Technical Meeting — 4 September 2019

Jonathan Abrahams, Head of Maritime Advisory, and Adam Williams, Plan Approval Group Leader, DNV GL, gave a presentation on *Alternative Fuels and the Propulsion Energy Transition for High Speed and Light Craft* to a joint meeting with the IMarEST attended by 33 on 4 September in the Harricks Auditorium at Engineers Australia, Chatswood.

Introduction

Jonathan began the presentation by saying that he would give an overview of alternative fuels and the regulations driving the marine industry towards them, while Adam would give more details of the technical aspects and how these were likely to affect high-speed and light craft, which is of particular interest to Australia, building a high proportion of these craft for the world.

Jonathan started with a slide showing the Maritime Environment Protection Committee in its 74th Session at the International Maritime Organisation in London in May this year. The session decided that there would be no delay in implementation, so there would be a ban on the carriage of non-compliant fuels (i.e. with more than 0.5% sulphur content, reduced from the current 3.5%) effective from 1 March 2020. Amendments to MARPOL have been completed, and guidelines and circulars finalised. Dialogue between ship, port state, and flag will be crucial to manage all the issues. The relevant options for compliance with GHG emissions remain compliant fuels, scrubbers, or the use of liquefied natural gas. With less than four months to go, predictions on fuel price and availability remain volatile. The procedural hurdles have been cleared away by agreeing impact assessment, which is a key issue for developing nations. Around 40 reduction measures in 14 categories were discussed. The primary focus was on short-term EEDI- and SEEMP-based measures; speed limits were proposed, but these were highly controversial. Consensus was reached that measures need to be approved at MEPC 76 at the latest for entry into force by the end of 2022. Further discussion will take place at two intersessional meetings prior to MEPC 75.

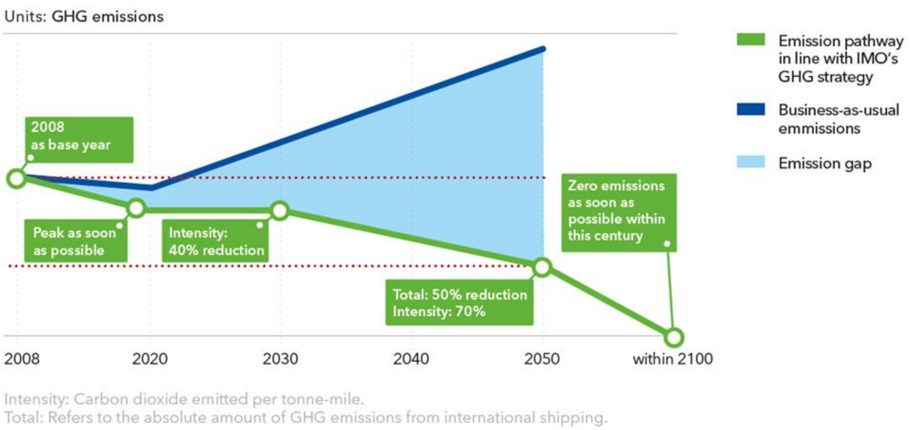
MEPC 74 in session at IMO on 17 March 2019
(Photo courtesy DNV GL)

IMO

IMO remains committed to reducing GHG emissions from international shipping and, as a matter of urgency, aims to phase them out as soon as possible in this century.

Their ambitions are to

- review EEDI with the aim of strengthening requirements;
- reduce the average carbon intensity (CO_2 emissions per amount of transport work) by 40% in 2030 and 70% in 2050 compared to 2008; and
- reduce total GHG emissions from shipping by at least 50% in 2050 compared to 2008.



IMO's vision for reduced GHG emissions from shipping
(Graph courtesy DNV GL)

What are the possibilities for emissions reductions, and what is the potential?

- Logistics and Digitalisation: Speed reduction, vessel utilisation, vessel size and alternative routes: more than 20%.
- Hydrodynamics: Hull coating, hullform optimisation; air lubrication and cleaning: 10–15%.
- Machinery: Machinery improvements, waste heat, engine de-rating and battery hybridisation: 5–20%.
- Fuels and energy sources: LNG/LPG, electrification, biofuel and synthetic/hydrogen, etc.: 0–100%

