Maintaining Capability & Freedom to Manoeuvre with a Net Zero Navy

Dr. Thomas Beard[1*], Toby Drywood[1]

[1]*BMT UK Ltd*

**Lead author: thomas.beard@bmtglobal.com*

Synopsis

The need to reach Net Zero means that navies will eventually have to change fuel type. The ever-tightening restrictions and the court of public opinion will mean that the defence dispensation will ultimately not be applicable. However, the change in fuel brings with it various concerns that need to be overcome, especially for Survivability, Operability and Availability. The many options for alternative fuel, excluding nuclear, are all less energy dense and as such would impact on range and possibly capability. Capability is an area that should be impacted as a last resort, especially when considering the increasing technological landscape of both weapons and threats. Survivability can only be overcome by the choice of fuel, however Operability and Availability are within control. Taking ownership of fuel production would mitigate against both aspects, and offer military advantage at all levels of operations; from Grand Strategic to Tactical. The use of strategically located Floating Nuclear Production Ships (FNPSs), in international waters, would provide an at sea capability that means there is a reduced reliance on ports for fuel. Rethinking the well to wake pipeline and managing this entire chain organically offers significant advantages to both nation states and military planners and operators. Steady state and surge capacity, in both peacetime and war, offers freedom to manoeuvre for nations and their allies. Furthermore, by using ships rather than static structures the capability provides the potential to join a carrier strike group, thus increasing the total range and providing greater resilience of the fleet.

Keywords: Resilience, Nuclear Ships, Fuel Production,

Author Biographies:

Dr. Thomas Beard has been working in decarbonisation for 10 years, starting with a doctorate in hydrogen safety. He is the co-chair of the National Maritime Hydrogen Working Group and a member of the Maritime UK group as well. Currently he is the lead for alternative fuels within BMT.

Toby Drywood served for 25 years as a surface ship marine engineer officer in the RN, completing operational tours in escort vessels, taskforces, on flotilla and headquarters staffs and in a variety of engineering support roles. Since joining BMT has delivered a range of projects, support transformation and delivery.

1. Introduction

There is much debate about what a future Navy will comprise of, with smaller uncrewed vessels likely to be part of any future flotilla (UK Ministry of Defence, 2023). However, there will still be a role for the more conventional vessels, with many of these having an expected life span beyond 2050. This end-of-life date and future builds provide an issue with respect to the fuel of choice as Net Zero 2050 approaches.

Whilst there is potential for defence dispensation to continue utilising fossil fuels for as long as possible, eventually there must be a change. This change will be forced by anyone of or a combination of multiple factors such as public pressure, regulatory requirements or more likely fuel availability and cost. NATO and allied navies currently operate on F76 but have the ability to use MGO if required, which maintains current freedom to manoeuvre, however this is not going to be the case in the future.

There are several potential options to power the deep-sea maritime industry; nuclear, synthetic/bio-diesel, ammonia, methanol or hydrogen as examples. Nuclear is not feasible to integrate into every vessel and as such other means of power will still be required. The reality is that there will be very few ports globally that will bunker the majority of alternative fuels, with many ports being part of a green corridor. This will impact on freedom to manoeuvre when fuel is not readily available at a NATO/allied bunker location or a vessel is operating far from such locations.

A potential way to ensure freedom to manoeuvre and maintaining, or even improving, capability is to produce the fuel at sea using dedicated vessels. This would be using nuclear powered vessels with a production facility onboard to generate the fuel. This is a similar concept to that of Core Power (Core Power, 2023), who are investigating the use of new nuclear (Molten Salt Reactors) for use as power sources and static offshore power generation. This idea for military use as well as the operating profile and Concept of Operations (CONOPS) will be covered in this paper. The exact details of what a vessel would look like and the quantities of production are not explained within this paper, due to the sensitivity in the quantity produced and the variability that it causes.

