Fuelling change: alternative fuels

By Gerrard Cowan, Europe Editor, **Jane's Defence Weekly** [London] 07-Aug-2009

The dangers of protecting extended supply lines, concerns of an over-reliance on foreign oil and the urgency of tackling climate change have prompted the world's militaries to rethink their fuels and equipment. Gerrard Cowan reports

The UK lost thousands of camels on the advance to Kandahar during the Second Afghan War in 1878-80, with a favoured enemy tactic being the intimidation and murder of local grass cutters who provided the fodder on which the supply-carrying animals survived.

Today, British soldiers travel along many of the same routes as their predecessors and, although their vehicles and aircraft make for superior transportation, they are just as reliant on oil as the camels were on grass. The fuel may have changed, but the military is just as vulnerable to threats to its supply.

The above comparison was made by Colonel John Pelton, the UK's Expeditionary Campaign Infrastructure IPT Leader, who manages the energy usage of Camp Bastion in Afghanistan, at a recent event at the Royal United Services Institute (RUSI) in London.

In such a context, he explained, and particularly given the stated environmental ambitions of Washington and London, it is unsurprising that the two largest contributors to the International Security Assistance Force (ISAF) and their allies, are working to reduce their dependence on foreign oil, increasing the efficiency of their engines and generators and developing new renewable and cleaner fuels.

The US Air Force (USAF), which as an organisation is the single largest consumer of energy in the world, has estimated that every USD1 increase in the price per barrel of oil costs it between USD66 million and USD130 million. Accordingly, in 2005 it set goals to wean its fleet off the need for foreign oil.

These targets are being pursued via a two-stage plan. By 2011 it aims to have certified its entire fleet to run on synthetic fuel. By 2016 it hopes that half the fuel it uses will come from synthetic sources, derived through the Fischer-Tropsch process, which combines crude-oil-based fuel with a synthetic blend made from natural gas, coal, plant matter and other crude oil substitutes.

In August 2008 a USAF F-15E Strike Eagle became the first fighter aircraft to flight-test Fischer Tropsch-derived fuel. Previous flights have involved a B-52 Stratofortress bomber (2006) and a C-17 Globemaster III medium multirole transport aircraft (2007). The first supersonic flight of an aircraft using a synthetic fuel blend - a USAF B1-B Lancer - also occurred in 2008, while tests took place in December of a T-38 at Edwards Air Force Base, California, and a C-5 at Memphis Air National Guard Base, Tennessee.

Arguably the greatest potential lies in coal-to-liquid, which has naturally attracted US interest given the abundance of coal in the country, which possesses 25 per cent of international reserves.

Mike Wynne, who as Secretary of the USAF from November 2005 to 2008 codified its early steps in the field of alternative fuels, said that coal would certainly loom large in the initial switch to synthetic fuels.

"We will be a coal-powered nation for years, so the choice of whether to use that resource or not has tremendous implications," he told Jane's. "But it's certainly controversial. No sooner had we certified jets for Fischer-Tropsch than hostile ads appeared in newspapers with pictures of dirty-faced miners."

Indeed, coal is not without its critics; converting it to liquid for use as a fuel generates relatively high levels of carbon dioxide pollution, raising questions over its effectiveness as an

environmentally friendly fuel source.

However, Bill Anderson, who served under Wynne as Assistant Secretary of the USAF for Installations, Environment and Logistics, has argued that: "If there is no such thing as 'clean coal' we are all in big trouble because global coal extraction and use is going to increase in the future and it is naive to deny this fact. Renewable energy sources, nuclear energy and conservation and efficiency efforts will help, but will not even begin to cover increasing global energy demand."

Wynne said that the US could combine fuels derived from both coal and biomass to meet its future energy needs.

"It's time to start thinking about what we have in our own cupboard. The US has desert land for biofuels and massive coal reserves. We should take advantage of both of these."

Some experts, though, are sceptical of the potential for synthetic fuels. The director of Cambridge Energy Research Associates' (CERA's) Global Oil advisory group, Julius Pretterebner, has said that the long-term usability of fuels based on the Fischer-Tropsch process is "not practical and uneconomical".

