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REVIEW



- Markets up in the air
- FIDs required
- FSRU projects
- 2-stroke favoured
- Methane slip
- LNG to fuel the future

2020



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SHIPPING REVIEW 2020

An LNG Journal
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PUBLISHER

Stuart Fryer

Tel: +44 (0)20 7253 2700

EDITOR

Ian Cochran

Tel: +44 (0)7748 144265
iancochran74@gmail.com

ADVERTISING SALES

David Jeffries

Only Media Ltd

T: +44 (0) 20 8674 9444

F: +44 (0) 20 8674 2743

djeffries@lngjournal.com

PRODUCTION

Vivian Chee

Tel: +44 (0)20 8995 5540

chee@btconnect.com

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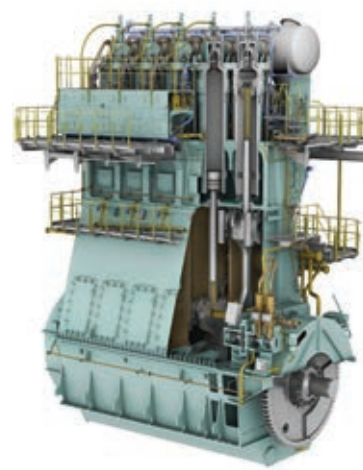
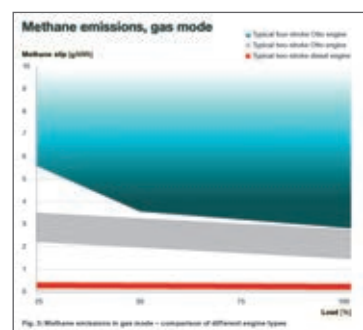
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NAKILAT has plans to significantly increase gas production to export more LNG.

In addition, the Qataris have reserved more than 30 LNGC newbuilding slots at Chinese and South Korean shipyards.

By the time these vessels hit the water, some of the earlier Q-Max and Q-Flex units will be nearly 20 years old.

Natural gas still on track to rule the world

Everyone involved in the LNG sector has been hit by this year's 'perfect storm' of oversupply, low gas prices and COVID-19.

Export and import projects have been delayed or suspended, ships idled, acting as floating storage units or slow steaming, little or no finance is available for projects, including ships.

Taking LNG as an energy source, it was thought to be the panacea when compared with more carbon intensive fuels, despite being carbon based itself. However, the world is now moving towards de-carbonisation, albeit at a slower pace than originally envisaged.

But before we reach that point, natural gas will become the world's largest energy source by the mid 2020s, according to those clever people at DNV GL.

Earlier this month, the German/Norwegian combine released its Energy Transition Outlook 2020, the fourth in the series, which tries to make sense of the world's energy mix through 2050.

The report claimed that as the least carbon-intensive fuel, natural gas will play a prominent role in the world's energy transition, at least until the mid-2030s, when it will start to decline.

As Greater China and the Indian sub-continent produce only a fraction of the gas they consume, these regions will account for more than 75% of natural gas imports from 2035.

Gas will see significant increases in inter-regional trades. A quarter of world gas demand will be traded regionally by 2035, much of this coming in the form of LNG exports, which will more than double over the forecast period, DNV GL said, thus giving hope to LNGC shipowners and operators.

As with oil production, North America,

Middle East and North Africa, and Northeast Eurasia are set to dominate natural gas production, accounting for around 75% of the world's supply throughout the forecast period.

These three regions will see strong ongoing domestic demand for gas, but will also supply much of the growing exports. When compared with the forecast for oil production, DNV GL said that offshore gas production will stay more competitive.

This forecast is partly down to a continued strong demand for gas, bringing more certainty that investments with longer horizons will make a return on investment, and partly due to the price advantage of regional supply by (offshore) pipelines over LNG imports, particularly in regions with well-developed gas infrastructure.

Liquefaction capacity is set to triple over the next decade, led by North America, as the region accounts for three fifths of a projected LNG capex spike in the mid-2020s. Middle East and North Africa (Qatar in particular) and OECD Pacific (particularly Australia) will make up much of the rest of LNG exports. Northeast Eurasia will supply Europe and Asia with natural gas, but largely via pipelines.

Speaking at its launch, DNV GL's head Remi Eriksen, said that overall, energy demand will fall by 8% this year, some 6-8% lower than forecast, primarily due to the pandemic.

Giving a snapshot of the future, he said that natural gas will surpass oil usage in 2026, peak in 2035, then slowly reduce as other forms of energy kick in, such as renewables and the development of hydrogen as a power source, which seems to be on everyone's lips today.

However, some leading shipping players

are saying that come 2050, oil and gas will still make up around 50% of the energy mix.

RALLYING CRY

In a keynote speech given at the virtual Gastech meeting this month, Joseph McMonigle, Secretary General, International Energy Forum (IEF) gave a rallying cry to the sector.

He said that focusing on collaboration between producers and consumers is critical to accelerating the natural gas market's recovery.

Despite nobody knowing how long the pandemic will last, natural gas technologies can help revive the global economic growth and facilitate energy transitions.

Natural gas demand is projected to decline by around 3% this year but is on track to make a robust recovery, he claimed.

In response to the slowdown of international gas trade and the downward convergence among regional gas price markers, exporters will add flexibility to long term contracts to improve their competitive edge, while importers will increase their positions in growth economies.

Both stand to benefit from the creation of greater natural gas markets' commoditisation, accelerated transitions from coal to gas, and deeper renewables integration.

There are short term risks. Natural gas supply will not recover as fast as demand, which has already caused regional natural gas benchmarks to rise and may further cause market turbulence over the coming months.

Gas market fundamentals remain strong, he stressed, despite the current problems. For example, China alone will import around 15 mill tonnes of LNG over the next five years.

Demand growth in South Asia and Southeast Asian economies could quadruple over the next longer-term, with India and Thailand taking the lead as the biggest growth markets. Africa and Latin America will benefit from greater producer-consumer dialogue and regional energy market integration, plus energy infrastructure investment. ■

“

...natural gas will become the world's largest energy source by the mid 2020s

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”

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Rates rising - still a long way to go

Headline timecharter rates continued to firm in early September, following months in the doldrums, according to broking sources.

As of 9th September, East of Suez rates were calculated at around \$50,000 per day, west of Suez at \$52,500, while the 12-month timecharter level was up to \$47,000 per day on average.

This compares with an overall average of around \$29,000 per day in June.

In a webinar held last month, Kristen Holmquist, Poten and Partners Short Term Forecasting head, thought that US LNG export volumes will increase in the next couple of months on the back of arbitrage economics.

US exports were briefly interrupted by Hurricane 'Laura' at the end of August but fortunately, little damage was reported to the Gulf plants.

Following the COVID-19 pandemic, demand from the major import centres was recovering, she said. However, the weather and the world's economic activity would play a major part in determining the direction LNG demand would take going forward in the near term.

September cargo cancellations were running at a much lower level than those seen for the past two to three months, giving rise to

optimism. October US cargo cancellations were thought to be running in single figures, compared to up to 50 during the middle of this year.

Current storage levels were forecast to remain quite high going into 2021. European storage would not return to near normality until 2022 and was expected to reach 2019 levels around the end of September or in October this year, she said.

European storage was reported to be running at around 91% at the end of August with September and October thought to be almost full, which could put a bearish slant on shipping activity. Ukraine was still a major area for storing gas, but was expected to slow in September, due to maintenance.

India was witnessing a strong rebound in demand and was expected to import around 28 mill tonnes of LNG by 2022, while both Bangladesh and Pakistan were also experiencing huge growth, which was forecast to continue.

However, the amount of LNG imported into the Indian sub-continent will be much less than seen in China, Japan and to a lesser extent, South Korea. India is still very much

price sensitive, buying its LNG on the spot market, as is Pakistan but to a lesser degree.

China is expected to keep to around last year's import levels, as the country has mainly recovered from the virus.

In addition, new buyers in Southeast Asia, China, Taiwan and South Korea are now looking for LNG supplies. Due to the low gas prices worldwide, this was seen as the right time to enter the market.

LONG MARKET

In the US, Holmquist expected a 'long' market next year, due to excess supply, saying that it will take exporters a long time to return to normal.

If FIDs are not taken on projects to enable them to come online by 2024-2026, this could lead to a tighter shipping market. It is generally accepted that once a FID is taken on a project then it won't come onstream for at least another two years, she explained.

LNGC rates were forecast to stay soft not varying much from an average of \$40,000 plus per day through November 2022 for a standard 160,000 cu m TFDE vessel, despite the current rise.



Indian importers are expected to ramp up their requirements

Poten's Jefferson Clarke thought at around \$4 per MMBtu and a freight rate of \$45,000-\$50,000 per day, US offtakers would see a profit.

One firm example of the rate rises was provided by Golar LNG in its second quarter financial report.

The company said that its 2Q20 average daily time charter equivalent (TCE) earnings were \$45,100 per day across the fleet, which was above the forecast and substantially higher than the \$24,400 achieved in 2Q19.

Clarke said that talking with shipowners at the beginning of September, he found a positive prognosis that rates will firm further in the next couple of months, maybe up to \$60,000 per day.

An adjustment in shipping strategy in the past few months is now being seen with players becoming more conservative. The tendency to tranship cargoes often at European ports involving Russian LNG from Yamal has had a knock-on effect on rates.

The number of fixtures had increased, both direct and relets/sub-lets. Clarke estimated that at the beginning of September, 60% of fixtures were relets. Some charterers were even fixing

more vessels than they actually needed and were sub-letting tonnage out as necessary.

Last winter when LNG had to be moved, there was a shortage of ships hence the rates spiked. This year could see a reversal of fortunes with a 'longer' shipping market developing, he said.

There could be slight peaks seen in the 2021/2022/2023 winter seasons, however, the market was thought to be well supplied with the number of newbuildings due to be delivered this year through 2023.

In addition, floating storage levels will remain high heading into this Autumn, compared to October, 2019, meaning that these cargoes will be vying with fresh supplies to find a home, leading to spot prices out of the US remaining low.

Some LNGCs were slow steaming at around 13-14 knots and re-routing via the Cape of Good Hope, rather than transiting the Panama or Suez Canals to keep their LNGCs on the water and thus out of the market.

If another lockdown scenario occurred this Autumn worldwide, this would be catastrophic for the LNG sector and for the world's industrial sector as a whole.

However, Holmquist thought that the 2021 downside risk mainly lay in the world's economic recovery not being as robust as forecast. Finally, she said that the world's economies should hope for a 'U'-shaped recovery pattern going forward.

At the beginning of September, Asian spot LNG prices had risen, due to supply issues in Australia and the US, while several buyers were looking for cargoes.

The average LNG price for October delivery into northeast Asia LNG-AS was estimated at \$4.5 per MMBtu, \$0.45 per mmBtu higher than recorded at the end of August.

This is the highest price since late January, according to Reuters price assessment data.

GORGON DELAY

After a two-month delay in restart of the Gorgon Train 2, due to maintenance works, operator Chevron Corp said it would further delay the restart to October from early September. Australia's second-largest LNG plant export terminal has been shut since May.

In the US, hurricane 'Laura' stopped

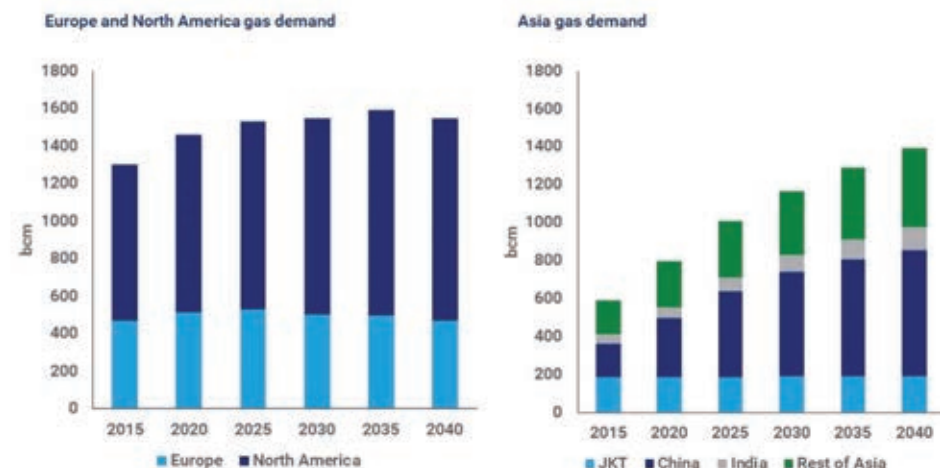
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Gas demand



Source: Wood Mackenzie

Forecasts for gas demand in Europe, North America and Asia through 2040

loadings at Cheniere Energy's Sabine Pass and Semptra Energy's Cameron LNG export plants in Louisiana.

Some analysts expected US LNG exports to rise later in September, due to the fewer cargoes being cancelled.

For example, China's Foran Energy was quoting for a cargo for November delivery, while South Korea's KOMIPO and India's Reliance were seeking October delivery cargoes.

In addition, China's Sinopec issued a tender for eight cargoes for delivery from November this year to March, 2021, and also awarded a 10-year tender to buy 1 mill tonnes of LNG annually to Qatargas.

Russia's Sakhalin 2 plant offered a cargo for October loading, Angola LNG was selling a cargo for delivery in September to October, while GAIL (India) offered cargoes from the US Cove Point terminal for next year.

Analysts earlier estimated prices could go as high as about \$6 per MMBtu for the peak winter season. For example, Platts Analytics expected JKM to have climbed to \$6 per MMBtu by January next year.

Last month, Bank of America Global Research also said that although global inventories were at their highest level ever for this time of the season, as we head towards the seasonal inventory peak in October, injections have slowed slightly by the end of August and there was lesser risk of congestion and resulting price collapse that month.

Moreover, once we look past the seasonal peak in inventories, LNG demand should see the largest seasonal ramp up ever from 27 mill

tonnes in August to 37 mill tonnes in December. This sequential tightening in the global LNG balance this winter should push December, 2020 JKM prices above \$6 per MMBtu, BofA said.

BofA thought that LNG cargoes could be filled a little sooner than normal, as LNG shipping rates were still very low, compared to previous years, making floating storage economical for the next couple of months, meaning LNGC rates should also firm this winter.

