SEA\LNG

LNG AS A MARINE FUEL – THE INVESTMENT OPPORTUNITY

SEA\LNG STUDY - NEWBUILD 300K DWT VERY LARGE CRUDE CARRIER (VLCC) SAILING FROM THE ARABIAN GULF TO CHINA

EXECUTIVE SUMMARY AND KEY FINDINGS

Liquefied Natural Gas (LNG) is a safe, mature, commercially viable marine fuel offering superior local emissions performance, significant Greenhouse Gas (GHG) reduction benefits and a pragmatic pathway to a zero-emissions shipping industry.

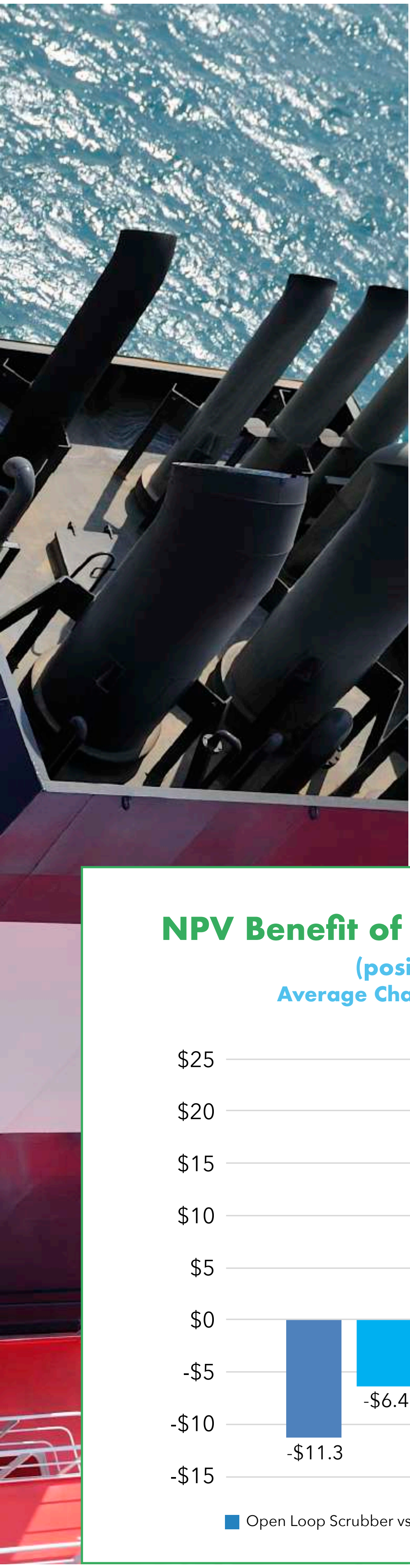
To support shipowners and operators in analysing options in an informed way, while simultaneously providing a deeper analysis of the assumptions that go into the 2020 decision process, SEA\LNG is commissioning a series of independent studies by simulation and analytics experts Opsiana. This VLCC study is the third in the series preceded by a 14,000 TEU container vessel operating on the Asia-US West Coast liner route, and a dual study examining an 8,000 CEU Pure Car and Truck Carrier (PCTC) on the Pacific and smaller 6,500 CEU on the Atlantic Trade Lanes. To ensure the best possible data was available to *Opsiana*, SEA\LNG members contributed maritime expertise and timely background information to ensure a high level of creditability in the study and results. The business case compares the relative investment performance of four propulsion alternatives: a conventional VLCC sailing with Very Low Sulphur Fuel Oil (VLSFO); a conventional VLCC equipped with Advanced Air Quality Systems (more commonly known as Exhaust Gas Cleaning Systems or scrubbers) sailing mostly with Heavy Fuel Oil (HFO); and two LNG powered vessels, including high-pressure (HP) and low-pressure (LP) 2-stroke (2s) engine variants.

This VLCC study clearly indicates that LNG as a marine fuel delivers a strong return on investment on a net present value (NPV) basis over a conservative 10-year horizon. The analysis is bolstered by compelling paybacks from three to five years for the 300K DWT VLCC trading from Arabian Gulf to China.

This route was chosen because it is the major energy trade corridor from the Middle East to China. Whereas both high pressure (HP) and low pressure (LP) LNG dual-fuel (DF) engines have clear benefits over other options; the study results portray one LNG technology investment as slightly better than the other. However, the potential characteristic advantages in operations and technology between differing LNG engines are not explored in this study.

The investment returns were calculated within traditional frameworks, without including the significant extra benefits and branding value gained by choosing LNG as a more environmentally friendly marine fuel, which could be worth hundreds of millions of dollars[1] across the global VLCC

[1] This is derived from the NPV gain of millions of dollars for one vessel being multiplied up for the global fleet.

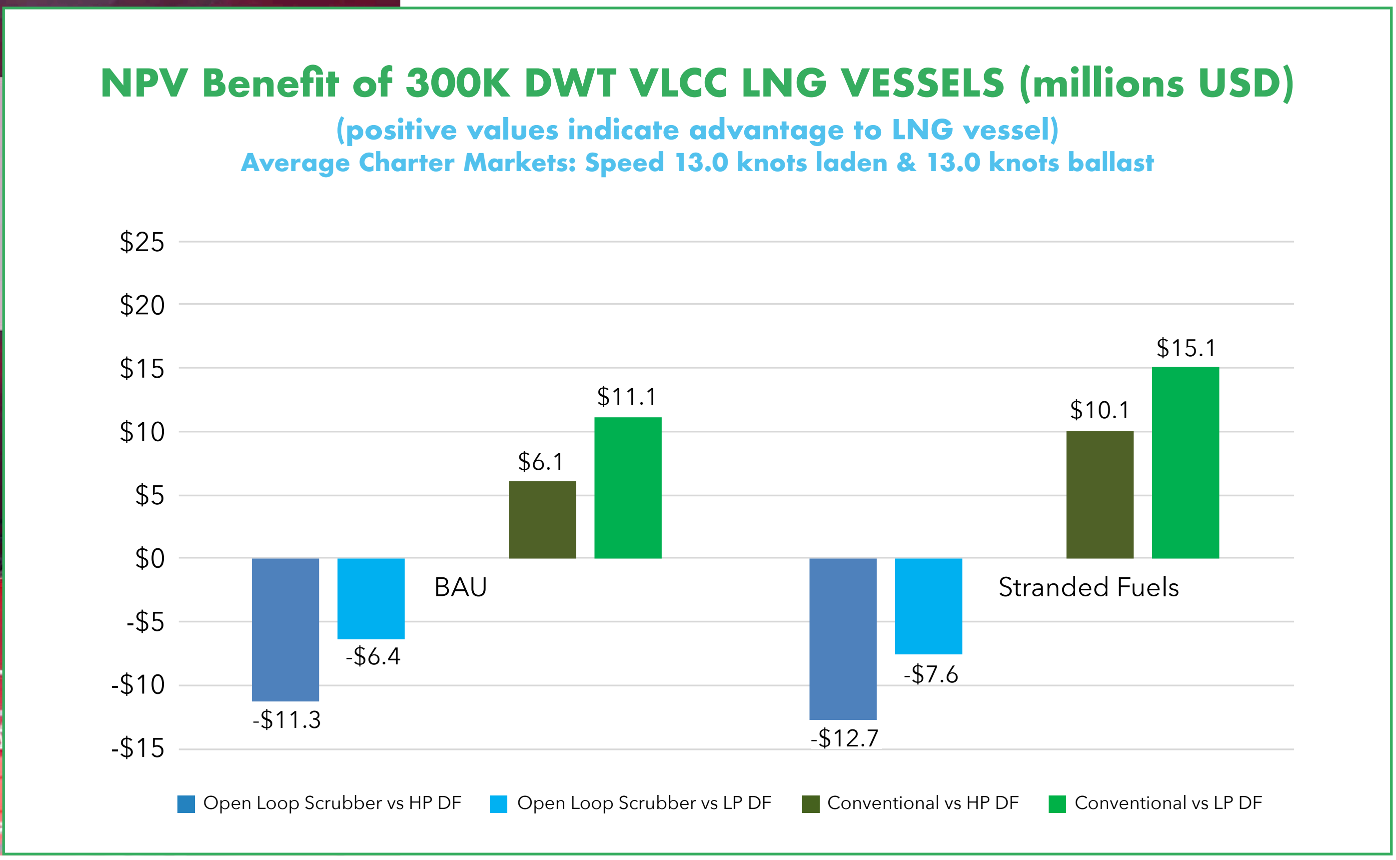


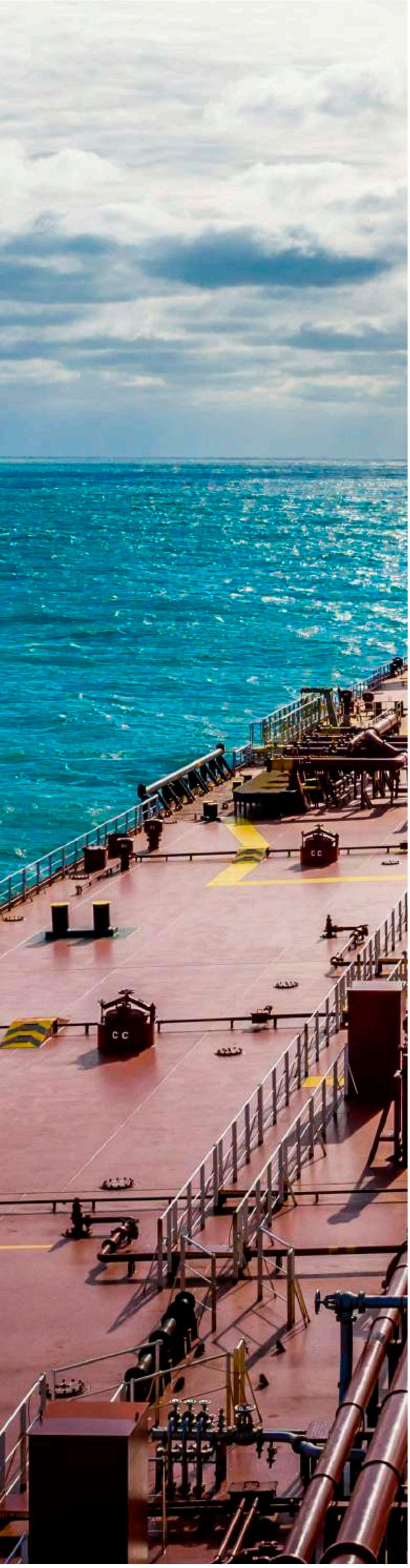
fleet. Consumers are demanding action from energy suppliers to address environmental sustainability goals. Recent actions by the European Union (EU) and International Maritime Organization (IMO) demonstrate the implementation of these goals with requirements for monitoring, reporting and verification of vessel fuel consumption which allows tracking of CO2 emissions. Should CO2 emission levels be assessed to have a financial value in the future, then LNG's low carbon footprint compared to traditional fuels will enhance its competitive financial advantage.

Overall, this study provides greater certainty for those investing in LNG as well as highlighting seven key findings surrounding the use of LNG as a marine fuel:

1. Better Return on Investment

LNG delivers a superior return on investment than conventional compliant fuels across all fuel scenarios investigated - business as usual "BAU", plus stranded fuels - and charter markets but trails behind the open-loop scrubber. Although to achieve the returns illustrated for the scrubber in business as usual or stranded fuels forecasts, shipowners would take on several risks surrounding HSFO future availability, pricing savings, future regulatory restrictions, and additional potential technical performance plus operational responsibilities.





The results for the 300K DWT VLCC show that LNG fuel employing DF engines provide compelling NPV savings versus compliant fuel ranging from $6.1M to $15.1M across the fuel scenarios. LNG fuel delivers less value than scrubbers in both the BAU and Stranded Fuels forecasts resulting in a negative savings of ($6.4M) to ($12.7M).

It should be noted that the stranded fuel scenario is predicated on the assumption that the price of HFO will be substantially discounted after January 2020. If this occurs, it is only likely to be until existing stocks of HFO are exhausted, at which point the price will normalise at a level not yet known, due to the low level of demand from vessels with scrubbers across the global fleet and the added costs for bunker suppliers to support the product.

2. Diminishing CAPEX Hurdle

Historically, the high capital expenditure (CAPEX) for LNG engines and fuel tanks was a barrier to adoption. However, recent shipyard prices signal substantially smaller LNG premiums above traditional vessels. LNG newbuilding experience and technology improvements have led to shipyard and other efficiency gains. These, together with current shipyard market conditions, continue to favour buyers of newbuildings. Recent changes in LNG engine manufacturing policy to focus on LP DF technology is likely to lead to increased competition reducing CAPEX further as well as improving GHG emissions performance.

3. 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. When priced against HFO the differential is nearly 22% because LNG contains more energy for a given mass. LNG as a marine fuel provides 49.32GJ of energy per ton, whereas HFO only provides 40.5GJ/ton on a Lower Heating Value (LHV) basis. Therefore, 2,000 tons of LNG provides the same amount of energy as 2,436 tonnes HFO. This study highlights the positive effect this additional energy availability from LNG has on investment.

4. Enhanced Environmental Performance

Energy suppliers are paying increasing attention to reducing their carbon footprint, demanding cleaner logistics chains in reaction to both tighter regulations, and the environmental climate. Environmental impacts are known to be of growing importance amongst leading charterers who as beneficial cargo owners give greater cargo volume preference to environmentally conscious transport providers. These customer demands create a strong competitive advantage for shipowners who embrace LNG as a maritime fuel.

LNG meets and exceeds all current compliance requirements for marine fuel content and emissions, which includes local and GHG. A recent independent study[2] by thinkstep showed GHG reductions of up to 21% are achievable now from LNG as a marine fuel, compared with current heavy oil-based marine fuels over the entire life-cycle from Well-to-Wake (WtW). Fossil-fuel LNG is a bridging fuel towards bio or synthetic methane, all of which are fully interchangeable and would utilise existing investments in LNG and LNG infrastructure. Further, blends of fossil-fuel LNG with bio or synthetic methane provide improved environmental performance today. For example, a blend of only 20% biomethane can reduce CO2 emissions by a further 13% compared with 100% fossil fuel LNG.

