

**Ministry of Defence
Team Defence Information
Arcadis**

Defence Hydrogen Conference & Workshop

Energy & Power Considerations at Deployed Operations

Wednesday 15 July 2026 | MOD Abbey Wood, Bristol



1. Introduction

The Defence Hydrogen Event continues to evolve through its fourth iteration. In 2024, the event took place in Leamington Spa with a focus on the Falklands deployed base. The 2025 event was held at DNV Spadeadam, featuring updates from Hydrogen organisations and discussions on hydrogen safety. This year, the one-day event will concentrate on **‘Energy and Power Considerations at Deployed Operations’**.

As future battlefields develop, there is an increasing need for electrical energy at the point of use. It has become evident that deployed power is not merely a commodity, but a critical core capability requiring comprehensive planning. Meeting this growing demand calls for a strategic approach to energy management—assessing current resources, identifying priorities, and determining effective integration as a defence capability—to address the present threat environment.

To fully utilise essential technologies like Directed Energy Weapons (DEW), Remote Autonomous Systems (RAS) including drones, Artificial Intelligence (AI), and quantum computing, the military must prioritise their developments. Electrical energy plays a pivotal role in helping land forces deploy and maintain operational abilities more quickly, with reduced logistical burden and vulnerability.

At present, Defence’s deployable electrical energy provision relies exclusively on hydrocarbon fuels and conventional analogue mechanical systems. To address the dynamic demands of future operational environments, Defence is progressing towards a more sophisticated and diversified energy portfolio. This transition seeks to supplement or potentially replace hydrocarbon fuels and traditional equipment while maintaining then improving operational effectiveness.

The consensus from previous hydrogen events is that hydrogen will not operate in isolation, but rather as part of a hybrid, integrated “*system of systems*”. This approach combines complementary energy sources—such as solar, wind, batteries, and hydrogen—to enhance overall energy security and resilience. Such integration is considered essential to ensure reliable, continuous power across a range of operational contexts, from fixed infrastructure on static bases to flexible, agile support for deployed operations.

Integrating new fuels and energy systems into existing operational functions inherently introduces additional complexity and potential operational risk. A proactive approach is therefore required to identify solutions and opportunities that use the energy transition to mitigate, rather than introduce, risk. This includes aligning new technologies with existing operational frameworks, ensuring interoperability, and targeting improvements in efficiency, reliability, and resilience. By adopting a structured and risk-informed implementation strategy, Defence can determine when and how to introduce the most

appropriate interventions, thereby enhancing operational performance while strengthening the overall resilience and sustainability of future capabilities.

1.1. Sponsor

This event is supported by **Arcadis** who brings deep expertise in hydrogen, infrastructure delivery, and whole life carbon reduction, with practical experience in decarbonising complex, large scale projects. Through its work on net zero construction, zero emission plant, and hydrogen supply chains, **Arcadis** bridges strategy and delivery—demonstrating how hydrogen can be integrated credibly, safely, and at scale. Their contribution to the event will ground discussions in real operational constraints, lifecycle carbon assessment, and system level thinking, helping Defence and industry move from concept to deployable, mission relevant energy solutions.

1.2. Event Format

The morning session will be dedicated to the conference component of the event, providing delegates with a series of insightful and informative presentations addressing both the current state and prospects of hydrogen. Participants will gain valuable perspectives on Defence’s approach to energy. The proposed speakers, timings, and running order are set out in **Appendix A**.

In the afternoon, the event transitions to its workshop segment. This portion will be organised by thematic groups, with delegates assigned according to their selected areas of interest. Each group will engage in focused discussions modulated by **Arcadis** on their assigned themes and, upon conclusion, present a summary of their discussions along with the main takeaways.

Together, the conference sets the context why change is needed, and the workshop addresses how it can be delivered.

1.3. Event Objectives

This event will bring together defence stakeholders to understand deployed energy needs, exploit decarbonisation opportunities, and shape a practical roadmap for an operational energy transition. The presentations will include specific industry experts to demonstrate and focus on the necessary capabilities in supporting this transition. This event aims to engage delegates in shaping the future of battlefield energy by addressing challenges related to the five essential pillars of energy:

- Generation,
- Storage,
- Management,
- Distribution,
- Deployed operations and use solutions.

Hydrogen, as an energy vector, must clearly demonstrate its operational value in supporting MOD deployed activities. This requires assurance that all elements of the hydrogen value chain—generation, storage, management, distribution, and end use—are fully integrated and resilient, with no potential points of failure that could disrupt supply. Seamless integration is essential to ensure that hydrogen can reliably support business-as-usual operations and maintain end-user capability under operational conditions, providing confidence that it can be adopted without compromising mission effectiveness.

The shared objective is to secure a military advantage in deployed operations by navigating the energy transition. It will focus on developing integrated and holistic energy ecosystems, with particular attention to hydrogen, to enhance operational capability in deployed settings.

- Examine power and energy requirements for both operational activities and support of deployed bases.
- Propose strategies for decarbonising operations and strengthening operational advantages through an effective energy transition.
- Establish a comprehensive roadmap to guide the energy transition for deployed operations with short-, medium- and long-term objectives.
- Identify suitable “*no-regrets*” field trials and next steps for implementation with opportunities to accelerate delivery of the roadmap.

2. Operational Energy

Operational energy refers to the energy needed for training, transporting, and supporting military forces and weapons systems during missions (Howard et al, 2024). Energy both empowers and limits military capabilities. Throughout the twentieth century, the demand for operational energy increased significantly. This enduring challenge has also shaped MOD thinking on deployed energy resilience, as illustrated by the **PowerFOB 2011** demonstration summarised in **Appendix L**. Table 1 provides a summary of this historical trend in major US combat operations. The amount of fuel consumed per soldier per day has increased significantly over time as military operations have become more mechanised and energy intensive. It is an overall fuel consumption rate that includes fuel for vehicles, aircraft, generators, and logistics convoys, often with high "*fully burdened*" delivery costs due to the need to transport it to remote, dangerous locations.

Table 1 Historical per-soldier daily fuel consumption by conflict. Adapted from NATO (2026).

