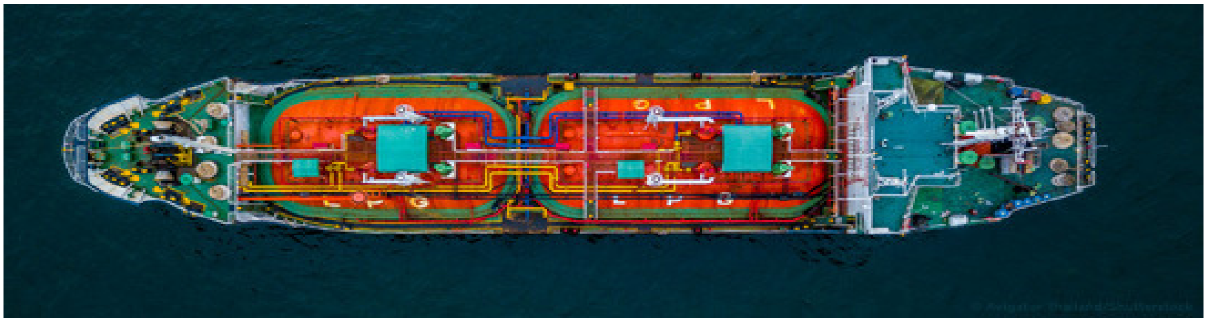
Environmental Compliance: Getting to a Decision

Event Date: December 6, 2018
Location: Marriot Hotel Asia, Istanbul
Time: 09:00 – 13:00. Followed by lunch.



ABS SEMINAR

Environmental Compliance: Getting to a Decision

ABS

6 December 2018
Marriott Hotel Asia | Kayısdağı Cad. No.1 Kozyatağı | 34752 Istanbul

You are cordially invited to attend an ABS seminar where ABS environmental compliance specialist will be on-hand to discuss the outcomes of MEPC 73 and the implications to the marine industry.

In an ever-changing regulatory landscape, shipowners, operators, and builders must manage compliance with numerous regional, domestic and international environmental requirements, while also minimizing operational impacts.

Additionally, we will explore each of the major 2020 compliance options – scrubbers and compliant fuels – examining the installation and operational challenges and safety impacts associated with each.

This is an invitation-only event and attendance is free.

Complimentary refreshments and lunch will be provided.

To register your attendance please contact:

- Contact: Miss Reyhan Cinbat
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OR

- Contact: Miss Gözde Akpinar
  - Tel: +90-216-651-16-93
  - Email: GAkpinar@eagle.org

Please register by Monday 3 December.

AGENDA

09:00	Registration and Coffee
09:30	Welcome and Introduction Seyfettin Tatli, ABS
09:35	MEPC73 Update Stamatis Fradelos, ABS
10:10	SIP/Risk Assessment Stamatis Fradelos, ABS
10:30	Coffee Break
10:45	Scrubber Briefing Stamatis Fradelos, ABS
11:00	LPG as Fuel Stamatis Fradelos, ABS
11:15	BWMS Operation Survey Stamatis Fradelos, ABS
12:00	Questions and Answers
12:30	Close

Guidance on Development of Ship Implementation Plan

Stamatis Fradelos, Director Business Development | November 2018

Guidance on Development of Ship Implementation Plan

- MEPC73 approved Guidance on the development of a ship implementation plan for the 2020 consistent implementation (MEPC.1/Circ.878)
  - risk assessment and mitigation plan (impact of new fuels)
  - fuel oil system modifications and tank cleaning (if needed)
  - fuel oil capacity and segregation capability;
  - procurement of compliant fuel;
  - fuel oil changeover plan
  - documentation and reporting
- The Committee agreed that reference to "*practical and pragmatic approach by port State control authorities*" not be included in the MEPC circular.

Node: 1. Fuel quality

Consequence	Risk Ranking			Effective Safeguards	Recommendations
	S	L	RR		
4. Fuel pump sticking, potential loss of propulsion if not rectified in time	5	3	N	corrective action (change of fuel batch)	
1. Potential wax formation, loss of fuel supply to engine due to blockage, loss of propulsion - For vessel operating in cold environment	5	5	U	1. Testing	15. Develop and provide crew training regarding use of fuel with low Sulphur content (example topics to include are: cold flow properties, compatibility, changeover, viscosity, use of proper lubrication)
2. Potential wax formation, loss of fuel supply to engine due to blockage, loss of propulsion - For vessel operating in warm environment	5	2	C	2. Heating as needed	
1. Equipment damage and potential engine performance issues	3	3	C	1. Temperature and viscosity monitoring	23. Consider means to maintain required fuel oil temperatures to maintain fuel oil viscosity. (e.g. coolers) Inadequate fuel viscosity can lead to equipment damage and potential engine performance issues.
				2. Manufacturer recommended practices	15. Develop and provide crew training regarding use of fuel with low Sulphur content (example topics to include are: cold flow properties, compatibility, changeover, viscosity, use of proper lubrication)

Risk assessment - impact of new fuels

- Fuel quality
  - Compatibility
  - Stability
  - CAT fines
  - Combustion characteristics
  - Density
  - Flash point
  - Procurement
  - Unusual components
  - Cold flow properties
  - Viscosity
  - Acidity
  - Lubricant selection
- Fuel transfer system
  - Fuel transfer pump specification
  - Leakage
  - Existing piping valves and instrumentation
- Fuel oil storage
  - Cleaning and flushing of tanks
  - Tank level gauges
- Combustion equipment
- Fuel changeover
- Documentation

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Fuel Quality - Compatibility / Stability

- Asphaltene and heavy sludge formation in the fuel oil system, potential blockage and loss of fuel supply
  - Ensure operating procedure include a step stating to use empty tank for bunkering a new fuel with different sulphur content to avoid fuel mixing of different blends in a tank
  - For new vessels: multiple storage tanks with dedicated fuel piping to prevent fuel commingling.
  - On board testing kit to test compatibility of bunker fuel with existing fuel in tank
  - Monitor developments on the new fuel quality standards and develop plan to adopt new standards.
  - Stratification capability in storage tank to prevent asphaltene buildup
  - Regular sampling (TSE/TSA in addition to TSP) of fuel if stored for long duration

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Fuel Quality - Cat fines

- Engine wear/damage, engine liner maintenance issues, operational issues, financial impact
  - Fine filter (10 micron) before engine
  - Procedure to handle CAT fines in fuel before fuel injection (potential options include: monitoring temperature of settling tank, additional time for settling, flow rate adjustment, sampling)
  - 2 purifiers in parallel
  - Considering settling and service tank with slop bottom
  - Considering service and settling tank cleaning on regular basis
  - Policy to not use the fuel before lab test result
  - Purification system test whenever new fuel is introduced to ensure purification system is defect free and is available to remove CAT fines from the incoming new fuel
  - Considering developing industry wide database on fuel quality statistics

