# The adaptable energy platform

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## Synopsis

The Netherlands Ministry of Defence (MoD) has issued an Operational Energy Strategy (OES) with ambition targets for energy independence and improvement of energy efficiency during the life time of naval platforms. A target is given in 2030 of 20 % reduced dependence on fossil fuels and in 2050 of 70 % reduced dependence on fossil fuels, compared to 2010. More stringent environmental emission (NOx, $CO_2$, etc.) requirements are to be expected as a result from IMO and (local) political regulations.

In the last decades the power consumption on board of naval platforms increased substantially as well as the complexity of integrated energy systems. Market surveys shows that the evolution of commercial green technologies are promising but have to be demonstrated in the coming years on low power and energy levels. They will not be de-risked in depth or well proven to be successful in time to be selected for the Royal Netherlands Navy (RNLN) new naval projects (2019 – 2025).

Furthermore, new technologies as energy resources and carriers ($H_2$, LNG, methanol, power-to-liquid (PTL), etc.) or new system technologies (DC on high voltage level, fuel cell systems, waste energy recovery, etc.) require a new approach for integration aspects like hazard and safety cases and energy efficiency. This is because the energy demand on board of naval platforms in several military operational modes differ from the merchant and off-shore branch.

In this paper an approach for an adaptable energy platform is described to design a new naval platform based on nowadays proven technology as fossil fuels that can be transformed during life time that can fulfill the expectations and requirements of the coming decades (non-fossil fuels, zero emission, improved energy efficiency). Aspects as a naval energy index as reference will be discussed as well as an evaluation of new technologies for new naval platform integration design parameters, such as power or energy demands, consequences of energy resources, energy control as well as build in ship construction safety measures.

*Keywords*: Energy transition, Propulsion; Power; Energy storage

## 1. Introduction: Prepared for a future proof energy transition

The traditional logistic energy chains will alter in the coming decades due to regulations and guidelines to limit climate change. International regulations and guidelines (MARPOL VI) aim to reduce emissions of SOx and NOx, and in the future probably $CO_2$ as well. The main focus in merchant marine is on the HFO fuelled ships. Although naval vessels use MDO instead of HFO for energy storage on board it also depends on the civil developments in the logistic chains and availability of these fuels. The expected cost growth for MDO in the coming decades will rise rapidly while the global availability will decrease in the near future.

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## Authors' Biographies

**A.J. Blokland** is a Senior Marine Engineer at DMO in Utrecht, NLD. He joined the RNLN in 1986. As a European Engineer, he has a background in both Mechanical and Electrical Engineering and has led several projects ranging from the delivery of automation, power, propulsion and silencing systems for the RNLN through to a wide range of technology studies and concept development work.

**Isaac Barendregt** graduated in 1989 as a mechanical engineer at Delft University of Technology in the field of transportation technology. In 1991, after military service in the Army, he joined the Royal Netherlands Navy in the bureau for research and development on propulsion and energy systems for navy ships. He did several studies in this area as well as management of R&D and international research projects. In this period, he became involved in research into fuel cells for naval applications. In 2000 he became technical coordinator for the platform systems in the conceptual design phase of the second Landing Platform Dock (LPD-II). Since 2005 he is employed by the Netherlands Defence Materiel Organisation, currently as a senior engineer in marine engineering and is involved in several new ship building projects for the Navy as well as research in future energy systems, fuels and emissions.

**Kees Posthumus** graduated in 1980 at the "College of Advanced Technology" in electrical energy engineering. In 1982, he started as a engineer at the energy system section of the Defence Material Royal Navy (DMKM) of the MOD. Since then he followed successfully several academic, post graduate and Master courses at Netherlands Universities. In 2000 he successfully graduated from the Netherlands Defence College for the Royal Netherlands Navy Management course. Kees Posthumus is a Chartered Marine Engineer and Fellow of the IMarEST (Institute of Marine Engineering, Science & Technology). Kees is chairman of the NATO Specialist Team Electrical Power and Controls. From 1995 till 2005 Kees Posthumus was involved as lead engineer and project engineer for several new build programs of the Navy, from Walrus class submarines to the Air Defence Command Frigates. From 2005 till November 2013 he was head of the section Electrical System Technology and since November 2013 he is head of Marine Engineering Office at the Maritime Systems Division of the DMO. This division is called "The Ingenieursbureau for the Netherlands Navy".

