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Defence Logistics
Concepts & Force Development

Delivering Sustainable Military Support in the Future Energy Environment (V0.2)

A Defence Logistics Concept Note Primer

defence logistics

LOGNET
Innovating, Developing & Delivering
the DEFENCE SUPPORT NETWORK

Document Information

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To be updated once document is finalised

Delivering Sustainable Military Support in the Future Energy Environment beyond 2030 – A Defence Logistics Concept Note Primer (Version 0.2)

What is the purpose of this high-level Delivering Sustainable Military Support in the Future Energy Environment Concept Note Primer?

This Concept Note Primer is intended to generate associated thinking, discussion and debate to help articulate what, at a strategic level, Future Energy-enabled military logistic support network could encompass and when, where and how any associated technology and capability options might be operationalised. As such, it compliments and underpins higher, Defence level Energy initiatives but should not be considered as leading this work***; its scope is limited to providing logistic support-related insights and implications only***. It seeks therefore to understand, through offering benefits realisation hypotheses and assumptions, where the Defence Support Enterprise might need to do things differently or do different things to meet the future energy demand signal. In addition, it considers the associated implications, set against the extant baseline, of likely requirements for increases in productivity and logistic mass necessary to service the needs of a Future Force cognisant of the changing face of operations in what has been referred to as ***'powering the electrified battlespace'***. Furthermore, proposed COAs must seek to meet the associated Defence Logistic Vision 'ends' of reduced logistic demand, footprint and whole-life costs[1] through sustainable means and to inform a Future Support Operations Force Joint Concept Note. But, whilst aligned with other future concepts and likely capabilities[2], and evidence-based where possible, it remains aspirational and unconstrained by some associated extant barriers, limitations and operating rules.

What could the Future Support Network Laydown look like?

The visualisation for the 2030-plus epoch Defence Support Network (DSN) is one that is more strategically prepared, globally responsive and operationally precise in the era beyond Defence Support Transformation programme delivery. This future network, in delivering discrete Support functions, must be **information-led, technology-enabled and distribution-driven**, possessing increased agility, higher degrees of real-time asset monitoring and visibility and able to move mass at various operational scales. This must be achieved, where necessary, over several strategic distances within short timescales, and in accordance with the policy-driving demand signal. The future network will be distribution-based with information replacing inventory to minimise the need for stockpiles, leading to a smaller deployed footprint. Modularity, standardisation and an open architecture will enable greater levels of interoperability and leverage interdependencies between the UK military, its industry and its international partners. The network will exploit its digital backbone, connecting people, machines and information to provide an enhanced logistic decision support capability at all levels and across the whole network. This will enable effective and timely C4I and optimise the number of nodes, modes, points of friction, points of vulnerability and human/manual input and activity as far as practicable[3]. Strat Base outputs and future J3-led warfighting 'tip of the spear' requirements will both drive the future demand signal spanning end-to-end support tasks where the dependency on likely increases in energy set against governmental and global policies[4] will shape how Defence obtains, delivers and exploits this vital commodity. Throughout, it embraces a ‘blended support force’ using traditional legacy and new capabilities,

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[1] Including Real Life Support, storage, maintenance, etc costs across the life of a capability/process.

[2] For example, other concepts include GST6, Future Force Concept, IOpC Future/CCSI, Anticipated Force Structure, funded Equipment Plan, etc whilst capabilities include (but are not limited to) Artificial Intelligence and Machine Learning (AI&ML), Robotics and Autonomous Systems (RAS) and Additive Manufacture (AdM).

[3] Referred to as ‘Focussed Logistics’.

[4] Such as the Government's Greening and Net Zero 35 and 50 Agendas, Paris Agreement and 2015, Kyoto Protocol 1997.

with the latter **optimising sustainability**[5] to be both re-useable and disposable where cost-effective, to deliver Support Advantage[6] through superior logistics.

> To illustrate this point, fuel consumption in the US Army increased from an average of one gallon per soldier per day during World War II, to 20 gallons per soldier per day during Operations Enduring Freedom and Iraqi Freedom. Supplying these fuels and moving them around conflict zones presents huge logistical challenges. Refined oil is cumbersome and volatile, making it difficult and dangerous to transport in large quantities. Fuel resupply convoys are slow-moving and conspicuous, making them easy, high-value targets for enemy forces. Over 3,000 American soldiers or contractors were killed in attacks on fuel supply convoys between 2003 and 2007 in Iraq and Afghanistan. A 2009 report by the US Army Environmental Policy Institute puts the estimate at one casualty for every 24 convoys. The logistic burden is substantial, and the loss of life resulting from it unacceptably high. Transporting diesel is not only highly dangerous, but highly uneconomical. Field data shows that for every gallon of generator fuel used during the Afghanistan conflict, seven gallons were used in transporting it there. Consequently, the accumulated costs of delivering each of those gallons to a forward operating base can add up to hundreds of dollars. The fact that oil's cost is determined by market forces also makes it hard to accurately forecast expenditure over long periods. Furthermore, heating, ventilation and air conditioning account for 75% of Forward Operating Base (FOB) energy demand, with up to half lost due to inefficient structures; one US Navy source has estimated demand at 1000 kWh per day for a company-sized base. This demand is currently met almost entirely by generators fuelled with diesel, which is delivered via an expensive, inefficient and dangerous supply chain that puts convoys in the enemy line of fire. Moreover, in considering the future, a high-powered, platform-mounted directed energy system will likely require more electrical energy than is currently available on a typical platform. Firing the weapon requires repeated, rapid delivery of power, which must either come from large storage cells or from a generator able to replenish the energy stores very quickly[7].

What does Delivering Sustainable Military Support in the Future Energy Environment include?

For the purposes of this Concept Note, the key term **'Delivering Military Support in the Future Energy Environment'** refers to the consideration of potential solutions (including what, how and when?) to meet the energy demands of the Future DSN for:

- Powering the future support network[8] (i.e. energy to ***enable*** the DSN'), and:

- Supporting the future power environment (i.e. energy ***delivery within*** network, including those commitments to international allies and partners). Of note, what has been previously as 'operational energy' as been re-titled to 'capability energy - see MoD Capability Energy Strategy detail below.

As such, it seeks to understand the support requirements of future platform energy sources but does not address what these might be. In addition, any proposed solution must be underpinned by the need to exploit sustainable options wherever possible, including renewable resources (i.e. those that can be replenished quickly) such as but not restricted to solar power, biomass, geothermal, hydro-electric, fuel cells, wind power and deployable fast reactor nuclear[9] power plus platform-based energy capture and generation capabilities. Within this bounding it includes

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[5] Sustainable MOD Strategy: Act & Evolve 2015-2025, DG HOCS & DCDS (Mil Cap), Sep 15.
[6] Battle-winning effect through the superior provision of support functions compared to that of the enemy.
[7] QinetiQ - Powering the Electrified Battlespace paper. [Link]
[8] Including warehousing/environmental storage, tracking, distribution, Support C4I, LDS, maintenance, etc.
[9] US Mobile Nuclear Power Plants for Ground Operations concept capability demonstrator based on a 40' HOLOS ISO container (design phase ongoing with demo due in 2023).

initiatives that maintain the commander's freedom of manoeuvre[10] by making more efficient use of available energy and the ability to store and use multiple sources of energy (noting that this is likely to drive future distribution options) plus options that reduce overall demand and those that help to meet national government-led and international targets plus NATO/MN interoperability requirements.

What does Delivering Sustainable Military Support in the Future Energy Environment not include?

For the purpose of this Concept Note, the key term **'Delivering Military Support in the Future Energy Environment'** does not include broader, non-logistic support based, Defence-wide initiatives including those designed to reduce the use or better utilisation of energy such as infrastructure improvements, Triad energy initiatives[11] seek to smooth price spikes via reduced consumption through resilience measures, etc which are the responsibility of DIO.