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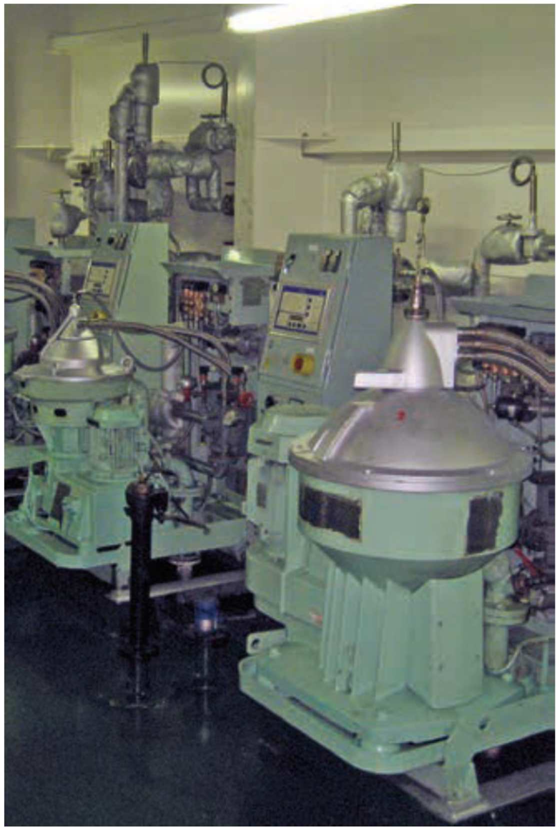
Fuel Quality - High Density/Low Flash point/Procurement

- High Density - Improper purification
  - Follow purifier manufacture recommendations on density
  - Maintenance for purification system for use of different density fuels
- Low Flash point - Potential for increase fire hazard
  - Ability to bypass heater / steam tracing
  - Follow handling requirement from laboratory
  - Update fuel management plan regarding use of fuel
  - Review hazardous area classification considering the use of the fuel with low flash point
- Procurement
  - Develop fuel purchasing procedure and provide plan of action if the compliant fuel is not available
  - Steps taken to ensure that the charter party provides timely delivery of compliant fuel
  - Use ISO 8217 and ISO PAS 23263 with required Sulphur content compliant fuel



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Fuel Quality - Unusual components/C.F.P./Viscosity

- Unusual components - Filter plugging
  - GCMS testing in addition to standard testing
  - Perform a test run on A/E with affected fuel to identify any issue
  - Provide spare parts for fuel system and engines
- Cold flow properties
  - Testing - Heating as needed – Crew training
- Viscosity
  - Consider means to maintain required fuel oil temperatures to maintain fuel oil viscosity. (e.g. coolers)
  - Temperature and viscosity monitoring
  - Follow Manufacturer recommended practices
  - Provide automatic control system for viscosity and temperature monitoring

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Fuel Quality – Acidity/Lubricant selection

- High fuel Acidity – degradation of lubricants properties
  - On board testing of lubricants
  - Lab testing
  - Manufacturer recommended practices
- Lubricant selection
  - Consult engine manufacturer to identify issue with lubricant
  - Consider providing suitable counter measure for piston ring to protect against seizure due to use of non-compliant lubricant
  - Provide crew training regarding use of proper lubrication
  - Perform drain oil sampling/monitoring as per OEM recommendation

Fuel oil transfer system

- Fuel transfer pump specification not compatible with new fuel
  - Review with manufactures to identify issue with fuel transfer pump operating on new fuel and provide guidance accordingly
- Leakage - incompatible flange gasket, seals
  - Perform pressure testing on fuel transfer system to identify any leakage
- Existing piping, valves and instrumentation
  - Review fuel system piping arrangement and modify accordingly to support duel fuel requirements.

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Fuel oil storage system

Potential contamination of new fuel oil

- Develop specific instructions for bunkering and use of compliant fuel for first time (e.g. flushing of the fuel system in addition to tank cleaning) to prevent any contamination issues
- Consider performing testing of storage tank bottom sludge content
- Consider option of tank content dilution to avoid confined space entry.
- Consider developing specific cleaning plan for service tank to avoid any impact on commercial operations of vessel as service tank cleaning will require complete shutdown of operations

- Tank level gauges compatibility with new fuel - faulty reading
  - Review tank level gauges and ensure they are compatible with new fuel.
  - Re-calibrate if needed.

Combustion Equipment

Poor performance, damages

- Perform test on A/E with affected fuel to identify any issues and then run the M/E
- Regular overhauling of fuel system equipment
- Consider having two type of fuel on board for emergency

Other:

- Develop and provide crew training regarding use of new fuels
- Providing spare parts for fuel system and engines
- Perform drain oil sampling and monitoring as per engine manufacturer recommendations
- Review and update fuel management plan for the use of new fuel
- Update P&ID to match piping modification done
- Provide clear labeling on piping and valves to identify modifications and fuel segregation
- Define sampling point location requirements

Documentation and Fuel oil changeover

Fuel oil changeover plan

- Ship-specific fuel changeover plan include measures to offload or consume any remaining non-compliant fuel oil
- the maximum time period required to changeover the ship's fuel oil system to use compliant fuel oil at all combustion units
- Expected date and time of completion of the changeover procedure
- Availability of adequately trained officers and crew.

Documentation and reporting:

- The shipboard fuel oil management plan should be updated
- The Ship implementation plan maybe be kept on board and updated
- A procedure for Fuel Oil Non-Availability Reporting (FONAR) about when and how should be used and who it should be reported.
- The capacity plan and stability and trim booklets be updated, if modifications carried out.

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LPG as fuel: Techno-economic study

Stamatis Fradelos, Director Business Development | November 2018

Topics

- Techno-economic Study Scope
- LPG as fuel concept description
- Regulatory Framework
- Approval roadmap
- Results and conclusions

Techno- economic study scope

- Feasibility study for DORIAN LPG on retrofitting existing VLGCs to SOx 2020 compliant
- Life Cycle Cost Analysis (LCCA)
  - Based on;
    - data on vessel trade route, operation profile
    - assumptions of fuel price (sensitivity analysis)
  - Compares the cost effectiveness of;
    - operating with compliant fuel, or
    - converting and operating with LPG as Fuel
  - Generate LCCA KPIs
    - providing a quantitative assessment of an investment

- LPG as fuel Technical Evaluation Study
    - Concept assessed for technical feasibility, design limitations and requirements, operating considerations and restrictions
    - a regulatory framework and approval procedure roadmap
    - specific technical comments and recommendations

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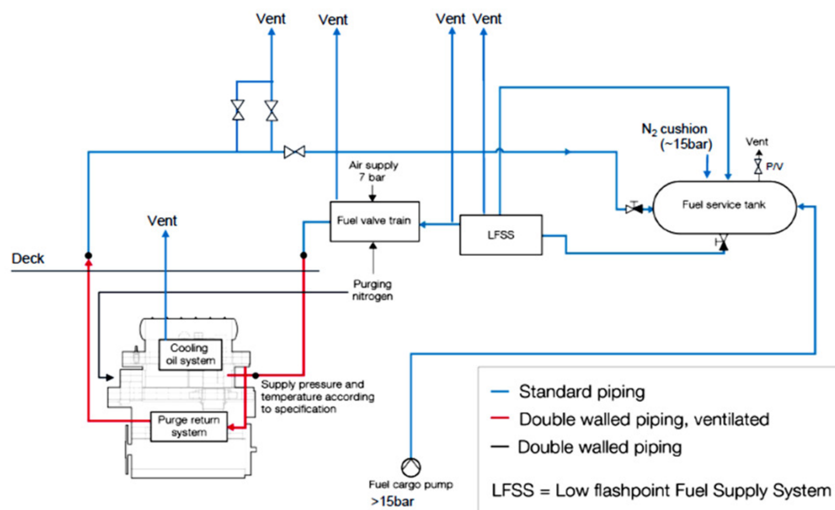
LPG as Fuel Concept Description