Furthermore, more stringent environmental emission (NOx, $CO_2$, etc.) requirements are to be expected as a result of national and local political (harbour) regulations as well as more stringent environmental requirements in relation to the health of ship crews. Ship crews can be exposed to diesel engine exhaust emissions depending on wind conditions and Health and Safety regulations are nowadays mandatory and more stringent then in the past.

The Netherlands MoD has issued an Operational Energy Strategy (OES) with ambition targets for energy independence and improvement of energy efficiency during the life time of naval platforms. A target is given in 2030 of 20 % independence on fossil fuels and in 2050 of 70 % independence on fossil fuels compared to 2010.

During the UN climate conference 2015 in Paris (Conference of Parties COP21) the Netherlands agreed with the conference results and signed the results in 2016 with 28 countries of the EU and will mandatory in 2020 and will result in an effort obligation by the government to reduce $CO_2$. The reduction of fossil fuel will allow the Netherlands MoD to take responsibility in this.

Another development is the energy usage aboard naval platforms. The reduction of ship crew sizes and expected new weapon systems during a ships life time, shifts the traditional ratio between the steady ship electrical service load and electrical high power loads and will demand fast deliverable high power reserves. The reduction of ship crew sizes also necessitates less maintenance on board and more reliable systems.

All these developments will change the energy system configuration on future naval platforms. Market surveys show that the evolution of new technologies are promising but have to be demonstrated in the coming years on low power and energy levels. Furthermore new technologies as energy resources (Hydrogen ($H_2$), Dimethyl ether (DME), Methanol, LNG, etc.) or new system technologies (DC on high voltage level, fuel cell systems, energy storage, waste energy recovery, etc.) require a new approach for integration aspects like hazard, safety cases and energy efficiency, because the base for energy demand and energy continuity on board of naval platforms in several military operational modes differ from the merchant and off-shore branch.

All developments will not be de-risked in depth or well proven to be successful in time to be selected for the RNLN replacement naval projects (2018 – 2025; like mine counter vessels, M-frigate and submarines) as well as modification of the existing naval platforms and is reason for the adaptable energy platform.

In this paper an approach for an adaptable energy platform is described for implementation on a naval platform based on current proven technology such as fossil fuels that can be transformed during the life time of the ship and can fulfil the expectations and requirements of the coming decades (non-fossil fuels, zero emission, improved energy efficiency). Aspects as a naval energy index as reference will be discussed as well as an evaluation of new technologies for new naval platform integration design parameters, such as power or energy demands, consequences of energy resources, energy control as well as build in ship construction safety measures.

## 2. Adaptable energy platform

The Netherlands MoD has issued the Operational Energy Strategy (OES) for the MoD organisation and not only for mobile platforms. For naval ships in operation the fossil fuel dependency in 2030 can be referred to the fuel consumption in 2010. For new Netherlands MoD navy projects the comparison to 2010 is not possible. To reduce the fossil fuel dependency and reducing emissions in new designs, civil methods can be adopted. The UN IMO MARPOL VI regulation introduces two mandatory mechanisms as an energy efficiency standard for ships; with the main objective of reducing international shipping's emissions via improved ship design and operations. These regulatory mechanisms are:

- Energy Efficiency Design Index (EEDI), for new ships
- Ship Energy Efficiency Management Plan (SEEMP), for all ships.

Furthermore, the MARPOL VI regulation introduces requirements on the NOx and SOx emissions of maritime diesel engines. New designs of ships (≥ 1 July 2008) shall fulfil the NOx TIER II requirements and TIER III is required for ships built after 1-1-2016 in so called Emission Control Areas (ECA's), in which more stringent emission reduction are required. (see figure 1).

- North American ECA (2016)
- Caribbean ECA (2016)
- Baltic Sea and North Sea (2021)
- Future ECA's.

Figure 1: ECA zones

Adaption of naval ship design to the MARPOL VI regulatory mechanism is not easy as discussed during EEAW VI paper 'Energy as a weapon the why and how of the energy-efficient ship' (Schulten et al., 2015) and EEAW VII paper 'Energy as a weapon' (Schulten et al. 2017), but new technologies from the civil energy transition will provide opportunities to decrease Life Cycle Costs and fossil fuel dependency on naval platforms in the near future as well as affordable energy supply. In this paper the implementation of new developments in an energy platform are discussed.