Even before the coronavirus pandemic and the oil price crash, this year was shaping up to be a year of oversupply in the global gas markets.

A record of almost 40 mill tonnes of supply was added in 2019, which was poised to put prices under pressure. And in the early part of this year, widespread coronavirus restrictions had an immediate impact on gas demand, Wood Mackenzie said in another report.

Woodmac predicted a rebound in GDP growth next year, provided there is not a widespread second wave of coronavirus. However, economic growth is unlikely to recover to pre-crisis levels. Output will still be subject to problems for several years to come.

There are also reasons to be positive about medium-term LNG demand growth. The supply dynamics, however, are more challenging, Woodmac warned.

LACK OF FIDS

LNG projects currently under construction are suffering from lengthy coronavirus-related delays. This will only serve to

exacerbate the existing slowdown in supply growth, due to the lack of FIDs taken leading up to 2019.

As the market recovers, corporate producers will exercise caution by spending less, even when presented with the same economic incentives.

In addition, as the energy transition takes hold, developers and financiers will increasingly factor in climate change risk to their LNG projects. That will make it more difficult for the majors and IOCs to sanction the projects, as they are stress-tested against lower long-term oil prices and rising CO2 price assumptions.

This changing investment climate, coupled with a slowdown in LNG contracting, means the appetite for LNG investment will as a result, slow over the next two to three years.

As demand recovers and continues to grow, new supplies will begin to be seen again in the late 2020s, when additional investment will be needed.

The impact will vary according to geography. For example, in Europe, the 'Green Deal' will push the bar higher: Progress has been made to reduce CO2 production targets, mostly in the power sector. Europe will need to look beyond that if it is to achieve net zero by 2050, and the threat to gas is significant, Woodmac said.

The residential sector faces added risks from increased electrification. As green hydrogen develops, other demand sectors will come under threat.

Higher Henry Hub prices in North America, driven by the near-term stall in associated gas growth, will set the stage for more renewable development in the power sector. Domestic gas demand will peak in 2036. After that, gas in the power sector will be rapidly displaced by renewables, the analyst said.

Woodmac expressed optimism for an upside for gas in Asian markets, where the energy mix, especially in emerging markets, is still dominated by coal. However, further adoption of hydrogen, carbon capture and storage technology and electrification could slow demand.

TERMINAL CONSTRUCTION

Asian regasification terminal capacity is expected to hit a 10-year high at 144 mill tonnes per annum this year. This includes 33 new terminals under construction, adding 92.8 mill tonnes, plus a further 51 mill of capacity, which is set to be added to existing terminals.



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Rates could rise to around \$60,000 per day by the end of the year. Picture credit - ABB

China, not unsurprisingly, is leading the regas capacity additions, accounting for over a third or 52.6 mill tonnes of total regas capacity, including 22.4 mill tonnes per annum at 10 new terminals.

Woodmac's Research Director, Giles Farrer, said: "Access to capacity in China is being shaken up, with the new national pipeline company, PipeChina, likely to take ownership of a number of national oil company-owned terminals soon.

"China also suffered from delays in capacity additions, due to Covid-19, with expected expansion of the Caofeidian and Rudong terminals facing risks of slipping to 2021," he said.

South Asian schedules have also been impacted by coronavirus, with delays to construction of pipeline infrastructure, limiting send-out from some of the terminals. India is building five new terminals with 20 mill tonnes per annum of total capacity.

Elsewhere, Europe may see up to 13 mill tonnes of additional capacity from expansion projects until 2025. This will involve the Netherlands, Poland, France, Greece, and UK.

Woodmac said that it expected seven regas terminals to take FID this year. Three new regas terminals – Cyprus LNG, and China's Yantai LNG and Tianjin LNG – already took FID in the first half of this year.

Farrer added: "We think a further four terminals have a good chance of reaching FID before the end of the year: Alexandropoulos LNG, in Eastern Greece, Hong Kong LNG, Vila do Conde terminal from Golar, located in North Brazil and Puerto Sandino, in Nicaragua."

Four new projects received cargoes this year. These included Brazil's Sergipe LNG, India's Mundra LNG, Puerto Rico's San Juan project and most recently Myanmar's Thanlyin project.

Woodmac's Asia LNG Research Analyst, Otavio Veras, explained: "Southeast Asia has been an important region for regas development this year. Vietnam and Myanmar have both completed terminals in record time to help stave off looming power shortages. Hai Linh Company has completed construction of a terminal in Vung Tau, Southeast Vietnam and plans to begin

commercial operations by Q2 2021.

"In Myanmar, a small-scale terminal, located in Thanlyin, near the capital Yangon, received its first LNG cargo from PETRONAS, in May, 2020," he said.

The developers of both the Vietnam and Myanmar regas projects have taken more risk to deliver their projects, according to the analyst. Both terminals are privately owned and started construction before any sales and purchase agreements (SPAs) were signed. In Myanmar, novel offloading systems, operated by LNG-Easy were used to begin imports before the terminal construction was complete.

Perhaps the most interesting development is the proposed regas in Southern Mozambique targeted for construction in the first quarter of next year.

Farrer said: "Although demand in Southern Mozambique is presently modest, the terminal will also target demand in Northern South Africa to replace decline at the Pande and Temane fields, which currently supply gas to more than 30 industries in the Maputo/Matola area and also to South Africa, through the 865 km ROMPCO pipeline." ■

Global gas industry set to resume growth post-pandemic

Following growth of more than 2% in 2019, global gas usage is set to fall by around 4% in 2020, as the Covid-19 pandemic reduces energy consumption across the global economies.

However, the resulting low gas prices, as well as clean air and climate policies, will promote further switching to gas from other more polluting energy sources, such as oil and coal, according to the International Gas Union's (IGU) 'Global Gas Report 2020'.

This trend was already underway before the pandemic, thanks to cost-competitive gas in key sectors, including power, industry and transport, and major regions including Europe, North America and Asia.

The report, produced in co-operation with research company BloombergNEF (BNEF) and Snam, the Italian-headquartered international gas infrastructure company, showed that medium-term growth will come from increasing cost-competitiveness and increased global access to gas.

A particular growth opportunity exists in LNG. LNG imports reached 482 bill cu m in 2019, up 13% from 2018, and while this figure is expected to fall by around 4.2% this year, it could rebound quickly to previous levels, as soon as 2021, depending on the persistence and longevity of the pandemic, the IGU said.

Ample natural gas resources exist to support demand growth, but greater gas infrastructure development is needed to support growth in the medium term. India is planning to almost double the length of its gas transmission grid, while China will grow its gas network by about 60% through 2025.

Ashish Sethia, global head of commodities at BNEF, commented: "The pandemic has created disruption in the global energy sector, but low gas prices will ultimately stimulate demand growth as the economy recovers. We have already seen unprecedented coal-to-gas switching in Europe, and clean air policies in major growth markets such as India and China

will drive more gas adoption in the next few years."

Joe Kang, IGU President, said: "This pandemic crisis comes at great cost to the industry, the economy and society at large. It also reminded the world about the value of clean air and healthy environment for wellbeing, providing a unique opportunity to rebuild better.

"Gas is an abundant, clean, accessible and flexible substitute to more polluting energy sources, and supporting greater fuel switching from coal and oil to gas in the immediate term, while ensuring infrastructure is ready to accommodate progressively greater scale of clean gas technologies in the coming decade, is the way to secure a sustainable and prosperous future," he said.

In the longer term, there are major opportunities to scale up the use of low-carbon gas technologies, but these depend on substantial policy action and infrastructure investment in the coming years, the report said.

CLEAN HYDROGEN

For example, clean hydrogen could abate up to 37% of energy-related greenhouse gas emissions, according to BNEF estimates. However, this would require a range of initiatives, including emissions pricing linked to clear, Paris-aligned long-term climate targets; harmonised standards governing hydrogen use; co-ordinated strategies regarding regional and global infrastructure roll-out, and the deployment of hydrogen-ready equipment, such as pipelines, gas turbines and end-use appliances.

Jon Moore, BNEF CEO, added: "It is increasingly clear that the goals of the Paris Agreement cannot be met without a substantial scale-up of clean gas technologies, such as

hydrogen. While the economics are challenging today, a joined-up policy approach could unleash the investment needed to bring costs down, develop scalable business models and drive adoption across the hard-to-abate sectors."

The development of an international hydrogen market could also accelerate adoption. The report found that Germany, which is pursuing rapid development in hydrogen, could procure cost-competitive hydrogen (at about \$1 per kg) in 2050 from a variety of sources, including via electrolysis from its own domestic renewable power, or via pipeline imports from North Africa or Southern Europe.

The report also covered the long-term outlook for natural gas under different existing scenarios, including those from the International Energy Agency, BNEF and IGU analysis. The IEA's Stated Policies Scenario, from its 2019 World Energy Outlook, forecasts gas use growing 1.4% per year to 2040, while BNEF's economics-led New Energy Outlook 2019 foresaw 22% growth in power sector gas demand to 2050.

In contrast, the IEA's Sustainable Development Scenario sees natural gas use declining from the end of the 2020s onward as the global energy demand flattens and the world embraces stronger climate action. Both IGU and BNEF analysis indicated that around one-third of energy-related emissions could be abated by adoption of clean gas technologies.

This divergence in outlooks highlighted both the risks and the opportunities for the global gas sector in the energy transition – and the importance of actions taken by both industry and government to capture the new opportunities and mitigate the risks for the sector in the coming decades, the IGU said. ■

FIDs hanging in the balance

Perceived oversupply, low gas prices and now the pandemic has all transpired to bring investment almost to a halt.

There are major projects still to be financed, as well as a flurry of newbuilding LNGCs, either ordered or planned.

An LNG project's progress is usually gauged on the operator's ability to take a final investment decision (FID).

There were several FIDs planned for this year, mainly involving US export facilities (liquefaction terminals), most of which have been postponed either to 2021 or indefinitely.

As for regasification terminals, Wood Mackenzie said in a recent report, that it expected seven terminals to take FID this year. Three regas terminals – Cyprus LNG, China's Yantai LNG and Tianjin LNG – took FID in the first half of 2020.

Another four were deemed to have a good chance or reaching FID by the end of this year – Alexandropoulos LNG, in Eastern Greece, Hong Kong LNG, Golar's Vila do Conde terminal, located in North Brazil and Puerto Sandino in Nicaragua (see page 8).

The delays in construction and investment could lead to a tightening of the LNG market, Bloomberg said in a snapshot of the latest FID

situation published in the middle of this year.

Few export project FIDs are expected for the rest of this year and next year could also be challenging. However, demand should overtake supply in 2024, Bloomberg said, driven by FID delays on numerous projects.

Once a FID is taken, it takes at least another two years before a project comes onstream.

Proposed terminals with about 230 mill tonnes a year in global export capacity sought FID thus far in 2020, many of which had target start dates of 2024. Some of these won't see the light of day, but the impact of Covid-19 and FID postponements will mean even fewer come to fruition. Moreover, projects that eventually make it through likely won't be operational until at least 2025.

In its research, Bloomberg assumed an average annual growth rate of 4% for demand. There was around 108 mill tonnes per annum under construction, but the pace of projects coming online will slow in 2021/23. Shell's LNG Canada and Total's Mozambique LNG are scheduled for 2025, but both could be delayed to the late 2020s, if completed,

further tightening the market.

With the delays in FIDs, US LNG projects with total annual capacity of almost 130 mill tonnes will likely compete to achieve FID next year, based on Bloomberg's calculations.

Next year's market should stay challenged, but some potential buyers that were reluctant to commit to long-term offtake agreements may be more willing in 2021 amid the expectation of a possible supply crunch in the mid-2020s.

Many approved projects aren't viable and few may reach FID through 2021. Those with more capacity already contracted have a better chance, such as Semptra's Port Arthur. For example, a lack of liquidity drove LNG Ltd to sell Magnolia assets for just \$2 mill.

Out of the liquefaction projects due to be sanctioned globally this year, it was expected that the smaller capacity facilities terminals would have the best chance of attaining FID, with Semptra's Energia Costa Azul in Mexico in the lead.

Exxon delayed FID at its Mozambique Rovuma project and it may not be confirmed next year, as difficult market conditions persist and capital spending could still be limited. Qatar Petroleum is seeking FID for about 49 mill tonnes per year in proposed capacity, and for operations to start 2025/27. There could be a move towards some capacity over the next 24 months, but not all.

Qatar is already a top LNG exporter and diversity of supply for offtakers is key.

There are international projects with about 104 mill tonnes of annual capacity that sought FID this year, according to Poten, most of which have been delayed.

According to Poten and Partners, major players had taken around \$80 bill of investments off the table by the beginning of June.

Several majors have sold assets to raise cash as financiers started to struggle to serve the market in late March and April. With many companies drawing on credit lines, banks became under stress. Royal Dutch Shell



Semptra's Port Arthur LNG could take FID next year

considered raising more than \$2 bill from the sale of a stake in the common facilities at its Queensland Curtis LNG plant in Australia, according to a sale flyer issued earlier this year.

Its stake if sold could be worth around \$2 bill - \$3 bill.

FUNDING COSTS SPIKE

Despite liquidity injections by central banks and the easing of capital requirements, funding costs had spiked by as much as 50% for some lenders by June. There was concern across all sectors that funding requests would be denied and that financing costs could go higher.

Up to the end of May, liquefaction funding projects worth about \$8.4 bill were closed.

For example, NLNG Train 7 is expected to cost \$5 bill. By the middle of this year, \$1.5 bill of ECA funds and the same amount from banks had been agreed for the 76 mill tonnes per annum project. The deal was oversubscribed, attracting 10 Nigerian banks and 15 other commercial banks.

In addition, \$3.4 bill was raised for the re-financing of Freeport LNG Train 3 after the project reached a substantial part of completion. Rated BBB by Fitch, the loan, due in 2027,

was supplied by 18 banks. Another \$2 bill in bonds maturing in 2030 was raised as part of Cheniere's ongoing re-financing programme. At the time, Mozambique LNG and Arctic LNG 2 also needed substantial funding.

This figure could rise this year if the \$34 bill Ichthys sponsors sign financing deals, which could be sizeable.

However, as mentioned, construction timelines for all the projects could struggle, due to the pandemic.

Bank margins are normally set by liquidity, as well as the project's characteristics and risks. Funding costs were up by 15-25% and any new deals are expected to see higher margins. The offtaker's and sponsor's strengths, plus the EPC contracts will determine a project's ability to secure funding, Poten said.