- The LPG Fuel Supply System Consists of:
  - One deck storage tank, connected to the cargo system for loading
  - A skid located in a deck shelter on the upper deck hosting the LP and HP booster pumps and one electric heater
  - A master gas valve located in the cargo area
  - Stand-alone control system capable for receiving control signals from the ME engine control system
  - Double wall pipe within the engine room suitable ventilation capacities and gas detection
  - Fuel Valve Train (FVT) outside engine room with block and bleed valves for proper LPG supply stop, purging, draining and inerting
  - Hazardous areas classification and certified equipment selection
  - Emergency Shut-Down (ESD) system philosophy assessed
  - Nitrogen supply provided



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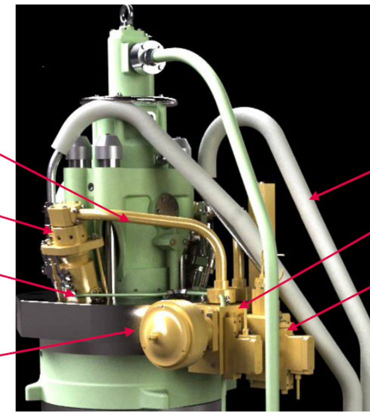
Main Engine LPG as Fuel Concept

- MAN ME-LGI engine;
  - Operates on 2-stroke diesel cycle mode
  - Conventional fuel oil injector plus low flashpoint liquid injector
  - Pilot diesel fuel oil of 5 to 10% at 100% load for ignition
  - LPG fuel supply to injector (liquid state at 40 bar pressure)
  - Hydraulic actuation
  - Separate cooling and sealing function
- Emissions compared to diesel;
  - SOx: 90-95% lower due to no sulphur content in LPG
  - NOx: 15-20% lower due to relatively lower combustion temperature when burning LPG
  - CO_2: 20% lower due to chemistry



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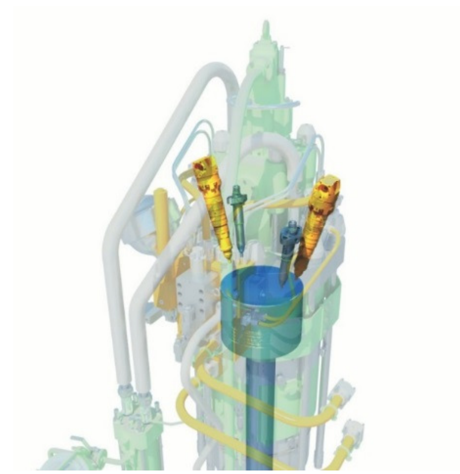


LPG as Fuel: Regulatory Framework

For Gas carriers (IGC) and all other ships (IGF)

Regulatory Framework for the specific project

- The concept assumed retrofitting of existing LPG carriers following the old IGC code (1993 edition)
  - Old IGC code allows only methane to be burned onboard gas carriers
  - Flag Administration would need to agree on applying new IGC code (2014 Edition) Section 16.9 for Alternative fuels and technologies
  - Reference to Section 1.4 of the code and ‘Equivalents’ approach and notifying IMO will most probably needed
  - ME retrofit may not be considered as major conversion as per MARPOL Annex VI/Reg.13;
    - Should remain at the Tier as delivered by the keel laying date (Tier II)
    - Perform emission measurements, update technical file
    - Flag administration confirmation on the above understanding

Approval Roadmap

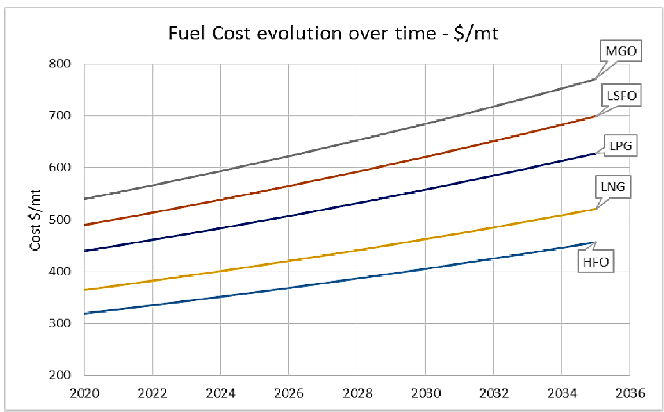
- ME retrofit;
  - ‘Type test’ to be repeated (DF engine), but reduced
  - Integration and demonstration of fitness for purpose test (onboard)
  - Base engine approved as ME-GI variant
  - Electronic Control System (ECS) already approved
- Load line certification, intact and damage stability to be reassessed due to increased lightweight
- Main deck reinforcements and storage tank location, connection arrangements and structures in compliance with ABS LGC guide and IGC code, as applicable
- Gas fuel supply piping, equipment and arrangements should comply with new IGC code (2014 edition), as per chapter 16 section 19
- Additional consequence studies will be needed for;
  - Storage tank bottom connections and low temperature protection (drip trays size)
  - Gas detection and ventilation arrangements and capacity, especially in the engine room (gas dispersion analysis)
  - Emergency shut down system and blow down philosophy (FMEA)
  - Provisions and operating procedures for storage tank and supply system maintenance

LPG as Fuel: Techno- economic study

Life Cycle Cost Analysis (LCCA)

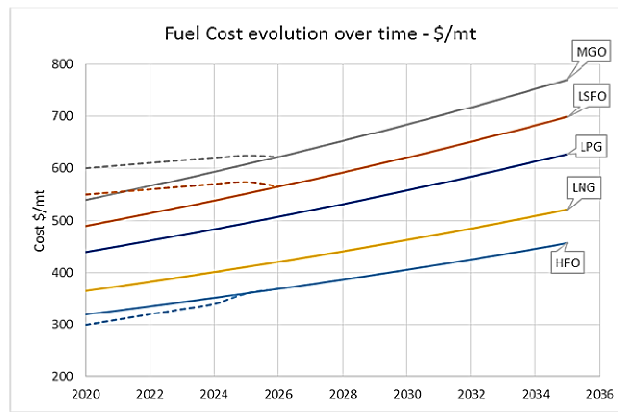
Assumptions

- System Life expectancy 20 years
- Initial Fuel Cost 2020 (2.4% annual increase)
- HFO: $320/mt, LSFO: $490/mt, MGO: $540/mt.
- LPG as fuel: 440 $/mt equivalent to 1 mt MGO



Temporary Increase of LSFO-HFO differential

Fuel Differential	HFO	LSFO	MGO
2020	300$/ton	500$/ton	550$/ton
2021	315$/ton	515$/ton	565$/ton
2022	330$/ton	530$/ton	580$/ton
2023	345/ton	545$/ton	595$/ton
2024	355$/ton	560$/ton	610$/ton
2025	360$/ton	575$/ton	625$/ton



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Assumptions (Cont'd)

Main Engine	Seagoing	Maneuvering	Port/Anchorage
Number Operating	1	1	0
Load (%)	75% - 90%	10% - 30%	0
Annual Running Hours	6,720	240	0

