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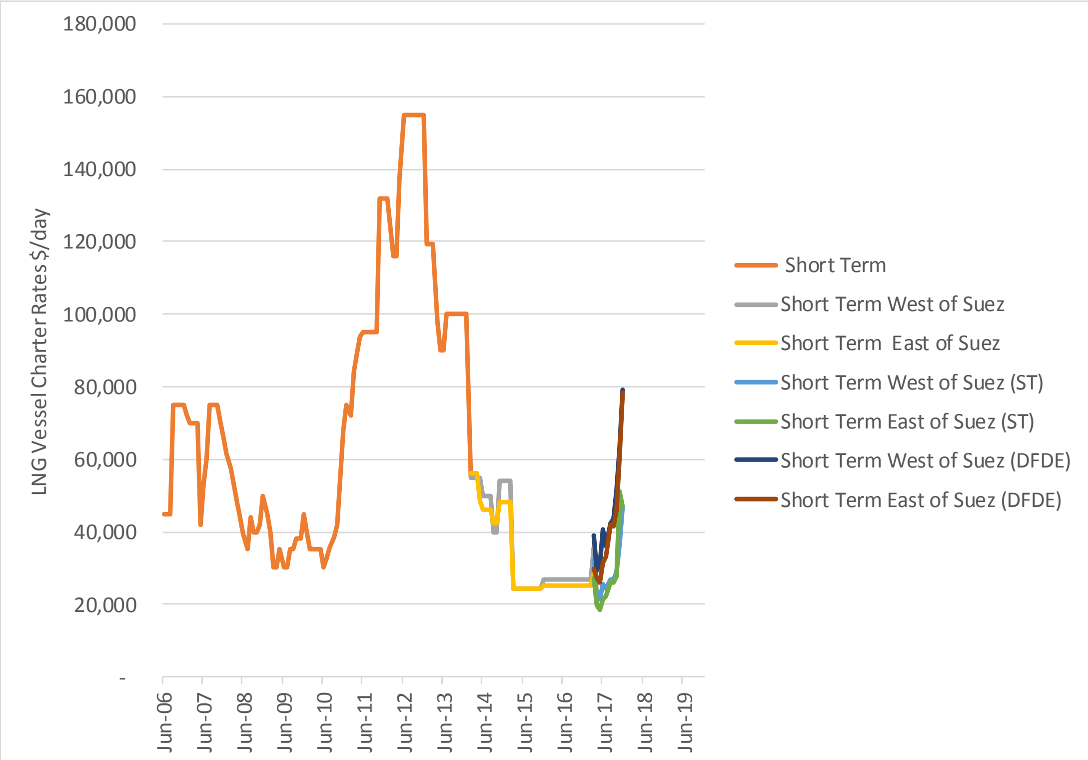
The LNG Shipping Forecast: costs rebounding, outlook uncertain

Introduction

The cost of shipping LNG has always been an important element to include in the assessment of new LNG project breakeven economics, or in selecting the optimum destination for a spot cargo of LNG. Such shipping cost calculations are often based on current short-term charter rate data disclosed by the analytical teams of specialist price reporting agencies or similar[1]. Short-term LNG charter rates rose dramatically in the early 2010s, apparently in response to Asian LNG demand and, subsequently, the Fukushima disaster which created a tight LNG spot market. From early 2013, LNG carrier short-term charter rates fell dramatically from $155,000/day in 2012 to $24,500/day in 2015, as shown in Figure 1.

Figure 1: LNG carrier short-term charter rates $/day, June 2006 to December 2017



Source: *Argus Global LNG*, monthly issues from July 2006 to January 2018.
(Note: ST = Steam Turbine; DFDE = Dual Fuel Diesel Electric (see later for description).)

[1] For example, *Platts*, *Argus*, *ICIS*, Poten & Partners

Charter rates then remained at around $26,000/day to mid-2017 but have subsequently risen. By December 2017 reported charter rates averaged $63,000/day; more than double the levels seen in the 2015 to mid-2017 period.

In order to assess the impact of LNG shipping costs on future fully built up LNG delivered or breakeven costs, (particularly when questions over the affordability of gas is an issue in potential growth markets where demand is likely to be price sensitive), this Energy Insight addresses the following questions:

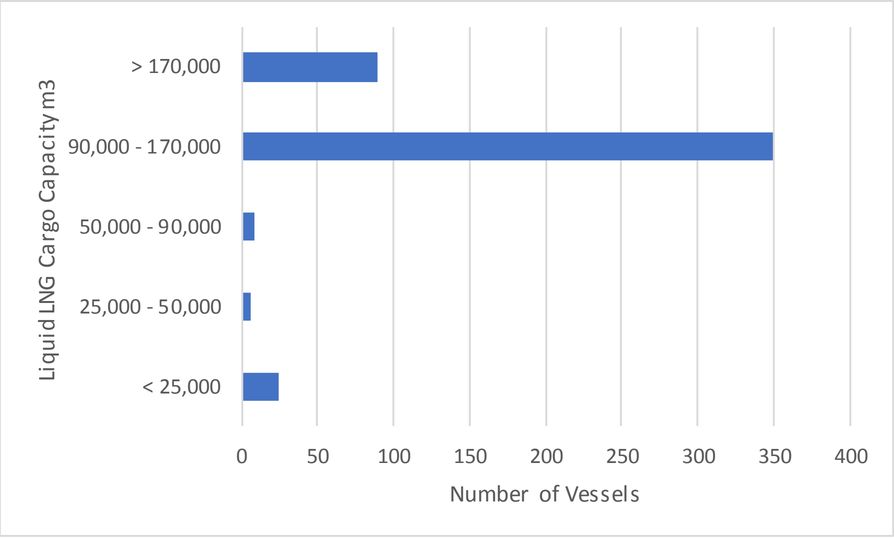
- how does the charter rate impact on total LNG shipping costs? What are the other key cost elements?
- What is a realistic long-term LNG transportation cost matrix given the trends in charter rates and fuel costs?
- What are the implications for future LNG projects in terms of affordability if LNG transport costs increase?
- What other factors should be taken into consideration in judging the relative attractiveness of, for example, European versus Asian LNG markets based on destination price references?

Background on LNG carriers

In developing this paper, it soon became apparent that the subject was more complex than anticipated. Before getting to grips with the above questions, it is necessary to establish some context. Overviews of LNG shipping tend to focus on the size and containment design of carriers and a very brief summary is given here.

According to GIIGNL[2], at the end of 2016, some 73% of the fleet of LNG tankers were in the size range 90,000 to 170,000 cubic metres[3]. Carriers above 170,000 cubic metres (sometimes referred to as 'Q max' vessels) are, at present, too large to transit the Panama Canal.

