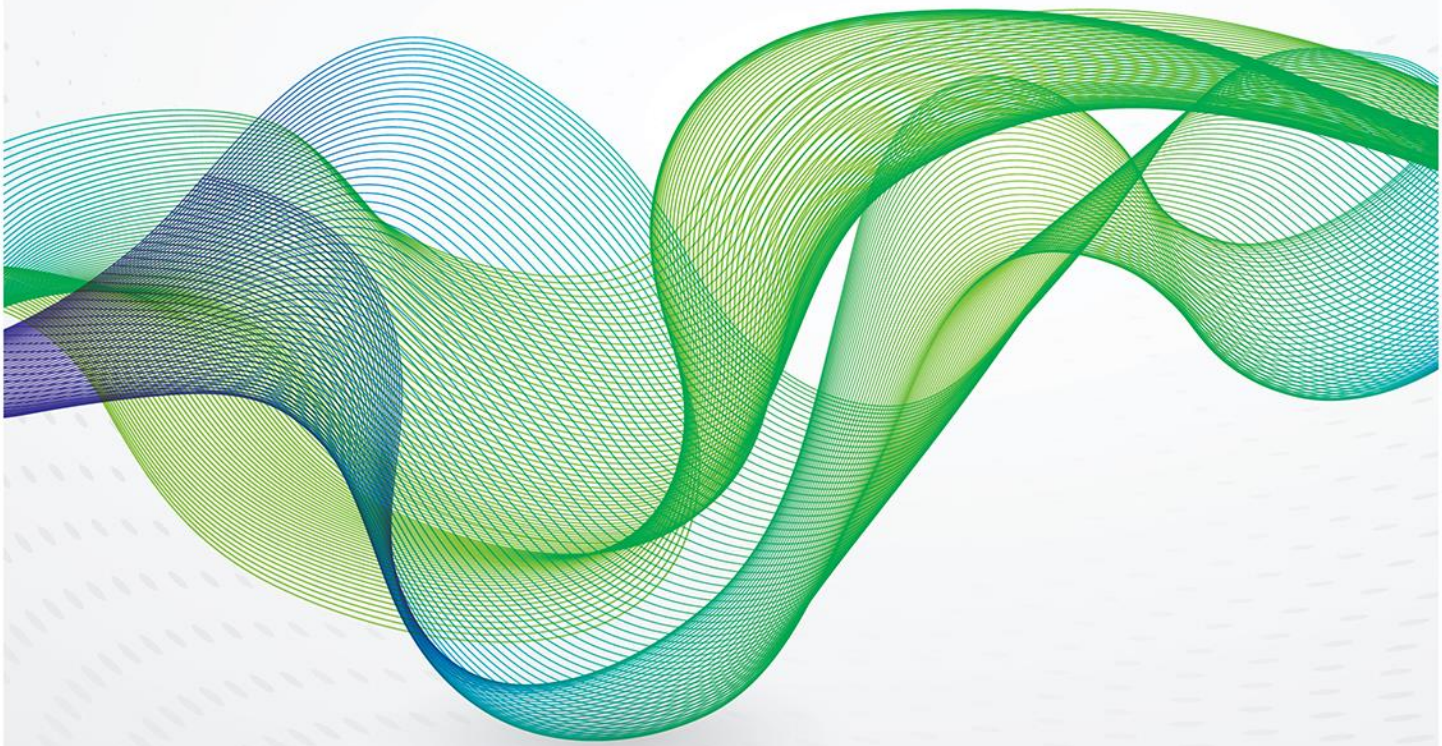
THE OXFORD INSTITUTE FOR ENERGY STUDIES

A RECOGNIZED INDEPENDENT CENTRE OF THE UNIVERSITY OF OXFORD

UNIVERSITY OF OXFORD

September 2019

Floating LNG Update – Liquefaction and Import Terminals



OIES PAPER: NG149

Brian Songhurst
Research Associate, OIES

ISBN: 978-1-78467-144-0

DOI: https://doi.org/10.26889/9781784671440

Acknowledgements

My thanks to the following industry colleagues for their review and comments on the draft:
Toby Chancellor-Weale, Chair, IChemE Oil and Natural Gas Special Interest Group (SONG)
John Rushbrook, Consultant
Chris Spilsbury, LNG Specialists Ltd
Huw Williams – Consultant

Their knowledge and input into this paper is greatly appreciated.

Preface

In two papers published in 2016 and 2017 Brian Songhurst identified the potential for wider use of floating liquefaction facilities to enable the development of remote gas fields and also the impact of floating storage and regasification units (FSRUs) to act as game-changers in the opening of new gas markets. Since those papers were published the global LNG market has continued to develop rapidly, and the use of floating technology has also progressed. As a result, Brian has produced this update which covers the full scope of the floating LNG market. He identifies current projects, assesses the progress in technology used throughout the value chain and evaluates the potential for floating lng production, regasification and storage facilities to have an increasing impact on the global gas economy. Given the high level of interest in his original papers, we hope that this update will prove equally interesting and useful to analysts of and participants in the gas sector, as floating technology continues to open new opportunities.

James Henderson
Director, Natural Gas Programme
Oxford 2019

Contents

Figures

Tables

Glossary

AiP – approval in principle

Bcf/d – Billion cubic feet per day. A flowrate or production output of typically natural gas commonly used in North America

Bcma – Billion cubic metres per annum. A flowrate or production output of natural gas commonly used internationally

BW Gas, BW Offshore – part of the BW Group shipping company

Capex or CAPEX – industry term for capital expenditure

Condensate – natural gas liquids separated from well stream gas normally comprising ethane and heavier hydrocarbons. LPG refers to the propane and butane portion of condensate.

Hoses – cryogenic hoses used to transfer LNG at ca. minus162^0C.

DSME – Daewoo Shipbuilding & Marine Engineering

EPC – engineering, procurement and construction

Excelerate – Excelerate Energy

FEED – front end engineering design

FID – final investment decision

FLNG – Floating liquefied natural gas

FSRU – Floating storage and regasification unit

FSU – Floating storage unit

GBS – gravity based structures

Golar – Golar LNG (LNG Tanker Company)

HHI or Hyundai – Hyundai Heavy Industries

Höegh – Höegh LNG (LNG tanker company)

Liquefaction – the process by which pre-treated natural gas is cooled to minus 160^0 Celsius when it becomes a liquid at atmospheric pressure.

LNG – liquefied natural gas

m^3 – cubic metres

m^3/h – cubic metres per hour

Membrane – LNG thermal insulation method using stainless steel or Invar sheets in contact with LNG

MMscf/d or mmscf/d – millions of standard cubic feet per day

MOL – Mitsui O.S.K. Lines

mtpa – millions of tonnes per annum

Opex or OPEX – industry term for operating expenditure

PLNG – platform liquefied natural gas

Qmax – Q-Max or Qatar Max - large LNG tanker with 266,000 m^3 storage capacity

Regas – regasification or vaporisation of LNG back into natural gas

SHI or Samsung – Samsung Heavy Industries

SMR – single mixed refrigerant

Sponson - a feature on a vessel that extends from the hull to aid stability while floating and provide space for additional other equipment.

tpa - tonnes per annum$ - US dollar

$/tpa – metric of capital cost US$/tonne/annum calculated by dividing the capital cost by the production rate in tonnes/ annum

1. Context and reason for paper

This paper provides an update on the floating LNG sector (both floating liquefaction and regas terminals) over the past two to three years. That is since the publication of the floating liquefaction (FLNG) paper NG 107 in November 2016 and the floating regasification and storage (FSRU) paper NG 123 in July 2017. It also includes an update on floating storage units (FSUs) and introduces a new industry acronym PLNG – Platform LNG.

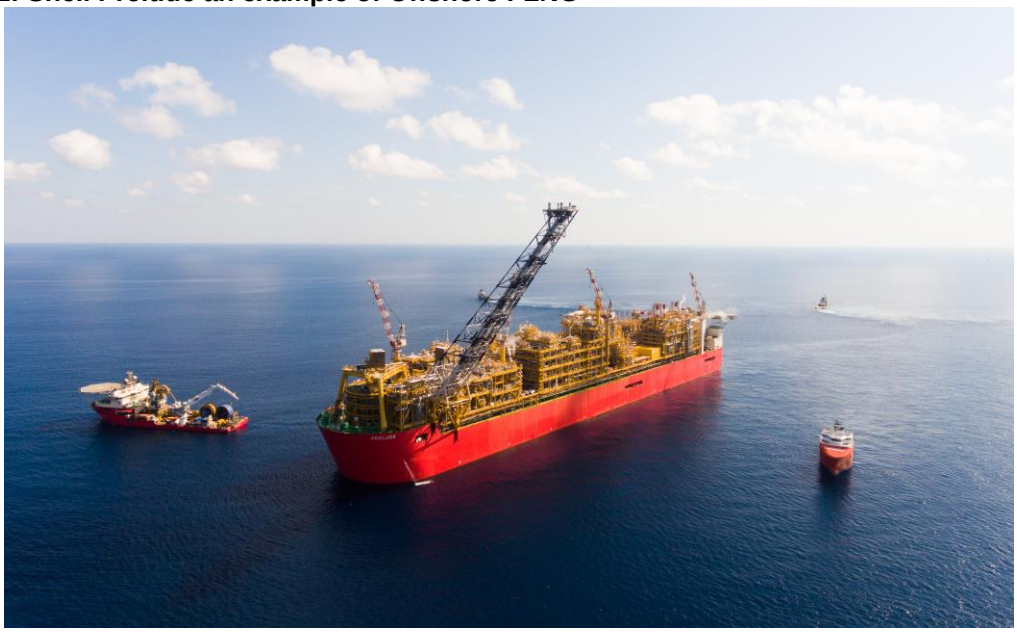
It also includes a review of the current attitude to risk given that the floating LNG business now has more than 20 years of operating experience albeit mostly with FSRUs and not the more challenging floating liquefaction facilities.

This paper does not repeat the information provided in the previous papers and in particular the specific project data. It only advises on what has changed since their publication.

One particular challenge associated with reporting the location of floating facilities is that they move and often at short notice. Whilst this feature of being a flexible asset is, in many ways, a real benefit when compared to the sunk cost associated with onshore installations, keeping up to date is a challenge and some changes may have occurred since the writing and publication of this report.

In this regard it is interesting to note that, even in the new of floating liquefaction sector with just four vessels completed and operational (Prelude, Tango, Cameroon and Satu), Tango and Satu have already been relocated demonstrating their advantage over onshore plants which are a sunk cost.

