Challenges for Marine LNG Import to Unlock Gas to Power+ across Africa

Gary Mocke

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Outline

- Advisian LNG Experience
- Africa LNG Market
- LNG Terminal Infrastructure
- Terminal Performance Indicators
- Terminal Siting & Design Approach
- Case Studies
Advisian LNG Experience

Africa LNG Market

LNG Terminal Infrastructure

Terminal Performance Indicators

Terminal Siting & Design Approach

Case Studies
Capability Overview

World-class capabilities
Advisian/WorleyParsons has executed more than 50% of the world-wide nearshore Liquefied Natural Gas (LNG) regasification projects (planned and in operation), making it the world leader as an independent engineering service provider to the FSRU and nearshore regasification market.

Specific areas of expertise include:
- LNG regasification technology studies
- Hull integration of topside process equipment
- Selection of candidate LNG carriers for conversion into FSRUs, FSUs
- Vessel hydrodynamic analysis for design of mooring systems
- Nearshore mooring design and breakwater design
- Coastal modelling, including sediment transportation dredging and
- Side-by-side and tandem offloading technology selection
- Hydrodynamic analysis of vessel interaction between floating LNG
- Regasification vessel and LNG carriers in side-by-side/tandem configuration
- Contracting strategy evaluations
- LNG supply logistics and planning
- Offshore and Onshore pipeline design including shore crossing
- Scoping and supervision of geotechnical, geophysical and metocean studies
- Regasification facility uptime/availability evaluation
- Gas demand and supply studies
- FSRU conversion and new build engineering
World Leader in Near Shore LNG Regasification Development

Centres of Excellence
- Houston
- London
- Melbourne

Project locations
- 1. Cabrillo Port FSRU
- 2. Oceanway
- 3. Jamaica LNG Storage and Regasification
- 4. FSRU Due Dilligence
- 5. Mejillones Bay GNL
- 6. WorleyParsons Marinised Regas Module
- 7. Quantum LNG Metocean Study
- 8. PetroSA FSRU
- 9. Mozambique Nearshore Regas
- 10. Malta FSRU Project
- 11. Egypt FSRU Project
- 12. Cyprus FSRU Project
- 13. Bahrain LNG Import Terminal Project
- 14. India East Coast Floating LNG Regas
- 15. Kakinada FSRU
- 16. FSRU Economics India
- 17. Pre-Feasibility 1MDB
- 18. Melaka Jetty Island Regas Terminal (Lekas)
- 19. LNG Import and Regasification Facility with Power Generation
- 20. Bumi Armada FSRU
- 21. Jakarta West Java Bay FRSU
- 22. West Java LNG Import Terminal and Power Plant Feasibility Study
- 23. Bangladesh FSRU
- 24. LNG Import Terminal Feasibility Study
- 25. Philippines FSRU
- 26. LNG Regasification and Storage Study
- 27. Pre-Feasibility Study for Regasification Terminal
Advisian LNG Experience
Africa LNG Market
LNG Terminal Infrastructure
Terminal Performance Indicators
Terminal Siting & Design Approach
Case Studies
Global LNG Outlook

Global demand for gas is expected to increase by 2% a year between 2015 and 2030 while LNG demand is set to rise at twice that rate at 4 to 5%. China and India were two of the fastest growing buyers, increasing their imports by a combined 11.9 million tones of LNG in 2016. This boosted China’s LNG imports in 2016 to 27 MT and India’s to 20 MT.

Total global LNG demand increased following the addition of six new importing countries since 2015: Colombia, Egypt, Jamaica, Jordan, Pakistan and Poland. They brought the number of LNG importers to 35, up from around 10 at the start of this century.

The growth of LNG importers has evolved into helping meet demand when domestic gas markets face supply shortages.

LNG trade also is changing to meet the needs of buyers, including shorter-term and lower-volume contracts with greater degrees of flexibility. Some emerging LNG buyers have more challenging credit ratings than traditional buyers, the report noted.

From 2020 to 2030 most new LNG demand growth will be driven by policy, floating storage regasification units (FSRUs), replacing declining domestic gas production, small scale LNG and transport.


Natural gas is the fastest growing fossil fuel globally, benefiting from its flexibility of use in multiple demand segments, its competitive economics and its relatively lower emissions profile. LNG is well positioned to account for a substantial share of this growth, as many markets do not have indigenous or adjacent natural gas resources which can be delivered by pipeline.