2. Floating Nuclear Production Ships (FNPSs)

The use of nuclear powered vessels similar to FPSOs would remove the potential constraint of fuel availability. FNPSs however, would differ from conventional static installations as they would have the ability to transit and move with any future flotilla. This concept would support carrier and littoral strike groups and may also be able to support smaller task groups. There is also the potential that if the fuel aligns with an area of commercial maritime then it could be sold as well.

The overarching FNPS concept to produce and transfer fuel is shown in Figure 1. The only given for any alternative fuel to be produced is the requirement to create hydrogen. The hydrogen production rate would ideally be paired with the hydrogenation rate of whichever fuel is required. Whilst the feedstock in Figure 1 implies a carbon based carrier, this can be changed to create any fuel of choice.

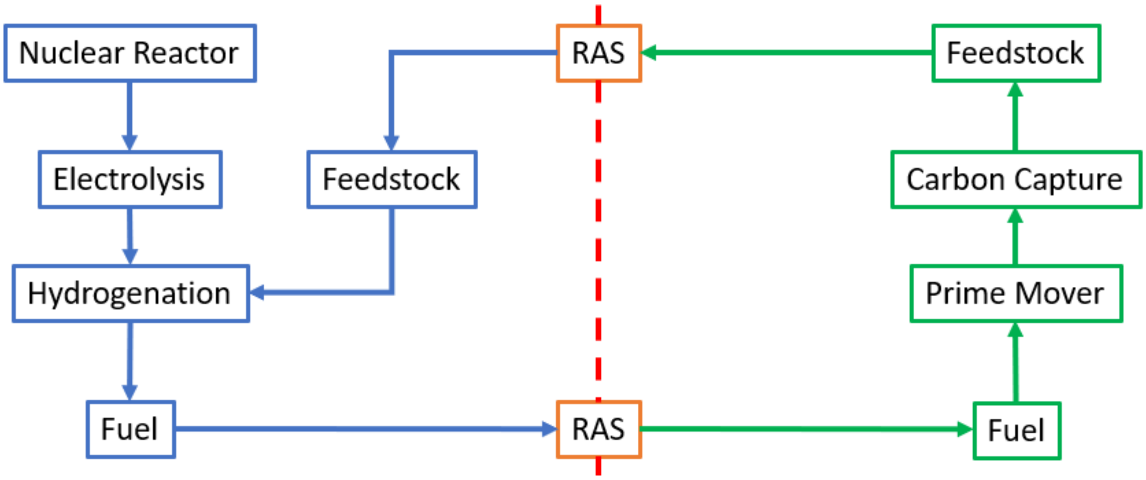

Figure 1 FNPS overarching concept

A carbon-based fuel, such as synthetic diesel, would require onboard carbon capture which is still in development. This would require additional tanks or storage onboard the warship to store the carbon dioxide. Current trials are aiming for 30% capture (Safety4Sea, 2022) with a long term aim of 80% capture (Maersk Mc-Kinney Moller Center for Zero Carbon Shipping, 2022). Therefore another carbon source will likely be required, it could be that the carbon that is entrained in the sea is used as this other carbon source (Scientific American, 2023).

The vessel will be a floating production platform with the equipment on board to create the fuel of choice. For all fuels the process begins with desalination of the sea water. However, the creation of brine can be considered a pollutant and as such care must be taken to ensure suitable levels of salinity in the discharge. The next step is the electrolysis of the water to create the hydrogen required.

For carbon-based fuels there would likely be carbon sequestration from the sea water as well. Exact quantities of sea water that may be required are unknown as there are several variables that need to be addressed. Such as the amount of fuel to be produce and/or the amount of carbon captured from the existing vessels. The carbon would then be used in conjunction with that from the onboard carbon capture to create the fuel of choice. During the production process some additives may be required, but the diesel would be produced via Fischer-Tropsch synthesis (National Energy Technology Laboratory, n.d.). It may be possible to create other carbon-based fuels as well, for example synthetic aviation fuel. This would allow support for aviation as well and as such reduce burdens even further.

