Technical Assistance on Liquefied Natural Gas Options for Myanmar Phase 1: Additional Analysis: Location 5 (Selection # 1216215)

Final Report Location 5 Kanbauk (Revised)

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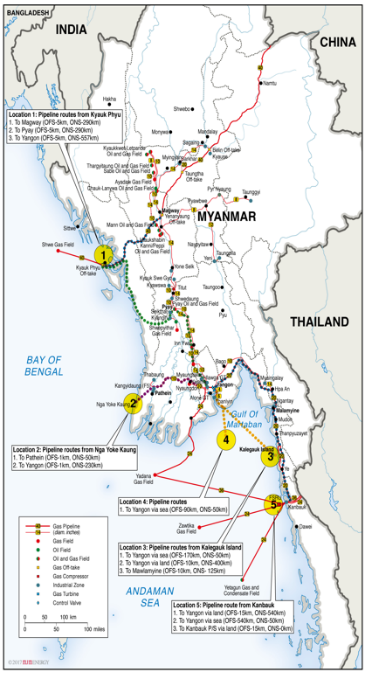
Abbreviations and acronyms

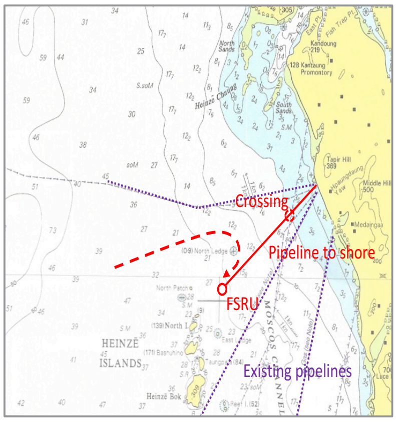
Abbreviation	Description
bbl	Barrels of oil
Bcm	Billion cubic metres
Btu	British thermal units
C&F	Cost and freight
cm	Cubic metres
FSU	Floating storage unit
FSRU	Floating storage and regasification unit
FY	Financial Year
GoM	Government of Myanmar
IOC	International Oil Company
IPP	Independent power producer
IRR	Internal rate of return
LNG	Liquefied Natural Gas
LNGC	Liquefied Natural Gas Carriers
mmbbl	Million barrels
mmbtu	Million British thermal units
mmcfd	Million cubic feet per day
MOGE	Ministry of Oil and Gas Enterprise
scf	Standard cubic feet
Tcf	Trillion cubic feet
ToR	Terms of Reference

Executive Summary



Section 1: Introduction – Following the delivery of a draft copy of the main report in November 2016 entitled 'Technical Assistance on Liquefied Natural Gas Options for Myanmar Phase 1: (Selection # 1216215)' the World Bank / IFC requested that two additional locations be assessed. This Report contains the results of the analysis on Location 5.[1]

Section 2: Location – Location 5 is offshore in the Andaman Sea, just to the north east of the island of Heize Bok (the northern most island of the Moscos Islands) with a landfall just to the north west of Zadi. The general area of the mainland is close to the town of Kanbauk. Location 5 is in 26 m of water at 14°29'00" N, 097°48'00" E (14.483°N 097.800°E), about 310 km south south east of Yangon.



Section 3: Weather – The metocean study identifies potential sea states higher than 2.0 m less than 0.1% of the time. Waves of this height would stress the mooring system if the LNGC was already alongside but would not prevent vapourisation and gas send out. Offshore winds can come from all sectors, with a mean hourly wind speed of 4.6 m/s over 20 years and with a standard deviation of 2.26 m. The wind in this location, although low in strength, is highly variable. By using a berth alignment with the LNGC/FSRU positioned bow to the prevailing waves, in this case west north westerly, wind limits are exceeded only from a south westerly direction and would only stop loading for 0.26% of the year (1 day). In terms of extreme weather, cyclones are rare (2 every 20 years), with May being the most likely month for a cyclone and April when the highest wind speeds are recorded. Any jetty must be built sufficiently above the maximum wave height to avoid green water over topping. The maximum expected wave height from a non-cyclonic storm is 3.0m.

Section 4: Environmental, Social & Cultural Impact – In terms of LNGC transit no issues or impacts are expected. The Muscos Islands whilst unihabitated are a designated wildlife sanctuary with the environmental sensitivity reducing slightly from south to north. Whilst coral is also present in this area, (its exact location and extent is unknown), and since the FSRU is sited 3-4 km from this area in deep water any impact is probably small or negligible, although this should be confirmed as soon as possible if this location is selected for development. The subsea pipeline to shore will use existing gas pipeline wayleaves for the offshore fields so no additional impact would be expected. FSRUs use seawater to vaporise the LNG, which is returned cooler and contains biocide into the local sea and could potentially damage coral. However, the berth is in deep water a significant distance from land so water recirculation is probably not an issue. The biocide required will also damage the local ecology which would affect any local fishing. The area around Dawei, 60 km to the south, is an

[1] *Use of terminology – The Main Report examined three locations as potential LNG import locations referring to them as Location 1, 2 etc. However, within each generic location a number of different sites were considered which were referred to as Site 1A, Site 1B etc. This report uses the same basic terminology, identifying the general location as Location 5 and any specific sites considered as Site 5A, Site 5B etc.*

important fishery in Myanmar. Given the proposed location of the marine facility there are no social, cultural or hazardous issues that might impact a local population. Whilst Total's corporate responsibility programme has provided improved health care, education and some physical infrastructure such as bridges, local communities have expressed concerns over the state of the roads and high dust levels caused by oil/gas traffic.

Section 5: Geology – The Sagaing Fault is a major strike-slip structure that cuts through the centre of Myanmar. This far south the Sagaing Fault has doglegged to be further offshore and is significantly weaker. The land directly to the east of Location 5 has a peak ground acceleration of about 0.2g. There have been recorded earthquakes in the area of the site but significantly further offshore. All these were of Magnitude 4 – 5.

Section 6: Navigation and marine issues – The water depth is 26 m and suitable for LNGCs, which would approach from the west before turning and approaching the jetty from the north west. All manoeuvres would be in water of sufficient depth so no dredging will be required. No specific details of low visibility events have been found and so is not considered a problem. An island berth or tower yoke mooring is suggested. If a jetty is selected the vessel bow would be positioned towards the west south west. Location 5 is close to the proposed port at Dawei, although there are no details of the number of movements or type of ship that may use it. Consultations are required with Myanmar Port Authority to determine traffic levels. Marine traffic levels are assumed to be light and there are no tugs available in the area. Port services such as tugs would therefore have to be purchased or brought in from another location. There are no known port rules for this site.

Section 7: Gas pipelines – The Project Team have estimated an offshore gas pipeline of 15km ($27million) and an onshore gas pipeline of 540km ($648million) connecting to Yangon. An alternative option was also considered with a direct subsea gas pipeline of 265km to Yangon.

Section 8: Infrastructure – There is no infrastructure at the proposed location therefore an island jetty or tower yoke will need to be created. Dawei is the closest city (state capital), 60 km to the south with a population of 139,000 (2004), it has a general hospital and a technological university. The area around Kanbauk is very rural with limited access to education. Healthcare has improved primarily because of Total's CSR programme. The local tin mine at Kanbauk which may provide some skills appropriate to oil and gas could complement the existing oil/gas infrastructure. Access to electricity around Kanbauk and further to the south via Dawei to Kawthoung is limited. In terms of transport, Total has a private airstrip at its Kanbauk pipeline centre and there is also a small airport at Dawei with good road and rail links to Yangon. In November 2010, the Myanmar Port Authority signed a deal with Italian-Thai Development to develop the seaport within the Dawei Special Economic Zone. Progress has been slow.

Section 9: Results of analysis – The results of the traffic light analysis were largely positive, with the preferred technology being a tower yoke mooring and a key financial driver being the location and cost of pipeline infrastructure. Therefore, three variations for Location 5 were analysed using SPT-Stage 3 (Discounted Expenditure Model); Site 5A with an onshore pipeline to Yangon; Site 5B with a direct subsea pipeline to Yangon and Site 5C with a gas to power plant near the beach. The conclusions are summarised in the following table.

Table 1 – Summary of the results of discounted expenditure selection

Site	Schedule (Months)	Capital Investment (US$ million)	Operating Expense (US$ million per annum)	Discounted Expenditure (DEX) (US$ million)
Site 5A	45	855	15.0	808
Site 5B	45	640	15.0	621
Site 5C	45	338	3.8	321

Section 10.1: Conclusions

In terms of the technology choice and site location a tower yoke mooring is proposed in 26 m of water behind the Moscos Archipeligo, which provides good levels of reliability. Whilst a significant proportion of the offshore costs can be shared with PTT/Total, the benefit of these cost savings are offset by the need to connect the site to Yangon, with a new 30 inch 540 km pipeline from Kanbauk to Yangon because of the poor condition of the existing pipeline.

Therefore two other options have also been considered. Firstly the construction of a 265 km direct subsea pipeline to Yangon, and secondly the development of a local power generation project. At present Total and Siemens are proposing a 450 MW CCGT power plant at Kanbauk and an upgrade of the proposed Yangon – Dawei electricity cable. Whilst this is a low cost option for Myanmar it only provides a limited amount of power and does not provide any gas to Yangon.

In conclusion then, Location 5 only makes sense if it will be used as a shared terminal with Thailand because, as earlier studies have shown, other locations that are just as viable are closer to Yangon (i.e. as a Myanmar only terminal). For example Location 3 is as good as Location 5 but 100 km closer to Yangon.

Section10.2 Recommendation

If one of the above sites in relation to Location 5 is going to be progressed further the following activities should take place

- Engagement with the appropriate marine authorities.
- An offshore gas pipeline study, given the potential sensitivity of the project to subsea pipeline construction costs.
- An onshore gas pipeline study, given the potential sensitivity of the project to onshore pipeline costs as well as the potential complexity of laying gas pipelines in Yangon.

1 Introduction

1.1 General

The high-level objectives of this project are to support the Government of Myanmar (GoM) in developing a gas sector development plan by focusing on the near-to-medium term options to meet the gas demand in Myanmar. Specifically the project focuses on import options of LNG, initially as a bridging fuel while new gas exploration gets underway in Myanmar, including assessment of potential technologies and locations for LNG receiving facilities. Given the aspirations of the GoM for deliveries of LNG in 2018 or 2019, this suggests prospects for development of floating regasification LNG terminals.

On November 8-11, 2016, the Draft Final Report for this Project was presented and discussed with GoM and industry stakeholders. As a result of these discussions, the original Terms of Reference for the consulting assignment have been expanded to include the analysis of two additional potential LNG locations, which shall be referred as Location 4 and Location 5, with the analysis of these additional locations prepared in the same manner and to the same level of detail as the analysis presented in the Draft Final Report for the original three locations.

Therefore, in keeping with the above objectives, this Report on Location 5 is submitted to the World Bank / IFC. In particular, this Report provides an analysis of Location 5 in order to assess its potential as possible location for LNG import facilities in Myanmar. (NB: This Report on Location 5 should be read in conjunction with the main project report in order to place these results in context. In addition, the main project report contains detailed explanations of technology choices, the traffic light model and estimated costs of infrastructure used as part of the assessment process.)

1.2 Structure of this report

As highlighted above this document provides reports for all three tasks 1(a), (b), and (c) and is therefore structured as follows:

- Section 1 – Introduction.
- Section 2 – Location.
- Section 3 – Weather.
- Section 4 – Environmental, Social & Cultural Impact.
- Section 5 – Geology.
- Section 6 – Navigation.
- Section 7 – Access to gas pipelines.
- Section 8 – Infrastructure.
- Section 9 – Results of analysis.
- Section 10 – Conclusions and Recommendations.

