4 FACILITY DESCRIPTION

4.1 Facility Layout

The MFP will be moored alongside the LNGC and jetty for LNG ISO Containers and Cryogenic LNG Bowser/Road Truck will be on the other side, as shown in Figure 4-1.

Figure 4-1 – Layout of LNGC, MFP and LNG ISO Container or Cryogenic LNG Bowser/Road Truck

4.2 LNG Filling Locations

LNG filling will take place via STS transfer operation to LNG ISO containers or Cryogenic LNG Bowser/Road Truck in Karachi Port. Trucks will arrive with empty LNG containers which will be parked on the Jetty in Karachi Port and will be filled via a Mobile Filling Platform (MFP) from an LNG Carrier.

Three (3) locations are proposed for the filling operation of LNG from the LNGC to the ISO Containers or Cryogenic LNG Bowser/Road Truck via the Mobile Filling Platform (MFP) as shown in Figure 4-2, Figure 4-3 and Figure 4-4 below:

- Berth 18/19
- Berth 19
- Berth 23

3 INTRODUCTION

LNG Easy Pte Ltd (LNGE) is planning to set up a Liquefied Natural Gas (LNG) receiving and offloading facility for LNG ISO containers or Cryogenic LNG Bowser/Road Truck filling. Trucks will arrive with empty LNG containers which will be parked on the Jetty in Karachi Port and will be filled via a Mobile Filling Platform (MFP) from an LNG Carrier.

DNV GL has been commissioned by LNGE to conduct a Quantitative Risk Assessment (QRA) of the LNG receiving and offloading facility (MFP) for LNG ISO containers or Cryogenic LNG Bowser/Road Truck filling at Karachi Port.

Three berths are proposed for the LNG filling operation from the LNGC to the ISO Containers or Cryogenic LNG Bowser/Road Truck via the MFP at:

- Berth 18/19
- Berth 19
- Berth 23

This QRA report will assess the risks due to the LNG filling operations at these three berths in support of the selecting the LNG filling location at Karachi Port.

3.1 Objectives

The aim of this QRA is to systematically assess the likelihood and consequence of all credible potential process hydrocarbon risks of the proposed facilities, and:

- Ascertain if such risks are tolerable in accordance to 'UK HSE and DNV GL Recommended Practice Individual Risk Criteria; and
- Recommend the Ignition Exclusion Zone (IEZ) and Marine Exclusion Zone (MEZ).

3.2 Scope of Work

The boundary of the study is limited to the following:

- LNG Vessel
- Filling operation of ISO containers or Cryogenic LNG Bowser/Road Truck and;
- Departure of the trucks from the jetty (excluding the transportation risk).

This assessment is limited to normal operations, with the focus on Major Accident Hazards (MAHs) identified from the HAZID (Ref./1/).

The following scopes are excluded:

- Maneuvring of the LNG Carrier to and from the berth.
- Transport routing of the Cryogenic LNG Bowser/Road Truck from jetty.

3.3 Report Structure

The remainder of this report is structured as follows:

- Section 4 briefly describes the proposed facility and process description;

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1 EXECUTIVE SUMMARY

Background

LNG Easy Pte Ltd (LNGE) is planning to set up a Liquefied Natural Gas (LNG) receiving and offloading facility for LNG ISO containers or Cryogenic LNG Bowser/Road Truck filling. Trucks will arrive with empty LNG containers which will be parked on the Jetty in Karachi Port and will be filled via a Mobile Filling Platform (MFP) from a LNG Carrier.

DNV GL has been commissioned by LNGE to conduct a Quantitative Risk Assessment (QRA) of the LNG receiving and offloading facility (MFP) for LNG ISO containers or Cryogenic LNG Bowser/Road Truck filling at Karachi Port. This report covers the QRA of this facility (MFP).

Objective

The aim of this QRA is to systematically assess the likelihood and consequence of all credible potential process hydrocarbon risks of the proposed facilities, and:

- Ascertain if such risks are tolerable in accordance to Acceptable Risk Criteria; and
- Recommend the Ignition Exclusion Zone (IEZ) and Marine Exclusion Zone (MEZ).

Findings and Conclusions

- For public risk, the intolerable risk for public, which is 1E-04 per year, does not extend beyond the MFP, and the broadly acceptable risk level of 1E-06 per year is contained within the jetty area. As such, the risk to public is considered to be within the ALARP region.
- The Individual Risk Per Annum (IRPA) for an individual working on the MFP is estimated to be 2.15E-05 per year. This is calculated based on the risk for an arbitrary person working at a particular location (in this case personnel is assumed to be positioned at the main pipe rack area of the MFP), with a 12 hours work shift per day (split of 70% of time spent outdoor, 30% indoor). The filling operation is assumed to take place 12 days in a month. This risk result shows that the **IRPA for workers on the MFP falls within the ALARP region** (i.e. between 1E-07 per year to 1E-04 per year).
- The furthest radial distance extended by the 1E-06 per year risk contour from the centre of the MFP is approximately 120m in length. 120m is thus recommended as the minimum distance between the centre of the MFP and any on-shore/off-shore facilities, if applicable.
- The Ignition Exclusion Zone (IEZ) has been determined to be approximately 120m from centre of the MFP (potential release at LNG filling hose connection at the filling bay). The marine exclusion zone distance set for LNGC is calculated to be 60m. This is the minimum distance for any passing vessels or marine vessels plying the area (except authorised vessel with appropriate ignition control measures in place) during LNG filling operations.
- Within the defined IEZ / MEZ radius, the following restrictions must be in place:
  - Unauthorised entry must be restricted within the IEZ / MEZ radius. Only dedicated personnel are allowed in the area.
  - On water, this restriction will include small boats, fishing vessels and other marine vessels.
  - No activities can be performed which can introduce ignition sources (e.g. hot work, hot surfaces, etc.).

Project name:	LNG Mobile Filling Platform for ISO Container or Cryogenic LNG Bowser/Road Truck at Karachi Port	DNV GL Singapore Pte. Ltd.
Report title:	Quantitative Risk Assessment (QRA) Report	Risk Management Advisory
Customer:	LNG Easy Pte Ltd	16 Science Park Drive
Customer contact:		Singapore 118227
Date of issue:	2021-05-25	Tel: +65 6508 3750
Project No.:	TC689379	
Organisation unit:	Risk Management Advisory	
Report No.:	TC689379, Rev. 2	
Document No.:	TC689379	

Applicable contract(s) governing the provision of this Report:

Objective:

DNV GL Singapore Pte. Ltd. (DNV GL) has been contracted by LNG Easy Pte Ltd to carry out a Quantitative Risk Assessment (QRA) for the LNG Mobile Filling Platform facility. This report documents the calculations and findings of the QRA study.

Prepared by:	Verified by:	Approved by:
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Keywords:
LNG, ISO containers, QRA

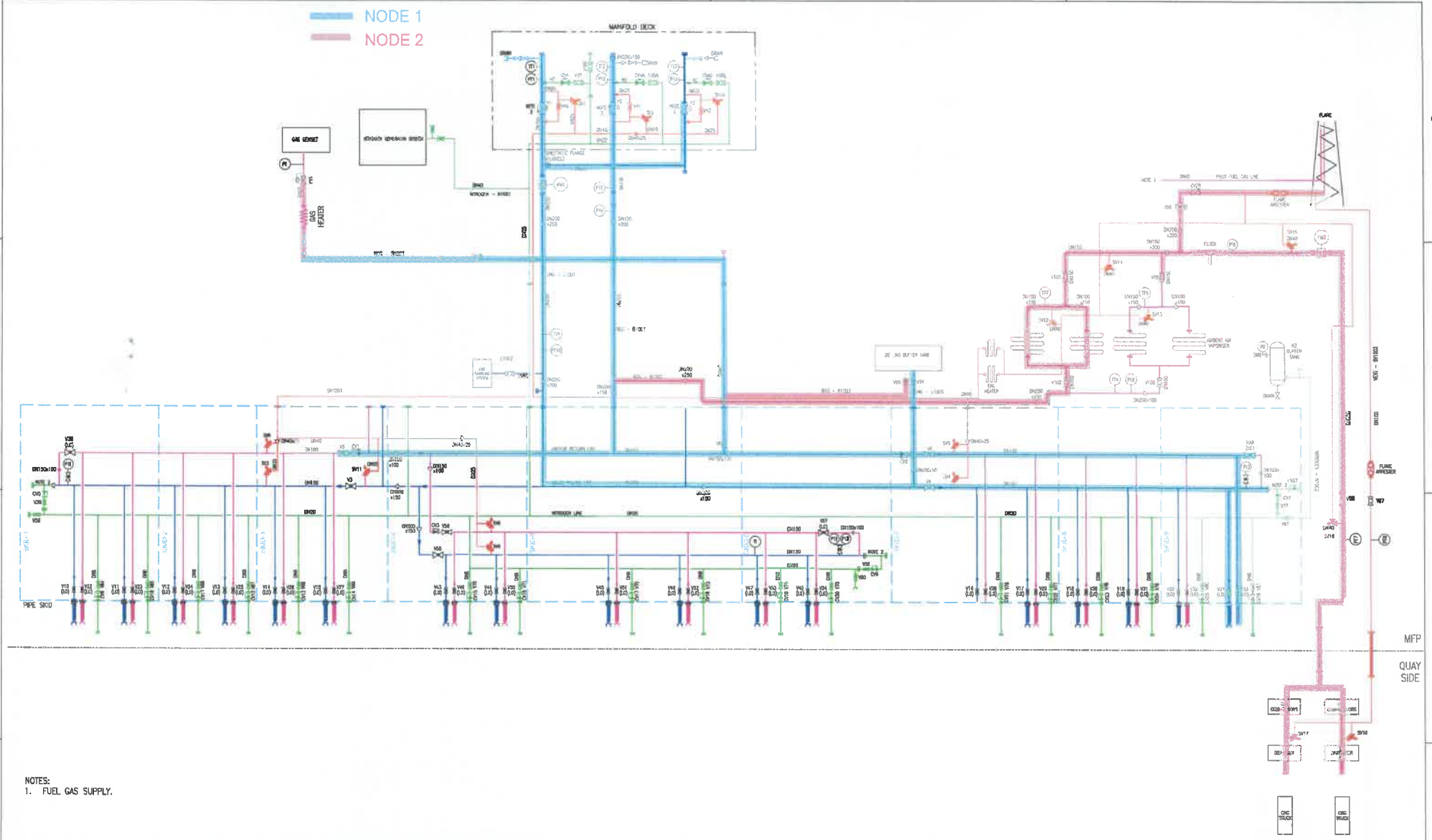
Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
A	26/03/2020	First issue	TCK	TPS	MZAB
0	31/03/2020	Final issue	TCK	TPS	MZAB
1	3/4/2020	Re-issued Final Report following additional comments	TCK	TPS	MZAB
2	25/5/2021	Revised Final Report following admin related comments following HAZID/HAZOP/SIL Report	TCK	TPS	MZAB

About DNV

Driven by our purpose of safeguarding life, property and the environment, DNV enables organizations to advance the safety and sustainability of their business We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil & gas and energy industries We also provide certification services to customers across a wide range of industries Operating in more than 100 countries, our professionals are dedicated to helping our customers make the world safer, smarter and greener

SIL Classification for Mobile Filling Platform

No.	Tag No.	Drawing no.	SIF Design Intent	Causes of Demand	Consequence of Failure	Final element	SIL Without IPL									IPL Description	IPL RRF	Comments	SIL with IPL						Final SIL	Required Actions & Recommendations
							Safety to Life (S)					Environment		Asset					RRF (S)	SIL (S)	RRF (E)	SIL (E)	RRF (A)	SIL (A)		
							C	F	P	W	SIL (S)	C	SIL (E)	C	SIL (A)											
1	TTLL-2	P265-01-067-MD2001	LL Temperature in BOG Return Line	LNG backflow into the BOG return line through isocontainer during filling operation	Potential liquid LNG back flow into the BOG compressor (on ship side) resulting into damage to the BOG compressor.		SA	FB	PA	W1	-	EA	-	AC	1			- The LNG liquid will move towards the low resistance path i.e. towards the LNG air vaporisers compared to the ship side.	0	-	0	-	0	1	1	
											-		-		-				0	-	0	-	0	-	-	



NOTES:
1. FUEL GAS SUPPLY.

REV	DATE	REVISION DESCRIPTION	DRAWN BY	CHECKED BY	APPROVED BY	REFERENCE DOCUMENT/DRAWING NO	DOC/DWG NO	TITLE	REV
A	22.02.2020	ISSUED FOR INFORMATION	EH	HJH	HYY				

CLIENT:

APPROVED BY: DATE:

CLASS:

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FAX : (65) 6271 4311
website : www.lngeasy.com

PROJECT TITLE: MOBILE FILLING PLATFORM

DRAWING TITLE: PIPING & INSTRUMENTATION DIAGRAM

LNG EASY DRAWING NO:	SHEET	REVISION	SCALE
P265-01-067-MD3000	1 OF 1	A	NTS

CLIENT DRAWING NO:

PAPER SIZE : A3

HAZOP Study Worksheet

Node: 2. BOG routing to Flare/CNG station through CNG Compressor

Drawings / References:

Design Conditions/Parameters: -162 degC / 10 barg

Deviations		Causes	Consequences	Effective Safeguards	Recommendations		Remarks
					Recommendations	Responsibility	
1.	No Flow/ Less Flow	1. Pneumatic valve V102 on the inlet line to Ambient Air Vaporiser is inadvertantly closed.	1. BOG will be routed to ship- no major consequence as this route will be always open for BOG	1. Local/remote indication	2 Include low flow alarm on the flowmeter FM2	LNGE	1. The valve to be indicated as pneumatic valve on the P&ID.
			2. Potential damage to CNG compressor due to loss of suction pressure				Ensure CNG compressor trip upon low suction pressure- to be confirmed once compressor design is selected and finalised.
		2. Manual valve V101 on the discharge line of Ambient air vaporiser closed in error	1. Same as above.				
		3. V98 flow control valve on the flare line is inadvertantly closed when required	1 Potential overpressurisation of the BOG line leading to delay in filling operation.	The piping design is rated for 10 barg.	3 Include high flow alarm on the flowmeter FM2	LNGE	
		4. Clogged filter	1. BOG will be routed to ship- no major consequence as this route will be always open for BOG				
			2. Potential damage to CNG compressor due to loss of suction pressure				
		5. Manual valve (V98) is closed in error	1. BOG will be routed to ship- no major consequence as this route will be always open for BOG				
			2. Potential damage to CNG compressor due to loss of suction pressure				
		6. CNG compressor tripped	1. BOG will be routed to ship- no major consequence as this route will be always open for BOG	1.			
2.	More Flow	1. Excessive BOG generation from Shipside/MFP	1. Potential overpressurisation of the BOG line leading to delay in filling operation.	Excess flow will be routed to flare by opening up the V98.			
3.	Reverse/Misdirected flow	1. Air ingress from the flare tip	1. Potential for flammable (BOG/air) mixture formation in BOG system	Check valve is provided			
4.	Low pressure	1. CNG compressor running during low/no BOG flow	Potential vacuum generation in compressor suction line leading to pipe rupture	Suction piping is designed for the full vacuum.			Ensure CNG compressor trip upon low suction pressure- to be confirmed once compressor design is selected and finalised.
5.	High pressure	1. CNG discharge line valves are closed in error	Potential overpressurisation of the compressor discharge line leading to LOC.				Ensure CNG compressor has high pressure and relief valve for overpressure scenario. This to be confirmed once compressor design is selected and finalised.
6.	Low temperature	1. Loss of heating from the vaporiser due to icing up the air vaporiser tubes	Potential failure of Carbon steel piping downstream of the air vaporiser leading to LOC.	Automatic changeover of the air vaporisers based on the low air vaporiser outlet temperature.			
				Low temperature alarm			
		2 Failure/misoperation of the air vaporiser pneumatic valve swithover	Potential failure of Carbon steel piping downstream of the air vaporiser leading to LOC.	Low temperature alarm			
7.	High temperature	1. Initial cooling of the LNG and Vapour Manifold and piping on the barge	1. Potential Thermal shock	1. Cooling down procedure			
8.	Low level	1. No cause identified for this deviation					
9.	High level	1. No cause identified for this deviation	1.				
10.	Contamination	1. No cause identified for this deviation	1.				
11.	Utility / Service Failure	1. Loss of N2 supply	No supply to actuted valves (fail open)				
12.	Sampling / Testing	1. No cause identified for this deviation					
13.	Maintenance / Isolation / Access	1. No cause identified for this deviation					
14.	Static	1. Not applicable.					
15.	Start-up / Shutdown	1. No additional cause identified for this deviation					
16.	Instrumentation	1. No cause identified for this deviation					
17.	Material Selection	1. SS304 is selected for the BOG system until Ambient air vaporisers and downstream piping is Carbon steel.					
18.	F&G / Fire Protection / Area Classification	1. Refer to HAZID report					

HAZOP Study Worksheet

Node: 1. LNG Filling Manifold/vapour return and filling piping to ISO Trucks
Drawings / References: Design Conditions/Parameters: -162 degC / 10 barg

Deviations		Causes	Consequences	Effective Safeguards	Recommendations		Remarks
					Recommendations	Responsibility	
5.	High pressure	1. Blocked in section between LNGC and V1/V3	1. Pipe overpressure due to thermal expansion of blocked-in LNG	Pressure relief valve is provided on both sides (LNGC and MFP)			
		2 Blocked in section between V3/V4 and V94 and V1/V3	Pipe overpressure due to thermal expansion of blocked-in LNG	Pressure relief valve is provided on the filling line.			
		Blocked in section between V4 and QCDC flange connecting to the isocontainer	Pipe overpressure due to thermal expansion of blocked-in LNG	Pressure relief valve is provided on the filling line.			
6.	Low temperature	1. LNG backflow into the BOG return line through isocontainer during filling operation	Potential liquid LNG back flow into the BOG compressor (on ship side) resulting into	1. Low temperature alarm on the BOG return line (TT2)			
				2 **ESD1 activation (TT2 low low temperature will result in closing pneumatic valves V1/V2/V107 on the manifold line (LNG liquid filling and return line)**	2 Indicate manual valve V8 on the supply line to Gas Genset as Lock Closed (LC) as this will be used only during emergency scenario.		
7.	High temperature	1. Initial cooling of the LNG and Vapour Manifold and piping on the barge	**1.** Potential Thermal shock leading to pipe damage	1. Cool down procedure			
8.	Low level	1. No cause identified for this deviation					
9.	High level	1. V94 open in error during filling operations	1. The LNG buffer tank will balance out the pressure with LNG filling line pressure. The LNG buffer tank is designed for 16 barg.	1. Level and pressure gauge on the buffer tank			
				2. SOP			
10.	Contamination	1. Moisture inside the hose prior to connection for STS operation	1. Potential hydrate formation during bunkering operation leading to delay in filling operation	1. N2 purging/draining operation prior to filling operation			
		2 Oxygen ingress into the MFP prior to filling operation\	Potential flammable mixture formation inside MFP pipework	2 N2 purging/draining operation prior to filling operation			
		3. LNG Quality/Specification	1. Customer complain	LNG sampling points are provided and tested during each filling operation.			LNG specification will be agreed up front with the supplier to meet customer's
11.	Utility / Service Failure	1. Loss of water supply	1. Unable to de-ice filling nozzle	1. None identified			
		2. Loss of N2 supply	1. Fail to purge, delay in filling operations	1. N2 buffer tanks for purging operation			
			2. No supply to ESD valves	1. All ESD valves are fail safe (fail close).			
				2 N2 cylinders for opening the ESD Valves\			
		3. Loss of power supply to ESD (from onshore supply)	1. No consequence identified as ESD valves are fail safe (Fail close)	1. 1 x 100% Gas generator as back-up			
				2. Diesel back-up generator			
				3 UPS system			
		4. Loss of communication link (e.g. optical) between LNGC and barge for STS operations leading to closure of ESD valves	1. Potential liquid build-up/overpressure in the transfer hose. The maximum pressure build up is 8.0 bar.	1. Pre STS operation checklist			
				2. ESD 1 will be activated upon loss of communication link between LNGC and barge			
				3 Pressure relief valve upstream of ESD valves.			
12.	Sampling / Testing	1. No cause identified for this deviation. Sampling point is provided on the LNG filling line.					
13.	Maintenance / Isolation / Access	1. No cause identified for this deviation as this is not continuous operation.					
14.	Static	1. Potential difference between LNGC and barge leading to generation of electrical continuity (potential ignition source)	1. Potential fire hazard	1. Insulating flange installed on LNGC			

APPENDIX B
HAZOP Worksheet

APPENDIX A
HAZID Worksheet

No.	Function Name	P&ID No.	Design Intent	Final Element	Classified SIL
1.	TTLL-2	P265-01-067-MD2001	LL Temperature in BOG Return Line	Close the valves (V1/V2/ V107) on LNG filling and BOG return manifolds	SIL 1

ID	Location/ Activity	Hazard/Guideword	Hazardous Event	Cause/ Threat	Residual Risk Ranking (with controls)		
					People (Health and Safety)	Environment	Property
5.3				Unintentional drive away of the LNG truck while loading is ongoing	NA	2A	1A

7 RESULTS

7.1 HAZID Results

Hazards were identified during the workshop, followed by identification of the possible causes of these hazards. The risk ranking exercise, taking in consideration preventative and mitigative controls in place, was then performed and are tabulated below.

Table 4-1 Hazards Identified, Causes and Residual Risk Ranking

ID	Location/ Activity	Hazard/Guideword	Hazardous Event	Cause/ Threat	Residual Risk Ranking (with controls)		
					People (Health and Safety)	Environment	Property
Node 1: Movement & (Un)mooring of LNGC/ Barge/ Container Vessel							
1.1	Tugs and other traffic	Loss of containment of LNG	Vessel in port collides with LNGC	Vessel operator loses control	4A	2A	4A
			Tug collides with LNGC	Tug operator loses control	4A	2A	4A
Node 2: Connection and Disconnection							
2.1	Disconnection of flexible hose for STS operations	Cryogenic Spill	'Refer to "Inadvertent disconnection of flexible hoses" hazardous event.				
Node 3: STS Operations between LNGC and Barge							
3.1	STS Operations	Loss of Containment LNG	Loss of Containment LNG	Hose/Fitting leakage/ rupture	4B	2B	3B

5.3 Additional Considerations

5.3.1 Inclusion / Exclusion of SIFs

Process Control Loops

The SIL Classification study does not include process control loops as they are considered as part of the Basic Process Control System. Hence, they reside in a separate protection layer.

Hand Switches

A SIL Classification study is also not very suitable for addressing hand switches. Since hand switches are manually operated in emergency situations, the probability of failure is determined by human factors, rather than technical issues. The SIL would therefore, pragmatically never be higher than SIL 1.

5.4 Independent Protection Layer / Risk Reduction Factor

The term "Independent Protection Layer" (IPL) is applicable to a safeguard which is capable of preventing a scenario from proceeding to its undesired consequence independently of the SIF, e.g. a PSV for overpressure protection or another SIF with independent initiators, logic solver and final elements. The SIL assignment takes credit for the IPL that reduce the likelihood or consequence.

For a protection layer to be considered independent, its performance should not be affected by the occurrence of the initiating cause, its consequences or by the failure of another protective function used to reduce the risk of the same hazardous event.

Where more than one IPL exists, the highest individual RRF value is assumed, without taking credit for all, as a conservative measure.

The rule set for IPLs is presented in Table 5-8.