"The main disadvantage with the Fischer-Tropsch process is the high capital required to build a manufacturing plant due to the large dimensions involved. For the same output, a Fischer-Tropsch refinery requires about five times the capital as an oil refinery."

His comments were echoed by the US Defense Science Board in a 2008 report, which expressed "strong concerns about the viability of this technology for a variety of reasons" including the high capital costs of building synthetic fuel plants and environmental systems to grow feedstock. Current production technology also produces a lot of wastewater, the report said.

"These large expenditures could be used for more productive contributions to the DoD's [Department of Defense's] most pressing energy challenges, rather than demonstrating synthetic fuel technologies that do not appear to have a viable market future or contribute to reducing battlespace fuel demand," said the report.

The goal of the USAF is to spur the commercial sector through the creation of a huge, guaranteed market for synthetic fuel products, acting as what Wynne described as a "market-maker". Anderson has labelled this a "Manhattan project for energy", in which the private sector would be revolutionised through the discoveries propelled by vast military investment; in much the same way that commercial nuclear power was only made possible through Oppenheimer's Second World War programme.

Commercial developments

While it is perhaps overly simplistic to attribute recent developments solely to the USAF's policy, there has indeed been a range of developments in the commercial sector in recent years. Jimmy Reed, the Director of Advanced Engine Programmes at Pratt and Whitney, said that his company was "highly supportive of the USAF's initiative". He pointed out that while 10-15 years of background work had gone into studying the potential for aviation use of synthetic fuels, this was mainly on the commercial side, with some aspects naturally further advanced than others.

"We've been looking at coal and gas as sources for jet fuel for 15 years and are looking at bio sources now," he said. "You can create a jet fuel from virtually any compound containing hydrogen and carbon."

However, Reed said that developing jet fuels from coal, gas or biomass introduced difficulties of its own. For example, he said that aromatics, which exist naturally in petroleum-based fuels, help engine seals to swell and therefore seal, preventing jet engine fuel system leaks. Synthetic fuels from coal, gas and biomass sources need additives to achieve the same effect.

"These things are being learned," he said.

Additionally, Reed said that other commercially available technologies aimed at improving

the efficiency of engines are now attracting interest from military customers. As an example he suggested engine washing, which the company says can reduce engine fuel burn by 1.2 per cent. Pratt & Whitney conducted 3,888 such washes in 2008, saving USD73 million in fuel and reducing carbon dioxide emissions by 533 million pounds - equivalent to the emissions of 26,675 cars, 116,000 people, or that stored by 41 million trees.

Lockheed Martin has concentrated on the potential of synthetic gases, explained Bjornulf White, its portfolio manager for synthetic fuel programmes.

"One of our key technology focus areas is gasification," he said. Essentially, this would see all types of waste, woody biomass and dedicated non food-based energy crops efficiently converted into a synthetic gas. It could ultimately be converted again into gasoline, diesel, or JP5 or JP8: liquid jet fuel.

"We need to make use of local biological material, including trash - now we're just burning it, but new technologies can gassify Twinkie wrappers," said Anderson.

This would not just have applications in helping meet the USAF's demands for synthetic fuel - it would also provide a useful way to dispose of the tonnes of waste generated by military bases.

"Depending on how you develop the system you can gasify almost any carbon-containing material. Some of the technologies are developed to handle municipal solid waste, others are optimised for woody biomass or energy feedstocks," White explained. "It's an exploding market. Ultimately the economic downturn will be but a small blip in the radar. There's a lot of private financing and a lot of support from the DoD and through the stimulus package. We're just seeing the beginning," he said.

In the land sector much has been made of hybrid electric drive (HED) engines and their potential to cut fuel burn and costs. The US Army is required by law to power 30 per cent of its vehicle fleet by HED or an equivalent by 2010. This is aimed at increasing fuel economy and supporting and expanding research into batteries. It would also dramatically reduce the need for fuel convoys on battlefields.

However, 2009 has seen the sector sustain two blows: the break-up of the US Future Combat Systems (FCS) programme - the vehicles for which would have been driven by a HED engine - and the decision of Sweden's Defence Materiel Administration to award a contract for 113 Armoured Wheeled Vehicles (AMVs) to Patria's Armoured Modular Vehicle, which employs a traditional diesel engine, over the BAE Systems Global Combat Systems Modular Armoured Tactical System, a HED vehicle.