Figure 2: Size distribution of LNG fleet at end 2016

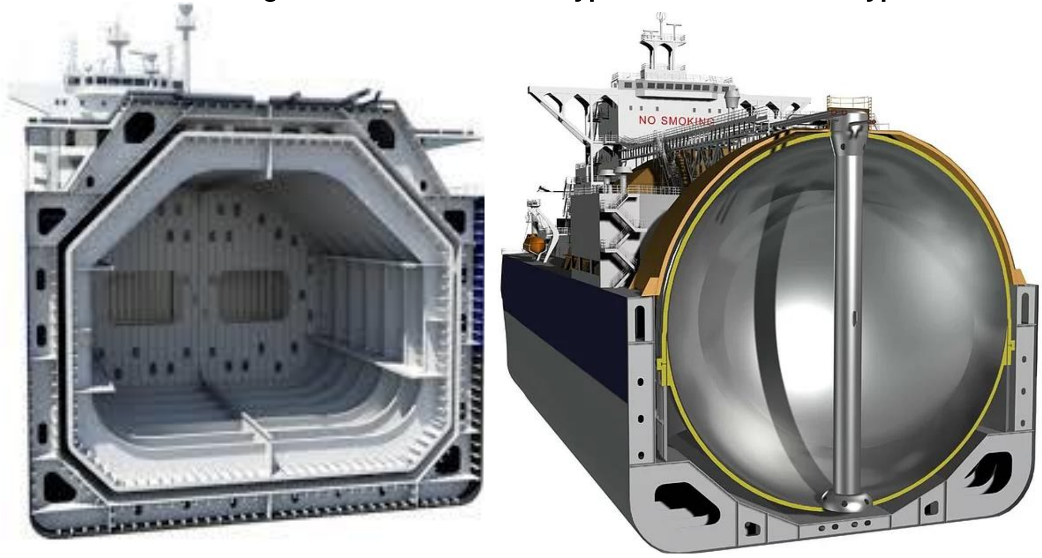


Source: GIIGNL 2017.

[2] GIIGNL 2017 Annual Report (International Group of Liquefied Natural Gas Importers)
[3] These volumes refer to the nominal cargo capacity of LNG (liquid phase).

LNG containment systems are either Membrane (quasi-rectangular) or Moss-type (spherical), as shown in Figure 3.

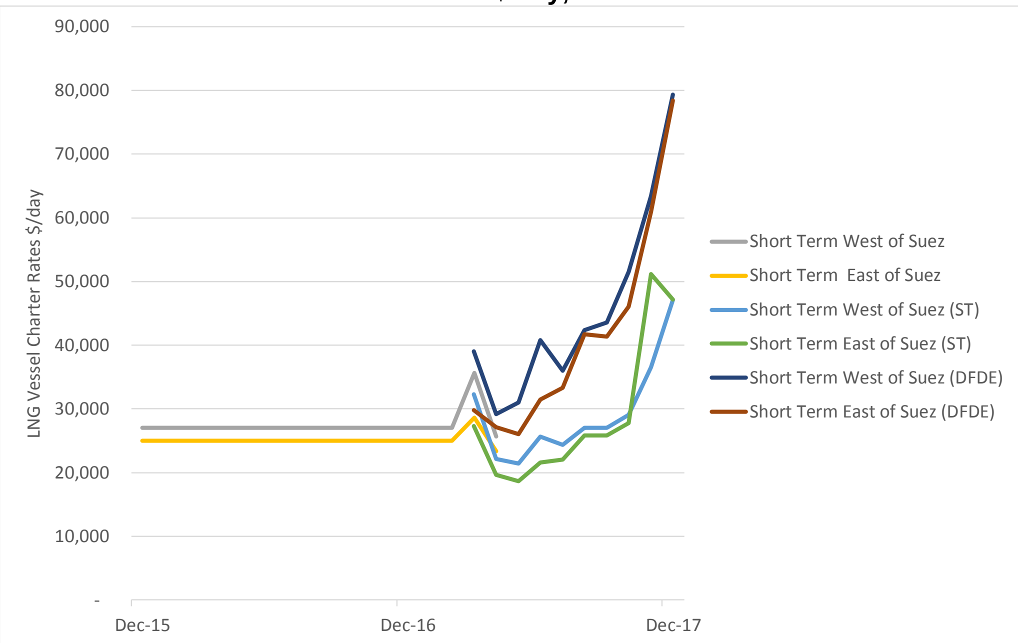
Figure 3: Schematic showing Membrane and Moss–type LNG containment types



Source: Glasgow Marine Academy.

Less frequently highlighted is the subject of propulsion mechanism for LNG vessels. This is important as the propulsion type has a direct bearing on factors such as vessel fuel type, and cost, and the efficiency of converting fuel combustion energy into carrier propulsion energy. As discussed later, these factors are increasingly reflected in the day rates in the LNG carrier charter market. Figure 1 shows the charter rate data reporting format, adopted by Argus from April 2017, divided into Steam Turbine (ST) and Dual Fuel Diesel Electric (DFDE) and also by East and West of Suez. Figure 4 shows the same data from December 2015 to December 2017.

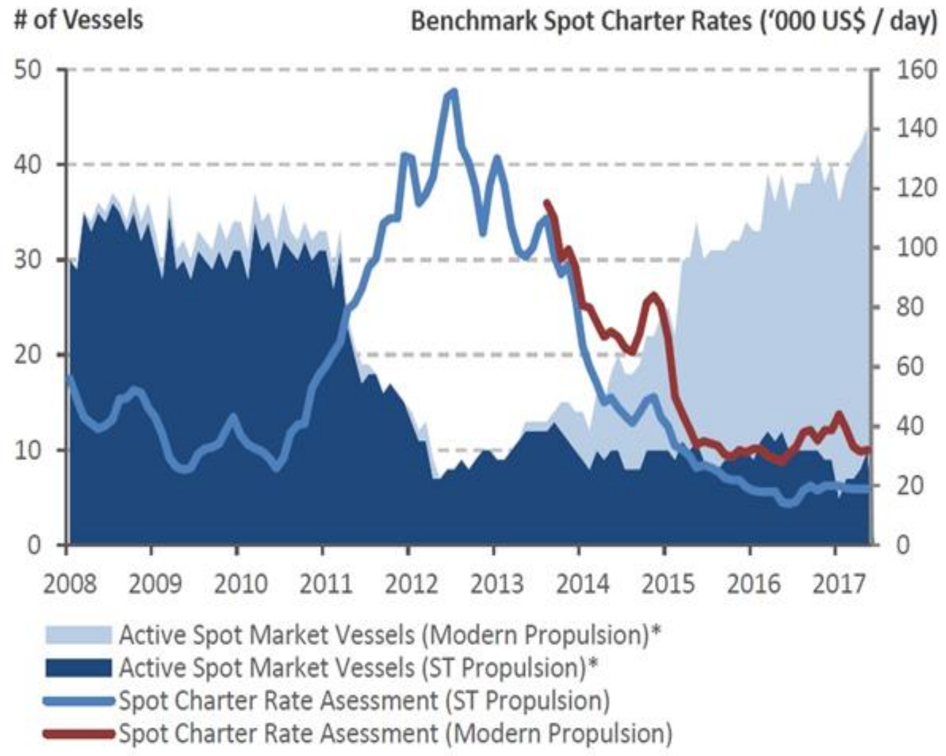
Figure 4: LNG carrier short-term charter rates $/day, December 2015 to December 2017



Source: *Argus Global LNG*, monthly issues from January 2016 to January 2018.

This apparent division of the market between ST vessels and DFDE vessels is also confirmed by data from Poten & Partners in Figure 5.