Auxiliary Engine	Seagoing	Maneuvering	Port/Anchorage
Number Operating	1	2	2**
Load (%)	35% - 55%	35% - 50%	75**%
Annual Running Hours	6,720	240*	6,037**

- * Total hours for 2 A/E running
- ** Total of Port and Other (load-discharge-cooling of cargo). ¼ of time with 3 A/E has been added in hours to the 2 A/E

Auxiliary Boiler	Seagoing	Maneuvering	Port/Anchorage
Number Operating	0	1	1
Load (%)	-	-	-
Annual Running Hours	0	240	763*

- * Total of port and other (load-discharge cooling of cargo)

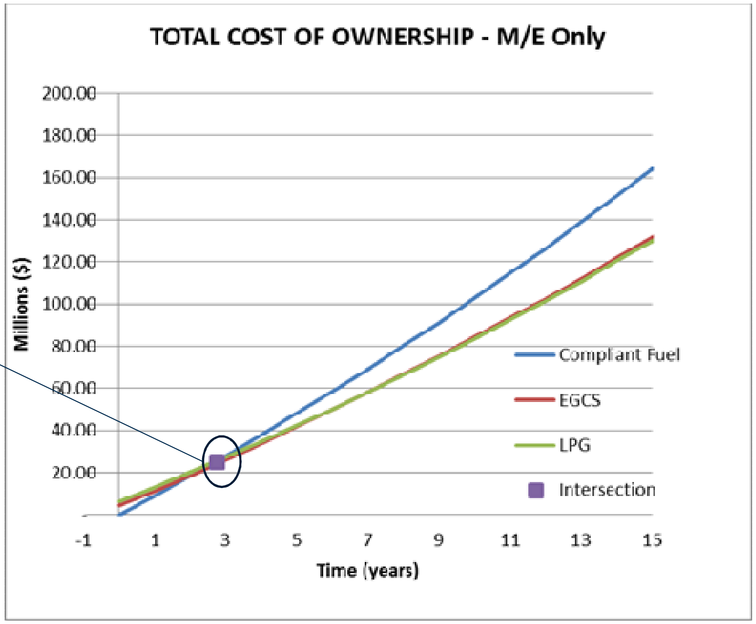
Fuel Consumption	M/E	A/E	A/B
Seagoing	1.90 mt/h	0.15 mt/h	0 mt/h
Maneuvering	0.63 mt/h	0.31 mt/h	0.23 mt/h
Port/Anchorage	0 mt/h	0.46 mt/h	0.23 mt/h

- 22% of time per year in ECA zones
- Based on the available data, there is around 7% gain in consumption in gas mode (including pilot fuel). Based on this, and $440/t LPG, annual saving $325,000

LCCA Results

- Simple Payback Period:

SPP	M/E Only
Compliant Fuel vs LPG	3.1 years



- Discounted Payback Period:

LPG	Discounted Payback Period
M/E Only	3.2

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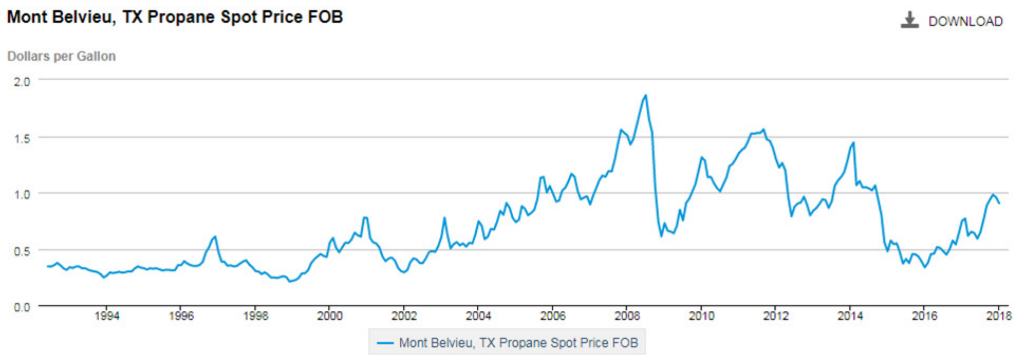
Future evolution of LPG

- Evolution of Propane price over last 25 years → Average approx. $360/mt



- Shale exploration boom
- Desire for energy independence of US

→ Possible scenario; price of LPG to drop and approach the cost of HFO

Updated Analysis

Assuming the LPG cost is the same as HFO ($320/mt), the results become:

- Discounted Payback Period:

LPG	Discounted Payback Period
M/E Only	2.1

- KPIs:

LPG	M/E Only
ROI (% per year)	45.64
NS	$45,074,590
SIR	9.6
AIRR	15.3

- ROI (Return On Investment - % per year);

  (Annual Profit x 100) / Capital Investment
- NS (Net Savings);

  NS is a current value expressing the net lifecycle benefit after costs are subtracted
- SIR (Savings to Investment Ratio)

  Present Value of Operational Saving/ Present Value of Additional Investment Cost over the life of the investment
- AIRR (Adjusted Internal Rate of Returns);

  ((1+r)*(SIR)^1/N)-1 with r the rate of reinvestment and N the number of anticipated lifetime of the investment (20 years in this case). A measure of annual percentage yield from an investment

Comparative Sensitivity LPG vs EGCS

- Comparison of DPP for LPG and EGCS

DPP Difference between LPG and EGCS - OPTION TO BE CHOSEN IS GIVEN IN CELL										
LPG	250	280	310	320	330	360	390	420	450	480
HFO										
410	LPG	LPG	LPG	LPG	LPG	LPG	LPG	BOTH	EGCS	EGCS
390	LPG	LPG	LPG	LPG	LPG	LPG	BOTH	EGCS	EGCS	EGCS
370	LPG	LPG	LPG	LPG	LPG	LPG	BOTH	EGCS	EGCS	EGCS
350	LPG	LPG	LPG	LPG	LPG	BOTH	EGCS	EGCS	EGCS	EGCS
330	LPG	LPG	LPG	LPG	BOTH	BOTH	EGCS	EGCS	EGCS	EGCS
310	LPG	LPG	LPG	BOTH	BOTH	BOTH	EGCS	EGCS	EGCS	EGCS
290	LPG	LPG	BOTH	BOTH	BOTH	EGCS	EGCS	EGCS	EGCS	EGCS
270	LPG	LPG	BOTH	BOTH	BOTH	EGCS	EGCS	EGCS	EGCS	EGCS
250	LPG	BOTH	BOTH	BOTH	BOTH	EGCS	EGCS	EGCS	EGCS	EGCS
230	LPG	BOTH	BOTH	BOTH	BOTH	EGCS	EGCS	EGCS	EGCS	EGCS
210	LPG	BOTH	BOTH	BOTH	BOTH	EGCS	EGCS	EGCS	EGCS	EGCS
190	BOTH	BOTH	BOTH	BOTH	BOTH	EGCS	EGCS	EGCS	EGCS	EGCS
170	BOTH	BOTH	BOTH	BOTH	EGCS	EGCS	EGCS	EGCS	EGCS	EGCS

Long Term Considerations

- SOx emissions from the combustion of LPG are reduced by 90–95%
- NOx emissions are also reduced by about 15-20%
- The daily consumption would drop by approximately 10%
- LPG is widely distributed around the globe
- CO2 emissions are also reduced by 20%

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ABS BWMS operational survey

Stamatis Fradelos, Director Business Development | November 2018

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BWMS Operational Surveys Background

Spring 2017

- ABS/MARTECMA
- Questionnaire Responses
  - 27 Shipowners
  - 220 vessels
- ABS led an open discussion with the shipowners using this aggregated data from the responses

Summer/Autumn 2018

- ABS/MARTECMA/INTERCARGO
- Questionnaire Responses
  - 62 Shipowners (Europe, US, Asia)
  - 479 installations
  - 7 types of BWMS

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Reported Operational Status 2017

13%

Reported as being regularly operated and subject to monitoring and/or efficacy testing

14%

Inoperable

30%

Operations problematic

43%

System running but not subjected to monitoring or efficacy testing to date

Survey results included responses from 27 owners representing 220 installations.