However, Donald Christian, the Director of BAE Systems' US Combat Systems, told Jane's that there was a bright future for HED. As the size and technological complexity of military vehicles increases, so does the amount of energy being turned over to the 'hotel load'. Originally a naval term, this refers to the energy requirements not connected to the propulsion of a vehicle.

"Very early on the automotive world became aware that making vehicles move was only one of several tasks," he said. "It's now clear that keeping the headlights on, powering radios - things that were so minor in the past - have continued to grow. This is even more important in military vehicles, in which navigation, computer displays, electronic countermeasures, jammers, etc, take up a larger fraction of the budget."

For example, if a vehicle is deployed in an observation-related role, it can sit for long periods of time, during which no propulsive power is being used. According to Christian, "the more a vehicle sits for a long time doing only hotel loads, the more it makes sense to base it on electricity".

*Four developers of HED systems - **BAE Systems**, Oshkosh, **QinetiQ** and Rolls-Royce - have cited five main advantages to HED in previous interviews with Jane's:*

- Fuel efficiency - HED vehicles can bring fuel savings of up to 30-40 per cent compared with diesel. The system is able to achieve this by using stored energy during periods of peak fuel

consumption and by reducing wasted energy during low fuel consumption by not using the engine at all. In addition, by using less fuel the system also releases fewer emissions;

- Signature - the energy that an HED system stores may be used to operate the vehicle in purely electrical mode, thus reducing heat and acoustic signatures;

- Stored energy - stored power can be used to provide sufficient electricity to drive external systems. Oshkosh told Jane's that its ProPulse HED system can power an airfield, hospital or command centre;

- Mobility - most HED vehicles use a hub-mounted electric motor in each wheel. This offers high levels of design flexibility, say developers, because the driveshaft is replaced with flexible umbilical cables. Benefits include improved vehicle performance, enhanced vehicle control and greater utility from common and modular base platforms. The vehicle is often lighter and easier to maintain because of this; and

- Smaller logistics footprint - HED vehicles need to carry less fuel and batteries do not have to be replaced for relatively long periods.

Speaking to Jane's in November 2008, a US Army spokesman said the variable power options of HED vehicles were among the main reasons behind the US Army selecting the system to propel the (now cancelled) FCS manned ground vehicles.

"We have selected HED vehicles to meet our robust power requirements. But by using HED in the FCS we are also looking at major fuel reductions. For example, on a 30-mile, paved road march our FCS vehicles will do about 1.6 miles to the gallon. That doesn't sound much until I tell you that on the same stretch of road a [comparable vehicle using diesel] would do 0.52 miles to the gallon," the spokesman said.

Interest in HED has been seen worldwide. The Australian Department of Defence, for example, has previously said it had not trialled HED vehicles and had no plans to do so. However, it added that it had not "ruled out" the future use of HED "as the technology matures". South Africa began trials in 2005 of Armscor's Combat Vehicle Electric Drive (CVED) demonstrator, based on a modified 28.5-ton Rooikat 8x8 armoured reconnaissance vehicle. Germany's Federal Office for Military Technology and Procurement awarded Krauss-Maffei Wegmann a contract in 2007 to develop the VT-E (Versuchstrager Elektrisch) electric-drive test bed.

US Navy supply challenge

The US Navy (USN) is also moving aggressively to meet the challenges of delivering energy supplies to far-flung bases in isolated locations. Oil shipments can take weeks to arrive at Diego Garcia in the Indian Ocean or Kwajalein Atoll in the Pacific and electricity coverage is often sporadic. The logistics of delivering energy to forward-deployed forces is becoming even more complex as the DoD shifts to a new global posture, outlined in the 2006 Quadrennial Defense Review. This calls for an expeditionary force structure consisting of small, joint bases spread across more regions of the world.

The navy's most ambitious project to meet the increasing demand for reliable energy supplies in remote locations is the Ocean Thermal Energy Conversion Plant (OTEC), which may one day dramatically reduce or even eliminate the need to ship oil to island locations. The aim is for the plant to harness energy from the ocean by mixing warm and cold water to produce both electricity and potable water.