Scope of the Challenge

'Delivering Sustainable Military Support in the Future Energy Environment' encompasses, but is not limited to[12], an approach that utilises where feasible proven/adapted Commercial and/or Military-Off-The-Shelf (C/MOTS) and near-to-market products, able to co-exist, compliment and blend with both new and legacy power provision and capabilities that will still be in use in 2030+ to support a digitally-enabled, resilient, agile, augmented and technology-reliant[13] DSN. The associated scope is illustrated below:

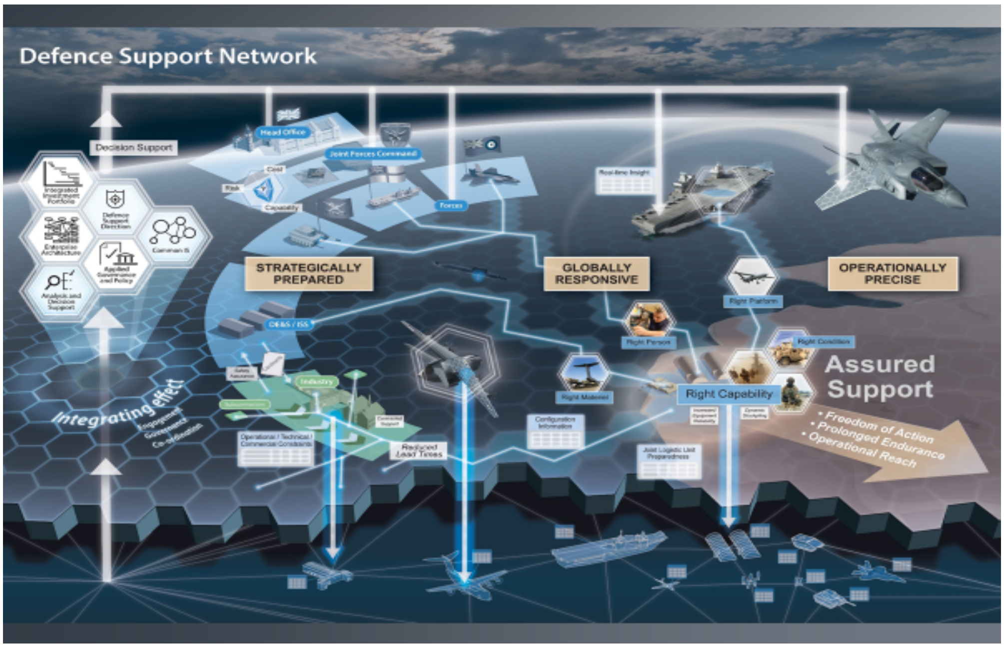

Figure 1 – The Defence Support Network Rich Picture Depiction

Of note, QinetiQ's 'Powering the Electrified Battlespace'[14] paper highlights that 'necessity has ushered in a new era of innovation. Countermeasures, platforms and situational awareness tools

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[10] FFC 2017 discusses, 'Innovation, greater automation and creative thinking, bolstered by well-prepared reversionary modes of operation to sustain our freedom of action'.
[11] ttps://modgovuk.sharepoint.com/sites/defnet/DIO/Documents/2018%20TRIAD%20leaflet%20vMOD.pdf#search=Triad%20 Energy
[12]i.e. where risk permits their use.
[13] including resilient and reusable autonomous and precision delivery and/or extraction systems (air, surface and subterranean); human-machine and machine-machine collaborations; remotely controlled platform systems (including tele-operated either through expert assistance to a human or by remote control of a maintenance/medical robot); automated guided systems; unmanned platform systems; swarming systems; computer programs and algorithms; manufacturing and VR-enabled robotic systems.
[7] QinetiQ - Powering the Electrified Battlespace paper. [Link]

are evolving at an astounding pace in response to changing threats and tactics. Directed energy weapons will soon knock out enemy communications or neutralise swarms of low-value targets at very low cost. Unmanned systems will resupply troops and deliver humanitarian aid, minimising human exposure to dangerous contested areas. Networks of smart sensors will collect and prioritise data to provide the fighter with a wide-ranging situational awareness picture, without causing cognitive overload. However, all of these revolutionary technologies rely on electrical energy, so can only be as effective as their power sources allow. In the race to provide this power, we must not sacrifice the mobility, survivability or lethality of our troops and platforms by overburdening them with batteries. Electrical technologies are also being shoehorned into a pre-existing infrastructure that was intended to support mechanical equipment. How do we deploy electrical weapons, platforms, or intelligence tools in a world powered by diesel? The evolution of military capability from mechanical to electrical will only fulfil its enormous potential if the underlying power infrastructure evolves in tandem'. It also notes that, 'we must break the habit of increasing the capacity and the number of generators, then supplying more diesel to feed them. We must stop weighing down people and platforms with more and more batteries. And we must stop focusing on the power demands of individual capabilities, instead taking a macro 'system-of-systems' view to tackle the issue at an infrastructure level. This will allow us to reduce demand and variability of demand, enabling supply to be precisely matched to the load'.

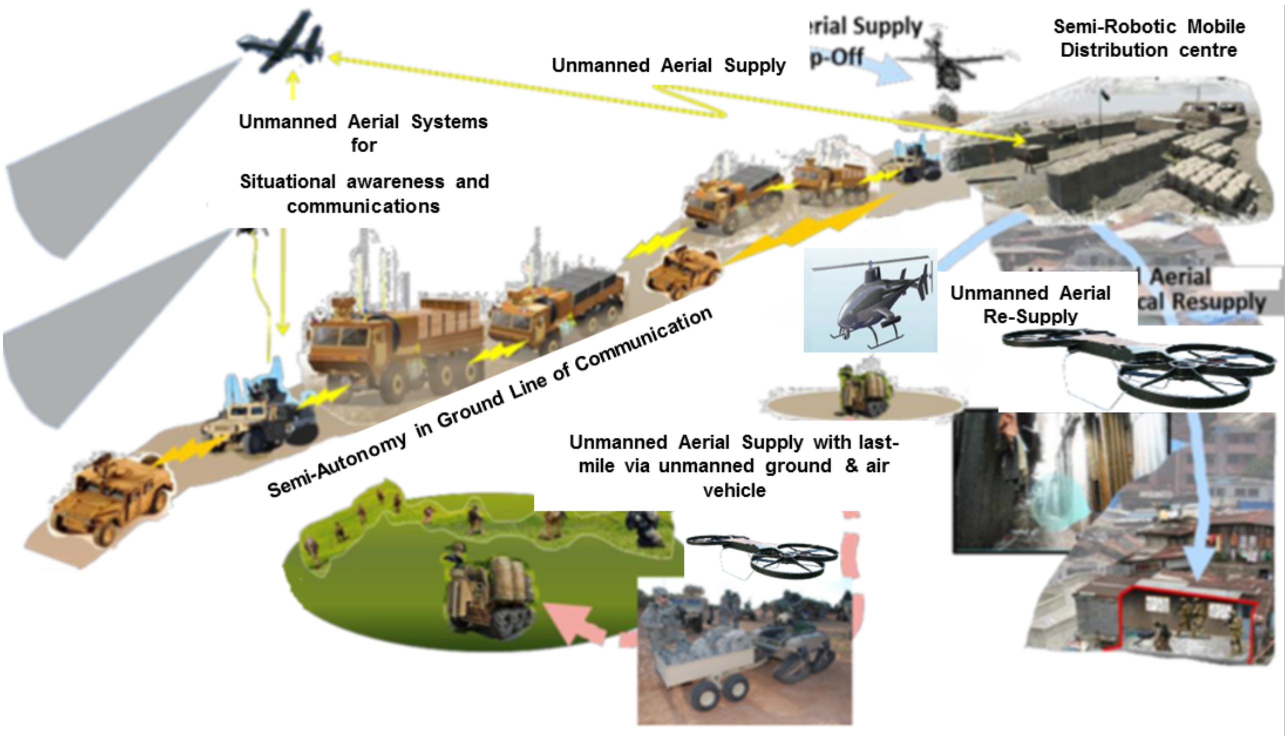

Figure 2 – Illustrative Future Battlespace

Furthermore, they highlight that, 'the challenge in deploying electrified technologies in battle is that a comparable infrastructure does not yet exist. A new piece of electrical equipment, such as a directed energy system or electrically-driven autonomous platform, may not be able to simply plug into an existing grid. Man-portable systems, such as computers, radios, sensors and life support, are designed and supplied with their own individual power sources (In Afghanistan, it was not uncommon for a British soldier to carry equipment totalling 58kg, which is circa 70% of typical bodyweight[15]). The outcome of this is a rampant multiplication of batteries and generators, each

[15] ThinkDefence.co.uk – "The recurring problem of overburdened soldiers".

devoted to powering a single piece of equipment. Such unconstrained proliferation of diverse and often incompatible power sources is costly and creates significant logistical challenges for those on the front line. From the smallest drone to the largest aircraft carrier, the space available for power sources on board platforms is generally very limited. Introducing more batteries or generators to a platform adds weight, reducing mobility and range. The challenge in all cases is to increase energy provision while maintaining or reducing the volume and mass of the power sources'. As such, 'the success or failure of electrical technologies in defence will depend on the quality of the infrastructure behind them. While power provision may not grab headlines like laser weapons or robotic systems, governments and industry must commit adequate money, time and resources to research and development projects that support the creation of that infrastructure. If they do not, the battle-winning potential of their headline-grabbing technologies will never be fully realised'[16]. Of note, the US MC also has an Expeditionary Energy Office addressing associated 'expeditionary economics' issues. Furthermore, the US has commented that, 'only nuclear power can provide the energy density necessary to have both a small footprint and a low logistical tail. It is not an exaggeration to say that the deployment of mobile, micro nuclear power plants would revolutionize military logistics for the 21st century'[17].