The thinkstep study confirmed that emissions of other local air pollutants, such as sulphur oxides (SOx) and particulate matter (PM), are close to zero when using LNG compared with current conventional oil-based marine fuels. Additionally, emissions of nitrogen oxides (NOx) are reduced by 95% with LNG fuel.

Improving regional air quality and human health is particularly important in busy ports and coastal areas where high population concentrations exist. There is increased societal and regulatory focus on reducing GHG emissions, and this should be planned for when investing in new vessels. As the cleanest fuel available in the quantities currently required by shipping around the globe, LNG provides a "future proof" compliance choice for ship-owners with present and planned emission requirements.

Current fuel use monitoring regulations facilitate measurement of emissions and the means to enforce reductions in local air pollution and GHG emissions towards the IMO goals of total fleetwide 50% GHG reduction by 2050 compared to 2008 base year.

[2] Thinkstep's 11 April 19 report – "Life Cycle GHG Emission Study on the use of LNG as Marine Fuel"

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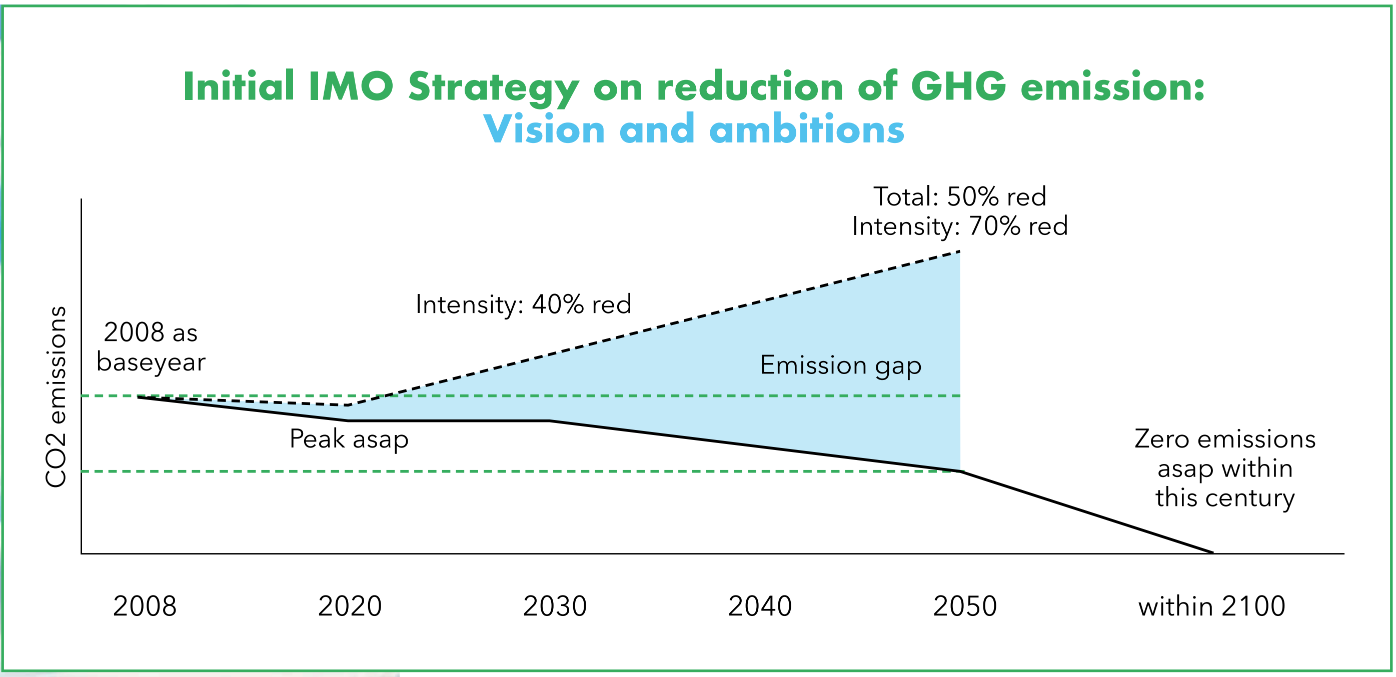


This study highlights the additional impact of imposed carbon emissions penalties. If $40[3] per tonne of CO_2 emitted is assumed, the net investment benefit for the 300K DWT VLCC fitted with 2s LP DF engine provides an increase of $4.4M[4] for LNG versus the open-loop scrubber ($3.5M versus compliant conventional fuel). These Net Present Value (NPV) investment gains will double as the carbon value doubles to $80 per ton of CO_2.

5. Most Financially Effective Long-Term Means of Complying with 2020 Sulphur Cap

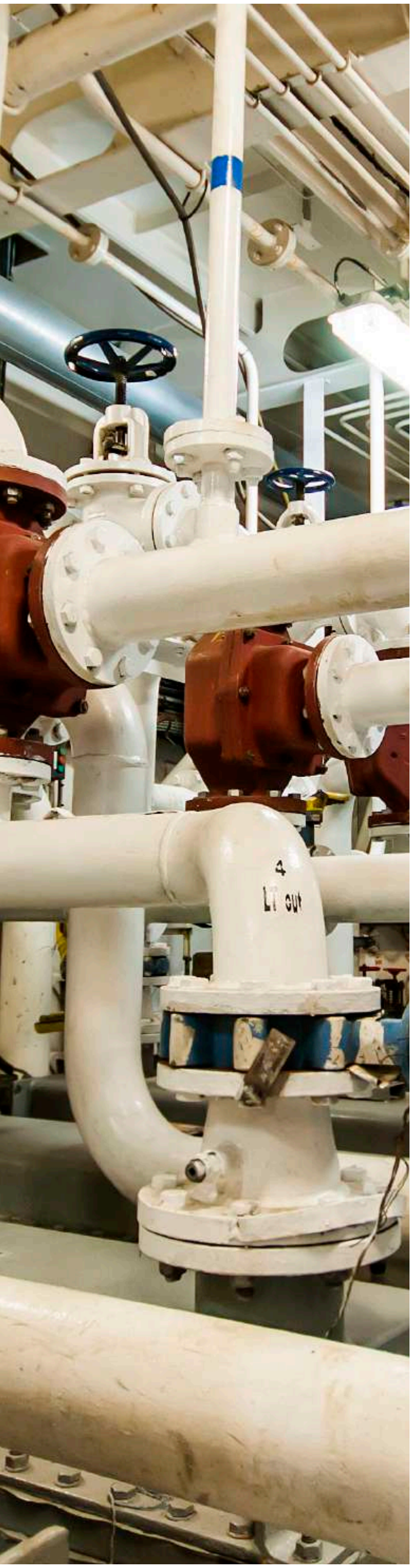
This study shows LNG as a marine fuel provides a greater return on investment than conventional compliant fuels across strong, average, and weak charter markets with NPV wealth gains of several million dollars. This study shows LNG fuel provides a lower return on investment for VLCCs than the installation of scrubbers in the stranded fuel forecast with plunging HFO pricing[5] . Indeed, as demand for HFO recedes substantially nearing 2020, the BAU basis responded and has fallen toward lower positions during 2019 Q3 approaching that of the 2020 stranded fuel forecast plunge levels.

While the case for scrubbers may appear marginally more favourable, the traditional business model excludes any impacts of CO_2 assessments to maintain a conservative approach to this investment case. However, there may be CO_2 credit or debit schemes in the future. If these CO_2 regimes are enacted, then the LNG business return for NPV improves favourably

[3] This figure was chosen as it is the same one used for investment analysis by BP (https://www.bp.com/content/dam/bp-country/fr_ch/PDF/bp-sustainability-report-2018.pdf), Total uses $30-$40, (https://www.total.com/sites/default/files/atoms/files/total_climat_2018_en.pdf), Equinor at least $50 (https://www.equinor.com/content/dam/statoil/image/how-and-why/climate/climate-roadmap-2018-digital.pdf), and Shell up to $85, (https://reports.shell.com/sustainability-report/2018/servicepages/downloads/files/shell_sustainability_report_2018.pdf).

[4] NPV of the annual CO2 savings occurring over the 10 year investment horizon discounted at WACC less 2% reflects environmental benefit requirements (8% - 2% = 6%).

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



by several million dollars. This scenario is explored by the model in later sections.

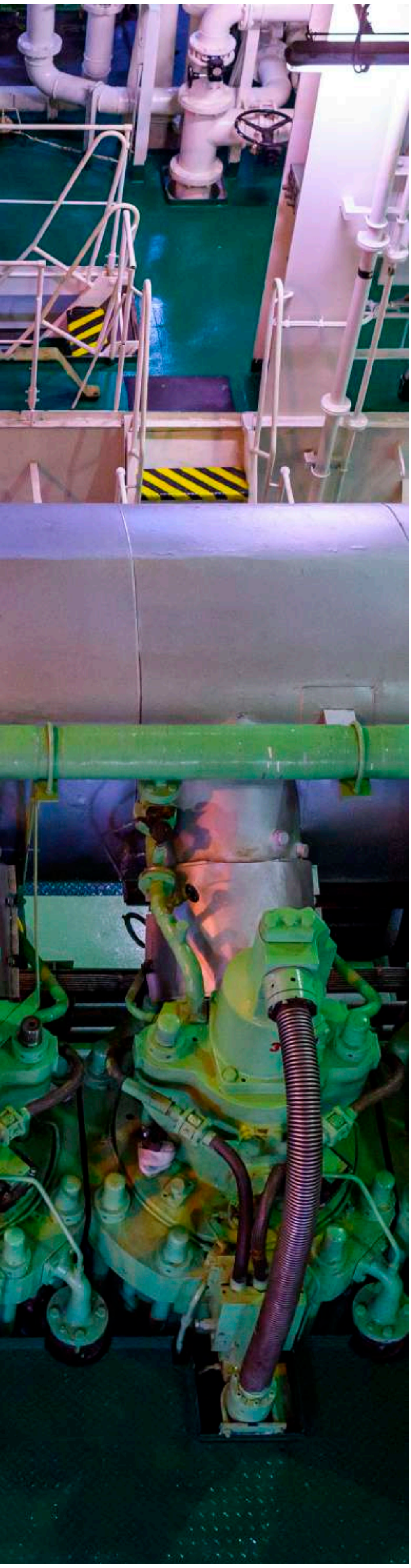
Although this stranded scenario is possible and analysed as such, it is deemed unlikely due to the growing, but relatively small number of scrubbers ordered in time to take advantage of the expected initial 2020 plunge in HFO pricing. The business case anticipates a VLCC ordered now is delivered in 2022 which will miss the first two years of favourable low HFO prices. A shorter opportunity window conveys much greater risk for the scrubber alternative dependent on sustained low HSFO pricing as the energy market and refineries make adjustments toward substantially lower volumes. This market realignment imposes greater price, quantity, and availability risks borne by the scrubber alternative that likely erase initial price benefits over the long term.

6. Scrubber Operation is Significantly More Expensive than Widely Reported

Despite the additional CAPEX for LNG over an open-loop scrubber solution of $13.2M, LNG fuel's operational expenditure (OPEX) cost savings balance out the CAPEX premium. Although the study assumed a conservative parasitic fuel penalty of only 1% for the supplementary power requirements to run scrubbers, there is considerable extra onboard ship management and onshore record-keeping required to operate scrubber-fitted vessels and ensure compliance with environmental legislation. Further restrictions prohibiting open-loop scrubber operations in various port jurisdictions are being debated and, in some cases, imposed. Where open-loop scrubbers are restricted, the additional cost for consuming costly Marine Gas Oil or the increased CAPEX for more complex hybrid/closed-loop Scrubbers must be added to the scrubber investment analysis.

7. The Cost of LNG is Stable

LNG marine fuel exhibits lower price volatility than traditional oil-based marine fuels because of the contribution difference from the underlying commodity to the total overall cost. The LNG cost structure is insulated from wild swings since the underlying commodity - natural gas - as variable cost represents a minor contribution (about 25%) in stark contrast to traditional marine fuels where total cost reflects the heavy dominance of fluctuating energy prices. Consequently, LNG pricing is much more stable than traditional maritime fuels which reflect the volatility of crude oil prices. Natural gas commodity prices have exhibited little fluctuation over recent history due to the steadily expanding global supply, which when combined with stable fixed costs for liquefaction and transportation allows LNG fuel to be contracted on a long term basis. Long term LNG



fuel price certainty provides a competitive advantage to those responsible for fuel payments. Vessel owner gains accrue for liner service or charters under voyage or contract of affreightment; charterers secure these benefits under bareboat or time charters. This relationship directly contrasts with HFO or diesel, where the underlying commodity dominates costs, and a century of infrastructure and refining improvements have driven these incremental costs downward. Hence, the cost of LNG marine fuel bunkers continues to remain less volatile than traditional oil-based marine fuels. While this may currently make the business case for LNG look slightly softer, it also underlines the cost volatility and instability risks inherent with HFO post-2020. Will there be sufficient availability? What will the price be? When taking these risk factors into consideration, the investment case for LNG is bolstered.

For ship owners and operators, the notion that fuel pricing is relatively stable creates a huge positive budget and business advantage. Given the high percentage of OPEX that marine fuel commands, having this pricing relatively stable over a long term is a strategic advantage for the shipping company as well as the underlying ultimate consumer of the service. With more stable fuel costs, fuel surcharges paid by customers of shipping services will be far less volatile over time.

Reader's Choice – whether Shipyard, Energy Supplier, Ship Owner or Charterer...

The four major stakeholders - shipyard, energy supplier, shipowner and charterer will benefit from insights and key perspectives obtained by utilising the "Reader's Choice" function to examine what makes the business-case work for all parties to achieve reasonable returns. While the results of this study are based on a set of fuel forecast assumptions, through "Reader's Choice" (see the end of this report), provision has also been made for each reader to impose their crystal ball on future costs and graphically determine quickly corresponding values that preserve the investment case wealth gain. Not only the reader's assumed decade average fuel prices for HSFO, LNG and/or VLSFO, but also the stakeholder may wish to understand first cost CAPEX impacts whose premiums may grow or shrink as a result of differences across three principal categories; market signals, technology choices, and/or physical differences such as vessel range.