Table 5-8 Ruleset for IPLs

Independent Protection Layer (IPL)	Risk Reduction Factor (RRF)
Pressure Relief Device	100
SIF - SIL 1	10
SIF - SIL 2	100
SIF - SIL 3	1000
PCS, when independent of initiating event	10
Internal mechanical safety trips that are independent of the SIS or PCS	10 to 100
Operator response under high stress, average training	1
Operator response to Alarms with procedures, low stress, recognized event and at least 5 minutes to respond	10
Single Check Valve	1
Double Check Valves (of different technology) designed for the hazardous scenario	10
Dikes when capable of mitigating the initiating event. This is an IPL only for environmental events.	100

Table 5-6 Environment Severity (E)

Risk Parameter (Environment)		Severity Level	Description
Consequence (C)	EA	Negligible	No measurable effect
	EB	Moderate	Minor, local effect
	EC	Significant	Measurable effect
	ED	Severe	Severe effect
	EE	Catastrophic	Chronic effect

Risk Graph for Environment

This leads to the risk graph for environment as presented in Figure 5-2 which is equivalent to the risk graph in IEC61511-1, Figure D.2:

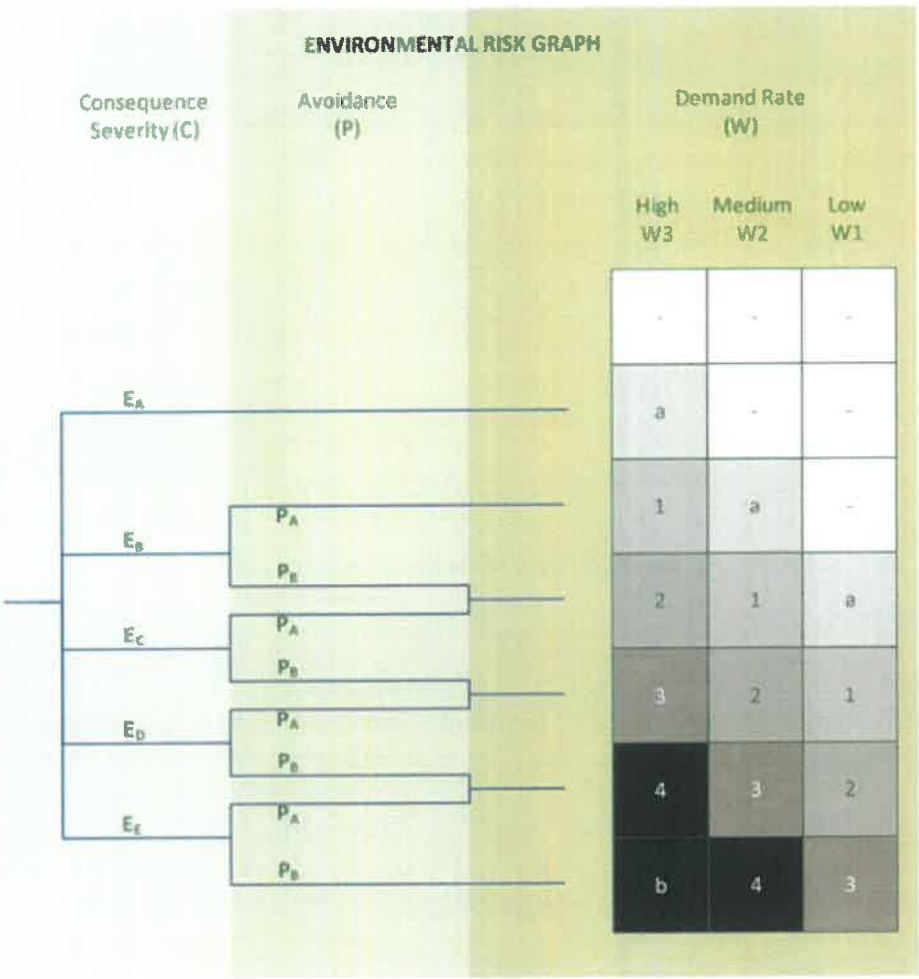


Figure: 5-2 Risk Graph for Environment

Probability of Avoiding Hazardous Event (P)

The "Probability of Avoiding the Hazardous Event" is defined as: The probability that exposed persons are able to avoid the hazardous situation which exists if the safety instrumented function fails on demand. This depends on there being independent methods of alerting the exposed persons to the hazard and there being methods of escape.

For the parameter "Probability of Avoiding the Hazardous Event", the set of possible values are presented in Table 5-5.

The conditions for choosing PA are very restrictive such all of the following conditions must be satisfied:

1. Facilities are provided to alert the operator that the SIF has failed;

2. Independent facilities are provided to shut down such that the hazard can be avoided, or which enable all persons to escape to a safe area; and

3. The time between the operator is being alerted and a hazardous event occurring exceeds 30 minutes or is definitely sufficient for the necessary actions.

Consequently, DNV proposed the selection of PB for all scenarios as it is unlikely that all the above conditions can be satisfied.

Table 5-5 Probability of Avoiding the Hazardous Event (P)

Possibility of Avoiding Hazard	Description
PA	Avoidance is possible under certain conditions.
PB	Frequent to permanent exposure in the hazardous zone

Risk Graph for People

This leads to the risk graph for people as presented in Figure 5-1, which is equivalent to the risk graph in IEC61511-1, Figure D.1.

Table 5-1 Possible Outcomes of a Risk Graph

SIL	Description
-	No safety requirements
a	A SIF is required, but there are no special safety requirements
1	SIL 1
2	SIL 2
3	SIL 3
4	SIL 4
b	A single SIF is not sufficient

The following sub-sections are the details of possible calibrated risk graphs that are proposed to be used for the SIL Classification workshop, taken from the IEC61511-3, along with consideration of the risk matrix used in the HAZID Study as attached in Appendix: B. Note that financial loss/risks are not to be considered in SIL assessment, and that consequence severity shall only be based on normal operations.

5.2.1 LOPA Methodology

LOPA is a Process Hazard Analysis (PHA) tool that builds on the information developed during the HAZOP study and enables semi-quantitative assessment of the required SIL for a given SIF. LOPA takes into account each identified hazard by documenting the initiating causes and the protection layers that prevent or mitigate the hazard. The total amount of risk reduction can then be determined and the need for more risk reduction assessed.

The LOPA methodology will be applied to SIFs that have been identified or recommended during the HAZOP Study and have been classified as SIL 2 or higher using the Risk Graph Methodology as described in previous section. Additionally, LOPA may be considered for a given PHA scenario in the following cases.

- If the requirement for additional SIF is unclear to the HAZOP team
- If more objectivity / quantification is desired to support related risk issues
- For complex SIF, involving multiple initiating causes and / or multiple independent layers of protection
- For SIF whose target is difficult to achieve

Considering simple nature of MFP and low number of SIFs, LOPA methodology is not used and calibrated risk graph method is used to determine the SIL levels.

5.2.2 People Risk

Demand Rate (W)

The demand rate (W) is defined as the number of times per year that a hazardous event would occur in the absence of the SIF under consideration. For the demand rates of the hazardous event, the proposed set of possible values is shown in Table 5-2.

5 SIL CLASSIFICATION/LOPA STUDY

The objective of the SIL Classification Study is to determine the SIL required for each Safety Instrumented Function (SIF). It also ensures that there are sufficient protection/safeguards for the systems; and to decide whether the risk from each individual scenario (based on current design) is at an acceptable level.

5.1 Study Approach and Methodology

The scope of this HAZOP focuses on the LNG filling operations – from the LNGC to filling barge manifold into ISO containers on the trucks. All of the SIFs associated with the LNG filling operations at MFP, which are documented in the P&IDs and ESD philosophy/Cause & Effect diagrams, are to be classified.

5.1.1 Study Approach

The SIL Classification workshop shall be based on the calibrated Risk Graph approach, carried out in accordance with the requirements of IEC 61508 and IEC 61511.

A structured approach will be applied to ensure that all loops within SIF have their SIL assigned. The basis for this approach lies in selecting the SIF identified in the HAZOP, and then to do a systematic assessment of SIL by using the risk graph method in consideration of the demand rate, probability of avoiding the hazardous event, occupancy and potential consequences.

The SIF loops shall be identified based on the list of SIFs listed on the ESD Philosophy/ Cause and Effect Matrix.

5.1.2 SIL/LOPA Methodology

The SIL required for all the SIFs analysed is defined based on the Calibrated Risk Graph methodology.

The SIL classification approach is basically divided into the following steps:

Pre-Workshop	• Scope definition and identification of SIFs – List down all loops to be SIL classified based on the Regasification C&E. • Development and approval of Terms of Reference (TOR). • Using a risk graph template to populate the IPFs, including initiating event, consequences, safeguards based on the HAZOP worksheets done.
SIL Classification Workshop	• With aid from facilitator, determine the items in pre-populated worksheets are applicable / correct • Hazard scenario identification and risk evaluation based on the Calibrated Risk Graph approach. Note that financial loss / risks are not considered in SIL assessment. • Each SIF evaluated and the required SIL for each SIF classified • Identification of IPLs to apply an RRF to the SIL levels derived • The outcome will be a list of SIL ratings

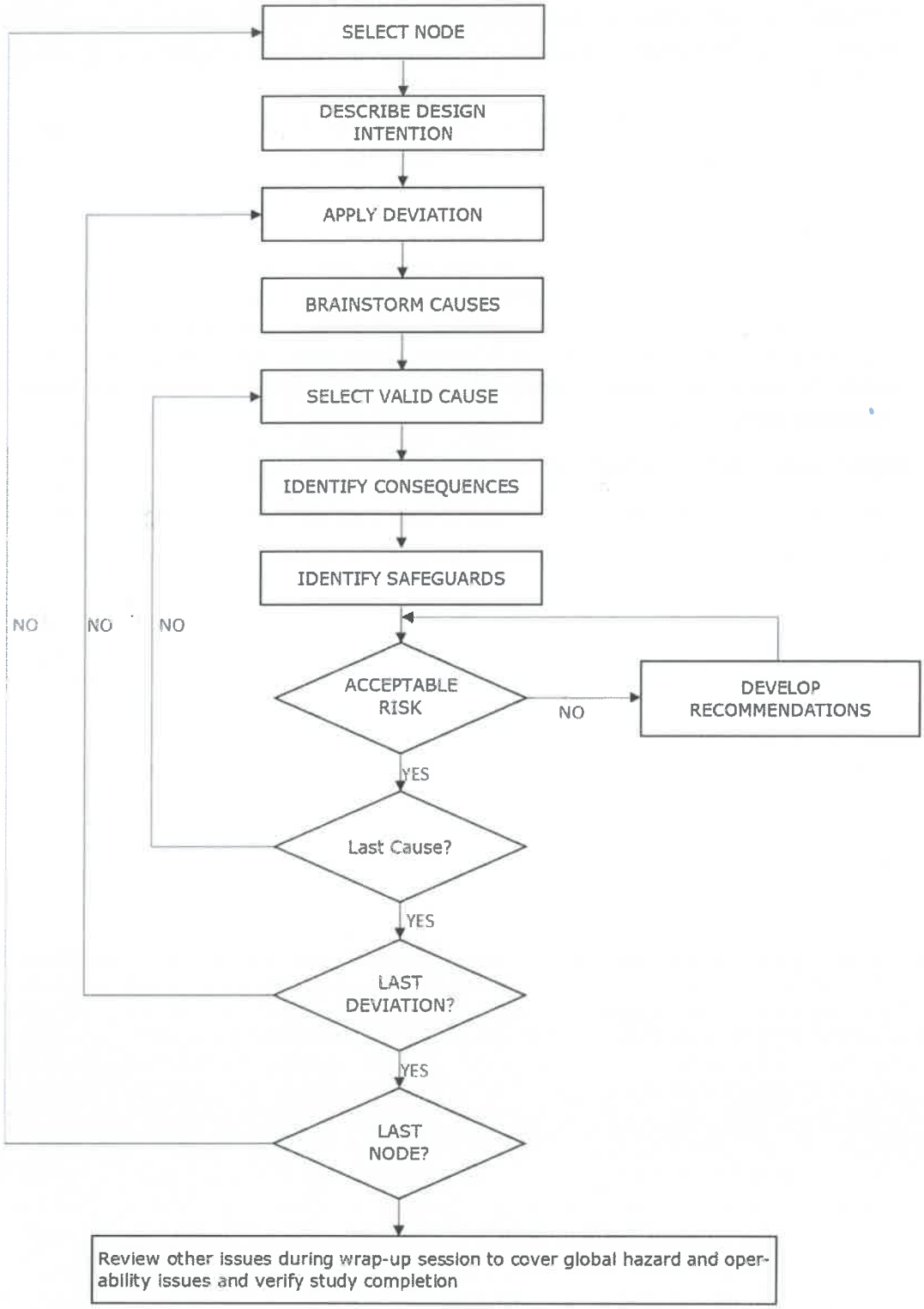


Figure 4-1 HAZOP Methodology

4 HAZOP SCOPE AND METHODLOGY

A HAZOP is a formal technique to systematically examine the process design of a facility, with due regard for the planned mode of operation, inspection and maintenance.

4.1 Objective and scope of work

The objectives of the HAZOP study are to:

- To systematically examine a system design (including the instrumentation and controls systems);
- To identify potential hazards and operability problems from all conceivable possible causes; and
- To make judgment as to whether the existing design or operational safeguards are adequate, or if further mitigating actions are required.

4.1.1 Scope of Work

The scope of this HAZOP focuses on the LNG filling operations – from the LNGC to filling barge manifold into ISO containers on the trucks. The HAZOP covered all appropriate and relevant Piping and Instrumentation Diagrams (P&IDs), Plot Plans, and other documents detailing the instrumentation design and control narratives.

4.1.2 Nodes

The basis of the HAZOP technique lies in dividing the process into a number of nodes that would be manageable enough to do a systematic review of each node. The following two nodes were reviewed and agreed upon prior to the HAZOP workshop. The marked-up P&IDs are given in Appendix C.

Total two nodes were studied during the HAZOP session on 18th May 2021.

Table 3-1 Proposed HAZOP Nodes

No.	Node Description
1	LNG Filling and vapor return manifold (STS operation)
2	BOG system including flare system and CNG Compression module

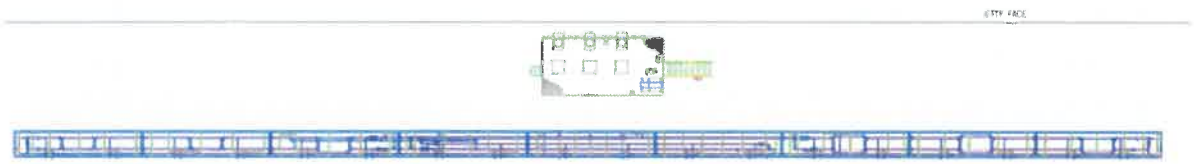
4.1.3 Workflow

The technique/methodology used in this HAZOP are as follows and is illustrated in Figure 3-2:

1. **Identify the node to be studied** – In order to assess the specifics of the process, the systems are broken down into a series of "nodes" and marked-up on the P&IDs for reference. Nodes are defined in a way that allows for the design intent of each part to be adequately defined. For each node, the following steps will be performed;
2. **Define the design intent of the node and the normal operating parameters of each node** - In order for all team members to share a common understanding of the design and intended operation of the node, a brief introduction of each node will be given;
3. **Apply a HAZOP deviation (e.g. NO/LESS FLOW) to the node** – the HAZOP team will consider each node in turn and apply each guideword in turn;
4. **Identify all possible causes for the deviation** – For each guideword, the team will identify all the possible causes that can create the deviation;

- **Identification of Preventive and Mitigating Measures:** For each hazard scenario, the next part of the study is to identify safeguards in place that can be expected to prevent an incident from occurring, as well as those intended to control its development or mitigate its consequences.
- **Risk Ranking:** The risk ranking will be done in accordance with the risk matrix, which is presented in Appendix E of this document.
- **Identification of action items:** If the HAZID team decide that the current provision of preventive or mitigating measures are insufficient to manage the hazard, or that further assessments are required in order to obtain a better understanding of the hazard, this will be raised as an action items during the workshop. These action items will be recorded in the worksheets and assigned to a responsible party.

Alt 1. Operation layout with MFP 1



Alt 2. LNG Filling manifold placed on the Jetty 1

3.3.2 HAZID Nodes

A structured approach was applied to ensure that all relevant hazards are revealed. The basis for this approach lies in dividing the LNG filling operation into a number of nodes/activities, and then to do a systematic review of each node to identify the relevant hazards that these nodes could be subjected to. The nodes were reviewed and agreed at the start of the HAZID workshop.

The following nodes were assessed as part of HAZID workshop:

Table 3-1 HAZID Nodes Description

No.	Node Description
1	Movement & (Un)mooring of LNGC/ Barge/ Container Vessel
2	Connection and Disconnection
3	STS Operations between LNGC and Barge

2 INTRODUCTION

LNG Easy Pte Ltd (hereinafter "LNGE") has requested DNV Singapore Pte. Ltd. (hereinafter "DNV") to conduct safety studies (HAZID, HAZOP, SIL/LOPA and QRA assessment) for the proposed LNG ISO container filling of LNG ISO containers to customers. LNG Easy Pte Ltd (LNGE) is planning to set up a Liquefied Natural Gas (LNG) receiving and offloading facility for LNG ISO containers or Cryogenic LNG Bowser/Road Truck filling. Trucks will arrive with empty LNG containers which will be parked on the Jetty in Karachi Port and will be filled via a Mobile Filling Platform (MFP) from a LNG Carrier.

2.1 Project Background

LNGE plans to charter a suitable LNG Carrier (LNGC) from the market to transport LNG to Pakistan. The LNGC will pick up LNG cargo from selected LNG export terminal and sail to Pakistan, where the ISO Containers/tank trucks filling will take place via the filling skid/manifolds. LNGE will use an area in the port in Pakistan.

The MFP will be moored alongside the jetty with the LNGC on the outside as shown in Figure: 2-1. Empty ISO containers/tank trucks will be driven by trucks to the Jetty side next to the filling skid and each truck will be filled up with LNG. Up to 18 trucks (3 bays) can be filled at any one time.

The selected LNGC has a storage capacity of 30,000m³ of LNG. As such, it is expected that the LNGC will be on location for 2 - 3 days per offloading 4 times a month.

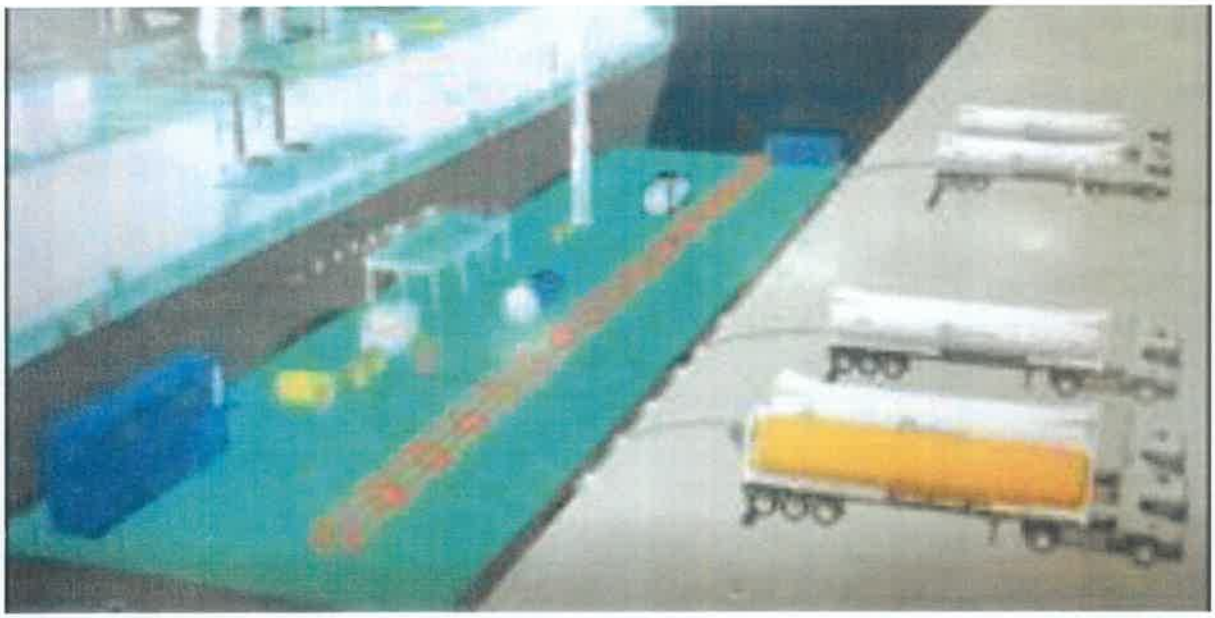


Figure 2-1: Layout of LNGC, MFP and LNG ISO Container or Cryogenic LNG Bowser/Road Truck

ABBREVIATION

Abbreviation	Description
CCTV	Closed-circuit Television
DNV	DNV Singapore Pte. Ltd.
ERP	Emergency Response Plan
ESD	Emergency Shutdown
HAZID	Hazard Identification
HAZOP	Hazard Operability
ISO	International Organisation for Standardisation
LC	Lock Closed
LNG	Liquefied Natural Gas
LNGC	LNG Carriers
LNGE	LNG Easy Pte Ltd
LO	Locked Open
LOPA	Layers of Protection Analysis
MAE	Major Accident Event
MFP	Mobile Filling Platform
PPE	Personal Protective Equipment
PRV	Pressure Relief Valve
SIL	Safety Integrity Level
SIF	Safety Instrumented Function
STS	Ship to Ship operation
TRV	Thermal Relief Valve

Project name:	LNG Easy HAZID/HAZOP – Mobile filling platform for LNG ISO container/Road truck filling for Karachi PORT	DNV Singapore Pte. Ltd. Oil & Gas Safety & Asset Risk Management 16 Science Park Drive 118227 Singapore Singapore
Report title:	HAZID, HAZOP and SIL Classification/LOPA Report	
Customer:	LNG Easy Pte Ltd	
Customer contact:	Hans J. Hvide/Erik He	
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Organisation unit:	RMA 298	
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P265-01-046-180425-033_1

Objective:

This document serves as the Hazard Identification (HAZID), Hazard Operability (HAZOP) and SIL/LOPA study report, documenting the credible risks identified and evaluated in the HAZID, HAZOP and SIL/LOPA workshops relating to the Mobile Filling Operation (MFP) facility at Karachi Port. This report document outlines the study scope, assumptions, methodology, credible risk results and assessments as well as actions determined within the HAZID, HAZOP and SIL/LOPA workshops.

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Keywords:
LNG, LNGC, ISO Container, Mobile filling platform, Trucking, STS operation

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
A	2021-05-21	First issue	MDLA	MZAB	MZAB
0	2021-05-24	Incorporating all comments- Final Issue	MDLA	MZAB	MZAB

population and overall social and economic uplift and development of Pakistan.

The cumulative impact on the National economy will be strongly positive. Significant additional resources will be realized by the nation as a result of this project, which is consistent with the government's long-term development plan. The additional licensing income, among other sources of additional income, will add to the government revenues and economic growth resulting from expanded and diversified business development in Pakistan in future.

A series of mitigation and monitoring measures have been included to address the risks involved in the handling of LNG/RLNG. Environmental Management and Monitoring Plan as well as safety and security measures would ensure that the Project will not create adverse environmental impacts that have not been mitigated or leave the safety and security concerns of the stakeholders unmitigated.

The Environmental Impact Assessment (EIA) study finds that the establishment of proposed LNG project is compatible with the aims and objectives of sustainable development in making available a sustainable energy source and thus contributing to economic development.

The Study therefore recommends that the Environmental Impact Assessment (EIA) report should be approved with the provision that the suggested mitigation measures will be adopted and the Environmental Management Plan (EMP) will be followed in letter and spirit.

	Hazardous spill	Spill on Land, Spill on Water	All operational areas	Continuous	SOPs	SHE Dep.	IMC
	Traffic management	Traffic Management Plan	Terminal approaches and exits	Continuous	Traffic Management Plan	SHE Dep.	IMC
	Health and Safety of workers	Accidents PPEs Annoyance Diseases	Terminal area	On quarterly basis	HSE Manual	SHE Dep.	IMC
	Accidents	Inspection and record checking.	Port area.	On quarterly basis	HSE Manual	SHE Dep.	IMC
	Compliance monitoring	EIA Commitments Mitigation Measures Conditions of Environmental Approval SOPs	All areas	Monthly	EMMP	IMC	SEPA

17	Water Quality	Sewage should be treated appropriately at each unit	SHE Manager	Monthly Monitoring
		Vehicle cleaning should be prohibited near water bodies	SHE Manager	Daily Monitoring
		Weekly/monthly water/wastewater/ groundwater quality monitoring should be conducted throughout operation	SHE Officer	Monthly (Operation) Monitoring if required
18	Solid Waste	Solid waste should be collected and stored in environment friendly manner	SHE Manager	Weekly Monitoring
		Certified solid waste contractor should be hired for disposal of waste	SHE Manager	Weekly, if required
		Solid waste should be kept in closed container	SHE Officer	Weekly Monitoring
19	Occupational Health & Safety	All procedures of Project Proponent related to SHE will be followed in letter and spirit.	SHE Manager	Daily Monitoring
		Grievance Policy of reporting incidence in place will be maintained Regular safety audits will be done	SHE Officer	Daily Monitoring
20	Community Health & Safety	Grievance Redressal Mechanism will be implemented by Project Proponent to ensure that Fisherman community complains are recorded.	SHE Manager	Monthly Monitoring
		Monitor the waterways in the vicinity of the Project for movements of local fishing boats	SHE Manager	Daily Monitoring
		Health screening of local fishermen will be conducted periodically	SHE Officer	Weekly Monitoring

Table 6.4- Environmental Monitoring Plan

Stage	*Monitoring Component*	*Parameters*	*Location*	*Monitoring frequency*	*Standard*	*Responsibility*	*Supervision*
Operations	Benthic Flora and Fauna	Visual checks ar [illegible] sampling of benthic material to assess the situation.	Sea Water	Once in a year	Comparison with previous records	SHE Dep.	IMC
	Wastewater	Wastewater minimization Storage and handling Recycling and reuse Treatment before disposal Primary Pollutants of SEQS	All effluent the discharge points	Monthly	SEQS	SHE Dep.	IMC

communication equipment available to count the number and condition of the personnel. In the event of fire, the execution or fighting phase will be implemented immediately.

Third stage: Response Operations: Response Operations refer to:

- Firefighting using extinguishers or pressure water network or foam.
- Spill control (of lubricants or fuel using absorbing material) or confinement.
- Dispersion of gas clouds. Access control to affected area.
- Medical assistance and evacuation of injured personnel.
- Evacuation of all personnel if their lives are in danger (in the event of earthquakes, tsunamis or other factors).
- Application of a monitoring program and a mitigation plan.

Fourth Stage: Evaluation of the Plan and of damages: Once response operations have concluded; the development and results of the Plan must be evaluated in order to issue recommendations that allow correcting deficiencies for the purpose of improving response operations. These recommendations will then form part of revision and subsequent annual approval of the Contingency and Risk Prevention Manual. A record of damages will be prepared as part of the final emergency report. The resources used, lost and recovered will be detailed in said register.