Attempting to meet the Future Energy demand signal could be managed using SMART tech, load and demand management, power grids (as detailed in the draft military adaptation of ISO 50001) to reduce the Energy Intensity[18] - an emerging field in the military expeditionary environment or as part of the disaster response phase of an operation, through numerous initiatives, approaches and systems, including but not limited to:

- Conservation - optimal driving and routing, more efficient sub-systems, behaviour change;
- Generation - use of platform-based, wearable and other agile power creation capabilities;
- Renewables - energy from a source that is not depleted when used, such as wind or solar power.
- Storage - use of advanced battery/storage technology that store off-peak energy production to mitigate short notice peak loads by storing energy using fly wheels, etc;
- Recycling - re-use of all types of waste to create energy;
- Alternatives – bio-fuels, geo-thermal, deployable nuclear, LNG, LPG, ammonia etc.
- Harvesting (power harvesting/energy scavenging/donation) – capturing or sharing energy from external sources (e.g. solar power, thermal energy, wind energy, etc) and storing it for small, wireless autonomous devices, like those used in wearable electronics and wireless sensor networks and/or reusing CO2 emissions combined with renewable energy sources for production tasks (i.e. food manufacture[19], etc). The recovery of certain waste products may also help to reduce the overall electrical load, such as using heat from generators to heat water. Water produced as a by-product of air conditioning units can also be recovered and re-used.
- There is also a case, indirectly, to adopt a more flexible approach to procurement which moves away from through life capability management to one where product development remains ongoing.

Furthermore, Future Energy solutions will have to integrate with planned in-service capabilities (i.e. as reflected in the 'Anticipated Force Structure' and funded Equipment Plan) and facilitate other new technologies such as but not limited to Additive Manufacturing (AdM), Robotics and Autonomous Systems (RAS) and Artificial Intelligence & Machine Learning (AI & ML), all of which are covered by separate, complimentary Concept Notes. It must be highlighted that there are

[16] QinetiQ - Powering the Electrified Battlespace' paper.
[17] CILT Monthly Bulletin – Nov 19.
[18] is a measure of the energy inefficiency of an economy, calculated as units of energy per unit of GDP.
[19] Solar Foods' presentation (PDF 2,7 MB)

constraints to moving to these new sources of energy; the production of new generation batteries and solar panels require ‘rare earth elements and materials’ the harvesting of which is currently a significant challenge, that potentially has other harmful environmental impacts. In addition, the future commercial energy model may not service Defence requirements[20] and so developments will need to be tracked, simulated and modelled in order for Defence to be able to assure the achievement of future Defence Tasks.

What associated Governance Strategy, overarching Concept and Future Challenge products exist?

A number of related strategy and concept docs exist that underpin and support this concept note including:

Sustainable MoD Strategy - Act and Evolve (2015 to 2025) [Link]

Role - The Sustainable MoD Strategy Act & Evolve provides the framework within which the Department delivers a sustainable approach to the delivery of Defence outputs through being ‘efficient in the use of assets and resources, our material security and supply chain, and planning for the long term’. Its subordinate Capability Energy portfolio is managed by DCDS (Mil Cap).

Governance - Both of the above portfolios are directed through the Co-Chaired Sustainable MoD & Energy Steering Group (SMESG) which acts as the single Departmental focal point for energy and sustainability issues, but which has not met for some time (although plans are being discussed about ‘re-invigorating’ the forum. It is through this group that energy targets are directed and issued across the FLCs via DSD, DPs and respective CPs. The SMESG also drives strategy execution and is supported by the Sustainable Energy Steering Group, Energy Programme Board, Sustainable ICT working Group, Procurement Working Group and Waste Working Group.

Activity - The strategy covers both **Act** (make resource use and assets sustainable - through energy efficiency and supply security) and **Evolve** (resilient to future threats) elements. Of note, associated materiality analysis identified ‘energy security’ as a high priority and ‘supply chains’ as a 'second priority', effected through improved efficiency and effectiveness of our capability and equipment assets. The related strategic objectives for Defence include:

> **Act** - 'we will increase our energy efficiency and reduce our dependency on fossil fuels to lower their associated risks to business and capability'.
>
> **Evolve** - 'we will make sure that our acquisition and infra business systems and processes take account of through life value and have the best evidence to make fully-informed decisions'.

Implementation - Intent is to effect activity through 'How Defence Works' and 5-year energy plans (15 to 20, 20 to 25, etc following each SDSR cycle) with key objectives set out in annual Defence Plans. The Strategy is owned by DG HOCS as the Department's Sustainability Champion supported by DCDS (Mil Cap) where it relates to capability.

MoD Capability Energy Strategy (Mar 16) [Link]

[20] For example, alternatives to diesel powerplants for some port operations, shoreside power provision and ROROs are expected to be in operation by 2040 so access to large volumes of diesel at POD/POEs may not be assured to the same levels as is the case today (source: LOGNET Energy SWG 5 Dec 19).

Originally termed ‘Operational Energy’, the title has changed to Capability Energy to reflect the explicit link to military capability thereby also allowing clarity over energy used on operations and that used to prepare for operations and business as usual.

Capability Energy is defined as: the energy required to train, deploy, sustain, recover and recuperate UK fighting forces and support elements globally now and into the future. This definition excludes the fuel and energy required to power domestic utilities, largely, but not exclusively, in the Strategic Base which remains the responsibility of DIO. Additionally, this strategy does <u>not</u> include Nuclear energy as this falls within the Nuclear portfolio and the responsibilities of the Defence Nuclear Executive Board (DNEB). It can be subdivided into:

> energy used for **business as usual**, ‘peacetime’ activity (usually to train and recuperate the force). In financial terms, business as usual energy is routinely funded from the core budget with operational energy predominantly funded from the HMT Reserve or OGDs.
>
> and
>
> that used for **operations** (to deploy, sustain and recover the force). A further factor that must be considered is that energy used on operations will usually include temporary operational bases and DOBs whereas for business as usual infrastructure energy is a separate portfolio owned by DIO.

Managing this complex portfolio requires continued stakeholder engagement to minimise the impact that energy has on our outputs. As such, associated work must endeavour to:

- Maintain energy interoperability with Coalition Partners.
- Increase efficiency of individual military platforms either to achieve savings or to improve range, endurance and reliability.
- Reduce the logistic burden and the vulnerability of fuel supply lines and supporting personnel.
- Enhance the Department’s resilience to energy price and supply volatility and disruption.
- Contribute to Government and where necessary, international energy targets such as reducing reliance of fossil fuels, cutting greenhouse gas emissions and stimulating innovation in industry.
- Remain coherent with the Department’s Sustainable MOD Strategy Act & Evolve.

The Defence approach also includes the need for:

- The Department to set intelligent energy targets and strive to reduce MOD equipment and operational fuel consumption through genuine efficiencies while building an understanding of current and future consumption.
- Energy to be viewed as a critical element within current military equipment and requirement setting for future equipment.
- Oversight and assurance to be maintained to ensure regulatory/technical standards including safety are sustained.
- Capability Energy resilience and security to continue to be developed supported by an effective Science and Technology (S&T) programme.
- The Department to capitalizes on energy expertise and resources through Allies and Partners, in other governmental organisations and the private sector.
- Defence to increase awareness of energy use and its value as a mission essential resource and capability.