The 14 candidate proposals considered at MEPC 74 were

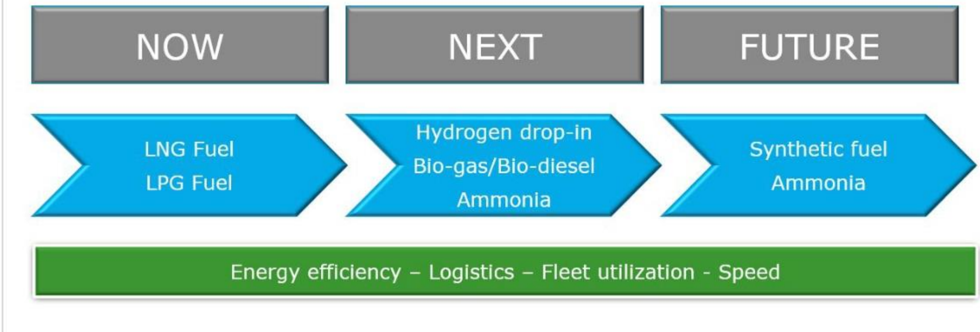
1. Improve the energy efficiency of existing ships building on the EEDI framework.
2. Further develop the EEDI framework for new ships.
3. Improve the energy efficiency of existing ships building on the SEEMP framework.
4. Identify appropriate operational energy efficiency indicators.
5. Develop a speed optimization and speed reduction mechanism.
6. Develop regulatory measures to reduce methane slip.
7. Develop regulatory measures to reduce emissions of Volatile Organic Compounds (VOCs).
8. Encourage the development of National Action Plans (NAPs).
9. Encourage port developments and activities to facilitate reduction of GHG-emissions from shipping.
10. Initiate and support research and development activities.
11. Encourage incentive schemes for first movers.
12. Develop lifecycle GHG/carbon intensity guidelines for all types of fuels.
13. Implementation programme for the effective uptake of alternative low-carbon and zero-carbon fuels.
14. New/innovative emission reduction mechanism.

Examples

Jonathan then showed a goal-based proposal by Denmark for existing ships on an EEDI basis:

- Each ship would be required to meet a certain carbon intensity target (use of EEDI reference line as proxy).
- IMO determines the target.
- Ships must document the CO_2 emissions per transport work amount and prove that it is reduced by at least 40% in 2030 compared to a comparable ship in 2008.
- Part 1 of SEEMP would be made mandatory:
    - all ships covered;
    - mandatory target for each ship; and
    - include SEEMP requirement in the IEE certificate.

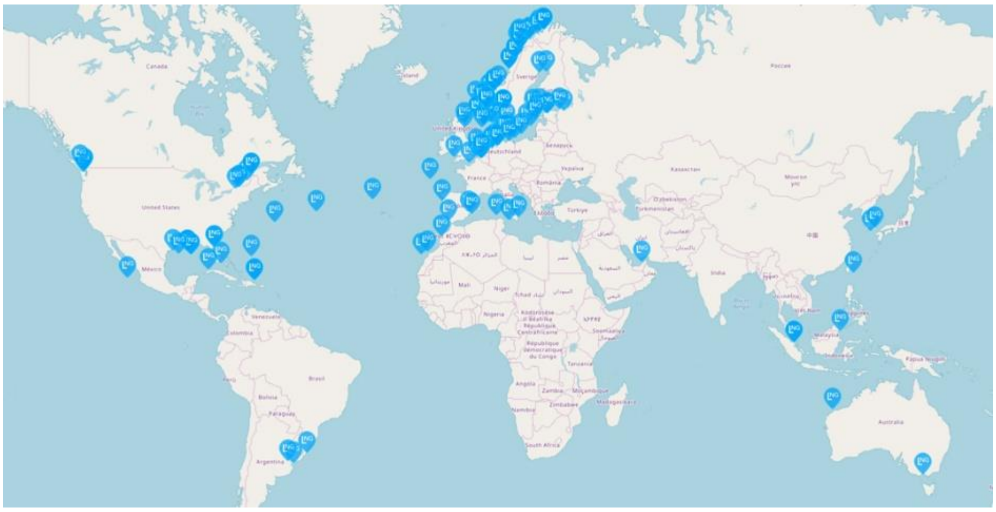
A scalable pathway with impact for reducing GHG emissions might look like that shown in the diagram.



A scalable path with impact
(Diagram courtesy DNV GL)

Liquefied Natural Gas

LNG-fuelled ships are already in operation in many areas, mainly Europe, the Mediterranean, and the east coast of the USA.

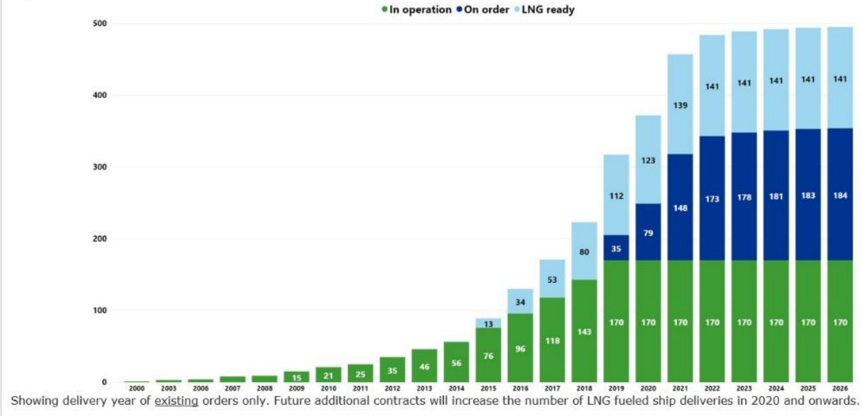


Areas where LNG-fuelled ships are in operation
(Map courtesy DNV GL)

Similarly, LNG bunkering infrastructure is being developed to supply the growing fleet.