Figure 5: Active spot market vessels vs headline spot charter rates

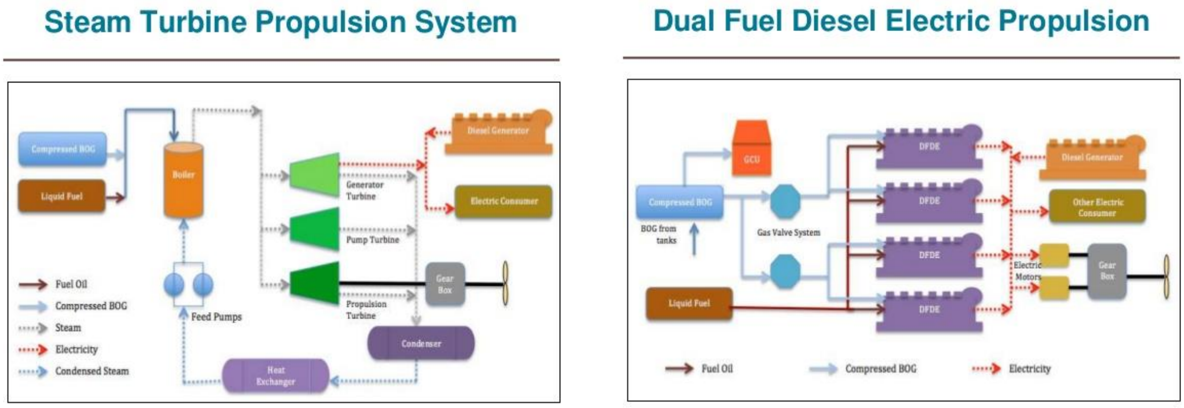


Source: Poten & Partners.

Poten & Partners distinguished between ST and DFDE[4] charter rates as early as 2014, but the interesting trend in Figure 5 is the rapid growth in DFDE vessels from 2014 onwards with ST vessel availability remaining stagnant. The demographics of the LNG carrier charter market in Figure 5 follow on from earlier shifts in preferred propulsion type for new vessels. In the last four decades of the 1900s, the simplicity of using LNG boil-off[5] (supplemented if necessary by fuel oil) to produce steam to drive turbines led to the ST being the dominant LNG carrier propulsion type. However, the adoption of DFDE on LNG carriers in the early 2000s was a clear evolutionary, irreversible step given the DFDE efficiency of 50% compared to the ST's 28%[6].

[4] Poten & Partners term 'Modern Propulsion' refers to DFDE.
[5] boil-off – the evaporation of LNG from its liquid to gaseous phase as a consequence of heat flux into LNG tanks from the ambient surroundings. This can either be consumed as fuel or re-liquefied and re-introduced to the cargo tank.
[6] 'Propulsion trends in LNG Carriers', MAN Diesel & Turbo, http://marine.mandieselturbo.com/docs/librariesprovider6/technical-papers/propulsion-trends-in-lng-carriers.pdf?sfvrsn=16]-, P. 5

Figure 6: Schematic contrasting Steam Turbine and Dual Fuel Diesel Electric Propulsion



Source: ICCT - The International Council on Clean Transportation.

Figure 6 contrasts the ST system which burns LNG boil-off and fuel oil to generate steam and, in turn, uses turbines to generate propulsive drive, with the DFDE system, which uses LNG boil-off in a diesel cycle engine which transmits energy to the ship's propellers.

Existing ST vessels still account for about 60% of the active LNG fleet (long-term contract and short-term charter) but if a charter contract is close to expiring, charterers will simply move to the more efficient DFDE propulsion system. Since, in maritime common practice, the fuel bill is not included in the charter daily rate, a comprehensive LNG voyage cost comparison between ST and DFDE vessels is required. This comparison gives the first indication as to why ST charter rates have languished below those of DFDE's in recent years.

Wärtsilä[7] in its online journal states '*Given a standard operating profile, a DFDE vessel can sail exclusively on natural boil-off-gas in laden conditions. On the other hand, with a steam turbine, it is necessary to force a remarkable quantity of boil-off (e.g. at 17.5 knots the usual forced boil-off-gas demand is in the range of 50 tons per day)*'.

This is an important insight. A key distinction is that while DFDE carriers typically achieve an average speed of 19 knots, ST carriers are limited to 14 knots to avoid needing forced boil-off and higher LNG consumption, or alternatively supplementing LNG natural boil-off with Heavy Fuel Oil to achieve higher speeds.

The secondary, but increasingly important point is that DFDE LNG carriers can achieve 19 knots on the basis of 'natural boil-off' – obviating the need to burn fuel oil. In this way they can assure compliance with stricter IMO restrictions on Sulphur emissions.

The author gained access to semi-completed quantitative analyses and published results by specialist consultants where key assumptions were, in some cases, unclear. Although there are still areas where it would be preferable to go back to first principles to substantiate the following analysis, it is questionable whether this would materially affect the ultimate conclusions.

[7] Natali, M and Mori, S, (25 April 2016) 'Back to the future: steam turbine to DFDE conversion for LNG carriers', 'In Detail', *Wärtsilä Technical Journal*, https://www.wartsila.com/twentyfour7/in-detail/back-to-the-future-steam-turbine-to-dfde-conversion-for-lng-carriers

How does the charter rate impact on total LNG shipping costs? What are the other key cost elements?

The LNG carrier charter cycle comprises;

- loading the vessel at the export port with LNG equivalent to 98 % of the nominal volume of the vessel, in this case 160,000 m3 of liquid LNG, assumed to take 1 day;
- voyage time which incurs the charter cost day rate. Voyage time is the distance between ports via a defined shipping route, assuming both outward and return journeys, during which fuel will be consumed to power the ship's engines:
    - in the case of a DFDE ship, LNG boil-off (as required, with re-liquefaction for the balance) with the ship travelling at 19 knots[8];
    - in the case of a ST ship, LNG boil-off supplemented with heavy fuel oil with the ship travelling at 19 knots.

Unloading of the vessel at the destination port is assumed to take one day. The return leg of the voyage, nominally to the point of origin, is assumed to be unproductive, but sufficient LNG must remain in the vessel to keep the storage structures at operating temperature and provide fuel. Use of the Panama or Suez Canals will incur additional transit charges. Port charges will also be incurred at the export and import ports.

Assumptions relating to specific costs are set out in Appendix 1.

In addition to the days assumed at the loading and discharge port, the charter duration is a function of shipping distance. Table 1 shows the distance in nautical miles between some of the more important future LNG supplier and importer locations.

Table 1: Shipping (one-way) distances between LNG ports

Loading Port	Discharge Port	Nautical Miles
Sabine Pass (US)	Isle of Grain (UK)	4897
	Gateway (NL)	5002
	Tokyo	15762
	Tokyo (via Panama Canal)	9209
	Tokyo (via Suez Canal)	14521
	Shanghai	15098
	Shanghai (via Panama Canal)	10081
	Shanghai (via Suez Canal)	13854
Barrow Island (Australia)	Tokyo	3727
	Shanghai	3322
Qatar	Isle of Grain (UK) (via Suez Canal)	6266
	Gateway (NL) (via Suez Canal)	6371
	Tokyo	6512
	Shanghai	5845
Mozambique	Isle of Grain (UK) (via Suez Canal)	6709
	Gateway (NL) (via Suez Canal)	6814
	Tokyo	6979
	Shanghai	6312
Canada West Coast	Tokyo	3838
	Shanghai	4678

Source: SEA-DISTANCES.ORG, https://sea-distances.org/.

[8] Knots = nautical miles per hour

Combining the data on voyage distances with the assumptions on the cost components for DFDE and ST LNG carriers, a model can be built to compute the LNG shipping costs based on charter rate assumptions, fuel and other cost elements. In order to focus on the key variables and to examine how the picture has changed through 2017, five routes have been selected with specific assumptions on charter rates for DFDE and ST vessels, East and West of Suez, and applying the destination region hub or spot price as the opportunity cost of boil-off fuel. The specific assumptions are shown in Table 2.