Figure 1: Shell Prelude an example of Offshore FLNG



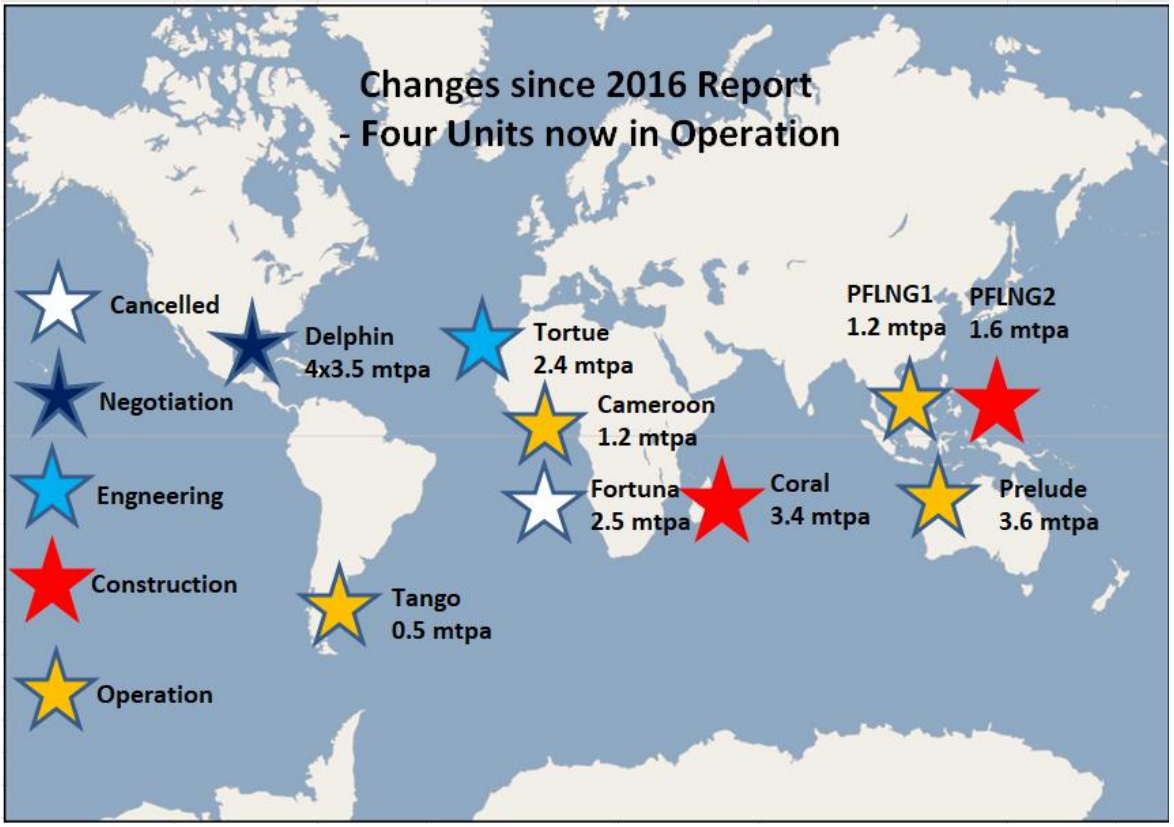
Source: Photograph courtesy of Photographic Services, Shell International Limited

2. Summary of major changes since the 2016 and 2017 Reports

Floating Liquefaction (FLNG) Sector

Figure 2 shows the locations, capacities and the current status of the eight active projects in the FLNG sector. At the time of writing this paper, Tango FLNG and the Prelude FLNG have both started operation and offloaded their first cargoes meaning this sector now has four floating liquefaction vessels in operation. This is a major step forward for the LNG industry.

Figure 2: FLNG changes since 2016 Report



Source: By author from published data

The cancellation of the Ophir project has been shown as the project was well advanced at the time of writing the 2016 paper and OneLNG[1] had been selected for the delivery of the project. OneLNG was a joint venture of Golar LNG and Schlumberger and the Golar LNG Gimi vessel had been selected for the project. The Gimi has now been assigned to the Tortue project in Mauritania again demonstrating the flexibility of FLNG assets when compared to onshore plants.

Similar recent examples of the flexibility of the FLNG vessels are the reassignment of the Exmar FLNG barge, originally constructed for Columbia (Caribbean FLNG), to Argentina (Tango)[2] and the relocation of Petronas PFLNG1 (Satu) from Sarawak to Sabah.[3] The Tango FLNG is moored inshore at Bahia Blanca at the same jetty as the original FSRU import terminal and liquefies natural gas produced and pre-treated onshore. The Satu vessel produced 19 cargoes on the Kanowit field before

[1] https://www.lngworldnews.com/schlumberger-quits-onelng-jv-and-fortuna-flng-project/
[2] http://www.exmar.be/sites/default/files/media/document_center/reports_and_downloads/press_releases/announcement_exmar_ypf.pdf
[3] https://www.offshoreenergytoday.com/petronas-moves-flng-satu-to-kebabangan-cluster-field/

being relocated to the Kebabangan field offshore Sabah. It is quite surprising that two of the four vessels constructed to date have already been re-allocated in just eight years of FLNG development.

Floating storage and regas (FSRU) sector

Figure 3 summarises the major changes in the more established FSRU sector. In summary the total number of vessels operating as FSRUs has only increased by one from 23 to 24 but the number operating as trading tankers has increased significantly from three to ten this being a third of the FSRU fleet.

The number in construction has dropped slightly from ten to nine but the number of construction options has dropped dramatically from nine to just one indicating that the FSRU market is slowing down from the rapid growth period of 2015-2017 when fifteen new vessels entered the market representing a 60 per cent increase in the size of the fleet. Many of these ten surplus vessels need to find terminal projects before more vessels are ordered.

Figure 3: FSRU changes since 2017 Report

Source: By author from published data

The other interesting change is that the number of owner/operators has more than doubled from six to fifteen with these nine new companies being energy companies and not leasing companies. This is a major shift from the original FSRU business model of leasing or tolling from the major leasing companies[4] to outright purchase as capital projects by the owners. Leasing refers to charging for the facility on a day rate basis ($/day) and tolling by charging a fee (typically $/MMBtu) for storage and vaporisation.

[4] Excelerate, Höegh and Golar and more recently BW.

Changes since 2017 are summarised as follows:

- Three projects have been cancelled – Puerto Rico, Uruguay and Ghana.
- Three terminals have closed – Argentina (Bahia Blanca), Abu Dhabi and Egypt (Ain Sokhna 1).
- Six new terminals have opened – Kaliningrad, Jamaica, Pakistan, Bangladesh (2), and Indonesia.
- Nine are in construction – Acu, Izmir, Jafrabad, Central Java, Greece, plus four to be assigned.
- Ten vessels are operating as trading tankers and not as terminals.
- One vessel is laid up.
- Bahrain platform regas/FSU terminal will commence operations in late 2019.
- Bali small scale FSRU is now operating.
- New FSRU markets are emerging in Australia and Germany.
- Fifteen terminals continue to operate at their previously reported locations.

As mentioned earlier, it would appear that the FSRU market has slowed significantly since the issue of the 2017 report. The research for this paper seems to indicate several reasons for this:

- Several FSRUs have left the South American market and moved to new projects due to lower demand for LNG for power generation and gas imports from Bolivia.[5] Hydroelectric power generation in Brazil has also increased with the rainfall returning after many years of drought.
- The drop in the number of new FSRU projects has resulted in an oversupply of vessels with ten now operating in the alternative back up mode as LNG tankers and not import terminals. This has not all been bad news as tanker day rates exceeded FSRU rates during late 2018[6] but rates have now returned to normal.
- The high demand from China has resulted in a shortage of LNG for FSRU short-term supply contracts.
- The expected terminals in Chile and Ghana have not been realised. In the case of Ghana this is due to Ghanaian gas now being produced from the Offshore Cape Three Project (OCTP) gas field.[7]

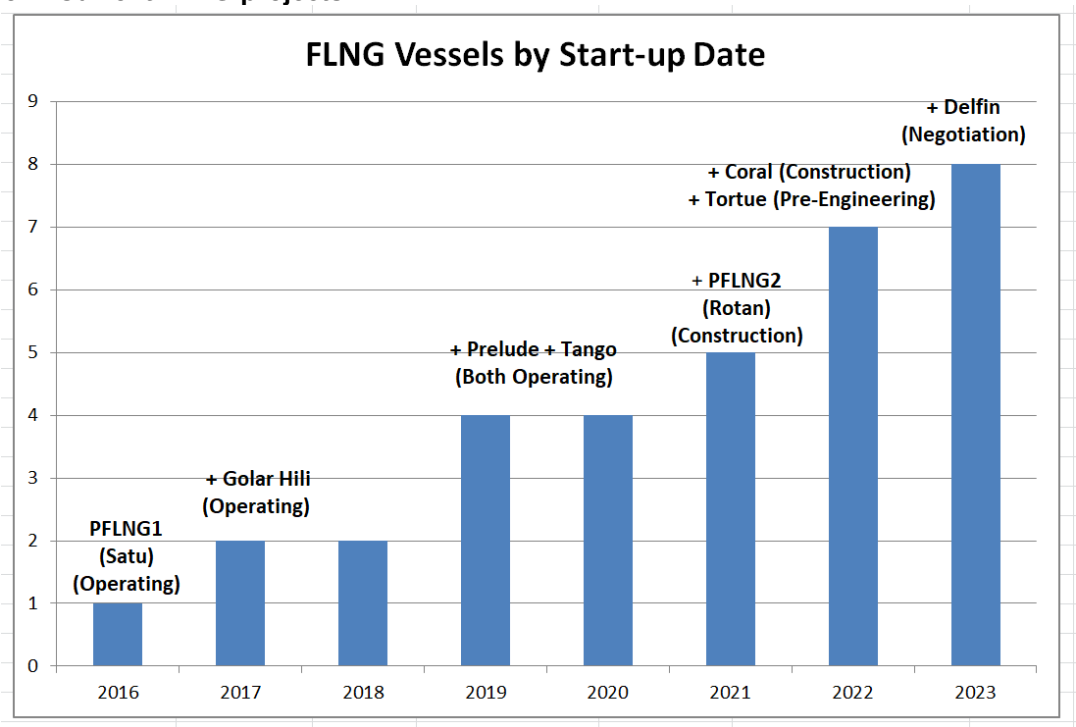
Appendix 2 includes the list of FSRU facilities listed in the 2017 paper and has been updated to show the current fleet and vessels in construction.

[5] https://www.petroleum-economist.com/articles/midstream-downstream/lng/2017/latin-americas-lng-slowdown
[6] https://www.petroleum-economist.com/articles/midstream-downstream/tankers/2019/shipping-s-surge-and-splurge
[7] https://www.eni.com/en_IT/media/2018/07/eni-starts-gas-production-from-octp-project-deep-offshore-ghana

3. Current floating liquefaction (FLNG) projects

As shown in Figure 4, four FLNGs are now in operation, two are in construction, one is at the engineering stage and one at the negotiation stage. Prelude and Tango have both commenced production since the issue of the 2016 report and offloaded their first cargoes in June 2109.

Figure 4: Current FLNG projects



Source: By author from published data

Operating vessels

The Petronas PFLNG1, also referred to as Satu,[8] was the first to start production offshore Sarawak on the Kanowit field in November 2016 but has now been relocated to the Kebabangan field offshore Sabah demonstrating the flexible nature of floating LNG facilities. Had the Kanowit field been developed using an onshore plant it would have been an expensive sunk cost. The Satu produced 19 cargoes from the Kanowit field before being relocated. Production of LNG at the new location commenced in May 2019. No reasons have been published as to why the vessel was moved.

