1 The United States

Washington became particularly interested in the concept of operational energy during the Iraq and Afghanistan campaigns. The first OE Strategy report of the Undersecretary of Defense of Acquisition, Technology and Logistics was published in 2011 (DoD, 2011), the second one in 2016 and the latest in 2022, called *Increased Resiliency and Lethality through Operational Energy Investment* (DoD, 2022). As noted by Greenley (2019), in FY2017 DoD consumed 707.9 trillion British thermal units (Btu) of energy, costing almost $12 billion, which was 76% of the entire federal government's energy expenditure and only 2% of its FY2017 budget. In 2014, the Operational Energy Working Group was established to re-enforce existing and future research in the hybridization of energy resources into military operations, such as advance power systems, microgrid designs, grid modernisation, battlefield energy among others (Hummel at al., 2022). Eventually, the 2022 National Defense Authorization Act established the Contested Logistics Working Group and appointed an Assistant Secretary of Defense for Energy, Installations, and Environment, who is responsible for updating near-term, mid-term and long-term OE strategies across each armed force (NDAA, 2021). This plan includes topics such as the effects of "transitioning from the production of internal combustion engines to the development and production of alternative propulsion system" on military readiness, assessment of alternative energy technologies, challenges presented by near-pear adversaries and even infrastructure investments of allies and partners that may affect OE availability (Hummel at al., 7-8). In the short-run, the U.S. is going for the low-hanging fruit as well, which means curbing installation energy and not specifying any targets for operational energy consumption. By 2025, the US Department of Defense (DOD) aims to increase the proportion of renewable energy consumed in its total energy consumption, which covers all federal government-owned buildings, installations, structures, and other properties, to a minimum of 25%. (Soni, 2020). Furthermore, there are two elements of U.S. OE Strategies that should be highlighted.

Firstly, *Microreactors* can produce 1-20 megawatts of thermal energy that can be used either as heat or as electricity (OfNE, 2021) to power commercial infrastructure or non-electric applications such as district heating, water desalination and hydrogen fuel production. They also require a higher concentration of uranium-235. Their most important features are: factory fabricated, transportable and self-adjusting. The U.S. Department of Energy launched the Advanced Construction Technology (ACT) initiative to reduce the construction costs of building new reactors by more than 10% while also making the progress safer. In a nutshell, they are small and secure enough to be used even in military bases (Finan, 2021). While the 2011 Strategy does not include either nuclear or microreactors, the 2016 Strategy mentions it as a non-traditional OE. That said, the 2022 paper not only includes it as an alternative to petroleum but highlights Advanced very Small Modular Reactors (AvSMR) and their potential to "provide energy resilience through assured access to reliable, quality power in support of critical missions and remote operations" (8). Furthermore, it also highlights Project Pele to

"(…) design, build, and demonstrate a prototype mobile nuclear reactor within five years" with a budget of $60M for FY2022.

As noted by Kelley Sayler (2022), the second element, *directed energy* (DE) *weapons* apply concentrated electromagnetic energy, rather than kinetic energy, to deal lethal damage to enemy forces. They include high-energy lasers (HELs) and high-powered microwave (HPM) weapons among others. Their main advantage is that "DE weapons could offer lower logistical requirements, lower costs per shot, and—assuming access to a sufficient power supply—deeper magazines compared to traditional munitions" (2022, 2). That said, their potential can be limited by weather conditions such as rain or fog. The report also highlights that the U.S. deployed its first DE weapon in 2014 aboard the USS Ponce. As for the OE Strategies, the 2011 (DoD) does not mention it at all, the 2016 (DoD) include DE weapons as means to improve combat effectiveness, while the 2022 (DoD) note it among electric and hybrid-electric technologies for the current and future ground vehicle fleet to provide unique military capabilities. That said, it appears from the document that while the Army invested more than $45 M in FY2021, it only requested $38 M for FY2022 to accelerate development.

