



Current & Emerging Trends and Technologies

Scottish Maritime Cluster

29th March 2019

Marine

Land

Aviation

Nuclear

www.babcockinternational.com



Agenda

- Brief Introduction to Babcock
- What is driving change in the Maritime Industry?
- What are the options/solutions to meet these changes?
- Adjacent Technologies
- Future Direction

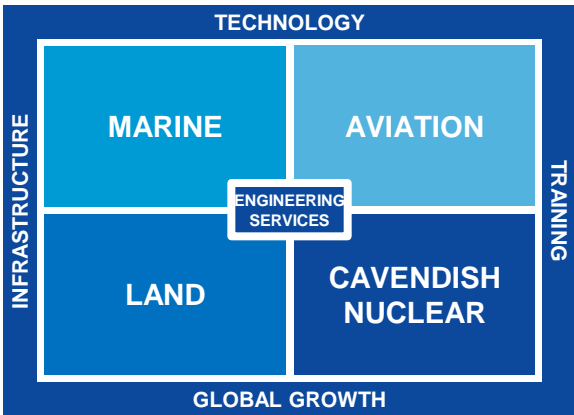


Babcock International - at a Glance

Operations in over **25 countries** across **six continents**

Employing a workforce of over **35,000** skilled personnel

Aerospace and Defence company



Revenue of over **£5.3 billion** In 2017/18

listed on the London Stock Exchange

Trusted to deliver services that are **complex, critical and bespoke**

Order book and pipeline of **c £31 billion**

Established in **1891**



Babcock LGE – at a glance

Rosyth
(near Edinburgh)
Scotland

Revenue growth
to more than
£100m by
development
and application
of Innovative
Technology

**Patents &
applications**
in multiple
countries for
LPG,
Ethane,
Ethylene
and LNG

Engineering
Procurement
Project
Management

100 people
80% with
Engineering
qualifications

**Our
customers
are world's
biggest
commercial
shipyards in
Korea, China
and Japan
and tier 1
ship-owners**

2016 winners of two **Queen's
Awards** *International Trade &
Innovation*

**Established
in 1967**

11 nationalities

Before we look at the technology.... ...what is driving change?

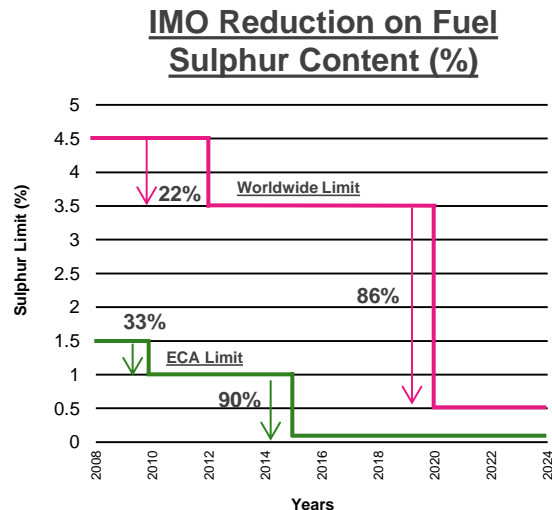


- Regulation / Environmental
 - UN COP Conferences (COP21, COP24)
 - International Maritime Organisation (IMO)
- New Technologies
 - Alternative fuels
 - Pollution mitigation systems
- Cost
 - Future price of fuels.....and the cost of doing nothing!
 - Market demand for efficiency improvements – lower footprint, less waste



Regulations will force change...

- **IMO 2020 Sulphur Emission Restrictions**
 - Marine fuels with a maximum sulphur content of 3.5 wt% is the current global maximum
 - In 2020, limit will be set to 0.5% SO_x emissions worldwide (ECAs remaining at 0.1%)
 - This reductions is estimated to save 40,000 lives on a global basis after 2020
- The industry will need to react!...there will be no transition period...
 - Financial Penalties
 - Reputational Damage
 - ...However, opportunity for Commercial Engagement...



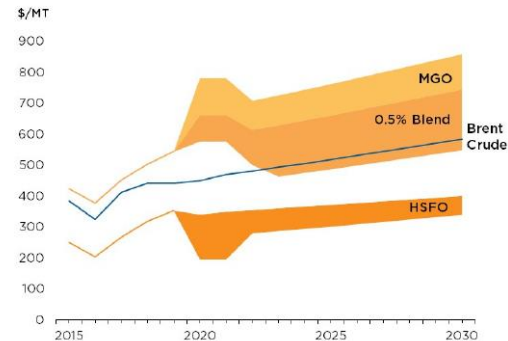


What Options do we have to meet these reductions...?

• Compliant Fuels / Low Sulphur Fuel Oil (LSFO)

- Advantages;
 - Minimal infrastructure work on the vessel
 - Minimal operational impacts for crew
 - Up to 80% of world fleet expected to opt for this
- Disadvantages
 - Unknown cost ; Supply vs Demand
 - Quality concerns due to blended products
 - Availability of supply

Illustration of future fuel price range



Source: World Energy Outlook 2016, Marakon analysis



What Options do we have to meet these restrictions...?