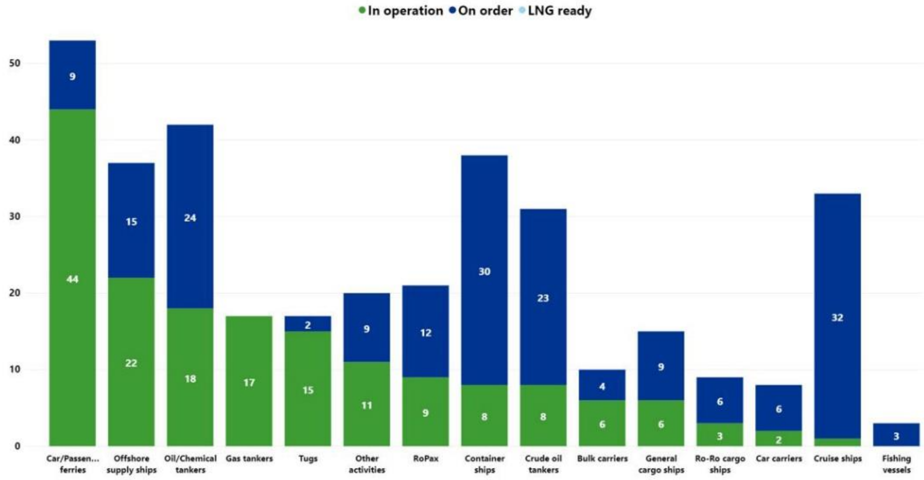
LNG bunkering worldwide
(Map courtesy DNV GL)

There are currently 354 confirmed LNG-fuelled ships, and 141 additional LNG-ready ships.



LNG ships
(Diagram courtesy DNV GL)

By vessel type, car and passenger ferries have currently had the biggest uptake of LNG as fuel, but cruise ships, container ships and tankers are set to increase significantly.



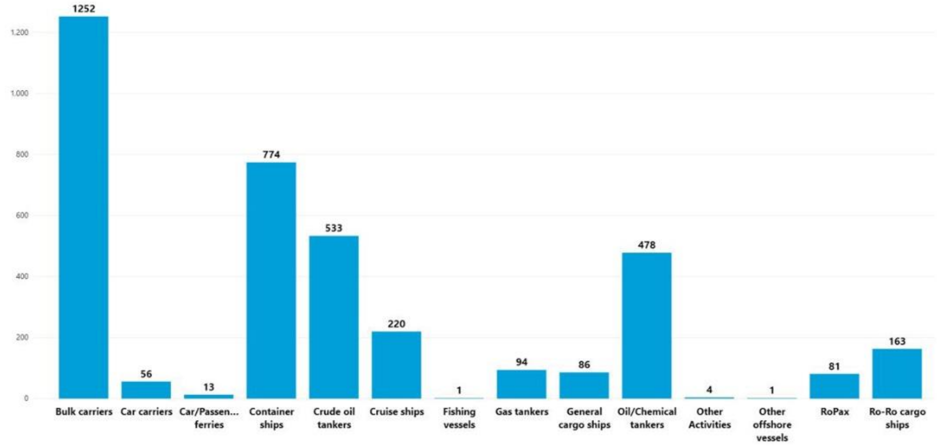
LNG uptake by vessel type
(Diagram courtesy DNV GL)

Scrubbers

A large number of vessels already has scrubbers fitted in order to meet the coming GHG emission requirements.

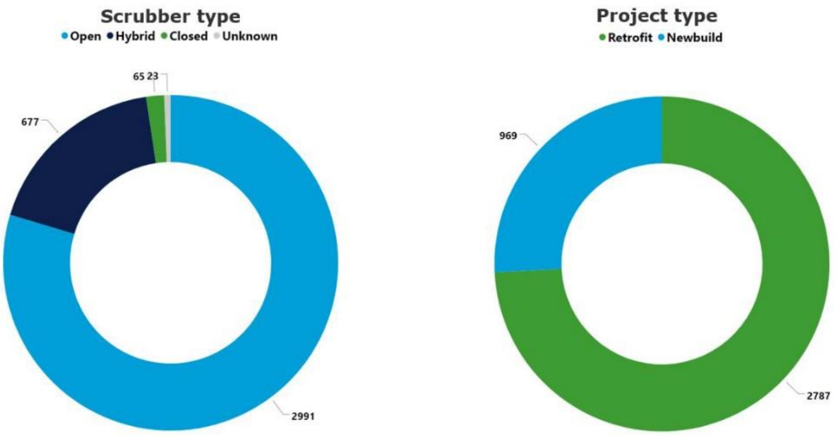
AIS positions of vessels with scrubbers fitted
(Map courtesy DNV GL)

By vessel type, bulk carriers, container ships and tankers have had the most scrubbers fitted.