3.2. NATO

NATO has been actively addressing energy security concerns since the 2008 Bucharest Summit. Key milestones in this process include the establishment of an Energy Security Section at NATO Headquarters (2010) and the accreditation of the NATO Energy Security Centre of Excellence in Lithuania (2012). In 2019, Allies agreed to consolidate NATO's role in energy security and endorsed the Climate Change and Security Agenda with an Action Plan to implement it. It was then adapted in 2021 and set targets to reduce greenhouse gas emissions by 45% in 2030 and become net zero by 2050. In the 2022 Strategic Concept, Allies committed to investing in their ability to prepare for and defend against hybrid tactics, including the strengthening of energy security and ensuring reliable energy supplies to military forces

(NATO, 2022). It held its 3rd Operational Energy Concept Writing Team meeting "in order to continue the intensive development of the NATO OEC and to prepare for the Concept experimentation" to reach the CO2 neutrality by 2050 for most members (NATO Energy Security Centre of Excellence, 2023). What is known about this OEC so far is that it will "(…) deal with Energy Management in its entirety (production, procurement, transportation, storage, distribution, quality control, accountability, data collection, security, protection, etc.) and provide guidance for the main principles in order to design future NATO energy standards" (NATO Allied Command Transformation, 2023, 1-2). Just like with the Single Fuels Concept, which requires all NATO forces to use the same fuel for aircraft, tanks and electricity generation, the organization could do the same with green technologies by standardization in certain areas (Patrahau et al., 2023). These steps show that the U.S., which is the main drive behind NATO, wants to ensure its power projection capabilities in the future as well by gradually addressing energy logistics related question on the national and multinational level as well.

3.3 The European Union

Back in 2019 the EU made a pledge to become the first continent to reach net-zero emission by 2050 (European Commission, 2019 a). Then these goals were set into law by the European Climate Law in 2021 (EUR-Lex, 2021). One of these goals is to reduce national net-carbon emissions, including those made by defence ministries, industries and militaries. On the one hand, there is the European External Action Service (EEAS) which established the Climate Change and Defence Roadmap and the EU Concept for Environmental Protection and Energy Optimisation for EU-led Military Operations and Missions, representing the EU policy framework (Council of the EU, a,b) On the other hand, there is the European Defence Agency which represents the institutional infrastructure to deliver on these objectives. The EDA has three interlinked pillars to support the EU's green defence initiative. These are: (1) Consultation

Forum for Sustainable Energy in the Defence and Security Sector (CF SEDSS); (2) the Energy and Environment capability technology group (EnE CapTech) and the (3) Incubation Forum for Circular Economy in European Defence (IF CEED).

The Consultation Forum was established in 2015 by the European Commission. It focuses on four key areas: energy efficiency and buildings performance; renewable energy sources; protection of defence-related critical energy infrastructure; and policy, research and technology, and funding for defence energy-related projects (EDA, 2022). Its current stage, Phase III, was launched in 2019 (ends in 2024) to "(…) contribute in preparing the defence sector to welcome and accommodate new trends in technology and to address challenges ranging from technical and human factors to hybrid threats and other risks" while also present the industry with opportunities to decrease their reliance on fossil fuels (EU Commission, 2019 b).

Energy and Environment CapTec serves as a platform for national governments and experts to exchange practices relating to energy transition and sustainability. The research projects include: energy management methodologies; alternative fuels and drive/propulsion systems; engine and power-distribution system-efficiency technologies; water and waste management (Smart Blue Water Camps, WANTED); defence energy data collection efforts (EDCAS) and lastly focusing and exploring technologies (ARTENET), which is using new technologies to deepen collaboration in sustainable energy projects in defence (EDA, 2014).

After the Russian invasion of Ukraine came the Versailles declaration in March about boosting the EU's defence capabilities and reducing its energy dependencies (European Council, 2022). Then in September its latest initiative, the *Circular Economy in European Defence*, was launched. Its general goal is to extend Circular Economy concept and policies to the defence sector. It is organised around two Incubation Clusters (ICs): Materials and Innovative Designs and Processes and Digitalisation. For instance, the first one includes critical raw materials, sustainable ecodesign and circular additive manufacturing. While the second one is a hub for spare parts management, waste framework directives or green procurements (EDA, 2022).

While there are certain similarities in terms of research and development, particularly when it comes to installation energy (non-combat vehicles and fixed military installations) and the operational energy landscape, the U.S. is approaching this question from a more pragmatic angle. On the one hand, it means giving more space to microreactors in its quest towards green defence. On the other hand, it wants to ensure its readiness over environmental or budgetary concerns and puts extra effort into developing new ways to use energy in military operations, other than that of passive. A prime example of this, as indicated above, is certainly the gradual deployment of directed energy weapons. This is no surprise, considering that while the EU wants to green its defence because of environmental concerns, the U.S. started it to adapt to difficult security landscapes and ensure its military readiness in foreign battlefields. The trend in microreactors and directed energy weapons is particularly interesting, considering their advantages in terms of OE and their limited availability as of now. One thing is for sure, the current great power competition in technology is accelerating R&D in many novel ways.