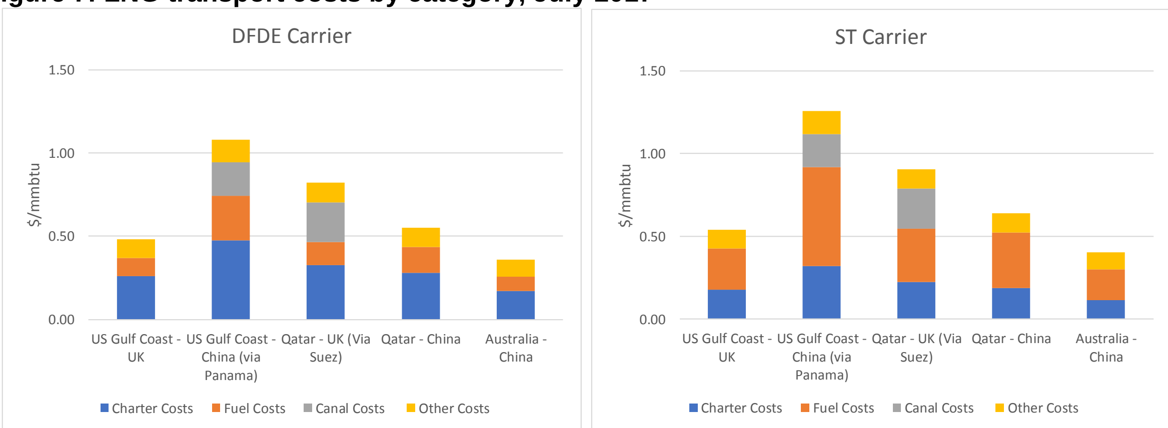
Table 2: Key fuel and charter rate assumptions for selected routes, July 2017

Type of Carrier	Route	Boil off Opportunity Cost $/MMBtu	HFO Cost $/Tonne	Charter Rate $/day
DFDE	US Gulf Coast - UK	4.7	286	36,000
DFDE	US Gulf Coast - China (via Panama)	5.5	286	33,286
DFDE	Qatar - UK	4.7	286	36,000
DFDE	Qatar - China	5.5	286	33,286
DFDE	Australia - China	5.5	286	33,286
ST	US Gulf Coast - UK	4.7	286	24,333
ST	US Gulf Coast - China (via Panama)	5.5	286	22,048
ST	Qatar - UK	5.5	286	24,333
ST	Qatar - China	4.7	286	22,048
ST	Australia - China	5.5	286	22,048

Source: *Argus LNG*, Platts Monthly Averages, CME Group.

Using these assumptions in the LNG shipping cost model yields the cost structure shown in Figure 7.

Figure 7: LNG transport costs by category, July 2017



Source: Author's calculations.

Figure 7 shows the LNG transportation costs on a $/MMBtu basis for the US Gulf Coast to the UK, the US Gulf Coast to China (via the Panama Canal), Qatar to the UK (via Suez), Qatar to China, and Australia to China. For the DFDE cases, charter cost is a more significant cost element than fuel cost. The reverse is true of the ST cases. A detailed comparison of Figure 7 results reveals that the ST is more expensive in terms of total transport cost, this premium being 10% to 16% above that of the DFDE carriers.

The second conclusion from Figure 7 is the confirmation of relatively low transport costs between key supply-demand nodes: namely US Gulf to NW Europe $0.51MMBtu, US Gulf Coast to China

$1.17/MMBtu, Qatar to NW Europe $0.86/MMBtu, Qatar to China $0.60/MMBtu, and Australia to China $0.38/MMBtu. (Note: these values are the average calculated for DFDE and ST carriers.)

Mindful of the escalation in both LNG carrier charter rates and fuel prices between the middle and end of 2017, the analysis was repeated using charter rate and fuel prices as reported for December 2017.

(Note: An example calculation of LNG shipping costs for the US Gulf Coat to China (via the Panama Canal) is shown in Appendix 2 for a DFDE carrier and in Appendix 3 for a ST Carrier based on July 2017 fuel prices and charter rates.)

The analysis was repeated for charter rates and fuel costs pertaining to December 2017.

Table 3: Key fuel and charter rate assumptions for selected routes, December 2017

Type of Carrier	Route	Boil off Opportunity Cost $/MMBtu	HFO Cost $/Tonne	Charter Rate $/day
DFDE	US Gulf Coast - UK	7.7	349	79,342
DFDE	US Gulf Coast - China (via Panama)	9.2	349	78,421
DFDE	Qatar - UK	7.7	349	79,342
DFDE	Qatar - China	9.2	349	78,421
DFDE	Australia - China	9.2	349	78,421
ST	US Gulf Coast - UK	7.7	349	47,125
ST	US Gulf Coast - China (via Panama)	9.2	349	47,125
ST	Qatar - UK	9.2	349	47,125
ST	Qatar - China	7.7	349	47,125
ST	Australia - China	9.2	349	47,125

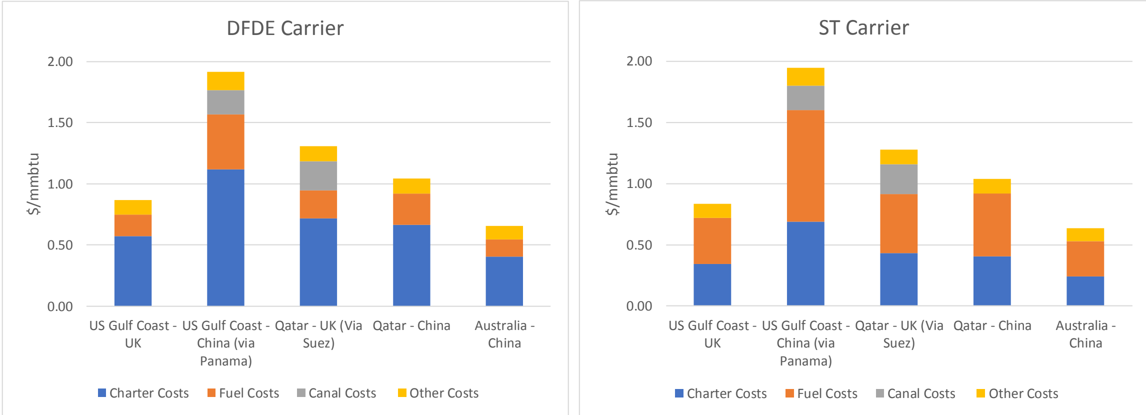
Source: *Argus LNG*, Platts Monthly Averages, CME Group.

Figure 8 shows the LNG transportation costs on a $/MMBtu basis for the US Gulf Coast to the UK, the US Gulf Coast to China (via the Panama Canal), Qatar to the UK (via Suez), Qatar to China, and Australia to China. For the DFDE cases, charter cost is a more significant cost element than fuel cost. The reverse is true of the ST cases. A detailed comparison of Figure 8 results reveals that at the prevailing fuel and charter cost assumptions, for these routes the total voyage costs of DFDE and ST carriers per mmbtu of delivered LNG are broadly equivalent. This is undoubtedly due to market forces whereby the charter costs of the more efficient DFDE vessels command a negotiated premium to the ST vessels.

Compared with the July 2017 situation however, the transport costs between key supply-demand nodes have risen substantially: US Gulf to NW Europe $0.85/MMBtu, US Gulf Coast to China $1.93/MMBtu, Qatar to NW Europe $1.29/MMBtu, Qatar to China $1.04/MMBtu, and Australia to China $0.65/MMBtu. Note: these values are the average calculated for DFDE and ST carriers.