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2 Location 5: Kanbauk

The location under examination is offshore in the Andaman Sea, just to the north east of the island of Heize Bok (the northern most island of the Moscos Islands) with a landfall just to the north west of Zadi. The general area of the mainland is close to the town of Kanbauk. Location 5 is in 26 m of water at 14°29’00” N, 097°48’00” E (14.483°N 097.800°E), about 310 km south south east of Yangon by sea or about 400 km by land routes.

Location 5 has been proposed by Total and also suggested as one possibility in a study by Japanese company, Mitsui.

The area around Kanbauk is the current landfall location for pipelines from the Yetagun, Yedana and Zawtika fields which are primarily piped to Thailand but also piped north through a 20 inch line to Yangon.

Figure 1 – Location 5 in relation to Myanmar

Figure 2 – Location 5 in relation to Kanbauk

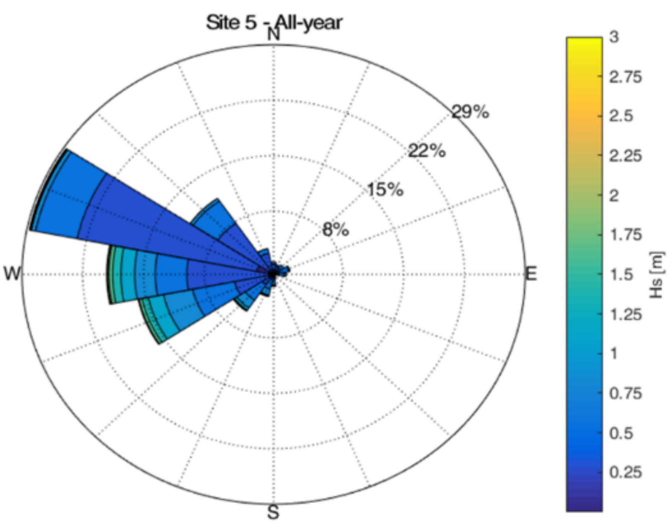
3 Weather

The purpose of this section is to examine the potential impact of weather on the proposed LNG import location. In particular the metocean analysis has examined the wave environment around the area of interest of the terminal location and a proposed pilot transfer station. The assessment is based on offshore waves over a 20 year period which have been propagated to the site by means of a numerical modelling exercise.

3.1 Waves

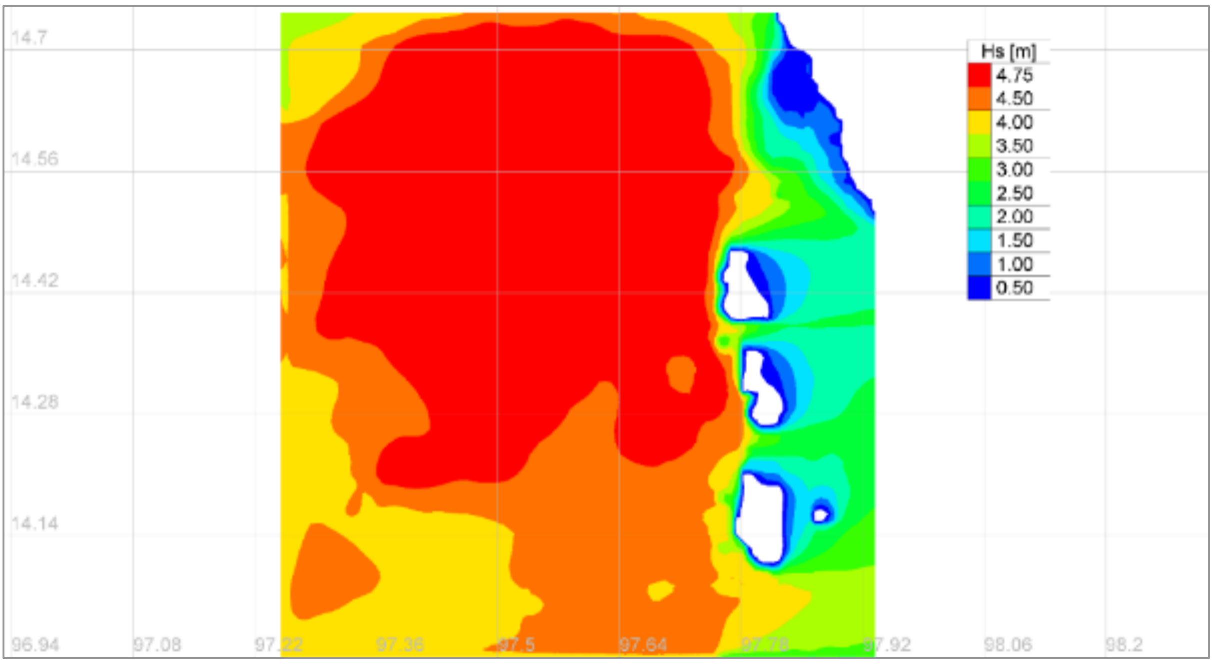
The offshore waves are predominantly from the west north western direction with some variation to the west and west south west. At this site over a 20 year period the mean significant wave height (Hs) is 0.54m and a standard deviation of 0.28 as shown below.

Figure 3 – Waves Rose



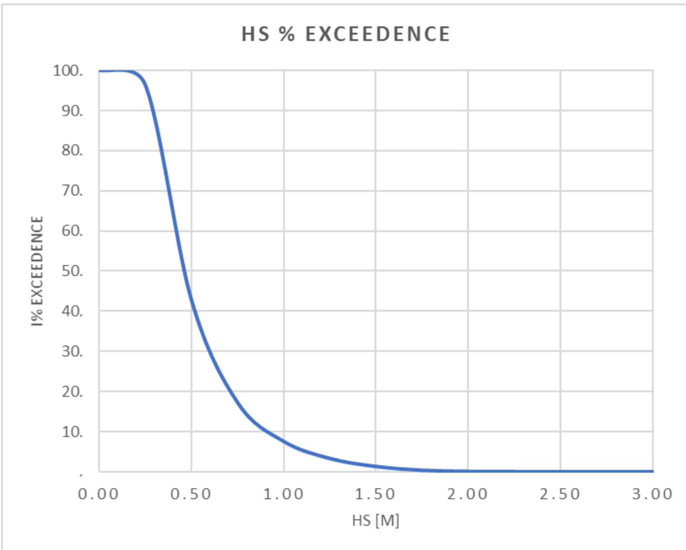
In the 20-year long period, the highest non-cyclonic significant wave height observed is 2.25m. Sea states higher than 2m are observed less than 0.1% of the time.

Figure 4 – Inshore Waves for non Cyclonic Storm



Waves of this height would significantly challenge berthing operations and would stress the mooring system if the LNG carrier was already alongside, but would not prevent vaporisation and gas send out.

Figure 5 – Wave height exceedance curve

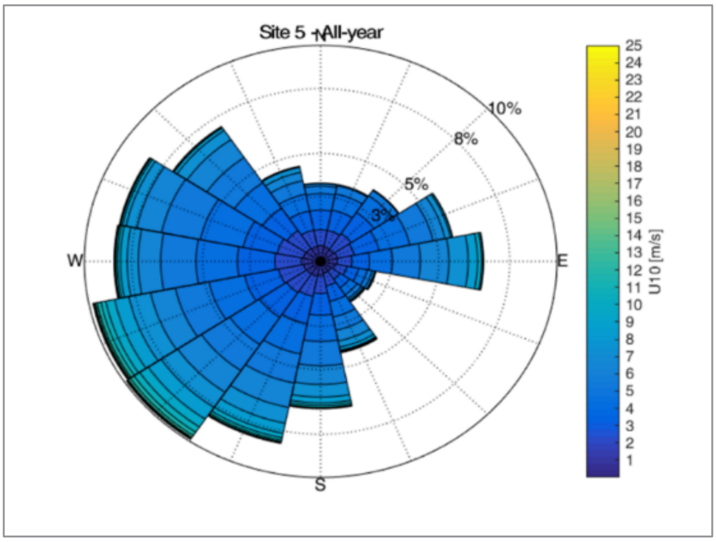


LNG carriers can berth and unload at a wave height of 1.5 m Hs for 98.6% of the year or 99.9% of the year at 2 m Hs. This is a very benign site, highly suitable for LNG transfer.

3.2 Wind

LNG carriers and FSRUs have high windage areas. The cargo is relatively light compared to water and therefore the flat side of the LNG carrier is out of the water and subject to wind loads. High winds can blow the vessel off the berth or onto the berth, preventing the LNG carrier escaping in an emergency. The metocean study examined offshore winds which can come from all sectors, with a mean hourly wind speed of 4.6 m/s (about 10 knots) over 20 years and standard deviation of 2.26, as shown in the following chart.

Figure 6 – Wind Rose

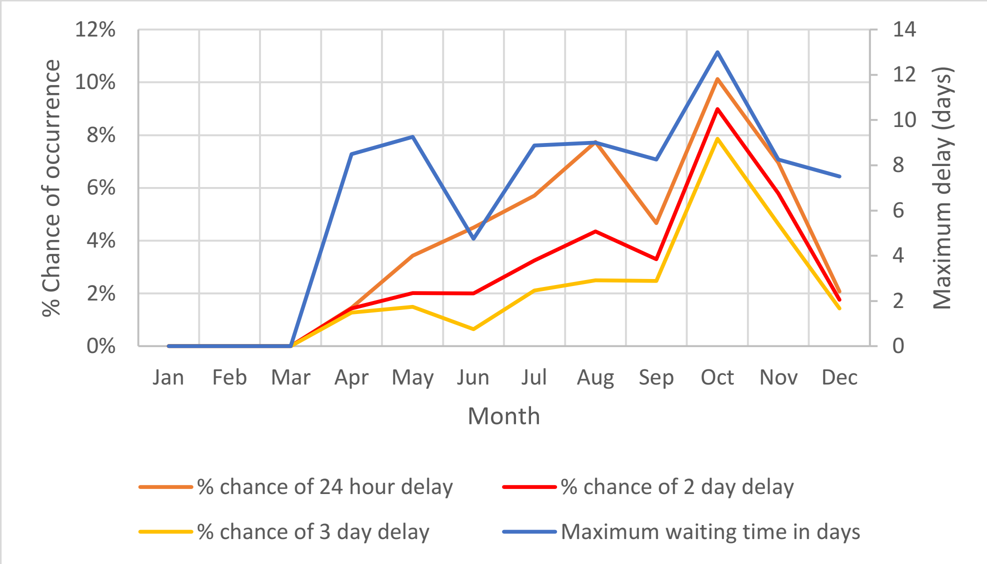


The wind at this location, although low in strength, is highly variable. LNG industry body SIGTTO provides wind roses for various operating criteria on LNG carriers. Based on a berth alignment where the LNG carrier/FSRU is positioned bow to the prevailing waves, in this case west north westerly, wind limits are exceeded only from a south westerly direction and only stop unloading for 0.26% of the year (1 day). The modelled wind levels never exceed typical strengths in mooring loads. Weathervaning at this location is not required, however variability of the winds may make a weathervaning solution more comfortable for the crew.

3.3 Storm durations

Storms that produce wind or waves that exceed operating limits of either the berthing/unloading process, vaporisation/send out or mooring need to be considered for prevalence and duration. The storm duration is important in defining LNG storage volumes. The following graph shows the probability of different durations of weather that prevent a 24 hour window of waves less than 1.5 m Hs which are typically required to unload a LNG carrier.