### *2.1. Short term 2019 - 2030*

For naval ships in operation the fossil fuel dependency in 2030 can be referred to 2010. It is of interest how this energy is used on naval platforms. The global energy demand for example of an M-frigate can be divided into the energy need during the period the frigate is in harbour (approx.30 %) and the energy need during the sailing period (approx.70 %). The energy demand during the sailing period can be divided into propulsion energy (approx.50 %), electrical energy (40 %) and energy for heating (10 %).

In 2017 the electrical energy for shore supply on the naval base in Den Helder was changed from fossil fuel dependent sources to the purchase of external green energy (e.g. hydro power). In Harbours like Rotterdam, Hamburg, etc. initiatives are under investigation to supply electrical shore energy by clean and fossil free energy sources on barges (e.g. LNG generator units, fuel cells, batteries).

### *2.1.1. Hydrotreated Vegetable Oil*

The dependence of fossil fuel can further be reduced by mixing non-fossil fuel (e.g. bio fuel) and fossil fuel. The specification of NATO diesel fuel F-76 i.a.w. STANAG 1385 allows 50 % mix of synthetic bio fuel and fossil fuel. A mix of F-76 and bio fuel Hydrotreated Vegetable Oil (HVO) will have consequences for lubrication properties, emissions, density (mass and volume) and aromatics content of the fuel.

HVO is a synthetic bio fuel and is produced from used cooking oil (UCO) of restaurants and other sources such as forestry. In a chemical process hydrogen is used to remove oxygen form UCO. HVO exist of hydrocarbon molecules which are comparable with fossil fuel molecules.

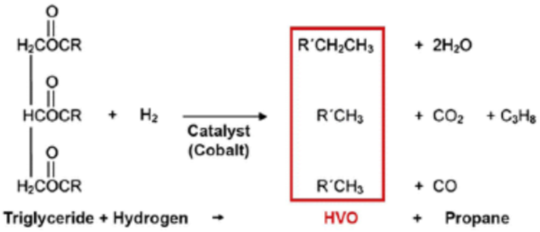

Figure 2: hydrogenate process HVO

The consequences of mixed fuels on the existing RNLN naval platforms was, on behalf of the office of Marine Engineering of the DMO, investigated for de-risking unexpected behaviour of diesel engines and auxiliaries. In table 1 some results of fuel analysis are given.

| | Unit | STANAG-1385 | | 0% | 10% | 20% | 30% | 50% | 75% | 100% |
|---|---|---|---|---|---|---|---|---|---|---|
| | | min | max | | | | | | | |
| Concentration synthetic component | van % v/v | - | 50 | 0 | 10 | 20 | 30 | 50 | 75 | 100 |
| Density | kg/m3 | 800 | 880 | 847.4 | 841.2 | 834.4 | 827.2 | 815.1 | 798.3 | 781.3 |
| Sulfur | concentratie | - | 1 | 0.05 | - | - | - | - | - | 0.01 |
| Viscosity (40 °C) | cST | 1.700 | 4.300 | 2.784 | 2.907 | 2.907 | 2.889 | 2.890 | 2.888 | 2.905 |
| Heating value | MJ/kg | | | 42.580 | - | 42.825 | - | 43.158 | - | 43.776 |
| Hydrogen | (H) % m/m | - | - | 13.1 | - | 13.5 | - | 14.1 | - | 15.1 |
| Carbon | (C) % m/m | - | - | 86.6 | - | 86.3 | - | 85.8 | - | 84.9 |
| HFRR | ¹m | - | 520 | 340 | - | 350 | - | 360 | - | 390 |

Table 1: Results HVO

The density of the mix will change with higher mix ratios. HVO is less dense then fossil fuel due to more H and less C molecules. An HVO mix of 50 % is the maximum allowed concentration in accordance with STANAG 1385, a higher HVO content will not fulfil the requirements of the STANAG. Furthermore, the capacity of the fuel tanks shall be able to store the 5% extra volume of the mixed fuel, or the range will decrease by 5%. Another consequence is the reduced lubrication of HVO, potentially causing additional wear in the diesel and fuel pumps. Additives will be necessary to fulfil the lubrication requirements. Also, the aromatics content of the fuel mix must be checked, since HVO does not contain the aromatics content that is required for F-76. The conclusion of these investigations is that HVO can be mixed up to 30 %, including some additives, without consequences in the short term.

### *2.1.2. SOx*

To meet the IMO TIER III emission requirements as well as for the health of ship crews, which can be exposed to diesel engine exhaust emissions for diesel engines, additional measures are necessary for diesel engines.