FEWER DEALS

Overall, fewer financing deals are on the horizon, due to FID delays this year. Many projects were already struggling to gain finance - the falling oil price coupled with COVID-19 has made the situation worse. The need for project sponsors to sign up customers will further act as a choke point.

Another problem was that recent US/China

tensions prevented Chinese buyers from signing US term LNG volumes.

In general, it is now harder for banks to assess and sell projects internally to their risk and credit committees - shifting price relationships create risks.

Remaining with the banks, commercial outlets can respond quickly to external funding issues and challenges. By and large, they will look for their own country's involvement in some form. However, they will double down on due diligence.

Development banks tend not to be large players for liquefaction projects but can fund regasification and gas-to-power projects. This situation is expected to continue and even increase going forward.

Bond yields have risen and are more challenging to access for lower rated companies. Strong companies having a good credit rating are more likely to be able to effectively price bonds, for example, Sabine Pass notes were worth \$2 bill in May.

However, Poten said that the financing tally for this year is still likely to be comparable with previous years. Re-financing could be an option when a train is nearing completion or on stream.

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Port State Control Detention Trends (%)

Legend: Marshall Islands (Orange), Liberia (Dark Grey), Panama (Light Grey)

Authority	Marshall Islands	Liberia	Panama
USCG	0.79%	1.24%*	1.08%*
Tokyo MoU	2.19%	3.01%	3.31%
Paris MoU	1.54%	2.05%	5.18%
AMSA	4.23%	7.46%**	6.02%**

* Liberia and Panama are targeted for additional PSC examinations by the USCG for having a detention ratio up to two times the overall detention average.

** Liberia and Panama have exceeded the overall AMSA average detention rate over the three years from 2017-2019 and Liberia is listed among the top five worst detention rates by flag State.

Sources: 2019 Port State Control Annual Reports.

International Registries, Inc.
in affiliation with the Marshall Islands Maritime & Corporate Administrators

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FERC Approved - Pre-FID US LNG Projects

Company	Project	mtpa	Planned FID	New FID
Tellurian	Driftwood	27.6	2020	2021
NextDecade	Rio Grande	27	2020	2021
Sempra	Port Arthur	13.5	2020	2021
Cheniere	Corpus Christi 3	10	2020	-
Freeport LNG	Freeport T4	4.5	2020	-
Shell/Enery Transfer	Lake Charles	16.5	2020	2021
Exelon	Annova	6	2020	-
Texas LNG	Texas	4	2020	2021
Venture Global	Plaquemines 1	10	2020	-
Sempra	Cameron T4-5	9	2021	2021
LNG Ltd*	Magnolia	8.8	2020	-
Eagle LNG	Eagle LNG	0.9	2020	-
Delfin Midstream	Delfin FLNG	13	2020	-
Kinder Morgan	Gulf	10	-	-
AGDC	Alaska LNG	20	-	-
Pembina	Jordan Cove	7.8	-	-

*Assets sold

Source: Bloomberg Intelligence, Poten, company filings

There is only a trickle of regasification project and power to liquids financing at present. Developing countries are finding it more difficult to raise cash.

Poten also said that the consultancy was expecting a lot of LNGC financing this year in the wake of huge Qatar and Arctic 2 vessel orders agreed recently.

As for events in Africa, two reports, produced in association with Wood Mackenzie, compared Africa Oil Week's (AOW) latest data with its first quarter view. Africa was hit hard with widespread cuts and project deferrals implemented.

According to AOW, striking changes in investment, production and value, was revealed, as companies adjust to the new market conditions. These include: upstream spend in 2020 was down to \$14 bill; foreign direct investments (FIDs) targeted in the next 18 months fell from 22 to just three; African upstream value was down one-third (\$200 bill); deepwater and LNG investment were hit the hardest.

Cuts were particularly severe in the deepwater and LNG sectors.

There were capital expenditure revisions on deepwater West African projects and deferrals on large LNG projects in Senegal,

Oil majors Shell, Chevron, ExxonMobil, Total and Eni are responsible for most of the African international investment in the upstream sector, and they are cutting heavily. Africa-focused Eni and Total account for the bulk of production cuts by the majors in the next five years.

AOW said that the oil and gas supply versus demand crisis had a hit investments to Africa hard, resulting in deep production losses, with upstream capital spend down \$14 bill in 2020, reducing by 23% over the next five years.

High cost deepwater projects in West Africa and LNG projects in East Africa also suffered the deepest cuts. The oil majors lead on cost cutting, with capital spend down \$6 bill in 2020. As a result, the expected foreign direct investments (FIDs) in 2020 have fallen from 10 to one.

Taking Total's Mozambique LNG as an example, by the end of July, it had completed \$16 bill in funding for the project, which is estimated to cost \$23 bill.

It is the largest foreign direct African investment thus far, according to law firm White & Case, which advised the financiers. Financial close is expected by the end of September.

The African Development Bank will provide \$400 mill in senior loans and the Japan Bank for International Co-operation signed a loan agreement for \$3 bill, it was confirmed.

Other projects, such as ExxonMobil's Rovuma LNG to be built adjacent to Total's facility, have been delayed. Mozambique LNG's funding effort raised \$600 mill more than planned, with pricing at pre-coronavirus levels, said Societe Generale, the financial adviser for the project.

Mozambique LNG will generate about \$50 bill in revenue for the government over 25 years, Total has claimed. ■

International LNG Projects Seeking FID

Company	Project	mtpa	Planned FID	New FID
Sempra	Energia Costa Azul	2.4	1Q20	2Q20
Exxon	Rovuma	15.2	2020	2021
Woodside	Pluto expansion	4.9	2020	2021
Qatar Pet	Qatar expansion	49	2020/21	2020/23
Pieridae	Goldboro	10	2020	-
Pacific O&G	Woodfibre	2.1	2020	2021
Exxon	PNG LNG	2.7	2020/21	-
Total	Papua LNG	5.4	2020/21	-
BP	Greater Tortue 2	3.8	2020	2022
BP	Greater Tortue 3	3.8	2020	2023
NOVATEK	Obskiy	5	2020	-

Source: Poten, company filings



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Growing competition between EU pipeline gas and LNG supplies amid Covid-19

The European Union (EU) plays a crucial role on the global gas market, with 55% share in the global net pipeline natural gas (PNG) imports and 20% share in the global liquefied natural gas (LNG) imports.

In this context, the latest developments on the EU gas market have a huge impact on the global gas industry in general and on the Gas Exporting Countries Forum (GECF) member countries (MCs) in particular.*

It is remarkable that most of the EU gas imports come from the GECF MCs, which have adequate gas infrastructure to supply both PNG and LNG.

Over the last four years, gas consumption in the EU has remained stable in the range of 470 to 490 bill cu m. In the meantime, EU indigenous gas production decreased by more than 40% over the last decade, driven by natural depletion of gas reserves and regulatory restrictions.

For example, it is worth noting the gradual phase-out of gas production at the Groningen field in the Netherlands. This field played a huge role on the regional market, with annual production at 50 bill cu m in the early 2010s. However, the production dropped to 11bill in 2019, and it is expected to be phased out by mid-2022.

Driven by these trends, the EU marketed gas production fell to 102 bill cu m in 2019, with its share in gas supply dropping to below 20%. A steady decline in indigenous gas production, coupled with the growing energy demand, has led to the increasing dependency on gas imports.

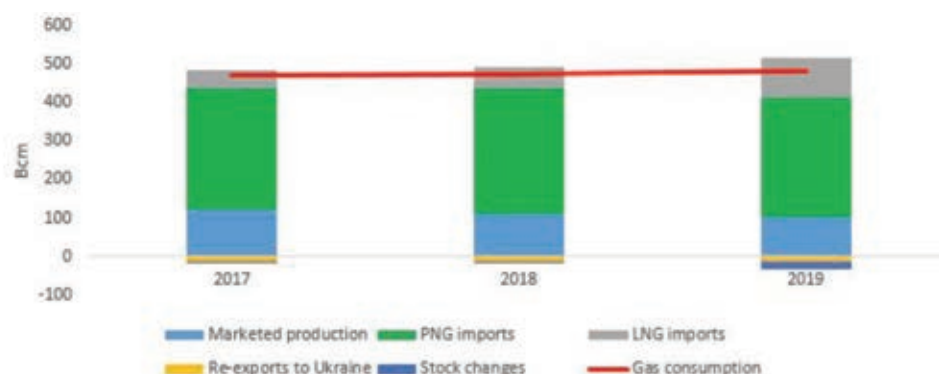


Figure 1. EU gas supply and consumption in 2017-2019. Source: GECF Secretariat, based on data from Cedigaz, AGSI+, ICIS, and McKinsey & Company

Until recently, PNG imports tended to fill the gas supply gap, created by the falling indigenous gas production. The share of PNG supply in total EU gas imports traditionally exceeded 80%. However, starting from 2019, the competition between PNG and LNG supplies has intensified, driven by the growing LNG imports (Figure 1).

Starting from 2020, the competition has been exacerbated by shrinking gas demand, driven by mild winter weather, imposition of lockdown measures to prevent Covid-19, and a high level of gas in storage.

Extra EU PNG imports, which started in late 1960s from Russia (then USSR), rely on traditional suppliers, such as Russia, Norway, Algeria, and Libya, with Azerbaijan joining

the club in the near future.

PNG IMPORTS

All EU countries, except Cyprus and Malta, import PNG. In 2019, extra-EU PNG imports dropped by 4% year-on-year to 311 bill cu m. Among the top six regional PNG importers, only Germany increased PNG offtake, while Italy, France, UK, Spain, and Belgium decreased their imports. Among those countries, only Germany does not have LNG regasification terminals.

Against the COVID-19 outbreak backdrop, the first half of 2020 witnessed a continuous reduction in extra-EU PNG imports, with supply shrinking by 19% y-o-y to 129 bill cu m (Figure 2).

LNG imports, which started in mid-1960s from Algeria, played a rather complementary role in most of the EU gas importing countries until recently.

However, 2019 turned out to be a milestone for regional LNG imports, which increased by 48 bill cu m to a record high of 102 bill cu m and to a certain degree displaced PNG imports, while accounting for 24% in the total EU gas imports.

A total of 13 EU countries imported LNG, with all of them, bar Malta, expanding imports. Spain, France, the UK, and Italy accounted for

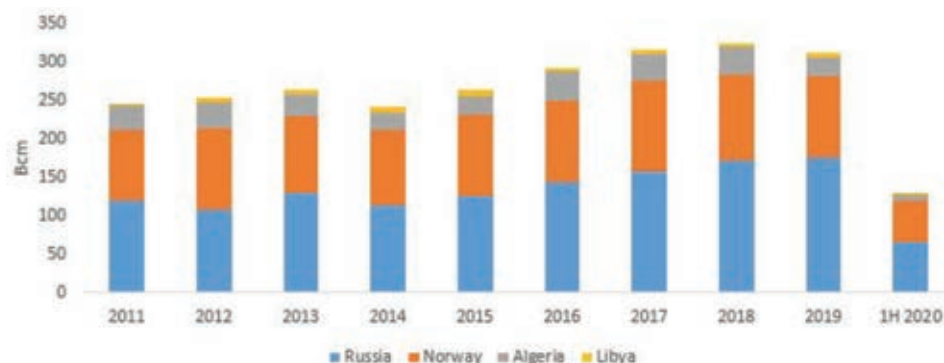


Figure 2. Extra-EU PNG Imports by Exporting Country. Source: GECF Secretariat, based on data from Cedigaz and McKinsey & Company



Figure 3. EU Net LNG Imports by Exporting Country. Source: GECF Secretariat, based on data from Cedigaz and ICIS

72% of the regional LNG imports. Despite the Covid-19 outbreak and subsequent decline in gas demand, the EU LNG imports continued to soar, rising by 12% y-o-y to 57 bill cu m in the first half of this year.

A recent trend in regional LNG imports was the emergence of the US as one of the major suppliers, which has contributed to the strengthening competition between PNG and LNG supplies.

Since February 2016, the US has commissioned 100 bill cu m of LNG liquefaction capacity. US LNG exports to the EU grew steadily to reach 16.5 bill cu m in 2019, which totalled 16% of EU LNG imports, 4% of EU total gas imports and 3% of EU gas

consumption. In the first half of 2020, the US continued to ramp up LNG supply to the EU, with its share in the regional LNG imports reaching 26% (Figure 3).

Meanwhile, the GECF remained the largest LNG supplier to the region in both pipeline gas and LNG forms. The share of the GECF MCs in the EU LNG imports was over 99% until 2017, after which it started to fall, due to the commencement of the US LNG supply.

As a result, the share of the GECF MCs declined to 84% in 2019 and to 74% in the first half of 2020, with Algeria, Angola, Egypt, Equatorial Guinea, Nigeria, Norway, Peru, Qatar, Russia, and Trinidad and Tobago supplying LNG to the region.

Among the top seven EU gas importers, only Spain imported more LNG than PNG in 2019, while Germany, Italy, France, the UK, Belgium, and Poland had PNG imports exceeding their LNG imports (Figure 4).

The true competition between PNG and LNG supplies occurs mainly in 12 EU countries, which have the capacity to import both PNG and LNG.

There were numerous factors, which have direct and indirect impact on the growing competition between PNG and LNG in the EU with some gaining prominence recently.