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Reported Operational Status 2018

25%

Reported as being regularly operated and subject to monitoring and/or efficacy testing

5%

Inoperable

59%

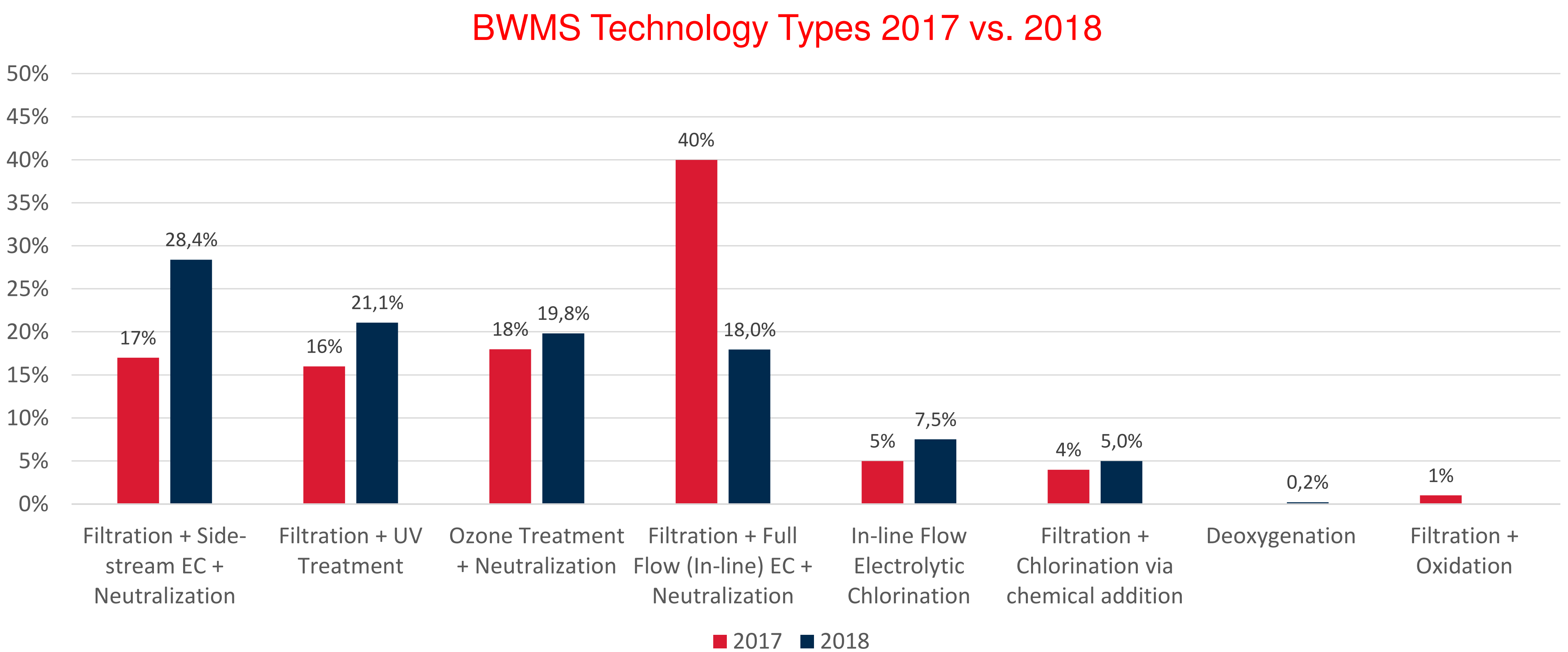
Operations problematic

11%

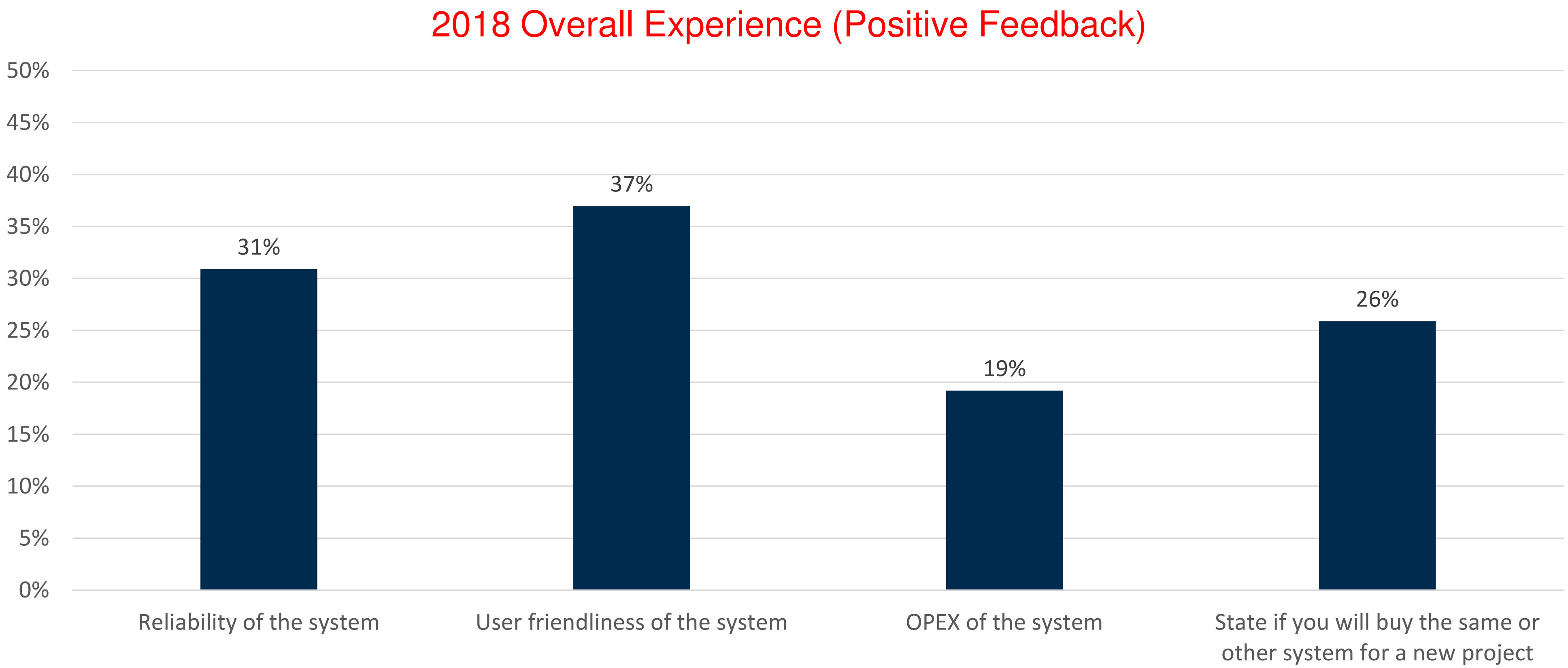
System running but not subjected to monitoring or efficacy testing to date

Survey results included responses from 62 owners representing 479 installations.