Chapter 4 – Taiwan

As the previous chapters showed, energy resilience and sustainability are becoming an important factor not only to countries but also to militaries. At the same time, it is clear that this discussion and change is mostly happening in affluent countries, with stable geopolitical environment and enough political incentives on the environmental front. Which brings us to the following question: what about countries that are resource poor and are facing an existential threat? The Republic of China (ROC), aka Taiwan or Formosa, was chosen as a case study because of various reasons. First and foremost, the island is facing China as its number one security issue. Secondly, it imports almost all of its energy sources. Finally, it has the technological know-how (semiconductors, high-tech manufacturing etc.) and the capital as well, which creates, at least ideally, a positive environment for innovation in the military in terms of energy, among others. Before going through the pillars of OE and IE in Taiwan, it is vital to understand the island's current situation, by addressing the question of invasion vs blockade and explaining its overall resource vulnerability, meaning energy, water and food in its economy. After all, as noted in chapter one, military logistics have everything to do with economies (Eccles, 1981; Gropman, 1997, Kress, 2002; Herman, 2012).

4.2 The harshest battlefield

Back in 2008, William S. Murray, a retired nuclear submarine commander in the U.S. Navy, argued for a "porcupine strategy", which entails "hardening, and building redundancy into its civil and military infrastructure and systems (…) to survive an initial precision bombardment, deny the PRC the uncontested use of the air, repel an invasion, and defy the effects of a blockade for an extended period" (Murray, 2008,19). However, as highlighted by Yujen Kuo (2023), "Taiwan has already been a porcupine. One of the most difficult battlefields of the World".[1] He explained that the geographical reality of the battlefield makes it very

[1] Kuo, Yujen PhD., interview by author, Kaohsiung City, Taiwan, April 25, 2023.

difficult to execute an amphibious landing and severely limits Beijing's possibilities. "Seventy percent of the island is mountains. 265 of them are over 2500 meters. The waters in the West of Taiwan are too shallow, on the East it would be ideal but the mountains are tilting that way, so they could not come over them". As a consequence, there are only two suitable locations for landing – Kaohsiung City in the South and the beaches around Taoyuan City in the North. This had been recognized by American troops during the Second World War when General MacArthur decided to take Iwo Jima and Okinawa instead of Formosa, after the U.S. War Department estimated that invading and holding the island would cost more than half a million men (Suciu, 2022).[2] Another factor that can make an amphibious landing more complicated is the weather. Although typhoons, that used to occur six to nine times between April and November, became less frequent in the Taiwan Strait due to climate change, winds and waves are generally increasing, especially in the southwest of the island (Turton, 2023).

If China ever decides to invade Taiwan, the PLA could expect to face a more significant obstacle as well: the island's interconnectedness due its location and size. Kuo (2023) noted that, "Unlike with Ukraine, we cannot talk about a Taiwan conflict as an isolated battleground". Then he added that "Any invasion against Taiwan is going to spill over to the Philippines and trigger regional hotspots – Russia against Japan at Hokkaido, North Korea against South Korea. Taiwan is too small; missiles and dogfighting could easily enter unwanted territories". Another problem is Taiwan's position in the regional and global economy. As home of Taiwan Semiconductor Manufacturing Co. (TSMC), which holds a 56% market share of global chip

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[2] "In order to attack Taiwan, they would have to mount an amphibious invasion combined with paratroopers and air assault, rotary wing helicopters, missiles, all the prep fires that would go into that; they'd have to isolate beachheads and then have to have the amphibious lift in order to do that; and cross basically a hundred miles of water, which is challenging in and of itself. Then they'd have to ensure that the subsurface of the water was secure, as well, from submarine attack. They'd have to clear mines, clear beaches, they'd have to go in and essentially attack and seize an urban area that's about three and a half million people, in a country that's very mountainous and lends itself to the defense. [...] So, the Chinese have not, at least to our knowledge, we have not seen the level of training and exercises that would be warranted to conduct that size, scale, scope of an invasion" – said General Mark Milley in a conversation with Foreign Affairs. May 2, 2023. https://www.foreignaffairs.com/podcasts/how-to-avoid-great-power-war-mark-milley