- **Exhaust Cleaning Gas Systems (Scrubbers)**
 - Advantages;
 - Allows continued used of 'standard' marine fuels
 - Cheaper than retrofit solution
 - Disadvantages
 - Expensive/large footprint to install
 - Doesn't solve the problem – 'displaces it'
 - Open-loop scrubbers are banned for certain ports
 - Additional power (~4%) consumption to run Sea Water Pumps
 - Exposure to future IMO rules on pollution
 - Supply of HFO could be limited





What Options do we have to meet these restrictions...?

• **Alternative Fuel Sources**

- Using alternative fuel sources which don't contain any Sulphur; no issue with meeting restrictions.
- Currently, LNG is the primary 'alternative fuel source' however, likely to only be a bridging fuel whilst other solutions are developed, e.g. hydrogen, methanol, ammonia, bio-fuels
- **Advantages;**
 - Greater security on fuel prices
 - LNG is readily available globally
- **Disadvantages**
 - Expensive to install
 - Operational impact for ships crew, ie. new system



Alternative Fuel Sources; Gas Carriers...using gas!

- **LPG Carriers (LPGC) / Ethane Carriers (VLEC)**

- Relaxation in IGC Code rules allows for LPG cargoes (and other non-toxic cargoes) to be used a fuel source
- MAN-ES develop LPG and Ethane Dual-Fuel engine
- Gas Ship Owner Exmar opt for newbuilding LPGC with Dual-Fuel engine, BW Gas opt to retrofit 4 LPGC built in 2015
- Navigator Gas retrofit Navigator Aurora to Ethane fuelled
- Potential opportunity here;
 - Cargo/Fuel conditioning and metering
 - Cargo/Fuel supply
 - Bunkering vessels...?

LNG - Bunkering Vessels

- LNG bunkering via a Gas Supply Vessel (GSV) is an option for LNG fuelled vessels – there are 436 LNG or LNG ready fuelled vessels in the world (March 2019)
- The 7,500 cbm 'Kairos' is a GSV (the largest in the world) that Babcock is a 50% Owner of as part of Babcock Schulte Energy (BSE) Joint Venture
- Babcock has developed patent pending *FGSV0*TM system with zero emissions to atmosphere during normal operations.
- With *FGSV0*TM, boil off gas and flash gas from LNG bunker fuel transfer operations are compressed and stored as CNG and used as fuel when required.
- Babcock are committed to a clean energy solution for the maritime industry, hence the *FGSV0*TM design and capital investment in Kairos





Alternative Fuel Sources; Gas Carriers...using gas!

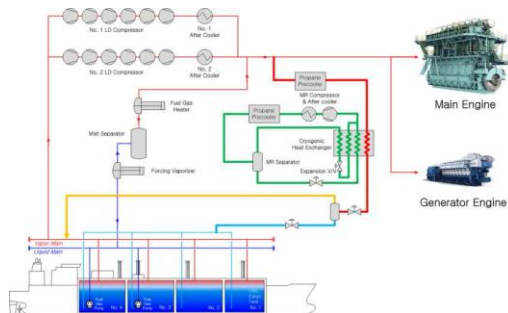
- **LNG Carriers (LNGC)**

- Standard LNGC use LNG Boil-off Gas (BOG) a fuel
 - This has been the norm for ~50 years
- Whilst this is therefore not an 'emerging market', new technology and vessel operating profiles has created new opportunities;
 - Increased efficiency of main engine = **excess BOG**
 - Increased performance of tank insulation = **reduced BOG**
 - Ship operating profiles have changed; longer periods of slow steaming and increased laden idle periods = **excess BOG**
 - Result = increased total BOG that needs managed; either incinerated through a Gas Combustion Unit or, reliquefied...

LNG Reliquefaction Technologies

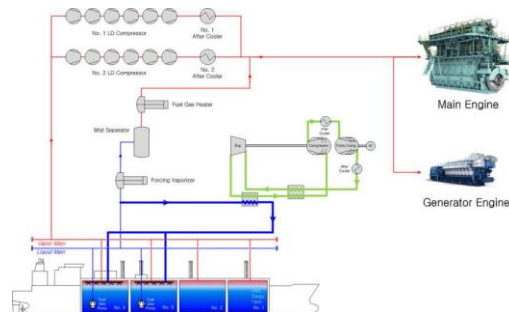
Reverse Brayton Nitrogen Plant

- Simple cycle but added complexity of compander for power recovery
- Low efficiency with poor COP resulting in high power consumption



Mixed Refrigerant (MR) Plant

- Requires external pre-cooling
- Multiple pieces of rotating equipment
- Risk of oil contamination of the PFHE



