LNG AS A MARINE FUEL – THE INVESTMENT OPPORTUNITY

SEA\LNG STUDY - NEWBUILD 14,000 TEU LINER VESSEL ON ASIA-USWC TRADE

EXECUTIVE SUMMARY AND KEY FINDINGS

Liquefied Natural Gas (LNG) is a superior marine fuel providing the best option to improve air quality and is the only scalable marine fuel that advances shipping's greenhouse gas (GHG) reduction objectives. To support shipowners and operators in analysing options in an informed way, while simultaneously providing deeper analysis of the assumptions that go into the 2020 decision process, SEA\LNG commissioned an independent study by simulation and analytics experts *Opsiana*. To ensure the best possible data was available to *Opsiana*, SEA\LNG members contributed maritime expertise and current, timely background information and data to insure a high level of creditability in the study and results. The study is based on a newbuild 14,000 TEU container vessel plying its trade on an Asia-US West Coast (USWC) liner routing. This study clearly indicates that LNG as a marine fuel also delivers the best return on investment on a net present value (NPV) basis over a conservative 10-year horizon, with fast payback periods ranging from one to two years.

The Asia - US West Coast route chosen for evaluation shows LNG is a sound investment on routes with very little voyage time (8%) in Emission Control Areas (ECAs). LNG is also proven to be the best investment across a broad spectrum of business climates from strong freight markets with elevated vessel operating speeds to weak freight markets where slow steaming is employed. Both high pressure (HP) and low pressure (LP) LNG dual fuel (DF) engines have clear benefits over other options. Although the study results from the LP LNG DF engine are slightly better than the HP LNG DF engine, potential advantages in efficiency and tank sizing for HP LNG DF engines are not shown.

This higher return was achieved without including the significant additional benefits gained[1] by choosing LNG as a more environmentally friendly marine fuel. Although not part of this investment study, the environmental effects of fuel choice do possess a currency value. Increasingly, end users of

[1] Benefits gained in terms of CO2 generated and pollutants produced per TEU transported.

transportation, especially major global brands and beneficial cargo owners, are demanding cleaner logistics chains and are including environmental impact pricing in their contracts with shipping companies. These customer demands create a competitive advantage for LNG as a maritime fuel.

1. DIMINISHING CAPEX HURDLE

Historically, the high capital expenditure (CAPEX) for LNG engines and fuel tanks was a barrier to adoption. However, recent shipyard prices demonstrate substantially smaller LNG premiums above traditional vessels. This is due to the extensive LNG newbuilding experience and technology improvements leading to shipyard efficiency gains, as well as current market conditions favouring buyers of newbuildings. These factors and the data for this study demonstrate a reduction in the CAPEX hurdle to LNG as a marine fuel and greater returns on investment.

2. COMPETITIVE ENERGY COSTS

Fuel is traditionally purchased on a dollar per ton basis, however the transaction is really about buying energy. LNG offers a lower energy cost per ton, whenever priced against Heavy Fuel Oil (HFO) by nearly 24% because it contains more energy for a given mass: LNG as a marine fuel provides 50GJ of energy per ton, whereas HFO only provides 40.5GJ/ton. 2,000 tons of LNG provides the same amount of energy as 2,469 tonnes HFO. This study highlights the positive effect this additional energy availability from LNG has on investment.

3. ECA VOYAGE TIMES NOT SO RELEVANT

LNG was once only considered a viable investment choice as a marine fuel for vessels whose voyages comprised a substantial percentage of their voyage time spent in ECAs. This study proves a compelling case for LNG as a marine fuel even for operations that spend a limited amount (single digit percentages) of the voyage in ECAs.

[2] The Stranded Fuel scenario envisages HFO initially plummeting towards $200 /mt beginning in 2020.

4. MOST FINANCIALLY EFFECTIVE LONG-TERM MEANS OF COMPLYING WITH 2020 SULPHUR CAP

This study shows LNG as a marine fuel provides a greater return on investment than installation of Advanced Air Quality Systems (more commonly known as Exhaust Gas Cleaning Systems (EGCS) or Scrubbers) across a majority (5 out of 6) of the fuel scenarios; the exception being a stranded fuel forecast with plunging HFO pricing[2] . Although this stranded scenario is possible and analysed as such, it is deemed unlikely due to the growing, but small, number of scrubbers currently ordered in time to take advantage of the expected drop in HFO pricing from 2020. Additionally, unlike LNG CAPEX, which is falling, the CAPEX costs for scrubbers are escalating as surging market demand outstrips supply and available slots for timely shipyard installation are disappearing. Hence the advantageous business window for scrubbers to capture savings is closing for late adopters.

5. SCRUBBERS ARE SIGNIFICANTLY MORE EXPENSIVE THAN WIDELY REPORTED

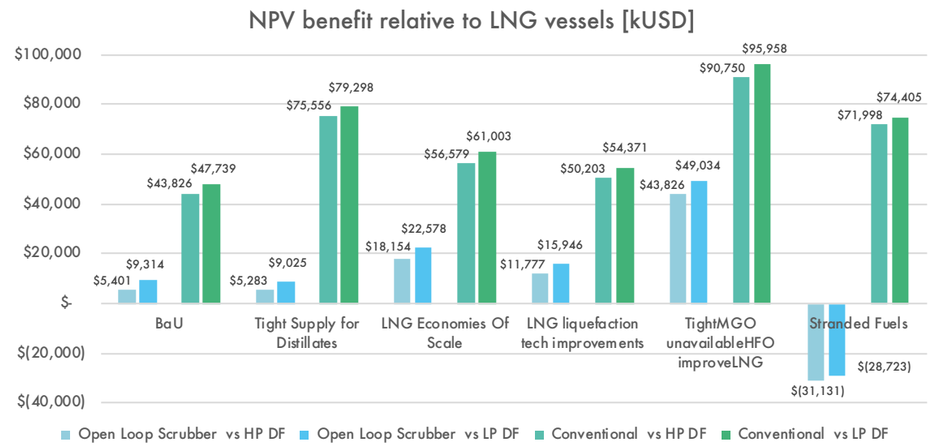
Media sources cite scrubber costs ranging from $2 million for new build and a bit more for retrofits to existing vessels. This perspective is for wet or dry bulk vessels of modest power approaching 10,000kW. For higher-powered ships the scrubber costs are much higher and therefore so too are LNG benefit gains associated with larger fuel consumption. In this study an industry accepted scrubber CAPEX figure of $8.6million for a newbuild 47,000kW container ship of 14,000 TEU capacity is used together with additional consideration for Tier III NOx abatement SCR equipment. Another key take-away from this study is that LNG fuel's OPEX cost savings dominate investment returns whose strong performance remains nearly the same when challenged by lower CAPEX scrubbers.