Emergency Response Manuals

Including the proponent's commitment to prepare written emergency plans for the pipeline, plant and marine terminal to cover emergency situations that could occur, based on the results of a Quantitative Hazard & Risk Assessment.

Monitoring and Review

Monitoring of different activities will be required to analyse the impacts of operation on the environment. Self-monitoring and reporting tools will be adopted to carry out monitoring as per EPA rules and regulations. SHE officer will coordinate with manager SHE, who will be the in-charge of monitoring procedures. Monitoring techniques will be identified and the frequency of selected parameters for monitoring will be followed as per the monitoring plan. SHE Head / Manager will keep a record of all nonconformities observed

Table 6.2: Emergency Equipment Inventory			
Equipment Category	*Equipment Type*	*Location*	*Description*
Personal Protective Equipment, Safety, and First Aid Equipment	Face Shields First Aid Kits/Stations (describe) Hard Hats Plumbed Eye Wash Stations Portable Eye Wash Kits (i.e. bottle type) Respirator Cartridges (describe) Safety Glasses / Splash Goggles Safety Showers Self-Contained Breathing Apparatuses (SCBA) Other (describe)		
Fire Extinguishing Systems	Automatic Fire Sprinkler Systems Fire Alarm Boxes / Stations Fire Extinguisher Systems (describe) Other (describe)		
Communications and Alarm Systems	Chemical Alarms (describe) Intercoms / PA Systems Portable Radios Telephones Underground Tank Leak Detection Monitors Other (describe)		
Additional Equipment			

Emergency Response training

Develop and practice a spill clean-up procedure including where to find emergency equipment and how to use it. Make sure all people on site are aware of emergency telephone numbers to call in the case of a large spill. Spill kit equipment on site should include: booms to contain liquids, material to prevent spills into drains, and material to absorb spills. Keep this absorbent material in a clearly labelled and easily accessible place.

Response Strategy

Upon the occurrence of the emergency, the Plan will be developed under the following conditions:

- First Stage: Notification

- Environmental Contamination (due to gas leaks into the environment, product spills on land and in the sea).
- Natural Risks that may affect the facilities and their resulting damage to property and the personnel.
  - Strong earthquake
  - Tsunamis (flood)
  - Typhoon/Cyclone
  - Lightening
- External risks arising from delinquent actions, terrorism or vandalism.
- Personnel Transportation Risks

All personnel must be instructed that in the event of automobile/barges/boat accidents while the personnel is being transported to/from the Plant, using own or third-party transportation contracted by the company, they must immediately notify the SHE Department so that it will provide the necessary assistance for the injured, and proceed to issue notices not only to the health care centres but also to external support institutions (National Civil Defence, Police, Fire, Fighters, etc.).

- Evacuation map is prominently displayed throughout the facility with assembly point(s), routes and roles and responsibilities for all employees.

Note: A properly completed Site Plan satisfies contingency plan map requirements. This drawing (or any other drawing that shows primary and alternate evacuation routes, emergency exits, and primary and alternate staging areas) must be prominently posted throughout the facility in locations where it will be visible or fires, such as:

- Uncontrolled gas leak (RLNG and liquefied natural gas) into the atmosphere.
- Fire/explosions.
- Hydrocarbon (gasoline, diesel).
- Application of the adequate response procedure

Table 6.1: Specific Responsibilities for Management & Coordination				
S.#	Strategic Objective	Proposed Implementation Process	Suggested In-charge	Suggested Priority
		management and accurate monitoring. ▪ Examine annual progress report and review with respect to the monitoring progress. ▪ Conduct self-monitoring regularly	▪ CEO and SHE Head/Manager ▪ SHE Head/Manager	▪ On-going ▪ High
03	To improve decision-making process for management.	▪ Develop an appropriate form of management process, specific to the environmental issues ▪ Develop a fully comprehensive database of impact and mitigation understandable for the management.	▪ SHE Officer ▪ SHE Manager/ SHE officer	▪ High ▪ High
04	To ensure coordination between contractor and Project Proponent.	▪ Obtain support for a Memorandum-of-Understanding between management and Contractor for the implementation of: ✧ EPA Requirements ✧ EMP ▪ Continue regular liaison between management of Project Proponent and contractor.	▪ SHE Head/Manager ▪ SHE Officer	▪ High ▪ On-going
05	To develop strategic policies for better Environmental management.	Develop strong coordination between SHE department and top management.	▪ SHE Head/Manager	▪ High

6.8 Operation Phase

action. The SHE department and the contractor will also prepare a weekly environmental report. Duplicates of the report will be provided to the higher managements of Project Proponent and of the contractor. Monthly monitoring reports will be submitted to Sindh EPA during operation.

Communication will play a vital role in good management practices. Steps given below will assist in effective communication and documentation.

Kick-off Meeting

The aim of organizing the kick-off meeting is to define the environmental responsibilities, awareness to EMP to the managing staff and to streamline the work plan according to the EMP. This meeting will be arranged prior to commencement of activities.

Quarterly Meetings

Initially quarterly meetings will be held after kick-off meeting however if situation demands for monthly meetings, it will be rearranged accordingly. Aim of this meeting is to review the progress of activities performed, explore ideas and problems, and discuss about the progress in acquisition and analysis of information. Deadlines are re-evaluated in it and if necessary, the project program is revised in these meetings.

Peer Review

The aim of this review is to predict and modify the conclusions and interpretation of assessment phases in the light of other professional opinions that mainly not involved in the proposed project, but just for the provision of a critical appraisal of the style and expression of documentation produced.

Minutes of Meetings

In the end of quarterly meetings, minutes will be issued which comprises of the discussion made in the meeting, issues discussed, and decisions taken with the time frame for their implementation. Main points of minutes for general employees may be incorporated in the record register. These meeting minutes will also be provided to the higher authorities of Project Proponent and the contractor for their own record.

Management, Co-ordination and Information

Although Project Proponent is keen in environmental management practices and already have plans to adopt preventive measures with environmental

approaches to be followed during the environmental management practices are given below:

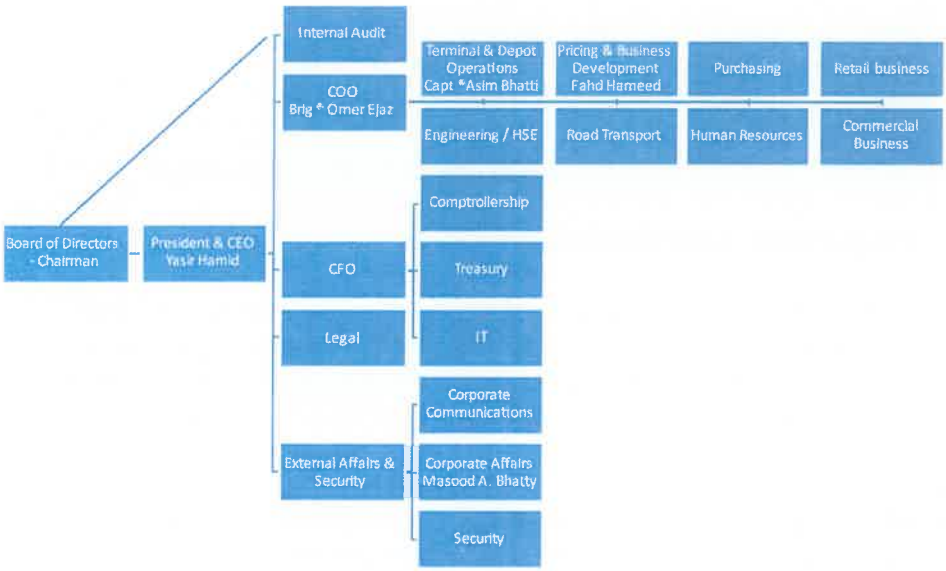


Figure 6.1: Indicative Organogram for Environmental Management

Compliance with EMP will be the responsibility of Project Proponents at each stage of project. Contractor and sub-contractor will work in environment friendly manner under the supervision of SHE department of Project Proponent. All the regulatory agencies including EPA will be contacted as and when required to get advice for environmental management and they will be kept informed of the environmental conditions of the area periodically by Project Proponents and their contractors/sub-contractors.

Some of the approaches to be followed during the environmental management practices are given below:

- Complying with the relevant legislation and regulations;
- Regularly reviewing of the impacts on the environment;
- Developing appropriate indicators to monitor core impacts;

- *Management systems:* Those systems employed in the management of the Project's operational activities. It will include financial systems; engagement and supervision of contractors; purchasing policies, etc.

- *Knowledge systems:* Those processes which build knowledge and capacity on environmental issues, principles and sustainable behaviours. It will include training; communications; campaigns; links with operational departments, etc.

- *Energy management:* The energy related aspects of the planning, design, operation and maintenance of the Project Activities.

- *Water management:* Aspects of supply, usage and disposal of water pertinent to the planning, design, operation and maintenance of the Project Activities.

- *Materials management:* Those services and activities which support the avoidance, resource recovery (e.g., reuse & recycling) and environmentally responsible disposal of solid and liquid waste materials.

- *Planning, design and development:* The planning, design and development of the Project's built form and associated infrastructure.

- *Pollution prevention:* Those aspects of planning and management which support minimization of air and water pollution and contamination of land resulting from daily routine activities.

- *Transport:* Programs, projects, systems and procedures which promote and support walking, cycling and public transport for trip-to-work, accommodation and other related travel.

- *Biodiversity & open space:* Those aspects of management and maintenance which support conservation and enhancement of biodiversity and environmentally sustainable use of open space across Project and other properties.

- Occupational Health & Safety includes hazards from operation of LNG and its risk assessment and control.

- Community Health and Safety includes the risk associated with LNG carriers, communicable diseases and hazards with pollution.

Operation of the project will affect the livelihood of the coastal communities in both positive and negative ways. In addition to employment opportunities, establishment of vendor industry, involvement in supply chain and other work will be some of the benefits that will be directly or indirectly accrued by the coastal communities. It seems impossible to provide any support to entire population/communities residing in the environs of KPT because of size of population, inadequacy in infrastructure, unorganized status of communities and other social and financial factors. However, LNGe, as a responsible project proponent, is willing to consider and plan activities to support the coastal community under a CSR scheme, for example, through Improvement of the Landing Facilities, Improvement of fish handling on board fishing vessels, improving biodiversity through plantation and sustained management of mangroves and improving the quality of life of the coastal communities through support in providing basic facilities at the villages.

Figure 5.14: Mangroves Plantation by KPT

Figure 5.13: Passing Traffic Distance for the Side-by-Side Arrangement Operation

The following are conclusions derived from the QRA study:

- For public risk, the intolerable risk for public, which is 1E-04 per year, does not extend beyond the MFP, and the broadly acceptable risk level of 1E-06 per year is contained within the jetty area. As such, the risk to public is considered to be within the ALARP region.
- The Individual Risk Per Annum (IRPA) for an individual working on the MFP is estimated to be 2.15E-05 per year. This is calculated based on the risk for an arbitrary person working at a particular location (in this case personnel is assumed to be positioned at the main pipe rack area of the MFP), with a 12 hours work shift per day (split of 70% of time spent outdoor, 30% indoor). The filling operation is assumed to take place 12 days in a month. This risk result shows that the IRPA for workers on the MFP falls within the ALARP region (i.e. between 1E-07 per year to 1E-04 per year).
- The furthest radial distance extended by the 1E-06 per year risk contour from the centre of the MFP is approximately 120m in length. 120m is thus recommended as the minimum distance between centre of the MFP and any on-shore/off-shore facilities, if applicable.
- The Ignition Exclusion Zone (IEZ) has been determined to be approximately 120m from centre of the MFP (potential release at LNG

5.3.7.14 Safety Zone

The PIANC report, 'Safety Aspects Affecting the Berthing Operations of Tankers to Oil and Gas Terminals (PIANC, 2012), provides categories for safety zones that would allow the safe berthing of LNG tankers and maneuvering past LNG facilities.

The safety zone is defined as:

• A Safety Zone is in place to prevent a natural gas release from igniting and leading to a serious incident. The primary means of preventing ignition is to exclude ignition sources from the area where gas can be ignited. The safety zone required on water side is referred as the Ignition **Exclusion Zone (IEZ).**

An ignition exclusion zone is required to be established around the LNG Filling and Receiving Facility to ensure that only essential personnel and activities are allowed in the area that could be exposed to a flammable gas in case of an accidental release of LNG or natural gas during facility operation.

5.3.7.15 LFL Distance

An un-ignited accidental release of natural gas will develop a flammable vapour cloud, which in the presence of an ignition source can lead to a flash fire. The flammable vapour cloud will travel downwind until sufficient heating and mixing with the turbulent atmosphere dilutes the vapour concentration below the limits of flammability. From a safety standpoint, interest is focused on the area covered by the unignited flammable vapour cloud before it can no longer be ignited.

5.3.7.16 Ignition Exclusion Zone

Based on assessment results, the largest LFL distance reached is 236m, from release from rupture case of ISO-01 LNG filling manifold at weather condition 1F. However, using a risk-based approach by considering the frequency of leakage, ignition probability and consequence, the predicted LFL distance at 1E-06 per year is determined to be 120m from the centre of the MFP. Figure 5.12 displays the flash fire risk contour exceeding 1E-6/year.

the ISO container filling). (Note that risk level higher than 1E-04/yr is not obtained, and hence not shown in the risk contours.)

Based on the plots, it can be seen that the operations involving filling of Cryogenic LNG Bowser/Road Truck is likely to result in a slightly lower risk level compared to the operations involving filling of ISO-containers. As such, the risk results for filling of Cryogenic LNG Bowser/Road Truck will not be assessed further.

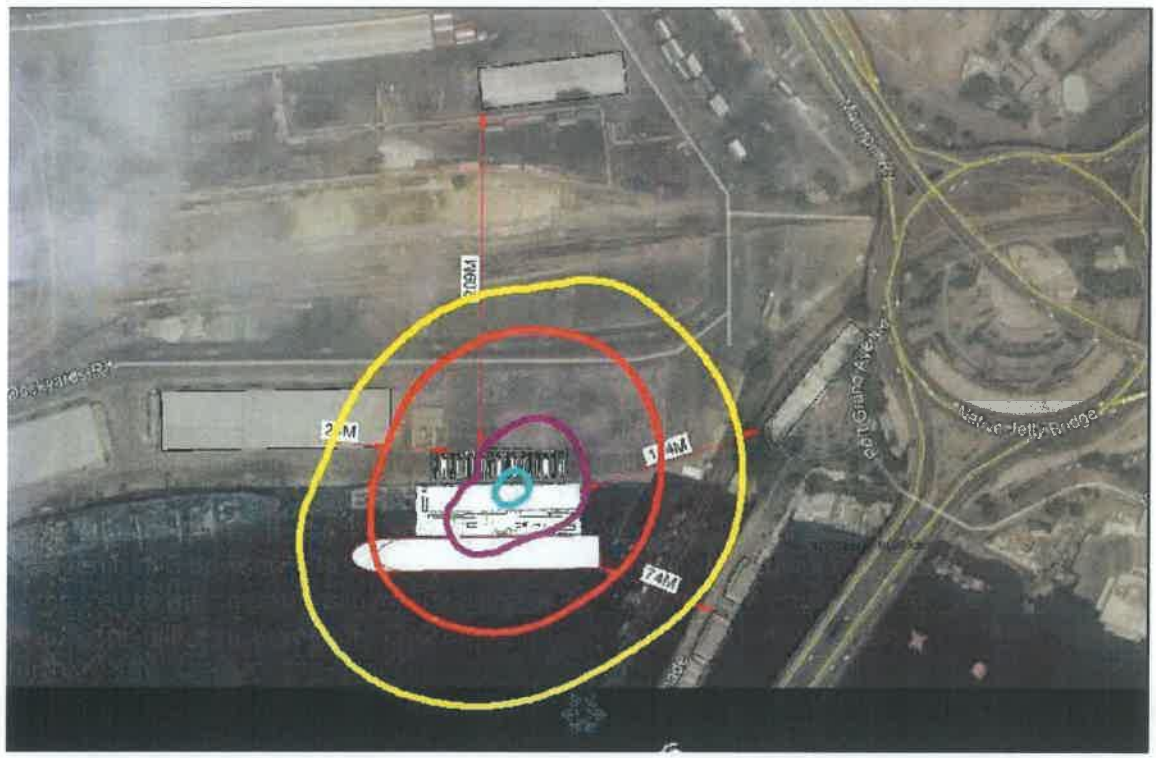


Figure 5.9: Risk contour for LNG Filling and Receiving Facility to Cryogenic LNG Bowser/Road Truck at Berth 18/19

Table 5.4: Top Risk Contributor Scenarios for IR

Scenarios	Sum of Risk Increment [/yr]	Sum of Contributions (%)
ISO-01 LNG Filling Manifold\Liq Filling\10mm\10mm Leak	**6.05E-09**	**0.0051%**
Continuous release with Rainout delayed Flash fire with eXplosion and Pool fire	2.37E-09	0.0020%
Continuous release with Rainout delayed Flash Fire with Pool fire	3.55E-09	0.0030%
Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects	1.30E-10	0.0001%
ISO-01 LNG Filling Manifold\Liq Filling\25mm\25mm Leak	**1.64E-08**	**0.0137%**
Continuous release with Rainout delayed Flash fire with eXplosion and Pool fire	3.51E-09	0.0029%
Continuous release with Rainout delayed Flash Fire with Pool fire	5.27E-09	0.0044%
Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects	7.61E-09	0.0064%
ISO-01 LNG Filling Manifold\Liq Filling\75mm\75mm Leak	**1.54E-07**	**0.1291%**
Continuous release with Rainout delayed Flash fire with eXplosion and Pool fire	3.98E-08	0.0333%
Continuous release with Rainout delayed Flash Fire with Pool fire	5.97E-08	0.0500%
Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects	5.45E-08	0.0457%
ISO-01 LNG Filling Manifold\Liq Filling\Rupture\200mm Leak	**1.65E-06**	**1.3820%**
Continuous release with Rainout delayed Flash fire with eXplosion and Pool fire	4.50E-07	0.3775%
Continuous release with Rainout delayed Flash Fire with Pool fire	6.75E-07	0.5662%
Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects	5.23E-07	0.4384%
ISO-02 Vapour Return Manifold\Vap Return\75mm\75mm Leak	**3.83E-10**	**0.0003%**
Continuous release No rainout Immediate Horizontal Jet fire Only	3.83E-10	0.0003%
ISO-02 Vapour Return Manifold\Vap Return\Rupture\150mm Leak	**9.18E-09**	**0.0077%**
Continuous release No rainout delayed Flash Fire Only	8.30E-10	0.0007%
Continuous release No rainout delayed Flash fire with eXplosion	5.53E-10	0.0005%
Continuous release No rainout Immediate Horizontal Jet fire Only	7.79E-09	0.0065%
ISO-03 LNG Filling Hoses-ISO Container\50mm\50mm Leak	**5.11E-05**	**42.8363%**
Continuous release with Rainout delayed Flash fire with eXplosion and Pool fire	1.35E-05	11.3552%
Continuous release with Rainout delayed Flash Fire with Pool fire	2.03E-05	17.0328%
Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects	1.72E-05	14.4483%
ISO-04 Vapour Return Hose-ISO Container\40mm\40mm Leak	**1.84E-07**	**0.1545%**
Continuous release No rainout delayed Flash Fire Only	2.87E-09	0.0024%
Continuous release No rainout delayed Flash fire with eXplosion	1.91E-09	0.0016%
Continuous release No rainout Immediate Horizontal Jet fire Only	1.80E-07	0.1505%
ISO-05 20'LNG Buffer Tank1\25mm\25mm Leak	**1.28E-08**	**0.0107%**
Continuous release with Rainout Delayed Flash Fire Only	1.05E-10	0.0001%
Continuous release with Rainout delayed Flash fire with eXplosion	7.03E-11	0.0001%

The IR contours for a person present continuously 100% of the time (i.e., 24 hours per day, 365 days a year) on the MFP are as presented in Figure 5.7.

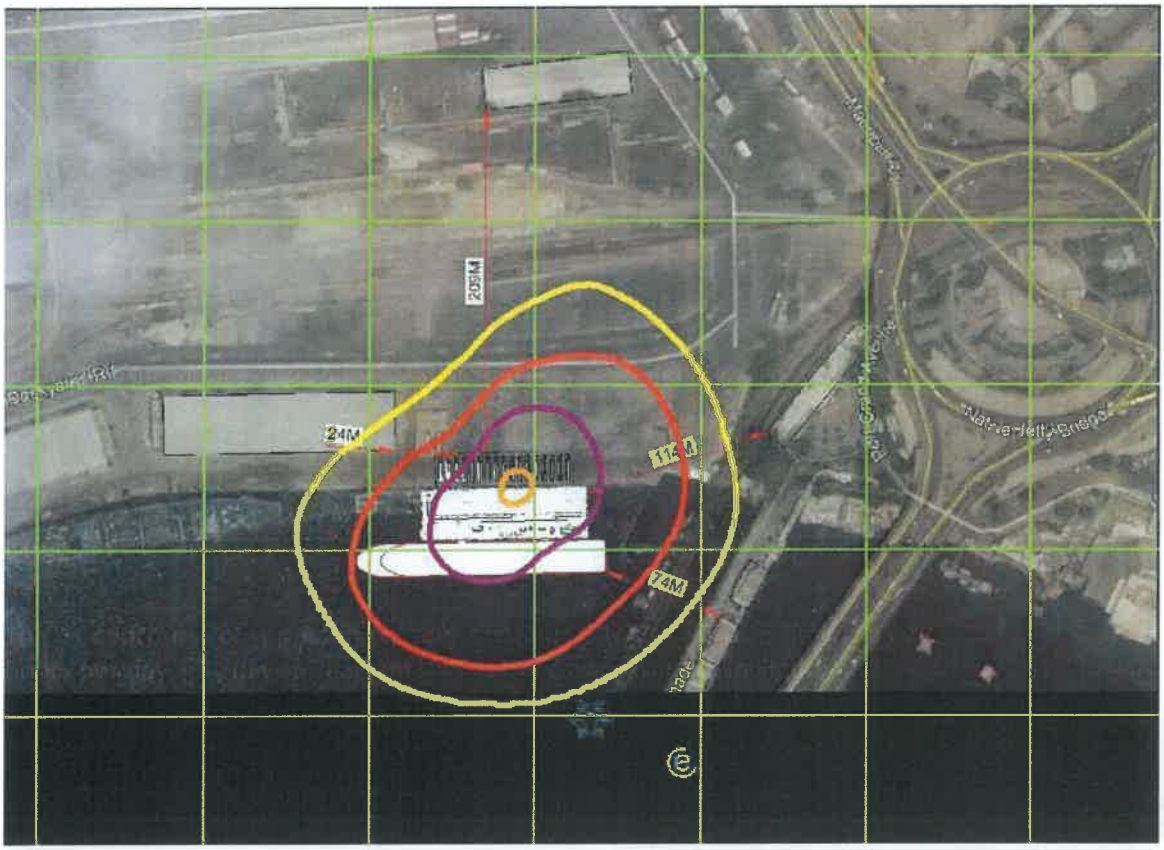


Figure 5.7: IR Fatality risk contour for LNG Filling and Receiving Facility (100m grid spacing)

The Individual Risk Per Annum (IRPA) for an individual working on the LNG Filling and Receiving Facility is estimated to be 2.15E-05 per year (regardless of which the berth the MFP will be located). This is calculated based on the risk for an arbitrary person working at a particular location (in this case personnel are assumed to be positioned at the MFP at the main header before splitting to the 3 filling bays), with a 12 hours work shift per day (split of 70% of time spent outdoor, 30% indoor in the indoor). The filling operation is assumed to take place 12 days in a month. The overall risk result shows that the IRPA for a worker on the MFP falls within the ALARP region (i.e., between 1E-07/year to 1E-04/year).

Figure 5.8 shows the risk transect across the risk contours, from the centre of the MFP extending outwards.

Figure 5.4: IR Fatality Risk contour for LNG Filling and Receiving Facility at Berth 19

IR Contours for Public for Berth 23

The IR contour arising from LNG filling operations at Berth 23 is presented in Figure 5.5, considering the risk contours extending outside of the LNG receiving and offloading facility. Figure 5.6 shows the zoom in view of the risk contour for better illustration.

Similar to Berth 18 and 19, the intolerable risk for public, which is 1E-04/yr, does not extend beyond the MFP, and the risk contour of 1E-06/yr is contained within the jetty area. As such, the risk to public is considered to be in the ALARP region.

Collision from an errant passing vessel with the LNGC while it is berthed for filling operation may result in potential leak of the cargo tank if the hull is breached. However, the berths in consideration are located at end of the channel, thus the size of vessels in the vicinity of the berths is limited to tugboats or small size vessels only. In addition, speed limit of vessel in traffic is limited to 3-5 knots. As such, these would limit the impact energy in the unlikely event of an errant vessel colliding with the LNGC causing breach or leak of LNGC cargo tank. Therefore, the risk due to an errant vessel collision with the LNGC resulting in a breach of LNG cargo tank causing leak of LNG is considered negligible.