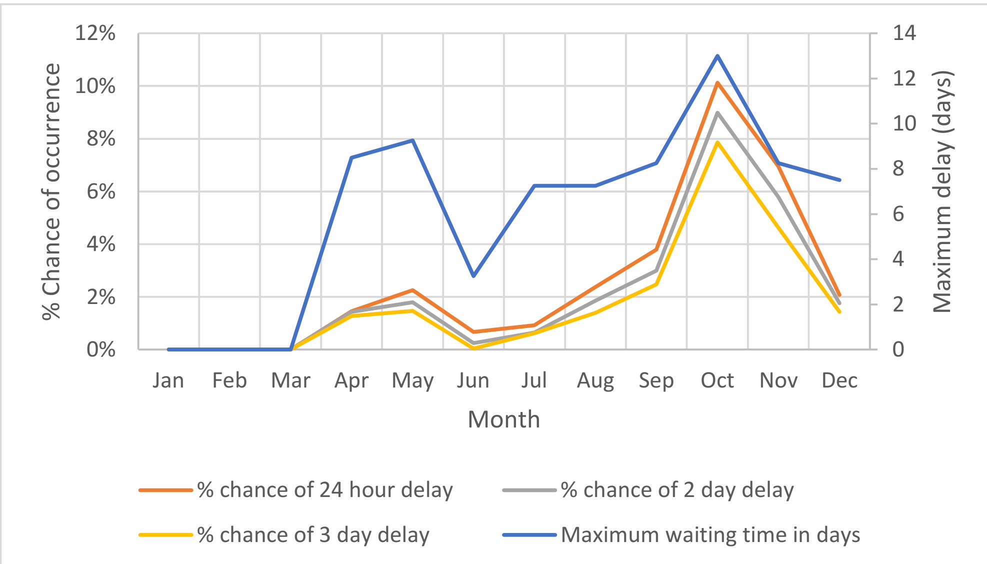
Figure 7 – Weather window durations and probabilities (1.5m Hs)



The above graph shows in blue and on the right hand axis the maximum recorded duration when a 24 hour unloading window is not possible. This is about 9 days apart from mid September and in October when it increases to 13 days. Building in 13 days of excess storage capacity would cover all historical events of the last 20 years but exceeds all industry norms and would result in the largest LNG carrier/FSRU ever built. More typically lower levels of storage are required. The red-orange lines and the left hand axis look at the probability of a 24 hour window not being available in any month, for 1, 2 or 3 days duration.

The probability of a 1 day delay peaks at about 10% in October and apart from a secondary peak in August is about 5%. There is a significant improvement if the delay increases to 2 days but much less important between 2 and 3 days. October is during the monsoon period so hydroelectric power should be available at this time.

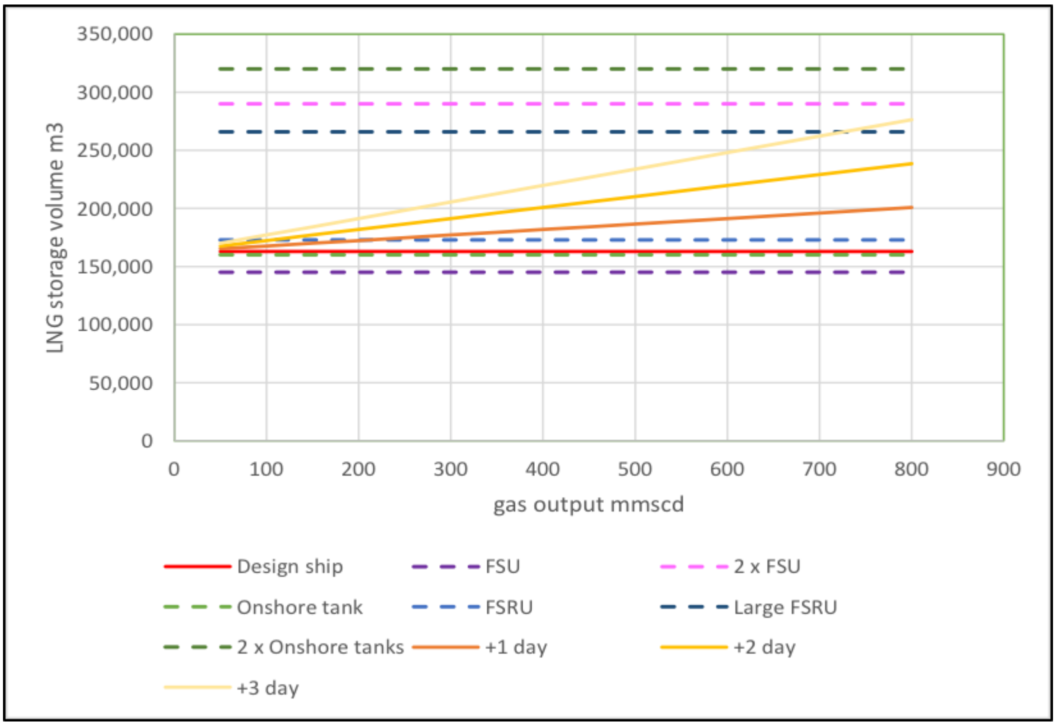
Figure 8 – Weather window durations and probabilities (2m Hs)



For 2m waveheights (weathervaning FSRU) the maximum delay days historically does not reduce, suggesting the if storms arrive they are “significant” for the area (although minor in magnitude). The probability of occurrence remains similar in October but has reduced to 1-2% for the rest of the year. Weathervaning may therefore have merits.

The following graph shows how large the LNG storage capability needs to be for the design ship (163,000m^3) and a variety of gas send out/LNG vaporisation rates for 1, 2 and 3 days additional storage.

Figure 9 – Vaporisation rate versus storage cover



Up to 3 days of storage reserve volume is possible but would require two FSUs. Maintaining two FSUs on the berth is possible but would require a large island jetty facility. With the FSRU, storage volumes of the same scale are possible but are not currently being built by the market except for deployment in Uruguay. The FSRU would therefore need to be a new build.

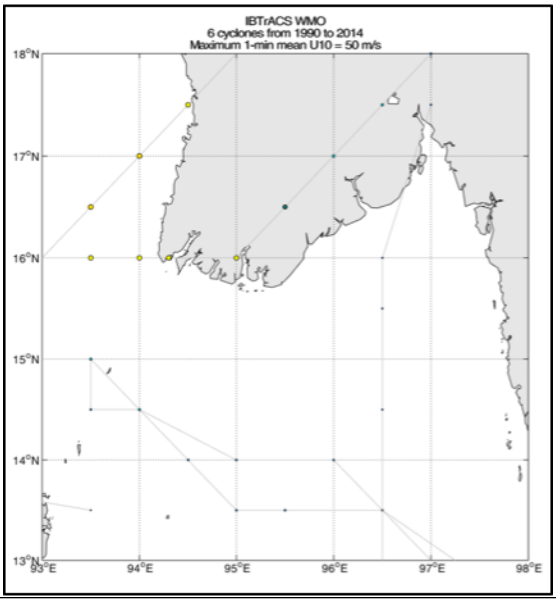
Alternatively a smaller design ship could be selected based on the contract negotiations with individual LNG suppliers.

Figure 10 – Tower Yoke Mooring in Indonesia

3.4 Extreme Weather

Cyclones tend to track up the Andaman Island chain and do not frequently enter the Andaman Sea. However cyclones do occaisionally impact this area.

Figure 11 – Cyclone map



IBTrACS WMO data – Area 3 – Period: 1990-2014													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All-year
Number of events []	0	0	0	1	2	0	0	0	0	2	1	0	6
Maximum 1-min U10 [m/s]	0	0	0	49	44	0	0	0	0	22	17	0	49
Mean 1-min U10 [m/s]	0	0	0	38	28	0	0	0	0	18	17	0	25

Historical cyclone activity analysis records 2 cyclones in 20 years, 1 every 10 years. May is the most likely month for a cyclone and along with April is when the highest wind speeds are recorded.

Flooding is not appropriate, so the jetty must be built sufficiently above the maximum wave height to avoid green water over topping. The maximum expected wave height from a non-cyclonic storm is less than 3 m at the berth location. The maximum wave height during a cyclone is also about 3m.

4 Environmental, Social & Cultural Impact

4.1 LNG carrier transit

The berth and approach are all through wide expanses of deep water so no issues/impacts are expected.

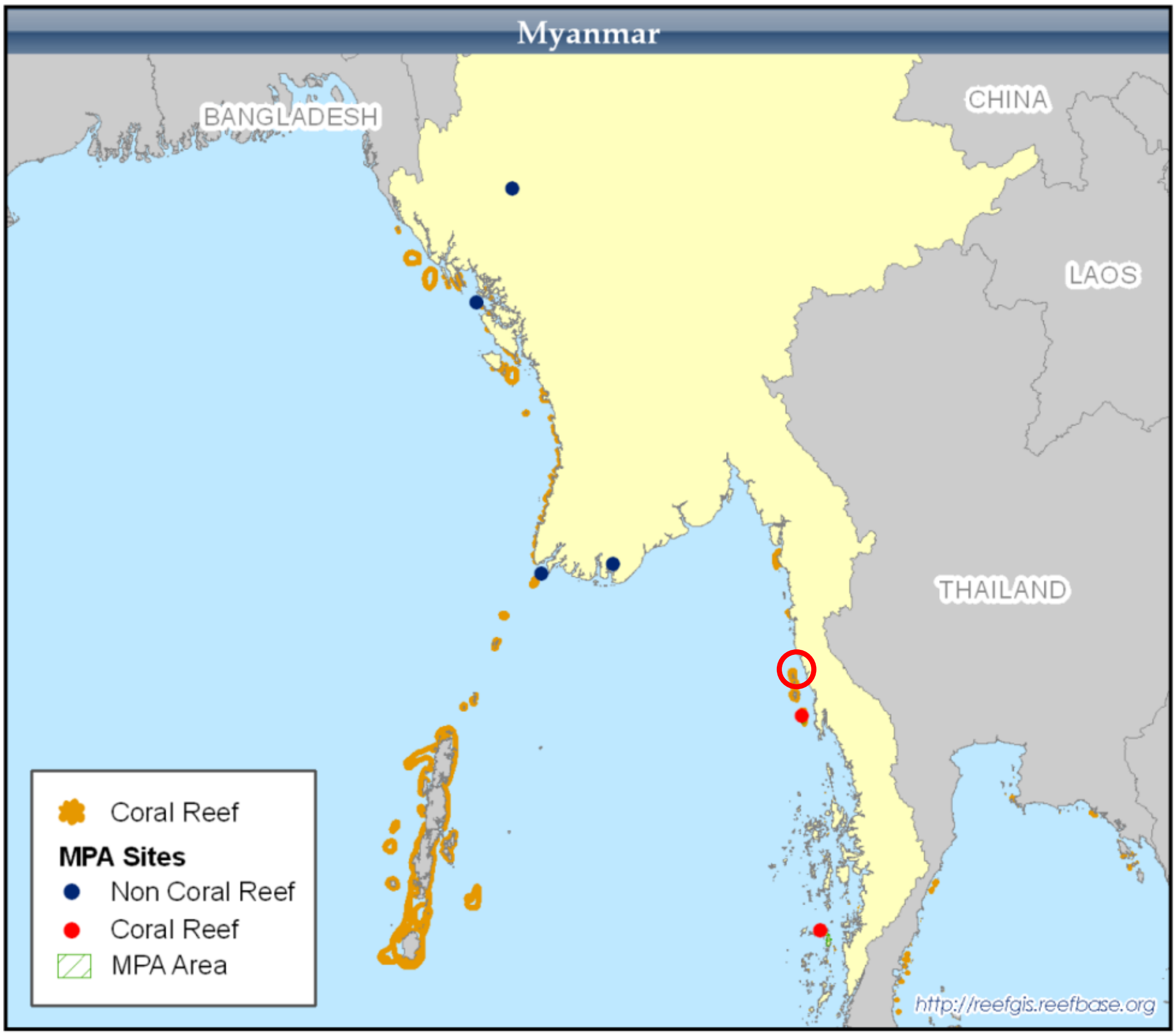
4.2 LNG facility

4.2.1 Environmental

The Muscos Islands are a designated wildlife sanctuary and has been for nealy 100 years. The islands are uninhabited and are home to several environmentally important bird and animal species most notably sea turtles and swiftlets. Local people are present in the summer and harvest turtle eggs and swiftlet nests which are edible. No tourism is currently allowed but some unofficial visits are made. The environmental sensitivity appears to reduce slightly from south to north.