production and produces 92% of the most advanced ones, an all-out war would have serious consequences. “The full social and economic impacts of a chip shortage of that scale are incalculable, but they would likely be catastrophic” (Vest et al., 2022). Not to mention that “90% of air traffic between Asia and the U.S. have to pass through Taiwanese air; 60% of global trade; 80% of undersea cables, 90% of South Korea’s energy and 80% of Japan’s energy is going through these waters” (Kuo, 2023). In a nutshell, there is a general consensus that a kinetic war between China and Taiwan would be so catastrophic that Beijing would rather use a series of grey zone operations and some form of blockade to choke off the island. (Nagy, 2023).[3]

Although cutting off the island from the outside world is a more likely action, because of the reasons mentioned above, a total blockade would also have drastic consequences, even for Beijing itself. That is why, as explained Kuo, “hard blockading Taiwan is very difficult and requires serious military capacity to regulate air and maritime traffic out of the blue, which China does not seem to have at the moment”. He also added that other forms of light blockade are feasible. “For instance, if China unilaterally announces to exercise its 2021 Maritime Traffic Safety Act by regulating international vessels to report to Chinese harbours before coming to Taiwan, by international law it is possible, without much military force. But it takes time and practice”. Other forms of blockade include virtual blockade, which is making Taiwan less competitive on the market by keeping the threat level high by searching vessels and conducting military drills to stem investments and raise costs to do business with the island. For instance, contract rates on the short-haul run between China and Taiwan surged so high recently, around $2,000 per forty-foot equivalent unit, that it cost just as much as shipping from Shanghai to Los Angeles, despite the latter being almost ten times longer (Miller, 2023). Nevertheless, Taiwan’s annual military drill focused on breaking a blockade, combat force preservation and maritime

[3] Stephen Nagy, Phd. Interview by author. Vienna. February 27, 2023.

interception (Blanchard &Tung, 2023). No matter which path Beijing choses to go down, it will definitely affect supply chains and lines of communications.

4.3 Taiwan's greatest vulnerability

Taiwan is isolated in the sense that it has no direct physical connections to its neighbouring countries in terms of power transmission. Furthermore, the island's access to indigenous sources of energy is quite limited. While there are some hydro and pumped storage options available, they are restricted by the lack of suitable river systems (Kucharski, 2022). Utility-scale solar power is also constrained by the limited amount of available land, and geothermal energy is hindered by a lack of appropriate locations and public opposition. Additionally, Kochanski highlights, Taiwan has no domestic sources of fossil fuels and faces resistance towards nuclear power, dams, and onshore wind installations. However, the country does benefit from favourable offshore wind resources in the Taiwan Strait, which partially helps to mitigate these challenges. It is no surprise then that the island imported almost 98% of its energy sources in 2021, mostly from Saudi Arabia (33%), Kuwait (20%), and the USA (20%). In fact, in the same year, ninety percent of energy sources were fossil fuels, oil representing 40%, coal 35% and natural gas 20%. As for electricity production, it is predominantly from coal (45%) and natural gas (35%)- coming from Qatar 27%, Australia 28%, and Russia 13,5% - with nuclear representing 10% (Ritchie & Roser, 2022).

Besides lack of indigenous energy sources, the other problem is the energy systems. Lately, the island was hit by widespread power outages and blackouts due to centralized and aging infrastructure (Ting-Fang & Li, 2022). In fact, Taiwan's electricity network is currently operated by state-owned Taipower, while two LNG terminals are in the hands of the state-owned CPC Taiwan and one in Taipower's (Davidson and Lin, 2023). A recent report called for faster decentralisation to achieve a greater degree of energy autonomy, citing it is a direct threat to energy resilience (Yiyang et al., 2022). For instance, in their 2021 sustainability report, TSMC noted power disruptions and grid instability as growing risks (TSMC, 2022). The giant accounted for 6% of Taiwan's total energy consumption, which is expected to rise to almost 13% by 2025 (Huo & Stapczynski, 2022). These factors could easily undermine its manufacturing industry, particularly the semiconductor industry, weakening Taiwan's all in all defence capabilities.