The Cameroon FLNG vessel named the Golar Hilli Episeyo was the second vessel to start production and is leased from Golar LNG for eight years to produce LNG from the Kribi field. Production started in Q2 2017 and the 1.2 mtpa production for the contracted eight years has been sold to Gazprom.[9] The vessel is a converted LNG tanker built in 1975[10] with the liquefaction plant mounted on new sponsons located[11] along each side of the hull. The conversion was undertaken by Keppel in Singapore.[12]

[8] https://www.nst.com.my/business/2019/03/468866/petronas-relocates-its-floating-lng-facility-pflng-satu-kebabangan-field
[9] https://www.reuters.com/article/us-golar-cameroon-flng/golars-cameroon-flng-project-starts-commercial-operations-idUSKCN1J029H
[10] http://www.golarlng.com/our-fleet/floating-liquefaction-vessels
[11] https://www.offshoreenergytoday.com/golar-hilli-episeyo-in-full-commercial-operation-off-cameroon/
[12] http://www.gasprocessingnews.com/news/keppel-proceeds-with-$735-mn-flng-conversion-job-for-golar-lng.aspx

The Prelude FLNG vessel shipped its first cargo of condensate in late March 2019[13] and the first cargo of LNG was offloaded in June 2019.[14] The development of Shell Prelude has been an extremely challenging project with significant delays and cost overruns. Prelude is a very complex vessel in terms of both size and processing and is a major technology step for a new concept. Shell has described it as a technology development project with the intent of designing one and building many. The vessel is the largest floating structure in the world and capable of producing 5.3 mtpa of liquids of which 3.6 mtpa will be LNG. Shell has not released any information about the reasons for the cost overruns and delays nor any information about the final cost. Hopefully the learning from this major project will be shared with the industry to lower costs and reduce development schedules for future vessels and thereby improve the competitiveness of LNG as a fuel.

The Exmar FLNG barge is completely different to Prelude. It is a simple inshore barge designed to liquefy lean, pre-treated[15] gas from onshore fields. It was originally named the Caribbean FLNG and destined for Columbia but was recently reassigned to Argentina and renamed Tango.[16] The vessel was transported using a heavy lift vessel[17] and is now on location as shown in figure 5. Production has started and the first cargo was exported in June 2019. This is again a demonstration of the flexibility of floating LNG assets when compared to onshore plants.

Figure 5: Exmar Tango an example of inshore FLNG

Source: Photograph courtesy of Exmar

Construction

The Petronas PFLNG2, also referred to as the Dua,[18] is currently being constructed at Samsung's shipyard in Geoje Island, South Korea. The vessel will have a liquefaction capacity of 1.5 mtpa and will be located on the Rotan field 130 km offshore Sabah. Production is scheduled to start in 2020. The project was suspended for two years following the oil price crash but has now restarted.

The final investment decision (FID) for Coral South FLNG was taken in June 2017 and the vessel is currently being constructed by Samsung in Korea. The design is being undertaken by Technip and JGC and production is scheduled for 2022.[19] The estimated cost is $7 billion and the production stated as 3.4 mtpa.

[13] https://www.offshoreenergytoday.com/report-shell-ships-first-cargo-from-prelude-flng/
[14] https://www.shell.com/media/news-and-media-releases/2019/first-lng-cargo-shipped-from-prelude-flng.html
[15] Condensate and bulk carbon dioxide removed onshore – often referred to as pipeline quality gas
[16] https://www.lngworldnews.com/tag/tango-flng/
[17] https://worldmaritimenews.com/archives/270855/exmars-tango-flng-touches-down-in-bahia-blanca-argentina/
[18] https://www.lngworldshipping.com/news/view,second-petronas-flng-vessel-to-start-operations-in-q1-2020_57369.htm
[19] https://www.sourcewatch.org/index.php/Coral_South_FLNG_Terminal

Engineering

BP has taken the final investment decision to develop the Tortue field, offshore Mauritania/Senegal, using a FLNG vessel. The decision for Phase 1 was taken in December 2018 and the vessel will be leased from Golar LNG. Keppel has been issued with a Final Notice to Proceed for the conversion of the LNG Tanker Gimi[20] which will be done in the same manner as the Hilli Episeyo for Cameroon. The vessel will also have the liquefaction units mounted on sponsons alongside the hull. It is expected to be delivered in the first half of 2022. The vessel will be located next to a breakwater consisting of 21 concrete caissons[21] as shown in figure 6. A platform-based facility (PLNG) is being proposed for Phase 2 (refer to chapter 6).

Figure 6: Greater Tortue Ahmeyim Project – Computer Rendition of the First Phase

Source: Photograph courtesy of BP

Negotiation

Delfin have completed the permitting process with the relevant authorities for up to four FLNG vessels development 50 miles offshore Louisiana.[22] The concept is being referred to as the Delfin LNG Deepwater Port. Pipeline quality gas will supplied from onshore via an existing subsea pipeline. Production is stated to be up to 13 mtpa and scheduled to start in 2023.[23]

Summary

The delivery of these 'first of a kind' projects has been very challenging for the owners with many experiencing delays and cost overruns. This is not unexpected for 'first of a kind' technology and the learning to date will hopefully benefit future designs. It is interesting to note that the small 0.5 mtpa and less complex Tango barge and Golar Hilli Episeyo tanker conversion projects appear to have gone more smoothly when compared to the more complex open ocean Prelude and Petronas PFLNGs. One possible lesson learned from this is that developers will favour FLNG for inshore or nearshore liquefaction of pre-treated gas rather than the more complex, higher risk, open ocean projects processing rich well stream gas.

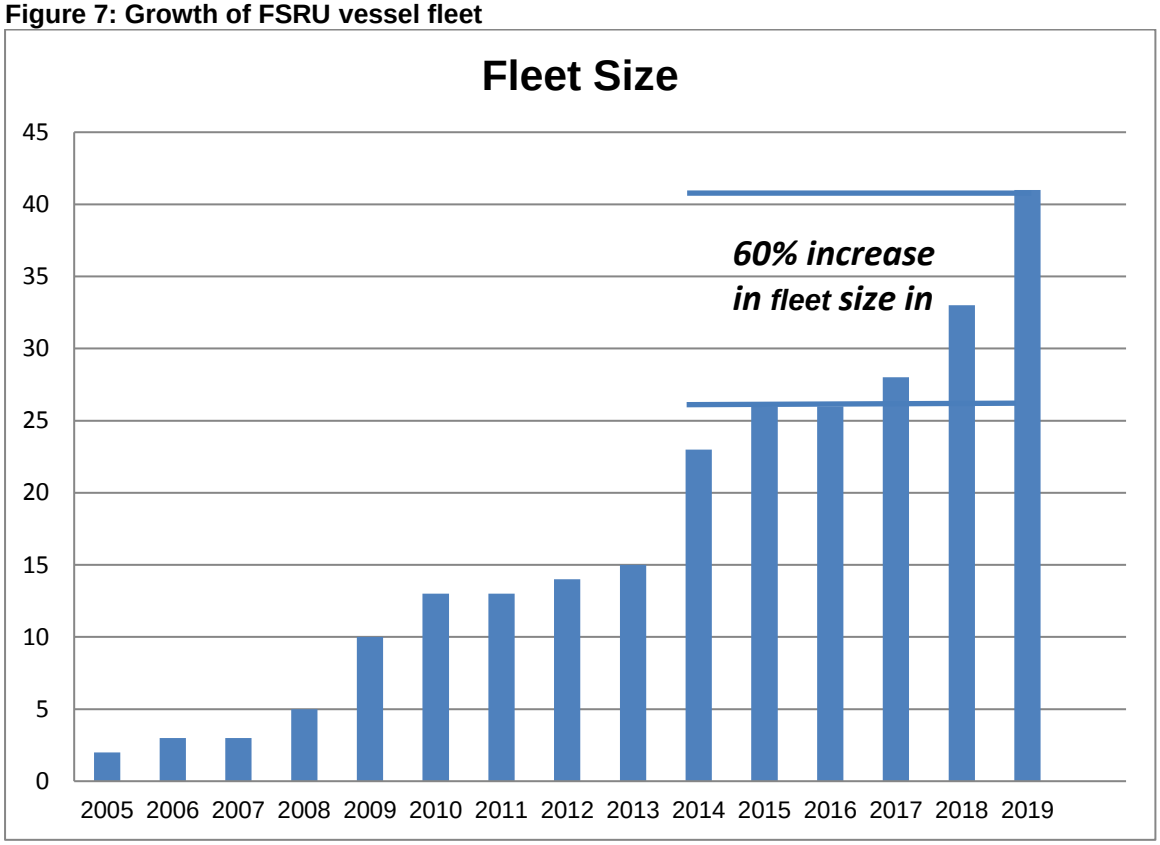
[20] https://www.offshoreenergytoday.com/keppel-gets-approval-to-begin-gimi-flng-conversion/
[21] https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-announces-final-investment-decision-for-phase-1-of-the-greater-tortue-ahmeyim-lng-development.html
[22] http://www.delfinlng.com/project-overview
[23] https://www.oedigital.com/news/463686-first-us-flng-project-moving-ahead

4. Floating storage and regasification (FSRU) projects

Figure 7 shows the growth of the FSRU fleet since the first vessel entered service in 2005 and this can be divided into four main growth periods.

- 2005-2008 slow growth as the sector was developing.
- 2009-2013 rapid growth in 2009 and then a slow period until 2013.
- 2014-2017 again rapid growth in 2014 and then slow until 2016.
- 2017-2019 rapid growth with the fleet increasing by 60 per cent in just four years.