Era / Conflict	Gallons per Soldier per Day	Litres per Soldier per Day	Source
World War II (1939 – 1945)	1	3.8	US Army historical records
Vietnam War (1955 – 1975)	8	30	Extrapolated from USNI data
Iraq Invasion (2003)	22	83	DoD / Strategy Page
Afghanistan (2001 – 2021)	15 – 22	57 – 83	Brown University / USNI Proceedings (2023)
Post 9/11 average (1998 – 2018)	22 (peak)	83	Brown University Costs of War

2.1. Fuel Consumption of British Armoured Units in Combat Operations

The British Army's armoured units are centred on the Challenger-2 Main Battle Tank (MBT) and the Warrior Infantry Fighting Vehicle (IFV). Brigade compositions, such as the 7th Armoured Brigade deployed to Iraq in 2003, typically consisted of around 120 Challenger-2 MBTs and 45 Warrior IFVs. Based on the cross-country fuel consumption rates provided in Table 2 and a typical daily operational distance of 60 km, the Challenger-2 fleet would require approximately 45,800 litres of fuel per day (calculated as 120 x 636 litres/100 km x 60 km), while the Warrior fleet would consume roughly 14,900 litres daily (calculated as 45 x 550 litres/100 km x 60 km), during full combat operations.

It should be noted that, once climate, terrain, and combat conditions are considered,

actual fuel consumption may exceed the manufacturer’s quoted cross-country figures by more than five times (Rhodes, 2026).

Table 2 Challenger-2 MBT and Warrior IFV fuel consumption data.

Vehicle	Image	Cross-Country Fuel Consumption
Challenger-2 MBT		636 ltr per 100 km
Warrior IFV		550 ltr per 100 km

2.2. Operating Base Energy Consumption

Energy consumption at operating bases is influenced by factors such as size, location, and function. Bases that include aviation operations are anticipated to use more fuel than those without such activities. Tactical front bases generally consume less energy compared to main bases that offer a higher level of comfort. Table 3 presents an overview of base-level energy consumption estimates from major United States combat operations.

Table 3 Operating Base Energy Consumption. Adapted from Noblis, 2010.

Base Size	Gallons per Soldier per Day	Litres per Soldier per Day	Source
25-man	1	3.8	USMC Energy Assessment Team
600-man	11	42	Don Pickard
1,100-man	4.4	17	Major Randy Boswell
15,000-man without aviation component	5.6	21	General James Conway
15,000-man with aviation component	33	125	General James Conway

2.3. Operational Energy System and the Defence Support Network

Overall energy requirements for operations, operating bases and combat vehicles have been highlighted. Delivering energy efficiently to the necessary locations is vital for supporting and maintaining missions. Effective operational energy planning is more comprehensive than logistics alone; it involves developing a robust operational energy system. Because fuel is currently the main energy source, this system is commonly known as the Joint Operational Fuel System (JOFS). The graphic in **Appendix B** illustrates a conceptual JOFS, which utilizes strategic fuel infrastructure alongside deployable and modular systems provided by the Defence Support Network (DSN). The JOFS functions within the DSN, benefiting from its support. As a mission-critical capability, the JOFS plays a key role in ensuring successful operations.

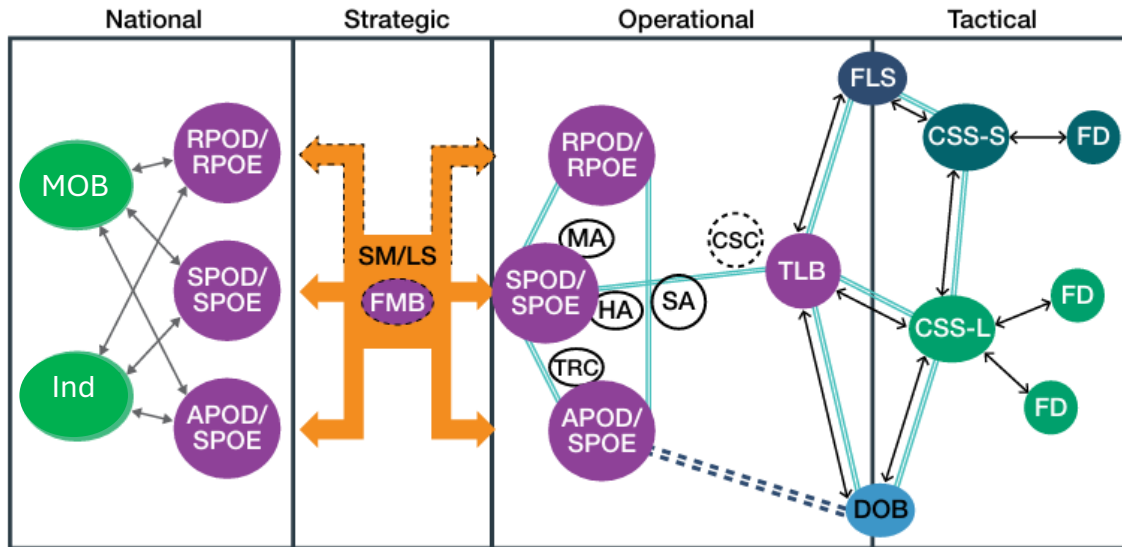
Future battlefields are projected to incorporate multiple energy vectors to facilitate and sustain operational activities. The integration of hydrogen and other alternative energy sources is not intended to replace the JOFS but rather represents its advancement in alignment with ongoing energy transitions. The DSN is integral to this process, ensuring that operational effectiveness, safety, and autonomy are preserved throughout the transition.

2.4. Energy Resilience & Security

Energy resilience and security in deployed operations require a diversified and robust approach to energy supply, ensuring that multiple future energy vectors remain fit for purpose under operational conditions. This depends on the effective management of a secure and adaptable supply chain, capable of sustaining business-as-usual activities even in contested or austere environments. The integration of new fuels and technologies must therefore be carefully assessed to ensure compatibility, reliability, and operational continuity. Hydrogen, when appropriately considered and implemented, offers a versatile and resilient energy vector that can support current and emerging Defence requirements, enhancing both flexibility and endurance. By pursuing energy-secure solutions in this manner, Defence can also realise consequential benefits, including reduced carbon emissions and a credible, operationally viable pathway towards net zero commitments.

3. Defence Support Network

The UK Defence Support Network (DSN) is the support framework from which the UK Armed Forces are deployed, sustained and recovered (Ministry of Defence, 2022). It is a network of interdependent nodes (including warehouses, fuel facilities and repair facilities) in the UK and overseas and the connectors linking them (for example, supply vehicles, aircraft, ships, rail connections and logistics information systems/data) involving the MOD, industry and allies. A typical DSN is highlighted in Figure 1.