Through exploring the reader's combinations amongst key attributes; fuel prices and CAPEX variations, the four stakeholders can gain valuable understanding of the robustness or fragility for the overall business case that otherwise may be obscure.

CONTEXT

The 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.

Today, as they have since the middle of the twentieth century, most ocean vessels rely on HFO which globally averages 2.5% sulphur. Of the total marine fuel demand of 680K metric tonnes of oil per day, 477K metric tonnes is 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 0.5% sulphur fuel-oil either:
    - Low Sulphur Fuel Oil (LSFO) or a blend of existing sulphurous HFO with no or low sulphur fuels such as 0.1% Low-Sulphur Marine Gas Oil (LS-MGO[6]) LS-MGO.
    - Continue consuming HFO and employ scrubbers to achieve alternative compliance.

The global shipping industry had to implement initial global sulphur limits only a few years ago. The introduction of restrictive Emission Control Areas (ECA)s 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.

Shipowners are challenged with making significant investment decisions in an unprecedented dramatic fashion under a range of uncertainties. Many have chosen the LSFO route. Around 94% of ships will likely be running on LSFO based on the relatively low level of orders for scrubbers and LNG fuelled vessels. This decision raises several questions: Will that prove to be the best solution? Can the higher fuel cost be recovered from customers? Will the quality, consistency and compatibility of future LSFO blends be available where and when it is needed?

[6] 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.

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 or PM 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 of decision-making. For many shipowners and operators, it will necessitate a portfolio approach[7] 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 this 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 300K DWT VLCC sailing from the Arabian Gulf to Eastern China. 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."

The study was undertaken to make sense of the investment case based upon three different fuel-pricing scenarios (Business as Usual, Stranded Fuels, and Reader's Choice) 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 BAU and Stranded Fuels forecasts, LNG against compliant fuels delivered the greatest return to shipowners and operators on an NPV basis over a conservative 10-year horizon, with compelling payback periods ranging from three to four years. This return excludes the NPV of the environmental benefits that LNG delivers. The Stranded Fuels scenario predicts a plunge in HFO toward $200/ton with the implementation of the 2020 IMO global sulphur cap and slow price recovery thereafter, as market forces and global oil refining capacity switch toward higher

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

demand and greater margin low sulphur fuels. As that occurs, supply will likely balance demand within a few years of implementation in early 2020. Therefore, most saving benefits, if any, will accrue to the early adopters and late adopters may find this window quickly closing. As this VLCC enters into service in 2022, it misses the advantage of the initial HFO plunge captured by the early adopters and will also have to cope with the price volatility of HFO at that point in time, which remains unclear.

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. There is also the risk of taking onboard non-compliant fuel and being penalised by State Port compliance authorities.

Scrubbers

Scrubber uptake, according to classification society DNV-GL, will 'be over' 3,500 vessels by 2020[8]. However, this only represents around 6% of the world trading fleet of 58,500 vessels. The technology, which in 2019 has seen an upsurge in uptake, does not offer any GHG reduction benefits and may be viewed as a short-term solution. Those opting for open-loop scrubbers may not be able to take full advantage of these systems due to recent legislative changes. Several nations, including Singapore and China, have 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. Although it may be the least predictable of the three main options for a vessel of this type, scrubbers do offer a short-term financial gain, provided the unit is operational and able to capture the benefits window commencing 1st January 2020. As mentioned though, as this VLCC will not come into service until 2022, it misses this early window of opportunity. It must also contend with the, as yet, unknown availability and cost of HFO. As the recent HFO price volatility demonstrates, this creates significant risks.

[8] https://www.hellenicshippingnews.com/sulfur-limit-debate-continues-scrubbers-seeing-a-faster-pace-of-adoption/

LNG

When analysing investment options for 2020, it is important to contextualise and recall why the 2020 rules were implemented. Although shipping has demonstrated that its focus is very much on the bottom line when analysing 2020 options, the 2020 legislation was devised to improve the environmental performance of the industry dramatically. Regional air quality, especially around major maritime ports, has been a concern for decades and continues to be a key human health issue around the world. LNG provides significant air quality improvements over traditional fuels which provides better human health for longer life.

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 95% fewer nitrogen oxides (NOx) and through the use of best practices and appropriate technologies to minimise methane leakage, reductions of GHG by up to 21% on a WtW basis, (28% on Tank-to-Wake) are achievable[9]. These benefits can and will see increases with a potential for up to 30% or more as technology develops, compared with conventional oil-based fuels. A blend of 20% biomethane as a drop-in fuel can reduce GHG emissions by a further 13% when compared to 100% fossil fuel LNG. LNG is a cleaner fuel and a clear winner when it comes to local emissions and contributes measurably to world health goals. It also represents a significant step forward in the reduction of GHGs and a potential pathway to meeting future carbon-related emissions targets.

This SEA\LNG Business Case study is intended to help the ship owning/operating community to analyse options in an informed way. The study simultaneously provides a deeper analysis of the assumptions that go into the 2020 decision process. Compared to many other case studies on this topic, this one sets 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 VLCCs, SEA\LNG has also produced similar studies for container and PCTC vessels, and are working on additional studies that analyse the investment case for other typical ships and common trades.

[9] Thinkstep's 11 April 19 report – "Life Cycle GHG Emission Study on the use of LNG as Marine Fuel"

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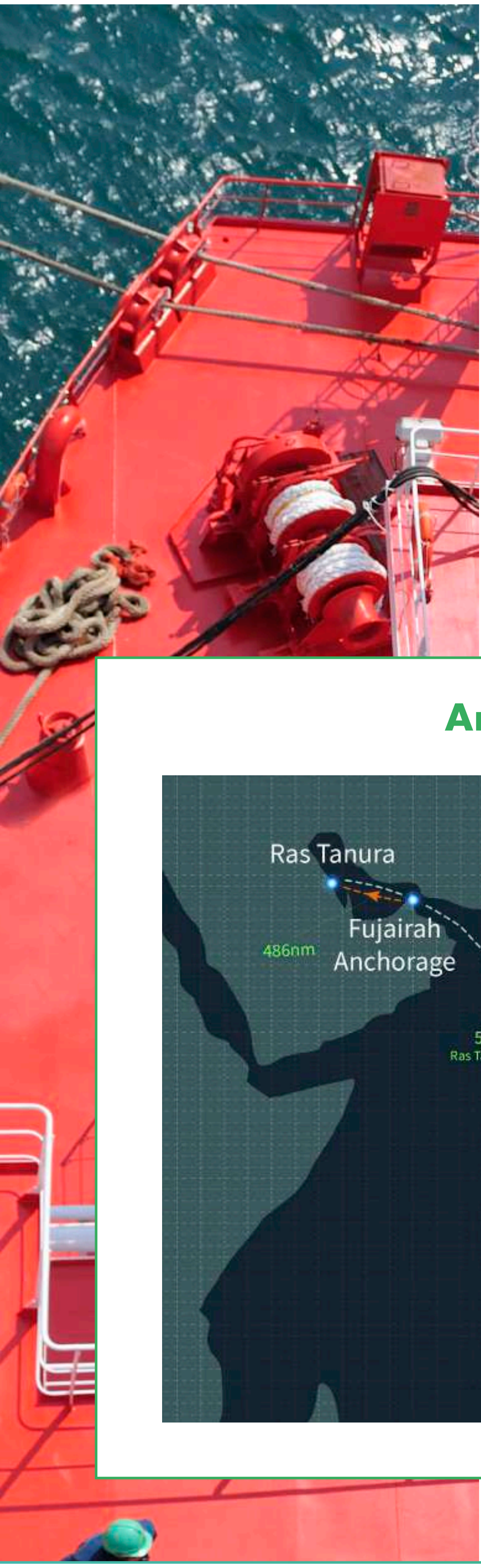
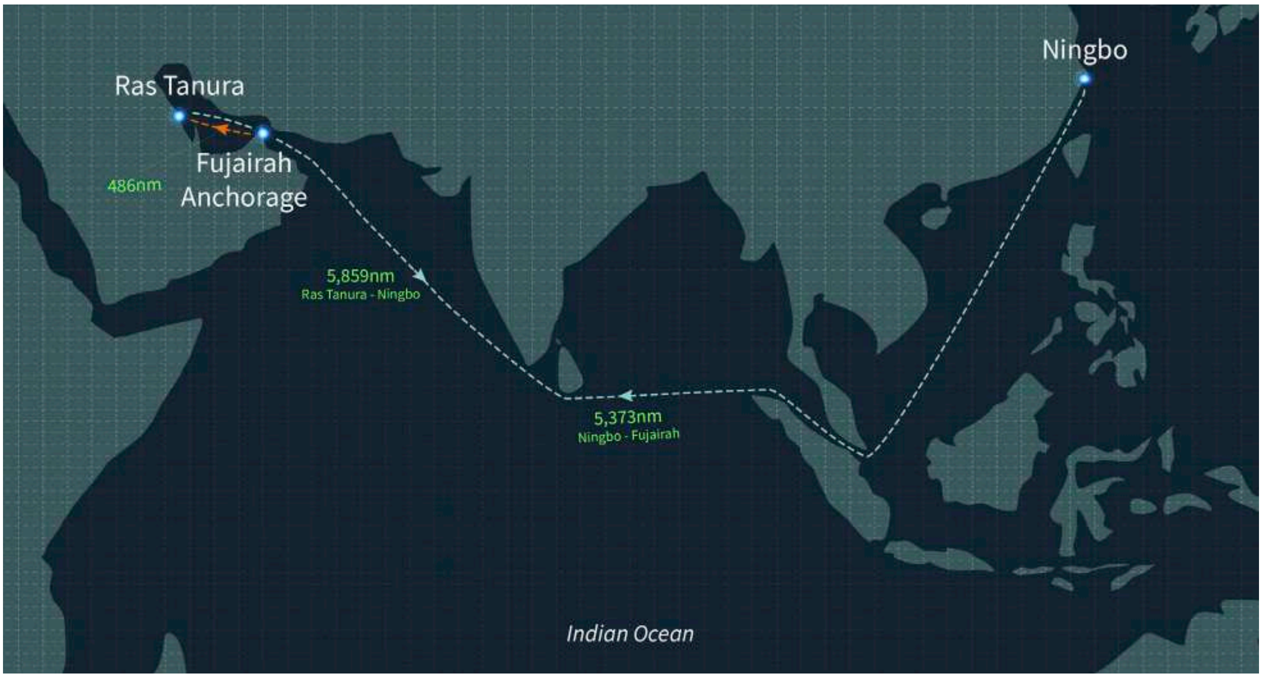


MAIN ASSUMPTIONS

The main assumptions include the following:

- The business case envisions three market phases; Strong Charter Spot Markets with sailing speed at 13.5 knots laden and 14.5 knots ballast; base case average spot markets at 13.0 knots both laden and ballast; Weak markets at 12.5 knots laden and 11.0 knots ballast.
- The VLCC Arabian Gulf-China route runs between ports Ras Tanura / Ningbo shown in the diagram below. The total sailing distance is 11,718nm. No distance is spent in a SECA or NECA, but there is no scrubber discharge for 106nm (0.9%) of the route. The vessel modelled waits for instructions at Fujairah Anchorage before loading crude at Ras Tanura.

Arabian Gulf - China Trade Route



Fossil-fuel LNG is a bridging fuel towards bio or synthetic methane, all of which are fully interchangeable and would utilise existing investments in LNG and LNG infrastructure.

- The VLCC enters into service beginning year 2022 as the initiation date in fuel forecast, which means it misses the lowest and most favourable HFO pricing point commencing 2020.
- The case assumes the VLCC is contracted in 2020 and therefore is subject to IMO EEDI Phase 2. The VLCC with LNG will meet the 2022 IMO EEDI Phase 3 requirements
- The VLCC is fitted with a pair of on deck LNG bunker tanks which hold a combined total of 7,200 m3 of fuel. This fuel quantity provides a range exceeding 23,000 nautical miles, which is sufficient to allow trading over most of the envisioned cargo routes for the vessel. Recent reports on VLCC LNG tank sizes are similar at 7,000m3[10] and 7,500m3[11].

Speed

The speed of a VLCC varies dramatically in ballast and less when laden as market conditions change. With so many influencing factors affecting both the laden and ballast legs, it is challenging to choose only one voyage scenario of laden and ballast speeds. The markets have a substantial influence on the ballast speeds, which impact the supply of tonne-miles available for a route. Strong markets exhibit naturally higher speeds (ship owners race back to fix another profitable spot cargo); and slower ballast return speeds (at lower fuel consumption costs to the ship owner's account) during weak freight markets. The price of crude also figures a modest and smaller influence on the route speeds, market supply, and cost of inventory in transit. The supply of vessels in the crude trades can also shift tonnage capacity as clean vessels enter the trade on inducement or vice versa exit.

While speed selection was difficult, reasonable, realistic laden and ballast speed choices were made representing the historical ranges for strong, base case normal, and weak charter spot markets.

