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POWERING THE FIGHT: WHY SECURING ENERGY ADVANTAGE IS CRITICAL

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THE UK Defence Operational Energy Strategy recognises that it is time to treat soldier, platform and base energy on operations as a critical capability rather than an abundant commodity. The move from fuel dependence to energy advantage will require consideration of multiple energy vectors (gaseous fuels, liquid hydrocarbon fuels, electricity, thermal energy, hydrogen, bioenergy etc.) from the point of extraction, through the home base, to the delivery of effect as part of a contested system.

The current UK energy system appears resilient. However, it is structurally dependent, tightly coupled and vulnerable to disruption. The energy transition presents both challenge and opportunity. The 2025 UK National Security Strategy recognises clean energy, supply chain resilience and infrastructure protection as mutually supporting pillars of national strength. Competitors are also seeking to gain geopolitical advantage through their national responses to the energy transition. China is leveraging state-backed investment to dominate clean energy supply chains and create structural dependencies, while Russia continues to weaponise hydrocarbon exports to shape global energy relations. This signals the dawn of a new arena of geopolitical energy competition.

MULTI VECTOR ENERGY SYSTEMS

Modern energy systems don't just fail when they lack supply, they fail because they cannot adapt. The term 'multi vector energy systems' is defined as a set of interdependent functions operating simultaneously and held together by continuous control and feedback. This approach allows the assessment of risks and opportunities, from the point of extraction of raw materials to the resilience of the home base, through strategic base outload to the delivery of effect at the edge. This offers a pathway to energy and operational resilience, but comes with trade-offs in terms of cost, time and complexity. There is already constant competition across the system, from sourcing and generation through to storage and distribution. Effectiveness is determined not by the strength of any single function, but by the system's ability to adapt, reconfigure and withstand disruption. Resilience depends on the speed of reconfiguration and adaption under disruption. Integration and storage provide the opportunity to move between energy vectors, but it is the system management through control and adaption that determine whether this flexibility can be exploited in time.

A multi-vector-energy-systems approach enables progression beyond energy security (having enough at the right time and place) and energy resilience (resistance to shocks). By treating energy as a contested system, it is possible to go further, to seek 'energy advantage' by generating, storing and distributing energy to enable our own operations, whilst also constraining our opponents. Crucially, multi vector energy systems is not about having more energy sources, but about enabling commanders to reconfigure energy effects faster than an adversary can disrupt them.

BREAKING THE ILLUSION

Within the UK, there is an apparent abundance of the existential necessities. The air is fresh; water comes without limits from a tap; supermarket shelves are stocked with food from all over the world; power, connectivity and entertainment come at the touch of a button; security, education and health care are managed; and supply chains operate without interruption. The system will continue to appear stable. Until it isn't. The current system has been optimised for efficiency, cost and just-in-time delivery. Recent national and global events show where the system is starting to strain.

The Kelly Review into the closure of Heathrow Airport following a fire at the North Hyde London substation on 21 March 2025 highlighted the importance of developing a systemic energy resilience strategy and the need to place more emphasis on identifying and preparing for risks linked to both critical national infrastructure and military vulnerable infrastructure in the UK. There is also a risk of more widespread disruption such as that experienced in the regional power cuts across England and Wales in 2019 and the catastrophic national power outage in the Iberian Peninsula in April 2025.

The *Blackout Report* shines a spotlight on the stark impact that a national outage would have on the UK, highlighting that unlike the Iberian Peninsula (where some areas were without power for 19 hours), the UK would take five-to-seven days to get the power back on. The 'Black Start' recovery process required would be more challenging due to the increasingly complex generation and distribution system across the UK national grid. An extended outage would provide significant challenges to other systems (internet, food, water, transport, communications, healthcare etc.) and wider social cohesion, with the *Blackout Report* grimly referencing an MI5 statement that we are only ever "four meals from anarchy".

Systemic energy disruption is also evidenced across the spectrum of modern conflict. The UK 2025 Strategic Defence Review outlines how Russia has targeted both critical national infrastructure and military vulnerable infrastructure to impose strategic pressure. In a statement to the Organisation for Security and Co-operation in Europe, the Foreign, Commonwealth & Development Office highlighted Russia's "systematic campaign of weaponising winter". Commenting on the conflict in the Middle East, the UK Foreign Secretary described the impact of damage to energy infrastructure and the restrictions on passage through the Strait of Hormuz as an attempt by Iran to "hijack the global economy".