This begs the question, raised initially by Figure 1, of whether recent low charter rates, up to the middle of 2017, and low propulsion fuel prices have engendered an overly optimistic consensus on future LNG transport costs? The answer is a cautious ‘probably’ as expounded in the following section.

Figure 8: LNG transport costs by category, December 2017



Source: Author's calculations.

The outlook for LNG shipping costs and wider implications

The current situation is one where it would appear that LNG shipping costs might rise as a consequence of:

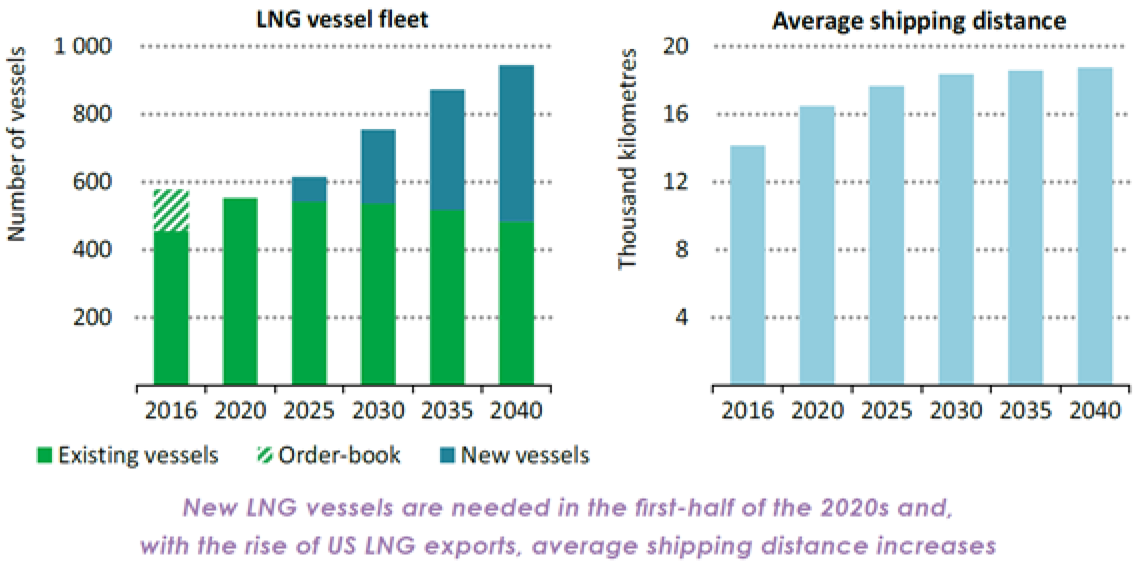
- crude oil prices rising to a sustained level of $70/bbl by the early 2020s, implying HFO prices will increase in tandem to around $380/tonne;
- opportunity cost boil-off gas prices for carriers trending to the higher delivered market levels required to incentivize investment in the next generation of new LNG supply projects, within the bounds of affordability for developing countries;
- the need, at some point, for charter rates to cover the cost of construction of new LNG carriers (likely to be DFDE type vessels).

The recent rise in LNG carrier short-term contract prices has come as something of a surprise, given that the period of historically low rates in 2015 and 2016 appeared to indicate a plentiful supply. The International Energy Agency's (IEA) position in its 2017 World Energy Outlook is shown in Figure 9, with commentary suggesting that the market will be reasonably balanced to the first half of the 2020s, after which new LNG carriers will be required.

The escalation of LNG carrier short-term charter rates during winter 2016/2017 may have been caused by a seasonal peak in China's LNG import requirements which needed more LNG carrier ship-miles than could be easily accommodated within the assumed LNG shipping capacity margin. China has only some 7.3 Bcm of underground storage working gas volume[9] and it appears likely that recent policy to convert space heating from coal to gas on a massive scale will result in a strong LNG seasonal import pattern for several years as new storage facilities take some four years to construct.

[9] http://www.chinagasmap.com/theprojects/gasstorage.htm

Figure 9: Evolution of the LNG vessel fleet and the average shipping distance in the IEA World Energy Outlook 2017 New Policies Scenario



Source: IEA World Energy Outlook 2017, p. 364.

General trends in the LNG sector appear to suggest a moving away from the integrated 'A to B' long-term contract model where LNG vessels were ordered as part of the complete project package. New projects may be largely funded by oil and gas majors with LNG portfolio trading capabilities, or effectively underwritten by the same majors signing up the LNG offtake from upstream and liquefaction projects owned by incumbents[10]. Clearly this trend towards fragmentation of the LNG supply chain requires, and assumes, that new LNG carrier construction will be funded either by the emerging LNG portfolio player majors (via long-term charter commitments) or by speculative investment by independent shipping companies in response to market signals in the form of short-term charter rates. Arguably such a market signal may have been delivered (earlier than widely anticipated) in the second half of 2017.

These developments necessitate assessment of the future landscape of LNG shipping costs. This is particularly so in an environment, as described by Jonathan Stern[11], where a high proportion of future gas demand growth in, mainly, Asian developing markets will be met by LNG **but** the demand sensitivity to price will limit incremental LNG demand above a certain delivered price. Add to this the uncertain outlook of Asian LNG demand on an individual country level and the consequent reluctance to sign long-term contracts linked to oil price, (which in the 2011 to 2014 period resulted in LNG contract prices above $15/MMBtu), and the situation becomes even more complicated. The final investment decision (FID) of many of the next wave of LNG projects may have to be taken on the assumption of volumes sold on a spot, short or medium-term basis priced on the prevailing spot/hub or traded reference in the market destination region, rather than on the basis of an oil-linked formula. This is radical shift. The key question for new FID's becoming 'is your expectation of the 25-year LNG market price in destination markets sufficient to give you an acceptable return on investment?'

[10] Rogers, H. V, (April 2017). 'Does the Portfolio Business Model Spell the End of Long-Term Oil-Indexed LNG Contracts?', Oxford, OIES, https://www.oxfordenergy.org/publications/portfolio-business-model-spell-end-long-term-oil-indexed-lng-contracts/

[11] Stern, J. (December 2017). 'Challenges to the Future of Gas: unburnable or unaffordable?', Oxford, OIES, NG 125, https://www.oxfordenergy.org/publications/challenges-future-gas-unburnable-unaffordable/

Clearly, as posited by Jonathan Stern, if price-sensitive LNG demand starts to diminish once the price is above $6/MMBtu and more so above $8/MMBtu, then this should be a warning sign to LNG project investors who require higher destination prices than these to break even. These investors are unlikely to be able to sign contracts, either on a fixed price or unrelated commodity basis, for example, oil, to achieve locked in prices above new market affordable prices.

Mindful of the importance of delivered breakeven costs for new LNG projects, it is possible to quantify a reasonable view of future LNG shipping costs, using the model described above, based on future assumptions.