- Main Supply Route (MSR)
- ⋯ Air Route (for use of Intra Theatre Airlift System [ITAS])
- Strategic Movement/Logistic Sustainment (SM/LS)
- ↔ National movement between national location and POD/E
- ↔ Movement to/from support areas

ACC	Air Component Command	LCC	Land Component Command
APOD	Air Port of Debarkation	LS	Logistic Sustainment
APOE	Air Port of Embarkation	MA	Marshalling Area
CSC	Convoy Support Centre	MCC	Maritime Component Command
CSS	Combat Service Support	MOB	Main Operating Base
CSS-L	CSS support to LCC	RPOD	Rail Port of Debarkation
CSS-S	CSS support to SOCC	RPOE	Rail Port of Embarkation
DOB	Deployed Operating Base (Log inst. ACC)	SA	Staging Area
FD	Final Destination (for deployment)	SPOD	Sea Port of Debarkation
FLS	Forward Logistic Site (MCC)	SPOE	Sea Port of Embarkation
FMB	Forward Mounting Base	SOCC	Special Operations Component Command
HA	Holding Area (containers)	TLB	Theatre Logistic Base
Ind	Industry	TRC	Theatre Reception Centre

Figure 1 Typical Defence Support Network. Adopted from Ministry of Defence (2022).

3.1. Levels of Movement and Resource Flow

Resources are moved through a system of nodes and lines of communication (LOCs). The functions of the nodes within the DSN are described in **Appendix C**. Nodes and LOCs can be categorised according to distinct levels within the movement system:

- **National movement.** The movement of personnel and/or materiel from a national location to a port of embarkation (POE) or from a port of debarkation (POD) to a national location. Coordination at operational level will be required to ensure a regulated flow into and out of the POE/POD.
- **Strategic movement.** The movement of personnel and/or materiel from an assigned POE to a POD. It includes the marshalling and embarkation of materiel and personnel at the POE onto strategic movement assets, and the debarkation and marshalling of personnel and materiel at the POD.
- **Operational movement.** The movement of personnel and/or materiel from a POD to an assigned area of operation (AOO) or from an assigned AOO to a POE.
- **Tactical movement.** The movement of personnel and/or materiel to or from the nodes within an assigned AOO.

3.2. Basing Levels and Node Functions

A main operating base (MOB) serves as an essential node for national-level movements. In contrast, a forward mounting base (FMB) acts as the central hub at the strategic movement level. At the operational and tactical levels, there are several types of nodes identified by their specific functions. The term forward operating base (FOB) is broadly used for these nodes, which include theatre logistic bases (TLB), staging areas (SA), and convoy support centres (CSC) (Noblis, 2010). FOBs are usually temporary facilities designed for specific missions, and their characteristics—such as function and structure—can vary greatly depending on the number of people supported, mission type and length, types of military units involved, and the available local infrastructure. Appendix D highlights the basing general characteristics and current energy and power design.

Appendix D provides a comprehensive overview of the principal basing characteristics, as well as the current approaches to energy and power system design.

The increasing lethality and transparency of the battlespace will necessitate that forces operate in a dispersed and highly mobile manner. While MOBs are permanent installations and FMBs are semi-permanent, both typically possess robust air defence systems to ensure their protection. In contrast, FOBs may not have comprehensive air defence capabilities and must remain temporary, agile, and mobile to mitigate risks of enemy detection and attack (Watkins, 2026).

4. Workshop

The integration of hydrogen and other alternative energy vectors into the JOFS is under consideration. Traditionally, JOFS has been optimised for liquid hydrocarbon fuels, focusing on single fuel concepts, bulk logistics, and strategic stockpiling. Hydrogen could be utilised as a vector to undertake existing JOFS operations in an energy secure manner. Due to their high energy density, liquid hydrocarbon fuels remain challenging to replace and are unlikely to be supplanted by alternative energy vectors in the near term. It is anticipated that hydrogen and other alternative fuels will coexist alongside liquid hydrocarbons on future battlefields for an extended period.

Operational energy transition—particularly hydrogen—changes the problem space. Hydrogen introduces fundamentally different infrastructure challenges. It is recognised that hydrogen introduction must address **production, storage, management, distribution, use and the wider integration to the DSN ecosystem** in both fixed and deployed settings.

By adopting hydrogen as an energy vector, Defence can reduce operational risk through a more diversified and resilient energy approach, enabling reliable support to business-as-usual MOD operations while strengthening energy security and operational resilience.

During the workshop, participants are invited to participate in developing a future operational energy system that incorporates hydrogen alongside other alternative energy vectors integrated with the JOFS. Important topics/questions to consider include, but are not limited to, are given in **Appendix E**.

References

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Acronyms

AI	Artificial Intelligence
AOO	Area of Operation
ATC	Air Traffic Control
BESS	Battery Energy Storage System
COP	Combat Outpost
CSC	Convoy Support Centre
CSS	Combat Service Support
DefSp	Defence Support
DEW	Direct Energy Weapons
DOB	Deployed Operating Base
DSN	Defence Support Network
ESTT	Energy & Sustainability Transition Team
FD	Final Destination
FLS	Forward Logistic Site
FMB	Forward Mounting Base
FOB	Forward Operating Base
HA	Holding Area
IFV	Infantry Fighting Vehicle
JOFS	Joint Operational Fuel System
LOC	Line of Communication
MA	Marshalling Area
MBT	Main Battle Tank
MEC	Microbial Electrolysis Cell
MOB	Main Operating Base
OEA	Operational Energy Authority
PB	Patrol Base
POD	Port of Debarkation
POE	Port of Embarkation
RAS	Remote Autonomous System
SA	Staging Area
TDI	Team Defence Information
TLB	Theatre Logistic Base
TRC	Theatre Reception Centre

Appendix A – Conference and Workshop Agenda

Programme

Time	Topic	Speaker	Organisation
Arrive on site 08:00 for entry	Security Passes & Site Registration		
08:30 – 09:00	Coffee & Event Registration		
09:00 – 09:05	Welcome & Site Safety	Dr Joseph Lam	DefSp OEA
09:05 – 09:10	Opening Address	Sarah Liggins / Col Pete Skinsley	DefSp ESTT / DefSp OEA
09:10 – 09:15	Aim & Running of the Day	Darin Tudor	TDI
09:15 – 09:30	Greening & Resilience	Lt Col Ali Beard	Strat Dir
09:30 – 09:45	Energy Security & Resilience: A roadmap to scalable, decarbonised energy security	Sally Rigby & Felicity Shiels	Arcadis
09:45 – 10:00	Creating & Storing Energy for Deployed Operations	Prof Peter Edwards	University of Oxford
10:00 – 10:15	Defence Energy Governance	Cdr Suzannah Curtis	DefSp ESTT
10:15 – 10:30	Coffee		
10:30 – 10:45	Distributed Waste-to-X Infrastructure for Defence Resilience, & Energy Sovereignty	Martin Stanley	GreenCo
10:45 – 11:00	Hydrogen Storage & Mobile Dispensing	Keith Croysdale & Jordan Cullen	Luxfer & ULEMCo
11:00 – 11:15	Self-Refuelling Hydrogen Drones – Deployable Power for Enhanced Operation	Jon Gibss & Isobelle Harrison	Savion Aerospace & Arcadis
11:15 – 11:30	LTC Case Study – Deploying Hydrogen on Construction Sites	Alex Johnson	Arcadis, on behalf of Lower Thames Crossing
11:30 – 11:45	Lesson learnt from innovative technology transition	TBC (Sarah Wallace)	TBC
11:45 – 13:00	Networking Lunch Technology Showcase		