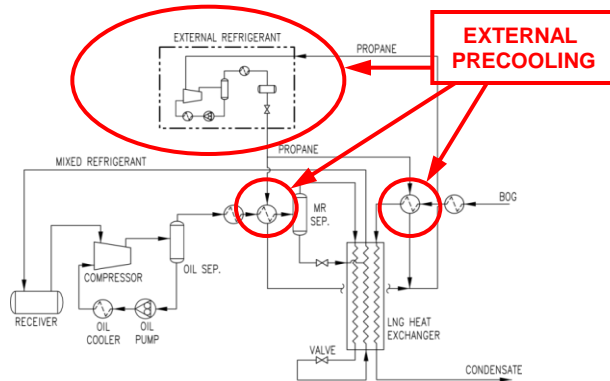


Babcock LGE ecoSMRT®

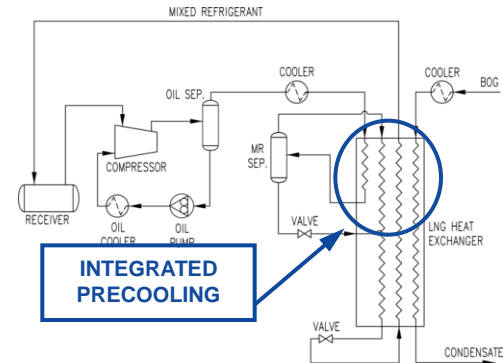
- Babcock LGE developed ecoSMRT®, an MR system that removes the need for additional equipment and, provides significant improvements
- ecoSMRT® is a disruptive technology within the LNG marine market, proven with over 20 systems sold in less than a year (35-40% total market)
- ecoSMRT® (Single Mixed Refrigerant Technology) was designed with the following objectives compared to similar MR systems;
 - Reduce CAPEX - reduced equipment & footprint by 40%
 - Reduce OPEX - reduced rotating machinery
 - Improve Performance - delivers up to 35% more reliquefaction capacity per kW absorbed power

ecoSMRT[®] – Design Development

Typical LNG MR Reliquefaction



ecoSMRT[®]



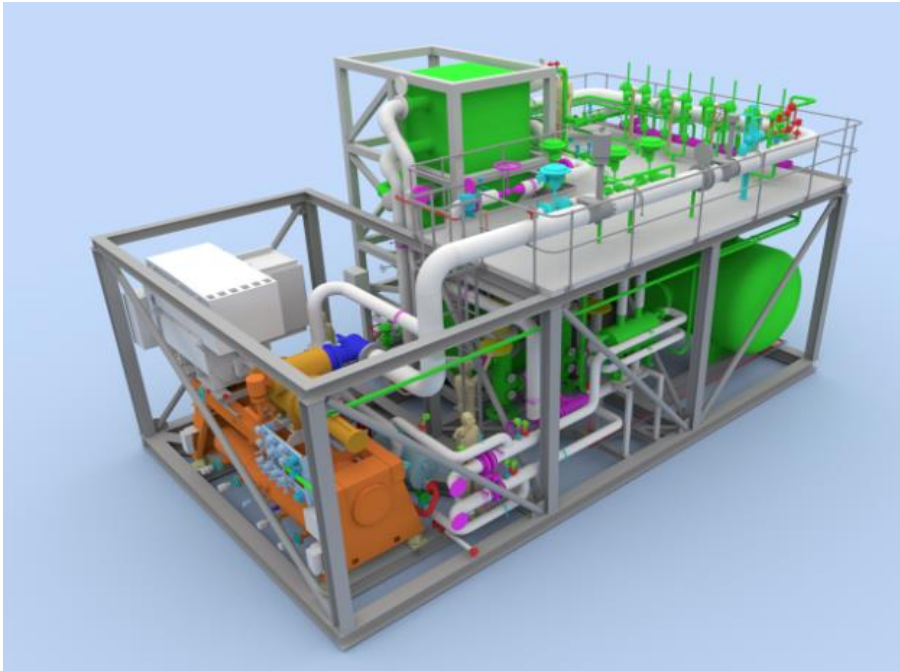
- Removal of secondary refrigeration loop comprising:
 - Screw compressor / motor and oil management system
 - Five heat exchangers
 - Additional pressure vessels



- Integrated cooling leads to a much simpler process and control system
- 40% reduction in footprint
- 50% reduction in maintenance
- Developed to use known and proven technology (no prototyping)



ecoSMRT[®] - Plant Visualisation





Future Direction

- **Ammonia (NH₃) Dual-Fuel Engines**

- Driven by the future IMO legislation on CO₂ emissions (reduce CO₂ emissions by 50% by 2050)
- One of the most widely traded commodities worldwide

- **Hydrogen (H₂) Fuel**

- Use as a marine fuel is still in its infancy – first hydrogen fuelled vessel due 2021
- Lot of work to be done (infrastructure, fuel handling, safety issues) but, '*fuel for the future*'

- **Carbon capture storage (CCS)**

- Been 'discussed' for a number of years but, following COP 21 and COP 24, 'something' is required
- CO₂ Carriers will be required; new vessels, modified technology, systems etc



Conclusion

- Legislation is driving change
 - Has and always will however, as we develop our understanding of environmental impacts, legislation will force further new technology
- Scrubbers / LS fuels / Alternative fuels
 - Options to meet legislation – pros and cons for each
- New Technology will breed New Opportunities
 - However, business justification is required if technology to develop on large scale.
- CO₂ 'management' will be the next step-change for the industry
 - Regulations such as IMO GHG regulations, EEDI and EU MRV on CO₂ will force the industry to consider new ways to mitigate carbon emissions

babcockTM