6. THE COST OF LNG IS STABLE

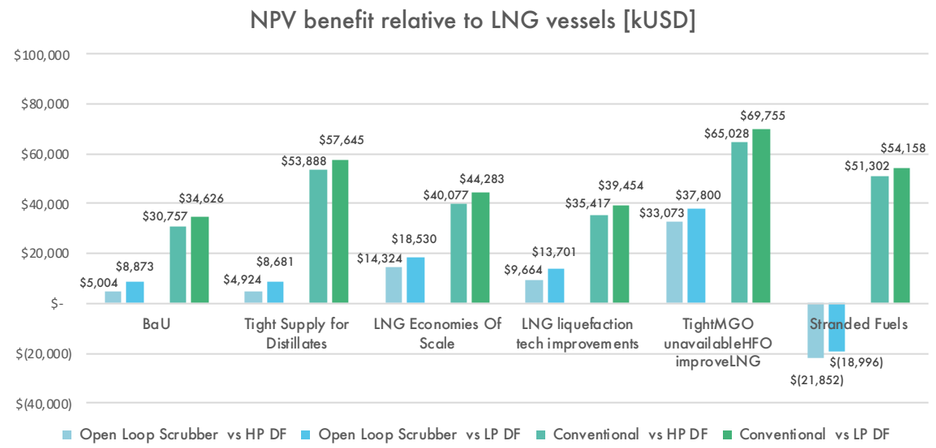
The cost of LNG is comprised of the natural gas (about 25%), which has fluctuated little in recent history, together with a generally fixed liquefaction fee to cool the natural gas to a liquid state and the transportation costs which can be contracted on a long term basis (about 75%). Consequently LNG pricing is much more stable than traditional maritime fuels which reflect the volatility of crude oil prices. This principal difference is why the underlying commodity element for LNG forms a small portion of its price structure and refining and distribution plays a disproportionately large portion. LNG is therefore relatively insulated against sharp commodity swings. This relationship directly contrasts with HFO or diesel where the underlying commodity oil dominates costs. A century of infrastructure and refining improvements has driven these incremental costs downward. As a consequence, the cost of LNG marine fuel bunkers continues to remain less volatile than traditional oil based marine fuels.

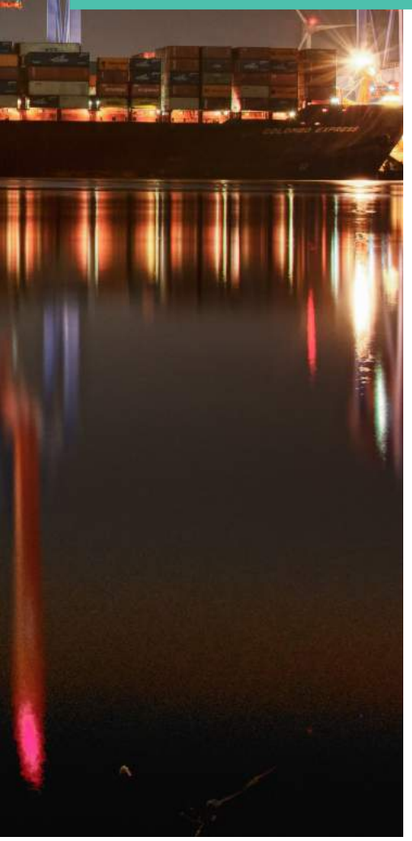
Comparison of the NPV of each engine option together with their relevant fuels clearly shows the economic benefits of choosing LNG as a marine fuel. The two graphs below, show the NPV benefit for strong freight and weak freight market conditions, highlighting the fact that LNG delivers better returns across a range of market conditions.

NET PRESENT VALUE COMPARISON
STRONG FREIGHT MARKETS, 20.5 KNOT VOYAGE



NET PRESENT VALUE COMPARISON
WEAK FREIGHT MARKETS, 18KN EASTBOUND, 16KN WESTBOUND





Net Present Value represents the increase in wealth accruing from an investment. The container ship business case evaluates alternatives where least cost is preferable but taking into account the CAPEX expenditure and Present Value of OPEX discounted at the time value of money. The results show LNG fuel employing Dual Fuel engines provides compelling Net Present Value Savings versus a scrubber[3] ranging from $4M to $49 million across the majority (5 of 6) fuel scenarios. LNG fuel delivers less value than scrubbers in only one case: the Stranded Fuels forecast results in negative savings of $19M to $31M. The Net Present Value Savings for DF alternatives overwhelms conventional fuels and surges across all 6 fuel forecasts toward tens of millions Net Present Value ranging from $34M to $95M. It is interesting to note that LNG alternatives win big as expected during strong freight markets with high fuel consumption and sustain a substantial win during weak freight markets where slow steaming mitigates fuel consumption.

[3] Open loop scrubber CAPEX range is from minimum $6.6M USD to report cited $8.6M USD; if the reader wishes to incorporate the minimum then subtract the difference of $2M USD from each NPV value shown in the bar chart.

CONTEXT

The International Maritime Organisation (IMO) global cap on marine fuel (bunkers) of 0.5% sulphur content (S) which comes into force from 1st January 2020 will affect an estimated 300 million metric tonnes (MMT) of bunkers. This landmark legislation will have wide-ranging ramifications beyond shipping as the new distillate diesel fuels demanded by shipping are the same ones used by other modes of transport including trains and trucks, as well as domestic heating.

Most ocean vessels rely on Heavy Fuel Oil (HFO) which globally averages 2.5% Sulphur. Of the total marine fuel demand of 5 million barrels of oil per day, 3.5 million barrels are high sulphur HFO. As the residual fuel left from the crude oil refining process, HFO is the cheapest and very often the most polluting fuel for a given energy output.

The main marine fuel options for shipowners beyond 2020 are:

- LNG fuel for newbuildings
- Use existing engines burning Low Sulphur Fuel Oil (LSFO) most likely 0.1% Low-Sulphur Marine Gas Oil (LS-MGO[4]) or a blend of existing sulphurous Heavy Fuel Oils (HFO) with no or low sulphur fuels such as LS-MGO.
- Continue consuming HFO and employ scrubbers to achieve alternative compliance.

The global shipping industry did experience imposition of global sulphur limits only a few years ago. The introduction of restrictive ECAs in 2015 caused 250-300 thousand barrels of oil per day to shift from high sulphur to 0.1% S representing a modest step change. However, the impact of the IMO's global 2020 0.5% S limit is a dramatic leap in comparison being ten times greater and impacting 3 million barrels of oil per day. Where the former caused a "tiger yawn" in 2015 global fuel markets, this much larger change could result in a "lion roar" during 2020.

[4] LS-MGO has a sulphur content of less than 0.1%. This marine fuel can be used in Emission Control Areas (ECAs), which among other things impose a sulphur emissions limit corresponding to that of LS-MGO.

Shipowners are now challenged with making significant investment decisions in an unprecedented dramatic fashion under a range of uncertainties. Many have chosen the LSFO route. Over 95% of ships will likely be running on LSFO based on the low level of orders for exhaust gas cleaning systems and LNG fuelled vessels. This raises a number of questions: Will that prove to be the best solution? Can the higher fuel cost be recovered from customers? Will the quality and consistency of future LSFO blends be available where and when it is needed?

Is there an opportunity to take advantage of the environmental and operational benefits of LNG and its ability to scale to meet the industry's needs? Will it be cost competitive? Are scrubbers a viable long-term cost-effective solution? Will open loop scrubber waste-water discharge be accepted in the trading regions the vessels operate? What if GHG emissions are taken into consideration, which option is best? Which option offers the most competitive advantage?

The huge variation in global shipping types, ages and the trading patterns of vessels adds to the complexity. For many shipowners and operators, it will necessitate a portfolio approach[5] to achieve compliance with the IMO 2020 global sulphur cap legislation and continue profitable trading for any given vessel.

To support shipowners and operators in analysing options in an informed way, while simultaneously providing deeper analysis of the assumptions that go into the 2020 decision process, SEA\LNG commissioned an independent study by simulation and analytics experts *Opsiana*. To ensure the best possible data was available to *Opsiana*, SEA\LNG members contributed maritime expertise and current, timely background information and data to ensure a high level of creditability in the study and results. The study is based on a newbuild 14,000 TEU container vessel plying its trade on an Asia-US West Coast (USWC) liner routing. Investment performance was measured utilising traditional NPV calculations as well as Payback. NPV carries the time value of money (TVM) and provides a strong measure of wealth gain. Payback ignores TVM but provides a valued liquidity measure of risk: "how long before I get my money back."

[5] Where specific fuel solutions will be chosen to suit individual vessels depending upon their classification, age and trading pattern.