According to Lockheed Martin, in geographical areas with cold deep water and warm surface water, the difference in the temperature can be used to drive a steam cycle that turns a turbine and produces power.

According to the company: "Warm surface sea water passes through a heat exchanger, vaporising a low boiling point working fluid to drive a turbine generator, producing electricity. This process can serve as a baseload power generation system that produces a significant amount of renewable, non-polluting power."

The naval sector has arguably had most success in translating targets into reality. It has

already adopted innovations like bulbous bows and integrated electric drive (IED) and a number of countries are committed to rolling out existing technologies such as nuclear propulsion.

Part of the Fiscal Year 2007 US Defense Authorization Bill stated that "it is the sense of Congress that the navy should make greater use of alternative technologies, including nuclear power, as a means of vessel propulsion for its future fleet of surface combatants". The US budget for 2009 provides USD828 million for naval reactors to deliver nuclear propulsion plants for submarines and aircraft carriers.

The potential for policy-makers to view nuclear propulsion unfavourably should, however, be acknowledged, with the World Nuclear Association citing "exaggerated fears about safety" as a reason for political restrictions on increasing the use of nuclear propulsion.

Yet the benefits of nuclear propulsion are particularly clear for vessels that need to be at sea for long periods of time without refuelling; for those that need to move quickly; and for submarines. Additionally, because using nuclear power reduces the need to visit foreign ports to refuel, the potential is reduced for further USS Cole-type attacks (the Arleigh Burke-class destroyer was damaged in an October 2000 attack while refuelling in Aden, Yemen, leading to the loss of 17 lives and repair costs of USD240 million).

The USN has also introduced a range of projects to cut fuel use. The Energy Conservation (ENCON) programme, for example, aims to reduce ship energy consumption by 10 per cent each year. This is to be achieved through energy-saving strategies such as 'smart steaming': the principle of maximising fuel efficiency without negatively affecting mission objectives. The approach is based on operating only the systems needed to support a mission and placing a ship's cargo and ballast to achieve a balanced weight distribution.

Energy storage

Another US project, implemented in late 2007, is the Fleet Readiness, Research and Development Program (FRR & DP), which is looking at ways to help USN ships to conserve fuel now and find long-term reduction solutions that allow the navy to meet all mission requirements against the backdrop of a volatile fuel market.

Additionally, the US Navy's Office of Naval Research (ONR) has been working on a hybrid power plant. A spokesperson recently said that the ONR was researching technologies to improve energy storage, power distribution and control and power conversion efficiency. Ship service power needs would be provided from propulsion turbines, eliminating the need for a redundant gas turbine, while additional fuel benefits would be obtained through the use of shipboard energy storage for single generator operation configuration.

"The level of performance and energy/fuel benefit is projected to be greater than 10 per cent," the spokesperson said. "However, final improvement in fuel efficiency is under study in co-ordination with Naval Sea Systems Command."

In the private sector, the Northrop Grumman/Rolls-Royce-developed WR-21 aero-derivative gas turbine powerplant - already selected as the propulsion unit of the UK Royal Navy's (RN's) Type 45 Daring-class destroyers - is said by the two companies to offer fuel savings of 25-27 per cent over existing simple-cycle marine gas turbine systems. The Daring class is also the first major surface combatant to use an all-electric integrated electrical propulsion (IEP) system. First-of-class HMS Daring achieved fuel consumption amounting to a quarter of that of its smaller predecessor, the Type 42, which ran on gas turbines alone.

Although the vast majority of energy burned by the military is for transportation, its bases and facilities are huge users in their own right. Indeed, change is often more difficult to initiate, due to their static positions in areas often unsuited to alternative fuel services, and their traditional dependence on old power-generation packages.

A controversial USAF energy project was a proposal to pursue small-package nuclear projects. Anderson said that the USAF had planned to sign an initial request for information with a consortium to pursue small-package nuclear concepts by the beginning of October

2008, but this was then postponed by the air force. However, he insisted the project was of key importance and should be pursued again. "From tiny reactors the size of trash cans to ones the size of a small room - maybe up to 50 MW - it would be possible to supply all the electrical and steam needs for everything from a small forward-operating location to a large fixed base and surrounding community," he said. "The biggest advantage is that these things can run for four to 20 years with no fuelling necessary, no carbon emissions and no logistics tail on the battlefield."