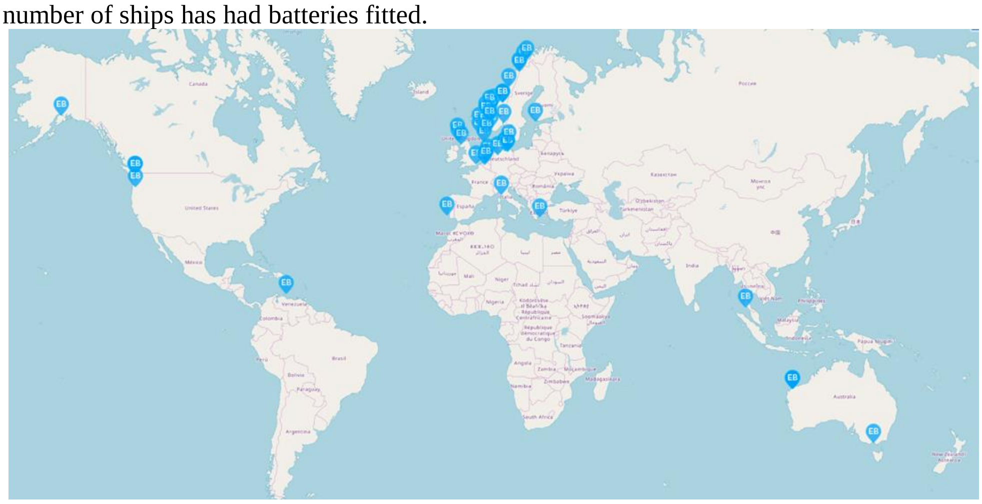
Scrubbers fitted by vessel type
(Diagram courtesy DNV GL)

Scrubbers can be of the open, closed or hybrid types, and the number in service is expected to quadruple with newbuilds.



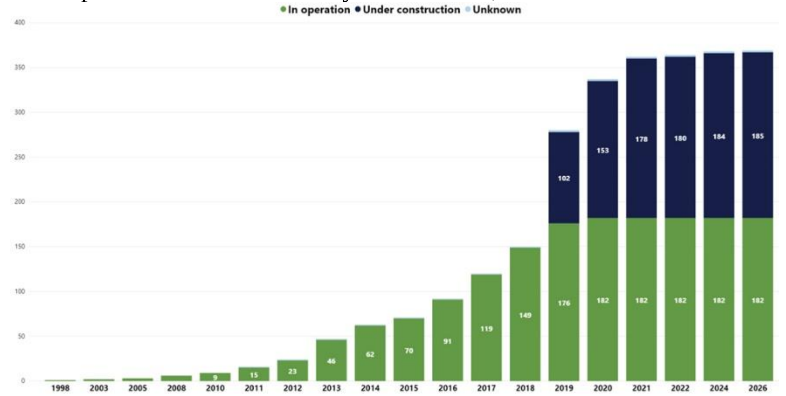
Scrubber types and retrofits vs newbuilds
(Diagram courtesy DNV GL)

Batteries
A smaller number of ships has had batteries fitted.



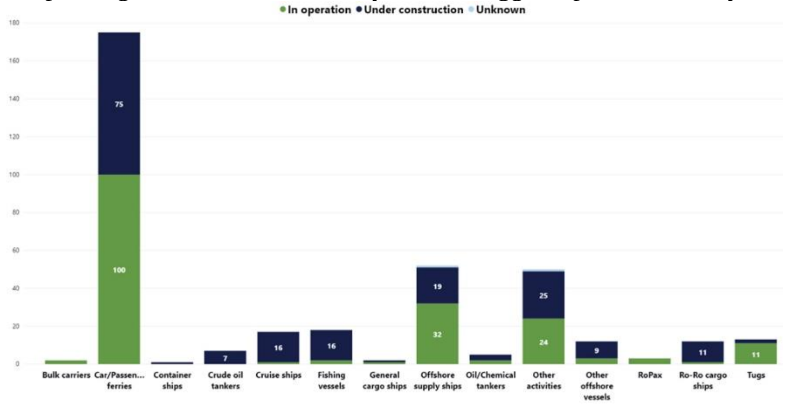
AIS positions of vessels with batteries fitted
(Map courtesy DNV GL)

There are currently 369 ships confirmed with battery installations, and more are under construction.



Confirmed and battery installations under construction
(Diagram courtesy DNV GL)

By vessel type, car and passenger ferries have currently had the biggest uptake of battery installations.