The study was undertaken to make sense of the investment case based upon six different fuel-pricing scenarios that – at the time of writing – are based on assumptions that are likely and reasonable. The exercise is not meant to endorse any specific fuel price forecast. While great care has been taken in building these forecasts, it is up to each individual to decide how they see the future, and place the corresponding weight on each forecast. In the majority (5 out of 6) fuels scenarios, all except the Stranded Fuels forecast, LNG delivered the greatest return to shipowners and operators on a net present value (NPV) basis over a conservative 10-year horizon, with fast payback periods ranging from one to two years.

The Stranded Fuels scenario predicts a plunge in HFO with implementation of the 2020 IMO global sulphur cap and slow pricing recovery thereafter as market forces and global oil refining capacity switching toward higher margin low sulphur fuels are expected to balance the supply with demand. Therefore the majority of saving benefits will accrue to the early adopters and late adopters may find this window quickly closing near middle of the decade.

LSFO

The vast majority of vessels are expected to fuel with LSFO, a straight low sulphur fuel oil, or – more typically – a blended fuel consisting of HFO and distillates. Some shipowners have even indicated that they will, during the initial phase after January 1st, 2020, look to purchase only MGO and thus avoid the potential risk of availability, and fuel quality issues such as stability and compatibility, as well as the risks of taking onboard non-compliant fuel.

SCRUBBERS

Scrubber take-up, according to classification society DNV-GL, will 'easily reach' 2,500 vessels by 2020. However, this only represents around 4% of the world trading fleet of 58,500 vessels The technology, which in late 2018 saw an upsurge in take-up, does not offer any GHG reduction benefits and may be viewed as a short-term solution from this perspective. Those opting for open-loop scrubbers may not be able to take full advantage of

these systems due to recent legislative changes. Several nation states, including Singapore and China have recently restricted the discharge of waste-water from open loop scrubbers in their territorial waters.

Environmental and operational challenges aside, the commercial case for scrubbers remains competitive. Though, it may be the least predictable of the three main options for a vessel of this type, with scrubbers offering a short-term financial gain provided the unit is operational and able to capture the benefits window commencing 1st January 2020.

LNG

When analysing investment options for 2020, it is important to contextualise and recall why the 2020 rules were implemented. While shipping has already shown that its focus is very much on the bottom line when analysing 2020 options, the 2020 legislation was devised to dramatically improve the environment, especially regional air quality which is a key concern of busy ports. LNG provides significant air quality improvements over traditional fuels.

In terms of environmental impact LNG performs well from an emissions perspective; LNG emits zero sulphur oxides (SOx) and virtually zero particulate matter (PM). Compared to existing heavy marine fuel oils, LNG emits 90% less nitrogen oxides (NOx) and through the use of best practices and appropriate technologies to minimise methane leakage, realistic reductions of GHG by 10-20% are achievable, with a potential for up to 25% or more as technology develops, compared with conventional oil-based fuels. LNG is a cleaner fuel, a clear winner when it comes to local emissions, and represents a significant step forward in the reduction of GHGs and meeting future carbon-related emissions targets.

The study is intended to help the ship owning / operating community to analyse options in an informed way, while simultaneously providing deeper analysis of the assumptions that go into the 2020 decision process. Compared to many other

case studies on this topic, this one spells out CAPEX and OPEX assumptions in detail, providing a level of insight thus far not communicated for an investment case in LNG from a newbuild perspective. While this study focuses specifically on the liner trade, SEA\LNG members are working on additional studies, which will analyse the investment case for a number of other ship types and routes.

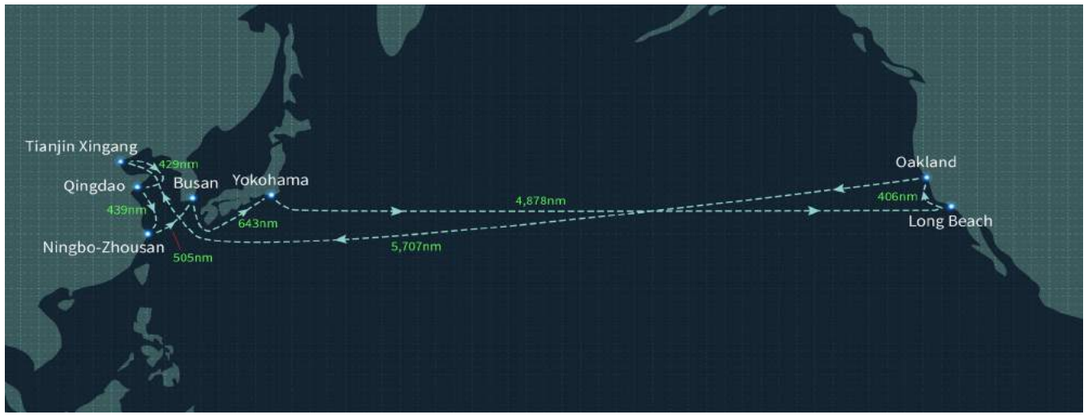
MAIN ASSUMPTIONS

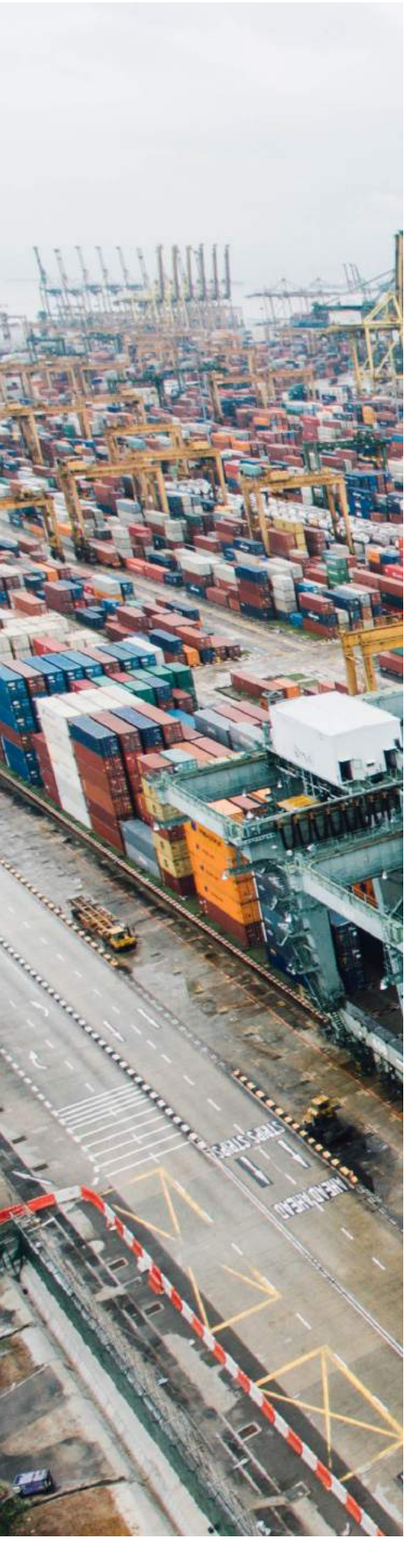
The Asia- US west coast Liner route chosen is shown in the diagram below. The total sailing distance is 13,007nm of which 8% is spent in ECAs. Two operational market conditions were modelled for this trade route:

a) Strong freight markets, which correspond to high demand for freight transport. The vessel speed is elevated to 20.5kn throughout with lost cargo space taken up by additional fuel tanks to support the LNG fuel requirements penalized at $200 net loss per TEU container slot per round trip.

b) Weak freight markets, which correspond to low demand for freight transport. The vessel speed is reduced to employ a slow steaming strategy with 18kn eastbound and 16kn westbound. Lost cargo space is not penalized as the vessel is assumed to sail with empty slots.