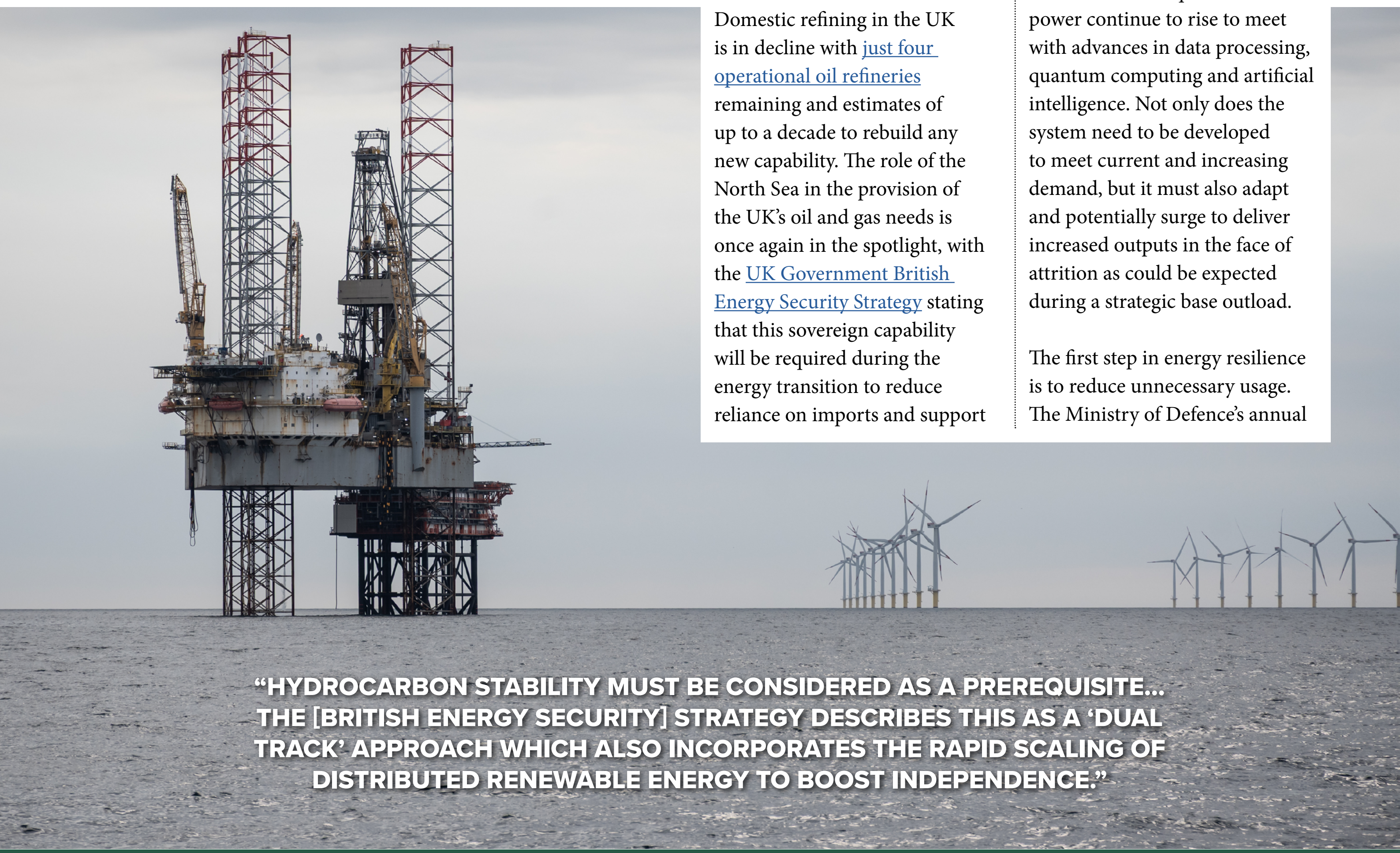
The UK has an energy net import dependency of 43 per cent meaning that it is heavily reliant on overseas energy imports (largely oil and gas) and, therefore, very susceptible to fluctuations in pricing and supply. This domestic vulnerability is now colliding with a volatile global landscape characterised by the US One Big Beautiful Bill Act (2025). The US shift to maintain dollar hegemony by flooding the market with domestic hydrocarbons acts as a strategic countermeasure in response to the accelerating global scramble for energy independence.

Domestic refining in the UK is in decline with just four operational oil refineries remaining and estimates of up to a decade to rebuild any new capability. The role of the North Sea in the provision of the UK's oil and gas needs is once again in the spotlight, with the UK Government British Energy Security Strategy stating that this sovereign capability will be required during the energy transition to reduce reliance on imports and support energy security. Hydrocarbon stability must be considered as a prerequisite for national security throughout the energy transition. The strategy describes this as a 'dual track' approach which also incorporates the rapid scaling of distributed renewable energy to boost independence through Great British Energy. This will require investment to ensure that the dependence on Russian pipelines or access through the Strait of Hormuz is not replaced with single source Chinese manufacturing of the components required for the renewable energy transition.