BWMS Operational Experience Questionnaire Results



BWMS Operational Experience Questionnaire Results 2018



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Sulfur Cap 2020
EGCS Techno-economic Study

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Regulatory Framework: Emissions

IMO MARPOL Annex VI

- Gaseous Emissions
- DCS
- GHG

EU

- Monitoring, Reporting and Verifying CO2 Emissions EU Reg. 2015/57
- Sulfur Directive 1999/32/EC as amended…2012/33/EU

CARB (California Air Resource Board)

- Oceangoing Vessel (OGV) fuel regulation

EPA

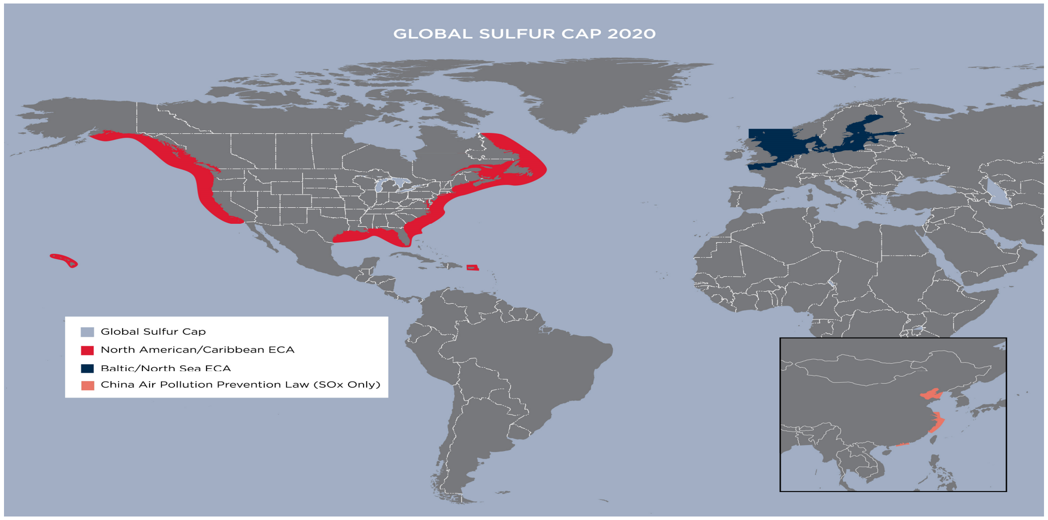
- 40 CFRs

CHINA

- China Air Pollution Prevention Law

- Regulation 14 – Sulfur Oxides (SOx) and Particulate Matter

- < 1 Jan. 2012: 4.5% S
- ≥ 1 Jan. 2012: 3.5% S
- ≥ 1 Jan. 2015: 0.10% S ECA
- ≥ 1 Jan. 2020: 0.5% S Globally



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Sulfur Cap: Compliance Options

- Low sulfur distillate fuel
- Low sulfur heavy fuel oil
- Blended 0.5% S Fuel
- Exhaust Gas Cleaning Systems (EGCS)
- Liquefied Natural Gas (LNG)
- Alternate fuels: LPG, CNG, methanol, ethanol, bio-fuels, fuel cells

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Pros and cons among different options

Fuels/Technologies	Pros	Cons
Low sulphur distillate fuels	• Widely used with few limitations • Very low CAPEX & small modifications	• Price difference compared to HFO • Low viscosity and lubricity • Existing vessels need modifications in FO storage, systems, boiler etc.
Low sulphur heavy fuel oil	• Price expected lower than distillate fuel oil • No modifications required for existing vessels • Low sulphur content, but behaves like HFO (heated fuel, higher viscosity)	• Limited availability
Blended 0.5% S Fuel	• Price expected lower than distillate fuel oil	• Limited availability • Not yet categorized as per ISO 8217. • Compatibility/Stability issues

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Pros and cons among different options

Fuels/Technologies	Pros	Cons
Exhaust Gas Cleaning Systems (EGCS)	• Reduces both SOx and PM • Continue using low cost HFO • Pay back period accelerated with high price differential	• High installation costs • Relatively new technology • Limitations on washwater discharge
Liquefied Natural Gas (LNG)	• Very clean fuel meets 0.1% SOx requirements • Low operating costs	• High CAPEX • Limited LNG bunkering infrastructure • lower energy density-need higher volume tank
Alternative Fuels (LPG, CNG, ethane, methanol, bio-fuel, solar power, fuel cells)	• Cleaner fuels pose no issues to meet SOx requirements	• Very new technologies and few applications are currently available • Some technologies are still in research and development stages

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Demand vs supply in 2020 (MEPC 70/5/3)

Sulphur (% m/m)	Petroleum derived fuels			LNG
	<0.10%	0.10-0.50%	>0.50%	
	Million tonnes per year			
Base case	39	233	36	12
High case	48	290	14	12
Low case	33	198	38	13

	Production in 2012	Production in 2020
Gasoline	963	1,086
Naphtha	256	305
Jet/Kero Fuel	324	331
Middle Distillate	1,316	1,521
of which MGO	64	39
Total Marine Heavy Fuel Oil (HFO)	228	269
of which Marine HFO (S ≤ 0.50% m/m)	0	233
of which Marine HFO (S > 0.50% m/m)	228	36
LPG	113	110
Other	784	537
Total	3,984	4,159

Fuel demand projections in 2020 based on the fuel consumption of ships in 2012

Global Refinery Production (2012 and 2020) - million tonnes per year

The model was run conservatively

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Refinery Input, Crude Oil and Quality (2020, (2012)) (MEPC 70/5/3)

	Africa	Asia	Europe	North America	Latin America	Middle East	Russia & CIS
Crude Oil (million tonnes per year)	136 (108)	1,328 (1,233)	527 (662)	932 (827)	323 (285)	448 (334)	320 (329)
API gravity	35.41 (35.92)	35.26 (35.76)	34.48 (35.71)	30.6 (30.8)	26.2 (25.2)	31.34 (31.46)	32.5 (32.5)
Sulphur %S (m/m)	0.68 (0.64)	1.07 (1.03)	1.01 (0.77)	1.59 (1.55)	1.44 (1.45)	2.01 (1.92)	1.32 (1.32)

- Future demand can be met due to several developments.
  - Capacity growth of crude distillation units enables production of larger quantities of fuel oil,
  - Expansion of hydrocracking capacity increases the potential supply of unconverted gas oil, with a very low sulphur content which can be blended with heavy fuel oil to lower its sulphur content
  - the increase in middle distillate and heavy fuel oil hydroprocessing helps meet the low sulphur requirements for marine distillates and heavy fuel oils

EGCS Retrofit and New Builds

- Uncertainty and potential savings due to large fuel differential have led to an increasing adoption rate in the last few months.