Financial

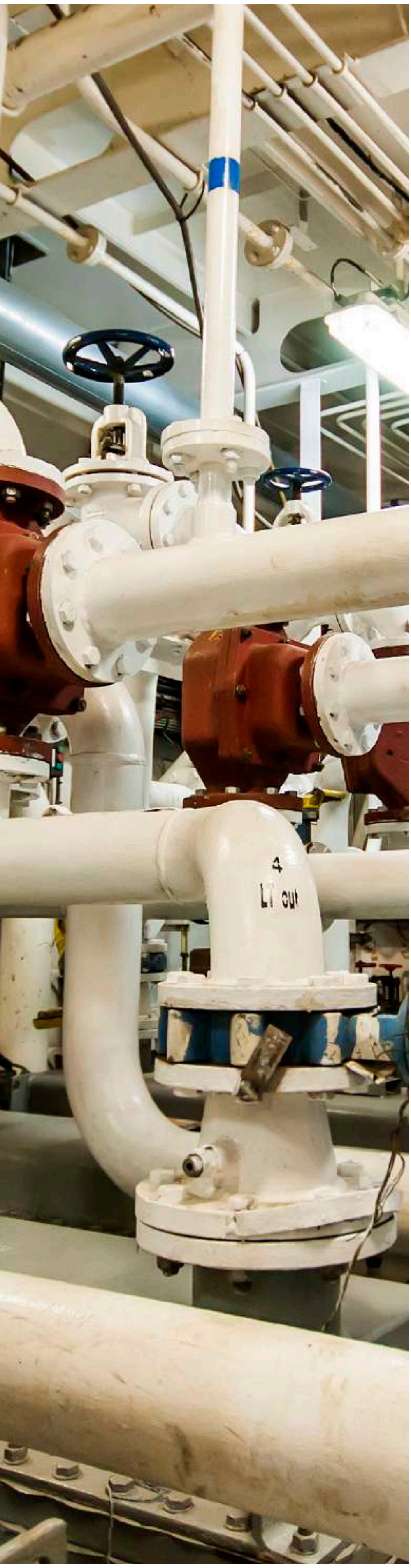
a) **Newbuilding LNG-fuelled vessel**

The study utilises 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 a significant future lifetime to justify the additional CAPEX investment.

b) **Investment Hurdle Rate**

The study utilises 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

[10] Trade Winds "Costco Tanker Outfit makes first move for VLCC fuelled by LNG" Irene Ang 14 November 2019.
[11] Trade Winds "Capital Maritime grabs first-mover role on LNG fueled VLCCs" Irene Ang and Lucy Hine 5 September 2019.



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 very conservative timeframe understanding that the economic life for VLCC vessels exceeds this substantially. The choice also recognises 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 the end of the investment horizon period as a very conservative condition. This assumption 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.

f) **CO2 Credits**

The traditional business model excludes any impacts of CO2 assessments to maintain a conservative approach to this investment case. However, there may be CO2 credit or debit schemes in the future. If these CO2 regimes are enacted, the business return on an NPV basis in favour of LNG improves by several million dollars. This scenario is explored by the model in later sections.

Capital Expenditure

Four types of main engine (M/E) configurations were fully priced and compared in this study: a dual fuel HP 2-stroke LNG engine (2s HP DF) with Tier III treatment, a dual fuel LP 2-stroke LNG engine (2s LP DF), a conventional diesel cycle low-speed engine fitted with an open-loop scrubber plus SCR, and a conventional diesel cycle low-speed engine fitted with SCR but without scrubber. The investment required for each

engine configuration, including key components, are 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.

2s HP DF

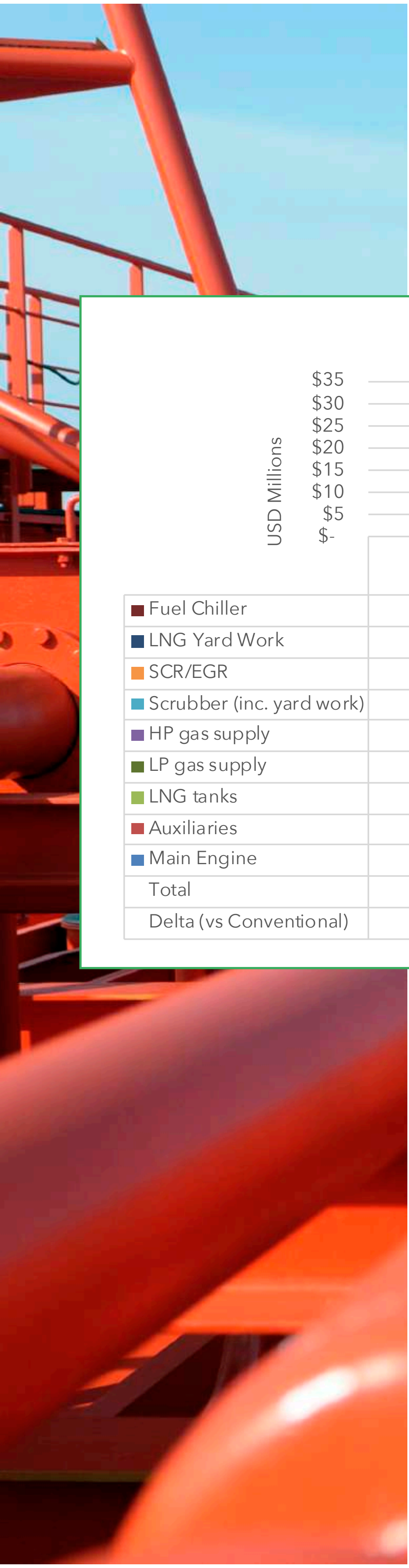
This configuration is modelled on a MAN 7G80ME-C10.5-GI for the 300K DWT VLCC using approximately 2% MGO pilot fuel with no methane slip. Although NOx Tier II compliant, the M/E requires Selective Catalytic Reduction (SCR) or Exhaust Gas Recirculation (EGR) to comply with Nox Tier III. The auxiliary engines (A/E) and boilers are assumed to be gas-only and do not require SCR. M/E Specific Gas Consumption (SGC) is 132.5 g/KWh: gas is supplied at 300-350 bar to the M/E and low pressure to the A/Es. The HP gas system CAPEX is costed at $1.70M, with the LP gas system at $700K for the vessel. There is no differential CAPEX attributed to the boilers and mechanical propulsion is assumed.

2s LP DF

This configuration is modelled on a WinGD 7X-82DF Winterthur Gas & Diesel engine for the VLCC which uses a 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 SGC is 136.3 g/KWh and about 0.6g MGO pilot fuel with low-pressure gas supplied to the M/E and A/Es. Once again, the LP gas systems are priced at $700K with no differential CAPEX attributed to the boilers, and mechanical propulsion assumed.

Open-loop scrubber vessel

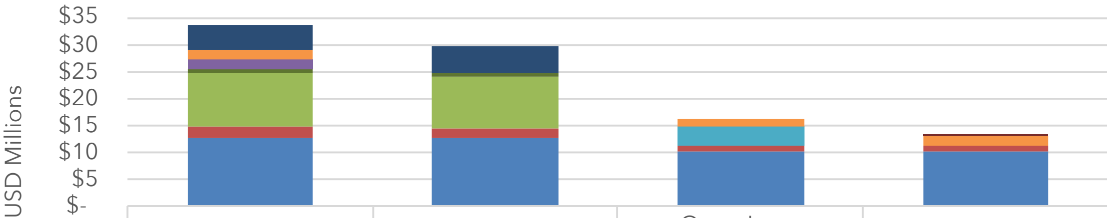
This configuration is based on a conventional diesel cycle, low-speed engine, MAN 7G80ME-10.5, with a scrubber fitted to cover exhaust from the M/E, A/E and one boiler rated at 5MW. The other boiler is assumed to be powered using waste heat recovery (WHR) and is therefore not scrubbed. Although the M/E is NOx Tier II compliant, an SCR is required to comply with NOx Tier III at an approximate cost of $1.62M for the vessel. M/E Specific Fuel Oil Consumption SFOC is 168.8 g/KWh on HFO, including scrubber load. The scrubber is open-loop and so does not consume Sodium Hydroxide (NaOH).



Conventional Vessel

This configuration is based on the same conventional diesel cycle, low-speed engines – MAN 7G80ME-10.5. Whereas the M/E is NOx Tier II compliant, an SCR is required to comply with NOx Tier III. M/E SFOC is 158.2 g/KWh using VLSFO. Additional CAPEX of $118K is assumed for a fuel chiller for the vessel since the M/E was designed to operate with fuels of higher viscosity relative to MGO.

CAPEX summary - VLCC

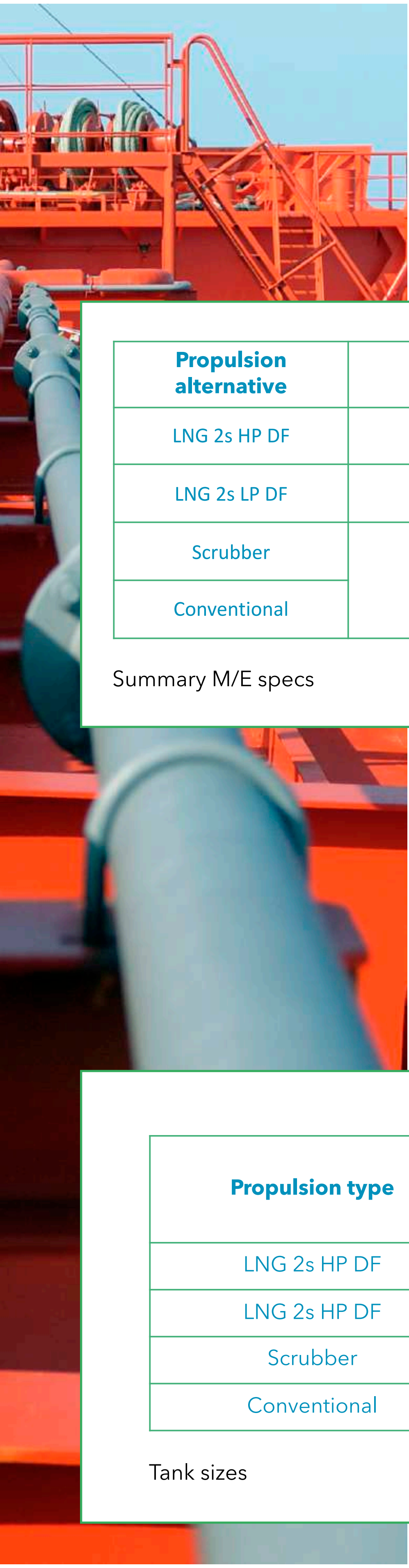


	2-s HP DF	2-s LP DF	Open Loop Scrubber	Conventional
Fuel Chiller				$118,000
LNG Yard Work	$4,653,750	$4,653,750		
SCR/EGR	$1,750,707		$1,626,055	$1,626,055
Scrubber (inc. yard work)			$3,412,723	
HP gas supply	$1,700,000			
LP gas supply	$700,000	$700,000		
LNG tanks	$9,940,528	$9,940,528		
Auxiliaries	$2,308,800	$1,730,000	$1,332,000	$1,332,000
Main Engine	$12,660,480	$12,660,480	$10,128,384	$10,128,384
Total	$33,714,265	$29,684,758	$16,499,162	$13,204,439
Delta (vs Conventional)	$20,509,826	$16,480,319	$3,294,723	$-

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

- 2s HP DF $20.5M
- 2s LP DF $16.5M
- Open-Loop Scrubber $3.3M

The CAPEX premium for LNG alternatives over a scrubber with IMO 2020 0.5% compliance is $17.2 M for a 2s HP DF M/E arrangement and $13.2M for a 2s LP DF M/E arrangement. One note of caution, the scrubber assumption is for an open-loop system. The open-loop scrubber CAPEX is lower than that for a more costly complex 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 waters, which is no longer be possible given recent restrictions.



Fuel Consumption

M/E fuel consumption is summarised in the table below. Scrubber consumption includes a very conservative 1% parasitic load as a lower range value. Energy consumption includes pilot fuels for the LNG DF engines. Indicative consumption figures in the table are for 13.0 knots. The table highlights the fact that LNG contains 22% more energy content for a given mass than conventional oil-based fuels.

Propulsion alternative	M/E archetype	R1 rating [MW]	SFOC [/kWh]
LNG 2s HP DF	MAN 7G80ME-C10.5-GI	32.970	132.5 g LNG + 3.0 g MGO
LNG 2s LP DF	WinGD 7X82DF	30.240	136.3 g LNG + 0.6 g MGO
Scrubber	MAN 7G80ME-C10.5	32.970	168.8 g HFO (incl scrubber load)
Conventional			158.2 g VLSFO

Summary M/E specs

Fuel tank size impacts

The report models a C type LNG tank of sufficient volume for the VLCC to achieve a range near 23,000 nautical miles with a 15% sailing margin. The study considers displaced cargo loss assessment. As the LNG tanks are located above deck for the VLCC, there is no cargo displacement loss and insignificant impact on weight or stability. The 7,200m3 LNG tanks' CAPEX is evaluated at $9.9M.

Propulsion type	Tank Sizes [m3]			
	LNG	HSFO	VLSFO	MGO
LNG 2s HP DF	2 x 3,600			200
LNG 2s HP DF	2 x 3,600			200
Scrubber		3,800		200
Conventional			3,500	1,000

Tank sizes

Fuel Costs

The study considers four fuels, LNG plus three oil-derived fuels. The oil-derived fuels are:

1. A conventional high sulphur fuel oil "HSFO" with as much as 3.5% S.

2. A marine gas oil "MGO" distillate containing 0.1% S

3. A very low sulphur fuel oil "VLSFO" which complies with 0.5% S.

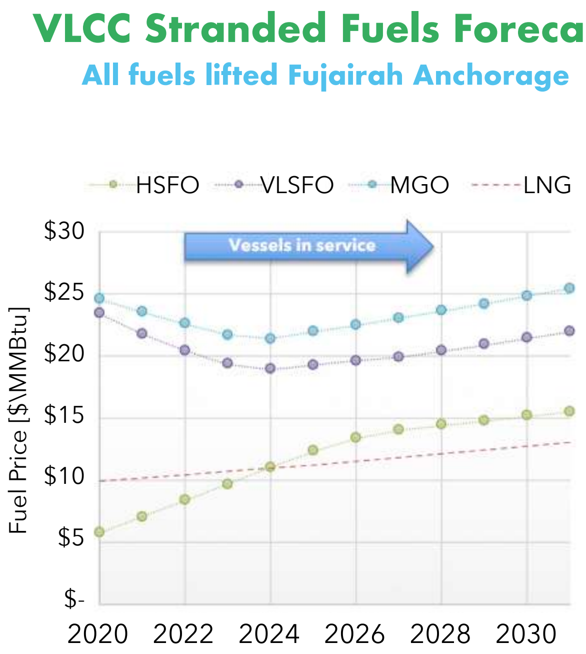
Although 0.5% S fuels can be achieved either through blending oils of different sulphur content or directly from the residual of a single naturally sweet crude, it is assumed that the price of these VLSFO alternatives would converge despite differences in their chemical composition. Throughout this document, we assume that VLSFO is a blend of 85% MGO and 15% HSFO[12]. The physical properties and prices for VLSFO are obtained accordingly.