Coral is present in this area, but the exact location and extent of the coral is unknown. It appears to be limited to coastal regions around the islands of Heize Bok. The FSRU is sited 3-4 km from this area in deep water so impact on coral is probably negligible. This should be confirmed early on if location 5 is selected for development. The subsea pipeline to shore is anticiapted to join with the existing gas pipeline wayleaves for the offshore fields so no additional damage would be expected.

Figure 12 – Coral [2]Distribution in Myanmar



FSRUs use seawater to vaporise the LNG. This water is returned cooler and containing biocide into the local sea and would potentially damage coral. However, the berth is in deep water a significant distance from land so water recirculation is probably not an issue. The biocide required will also damage the local ecology which would affect any local fishing. The area around Dawei, 60 km to the south, is an important fishery in Myanmar primarily for dried fish, dried prawns, dried shrimp and shrimp paste. It is unclear how far north this fishery stretches. The extent of damage to marine life will be highly localised.

4.2.2 Social & Cultural

The jetty/tower yoke morring is in deep water a significant distance from land and the Heize Bok islands appear to be uninhabited. It is doubtful that the FSRU would be visible from the mainland at this distance, therefore no impact on the social and cultural heritage is expected.

Total has had a widespread corporate responsibility programme operating in the local area since 1995. This has provided improved health care, education and some physical infrastructure such as

[2] *Summary Report for MPAs in Myanmar.*

bridges. Microfinance has also been provided to local businesses. On the downside local communities have expressed concerns over the state of the roads and high dust levels caused by oil/gas traffic.

4.2.3 Hazard

The facility is located a sufficient distance from land so no hazard scenarios would impact the local population.

The isolated nature of the facility would make emergency response more difficult potentially increasing individual worker risk. A stand by vessel capable of firefighting could substantially mitigate this risk.

4.3 Pipeline

A new subsea gas pipeline is required. This would connect into the existing natural gas pipeline infrastructure, assumed to be at or near Total's existing site. Beyond this there are multiple options including:

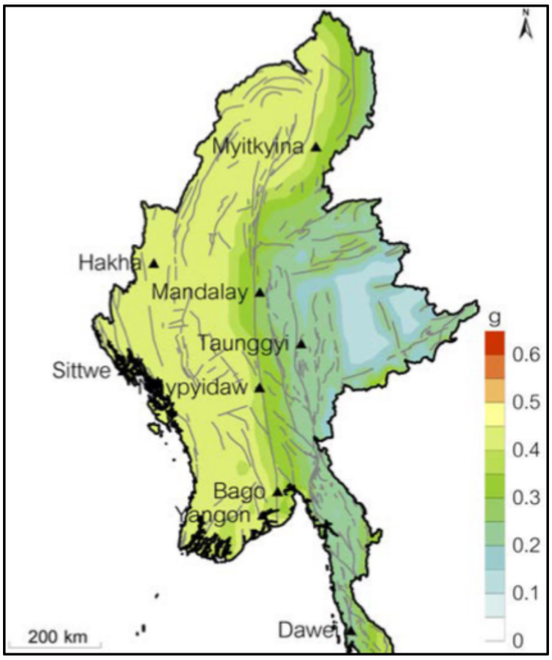
- Connection to the existing 20 inch pipeline to Yangon.
- Connecting to a new 30 inch pipeline to Yangon in the same wayleave.
- Connecting to the existing pipeline to Rachaburi in Thailand.
- Generating power near Kanbauk and transmitting this via the proposed north south interconnector between Yangon and Dawei.

5 Geology

Earthquakes run along the Sagaing plate boundary. The Sagaing Fault is a major strike-slip structure that cuts through the centre of Myanmar broadly dividing the country into a western half including Locations 1 and 2 moving north with the Indian plate, and an eastern half including Location 3 attached to the Eurasian plate. The Indian plate continues to move north at about 35 mm per year putting a sideways pressure onto the Eurasian plate in Myanmar.

This far south the Sagaing Fault has doglegged to be further offshore and is significantly weaker. The land directly to the east of location 5 has a peak ground acceleration of about 0.2g, Figure 13. There have been recorded earthquakes in the area of Location 5 but significantly further offshore. All these were of Magnitude 4 – 5.

Figure 13 – Geological faults in Myanmar

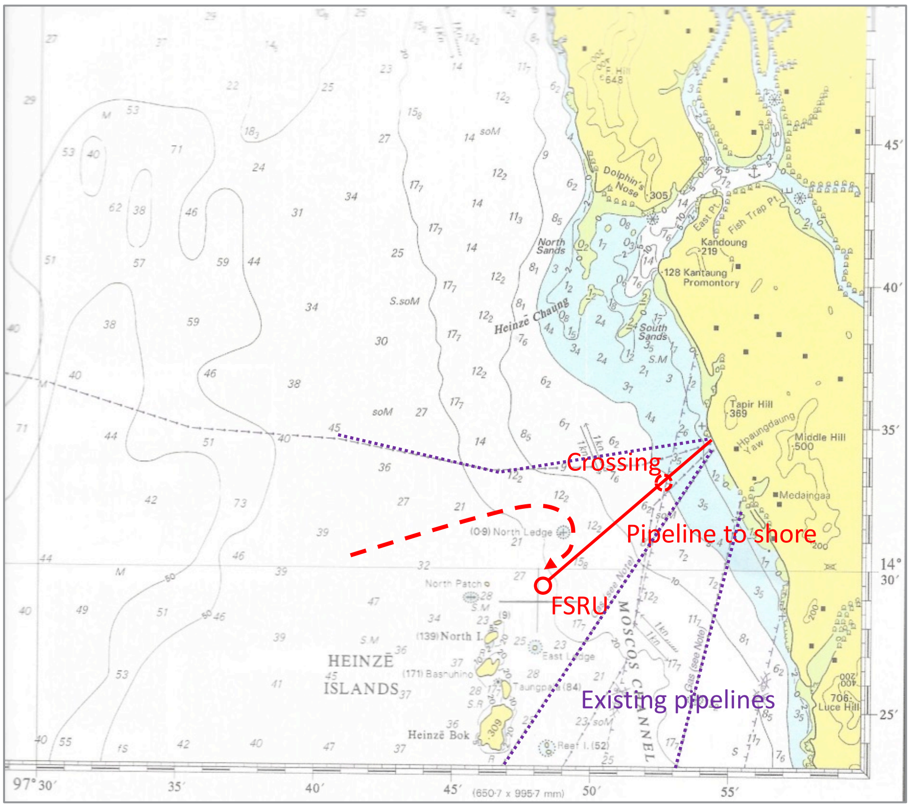


6 Navigation and marine issues

6.1 Navigation routes

UK Admiralty Chart No. 826, shows the area around the proposed berth. The water depth is 26 m and therefore appropriate for LNG carriers which would approach initially from the west before turning about 2 nm northwest of the berth and approaching the jetty from the north west. All manoeuvres would be in water of sufficient depth so no dredging will be required.

Figure 14 – Navigation route



No specific details of low visibility events have been found in public domain documents. Snow only occurs in the northern inland parts of Myanmar so is not considered a problem.

6.2 Jetty Length

An island berth or tower yoke mooring is suggested. If a jetty is selected the vessel bows would be positioned towards the west south west. There is no trestle from the jetty head to shore.

6.3 Marine traffic

Location 5 is close to the proposed port at Dawei but there are no details of the number of movements or type of ship that may use it. Consultations are required with Myanmar Port Authority to determine traffic levels and whether ships regularly transverse this area. Marine traffic levels are assumed to be light.

6.4 Towage

There are no tugs available in the area. Port services such as tugs would therefore have to be purchased or brought in from another location, for example Kyak Phyu or Malaysia/Singapore.

6.5 Port Rules

There are no known port rules for location 5.

7 Access to gas pipelines

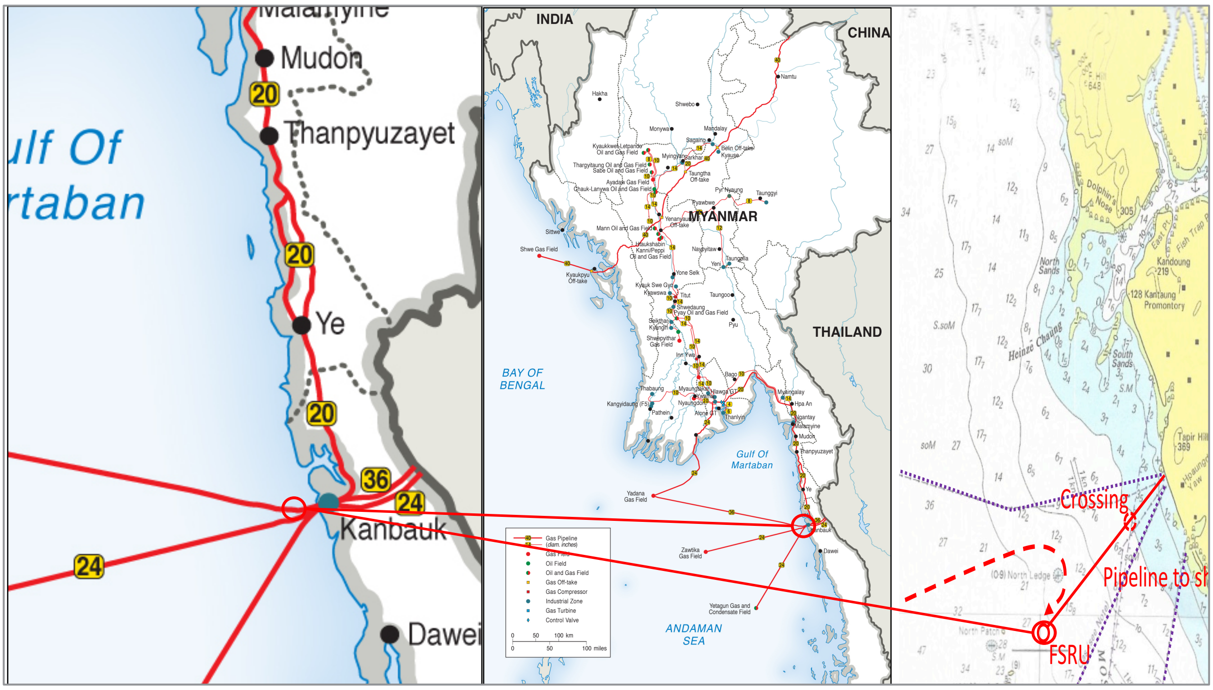
The purpose of this section is to provide an analysis of the issues concerning access to Myanmar's high-pressure gas pipeline network, focussing on costs in the following areas.

- Overview of the location and associated issues.
- Review of offshore gas transmission pipeline costs.
- Review of onshore gas transmission pipeline costs.
- Gas network reinforcement costs.
- Concluding discussion.

7.1 Overview of Location 5 and associated issues

Given the position of Location 5, offshore in the Andamman Sea, just north east of the island of Heize Bok (the northern most island of the Moscos Isalnds) with landfall just the north west of Zadai, a short subsea gas pipeline will be required to connect the site to the shore. The area around Kanbauk is the current landfall location for pipelines from the Yetagun, Yedana and Zawtika fields which are primarily piped to Thailand but also piped north through a 20 inch line to Yangon. Alternatively a direct subsea pipeline connecting to Yangon has also been examined.