Battery installations by vessel type
(Diagram courtesy DNV GL)

Regulations on the Horizon

IMO is not the only regulator with works in the pipeline. Coming regulations include

- Invasive species and hull bio-fouling, with an increasing focus on biofouling.
- Particulate matter & NOx: the EU focus is on PM2.5and NOx emissions in their own coastal areas.
- Underwater noise, primarily driven by concern for cetaceans.
- Ship recycling, with the EU regulation already in force, and the Hong Kong Convention moving slowly.
- Plastics from ships—work has started, with completion towards 2025.

Expect an increasing number of domestic, port and local regulations!

IMO strategy and Workplan on GHG Reductions

The IMO strategy will start to impact vessel design and operation in the early 2020s. Energy efficiency and logistics measures matter, but development and widespread use of carbon-neutral fuels is critical. Ships have changed a lot over the last 150 years, and further radical changes can be expected by 2050!

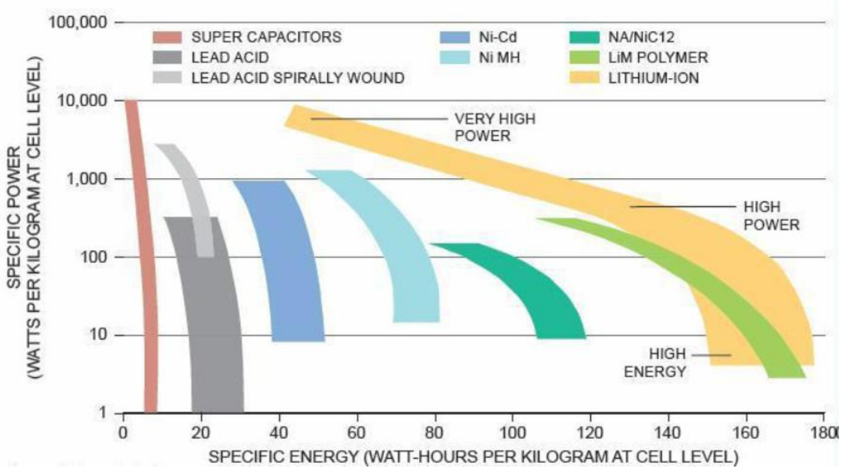
The Propulsion Energy Transition for High-speed and Light Craft

Here Adam took over the presentation, saying that there are many new developments in marine propulsion energy. DNV GL is leading the charge in supporting research, development and application to ships and—of particular interest to the Australian industry—to High Speed and Light Craft (HSLC). The global maritime market is being driven towards significant reduction in greenhouse gas (GHG) emissions, with IMO targeting for shipping to reduce GHG emissions by at least 50% of 2008 levels by 2050. This target will need to be addressed by all shipping segments, and Australia's significant contribution to the high-speed and light craft of the world can be part of the solution. This will require energy-efficient measures and the uptake of fuels with high GHG-reduction potential and/or propulsion systems which make use of batteries and hybrid installations. There are many challenges to be addressed for such measures, and how these are tackled will fundamentally change how HSLC vessels are designed, operated, and fuelled. Among the new technologies are batteries, fuel cells and gas fuel installations.

Batteries

Looking at some of the battery chemistries, we find the following:

- Lithium cobalt oxide ($LiCoO_2$): High energy density, but lower power (rate) capability and short cycle life.
- Lithium manganese oxide spinel ($LiMn_2O_4$): High power, low energy capacity and short cycle life at higher temperatures, but high thermal stability.
- Nickel Manganese Cobalt Oxide ($Ni_{1-x-y}Mn_xCo_yO_2$): Dominant technology in the electric vehicle industry; modifiable chemistry (tweak power and energy properties) and high cycle life.
- Lithium iron phosphate ($LiFePO_4$): Low energy density, low power capability, and reduced risk of thermal runaway due to lack of oxygen at the cathode.



Energy and power density for various battery technologies
(Diagram courtesy DNV GL)

Main Principles of DNV GL Rules Relevant to Batteries

Battery Management System

This comprises the control, monitoring and protective functions of the battery system. It must monitor the system voltage, state of charge, state of health, temperature, and voltage balance between cells.

Ventilation

Abuse or failure causes lithium-ion batteries to generate gases followed by combustion events. The off-gases are possibly corrosive, toxic and flammable, as well as potentially explosive. Design should therefore prevent build-up of flammable gases or dispersion of toxic gases to other ship compartments.

Power System Integration

The battery installation must be properly integrated into the power system, which may consist of shore connection, generators, distribution and consumers.

Fire Protection

Battery fires may comprise different substances, including solid combustibles (often categorized as Class A fires), flammable combustible liquids (Class B) and electrical fires (Class C) or metal (Class D). Due to the importance of heat dissipation, water is often being selected as the preferred cooling medium.