The Fischer-Tropsch process combines carbon monoxide and hydrogen (syngas) to create liquid hydrocarbons, performed in the presence of (Höök, 2014). The creation of the carbon monoxide would require a reverse water-gas shift reaction from the stored/sequestered carbon dioxide with hydrogen, this is the opposite process to steam methane reforming (LeValley, 2014). This combined process is similar to automotive research into synthetic fuel production (Audi MediaCenter, 2017).

The nuclear reactor could be one of the potential new nuclear concepts in development, such as a molten salt reactor. However, some nations already have knowledge of marine nuclear reactors and as such it would be possible to utilise a similar reactor to those already in use today.

Whilst the above process is for a carbon-based fuel, it may be possible to utilise the energy from the reactor in several other methods. For example creating Liquid Organic Hydrogen Carriers, which only require hydrogen and hydrogenation. It could also be used to charge electric powered vessels, although it would require significant energy storage. However, one potential option is the use of batteries which could be charge onboard and then transferred to the vessel that requires them. Swapping the batteries rather than tethering to charge, similar to concepts in Asia for scooters (Autoblog, 2023).

3. Operating Profile

The creation of such a capability is not possible for a single nation, possibly with the exception of the USA. Therefore this would require a unified approach within NATO and its allies. This is beneficial since there are a few NATO nations that operate nuclear naval vessels and Australia whilst not a member is creating a nuclear-powered capability as well.

The creation of such a capability is anticipated to be expensive, however the cost could be shared amongst NATO and collaborating nations. If nations are not willing or able to participate then another option is to sell the fuel to them after production. Depending on the NATO navy fuel of choice there may be no option but to either join a partnership or buy the fuel.

4. DLOD+

Currently such a technology would score low to medium on any Defence Lines of Development plus (DLOD+) scale (UK Ministry of Defence, 2023). DLOD+ is an enhancement of DLOD that is used by the UK MoD to assess and manage military capability, programme or strategy normally within acquisitions. However when creating such a matrix the potential future should be accounted for. Table 1 shows current and future readiness level scores for the DLOD+ elements, based on a possible In Service Date of an initial FNPS of 2040. This date is chosen due to the timescales to set requirements and procurement for large projects.

The DLOD+ scores range from 0 – 10, with 0 low and 10 high. The readiness levels are derived from technology readiness levels, in that the lower score the less feasible.

Table 1 DLOD+ readiness levels

DLOD+ Element	Current Readiness Level	Future Readiness Level c2040
Training	6	8
Equipment	4	8
Personnel	6	9
Information	4	9
Doctrine & Concepts	4	9
Organisation	5	8
Infrastructure	3	7
Logistics	8	9
Integration	3	7
Safety	6	8
Climate Change & Sustainability	7	8
Capability Protection/Security	7	8
Regulations & Certification	4	8
Test & Evaluation	3	7
Commercial	3	6
Finance	2	5

Training will be required for any alternative fuel, however the benefit of the FNPS concept is that it utilises much of what a nuclear navy already does. The only training required is on the equipment to create the alternative fuel, for which transferable skills, attributes and knowledge would be available from the civilian sector.

Equipment that is new to defence will be required, however depending on the new fuel the equipment may be something already available commercially. This would then just require adjustment for marine and defence applications. Technology risk is low, but integration and safety will require some focus.

Personnel would have significant time to develop skills and knowledge to operate such a platform. Skills development can be overcome by equivalent shoreside infrastructure for fuel creation, whilst nuclear navies already have the knowledge to operate nuclear powered vessels.

Information is already known about the fuel requirements. When going 'green' there will be an inherent lack of information to start with which will increase with time.

Doctrine & Concepts will need to change when taking ownership of fuel production, especially when using FNPSs. This is covered in greater detail in later section.

Organisation may require changing. Currently it is auxiliary vessels that provide the refuelling function for warships. This may require a change if using FNPSs, they may become flagged and operated as Warships which may be caused because of the nuclear reactor. Since it is mainly Warships that operate nuclear reactors at sea.

Infrastructure will be required to provide a docking facility, specialist maintenance and support facilities. This is already in place for submarines within the UK and other nuclear navies that have this capability. It may be that the infrastructure is shared amongst allies.