Increased action around the world to reduce the carbon intensity of economic activity provides additional support for the long-term prospects for LNG.

LNG players will have to adapt to new and different customer expectations and more short-term and flexible commercial arrangements.

More complex market, moving away from high volume, long-term, point-to-point supply arrangements of the past toward more flexible physical supply and commercial arrangements.

Evolving new external parameters will likely drive the emergence of new types of participants, such as financial intermediaries, traders, hub operators and more. These are expected to generate new business models to unlock profit down the value chain.

Source: "Navigating the new world of LNG." Deloitte’s (2017)
LNG Landed Prices

Price in Million BTU

Landed Price: 2014

Landed Price: 2016

Delivering Gas to Power – LNG Terminal Requirement

[Graph showing primary inputs for power generation and trade in gas as a share of global consumption.]

Source: Monetizing Gas Africa (MGA)

Population without access to Electricity (million)

World Energy Outlook, Africa Energy Outlook, 2015
African Ports & Terminals – Planned Investments

Note: Project info extracted from multiple opportunity databases

TIC relates to marine terminal values only

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<tr>
<th>Commodity</th>
<th>TIC (m USD)</th>
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<tr>
<td>Container</td>
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<td>LNG/LPG</td>
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<td>Dry Bulk</td>
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<td>Hydrocarbons</td>
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<td>Other</td>
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<td>Multi Purpose</td>
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<td>Ship/Rig Repair</td>
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<td>Total</td>
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Market Value: Eastern Africa

IPP Office: LNG Terminal Port of Richards Bay

Source: Information Memorandum, IPP Programme (Oct 2016)

Source: Base image Google Earth
LNG Terminal Siting – Port of Ngqura (Coega)

Source: Information Memorandum IPP Programme (Oct 2016)

Source: Google Earth
## Current LNG Terminal Opportunities (SSA)

<table>
<thead>
<tr>
<th>Client</th>
<th>Project</th>
<th>Location</th>
<th>Stage</th>
<th>Comments</th>
<th>Start</th>
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<td>IPP Office</td>
<td>Richards Bay LNG Terminal</td>
<td>Richards Bay Port</td>
<td>Pre-RFQ</td>
<td>Gas to Power (G2P) IPP will be implemented in 2 locations, Coega (1000MW), Richards Bay (2000MW)</td>
<td>Q2 2018</td>
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<td>Transaction Advisory (TA)</td>
<td>LNG Terminal &amp; Gas pipelines</td>
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<td>Ministry of Energy Mauritius</td>
<td>Port Louis LNG import Terminal</td>
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<td>RFI</td>
<td>Possible BOT for gas supply to CEB</td>
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<td>EOI</td>
<td>BOT model</td>
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### West Africa LNG Terminal Developments

Types of LNG Offloading terminals

**Offshore gravity based structures – Caisson base**
- Can provide limited wave protection
- High CAPEX & extended delivery schedule
- Limited examples & high decommissioning cost

**Nearshore receiving terminals**
- Metocean vulnerability at jetty (or turret/SBM)
- FSRU/FSU – ship to ship transfer
- Offloading Jetty with onshore re-gas – cryogenic line length restriction
- Reduced land footprint & early gas. Lowest CAPEX but high OPEX

**Onshore/port terminals**
- Shore based offloading (benign metocean conditions)
- LNG Carrier enters the harbor – navigation demands
- Exclusion zones with potential port operations sterilization during LNGC transit & offloading
- Large land footprint if onshore re-gas. High CAPEX.
## Offloading Configurations

**Side-by-Side**

<table>
<thead>
<tr>
<th>Offloading Configuration</th>
<th>Shuttle tanker loading method</th>
<th>Shuttle tanker requirements</th>
<th>Approach / Mooring (Hs)</th>
<th>Offloading / Disconnecting (Hs)</th>
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<td>Side-by-Side</td>
<td>Mid-ship manifold</td>
<td>Any tanker</td>
<td>1.5 – 2.0 m</td>
<td>2.5 – 3.0 m</td>
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<td>Tandem</td>
<td>Bow</td>
<td>Non-DP Shuttle Tanker</td>
<td>3.5 – 4.5 m</td>
<td>4.5 – 5.0 m</td>
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<td></td>
<td>Bow</td>
<td>DP Shuttle Tanker</td>
<td>4.5 – 5.5 m</td>
<td>5.5 – 6.0 m</td>
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</table>