4.4 Energy policy

In 2016, the current government set an ambitious plan to become net-zero by 2050, generating 60-70% of its electricity from renewables by that time. In 2020, renewables only accounted for 5.5% of total electricity generation (Bureau of Energy, 2020). As highlighted by Chia-Chien Chang (2023)[4], there are four main priorities: green energy promotion, with a focus on solar and wind; reducing coal and increasing gas usage; and phasing out nuclear by 2025. However, as a recent study pointed out there are severe limitations. While rooftop solar photovoltaic (PV) have self-evident space constraints, ground-based solar PV installations encounter competition for limited arable land and other land uses. On-water solar PV is restricted to calm waters or inland lakes. Additionally, solar PV exhibits a low capacity-utilization factor, estimated at approximately 11% (Lau and Tsai, 2022). The authors note that onshore wind also lacks suitable land and that offshore wind lacks typhoon-resilient design and is limited by water depths of up to 120 meters, shortage of installation vessels and adequate manufacturing capabilities, coupled with low capacity, only 28%. As for nuclear, current studies suggest that shutting down all reactors by 2025 may result in power shortages and blackouts (Wu et al., 2018). That said, as another study noted "The three existing nuclear power plants are located within 8 km of active faults; thus, these plants face considerable risks (…) and should be urgently decommissioned" (Yue et al., 2022, 5). According to Chang, energy policies have never been significant issues during elections, as there were not many blackouts

[4] Chang, Chia-Chien. Interview by author. Kaohsiung City, April 26, 2023.

before 2021. The primary political struggle between the two parties, DPP and KMT, has always centred around economic development, national identity, and national security. He added that "people don't see the clear relation between economic development and energy security". One of the reasons for that is abundance in the past coupled with low prices. In fact, "Taiwan's household electricity price is the second lowest in the world, while its industrial electricity price is the seventh lowest globally due to public subsidy" (Lau and Tsai, 2022, 3).

4.5 Water

Water is a key component in Taiwan's top two economic drivers: namely agriculture and semiconductors. Unfortunately, the island is facing the worst drought it had in a century, due to lack of rainfall, typhoons and very little storage, depleting reservoirs are making the government face some tough choices. "This is the third year in a row that rice farmers in southern Taiwan have not been allowed to plant their crops. Instead, the government is paying them subsidies not to grow rice this season. The rice uses scarce water that semiconductor factories nearby need" (Feng, 2023). Besides ruining the agricultural sector that is losing brand and clientele, the draught is also affecting the electricity systems, resulting in two large-scale electricity blackouts in less than one week in 2022, and thus the semiconductor industry. With a chip plant requiring around 10.000 tons of water a day, the semiconductor industry is responsible for 20% of Taiwan's annual water consumption. Hence, TSMC and others had to develop their own contingency plans by renting water tanks and putting water conservation measures in place, while cities started preparing for constraints (Li, 2023). Scientist warned that climate change is affecting typhoon pathways in the Pacific, potentially bringing less typhoons and rainfall to Taiwan (Lai, 2022). As a consequence, the government should come up with a long-term plan mostly by addressing the massive water consumption problem. The fact that Taiwanese are taking water for granted is a result of abundance in the past and its extremely cheap price due to state subsidies. Lai explained that "At NT$11 (USD$0.39) a ton, water rates in Taiwan are among the lowest in the world, costing four times lower than that of the US and six times lower than in the UK” and as a result an average residential water consumption in Taipei is 332 litres per day, compared to 144 litres in Europe. This problem can not only affect Taiwan’s industry, its energy resilience but is already disrupting the farming sector, further decreasing its deterrence value.

4.6 Food

Taiwan is highly reliant on other countries when it comes to food. For instance, the island is importing eggs from eight different countries to make up the fallout caused by cold weather and bird flu, which resulted in egg shortages and long lines. Something the government expects to come to an end by the end of May (Everington, 2023). However, eggs are not the only thing that is being imported. In fact, most of its annual caloric intake was covered by food imports in 2021, which accounted for over two-thirds of its total consumption (Ferreira and Critelli, 2023). As noted by Ferreira and Critelli “A lack of storage management (for example, proper refrigeration or adequate packaging) and the discard of low-quality or damaged food have also undermined food self-sufficiency, resulting in high rates of food loss (40% in 2018) throughout the supply chain”. All in all, the authors concluded that Taiwan has six months’ worth of footstock, with feed grains, animal protein and farming chemicals being mostly affected in case of a blockade or disruption. Food insecurity is probably the most important, as it can lead to drastic changes in diet and even to famine, which can hugely impact a country’s morale, especially in times of war.