Firstly, it is important to try to define the short-term charter rate that equates to a long run marginal cost, or breakeven rate for new LNG carrier investment. In the media this is hinted at as follows:

'By the end of 2017 owners of modern LNGCs carrying cargoes to Asia were commanding spot rates of up to US$85,000/day, well above breakeven, and the number of spot fixtures had reached record levels.'[12]

'With utilisation of the spot LNG carrier fleet tracking at close to 50% through the first seven months of the year, the effective rate earned by vessels not under fixed-rate contracts is about USD15,000/day, compared to a cash breakeven level of USD50,000-60,000/day," said Chappell.'[13]

So, the apparent breakeven range for LNG charter rates would appear to be in the $50,000 to $60,000/day range. In terms of the capital cost of new LNG carriers, this seems to have fallen in recent times:

'Regardless, we haven't seen many orders. So this goes to the point we mentioned earlier that even though prices are probably well below even $190 million, there haven't been a lot of opportunities for ordering, as evidenced by the fact that only five orders have taken place since October 2015," said Speers.'[14]

In an attempt to verify these comments, the author performed a rough calculation based on a carrier capital cost of $180 million, with operating costs of 5% per year of total capex[15]. Assuming an operating life of 30 years, a $55,000/day charter rate, for every day of the year, would generate a rate of return of 4.4% on investment. This was deemed to be just within the bounds of credibility and so $55,000/day, in line with the above quote, seems a reasonable average assumption for future LNG carrier charter rates.

Other assumptions for future LNG shipping costs in the 2020s were:

- HFO costs of $380/tonne are compatible with an assumption of future crude oil price of $70/bbl based on the current ratio of HFO price to crude oil price;
- European hub prices of $7/MMBtu and Asian LNG spot prices of $8/MMBtu. These being broadly in line with an initial view of LNG delivered costs but higher than 1st quarter 2018 forward curves.

These assumptions are then applied to the five key routes shown in Figures 6 and 7.

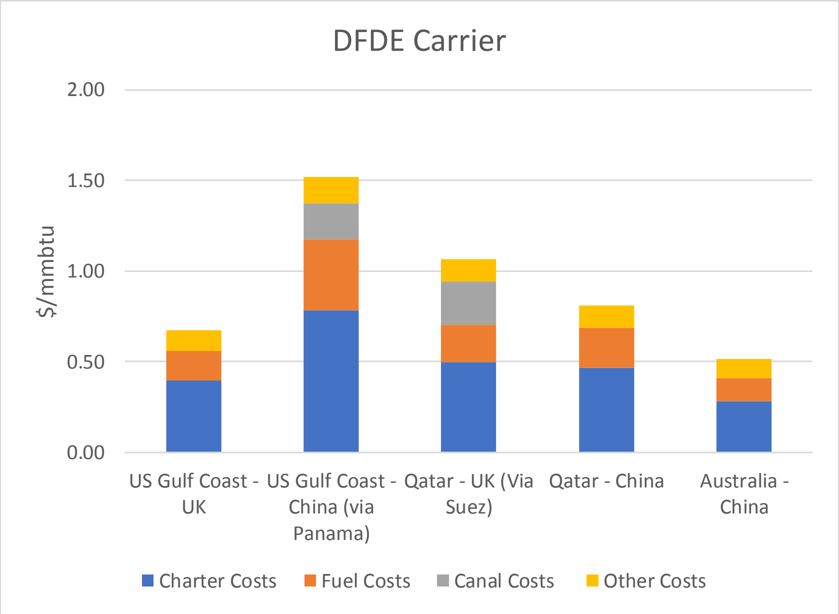
[12] https://www.lngworldshipping.com/news/view,healthy-freight-rates-and-2018-lng-shipping-predictions_50323.htm
[13] https://fairplay.ihs.com/article/19012/lng-carriers-form-spot-pool (free registration required)
[14] https://www.lngworldnews.com/lng-newbuilding-prices-dropped-sharply-but-orders-remain-weak/
[15] This being a broad, upstream oil and gas rule of thumb in the absence of better information.

Table 4: Key fuel and charter rate assumptions for selected routes, 2020s

Type of Carrier	Route	HFO Cost $/Tonne	Charter Rate $/day
DFDE	US Gulf Coast - UK	380	55,000
DFDE	US Gulf Coast - China (via Panama)	380	55,000
DFDE	Qatar - UK	380	55,000
DFDE	Qatar - China	380	55,000
DFDE	Australia - China	380	55,000

Source: Author's assumptions

Figure 10: LNG transport costs by category, 2020s



Source: Author's calculations

As shown in Figure 10, the transport costs between key supply-demand nodes have risen substantially compared to July 2017. US Gulf to NW Europe $0.67/MMBtu, US Gulf Coast to China (via the Panama Canal) $1.52/MMBtu, Qatar to NW Europe $1.06/MMBtu, Qatar to China $0.81/MMBtu, and Australia to China $0.51/MMBtu.This data is shown in Table 5.

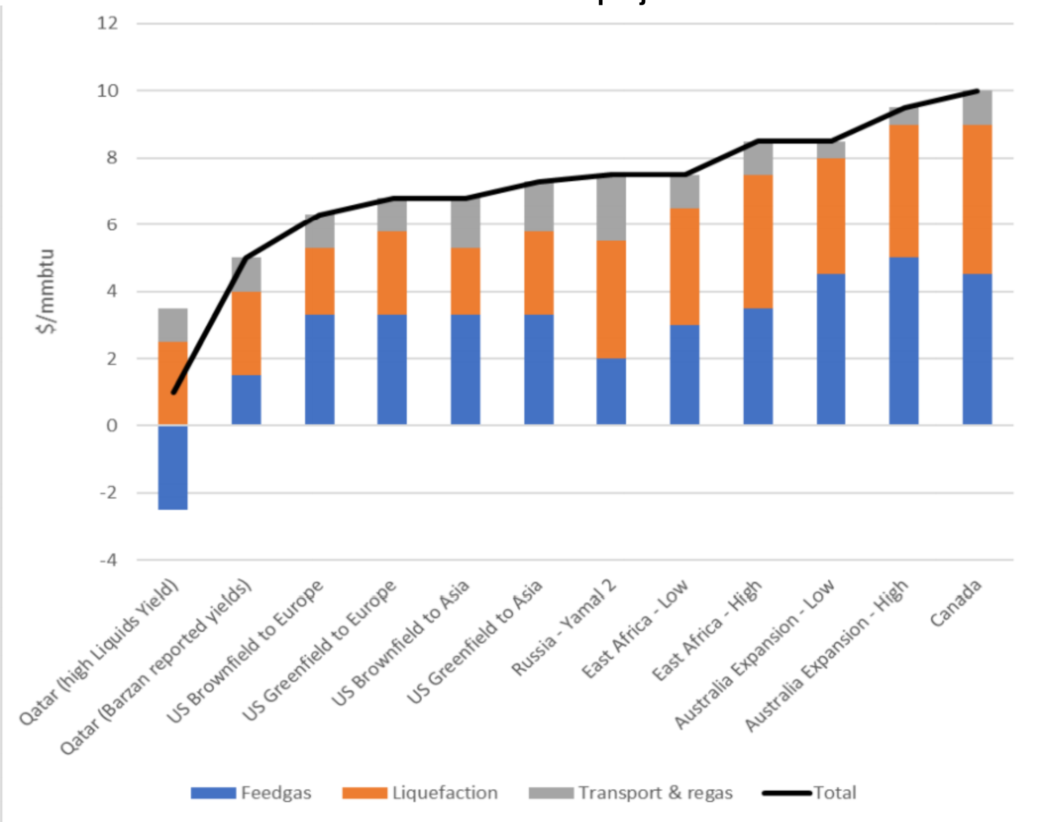
Table 5: LNG transport costs by category, 2020s

	Charter Costs	Fuel Costs	Canal Costs	Other Costs	Total
US Gulf Coast - UK	0.40	0.16	0.00	0.11	**0.67**
US Gulf Coast - China (via Panama)	0.78	0.39	0.20	0.14	**1.52**
Qatar - UK (Via Suez)	0.50	0.21	0.24	0.12	**1.06**
Qatar - China	0.47	0.22	0.00	0.12	**0.81**
Australia - China	0.28	0.12	0.00	0.11	**0.51**

Source: Author's calculations

In Jonathan Stern's recent paper[16], Figure 11 shows the breakeven price for key potential future LNG projects, assuming aggressive upstream and liquefaction cost reductions and the then prevailing view of LNG shipping costs.