HOMELAND RESILIENCE

Warfighting readiness must be considered in the context of the challenges to the strategic home base highlighted above, and through the multi-vector -energy-systems approach that will be required during the energy transition. As a result of historic underinvestment in the estate and the requirement to prioritise safe and legal work, there is considerable activity to be done to deepen resilience. At the same time, the requirements for power continue to rise to meet with advances in data processing, quantum computing and artificial intelligence. Not only does the system need to be developed to meet current and increasing demand, but it must also adapt and potentially surge to deliver increased outputs in the face of attrition as could be expected during a strategic base outload.

The first step in energy resilience is to reduce unnecessary usage. The Ministry of Defence's annual



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domestic utilities bill is reported at £600 million, with considerable opportunity for reduction. The cost, time and complexity challenge for control and adaption to reduce consumption begins with governance. There is no single owner of domestic energy and utilities. The Defence Infrastructure Organisation within National Armaments procures the utilities, the Army Headquarters pays the bill, and the end user at base level uses the resource with minimal checks and balances.

A lack of sub-metering or building energy management systems and no inclusion of energy management and control within the assurance and inspection regime means that there is insufficient agency or incentive for units and personnel to behave differently. Within the Army Headquarters in Andover, the heating runs at full power throughout the winter and halogen light bulbs burn brightly at all times. Staff officers control the temperature by opening and closing the windows. This is not a local failing, but a systemic outcome of unclear governance, a lack of incentives and assurance misalignment. Without clear accountability, resilience investments will default to cost-minimisation rather than warfighting readiness, regardless of technology.

There are relatively straight forward steps required to reduce energy usage and to prioritise critical systems in the event of restricted access to the grid. The next stage in ensuring energy resilience is to minimise grid dependence and create self-sufficiency through independent power architecture at the point of need. A multi vector microgrid approach can deliver this capability, as demonstrated by the US Air Force at their Yokota Air Base in Japan. This distributed solution highlights the importance of base level resilience as a key component of wider systemic resilience. The responsibility for

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heads of establishment in the UK is described in *Joint Service Publication 503 (Defence Manual of Resilience)*. The challenge is in delivery and enablement, which will require complex utilities expertise and investment expense.

Energy solutions must also have multi-layered redundancy and be digitally secure by design, with active solar array components, remote utilities management systems, electric vehicles and electric vehicle charging infrastructure all potentially at risk of remote access or cyber interference. By way of example, the UK government mandated the complete removal of Huawei equipment from 5G and sensitive Internet of Things applications following advice from the National Cyber Security Centre in 2020. Understanding this kind of challenge in the home base provides a useful testbed for further experimentation on deployed systems. Similar operational lessons can also be taken from measures to reduce demand, provide continuity under disruption, and experimentation with solutions to deliver assured supply.

OPERATIONAL ENERGY

Multi vector energy systems solutions in the home base are likely to have utility on operations, but this doesn't mean that one size fits all. It might seem logical to take an approach to the development of battery energy storage systems that could be used in barracks and then deployed, but this would potentially risk over-engineering (e.g. for temperature extremes and ruggedisation), which might make it economically unviable for widespread domestic use. In addition, as our systems become more complex, there will potentially be increased dependencies and more potential points of failure. Land Open Systems Architecture exists as the authoritative approach to provide a standardised, interoperable, modular and scalable framework for integrating power (and digital systems and data) across three core land domains: soldiers, vehicles and bases. However, stronger architectural enforcement and a shift from legacy platform-centric procurement will be required to deliver a coherent multi-vector-energy-systems approach. This challenge becomes even more acute in the face of the exponentially increasing energy demand.

Fuel-dependent warfare has played a key role on the battlefield since the domestication of livestock and the early Roman Empire through to the advent of mechanisation in the early 20th century. During the Second World War, a quartermaster serving in the US 3rd Armoured Division calculated that it took 125,000 gallons of fuel for the whole division to move 100 yards.[1] As the requirement for energy rises, this tether remains. Studies show that the average fuel consumption per soldier on operations has increased from one gallon per solider per day in 1940 to 27 gallons today (and is still rising). The House of Commons Defence Committee noted that the British Army lacked the equipment and logistics to provide the fuel and the thousands of tonnes that a warfighting division requires on a daily basis.