Chapter 5 – Greening Taiwan's Defence

The previous chapter explained the factors one must keep in mind when talking about invasion versus blockade, including geography, weather, and being at the heart of international trade. Furthermore, it also showcased the vulnerabilities in terms of Taiwan's resilience, meaning energy, water and food. The final chapter is looking at ways the island is trying to address energy resilience, OE and IE summarized below[5], with the main focus on the military and how the implementation of such strategies is limited by its current defence posture. Due to the dual-use nature of energy technologies, this section will cover all OE and IE related initiatives that can be used for making the island's energy more buoyant.

Table 1: Overview of pillars and methods for the implementation of operational and installation energy

Pillars of OE and IE Strategy:	
Diversification of energy sources	Renewables, alternative fuels, hybrid power systems
Improved energy efficiency	Investing in robust infrastructure such as energy storage and smart grids.
Implementation of energy resilience/ climate plans	Conducting comprehensive assessments of the country's energy systems, identifying vulnerabilities and risks, setting clear goals and objectives for resilience.

5.1 Diversification of energy sources

Limitations of solar and wind deriving from lack of land and technological challenges were mentioned previously. Nevertheless, the military has been using green energy to cover some of their energy usage. For instance, in line with the Policy of Installing Solar Panels on

[5] Table is created by the author.

state-owned property, the MND installed solar panels at 41 sites until the end of 2020, and planned to complete 13 more sites in 2021 (Ministry of National Defence, 2021).

When it comes to alternative fuel, the question is a bit more complicated. Nagy (2023) highlighted that we must also think about fighter jets and tanks that use a special high-grade fuel. As for capabilities, Kuo (2023) noted that "more than 90% of Taiwan's weapon systems on the ground, in the air, and in the sea are from the U.S.". Which means that Taiwan need to keep buying U.S. capabilities, for the sake of interoperability (Lin, 2023). The same goes to alternative fuels, Taiwan cannot just change to a new fuel, even if it is cheaper and greener, due to logistical issues.

Hybrid power systems are mentioned under The Program of Key Technological Upgrade for Power Electronics and Integrated Application and Development for Communications and Green Energy Industries, which aims to merge communication technologies with green energy in the form of high-power radar modules, radio devices and electric cars (Ministry of National Defence, 2022).

5.2 Improved energy efficiency

As mentioned in the previous chapter, the current critical energy infrastructure is old and heavily centralized, with steps made towards decentralization in the electricity sector, which did not bear much fruit since 2017. Fortunately, the energy storage and grid situation appear to be better addressed.

The Executive Yuan of Taiwan started the "Green Energy Technology Industry Innovation Promotion Plan" which aims to promote innovation and development in energy creation, energy saving, energy storage, and smart system integration, with a focus on solar, wind and smart grids (Bureau of Energy, 2022). According to current estimates based on policy initiatives and market models, Taiwan's energy storage market is expected to increase by 62.42

% per year on average from 2022 to 2030 (Chuang et al., 2022). In fact, as the same study noted, the development of the energy storage industry is heavily prioritized by the government, evident through recent amendments to the Electricity Act and its recognition as a key technology research and development project under the Industrial Innovation Regulations.

On the other hand, back in 2019, the government initiated the The Smart Grid Master Plan, which aims to ensure stable supply of electricity by utilizing technologies such as AI, big data and telecom technologies (Bureau of Energy, 2021). All in the name of improving grid operation stability, enhancing grid resilience and power quality, and encouraging energy conservation among the public and in government-owned properties.

5.3 Implementation of energy resilience and climate plans

The 2021 ROC National Defence Report only mentions climate change twice, in the context of natural disasters. However, it has a whole section on environmental protection and green energy. It says that "(..)the Ministry of National Defence (MND) has been implementing measures to conserve energy and maintain a sustainable utilization of environmental resources (including) energy saving and carbon reduction, green procurement, and airfield noise control", some of which covered above (Ministry of National Defence, 2021, 105). Following the Regulations on Energy Saving and Management of the Armed Forces, the army started using simulations to curb emissions from training and decommissioning obsolete weapons (Ministry of National Defence, 2022). They have been also placing priority on purchasing Green Mark products, which are defined in the Appraisal Methods as having a lesser impact on the environment.