Figure 11: Estimated breakeven costs of new LNG projects



*Note – Due to the specific nature of the ice-breaking Yamal LNG carriers, the Yamal shipping costs were taken from the Novatek Strategy Presentation in December 2017, "Transforming into a Global Gas Company: From 2018 to 2030", http://www.novatek.ru/en/investors/strategy/, slide 56

Source: Jonathan Stern, OIES

The importance of European regas and system entry costs

Consideration must now be given to the different nature of European and Asian destination market prices and the impact these have on netbacks and, hence, the decisions of LNG portfolio players in terms of cargo destinations.

Spot cargoes in Asia are sold at a price related to the JKM (Platts' Japan Korea Marker), or similar index. This price reference relates to the price paid for cargoes where ownership title passes at sea, upstream of regas terminals and in-country transmission grids.

In Europe the situation is very different. The key hub prices, NBP and TTF, relate to traded prices inland. To sell an LNG cargo at NBP or TTF prices it is necessary, in addition to the port cost elements quantified above, to pay for the regassification of the LNG and the entry and commodity charges for accessing and using the relevant national gas transmission network to get the LNG to the trading hub.

[16] Stern, J. (December 2017). 'Challenges to the Future of Gas: unburnable or unaffordable?', Oxford, OIES, NG 125, https://www.oxfordenergy.org/publications/challenges-future-gas-unburnable-unaffordable/, p29, Figure 14.

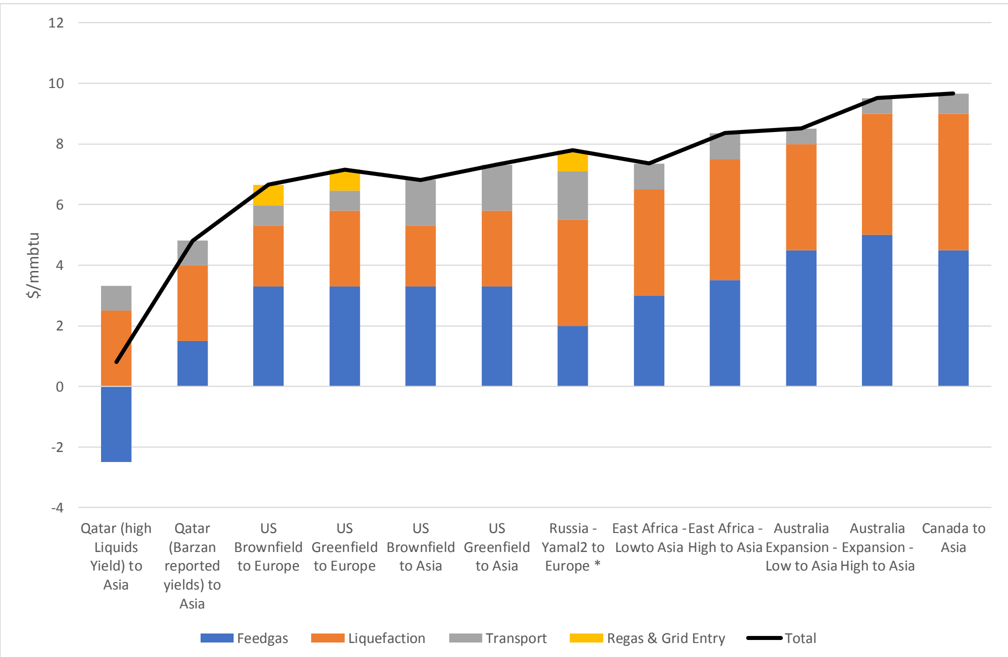
In terms of regas costs it is difficult to obtain current information. Regas capacity normally comprises primary capacity which is owned by the investors in the terminal or those who underpinned the initial investment by entering into a long-term capacity contract. Secondary capacity is available at European regas terminals but on a negotiated basis, and the fees are not disclosed.

The most recently constructed European regas terminal is the Dunkirk facility. The capital cost was estimated, applying historic €/$ exchange rates, at $1.48 billion[17]. Assuming a four year capex phasing and an annual operating cost of five per cent of total capex, the regas fee required to remunerate a 9.6 per cent return on this 13 bcma facility at a 77 per cent utilisation level is $0.7/MMBtu. It may well be that, for terminals built before the mid-2000s escalation in capital intensive project costs, the breakeven utilisation fee is lower than this. An industry rule of thumb of $0.4/MMBtu has been used in the past.

The author was only able to quantify the entry and commodity charge relating to the UK National Transmission System (NTS). Based on the Isle of Grain regas facility, the entry charge equates to $0.04/MMBtu and the commodity charge $0.25/MMBtu, a total of $0.29/MMBtu.

The issue here is that, when illustrative LNG project destination breakeven cost graphs are presented, the recipient understandably compares these with their own view of future regional price references. For this reason, an updated view of Figure 11 is presented in Figure 12, including a European regas fee of $0.4/MMBtu and a system entry cost of $0.29/MMBtu. The total of the fully built up cost of LNG supply to Europe can thus be compared with the reader's view of future European hub prices. Detailed data is shown in Table 5.

Figure 12: Estimated breakeven costs of new LNG projects, with detailed shipping costs modelled



Source: Author's estimates and calculations.

*Note: Due to the specific nature of the ice-breaking Yamal LNG carriers, the Yamal shipping costs were taken from the Novatek Strategy Presentation in December 2017, "Transforming into a Global Gas Company: From 2018 to 2030", http://www.novatek.ru/en/investors/strategy/, slide 56

[17] https://www.lngworldnews.com/frances-dunkirk-lng-terminal-receives-first-cargo/

Table 5: Values contained in Figure 12

	$/MMBtu				
	Feedgas	Liquefaction	Transport	Regas & Grid Entry	Total
Qatar (high Liquids Yield) to Asia	-2.5	2.5	0.81		0.81
Qatar (Barzan reported yields) to Asia	1.5	2.5	0.81		4.81
US Brownfield to Europe	3.3	2.0	0.67	0.69	6.66
US Greenfield to Europe	3.3	2.5	0.67	0.69	7.16
US Brownfield to Asia	3.3	2.0	1.52		6.82
US Greenfield to Asia	3.3	2.5	1.52		7.32
Russia - Yamal2 to Europe *	2.0	3.5	1.60	0.69	7.79
East Africa - Lowto Asia	3.0	3.5	0.86		7.36
East Africa - High to Asia	3.5	4.0	0.86		8.36
Australia Expansion - Low to Asia	4.5	3.5	0.51		8.51
Australia Expansion - High to Asia	5.0	4.0	0.51		9.51
Canada to Asia	4.5	4.5	0.67		9.67

Source: Author's analysis

The changes of significance relative to Figure 11 are the increased combined transportation and regas costs from US projects to Europe and US projects to Asia.