- **Tandem**

- **Shuttle tanker loading method**
  - Bow
  - Any tanker

- **Shuttle tanker requirements**
  - Non-DP Shuttle Tanker
  - DP Shuttle Tanker
Offshore Mooring Configurations

Berthing Island Mooring

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<th>Mooring Type</th>
<th>Permanent/Instant-Port</th>
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<tr>
<td>Typical Water Depth</td>
<td>Shallow water: up to 20m</td>
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<tr>
<td>Limit environmental conditions</td>
<td>Mild Environment (&lt; 2m)</td>
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<tr>
<td>Offloading</td>
<td>SBS</td>
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<tr>
<td>Examples in AFRICA</td>
<td>-</td>
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</table>
Offshore Mooring Configurations

**Spread Mooring**

- **Mooring Type**: Permanent
- **Typical Water Depth**: Very Shallow (15m) to ultra-deep water (3000m)
- **Limit environmental conditions**: Moderate to Harsh Environment (Hs=3m-4m)
- **Offloading**: SBS possible
- **Examples in AFRICA**: ANGOLA: Girassol FPSO / Kizomba B/ Ghana Quantum

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**Offshore Mooring Configurations**

1. Floating Storage and Regasification Unit (FSRU)
2. “Spread” mooring
3. Visiting LNG carrier moored side-by-side for ship-to-ship transfer
4. Riser
5. Pipeline End Manifold (PLEM)
6. Subsea pipeline to shore, 24 inch diameter, 12 km length
7. Landfall and metering station
8. 1,200 MW of existing generation

Source: Quantum Power – Ghana LNG
Trends: Small Scale LNG and LNG Bunkering

Small LNG Carriers

While conventional LNG carriers are designed to load, transfer and unload full cargoes between two terminal points, small scale vessels have been designed to distribute partial loads to coastal areas in regions such as Africa, the Indian subcontinent, Southeast Asia, the Caribbean, and Northern Europe.

Designed to operate at shallow drafts less than 5m, such carriers can deliver cargoes in areas where conventional LNG carriers cannot access.

Source: Wison

LNG Bunkering

Following the establishment of the emissions control areas (ECAs), ship owners are looking for solutions to meet new legislation. LNG is a preferred method to reduce not only SOx and NOx, but also a substantial amount of CO2 emissions.

There is a growing number of European LNG bunkering projects that have been initiated by oil and gas majors.

Liquefied gas carriers which designs meet a variety of capacity requirements for the small-scale market, from 500-cbm to 7,500-cbm capacity

Source: Damen
Advisian LNG Experience
Africa LNG Market
LNG Terminal Infrastructure
Terminal Performance Indicators
Terminal Siting & Design Approach
Case Studies
Key Parameters Determine FSRU Terminal Viability

**Offloading Availability**
- To determine the period of time in which offloading from an LNGC to the FSU/FSRU can take place.

**Gas Export Availability**
- To determine the period of time where gas can be exported from the FSRU to the shore via a pipeline.

**LNG Supply Agreement**
- e.g. take or pay agreements and their limitations

- Can LNGCs berth and offload at scheduled times?
- Is there enough LNG to be regasified and sent to shore at all times? Can gas export be performed at all times?
- Fixed offloading schedule? How does it affect demurrage and cargo cancellation?
Wave Operability Limit Curves – LNG Terminals

![Wave Operability Limit Curves](image)

- Wave height
- Wave period
- Wave Operability Limit Curves
- Offloading
- Gas Export and Jetty Mooring

Wave Operability Limit Curves

Wave height vs. Wave period:
- Offloading curve
- Gas Export and Jetty Mooring curve

Tp (s)

Wave period

Hs (m)
Sea State Conditions

Mean Significant Wave Height - July

Source: ERA-40 1971-2000
Historical Cyclone Tracks
Key Performance Parameters

Offloading Availability - The period where berthing/offloading/de-berthing operations can be completed.

Uptime/Throughput - The period when there is gas demand and gas is exported.

Downtime - The period when there is gas demand and no gas is exported.

Demurrage - The period when the charterer remains in possession of an LNGC after the period agreed to offload LNG.