High competitiveness of PNG imports: -

- The EU boasts of huge gas pipeline infrastructure to import PNG from major suppliers, such as Russia, Norway, Algeria, Libya, and Azerbaijan, with export capacity of gas pipelines from these countries exceeding 450 bill cu m per year equalling to over 93% of the regional gas consumption.
- PNG supply usually has lower transportation costs, while LNG supply is notable for high liquefaction, transportation, and regasification costs, especially for newer LNG projects.
- Long-term contracts, signed by PNG importers and exporters, usually guarantee a high minimum level of PNG supply under a take-or-pay clause, which ensures the security

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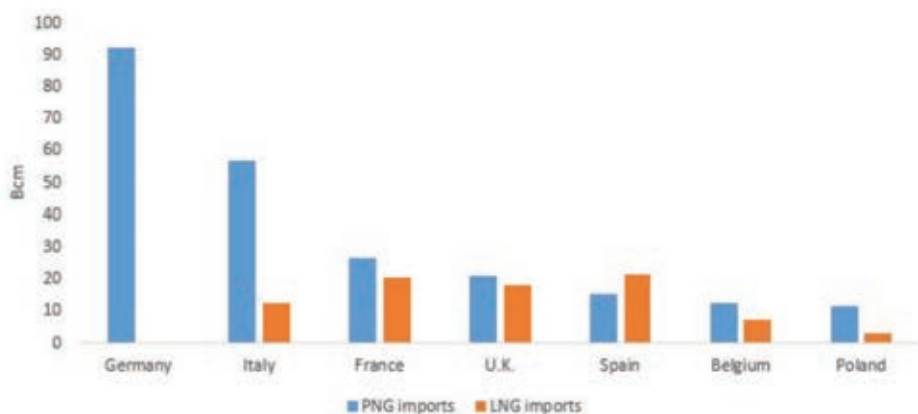


Figure 4. Extra-EU PNG and LNG Imports in Major EU Countries in 2019. Source: GECF Secretariat, based on data from Cedigaz, McKinsey & Company, and ICIS

of gas supply.

- Various PNG suppliers have diversified the pricing mechanisms in long-term contracts by adding mechanisms based on gas hub and hybrid indexation.
- A few PNG suppliers have diversified supply opportunities to embrace spot gas trade, with its share in PNG supply of some exporters reaching almost 10%.
- Some PNG exporters have completed or are going to commission new gas pipelines, with TurkStream, Nord Stream 2, and Southern Gas Corridor, as stand out examples, which increases security of gas supply and decreases gas transportation costs.

The growth of LNG imports: -

- An increase in global LNG liquefaction capacity by 24 mill tonnes per annum to 444 mill tonnes and growth in global LNG trade by 37 mill tonnes to 352 mill tonnes per annum in 2019, laid the foundation for global LNG oversupply and incremental LNG supply to the EU as the market of last resort.
- The EU possesses large LNG infrastructure, including 23 large-scale LNG regasification terminals with total send-out capacity of 209 bill cu m, with Spain (61 bill), the UK (49 bill), France (35 bill), and Italy (15 bill cu m) representing 77% of the regional capacity.
- Huge under-utilisation of regasification capacity in the EU, with utilisation rate reaching only 49% in 2019 and 55% in the first half of 2020, implies that there is a potential to increase LNG imports in the short term.
- A sharp fall in spot prices at the European gas hubs, with the average TTF price dropping from \$7.90 MMBtu in 2018 to \$4.79 MMBtu in 2019 and to \$1.83 MMBtu as of 1st July, 2020, has boosted spot LNG imports with hub-based indexation.
- A fall in spot LNG price spread between Asia and Europe to below \$1 MMBtu in 2019 and 2020 has dislodged Asia from the status of a premium market, with supply to Europe

becoming more profitable for various exporters.

- The imposition of import duties on the US LNG by China, as a result of the bilateral trade war, has diverted much of the US LNG from China to the EU, with the prospects of resumption of large-scale LNG exports from the US to China still uncertain.
- A fall in LNG shipping costs, driven by a decrease in charter rates and shipping fuels prices, has raised the competitiveness of long-haul LNG supply from remote regions, with the average LNG shipping cost for spot cargoes from the US to the UK declining to \$0.85 MMBtu in 2019 and to \$0.47 MMBtu in June, 2020.
- LNG has been gaining momentum in the EU transportation sector, specifically as a fuel for LNG-fuelled trucks and as bunkering fuel, which boosts demand.
- European major oil and gas companies, holding long-term offtake contracts with LNG plants worldwide and acting as global portfolio players, have recently had an incentive to supply LNG to Europe as a market with higher margins.
- The expanding practice of supplying regasified LNG to landlocked and isolated EU countries creates new market opportunities for LNG suppliers.
- The existing spreads in spot prices at different European gas hubs encourage market operators to deliver LNG to one country and then re-export regasified LNG by gas pipelines to other countries.

However, there is one factor that has eased the competition between PNG and LNG supplies. In 2019, underground storage (UGS) facilities absorbed excess gas supply, with large injections balancing the regional gas market.

As of 1st July, 2020, the volume of gas in storage in the EU reached 82 bill cu m, or 80% of UGS capacity. That represented a very different picture to 74 bill cu m as of the same date in 2019 and the five-year historical average of 57 bill cu m.

UGS facilities might be almost full by

September 2020. In this context, demand for imported PNG and LNG supplies might tend to decrease.

RECOVERY PACE

In the short term, volumes of PNG and LNG supplies to the EU will largely depend on the pace of the recovery of gas demand after lockdown measures are lifted in the region.

By the end of this year, PNG imports are likely to remain below the 2019 level, with all PNG exporting countries impacted. PNG imports could be continuously pushed out of the supply mix by LNG imports. However, the contractual obligations of the EU importers under take-or-pay clauses will prevent PNG supply from seeing a greater drop.

Unlike PNG, LNG imports may stay flat or even increase slightly by the end of 2020 because of the global LNG oversupply and narrow price spread between Europe and Asia, with the EU remaining the market of last resort.

Despite the cancellation of multiple US LNG cargoes with deliveries due this summer, LNG supply may be near a 30% share in the EU total gas imports across the full year.

In any case, global LNG oversupply, combined with high level of gas in storage in the region, will continue to have huge downward pressure on spot prices.

Under this scenario, the biggest winners from the increasing competition between PNG and LNG supplies will be the EU gas importing countries, which will benefit from the plunging gas prices, improved security of gas supply and enhanced diversification of gas sources and routes.

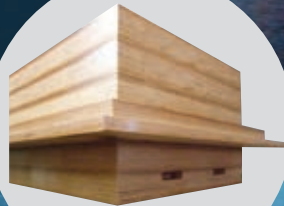
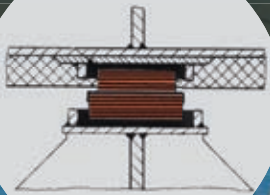
The GECF MCs will remain the largest suppliers of both PNG and LNG to the EU market. Their share of total EU gas imports reached 96% in 2019, and it is expected to remain over 92% in the short term, despite the growing LNG supply from non-GECF countries.

The member countries have competitive advantages over other gas suppliers and have long-term energy relations with the EU. They have expressed a determination to strengthen global energy security as reliable suppliers of natural gas to meet the world's energy demand, as illustrated by the Declaration of Malabo, which was the outcome of the Fifth GECF Summit of Heads of State and Government in Equatorial Guinea in November, 2019. ■

**This article was written by the GECF, which is an inter-governmental organisation of 11 natural gas producers - Algeria, Bolivia, Egypt, Equatorial Guinea, Iran, Libya, Nigeria, Qatar, Russia, Trinidad and Tobago and Venezuela.*

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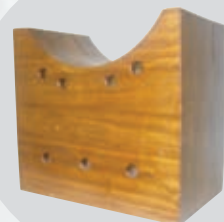


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Several FSRU projects still on the table

This floating terminal offers a 'quick fix' for LNG importers by way of costing less than a fixed terminal and by being available around 18 months from an agreement being signed if necessary.

Some units also have the flexibility of being quickly converted to operate as LNGCs, while waiting for a terminal charter or to take advantage of market conditions.

As of the middle of this year, there were 37 FSRUs on the water, excluding two smaller barges, an increase of two during the year to date.

Of these, 27 are operating as FSRUs and 10 are available and/or trading as LNGCs. Four purpose-built and four converted FSRUs are on order, of which six have firm long-term contracts.

The main players are Excelerate Energy with 10 units, Höegh LNG, which also has 10 and Golar LNG with eight - four newbuildings and four conversions.

In addition Maran Gas ordered an FSRU and recently delivered her to Excelerate Energy under a long term contract, while MOL has one in service and another on order and Swan Energy has one building earmarked for an Indian project.

On 10th June this year, Excelerate Energy took delivery of the Maran Gas ordered 'Excelerate Sequoia' from Daewoo Shipbuilding and Marine Engineering (DSME) shipyard in South Korea, making her the 10th FSRU to be operated by the US-based company.

FSRUs have gained in popularity since the first unit entered service in 2005.

She has a storage capacity of 173,400 cu m and is capable of operating as both an FSRU and a fully tradeable LNGC. In September 2019, Excelerate and Maran Gas Maritime (MGM) signed a five-year bareboat charter agreement for the FSRU, which includes a purchase option during the charter.

The vessel completed her first gas-up and cool-down operations at POSCO Energy's Gwangyang LNG Terminal in Jeonnam, South Korea on 21st June, 2020.

This facility is South Korea's first private LNG terminal and has carried out gas-trial and gas-up/cool-down operations for more than 150 vessels since 2005. Gas-up is a mandatory procedure that an LNGC must perform to ensure that the vessel is ready to receive LNG cargoes.

'Excelerate Sequoia' has joined Excelerate's existing fleet of nine FSRUs, all built by DSME. Excelerate Technical Management, a wholly-owned subsidiary of Excelerate, is providing shipmanagement for this vessel.

Excelerate purchased most of its fleet from Exmar a few years ago, which kept the vessels' management.

Of course, many terminal projects, both fixed and floating, have been delayed due to the COVID-19 pandemic.

Höegh LNG claimed that the main effect from the virus was delays to scheduled crew changes. The company said that it was continuously working on ensuring the welfare of its maritime personnel by making these delays as short and few as possible.

All of the company's FSRUs and LNGCs were fully operational by the end of July and crewed in accordance with relevant safety requirements, and all charter parties were unchanged and in force, the company claimed.

On the business development side, new potential FSRU projects are emerging, due to the continued declining LNG prices caused by the Covid-19 effects on the energy markets. In the established project pipeline, Höegh said that the majority were keeping to their original schedules, while only a minority were being negatively affected by the pandemic.

LONG TERM CONTRACTS

Höegh said that its primary objective was to secure long-term FSRU contracts by the end of 2021 for all the units currently trading on short-term LNGC contracts, which currently number four.

Chartering out an FSRU is much more lucrative than chartering out an LNGC. For example, the FSRU 'Hoegh Esperanza' operated as an LNGC in the second quarter of this year. She earned some \$1.1 mill less during the quarter than in the first quarter when operating as an FSRU. 'Hoegh Galleon' also suffered from a lower market in 2Q20, with her results declining by \$2 mill. She came off charter at the end of April, and has



GasLog is supplying a converted LNGC for Gastrade's receiving terminal offshore Greece



The Indian sub-continent is perceived as a potential market for more FSRUs, such as Bangladesh's Summit terminal

been trading on a lower rate since and also suffered some idle time during 2Q20. Consequently, her overall results declined by \$2.8 mill.

FUTURE POSSIBILITIES

In a presentation, Höegh also gave examples of potential FSRU business going forward. On 15th July, Philippines-based First Gen Corp (FGEN) confirmed that Höegh LNG was among the three preferred FSRU providers for FGEN LNG Corp's interim offshore LNG terminal at Batangas. This project has an anticipated start-up in the first quarter of 2022.

In addition, Australia Industrial Energy (AIE) secured pipeline access from both APA group and Jemena to connect the Port Kembla gas terminal project in New South Wales to their pipeline grids. This will allow gas transport from the terminal to the major markets in New South Wales.

Remaining in Australia, AGL Energy's (AGL) project at Crib Point, Victoria, was in the middle of the Environment Effects Statement (EES) process in July and this was made available for public consultation. The public had until 26th August to consider the documents and to make any submissions.

AGL expects to reach the final investment decision (FID), subject to and following EES approval expected by the first half of 2021.

However, the revised timeline for the EES approval is not expected to significantly affect the planned start-up date for the Crib Point project, Höegh said.

In Cyprus, where Höegh LNG applied for a licence to install an LNG import terminal in April, 2020, there is interest in a proposal to accelerate Cyprus' access to LNG.

Höegh is shortlisted for a project in Latin America for an FSRU. The terminal operator expects to take the FID this year. The

company is also continuing to work on a second project in the region with preferred bidder status, but today, this project has a lower probability of completion owing to competition from alternative import solutions.

During the second quarter of this year, Höegh decided to halt further work on a third potential project in the region.

On the Indian sub-continent, Höegh LNG is currently involved in two FSRU projects where it has exclusivity in one and is in a formal tender process for the other.

However, the uncertainty created by Covid-19 has led to these projects being delayed and progress during 2Q20 was described as slow. Höegh LNG also claimed to have a healthy pipeline of other projects at various stages of development, including several short-term FSRU contracts, which have short lead times and could contribute to increased contract coverage in 2022.

To combat any project delays, in early March, the company instigated a cost saving plan. The target was to save or postpone around \$11 mill of costs. In the second quarter of this year, Höegh reported a 38% decline in SG&A on a quarter-over-quarter basis.

The company said it was very focused on continuing cost reductions and is actively pursuing additional longer term cost optimisation for SG&A and OPEX in particular.

As for Golar, by virtue of its integrated business model, the company said that to a large extent, it had insulated itself against LNG price volatility. For example, high LNG prices supported the company's upstream FLNG offering, while low LNG prices created strong growth opportunities for Hygo Energy Transitions' (formerly Golar Power) downstream business.

The latter is clearly evidenced by a surge in business and investor inquiries currently being fielded by the joint venture, the company claimed.

During the second quarter of this year, Hygo benefited from the first full quarter of the Sergipe power plant operations and the FSRU 'Golar Nanook' generated revenue, less operating costs, of \$51 mill.

'Golar Nanook', together with other FSRU and FSU terminals being developed by the company, can be used as a transshipment location for LNG for onward downstream distribution. For example, small-scale vessels can carry offloaded LNG along coasts/up rivers and connect to onshore truck loading facilities where LNG can be transferred to ISO containers.

These would then be distributed to industrial, commercial and residential off-takers, which are currently underserved by traditional pipeline networks, Golar explained.

Golar said that it also intended to convert the Memorandum of Understanding (MoU) signed with Norsk Hydro into an agreement for LNG and regasification capacity in Barcarena, Brazil and take a FID on the terminal within four to six months, followed by a FID on the associated 605 MW power station.

FIRST TERMINAL

This project represents the first LNG terminal in the North of Brazil. The initial aim is to supply gas to both Norsk Hydro's Alunorte Aluminum plant from mid-2022 and the 605 MW thermal power plant - previously contracted under a 25 year PPA - from 2025.