Summary and conclusions

The impetus for writing this Energy Insight was a perception that convenient rules of thumb for LNG transport costs were becoming outdated. This was prompted by the emergence of charter rate quotes for East and West of Suez and for two different LNG carrier types, DFDEs and STs., the implications of which have been very much off the radar screen of most LNG generalists. Market perceptions were that the low charter rates, prevalent in 2015, 2016 and for the first half of 2017, would continue due to the apparent willingness of shipbuilders to add to the fleet of LNG carriers in excess of requirements. However, this paradigm has been challenged by the more than doubling of LNG carrier charter rates between July 2017 and December 2017. It appears that the high seasonal demand for LNG imports by China has strained whatever shipping-mile reserve existed in the industry.

Against a background of increasing fragmentation of the LNG supply chain, it is less than clear whether new carriers will emerge as part of new integrated projects or whether the new oil and gas major LNG portfolio players will themselves, directly or otherwise, invest in new capacity.

During the development of this short paper, the focus has been to attempt to de-mystify the LNG shipping cost sphere through the development of a model for both DFDE and ST carriers which has been benchmarked against mid and end 2017 charter rate and fuel cost data. The model was also used to quantify a realistic estimate of future shipping costs for the 2020s on the assumption that DFDE's continue to be the dominant carrier type, that charter rates align to breakeven/investment levels, and that HFO prices align to a $70/bbl crude reference. This enabled a fresh look at the fully built up costs of new LNG supply projects by source. Other than the increase in the estimates of fully built up costs of US LNG projects to Europe and Asia, the changes compared to the previous estimates were minor. The work described in this Energy Insight, however, provides more confidence in the ability to respond to changes in the LNG shipping world assumptions with quantitative analysis rather than relying on increasingly outdated rules of thumb.

Appendix 1: Key assumptions

Nominal Carrier Size:160,000 cubic metres

LNG liquid cubic metres to MMBtu: 23.12 (GIIGNL 2017 Annual Report, Page 36)

Fuel oil price: taken from *Argus Global LNG* 'Competing Fuel' 1pc fuel oil NW Europe series. In December 2017 this was $348.80/tonne. Future prices are scaled with crude forward curve prices based on current fuel oil – North Sea dated crude relationship.

Opportunity cost of gas (for boil off fuel cost calculation): Either European hub price or Asian LNG spot price.

Average carrier speed: 19 knots for DFDE and ST.

Fuel Consumption: 72 Tonnes/day LNG equivalent[18] for DFDE; 145 Tonnes/day LNG equivalent for ST – comprising LNG boil-off and Heavy Fuel Oil for ST).

Boil-off assumptions: around 0.1% of cargo per day for DFDE, 0.15% of cargo per day for ST.

LNG heel: for the assumed return leg of the journey the LNG storage compartments/tanks need to be kept cool; hence there is a need to keep back some of the original cargo. It has been assumed that 4% of the cargo is retained as the heel..

Port costs: difficult to quantify and needs to be separated from re-gas charges. Assume $100,000 per cargo based on non-unloading costs at Montoir and Fos Tonkin terminals[19].

Suez Canal costs: Timera Energy suggests a range of $300,000 to $500,000/LNG ship[20]. Assume $400,000.

Panama Canal costs: The US Energy Information Administration (EIA) estimate a cost of $0.20/MMBtu for a round trip voyage (outbound and return transit)[21].

Other costs: broker's and ship agent's costs are assumed at 2% of the total charter fee; insurance appears to average some $2,600/day, based on averaging data in Argus Global LNG, January 2018, Page 26.

[18] Natali, M and Mori, S, (25 April 2016) 'Back to the future: steam turbine to DFDE conversion for LNG carriers', 'In Detail', Wärtsilä Technical Journal, https://www.wartsila.com/twentyfour7/in-detail/back-to-the-future-steam-turbine-to-dfde-conversion-for-lng-carriers
[19] https://www.elengy.com/en/contracts-and-operations/tariff-conditions/what-are-the-values-of-the-tariff-terms.html
[20] https://www.timera-energy.com/getting-to-grips-with-lng-shipping-costs/
[21] https://www.eia.gov/todayinenergy/detail.php?id=26892

Appendix 2: Example calculation for Dual Fuel Diesel Electric (DFDE) carrier

Example route: Sabine Pass to Shanghai (via Panama Canal) is 10,081 nautical miles (one way).

Average carrier speed: 19 nautical miles/hour.

Nominal vessel size: 160,000 m3 liquid LNG.

At 98% loading: 156,800 m3 liquid LNG (3,625,216 MMBtu). Assume heel left at end of return (ballast) voyage (4%) = 145,009 MMBtu.

Charter rate: $33,286/day (July 2017 figure).

Daily LNG boil-off: 3,673 MMBtu/day.

Opportunity cost of LNG boil-off: $20,204/day (assuming destination price of $5.5/MMBtu).

Voyage days: 22.1 days each way.

Port days: 3, outbound port, destination port and return destination port.

Charter costs: 44.22+3=47.2 days at $33,286/day = $1,571,596 (allowing for rounding).

Fuel costs: LNG boil-off for 44.22 days: 20,204x44.22 = $893,315 (allowing for rounding).

LNG delivered at destination: 3,317,787 MMBtu (initial loading less boil-off on outward voyage, less boil-off and heel reserved for return (ballast voyage)).

Panama Canal fee: outbound and return voyage is $0.2/MMBtu = $663,557 based on size of delivered cargo.

Port costs: 3 days at $100,000/day = $300,000.

Agents and broker fees, and insurance: 2% of charter cost plus $2,600/day for insurance. This equates to $154,191 (allowing for rounding).

Summarising:

Charter costs:	$1,571,596
Fuel costs:	$893,315
Panama Canal fee:	$663,557
Port costs:	$300,000
Agents and broker fees plus insurance:	$154,191
Total:	**$3,582,658**

Based on the delivered cargo of 3,317,787 MMBtu, the total cost is $1.08/MMBtu.

Appendix 3: Example calculation for Steam Turbine (ST) carrier

Example Route: Sabine Pass to Shanghai (via Panama Canal) is 10,081 nautical miles (one way).

Average carrier speed: 19 nautical miles/hour.

Nominal vessel size: 160,000 m3 liquid LNG.

At 98% loading: 156,800 m3 liquid LNG (3,625,216 MMBtu). Assume 'heel' left at end of return (ballast) voyage (4%) = 145,009 MMBtu.

Charter rate: $22,048/day (July 2017 figure).

Daily LNG boil-off: at 0.15% per day) = 5,437.8 MMBtu/day.

Additional HFO daily consumption required: 48.1 tonnes/day

Opportunity cost of LNG boil-off and cost of HFO consumed: $43,662/day.

Voyage days: 22.1 days each way

Port days: 3, outbound port, destination port and return destination port.

Charter costs: 44.2+3=47.2 days at $22,048/day = $1,040,994 (allowing for rounding).

Fuel costs: $1,930,537 (allowing for rounding).

LNG delivered at destination: 3,239,774 MMBtu (initial loading less boil-off on outward voyage, less boil-off and heel reserved for return (ballast voyage)).

Panama Canal fee: outbound and return voyage is $0.2/MMBtu = $652,114 based on size of delivered cargo.

Port costs: 3 days at $100,000/day = $300,000.

Agents and broker fees, and insurance: 2% of charter cost plus $2,600/day for insurance. This equates to $ = $143,579 (allowing for rounding).

Summarising:

Charter costs:	$1,040,994
Fuel costs:	$1,930,537
Panama Canal fee:	$652,114
Port costs:	$300,000
Agents and broker fees plus Insurance:	$143,579
Total:	**$4,067,224**

Based on the delivered cargo of 3,239,774 MMBtu, the total cost is $1.26/MMBtu.