The sulfur oxide (SOx) emissions are bound by limits in MARPOL 73/78 Annex VI regulation 14. From May 2005 the maximum sulfur content in fuels was globally limited to 4.5%. This was changed to 3.5% after 1 January 2012, and to 0.5% after 2020.The SOx emissions are primarily solved by using low sulfur fuel. The SOx can also be washed out by water-scrubbers.

The RNLN normally uses low-sulfur fuel with an average sulfur content of 0.1%, which is required in ECA zones from 2015. The fact that scrubbers would have an undesirable impact on the ship design the solution which fuel with max. 0.1%. sulfur content should be adequate.

### *2.1.3. NOx*

Though, sulfur emissions can be a problem for the crew. SOx in the exhaust plume is harmful to the personnel that is working on the open decks. This also holds for the NOx emissions. The Marpol Annex VI regulation 13 mentions very stringent limits to the nitrous oxide (NOx) emissions which apply to marine diesel engines with power output > 130 kW installed on a ship constructed after 1 January 2000. The regulations are introduced in three steps: Tier I (1-1-2000), Tier II (1-1-2011) and Tier III (1-1-2016).

One possible solution for meeting the NOx emission limitations for diesel engines is to perform after treatment on the exhaust gasses before these are ejected into the environment. The process of Specific Catalytic Reduction (SCR) is by far the most well-known method for converting the undesirable NOx-gasses into harmless components like water and nitrogen. The basic concept is to react the exhaust gasses, that contain the NOx-gasses, with urea [(NH2)2CO] in a specially designed reactor, at the correct temperature to convert a certain minimal amount into nitrogen + water, resulting in an exhaust gas mixture that will comply with the NOx emission limitations. A SCR installation can reduce fuel consumption and reduce soot particles if the diesel engine works on higher pressures and temperatures.
The main consequence of introducing urea is the need for an additional capacity of tanks to be able to store approximately 5-7% extra volume and the need for an additional logistic supply chain.

Another possible solution for meeting the NOx emission limitations with diesel engines is to recycle part of the exhaust gasses for another combustion cycle before these are ejected into the environment. The process of Exhaust Gas Recirculation (EGR) is a more experimental method for reducing the emission of NOx-gasses. This method relies on ‘cooling’ the combustion process, preventing NOx formation by moving the entire combustion process to a lower temperature.
EGR works by recirculating a portion of an engine's exhaust gas back to the engine cylinders. This dilutes the O2 in the incoming air stream and provides gases inert to combustion to act as absorbents of combustion heat to reduce in-cylinder peak temperatures. NOx is produced in high temperature mixtures of atmospheric nitrogen and oxygen that occur in the combustion cylinder, and this usually occurs at cylinder peak pressure. EGR is also used to achieve a richer fuel to air mixture and a lower peak combustion temperature. Both effects reduce NOx emissions but can negatively impact efficiency and the production of soot particles, which is a direct result of the richer combustion mixture.

The consequences of additional auxiliaries for diesel engines results in extra volume and weight (amongst others., SCR and mixing section in the upper structure of the ship, etc.) and the highly uncertain future oil prices due to international market conditions will stretch the implementation of alternative fuels and new power conversion technology (e.g. fuel cells) in the near future.

### *2.1.4. Energy savings*

The energy consumption on new naval platforms can also be reduced to limit the dependence on fuel. Focus shall be on the continuous large energy consuming loads, e.g. introduction of frequency controlled pumps and ventilation, more efficient electric motors (3 %), waste heat recovery (5 %), nanocoating of hull and propellers (5%).

An example is the continuous operation of water cooling pumps and chilled water plants. The water cooling systems are designed for world-wide operations with cooling water temperatures up to 36C. The main area of operation is the North Sea. The temperature of the North Sea water for 75% of the time is between 2 ˚C and 10 ˚C. Not only temperature controlled pumps are of interest but also free cooling of the chilled water plant with a sea water heat exchanger is of interest to reduce the capacity and running hours of chilled water plants.

### *2.2. Mid term 2030 – 2050*

The energy carrier of the future is uncertain and adaption to new technology is necessary. The forecast for a specific new technology market breakthrough for green energy is not yet clear, but from a system design perspective the dynamic behavior of energy systems will change. For all developments an electrical energy network is used as energy transport medium. On naval platforms the introduction of High Energy Weapons (HEW), introduction of a majority of non-linear loads instead of inductive loads, crew size reduction and grade of automation change the static and dynamic design of electric energy systems in which Electrical Energy Storage (ESS) has a key function. Furthermore, new naval platforms like the RNLN replacement programs which will have an end-of life beyond 2050 and the non-dependence on fossil fuel of 70 % in 2050 of the Netherlands MOD OES will not be reached with green electrical shore supply and mixed fuels only.