Figure 7: Growth of FSRU vessel fleet

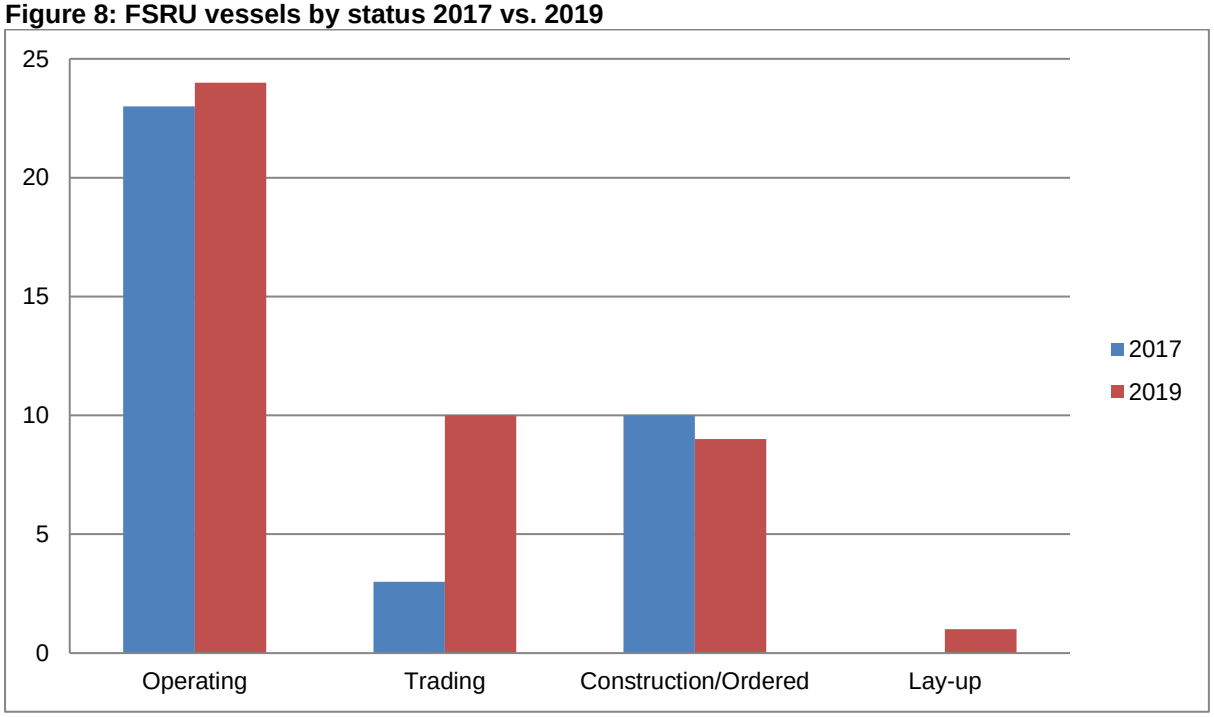


Source: By author from published data

Figure 8 compares the status (utilisation) of the FSRU vessel fleet as presented in the original report in 2017 and the current situation. In the past two years there has only been an increase of one additional FSRU operating as an import terminal indicating a slowdown in the floating terminal market. Based on the rapidly expanding market during 2014–2015, the major leasing companies decided to invest in new vessels on a prospective basis. Most of these prospects did not materialise and the majority of the additional vessels have been assigned to operating as trading tankers and not import terminals. This has resulted in ten of the 34 vessels now operating as tankers – a significant 30 per cent of the fleet. This must be a disappointment for the leasing companies as the day rates for tanker services are normally much lower, at typically $80,000/day, than for import terminal operation at typically $120,000/day.[24]

[24] Chapter 8 Commercial provides for more information on vessel rates

Figure 8: FSRU vessels by status 2017 vs. 2019



Source: By author from published data

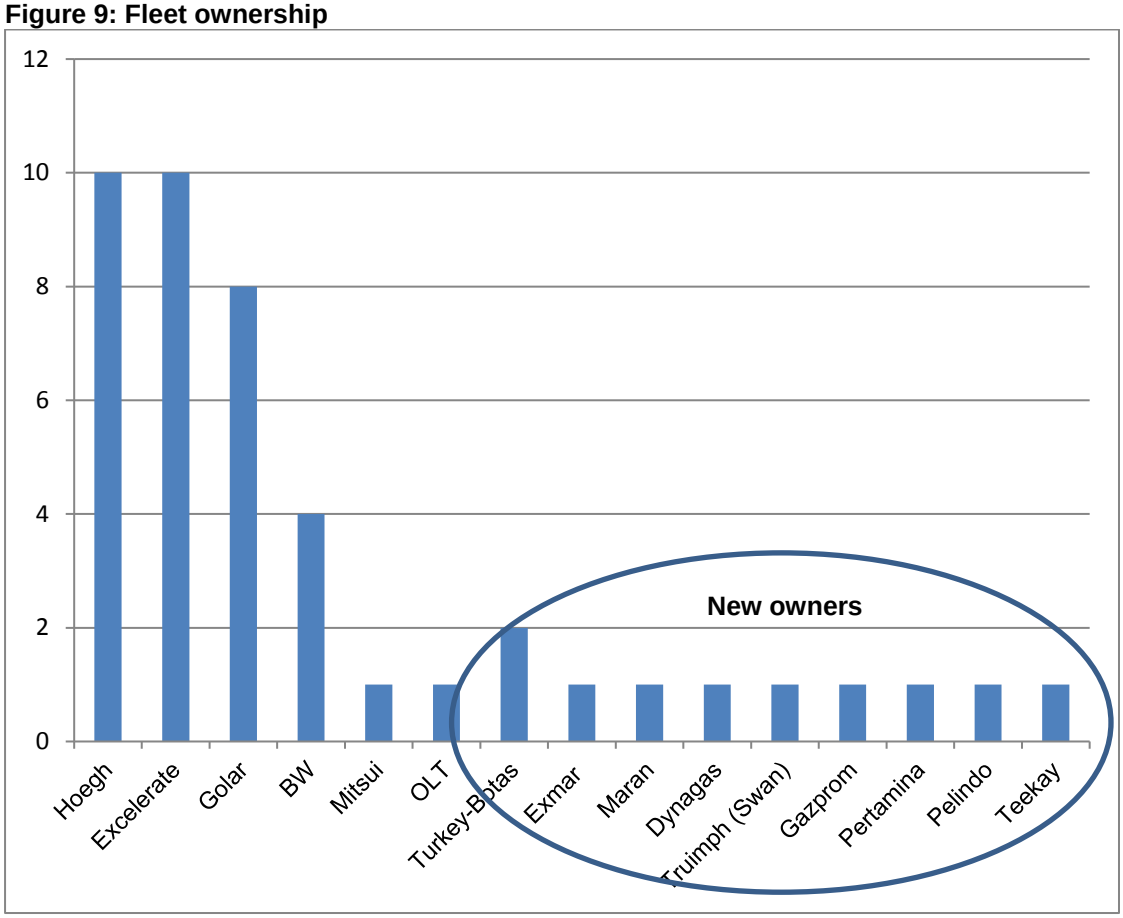
The number of vessels in construction has only dropped slightly from ten to nine, but the major change is that these new vessels are being purchased directly by the energy companies and not the leasing companies. It would appear that there is little point in the leasing companies ordering new vessels just to go into tanker service at lower day rates.

Figure 9 shows the current fleet ownership which has more than doubled from six to fifteen companies since the 2017 report. As mentioned earlier these new companies appear to prefer owning and operating their own vessels rather than leasing or tolling from the traditional companies. This probably indicates that they expect to operate them for a longer period so owning will be cheaper in the longer term. Most leasing rates are typically based on cost recovery by the owner over an eight to ten year period. A recent example of reducing costs by switching from leasing to owning was the Lithuanian government's decision to take up the option to purchase the vessel from Höegh[25] as they presumably see a long-term need for the terminal. This was always an option in the contract.

This move from leasing or tolling to owning has also exacerbated the surplus of FSRU vessels owned by the leasing companies which have been forced to assign them to alternative tanker service at, normally, lower day rates, as discussed previously.

[25] https://www.lngworldnews.com/lithuanian-parliament-approves-fsru-acquisition/

Figure 9: Fleet ownership



Source: By author from published data

Whilst the traditional major leasing companies - Höegh, Golar LNG and Excelerate - have increased their fleets from twenty two vessels in 2017 to, currently, twenty eight, most of these have not found import terminal projects and have been assigned to tanker service at a lower day rate. On this basis these companies are unlikely to order any new vessels until this spare capacity is taken up. This is borne out by the fact that the leasing companies only have two vessels currently on order and both are assigned to terminal projects – one for BW (BW Magna) for the Port Açu project in Brazil[26] and one for Höegh for one of the planned Australian import terminals, either the Crib Point terminal[27] or Port Kembla.[28]

[26] https://www.lngworldnews.com/bw-takes-delivery-of-its-third-fsru/
[27] https://www.lngindustry.com/regasification/21122018/hegh-lng-to-provide-fsru-for-agls-crib-point-lng-project/
[28] https://www.lngworldnews.com/aie-selects-hoegh-lngs-fsru-for-its-port-kembla-import-project/

5. Floating storage (FSU) projects

The overall number of FSU terminals remains at four, as reported in the 2017 paper. The Jamaican FSU has been closed and the Bahrain FSU added.

The Jamaica FSU has been replaced by an FSRU - the relocation of the Golar Freeze FSRU from Dubai.[29] A 15 year charter has been agreed between New Fortress Energy and Golar LNG.

The Bahrain FSU forms part of the new import terminal where the LNG is stored in the FSU and the regasification facilities are located on a fixed platform structure.[30] The FSU vessel is the new build Bahrain Spirit,[31] provided by Teekay on a twenty year charter. The terminal is expected to start up in the second half of 2019 and the Bahrain Spirit is currently operating as a trading tanker until that time.

The following FSUs listed in the 2017 report continue to operate:

- Marsaxlokk Bay FSU located in Malta.
- Melaka Tenaga Satu in Malaysia.
- Melaka Tenaga Empat in Malaysia.

The Bali FSU was not reported in the 2017 paper but has since been replaced by a new barge type FSRU constructed at the PaxOcean shipyard in China.[32] The vessel is named the Gift of the Gods and is included in the FSRU vessel count in this paper. The vessel is the world's first small scale or mini floating FSRU. It has a storage capacity of 26,000 m3 LNG and a send out capacity of 50 MMscf/d. This mini FSRU configuration can meet the gas needs of a 200-250 MW power station and is ideally suited to small islands where there is a wish to change from fuel oil to gas firing.

[29] https://www.lngworldnews.com/fsru-golar-freeze-to-arrive-off-jamaica-soon/
[30] https://bahrainlng.com/
[31] https://www.lngworldnews.com/report-bahrain-spirit-fsu-arrives-in-persian-gulf/
[32] https://www.rivieramm.com/opinion/opinion/a-feather-in-the-lng-cap-new-fsru-bolsters-expertise-in-china-and-indonesia-22069

6. Platform LNG (PLNG) projects

Whilst the acronym PLNG has just appeared in the industry, the concept of offshore liquefaction facilities located on a fixed structure has been frequently studied although not used to date, but this may be about to change. A paper was published at Gastec in 2005[33] and this concept was considered for the Tassie Shoal project also some 15 years ago.[34]

The use of structures fixed to the sea bed typically limits the water depth to 500 metres which normally means location on a continental shelf. Deeper water gas fields can be developed using subsea wells tied back via subsea flowlines to the fixed structure. Whether this is a lower cost option than bringing the gas back to shore has to be studied on a case by case basis.

These structures can be fabricated from steel and piled to the sea bed or concrete and sit on the sea bed (GBS).[35]

Near shore fixed structures can also be used and are well suited for harsh or remote locations, for example, in the Arctic. Kvaerner and KBR, as well as others including Total,[36] have developed this concept.[37] Novatek are considering GBS liquefaction plants for their Arctic LNG2 project[38] and have stated major cost savings are expected. The GBS facilities would be constructed locally and support three 6.6 mtpa liquefaction plants. An advantage of GBS structures is that they can be constructed locally increasing the often politically important local content.

Offshore steel structures are also possible and have been proposed by LoneStar.[39]

It is understood that BP are looking at a fixed structure arrangement for the Phases 2 and 3 of the Tortue development offshore Mauritania/Senegal and recently awarded KBR a pre-engineering contract.[40] The referenced article states that the ultra-deepwater gas will be connected back to fixed platforms using subsea flowlines for processing. At this early stage it is not clear whether the liquefaction will be located on these platforms or on FLNG vessels. These options will likely be considered and evaluated during the pre-engineering studies.