The Department's energy demand for Joint Force 2025 and the longer term is not clear but it is likely that capability energy demand will rise in the medium term as new capabilities are introduced into service. In order for Defence to maintain the required level of capability, it must therefore behave more pro-actively to make energy efficient capabilities a key consideration in requirements-setting and acquisition. Where possible, it should also seek to improve energy efficiency within existing platforms and processes and make investment in critical components of the energy support network. This should be supported through improved energy data collection, forecasting, intelligent target setting, lessons, interoperability (allies and partners for both platform and equipment levels) and S&T.

Future Force Sustainability/Future Support Operating Concept Strawman - Draft

The underlying presumption of this concept is that, within the time frame out to 2035, a high proportion of the equipment currently in service will remain so, but that the character of those operations will have changed in light of the pressures from an evolving strategic context. As such, the challenge facing Defence is to transform how it thinks about sustainability to provide advantage through this paradigm when faced by the threats of tomorrow.

Analysis of high-level supporting products[21] suggests that the Future Force is likely to be operating at range from the UK and at distance from the established and well-found support infrastructure. Units may be required to operate in regions where they are dislocated from each other and support, potentially behind any defined enemy lines; but will still need to be sustained through some form of a national support network. This model is likely to be unsustainable in the contemporary context and consequently, units in the Maritime, Land and Air domains will need to be more self-sufficient as support will follow a networked vice a traditional linear model.

A key theme is the drive to reduce the UK's net carbon emissions to zero which will lead to a national transition away from fossil fuels and towards renewable forms of energy. This national transformation of energy generation will impact on the way in which Defence operates both at home and when deployed across all the physical domains.

McKinsey Energy 2050 Estimate[22] [Link]

Of note, the above appears to be a significant challenge given the McKinsey Energy 2050 Estimate that in 2050 coal, oil, and gas will continue to be 74% of primary energy demand, compared with a level today of 82%; after 2050 this rate was likely to accelerate. However, the report identified a number of insights, including that:

- Global energy demand will continue to grow, but growth will be slower by an average of about 0.7 percent per year through 2050.

- Demand for electricity will grow twice as fast as that for transport, noting that China and India will account for 71 percent of new capacity and that, by 2050, non-hydro renewables will account for more than a third of global power generation.

- Fossil fuels will dominate energy use through 2050 due to the massive investments that have already been made and because of the superior energy intensity and reliability of fossil fuels.

[21] Including GST6, FOE 35, IOpC Future, CCSI, FFC, etc.

[22] https://www.mckinsey.com/industries/oil-and-gas/our-insights/energy-2050-insights-from-the-ground-up.

- Energy-related greenhouse-gas emissions will rise by 14 percent in the next 20 years, in direct contrast to the goal of the 2015 Paris climate conference.

Global Strategic Trends 6 [Link]

Furthermore, GST 6 (which encompasses FCC and FOE deductions) highlights that 'the future starts today' set against a 2050 horizon, particularly in terms of the need to act set against extant capability acquisition cycle timelines. Within the context of Capability Energy, one critical task will be to ensure that, across Defence, sufficient emphasis is placed on choices of today not undermining the sustainability of the Future Force (i.e. through constraining it by an inability to sustain future operations). CFD team analysis highlighted other key Support insights including that:

- There will be an increase in competition and demand signal for energy (including for fuel, water generation, future weapon operation and food production). This will be exacerbated by congested and contested access to the global commons, so Defence will need to consider alternative sources including renewables, nuclear and fusion tech and a move away from oil towards gas;

- Future operations are likely to be prosecuted in different environmental conditions to that of the last 30 years, where specialist equipment capability and operating concepts may need to be tested and adapted iot deliver success. Defence should ensure that it remains alive to the associated challenges through its long-term Force Development tasks including the ability to provide a rapid and assured global distribution capability;

And that further work is required to:

- Understand the extent and construct of the support demand signal in this era to help inform and drive future Support planning, Equipment Plans and Defence Planning Assumptions, including the likely future weapons requirement[23], its associated support solution and demand profile;

- Confirm the level of assurance necessary for future Support in this era, set against assumptions covering revised DPAs, resilience and reversionary capability requirements.

NATO Direction - Petroleum Committee Vision of Future Fuels (31 May 17) [Link]

Notwithstanding the above, the extant view of NATO regarding future fuels is that,' the military is a rather small user of petroleum products and, therefore, that its influence on future developments is limited. Therefore, it is vital that NATO nations, the PC (through its subordinate bodies) and the Science and Technology Organization/Applied Vehicle Technology (STO/AVT) engage in close partnership with the Original Equipment Manufacturers (OEMs) and the oil manufacturers to develop future equipment and fuel specifications that are congruent with all the prevailing and forthcoming performance and environmental requirements. While liquid hydrocarbons, synthesised from different feedstocks can be available indefinitely, the issues of cost, security of supply, and the effect on the environment remain paramount. <u>Thus, our endeavours should be targeted at improving equipment performance by making it more energy efficient and compliant with the use of alternative fuels. For all land-based military equipment, compliance with the NATO SFP remains unchanged</u>. Clearly, this will need to overcome many obstacles, not

[23] Directed Energy Weapons (DEW), etc.

least the apparent shift of UK industry from further development of more efficient diesel and petrol engines to electric-based solutions. As such, efficiencies may be limited to the adoption of synthetic training environments and harnessing the efficiencies that other technology strands (AI/ML, RAS, AdM) may bring.

What Future Strategy activity is planned?

HMG strategy. A new HMG Climate Change Strategy is due publication before Christmas 2019. The strategy will adopt a draft policy framework of 'Reducing Emissions' and 'Building Resilience' each of which has 'Domestic & International' aspects. The MOD will follow the same framework by *considering:*

- **Reducing Emissions** – through seeking to maximise the opportunity to deliver sustainable military capability while minimising our contribution to global climate change (i.e. Defence's impact on the climate), and;

- **Building Resilience** – through seeking to develop effective military capability for the more challenging security environments caused by climate change (i.e. the impact of climate change on Defence). Of note, DCDC has been tasked to lead a coordinated research project into the implications of climate change for national security and force development.

In addition, the department publishes its sustainability objectives annually in the Defence Plan and TLBs report performance against their Command Plans. A Sustainable MOD team provides scrutiny and oversight and the department is scrutinised externally to validate our reported performance. Intent is to run an exercise to measure performance against goals and targets to allow the department to identify lessons to improve future implementation activity. This will provide both the opportunity to review and develop the parameters used historically and enable realistic target-setting for the future.

The Challenge of Delivering Sustainable Military Support in the Future Energy Environment - Functions and Effects.

A Future DSN will need to address **changes in the demand for energy** and in the way that it is created, stored, distributed and consumed. This will be driven, in part, by Defence's digital transformation initiative and its growing reliance on an associated digital backbone[24] necessary to permit many logistics functions such activities[25] enabled through augmentation or replacement by AI & ML-enabled autonomous systems and agile manufacturing capabilities that span the Defence Support Enterprise from the Strategic Base to the front line. The requirements of the deployed 'front line' users, potentially from the use of direct energy weapons and alternate platform power plants to the exploitation of wearables and health monitoring technologies, will also need to be fulfilled.

It is envisaged, therefore, that the demand for the provision of Future Energy in the Support arena will be most notable in several key areas:

C4I. This capability will be at the core of the new technologies, linking the strategic base and operational headquarters to the deployed forces right down to the individual serviceperson, advanced robotics and to tactical equipment types such as sensors. The

[24] Encompassing the delivery of digital transformation across Defence (including hardware, software, data sets, etc) that permits optimal information exploitation.

[25] Processes and actions including acquisition, storage, movement, distribution, maintenance, recovery and disposal and the function of delivering Class I to V supplies including food and water, clothing, medical stores, med log, weapons, tools, spare parts, vehicles/platforms (where practicable), petroleum (including air/aviation and ground vehicle fuel), oil and lubricants, construction materials plus ammunition, and explosives throughout the DSN and Joint Operating Areas.

amount of information being exchanged are likely to increase by orders of magnitude and the information coordination requirement will increase correspondingly as will the requirement for processing power whilst remaining secure and able to combat cyber-attacks. The power required to support this integrated technology will be complex and layered with deployed personnel requiring a light but high endurance, resilient and agile power supply. The challenge for the support network will be in supplying the power and maintaining the associated equipment. As machines replace or augment humans, the nature and balance of the energy requirement will also change from one based on nutrition to other power sources.