On RNLN platforms it is typical practice to operate two generators on a fixed frequency (60 Hz). If one generator fails, there will be no black-out through selective load switch off functionalities and continuity of energy supply to primary loads is guaranteed. To limit fuel consumption and reduce maintenance a back-up by energy storage is a next step. Diesel generators can run on flexible and optimized speed if connected by power electronics to the electrical distribution system and dynamic load steps will be taken by the energy storage system and will improve system efficiency by another 3 – 10 % but will not decrease the dependence on fossil fuels.

New developments of fuel cells, renewable energy carriers such as $H_2$, methanol, PTL, are necessary to limit the dependence on fossil fuel. New technologies are dependent on chemistry and other processes and will have different static and dynamic behavior. If classical diesel generator units are to be replaced by fuel cells the energy storage must also provide short circuit current for selective scheduling within the electrical distribution system. Furthermore, de-risking of new technology is also necessary for implementation within a naval platform.

In practice most of the new technologies will be demonstrated in 20 ft or 40 ft containerized units on shore. To design an adaptable naval platform for the future the main power sources shall preferably be sized within standard containerized dimensions to provide flexibility for exchanging main power sources on board to more affordable, efficient and less fossil fuel dependent main power sources.

In 20 ft containers nowadays the following capacities can be incorporated:

| | | |
|---|---|---|
| - Diesel engines | 1,5 – 2 MW | weight approximately 21 – 24 t |
| - Super capacitors | 5 – 6 MJ | weight approximately 11 – 14 t |
| - Lithium Ion batteries | 1 – 1,5 MWh | weight approximately 7 - 8 t |
| - Fuel cells | 0,5 – 1 MW | weight approximately 14 – 16 t |

Figure 3: Example 20 ft Lithium Ion battery container

In respect to the power consumption these technologies can be applied for ship service supply and propulsion up to cruising speed. The ability to reach a target of 70 % non-dependence on fossil fuel in 2050 also depends on the awareness of the ship operator and average speed profile of the ship, but in most operational speed profiles high speed operation is limited. The exchange of main power sources during life time will provides greater flexibility against the implementation of new loads on board and response to uncertain developments on emission legislation and oil price.

## 3. Electrical system

The implementation of all types of new technology on the electrical energy system are based on static power conversion. If conventional diesel generator units are to be replaced by fuel cells the electrical system selectivity will become more complex and the control of the power quality must also be more advanced. The electrical energy storage in this case will be a key element for safety and stabilisation of the network.

### *3.1. Electrical Energy Storage (ESS)*

Electrical energy storage will not only improve the dynamic behaviour of next electrical energy systems but also reduce the life cycle costs (fuel, maintenance).

Depending on the expected dynamic load several electrical energy storage technologies are available e.g. Fly-wheels, super capacitors and batteries. The combination of storage devices depends on the expected load.

The application of Lithium-ion (Li-ion) batteries is becoming more common. From application fields like consumer electronics and electric vehicles to large scale stationary applications (i.e. wind turbine parks and ships). A major concern with Li-ion are potential risks in a naval platform application. The composition of materials of the Li-ion cell presents safety challenges in the event of overcharge, overheating or physical damage. This emphasizes the importance of the Battery Management System (BMS) and the mechanical casing.

The safety concerns on Li-ion cells mainly stem from examples of burning laptop and smartphone batteries and are maintained by recent incidents, like those of the Li-ion batteries on board the Boeing Dreamliner aircraft (2013), stationary battery fires in Brussels, Belgium (11 Nov 2017) and several places in South Korea (2017), and the fire in a storage hall with Li-ion batteries of electric bicycles in Nunspeet, NL (11 July 2018). The experience gained from incidents in the past generally has led to a shift in safety philosophy from 'keeping the probability of a single cell failure/fire as low as possible' to 'assuming that a cell may go on fire (although the probability is very low) and taking mitigating measures to reduce and/or contain the effects'.