ASIA - USWC LINER ROUTE





FINANCIAL

A) NEWBUILDING LNG FUEL VESSEL

The study utilizes a new build LNG dual fuel vessel as this is most likely to occur in the marketplace. This acknowledges that LNG retrofits often carry a premium CAPEX and also require a young candidate vessel with significant future lifetime to justify the additional CAPEX investment.

B) INVESTMENT HURDLE RATE

The study utilizes a finance investment hurdle rate traditionally known as the Weighted Average Cost of Capital (WACC) for the time value of money. The WACC value for the study of 8% was derived from these assumptions:

Debt loan rate 6% and 60% portion

Equity return rate 11% and 40% portion

Tax rate of 0%

Formula:

WACC = Loan Rate × Debt Portion × (1-tax rate)+ Equity Rate × Equity Portion

Substituting in Values...

WACC = 6% × 0.60 × (1-0) + 11% × 0.4 = 8%

C) INVESTMENT HORIZON PERIOD

The study chose a 10-year investment horizon as a conservative timeframe understanding that the economic lifetime for containerships exceeds this substantially. The choice also recognizes that over much shorter investment horizons of only a few years an elevated CAPEX recovery charge often makes short lifetime projects not viable.

D) TERMINAL RECOVERY VALUE

The study ignores a salvage or recovery value at end of the investment horizon period as a very conservative condition. This avoids the risks inherent with terminal value and its presumed future cash flows or growth rates.

E) INFLATION AND NOMINAL VALUES

The model employs an inflation differential of 2.5% per year to maintain nominal values throughout the investment period.

CAPITAL EXPENDITURE

Four types of main engine configurations were fully priced and compared in this study: a dual fuel HP 2-stroke LNG engine (2-s HP DF) with Tier III treatment, a dual fuel LP 2-stroke LNG engine (2-s LP DF), a conventional diesel cycle low speed engine fitted with an open-loop scrubber plus Selective Catalytic Reduction (SCR), and a conventional diesel cycle low speed engine fitted with SCR but without scrubber. The investment for each configuration and its components is detailed in the CAPEX summary.

4-stroke engines were not modelled as the overwhelming majority of ships of this type on these trade routes utilise 2 stroke technology. However technology advancements and the requirement to burn higher quality fuel oils to comply with tighter environmental regulations mean that 4-stroke engine configurations may become a viable alternative for powering ocean vessels, especially in environmentally sensitive areas and within ECAs.

2-S HP DF

This configuration is modelled on a MAN ME-GI main engine (M/E) using 1.5% S pilot fuel with no methane slip. Although NOx Tier II compliant, it requires Selective Catalytic Reduction (SCR) or Exhaust Gas Recirculation (EGR) to comply with NOx Tier III. The auxiliary engines (A/E) and boilers are assumed to be gas only and do not require SCR. M/E Specific Fuel Oil Consumption (SFOC) is 167.5g/KWh, gas is supplied at 250-300 bar to the M/E and low pressure to the A/Es. The HP gas system is $1.2M, LP gas system is $700K. There is no differential CAPEX attributed to the boilers and mechanical propulsion is assumed.

2-S LP DF

This configuration is modelled on a WinGD 9X-92DF Winterthur Gas & Diesel engines which use lean-burn Otto-cycle combustion with approximately 1% S micro-pilot. It complies with NOx Tier III in gas mode so is modelled without an SCR. M/E SFOC is 169g/KWh with low-pressure gas supplied to the M/E and A/Es. Once again, the LP gas system is priced at $700K with no differential CAPEX attributed to the boilers and mechanical propulsion assumed.

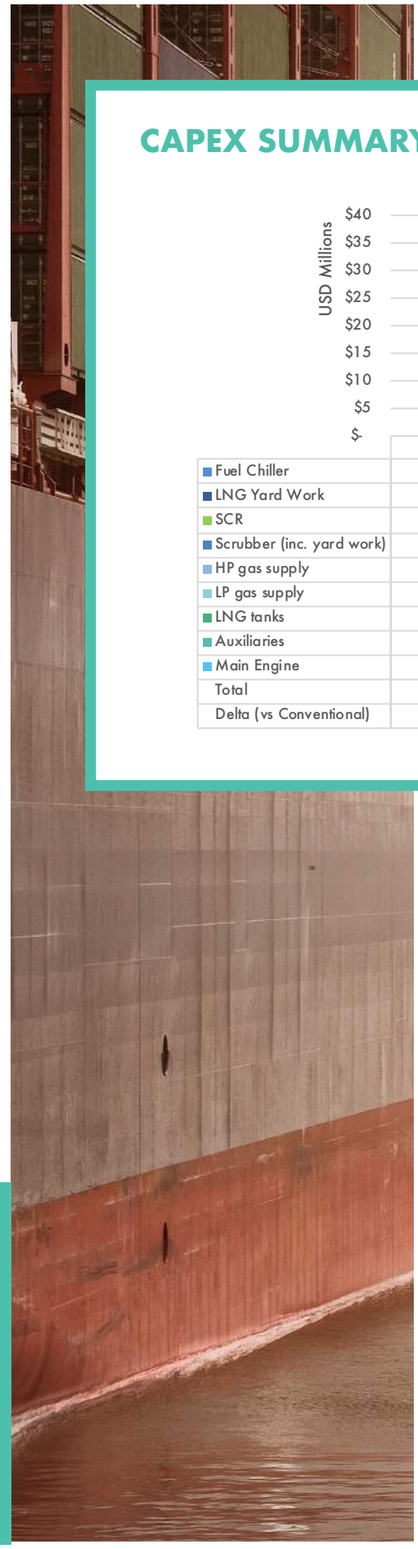
OPEN-LOOP SCRUBBER VESSEL

This configuration is based on conventional diesel cycle, low speed engine, with a scrubber fitted to cover exhaust from the M/E, A/E and one boiler rated at 5MW. The other boiler is assumed to be powered using waste heat recovery (WHR) and is therefore not scrubbed. Although the M/E is NOx Tier II compliant, an SCR is required to comply with NOx Tier III at a cost of $3.2M. M/E SFOC is 170g/KWh with a 2% fuel consumption penalty applied within 0.1%S ECAs and a 1% penalty within 0.5%S areas. The scrubber is open loop and therefore doesn't consume Sodium Hydroxide (NaOH).

CONVENTIONAL VESSEL

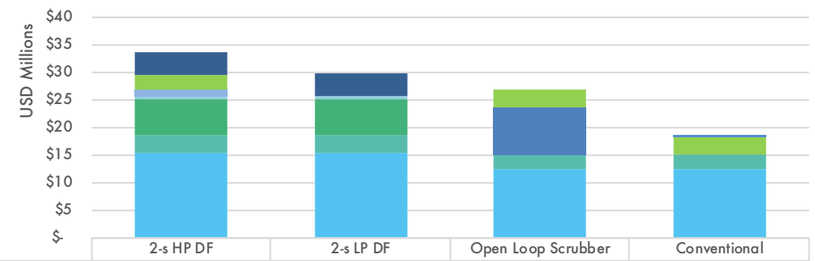
This configuration is based on conventional diesel cycle, low speed engine. Although the M/E is NOx Tier II compliant, SCR is required to comply with NOx Tier III. M/E SFOC is 170g/KWh. Additional CAPEX of $120K is assumed for a fuel chiller, since the M/E was designed to operate with fuels of higher viscosity relative to MGO.

LNG pricing is much more stable than traditional maritime fuels.



The CAPEX for all engine configurations is summarised below.