Logistics would pertain to the movement of the created fuel to the vessels that require it. It is anticipated that it would operate in a similar manner to current refuelling. Personnel could either be transferred when at dock or by helicopter.

Integration of this concept could be seamless. However, there will be difficulties whilst the vessels are being built. This could lead to a problem where the fleet requires a phased transition to any alternative fuel. This is not the case if the FNPS produces synthetic diesel.

Safety is a key requirement for any fuel transition and production facility. This is increased further with a nuclear reactor in-situ. However, peacetime operations would have a negligible risk as equipment would be designed to operate together. Minimising the risk of dangerous atmospheres forming.

Climate Change & Sustainability would have minimal impact as this concept can produce various fuels. The sustainability difficulty is that it relies on nuclear power and as such increases concerns about disposal at end of life. The exact fuel or reactor is a decision to be made. However this solution provides a transition capability as the world grapples with the challenge of global warming over the remainder of this century.

Capability Protection/Security this vessel would likely operate within a flotilla and as such would have force protection with it. The loss of this vessel would remove the fuel production from a flotilla which would cause significant issues. However, that is no different to the current flotilla vulnerability with oilers. The loss of a nuclear asset is on par with the loss of a UK submarine or a US aircraft carrier.

Regulations & Certification would require updating and/or creation depending on the nation that develops this capability. Some nations already have this in place due to operating nuclear powered surface vessels. There is the further risk that a vessel of this type may not be allowed to enter sovereign nation waters and/or ports. However, this gives the benefit of allowing the rest of the fleet to transit anywhere globally.

Test & Evaluation could be broken up into suitable areas to show that this concept is suitable. The nuclear power aspect has already been shown viable. Land-based infrastructure should be created to not only teach crew but also to provide another means of fuel production.

Commercial aspects with this concept are anticipated to follow general ship procurement procedures. However, there are ramifications when looking at the funding route. This is likely to be expensive and as such the cost may be shared amongst nations, which could cause commercial problems. Currently nuclear vessels are not allowed in some sovereign waters or ports which could have problems in the future.

Finance is likely to be a problem for such a concept. These vessels are unlikely to be cheap and as such the cost will ideally be shared amongst allied nations. However, if this is not the case then there is the possibility of selling the produced fuel to other nations. Whilst the upfront cost is anticipated to be high, there will be a significant reduction in operating expenditure for fuel across an entire fleet.

5. CONOPS

There are various potential means of operating an FNPS, however this paper will investigate some of the more probable operations. This is operations within Flotillas, both carrier strike and littoral strike, as well as disaster relief. Potential additional capability strings to the FNPS's bow is electrical vessel charging, be they uncrewed or crewed, sub surface, surface or air vessels, small or large. It could also provide a range of fuel stocks, for navies at various stages of transition to a NZ50 future. The inherent flexibility of fuel type production, and in service modifications would allow multiple navies to utilise the FNPSs supply, concurrently, enabling multinational taskforces still to be formed, exercised and operated in time of conflict as required.

Carrier Strike would require the ability to produce fuel for a significant number of vessels and likely the aircraft as well. A FNPS that is deployed with a carrier task group would be protected by the escorts and as such have a vulnerability similar to the aircraft carrier.

The FNPS would likely transit behind the carrier, protected by the various escort ships. There may be a requirement to maintain an oiler with the task group to support the refuelling of the flotilla. When approaching ports, it would be expected that the FNPS remains at sea further from the port. This removes any potential risk around a nuclear vessel in port. This type of FNPS would need to be large to accommodate the quantity of fuel required to maintain Carrier Strike operations.

It is also possible to operate an FPNS a long way from the threat, outside possible enemy engagement range, and utilise smaller, feeder, tankers to provide the fuels to the taskforce elements, including forces ashore, when considering Littoral Strike operations.

Littoral Strike would require a smaller variant of FNPS, since the number of vessels is likely to be lower. With the landing craft and inter-theatre lift vessels being supported by their mother ships. To increase survivability it is likely that a small oiler could be used to transfer fuel as required. However, there could be the possibility when creating the fuel to store it in portable tanks alongside production for a fleet, thus allowing helicopter transfer of the fuel.