Concluding final agreements with Norsk Hydro will therefore be an important step toward FID for the terminal. Assuming a FID is taken within this timeframe, Hygo expected to bring an FSRU into operation during the first half of 2022.

Following the Norsk Hydro announcement, Hygo claimed that it had been approached by a number of other mining companies seeking a similar solution. These opportunities will be pursued, the company said.

In addition, arrangements for locating an FSU at Suape, Brazil were on track to be finalised later this year.

Key regulatory and environmental licenses have also been secured to develop the Santa Catarina FSRU terminal on the southern coast of Brazil. Hygo owns 100% of Terminal Gas Sul Ltda, the project company responsible for developing the terminal.

Replicating the success of the Brazil



Höegh LNG's 'Independence' is performing well at Klaipeda

gas-to-power business internationally remains a focus for the remainder of 2020 and into 2021, the company said.

As at 30th June, Hygo had 185 LOIs signed or under discussion, another nine contracts under negotiation and five executed contracts.

LARGEST UNIT

MOL takes the honour of owning the largest FSRU, an 263,000 cu m unit built by Daewoo and delivered in 2017.

Last year, the Japanese conglomerate announced that it had signed a long term charter contract for the 'MOL FSRU Challenger' to operate in Hong Kong.

The contract called for the supply of an FSRU, as well as jetty operation & maintenance services and port services for the Hong Kong Offshore LNG Terminal Project for Hong Kong LNG Terminal Limited.

She was originally employed on a mid-term charter contract for a Turkish project

Hong Kong's LNG Terminal will be located to the east of the Soko Islands. The FSRU will be delivered to Hong Kong to begin testing and commissioning when the project finishes construction.

The FSRU will supply gas to two Hong Kong facilities, the Black Point Power Station

located in the New Territories and Lamma Power Station on Lamma Island.

This project is being developed to support the Hong Kong Special Administrative Region (HKSAR) Government's plan to increase the percentage of power generation from natural gas to meet its pledged environmental targets.

In addition, MOL signed an agreement with Royal Vopak to assist in the project development related to the jetty operation & maintenance services.

As for her near sister, she is also being built by Daewoo and is destined to be located at Wilhelmshaven in Germany, under a long term charter to a Uniper subsidiary, in about 2023. She is to be fitted with GTT's No96 membrane containment system.

Finally, in March of this year, it was reported that Mitsui OSK Lines (MOL) had earmarked one of its managed LNGCs for conversion into an FSU for Swan Energy's Indian Jafrabad project.

In 2008, Swan Energy announced plans to develop an FSRU import terminal at Jafrabad in Gujarat state, which would have a total capacity of 5 mill tonnes per annum.

Fast forward to 2017 and MOL signed agreements with Swan LNG for a stake in the LNG receiving terminal.

Under the terms of the agreement, MOL is

to undertake the long-term operation/ maintenance of a newbuilding FSRU at Hyundai Heavy Industries and also provide an FSU that will serve as the main receiving facilities.

The newbuilding FSRU is of 180,000 cu m capacity and the FSU earmarked by MOL for the project is of about 135,000 cu m capacity. In addition, a breakwater, jetty mooring and accompanying onshore facilities will also be built.

In 2017, MOL said that this move was in line with the company's desire to promote its FSRU business being the only Japanese FSRU owner and operator.

Finally, GasLog took a 20% stake in Gastrade, the developer of the Alexandroupolis offshore gas terminal a few years ago.

GasLog will operate the terminal and is hopeful of supplying an FSRU for the project with a commercial startup scheduled for the third quarter of 2022.

The FSRU will have a nominal regasification and send-out capacity of 5.5 bill cu m per year and a peak technical regasification and send-out capacity of 22.8 mill cu m per day.

GasLog is also providing the 155,000 cu m LNGC 'Gaslog Singapore' for use as an FSRU for Sinolam's LNG-to-power project in Panama.

FLNGs - a mixed story

The FLNG concept has been rather slow to gain traction, probably partly due to COVID-19 putting a dent in financing such projects this year for the time being, plus the drop in gas prices worldwide.

Today, the number of projects involving an FLNG can be counted on the fingers of one hand.

Unfortunately, Shell's giant 'Prelude' FLNG has been hit by problems and hasn't delivered a cargo since earlier this year. She is installed some 300 miles off the northwest Australian coast on a Shell operated oil and gas field.

'Prelude' was forced to shut down in January of this year, due to technical failures on board and thus far, no date has been revealed for her restart.

Goldman Sachs analysts recently said that when 'Prelude' is operational, she is the world's most expensive new LNG project with a "commercial break even" cost of almost \$20 per thousand cu ft.

However, today's natural gas prices make it virtually impossible for Shell to operate the FLNG economically.

When 'Prelude' was ordered at Samsung, Shell unveiled a plan to build several different

standard designed FLNGs, but none have materialised as yet.

However, rumours circulating at the beginning of September suggested that Shell Australia is considering bringing her back into service.

One company having better luck is Golar.

The company's FLNG 'Hilli Episeyo' has off-loaded 42 cargoes, with 100% commercial uptime maintained to the end of the second quarter of this year, since she entered into service. The cargoes amounted to in excess of 2.5 mill tonnes of LNG exported over the nine quarters since start-up, Golar said.

'Hilli Episeyo' continued to operate at 100% commercial uptime, Golar claimed and continues to reliably deliver quarterly LNG tolling revenues, less operating costs, of around \$40 mill; 50% of which is for Golar LNG's account.

In future, a significant reduction in associated gas, as a result of lower US oil production, together with the higher cost of non-associated US gas production, is expected

to result in a higher Henry Hub gas price.

This is expected to place enough upward pressure on global LNG prices to discourage further investment in onshore US LNG export projects but simultaneously create new opportunities for competitive gas elsewhere, including West Africa.

A shift toward LNG buyers favouring short-term contracts and smaller volumes also threatens project developers who rely on long-term contracts for substantial volumes to secure financing.

'Hilli Episeyo' is a fully financed, moveable facility with 1.2 mill tonnes per year of spare capacity. Ongoing discussions with the vessel's current charterer and potential new charterers suggest that the vessel will remain under long-term charter beyond 2026 and that utilisation will increase, Golar said.

The attractiveness of FLNG over land based facilities is becoming better understood by gas asset owners, resulting in an increased interest in FLNG over the last quarter (2Q20).



Despite being hit with a force majeure, the 'Gimi' conversion is continuing at Keppel

Golar's second FLNG, currently under conversion from the LNGC 'Gimi', was hit by a *force majeure* claim from BP Mauritania Investments in relation to a delay of around 12-months to the target connection date.

A *force majeure* delay claim from the shipyard handling the conversion project, Keppel Offshore & Marine, has also been received.

'Gimi' is being converted into an FLNG under a 20-year charter for BP's Greater Tortue Ahmeyim project offshore West Africa.

In July, Golar said that discussions were progressing well to agree a revised plan for her delivery.

Although most parts of the FLNG 'Gimi' supply chain quickly recovered from delays as a result of lockdowns, progress in the yard was impacted during the second quarter of this year by the 'Circuit Breaker' in Singapore.

While the situation was stabilising and construction manning ramps up, recovering the lost yard time within the original schedule was no longer possible.

The contemplated delay to the company's ability to deliver the vessel is anticipated to be less than that currently claimed by BP, and constructive discussions with BP to agree

these two schedules were continuing, Golar said during its second quarter results presentation.

NEWBUILDING MARKETED

Golar said that it will also continue to develop and market its Mark III newbuilding FLNG. The company said that it was increasingly comfortable that this solution could be delivered at a cost per tonne of LNG that is comparable with the converted 'Hilli Episeyo' and significantly cheaper than most greenfield land-based LNG facilities.

'Hilli Episeyo's' conversion saved about 33% of greenhouse gas emissions when compared with a newbuilding, Keppel claimed.

These findings were part of a study conducted by consultants Environmental Resources Management (ERM) for Keppel.

The study took into account the entire project life cycle, from the end of life of the LNGC, converting or building an FLNG, and the unit's maintenance and found that the conversion saved 63,343 tonnes of GHG emissions.

LNGC conversions into FLNGs contributes to the circular economy, adding decades to the life of the vessel, Keppel claimed, adding that

this also leads to recapturing value that would have been lost through the vessel's disposal. A conversion also leads to reducing the consumption of materials that would have been needed for a newbuilding unit.

For example, conversion of FLNG 'Hilli Episeyo' led to a 39% reduction in virgin steel usage, Keppel said.

'Hilli Episeyo' was the world's first converted FLNG having a capacity of 2.4 mill tonnes per annum from two trains. She is currently operating offshore Cameroon's Kribi.

Last month, Iain Ross, CEO of Golar LNG, developer, owner and operator of the FLNG 'Hilli Episeyo', and 'Gimi', said: "Golar has long understood the merits of re-purposing its fleet of high quality assets, having re-purposed five vessels over the last 13 years with a further two currently in the process of being converted.

"The company has never scrapped an asset. The advantages of cost and speed to market have always been well understood and easy to quantify. Golar has consistently believed in the sustainability of this approach too and Keppel's study now quantifies the environmental advantages of this part of our FLNG business model.

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“Sustainability is integral to Golar’s business strategy and an FLNG conversion solution helps us minimise our carbon and environmental footprint. Use of FLNG also allows our customers to minimise theirs,” he explained.

Malaysian energy conglomerate Petronas operates two purpose-built FLNGs.

The first, FLNG ‘PFLNG Satu’, started production in 2017 at the Kanowit field offshore Sarawak. Last year, the unit was moved to the Kebabangan cluster, 90 Km offshore Sabah.

Built by Samsung Heavy Industries, the second unit, the 393 m long ‘PFLNG Dua’, is being commissioned at the Rotan gas field, offshore Malaysia in a water depth of 1,300 m.

She was expected to come onstream by mid-2020 with provisional acceptance (PA), due by the end of this year.

When ready, the ‘PFLNG Dua’ will be operated by a 120 crew and is expected to produce one LNG cargo every two weeks. She has the capacity to produce 1.5 mill tonnes of LNG per annum.

Last December, a Petronas executive said the company could build a third unit but this has not materialised into a firm order, thus far.

Elsewhere, Eni has launched the the ‘Coral Sul’ FLNG hull at Samsung’s Goeje shipyard in South Korea. This unit is earmarked for operation on the Rovuma project, offshore Mozambique.

This unit will form part of the Coral South project, which will produce 450 bill cu m of gas from the giant Coral reservoir. The planned production startup of the Coral South Project is 2022.

‘Coral Sul’ will have a gas liquefaction capacity of 3.4 mill tonnes per year when operational and will be the first FLNG to be deployed in deepwater off the African continent. The unit, which will be 432 m long and 66 m wide and of about 220,000 tonnes, will be able to house up to 350 people.

She will be anchored at a water-depth of around 2,000 m by means of 20 mooring lines that weigh a combined 9,000 tonnes.

OTHER PROJECTS

There are many other projects on the drawing board, some of which are at the concept stage.

One, Excelsate’s patented floating liquefaction storage and offloading (FLSO) vessel allows suppliers of natural gas to effectively monetise both onshore and offshore gas reserves, according to the company.

The FLNG technology is not only applicable to stranded or smaller reserves that

might not otherwise be developed by conventional means, but, given its cost-competitiveness, it is also a viable alternative to conventional onshore facilities.

Excelsate claimed that unlike any other floating liquefaction design, the FLSO provides an effective solution at minimal cost. It is an autonomous floating structure that does not rely on any shore-based utilities to function.

The unit is able to tap directly into a natural gas source, liquefy the gas and subsequently offload the LNG to either a traditional LNGC or an FSRU.

The advantages claimed are -
Value driven

- Lower capital cost and shorter time to market than comparable land-based alternatives.
- Early gas and/or LNG monetisation.
- Greater cost control with construction in a controlled shipyard environment.

Minimal footprint

- Minimisation of fixed infrastructure and overall environmental impacts.

Design flexibility

- Beneficial for conventional or stranded reserves.
- Modular design with capacity variants of 1 - 4 mill tonnes per year.
- Mobility allows movement between multiple reserves over a project’s life.

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LNGCs and 2-stroke propulsion

Up to 2010, LNGCs were generally fitted with steam turbines for propulsion. While these vessels still make up a large percentage of the fleet, they have a cost disadvantage compared with modern vessels, due to higher fuel consumption.

Around 2002, owners and operators started building LNGCs with dual fuel diesel engines or tri-fuel diesel engines, which today make up the bulk of the current modern tonnage.

In about 2012, engine designers started offering engines with slow speed 2-stroke engines - today MAN's MEGI (high pressure) or WinGD's X-DF (low pressure) - being specifically designed for ships powered by gas.

Owners currently have the choice of these two different engine solutions

The MEGI diesel engine, developed and marketed by MAN Energy Systems, applies the principle of non-premixed combustion (the Diesel principle). The first LNGC powered by an MEGI engine was delivered in 2016.

The dual-fuel 2-stroke engine is based on the combustion principle of operating on heavy fuel oil (HFO) or marine diesel oil (MDO), together with high-pressure natural gas, where the fuel is injected and burned directly as opposed to the premixed or Otto-cycle combustion.

Briefly, two or three gas fuel valves inject high-pressure natural gas to the combustion chamber and to ensure an optimally controlled combustion, a small amount of pilot oil is injected simultaneous with the natural gas, via two or three conventional fuel oil injectors.

MEGI engines are equipped with additional safety systems that ensure a safe operation on gas without requiring rupture discs in the scavenge air receiver, the exhaust gas receiver, and in the exhaust gas piping.

Owners and operators are provided with maximum fuel flexibility and, depending on the relative price and availability of gas and fuel oil, are free to choose the most competitive fuel, as the engine operates with the same efficiency on both gas and fuel. The Diesel-cycle ensures stable gas combustion under all weather conditions, such as heavy weather and high ambient temperatures,

Newbuilding LNGCs first appeared on the scene in 1964.

without any risk of misfiring or knocking.

All LNG qualities can be burned with the same high efficiency, and the engine has no specific requirement to the methane number. The dual fuel engine can operate on natural gas in the load range from 10% to 100% load. Furthermore, depending on the fuel availability on board, the engine can combust any ratio of natural gas and HFO/MDO.