CAPEX SUMMARY



	2-s HP DF	2-s LP DF	Open Loop Scrubber	Conventional
Fuel Chiller	$-	$-	$-	$118,000
LNG Yard Work	$4,230,000	$4,230,000	$-	$-
SCR	$2,495,700	$-	$3,260,340	$3,260,340
Scrubber (inc. yard work)	$-	$-	$8,620,560	$-
HP gas supply	$1,190,621	$-	$-	$-
LP gas supply	$708,654	$708,654	$-	$-
LNG tanks	$6,382,837	$6,382,837	$-	$-
Auxiliaries	$3,327,600	$3,327,600	$2,662,080	$2,662,080
Main Engine	$15,396,552	$15,396,552	$12,317,241	$12,317,241
Total	$33,731,963	$30,045,642	$26,860,221	$18,357,661
Delta (vs Conventional)	$15,374,301	$11,687,981	$8,502,560	$-

The additional CAPEX for each configuration option over the conventional vessel is:

- 2-s HP DF $15.37M,
- 2-s LP DF $11.68M,
- Open Loop Scrubber $8.5M

The CAPEX premium for LNG alternatives over a scrubber with IMO 2020 0.5% compliance is $6.87M for a 2-s HP DF M/E arrangement and only $3.18M for a 2-s LP DF M/E.

One note of caution, the scrubber assumption is for an open loop system. The open loop scrubber CAPEX is lower than for a hybrid or closed loop system and its OPEX is generally lower. This study also assumes that a vessel using an open loop system can fully operate in all territorial waters, which may no longer be possible in all territorial waters.

FUEL CONSUMPTION

M/E fuel consumption is based on the contract maximum continuous rating (CMCR) power and CMCR speed in all cases. A/E power is assumed at 40% of rated speed at sea, 30% during idling in port and 70% during active operational in port. Boiler consumption is included within A/E estimates. Scrubber consumption includes a parasitic load in ECAs. Energy consumption includes pilot fuels for the LNG DF engines.

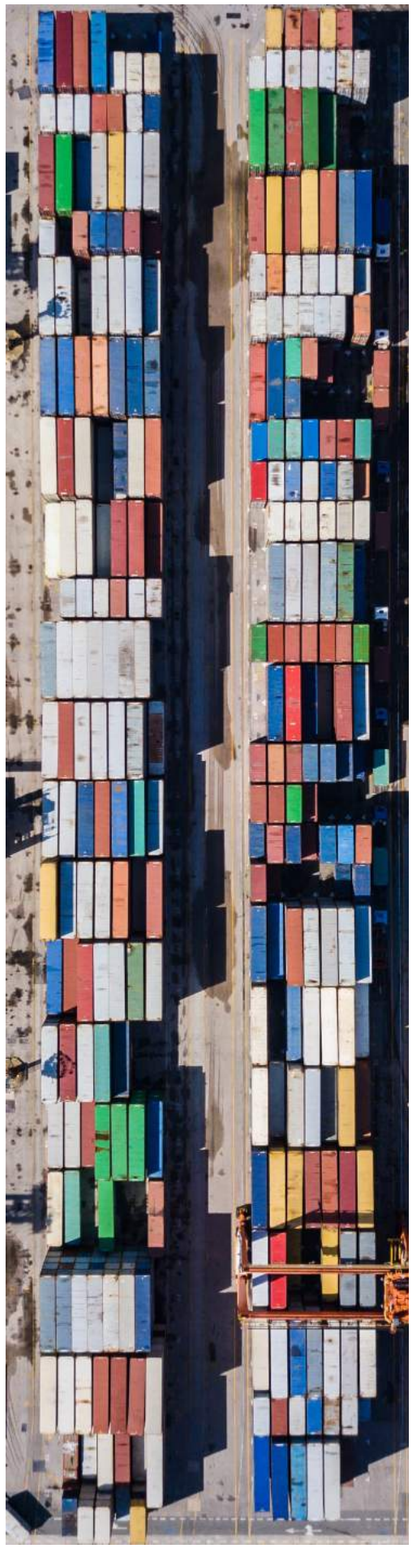
Fuel consumption for each engine configuration is summarised in the table below.

Propulsion Technology	Design Consumption [tpd]				Energy Consumption [MMBtu/hr]	M/E SFOC [g/kWh]	A/E SFOC [g/kWh]
	LNG	HSFO	VLSFO	MGO			
2s HP DF	122.0	2.0	-	-	240.9	168	180
2s LP DF	123.6	-	-	1.3	242.8	169	180
Open-loop scrubber	-	154.2	-	-	246.6	170	180
Conventional	-	-	145.9	-	244.1	170	180

Indicative consumption figures in the table are for 20.5 knots eastbound. The table highlights the fact that LNG contains 24% more energy content for a given mass than conventional oil based fuels.

FUEL TANK SIZE IMPACTS

The LNG powered vessels are assumed to use C-type tanks sized at 8,581 cubic meters, which cannibalize space that would be filled with containers in a conventionally powered vessel. For a 14,000 TEU vessel this study assumes the loss of cargo space equates to 300 TEUs or approximately 2% of capacity.



It is assumed that vessels "cube-out" rather than "weight out", therefore the extra weight of scrubbers has no relevant impact on cargo capacity. Similarly the bunker tanks for fuel oils are as traditionally placed and do not affect container capacity.

Propulsion Technology	Tank Sizes [m3]				TEU loss
	LNG	HSFO	VLSFO	MGO	
2s HP DF	8,581	304	-	59	300
2s LP DF	8,581	-	-	75	300
Scrubber	-	4,866	-	-	-
Conventional	-	-	5,234	733	-

The profit impact of the lost cargo capacity is calculated on the displaced profit before tax per TEU basis multiplied by the number of round trips per year. $200 per TEU is assumed in a strong market and zero per TEU in a weak market, as the 14,000 TEU vessel is expected to be operating below 98% utilisation and therefore incur no profit penalty.

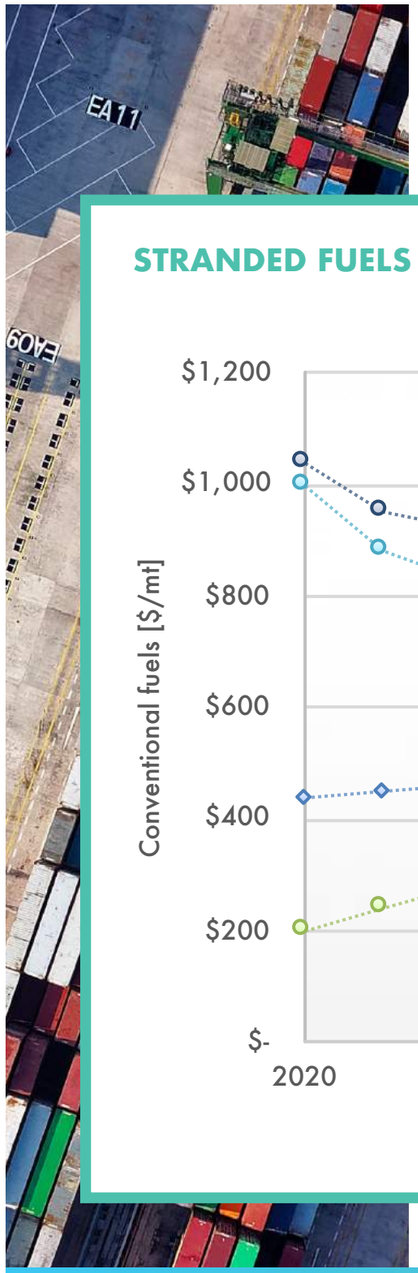
FUEL PRICING

The study considers four fuels, LNG plus three oil-derived fuels. A conventional high sulphur fuel oil "HSFO" with as much as 3.5% S, a marine gas oil "MGO" as a distillate containing 0.1% S, and very low sulphur fuel oil "VLSFO" which complies with 0.5%S. Although 0.5%S fuels could be achieved either through blending or directly from residual of a naturally sweet crude, it is assumed that the price of these alternatives would converge, regardless of their chemical composition.