Figure 15 – Overview of Location 5 for FSRU



7.2 Review of offshore gas transmission pipeline costs

The length of the offshore gas pipeline from the FSRU berth to landfall in the vicinity of Kanbauk will depend on the choice of landing point for the pipeline and the onshore logistics of connecting to the local gas network. However, given the presence of both offshore and onshore gas pipeline infrastructure, ideally one would expect the new offshore subsea gas pipeline from the FSRU to land in the vicinity of one of the existing landing points. Similarly, given the presence of local high-pressure gas pipelines one would expect to connect to these, even if the existing network needs to be enhanced.

In addition to the above the Project Team have also examind the possibility of a direct subsea pipeline from the FSRU to Yangon, this estimated to be around 265 km.

Figure 16 – Overview of possible offshore pipeline landing point

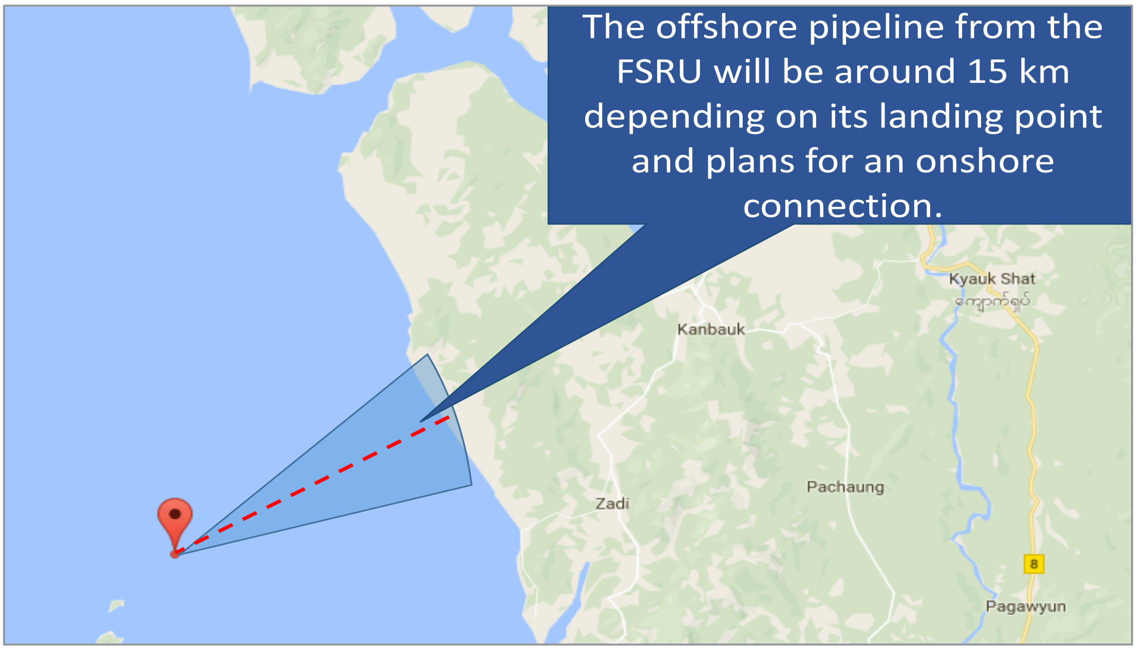


Table 2 – Summary of offshore gas transmission pipeline costs for Sites 5A and 5B

Site description	Offshore gas transmission pipeline	Cost ($ million)
Site 5A (Subsea connection, which will be combined with an onshore pipeline to Yangon)	15 km of 30” offshore gas transmission pipeline at $1.8 million per km	27
Site 5B (Direct subsea pipeline to Yangon)	265 km of 30” subsea gas transmission pipeline at $1.8 million per km.	477

Notes

1. Option 1 involves a short subsea pipeline to shore in combination with a long (540 km) onshore gas pipeline to Yangon to connect to the 20” pipeline in Yangon.
2. Option 2 involves a long subsea pipeline to land onshore in Yangon with a short (30 km) onshore pipeline to connect to the 20” pipeline in Yangon.

7.3 Review of onshore gas transmissions costs

Therefore, when considering the route and cost of the onshore connecting pipeline the Project Team have assumed that at least some of the RLNG will be delivered into the local gas network using the existing ROWs in the area, with the most likely connection being on the 20" pipeline to Yangon.

Figure 17 – Delivery of RLNG from Site 5A into exiating high-pressure gas pipeline network

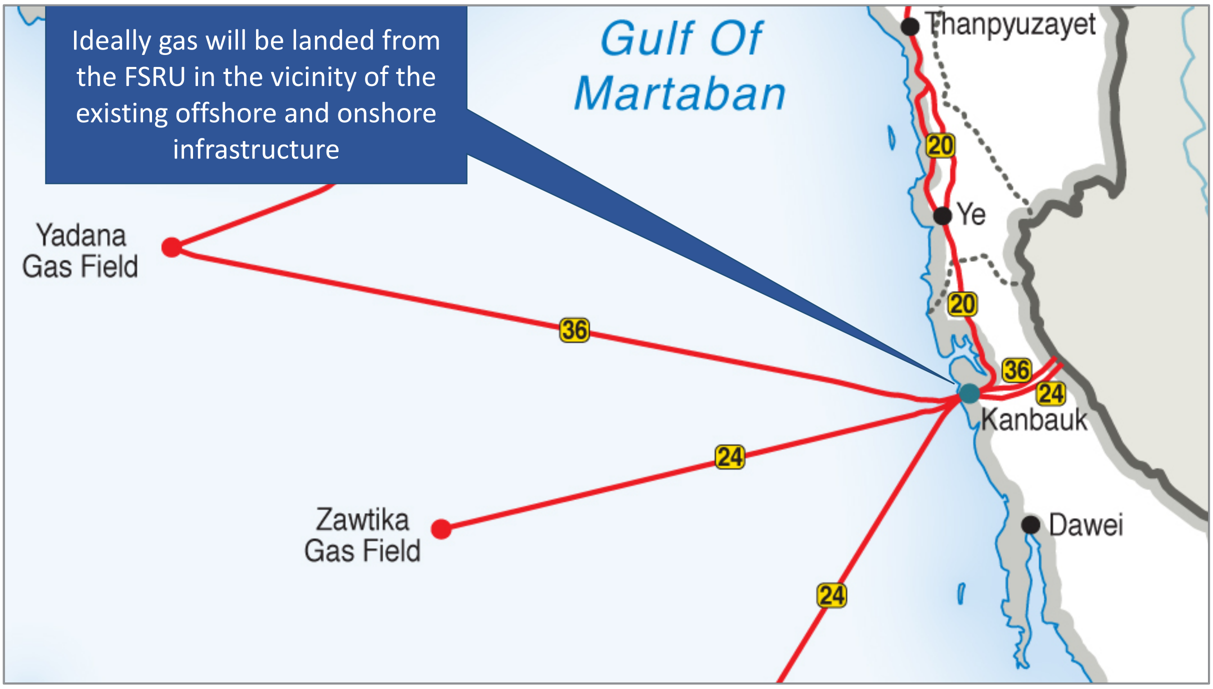


Table 3 – Summary of onshore gas transmission pipeline costs for Sites 5A and 5B

Summary of onshore gas transmission costs for Site 5A		
Site description	**Onshore gas transmission pipeline**	**Cost ($ million)**
Site 5A – (Onshore gas transmission pipeline)	540 km of 30" onshore gas transmission pipeline at $1.2 million per km	648.0
Notes 1. It should be noted that this figure of 540 km is the absolute worst case and assumes that a completely new pipeline is required all the way to central Yangon.		
Summary of onshore gas transmission costs for Site 5B		
Site description	**Onshore gas transmission pipeline**	**Cost ($ million)**
Site 5B – Option 2 (Onshore gas transmission pipeline)	50 km of 30" onshore gas transmission pipeline at $1.2 million per km	60.0
Notes 1. This additional 30 km pipeline is required to connect the subsea pipeline landing near Yangon to the local network.		

7.4 Gas network reinforcement costs

As part of this process the Project Team raised a number of questions with MOGE regarding local reinforcement costs. Whilst not all these questions were answered the Project Team did learn that the 20" pipeline between Yangon and Mawlamyine is in a poor state of repair with a current capapcity of 25 MMCFD, whilst its capacity will increase as MOGE undertakes pipeline repairs and replacements this is very slow at the rate of 10-30 miles per year depending on budget availability.

Therefore the Project Team has made the working assumption that little or no spare capacity will be available in the existing gas network to accommodate new supplies, without significant additional investment in pipeline infrastructure. However, this may not be a problem if the majority of the RLNG is consumed by power generation plant in the vicinity of the subsea landing point. In addition, given that the landing point of the subsea pipeline will be within a relatively short distance of the existing 20" and 24" pipelines supplying Yangon the Project Team have allowed for 50 km onshore connection on the basis it would be technically and strategically benefical to be able to supply even limited quantities of RLNG into Myanmar's gas network.

7.5 Discussion on pipelines

In the light of the above the following table provides a summary of the estimated costs associated with connecting and delivering the RLNG into Myanmar's gas transmission network as follows:

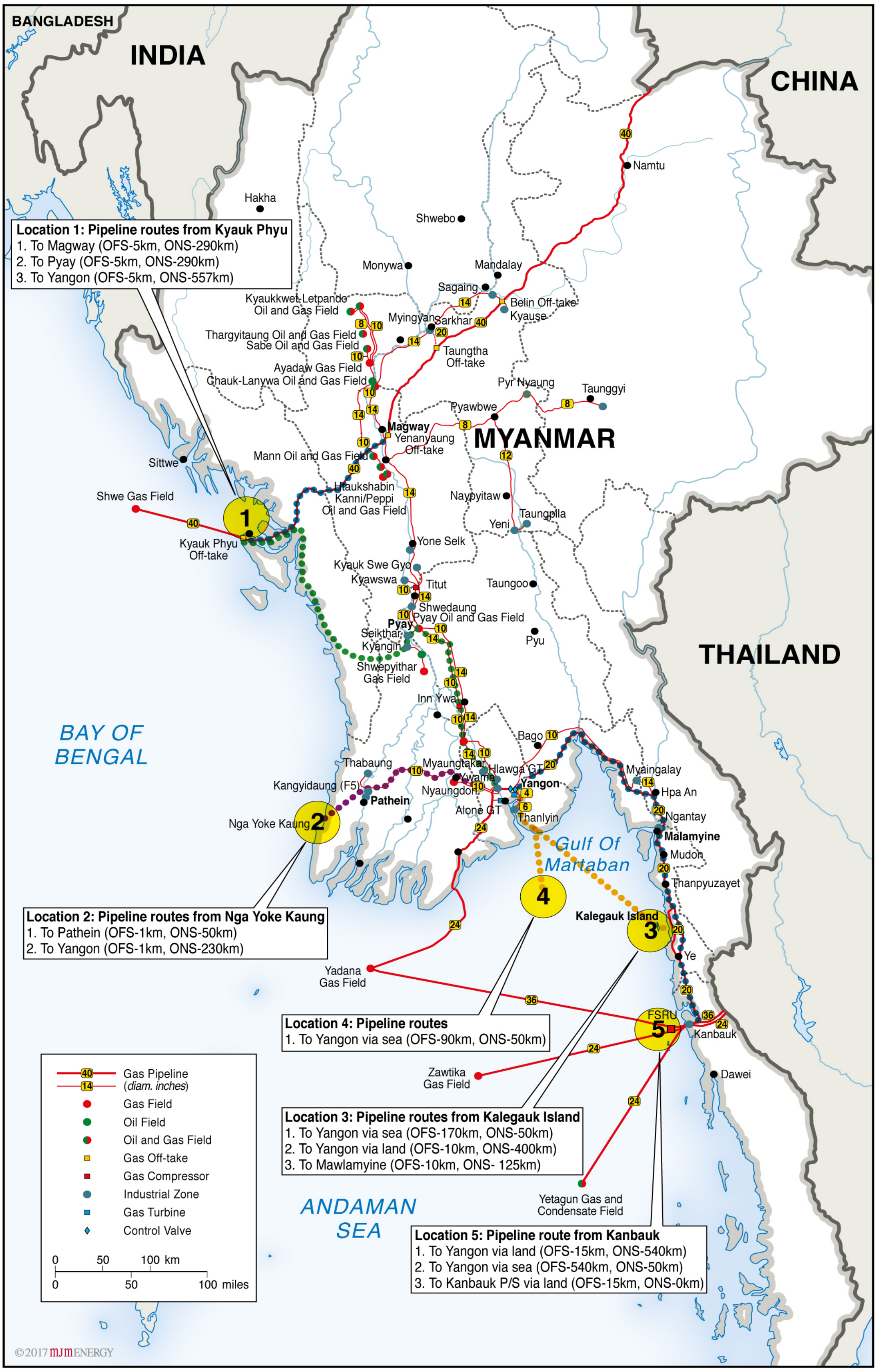
Table 4 – Summary of gas pipeline costs for Sites 5A and 5B