It will be interesting to see how these platform LNG projects develop over the coming years and, in particular, to see if the cost and schedule benefits, as stated in the technical press, of using gravity based structures on the Arctic LNG2 project are realised.

[33] http://www.ivt.ntnu.no/ept/fag/tep4215/innhold/LNG%20Conferences/2005/SDS_TIF/050152.pdf
[34] http://www.melbana.com/site/cpfile/2473_1/20180116tassieshoallngprojectflyermelbana.pdf
[35] GBS – gravity based structures
[36] https://www.ep.total.com/en/areas/liquefied-natural-gas/lng-projects-gravity-platforms-make-many-things-possible
[37] https://www.kvaerner.com/Global/images/Products/Concrete/Concrete%20GBS%20LNG%20Solutions.pdf
[38] https://www.lngworldnews.com/novatek-tags-technipfmc-for-arctic-lng-2-plant-job/
[39] http://lonestar-lng.com/technology/case-studies/
[40] https://www.lngworldnews.com/kbr-wins-greater-tortue-ahmeyim-lng-phases-2-and-3-job/

7. Technology update

FLNGs

The only new floating liquefaction facility to be awarded is the Tortue project for Mauritania which is in the design stage and will use the well proven Black & Veatch PRICO process. The PRICO process is also used on the Exmar Tango FLNG in Argentina and Golar Hilli Episeyo FNG in Cameroon. The units are small, at 0.6 mtpa, and use a single mixed refrigerant making them easy to modularize. Golar LNG has taken the approach to standardise the design of their liquefaction plants and treat them as repeatable units and not as project bespoke. This approach is now also being applied on onshore liquefaction plants to reduce cost and schedule and particularly in the USA.

Hyundai Heavy Industries (HHI) has recently received approval in principle (AiP) from DNV GL for the design of an inshore liquefaction barge. The press release stated that 'The FLNG market is beginning to emerge, and nearshore projects are expected to be at the forefront of these developments'.[41] The first FLNG inshore barge Tango (originally the Caribbean FLNG) is already producing LNG in Argentina. Inshore developments are much simpler as they do not have to cope with the wind, waves and access associated with open ocean locations.

FSRUs

A standard design approach is also used for FSRUs with the industry model now being a 170-174,000 m^3 membrane tanker with the regasification plant located at the bow and integrated into the deck structure[42] and not a separate module or modules as often seen on older vessels.

A Qmax FSRU (266,000 m^3) was developed by MOL for Uruguay but the project was cancelled and the vessel is currently assigned to Turkey and likely to move to Hong Kong in 2020. The use of a Qmax sized vessel appears to be a one off with developers preferring FSRUs based on the standard 170-174,000 m^3 tankers as stated above. This decision to favour standard tankers helps in reassigning them to tanker service where there is not a terminal application.

Mini FSRUs

The Bali FSRU as shown in figure 10 is the world's first mini FSRU and was constructed at the PaxOcean shipyard in China.[43] The vessel is named the Gift of the Gods. The vessel is referred to as a FSWFRU and has a storage capacity of just 26,000 m3 LNG and a send out capacity of 50 MMscf/d. This is sufficient to generate 200-250 MW of electricity and ideal for island communities who wish to switch from oil to cleaner gas firing.

Figure 10: Bali FSRU - the FSRU was design and build by PaxOcean Group

Source: Photograph courtesy of PaxOcean Group

[41] LNG INDUSTRY June 2019
[42] http://www.bw-group.com/our-business/bw-lng/bw-gas-solutions
[43] https://www.rivieramm.com/opinion/opinion/a-feather-in-the-lng-cap-new-fsru-bolsters-expertise-in-china-and-indonesia-22069

Integrated FSRU/Power Units

The previous paper reviewed the concept of integrated FSRU/Power units where the power generation plant is located on the vessel. This concept was being developed by Golar Power Ltd – a joint venture of Golar LNG and Stonepeak Infrastructure Partners. They have been selected for the Croatian Power Project[44] on the island of Krk but the arrangement appears to use a regular FSRU with power generation onshore. Kawasaki has just announced their development of a 30-80 MW LNG Floating Power Plant[45] which incorporates LNG storage.

Cryogenic Hoses

Another technology development included in the 2016 paper was the possible use of large (16" and 20") cryogenic hoses but these have not yet been applied with developers still appearing to prefer the use of articulated loading arms or smaller diameter composite hoses.

Jettyless LNG Transfer System with Universal Transfer System (UTS™)

Connect LNG AS has developed a flexible LNG loading/offloading system for smaller LNG liquefaction or import terminals as shown in figure 11. It has been stated that it is 50 per cent cheaper and can be installed six times more quickly that traditional fixed jetty structures. The system looks ideal for the transfer of smaller LNG cargoes and uses cryogenic hoses. It can be used for ship-to-shore or ship-to-ship transfers. The first unit has been tested in Norway through a joint partnership with Union Fenosa and more information is available on their website.[46] They are currently seeking opportunities for this new system.

Figure 11: Connect LNG and the UTS (Universal Transfer System)

Source: Photograph courtesy of ConnectLNG

[44] https://www.reuters.com/article/croatia-lng-tender/croatia-picks-golar-power-to-supply-future-lng-terminal-idUSL8N1XK77P
[45] https://global.kawasaki.com/en/energy/solutions/energy_plants/lng_floating.html
[46] https://www.connect-lng.no/?gclid=Cj0KCQjwi43oBRDBARIsAExSRQHpCXMhz8t3efjQK3z2aG0jHHmm98u-SdSVpS-KSC-tvozyvGYN674aAnp9EALw_wcB

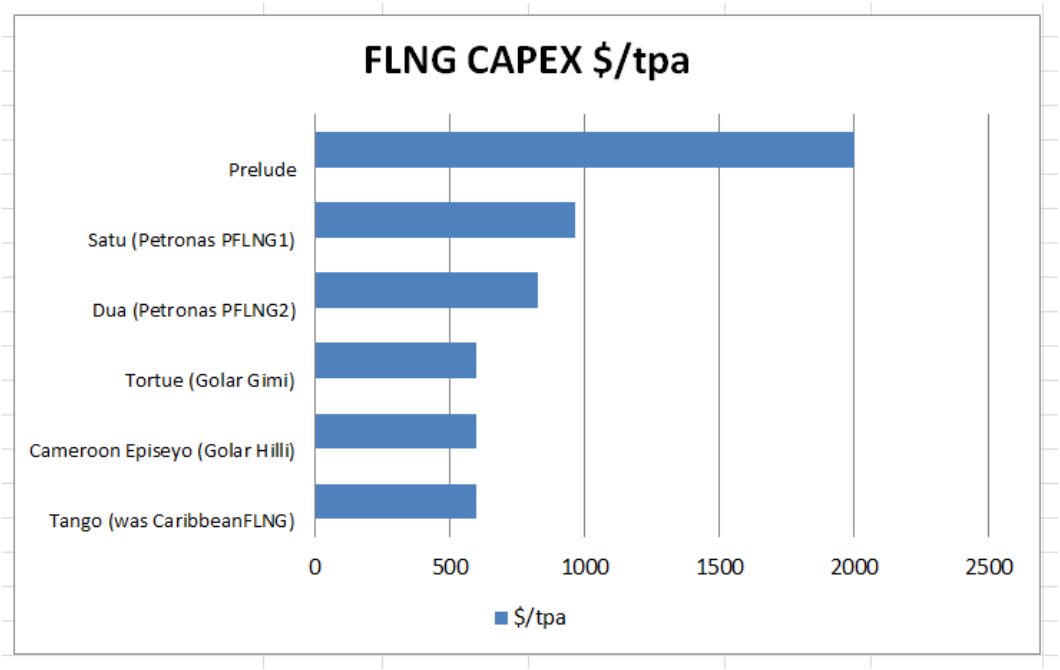
8. Commercial trends

Capital and leasing costs

There has been little change in the reported costs of FLNG and FSRU projects since the publication of the previous papers. FLNG costs are shown in Figure 12 and have been updated to include Tortue.

FSRU costs are made up of the cost of the vessel and the jetty and infrastructure to deliver the gas to the pipeline entry point. Delivered FSRU vessels costs have remained at approximately $250-300 million, similar to the FSRU paper costs as shown in Figure 13. The cost of the jetty and infrastructure vary considerably on each project depending on the scope.

Figure 12: FLNG costs



Source: By author from published data

Figure 13: FSRU vessel costs (reprinted from previous paper)

Vessel	Owner	Storage	Send-out	Send-out	Shipyard	Order Placed	Order Value
		m^3	mtpa	mmscfd			$m
Giant (FSRU#7)	Höegh	170,000	6.2	750	Hyundai	Jun-11	236
Gallant (FSRU#8)	Höegh	170,000	4.1	500	Hyundai	Jun-11	250
Independence	Höegh	170,000	3.2	384	Hyundai	Jun-11	250
FSRU#9	Höegh	170,000	8.3	1,000	Hyundai	Jan-17	236
FSRU#10	Höegh	170,000	8.3	1,000	Samsung	Jan-17	270
Experience	Excelerate	173,400	8.3	1,000	DSME	Aug-11	280

Source: By author from published data

Leasing vs. capital projects twist

There appears to have been a reversal in the lease/tolling vs. capital project business model for FLNG and FSRUs.

FLNG business model trend

Whilst the first 0.5 mtpa barge 'Caribbean FLNG' was built by Exmar and contracted on a leasing basis, the four major projects that followed (Prelude, Satu, Dua and Coral South) were executed as capital investment projects financed by the operators. However, the adoption of the leasing (day rate) or tolling model (per ton LNG produced) for floating liquefaction appears to be gaining traction. Golar contracted the Hilli Episeyo for Cameroon[47] on a tolling basis and this has now been followed by BP selecting Golar to provide the FLNG Gimi on a 20 year lease[48] for the Tortue development offshore Mauritania/Senegal. Golar was in discussion with Delfin for the joint development of one FLNG vessel for the Delfin Deepwater Port offshore Louisiana but Delfin LNG has now decided to develop their own vessel as a capital project.[49] Figure 15 shows a conceptual view of the Delfin FLNG. If the Tortue project is realised Golar LNG would have three vessels liquefying LNG on a leased or tolling basis. Adding the Exmar Tango FLNG barge in Argentina would mean four vessels would be contracted on a leased/tolling basis the same number as the traditional capital investment projects – Prelude, Coral South, Satu and Dua. This interest by the operators in a leasing or tolling model for liquefaction is an interesting turn of events and could be the way forward.

Figure 14: Delfin LNG Possible Arrangement

Source: Photograph courtesy of Delfin LNG

It will be interesting to see if the other two major FSRU leasing companies – Excelerate Energy and Höegh wish to re-enter to floating liquefaction FLNG leasing business in the same way as Golar LNG. They were both very active but decided leave that market and focus on the FSRU business.