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Time	Topic	Speaker	Organisation
13:00 – 13:15	Update	Dr Daniel Carlotta-Jones	BYOHM (formerly Wastewater Fuels)
13:15 – 13:30	Update	John Taylor	Prometheus
13:30 – 13:45	Ammonia for Power Generation in Rural Location	Sivachidambaram Sadasivam & Syed Mashruk	Cardiff University
13:45 – 14:00	Deployed Operations – Context for the workshop	Dr Joseph Lam / TBC	DefSp OEA / Arcadis
14:00 – 15:30	Workshop	By Table Themes	Arcadis
15:30 – 15:45		Coffee	
15:45 – 16:30	Plenary	Workshop Leads	Arcadis
16:30 – 17:00	Closing Remarks	Darin Tudor / Sarah Liggins / Col Pete Skinsley / TBC	TDI / DefSp ESTT / DefSp OEA / Arcadis
17:00		Dispersal	

Technology Showcase

	<p>ULEMCo HyTANKa</p> <p>HyTANKa is a self-contained mobile hydrogen refuelling vehicle that addresses a key barrier to hydrogen adoption in construction: dependable on-site fuel supply.</p> <p>Designed to offer the flexibility of a diesel bowser, HyTANKa delivers fuel directly to equipment, enabling hydrogen-powered machinery to operate efficiently in remote or early-stage site environments.</p>
	<p>Luxfer GStor Pro Bundle</p> <p>The GStor Pro Bundle is a high-pressure gas storage solution using reliable Luxfer Type 3 cylinders. Its advanced cylinder processing reduces weight, increases capacity, and enables higher-pressure storage, providing more gas in a</p>

	<p>lightweight, compact package ideal for gas transport.</p>
	<p>Metier Technologies Hydrogen Truck</p> <p>Metier Technologies specialises in Hydrogen Internal Combustion Engine (H2ICE) technology. Its flagship solution enables existing diesel trucks, such as the 18-tonne DAF LF, to be converted into zero-emission vehicles by replacing the diesel engine with a purpose-built hydrogen engine and fuel system.</p> <p>This approach provides a practical, cost-effective route to decarbonising heavy-duty transport without requiring operators to replace entire vehicle fleets.</p>

Appendix B – Joint Operational Fuel System

Joint Operational Fuel System is the fuel-handling capability that enable the receipt, storage, distribution and dispense of fuel on the battlefield. It uses DSN's modular, deployable systems with strategic fuel infrastructure.



de&s
LAND EQUIPMENT
BATTLEFIELD UTILITIES



All Weather Ship to Shore System
JOFS will enable the bulk transfer of fuel from surface vessels to shore based storage via sub-sea pipelines up to 5km offshore.



Tactical Ship to Shore System
JOFS will enable fuel to be discharged from Towed Flexible Barges to shore based bulk storage. This system can be constructed within 12 hours providing expeditious support to advancing forces.



Existing Infrastructure
JOFS will provide the capability to use existing Host Nation infrastructure for the storage and movement of fuel.

Joint Operational Fuel System

Joint Operational Fuel System is the future fuel-handling capability that will enable the receipt, storage, distribution and dispense of fuel on the battlefield.





Cross Country Pipeline System
JOFS will use flexible hoses to distribute fuel from the rear area towards the battlefield. These will be deployed and retrieved using storage reels to reduce manpower and construction times.



Bulk Fuel Storage
JOFS will provide bulk fuel installations that can be quickly constructed via pre-mounted ISO racks thus reducing manpower requirements.



Aircraft Refuelling
JOFS will provide the capability to refuel aircraft from airfield-based storage or a C130 Hercules.



Issue of Fuel
JOFS will enable the filling of Bulk Fuel Carrying Vehicles, vehicle convoys, inland waterway barges, rail tankers and jerricans for greater flexibility in the movement of fuel.



Light Forces Equipment
JOFS will support forward operating units and bases with Air Portable Fuel Containers and air-deployed equipment that can be quickly deployed and used to refuel helicopters and light forces.

Appendix C – Defence Support Network Nodes

The function of the nodes within the DSN are described as follows from home base to frontline (refer to Figure 1):

Main Operating Base (MOB). A MOB is a permanent or semi-permanent UK airfield with robust infrastructure for sustained military operations. It features advanced air traffic control (ATC), navigational systems, refuelling, and extensive support services, serving as a secure hub for operational readiness and rapid deployment.

Port of Embarkation/Debarcation (POE/POD). At POE/POD personnel and materiel are loaded onto or unloaded from a means of transport. Functions of a POE/POD include reception, processing, staging of personnel, transit, in-transit storage, marshalling of materiel and the transshipment of personnel and materiel between different modes of transportation.

Forward Mounting Base (FMB). A FMB facilitates re-configuration of the forces and provides all relevant logistics support. Usually, it is established within the operational area to support operations. The establishment of a FMB is determined by the specific operational requirements of the situation.

Theatre Reception Centre (TRC). A TRC is a location established to receive forces into a theatre of operations, conduct essential administrative tasks and establish the personnel tracking process. A TRC is usually located at an air POE/POD.

Marshalling Area (MA). A MA is a location in the vicinity of a reception terminal or prepositioned equipment storage site where arriving unit personnel, equipment and accompanying supplies are reassembled, returned to the control of the unit commander, and prepared for outward movement. Ideally, it will be close to the POE/POD to allow a quick off-load/on-load but at a sufficient distance to avoid congestion.

Holding Area (HA). A HA is a waiting area that forces use during traffic interruptions or deployment from an aerial or seaport of debarcation. It will be established to temporarily hold personnel and materiel to prevent congestion, which could hamper the (un-) loading at an airport or seaport

Staging Area (SA). A SA is a location where personnel and materiel are temporarily held and organized to prepare for movement. During redeployment, they are organized into an administrative movement component and prepared to dispatch from the Joint Operating Area. Refuelling, regrouping, training, inspection and distribution of troops and materiel are likely activities to occur in a staging area. There may be a requirement to establish and use one or more SAs.

Convoy Support Centre (CSC). Based upon time and space there may be a requirement to establish one or more CSCs. Typical activities in a CSC include vehicle refuelling, maintenance, recovery support, force protection, accommodation and messing facilities.