Ying-Yu Lin (2023) explained that he doesn't worry about fighter jets, tanks and vessels not moving because of lack of fuel. "That is not the real issue in Taiwan. The real question is how to keep, how to store the energy". Taiwan has been actively addressing that question. Oil refinery operators and importers must maintain a minimum of sixty days' supply as an oil security stockpile, while the government is also obligated to maintain its own stockpile of no less than 30 days (Bureau of Energy, 2023). As for their gas stockpile, the storage capacity was required to be at least 15 days in 2019 and will be at least 24 days in 2027. (Bureau of Energy, 2023 b). However, due to increased electricity usage during summer, fifteen days stockpile only sufficient for a bit more than a week (Qian, 2022). Not to mention, that the government aims to rely on gas for 50% of its electricity production by 2030, which means that the island must increase its gas reserves by a magnitude. According to Yu Cheng Chen (2023)[6], other than expanding storage places, the government does not have a well-established strategy for energy resilience in case of a blockade. Interestingly both Chang (2023) and Chen (2023) mentioned retired generals who believe that "the U.S. should help storing energy resources for Taiwan – coal, oil and gas – somewhere on the first island chain".

Another angle of energy resilience is critical infrastructures. The paper already touched upon its importance for morale and the growing threat of cyber-attacks against a system which is increasingly digitalized. Taiwan is definitely not an exception. According to several experts, power plants and energy systems are listed in the top three targets of the PLA, after airports and communications. (Kuo, Chang, Lin, Chen 2023). Currently, the U.S. is preparing the Taiwan Cybersecurity Resiliency Act. In addition to offering cybersecurity training and exercises, the proposal entails increased involvement of the US in Taiwan's cyber defence. It includes the utilization of US cybersecurity technologies to strengthen Taiwan's defence capabilities, particularly in the areas of military networks, infrastructure, and systems. Notably, the proposal also emphasizes the need for the US to address and eliminate "ongoing malicious cyber activity targeting Taiwan," indicating a potential focus on offensive hacking (Ikeda, 2023). This is no

[6] Chen, Yu Cheng. Interview by the author. Taipei City. 28 April, 2023.

surprise, after all, as pointed out by Chen (2023), Taiwan is facing tens of millions of cyber-attacks each month, that specifically targeting public infrastructure and military installations.

5.4 A unique military build-up

As noted by the 2021 National Defence Report (Ministry of National Defence, 2021), Taiwan must maximize its asymmetric advantages by targeting the People Liberation Army's (PLA) weakness: the sea transit. The reports pointed out that this include: "(…) countering hostile fixed-wing aircraft or airborne operations with mobile surface to-air missiles; countering large surface ships with small, fast, mobile, and seaworthy resilient platforms (…) equipped with anti-ship missiles; and countering the enemy's triphibious landing operations with mobile coastal defence cruise missiles, defensive naval mines, and landmines." (67) This is also supported by Kuo (2023) who noted that since 2016, the government started adding more indigenous capabilities into the island's overall military procurements. "Our main focus is, indeed, on missiles" then added that "You don't see foreign missiles in Taiwan. They are almost 100% researched, developed and made in Taiwan". Ying-Yu Lin (2023)[7] noted that currently, Taiwan can produce around 300 missiles annually, with plans to extend anti-ship missile production capacity to 500.[8] What does this mean for operational energy?

By prioritizing asymmetric ways of warfare, it means that they will not do huge military manoeuvres nor will they use power projection capabilities over contested territories. Effectively cancelling out the need to be concerned of fuel scarcity. On the other hand, the conventional capabilities they have, meaning tanks and fighter jets, have to be interoperable with that of the U.S.'s. The paper already explained this with alternative fuels, but the same

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[7] Lin, Ying-Yu. Interview conducted by author. Taipei City. 2 May, 2023.
[8] Taiwan is currently waiting for its 760 Harpoon missiles from the U.S. https://www.cato.org/commentary/taiwan-competing-arms-middle-east-not-ukraine

goes to any major changes that might limit their logistical ability to coordinate with Washington on defence related matters.