5.3.7.12 Risk Results – ISO Containers

IR Contours for Public for Berth 18/19

The IR contour arising from LNG filling operations at Berth 18/19 is presented in Figure 5.3, considering the risk contours extending outside of the LNG receiving and offloading facility. The intolerable risk for public, which is 1E-04/yr, does not extend beyond the MFP, and the risk contour of 1E-06/yr is contained within the jetty area. As such, the risk to public is considered to be in the ALARP region.

Figure 5.3 shows that the 1E-06/year risk contour is encroaching the railway. However, based on the UK HSE Risk Criteria, 1E-06 is considered to be "broadly acceptable risk level", and hence deemed to be an acceptable risk for the public.

5.3.7.10 Jet fire

Dispersing clouds of hydrocarbons can be ignited anywhere where the concentration is above the LFL and below the UFL. The majority of clouds which are ignited do so at their edge as they disperse and meet a strong ignition source (e.g. open flame, internal combustion engine, sparks). An ignited cloud will "flash back" across all its flammable mass (i.e. that part within the flammable range – between the UFL and LFL).

It will then burn at the UFL boundary until all the hydrocarbon is consumed. This will almost always flash back to the source and lead to a residual jet fire. Factors affecting this include the material flame speed, the concentration (maximum speed at stoichiometric concentrations, lower speeds at LFL and UFL), the temperature, condensed moisture, the degree of turbulence and the presence of congestion or objects that enhance turbulence.

5.3.7.11 Risk Assessment

Risk assessment is a process by which the results of a risk analysis are used to make judgments, either through relative ranking of risk reduction strategies, or through comparison of the risk assessment with risk targets /criteria. The risk assessment stage (see Figure 5.2) determines whether the risks are tolerable, or if risk mitigation measures are required to reduce the risk to a level which can be considered as low as reasonably practicable.

Risk Criteria

Individual risk (IR) may be defined as the annualized frequency at which an individual may be expected to sustain a given level of harm from the realization of all hazards at a given location. The acceptance criteria for offsite population depend on numbers of persons in the impacted zone, their sensitivity (vulnerable populations such as the elderlies) and the intensity of the development in this area.

Individual Risk Criteria

For Public

Refer to UK HSE ALARP Principle (Ref. /4/), the following IR criteria for public are used in this study:

- Maximum tolerable risk for public: 10-4 per year – above which risk is considered intolerable.
- Broadly acceptable risk for workers: 10-6 per year.
- Within the intolerable and broadly acceptable risk levels, is the "As Low As Reasonably Practicable" (ALARP) region.

5.3.7.5 Rapid phase transformation

Rapid phase transformation (RPT) is a physical phase transformation of LNG to methane vapor mainly due to submersion in water. RPT does not involve any combustion and cannot be characterized as a detonation.

The pressure pulse created by small pockets of LNG that evaporate instantaneously when superheated by mixing in water will travel at the speed of sound and decay like any other pressure pulse. This is unlikely to damage a ship's large structural elements. No specific modelling is undertaken for RPT as it is unlikely to increase the hazard range of a major spill that has already occurred.

5.3.7.6 Flash fire

Dispersing clouds of methane (and any other hydrocarbons present) can be ignited anywhere where the concentration in the air is above the Lower Flammable Limit (LFL) and below the Upper Flammable Limit (UFL) for the given temperature and pressure.

The majority of clouds which are ignited do so at their edge as they disperse and meet a strong ignition source (e.g. open flame, internal combustion engine, sparks). An ignited cloud will "flash back" across all its flammable mass (i.e. that part within the flammable range – between the UFL and LFL). It will then burn at the UFL boundary until the entire hydrocarbon is consumed. This will almost always flash back to the source and ignite the pool.

Flash fire zones move at different speeds through flammable clouds. Factors affecting this include the material flame speed, the concentration (maximum speed at stoichiometric concentrations, lower speeds at LFL and UFL), the temperature, the condensed moisture, the degree of turbulence and the presence of congestion or objects that enhance turbulence.

When the flash fire reaches the evaporating spill of LNG, it will cause this to ignite and burn as a pool fire.

5.3.7.7 Pool fire

If LNG spills near an ignition source, the evaporating gas in a combustible gas-air concentration will burn above the LNG pool. A pool fire may result after a flash fire. An LNG pool fire generates significant thermal radiation. Large LNG fires tend to be smoky (experience indicates little smoke for pool fire diameters exceeding 30 meters) and this smoke absorbs a substantial fraction of the thermal radiation. An additional factor is that the spreading LNG spill

5.3.7.1 Release of liquefied natural gas

At atmospheric pressure, LNG will boil at -162°C, presenting a cryogenic hazard causing embrittlement of carbon steel structures and potential frost burns to exposed personnel.

Boil off Gas from LNGC is typically warmer than -130 °C, natural gas at around -120 °C is lighter than air (Ref. /6/).

Evaporated natural gas will be cold and heavier than air and will thus be spread by gravity. LNG is neither carcinogenic nor toxic. It is, however, an asphyxiant which dilutes or displaces the oxygen containing atmosphere, leading to death by asphyxiation if exposure is long enough. Since natural gas in its pure form is colorless and odorless, confined spaces are subject to special attention. With large uncontrolled release quantities, personnel in direct surroundings may be suffering from low oxygen concentrations (<6-15 V%), which should be mitigated by technical and procedural solutions.

When the natural gas is mixed with air, it will gradually become flammable. Natural gas is only flammable within a narrow range of concentrations in the air (typically between 5% and 15% for pure methane). Less air does not contain enough oxygen to sustain a flame, while more air dilutes the gas too much for it to ignite. In the event of a spill, LNG vapors will disperse with the prevailing wind. Cold LNG vapor will appear as a white cloud.

The cryogenic nature of LNG facilities represents a risk of the personnel, structural steel, equipment, instrumentation or control and power cabling being exposed to potentially injurious low temperatures. The cryogenic exposure of personnel causes frost burns; whilst the cryogenic exposure of carbon steel causes embrittlement, possibly resulting in structural failure. Consequently, protection from cryogenic exposure, as well as from fire exposure, is needed.

5.3.7.2 Non-pressurized liquefied natural gas spill

LNG is stored in bulk storage tanks at its atmospheric boiling point (approximately -162°C). Any boil-off gas is collected, and pressure relief valves are set to only allow a very low net positive pressure.

Most spill scenarios for the storage tank occur at atmospheric pressure plus any liquid head of LNG (i.e., the static liquid column above the point of release). The significance of this is that there is no pressure flashing of LNG to methane; the phase change occurs due to very rapid heat transfer and boil-off.

- A CO2 system for protecting machinery including the ballast pump room, emergency generators, and compressors.

- Certain areas of LNG carriers are also fitted with dry chemical, powder-type extinguishing systems and CO2 smothering systems for fighting fires.

Marine Hazard: Shipments of LNG will be transported to the project site through the KPT navigational channel. LNG carriers will be equipped with safety devices and the crews will be trained in safe handling and emergency response procedures. LNG carriers will comply with IGC Code, International Maritime Organization 1993. Coordination of ship arrivals and departures will be controlled by KPT.

Mitigation Measures:

- LNG Shipment will comply with the IGC Code, International Maritime Organization 1993. Procedures for inspection and safety checks will be performed on each shipment, prior to the unloading/loading operations and before the vessel is released from the terminal.

- Worldwide there is no record of serious incident of an LNG carrier involved in product transport as envisioned for the proposed LNG project. By implementing the management controls and following internationally accepted codes and standards, Project Proponents expect no marine safety-related impacts due to the shipments of LNG.

Workplace Hazard: The workers are vulnerable to potential hazards and their safety may be at risk during the operation phase as a result of increased activities at project site. The potential hazards to which worker's safety is at risk during the operation phase include exposure to materials at extremely low temperature; oxygen depletion hazards, increased fire hazards, and hazards associated with high-pressure systems.

Mitigation Measures:

- All LNG Carriers and shipping craft would be required to comply with International Convention for the Prevention of Marine Pollution from Ships (MARPOL), an international convention that aims to prevent operational or accidental pollution of the marine environment by ships (IMO 1978). For these reasons, any impact to water resources from accidental releases would be unlikely; but in case of occurrence of a spill, the impact would be of temporary nature and localized to the microenvironment of the spill.

- Fuel Spills
- Fire and explosion
- Marine Hazard
- Workplace Hazard

Fuel Spills: Spills of fuel oil can have a potential impact on soil, groundwater and surface water in particular during the operational phases of the project. These operations will be managed in a manner consistent with the requirements of the spill plan. Impacts of limited nature are anticipated from occasional equipment leaks from fuel and hydraulic systems. The potential area of impact will be minimized by implementing a schedule of preventative maintenance for equipment and by instructing personnel of the importance of controlling the area potentially impacted by release and providing immediate spill response and clean-up measures.

Mitigation Measures:

- The potential for equipment leaks from fuel and hydraulic systems will be avoided and/or reduced by implementing a scheduled mechanical preventive maintenance for equipment.

- Fuel tanks will be provided with a secondary containment system that will limit the potential impact of releases due to tank failure. The area impacted by a worst-case tank failure would be limited to the area of the secondary containment, which will be impervious to the fuel oil and sized to contain the entire contents of the tank. Operators will be provided with spill response materials and training to adequately respond to a pipe leak and minimize the land area potentially impacted by the release. Following transfer, the lines will be blown through to the tanks to minimize potential releases from the piping system between delivery operations.

- The potential impacts from spills of materials other than fuel oil will be minimized and controlled in a similar manner. During the operational phase, chemicals will be stored in a secure warehouse provided with secondary containment arrangements. The warehouse will be supplied with sorbent and other materials appropriate to minimizing the area impacted during a release and clean-up of the spill.

- *Fire and explosion:* Fire and explosion hazard impacts to surrounding islands, inhabitants, workers, and marine resources are not expected during the operations due to the limited quantities of flammable and combustible materials to be provided/transported to the site. The availability and use of portable extinguishing systems would limit the

Any acute exposures to LNG or smoke from LNG-related fires may lead to a range of health problems such as a worsening of asthma conditions; irritation of the eyes, nose, and throat; and difficulty in breathing. The symptoms of exposure may be of greater magnitude to people immediately downwind of the fire at the edge of a safety and security zone, and sensitive populations (children, elderly, or chronically ill persons). This could be a significant impact, being most severe in Hazard Zone 1 (500 m) and decreasing outward through Hazard Zones II (1600 m) and III (3500 m). However, because of the implementation of safety and security measures during marine transit, the likelihood of an LNG spill would be extremely remote and therefore is highly unlikely to impact air quality.

One of the principal GHG gases is CO2. It is a major contributor to global warming because of the huge volume of CO2 emissions into the atmosphere from burning of fossil fuels. Table presents the estimates on average CO2-e emissions per MJ delivered using different ship types.

Table 5.3: Average CO_2-e emissions per MJ delivered using different ship types

Ship size (m^3)	137,000	145,000	155,000	210,000	265,000
Diesel Consumption (t/day)	35	35	25	30	35
t CO_2-e/t Diesel fuel	3.4064	3.4064	3.4064	3.4064	3.4064
LNG BOG consumption (t/day)	369.53	389.69	416.56	Nil	Nil
t CO_2-e/t LNG BOG	2.4173	2.4173	2.4173	2.4173	2.4173
GHG Index (t CO_2-e/t LNG)	0.028779	0.027896	0.011376	0.010083	0.008859
Average inflow gas quality (Btu/scf)	1092.2	1092.2	1092.2	1092.2	1092.2
Average emissions (g CO_2-e/MJ of LNG delivered)	1.5702	1.5220	0.6207	0.5501	0.4833

Source: Life Cycle Assessment (LCA) of Liquefied Natural Gas (LNG) by Paul Jonathan Barnett

Mitigation Measures:

- Air quality impacts from operation of the project's power production system will be minimized by appropriate technology to reduce the impact of emissions to conform to SEQS and applicable international standards. The power production system will be designed for high efficiency with advanced combustion controls to minimize fuel consumption and pollutant emissions.

are proposed for the filling operation of LNG from the LNGC to the ISO Containers or Cryogenic LNG Bowser/Road Truck via the Mobile Filling Platform (MFP): Berth 18/19; Berth 19; Berth 23. Final selection of preferred alternative will, however, be based on review of the site safety requirements that have been considered in the detailed QRA and other associated studies conducted by Project Proponents.

5.3 Screening of Potential Environmental Impacts

Karachi port has allowed unloading of LNG cargos, including LNG ISO Containers / Cryogenic Bowsers, at Berth 18/19; Berth 19; Berth 23. It is proposed to undertake unloading/loading of LNG ISO Containers/Cryogenic Bowsers pre-filled at source ports overseas and also by using mobile LNG container filling system through which LNG will be filled in 40 feet ISO Containers/LNG Bowsers on trailers parked on the berth.

Initially small-scale LNG vessels of 10,000 to 30,000 cubic meter size will be used which will discharge LNG into ISO Containers/Cryogenic Bowsers at the allocated berths at Karachi port through Mobile Filling Platform (MFP) moored at the berth. The LNG vessel will be moored on the outside of the MFP. The MFP will be removed from the berth immediately upon completion of discharge activity.

The entire operation will not require construction of any permanent/fixed structure, re-gasification or storage at the port and is confined only to unloading of pre-filled LNG ISO Containers/Cryogenic Bowsers and/or from LNG Vessel through MFP to the LNG ISO Containers/Cryogenic Bowsers on 40 feet trailers on the berth.

Thus, this project would not require any site preparation works (dredging and/or reclamation activities) and would therefore have 'No' impact on the marine ecosystem in particular the mangroves and benthic ecology.

Screening of potential impacts due to proposed Virtual Pipeline for supply of Small-Scale LNG in ISO Cryogenic Tanks at Karachi Port are related to:

5.3.1 Waste Discharges

Water withdrawals and discharges due to operation of the proposed project will include the following:

Ballast water withdrawals: During the offloading of LNG, the LNGCs take on ballast water to offset the tonnage of LNG. The ballast water is used to correct for trim, list, and structural items. In addition to taking on ballast water, the

Table 5.1: Safety Parameters for Siting LNG facility	
Navigable Depth	Not less than 10m CD but dependant on the vessel deployed for FSRU and LNGC.
Ignition Source	Should be excluded from within the pre-determined radius from the jetty manifold.
Mooring Layout	Should hold the carrier safety alongside in all condition of wind and current (spacing about 150-290m and 40-50m inshore of berthing face).
Hooks	Quick Release hooks must be provided.
Emergency Release System	At each hard arm at the terminal. Emergency Release System (ERS) should be interlinked to the ship's Emergency Shutdown System (ESS).
Operating Limits	Should be established for berthing, stopping, cargo transfer, hard arm, disconnection and departure from berth.
Standard Area Limits: 150-250m around the vessels & jetty (Berthed / Discharging Cargo) (Refer Dispersion Modelling)	
LNG terminal, berths should not be sited on the outside of channel bends	
Pilots are mandatory on all vessels over 200 gross tons	
A minimum of two fast patrol craft required to enforce moving safety and security zones and to clear the channel and berth area in advance of the LNG vessel.	
Two dedicated handling boats, with a minimum of 400 HP required for mooring services.	
Buoys with range markers and radar reflectors on the tower are required for safe navigation	

The site location process has duly followed the siting criteria and guidelines and has been done in accordance with the following steps:

- Carried out Quantitative Risk Assessment to industry standards
  - Hazard identification to determine list of scenarios to be studied (HAZID process)
- Environmental & Social Impact Assessment (ESIA)

There was no interference by vessels and tugs within the LNG Industry safety practices have ensured safe operations with no incidents on LNG facilities or vessels since many decades. Table 5.2 presents the properties of LNG in comparison with other liquid fuels such as liquefied petroleum gas (LPG), gasoline and fuel oil. Unlike gasoline and fuel oil, LNG is a cold, nontoxic, non-corrosive substance that is transferred and stored at atmospheric pressure. Natural gas consists mainly of methane, which accounts for the good safety record of LNG terminals. Since methane is lighter than air, it disperses relatively easily if there is a gas leak. In contrast, LPG, which is a generic name for

would also require appropriate design to ensure health and safety parameters are met at nearby industrial activities and terminals and any adjacent residential areas. The onshore facility would involve the installation of insulated cryogenic pipelines, landfalls, road crossings and pipeline pressure relief systems. Critically, it would involve construction work that may exceed 05 years. About 25-30-hectare flat land would be required within 4 km distance from jetty location to accommodate the land-based terminal of about 5 million tonnes per annum (MTPA) gas throughput capacity. The surface area of the marine jetty platform shall be of sufficient size for operation of the land-based facilities taking into account lay-down and working space for construction. In order to accommodate LNG vessels, a dedicated berth structure/ Jetty facility and dredging, as per port conditions, are also required. An onshore regasification terminal without storage tanks was also considered. In this concept, the LNG carrier at the jetty would unload LNG directly into the onshore regasification plant. However, this option does not offer a continuous LNG supply as no regasification will be possible on the departure of empty LNG carrier. Concepts involving		Diesel will only be used as a backup and for initial start-up. Under normal conditions, there will be no venting of HC/gas and emissions and BOG is a clean fuel with no sulphur content and very little particulates. The floating storage and regasification unit (FSRU), moored at the near shore jetty, provides all the functionalities of a land-based terminal and thus includes LNG storage, regasification facilities and related utilities, cargo transfer systems, safety systems etc. An island jetty platform structure and a breakwater are required in this solution to accommodate the FSRU and the incoming LNG carrier ship. For this solution a HP gas subsea pipeline from jetty to the landfall point (considerable shorter length) would be required to transfer regasified LNG (RLNG). These were further assessed based on the following criteria: ▪ Schedule risks ▪ Cost ▪ Expandability ▪ Proximity to selected site ▪ Throughput flexibility The FSRU based (floating) terminal would offer the following: ▪ Will have the least schedule risks; ▪ Have lowest CAPEX; ▪ Will be relatively safe and reliable solution providing a high availability level;	LNG from the LNGC will be unloaded to the LNG ISO containers or Cryogenic LNG Bowser/Road Truck will be filled via the Mobile Filling Platform (MFP) at the jetty. Operators will need to connect the filling hose and vapour return hose to each ISO Container or Cryogenic LNG Bowser / Road Truck. Vapour return from the ISO containers will be sent to LNG buffer tank where the gas will be heated and sent as fuel gas to the gas generators. Up to 18 ISO containers or Cryogenic LNG Bowser/Road Truck can be filled simultaneously. Once filling is completed, operators will disconnect the hoses and the ISO containers/trucks will leave the jetty. The filling rate to each ISO containers is 40m3/hr. It is anticipated that it will take 1hr to fill the ISO containers. For offshore operation, flowrate of up to 720m3/hr (40m3/hr x 18 ISO tanks) is envisaged. LNG from LNGC will be pumped from cargo tank to fill the 40' LNG ISO containers. The in-tank main cargo pump design flowrate is 1400m 3/hr and since the pumping capacity is much higher than the flowrate into the ISO containers, throttling is necessary from the LNGC. The flowrate can be reduced to 420m 3/hr with throttling. Boil off gas (BOG) will be generated and returned to the LNGC via the vapour return line and needs to be handled on the LNGC. Spray pump on the LNGC will be used during start-up/ initial filling to cool down the whole system before

shortage of gas. Recent field gas supply projection reports depict that Pakistan will have its fields depleted in next 10 years. This critical situation is not addressed by the 'no action' alternative.

The energy procurement alternatives for Pakistan comprise:

- Continuation of import of crude oil for further refining;
- Import of petroleum products including high sulphur furnace oil (HSFO), gasoline, high speed diesel (HSD) oil, and LPG
- Local indigenous production of gas
- Import of NG or pipeline gas and
- Import of LNG through LNGC and deliver as LNG/RLNG

Inadequate refining capacity in the country is a major constraint in alternative (1) while alternative (2) involves import of petroleum products whose ever-increasing cost demands provision of hydrocarbons in alternative form or providing power from an alternative energy source. In addition, environmental degradation is a serious concern as a result of increased carbon emissions. As regards alternative (3) and (4), the indigenous oil and gas resources have been depleted to the bare minimum, while the import of gas by pipeline despite being viable has become part of international politics and there is no viable solution to this effect in the offing. This leaves import of LNG as the only alternative that can deliver the gaseous hydrocarbon at the earliest and thus resolve the looming crisis that the Country is faced with. (5) Import of LNG through LNGC and delivery as LNG/RLNG offers an economically viable alternative since:

RLNG constitutes extractable hydrocarbon components other than methane depending upon the source and if rich,

Natural gas is an eco-friendly fossil fuel, while the use of HSFO & HSD as fuel for power generation on large scale is least desirable due to high content of sulphur and consequent emissions of SOx & NOx.

Import of LNG is the preferred alternative for procurement of NG by which multiple objectives would be achieved. Additionally, the project brings environmental benefit on a macro scale to the macroenvironment and global environment.

The proposed Project therefore provides a more sustainable solution to meet the expected increase in energy demand.

completely for the damage done as a man-made system cannot provide the same resilience as a natural mangrove ecosystem. Ecosystem services cost must be paid by every proponent to enable SFD to implement sustainable programs for mangrove plantation/replantation.

- We support sustainable development and welcome development projects along Karachi's coastal areas, but efforts need to be made to minimize the harmful impacts on the environment. The current pace of developmental activities in the environs of KPT needs to be evaluated comprehensively as the cumulative impacts of several development projects can cause irreversible environmental impacts.

- With the passage of time, the space between the residential areas and the industrial areas has been reduced which can cause problems from an administrative point of view and increase the risk of environmental damage. There should be a buffer zone between industrial zones and populated areas.

- We are uncertain regarding the potential impacts from the proposed LNG Terminal on the environment and local community of the area. Local communities have not seen any significant benefits from past development projects. Very few industries have hired local communities which represent a minor proportion of locals seeking alternate employment. Fishing community welcome development in the area and believe it will benefit the country, but the local communities must be made part and parcel of the development process.

- People are switching their profession from fishing because of the decline in the fishing industry. For communities with lack of alternate skills, switching to a new sector is difficult, while those who possess alternate skills, new sources of employment are providing them a better standard of living than fishing. With respect to the proposed development, the fishing grounds of the local communities need to be safeguarded. Already, past development projects have done enough damage to the smaller fishermen by restricting their traditional fishing routes. Due to past developments in the area, fishermen now have to travel longer and farther to reach their fishing grounds that has not only increased the cost of fishing but also reduced their profit.

- Karachi Port Trust (KPT) has initiated mangroves plantation campaign 2020-21 adding leaf to the clean and green initiative of GOP. According to the initiative, the authority would plant 100,000 mangroves every quarter through plantation campaigns and activities like public awareness drive in educational institutions, conferences and symposia arrangements.

The stakeholders were briefed during scoping sessions about the background and objectives of the Virtual Pipeline for supply of Small-Scale LNG in ISO Cryogenic Tanks, its needs, and the necessity of introducing the EIA process.

The primary & secondary stakeholders submitted the following observations:

- Pakistan is currently facing a shortage of gas. The two existing Floating Storage Regasification Units ("FSRU") – namely Exquisite and BW Integrity, which are based at Port Qasim, east of Karachi, are working at full capacity sending gas to shore to power generation companies and fertilizer plants. However, lots of demand remains unmet. For instance, a lot of the 3,000 Compressed Natural Gas ("CNG") stations are stranded without pipeline gas supplies. The size of the shortage is said to be 600mmscf/d or about 12,000t of LNG per day.

- Another bottleneck Pakistan is facing is pipeline capacity. Currently only 25% of the population is connected to the grid. Once the government finalize pipeline construction contracts it will take further 3/4 years' time to complete. Before that, pipeline connection coverage remains at about 13%. At the moment, Exxon-Mobile and DGI from Japan are applying to set up additional FSRU terminals however, they will have to wait until new pipeline capacity is available.

- LNG has never been considered a retail fuel. The main importers (Japan, Korea, Taiwan) use it for power generation. The countries where pipeline gas is available such as US and Europe, gas-to-power is the main form of consumption. Only in China, due to availability of cheaper fuel such as coal and hydro, LNG has been developed into a retail fuel, even residential fuel. Whilst the countries achieving earlier industrialization and advanced economy status are using coal gas, LPG and synthetic gas for residential gas grid, China has been able to connect over 500 million residents to the city gas network. China is also pioneering the use of virtual pipeline to distribute LNG – some 27 million tons in 2019 were transported by some 13,000 road tankers[41] and ISO tank containers in the country. China has over 600,000 LNG fueled heavy duty trucks, taking up 98% market share in the fleet of global LNG trucks. It is the opinion of LNGe that selling LNG to residential customers by virtual pipeline is the future as opposed to the more traditional big B2B sectors of power generation etc.

- LNG can be a major contributor in discontinuing the use of domestic gas and more expensive petroleum fuels and LPG.

[41] Pakistan Government calls "Road tankers" as "Cryogenic LNG Bowzers". Both terms are used interchangeably.

5.0 Stakeholders Engagement, Screening of Potential Impacts & Proposed Mitigation Measures

This section presents the screening process that identifies the environmental aspects and makes assessment of impact of different activities on the physical, biological and social environment. The screening process has through review of literature, screening of potential environmental and social aspects raised by the stakeholders, primary as well as secondary baseline data, and expert judgment, made assessment of the potential impacts of said activities on the physical, biological, and socioeconomic environment of the Project. Mitigation measures have been proposed to reduce, minimize or compensate for the identified potential negative impacts & their adoption has been recommended.