A FNPS can support the land-based troops in the initial phases, whilst a suitable Forward Operating Base (FOB) is created with self-sustaining power generation although the details of a land-based reactor for land usage are outside of scope of this paper. This would then allow ground troops to operate with more freedom, since they are less limited by the fuel available in the initial phases of landing.

The ability to produce fuel for both Carrier and Littoral strike removes significant dependency on ports, especially with lower availability of MGO as this becomes less available to commercial vessels. It also allows vessels to stay on station for longer, solid stores become the limiting factor for maintaining time on station.

The operating model for an FNPS is likely to be a combination of hub & spoke (FNPS as hub, conventional tankers as spokes) and more organically attached to a flotilla (with a smaller requirement for tankers). Ideally a FNPS would be co-located with pre-positioned forces to maximise availability of resources and lessen the burden on fuel transportation. They would also be suitable to be assigned to flotillas or areas of operation that will always have vessels operating, such as US 5th Fleet or NATO AOAs.

Disaster Relief is likely to be a significant amount of the work performed by a FNPS. This is because it is an off-shore power station. This coupled with the ability to create a fuel that is aligned with suitable prime movers would support on-site power generation in areas that have lost that capability. It would operate in a similar manner to Littoral strike operations. When coupled with a suitable vessel, this would significantly increase the abilities of civilian organisations in the short-term effects of a disaster. The installed power will also enable significant quantities of fresh water to be generated, a vital resource in any natural disaster.

A FNPS would ensure that all other vessels can act as floating embassies anywhere globally since they are not nuclear powered. This increases the potential to influence nations and is likely to be considered a demonstration to support trade. There may also be potential for technology export for such vessels. There are considerable economic benefits, since there is a significantly reduced through-life cost associated with fuel for entire Navies and potential aircraft as well.

6. Next Steps

To mature the FNPS concept coordinated feasibility studies need to be conducted initially into the technical, economic and political aspects of developing an initial capability by 2040. The engineering is feasible, integration manageable, and benefits clear.

7. Conclusion

The use of FNPSs has the ability to change how naval vessels operate. The normal limiting factor for operations is the fuel available, this would no longer be the case. This transitions the limitation to solid stores. A FNPS could have the ability to create any fuel, provided with the correct feedstock. One thing is certain, that it will have to create hydrogen.

The creation of a FNPS fleet is going to be expensive initially but this may be overcome by sharing the cost amongst allies or charging them for fuel. However, there will be a significant reduction in the operating cost of an entire fleet when the fuel production is sustained within it.

The most likely user cases for a FNPS are to support Carrier & Littoral Strike, with a secondary function for disaster relief. Supporting both types of strike group is likely to give a significant operational advantage by removing the requirement to resupply. This is especially advantageous in a future where it is probable that the fuel of choice will be less energy dense.

There is increased operational advantage for land-based troops in the early phases of littoral strike since it gives the possibility of providing power whilst other more suitable means are created. It also allows disaster relief to be increased, since the fuel will continuously be produced. Decreasing pressure on civilian infrastructure whilst it is repaired.

It is anticipated that by 2040 there will be minimal barriers to adoption technically, as shown by the DLOD+ scoring matrix. The lowest technical scores, still rated a 7, being Infrastructure, Integration and Test & Evaluation. The biggest barriers with respect to the DLOD+ are Commercial and Financial (political and economic). However if the concept is articulated in the correct manner, then it should be possible that those barriers would be removed. Then the more difficult issue is where to build them.

Whilst the use of a land-based facility would seem to be more viable, there are a few problems with such a facility. Firstly, the time to create such a facility is extremely lengthy, the first announcement was in 2010 (BBC, 2010), with several more years until completion (Energy Live News, 2023). However, the major concern is still a reliance on local port bunkering when on deployment. As stated previously, there is not a single choice at the moment for maritime fuel and as such this poses a risk for bunkering when on deployment.

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