Theatre Logistic Base (TLB). A primary logistic hub inside an operational theatre from which theatre-level sustainment is coordinated and delivered. It supports the force once it has entered theatre and sits above forward or tactical logistic nodes.

Forward Logistic Site (FLS). A temporary or semi-permanent logistics node established forward in theatre to improve responsiveness, tempo, and resilience of sustainment. It is a forward supply hub that holds and redistributes logistics to units nearer the front, reducing distance, delay, and vulnerability in the sustainment chain.

Deployed Operating Base (DOB). A force basing node, not a logistics hub. It is where fighting units live, plan and launch operations. It is the place in theatre where forces are based and from which they conduct operations, consuming logistics rather than managing or distributing it.

Combat Service Support (CSS). A logistic node dedicated to providing sustainment and enabling services to combat forces. Its function is not command-and-control, but support, ensuring forces can continue to operate effectively.

Final Destination (FD). When the term is used in movement planning, the FD is a tactical location, within the Joint Operating Area, that has been designated for an organization from which it will mount an operation.

Appendix D – Operating Base Characteristics

Deployed operations use a structured range of base types, from Main Operating Bases (MOBs) to Patrol Bases (PBs), each offering different levels of permanence and capability. These bases support command, logistics, and flexibility, making it important to understand their roles when integrating energy solutions, logistics, and new technologies across the base network.

Main Operating Base

A MOB is a permanent and fully developed facility that serves as the primary anchor for sustained air and ground operations. It is characterised by robust infrastructure, including air traffic control, navigational aids, and full aircraft refuelling and defueling capabilities. They also possess comprehensive logistic, engineering, and medical support, enabling long-term operational endurance. This depth of capability allows MOBs to support resident units, coordinate theatre-level activity, and maintain enduring mission effectiveness with minimal reliance on forward improvisation.

Forward Mounting Base

A Forward Mounting Base (FMB) acts as an operational hub for mounting and sustaining forward operations. While not as permanent or comprehensively equipped as a MOB, an FMB provides command and control, logistics, maintenance, bulk supply, and limited medical support. It is resourced to support a wide range of tactical activities and multiple subordinate bases. FMBs play a critical role in coordinating deployed forces, enabling operational reach, and sustaining tempo across a theatre.

Forward Operating Base

A Forward Operating Base (FOB) is a DSN node in the operational and tactical area to directly support manoeuvre forces. They are typically constructed rapidly using modular and adaptable infrastructure, allowing them to respond to changing operational requirements. They provide only the minimum essential services needed to sustain the force, including basic logistics, force protection, and limited support functions. The design philosophy of a FOB prioritises agility and proximity over endurance, enabling forces to remain close to the fight while maintaining an acceptable level of sustainment.

Patrol Base

A PB, also known as a Combat Outpost (COP), represents the most austere and temporary form of deployed base. PBs are generally established by small units, often at platoon level, to enable localised operations within a defined area. They are designed to be discreet, rapidly emplaced, and short-lived, with only the most essential resources and sustainment supplies. PBs do not function as staging or mounting bases; instead, they support short-duration missions where concealment, adaptability, and minimal

footprint are paramount. Their inclusion ensures comprehensive consideration of all operating base types, from enduring infrastructure to the most forward edge of operations.

Characterising Adaptive-Basing Archetypes

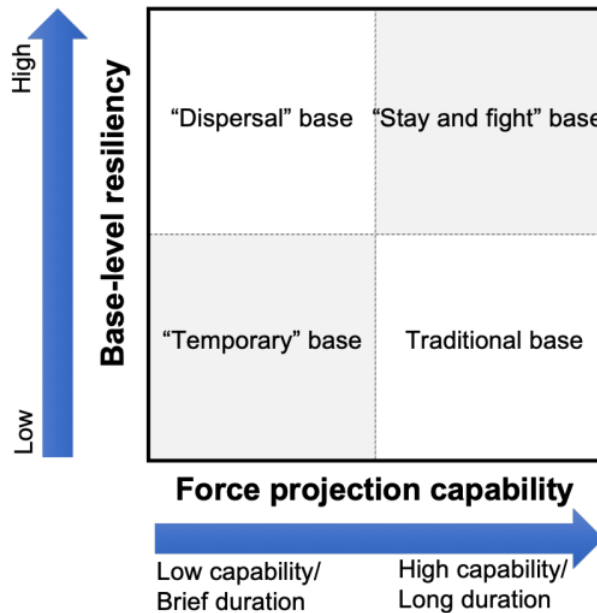


Figure 2 Framework for characterising adaptive-basing archetype. After Mills et al (2020).

FOBs can vary significantly depending on their specific role and the prevailing operational context. However, they can broadly be characterised using the framework outlined in Figure 2. In response to the evolving nature of modern warfare, there is a clear shift away from **“Traditional”** and **“Stay-&Fight”** bases towards more agile **“Dispersal”** and **“Temporary-Use”** models.

Traditional base: A well-established, robust base located outside the enemy’s effective threat range. It supports sustained, long-duration operations but typically has limited investment in resilience measures due to its presumed security.

Stay-&fight base: A permanent or semi-permanent base designed for prolonged operations within a contested environment. It incorporates significant resilience measures to withstand and operate under attack.

Dispersal base: A highly resilient but minimal footprint base intended for short-duration use, enabling rapid recovery, refuelling, or re-arming of aircraft dispersing from higher-threat locations.

Temporary-Use base: A lightly equipped base with minimal resilience investment and limited force projection capability, established to provide short-term or opportunistic operational support.

Table 4 General basing characteristics illustrating how size and role evolve nearer the frontline.





Basing Level	MOB	FMB	FOB	PB
Conceptual Sketches				
Location	Secure / Home Territory	Theatre of Operations (Rear)	Within Combat Zone	Deep in Hostile Territory
Primary Goal	Strategic Reach	Operational Support	Tactical Support	Frontline Engagement
Risk Level	Low	Moderate	High	Very High
Permanence	Permanent	Semi-permanent	Temporary / Tactical	Temporary / Tactical
Purpose	Centralized command, control, and logistics hub; permanent or semi-permanent air operations and sustainment node.	The “ <i>waiting room</i> ” for combat. Used to assemble forces & equipment before deployment.	Operational hub for a specific region or brigade. Tactical support close to operations	Temporary position for short-term missions (24-72 hr)
Duration of Operations	Months to years	Weeks to months	Days	Days
Typical Features	Permanent buildings, runways, hospitals, and “ <i>home comforts</i> ”.	Large warehouses, staging areas, and high-level maintenance.	Vary significantly depending on their specific role and the prevailing operational context	Highly austere, camouflaged, and focused on security / recon.
Population	2,000 to 10,000	500 to 2,000	50 to 250	10 to 50
Vehicles	Full station fleet	Logistics, force protection, engineering vehicles	Light logistics & tactical	Tactical

Table 5 Current basing energy and power design.