- Clarkson state 1286 vessel with retrofitted EGCS or on order.
- Regarding the split of system types (Open Loop, Closed Loop, Hybrid), we expect more Open Loop systems (due to simplicity and cost), but in most cases this is not specified:
  - 988 Not specified
  - 113 Open Loop
  - 162 Hybrid
  - 23 Closed loop (mostly Ferries and some Bulk Carriers in Great Lakes)

Life Cycle Cost Analysis

General Assumptions - CAPEX

- Tankers:

CAPEX	13K OIL/CHEMICAL			MR OIL/CHEMICAL			PANAMAX OIL		
	M/E	M/E + A/E	M/E + A/E + A/B	M/E	M/E + A/E	M/E + A/E + A/B	M/E	M/E + A/E	M/E + A/E + A/B
Open Loop	$945,000	$1,035,000	$1,305,000	$-	$-	$1,495,000	$1,400,000	$1,615,000	$1,895,000
Hybrid	$-	$1,415,000	$1,510,400	$-	$-	$1,825,000	$1,750,000	$2,020,000	$2,400,000

CAPEX	AFRAMAX OIL			SUEZMAX OIL			VLCC OIL		
	M/E	M/E + A/E	M/E + A/E + A/B	M/E	M/E + A/E	M/E + A/E + A/B	M/E	M/E + A/E	M/E + A/E + A/B
Open Loop	$1,225,000	$1,325,000	$1,750,000	$1,355,000	$1,555,000	$-	$1,380,000	$1,670,000	$1,950,000
Hybrid	$1,450,000	$1,750,000	$2,050,000	$1,620,000	$1,850,000	$-	$1,650,000	$1,900,000	$2,280,000

- Bulk Carriers:

CAPEX	114K BULK CARRIER			170K BULK CARRIER			180K BULK CARRIER		
	M/E	M/E + A/E	M/E + A/E + A/B	M/E	M/E + A/E	M/E + A/E + A/B	M/E	M/E + A/E	M/E + A/E + A/B
Open Loop	$1,355,000	$1,555,000	$-	$1,490,000	$1,535,000	$1,855,000	$-	$1,600,000	$-
Hybrid	$-	$-	$-	$-	$-	$2,095,000	$-	$-	$-

- Gas Carriers:

CAPEX	34K LPGCARRIER			84K LPG CARRIER		
	M/E	M/E + A/E	M/E + A/E + A/B	M/E	M/E + A/E	M/E + A/E + A/B
Open Loop	$-	$1,270,000	$-	$1,280,000	$1,400,000	$1,630,000
Hybrid	$-	$1,760,000	$-	$1,600,000	$1,780,000	$1,900,000

- Container Vessels:

CONTAINER VESSELS – EGCS All Stream (M/E + A/E + A/B)						
CAPEX	1000 TEU	1300 TEU	1700 TEU	2500 TEU	2800 TEU	4300 TEU
Open Loop	$750,000	$800,000	$1,200,000	$1,475,000	$1,575,000	$1,650,000
Hybrid	$1,300,000	$1,350,000	$1,800,000	$2,075,000	$2,175,000	$2,300,000
Closed Loop	$1,300,000	$1,350,000	$1,800,000	$2,075,000	$2,175,000	$2,300,000

- Analysis based on average of makers replies
- Installation costs 110 to 140% of Equipment cost
- Off-hire costs during installation are not included. Except for Suezmax and 180k Bulk carrier. (25 days Open Loop, 30 days Hybrid)
- Design and Class costs: $125,000 Open Loop, $150,000 Hybrid

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General Assumptions - OPEX

- System Life expectancy of system 15 years.
- Initial Fuel Cost 2020 (2.4% annual increase in bunker cost): HFO: $300/mt, LSFO (0.5%): $550/mt, MGO (0.1%): $600/mt
- Additional 1% M/E Fuel consumption due to increased back pressure
- Maintenance is assumed as 2% of CAPEX per year for open loop and 3% for Hybrid.
- Service Engineer and Crew training: $15,000 per year.

Assumptions	OIL/CHEMICAL		OIL CARRIER				LPG CARRIER		BULK CARRIER			CONTAINER VESSEL					
	13K	MR	PANAMAX	AFRAMAX	SUEZMAX	VLCC	34K	84K	114K	170K	180K	1000 TEU	1300 TEU	1700 TEU	2500 TEU	2800TEU	4300TEU
% Time in ECA	40	30	5	7	3	6	15	10	4	0	5	11	22	1.1	14.8	13.7	0.9
% closed operation	10	10	10	25	10	25	10	25	10	10	10	10	10	10	10	10	10
Days at sea/year	141	189	213	139	235	243	185	260	240	270	260	184	195	208	251	221	252
NaOH cost	$300	$250	$300					$250	$300	$250	$300	$300					
Bunkering	$5000	$2500	$5000					$2500	$5000	$2500	$5000	$5000					
Add. Consumption from using EGCS	[redacted]											[redacted]					
Min t/day	0.2	0.7	0.9	1	1	1.4	0.7	0.7	1.1	0.8	1	0.9	1	1.2	1.6	1.6	1.7
Max t/day	0.4	0.8	1.3	1.4	1.5	1.9	0.9	1.3	1.3	1.8	1	1.2	1.3	1.5	1.8	1.8	1.9
CO2 $/year	1,100	1,450	7,900	6,600	10,800	$13,000	$5,000	$8,000	9,500	9,500	7,800	7,100	7,800	10,800	14,000	12,200	14,700

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LCCA Results

- Discounted Payback Period (years to repay the investment, based on present value savings) for Open Loop Systems. Best solution is highlighted in bold.

Discounted Payback	OIL/CHEMICAL		OIL CARRIER				LPG CARRIER		BULK CARRIER			CONTAINER VESSEL					
	13K	MR	PANAMAX	AFRAMAX	SUEZMAX	VLCC	34K	84K	114K	170K	180K	1000 TEU	1300 TEU	1700 TEU	2500 TEU	2800 TEU	4300 TEU
M/E only	1.6	-	**1.1**	3.3	**1.1**	**0.8**	-	1.9	**1.0**	1.1	-	-	-	-	-	-	-
M/E & A/E	2.5	-	1.1	2.6	1.1	0.9	**1.3**	**1.7**	1.0	**1.0**	**1.6**	-	-	-	-	-	-
M/E, A/E & A/B	**1.0**	**1.8**	1.2	**2.2**	-	0.9	-	1.9	-	1.3		**1.4**	**0.8**	**1.4**	**0.8**	**1.0**	**1.0**

- Results are based on the vessel assumptions shown previously and operational profile (example shown below)

VLCC	Main Engine			Auxiliary Engine			Auxiliary Boiler		
	Seagoing	Man/vering	Port/ Anchorage	Seagoing	Man/vering	Port/ Anchorage	Seagoing	Man/vering	Port/ Anchorage
Number Operating	1	1	0	1	2	2	0	1	2
Load (%)	70%	50%	0	60% - 70%	40 - 50%	60 - 70%	-	-	-
Annual Running Hours	7,000	100	0	10,000	200*	600*	0	100	600**