Partial Offloading - The event when an LNGC can only offload part of its LNG parcel due to insufficient storage space in an FSRU to receive the full LNG parcel.

Cancelled Cargoes - Cancelled shipments due to terminal unavailability, critical to take or pay agreements.
What is the cost of underperformance?

Levelled cost of energy (LCOE) is a singular value to represent the indicative cost that, if assigned to every unit of gas produced (in mmBtu), will equal to the total net present cost (NPC) of the project.

Depending on the throughput, typical LCOE of a 25 year project is in the range of 80-290 cents/mmBtu.

Gives indication of expected operational cost implications due to:

<table>
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<th>Scenario</th>
<th>Cost (USD)</th>
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<td>Downtime</td>
<td>46-83M</td>
<td>5% downtime, 250mmSCFD</td>
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<tr>
<td>Demurrage</td>
<td>1.2-2.4M</td>
<td>≈30 days, per year</td>
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<tr>
<td>Cancelled Cargoes</td>
<td>30-54M</td>
<td>140,000m³ LNGC, per year</td>
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<tr>
<td>Partial Offloading</td>
<td>7.5-13.5M</td>
<td>5% loss cargo, 5 offloads</td>
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Total: USD 85M to USD 150M/yr

This underperformance amounts to LCOE of 34-61 cents/mmBtu.
Simulation Critical Input Data

- **Metocean Time Series**
  - Historical hindcast metocean time series transformed to site location

- **Mooring Analysis**
  - Offloading operability limit curves
  - Gas export operability limit curves

- **Navigation Study**
  - Tugs operability limits

- **LNG Supply and Sales Agreement conditions**
  - LNGC schedule
  - Laytime
  - Demurrage
  - Laydays
  - Laycan

**UPTIME ASSESSMENT**
Simulation Critical Parameters

- UPTIME
  - FSRU & LNGC Capacities
  - Buffer Storage
  - LNG/Gas Demand
  - LNG Supplies Agreement
  - LNGC Offloading Schedule
  - Operability Limits
  - Equipment RAM
  - Gas Export Equipment Capacity
  - Regas Unit Capacity
  - Offloading Equipment Capacity
  - Night Time Restriction
  - Tugs Capabilities
  - Downturn
  - Partial Offloading
  - Demurrage Management
  - Equipment RAM
Example: Good vs Bad Performing Terminal

**Offloading Availability**

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**Uptime**

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**Downtime**

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**Offloading Availability**

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Example:
Good vs Bad Performing Terminal

Demurrage

Cancelled Cargoes

Partial Offloads

VS

Demurrage

Cancelled Cargoes

Partial Offloads
Advisian LNG Experience
Africa LNG Market
LNG Terminal Infrastructure
Terminal Performance Indicators
Terminal Siting & Design Approach
Case Studies
Value of early site & project concept selection

Important to **Select** the “project” appropriately in early phases

- After **Selection** … the project maintains value by keeping to cost & schedule (or erodes value through poor execution)
Marine Infrastructure Scope

LNG storage and regasification facilities (using Floating Storage and Regasification Unit (“FSRU”) technology or equivalent facilities such as Floating Storage Units plus shore-based or barge-based regasification facilities);

Supporting port infrastructure including:

• the LNG berth, including the loading platform, with associated topside infrastructure, and mooring and berthing dolphins;

• dredged modifications necessary to the berth pocket;

• terminal access and services trestle; and

• gas transmission pipelines.

Supporting Studies:

• Coastal Modeling for metocean (sea-state) & meteorological quantification – Uptime Analysis

• Mooring & navigations studies (numerical & physical modeling)

• Environmental, including outfall dispersion modeling

• Safety (ie exclusion zone) & risk
Siting Optimization - Numerical Modelling

Numerical models are efficient tools to assist in projet siting & understanding, forecasting and managing LNG berthing facility development and operations.