Asset Tracking. As the level of technology deployed into the battlespace increases so the need to track assets whilst in-use and whilst in the support network will also increase. There will be a need to provide, maintain and exploit a real-time picture of assets, their condition, state and location to plan the associated provision of consumables, replacements and maintenance. The exploitation of power consumption data and management will also be an important element of this task.

Warehousing. **Warehousing**. Automation, through the use of AI & ML and RAS-enabled functions, will increase stock management efficiency, assuring the provision of correct and serviceable items, whilst minimising potential injury to and increasing the productivity of any supplementary human workforce. This will be enabled through the digital backbone by predictive demand planning and forecasting utilising conditions-based monitoring and smart packaging sensors and standardised stock size (in line with commercial standards) to help drive and manage optimal stock levels and their disposition. It may also further be combined with embedded AdM capabilities to deliver both static and agile options. This is likely to result in an increased and mobile power requirement set against the extant laydown and doctrine (noting that there will be an offset against the support requirements associated with the reduction in personnel). Furthermore, there may well be a need to store energy in warehouses[26] for distribution across the battlefield, including from places of excess generation to those requiring it.

Figure 3 – Illustrative Agile Warehousing options

Distribution. The overarching Future Support Operating Concept envisages rapid, efficient and agile distribution, delivery and returns accomplished through automated loading/unloading, distribution planning, routing and tasking systems. This will utilise effective combinations of extant and unmanned and self-guiding (leader-follower and platooning) surface or air platforms, from the strategic to the tactical levels. Each will be capable of tracking through ‘Identification Friend or Foe’ systems and tailored to assure last bound delivery via route clearance, optimal routing/re-routing and effective load planning and allocation to the point of use when required. Information feeds will contribute to a real-time logistics picture available to globally-dispersed mobile devices to assure timely delivery and improve trust in the DSN. As above, the energy demands associated with this aspiration will need to be assessed and understood. Any related need to also move energy throughout the network will generate an increased need for 'energy' convoys, etc. and a

[26] https://en.wikipedia.org/wiki/List_of_energy_storage_projects.

requirement for Transportable Energy Storage Systems. But if we are to be truly transformational then we must consider alternative methods such as the potential to beam energy over short distances, the possibility of delivery via wireless methods, etc. Furthermore, the Defence Energy lead will need to apply equitable effort on providing resilient and sustainable solutions, able to operate in EMC/cyber environments, suitably concealed and protected from attack/interference.

Figure 4 – Illustrative Blended Distribution Options

Front Line Support. A meshing of man-machine interfaces, exoskeletons/exosuits, mules, drones and wearables will reduce the physical and cognitive burden on the serviceperson to increase endurance, persistence and reach to enable sustained operations in contested, degraded and austere environments. Reach back through tele-support will permit the completion of highly skilled operations, including maintenance and medical tasks, by providing expertise via a virtual assistant 'at range' thereby generating greater agility and global coverage than that previously achieved. This poses a particular challenge in achieving requisite levels of energy generation, provision and distribution, especially considering that required at range and, in many cases, through self-sustainment only options for extended periods of time[27]. Work will need to be conducted to understand the expectation/balance of self-sustain energy provision at unit level (i.e. that effected from outside of the DSN) and that enabled through the DSN.

Figure 5 – Illustrative 'Last Mile' Delivery Options

Med Logs. Medical Practitioners are responsible for the lives and health of their patients; medical logistics is unique in that it seeks to optimize effectiveness rather than efficiency. Med Log considerations will be required, especially wrt cold chain, MEDEVAC, CASEVAC and field hospital (at all levels) requirements.

Primary Effects. In terms of effects, the Emerging Tech for Defence TDX Position Paper on Power, 25 Mar 19, neatly identifies the (non-exhaustive number of applications) to include:

- Higher power – Weapons including DEW.
- Longer endurance – UXVs, dismounted soldier, platforms.
- Higher power and energy weight and volume ratios – all applications.

[27] As directed in DSD 16 for Strike Brigades and MTG operations.

- Higher charge/recharge cycles - UXVs, dismounted soldier, platforms, bases.
- Faster start up times – weapons.
- Reduce fuel consumption – platforms, bases.'

Secondary Effects. It is worthy of note that some alternative energy generation capabilities can, as a by-product, provide other benefits and fulfil other requirements such as the production of potable water, etc. As such, an end-to-end assessment of all possible options must be considered iot understand the true viability and benefit realisation potential of any solutions to the future energy challenge.

Future Energy effects on the different levels of military planning and operations

New Defence technology solutions will bring with them a different energy demand signal and, when set against global environmental targets, will drive a need for resilient, agile and sustainable alternative power solutions. In particular, there is likely to be a need for rapid charging of vehicles, comms equipment and possibly future weapons, perhaps through proximity/inductive options, and sufficient power to service the digital backbone and all systems and services that connect to it. The use of RAS and AdM capabilities, health monitoring and wearables, whilst possibly reducing overall Defence energy requirements, will require discrete energy provision at the point of need which could be at the forward edge of the battlespace. Thus, the energy laydown, its generation and its distribution, possibly over significant distances, may well need to change significantly from that of today. This can also be considered at the three levels of command, as follows:

Strategic level. It is envisaged that a combination of AI & ML capabilities, modelling and simulation will help enhance knowledge and understanding to inform long-term strategy, policy and plans. From this, Future Energy will then be required to help enable those capabilities necessary to address the associated challenges and trends of the future contested and degraded operating environment, including increased complexity, congestion and uncertainty on a global scale. This will, in turn, help to change the extant paradigm and enable Information and Joint Advantage through greater support agility, speed of responsiveness, preparedness, readiness, resilience, effectiveness and improved efficiency/productivity.[28] This will require sufficient data capture and exploitation through sufficient processing power, including that necessary to aid in the planning and execution of energy laydown across the network.

Operational level. An envisaged increase in productivity, effected through exploiting a combination of AI & ML, RAS and AdM (and other) technologies and achieved by the lack of constraint from either humans or policy, is likely to enhance our ability to operate at full capacity when required, with minimal or no safety stock. In addition, it could help to generate much improved confidence in the DSN through transparency and the provision of effective C4I and greater distribution velocity (in processing, decision and action/distribution) via an accelerated decision and action cycle[29]. Furthermore, it should help to break the '4th to 1st echelon paradigm' and/or equivalents through fewer storage nodes in a networked vice linear laydown. However, this may well change extant demand levels and profile of assured and resilient energy provision and solutions that meet these requirements will need to be developed. As such, it is likely that the planning and management of **<u>energy as a commodity</u>** or class of supply across the network will need to be a key activity.

Tactical level. Wearables, sensors and automated asset tracking will combine to improve the predictability of the demands on existing platforms, some elements of infrastructure and personnel, and help to deliver improved logs pace, momentum, output and accuracy in the provision of support for those on the front line. It will enable greater operational agility,

[28] Including in increasingly challenging urban and littoral environments.
[29] Operating at machine speed and endurance levels.

flexibility and tactical mobility through its ability to mitigate against likely Anti Access & Area Denial constraints. For static locations, automated power distribution systems will optimise power management (through load and demand management and understanding timelines and urgency) and minimise demand and replenishment burden, but a solution will need to be sought that delivers necessary agility, mobility and survivability levels. But detailed analysis will need to be conducted to understand the net energy requirement in the battlefield area as there is potential, notwithstanding the implementation of efficiency measures, for this to be greater than the current baseline.