* Total hours for 2 A/E running

** Total hours for 2 A/B running

LCCA Results (Cont'd)

- Life Cycle Cost Analysis indexes for the solutions with the shortest payback:

KPIs	OIL/CHEMICAL		OIL CARRIER				LPG CARRIER		BULK CARRIER			CONTAINER VESSEL					
	13K	MR	PANAMAX	AFRAMAX	SUEZMAX	VLCC	34K	84K	114K	170K	180K	1000 TEU	1300 TEU	1700 TEU	2500 TEU	2800 TEU	4300 TEU
ROI (% per year)	74.35	44.24	71.04	35.39	72.02	97.21	59.77	53.30	83.03	91.10	47.34	54.50	95.49	55.97	93.56	77.26	76.94
NS	$14M	$14M	$25M	$20M	$36M	$48M	$19M	$26M	$29M	$36M	$25M	$12M	$25M	$20M	$43M	$37M	$39M
SIR	**15.6**	**7.1**	**11.4**	**5.7**	**11.5**	**15.6**	**9.6**	**11.2**	**13.3**	**14.6**	**7.6**	**8.7**	**15.3**	**9.0**	**15.0**	**12.4**	**12.3**
AIRR	18.2	17.4	21.1	15.6	21.2	23.7	19.7	16.2	22.4	23.1	17.9	19.0	23.5	19.2	23.4	21.8	21.8

- ROI (Return On Investment - % per year) → (Annual Profit x 100) / Capital Investment
- NS (Net Savings) → NS is a current value expressing the net lifecycle benefit after costs are subtracted.
- SIR (Savings to Investment Ratio) → Present Value of Operational Saving/ Present Value of Additional Investment Cost.
- AIRR (Adjusted Internal Rate of Returns) → ((1+r)*(SIR)^1/N)-1 with r the rate of reinvestment and N the number of anticipated lifetime of the investment (15 years in this case). A measure of annual percentage yield from an investment.

180K Bulk Carrier – Effect of changing CAPEX

- Effect of changing CAPEX on KPIs, Open Loop System.

M/E and A/E				
Equipment Cost	TOTAL CAPEX	KPIs		
		NS	SIR	DPP
$ 1,100,000	$ 2,817,500	$ 26,607,127	10.4	1.2
$ 1,200,000	$ 3,027,500	$ 26,371,251	9.7	1.3
$ 1,300,000	$ 3,237,500	$ 26,135,375	9.1	1.4
$ 1,400,000	$ 3,447,500	$ 25,899,499	8.5	1.5
$ 1,500,000	$ 3,657,500	$ 25,663,624	8.0	1.6
$ 1,600,000	$ 3,867,500	$ 25,427,748	7.6	1.6
$ 1,700,000	$ 4,077,500	$ 25,191,872	7.2	1.7
$ 1,800,000	$ 4,287,500	$ 24,955,996	6.8	1.8
$ 1,900,000	$ 4,497,500	$ 24,720,120	6.5	1.9
$ 2,000,000	$ 4,707,500	$ 24,484,244	6.2	2.0
$ 2,100,000	$ 4,917,500	$ 24,248,368	5.9	2.1
$ 2,200,000	$ 5,127,500	$ 24,012,492	5.7	2.2
$ 2,300,000	$ 5,337,500	$ 23,776,617	5.5	2.3
$ 2,400,000	$ 5,547,500	$ 23,540,741	5.2	2.4
$ 2,500,000	$ 5,757,500	$ 23,304,865	5.0	2.5
$ 2,600,000	$ 5,967,500	$ 23,068,989	4.9	2.6
$ 2,700,000	$ 6,177,500	$ 22,833,113	4.7	2.7

- Analysis based on average of makers replies
- Installation costs 110% of Equipment cost
- Off-hire costs based on 25 days.
- Design and Class costs: $125,000 Open Loop.

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VLLC – Effect of Savings on discounted payback.

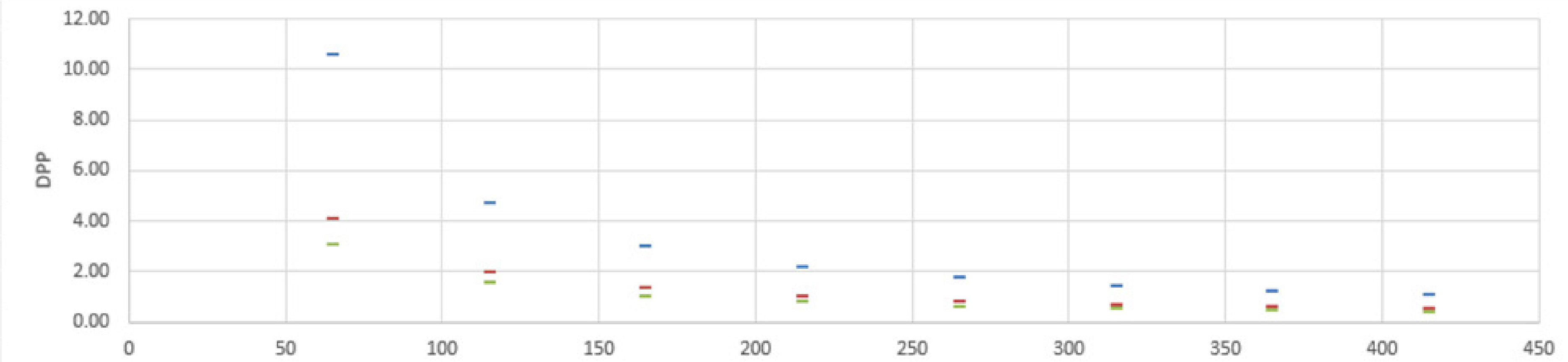
- Share of Savings to be passed to Owner of EGCS/Vessel and effect on discounted payback.

M/E Only DPP									
	LSFO	350	400	450	500	550	600	650	700
	HFO-LSFO Spread	50	100	150	200	250	300	350	400
% Savings to Owner	100%	1.63	1.42	1.21	0.99	0.79	0.66	0.56	0.49
	90%	1.73	1.51	1.30	1.08	0.88	0.73	0.62	0.54
	80%	1.84	1.63	1.41	1.20	0.99	0.82	0.70	0.61
	70%	1.99	1.78	1.56	1.35	1.13	0.94	0.80	0.70
	60%	2.20	1.97	1.76	1.55	1.33	1.12	0.93	0.82
	50%	2.49	2.26	2.04	1.82	1.61	1.39	1.18	0.98
	40%	2.93	2.70	2.48	2.25	2.02	1.81	1.59	1.38
	30%	3.70	3.46	3.22	2.98	2.76	2.53	2.30	2.08

- Note: This variation can be due to Charter Party terms, bank loan,…

VLCC – Sensitivity to No. of days at sea

- Effect on Discounted Payback Period from varying the HFO/LSFO differential and the annual days at sea from 110 to 310, for the M/E only EGCS.



	HFO/LSFO	65	115	165	215	265	315	365	415
Low	110.00	10.55	4.66	2.98	2.19	1.73	1.43	1.22	1.06
Ref	243.00	4.07	1.98	1.31	0.97	0.78	0.65	0.55	0.48
High	310.00	3.03	1.52	1.01	0.76	0.61	0.51	0.44	0.38

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Thank You

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