Conclusion

This paper started on the premises that a country who is so energy poor as Taiwan and has a positive environment for military related research and development, due to its high-tech manufacturing industry and willingness to spend on capabilities because of China, will proactively address energy resilience along the pillars of operational and installation energy. As it turns out the situation is not entirely like this. Although the island does invest in installation energy in the form of photovoltaics, wind turbines, smart grids and by connecting green energy to communications, the extent of this is fairly limited. They also started some initiatives in the last years, aiming to improve grid operation stability, enhance grid resilience and power quality, and encourage energy conservation among the public and in government-owned properties, these will need years to bear fruit. From the research conducted in this paper, the following points can be concluded about the implementation of operational energy in Taiwan and in general:

First and foremost, the paper found that energy security hadn't been recognized as an issue up until the last three years effectively, and became one only after Covid and the war in Ukraine disrupted supply chains. As a consequence, the importance of energy resilience did not reach either the populace or the military in a way that the paper anticipated. For instance, I also reached out to the two main parties, DPP and the KMT, and the Green Party of Taiwan, but even they refused to engage with me writing "This topic is out of the bounds of GPT's focus and we're not sure if we can really be of help".[9] In my 30 days in Taiwan, I got into contact with a good amount of people, in civilian settings, and to my surprise they hadn't known about their huge dependency on energy imports, but all mentioned the problems of blackouts and the

9 【綠黨秘書處】Green Party Taiwan, email message to author, March 4, 2023.

officials usually blaming it on “Snakes and squirrels getting into the system”.[10] During my interviews with several experts, after they were asked about how the military is thinking about energy resilience, their usual answer was that “I am a military strategist. Not an energy expert”.[11] From these, and from the vulnerabilities mentioned throughout the paper, it is clear that Taiwan is not devoting enough time to think about energy concerns in the military. Why is that military energy security does not seem to bear a strategic attractiveness to Taiwan? After all, even NATO is currently developing its own operational energy strategy, which means that there must be something else than the concept and the technology simply being in its infancy.

On the one hand, the focus on asymmetric warfare in Taiwan's military build-up, aimed at countering the People's Liberation Army's sea transit with missiles, mines and landmines, reduces the need for extensive power projection capabilities and large-scale battlefield manoeuvres. As a result, concerns over fuel scarcity are effectively mitigated, allowing for a more focused approach to operational energy planning. This is also supported by the ROC National defence Report 2021 (Ministry of National Defence, 2021), which mainly mentions resilience, “self-reliance”, in the context of its indigenous defence industry. The only exception, as noted in the last chapter, is the energy storage industry, which is a key technology but very much in its early stages as of now.

On the other hand, several experts highlighted the significance of U.S. support in case of a conflict, especially since the war in Ukraine. This is why it is imperative for Taiwan's military to maintain interoperability with the United States. This interoperability extends beyond broader defence capabilities and also encompasses energy generation, storage, and overall system compatibility. Failure to ensure interoperability risks undermining Taiwan's ability to effectively coordinate with Washington and leverage the benefits of close cooperation

[10] Conversation with a group, April 22, 2023.
[11] Conversation with several experts throughout April, 2023.

between the two. Which means that Taiwan could not produce disruptive technologies in operational energy without the U.S, at least in a quantity that would make a difference.

Taken together, these factors emphasize the importance of tailoring Taiwan's operational energy strategies to adjust to its defence priorities and maintain close alignment with the United States. Otherwise, OE sounds great as a promise to environmentalism but does not offer substantial strategic consideration. These lessons about this novel concept in military energy then can be applied in a broader context, underlining some important observations for future studies beyond the environmental factor.

Firstly, the Taiwan case highlighted that operational energy concerns, generally speaking, come into question when we have to talk about *power projection* capabilities. The existing literature about operational energy do mention electrification and efficiency as a possible strategic advantage, because of reduced noise for drones and cost benefits for instance. However, it does not mention power projection or defence posture as an important strategic imperative, underpinning the implementation of operational energy (Clark et al., 2023; Barry et al., 2022; Kõrts, 2023; Patrahau et al., 2010; Smil, 2004).

This also explains the second point, which is *interoperability*. After all, the only country with significant power projection capabilities across the globe is the U.S., who must work closely with its allies to keep up the status-quo. To do that Washington has to make sure that they do not hinder its own power projection capabilities by implementing something that undermines its operational energy strategy, or its gradual implementation. Hence the 2022 National Defense Authorization Act, which specifically mentions the role of allies in operational energy and the push in NATO to develop its Operational Energy Concept. One thing is for sure, new energy sources are slowly finding their way into our life, including the militaries, and we must observe and study their implications for the future of life and warfare.

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