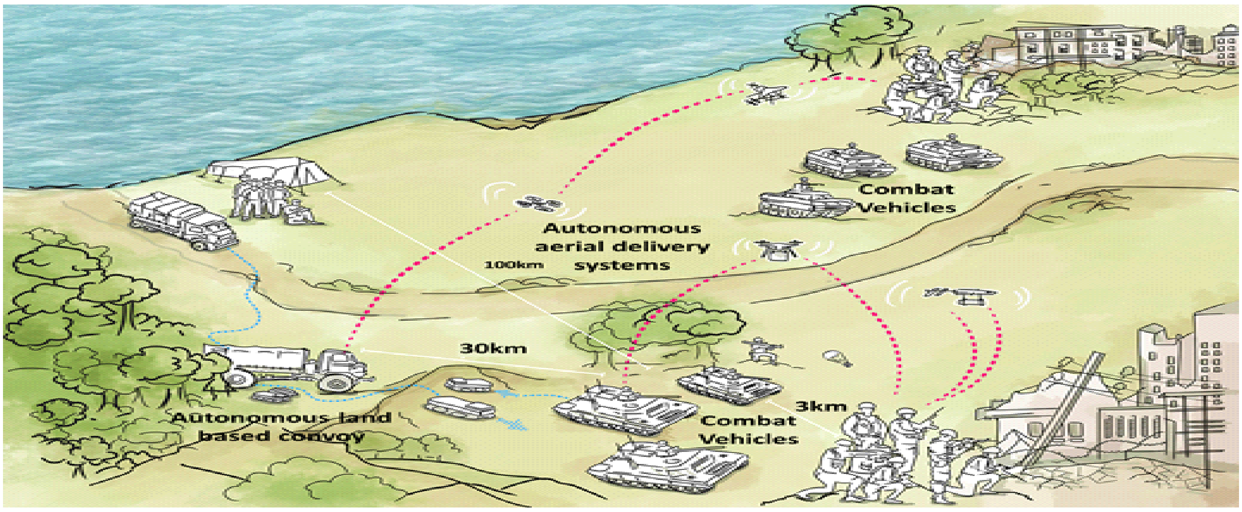

Figure 6 – Illustrative Future Tactical Laydown

Supporting Benefits Hypotheses

It is expected that activity related to Delivering Support in a Future Energy Environment will:

- Provide solutions that can successfully self-sustain future Defence activity iaw policy requirements.
- Reduce the physical storage and distribution/replenishment of bulk/packed fossil fuel over time, nominally to zero by 2050.
- Transition to new energy sources will gradual, vice a big bang approach.
- Make greater use of non-fossil fuel energy provision at the individual level.
- Need to service a potential increase in the overall deployed power demand footprint, especially for forward deployed capability.
- Pursue options that reduce energy consumption and improve efficiency of power usage without increasing demand elsewhere (i.e. reconstitution requirements, etc).
- Enable more agile future Forces and hence deliver greater freedom of action.
- Reduce through life costs and risk (via less impact of price fluctuations plus lower storage and distribution burden) on packed/bulk fuel.
- Provide options that offer sufficient levels of energy self-generation and portability as viable alternative to and/or replacement for current energy provision systems.
- Realise benefits for all domains, including Maritime Land, Air and Space.
- Include viable options that cover all climatic and environmental conditions (as required by Defence Strategic Direction and Defence Logistic Direction).
- Be able to utilise sufficient alternative energy sources to support the operation of a optimum blend of manned and unmanned capabilities necessary to achieve logs mass effect.
- Use scavenging, harvesting (Piezoelectric, Thermoelectric, Pyroelectric) and exchangers
- Augment and/or supplement those legacy energy provision capabilities that remain within the Defence Inventory and Anticipated Force Structure in the near to mid-term.

- Retain alignment with the commercial market and societal values.

Assumptions

Delivering Support in a Future Energy Environment include the realisation of the following assumptions:

- Suitable funding and high-level sponsorship, support and leadership (including appetite for risk) will be secured from both Defence and industry partners to cover future 10-year SDSR quinquennial cycle.
- Some future energy options will require specialist storage requirements and distribution methods, outside that currently used by Defence.
- Future energy options will be influenced to ensure interoperability, including with allies and partners, through standardisation and joint COMEMPs/CONOPs.
- MOD will source energy in an ethical manner.
- Support requirements will not be traded out and will influence the CADMID cycle.
- The identification of future energy requirements will be optimised through better forecasting and resource planning capability.
- COTS/MOTS options will be used / adapted wherever possible in providing solutions.
- Future energy will be part of a 'system-of-systems' approach, integrated with other capabilities such as RAS, AM and AI & ML.
- SpTx will, by 2030, have delivered data integration systems across the network capable of operating at machine speeds.
- Future energy solutions will encompass sufficient redundancy/reversionary modes, resilience and independent operating capabilities to provide assured energy delivery.
- The suite of future energy capabilities will be domain-agnostic and cover the need to function successfully in all climatic and environmental conditions as required by Defence.
- Defence will be able to absorb any changes to the associated demand signal for energy provision.
- UK will continue to maintain a global presence, incl the ability to prosecute expeditionary warfare in austere environments.
- The introduction of future energy solutions will not create 'bad behaviours' elsewhere in Defence (e.g. over-demanding of the commodity) but will deliver overall efficiencies through its effective exploitation.
- Transition to new energy sources will gradual, vice a big bang approach.
- The requirement for interoperability, through the implementation of generic architecture (Def Stans 23-09, 23-12 and 23-13), has been implemented across Defence.
- Environmental Management Requirements for Defence Systems (Def Stan 00-051), will become mandatory (currently it is not) for all products, systems and services procured by the MOD.
- A pan-DLOD analysis s will be considered.

Current evidence – supporting examples

Many elements of future Energy provision already exist within commercial organisations or are being developed around the world by industry, academic institutes and militaries. Examples include:

C4I. Scalable C4I systems are already commercially available. They cover the whole battlespace from strategic HQ to operational bases, using more conventional communications, and further to deployed units with Low Power Wide Area Networks (LPWANs) and Internet of Things (IoT) communication using IP as a standard communications protocol which allows a wide selection of COTS equipment to work together.

Australia's C4i, provides end-to-end interoperable C4I systems for mobile front-line units, forward operating bases and command centres.

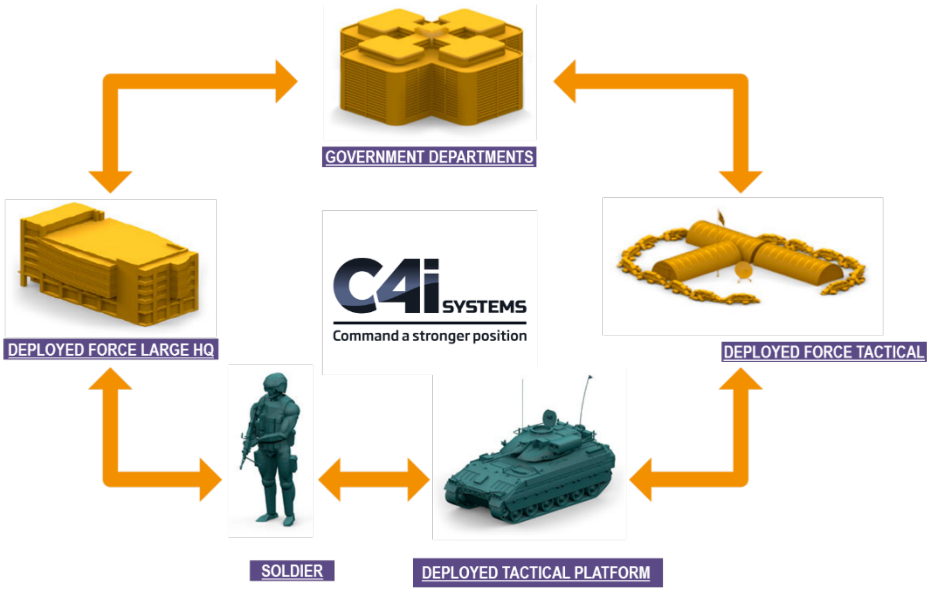

Figure 7 – Australia C4I System Schematic

Asset Tracking. Asset tracking is the fastest growing industrial IoT market and most connected devices will be location aware within the next decade. Driving this growth is the relentless improvements in low power RF chip technologies and the adoption of LPWANs and Bluetooth Low Energy (BLE) beacons that are creating new asset tracking IoT solutions. Of note, Projects BOZAL and WATERGUARD is leading the Defence effort in this arena. Other initiatives include:

AIRcable Gateway combines WiFi and BLE and is a very small Bluetooth smart mesh and beacon interface to the cloud.