The uncertainty of the energy transition is recognised in the Defence Operational Energy Strategy, which highlights the growing requirement for energy for the deployed force due to more sophisticated and powerful systems and the opportunity for greater freedom of manoeuvre, stealth and resilience available through innovation and a move away from single energy vector dependence. This is an area where there are tangible lessons that can be taken from Ukraine's measures to enhance operational resilience whilst responding to sustained

[1] *The Logistics of WW2, John Norris.*

Russian attacks on their energy infrastructure.

The requirement for energy transformation is further driven by the Chief of the General Staff's vision for increasing innovation and lethality. The intent to reduce the reliance on heavy crewed platforms in the survivable layer may provide some relief to the logisticians. However, the increase in autonomous platforms in the attritable layer, and in one-way effectors in the consumable layer, creates a fundamental logistics paradox. To deliver greater persistence and range, a different approach is required to support the high-volume, high-tech digital tail that the current logistic system is not yet designed to handle. Modern lethality's requirement for power hungry processes such as artificial intelligence at the edge and high energy weapons systems further increases the energy demand. Fortunately, there are several opportunities to meet this continuously increasing requirement.

Once again, the first step is to reduce unnecessary usage. In Afghanistan the abundance of comfort in places like Camp Bastion was evident as the force transitioned from an expeditionary to a campaign mindset. The generator farms grew to meet the demands of the air-conditioned tented city and the kettles, televisions and irons of the deployed force. Even some of the more austere forward operating bases managed to develop their makeshift gymnasiums and welfare hubs as the supply of fuel became more assured, despite the volatility of the supply lines and the NATO £1.5 billion annual fuel spend.

At the base level, effective power management is central to make better use of multi vector energy generation and storage assets to meet demand with the minimal fuel burden. Traditional military generators are universally oversized and run constantly, which causes poor fuel economy and mechanical degradation. Power management allows the calculation of optimal power flow balance and introduces storage systems to act as a buffer. Use of power management and integration through microgrids can reduce fuel use by 30 per cent, increasing to above 50 per cent when other energy vectors such as photovoltaics are added. Other benefits include reduced acoustic and thermal signatures and the ability to link to vehicle platforms.

For vehicle platforms, hybrid-electric and electric drivetrains offer a step change in sustainment. The potential reduction in mechanical complexity and lower volume of the spares supply chain provides the opportunity to increase both reliability and sustainability. The British Army has been at the forefront of hybrid electric drive and tactical microgrid technology experimentation. The Technology Demonstrator 6 programme (using the Jackal combat reconnaissance vehicle, MAN support vehicle and Foxhound patrol vehicle) investigated the potential for wider use of hybrid electric drive technology and identified significant additional benefits. These vehicles outperformed their internal combustion engine counterparts in terms of manoeuvrability and torque and generated a lower acoustic and thermal signature, making them harder to detect and target. Most significantly, they also provide the ability to offboard power from the onboard battery to other battlefield systems at the point of need and integrate into tactical microgrids. Other militaries have also noted the opportunities in hybrid electric drive technology with the US now leading the way with their new 50 per cent more fuel efficient Abrahams M1E3 hybrid electric drive tank arriving in 2026 .

As other allies develop their own multi vector solutions, the importance of interoperability will need to be carefully considered. Innovation ranges from microgrid and platform solutions to the development of scalable synthetic fuel production plants to small modular nuclear reactors. A race to achieve energy advantage risks the development of energy silos of excellence and the current benefits of operating within a NATO single fuel policy. There is little point in developing a tactical microgrid if it isn't possible to on and off-board power with partners on combined operations.

SUMMARY

The illusion of resilience currently persists because the current energy system appears to work. Shocks are absorbed, failure is rare and overall accountability and responsibility is diffuse. In multi vector energy systems terms, the current perception of abundance masks the challenges of adapting under disruption. As the energy transition deepens, resilience becomes less about having enough and more about sensing, controlling and reconfiguring the system at speed.

Multi vector energy systems offers a practical framework to design and build in resilience to deliver energy advantage. However, this will require a shift in mindset and the development of a new technical energy skill set for planners, operators and maintainers. To achieve 'energy advantage' the Army first needs to instil 'energy discipline' with the same vigour that it applies to other core training skills.

Energy advantage will require targeted investment. True resilience is expensive and must compete against both the relentless drive for efficiency and the inevitable focus on the urgent at the expense of the important. Transformation is also complex and will take time, but this should not be a reason to wait. The risk of fast followership in this space is getting left behind by both our allies and our adversaries.

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Hybrid experimental prototypes of the Army's Foxhound (rear), Jackal (front) and MAN support vehicles.