Employing a range of software, one can undertake the following critical studies:

**Sediment Modelling**
- Impact on the coastline
- Sediment transport
- Dredged channel sedimentation
- Evaluation of dredging plans and sediment spoils

**Simulation of Waves**
- Design Wave
- Wave disturbance
- Navigation

**Hydrodynamic Simulation**
- Current and water level fields
- Navigation

**Other models**
- Oil spills
- Dredging spills

SWAN offshore wave transformation
Berthing jetty & breakwater orientations
Climate Change Resiliency

- Sea Level Rise (SLR)
- Frequency & intensity of Storms/ Cyclones
- Increased Inundation and flooding of coastal land
- Increased shore line erosion and damage to coastal infrastructure
- Increased Coastal Water Temperatures & Ocean Acidification

Impacts

- Project Risks
- EIA Complexity
- Infrastructure Requirements
- Capital Costs
- Operating Costs

Siting is critical

SLR. Source: IPCC (2013)
Hurricane Matthew. Source: www.porttechnology.org
Advisian LNG Experience
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Project 1: PetroSA LNG Terminal Mossel Bay

Nearshore wave conditions – Project 1
LNG Import Unfeasible – Sea State Conditions

**Background:** Offshore LNG carrier (LNGC) transfer to floating re-gassification unit (FSRU). Transfer of gas via marine & land pipelines to several offtakers.

Project Suspended as requires wave breakwater to achieve target operability due to sea state conditions

**Possible Alternative:** Smaller scale LNGC – FSRU transfer in vicinity of wave sheltered harbour.
- Dredging requirement
- Reduced LNG carrier size & LNG throughputs

---

Simulated wave heights for LNG berthing
(source: Mocke et al. FLNG, London, 2014)
### Project 2: IPP Programme (RSA)

Richards Bay key site challenges – Exclusion zones

<table>
<thead>
<tr>
<th>Area</th>
<th>Extent of Exclusion Zone</th>
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<tbody>
<tr>
<td>LNG carrier</td>
<td>500m ahead, 250m abeam and astern while transiting along shipping channels</td>
</tr>
<tr>
<td>Load-out berth</td>
<td>250m radius safety zone while unoccupied by LNG carrier</td>
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<tr>
<td></td>
<td>250m radius commercial shipping safety zone during loading operations</td>
</tr>
<tr>
<td></td>
<td>1,000m public exclusion safety zone during loading operations</td>
</tr>
<tr>
<td>Cryogenic pipeline</td>
<td>50m each side of the pipeline</td>
</tr>
<tr>
<td>Storage facility</td>
<td>Site perimeter boundary to be located 500m from storage facility</td>
</tr>
<tr>
<td>LNG processing plant</td>
<td>250m clearance zone to other hazardous industry inventory</td>
</tr>
<tr>
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<td>1,000m clearance to residential areas</td>
</tr>
</tbody>
</table>

**LEGEND**
- 500 m exclusion zone
- 250 m exclusion zone

[Image of Richards Bay area with exclusion zones marked]
Coega Port LNG Terminal challenges – Long waves

Source: Information Memorandum IPP Programme (Oct 2016)

Simulated surface elevations due to long waves
Project 3: LNG Import Terminal Success Story

**Objectives**
- Achieve Safety and Environmental Performance
- FSRU and facilities interfaces well aligned
- Achieve Safety and Environmental Performance
- Available

**Success Factors**
- Community Engagement
- Reliability Consistent with Supply Contracts
- Cost Effective
- General Location – area defined
- Government Support
- No cross border impact
- Local Community acceptance
- Opportunity
- Givens
- Unknown Information
- Cost Competitiveness
- Economic Return
- Acceptable level of risk
- Pipeline tie in location and requirements
- Additional regulatory approval requirements
- Bunker operations
- Additional sales
- Balance between reliability and cost
- Robust data for option analysis
- Well defined option assessment
- Concept Study timing
- On schedule first gas
- Within defined area
- Local pipeline
- Reliability consistent with a system having Diesel back-up
- First gas 2019

**Schedule**
- Align to existing infrastructure
- Schedule
- Cost Effective
- Reliability consistent with supply contracts
Closing

- Ramp up of LNG across Africa, combination of lower pricing, alternative power & transport fuel source & even new gas producing countries turning to LNG to increase gas supply security whilst ramping up gas production
- New LNG supply & contracting models (ie. Small scale LNGC)
- For terminal developments ensure that more is done to mitigate risk and improve certainty. Critical initiatives include:
  - Conducting robust technical and financial feasibility studies up front;
  - Carry out comprehensive terminal siting & layout optimisation studies early in the process;
- Fully explore latest LNG technologies (Terminal, carriers, etc)
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