Type of gas transmission infrastructure	Details of pipeline infrastructure	Cost ($ million)
Site 5A (Offshore gas transmission pipeline)	15 km of 30" gas transmission pipeline at $1.8 million per km	27
Site 5A (Onshore gas transmission pipeline)	540 km of 30" gas transmission pipeline at $1.2 million per km	648
Total estimated cost for delivering RLNG into the Myanmar network		675
Type of gas transmission infrastructure	Details of pipeline infrastructure	Cost ($ million)
Site 5B (Offshore gas transmission pipeline)	265 km of 30" gas transmission pipeline at $1.8 million per km	477
Site 5B (Onshore gas transmission pipeline)	50 km of 30" gas transmission pipeline at $1.2 million per km	60
Total estimated cost for delivering RLNG into the Myanmar network		537

7.6 Location 5 in relation to other analysis

Since this report on Location 5 is an addendum to the overall analysis for five possible LNG import locations for Myanmar, the following figure 18 has been included to place the analysis for Location 5 into the wider context.

Figure 18 – Overview of all five potential LNG import locations



8 Infrastructure

There is no infrastructure at the proposed location. An island jetty or tower yoke mooring will need to be created.

Dawei is the closest city, 60 km to the south with a population of 139,000 in 2004 and is the state capital. It has a general hospital and a Technological University offering civil, electrical and mechanical engineering degrees potentially of use to the project. There is also a Dawei University and Computer University but no details have been identified.

The area around Kanbauk is very rural with limited access to education. Healthcare has improved primarily because of Total's CSR programme and a small hospital is sited in Kanbauk as is an ambulance. Note; people farm pigs and cattle which is becoming increasing important as is rubber cultivation. Local rice is of poor quality and only used locally.

There is a large tin mine at Kanbauk which may provide some skills appropriate to oil and gas to complement the existing oil/gas infrastructure. A "training centre" is provided by Total but this appears to be more based on wider community familiarisation than specialist skills training.

Access to electricity around Kanbauk and further to the south via Dawei to Kawthoung is limited.

Total has a private airstrip at its Kanbauk pipeline centre and there is also a small airport at Dawei.

There is a major road from Yangon via Mawlamyine to Dawei. This passes within 30 km (by road) to Kanbauk. Similarly the Dawei to Yangon railway line also passes Kanbauk with a probable station at Eindayaza (12- 15 km by road).

There are plans to construct a deep water port in Dawei. In November 2010, the Myanmar Port Authority signed a deal with Italian-Thai Development to develop the seaport within the Dawei Special Economic Zone. Progress has been slow and local people have reported land ownership and environmental concerns. The port development also includes road and rail links to Thailand (and then on to Cambodia and Vietnam).

9 Results of analysis

The purpose of this section is to present a summary of the results of the analysis, however as previously highlighted, the broader context for this analysis and in particular the methodology used by the Project Team is contained in the main report.

Key ares covered in this section include the following:

- The traffic light scores.
- Technology and site selection.

9.1 The traffic light scores

This study is necessarily limited within the TOR, and cannot provide a full assessment of the feasibility of LNG importation at the potential sites. This study is therefore a screening activity to the full site selection process and is only aimed at highlighting major issues that might prevent a later, more detailed approach being successful. As study work and data are not available in detail at this stage, a qualitative ranking system is acceptable. The primary ranking system is based on the familiar worldwide concept of traffic lights, which provide a visually clear means of recording the site selection process. Green is go or in this case good, red is stop or bad. To improve granularity both yellow and orange are used as intermediary points, with yellow being closer to green and orange being closer to red. Qualitative by definition means comparison in a loose way between sites and international norms, and not specific scores against attributes to form a numerical conclusion.

The traffic light approach is summarised in the figure below.

Figure 19 – The traffic light approach

Colour	Implication
	A red light indicates that the site has an issue which may prevent the site being cost effectively developed as an LNG facility. One red light may not be sufficient to stop the project, but will impact cost and/or schedule in a major way. Multiple red lights indicates the project is not viable
	An orange light indicates that the site has significant issues that will impact either capital expenditure or schedule
	A yellow light indicates that the site has some issues but these are anticipated to be corrected with only minor capital expenditure or short schedule delays
	A green light indicates that the site has no significant issues and could reflect worldwide best practice in the LNG industry

The traffic light scoring for Location 5 is shown in the following table.

Table 5 – Location 5 traffic light scoring

		Near shore Site 5						
		Onshore terminal	FSRU on Jetty	Midwater FSRU	Deepwater FSRU	FSU on Jetty	LNGRV in Deepwater	GBS
GETTING LNG TO THE TERMINAL								
1	How much dredging is required to create a channel to the terminal?							
2	What Jetty length is required to be able to moor a near shore FSRU/LNG Carrier?							
OR	What Subsea pipeline length is required to connect a midwater or deepwater FSRU or LNGRV							
3	How much marine traffic is currently being experienced?							
4	Are there local visibility limitations?							
5	Are there any other factors that limit the site?							
STORING LNG								
1	What is the wave environment like?							
2	How variable is the wind/wave environment?							
3	Might the LNG facility be impacted by extreme weather?							
4	Will the site cause any destruction or exclusion to environmentally sensitive areas?							
5	Will the site cause any destruction or exclusion to culturally and historically sensitive areas?							
6	Will the site development and operation impact the local community in any detrimental way?							
7	Will the site development and operation increase the risk of harm/fatality to the local community?							
8	Are there risks to the LNG facility from geological events?							
GETTING GAS TO MARKET		Onshore pipeline						
1	Can LNG be vaporised in sufficient volume and in an environmentally acceptable way?							
2	What is the onshore pipeline length?							
3	What is the difficulty in laying the onshore pipeline?							
4	What is the offshore pipeline length?							
5	What is the difficulty in laying the offshore pipeline?							
LOCAL INFRASTRUCTURE								
1	Is there sufficient towage available to berth the LNG carrier?							
2	Is there currently any port rules and infrastructure appropriate to hydrocarbon importation at the proposed LNG site?							
3	Is there sufficient infrastructure to accommodate workers and their families, expatriates and vendor personnel?							
4	Is there emergency response and Health care capability?							
5	Education and Skills?							
6	Is there access to a major port with connecting roads?							
7	Is there access to an international airport with road/rail links?							
8	How adequate is the marine infrastructure?							

9.2 Technology & site selection

9.2.1 Site selection

From a marine persopective this is a very good location. The downside of this location is its remoteness from Yangon. A pipeline connection would be long and expensive. The site's remoteness is also noticed in the degree of infrastructure available despite investment by Total and others.

This site is primarily suited to importing gas to Thailand. There are positives to this in that the cost of the development could be shared across the two projects and that utilisation of the asset would be high as Thai gas flows are considerable. In terms of cost sharing most of the costs for this site are in the onshore connecting pipeline to Yangon which would not be shared.

Lower cost options for transmitting energy to Yangon need to be explored. These include:

- Generating power at Kanbuack and transmitting this via a new 240 or 500 kV line to Yangon which is being proposed for 2021 and appears to funded by the Asian Develoment Bank.
- Lay a subsea pipeline from the FSRU direct to Yangon.

9.2.2 Viable technology options (A jetty mounted FSRU)

This location is sufficiently benign that some form of island jetty could be used despite additional costs from the depth of the water (26 m rather than the normal 15 m). A tower yoke mooring would offer greater flexibility given the moderate deviations in wave directions at the site.

9.3 Analysis of Location 5 using the Site Prioritisation Tool (SPT)

9.3.1 Site 5A

Having identified the viable technology options for Site 5, the Project Team have undertaken an analysis of Site 5 based on the main parameters.

- ***FSRU details*** – Purchase and conversion of a 10 year old, 157,000 m^3 Seri B series LNG carrier (chartered by Total to serve Yemen LNG) moored in 26 m of water on a tower yoke mooring.
- ***Use of breakwater*** – None.
- ***Dredging*** – No dredging is required.
- ***FSRU export rates*** – Gas from the FSRU is vaporised at an average rate of 680 mmscfd (85% of 800 mmscfd) using an open loop sea water system with 350 mmscfd (58%) going to Thailand and 250 mmscfd (of a potential 450 mmscfd) to Yangon.
- ***Pipelines (Offshore)*** – The RLNG from the FSRU is injected into a new 15 km, shared 30" subsea pipeline (MOEE 56.25%, PTT et al 43.75%) which makes landfall adjacent to the existing pipelines from the offshore fields.
- ***Pipelines (Onshore)*** – A long, 540 km 30" onshore pipeline wholly owned by MOEE which runs parallel to the existing (but compromised) 20 inch pipeline which connects the gas to the existing network to the east of Yangon.
- ***Infrastructure*** – none.

Based on the above parameters and the general analysis of Site 5A and its associated metocean, technical and environmental parameters the Project Team undertook further analysis. The SPT software is not suitable for directly developing the required costs based on revenue and cost sharing so the model has been manipulated manually to give the following results.

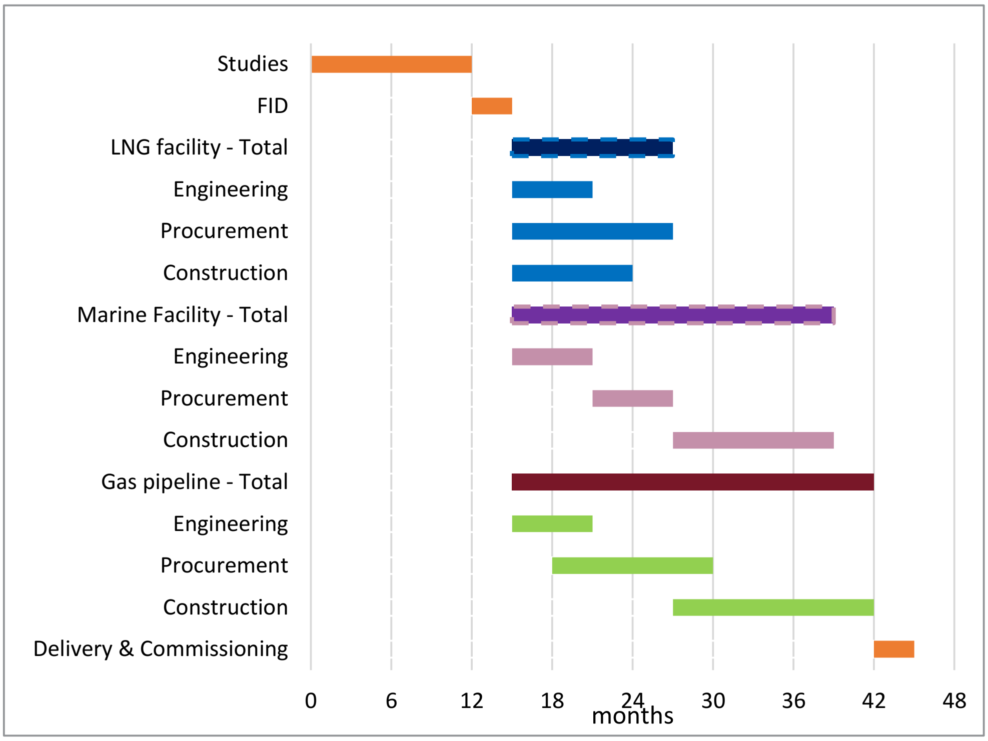
Table 6 – Summary data inputs for the analysis for Site 5A