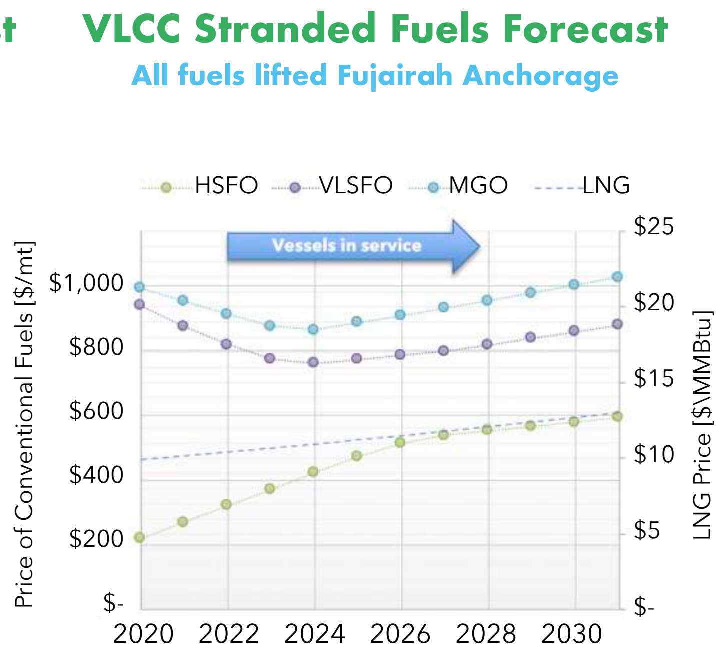
Three scenarios are modelled in the study representing fuel price forecasts beginning in 2020 with the vessel entering into service from 2022 for an investment horizon extending out ten years:

1. **Stranded Fuels**
   The rationale behind this forecast is that HSFO stocks will become stranded at 2020 due to low penetration of scrubbers. Penetration of scrubbers to grow gradually towards 2027, leading to a gradual recovery of HSFO prices. MGO and distillates will see very high demand in 2020 and price pressure. As LNG and scrubbers increase their penetration and additional refinery capacity comes on-line, MGO prices will level down, before increasing with inflation. 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 rise gently with inflation through 2030.

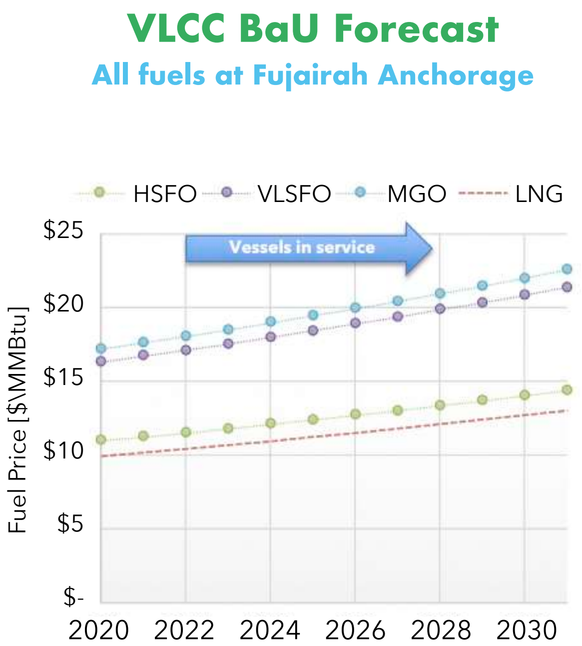
[12] We assume an average sulphur content of 2.76% for HSFO. Blending of 85% MGO and 15% HSFO then leads to 0.5% sulphur content

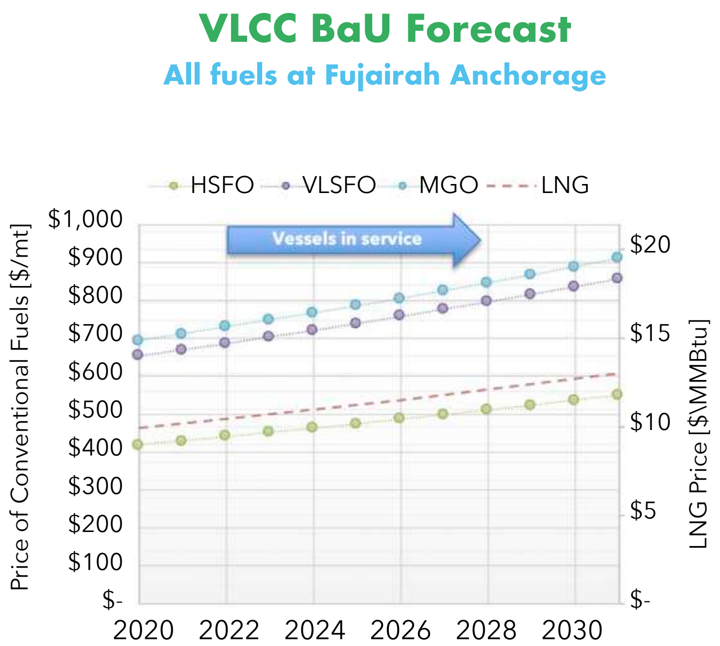
LNG is a clear winner when it comes to local emissions and world health goals.





2. **Business as Usual "BAU":**
   Relative prices remain as they were as of Q3 2019.





3. **Reader's Choice**

   For a given vessel on a trade route, a fresh perspective-seeking reader may ask: "If one fuel price is X what is the tipping point for the alternative fuel price Y for the business case to be neutral on NPV?" The "Reader's Choice" sensitivity plot for the BAU case provides additional insights.

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

Initial LNG Pricing

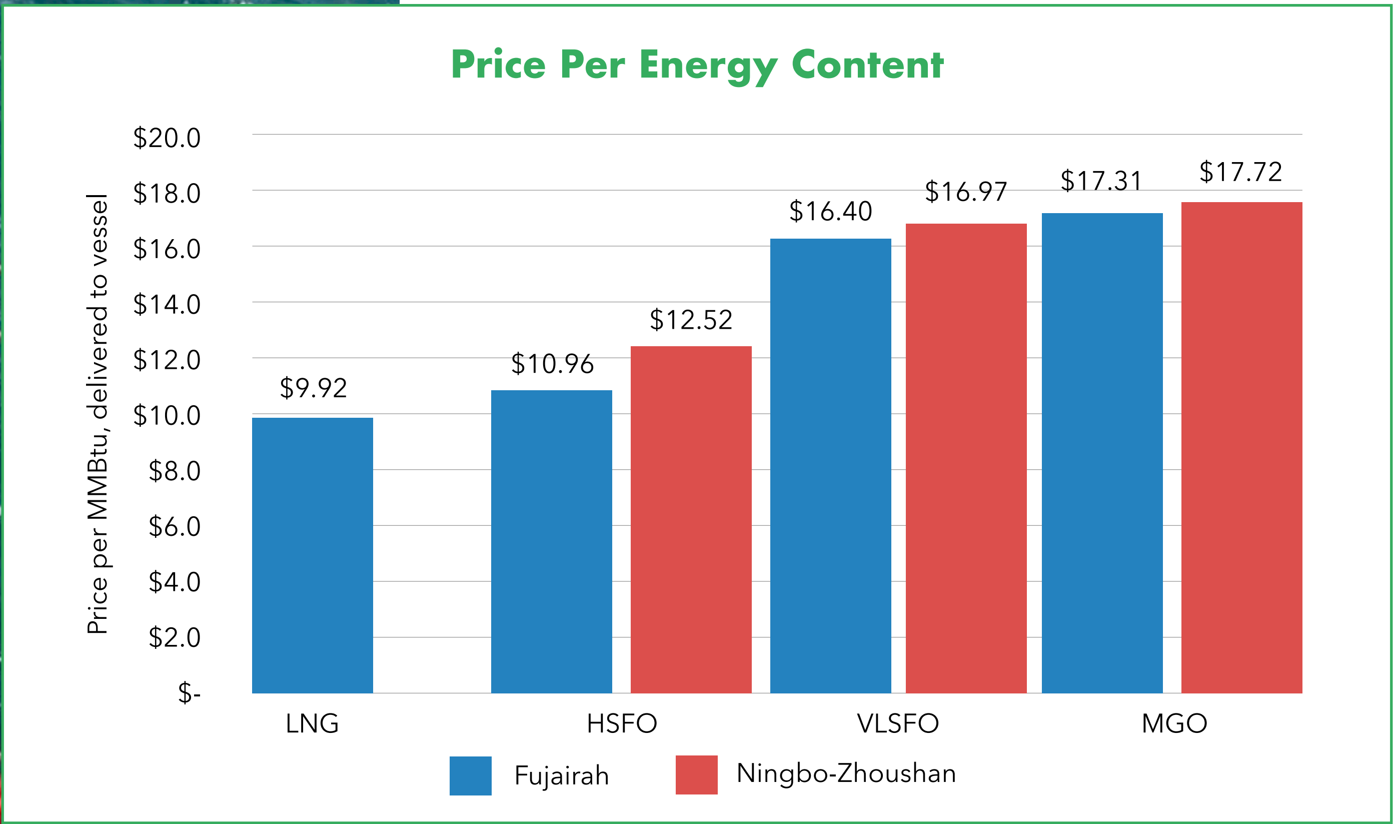
It is assumed that all vessels would take fuels at Fujairah Anchorage while awaiting instructions to proceed for loading at Ras Tanura. LNG is sourced from Sohar and transported to Fujairah Anchorage by a bunkering vessel for vessel-to-vessel transfer to the VLCC. LNG pricing is set at 12% of Brent, FOB the bunkering vessel. The model used the price of Brent at $66/bbl based on historical data[12]. These assumptions lead to LNG FOB price of $7.92 / MMBtu. $2.0/MMBtu is added for delivery of LNG to the VLCC. With this, the price of LNG delivered onboard the vessel is $9.92 / MMBtu.

Fuel Type	Fujairah Anchorage	Ningbo-Zhoushan
HSFO	$ 420.9	$ 480.6
VLSFO	$ 658.6	$ 681.7
MGO	$ 700.5	$ 717.2

Average Fuel Prices, July 2019 [USD/mt]

[12] Two-year median taken on Aug 2nd 2019 from the U.S. Energy Information Administration webpage.

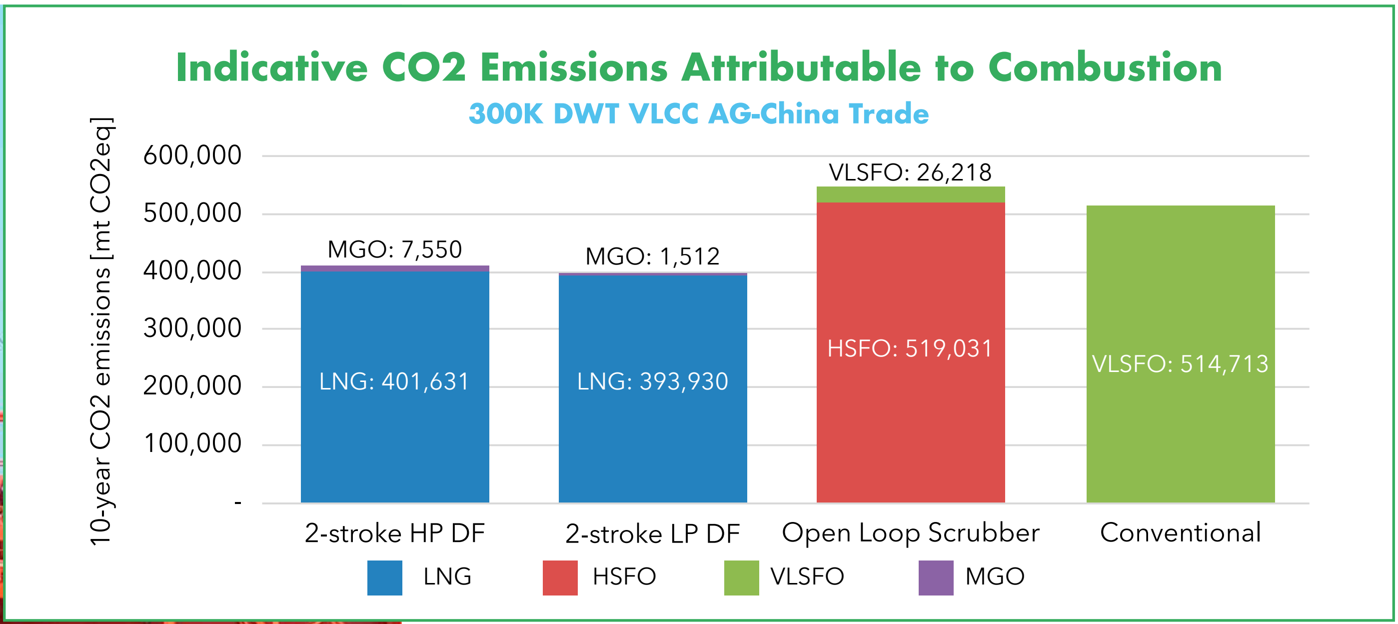
Taken together these fuel cost assumptions result in the following costs on an energy basis for 2020:



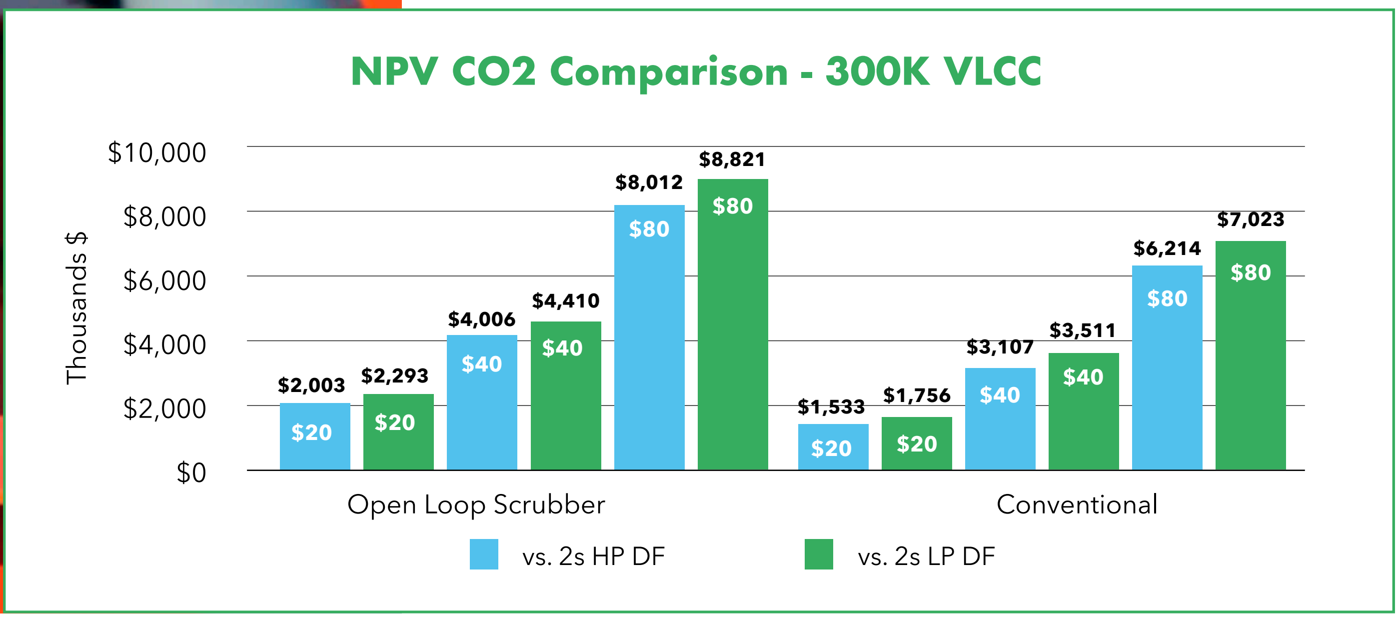
All of the above fuel forecasts are assumptions; however, the investment model can be adjusted for other fuel scenarios should the basis for these forecasts change.

Carbon Costs

IMO regulations, introduced on 1st January 2019, mandate that all vessels record fuel consumption. These records allow vessel GHG emissions to be calculated and reflects the additional regulatory focus that may follow in coming years to promote GHG emissions/efficiency. The IMO is retaining the information on a vessel type basis, providing them with the opportunity to baseline performance. It is considered likely that the IMO or others will set tighter standards on GHG emissions. Such standards are in place already for NOx emissions and individual Energy Efficiency Design Index (EEDI) requirements for newbuildings. The EU has a similar program of CO2 reporting, which began on 1st January 2018, but the values are retained per vessel IMO number. This means each vessel's history is kept specific to it, not homogenised into a vessel category as per the IMO CO2 records.



If a carbon value of $40 per ton of CO_2 emitted is assumed, (as shown in the middle bars below), the NPV gains for the 300K DWT VLCC fitted with 2s LP DF engine increase to $4.4M[13] for LNG versus the open-loop scrubber (up to $3.5M versus compliant conventional fuel). The NPV investment gains double as the carbon value doubles to $80 per ton of CO_2 (right-hand bars). In effect, an additional $8M can be achieved in wealth gain if CO_2 consumption is factored in at the higher per tonne rate. While this is not yet included in the normal investment profile of CAPEX dollars for fuel savings or money spent, it ought to be considered as environmental factors increasingly become a benefit rather than a cost. Taking carbon pricing into account, any benefits currently achieved through scrubbers will be negated even further and, with the inclusion of drop-in fuels, the NPV for LNG- fuelled vessels will improve substantially.



[13] NPV of the annual CO2 savings occurring over the 10 year investment horizon discounted at WACC less 2% reflects environmental benefit requirements (8% - 2% = 6%).

RESULTS

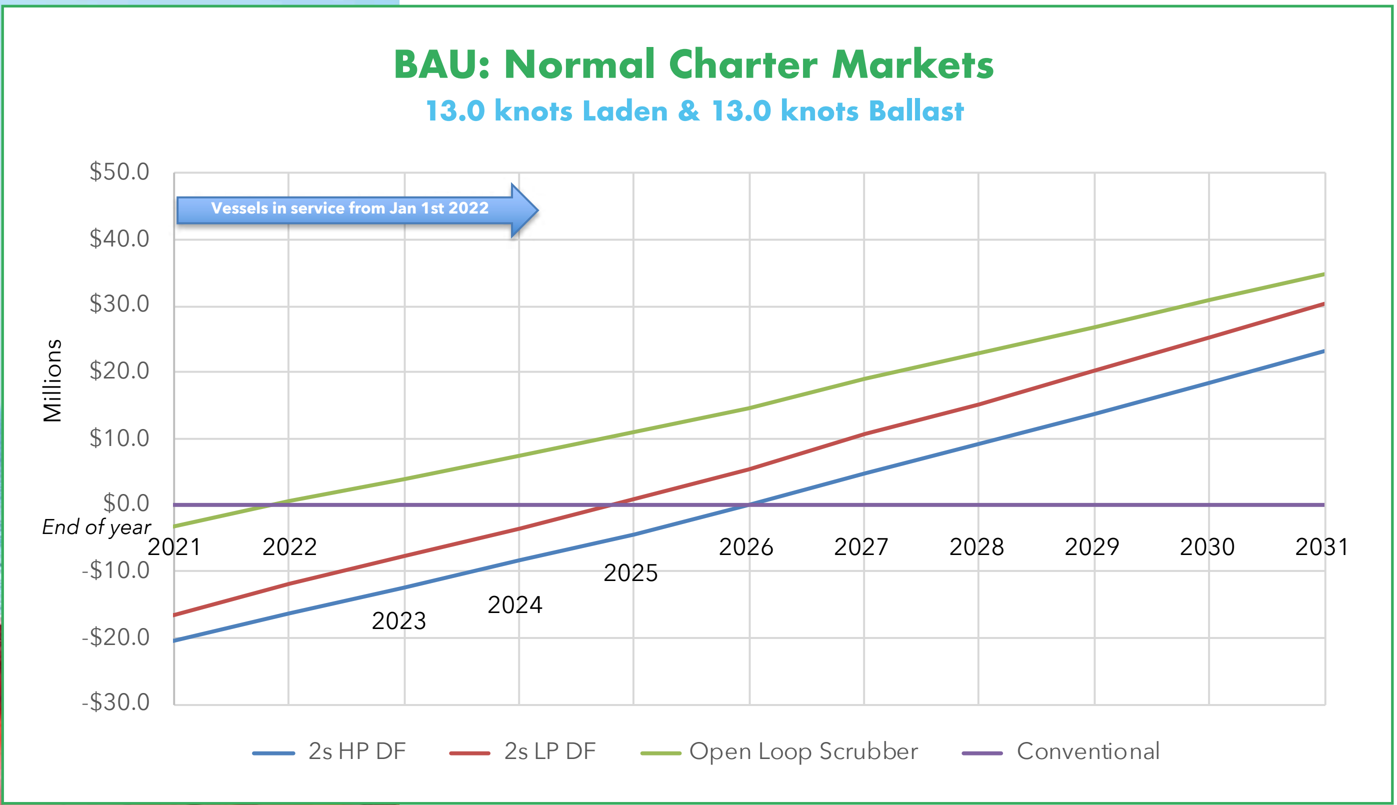
This study clearly indicates that LNG as a marine fuel delivers a strong return on investment on an NPV basis over a conservative 10-year horizon against conventional compliant fuels. The LNG payback periods are compelling, ranging from three to five years. While LNG delivers a marginally less favourable return on investment than open-loop scrubbers in two scenarios; to achieve the returns illustrated in the stranded fuel and BAU examples scrubbers need to be installed and working at the start of 2022. Current orders and shipyard capacity mean than any scrubbers ordered now will not be operational until 2022, at the earliest. It is also important to reiterate that open-loop scrubbers deliver no CO2 benefits, which, if carbon emissions attract a financial value through regulation, would improve the NPV significantly for LNG fuel, and even more so with the addition of drop-in fuels.

With lower demand for HFO following the implementation of the sulphur cap in 2020, the availability of HFO on a global basis is unknown. How many bunker suppliers will keep "dirty" bunker supplies and at what cost? Consequently, any investment decisions taken based on this scenario are deemed high risk.

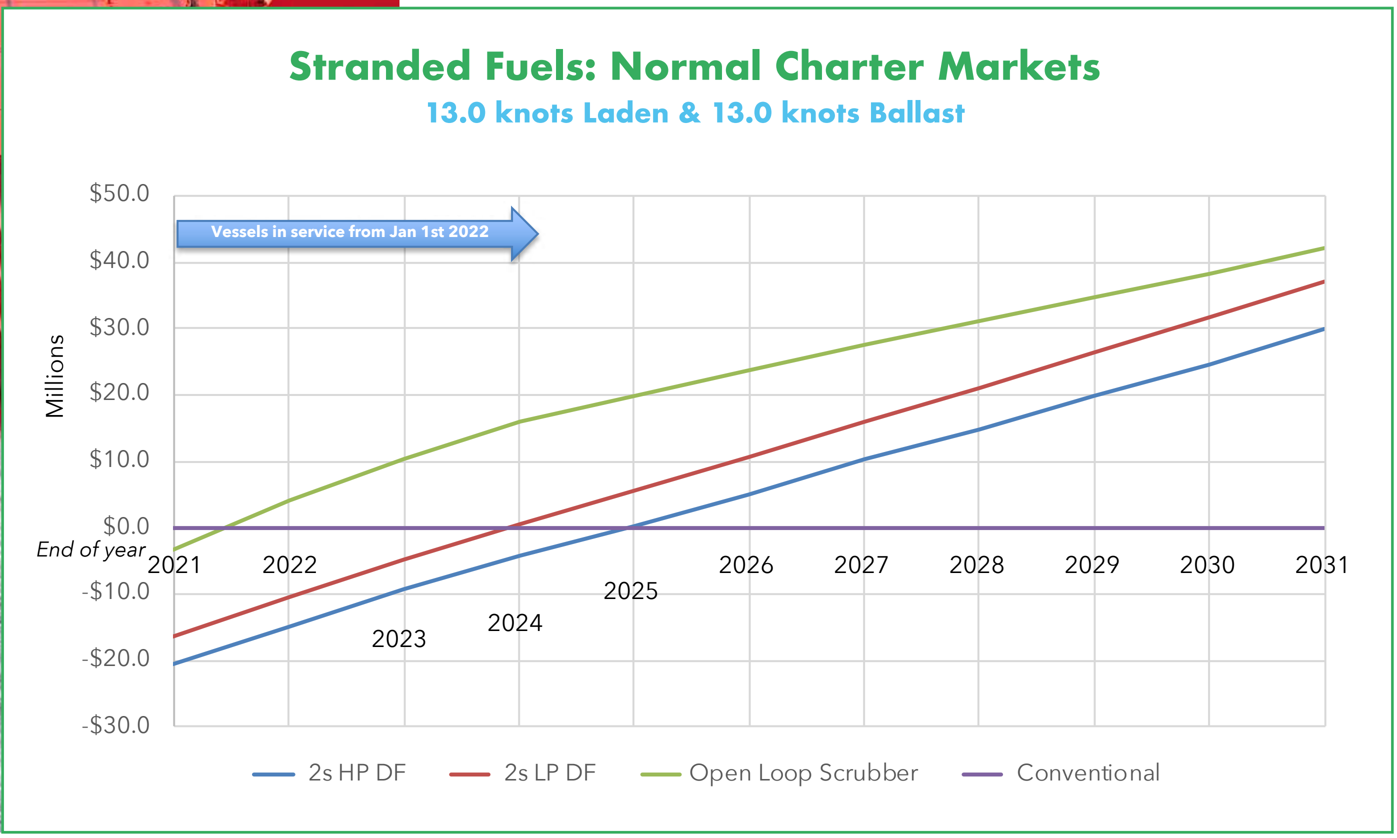
This study clearly indicates that LNG as a marine fuel delivers a strong return on investment on a NPV basis over a conservative 10-year horizon with fast payback periods ranging from three to five years.