Aruba Networks is a leading provider of next-generation network access solutions for the mobile enterprise. Their tracking solution reduces equipment costs and helps businesses track assets with their BLE-enabled Aruba WLAN infrastructure and BLE tags.

The Asset Tracker from Particle is a solution for tracking and monitoring using cellular technology. The device is equipped with a weather-proof enclosure and a GPS shield and uses 3G or 2G to communicate with the Particle Cloud and the world at large.

The AT&T IoT Shipping Container and Trailer Monitoring Devices are a solution for tracking the condition of your containers and their contents throughout the duration of their trips. The devices attach to your containers or trailers and gather at a from a variety of sensors that collect data and send it to the cloud for you to view using an application that sends alerts and notifications and is customizable.

Warehousing. There is already widespread development of warehousing to make it more cost and energy efficient. Automation and robotics are key areas where savings are being made in terms of the speed and efficiency of the storage and retrieval of freight, although currently robotics tend to require more room and flat floors to operate. Whilst automated warehouses won't necessarily need lighting or heating, they will require energy to power the sensor and guidance and systems. One example is:

> OrderWise Warehouse Robotics who provide scalable warehouse automation to suit both small and large-scale warehouse operations with the flexibility to use existing ERP or WMS solutions.

Distribution. There is widespread ongoing experimentation to make distribution more efficient and effective. Automated vehicles have been trialled by UPS, DHL and Amazon amongst others. Vehicle platooning has been successfully demonstrated by the EU-financed SARTRE project; Drone "last-mile delivery" has been trialled by Amazon and the Co-Op has introduced a robot delivery service in Milton Keynes. Transportable Energy Storage Systems (TESSs) are already commercially available, for example:

> Bioenno Power's Transportable & Renewable Energy Storage System is a modular system which includes solar panels, a rugged, metal enclosure comprising of a solar charger controller, DC-to-AC inverter, DC/AC outputs, and a built-in Lithium Iron Phosphate (LiFePO4) battery. This transportable and renewable energy storage system can be used for powering notebook computers, mobile phones, small lamps, portable radios, portable TVs, and other small appliances. During daylight, the solar panel charges both the battery and provides power to electronics and other appliances. When there's no available sunlight, the system operates using the built-in battery.

Figure 8 – Illustrative Deployable Power Options

Wireless Power systems utilise time-varying electric, magnetic, or electromagnetic fields to transmit power, and can be broken down into two categories: non-radiative and radiative or near and far field. Non-radiative systems transfer power over short distances using inductive coupling between two wire coils, or electric fields using capacitive coupling in between a pair of electrodes. This category is most notably used for recharging mobile devices and other applications where distance isn't a factor. Radiative systems, on the other hand, beam power over long distances via beams of electromagnetic radiation, utilizing microwaves or lasers. The wireless transmission of power, at least at short range, is still an enduring endeavour as engineers continually trying to improve on the power-transfer efficiencies and rates.

Generation and Storage. In the wider context, Energy Storage systems are not new and hydro-electric reservoirs where water is pumped back up to the reservoir using off-peak electricity have been in use for decades. Most of the systems in use or under development are also designed to manage peak consumption through the storage of different types of energy. They include batteries, flywheels, thermal energy (both hot and cold) and compressed air. Battery based systems range from massive (800MWh in the Dalian Vanadium Flow Battery energy storage system in China) to ISO container-sized Lithium battery systems and smaller such as the Bioenno TESS system.

In terms of mass, Capability Energy is predominately about the production of electricity in the quantities necessary to power a deployed land force, a major maritime platform and in the longer term an aircraft. Hydrogen Cells have recently been installed in Cruise Liners to provide the power for domestic services;[30] with a long-term aspiration to provide the propulsive power. The feasibility of a hydrogen cell powered high speed ferry has been proven in San Francisco.[31] In addition, the by-product of Proton Exchange Membrane technology is water. This technology may provide power and water in an environmentally sustainable manner.

In addition, other renewable examples include the AutoNaut surface vehicle which is propelled entirely by the motion of the waves and the Airbus Zephyr which can conduct continual aerial operations for weeks at a time, powered only by the sun.

Management. SMART Grids manage energy resources to meet consumption changes. As an example, the PowerFOB demonstration successfully validated analysis which identified that a significant reduction in FOB energy consumption could be achieved by using a system that intelligently manages energy demand while incorporating energy storage, noting that:

- Energy storage produced a 22 per cent fuel saving;
- Energy storage plus demand management produced a 37 per cent fuel saving;
- Energy storage plus demand management plus renewables gave 40–50 per cent fuel saving depending on mix of renewables that were used.

Front Line Support. The current trend is to augment or replace the serviceperson with automated equipment. In the 2016 Exercise Unmanned Warrior, the Royal Navy demonstrated 50+ Unmanned and autonomous systems. QinetiQ North America have developed the Titan Robot (unmanned tracked) large Unmanned Ground Vehicle (UGV) that provides “lighten-the-load” support for small dismounted military operations. BigDog is a dynamically stable quadruped military robot created in 2005 by Boston Dynamics (now owned by SoftBank Group) with Foster-Miller, the NASA Jet Propulsion Laboratory, and the Harvard University Concord Field Station, supported by associated battery technology[32].

In addition, the DOD’s $1.6 billion-a-year energy RDT&E effort addresses challenges in the following areas:

- *Dismounted soldiers and small troop units* carrying increases in electronic gear that they must be able to power, without battery resupply, for longer-duration missions.
- *Contingency bases* facing a growing demand for electric power; able to automate the control and distribution of power to and from multiple sources and loads.
- *Fixed installations (bases)*, which rely on a vulnerable commercial grid, with an ability to maintain continuous power to critical loads during extended grid outages.
- *Manned platforms* (aircraft, ships, ground vehicles) able to control and distribute power efficiently in support of increasing amounts of onboard electrical equipment.
- *Autonomous systems* (e.g., drones) with sufficient power to remain operative for long periods, travel for extended distances, and in some cases carry sizable payloads.
- *Directed Energy Weapons* that require energy storage systems with extremely high-power density, rapid recharge capability, and advanced thermal management.

Future planned activity

[30] http://www.abb.com/cawp/seitp202/f604a6bdc96ffe17c12581d2004b36fc.aspx
[31] https://maritime-executive.com/features/feasibility-of-hydrogen-powered-high-speed-ferry-proven
[32] https://modgovuk.sharepoint.com/:b:/r/teams/11023/Research/Updates/20191014-Dstl_Power_Overview-OS.pdf?csf=1&e=giZ60h

Efforts should aim to prove or disprove the benefits hypothesis included in this note to inform work which will build increased autonomy throughout the DSN over three timeframes:
Near-Term (0-2 yrs out to end 2021):

- Engage and support associated FLC and MN initiatives, seeking initially to reduce energy demand, including better-enable ownership of energy at FLC level by better alignment of responsibility, accountability and governance.
- Determine, through exploiting the developing sensor network[33] and data[34] in concert with J3 and J6 requirements, the current and likely future energy demand signal in concert with associated AI & ML efforts including a detailed understanding of FLC Capability Energy sub-portfolios covering an assessment of supply and demand for Joint Force 2025.
- Implement targets for better data capture.
- Understand the challenges, shortfalls, predictions, regulations/legislation (adoption and creation), standards, threats (incl anti-EW), training requirements, risks, etc in implementing Future Energy options/solutions.
- Continue to engage with industry market leaders and academia, via LOGNET, to develop a technology roadmap to drive and develop achievable ends and help define the requirement through adoption, adaptation and development[35] of COTS/MOTS-based Future Energy capability.
- Seek to secure resources to co-fund development of Future Energy options with industry partners.
- Seek to influence an appropriate culture and behaviours to address the future energy challenge through capability sponsors, DE&S, Chiefs, etc plus doctrine, future organisation laydown, by creating awareness of Energy as a scarce commodity.
- Seek to influence the design potential energy efficiency and generation capability requirements into fleets/future equipment/processes ASAP via retrofitting existing systems plus new policy and direction (DSD, DLD, etc) including for new equipment, mid-life updates and future capability procurements.
- Focus effort on those areas of interoperability that provide tangible, early benefit to the delivery of efficiencies across the Department's Capability Energy portfolio.
- Make maximum use of the Dstl-led LTI 'future fuel' study, seeking to identify alternative fuels for military use.