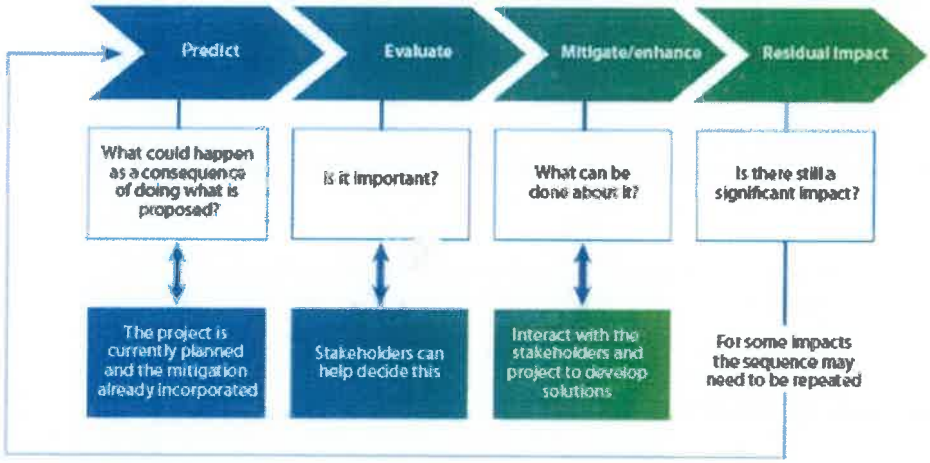


Figure 5.1: Impact Assessment Approach

5.1 Screening of potential environmental aspects raised by stakeholders

The EIA process is considered incomplete without active public participation. Accordingly, the Sindh Environmental Protection Act 2014 as well as the rules & regulations framed thereunder demand robust public participation in the formulation and implementation of all development projects.

Public consultation & participation process is the means to communicate the pros and cons of the project to those directly & indirectly affected by the project and to ensure that the EIA process is open, transparent and robust, characterized by defendable analysis to attain sustainability in the design, implementation, operation & management of development proposals. The stakeholders are provided the opportunity to directly express their concerns before the feasibility of the project is ascertained.

The main villages / towns near the project area are Keamari, Manora, Sultanabad, Sher shah, Machar Colony, Bhuta village and Baba Bhit, Gabo pat, and Mauripur.

4.3.16.3 Mother Language

The most commonly spoken language in Karachi is Urdu, the national language. Other national languages spoken in Karachi are Sindhi, Punjabi, Pashto and Balochi and are widely spoken in the city.

4.3.16.4 Ethnicity / Tribes near the Project Area

The population near the project area is a mixture of various heterogeneous groups and cultures. The main tribes are Talpur, Memon, Syeds Baluchs, Somro, Mirzas, Sheikh, Khatris, Qureshis, Abbasis, Bhurgari, Lashari, Laghari, Ranghar, Panwhar, Halepota, Mari, Banglani, Gorchani, Khosa, Sameja, Gurgaj, Bhanbhro, Jat, Arain, Qureshi and Sheikh. Many people from Punjab and North West Frontier Province (NWFP) have settled in the project area.

4.3.16.5 Main Occupation Dwellers near the Project Area

The entire community in the nearby islands has a fisheries-based economy and there is a tendency among the young men to search for employment in shipping related services and on passenger / pleasure boats. The contribution of women in earning a living used to be very small as compared to men. However, with the promotion of educational awareness by the big school setup by Pakistan Navy League (an organization of retired Naval Officers) the girls are getting educated and are joining the teaching profession after acquiring PCT certificate. 20 girls from the same school have already obtained PCT certificate.

4.3.16.6 Industry

The Industry near the project area comprise of Oil Handling Setups in the Oil Installation areas and mostly marine related workshops, cargo/container storage depots, ship chandlers, etc in the Keamari Timber Pond Area. These give employment to thousands of skilled and unskilled workers. The Port Operations including cargo handling also employ thousands of workers.

4.3.16.7 Other Facilities of Life

The availability of basic amenities of life to the community living near the project area is an indicator of its socio-economic conditions.

URC reports that women respondents complain about non-availability of female seats, having to sit on hot engine cover in buses, harassment, and unnecessary touching by male drivers and conductors.

The urgent need for a public transport system specifically for just one sub-set of the population can be gauged form the fact that morning peak hour traffic is largely generated by travel to educational facilities. A research study conducted by JICA in 2005 reports 15.43 million trips to educational facilities per day. Out of a total of 24.227 million trips made on a typical weekday, 60% are for schooling purposes. This number sheds light on the immediate need to address the transportation needs of the education sector. In order to substantially reduce traffic congestion, there is a need for providing student specific transportation on various routes, providing reserved seats for students, and involving private educational institutions to provide transport facilities for students.

4.3.15.20 Roads

The Karachi Metropolitan Corporation (KMC) is responsible for the maintenance and upkeep of all major roads within the city, and District Municipal Corporations (DMC) are responsible for the secondary/tertiary roads (176 KM in length) along with associated drainage and street lighting. Maintenance budgets come from federal, provincial and district sources and new construction and maintenance works are contracted out - although contractors frequently hire back the plant owned by the Works and Services department in order to undertake the works.

4.3.15.21 Fire Services

Under the Sindh Local Government Ordinance (SLGA) of 2013, the KMC is responsible for the maintenance of a fire brigade for the prevention and extinction of fires. However, the Karachi Fire Brigade does not possess adequate staff, fire stations and equipment to cover a city of over 13 million people which creates a serious shortfall in fire service coverage. There is a serious need for trained fire-fighting staff as well as hydrants – of which there are only nine in the city.

4.3.15.17 Solid Waste

Solid waste management has become a daunting task for KMC and DMC authorities which seem to lack the capacity to deal with the escalating waste production. Statistics indicate that on a daily basis, approximately 12,000 tons of solid waste is generated in Karachi alone, out of which forty percent can be found on the city streets. Improper management of solid waste is causing the spread of infectious diseases and environmental pollution.

Solid Waste Management within the City is the combined responsibility of Sindh Solid Waste Management Board (SSWMB) and DMCs. In addition, the Cantonment Boards, Karachi Port Trust and Pakistan Steel Mills carry out their own waste collection and waste transportation. The key agencies responsible for collection are the town councils who either use their own equipment or contract private sector operators for managing and operating the primary collection system. KMC is responsible for the maintenance and operation of the land fill sites at Jam Chakro and Gond Pass located each at 35 km from the city center.

Public opinion and perception of solid waste management system is characterized by irregularity and inefficiency of the collection system as well as poor monitoring of the private waste service providers by the local authorities. Most of the households recognized solid waste management as a major problem. It was also revealed that residents currently pay for waste management services to private waste pickers. Strategies to address solid waste problem will need to consider an adequate supply of containers, intensive public education and introduction of user fees for waste management services.

4.3.15.18 Power Supply

Supply of water depends on the availability and quality of electricity in the towns, although almost all of the households were reported to have an electric connection in their household. However, electric supply was found to be very erratic in informal settlements. Due to irregular electric connections, operation of water pumps is interrupted, and a steady supply of water is stalled. It has been observed that many settlements get water only once in a week. This has serious implications on enhancing coverage by generating a demand for piped water supplies because it invariably requires pumping.

collaboration between the government and the NGO sector regarding provision of sewerage in Karachi.

Over time, water and sanitation services are provided but growing population pressures, commercialization land use, and unorganized development due to housing shortages has led to unregulated urban growth and the development of unauthorized katchi abadis stresses service delivery in water and sanitation sector.

Apart from inadequate investment water and sewerage deficiencies, the overall shortage is due to the following factors: poor collection of revenue from users; deficient maintenance because of under-trained staff and lack of required funds; lack of appropriate policies; and limited capacity of the management. Charges for water are low relative to both the costs and to the rates charged by private vendors. In most districts, there are no charges for sewerage and drainage services. Further the existing sewers have outlived their design life and suffer from insufficient hydraulic capabilities, heavy silt deposition and severe choking due to dumping of solid waste.

4.3.15.16 The Drainage System

There are two types of drainage in Karachi — storm water drainage and surface drainage. Karachi's drainage situation is complex; it has several natural and man-made drainage systems, two drainage basins, large natural drains, storm water drains along roads and combined 'sewer and storm' water drains.

According to the Orangi Pilot Project, Karachi has 41 major drains. These drains are about 167 KM in length and discharge into two non-perennial rivers, i.e., the Malir and the Lyari, which run through the city districts.[36] Gujjar Nala is among the main streams of Karachi beside the Orangi stream which is a tributary of the Lyari River. The Gujjar Nala is an ephemeral stream which flows through the megacity of Karachi from north-east (North Karachi Sector 11J) to the center and merges with Lyari River in Liaqatabad Area before draining into the Arabian Sea. Most of the Gujjar Nala passes through the Karachi Central District while the remaining passes through Karachi West District. The Nala carries waste generated from industrial and domestic activities — these activities can generate up to 472 MGD of waste water in Karachi. Minor drainage networks

[36] These drains include Gujjar Nala, Orangi Nala, CBM Nala, Chakra Goth Nala, Nasir Colony 2100 Road Nala, Chakore Nala, Soldier Bazaar Nala, PECHS Nala, Mahmood Abad Nala and other drains scattered across the city.

Table 4.15: Water sources in Karachi, by districts (per cent)

District	Purpose	Piped	Public Tap/ Filtration Plant	Boreholes/ Tube well/ Hand pump	Tanker/ bottled	Other
Karachi	Drinking	66.2	3.7	3.8	23.2	3.0
	Other	71.0	0.3	18.0	9.1	1.7
East	Drinking	70.8	2.5	7.0	18.4	1.3
	Other	73.2	0.0	24.1	2.7	0.0
Central	Drinking	79.9	2.3	4.8	11.2	1.7
	Other	85.9	0.0	9.0	2.6	2.6
West	Drinking	46.9	2.2	2.4	40.7	7.8
	Other	63.6	0.0	13.6	18.2	4.5
South	Drinking	67.2	9.7	1.6	20.1	1.4
	Other	73.9	0.9	3.6	19.8	1.8
Malir	Drinking	64.8	2.5	2.8	26.7	3.2
	Other	30.8	0.0	61.5	5.1	2.6

Source: Multi Indicator Cluster Survey 2015-16 dataset

On average, approximately two-thirds of Karachi's population relies on piped water for drinking and 71 per cent for other purposes. About one-fourth of the population in Karachi purchases water through tankers or water bottles, or other sources.

In the two districts – East and Central, the reliance on piped water is slightly higher than the average. In District East, the reliance of other (privately installed) investments such as boreholes, tube wells or hand pumps is also slightly higher.

In the case of water supply, among the minimum critical sustainability criteria included is the provision of an average of 5 liters of water per capita per day for drinking and cooking. The Strategic National Master Plan for Water and Sanitation also makes it mandatory in addition to potable water. However, international guidelines widely followed, use a broader definition of daily human requirements for water, including basic consumption, hand washing and food preparation needs, suggesting a volume of about 20 liters per capita per day.[35]

[35] (e.g., World Health Organization, 2003; IFC, 2007; DFID, 1998).
World Health Organization (WHO). 2003. Domestic Water Quantity, Service, Level and Health

and Gharo through an extensive generation, filtration, pumping/boosting and piping system. Against a demand of about 1080 MGD which is estimated for a population of about 20 million people, the KW&SB has the capacity of supplying approximately 640 MGD, out of which 20-40% is lost during transmission due to pilferage and leakages in the aging and dilapidated service delivery system. According to one study, if 40% of the leakages in the transmission routes could be plugged, water supply could be increased by approximately 81 MGD. The shortage is due to many reasons, such as insufficient supply from the two main sources (Indus & Hub Rivers), low levels of ground water, and inadequate and aging water transmission and storage facilities.[33]

An inefficient delivery system has forced people to make alternate arrangements through unregulated extraction, illegal online motors to boost pressure, etc., — with severe negative effects on water availability and water quality. Those most affected by this shortage are the poor who have no option other than buying water from high-priced private sources that operate in the city. In addition to the shortage of water in Karachi, substandard quality is another problem: drinking water seldom meets acceptable standards of filtration and treatment. A number of poor localities/squatter settlements have pooled money to build their own water supply systems by laying piped water networks that tap into government's main transmission lines or storage tanks. It has been observed that in settlements having larger dependence on community sources of water like boreholes, women play a crucial role in collection of water.[34]

Incidence of diverting water pipelines for personal usage are rampant leading to massive wastage and decrease in the already low water pressure supply at the tail end of the distribution chain. Water requirements peak during certain times forcing many households to obtain supplementary water supplies at high costs. Tankers and pushcarts provide complimentary services in unauthorized colonies and slums.

The many challenges in delivering proper water services include: improving the quality of raw water, providing household connections to the poor, efficient provisioning of services, checking illegal tapping and transmission leakages, setting up distribution networks in highdensity informal settlements with metering, strengthening weak grievance redress and voice systems, proper

[33] ibid
[34] FGDs

employed labor force in Sindh, and out of the total number of large-scale units in Sindh, 72.7% were located in Karachi producing 74.8% of the total large-scale output of the province.[29] According to the 1998 census, employment has fallen from 33.43% in 1981 to 27.58%, with the worst affected being the population above 60 years of age.

Table 4.14: Labour Force Participation 1981-98

Employment	1981		1998	
Male	1,235,104	95.06	1,920,895	94.33
Female	64,126	64.94	115,406	5.67
Total	**1,299,230**	**33.43**	**2,036,301**	**27.58**
Pop. 10 and above	3,886,152		7,384,156	

Source: Arif Hasan and Masooma Mohib, 2001

The pattern and nature of employment can be judged from one sample study that was conducted in 2005 and consisted of 5,000 households in 18 towns of Karachi Division which shows that out of the total population, 81% is employed, out of which 50% are self-employed, 31% are employed by the private sector, 3% by the semi-private sector and 16% by the public sector. Out of the self-employed, 32% are shopkeepers and 12% are laborers. However, out of the total population, a large proportion of the city population, i.e., 75% is employed by the informal sector comprising of small scale or cottage industry, trade and provision of services including water, waste disposal, health, education and housing.[30]

The growth in the service sector has attracted many people to new jobs in the city; however, the existing infrastructure has been unable to cope with the growth. As a result, the poorer populations, though an integral part of the growing service sector, have been pushed out into relocation colonies far from the city center to make way for new development in line with the economic growth of the city. The distance of these relocation colonies from the city often results in a total disconnection from livelihoods and limited access to basic services — further deepening the cycle of poverty.

4.3.15.12 Informal Sector

The informal labor market is characterized by lack of regulation, lack of security in conditions of employment and ease of entry. It includes small, unregulated

[29] Khuhro, Hamida & Mooraj, Anwer (1997) Karachi, Mega City of Our Times, OUP, Karachi

[30] ECIL, 2005

issuing any such NOCs. Housing needs of approximately 50% of Karachi's population requiring low-income housing are met via densification of existing Katchi Abadis and slums, vertical growth of existing settlements and horizontal growth on vacant land and encroachment on natural drains.

Comparison of housing data from 1980 and 1998 reveals that the total stock of one room houses fell from 44.94% to 30.09% and the total stock of three-room houses increased from 13.96% to 21.12%; the number of houses with electric connections increased from 65.78% to 93.79%; the number of houses with piped water connections increased from 44.45% to 74.38%; and the percentage of houses with reinforced concrete roofs increased form 42.5% to 56.04%.[25]

These large sections of the city's population living in unplanned settlements have minimal or no access to basic services. Karachi's high intensity construction and densely built areas add to the immense pressure on the city's water, sanitation, sewerage and solid waste management services.

The current housing demand in Karachi is estimated at 80,000 new units per year. "The formal sector supplies 32,000 housing units and another 32,000 are built in katchi abadis. Meanwhile, 75.5pc of the city's residents are classified as poor, and as such they constitute the majority of the unmet demand. The result has been the continuous demand for katchi abadis.[26]

4.3.15.10 Economy

Karachi is the financial capital of Pakistan and contributes towards a substantial percentage of the national GDP and revenue. Karachi's economy has grown steadily in the past 18 years and per capita income has remained the highest in the country. Depending on the methodology used, Karachi's contribution to gross domestic product (GDP) is estimated to range from 11 to 20 percent. According to various estimates, Karachi generates approximately 65% of the total national revenue (federal and provincial taxes, customs and surcharges). At the Sindh provincial level, the city's share of the provincial tax receipts is as high as 70%.

Karachi is home to Pakistan's premier port which handles almost 95% of all foreign trade - in 2001 alone the Karachi Port handled more than 29 million tons of cargo. The city produces 30% of manufactured goods and about 42% percent

[25] Arif Hasan and Masooma Mohib, 2001
[26] Arsam Saleem, 'Evictions, dispossessions and urban sprawl in Karachi, Karachi Urban Lab, 2018

The presence of private sector health facilities has helped in improving health related incidences of poverty. The current infant mortality rate under 5 years [per 1000 live births] has improved to 59 and the maternal mortality to 180. These positive changes reflect increasing levels of awareness, education and the availability of decentralized governance of Sindh Katchi Abadis. An increasing number of young people in Karachi are benefiting from preventive health facilities and the adoption of family planning presence of private sector health facilities helped improve health related incidences of poverty. The current infant mortality rate under 5 years [per 1000 live births] has improved to 59 and the maternal mortality to 180. These positive changes reflect increasing levels of awareness, education and availability of decentralized governance of Sindh Katchi Abadis. The preventive health facilities and adoption of family planning practices by an increasing number of young peoples in Karachi practices.[19]

4.3.15.6 Disability in Urban Sindh

During the year 2017-18, 3,232 men and 5,680 women at the age of 15 or above were reported to have disabilities – almost twice the number in rural Sindh. [20]The disability statistics are based on the framework of WHO's International Classification to take into account six core functional domains namely, seeing, hearing, communication, cognition, walking, and selfcare[21].

4.3.15.7 HIV

Karachi is among the top cities in the world which have recorded an 'alarming' increase in HIV prevalence, according to a senior official of the Joint United Nations Program on HIV/AIDS (UNAIDS). In 2017, the Sindh Aids Control Program (SACP) reported 11,464 HIV patients who were undergoing treatment in Karachi out of which 11,225 were HIV positive patients while the remaining 239 were full-blown AIDS cases.[22]

[19] Sindh District –Based Multiple Indicators Cluster Survey (MISC) 2003-4, Planning & Development Department, Government of Sindh, Karachi, Nov. 2004
[20] The Pakistan Demographic and Household Survey, 2017-18
[21] Person who have difficulty in functioning according to domain, by the highest degree of difficulty in at least one domain, and percentage with a lot of difficulty or cannot do at all in more than one domain, according to background characteristics, Pakistan DHS 2017-18
[22] Dawn, April 27th, 2017

people; and a trend towards the formation of nuclear families as opposed to extended ones.

In 2017, Karachi's literacy rate was 87 percent and nationally, Karachi ranked 59th in terms of school infrastructure and availability of facilities.[15] Karachi stands 43rd in national and first in district education. In 2016, Karachi's Education Score was 72.18, Enrollment Score was 73.70, Learning Score was 67.90, Retention Score was 58.00 and Gender Score 89.13 as presented in the following Graph.[16] The Figure 4 provides details of literacy and education ranking.

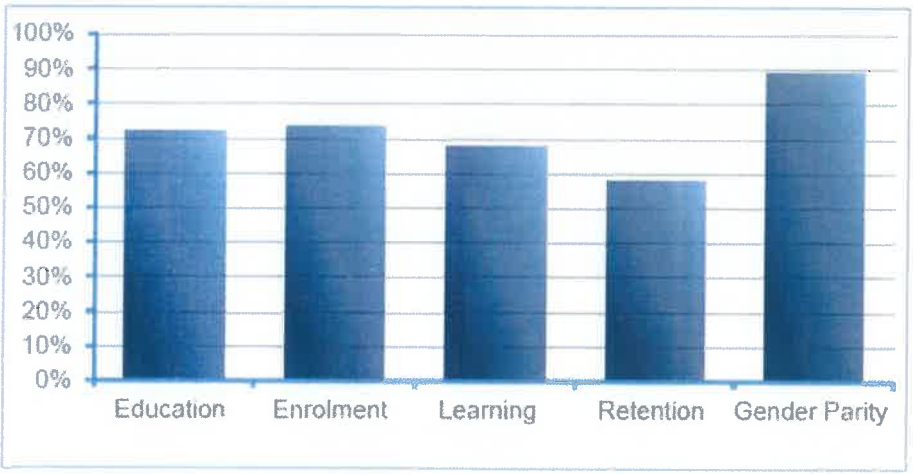


Figure 4.28: Literacy and Education Ranking

Education is one of the most important factors that distinguish the poor from the nonpoor. It is a vital prerequisite for combating poverty, empowering women, protecting children from hazardous and exploitative labor, protecting the environment and influencing population growth. However, literacy rate in Katchi Abadis exhibits a dismal picture. Overall literacy rate in Katchi Abadis is 71 per cent with a significant gender gap with 76 per cent for males and 66 per cent for females. The adult literacy rate in Katchi Abadis is low at 45 per cent, and ranges from 30 to 48 per cent in different areas with a primary enrollment rate at 54 per cent.

[15] Federal Bureau of Statistics through PSLM survey, 2017

[16] SDPI, Pakistan District Education Ranking, 2016

- Congestion at Karachi Fish Harbour. There are more than 16,000 fishing boats operating in the Sindh zone.
- The storage capacity is only 10,000t which is not sufficient to cater for future requirements.

Aquaculture

Marine aquaculture does not presently occur in Pakistan. However, freshwater aquaculture is fairly developed. The Government of Pakistan planned to take various measures to increase the export of seafood by adopting measures such as:

- Upgrading of fishing vessels to control post-harvest losses.
- Provision of modern peeling sheds for providing raw material to fish processing industry.
- Flake ice plants on harbours.
- Intensive marketing efforts at international level.
- Promotion of marine aquaculture.
- Human resource development through training.
- Regular monitoring of resources through stock assessment surveys and exploratory fishing.
- Procurement of handling and cleaning equipment for fish harbors; and
- Construction of a coastal highway.

4.3.15 Socioeconomic Status of the Macroenvironment

4.3.15.1 Population Distribution

The City is comprised of six urban districts with unevenly distributed population where the potential subprojects of the proposed KWSSIP will be identified, planned, constructed and operated. Population distribution across its 6 districts (Census, 2017), shown in the graph below, indicates much lower populations in Malir and Karachi South as compared to other districts. On the other hand, Karachi West and Central have the highest residential population densities — some parts of the districts comprise of congested residential apartments which are extremely difficult to access.

Looking at the age composition from the 1998 Census, out of the total population 37.6% is under 15 years of age and 58% of the population between 15 to 50 years of age.

These numbers point to the fact that Karachi is a young city, which implies substantial future needs relating to municipal services, water supply & sanitation, housing, education, health, employment, and transportation etc. that the city has to address.

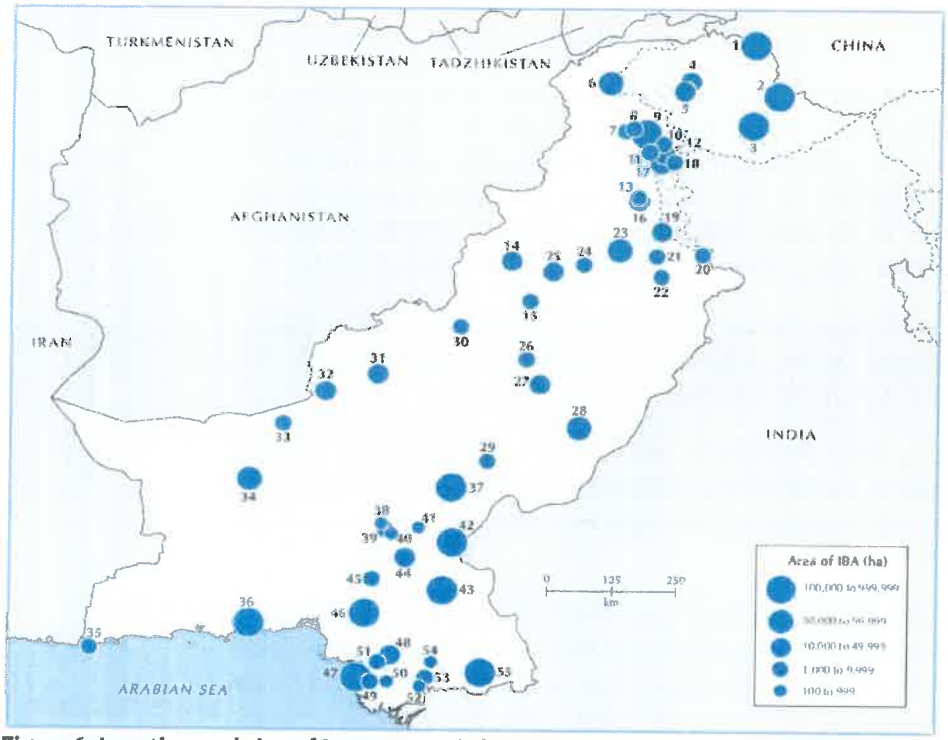


Fig 4.26: Location and size of Important Bird Areas in Pakistan

Source: Birdlife
http://www.birdlife.org/datazone/userfiles/file/IBAs/AsiaCntryPDFs/Pakistan.