FSRU business model trend

Conversely the FSRU business, which was essentially a leasing/tolling business, appears to be shifting to a capital investment business with major energy companies now purchasing the vessels on an outright basis. As shown in Figure 9, thirty three vessels are owned by the five leasing companies but nine of the vessels currently under construction are being purchased outright by the energy companies. This decision to purchase and not lease is assumed to be based on these companies seeing these vessels being operated as longer term terminals where outright purchase will be cheaper than leasing or tolling. This is probably the reason for the recent decision by Klaipedos Naftha to purchase the Lithuanian FSRU Independence from Höegh. A recent article stated that 'This

[47] https://www.offshoreenergytoday.com/golar-hilli-episeyo-in-full-commercial-operation-off-cameroon/
[48] https://www.offshoreenergytoday.com/golar-wins-tortue-ahmeyim-flng-deal-with-bp-keppel-to-build-the-unit/
[49] https://www.theadvocate.com/baton_rouge/news/business/article_f12a9244-ce8a-11e9-b812-bb8f7ab50896.html

decision is based on rational logics, thorough calculations, is of strategic importance and most importantly useful for all gas consumers'.[50]

FLNG schedules

It was initially thought that the construction of floating liquefaction vessels would be quicker in a shipyard than onshore. However the major FLNG vessels – Prelude, Coral and Satu – have taken 60-72 months which is more in line with grass roots onshore plants. The LNG tanker conversion projects by Golar LNG and the small liquefaction barge by Exmar offer shorter construction times. The conversion of the Golar Hilli Episeyo took just 36 months to construct followed by six months for installation and commissioning – a total of 42 months.[51] The Exmar FLNG barge was constructed in a similar time.

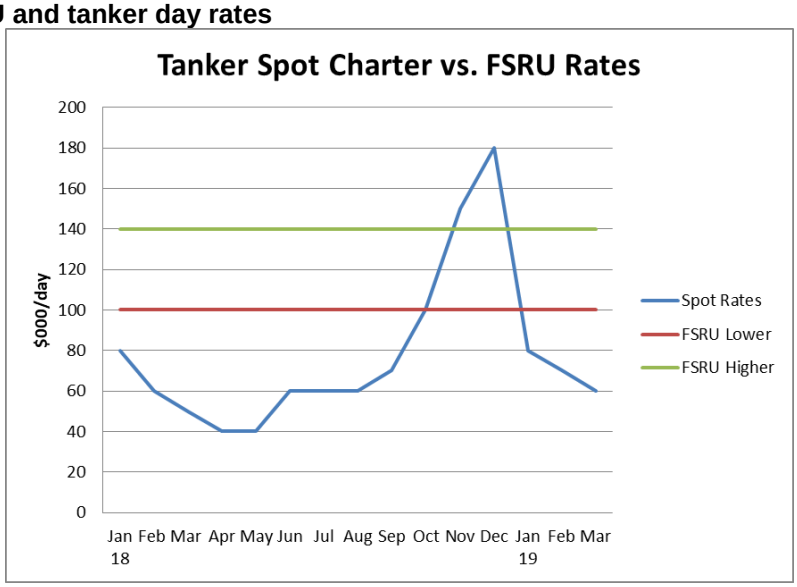
These longer than expected schedules are not helpful for promoting FLNG as an alternative to onshore plants. However, whilst this may be true when looking at building liquefaction plants in developed industrial areas such as the USA and Qatar, this may not apply to less developed areas such as Mozambique and Tanzania where onshore construction will take considerably longer. In these cases FLNG may still offer considerable schedule savings and these need to be evaluated for each project on a case by case basis.

Spot charter tanker rates higher than FSRU rates late 2018

FSRU rates have fallen by 20 per cent in the last five years and are now typically in the range $100-140,000/day and the average LNG tanker rates over the past 12 months have been $80,000/day. This higher than expected rate for FSRUs covers the capital cost of the additional regasification facilities, which are typically $50 million.

However, during November and December 2019 LNG tanker rates peaked at $170-180,000/day as shown in Figure 16 – far exceeding the rate of FSRUs. But this was a short two to three month peak and rates dropped back to $60,000/day[52] in the first quarter of 2019 providing the differential expected for the more complex FSRU vessels. It must be noted that FSRUs are contracted over periods of five to 15 years whereas spot rates for tankers are volatile and driven by short term supply and demand.

Figure 15: FSRU and tanker day rates



Source: By author from published data

[50] http://www.xinhuanet.com/english/2018-11/22/c_137622810.htm
[51] https://www.lngworldshipping.com/news/view,keppel-lng-carrier-conversions-set-the-benchmark_55653.htm
[52] https://www.hellenicshippingnews.com/gaslog-ltd-expects-lng-shipping-rates-to-improve-in-second-quarter/

9. Attitude to risk

With regard to the industry's attitude to risk, different organisations were approached for their view. These included operators, banks, insurance companies, contractors and consultants. Their views were very similar and are summarised below:

- FLNGs are considered to have a high project risk and need careful management. The cost and schedule overruns experienced to date have made the industry very wary. Whilst there is concern about remote complex facilities producing LNG and liquids, the industry attitude was more relaxed when looking at simple nearshore or inshore facilities liquefying treated gas, such as Golar Hilli Episeyo in Cameroon and Exmar Tango in Argentina.
- New FSRUs are considered to have a low technical, cost and schedule risk, and operational risk, with 33 vessels now in service and experience gained from 18 years of operation. This acceptance is enhanced by the fact that the majority of the new vessels are designed based on a standard industry 174,000 m^3 tanker and a one Bcf/d vaporisation capacity using well proven equipment. From a commercial point of view, there is the risk of vessel over supply as is being currently experienced in this sector, but this can be mitigated by transferring the vessels to tanker service albeit at a lower day rate.
- FSU risk was also considered low as the vessels are essentially tankers with minor modifications for permanent mooring and pumping small flows of LNG to onshore regasification facilities.

Referring to the attitude that floating liquefaction currently offers a significantly higher risk than onshore liquefaction plants, the incorporation of the lessons learnt from the execution of the recent FLNG projects is vital to improving the designs and construction methods and reducing these risks for future projects. This requires managing the difficult balance between confidentiality/commercial advantage of the current developers and an openness that benefits the FLNG business overall by reducing LNG production costs. Also, as experience is gained from the operation of these facilities, confidence should grow providing they perform as expected. However, it must be noted that these are early days as the current floating liquefaction facilities have only been operating for a maximum of two to three years so a few more years are needed to give the confidence that these vessels do perform as expected.

10. Market opportunities

FLNG

Whilst there are many offshore fields suitable for floating liquefaction vessels, the likely realisation of the open ocean projects is very questionable given the cost and schedule overruns experienced to date. However, this is not the same for the inshore/nearshore opportunities where the lower costs, shorter schedules and simpler processing make them appear far more viable.

The initial wave of FLNG projects were approved during a period of high oil prices but the fall in prices in 2014 has quenched this initial flurry. At the time of writing the FLNG paper in 2016, 17 serious prospects were identified but none of them have passed FID and moved into construction

Appendix 1 includes the original list updated with the current status and is summarised as follows:

- One has been added and is progressing – Tortue (Mauritania). It should note that FLNG is only proposed for Phase 1 to produce early gas, Phase 2 may use platform based liquefaction plants.
- Three are still in the planning/feasibility stage – Delfin, Cambridge Energy and Main Pass (all USA).
- Five are on hold – Sunrise (Australia), Etinde (Cameroon), Orca and Triton (Canada), NewAge (Congo).
- Eight have been cancelled – Scarborough and Browse 1&2 (Australia), Abadi (Indonesia), Mzia (Tanzania) and Lavaca USA.

The fact that not one of a list of seventeen prospects listed in the 2017 paper has progressed to construction is disappointing. However, Tortue has been added and three USA projects are still in the feasibility stage with Delfin quite advanced, being fully permitted andfollowing the completion of a front end engineering design for a conversion FLNG Vessel as well as the parallel development of a newbuild FLNG design in conjunction with Samsung and Black and Veatch.

The Australian FLNG projects have been cancelled. The gas will be transported by pipeline to shore and liquefied in the existing onshore plants as spare capacity becomes available - for example, Scarborough gas will be sent to the Pluto plant.

Regarding Abadi, a decision[53] was made to go for an onshore project driven by the need for local construction content. However, it has been reported that FLNG is being considered again.[54]

This lack of uptake is probably due to a combination of concern over higher project risk and the relatively high costs and delays experienced to date with this new technology. This should hopefully change as developers become more comfortable with the risks as more units come on stream and costs and schedule overruns are reduced. The Golar LNG vessels based on tanker conversions are certainly more competitive than new builds and more likely to be delivered in a shorter time. This is evidenced by Golar LNG being proposed for two upcoming projects - Tortue and Delfin, albeit Delfin would appear to be new build vessels.

A report by Westwood Global Energy,[55] published in November 2018, outlines an optimistic outlook for the FLNG business stating that expenditure in this sector could be $42 billion in 2019-2024 a 172 per cent increase over the $15.5 billion spent between 2013-2018. However, as mentioned earlier, time will tell whether this optimism can be delivered as real projects, particularly for the open ocean

[53] https://uk.reuters.com/article/us-shell-abadi/shell-pursuing-1-billion-exit-from-indonesia-lng-project-sources-idUKKCN1S90WK
[54] http://interfaxenergy.com/article/34197/flng-still-an-option-for-indonesias-abadi-field
[55] https://www.offshore-mag.com/field-development/article/16761963/flng-market-gears-up-for-second-wave-of-projects

opportunities where developers and investors are concerned about the high risks of costs and schedule overruns. It should be noted that the first wave of FLNG projects were approved when oil prices were high but they are still low at the time of writing this paper. But, as stated earlier, this is not the same for the simpler nearshore/inshore projects where the risks and costs are lower and the schedules shorter.

FSRUs

The FSRU business, traditionally operated by the major leasing companies, appears to be slowing down with many of their vessels now operating as LNG tankers and not terminals. However, the energy company owned FSRU business where the energy company purchases the vessel outright and operates it themselves, as compared to the traditional leasing model, looks much stronger. This recent slowdown for the leasing companies may, in part, be due to the recent high demand by China resulting in little LNG being available for the spot market for short term marginal import terminals.

Table 1 lists 30 prospective full scale FSRU opportunities by region. Most of these prospects are associated with gas to power projects. In addition to these full scale terminals, numerous small scale floating FSRU facilities (up to 1 mtpa) have been identified on many of the smaller Indonesian Islands to replace current oil firing for power generation. The recent installation of the Bali FSRU is an example. A full list of these prospects with references is included in Appendix 3.