Payback scenarios for VLCC

a) BAU

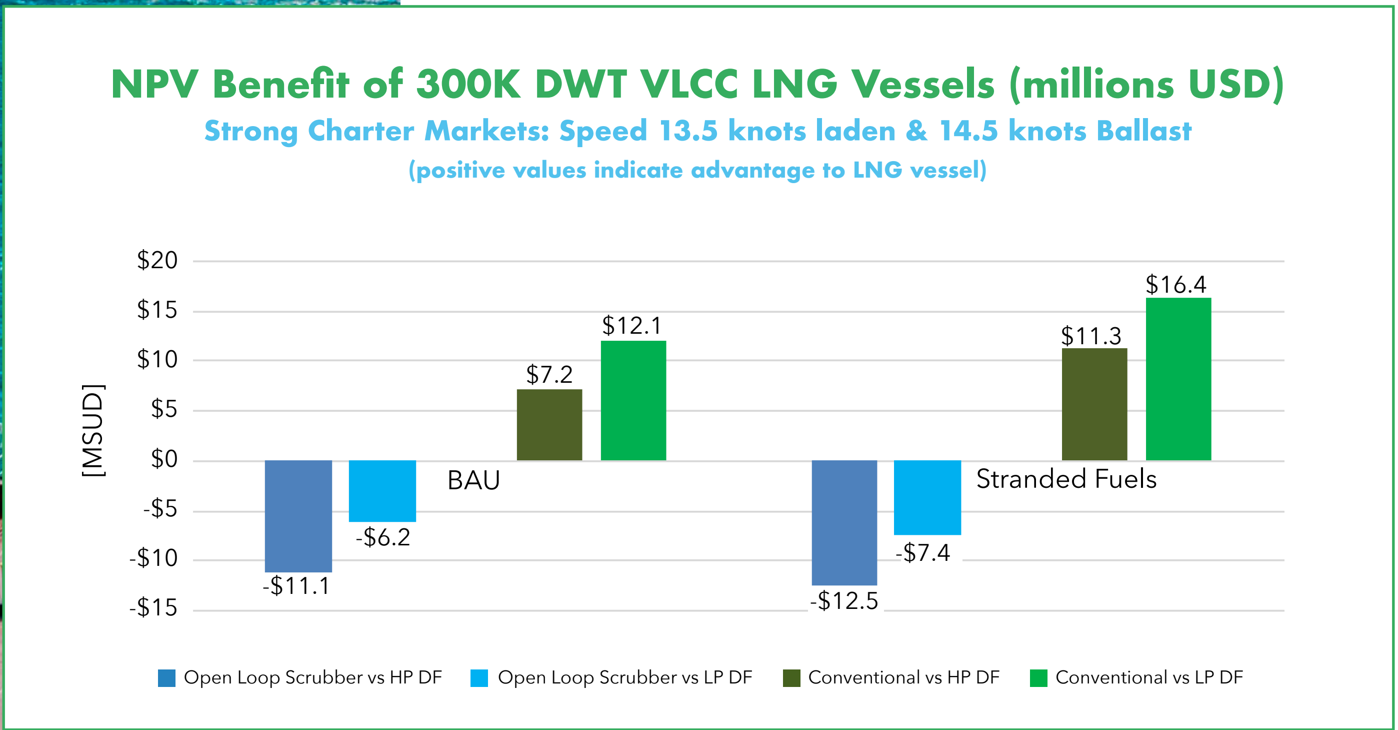


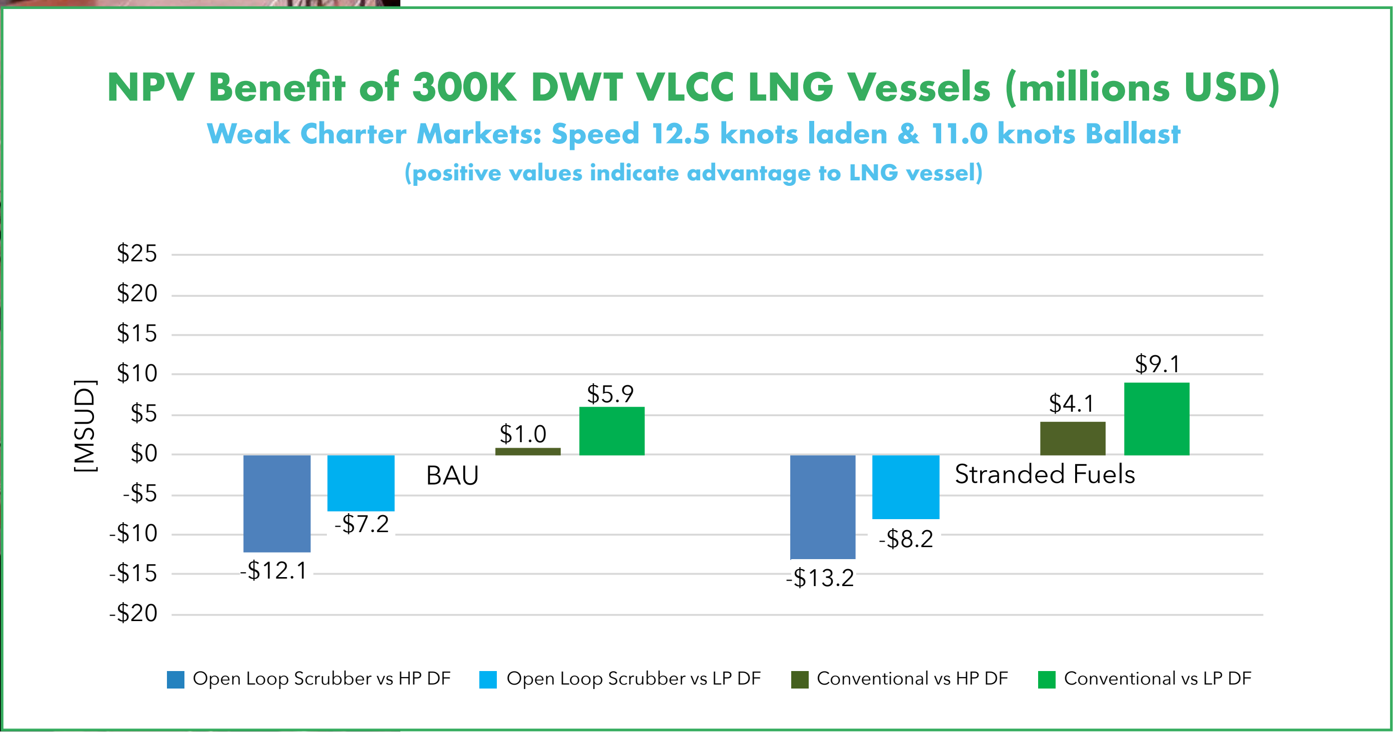
b) Stranded Fuels

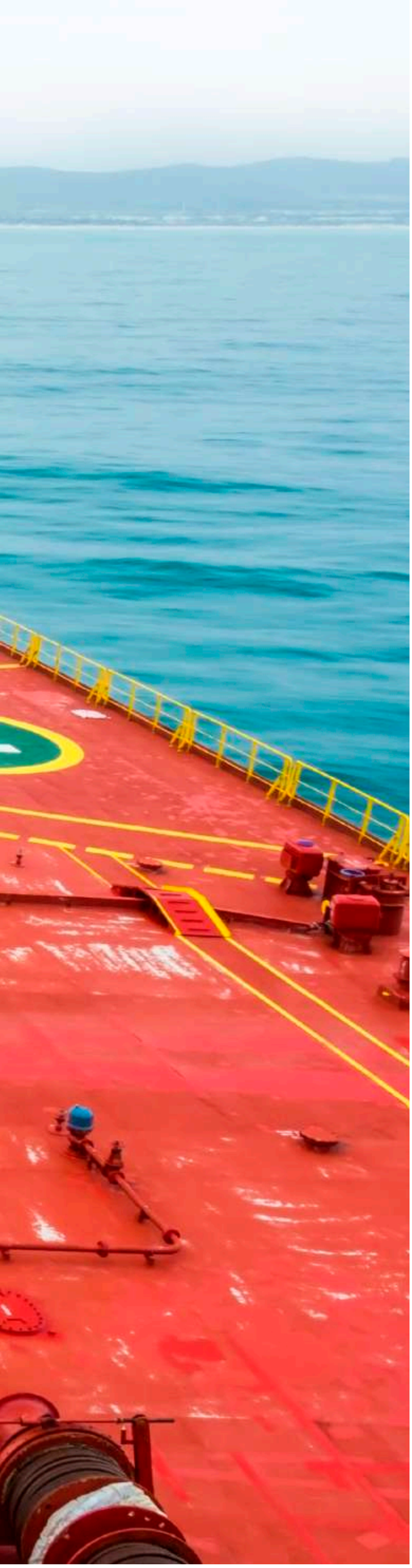


Net Present Value benefit for LNG on 300K DWT VLCC

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 graphs below show the NPV benefit for the VLCC, highlighting the fact that LNG delivers a better return on this trade against a vessel using low sulphur fuel oil. There is no consideration of carbon pricing included in these figures.







Net Present Value represents the increase in wealth accruing from an investment. The VLCC vessel returns demonstrate superior NPV savings versus conventional compliant fuels for the BAU scenarios of Strong Charter Markets ($7.2M to $12.1M) and Weak Charter Markets ($1.03M to $5.9M). The NPV LNG advantage against conventional compliant fuel magnitude grows in the Stranded Fuel Scenarios under Strong ($11.3 to $16.4M) and Weak ($4.1M to $9.1M) respectively. The LNG fuel case weakens against the scrubber with results in the negative range across both BAU and Stranded Fuels forecast. However, the NPV calculations are based on a vessel trading from 2022 and take no account of potential financial values being applied to carbon emissions. Any newbuild vessel ordered today, would not be trading until 2022. The NPV for Average Charter Markets for vessel speeds of 13.0 knots Laden and 13.0 knots are illustrated in the executive summary.

Reader's Choice Fuel Forecasts

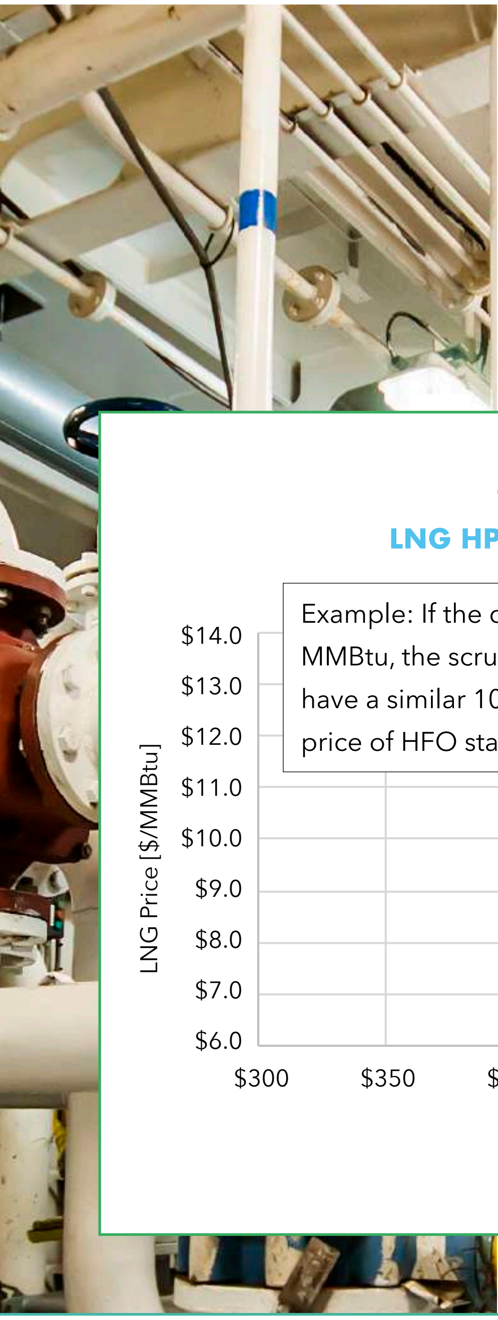
While the results of this study are based on a set of assumptions, through the "Reader's Choice" modelling, provision has also been made for each reader to select their variables in line with personal projections. The "Reader's Choice" sensitivity plot for the BAU case provides additional insights, plotting higher and lower CAPEX options. For a given vessel on a trade route, a perspective-seeking reader may ask: "If one fuel price is X what is the tipping point for the alternative fuel price Y for the business case to be neutral on NPV?" The "reader's choice" sensitivity plot for the BAU case provides additional insights.

CAPEX premiums may change as a result of differences across three principal categories; market, technology, and/or physical. A market signal CAPEX change arises where a tough business climate forces shipyards to take contracts at historically low prices, or the reverse under expansionary periods. Similarly, market elements may also alter prices as a result of lower risk due to experience and/or cost advantages shared from long-running vessel series. On the technical side, a shipowner may decide to use another approach for his VLCC, such as manganese material in C type tanks, or the installation of a membrane design. Physical differences that impact CAPEX arise when an owner prefers a different vessel trading range and thus a smaller or larger LNG tank capacity or other vessel characteristic change with resulting price reduction or additional cost.

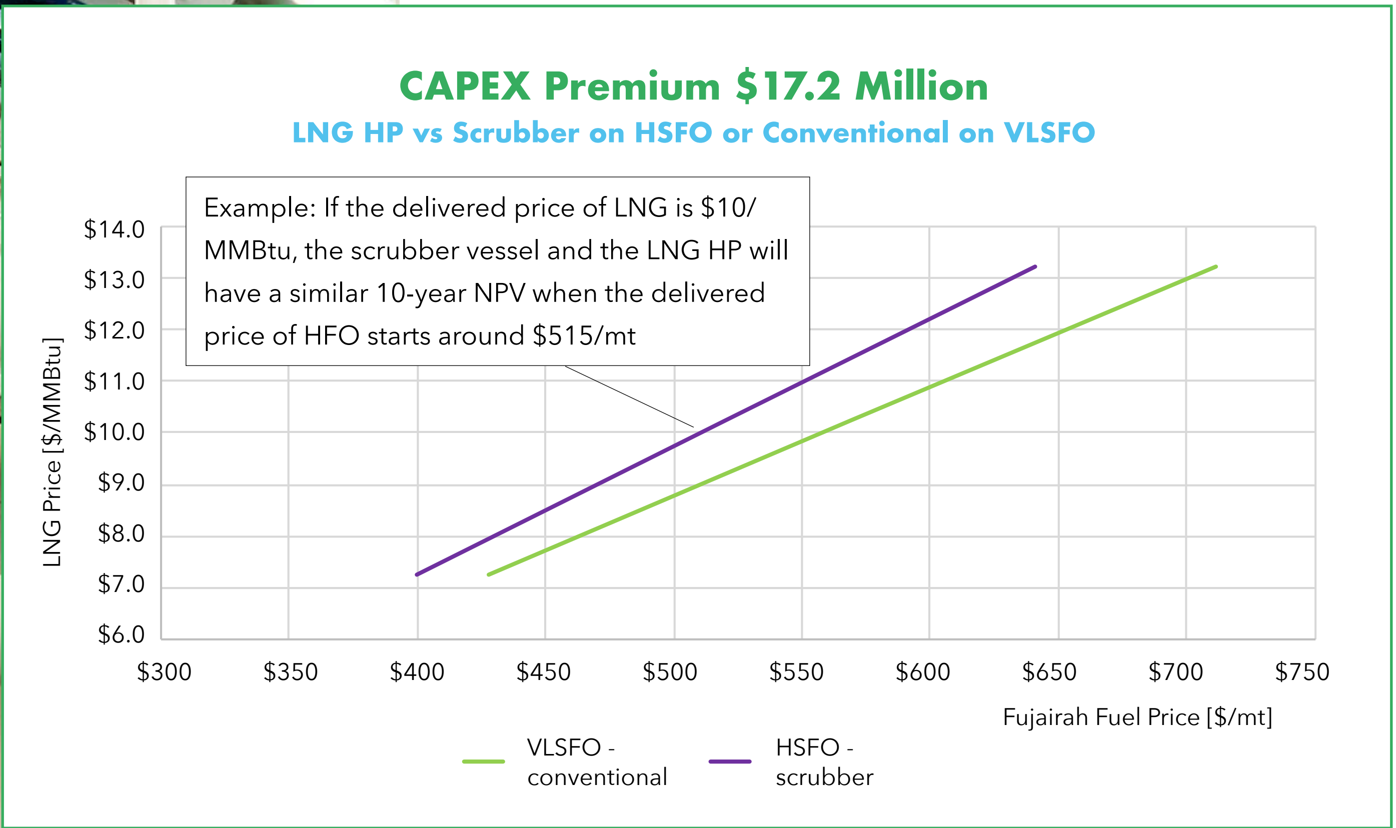
Key stakeholders, such as shipyards, vessel owners, energy providers, and charterers, can utilise the "Reader's Choice" to gain perspective on what key attributes balancing CAPEX and OPEX make the business-case work for all parties. If any combination of major stakeholders take monetary positions outside accommodative ranges, then the business case fails for the remaining parties. Ideally these stakeholders will obtain valuable guidance from their interpretation of "Reader's Choice" about positions where business opportunities yield returns sufficient for all to engage. For example:

- **Shipyards** - insight into what LNG CAPEX premium yields reasonable returns for the other principal stakeholders
- **Vessel owners** - gain informative guidance on the relative price balance amongst energy alternatives, while achieving competitive returns satisfying the additional LNG CAPEX burden
- **Energy suppliers** - understand the competitive positioning of different fuel alternatives OPEX positioning across various CAPEX values
- **Charterers** - determine whether a satisfactory charter hire premium is sufficient and justifies obtaining reduced supply chain CO2 emissions.

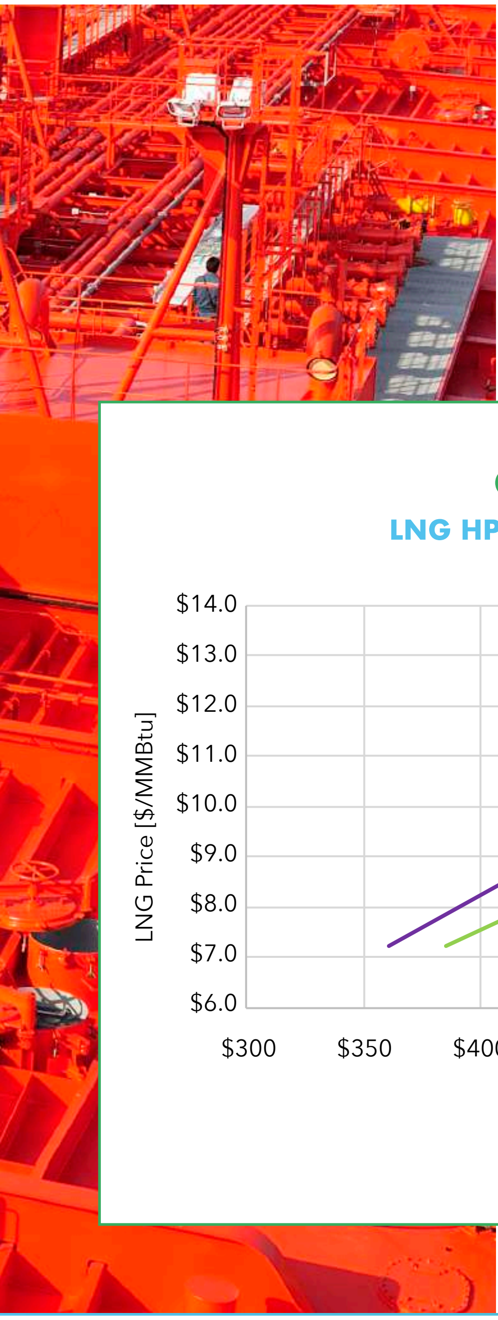
Key stakeholders, such as shipyards, vessel owners, energy providers, and charterers, can utilise the "Reader's Choice" to gain perspective on what key attributes balancing CAPEX and OPEX make the business-case work for all parties.



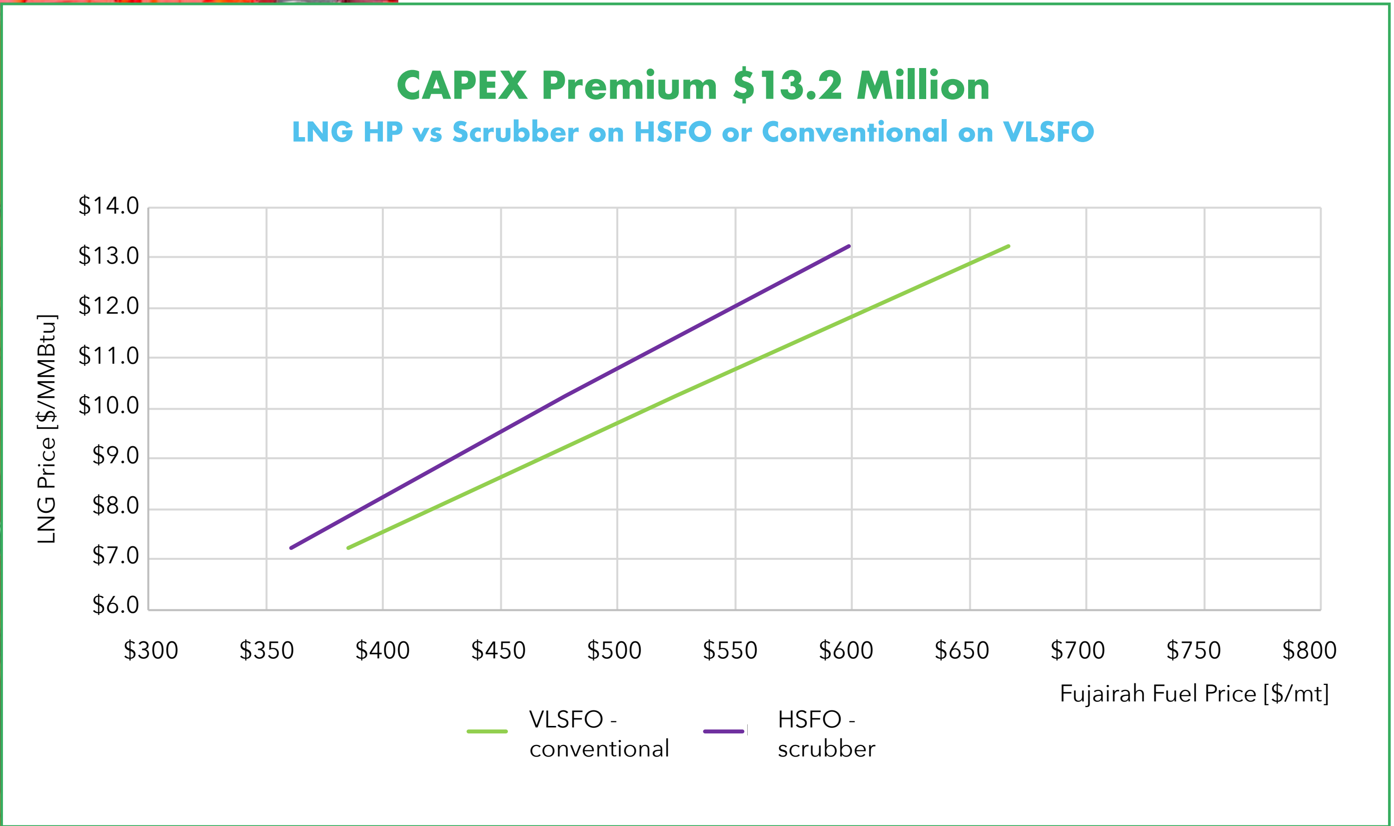
The chart below illustrates the fuel price tipping points resulting in the same business case outcomes for the 300K DWT tanker on the Arabian Gulf-China trade when the HIGH CAPEX premium for LNG over a scrubber vessel is $17.2 million or conventional compliant $20.5M. The tipping point is illustrated by the straight diagonal line labelled "10-year NPV Tipping Point Line", with a purple solid-line for the LNG 2s versus conventional HSFO with a scrubber, and the light green solid line for the LNG 2s versus conventional LSFO.



LNG marine fuel exhibits lower price volatility than traditional oil-based marine fuels because of the contribution difference from the underlying commodity to the total overall cost.



A second "Reader's Choice" plot provides this additional 'LOW' CAPEX perspective. This chart below illustrates the fuel price tipping points resulting in the same business case outcomes for the 300K DWT tanker on the Arabian Gulf-China trade when the CAPEX premium for LNG over a scrubber vessel is only $13.2 million or versus the conventional compliant of $16.5M. The tipping points are illustrated as before, but have now shifted due to the lower CAPEX premium for LNG over the scrubber fitted VLCC.



LNG is a solution – available now - that could move the industry forward, on a pragmatic pathway towards carbon-neutral bio and synthetic methane produced from renewable energy.

The CAPEX High and Low Readers Choice charts provide valuable business case insights amongst the principal four stakeholders: shipyard, energy provider, shipowner, and charterer. Each stakeholder can model how their cost basis for the business case impacts other participants' investment viability, given the need to accommodate reasonable return risk profiles for success under the business case assumptions.

The impact of CAPEX premium for LNG fuel alternative can be obtained by interpreting the "Readers Choice" charts. For example, consider HSFO plus scrubber with an assumed BAU fuel price of $400 per ton: for the High CAPEX chart we find the same business NPV outcome for LNG when priced $7.20 /mmBTU. A check on the Low CAPEX readers choice finds for the same BAU fuel price the LNG tipping point value rises to about $8.25 /mmBTU. This is understandable since a low CAPEX upfront cost when considering the overall business case investment horizon allows the recurring annual OPEX fuel cost to rise while resulting in the same result for the time value of money analysis.

Interpretation of the combined charts provides a valuable perspective, a $4M CAPEX premium growth results in an LNG tipping point price reduction of nearly $1.00 /mmBTU to provide the same NPV investment return. Note that these charts relate to the quantity of energy consumed on this cargo route by a modern VLCC of 300K DWT under the model assumptions. Other ships and trades will have different values. Note that the trends will be similar; a higher CAPEX premium for LNG then must find a reduction in LNG fuel price so that the recurring annual OPEX costs generate the same investment return.

With unrivalled emissions credentials, LNG cuts SOx and particulate emissions to negligible amounts, reduces NOx by around 95% and reduces CO2 emissions by up to 21% on a well-to-wake basis today.

WAY FORWARD

With the implementation of the IMO's 1st January 2020 0.5% global sulphur cap on marine fuel becoming mainly an operational issue, owners' attention is increasingly focused on the IMO GHG emissions reduction targets for 2030 and 2050. Environmental consciousness is the new normal. Demand is growing for goods that are both sourced and transported in more sustainable ways. Marine LNG is set to play a central role.

While there are a variety of lower or zero-carbon alternative fuels that could help to meet these future GHG reduction targets and current air quality legislation, most of these alternatives require significant development to meet the shipping industry's needs. But none are available now at scale, nor expected to be for the foreseeable future.

However, LNG is a solution – available now - that could move the industry forward, on a pragmatic pathway towards carbon-neutral bio and synthetic methane produced from renewable energy. With unrivalled emissions credentials, LNG cuts SOx and particulate emissions to negligible amounts, reduces NOx by around 95% and reduces CO2 emissions by up to between 21% on a well-to-wake basis today.

Shipping represents one element of an inter-twined, highly efficient, international multimodal logistics chain. Recent efforts to curb CO2 emissions have included advocates pressing for speed restrictions to reduce global warming. While mandatory speed reduction may seem appealing, it is not a good answer to the decarbonization question on multiple fronts. First this may have unintended consequences as older inefficient vessels may find a longer lifetime and remain active thereby generating higher emissions that add to the pollution problem rather than being phased out by more efficient vessels. Slower delivery by sea means time-sensitive cargoes may miss efficient stack train land channels and opt for direct faster trucking with elevated emissions. Secondly innovation on several technical fronts including prime movers, emissions management, and or vessel efficiency may lose momentum. Third a speed reduction may reduce otherwise fast-paced implementation of alternative fuel programs or other advances that are needed to achieve the IMO targets.

While there remain many unanswered questions about the choice and prices of marine fuels going into 2020 and beyond, SEA\LNG remains committed to working with independent consultants to bring factual, evidenced information to the market. In addition to recent research, for

example the Life Cycle Greenhouse Gas Emissions Study, conducted by thinkstep, the Alternative Marine Fuels Study undertaken by DNV GL, and previous investment studies from Opsiana, 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. This credible independent research modelling will be repeated to study the investment cases for common ships in typical trades, and a study which explores the potential availability of bio and synthetic methane, undertaken by Delft, will also be imminently released.

The investment case for LNG as a marine fuel is compelling. The direction of emissions legislation, the advancement of technology, and continuously expanding infrastructure to support LNG all mean the commercial advantages of LNG are increasing. It is the only practical option that meets today's emissions challenges and provides a pragmatic pathway to future decarbonisation goals while safeguarding a competitive advantage for the ship owners and operators who facilitate global trade.

The investment case for LNG as a marine fuel is compelling. The direction of emissions legislation, the advancement of technology, and continuously expanding infrastructure to support LNG all mean the commercial advantages of LNG are increasing.

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