Table 4.13: bird populations which are located within the Outer Indus Delta Ramsar site (as referred to in Ramsar Criteria 3)	
Bird species	
Common name	**Latin name**
Dalmatian pelican	*Pelecanus crispus*
Greater flamingo	*Phoenicopterus rubber*
Wigeon	*Anas phenelope*
Black-tailed godwit	*Limosa limosa*
Pochard	*Aythya farina*
Common coot	*Fluca atra*

Source: Information sheet on Ramsar Wetlands

More locally, over 50 species of birds are known to utilize the area, some resident and some migratory, many of which use the mangrove habitat in Chinna Creek for feeding and roosting sites.

Fisheries

The coastal fishery plays an important role in the national economy. It provides employment to about 300,000 fishermen directly. In addition, another 400,000

Natural Fish Resource

There are a number of fish found off the coast of Karachi including mullet *Liza* sp., scat *Scatophagus* sp., catfish *Ariidae*, sciaenid fish, triple spines *Pseudotricanthus* sp., lady fish *Elopidae*, file fish *Monacanthidae*, pony fish *Leiognathus* sp. and others.

The mangrove ecosystem around Manora is an important nursery area for many species of fish and shellfish species and provides shelter for many other marine and brackish water species. There are also nursery areas located in the Chinna Creek mangrove forest in the Eastern Backwaters of the Harbour approximately 3 nautical miles east of the project area. However, these species remain under severe attack of City's industrial effluents, mostly untreated.

Turtles

The Sandspit / Hawksbay recreational beaches, habitat to the endangered green turtle *Chelonia mydas*, are located approximately 6km west of Manora. The Green Turtles enjoy a protected status. The Sandspit / Hawksbay beaches represent the most important turtle nesting and breeding habitat in Pakistan.

Sea turtles enjoy a protected status in Pakistan, either directly or indirectly through the following legal and regulatory provisions:

- According to the Second Schedule of the Sindh Wildlife Protection Ordinance 1972, all marine turtles in the Sindh province enjoy the status of a Protected Animal;
- The Clause 5 (Export Restriction) in the Pakistan Fish Inspection and Quality Act 1997, of the Federal Ministry of Food, Agriculture and Livestock, Government of Pakistan, forbids the export and domestic consumption of Aquatic Turtles;
- Pakistan is a signatory to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) which includes all marine turtles for protection under Appendix I of CITES; and
- The Government of Pakistan acknowledges the IUCN Red List of Threatened Species that lists the green turtle as a Threatened Species.

Coral Reefs and Sea-Grass Beds

Coral reefs do not exist in the vicinity of the Project Area. The nearest ones are around 20 nautical miles from the project area i.e., near Churna Island where more than 60 types of coral are known to be found.

Sea-grass beds are located off the coast, with the closest area approximately 6 nautical miles, west of the project area.

Phytoplankton Study on the Karachi Coast

The coastal waters along Clifton and Manora beaches seem to be highly productive. Studies on phytoplankton which have focused on Karachi Harbour and Manora channel recorded the presence of 8 general and 52 species of thecate dinoflagellates in Manora Channel. 101 species of centric diatoms have been recorded in the harbour belonging to 30 genera, which is a more diverse flora than that recorded from the Arabian Sea coastal waters (DHA, circa 2007). This diversity may be explained by the variety of salinities and the diversity of aquatic habitats in the creek system.

Species composition of diatoms in Karachi Harbour and outside Manora Channel has changed over the last couple of decades in mangrove habitat of the Sandspit area the bloom of *Naviclula cancellata*, a pennate diatom, was reported for the first time in NE monsoon season in 1992 (DHA, circa 2007).

Zooplankton

Studies undertaken on the zooplankton abundance indicate that that copepods, *chaetognaths, coelenterate medusa* (jelly-fishes), *pteropods* (mollusc), krill *euphausiids*, fish-eggs and larvae (icthyoplankton), crab larvae (Zoea) and shrimp larvae (*Zoea* and *Mysis*) are the most common groups of zooplankton found in the coastal waters of Pakistan (DHA, circa 2007).

It is also evident from these studies that the Arabian Sea zooplankton biomass remains high throughout the year. However, the distribution and abundance of zooplankton may be influenced by the two monsoons (southwest and northeast monsoons) which prevail in this region (DHA, circa 2007).

Benthos

The Manora Channel and the berthing area of the harbour are subject to sedimentation due to the combined inputs from the Lyari River outflow and tidal movements that sweep sediments into the harbour area. The sedimentation is kept under control by dredging. This activity has a drastic effect on the natural benthos that is thus constantly removed.

The water quality in the existing harbour area is poor and tidal exchanges appear insufficient to replace it every 12 hours. There is some floating oil and floating garbage with plastic as a conspicuous element. Despite the low quality of the water, some marine species survive. The small xanthid crab *Nursia abbreviata*, often associated with sponges and the mussels *Perna viridis* and *Modiolus matcalfi* are reported to be present in small numbers.

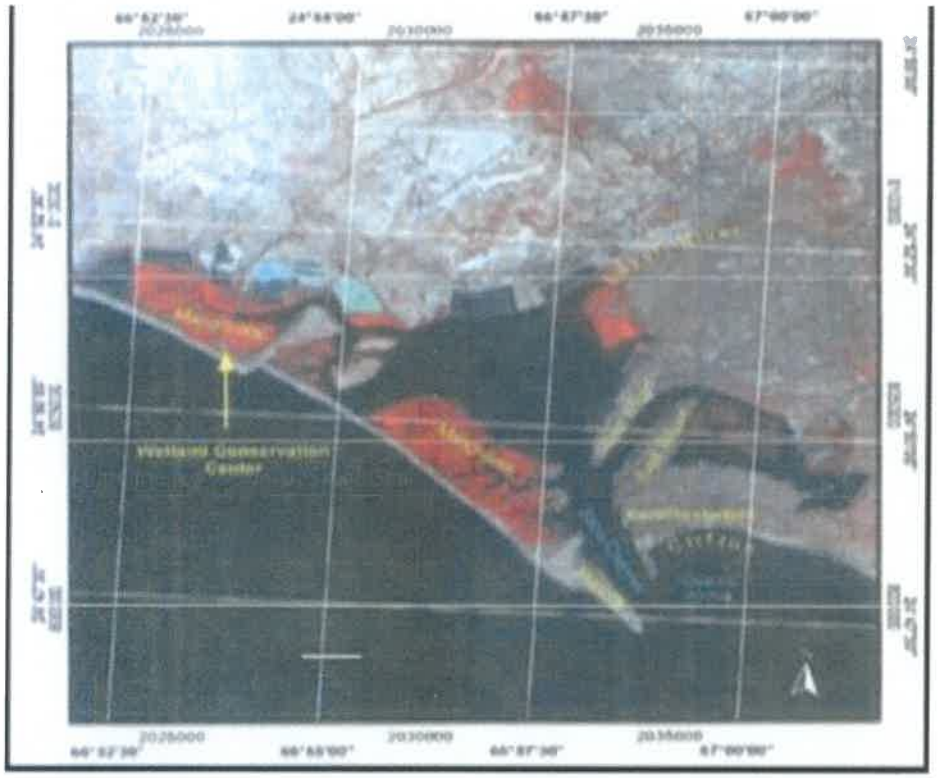


Fig 4.24 Mangroves in Karachi Harbor

12:00PM	0.57	4.8	31	0.1
1:00PM	0.42	8.3	37	0.17
2:00PM	0.63	12.9	39	0.26
3:00PM	0.38	7.1	51	0.23
4:00PM	0.76	26.9	58	0.19
5:00PM	0.93	30.1	43	0.31
6:00PM	0.38	15.3	30	0.12
7:00PM	0.19	10.8	26	0.16
8:00PM	0.13	9.3	21	0.14
9:00PM	0.16	11.7	27	0.23
10:00PM	0.18	13.4	38	0.18

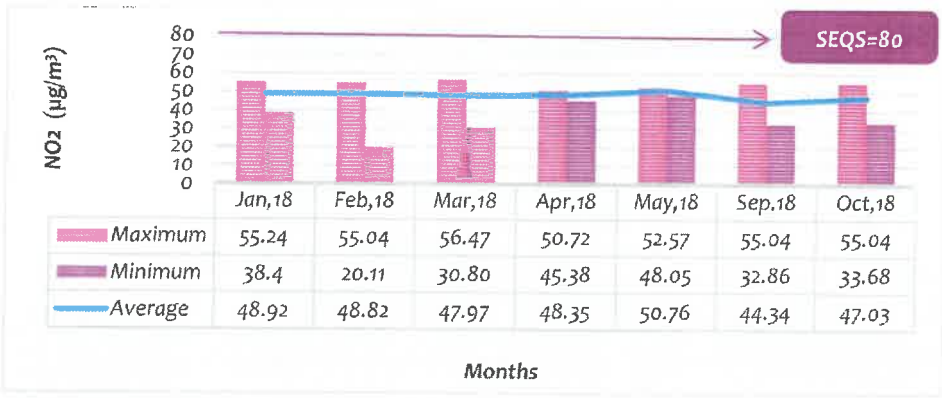
This may be noted that during the conduct of air monitoring the Oil Tanker 'Quetta' belonging to Pakistan National Shipping Corporation' was discharging crude oil at OP-I, which accounts for higher values of VOC in the ambient air. Also due to the westerly wind, blowing throughout the monitoring session the emissions from the oil tanker remained directed towards the sampling station.

4.3.13 Solid Waste Issue

Although Karachi is spatially a large city of 3,780 sq kms (with a built up area of approximately 500 sq kms), it has only two landfill sites, both next to each other and in District West. Consequently, solid waste has to be carried for over 40 kms from the eastern edge of the city so as to reach the landfill sites. Because of this distance, and the time and costs entailed, solid waste from most of Karachi does not reach the landfill sites, and is dumped at numerous informal dumping sites along the Korangi Creek and various other open areas and **nullahs** that join it. Proposals for additional landfill sites have been made since 1975 and, in a 2001 report, one landfill site for each district was suggested, but never implemented.

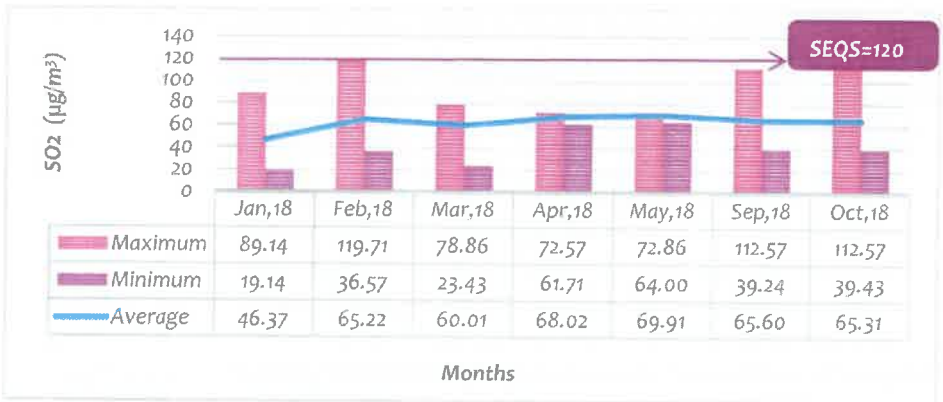
Meanwhile, a solid waste recycling industry, mostly in the informal sector, developed in Karachi over the years. This recycling industry, which is growing rapidly, acquires recyclable material from two streams. One is known as the clean stream, whereby housewives and markets sell bottles, newspapers, metal objects and cans to **kabaarris**, who then sell them to the recyclers. The other stream is known as the dirty stream, wherein young boys, mainly of Afghan origin, are organised by contractors to pick all recyclable material from **kachra kundis** or neighbourhood dumps. They carry it on bicycles to abandoned parks, empty plots or spaces under bridges, where it is sorted out into different categories and sold to the recyclers by weight.

Bones are crushed into powder and mixed with chicken feed; rags are turned into fluff by rag-pulling machines and used for upholstery; small pieces of paper are recycled into board; and plastic items are granulated and the granules are sent to the Punjab for being turned into utensils and toys. The contractors



	Jan,18	Feb,18	Mar,18	Apr,18	May,18	Sep,18	Oct,18
Maximum	55.24	55.04	56.47	50.72	52.57	55.04	55.04
Minimum	38.4	20.11	30.80	45.38	48.05	32.86	33.68
Average	48.92	48.82	47.97	48.35	50.76	44.34	47.03

Source: EPA Sindh



	Jan,18	Feb,18	Mar,18	Apr,18	May,18	Sep,18	Oct,18
Maximum	89.14	119.71	78.86	72.57	72.86	112.57	112.57
Minimum	19.14	36.57	23.43	61.71	64.00	39.24	39.43
Average	46.37	65.22	60.01	68.02	69.91	65.60	65.31

Source: EPA Sindh

	Jan,18	Feb,18	Mar,18	Apr,18	May,18	Sep,18	Oct,18
Maximum	4.41	2.58	1.24	0.83	0.61	1.61	1.61
Minimum	0.55	0.49	0.30	0.50	0.38	0.24	0.30
Average	1.44	1.36	0.67	0.64	0.48	0.65	0.58

Source: EPA Sindh

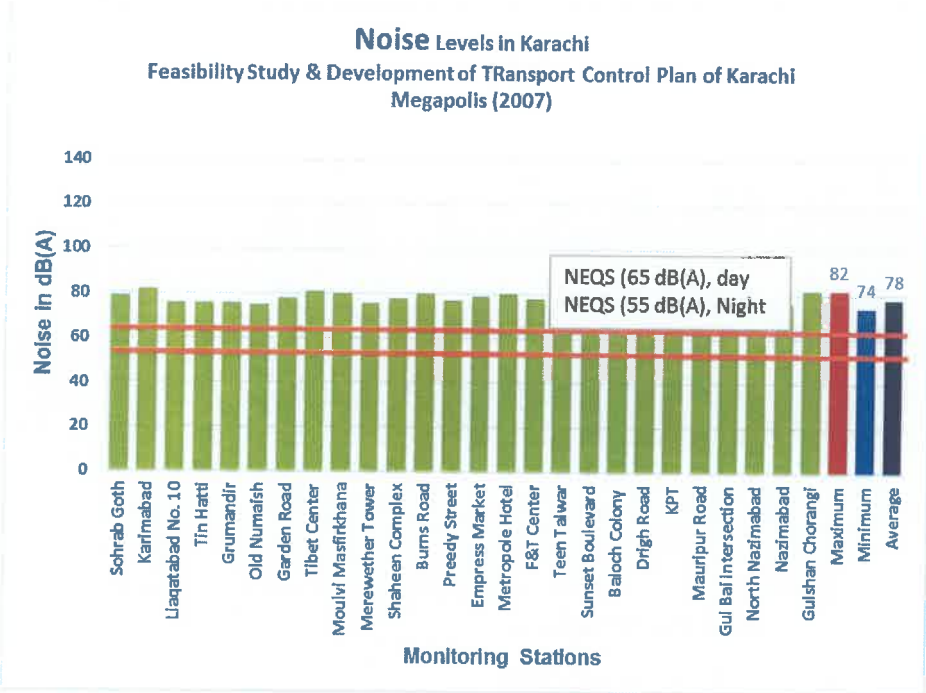


Figure 4.21: Noise Levels in Karachi

Finally, another report[12] quotes the World Bank's data with the following maximum values: PM2.5 201 µg/m³; SO2 173 µg/m³; NO2 122 µg/m³; O3 86 µg/m³; CO2 mg/m³. For reference, WHO's interim target for PM2.5 is 35 µg/m³, whereas its guideline is 10 µg/m³. WHO guideline for O_3: 100 µg/m3 8-hour mean. Both NO2 and SO2 are within WHO's guideline for short term average concentration. (200 and 400 µg/m³ respectively). Data by this same author show excessive levels of PM at major intersections, including some along the BRT corridor, as well as SO2, NO_X, O_3 and CO, all exceeding WHO limits, based on data taken by SUPARCO in 2004.

PAQI has been measuring particulate matter ($PM_{2.5}$) levels in Karachi since October 2016. The measurements show a $PM_{2.5}$ concentration of 47 micrograms per cubic meter of air (µg/m³) for October to December 2016. The World Health Organization (WHO) prescribes 10 µg/m³ as the guideline value for ambient air. Exceeding this value leads to serious public health issues.

[12] Kalwar 2014

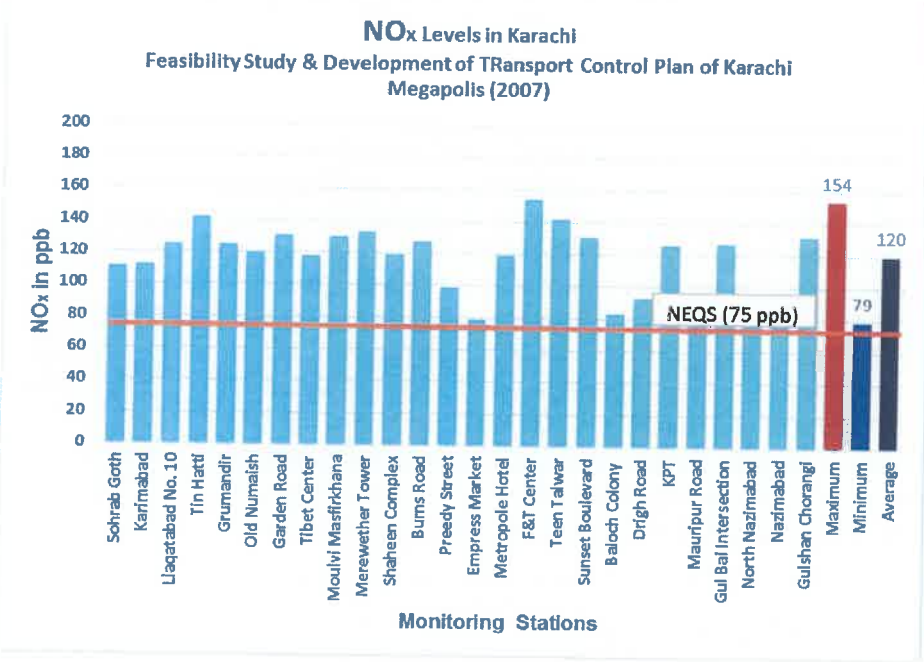


Figure 4.17: NOx Levels in Karachi

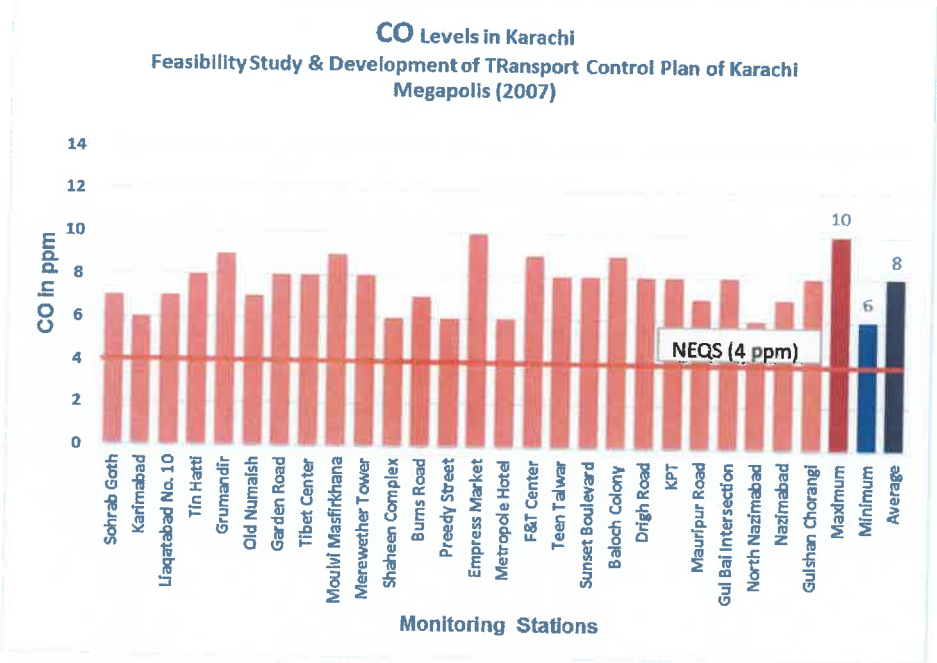


Figure 4.18: CO Levels in Karachi

4.3.12 Ambient Air & Noise Quality

Primary source of air pollution on and along the major corridors of Karachi is transport sector, so the primary pollutants in ambient air quality in the City in general and project area in particular are directly linked with fuel consumption.

According to available estimates, country's consumption of petroleum products has shown exponential growth, of which one-half is consumed by the transport sector. The high content of Sulphur in diesel (0.5-1 %) and furnace oil (1-3.5 %) is a major contributor to air pollution. Vehicular emissions are major source of $PM_{2.5}$ and these fine particulates are responsible for respiratory problems in Karachi. The number of diesel trucks and buses have increased and a major share of the emission load from motor vehicles can be attributed to low quality diesel fuel and oil burning two-stroke engines.

Karachi has also witnessed an increase in vehicles fueled by compressed natural gas (CNG) in recent years and many formerly diesel fueled vehicles have been converted to run on CNG which has added another burden on the existing air-shed besides causing public safety issue. Buses and trucks cause significant air pollution and since the main sources of pollutants are traffic, and traffic has increased on the major corridors including the mass transit corridors (project area), it is assumed that air quality has deteriorated as a result.

The primary pollutants Oxides of Nitrogen (NOx), Sulphur dioxide (SO_2) particulate matter (PM10, PM with diameter of 10 microns or smaller and PM2.5, i.e., PM 2.5 microns or smaller) and carbon monoxide (CO). Most of the PM emissions (>80%) comes from diesel-run vehicles. Sindh Environmental Quality Standards (SEQS) for these parameters in addition to lead (Pb) and ozone (O_3) are set by the Government and have been promulgated at provincial level by the Government of Sindh as well as standards for vehicle emissions in line with Euro II. Finally, the Government has promulgated tailpipe emissions standards.

All these standards are discussed in Section 03 of this EIA. Studies undertaken between 1987 and 1994 had raised concern on the deteriorating air quality and noise levels. Studies over the past decade, had quantified the problem and identified the tremendous growth in volume of traffic as the main factor responsible for increasing congestion all over Karachi roads and aggravating the problem. A 1990 survey[10] monitored CO at 9-10 ppm along the busy urban streets; maximum NO_2 concentrations were 0.3-0.5 ppm during the daytime; with an ozone maximum around noon of 40 ppb and 50 ppb, below WHO's interim quality guideline. A 2005 study[11] that shows hourly readings over 24 hours for O_3, SO_2, CO and NO_2 measured at five locations in Karachi. O_3 concentrations

[10] Ghauri et.al. 1994
[11] Hashmi et.al.

mangroves forest on the North of Mai Kolachi road. It brings in around 27 mgd of untreated industrial wastewater/sewage into the harbour.

4) Railway Nallah

This nallah connects the old city areas of sadder town, to Chinna creek. It brings in around 4 mgd of municipal effluents.

5) Pitcher Nallah

This nallah connects the old city areas of Lyari town, sadder town, Keamari town to the western backwaters. It brings in around 7 mgd of industrial and municipal effluents.

6) Karli Nallah

This nallah connects the old city areas of Lyari town and Keamari town to the Western Backwaters. It brings in around 7 mgd of industrial and municipal effluents.

The major and over-riding factors affecting water quality and aquatic ecosystems in the harbour are untreated effluents from Karachi and activities from within the port are contributing.

pollutants play havoc with the marine environment and have jeopardized the marine ecosystem.

The high toxicity present in the untreated industrial effluents and the oxygen starvation caused by the raw sewage have gradually strained the marine life.

The mangroves, which are essential component of the food chain and a great natural resource, do not flourish due to toxicity. The mangroves also suffer when sewage sludge, plastic bags, etc cover their aerial roots.

In addition, the floating garbage and suspended plastic bags pose operational difficulties in the harbour and are aesthetically unpleasant. The suspended polyethylene bags have far-reaching adverse impact once they choke the cooling water intake of operational crafts. The crafts at time suffer severe damage resulting in their prolonged unavailability to attend the ship's berthing / un-berthing. The delay in ships movement affects other ships and cumulatively tantamount to great economical loss to the nation.

The prominent drains, which transport land based industrial cum-municipal waste to the harbour area as follows

1) Lyari River 220mgd
2) Nehre Khayyam 16mgd
3) Solider bazaar nalla 30mgd
4) Railway nalla 4mgd
5) Pitcher nalla 7mgd
6) Karli nalla 7mgd

1) Lyari River

The Lyari River existing track comprises 18 km dry outside the city in the North and 26 km stretch in the city from Surjani town to its outfall in Karachi harbour. This latter stretch is kept alive by the untreated wastewater of the city round the year and by rains during monsoon. Starting from Surjani Town, Sohrab Goth, Gulshane Iqbal, Liaquatabad,Tin Hatti, Garden East, Shershah, Agra Taj Colony, and drops finally in Western backwaters of Karachi harbour. Out of these five tributaries, the Gujro nalla and Orangi nalla are the two main drains serving Federal B area, FC area, Liaqatabad and areas in and around Orangi town from Mangho Pir road to Nazimabad.