Table 1: FSRU opportunities

Region	Countries	Comments and References
Central & South America	Chile, Brazil (2)	Chile (delayed), Brazil
Europe & North Africa	Germany, Croatia, Tunisia, Turkey (2)	Wilhelmshaven, Germany, Rabat, Tunisia, Krk, Croatia (Golar LNG), Turkey- Hatay/Dortyol and Gallipoli
Middle East	UAE, Pakistan, Lebanon (3)	Sharjah.[56] Pakistan – power shortages. Lebanon - switch from oil firing to gas
Central & Southern Africa	South Africa (2), Guinea-Bissau	South Africa, Guinea Bissau
India & Pakistan	Pakistan, India (2)	Pakistan 3rd FSRU, India East Coast - Kakinada and Krishnapatnam
South East Asia	Thailand, Myanmar (3), Vietnam (2), Indonesia (2), Philippines	Gulf of Thailand, Myanmar, Vietnam, Indonesia, Philippines
Far East	China (3)	Multiple FSRUs for China according to Höegh
Australia	Australia (2)	NSW and Victoria

Source: By author summarised from published data

FSUs

The FSU business is very bespoke and geared towards developments where regasification facilities are already available onshore or located on another facility and only additional LNG storage is necessary. It is interesting to note that the FSU facilities in Jamaica and Bali have been replaced by full storage and regasification FSRU facilities.

[56] http://www.seatrade-maritime.com/news/middle-east-africa/sharjah-to-go-ahead-with-fsru-for-lng-imports.html

11. Conclusions

Floating liquefaction

The good news for the floating liquefaction sector is that there are now four vessels in operation – Prelude, Satu, Hilli Episeyo and Tango - two more than reported in the 2016 paper. The bad news is that none of the seventeen prospects identified in that paper have materialised. This is probably due to 1) concerns over the cost overruns and extended schedules experienced with the current projects and 2) the industry's perception that these are high risk projects when compared to onshore liquefaction. This is borne out by the decision of the developers of gas fields offshore the NW Shelf in Australia not to go down the FLNG route but wait until spare capacity is available in the existing onshore plants. The industry appears more comfortable (or perhaps less uncomfortable) with less complicated inshore or nearshore vessels liquefying lean treated gas.

The recent relocation of the Petronas Satu FLNG from Sarawak to Sabah and the Exmar Caribbean FLNG, renamed Tango, to Argentina bears out the major advantage of floating LNG facilities in their ability to be relocated ('chase the gas'). If these developments had been onshore they would have been a sunk cost.

Given the challenges floating liquefaction faces in terms of perceived high risk and higher costs than onshore plants, it is likely to remain as a niche player in the LNG supply chain when compared to the major onshore production planned for Qatar, Russia, Mozambique and the USA.

Floating storage and regas

Overall the FSRU market appears to be slowing down with less new vessels planned. This is probably due to a surplus of vessels following the market upturn in 2017 where many orders were placed for new vessels. This oversupply is demonstrated by the fact that a third of the current vessels are now working as tankers at a lower day rate than as import terminals. Whilst this alternative use is one of their major strengths they typically cost 25 per cent more to build than a tanker and require a higher day rate.

Interestingly the number of operators has more than doubled, with the new companies preferring to build, own and operate their own vessels and not lease from the four major leasing companies. The move towards own and operate rather than lease is probably driven by two considerations; 1) the energy companies now regard FSRU projects as low risk as the technology is relatively simple and well proven, and 2) as the facilities are likely to be in place for more than ten years owning will be cheaper than leasing.

Despite the apparent slow down a recent report by Poten and Partners sees a doubling of the FSRU terminals over the next six years with the major growth area being in Asia. The growth of mini FSRUs, as recently installed in Bali, that can supply gas for a 200-250 MW power station looks very promising for small islands that wish to fuel switch from oil to cleaner burning gas.

Floating storage units

The number of FSUs remains at four vessels. The FSU installed in Jamaica has been replaced by a full storage and regas vessel and the Bahrain FSU added which becomes operational later in 2019. The industry considers FSUs low risk and often a cheaper way of providing LNG storage in the shorter term when compared to onshore tanks particularly if low cost retired tankers are available. However, it is interesting to note that Bahrain LNG has purchased a new build tanker, the Bahrain Spirit.

Commercial considerations

Capital costs for both FLNG and FSRU units do not appear to have really changed since the previous reports and the same can be said for operating costs.

As mentioned above, the traditional leasing or tolling business model for FSRUs seems to be moving towards outright purchase by the energy companies whereas the reverse is happening in the floating liquefaction business. The first four major FLNG vessels were awarded as capital projects but the industry appears to be seriously considering the lease/tolling model. This shift is evidenced by the Cameroon, Mauritania and the Delfin Deepwater Port projects where Golar LNG is contracting the liquefaction vessels on a leased basis. It will be interesting to see if this change of approach continues to gain traction as energy companies try and reduce costs to ensure LNG remains competitive as a clean fuel. Also it will be interesting to see if the other two major leasing companies, Höegh and Excelerate, decide to re-enter this business given this possible turn in contracting approach. They both offered FLNG vessels but withdrew to focus on the FSRU business.

New technology

There has been little progress in the development of new technology. The lack of take up of large cryogenic hoses to replace fixed articulated arms is disappointing. The 'Jettyless' concept to replace traditional jetties could offer significant cost and schedule savings for smaller developments.

Market outlook

There are many offshore gas fields around the world that could be developed using floating liquefaction and this sector is expected to grow. However, it will probably be slow and remain slow while developers and investors remain concerned about the cost and schedule overruns experienced with these complex projects to date and monitor the performance of the current vessels considering the first one (Satu) only started operating three years ago. Growth in the inshore and nearshore sector is likely to be quicker due to less risk, simpler technology, and repeatable units with lower costs plus the opportunity to lease or toll and improve cash flow. At this time it is not possible to predict with any certainty what the next projects might be. On this basis, and looking forward, floating liquefaction is likely to remain very much a niche player when compared to onshore plant production.

The FSRU sector is also expected to grow at a steady but slower rate than the high growth period of 2015-2017. New FSRU markets are appearing in Europe, Asia and now Australia with two new terminals planned and these are summarised in Table 1. Construction of new FSRU vessels is likely to slow down in the short term until the current surplus of some ten vessels currently operating as tankers have been assigned to import terminal projects. One area of considerable growth may be in the mini FSRU sector as recently installed in Bali. These small vessels are ideal for switching from oil to gas on small islands to typically fuel 200-300 MW power stations and there are numerous small islands around the world that could take advantage of this switch.

The FSU market is likely to remain static. Some existing units may be upgraded to full FSRU terminals and new FSU added but this is a very small market.

Appendix 1. FLNG prospect update

Country	Developer	Project	mtpa	Start-Up	*Update*
Construction					
Malaysia	Petronas	PFLNG Satu, Kanowit Field	1.2	2016	*Operational 2016 – moved to second field*
Australia	Shell	Prelude	3.6	2017	*In commissioning - first cargo of condensate exported*
Cameroon	SNH/Perenco/Golar LNG	Kribi (Golar Hilli Episeyo)	1.2	2017	*Operational 2017*
Malaysia	Petronas	PFLNG2, Rotan Field	1.5	2020	*In construction*
Equatorial Guinea	Ophir	Fortuna (Golar Gandria)	2.2	2019	*Cancelled – was well advanced but Ophir licence expired*[57]
TBA	Exmar	Caribbean FLNG	0.5	TBA	*Relocated to Argentina – in commissioning*[58]
TBA	Exmar	Speculative	0.6	TBA	*Cancelled*[59]
Planning/Pre-engineering Phase					
Australia	ExxonMobil	Scarborough/Thebe	6.5	TBA	*Cancelled – now planned as onshore using an existing plant*[60,61]
Australia	Woodside	Browse FLNG1	3.6	TBA	*Cancelled – now planned as onshore using an existing plant*[62]
Australia	Woodside	Browse FLNG2	3.6	TBA	*Cancelled – now planned as onshore using an existing plant*[63]
Australia	Woodside	Sunrise	4.0	TBA	*On hold*[64]
Cameroon	NewAge/Euroil/Lukoil	Etinde	1.0	TBA	*On hold*[65]
Canada	Altagas/EDFT/Idemitsu	Exmar Kitimat	0.6	2018	*Cancelled*[66]
Canada	Orca LNG	Orca LNG	4.0	2020	*On hold* [67]

[57] https://www.offshoreenergytoday.com/ophir-loses-fortuna-discovery-license-offshore-e-guinea/
[58] https://worldmaritimenews.com/archives/270855/exmars-tango-flng-touches-down-in-bahia-blanca-argentina/
[59] https://www.lngworldnews.com/exmar-to-take-delivery-of-caribbean-flng-in-april-cancels-order-for-2nd-unit/
[60] https://www.offshore-mag.com/field-development/article/16761963/flng-market-gears-up-for-second-wave-of-projects
[61] https://www.woodside.com.au/our-business/burrup-hub/scarborough-to-pluto
[62] https://www.sourcewatch.org/index.php/Browse_LNG_Terminal
[63] https://www.sourcewatch.org/index.php/Browse_LNG_Terminal
[64] https://lloydslist.maritimeintelligence.informa.com/LL1127109/East-Timor-closes-Greater-Sunrise-fields-deal
[65] https://www.petroleum-economist.com/articles/upstream/technology/2018/flng-enters-new-age
[66] http://northwestinstitute.ca/index.php/lng/projects
[67] https://www.sourcewatch.org/index.php/Orca_LNG_Terminal

Canada	Altagas	Triton	2.0	2020	*On hold*[68]
Congo	NewAge/SNPC	BLNG	1.0	2019	*On hold*[69]
Indonesia	Inpex/Shell	Abadi	7.5	On hold	*Cancelled – now planned as onshore plant*[70]
Israel	Noble Energy	Tamar	3.4	TBA	*Shelved*[71]
Mozambique	ENI	Coral South	2.5	2020	*In construction – now referred to as Coral FLNG*[72]
Tanzania	Ophir/BG/Statoil	Mzia/Chaza/Jodari	2.5	TBA	*Cancelled – now planned as onshore using an existing plant*[73]
USA	Excelerate Energy	Lavaca Bay	4.4	On hold	*Cancelled*[74]
USA	Delfin	Delfin LNG	5.0	TBA	*Planning – Golar LNG selected*[75]
USA	McMoran Exploration	Main Pass Energy	4.0	TBA	*Feasibility stage*[76]
USA	Cambridge Energy	CE FLNG	2.5	TBA	*Feasibility stage*[77]
Canada	*Steelhead LNG*	*Kwispaa LNG - Four 3.5 mtpa FLNG units*	*14*	*TBA*	*Cancelled/on hold*[78]
Mauritania/Senegal	*Kosmos/BP*	*Tortue*	*2.5*	*20122*	*Added – not identified in 2016 report. Golar FLNG selected*[79]

Source: By author from published data

[68] http://northwestinstitute.ca/index.php/lng/projects
[69] https://www.petroleum-economist.com/articles/upstream/technology/2018/flng-enters-new-age
[70] https://www.inpex.co.jp/english/news/pdf/2018/e20180330.pdf
[71] https://www.sourcewatch.org/index.php/Tamar_FLNG_Terminal
[72] https://www.offshoreenergytoday.com/eni-cuts-first-steel-for-coral-south-flng/
[73] https://www.reuters.com/article/us-equinor-tanzania-lng/equinor-set-to-start-talks-with-tanzania-over-lng-project-idUSKBN1O30UC
[74] https://www.lngworldnews.com/excelerate-scraps-lavaca-bay-lng-project/
[75] http://www.delfinlng.com/home-page
[76] http://www.mpeh.com/
[77] https://www.globaldata.com/store/report/gd-195366--ce-flngce-cambridge-energy-floating-lng-louisiana/
[78] https://www.straight.com/news/1202346/steelhead-lng-halts-work-kwispaa-plant-according-huu-ay-aht-first-nations
[79] https://www.offshoreenergytoday.com/golar-wins-tortue-ahmeyim-flng-deal-with-bp-keppel-to-build-the-unit/