Basing Level	MOB	FMB	FOB	PB
Primary Power	Commercial Power Grid	Large Tactical Quiet Generators (60 kW to 1 MW)	Small mobile Tactical Generators (10 kW to 60 kW)	Light armoured vehicle on-board vehicle power system
Secondary Power	Diesel Generators (2 MW)	BESS	BESS	Portable Battery Pack
Grid Type	Fixed / Permanent	Expeditionary Microgrid	Tactical / Point-of-Use	None
Energy Priority	100% Coverage	Command and Medical	Critical Electronics	Critical Electronics
Fuel Storage	Massive strategic fuel reserves (millions of litres) stored in permanent fuel farm	Fuel bladders holding 50k to 200k litres of fuel	Jerrycan holding 2k to 5k litres of fuel	None
Fuel Delivery	Pipeline / Commercial Road/Rail Tankers	Frequent Heavy Tanker Convoy	Tactical Refuel / Helicopter	None
Primary Fuel	Diesel / Jet A / Natural Gas	Diesel / Jet A	Diesel	N/A

Appendix E – Workshop Topics/Questions to Consider

For additional context, refer to **Appendices F** through **K** for comprehensive commentary, supporting information, and relevant case studies that enhance the discussion.

Production:

- Under deployed operational conditions, what are the decisive constraints (power availability, water, waste streams, logistics burden, force protection, workforce, and time) that determine whether in-theatre hydrogen production is viable, and how do these constraints vary by DSN node?
- Which technology—water electrolysis, ammonia cracking, or plastic pyrolysis—is most suitable for hydrogen production at the designated nodes within the DSN, considering the necessary resource requirements? Please provide a rationale for why the chosen technology represents the optimal solution.
- What scale and rate of hydrogen production is realistically achievable at deployed locations, and is this sufficient to support meaningful operational use cases rather than niche or experimental applications?

Storage:

- Which DSN nodes offer the greatest operational advantage for hydrogen storage under deployed conditions, and what constraints (force protection, footprint, safety standoff, logistics signature, and integration with the JOFS) ultimately determine where storage is viable?
- Among the available hydrogen storage technologies—compressed hydrogen, cryogenic hydrogen, hydrogen carriers (such as ammonia and plastics), or metal hydride—which option is most appropriate for use at the designated nodes within the DSN? Please provide a reasoned justification demonstrating why the selected technology constitutes the optimal solution.
- At what scale does hydrogen storage at deployed DSN nodes become operationally credible, and how do different storage options affect logistics footprint, resupply frequency, and detectability?

Management:

- At what scale and throughput does hydrogen storage at deployed DSN nodes become operationally viable, and how do the various storage technologies influence the overall logistics footprint, frequency of resupply, and operational detectability? Furthermore, what considerations must be addressed to ensure that storage solutions are both practical and secure in field conditions?

- How should hydrogen utilisation be matched to deployed demand profiles—continuous electrical loads, peak power requirements, or mobility—and which DSN nodes best support each profile?
- How should hydrogen safety, competence, and duty holder responsibilities be managed across deployed DSN nodes, particularly where infrastructure is temporary, mobile, or rapidly reconfigured?

Distribution:

- How should hydrogen distribution methods (compressed gas, cryogenic liquid, hydrogen carriers, or direct production-to-use models) be matched to DSN nodes and LOCs, and where does each approach provide the greatest operational advantage?
- Given hydrogen's low volumetric energy density, what scale and distribution rate can realistically be achieved along DSN LOCs, and is this sufficient to support sustained operational demand rather than niche or demonstrator use cases?
- Should hydrogen distribution in deployed operations be designed as an incremental adaptation of existing fuel distribution systems, or as a fundamentally different logistics model—and what are the implications for the DSN?

Use:

- Which nodes within the DSN offer the greatest operational advantage for hydrogen utilisation in deployed settings, and what constraints (power demand profile, logistics burden, force protection, safety, and integration with the JOFS) ultimately determine suitability?
- In deployed operations, where does hydrogen deliver greater operational value: as a stationary power source for electricity generation or as a mobility fuel for vehicle powertrains, and why?
- Where can hydrogen be most effectively introduced as an incremental enhancement to existing deployed energy systems, rather than as a full replacement for hydrocarbon fuels?

DSN Ecosystem

- In deployed operations, hydrogen fuel cells can generate potable water as a secondary output, potentially reducing the logistical burden associated with transporting fresh water to operating bases. Beyond electricity, which hydrogen and/or alternative energy technologies can deliver *secondary operational outputs* (water, heat, waste reduction, signature reduction) that measurably reduce DSN logistics burden—and how should DSN value those outputs in capability decisions?

- Within the DSN, how can energy systems be designed to deliver multiple DSN functions—power, water, waste reduction, and resilience—so that deployed nodes require fewer resupply flows and expose fewer vulnerabilities
- What characteristics must a future DSN ‘energy distribution system’ must be interoperable with allies while remaining deployable and scalable?

Appendix F – Hydrogen Technology: Secondary Outputs & Resource Integration

Hydrogen should be integrated as part of a holistic energy ecosystem, valued for its secondary outputs—such as heat, water, and resilience—which enhance operational capability and reduce logistical demands in deployed environments.

Water

Hydrogen fuel cells generate electricity through the electrochemical reaction of hydrogen with oxygen, producing water and heat as inherent by-products. Approximately 9 kg of water can be produced from every kg of hydrogen consumed, with the exhaust water typically of very high purity, often meeting recognised drinking water standards. In deployed operations, this presents a valuable secondary operational function: water can be captured for potable or non-potable use or recycled back into hydrogen production processes. This capability can materially reduce freshwater demand, and lower resupply at DSN nodes, and improve overall operational resilience and self-sufficiency.

Wastewater

Hydrogen production via microbial electrolysis cells (MECs) offers operational value by coupling energy generation with wastewater treatment. In this approach, organic matter in wastewater is biologically converted to hydrogen through microbial activities, while the wastewater itself is treated and made suitable for non-potable reuse, such as toilet flushing and clothes washing. This secondary operational output reduces overall freshwater demand, alleviates the logistical burden of water resupply, and minimises the requirement to store, transport, and dispose of wastewater safely. By simultaneously addressing energy, water, and waste challenges, MECs support a more resilient, self-sustaining deployed energy and resource ecosystem.