The MEGI engine is ignited on diesel, and changeover to gas operation can take place at 10% engine load. Both HFO and MDO can be used as a pilot fuel.

Another advantage of gas-fuelled tonnage is the ability to adjust the operation according to the changing fuel prices and exhaust-emission limits. Service experience shows that the MEGI engine delivers significant reductions in CO₂, NO_x and SO_x emissions.

MEGI vessels generate negligible methane slip during gas operation (see page 27) making them environmentally-friendly. The reduction of greenhouse gas emissions, including methane slip, has been found to be 22% lower, compared to operating on fuel oil.

X-DF TECHNOLOGY

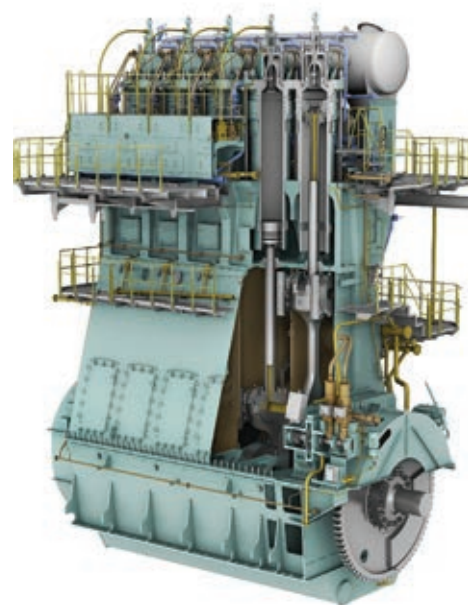
In view of the increasing demand for low-speed, dual-fuel engines, WinGD developed the lean burn Otto combustion process with low-pressure gas admission and micro-pilot ignition for its 2-stroke engine portfolio.

The first LNGC fitted with an X-DF designed engine was delivered in 2017.

This low-pressure dual-fuel technology, known as the X engine series, is a further development of the Wärtsilä's medium-speed dual-fuel engines.

In contrast to high-pressure gas injection engines, which operate on the Diesel cycle, WinGD's low pressure X-DF engines work on the Otto cycle when operated in gas mode - ie ignition of a compressed lean air/gas mixture by injection of a very small amount of liquid pilot fuel.

The gas distribution and admission system



South Korean LNGC owner SK Shipping has chosen X-DF propulsion units for its LNGCs

has been specifically designed for the requirements of the 2-stroke engine. Gas is supplied and distributed in gas manifolds, along both sides of the engine, to feed gas to each cylinder.

Two hydraulically actuated gas admission valves (GAV) inject gas directly into each cylinder through the cylinder's liner wall. Since the gas is injected at the beginning of compression, depending on the selected rating point, a low gas pressure feed of 10-13 barg is sufficient to achieve a homogeneous air/gas mixture, even at full engine load.

In the latest generation X-DF engines, the gas feed is regulated by the built-on engine integrated gas pressure regulating unit (iGPR), which gives greater freedom to optimise the engine room design, enabling significant savings on space, steel construction, ventilation, cabling - effectively driving down the vessel price further.

This is achievable thanks to the introduction of the iGPR, which replaces the need for a dedicated compartment for an open type gas valve unit (GVU) or enclosed type GVU.

The WinGD X-DF engines meets IMO's Tier III NO_x limits regulations in gas mode in ECA by considerable margins without any additional exhaust gas abatement measures,

such as an EGR or SCR.

With liquid fuel consumption for pilot ignition below 1% of total heat release and with practically no sulfur content in LNG, X-DF technology is said to be a reliable solution to achieve the 0.5% global cap on sulfur in marine fuels that became effective in January, 2020.

Particulate matter emissions on X-DF engines are reduced to almost zero, and the CO₂ emissions, inherent to burning natural gas, are further reduced. The total hydrocarbon content of X-DF is considerably lower, compared to 4-stroke low-pressure DF engines, which employ the same technology and are used as vessel auxiliaries.

NEW TECHNOLOGY

Recently, WinGD unveiled a new technology designed to slash methane emissions and cut fuel consumption in its X-DF dual-fuel engines.

The launch of Intelligent Control by Exhaust Recycling (iCER) was the first development to be introduced as part of X-DF2.0, WinGD's second-generation dual-fuel engine platform.

The iCER system delivers enhanced combustion control through the use of inert gas. The result is a reduction in methane slip emissions of up to 50% when using LNG and a significant reduction of fuel consumption, of 3% in gas mode and 5% in diesel mode.

These technologies are aimed at minimising methane slip in expectation that these emissions will be regulated by IMO to help meet its 2050 greenhouse gas targets. Improved fuel efficiency will also be a key factor in reducing emissions further during the first phase of the transition.

Like all future X-DF2.0 technologies, iCER will be available for any new X-DF engines. It is currently completing trials at one of WinGD's dedicated test engine facilities – the final step in a two-year testing programme. The company is also finalising plans for a pilot installation.

As well as using fossil LNG, X-DF engines can also burn carbon-neutral synthetic or bio-derived LNG when it becomes available.

TYPE APPROVAL

In addition, WinGD received type approval for the largest and most powerful LNG-fuelled engines yet built.

Class society Bureau Veritas (BV) awarded the approval for WinGD's dual-fuelled 12X92DF engines, the first series, currently being built by China State Shipbuilding Corp (CSSC) to power nine ultra-large containerships (ULCS) to be operated by CMA CGM.

Once delivered, these vessels will become the largest containerships powered by LNG. The type approval was awarded following a series of extensive full-load tests in diesel and gas operation.

CMA CGM said in a statement; "The certification ceremony marks a new stage in the construction of the CMA CGM's nine 23,000-TEU LNG-powered vessels. These vessels are the world's largest containerships powered by LNG. CMA CGM's ground-breaking choice in favour of LNG is a major step forward and a clear illustration of our resolute commitment to environmental protection and to the energy transition of the maritime industry. This certification is a major milestone as it marks the recognition of the

technological efficiency of our dual-fuel engine project."

Olivier Cartier, BV's Technical Vice President, added: "The certification process of WinGD's 12X92DF engine was a long process, due to the size and complexity of the engine. We mobilised our worldwide teams of engine specialists, especially in China, in France and in Germany, at each of the critical phases of the certification process.

"Progressive Type Approval Tests were necessary where at each test significant progress and refinement were noted, so that we remained confident that final certification at 100% of the power using gas as fuel was an achievable objective – and this has now been achieved."

"With the type approval of our biggest engines to date, we are opening up the possibilities of LNG-fuelled ship propulsion to yet another vessel segment, a testament to its cost-efficiency, reliability and sustainability," said Klaus Heim, WinGD CEO. "This is an important step towards the sustainable energy transition within the shipping industry and we are incredibly proud of the role WinGD plays in this journey."

"WinGD's X92DF engines offer the most sustainable emissions footprint currently available, outperforming expectations for NO_x, SO_x and PM emissions and with CO₂ levels over 20% lower than typical diesel engines. With its unique combination of Otto (lean burn) and Diesel cycle technology these engines can adapt for any of the potential sustainable fuels of the future making them a secure asset for a long time to come." claimed Dominik Schneider, WinGD's Vice President, for Research and Development. ■



GasLog is a major customer for WinGD designed X-DF engines

Reducing the methane slip problem

In the transition from oil to gaseous fuels - Maritime Energy Transition - LNG fuelling is the first step in preparing engines for the broader use of a range of synthetic fuels, on the way to carbon-neutrality.

A paper, recently published by MAN Energy Solutions (MAN), describes the increased benefits of operating on LNG by decreasing methane slip.

With its high heating value combined with low carbon content, LNG enables a significant reduction in emissions of greenhouse gases (GHG), while an absence of sulfur content also enables reductions in emissions of particulate matter (PM) and oxides of sulfur (SOx) – coming at lower fuel costs.

Methane slip issue has received a lot of attention recently and raised questions on the climate benefits of LNG as a fuel. LNG is typically 85% to 95% methane (CH₄), a GHG considerably more potent than CO₂.

In some contemporary reciprocating engines, its use can lead to emission of small but significant quantities of unburned CH₄ into the atmosphere.

For its 2-stroke engines, MAN already offers technical solutions to minimise methane slip. For its 4-stroke spark-ignited (SI) gas and dual-fuel (DF) engines, the company is currently working on solutions.

MAN's ME-GI 2-stroke dual-fuel engines employ the Diesel combustion process. LNG is injected directly into the combustion chamber just after a liquid fuel pilot jet has initiated combustion. This minimises unburned residues and allows the company to quantify and guarantee methane slip levels in a range from 0.2–0.3 g/kWh over the ME-GI engines' load range.

In the 4-stroke gas-burning engines range, which employ the Otto combustion process, MAN has halved the methane slip over the past 10 years to a level where the combined GHG impact of CO₂ and CH₄ is now notably below the respective figure for liquid burning diesel engines.

Three separate routes are being examined to achieve lower levels - First, ongoing improvements to internal engine design and electronic controls will further increase fuel efficiency and minimise emission: Second, newly developed after treatment solutions, namely oxidation catalysts, have the potential to reduce methane slip by high double-digit percentages: Third, MAN is also evaluating options to bring the negligible methane slip of its ME-GI 2-stroke dual-fuel engines to its medium speed dual-fuel engines by transferring the ME-GI Diesel combustion principle to its 4-stroke dual-fuel engines.

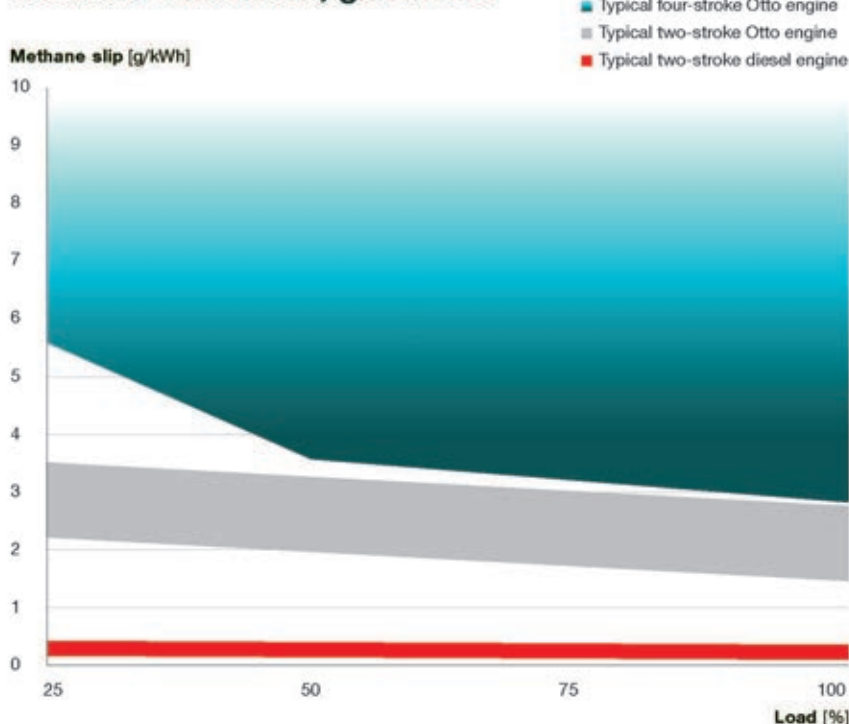
The global energy economy is forecast to steadily move from mineral oil to natural gas, as oil production peaks but production of lower priced natural gas continues to rise for several years, which is positive news for large engine users.

Fuelling ships with LNG also has environmental benefits. LNG is CH₄, which is the simplest combination of carbon and hydrogen. With only one carbon atom per molecule, methane's combustion in air produces the lowest emissions of GHG CO₂ of any hydrocarbon fuel. In addition, LNG combustion produces very low emissions of PM and virtually no SOx - commercially available LNG is sulfur free. At the same time, lean burn combustion technology is already widely used in large gas engines employing the Otto combustion process.

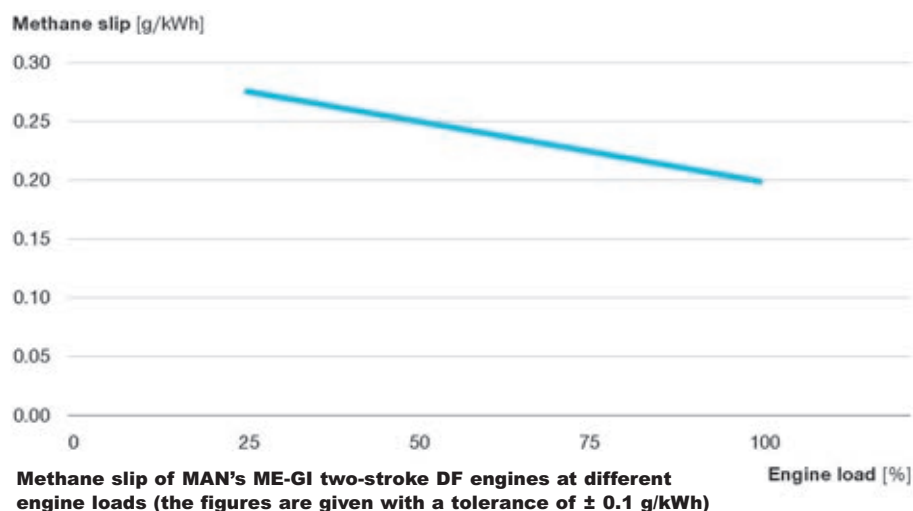
It also has the benefit of enabling fuel-efficient combustion combined with low NOx emissions, in compliance with strict international limits without exhaust gas after treatment. In addition, LNG used to power gas and dual-fuel engines has the potential to lower CO₂ emissions by up to 25% compared to oil-fuelled engines.

Highly compressed and readily transportable, LNG occupies only a fraction of the volume of the gaseous form of natural gas at pipeline transmission pressures. Operators of both large marine and stationary engines are becoming

Methane emissions, gas mode



Methane emissions in gas mode – comparison of different engine types



aware of the potential of fuelling large engines with LNG as a route to compliance with emissions limits (eg SOx).

DEMAND INCREASING

Moreover, as well as orders for new engines, MAN PrimeServ, the company's after-sales organisation, is seeing growing demand for conversions of existing oil-fuelled engines to LNG fuelling on both land and sea. Accordingly, PrimeServ has developed a capability to retrofit MAN's major diesel engine series for gaseous fuels, with packages designed to ensure that the existing MAN 2- and 4-stroke engines remain viable assets.