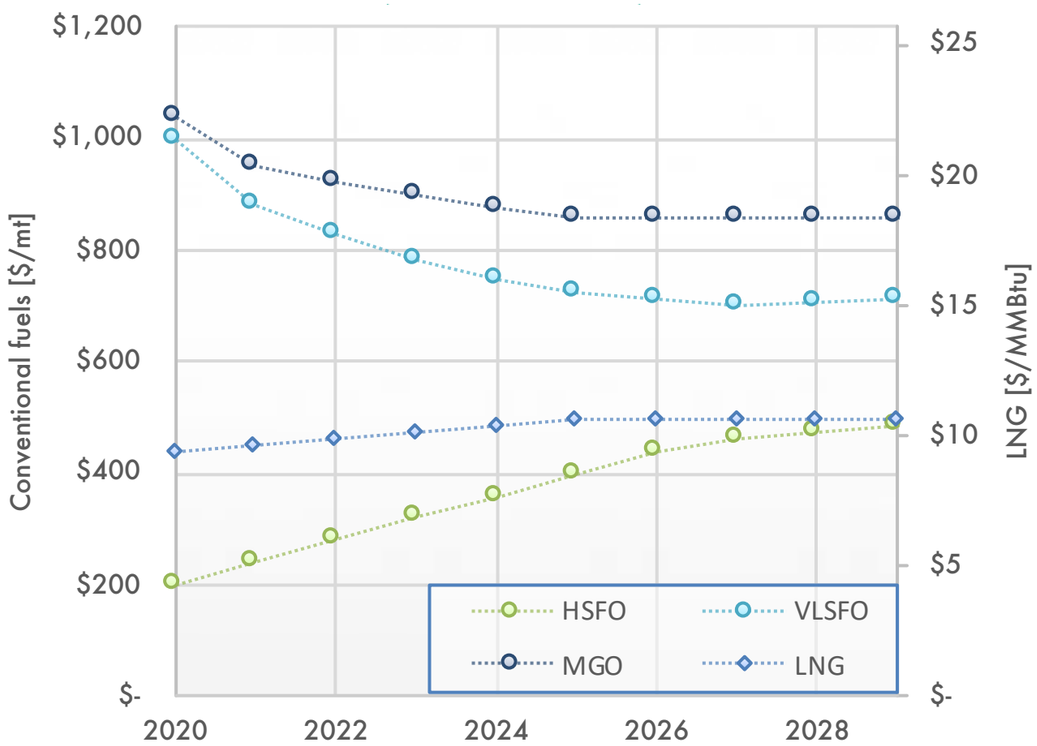
Six scenarios are modelled in the study representing:

1. **STRANDED FUELS:**
   Initially the price HSFO plummets with IMO 2020 implementation followed by transitional recovery years. While considered in the study, it is unreasonable to assume HSFO pricing will remain depressed as demand will be minimal as the sulphur ban is fully implemented and only scrubber equipped vessels can utilise this product.
2. **BUSINESS AS USUAL "BAU":**
   Relative prices remain as they were as of Q3 2018.
3. **TIGHT SUPPLY FOR DISTILLATES:**
   MGO increases in price by 20% relative to Q3 2018 due to high demand for low-sulphur fuels in 2020. HSFO and LNG remain as of Q3 2018.
4. **LNG ECONOMIES OF SCALE:**
   LNG liquefaction and delivery costs reduced by 20% due to increased adoption and associated economies of scale.
5. **LNG LIQUEFACTION TECHNOLOGY IMPROVEMENTS:**
   Liquefaction cost reduced by 20% due to technology improvements in small scale liquefaction.
6. **TIGHT MGO, UNAVAILABLE HSFO, IMPROVE LNG:**
   MGO increases in price by 20% due to high demand for low sulphur fuels. HSFO goes up in price by 20% because it is no longer widely available. These increases are viewed as conservative and price increases may be much greater, especially when set against the Q3 2018 benchmark. LNG liquefaction and delivery prices decrease by 20% due to economies of scale.

The Stranded Fuels scenario entails a complex dynamic whereby HSFO stocks become stranded in 2020 due to low penetration of scrubbers. The penetration of scrubbers is modelled to grow gradually towards 2027, leading to a gradual recovery of HSFO prices. MGO and distillates are forecasted at very high demand in 2020. As LNG and scrubbers increase their penetration and additional refinery capacity comes on-line, MGO prices will level down. VLSFO is initially very tightly coupled to MGO. As new blends are tested and accepted by the market, there is a gradual decoupling. LNG prices will be low as in "Liquefaction Technology Improvements" (explained above) through 2025. After 2025, renewables start to displace LNG for land-based applications and LNG prices level off.



STRANDED FUELS FORECAST (NATIVE UNITS)



The study is intended to help the ship owning/operating community to analyse options in an informed way, while simultaneously providing deeper analysis of the assumptions that go into the 2020 decision process.

For the other five scenarios, prices are forecast to grow with inflation (assumed at 2.5% p.a.) after 2020.

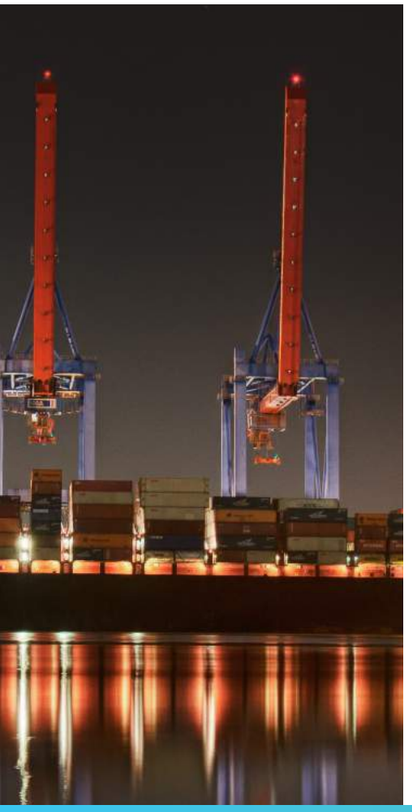
Common assumptions and sources for the fuel forecasts:

- The model assumes that HSFO, VLSFO, and MGO prices will be established relative to Rotterdam prices.
- Molecules at Henry Hub for 2018 estimated (Ycharts) at $2.8/MMBtu and marked up by 15% to $3.22/MMBtu following "Cheniere formula" (Ripple). Conversion to LHV increases molecule cost by 10% to $3.54.
- LNG "Sabine Pass" liquefaction cost, estimated at $3.0/MMBtu (Ripple) for 2018
- LNG logistics and bunkering estimated at $3.0/MMBtu (Braemar) for 2018
- Base price of LNG at USGC is given by the sum of three quantities above: $3.54 + $3.0 + $3.0 = $9.54/MMBtu
- Rotterdam HSFO for July 9 2018 $442/mt (Ship & Bunker)
- Rotterdam MGO for July 9 2018 $644/mt (Ship & Bunker)
- VLSFO 0.5%S price is obtained by adding 85% of the MGO price to 15% of the HSFO price.
- Prices increase by 2.5% every year

As all of the above fuel forecasts are assumptions, the model used by SEA\LNG can be adjusted for other fuel scenarios, should the basis for these forecasts change. SEA\LNG will review the fuel forecasts used every time a new vessel type or revised voyage is modelled.

As LNG and scrubbers increase their penetration and additional refinery capacity comes on-line, MGO prices will level down.

LNG delivers a greater return on investment than open-loop scrubbers in all scenarios, except stranded fuels.