The total catchments area of Lyari River is 792 square miles and is one of the main sources of pollution into Karachi harbour. The major industrial areas of SITE, North Karachi, FB area and smaller industrial blocks in most of the

TDS	1095- 2026
TSS	128- 421
Ammonia	9.3 - 10.25
BOD5	200- 229
COD	456 – 664
Cyanide	0.057 - 0.11
Detergents	1.50- 1.73
Dissolved oxygen	BDL
Phenols	0.77- 0.84
As	0.027- 0.252
Cd	0.001 - 0.01
Cu	0.25- 2.89
Cr	0.005 - 2.00
Pb	0.20- 0.57
Ni	0.33 - 1.9
Zn	0.30- 0.60

Fresh analysis of water samples

Fresh samples were withdrawn from project area and analyzed at the Institute of Environmental Sciences of Karachi University in Nov 2018 and April 2019. The result charts and comments on the same are as under.

Table 4.7: Water Chemical Analysis Results (April 2019)

Sample	pH	BOD (mg/l)	COD (mg/l)	Salinity (ppt)	TSS (mg/l)	Temp. (°C)	Sulphate (mg/l)
W-1	7.5	425	875	28.4	241	35	414
W-2	7.7	386	960	28.8	249	35	398
Average values	7.6	405	918	28.6	245	35	406

Note: Samples were drawn during mid-ebb tide.

Table 4.8: Microbial tests of water samples from Karachi Harbour-Nov 2018

S. No	Sample Code	MPN	Faecal Coliforms
1	DS1 BH2	1100	Positive
2	DS1 BH3	1100	Positive
3	SD1	1100	Positive
4	SD2	1100	Positive

*MPN = Most probable number of micro-organisms per 100ml

In the given results the value of pH was found to be above 7 within permissible limits. The COD and BOD are quite high as the samples were drawn during ebb tide which means that the City's municipal effluents dominated the harbor water. For same reason the water found contaminated with fecal coliforms. Total coliforms (TC), faecal coliforms (FC), and enterococci (EC) are assumed to be beneficial bioindicators of faecal pollution as they are present in the

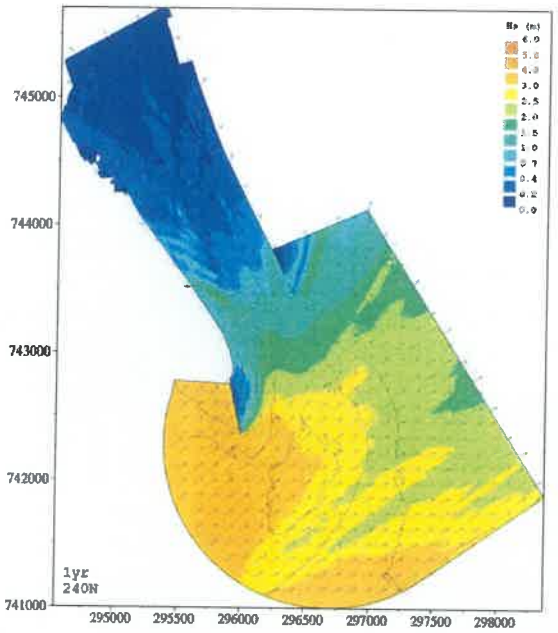
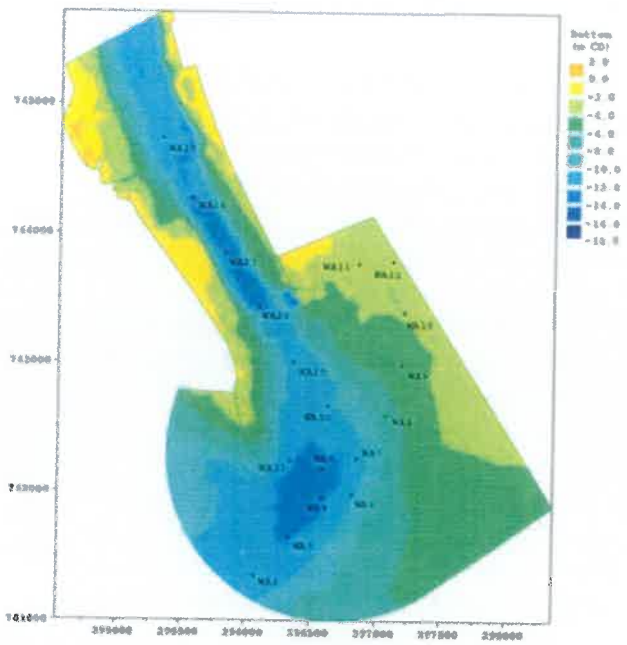


Fig 4.13: Existing Wave Height and Mean Wave Direction from ARTEMIS in the area around the proposed PDWCP



Source: HR Wallingford (2010)

Fig 4.14: ARTEMIS model of existing wave height prediction points

The table below shows the significant wave heights at wave prediction points.

Table 4.4: significant wave heights at wave prediction points.

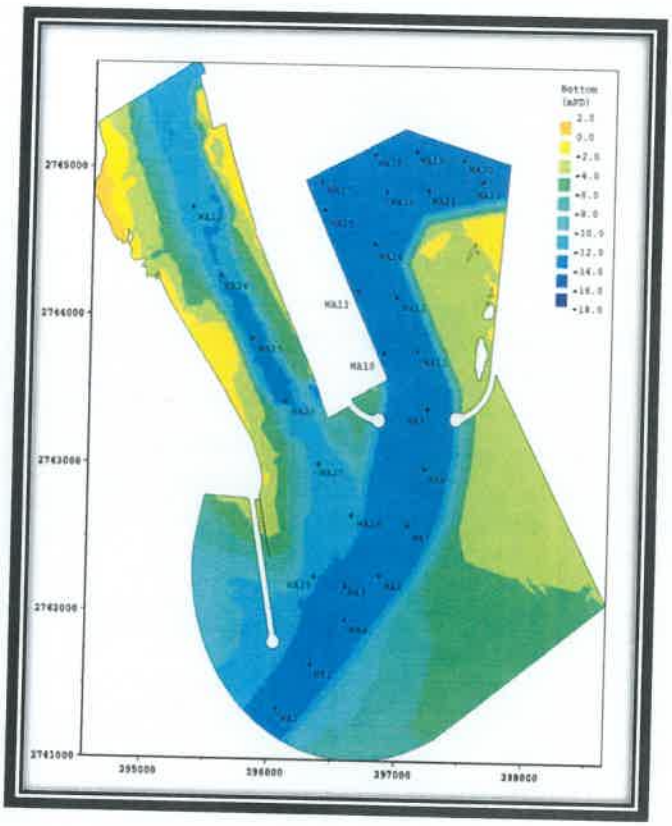
Return Period Offshore Direction	1 Year 2100 N	1 Year 2400 N	1 Year 2100 N (-100 sensitivity)
Tm	7.8	7.8	7.8
Tp	10.9	10.8	10.9
WA1	n/a	n/a	n/a
WA2	2.31	2.82	2.26
WA3	2.13	2.62	2.06
WA4	1.58	1.76	1.90
WA5	1.06	0.97	1.53
WA6	1.36	1.40	1.57
WA7	1.16	1.15	1.37
WA8	0.83	0.70	1.17
WA9	0.49	0.36	0.89
WA10	0.08	0.07	0.12
WA11	0.25	0.19	0.53
WA12	0.10	0.09	0.15
WA13	0.08	0.06	0.12
WA14	0.09	0.09	0.14
WA15	0.11	0.08	0.16
WA16	0.16	0.11	0.22
WA17	0.10	0.06	0.14
WA18	0.18	0.10	0.28
WA19	0.17	0.13	0.31
WA20	0.14	0.14	0.27
WA21	0.13	0.10	0.22
WA22	0.13	0.08	0.22
WA23	0.06	0.06	0.08
WA24	0.10	0.08	0.13
WA25	0.15	0.12	0.20
WA26	0.31	0.24	0.42
WA27	0.37	0.25	0.53
WA28	0.71	0.54	1.11
WA29	0.69	0.49	0.90

Note: It has been observed that after the construction of the new longer Manora Breakwater, the lower harbour and entrance to DWCP has been more protected from the sea waves.

A 2010 application of the ARTEMIS Wave Disturbance Model in the Keamari Groyne area, shown below in Figure 4.12, indicates that a large amount of wave energy reflects off the east side of the channel into the Lower Harbour. The

240	4.1	8.7	228	3.6	8.5	11.1
270	2.7	7.0	244	2.2	6.8	9.0
180	4.4	9.0	205	4.0	9.0	11.5
210	6.1	10.6	211	5.8	8.7	13.6
240	6.1	10.5	228	5.5	10.4	13.5
270	4.6	9.2	243	3.7	9.1	11.9
150	5.8	10.3	196	5.0	10.9	13.2
180	7.6	11.8	207	7.4	12.2	15.1
210	9.3	13.0	212	9.2	13.4	16.8
240	9.3	13.0	229	8.6	13.1	16.7
270	8.0	12.1	243	6.8	12.3	15.5
300	5.2	9.7	252	3.5	9.9	12.3

HR Wallingford Modelling Study-2010 for the deep-water container port predicted significant wave heights at wave prediction points (WA1 to WA29). WA2 to WA22 and WA28 & WA29 are located from the entrance channel of deep-water container port (near the southern end of New Manora Breakwater) to the northern end of its basin. WA23 to WA27 are located in the Lower Harbour as shown below.



Current patterns at times of peak flood flow, Neap Tide	Current patterns at times of peak ebb flow, Neap Tide

Current patterns at times of peak flood flow, Spring Tide	Current patterns at times of peak ebb flow, Spring Tide

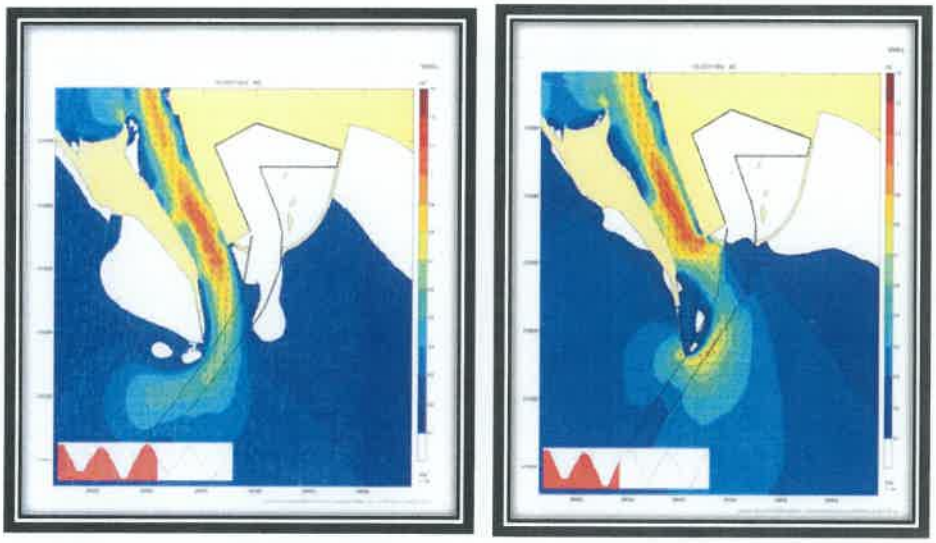
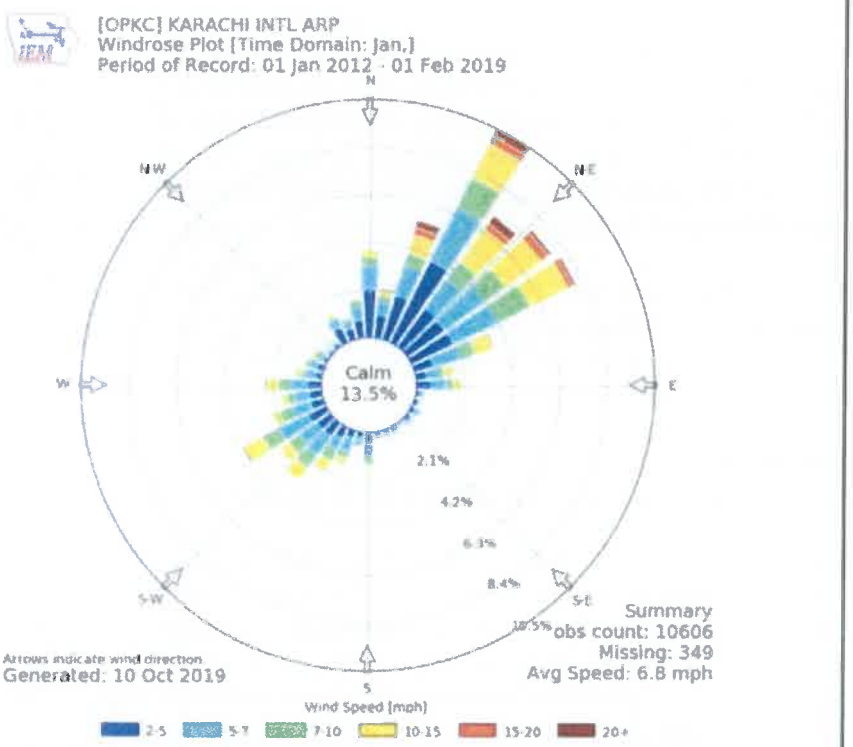


Figure 4.9: Current Patterns of tide.

Current Patterns: The above four diagrams (HR Wallingford 2010) show current patterns in the entrance area to Deep Water Container Port (DWCP) and also in the lower harbour of the main port, at times of peak flood flow and

Weather data from Karachi Airport is provided by LNGE and the wind data considering the wind speed and wind direction have been compiled and represented in the wind roses below. The wind roses indicate the wind data for each month over a 7-year period.



Visibility: Weather in Karachi is generally fine throughout the year with visibility ranging up to 10 nautical miles. Haze generally prevails in the morning but clears by noon. In the SW monsoon however, the visibility is reduced to about 2 to 5 nautical miles with the sky mostly overcast while in the NE monsoon the sky is clear, and visibility is often 12 nautical miles or more. In winter, fog can descend on the city reducing visibility to less than 1 nautical mile, but it dissipates by the noon. This occurs maximum 3 to 4 days in a month over the winter period.

4.3.8 Hydraulic Regime

Tide: The tides in Karachi are primarily semi-diurnal which means that there are two high waters and two low waters each day. Diurnal inequality exists

Sindh National Calamities (P&R) Act 1958. Karachi East and Malir being most affected. Fully 70% of areas were difficult to access due to damages to the road/ streets or the presence of stagnant water, 0.3% of houses were completely or partially damaged. 27% of bridges and walkways are partially damaged. Electricity breakdown reported in all areas for 10 – 34 hours.

The critical areas where rainwater accumulated or flooded the localities were Gujjar Nullah in Liaquatabad, Sher Shah Suri Road where pillars of Green Line infrastructure had been constructed within the drain, Kashmir Colony at the tail end of Orangi Nullah, Gulistan-i-Jauhar where encroachment had emerged and desilting could not be done, Gulshan-i-Zafar adjacent to PECHS where encroachment issues were the main causes, Zaman Town in Korangi which also had encroachment issues and Soldier Bazaar Nullah at Police Lines which was deliberately choked by putting heavy stones in the drain.

After July 17 rains, PECHS & Shahrahe Faisal were choked for a few hours at Rumi Mosque due to encroachment at Gulshan-i-Zafar. Zaman Town was flooded due to encroachments there. It was pointed out that most of the previous year problematic areas remained normal because their issues were addressed.

On July 26, it rained more than 86mm within an hour resulting in accumulation of rainwater in Gulistan-i-Jauhar where a private educational institution had encroached upon the drain whose desilting could not be done. According to the local government, the Green Line infrastructure disconnected old drainage systems in Gujjar Nullah, which caused flooding in the area.

On July 27, it rained over 74mm in one hour. The water from hill torrents inundated Orangi Town and caused Gujjar Nullah to overflow. Due to the Green Line, rainwater inundated KDA Chowrangi, Sakhi Hassan and Nagan Chowrangi. Heavy rains in Orangi Town inundated Kashmir Mohalla, a low-lying katchi abadi.

Karachi Metropolitan Corporation had 38 drains and they all were being cleaned under a World Bank project called SWEEP.

Apart from KMC, the district municipal corporations had 514 smaller nullahs and they were responsible for the cleaning for which the Sindh government was providing them additional funds.

The Sindh government invested an amount equal to $8 million from its own sources which would be reimbursed by the WB. It had released Rs200m as a stopgap arrangement for cleaning the drains. Gujjar Nullah in district Central, Mehmoodabad Nullah in district East, Songal Nullah in district Malir/East and City Nullah, Pitcher Nullah, Kalri Nullah in district South had been cleaned. 3,966,193

During the winter, the rainfall is very small.

Wind: During the SW monsoon (May to September), the wind direction is mostly south-westerly but varies from south-southwest to west with a force generally 4 to 5 on the Beaufort scale. Occasionally, the wind reaches Beaufort Scale 6 to 7 on account of low atmospheric pressure due to disturbances.

During the NE monsoon (December to February), the wind direction is from north to north-east with a wind force averaging about 2 on the Beaufort scale. During the transition periods between two monsoons, the wind has variable speed and direction.

Cyclones in the North Arabian Sea generally occur during the summer months of May/June and during October/November. Although Karachi avoids the destructive force of the cyclones, it does suffer from the effects of strong winds and heavy rain from passing cyclones.

Visibility: Weather in Karachi is generally fine throughout the year with visibility ranging up to 10 nautical miles. Haze generally prevails in the morning but clears by noon. In the SW monsoon however, the visibility is reduced to about 2 to 5 nautical miles with the sky mostly overcast while in the NE monsoon the sky is clear and visibility is often 12 nautical miles or more. In winter, fog can descend on the city reducing visibility to less than 1 nautical mile but it dissipates by the noon. This occurs maximum 3 to 4 days in a month over the winter period.

Climate: The coastal meteorology and hydrography of Karachi is controlled by the seasonal change in the North Arabian Sea i.e., monsoonal system. The data collected from various studies along the coast clearly show the influence of NE and SW monsoon winds. A general summary of meteorological and hydrological data is presented in the following section in order to understand the coastal hydrodynamics investigated in this study. The entire coastal area of Sindh is included in the warm monsoon climatic region. The climate is characterized by pleasant weather due to a sea breeze which blows all year round except for local disturbances during winter and summer months. Mild winter extends from November to February and a few cold spells occur occasionally due to western weather disturbances. Similarly, summer extends from March to June and hot weather sets in when ho winds start blowing from Rajasthan, India. When the pressure vacuum builds up in the north Arabian Sea or over Sindh-Kathiawar coast it stops the sea breeze over the Indus delta. Thereafter the temperature increases up to as high as 48oC, making the hot weather along the coast very uncomfortable. Seasonal fluctuations in temperature and monsoon rains characteristically indicate the climate of dry

Seismic activity in the region is the result of the triple junction as well as the Karachi Arc, located in southeastern Pakistan, as a large fold and thrust belt that shows Neogene thin-skinned eastward movement (Sarwar and DeJong, 1979; Schelling, 1999). Seismic activity in and around the region shows that the Karachi Arc has been active since long in prompting the eastward movement of the delta. It is possible that the movement is related to the rebound that takes place after mass shift. Sarwar has suggested that the eastward creep of Karachi Arc is directly related to active subsidence of the Hyderabad graben that underlies it and also defines the northern and southern limits of the Karachi Arc.[9]

It may be added that subsidence such as that on Southern coast of Sindh, occurs naturally as a result of plate tectonic activity above active faults, and in places where fluid is expelled from underlying sediments and is common at river deltas that may have receded. Earthquakes arise and result from the release of the force along the growth fault plane. As a result, many different growth faults are created as sediment loads shift basin ward and landward.

The seismic zoning for Karachi is Zone 2B, i.e., moderate damage, with a seismic factor of between 0.16g and 0.28g (ACEP, 2000). The PIANC seismic design Coefficients are quoted in following Table.

Table 4.1: Seismic Design Coefficient

Earthquake Event	Return Period (years)	Seismic Coefficient (%g)	Gesign Life (years)	Probability of Occurrence (%)
PIANC L1	75	15	50	50
PIANC L2	475	20	50	10

These coefficients comply with the guidelines set down in the Karachi Building code of ACEP / KBCA, "Seismic Zones of Karachi and Recommendations for Seismic Design of Buildings", April 2000.

4.3.7 Meteorological & Climatic conditions

Meteorological conditions in this region of the Arabian Sea are governed by the two monsoon seasons, the south west monsoon in summer from May to September and the North East monsoon in winter from December to February.

[9] (Sarwar, G., 2004. Earthquakes and the Neo-Tectonic Framework of the Kutch-Hyderabad-Karachi Triple Junction Area, Indo-Pakistan. Pakistan Journal of Hydrocarbon Research, 14, 35-40).

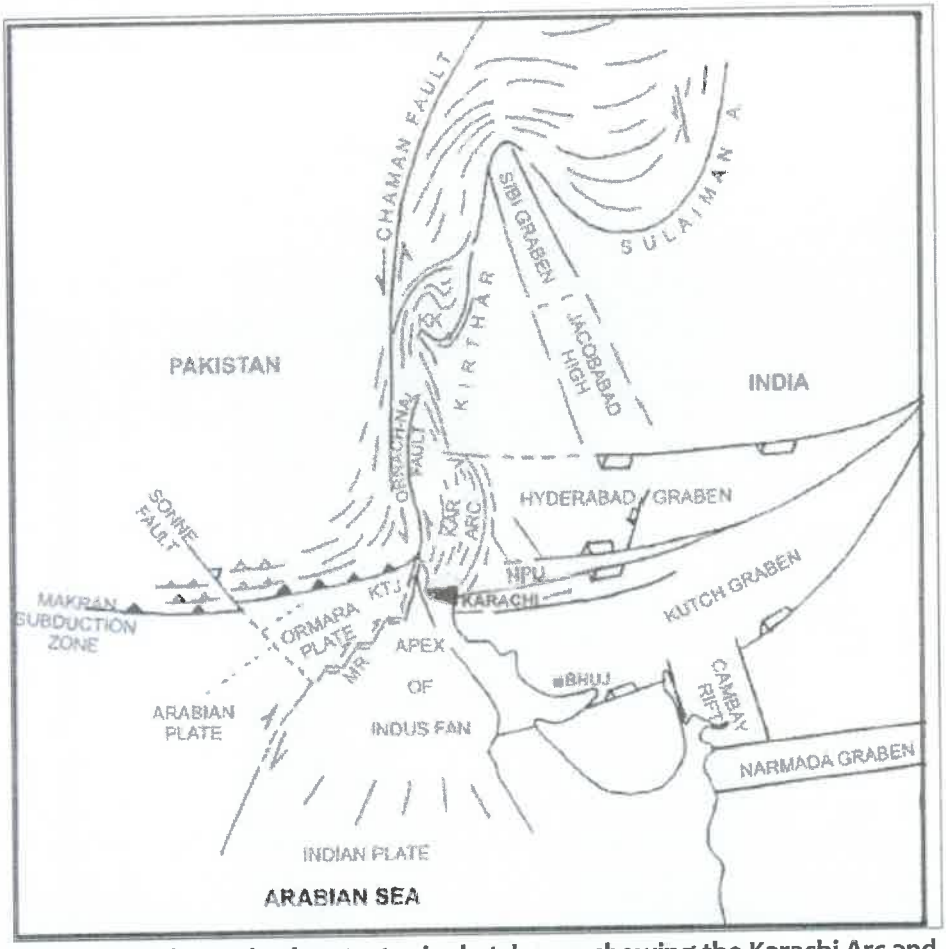


Figure 4.7: Schematic plate tectonic sketch map showing the Karachi Arc and its regional tectonic framework.

sand and gravel (pseudo Conglomerate). Sandstone is thick, porous and friable and also contains bands of conglomerate.

The clay/shale has different colours varying from grey, brown, chocolate and orange, but the most frequent variety is light brown and dark grey in colour. Sandy layers are also found inter-bedded with clay and gravel.

The mudflats are recent deposits of the delta area while soil cover is the drift type that has been slightly withered with time and marine activity. It seems to have been transferred with the flood flows from Malir River and the Indus on the east.

Historically the coastal region is found to be of tertiary and post-tertiary origin. The region has been formed by the upheaval of land from the Tethys Sea, which once extended up to the northern border of Pakistan but, gradually withdrew with the rising of the Himalayas. The underlying rocks are mostly of marine origin, highly folded, faulted and fissured everywhere. They consist mainly of fine micaceous sand. The soil is derived from land drainage and river discharge. It is rich in salts such as sodium chloride, sulphates and carbonates, which come from shell fragments. The pH of the soil ranges from 8.2 to 8.4. In addition to Oyster Rocks there are hard subsea rocks at the tip of Keamari Groyne extending seawards.

4.3.6 Seismotectonics of the Area

Seismotectonic Study for macroenvironment of Project site aims at elucidating the impact of tectonic movement induced seismicity on the microenvironment. Seismicity in the Karachi region is related to the pressure potential being built at the convergence of the three lithospheric plates: Indian, Arabian, and Eurasian at the Triple Junction formed by the intersection of Owen fracture zone, the Makran subduction zone and the Ornach-Nal fault. The Murray Ridge extends northward into Pakista , to unite the Ornach-Nal-Chaman Fault system onshore, displaying a strike-slip boundary between the major tectonic plates of India and Eurasia[6].