PHYSICAL PARAMETRS:		Data
LNG facility size		Conversion of a 10 year old, 157,000 m^3 Seri B series LNG carrier
LNG facility type		FSRU
Location		Mid water (26 m)
Ownership		Owned (MOGE and PTT/Total)
Geology		<0.4 g acceleration
Jetty length		Tower yoke mooring
Breakwater		None
Dredging		None
Gas pipeline		15 km of 30" offshore pipeline (co-owned with PTT/Total) + 540 km of 30" onshore
Design LNG ship		145,000 m^3
FINANCIAL AND ECONOMIC PARAMETERS:		Data
Project start year		2017
LNG import term		10 years
Discount rate		10%
Purchase and conversion cost		147 US$ million to MOGE (115 US$ million to PTT/Total)
Fuel oil cost		470 US$/ton 380 cs Singapore
Electricity cost		0.05 US$/kWh (70 kyats/kWh)
Tug cost		US$ 15,000/day each (4 days mobilisation)
CAPITAL COSTS: Description of key areas		Value
FSRU		147 US$ million (MOGE share)
Tower Yoke		45 US$ million (MOGE share)
Breakwater		0 US$ million
Dredging		0 US$ million
Gas pipeline		663 US$ million (MOGE share)
Local infrastructure		0 US$ million
TOTAL		855 US$ million (MOGE share)
OPERATING COSTS: Description of key areas		**Operating costs**
FSRU lease		0 US$ million pa
Fixed costs	Labour	1.7 US$ million pa (MOGE share)
	Insurance	1.1 US$ million pa (MOGE share)
	Inspection and maintenance	1.1 US$ million pa (MOGE share)
	Supporting infrastructure	1.2 US$ million pa (MOGE share)
Variable costs	Fuel oil	4.4 US$ million pa (MOGE share)
	Electricity	0 US$ million pa (MOGE share)
	Towage	5.5 US$ million pa (MOGE share)
TOTAL		15.0 US$ million pa (MOGE share)

9.3.1.1 Schedule to implementation

The following design/construction schedule has been estimated with a total completion time of 45 months. The gas pipeline is the longest schedule activity. The conversion of the LNGC to an FSRU allows for a short LNG schedule.

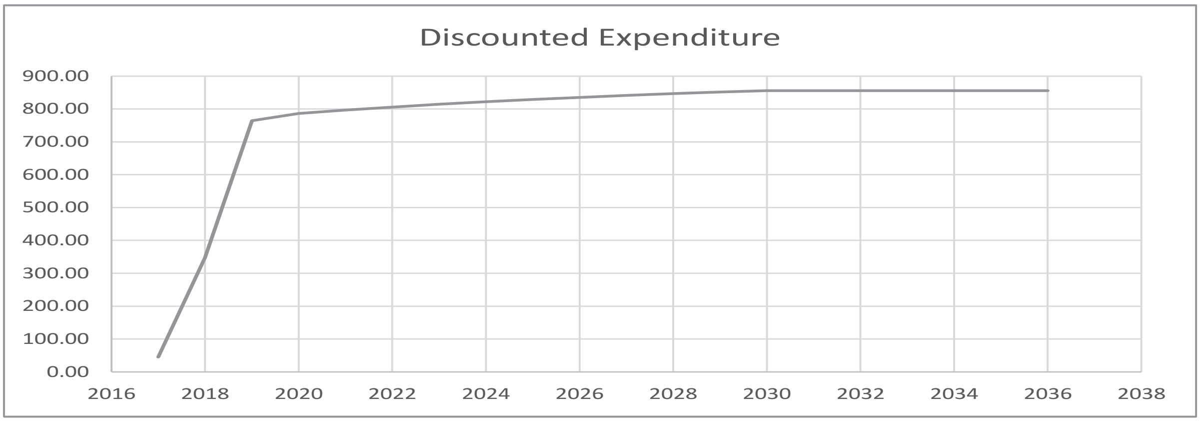
Figure 20 – Estimated design/construction schedule for Site 5A



9.3.1.2 Discounted Expenditure

The above parameters have been combined into a discounted expenditure figure of: 808 US$ million, which is shown in the following chart.

Figure 21 – Breakdown of the discounted expenditure for Site 5A



9.3.2 Site 5B - Subsea pipeline to Yangon

Location 3 demonstrated that costs could be reduced by replacing the long new onshore gas pipeline with a shorter, more direct subsea pipeline. A similar analysis has been performed here to determine whether cost reductions are possible.

- ***FSRU details*** – Purchase and conversion of a 10 year old, 157,000 m^3 Seri B series LNG carrier (chartered by Total to serve Yemen LNG) moored in 26 m of water on a tower yoke mooring.
- ***Use of breakwater*** – None.
- ***Dredging*** – No dredging is required.
- ***FSRU export rates*** – Gas from the FSRU is vaporised at an average rate of 680 mmscfd (85% of 800 mmscfd) using an open loop sea water system with 350 mmscfd (58%) going to Thailand and 250 mmscfd (of a potential 450 mmscfd) to Yangon.
- ***Pipelines (Offshore)*** – The RLNG from the FSRU is injected into two new subsea pipleines. One connecting into the existing Myanamar-Thailand lines at Kanbauck (wholly funded by PTT) and the second, a 265 km, 30" subsea pipeline making landfall to the south east of Yangon wholly funded by MOEE or private investors.
- ***Pipelines (Onshore)*** – A short, 50 km 30" onshore pipeline connects the subsea line to the existing network and to existing and future CCGT power plants to the south east of Yangon.
- ***Infrastructure*** – none.

Based on the above parameters and the general analysis of Site 5B and its associated metocean, technical and environmental parameters the Project Team undertook further analysis. The SPT software is not suitable for directly developing the required costs based on revenue and cost sharing so the model has been manipulated manually to give the following results.

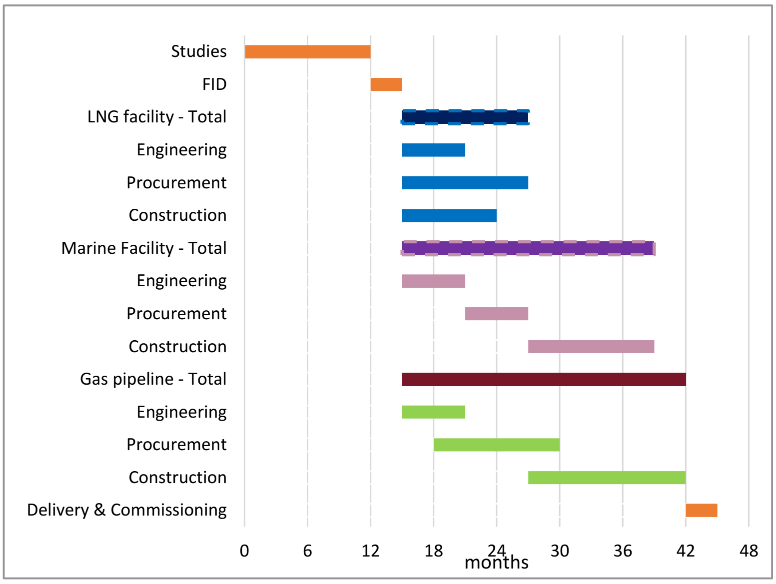
Table 7 – Summary data inputs for the analysis for Site 5B

PHYSICAL PARAMETRS:		Data
LNG facility size		Conversion of a 10 year old, 157,000 m^3 Seri B series LNG carrier
LNG facility type		FSRU
Location		Mid water (26 m)
Ownership		Owned (MOGE and PTT/Total)
Geology		<0.4 g acceleration
Jetty length		Tower yoke mooring
Breakwater		None
Dredging		None
Gas pipeline		265 km of 24" offshore pipeline 50 km of 24" onshore (wholly owned by MOGE)
Design LNG ship		145,000 m^3
FINANCIAL AND ECONOMIC PARAMETERS:		Data
Project start year		2017
LNG import term		10 years
Discount rate		10%
Purchase and conversion cost		147 US$ million to MOGE (115 US$ million to PTT/Total)
Fuel oil cost		470 US$/ton 380 cs Singapore
Electricity cost		0.05 US$/kWh (70 kyats/kWh)
Tug cost		US$ 15,000/day each (4 days mobilisation)
CAPITAL COSTS: Description of key areas		Value
FSRU		147 US$ million (MOGE share)
Tower Yoke		45 US$ million (MOGE share)
Breakwater		0 US$ million
Dredging		0 US$ million
Gas pipeline		448 US$ million (MOGE share)
Local infrastructure		0 US$ million
TOTAL		640 US$ million (MOGE share)
OPERATING COSTS: Description of key areas		**Operating costs**
FSRU lease		0 US$ million pa
Fixed costs	Labour	1.7 US$ million pa (MOGE share)
	Insurance	1.1 US$ million pa (MOGE share)
	Inspection and maintenance	1.1 US$ million pa (MOGE share)
	Supporting infrastructure	1.2 US$ million pa (MOGE share)
Variable costs	Fuel oil	4.4 US$ million pa (MOGE share)
	Electricity	0 US$ million pa (MOGE share)
	Towage	5.5 US$ million pa (MOGE share)
TOTAL		15.0 US$ million pa (MOGE share)

9.3.2.1 Schedule to implementation

The following design/construction schedule has been estimated with a total completion time of 45 months. The gas pipeline is the longest schedule activity. The conversion of the LNGC to an FSRU allows for a short LNG schedule.

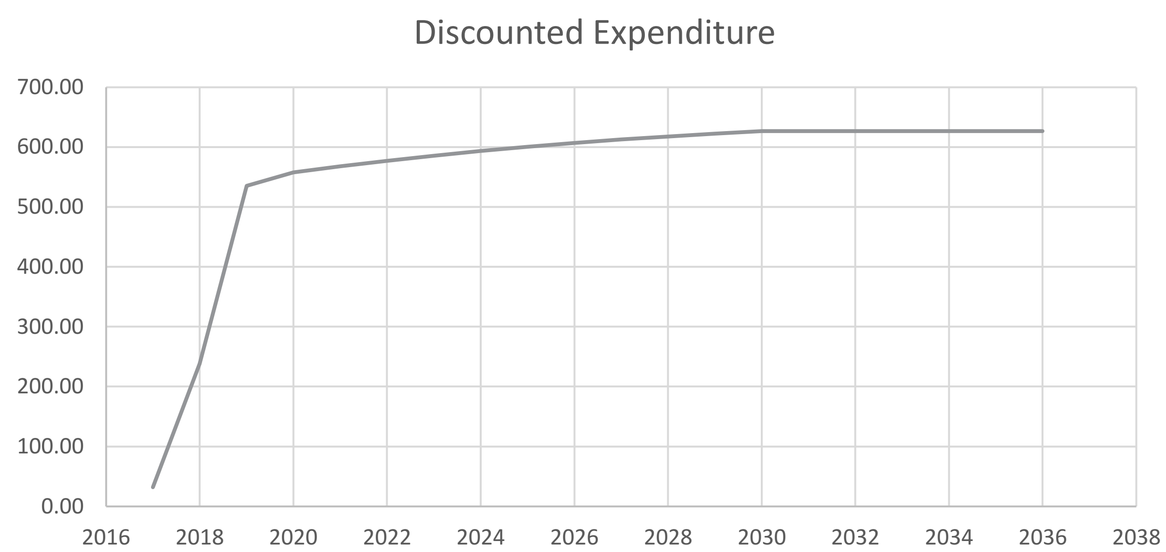
Figure 22 – Estimated design/construction schedule for Site 5B



9.3.2.2 Discounted Expenditure

The above parameters have been combined into a discounted expenditure figure of: 621 US$ million, which is shown in the following chart.