Thermal Management System

Battery systems may produce significant quantities of heat. They can be sensitive to operation at high temperature, which can pose both a safety risk and a performance risk leading to accelerated degradation. Many battery systems require cooling systems

Inverter

Battery systems operate electrochemically, using DC power, and therefore require an inverter or power converter in order to interface with an AC ship distribution system. The battery can be installed on any bus or switchboard on the ship, allowing a great deal of flexibility with regard to placement.
Here Adam showed photographs of what a battery fire looks like, starting with significant off-gas after impact, well beyond any recoverable state. This progresses with the off gases igniting and the packaging beginning to burn, and the rest of the battery will inevitably be consumed.

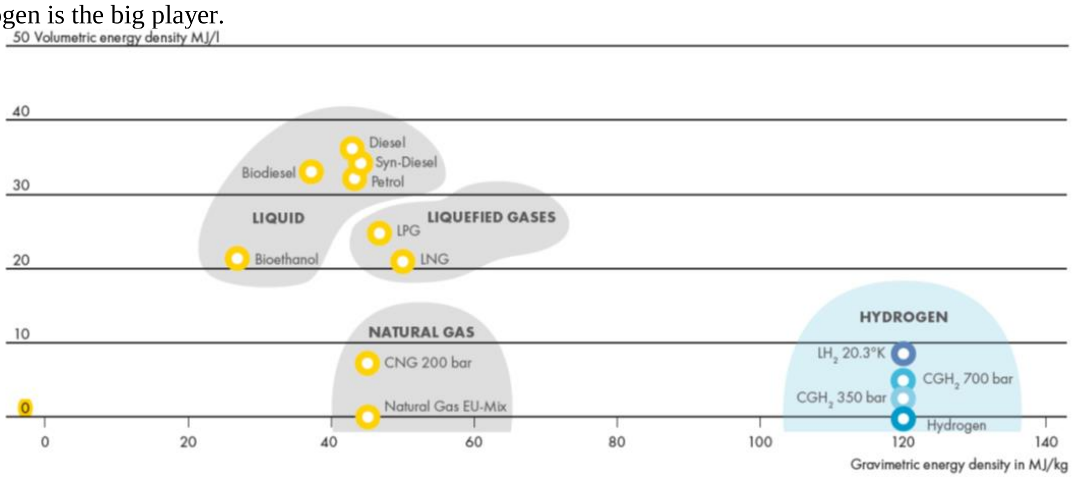
Norwegian Vessels
Vision of the Fjords is a Norwegian catamaran vessel, launched in 2016, launched in 2016 and carrying 400 passengers on the Flom–Gudvangen route. She has a diesel hybrid power system with two 150 kW electric motors and 600 kWh batteries giving a service speed of 19 kn.

Vision of the Fjords
Photo courtesy DNV GL)

A sister vessel, *Future of the Fjords*, launched in 2018 and carrying the same 400 passengers, is all-electric, with two 450 kW electric motors and 1800 kWh batteries giving a service speed of 16 kn. She berths alongside a "Powerdock" which has 5.5 t of batteries which trickle charge during the day, but can re-charge the ship's batteries in 20 minutes while alongside, and the ship is then back on the run.

DNV GL Rules for Batteries
The DNV GL rules for batteries are contained in Part 6 Chapter 2 Propulsion, Power Generation and Auxiliary Systems.
The rules contain requirements for redundancy and location. In addition, the time or range that the battery can supply energy shall be calculated and taken into account for the planned operation/voyage.

Fuel Cells
Fuel cells convert energy by interchanging ions and electrons. They have the advantages of low emissions to air, high efficiency (especially in part load), low vibration excitation and low noise emissions.
Typical fuel cells use hydrogen, helium, methane or nitrogen. The energy density of these fuels shows that hydrogen is the big player.



Energy density of fuels
(Diagram courtesy Shell Hydrogen Study)

Adam also showed a number of charts showing the density of the gases, their diffusion in air, energy content, flammability range and minimum ignition energy.

Aquon One is a 63 ft (19.2 m) luxury vessel using hydrogen fuel cells and, in addition, produces additional energy from solar power. This allows the yacht, designed by Swiss Sustainable Yachts, to cruise in silence and be energetically self-sufficient for several days. At full speed, she is expected to reach 18 kn. She will become the first multihull yacht on the market powered by solar power and green hydrogen, and DNV GL will certify the vessel's hydrogen system and propulsion system [*see https://www.aquon.ch/news/tomorrows-superyachts-exploring-alternative-technologies/?lang=de for more details and an image of the vessel* — Ed.]

Race for Water is a vessel using fuel cells coupled with battery power and wind [*see https://blog.nationalgeographic.org/2017/01/26/race-for-water-launches-its-second-odyssey/ for photographs of the vessel which was designed by LOMOcean Design, built by Knierim Yachtbau in Kiel, Germany, and has a top speed of 14 kn* — Ed.]