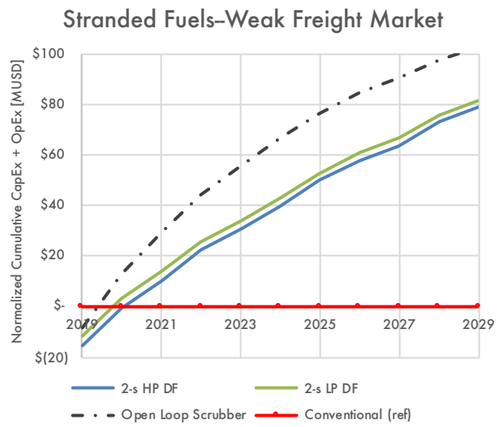


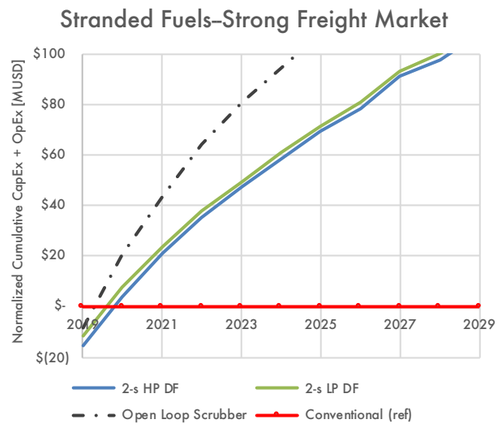
RESULTS

This study clearly indicates that LNG as a marine fuel delivers the best return on investment on a NPV basis over a conservative 10-year horizon with fast payback periods ranging from one to two years. This works in all modelled scenarios when compared to a conventional powered vessel burning LSFO. LNG also delivers a greater return on investment than open-loop scrubbers in all scenarios, except stranded fuels. Although to achieve the returns illustrated in the stranded fuel example would require the scrubbers to be installed and working at the start of 2020. Current orders and shipyard capacity mean than any scrubbers ordered now will not be operational until mid-2020. Existing orders, especially those fitted to very large vessels, and those expected mean that the very low HFO market demand conditions necessary for the stranded fuel scenario to arise have all but disappeared and its likelihood of occurrence is considered small. Therefore investment decisions taken on the basis of this scenario are deemed high risk.

This study clearly indicates that LNG as a marine fuel delivers the best return on investment on a NPV basis over a conservative 10-year horizon with fast payback periods ranging from one to two years.

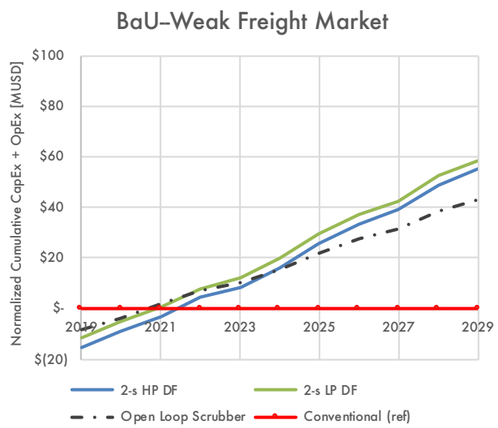
RESULTS 1/6

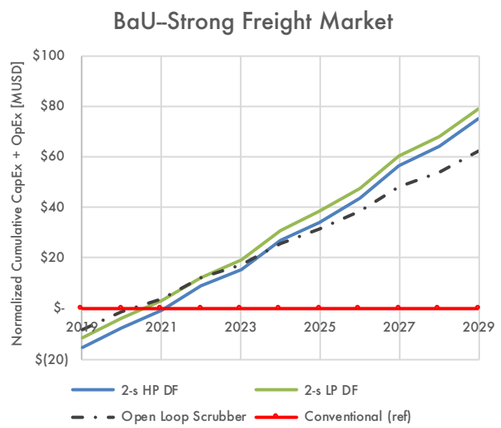




Notes: All cash flows are normalized using the "Conventional Vessel". Therefore the conventional vessel's graph coincides with the horizontal axis.
Dates in the horizontal axis corresponds to the end of the year. For instance, "2019" refers to Dec 31, 2019.
The vessels begin operation on Dec 31, 2019.

RESULTS 2/6





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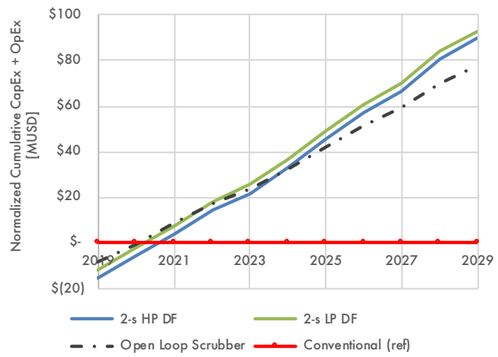
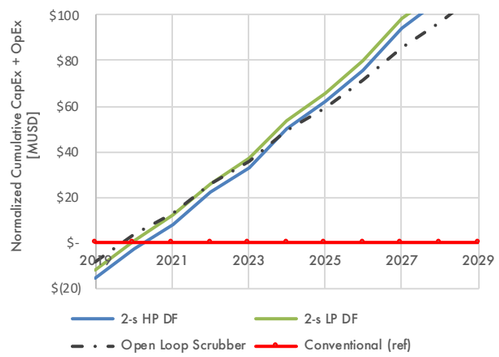
RESULTS 3/6

Tight Supply for Distillates–Weak Freight Market



Tight Supply for Distillates–Strong Freight Market



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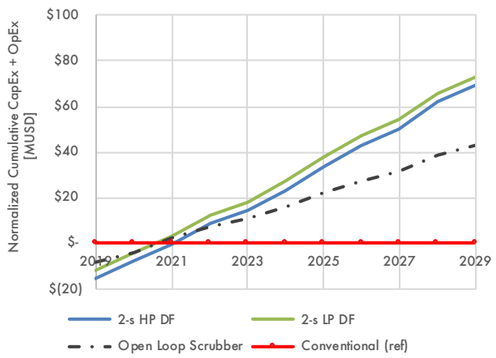
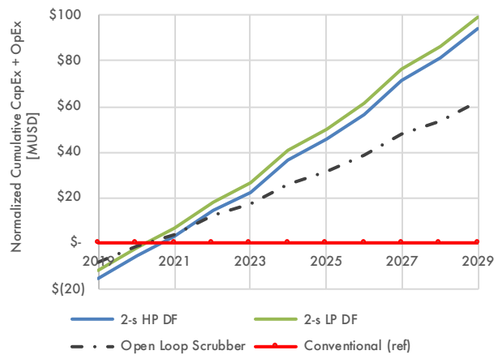
RESULTS 4/6

LNG Economies Of Scale–Weak Freight Market



LNG Economies Of Scale–Strong Freight Market



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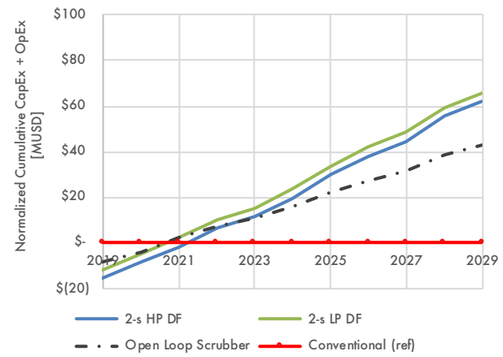
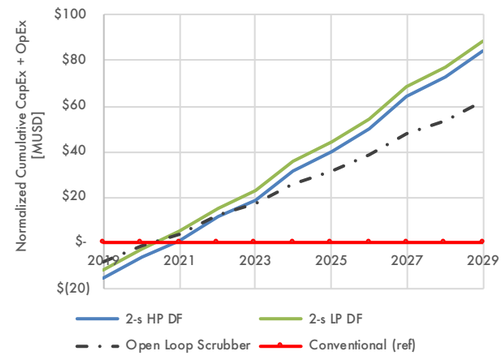
RESULTS 5/6