Waste Plastics

Producing hydrogen from waste plastics delivers a valuable secondary operational advantage by transforming a persistent logistical and environmental challenge into practical energy resources. Typical deployed waste—such as plastic bottles, food packaging, and other polymer materials—can be catalytically converted to hydrogen, while creating black carbon as a secondary by-product. This black carbon can serve as a solid fuel for furnaces or heaters, providing additional heat and energy. Importantly, this method eliminates or significantly reduces the need to store, transport, or dispose of plastic waste in operational theatres. By simultaneously tackling waste management and energy production, plastics-to-hydrogen systems foster greater self-sufficiency, lower logistical demands, and enhance environmental stewardship during deployed operations.

Appendix G – Energy Vector Comparison for Deployed Logistics & Ecosystem Integration

The table on the following page compares key energy vectors that may be used in deployed operations, focusing on logistics, environmental burden, and integration with base ecosystems. It highlights how plastics-to-hydrogen differs from diesel, batteries, and compressed hydrogen by offering secondary operational benefits alongside energy delivery.

Plastic-to-hydrogen systems integrate naturally into deployed base ecosystems by linking energy generation, waste management, and thermal demand into a single, mutually reinforcing loop. This creates a dual-use system where plastics act both as a planned energy feedstock and as an in-theatre waste sink. The hydrogen produced supports electrical generation, while carbon by-products can be recovered and used for cooking or space heating, further displacing supplied fuels. This approach directly supports a more self-sustaining, circular base ecosystem, reducing dependency on external supply chains and improving environmental performance in theatre.

From a logistics perspective, plastic-based hydrogen offers significant advantages across forward and reverse supply chains. Plastics are benign solids, requiring no specialist transport or dangerous goods handling, unlike compressed hydrogen cylinders which remain regulated even when empty. Plastic pellets are compact, stackable, and robust, easing storage and improving transport efficiency. The system performs well in hot climates, where polyethylene's high melting point avoids pressure-limited compressed gas systems

Crucially, reverse-logistics burdens are reduced: packaging used to deliver plastic pellets, as well as operational plastic waste, can be consumed as feedstock rather than returned for disposal. This lowers transport demand, reduces waste handling risks, and cuts environmental management overheads. The use of carbon by-products as solid fuel further minimises residual waste streams. Collectively, these factors reduce logistical exposure, resupply frequency, and disposal complexity while increasing deployed resilience.

Table 6 Energy vector deployed logistics and ecosystem integration comparison.

Energy Vector	Plastics → Hydrogen	Diesel	Batteries (Li-ion)	Compressed Hydrogen
Primary Logistics Form	Benign solid (plastic pellets & waste plastics)	Liquid fuel (hazardous)	Finished energy device	High-pressure gas (350–700 bar)
Dangerous Goods Classification	No	Yes	Yes (depending on type/state)	Yes (always, full, or empty)
Forward Transport Burden	Low – stackable, robust, no special vehicles	High – tankers, protection, spill risk	High – weight and volume scale with demand	High – specialist cylinders, safety compliance
Hot Climate Suitability	Excellent (high melting point plastics)	Good (with fuel handling risks)	Degraded performance & thermal risk	Constrained (pressure derating required)
Reverse Logistics	Minimal – waste plastics consumed on-site	High – packaging, spills, contaminated waste	High – damaged and/or expired units returned	High – empty cylinders treated as full
Waste Management Function	Yes – disposes bottled water, food packaging, bags	No – generates contaminated liquid & solid wastes	No – creates hazardous waste at end-of-life	No – mishandle could lead to damaged cylinders
Secondary Operational Outputs	Hydrogen & solid carbon for heat	Heat only	None	None
Integration with Base Ecosystem	High – couples energy, waste & heat	Low – fuel only	Low – energy only	Low – energy only
Impact on DSN Node Sustainability	Reduces energy, waste & disposal demand simultaneously	Increases logistics dependency	Increases resupply & waste burden	Increases regulatory & logistics burden
Operational Resilience Contribution	High – circular, dual-use system	Moderate	Low–moderate	Low

Appendix H – Comparison of Energy Supply and Transport Needs

This case study is intended to provide illustrative data for discussion purposes; it should not be considered definitive for decision-making without thorough analysis.

A succinct comparison of the essential supply quantities and vehicle requirements for transporting diesel, compressed hydrogen, and plastic pellets for a ten-day operation is presented. The information provided enables a clear evaluation of the logistical considerations for each energy vector, highlighting the scale and type of vehicles necessary to meet operational demands efficiently.

Assumptions and Calculations

- Assume a base with 1,100 personnel and a fuel requirement of 17 litres per soldier each day (see Table 3).
 - Total daily diesel consumption is 18,700 litres (17 x 1,100).
 - Over a period of 10 days, the diesel requirement totals 187,000 litres (18,700 x 10).
- A large fuel truck—like the Close Support Tanker—can carry 20,000 litres of diesel per trip.
 - To deliver 187,000 litres, 10 truckloads are needed (187,000 / 20,000).
- A medium fuel truck—such as the Unit Support Tanker—carries 7,000 litres per trip.
 - Transporting 187,000 litres requires 27 truckloads (187,000 / 7,000).
- Diesel generator efficiency is assumed at 40%, with each litre of diesel containing 10.5 kWh of energy.
 - From 187,000 litres of diesel, 785,400 kWh of electricity can be generated (187,000 x 10.5 x 40%).
- Hydrogen fuel cells produce 25 kWh per kilogram of hydrogen.
 - To generate 785,400 kWh, 31,416 kg of hydrogen are required (785,400 / 25).
- A large composite tube trailer has a capacity of 1,000 kg of hydrogen.
 - Delivering 31,416 kg of hydrogen would require 32 truckloads (31,416 / 1,000).
 - **The UK military currently does not operate this vehicle type.**
- A medium composite tube trailer holds 500 kg per trip.
 - It would take 63 truckloads to transport 31,416 kg of hydrogen (31,416 / 500).
 - **The UK military currently does not operate this vehicle type.**
- The hydrogen yield from plastics is 0.1124 kg per kg of plastic.
 - Producing 31,416 kg of hydrogen requires 279,502 kg of plastics (31,416 / 0.1124).
- A large logistics truck, like the MAN SV 15T, carries 15 tonnes per trip.
 - Moving 279,502 kg of plastic pellets needs 19 truckloads (279,502 / 15,000).
- A medium logistics truck, such as the MAN SV 6T, carries 6 tonnes per trip.

- Transporting 279,502 kg of plastic pellets would require 47 truckloads (279,502 / 6,000).

Key Findings

Diesel emerges as the most efficient energy carrier, requiring either 10 large or 27 medium vehicles to supply a base of 1,100 individuals for a 10-day period. In comparison, plastic pellets necessitate nearly twice the transportation resources, while compressed hydrogen demands over three times as much. Utilizing waste plastics onsite may reduce the need for imported plastic pellets and warrants further investigation (refer to **Appendix J**). Additionally, when assessing hydrogen fuel cell power generation, it is important to account for secondary advantages such as water production (refer to **Appendix I**), which could significantly influence the comparative evaluation of diesel and hydrogen.