Without countermeasures, there are several routes by which methane can escape unburned into the atmosphere from both 2- and 4-stroke gas burning engines. This methane evades combustion and is emitted via the engine exhaust, as well as the crankcase ventilation - the methane slip.

With legislators' eyes now firmly on GHG, this gas engine operating aspect has moved into focus, and if not properly addressed, could severely limit the expansion of LNG as fuels for large engines.

Typically, from 85% to 95% of natural gas and LNG is CH₄ and methane as a GHG is several times more potent than CO₂. A recent study calculated the Global Warming Potential (GWP) of methane - ie, its capability to trap heat in the atmosphere compared with the same mass of CO₂ (CO₂ equivalent or CO₂e) - at 84-86 over 20 years and 28-34 over 100 years.^[1]

As well as a source of GHG leakage into the atmosphere, methane slip is also wasted fuel, thus not converted into energy.

This phenomenon is most prevalent on gas-burning engines operating according to the Otto combustion process, where gas fuel and air are mixed homogeneously prior to ignition

and combustion. It affects engines in which the premixed fuel and air are ignited by a spark-plug - so called spark-ignited (SI) gas engines - as well as dual-fuel (DF) engines where a liquid fuel 'pilot' initiates ignition of the air-gas mixture.

Understandably, methane slip is also now firmly on the IMO's radar and in 2019, it declared that the aim was to produce 'concrete proposals to reduce methane slip and emissions of volatile organic compounds'^[2]. The aim is that GHG should peak at the earliest date and then decrease by 2050 to only 50% of 2008 levels, in pursuit of the 100% marine transport's de-carbonisation^[3].

2-STROKE

In its 2-stroke engine programme, MAN is already offering what it claims to be a very effective solution to minimise methane slip. ME-GI 2-stroke dual-fuel (DF) engines are achieving low levels of unburned methane emission, due to operation on the Diesel combustion principle (see graphic on page 27).

This low methane slip is explained by the fact that in the ME-GI 2-stroke DF engines, the gaseous fuel is injected into the compressed charge air around top dead centre and only slightly after the liquid fuel pilot, when the pilot has already ignited. This ensures complete, very fuel-efficient combustion with maximised heat release, MAN said.

Since the gaseous fuel only enters the cylinder after the exhaust valve has closed and ignites immediately, there is no opportunity for methane to escape during cylinder scavenging. In addition, virtually no unburned methane is trapped in crevice volumes, such as the 'top land' between the piston and cylinder liner. MAN can quantify and guarantee methane slip levels in a range from 0.2-0.3 g/kWh over the ME-GI engines' load range. The very high rate of combustion efficiency

(the measure for combustion completeness), as well as the higher compression ratio achieved by Diesel combustion with direct gas injection in MAN's ME-GI 2-stroke DF engines, has further major benefits, MAN claimed. They enable lower fuel consumption, and thus lower CO₂ emissions than DF engines with Otto combustion and pre-mixed gas admission. In addition, with direct gas injection, ME-GI engines also achieve very stable operation on all commercially available LNG grades.

This contrasts with engines operating on the Otto combustion principle, which can be subject to knocking and require LNG with a minimum methane number of around 70 to maintain optimum performance.

Taking pollutant emissions, besides high combustion efficiency, the elevated combustion temperatures within the Diesel combustion process of ME-GI engines also cause NO_x emissions at almost the same level as oil fuel combustion, which need to be abated by either EGR or an SCR catalyst for compliance with IMO Tier III limits.

However, such abatement technology is not limited to use in gas mode operation but can also be activated in liquid fuel mode in order to comply with IMO Tier III limits, thus providing full fuel flexibility under all boundary conditions.

With regard to the possible use of exhaust after treatment to minimise the methane slip from 2-stroke DF engines, oxidation catalysts are not found to be feasible given that the exhaust gas temperatures typical of 2-stroke engines are too low to trigger a reaction with the unburned methane.

MAN's engines modular design supports retrofitting to various engine configurations and the electronically controlled ME-C engines can be readily converted to dual-fuel operation. The resulting dual-fuel engines can, in turn, be retrofitted for operation on other fuels: for example, methanol engines (ME-LGIM) can be retrofitted to operation on LPG (ME-LGIP), etc. Furthermore, MAN is working towards offering engines and retrofit solutions for use with ammonia (NH₃) as a fuel. The aim is to have an ammonia-burning engine ready by 2024.

4-STROKE

For the 4-stroke models, MAN has been addressing methane slip ever since it introduced DF engines in the mid-2000s. For example, since the launch of the 4-stroke MAN 51/60 DF engine, countermeasures have more than halved its methane slip, giving this engine type a 5% to 15% advantage over

liquid fuel engines in terms of GHG emissions, even when the methane slip is considered in the calculation.

MAN’s technical department has already identified three routes to considerably lower methane slip. First, ongoing improvements to internal engine design and electronic controls will further increase combustion efficiency and thus fuel efficiency: Second, newly developed after treatment solutions, namely oxidation catalysts, have the potential to reduce methane slip by 70%: Third, MAN engineers are evaluating ways to apply the technology of direct gas injection, as used on MAN’s 2-stroke DF engine to its 4-stroke DF engines.

This will give the potential to reduce methane slip by a value greater than 90%. The countermeasures devised and under investigation at MAN’s technical department for 4-stroke engines involve all the major aspects of internal engine design: control of engine operation; combustion processes and their control; basic engine architecture.

As they mature, measures are being applied in both new 4-stroke DF engines ie the 51/60 and 35/45 DF, and diesel engines being retrofitted by the MAN PrimeServ after-sales department to run on LNG, such as 48/60 diesel to 51/60 DF conversions.

AFTER TREATMENT

While an oxidation catalyst (oxicat) is not an option for 2-stroke engines because of unsuitably low exhaust gas temperatures, it is a well-established technology for removing unburned hydrocarbons and carbon monoxide from 4-stroke engine exhaust gases.

The exhaust gas temperatures from MAN’s four-stroke SI and DF engines are sufficient to support the oxidation of methane slip and

MAN is participating in the IMOKAT project supported by the German Federal Ministry for Economic Affairs and Energy.

The aim is to develop methane oxidation catalysts capable of a methane slip reduction of 70% on both SI and DF gas engines.

In laboratory tests with synthetic exhaust gas, the 70% methane conversion rate was achieved. The next step will be tests on a full-size engine.

A particular challenge with the oxicat is the need to integrate the catalyst on the engine before the turbocharger, where exhaust gases are hotter, since variations in exhaust gas temperature represent a particular challenge in terms of control engineering.

Direct gas injection technology used on MAN’s ME-GI 2-stroke gas engines can also be applied on 4-stroke DF engines, switching the engines to the Diesel combustion principle. It is estimated that this step would enable a further reduction in methane slip estimated at greater than 90%, compared to Otto gas engines with premixed cylinder charge.

As in the ME-GI, 2-stroke DF engines, gaseous fuel would be injected with the diesel-fuel pilot into the compressed charge-air at around top dead centre, which will leave no scope for methane to escape during the 4-stroke cylinder scavenging process. MAN’s engineers are assessing the feasibility of direct gas injection on 4-stroke gas engines and will be able to apply the technology, when the market demands it.

As with MAN’s ME-GI 2-stroke DF engines, the direct injection of gas into the cylinder when compression is at its highest demands much higher gas inlet pressures. These demand a more powerful compressor than for the low-pressure principle presently used on MAN’s 4-stroke Otto gas engines,

where an air/gas mixture is admitted during the induction stroke.

RETROFITTING

To meet the 2050 climate goals, large parts of the existing global shipping fleet will need to be retrofitted from liquid fuel to dual-fuel liquid/gas operation. Incorporating the capability to take advantage of a range of low carbon and carbon-neutral fuels will enable engines to run, for example, on carbon-neutral synthetic gas without further technical modifications.

For 4-stroke engines, today LNG is the only available fuel to meet environmental standards on polluting emissions and to reduce CO2 emissions by up to 26%, compared to 4-stroke oil-fuelled engines – with the option to use SNG as soon as available, either as a drop-in fuel or up to 100%.

The costs of a retrofit depend on the scope of technical solutions and conversions, ranging from very low in the case of LNG to synthetic natural gas, where no technical adaptations are needed, and up to 50% to 75% of a new engine for an initial liquid to gaseous fuel conversion. However, the higher costs can be offset when the liquid fuel engine is due for a full overhaul.

Values of 23% reduction in GHG emission have been measured on recent ME-GI engines, MAN claimed. In the 4-stroke sector, MAN expected a combination of engine-internal and after treatment measures to achieve methane slip levels that will enable continued expansion of the global 4-stroke gas engine population.

MAN has already reduced methane slip from its 4-stroke gas-burning engines by more than half in the last 10 years, leading to a GHG benefit of around 5% to 15%, compared to conventional diesel engines, the company claimed.

Fuel types	MC	ME-B	ME-C	ME-GI	ME-GA*	ME-GIE	ME-LGIM	ME-LGIP
0.0–0.5 % S VLSFO	Design	Design	Design	Design	Design	Design	Design	Design
High-S HSHFO	Design	Design	Design	Design	Design	Design	Design	Design
LNG	–	–	Retrofit***	Design	Design	Retrofit***	Retrofit***	Retrofit***
LEG (Ethane)	–	–	Retrofit***	Retrofit***	–	Design	Retrofit***	Retrofit***
Methanol/Ethanol	–	–	Retrofit**	Retrofit**	–	Retrofit**	Design	Retrofit**
LPG	–	–	Retrofit**	Retrofit**	–	Retrofit**	Retrofit**	Design
Biofuels	Design	Design	Design	Design	Design	Design	Design	Design
Ammonia****	–	–	(Retrofit**)	(Retrofit**)	–	(Retrofit**)	(Retrofit**)	(Retrofit**)

Fuel flexibility – which MAN two-stroke engines can burn which fuels? *

- * Otto-cycle gas engine
- ** Only one second fuel per retrofit
- *** Both LNG and LEG for same engine possible
- **** Ammonia burning engine development started

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The future fuels conundrum

Out of the three recently marketed fuels that are available today, LNG is the most viable, Marios Ioannou, Manager ABS Global Ship Systems Centre said in a recent webinar.

The other two fuels- LPG and methanol- were mainly being used to power LPG and methanol carriers, he explained.

Highlighting the plus points, he said that LNG complied with SOx regulations, it is a cleaner fuel by way of lower NOx and particulate matter (soot) emissions, LNG is cheaper than low sulfur fuel oil and its safety record has been proven by being used in many LNGCs down the years.

Despite these advantages, shipowners, operators and managers must take into account the forthcoming IMO greenhouse gas (GHG) legislation; the perceived lack of infrastructure to back the use of LNG, such as bunkering facilities; various rules pending as to its use; extra CAPEX needed in installing machinery either at the newbuilding stage or as a retrofit; taking into account safety and new technology risk aspects of using the fuel and crew training.

The fuel comes in the form of LNG and/or boil-off gas (BOG), which is normally supplied to the main engine and auxiliaries through a fuel gas supply system (FGSS). Ioannou stressed that a BOG management plan must be in place to enable its use to run smoothly without the danger of accidents.

During the webinar, he highlighted two dual fuel engine OEMS - MAN Energy Solutions and WinGD.

Through its licensees, MAN offers the ME-GI HP-DF type, which is based on a Diesel cycle. It is a 300 bar high pressure engine with stable consumption in gas or direct operations.

The Swiss offering is the WinGD X-DF LP-DF, which is based on the Otto cycle with a lean burn (pre-mixed) combustion at 13 bar injection pressure, ie low pressure.

However, the question of methane emissions must be taken into account, which are primarily - well to wake, well to tank and tank to wake methane slip. Slippages can occur in the supply chain and LNG as a marine fuel where unburned methane escapes

(see page 27).

Dual fuel engine methane slips can occur through the exhaust valve, eg the injection timing and misfiring, by incomplete combustion, flame quenching on or near surfaces and crevice volumes, such as liner piston, exhaust valve.

There have been studies undertaken by Sintef, ICCT and Thinkstep, which looked at the well to wake GHG emissions when a ship switches from diesel to LNG as a fuel.

As for the FGSS, for a high pressure dual fuel engine using LNG, two cryogenic low pressure centrifugal pumps, plus a pump vaporiser unit consisting of three high pressure reciprocating pumps and one high pressure vaporiser (heat exchanger) will be needed.

For BOG, a small high pressure reciprocating compressor needs to be fitted, while low pressure dual fuel engines running on LNG will need two low pressure cryogenic centrifugal pumps and one low pressure vaporiser to be fitted.

QUALITY ISSUES

Over the past five years or so, there have been initial engine design and quality issues, which was to be expected, Ioannou said. However, development is still ongoing.

He said that the choice of propulsion and fuel system was down to the vessel's characteristics and her operational profile. "It is a case specific decision on the two different systems involving the FGSS and engine selection," he explained.

He said that there were five parameters to consider when opting for a dual fuel engine -

- Safety
- Compliance with GHG regs
- CAPEX and OPEX- the cost of conversion
- Infrastructure- bunkering etc
- Technical aspects.

There will be issues but these can be resolved today at a faster pace, as the OEMS have increased the number of testing facilities and test engines installed in their facilities.

Ioannou concluded by saying that owners could opt to fit one or two vessels with dual fuel engines and then provide feedback to the OEMs and the class societies, plus other interested stakeholders.

RETROFITS

LNG as fuel has long been considered the industry's last, best hope to meet the IMO's ambitious targets to reduce greenhouse gas emissions by up to 40% by 2030 and by 70% in 2050. So why aren't we seeing more LNG retrofits on existing tonnage?

As the IMO did not specify how these targets might be met, this left owners with more questions than answers. What alternative fuels make sense? Is there adequate bunkering infrastructure? And who pays?

The introduction of other alternative fuel solutions, such as hydrogen, ammonia, bio-fuels and battery hybrid systems, caused many owners to hesitate: Why invest in LNG retrofits, if natural gas will be replaced by other fuels that have lower GHG impacts?

In a February presentation in London, DNV GL's Maritime CEO Knut Ørbeck-Nilssen acknowledged that low carbon biodiesel, hydrogen, ammonia and synthetic fuels are promising, but said that they would take time to develop. "The pathway to carbon neutral fuels starts with gas," he said. "It is important to act now and not to wait for the 'perfect' fuel."