Water go Round is a 70 ft (21.3) m catamaran designed by Incat Crowther and carrying 84 passengers with a high-visibility window arrangement. She houses an array of 264 kg tanks of 250 bar compressed hydrogen on the upper deck, providing up to two full days of operation. She has two 300 kW shaft motors (one in each demihull), and 100 kWh batteries in the hulls provide boost power to achieve 22 kn. This project was supported by the California Climate Investments program.

Water go Round
(Photo courtesy Incat Crowther)

Regulatory Situation

The IGF Code entered into force 1 January 2017 and is mandatory for all ships using gas as fuel (not to be mistaken for gas carriers which follow the IGC Code). Other low-flashpoint fuels are allowed, and approval is based on an alternative design approach. The IGF Code is currently extended for methanol, low-flashpoint diesel and fuel-cell systems (storage of hydrogen will not be covered).

There are no fuel-specific requirements for hydrogen, and no prescriptive hydrogen requirements are available. The applicable part of the IGF Code (Part A) requires that an "alternative design" approach be followed.

Alternative Design

SOLAS Regulation 55 provides a methodology for alternative design and the arrangements for machinery, electrical installations and low-flashpoint fuel storage and distribution systems. It refers to *Guidelines for the approval of alternatives and equivalents as provided for in various IMO instruments* (IMO Document MSC.1/Circ.1455).

The safety, reliability and dependability of the systems shall be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery (IGF 3.2.1).

DNV GL Rules for Fuel Cells

The DNV GL rules for fuel cells are also contained in Part 6 Chapter 2 Propulsion, Power Generation and Auxiliary Systems.

The scope of the Fuel Cell notation includes requirements for the design and arrangement of fuel-cell power installations and the spaces containing such installations. It covers all aspects of the installation from primary fuel supply up to, and including, the exhaust gas system. The following are also covered:

- reformers used to convert liquid or gaseous primary fuels to reformed hydrogen rich gas;
- control, monitoring and safety systems; and
- manufacture, workmanship and testing.

The use of fuel cells is currently not covered by international conventions, so such installations will require additional acceptance by the flag authorities.

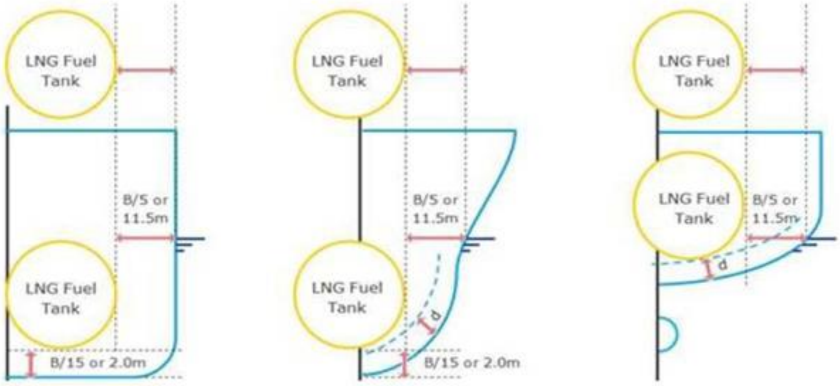
Gas Fuel Installations
The principal player in the field is liquefied natural gas (LNG), which is natural gas (predominantly methane, CH_4, with some mixture of ethane, C_2H_6) which has been cooled down to liquid form for ease and safety of non-pressurized storage or transport. It takes up about 1/600th the volume of natural gas in the gaseous state (at standard conditions for temperature and pressure). It is odourless, colourless, non-toxic and non-corrosive. Hazards include flammability after vaporisation into a gaseous state, freezing and asphyxia. The liquefaction process involves removal of certain components, such as dust, acid gases, helium, water, and heavy hydrocarbons, which could cause difficulty downstream. The natural gas is then condensed into a liquid at close to atmospheric pressure by cooling it to approximately −162°C; maximum transport pressure is set at around 25 kPa.
Francisco is a 99 m wave-piercing catamaran ferry designed by Revolution Design and built by Incat Tasmania, capable of carrying 1024 persons (passengers and crew) and 450 t deadweight. She is powered by LM2500 gas turbines capable of running on LNG and distillate, giving a service speed of 51.8 kn.

Francisco
(Photo courtesy Incat Tasmania)

Main Principles of DNV GL Rules Relevant to Gas Fuel Installations
Segregation
The gas fuel installation must be protected from external events: Collision/grounding, away from high fire-risk areas, away from areas which may cause mechanical damage (cargo operations, crane lifting, etc.), and away from explosion risk.
Double Barriers
The ship must be protected against leakages of gas: Second barriers for tanks (depending on tank type, but not for Type C tank), hold space and tank connection space (no need for the fuel tank in open deck), secondary enclosures for fuel piping, and fuel-preparation room for holding fuel piping.
Leakage Detection
To give warning and enable automatic safety actions: Low temperature or gas detection in the tank connection area, fuel preparation room, secondary enclosures, glycol expansion tank and in engine room.
Automatic Isolation of Leakages
To reduce consequences of a leakage: Fuel gas safety system for emergency shut-down of fuel supply and bunkering and isolate ignition source.