LNG liquefaction tech improvements–Weak Freight Market



LNG liquefaction tech improvements–Strong Freight Market



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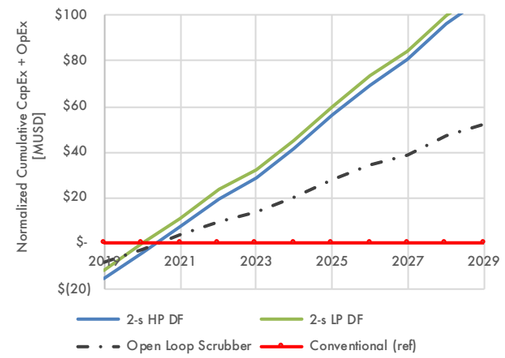
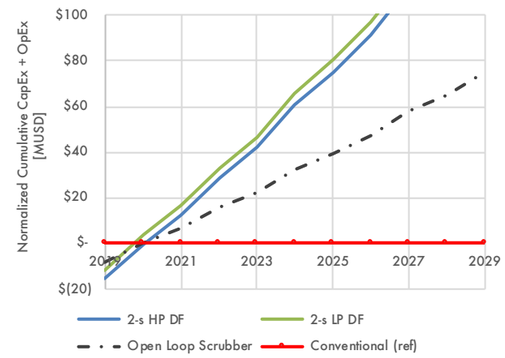
RESULTS 6/6

TightMGO unavailableHFO improveLNG–Weak Freight Market



TightMGO unavailableHFO improveLNG–Strong Freight Market



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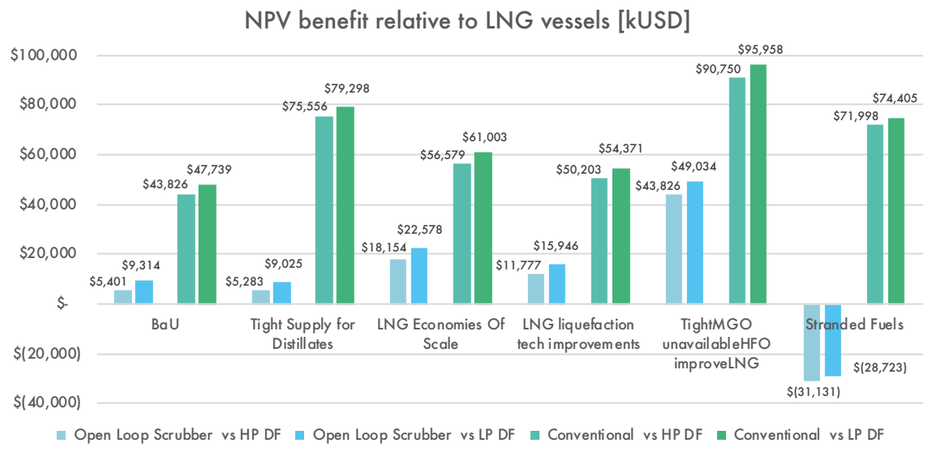
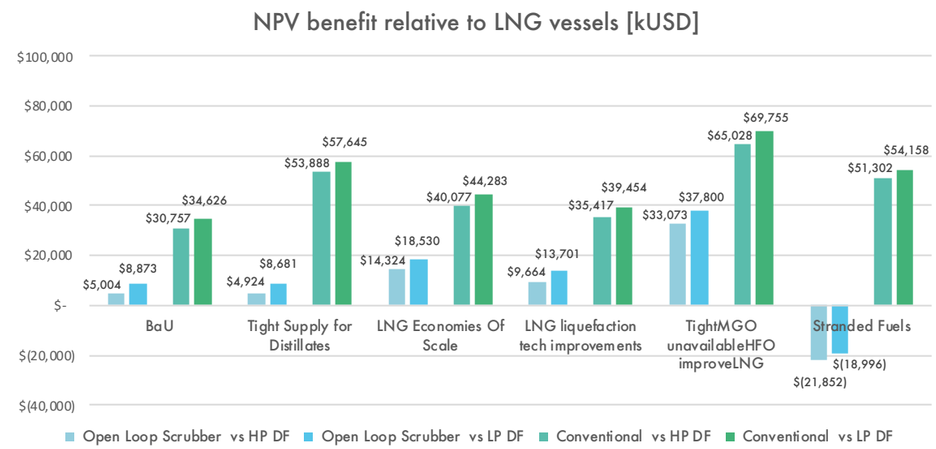
NET PRESENT VALUE COMPARISON
STRONG FREIGHT MARKETS, 20.5 KNOT VOYAGE



NET PRESENT VALUE COMPARISON
WEAK FREIGHT MARKETS, 18KN EASTBOUND, 16KN WESTBOUND



Liquefied Natural Gas (LNG) is a superior marine fuel providing the best option to improve air quality and is the only scalable marine fuel that advances shipping's greenhouse gas (GHG) reduction objectives.

Increasingly, end users of transportation, especially major global brands and beneficial cargo owners, are demanding cleaner logistics chains and are including environmental impact pricing in their contracts with shipping companies.

WAY FORWARD

With the IMO's 1st January 2020 0.5% global cap on heavy fuel sulphur content less than 365 days away, the shipping industry's focus this year will continue to be on marine fuel. As 2020 looms, there is growing consensus that LNG is the best solution for today and into the future, certainly towards 2050. There are no real, viable alternative solutions that can match LNG's emissions profile and scalability. Further, because of the growth of LNG infrastructure worldwide, the concerns about supply of LNG to the maritime community are being effectively addressed.

While there remain many unanswered questions about the choice and prices of marine fuels going into 2020, SEA\LNG will continue its commercially focused studies to provide authoritative intelligence regarding the investment case for LNG as a marine fuel for shipowners, shipyards, ports and wider stakeholders. SEA\LNG is repeating this independent research modelling to study the investment case for different vessel types and additional Liner trade lanes.

As the months progress we expect to see an acceleration in decision making in favour of LNG due to three key factors: economic, environmental and evolutionary.

Economically, this study has shown LNG as a marine fuel to be the best option for a large 14,000 TEU Liner vessel in the transpacific trade. While there will need to be a portfolio of marine fuel options for existing vessels within a corporate fleet, the direction of legislation affecting marine fuel and the advancement of technology and expanding infrastructure to support LNG mean the advantages of LNG will become greater.

Environmentally, LNG is the only practical industry wide marine fuel today that provides a solution to power ocean shipping and advance the environmental standards - reducing pollutant particulates, noxious nitrogen and sulphur oxides and GHG emissions. So while IMO 2030 and IMO2050 seek reductions in carbon intensity of at least 40% by 2030 and towards 70% by 2050

necessitating a move in marine fuel to non-fossil fuels, LNG will be a long term solution for multiple vessel life cycles.

The world continues to evolve and environmental consciousness is now no longer a movement, rather a reality. There is growing demand from the ultimate customers for goods, the consumers of the world, that products are not only sourced but also transported in more environmentally sustainable ways. LNG as a marine fuel provides a positive choice for shipowners, not just in terms of reducing pollution but also in demonstrating to their customers that they are continuing to make positive strategic changes in business practices which match the demands of the world's consumers.

The economic, environmental and evolutionary realities of global transportation are demanding changes and LNG can and does satisfy the demand for cleaner air and GHG reductions.

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Unless otherwise indicated, access to all hyperlinks verified on August 8, 2018.

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