As for emissions, Ørbeck-Nilssen pointed out that methane leakage had been drastically reduced in modern engines, and further improvements could be expected. Citing data provided from the engine manufacturer Wärtsilä, he said that over the last decade, gas engines outperformed engines running marine gas oil (MGO) in terms of GHG emissions.

ENGINE TECHNOLOGIES

Cato Esperø, Wärtsilä's Head of Marine Sales (Norway) confirmed that the company's engineers have continuously improved the

emissions performance of dual fuel engines (notably the 46DF, 50DF, 31DF), which allow ships to operate using a broad range of fuels, including heavy fuel oil, MGO, light fuel oil, bio-fuel and LNG.

The company has also introduced the 31SG, an engine optimised to run on gas alone, and can also provide customers with the Wärtsilä Methane Number Calculator, a tool to help shipowners and operators calculate methane values in the fuel gas.

Esperø acknowledged that LNG retrofits are expensive, but pointed out that owners willing to make the investment now will be in a better position to migrate to other alternative fuels as they become available. “It is important that owners secure fuel flexibility to fit their operational profile, in the short, mid and long term,” he said. “For most owners, a dual fuel/LNG setup reduces business risk and provides flexibility with regards to availability of new fuels during the transition.”

TIME TO ACT

Lianghui Xia, Managing Director of Newport Shipping UK, a global shiprepair and retrofit service provider, agreed that further delays will all but ensure the industry will fail to meet IMO targets. “The time to act is now,” he said. “Natural gas may not be perfect, but let us not make perfect the enemy of good.”

Xia also acknowledged that more promising fuels were on the horizon, but for the next five to 10 years, LNG as fuel represents the only credible and achievable mid-term solution in cutting emissions.

“Newport Shipping recognises that the number one challenge for owners is cost, so in addition to providing turnkey solutions that includes equipment procurement, full-scope design work, on-site project execution, we offer a five to seven year payment plan without fixed vessel mortgage collateral,” he explained.

Xia also noted that if the world is serious about cutting maritime emissions, it will require more than efficient engines, skilled yards and short-term financing options. “Right now, many owners willing to make the change simply don’t have the capital to invest in conversions,” he said. “To reach IMO targets will take a collective effort.”

He suggested that governments could offer tax incentive schemes to reward owners and charterers, which would help subsidise conversions to achieve lower emissions throughout the value chain.

Ports could work with logistics providers to



Newport Shipping's Managing Director Lianghui Xia

improve bunkering access, and energy companies, which would benefit from greater demand, could help by lowering the production and delivery costs of natural gas. “If climate change is a shared challenge, then so is the solution,” he said. “Owners should not be forced to bear the costs alone.”

Xia expressed confidence that conversions using existing technology offers the shipping industry a credible and achievable mid-term solution in cutting emissions for shipowners to meet the 2030 target.

Newport Shipping’s turnkey solutions encompasses equipment procurement, full-scope design work, on-site project execution at the shipyard with deferred payments option.

The company recently announced a tie-up with LNG market service provider Gloryholder Liquefied Gas Machinery (DL) Co, Ltd (LGM Engineering).

The agreement signed earlier this year, will see LGM Engineering supply Newport Shipping’s LNG retrofit projects with its solutions.

In June, LGM signed a contract to design and supply LNG FGSS for two 13,000 dwt chemical tankers building at Jiangsu New Yangzi Shipbuilding Co Ltd (YZJ) for Tarbit Tankers. The class society involved is Bureau Veritas (BV).

LGM will deliver the complete LNG

FGSS, including the design and manufacture of double vacuum insulated LNG fuel tanks with integrated tank connection space (TCS), LNG bunkering station modules, water glycol system, ESD systems, gas detection system, installation guidance, commissioning, crew training, etc.

The Group has a network of 12 shipyards with 28 docks capable of handling all vessel sizes. They include yards in Turkey, China, Singapore and Middle East, catering for around 2,100 dockings annually.

Talking exclusively with *LNG Shipping Review*, Xia said that the requirement by IMO target for de-carbonisation means it is not sufficient to just equip newbuildings with LNG fuel system.

“The driving factor here is not only being economical but more importantly, the scale of ‘fleet upgrading’ that is needed. Depending on the vessel operational profile and age profile, the right retrofit solutions, combined with certain financial support to owners, can be both more practical and more economical than a newbuilding project with LNG fuel system,” he said.

He explained that in principle, we are talking about all vessel sizes and vessel types. However, in practice, the vessel’s trading and age profile can have an impact on a project’s feasibility. ■

Chart buoyed by equipment awards for new projects

In June of this year, Venture Global LNG began to install the first batch of equipment to liquefy natural gas at its Calcasieu Pass export facility under construction in Cameron Parish, Louisiana.

This consisted of two Chart Industries (GTLS) brazed aluminium heat exchangers (BAHX), known as cold boxes, which were the first of 18 boxes that will form part of the Calcasieu Pass LNG liquefaction process system.

Manufactured in the US, the BAHX were delivered more than four months ahead of schedule and some 10 months after the project's final investment decision (FID).

Installing the first modules of the process system was claimed to be an important milestone for the project, which is composed of 18 mid-scale, modular liquefaction trains, factory-fabricated in Italy by Baker Hughes. Chart's CEO, Jillian Evanko, told *LNG Shipping Review* that the BAHX and cold boxes were commonly used on small-scale, mid-scale and base load LNG export terminals.

She added that they have been installed at Wheatstone and Caclasiu Pass. The equipment will also be delivered to Cheniere's Corpus Christi Stage Three, Venture Global's Plaquemines and Tellurian's Driftwood projects.

In addition, they have been fitted on three FLNGs thus far - Exmar's 'Tango' FLNG and Golar's 'Hilli Episeyo' and 'Gimi', which is currently undergoing conversion at Keppel.

Chart's patented IPSMR LNG liquefaction process can also be applied to FLNGs and the company is currently involved in a number of pre-FEED projects involving this application, Evanko said. This process also uses Chart's

BAHX and cold box technology for liquefaction.

BOG SYSTEMS

In addition, Chart has provided a number of BAHX installed in boil-off gas (BOG) reliquefaction systems on board LNGCs. Multiple other products are being fitted for these applications, she claimed.

For ships, Chart can supply fixed LNG fuel tanks of up to 700 cu m/185,000 gallons, LNG cargo tanks of up to 700 cu m, replaceable fuel tanks/IGF Code ISO containers, fuel gas supply systems (FGSS) with vaporisation & pressure build up capabilities and vacuum insulated on board bunker piping.

On other floating facilities, Chart can supply deck tanks/buffer tanks of up to 700 cu m/185,000 gallons, BAHX & coldbox for FLNGs, BAHX on on board liquefaction LNGCs (Babcock), forced draft vaporisers, water/glycol vaporisers, gas fired intermediate fluid vaporisers, LNG pump skids and LIN skids.

As for shore terminals, Chart's equipment offering includes - multi-function SSLNG terminals of up to 10,000 cu m/2.6 mill gallons, fixed storage tanks of up to 1,500 cu m/396,000 gallons, marine loading arm/jetty module, re-export/bunkering pump skids, ISO containers & semi-trailer loading bays, vaporisation & pressure build up units, vacuum insulated piping and mobile power packs (LNGPacs).

Another major contract was reported in July.

This involved Risco Energy Solutions' signing of an exclusive agreement with Chart to supply a large amount of equipment for Indonesian projects.

Chart will supply storage tanks, ISO containers, trailers, mobile equipment and fuelling stations, to support the rapidly growing domestic gas-to-power infrastructure needs.

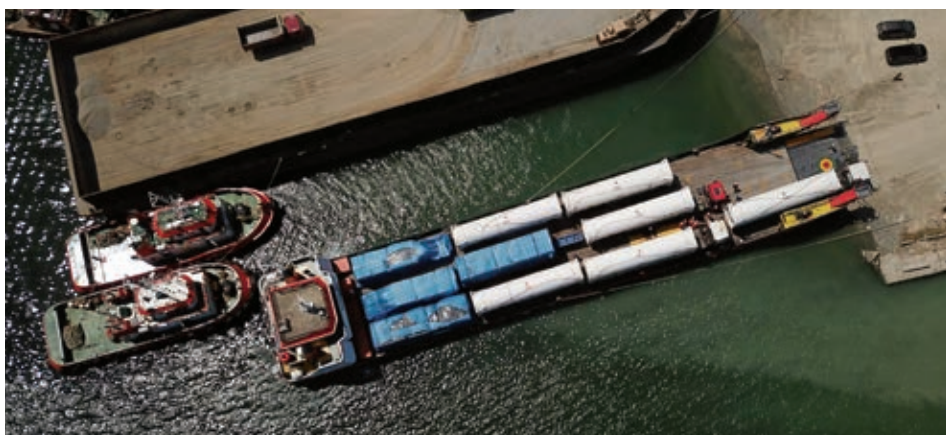
This agreement comes as Indonesian state-owned oil and gas concern, Pertamina and PLN plan to expand gas power and infrastructure across Indonesia, which is made up of a myriad of islands, many of which have large populations.

Risco is a gas infrastructure provider to PT Perta Gas Niaga (PTGN), a Pertamina subsidiary and said that it planned to purchase hundreds of logistic support tanks and large volumes of ground storage tanks from Chart over the next two years.

"PTGN has co-operated with Risco since 2018 to supply gas infrastructure for PLN requirements in Kalimantan, Central and Eastern Indonesia. This agreement will further support PTGN and RISCO's plans to continue working on developing more gas-to-power projects for PLN, industrial private sector, fuel conversion projects and smelters. Together we hope to meet the needs of the government growing demands for power across Indonesia," said PTGN's President Director, Linda Sunarti, at the time of the signing of the agreement.

"Risco has been operating LNG logistic facilities in Sambera, East Kalimantan and has conducted LNG deliveries to Papua. In the first year of operation at Sambera, there were zero incidents (LNG spills) and Risco has delivered over 1 mill MMBtu of LNG to PLN. Risco/Chart collaboration enhances Risco's ability to provide total turnkey LNG infrastructure solutions to meet Indonesia's gas to power demand," added Risco Gas Infrastructure's Director, Aditya Pratama.

Risco Energy is an independent, privately-owned energy investment company focusing on oil and gas, and infrastructure. ■



Risco equipment being barged at Sambera, Kalimantan

LNG OneWorld.com



X-DF2.0

By WinGD

A smarter perspective on a low carbon future



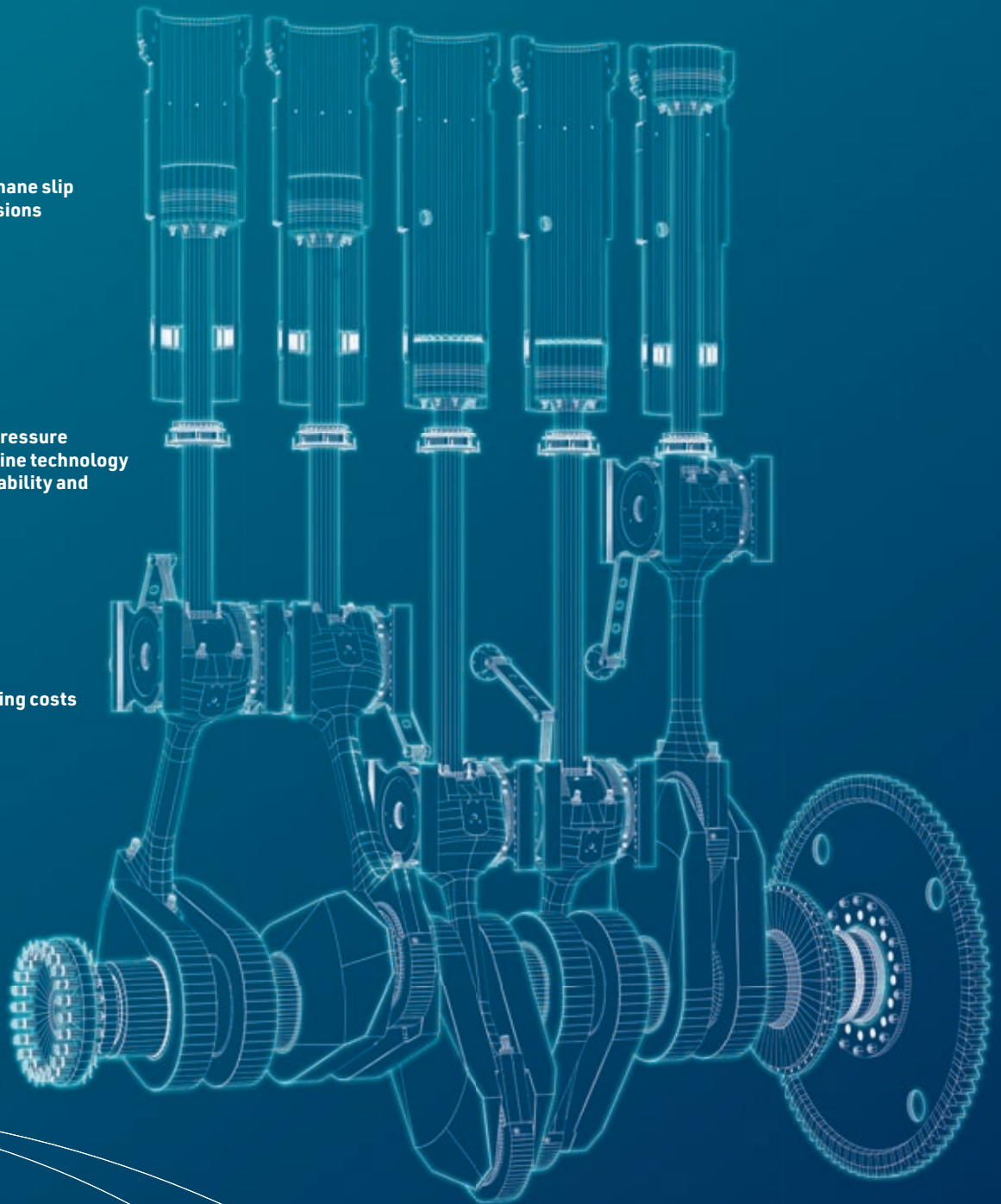
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and CO₂ emissions



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