Energy Vector	Diesel	Compressed Hydrogen	Plastic Pellets
10-Day Supply Requirements	187,000 ltr	31,416 kg	279,502 kg
Large vehicle requirements for energy transport	10	32	19
Medium vehicle requirements for energy transport	27	63	47

Appendix I – Comparison of Water Supply and Transport Needs

This case study offers sample data for discussion but is not authoritative for decisions without detailed review. It analyses supply and vehicle needs for water transport for a base with 1,100 people for ten days. It shows how diesel and fuel cell power generation affect water requirements.

Assumptions and Calculations

- Assume a base of 1,100 people with a daily water requirement of 20 litres/soldier.
 - The total daily water consumption amounts to 22,000 litres (20 x 1,100).
 - Over 10 days, the water demand reaches 220,000 litres (22,000 x 10).
- A large water truck, such as the Close Support Tanker, can transport 20,000 litres of water per trip.
 - To supply 220,000 litres of water, 11 truckloads are needed (220,000 / 20,000).
- A medium water truck, like the Unit Support Tanker, carries 7,000 litres per journey.
 - Supplying 220,000 litres would require 32 trips by this truck (220,000 / 7,000).
- For hydrogen fuel cells, assume a requirement of 31,416 kg of hydrogen (refer to **Appendix H**) and a water conversion rate of 9 kg of water for every 1 kg of hydrogen (see **Appendix F**).
 - This process generates 282,744 kg of water from 31,416 kg of hydrogen (31,416 x 9).
 - With a water density of 1 kg per litre, this equates to 282,744 litres of water.

Key Findings

The data indicate that hydrogen fuel cells can produce sufficient electricity and water to support a base of 1,100 individuals for a period of 10 days, thereby removing the necessity for water transportation.

When assessing both energy (see **Appendix H**) and water transportation requirements, plastic pellets employed as a hydrogen carrier present a reduced logistical burden even compared to the default fuel, diesel.

Base Main Power Plant	Diesel Power Generator	Hydrogen Fuel Cells Power Unit
Base Water Requirements	220,000 ltr	220,000 ltr
Water Generation	N/A	282,744 ltr
Net Water Supply Requirements	220,000 ltr	0 ltr (62,744 ltr – surplus to demand)
Large vehicle requirements for water transport	11	0
Medium vehicle requirements for water transport	32	0

Appendix J – Plastic Waste

This case study presents sample data intended for discussion purposes; it should not be considered definitive for decision-making without comprehensive evaluation. The analysis examines plastic waste generated by a base of 1,100 individuals over a ten-day period and demonstrates that utilising this waste can help alleviate logistical burdens.

Assumptions and Calculations

- Assume a base of 1,100 people with a daily plastic waste generation at 1 kg/soldier (U.S. Marine Corps, 2013).
 - The total daily plastic waste amounts to 1,100 kg (1 x 1,100).
 - Over 10 days, the plastic waste reaches 11,000 kg (1,100 x 10).
- A large logistics truck, like the MAN SV 15T, carries 15 tonnes per trip.
 - Moving 11,000 kg of plastic waste needs 1 truckloads (11,000 / 15,000).
- A medium logistics truck, such as the MAN SV 6T, carries 6 tonnes per trip.
 - Transporting 11,000 kg of plastic waste would require 2 truckloads (11,000 / 6,000).

Key Findings

The analysis indicates that disposing of plastic waste generated by a base of 1,100 individuals over a 10-day period requires either one large vehicle or two medium-sized vehicles. Utilizing the plastic waste for hydrogen generation decreases the volume of plastic pellets that need to be transported to the base, resulting in a reduction equivalent to one large or two medium truckloads. This approach offers dual advantages by streamlining both disposal logistics and supply logistics.

Appendix K – Logistics Support Vehicles

The logistic support vehicles listed in **Appendices H** through **J** are provided below for reference and information.



Unit Support Tanker (7,000 ltr)



Close Support Tanker (20,000 ltr)



Medium Tube Trailer (500 kg)



Large Tube Trailer (1000 kg)



MAN SV 6T



MAN SV 15T

Appendix L – PowerFOB 2011



PowerFOB 2011 was a multinational MOD-led demonstration designed to reduce fuel consumption at Forward Operating Bases (FOBs) by applying a whole-system approach to energy. Conducted in Cyprus using realistic operational energy profiles from Afghanistan, it addressed a critical operational issue: a large proportion of deployed logistics effort was devoted to transporting fuel, increasing risk to personnel and limiting operational resilience. The programme therefore reframed energy efficiency as a force protection and capability issue, rather than an environmental one.

The demonstration showed that meaningful reductions in fuel use require **integrated energy systems**, not isolated technologies. By combining optimised diesel generator operation, battery storage, smart demand management, and renewable generation (e.g. solar and wind), PowerFOB demonstrated potential fuel savings of up to ~50%. Key enablers included energy storage (allowing generators to run efficiently or switch off entirely for periods), intelligent control systems to prioritise loads, and demand reduction measures such as improved insulation and more efficient use of air conditioning. Additional applications—such as solar-powered services and off-grid battery charging for tactical equipment—further reduced reliance on diesel generation.

The primary lesson was that **energy performance in deployed environments is a systems engineering challenge**, where the greatest benefits come from integrating generation, storage, and demand-side measures within a coherent architecture. Real-world testing also proved essential, revealing inefficiencies and operational behaviours not visible in theoretical analysis, and confirming that energy interventions can

simultaneously improve resilience, reduce logistic burden, and enhance operational effectiveness.

These lessons directly underpin the UK MOD hydrogen strategy. First, PowerFOB reinforces that hydrogen should be integrated as part of a **hybrid energy system**, complementing batteries and renewables rather than acting as a standalone solution. Second, its emphasis on **energy storage as a key enabler** aligns with hydrogen's role in providing longer-duration storage and resilience beyond battery capability. Third, the clear priority placed on **demand reduction** highlights that hydrogen must be deployed on optimised systems to be effective and efficient. Finally, the demonstrated link between reduced fuel demand and **lower operational risk** supports hydrogen's strategic value in reducing dependence on fuel logistics, particularly if combined with local production concepts.

In essence, PowerFOB provides an early, evidence-based foundation for MOD's transition towards integrated, low-carbon operational energy systems, with hydrogen representing a natural extension of the same system-level approach to improving resilience, efficiency, and operational advantage.

A video on PowerFOB 2011 is available on YouTube via the link below:



[PowerFOB 2011 - YouTube.](#)