Figure 23 – Breakdown of the discounted expenditure for Site 5B



9.3.3 Site 5C – CCGT at Kanbauck

Total have proposed building a 450 MW power plant at Kanbauck and then back feeding the power generated to Yangon via a new 240 kV transmission cable that is proposed to run down the coast of Myanmar through Mon State and via Mawlamyine. The financing of this transmission cable is under advanced discussion with the Asian Development Bank. The line may need to be upgraded to 500kV.

The Project Team have undertaken an alternative analysis of Site 5C based on the following main parameters.

- ***FSRU details*** – Purchase and conversion of a 10 year old, 157,000 m^3 Seri B series LNG carrier (chartered by Total to serve Yemen LNG) moored in 26 m of water on a tower yoke mooring.
- ***Use of breakwater*** – None.
- ***Dredging*** – No dredging is required.
- ***FSRU export rates*** – Gas from the FSRU is vaporised at an average rate of 420 mmscfd (84% of 500 mmscfd) using an open loop sea water system with 350 mmscfd (83%) going to Thailand and 62 mmscfd (15%) to a CCGT power plant at Kanbauk.
- ***Pipelines (Offshore)*** – The RLNG from the FSRU is injected into a new 15 km, 30" subsea pipeline which makes landfall adjacent to the existing pipelines from the offshore fields.
- ***Pipelines (Onshore)*** – A short, 15 km 30" onshore pipeline connects the gas to the existing Total pipeline hub. Here the PTT gas will continue through existing pipelines to Thailand and 62 mmscfd will be consumed in a new 450 MW CCGT (the cost of the CCGT from Siemens is ignored as it will be required for all the other projects but at Yangon).
- ***Infrastructure*** – Power from the CCGT will be exported via the proposed new transmission line extension between Yangon and Dawei. This line will need to be upgraded from 230 kV to 500 kV for this new electrical supply. This upgrade cost is assumed to be paid for by this project.

Note – This site will not provide the same level of power availaibility as the other options. This schemes provides 62 mmscfd of gas sufficient for 450 MW of generation. The other schemes deliver up to 420 mmscfd – seven times as much.

Based on the above parameters and the general analysis of Site 5C and its associated metocean, technical and environmental parameters the Project Team undertook further analysis. The SPT software is not suitable for directly developing the required costs based on revenue and cost sharing so the model has been manipulated manually to give the following results.

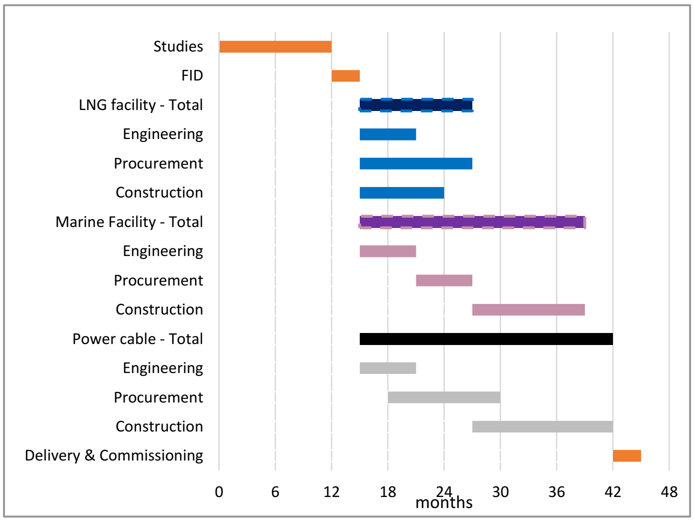
Table 8 – Summary data inputs for the analysis for Site 5C

PHYSICAL PARAMETRS:		Data
LNG facility size		Conversion of a 10 year old, 157,000 m^3 Seri B series LNG carrier
LNG facility type		FSRU
Location		Mid water (26 m)
Ownership		Owned (MOGE and PTT/Total)
Geology		<0.4 g acceleration
Jetty length		Tower yoke mooring
Breakwater		None
Dredging		None
Gas pipeline		15 km of 30" offshore pipeline (co-owned with PTT/Total) + 15 km of 30" onshore
Design LNG ship		145,000 m^3
FINANCIAL AND ECONOMIC PARAMETERS:		Data
Project start year		2017
LNG import term		10 years
Discount rate		10%
Purchase and conversion cost		147 US$ million to MOGE (115 US$ million to PTT/Total)
Fuel oil cost		470 US$/ton 380 cs Singapore
Electricity cost		0.05 US$/kWh (70 kyats/kWh)
Tug cost		US$ 15,000/day each (4 days mobilisation)
CAPITAL COSTS: Description of key areas		Value
FSRU		38 US$ million (MOGE share)
Tower Yoke		12 US$ million (MOGE share)
Breakwater		0 US$ million
Dredging		0 US$ million
Gas pipeline		19 US$ million (MOGE share)
Local infrastructure		270 US$ million (upgrade of cable to 500 kV)
TOTAL		339 US$ million (MOGE share)
OPERATING COSTS: Description of key areas		**Operating costs**
FSRU lease		0 US$ million pa
Fixed costs	Labour	0.5 US$ million pa (MOGE share)
	Insurance	0.3 US$ million pa (MOGE share)
	Inspection and maintenance	0.3 US$ million pa (MOGE share)
	Supporting infrastructure	0.3 US$ million pa (MOGE share)
Variable costs	Fuel oil	1.1 US$ million pa (MOGE share)
	Electricity	0 US$ million pa (MOGE share)
	Towage	1.3 US$ million pa (MOGE share)
TOTAL		3.8 US$ million pa (MOGE share)

9.3.3.1 Schedule to implementation

Discussions with MOEE have suggested that the installation schedule for a high voltage power distriburtion system is similar to that for a gas pipeline. On this basis the design/construction schedule has been estimated with a total completion time of 45 months. The power cable is the longest schedule activity. The conversion of the LNGC to an FSRU allows for a short LNG schedule.

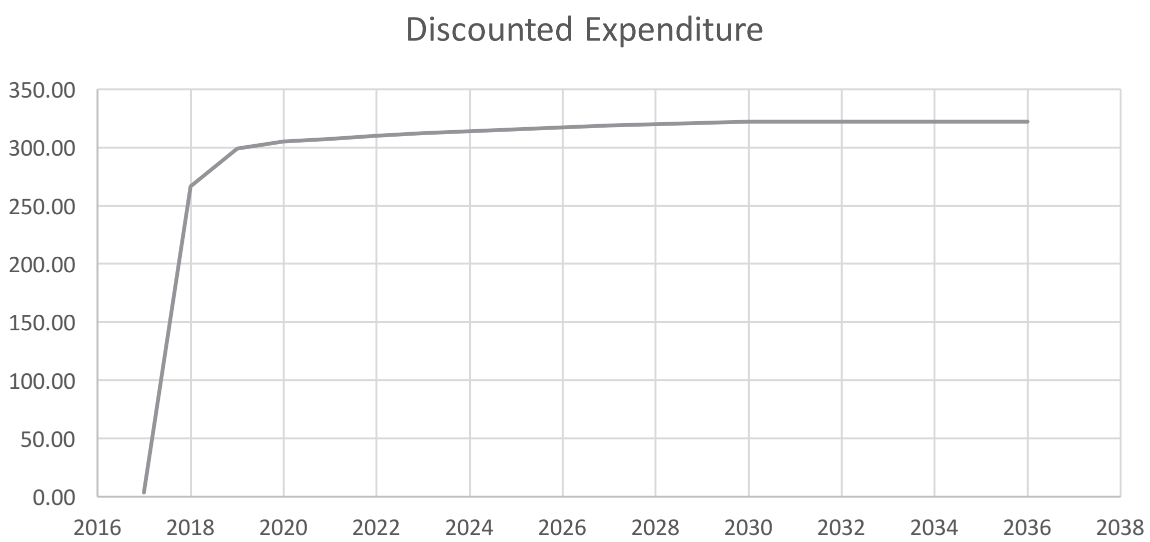
Figure 24 – Estimated design/construction schedule for Site 5C



9.3.3.2 Discounted Expenditure

The above parameters have been combined into a discounted expenditure figure of: 321 US$ million, which is shown in the following chart.

Figure 25 – Breakdown of the discounted expenditure for Site 5C



10 Conclusions and recommendations

10.1 Conclusions

Key points to note in relation to Location 5 are as follows:

- ***Cost Sharing*** – The offshore costs are shared with PTT/Total reducing the cost to MOGE, although the high cost of a connecting pipeline to Yangon reduces this benefit.
- ***Marine perspective*** – A tower yoke mooring is proposed in 26 m of sheltered water behind islands of the Moscos Archipeligo.
- ***Geographical location*** – This site is a long distance from the major power consumption centre of Yangon. The presence of the existing offshore/gas pipeline centre is helpful.
- ***Pipeline connections*** – The existing onshore pipeline from Kanbauk to Yangon is in poor condition so a new 540 km pipeline in the same wayleave is required. This is expensive and the rate determining step. A shorter subsea 265 km pipeline is also an option.
- ***Local Power Generation*** – Total and Siemens are proposing a 450 MW CCGT power plant at Kanbauk and an upgrade of the proposed Yangon – Dawei electricity cable. This is a low cost option for Myanmar but provides only a limited amount of power and does not provide any gas to Yangon. However attractive it may be this is a different project.

Please find below a summary of the results produced by the SPT model.

Table 9 – Summary of discounted expenditure analysis for Location 5

Site	Schedule (Months)	Capital Investment (US$ million)	Operating Expense (US$ million per annum)	Discounted Expenditure (DEX) (US$ million)
Site 5A	45	855	15	808
Site 5B	45	640	15	621
Site 5C	45	339	3.8	321

In conclusion then, Location 5 only makes sense if it will be used as a shared terminal with Thailand because, as earlier studies have shown, other sites that are just as viable are closer to Yangon (i.e. as a Myanmar only terminal). For example Location 3 is as good as Location 5 but 100 km closer to Yangon.

10.2 Recommendations

As previously stated this analysis has been relatively high-level with a minimal engagement with the authorities in Myanmar apart from MOGE. Therefore if Location 5 is going to be progressed further the following activities should take place.

- ***Engagement with the appropriate marine authorities*** – It will be important to take the time to enage with the MPA (Myamar Port Authority), the Myanmar Navy and other stakeholders involved in marine activities in order to have a fuller understanding of developing Location 5.
- ***Offshore gas pipeline study –*** As one would expect Location 5 is sensitive to subsea pipeline construction costs in particular the length and landing point of the subsea pipeline. Therefore, given the disparity between MOGE's initial offshore pipeline costs and international benchmarks we recommend that MOGE undertake a feasibility study of the offshore subsea pipeline costs from Location 5 to Yangon.

- ***Onshore gas pipeline study –*** Whilst the proposed length of the onshore gas pipeline may vary from the proposed 50km by +/- 20km the overall impact on the project will not be huge. However, it will be important to have a good understanding of the condition of the local gas transmission network in Yangon and its ability to absorb additional RLNG not consumed in the local power stations. In addition, laying onshore gas transmission pipelines in the vicinity of large congested city such as Yangon can be complex and expensive. Therefore, we recommend that MOGE undertake a commercial and operational study of the proposed connecting pipeline to establish a more accurate estimate of its cost.