Mid-Term (3-5 yrs out to end 2024):

- Develop an understanding of potential DLOD costs and risks versus potential efficiencies (based on through-life cost benefit analysis) to develop an optimum energy support model.
- Develop an understanding of how Future Energy options would function in a future environment, including in all domains.
- Exploit the Defence Exercise Programme (DXP) and wargaming as far as possible and develop an experimentation programme to test Future Energy concept capability demonstrators, including testing resilience and sustainability, for military support tasks and verify the stated hypotheses.
- Drive initiatives for the rationalisation energy consumption for support functions.
- Help develop a set of common standards and regulations for the generation, storage and distribution of Future Energy capability.

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[33] Including expanding sensor coverage where coverage where necessary.
[34] Including using current data better, improving data quality, developing data right policy and understanding what data is required (i.e. identifying gaps and securing required data rights) to inform associated development work utilising a common data repository.
[35] **Adopt** – to do better with technology or processes already in existence; **Adapt** – to change processes or technology to something that is being developed; **Develop** – conduct R&D into areas to completely change the process or technology that is being used. Do it Better, Do it Differently, Do something else.

- Build an OA evidence base to inform the development of an optimal future support model / digital twin (starting with the high threat/deployed space) that generates sufficient supporting energy provision for Support enablers.
- Develop a Support Model (via a digital twin) and associated Tactics, Techniques and Processes that enables flexible Future Energy capabilities, through a blended solution able to deal with a rapidly-changing operational scenario focussing on storage and distribution tasks.
- Include Capability Energy across the training line of development.
- Contribute to the MoD target of a 20% increase in the proportion of alternative energy consumed by white fleet and B class vehicles through targeted technology insertion and adoption of hybrid and electric technology
- Focus on steadily integrating suitable COTS, MOTS and/or near-to-market solutions.

Long-Term (5-10 yrs out to end 2029):

- Aim to optimise sustainment through the adoption of a suite of Future Energy options across the Support Enterprise.
- Support work seeking to increase energy efficiency of new platforms and military equipment by 25% set against the FY09/10 baseline.

Further Reading and References

More detail on the use of Future Energy in both a military and civilian context head to these websites:

- **Power generation (either at the point of need, or then distributed)**.
    - http://www.renovagen.com/
    - https://eclips.engineering/products-and-services/renewable-power/
    - http://upriseenergy.com/50kw-portable-power-center
    - http://www.tacticaldefensemedia.com/pdf/dod/PeP_Web.pdf
    - https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/498482/Sustainable_MOD_Strategy_2015-2025.pdf

- **Reduction in power usage through more effective alternatives**.
    - https://modgovuk.sharepoint.com/teams/11023/Research/OutputsEvidence/20190903-QinetiQ_Powering_the_Electrified_Battlespace-O.pdf?csf=1&e=ddH1OP&cid=6cf79df1-ade8-46c3-b5d2-b7d2080e478e

- **Optimization of current generation and processes to improve efficiency**
    - https://powerstar.com/what-is-voltage-optimisation/
    - https://www.dur.ac.uk/dei/research/smartgrids/
    - https://www.hqmc.marines.mil/e2o/E2O-Home/About-Us/
    - https://en.wikipedia.org/wiki/Energy_intensity

- **Likely new technologies requiring energy**

- 'A Quick Guide: Preparing for Automated Warehouse Robots' - https://www.rfgen.com/blog/a-quick-guide-preparing-for-automated-warehouse-robots

- 'Robotics in logistics – Humans and Robots Working Side by Side' - www.dhl.com/en/about_us/logistics_insights/dhl_trend_research/robotics_in_logistics.html

- 'Tesco achieves 1-hour automated deliver' - https://www.retailgazette.co.uk/blog/2017/06/automated-tesco-delivery-trial/

- 'Lowe's prototype exoskeletons give warehouse workers a boost' - https://www.theverge.com/2017/5/15/15640176/exoskeleton-warehouse-lifting-lowes-virginia-tech

- 'Robot Wars – Drones to support front line operations' - https://ukdefencejournal.org.uk/robot-wars-drones-to-support-front-line-operations/

- 'Zipline drone used for medical supplies in Africa' - https://www.healthcareglobal.com/technology/airbus-and-international-sos-collaborate-drone-cargo-medical-delivery-systems?utm_campaign=706402_DV_Aerospace_July18&utm_medium=email&utm_source=imeche&dm_i=3X32,F52A,2Z8SZV,1NSX3,1

- 'US Defense Advanced Research Projects Agency (DARPA) Aerial Reconfigurable Embedded System (ARES) project leveraging UAS capability for: cargo resupply; casualty evacuation (CASEVAC); and other functions' – https://www.darpa.mil/program/aerial-reconfigurable-embedded-system

- https://modgovuk.sharepoint.com/:b:/r/teams/11023/Research/HorizonScanning/20190325-HS%20Bulletin%20Issue%2014_MOD.pdf?csf=1&e=8ip9Ei

The following documents were also used to shape this Concept Note:

- MCDC 2019-2020 Military Uses of Artificial Intelligence, Automation and Robotics, MCDC.

- 'Wearable Robots: Biomechatronic Exoskeletons' by Jose Pons.

- British Army Capability Management Sub-Strategy 2018, British Army.

- Future Technology Trends in Security 2018, DASA.

- A Primer on Artificial Intelligence for Military Leaders by Stoney Trent and Scott Lathrop, Small Wars Journal, August 22, 2018

- BBC News Website: Automation could replace 1.5 million jobs, 25 Mar 19.

- Future Force Concept 35

- Capstone Concept for Strategic Integration and Integrated Operating Concept

- Global Strategic Trends 6

- US Capstone Concept – Globally Integrated Logistics (2015)

Potential Future Activity

Enabling technologies and innovations for platforms DefStan 23-009

– Smaller, lighter, higher energy density batteries, to enable longer operation times and support more power-consuming equipment without reducing platform mobility

– Remote charging stations deployed in the field, which electrical platforms can 'leapfrog' between to expand their range

– Renewable energy sources to service low-level power requirements, such as wave-powered propulsion for maritime vehicles and solar cells to power self-sufficient smart sensors

– Wireless power transfer, either on contact or beamed from a directed energy system, to enable recharging with minimal disruption to operations

– Ultra high-power batteries and flywheels that can deliver huge bursts of energy in a very short space of time before returning to their full storage capacity within a matter of minutes, essential for technologies such as directed energy systems and EMALS

– Hybrid electric drive systems for land platforms, which create new design options that improve mobility, survivability and lethality

– Structural and conformable batteries, solid electrolyte batteries and load-bearing supercapacitors that form part of the hull, wing, fuselage or chassis of a platform, saving internal space and allowing for alternative weight distribution

Enabling technologies and innovations for the dismounted soldier DefStan 23-012

– Advanced situational awareness tools, such as head-up displays, gunshot localisation, and navigation that works in GPS-denied environments

– Batteries or fuel cells with greater power density, to provide more power without increasing the physical burden on the individual

– Easily portable power systems to fuel equipment and recharge on-person power in remote locations– Integrated and ergonomic body-worn power systems that can draw power from multiple sources and supply it to any piece of equipment necessary, based on modular architecture so kit can be removed at pace in an emergency

– Situational awareness provided by remote smart sensors, such as those mounted on unmanned platforms, which process data at the delivery end to reduce the computing power needed at the receiving end

– Where practical, resupply using unmanned or autonomous systems to further reduce the burden on the soldier

Enabling technologies and innovations for operating bases DefStan 23-013

– Advanced materials that improve the thermal performance of structures, minimising the loss of hot or cold air and reducing the power generation requirement through decreased wastage

– Sustainable power sources, such as large rapidly deployable solar panels, or turbines driven by wind or water, to supplement diesel generated power

– Hybrid field power units – small, lightweight diesel generators combined with fuel cells, batteries and inverter systems to reduce diesel consumption for small command posts by up to 80%

– Energy informed operations microgrids, in which power input, output and storage are monitored, informing decisions on energy generation, storage and conservation

– Integration of microgrids with external power consumers and providers to offer a system-of-systems view of total power availability and demand

– AI-enabled power management system, which integrates power data from all sources and takes automated steps to increase generation, reduce consumption, or redirect energy from other sources