Kevin Billings, who was Anderson's successor as Assistant Secretary of the USAF for Installations, Environment and Logistics, said the project was postponed was for two reasons. First because the USAF is changing tack to work more with the navy and the army and second because 25 per cent of the USAF's civil engineers were deployed in Iraq and Afghanistan: the very people who would work on the project.

Less controversial is the USAF's 'Model Base Initiative' to reduce energy consumption at its bases: a project that all three services have turned their attention to. McGuire Air Force base in New Jersey, for example, has a goal to reduce energy consumption by 50 per cent by 2011 (based on a 2003 baseline) and 60 per cent by 2013.

One approach that the US Army has floated would involve generating clean energy on a base to be used by military personnel and selling unused energy on the local community's electric grid. This could provide some competition for local power companies, which might then have to consider clean alternatives as well.

"We might not [use] enough to constitute an entire market, but we can be market initiators," former Deputy Assistant Secretary of the Army for Energy and Partnerships Paul Bollinger Jr. said at a 17 November press conference.

UK government departments are mandated to reduce their carbon emissions by 12.5 per cent by 2010-11 and 30 per cent by 2020. The Ministry of Defence (MoD) has so far achieved a 10 per cent reduction, which senior figures have conceded as being too little.

Speaking at RUSI on 9 July, Vice Admiral Tim Laurence, the chief executive of Defence Estates, said that while "we are making reasonable progress, we still have a long way to go towards meeting the 2020 target".

The move is also driven by financial considerations, which weigh particularly heavily at a time of economic crisis.

"Our annual total spend on energy is over GBP300 million (USD508 million), so financially it is a very significant factor in a defence budget that is being squeezed," Vice Adm Laurence said. "There is little doubt that the price of traditional fossil fuelled energy will continue to rise, and therefore we must reduce our consumption as well as investigate alternative sources of energy to help minimise the impact of these rising prices."

The top 220 of the MoD's sites account for 76 per cent of all its consumption and these have, therefore, been targeted. Catterick Garrison in Yorkshire has been identified as a pioneering site; it will undergo a major infrastructure development programme and best practices identified will potentially be rolled out to all major MoD sites. The MoD has also laid plans for biomass heat-generating sites at RAF Valley in Wales, HM Clyde naval base in Faslane and Bovington Camp and RM Poole in Dorset.

Additionally, SMART meters have been established across 10 naval sites in the South West of England to monitor energy consumption.

Increasing energy efficiencies at bases also has a security dimension. Colonel Pelton said that the message he wanted to give personnel in Camp Bastion in Helmand province, Afghanistan, is that "if you flick a switch in a tent you are consuming fuel, and that is costing lives", referring to military efforts to secure the supply chain.

Squaring the circle

The problem with a cultural and physical revolution on such a scale is one of satisfying both a long-term focus and short-term needs.

While the economic, environmental and security cases for alternative fuels and technology is utterly compelling, the reality is that relatively cheap oil is currently available on the world market and that the priorities of militaries, certainly those of the US and UK, are tied up with the day-to-day needs and necessities of the war on terror and its Afghan hub.

However, Anderson said that it was possible, and indeed vital, to square this circle.

"We can and have to do both," he explained. "The looming global energy and environmental sustainability problem really hit us in the mid-to-late 1990s, but with the recent boom in China and India and impending development in Africa we will be in a world of hurt if there is no significant paradigm shift quickly.

"Look how many people we have in the [US] military, including civilians. If we can't pull aside a few thousand people to work on energy then what the hell's wrong with us?"

Wynne said that he felt there was cause for optimism during the presidency of Barack Obama. "The new administration is more green [than that of predecessor George W Bush] so there is less pushback. However, there are still problems. This is not due simply to the president or vice-president, but as well to the inclination and interest of the rest of the administration."

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For more information on alternative fuels see the January 2009 edition of Jane's Industry Quarterly (<http://jdw.janes.com>)