Appendix 2. FSRU fleet update by vessel

Vessel Name	Status	Storage m^3	MMscf/d Baseload	mtpa	Delivered	Open/ or Closed Loop[80]	*Update May 2019*
Excelerate Energy							
Excelsior	Operating	138,000	500	4.1	2005	Open & Closed	*Israel*
Express	Operating	150,900	500	4.1	2009	Open & Closed	*Trading Tanker*
Excellence	Operating	138,000	500	4.1	2005	Open & Closed	*Bay of Bengal 1*
Explorer	Operating	150,900	500	4.1	2008	Open & Closed	*Dubai*
Experience	Operating	173,000	800	6.6	2014	Open & Closed	*Brazil - Salvador*
Exquisite	Operating	150,900	500	4.1	2015	Open & Closed	*Pakistan – Port Qasim*
Excelerate	Operating	138,000	500	4.1	2006	Open & Closed	*Bay of Bengal 2*
Expedient	Operating	150,900	500	4.1	2009	Open & Closed	*Trading Tanker*
Exemplar	Operating	150,900	500	4.1	2010	Open & Closed	*Trading Tanker*
Golar LNG							
Golar Spirit	Retire June 2017	129,000	242	2.0	2008	Closed	*Laid up*
Golar Winter	Operating	138,000	500	4.1	2006	Open & Closed	*Brazil*
Golar Freeze	Operating	125,000	475	3.9	2010	Open (IFV)	*Jamaica*
Nusantara Regas Satu	Operating	125,000	485	4.0	2012	Open (IFV)	*Indonesia*
Golar Igloo	Operating	170,000	728	6.0	2014	Open (IFV)	*Kuwait*
Golar Eskimo	Operating	160,000	728	6.0	2015	Open (IFV)	*Jordan*
Golar Tundra	Pending	170,000	728	6.0	2015	Open (IFV)	*Trading Tanker*

[80] These are best estimates based on public domain data but should be confirmed if taken further

Golar Viking	*Conversion*	*140,000*	*250*	*2.5*	*2005*	*TBA*	*Nominated for Krk, Croatia*
Golar Nanook	*Trading*	*170,000*	*728*	*6.0*	*2018*	*Open*	*Trading*
Höegh LNG							
Grace	Operating	170,000	500	4.1	2016	Open (IFV)	*Cartagena, Columbia*
Gallant	Operating	170,000	500	4.1	2015	Open (IFV)	*Trading Tanker*
Independence	Operating	170,000	384	3.2	2014	Open (IFV)	*Lithuania - Lithuanian government has approved purchase from Höegh*
PGN Lampung	Operating	170,000	360	3.0	2014	Open (IFV)	*Sumatra*
GdF Suez Cape Anne	Operating	145,000	750	6.2	2013	Closed	*Trading – nominated for HEnergy, India*
GdF Suez Neptune	Onsite	145,000	750	6.2	2017	Closed	*Aliaga, Turkey*
Giant	Pending assignment	170,000	750	6.2	2017	Open (IFV)	*Trading Tanker – may go to Crib Point, Australia*
Gannet	*New*	*170,000*	*1000*	*8.2*	*2018*	*TBA*	*Trading*
Galleon	*New*	*170,000*	*750*	*6.2*	*2019*	*TBA*	*Nominated Port Kembla, Australia*
OLT							
FSRU Toscana	Operating	137,500	530	4.4	2014	Open/Trim Heaters	*Permanent terminal*
MOL							
GNL Del Plata	Delivered	263,000	350	3.0	2018	Open/Trim Heaters	*Renamed Challenger – Turkey then Hong Kong*
Jawa 1	*Planning*	*170,000*	*300*				*TBA*
Uniper	*Planning*						*Willemshaven*
BW Offshore							
BW Singapore	Operating	170,000	750	6.2	2015	n/a	
BW Integrity	*Operating*	*170,000*	*750*	*6.2*	*2018*	*TBA*	*Pakistan – Port Qasim*
BW Courage/Magna	*Construction*						*Brazil – Port Acu*

GDF Suez	*Conversion*						*TBA*
Other Operators – all new since 2017 Report							
Dynagas	*New 2019*	*Hudong-Zhonghua Shipbuilding*					*Order placed in China*
Dynagas	*New 2020*	*Hudong-Zhonghua Shipbuilding*					*China - Option*
Maran Gas Maritime	*New 2020*	*DSME*					*Hull 2477 - TBA*
Pertamina	*New 2019*	*Samsung*					*Central Java*
Gazprom	*New 2019*	*HHI*					*Kaliningrad – Marshall Vasilevskiy*
Triumph Swan	*New 2019*	*HHI*					*India – Jafrabad*
Botash Kolin Kaylon	*New 2020*	*HHI*					*Turkey – Izmir*
Botash Kolin Kaylon	*New 2020*	*HHI*					*Turkey - Adana*
Pelindo Energi							Indonesia - Bali

Source: By author from published data

Appendix 3. FSRU prospect update by country

The following table lists 30 prospective full scale FSRU opportunities by country with hyperlink references for further details.

Country	Number FSRUs	Comments and References
Chile	1	http://interfaxenergy.com/article/32299/contract-expires-for-hoeghs-chilean-fsru
Brazil	2	https://www.mayerbrown.com/files/Event/2279dea4-a2e7-4ba3-86cd-ec59ee90e6c1/Presentation/EventAttachment/d420e3c9-080e-4878-9482-12c94e042d34/171102-Developing-LNG-and-Gas-to-Power-Projects-in-Brazil.pdf
Germany	1	https://lng-wilhelmshaven.com/en/?gclid=Cj0KCQjwv8nqBRDGARIsAHfR9wDVWiRe3Fp3VSIKagwHSnodRBzUGMKM0TYLT_lVWK5-5QRsoNlWXmcaAkJ8EALw_wcB
Croatia	1	https://www.lngworldnews.com/golar-power-to-provide-fsru-for-croatias-1st-lng-import-project/
Tunisia	1	https://www.lngworldshipping.com/news/view,the-middle-east-and-north-africa-thirsty-for-lng_49109.htm
Turkey	2	http://www.tpic.com.tr/en/news/news/two-new-fsru-facilities-to-be-launched-in-turkey
Lebanon	3	https://logi-lebanon.org/KeyIssue/deadline-for-gas-terminals-extended
UAE	1	http://www.seatrade-maritime.com/news/middle-east-africa/sharjah-to-go-ahead-with-fsru-for-lng-imports.html
Pakistan	1	https://www.upstreamonline.com/hardcopy/1732785/pakistan-eyes-fsru
South Africa	2	https://www.petroleum-economist.com/articles/politics-economics/africa/2019/lng-to-power-a-hard-nut-to-crack-in-africa
Guinea-Bissau	1	https://archive.crossborderinformation.com/Article/West+African+LNG+import+schemes+proliferate.aspx?date=20190328
India	2	https://www.thehindubusinessline.com/economy/govt-drafting-policy-on-fsru-based-lng-import-facility/article25252215.ece
Thailand	2	https://www.lngworldnews.com/fluor-starts-feed-work-for-thailands-fsru-project/
Myanmar	3	https://eng.rim-intelligence.co.jp/news/select/article/150182
Vietnam	2	http://www.jccp.or.jp/country/docs/4_CPJ-5-18_MOIT.pdf
Indonesia	2	https://www.thejakartapost.com/news/2018/10/03/pln-holds-tender-for-five-fsru-projects.html
Philippines	1	https://www.bworldonline.com/us-firm-proposes-lng-facility-in-philippines/
China	3	https://www.tradewindsnews.com/gas/1750983/hoegh-lng-sets-sights-on-multiple-fsrus-for-china
Australia	2	https://www.lngworldshipping.com/news/view,fsru-projects-race-to-meet-australias-domestic-gas-demand_56353.htm

Source: By author summarised from published data

Bibliography

Adeosun, M. (2018). 'FLNG market gears up for second wave of projects', *Offshore Magazine*: https://www.offshore-mag.com/field-development/article/16761963/flng-market-gears-up-for-second-wave-of-projects

Corbeau, A-S., and Ledesma, D. (eds.) (2016). *LNG Markets in Transition: The Great Reconfiguration*, Oxford, OIES, Chapter 4.

IGU 2018 World LNG Report. 27th World Gas Conference Edition. https://www.igu.org/sites/default/files/node-document-field_file/IGU_LNG_2018_0.pdf

Kelleher, L. (2019) 'Change of course as FLNG players take second look at financials', Wood Mackenzie, 30/01/2019: https://www.woodmac.com/news/editorial/change-of-course-as-players-take-second-look-at-flng-financials/

LNG World News, 'FSRU': https://www.lngworldnews.com/tag/fsru/

Oil & Gas iQ, (2018). 'Top 10 FLNG projects of all time', Oil & Gas IQ Editor, 30/10/2018: https://www.oilandgasiq.com/fpso-flng/news/top-10-flng-projects

Oil & Gas iQ, (2019). 'FLNG market surges', Oil & Gas IQ Editor, 21/01/2019: https://www.oilandgasiq.com/fpso-flng/news/flng-market-surges

Oil & Gas iQ, (2019). 'The FSRU Market Report 2019 and Beyond', June 2019: https://www.oilandgasiq.com/events-fsrusummit/downloads/the-fsru-market-report-2019-and-beyond

Owen, W., (2019). 'Global FSRU Market 2018 – 2022', *LNG Industry*, 02/01/19: https://www.lngindustry.com/liquid-natural-gas/02012019/global-fsru-market-2018-2022/

Songhurst, B. (2016). Floating Liquefaction (FLNG): Potential for Wider Deployment, Oxford, OIES, Paper NG107. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2016/11/Floating-Liquefaction-FLNG-NG-107.pdf?v=79cba1185463

Songhurst, B. (2017). The Outlook for Floating Storage and Regasification Units (FSRUs), Oxford, OIES, Paper NG123. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2017/07/The-Outlook-for-Floating-Storage-and-Regasification-Units-FSRUs-NG-123.pdf

Westwood Global Energy Group, 'World FLNG Market Forecast 2019-2024' 18/07/2018. For purchase but not read by Author but would appear to be comprehensive from the overview. https://www.westwoodenergy.com/product/world-flng-market-forecast-2019-2024/

Wood Mackenzie Commodity Market Report, (2019). 'Global FLNG Overview 2019'. For purchase but not read by the author: https://www.woodmac.com/reports/lng-global-flng-overview-2019-34632/

Zawadzki, S., (2018). 'For the global LNG industry, is the FSRU honeymoon over?' *Reuters*, 18/07/18: https://www.reuters.com/article/us-lng-fsru-analysis/for-the-global-lng-industry-is-the-fsru-honeymoon-over-idUSKBN1K80R2