Given the performance benefits, the RNLN has shown interest in Li-ion batteries for naval applications. On the other hand, they have become increasingly aware of the safety incidents related to Li-ion batteries and the shift in safety philosophy mentioned above. Due to a number of recent (non Li-ion related) safety incidents within the Netherlands' MoD, improving safety is a strong focus point. This means that the issue, whether the RNLN should consider Li-ion batteries for future naval power and propulsion systems, is predominantly a safety question. Therefore, DMO asked DNV GL to build a sound knowledge base on Li-ion batteries, so DMO and RNLN can make informed decisions regarding Li-ion safety (risk profile) for their upcoming fleet upgrade and replacement programs. This knowledge base should initially be based on the existing knowledge and state of development of Li-ion battery safety, drafted in such a way that it is easily updated, when new insights, information and developments become available.

Ship integration of Lithium Ion batteries is favoured due to its higher specific energy (Wh/kg) and energy density (Wh/m$^3$) as well as increased lifespan and reduced maintenance in comparison with traditional lead-acid battery types. The thermal runaway consequences are dependent on the anode, cathode and electrolyte chemistry. Risk mitigation measures shall be foreseen for batteries. Lithium Ion batteries are not different in this respect to lead-acid batteries. Specific battery spaces are necessary with facilities to condition the temperature of the space and it is considered that special ducting shall be required to ventilate the battery space in case of battery failure. The OEM's of Li Ion batteries are improving the performance of the battery pack, but also focus on cost reduction. During the construction phase of the ship the selected Li Ion battery OEM shall provide validated data for expected toxic gasses, pressure and temperatures duct and cooling requirements and shall include a margin for future improvements.

### *3.2. Energy Management Control*

In an electrical distribution configuration with a combination of different types of technology the energy management control system will optimise the use of the components and system efficiency. Several optimisation goals such as fuel consumption, emission reduction, maintenance reduction, etc. are possible. With advanced energy management algorithm additional fuel savings (5 – 10 %) are possible but will have a drawback on the other parameters.

Due to the uncertain evolution of new technologies the energy management control shall also be scoped to accommodate the different interfaces and control principles of power components (e.g. Battery Management System), but also new threats as cyber security. The integration aspects need a dedicated electrical integrator with experience of new power and propulsion systems as well as communication and control technology.

## 4. Ship integration

The implementation of the adaptable energy platform concept needs a multi-disciplinary engineering approach in the concept ship design phase to enable the promising expectations. The concept design of a new ship shall have a balanced flexibility to adapt the modifications during life time to make the concept affordable. The possible integration during a vessel's life time of high energy weapons and modifications to achieve the constraints of the OES and uncertain future exhaust emissions regulations, will change typical design parameters as future growth and needs the awareness of engineers and naval architects. If during the life time of a naval platform, for example, the diesel generators are replaced by fuel cells, or other types of fuel are applied, volume and weight are important parameters for naval architects to consider in respect to ship stability and compartment sizing. The electrical engineer shall analyse the consequences on the protection schemes and electrical network stability and mechanical aspects like cooling capacity will changed. Furthermore, ship operators shall deal with other system behaviour and maintenance issues.

The selection of an adaptable energy configuration, including electrical energy storage, reduces the consequences of modifications and provide more flexibility but during the concept design phase a realistic view on the required flexibility is necessary.

## 5. Conclusions

The adaptable energy platform provides a solution to uncertain developments in local emission legislation, oil price and future modifications of a naval platform, but provides also flexibility to introduce new main power sources to reduce the dependence on fossil fuels. An adaption on standardized dimensions of 20 ft and 40 ft containers can simplify the implementation of affordable COTS proved technology.

## Acknowledgements

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## Glossary of Terms

| | |
|---|---|
| COTS | Commercial Of-The-Self |
| $CO_2$ | Carbon Dioxide |
| DC | Direct Current |
| DME | Dimethyl Ether |
| DMO | Defense Materiel Organization |
| ECA | Emission Control Area |
| EEDI | Energy Efficiency Design Index |
| ESS | Energy Storage System |
| HEW | High Energy Weapon |
| HFO | Heavy Fuel Oil |
| HVO | Hydrotreated Vegetable Oil |
| IMO | International Maritime Organization |
| MARPOL | International Convention for the Prevention of Pollution From Ships |
| MDO | Marine Diesel Oil |
| $NO_x$ | Nitrous Oxide |
| OEM | Original Equipment Manufacturer |
| OES | Operational Energy Strategy |
| PTL | Power To Liquid |
| RNLN | Royal Netherlands Navy |
| SCR | Specific Catalytic Reduction |
| SEEMP | Ship Energy Efficiency Management Plan |
| $SO_x$ | Sulfur Oxides |
| UCO | Used Cooking Oil |
| UN | United Nations |