Collision Protection
The fuel tank shall be protected from external damage caused by collision or grounding (IGF Code):

- Minimum distance from side: B/5 or 11.5 m (whichever is less) 5.3.3.1.
- At no point closer to sides/bottom than B/10 but in no case less than 0.8 m. However, this distance need not be greater than B/15 or 2 m (whichever is less) where the shell plating is located inboard of B/5 or 11.5 m, whichever is less, as required by 5.3.3.1.



LNG tank location
(Diagram courtesy DNV GL)

Tank Types

Type C tank: Designed for pressure build-up; commonly used in LNG-fuelled ships; leak-free tank, leaks only possible from valves.

Type B tank: Only minor leaks from the tank structure possible; limited liquefied gas release has to be handled.

Type A and membrane tank: Complete first barrier failure not excluded; liquefied gas release has to be handled.

Only type C tanks have been applied for ship fuel tanks so far, but ships with prismatic tanks will soon be a reality.

Machinery-space Concepts

A gas-safe machinery space requires fully-enclosed, gas-tight double-wall pipes in the engine room , all the way to the combustion chamber. The room around is an ordinary machinery space without special requirements. The concept is mandatory for high-pressure piping (< 10 bar) but can also be used with low-pressure installations. A single failure will not lead to the release of fuel gas into the machinery space, because all leakage sources are protected by a second barrier.

An emergency shut-down (ESD)-protected machinery space is considered gas safe in the normal mode, but changes status to gas dangerous on detection of gas. There is a single barrier against leakage (i.e. no double-walled pipe required). There are leakage detection and extended ventilation requirements, and the pressure in the gas supply lines must be less than 10 bar. Explosion analysis is required for ESD-protected machinery spaces. Because of the shut-down requirement for an ED-protected machinery space, the power generation for propulsion and manoeuvring must be divided between two or more engine rooms which are independent of each other.

Bunkering

The bunkering process involves initial pre-cooling of the LNG, arrival and mooring of the vessel, connection of hoses, inerting of the system, transfer of the LBG, draining and inerting of the system, disconnection of hoses, and departure of the vessel.

The bunkering stations require natural ventilation; closed or semi-enclosed bunkering stations are subject to special consideration, i.e. forced ventilation, segregation, CCTV etc.

Regulatory Situation

The IGF Code entered into force 1 January 2017, and practically all LNG-fuelled ships ordered after the adoption of the IGF Code in June 2015 follow this code. It is mandatory for all ships using gas and other low-flashpoint fuels. There are detailed requirements for natural gas (LNG and CNG).

DNV GL Rules for Gas Fuel Installations

The DNV GL rules for gas fuel installations are also contained in Part 6 Chapter 2 Propulsion, Power Generat5ion and Auxiliary Systems.

Section 5 Gas Fuelled Ship Installations, Notation GAS FUELLED LNG
Section 6 Low Flashpoint Liquid Fuelled Engines, Notation LFL FUELLED
Section 13 Gas Fuelled Ship Installations, Notation GAS FUELLED LPG

Gas fuelled LNG notation, LFL Fuelled and Gas fuelled LPG

The scope for these additional class notations includes requirements for the ship’s gas fuel system, covering all aspects of the installation, from the ship’s gas fuel bunkering connection up to and including the gas consumers.

This section has requirements for arrangement and location of gas fuel tanks and all spaces with fuel gas piping and installations, including requirements for the entrances to such spaces. Hazardous areas and spaces, due to the fuel gas installations, are defined. Requirements for control, monitoring and safety systems for the fuel gas installations are included

Conclusion

The transition to alternative fuels in the marine industry is being driven by the IMO target to reduce GHG emissions by at least 50% of 2008 levels by 2050. This target will need to be addressed by all shipping segments, and Australia's significant contribution to the high-speed and light craft of the world can be part of the solution. Principal among the alternative fuels are batteries, fuel cells and liquefied natural gas. DNV GL is leading the charge in supporting research, development and application of all of these to ships.

Questions

Question time was lengthy and elicited some further interesting points.

Jonathan Abrahams (L) and Adam Williams (R) accepting their certificates
and "thank you" bottles of wine from Graham Taylor
(Photo Phil Helmore)

The vote of thanks was proposed, and the certificate and "thank you" bottle of wine presented, by Graham Taylor.

The presentation was recorded and is now available as a webcast at
https://www.youtube.com/channel/UChb1sfHbWfQmG-iwpp_QGJg/videos?view=0&sort=dd&flow=list&live_view=500