Karachi and its environs fall in the synclinorium, described earlier as being part of Indus deltaic region. Recession of the delta and its retreat towards the southeast dried up its numerous channels, estuaries and creeks that characterize the synclines and are part of the active faults. Tectonic instability

[6] (Baloch, S.M. & Quirk, D.G., Mesozoic to Neogene Tectonism and Evolution of Murray Ridge, Pak. Jour. of Hydrocarbon Research, Islamabad, 13).

Figure 4.4: Karachi Harbour Map 1889

4.3.4 Topography of the Microenvironment

The topography of the Project area is completely altered from what was swampy mud flats. The entire area from the Manora Channel to Clifton has been reclaimed by filling the low marshy lands. The flat sandy plain built along the seacoast on the recently filled silt and sand sediments has following three types of coastal sediments.

- *Sand bar deposits:* The sand bar deposits have medium to coarse sand, micaceous and shifting sand dunes as the main constituents.
- *Coastal sand dune deposits:* These comprise medium size sand and shifting sand dunes.
- *Beach sand deposits:* Medium to coarse grained, unconsolidated sand with pebbles and broken shells are the main constituents of beach sand deposits. These have been marked but keep on shifting by wind into small coastal dunes.

4.3.1 General Description of Karachi Harbour and Existing Aids to Navigation Facilities

Karachi Port, main harbour has about 15.6 km long channel which provides safe navigation for vessels up to 75,000 DWT. It has 7.8 km approach channel which is 300m wide and has declared depth 16m. The main areas of port activity are two wharves; East Wharf with 17 vessel berths and West Wharf with 13 vessel berths and three Oil Piers in the lower harbour for handling liquid cargo (POL /Non-POL). The maintained depths of the channel bend, the lower harbour and the upper harbour are 12.2m, 12.0m and 13.0m respectively. The berths in the upper harbour have depths 10.5m to 13.0m while at three Oil Piers, the maintained depth is 13.4m. A turning basin of 400m diameter exists in the lower harbour opposite OP-I. Two private container terminals (KICT & PICT) are situated in the upper harbour.

4.3.2 Aids to Navigation

The existing channel starts from the first pair of channel buoys at the approach channel to the extreme end of the Juna Bandar in the upper harbour of the main channel. The channel is well marked with 12 buoys (S-1 to S-23; odd numbers) on the starboard side (Green) and 13 buoys (P-2 to P-26; even numbers) on the port side (Red). To facilitate safe navigation in the approach channel, two new leading lights (FLL and RLL) are marked on the Oyster Rock Breakwater (ORB). The existing Oil Pier-I is located in the Lower Harbour at a place between the channel buoys S-23 and P-26.

The Pakistan Deep Water Container Port (PDWCP) has been constructed at the East of Keamari Groyne. It has 10.6 km long channel starting from the first pair of buoys at the approach channel to the extreme end of its basin at the North. The channel, basin and the berths of the PDWCP have declared depths 16m. A Preferred Mid channel buoy is also marked at the place where the PDWCP entrance channel (Tipu Sultan Channel) starts. The PDWCP entrance channel and basin are marked with 7 buoys (TS-1 to TS-13) on the starboard side (Green) and one buoy (TS-4) on the port side (Red). The third container terminal at Karachi Port (SAPT) is located at the PDWCP with four berths, each of 375m length.

KPT has planned to undertake capital dredging in near future, to dredge the lower and upper harbour to 14m below datum and approach channel to 18m below datum to facilitate handling of bigger size ships.

with the rest of the city were undertaken. About five years later, construction of Manora Breakwater, Keamari Groyne, the Napier Mole Bridge, Native Jetty and the Chinna Creek were started which gave shape to the port.

The construction of the wharves started in 1882, and by 1914 the East Wharves and the Napier Mole Boat Wharf had been completed. During the period between 1927 and 1944, the West Wharves of the Port, the lighterage berths and the ship-repair berths were constructed. Most of these facilities were obsolete by the time Pakistan came into existence in 1947. Since then, the port administration has embarked on extensive development of the port on modern lines.

At the time of independence in 1947, the Port capacity was about 1.5Mt of dry cargo and 1Mt of petroleum, oil and lubricant (POL) products per annum. Karachi Port is now handling over 14M tons of liquid cargo and 26 M tons of dry cargo, including 1,213,744 TEUs (Twenty-foot equivalent units) which constitute about 60% of import/export for the country.

4.3 Karachi Port

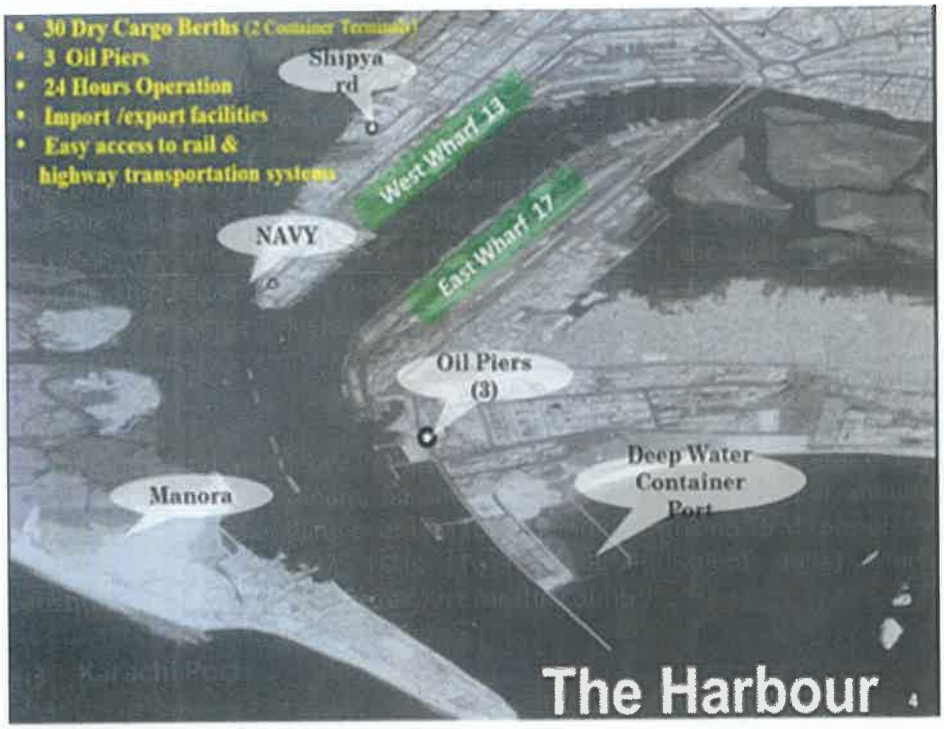


Figure 4.2: Karachi Port

Design temperature:	50℃
Operating temperature:	-20℃~50℃

4.0 Insulation

Insulation type:	High vacuum multi-layer insulation (MLI)
Static evaporation:	≤0.23%/day （LIN）

5.0 Piping &Valves

Piping types:	See from attached GA drawing
Piping sizes:	See from attached GA drawing
Valve types:	See from attached GA drawing

6.0 Frame

Material:	Q345D
Dimensions:	12192x2438x2591mm (LxWxH)

7.0 Cabinet

Material:	Q235B
Position:	Rear

3.11 Quantitative Risk Assessment ("QRA")

At the invitation of KPT, LNGe has conducted a QRA for our method of filling with DNV-GL. The main findings of the QRA are included in impact assessment.

compassenergy
Intelligent Engineering

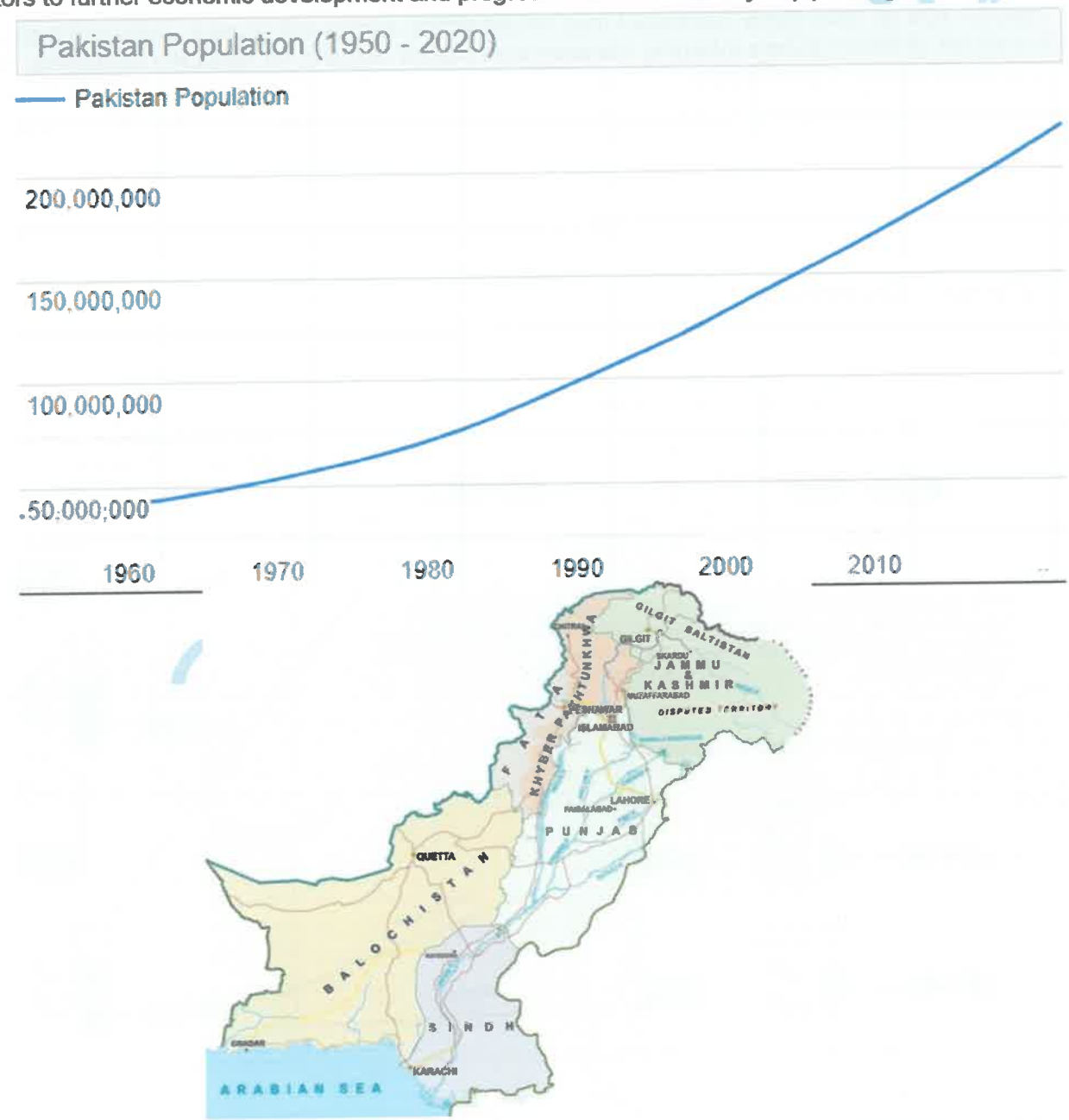
LNG Virtual Pipeline Project at Karachi Port

Feasibility Report

2.0 PURPOSE OF PROJECT

Pakistan is the 6th most populous country in the world, with a population exceeding 230 million people. With an estimated land area of 881,913 km^2, and a coastline of about 1,000 km, it is the 34th largest nation by total area. Ranked among the emerging and growing-leading economies of the world, the progress in Pakistan is supported by one of the world's largest and fastest growing middle class.

The country, however, continues to face challenges that need to be resolved. One of the limiting factors to further economic development and progress is the accessibility to pipeline gas.



3.0 DESCRIPTION OF LNG

3.1 LNG Compared with other fuels

	LNG	CNG	LPG	Diesel
Composition	Mostly Methane (CH_4)	Mostly Methane (CH_4)	Mostly Propane (C_3H_8) and Butane (C_4H_{10})	Hydrocarbons ranging from $C_{10}H_{22}$ to $C_{15}H_{28}$
Physical State for Storage	Cryogenic Liquid	Compressed Gas	Pressurized Liquid	Liquid
Volumetric Energy Density	20.3-22.5 MJ/L	9 MJ/L	25 MJ/L	34.0 - 38.6 MJ/L
Calorific Value	12,500 kcal/kg	12,000 kcal/kg	11,920 kcal/kg	10,000 kcal/kg
Source	Liquefaction of natural gas (from gas well, condensate well, oil wells, coal bed methane wells)	Compression of natural gas	By-product of natural gas process and petroleum refining	Fractional distillation of crude oil
Environmental Friendliness	Regarded as cleanest fossil fuel source with low NOx and SOx emissions, 25% reduction in CO_2 emissions	Regarded as clean fuel source with low NOx and SOx emissions, 25% reduction in CO_2 emissions	Less CO_2 emission than diesel. Significant NOx and SOx emissions	High levels of SOx and NOx emissions
Safety	Safe	High risk when leaking	Harmful for humans if 1% leakage	Dangerous
Usage	Good for both internal and external combustion	Ditto as LNG	Good for external combustion	Good for internal combustion
Logistics Costs (reduction in volume)	LNG is 1:600 of gas in volume.	CNG is 1:200 of gas in volume.	Same as LNG	Cheaper than LNG
Obvious drawbacks	BOG losses (but it can be dealt with)	High pressure risk @ 200 bar, some are at 250 bar	Consistent 10% residual loss	15-20% pilferage during transportation process
Conclusion	LNG is the cheapest, cleanest, safest fossil fuel, hence considered the best transitional fuel to a carbon neutral future. LNG reduces Greenhouse Gas (GHG) emissions by 50% compared to coal and 25% compared to diesel, but it eliminates SoX, NoX and particular matters emissions by more than 95%.			

3.2 Benefits of LNG

3.2.1 Cleaner

The regulations designed to reduce the pollution caused by fine particles and greenhouse gases are becoming more and more stringent. LNG produces significantly less sulphur dioxide (SOx), nitrogen oxide (NOx) and particulates than diesel, plus the carbon dioxide (CO_2) emissions are 20% lower too.

3.2.2 Safer

LNG is a safe fuel, as it's both non-toxic and non-corrosive. It has a high auto ignition temperature of 650°C, more than twice as high as that of diesel, which means it cannot spontaneously ignite. LNG is also lighter than air, so even if it did escape it would immediately rise, leading it away from any possible ignition sources.

3.3.3 Pressurized liquefied natural gas spill/leakage

In an LNG fuel supply chain, pressurised storage and transfer of LNG can occur via a truck storage tank or LNG cargo tank and other smaller intermediate storage units (e.g. LNG buffer tank and ISO Containers/Bowsers), as well as in piping.

In such cases, the spill rate of LNG will depend on the pressure in the intermediate storage tank in addition to the static head, and in cases where LNG has been stored for some time, the immediate flashing will depend on the level of superheating.

Due to the pressure, the reach of liquid sprays and jet scan can be significant, but the formation of liquid pools will be similar with unpressurised non-pressurized LNG spill.

3.3.4 Dispersion

Methane gas (plus other associated heavier hydrocarbons if present) that boils off from the pool will form a dense gas due to its cold temperature (initially -162°C). The condensation of atmospheric moisture will further contribute to increased gas density above the pool. As the cloud disperses with the wind, it spreads due to gravitational (density) effects and mixes with air due to atmospheric turbulence (characterized by a stability measure). Processes also affecting this mixing include heat transfer with the air and the re-evaporation of condensed moisture.

Eventually, the cloud will reach a point of neutral density, at which point dense gas processes cease to be important and atmospheric turbulence dominates the mixing. Depending on circumstances, the cloud may eventually become buoyant as methane is much lighter than air (mole weights of 16 g/mol and 29 g/mol respectively); however, the presence of heavier hydrocarbons and cold will reduce the buoyancy and the cloud may be so diluted before this occurs that the effect may not influence flammable hazards.

3.3.5 Rapid phase transformation

Rapid phase transformation (RPT) is a physical phase transformation of LNG to methane vapour mainly due to submersion in water. RPT does not involve any combustion and cannot be characterised as a detonation. Pressure pulse created by small pockets of LNG that evaporate instantaneously when superheated by mixing in water will travel at the speed of sound and decay like any other pressure pulse. This is unlikely to damage a ship's large structural elements. No specific modelling is undertaken for RPT as it is unlikely to increase the hazard range of a major spill that has already occurred.

3.3.6 Flash fire

Dispersing clouds of methane (and any other hydrocarbons present) can be ignited anywhere where the concentration in the air is above the Lower Flammable Limit (LFL) and below the Upper Flammable Limit (UFL) for the given temperature and pressure. The majority of clouds which are ignited do so at their edge as they disperse and meet a strong ignition source (e.g. open flame, internal combustion engine, sparks). An ignited cloud will "flash back" across all its flammable

Within methane (natural gas) clouds, flame propagation is slow, and the flame may be extinguished prematurely and not be sustained throughout the cloud. Sufficient flame velocity (i.e. >100 m/s) to create significant explosion overpressures will not occur over water if there is no congestion or confinement.

3.3.10 Jet fire

Dispersing clouds of hydrocarbons can be ignited anywhere where the concentration is above the LFL and below the UFL. The majority of clouds which are ignited do so at their edge as they disperse and meet a strong ignition source (e.g. open flame, internal combustion engine, sparks). An ignited cloud will "flash back" across all its flammable mass (i.e. that part within the flammable range – between the UFL and LFL). It will then burn at the UFL boundary until all the hydrocarbon is consumed. This will almost always flash back to the source and lead to a residual jet fire. Factors affecting this include the material flame speed, the concentration (maximum speed at stoichiometric concentrations, lower speeds at LFL and UFL), the temperature, condensed moisture, the degree of turbulence and the presence of congestion or objects that enhance turbulence.

5.0 SECURITY RISK ASSESSMENT

LNGe engaged DNV GL to carry out a security risk assessment study as a typical HAZID-type risk assessment with a check list to look into facility security assessment to cover the following:

1. Physical security measures (e.g. fence condition, working lights, cameras etc.);

2. Cargo facilities, storage areas and cargo handling equipment;

3. Electrical distribution systems, radio and telecommunication systems, computer systems and networks;

4. Cargo transfer piping/hoses and other utility supplies.

The studies are attached as separate document.

7.0 PROJECT SHAREHOLDERS

The following companies are the shareholders in LNG Easy (Private) Limited, a company incorporated in Pakistan under Companies Act 2017;

LNG Easy Pte. Ltd Singapore + YH

LNG Easy Pte. Ltd. Singapore are pioneers in Small-Scale LNG distribution through Virtual Pipeline concept and are successfully operating similar projects in China, Malaysia, Myanmar, Bangladesh and Vietnam. The operation is carried out using proprietary Mobile Filling Platform (MFP) through which LNG is transferred from Small-Scale LNG Carriers directly into eighteen truck mounted 40 feet ISO Containers. LNG Easy is also transporting LNG in twenty feet ISO containers from Singapore to Malaysia where it is distributed to off-grid industrial, commercial and residential consumers.

Punjab Group

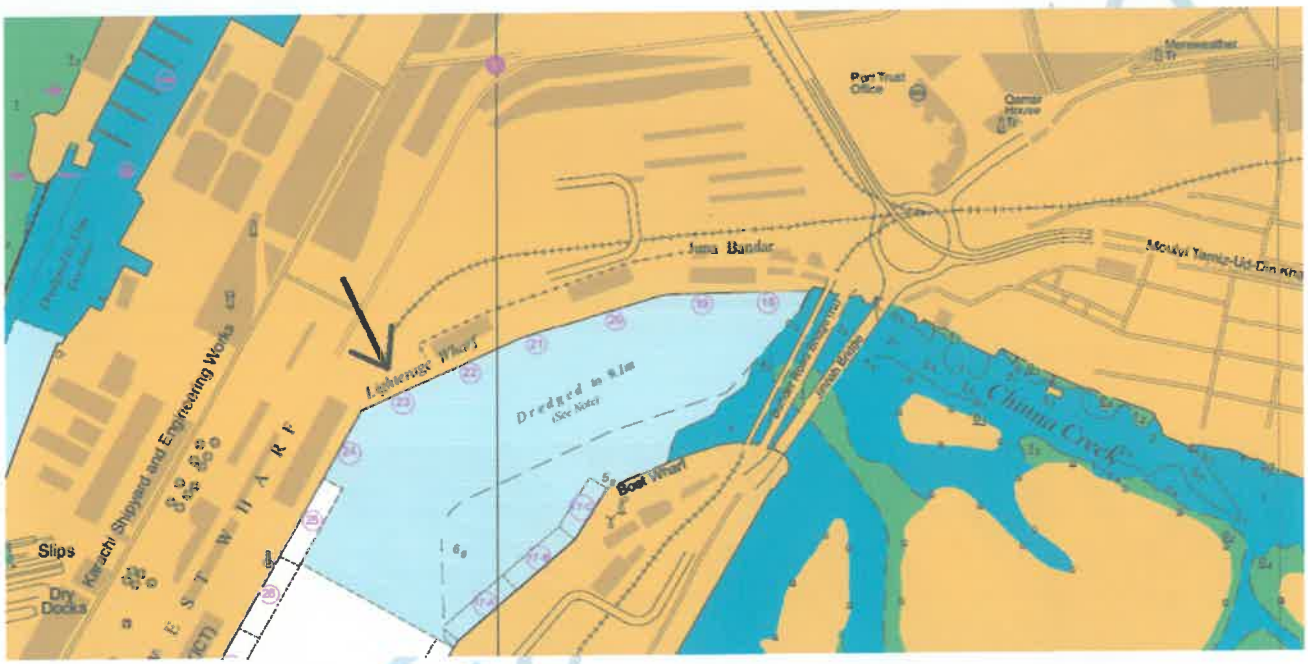
Punjab Group, has diversified experience and investment portfolio in various sectors including Liquefied Natural Gas (Pakistan GasPort Limited), academics, mass media, urban development, renewable energy solutions, health care, technology and corporate farming. Some of the many prominent ventures of the Group are:

- Punjab Colleges – Presence in 124 cities
- Allied Schools – Over 850 campuses across Pakistan.
- University of Central Punjab, Lahore.
- Capital University of Science & Technology, Islamabad.
- Muhammad Ali Jinnah University, Karachi.
- Dunya Media Group (Dunya News & Lahore News).
- Lahore Medical & Dental College.
- Doctors Hospital & Medical Center, Lahore.
- Union Developers in Real Estate Sector.
- Zero Carbon, Renewable Energy Company.
- Tower Technologies, IT service provider.

9.0 PROJECT DESIGN

9.1 KPT Berth # 23 layout with MFP and SSLNGC

The layout of berth 23 is shown below relative to Karachi Port.



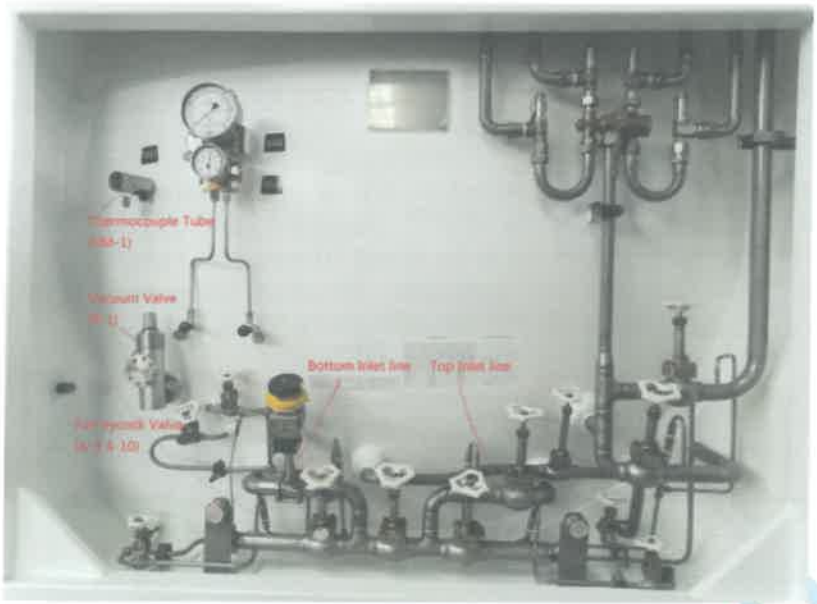
9.2 MFP™ Operational layout and process Description

LNG from the LNGC will be unloaded to the LNG ISO containers or Cryogenic LNG Bowser/Road Truck will be filled via the Mobile Filling Platform (MFP™) at the jetty. Operators will need to connect the filling hose and vapour return hose to each ISO Container or Cryogenic LNG Bowser/Road Truck. Vapour return from the ISO containers will be sent to LNG buffer tank where the gas will be heated and sent as fuel gas to the gas generators or as CNG.

Up to 18 ISO containers or Cryogenic LNG Bowser/Road Truck can be filled simultaneously. Once filling is completed, operators will disconnect the hoses and the ISO containers/trucks will leave the jetty. The filling rate to each ISO containers is about $40m^3$/hr. It is anticipated that it will take 1hr to fill the ISO containers. A flowrate of up to $720m^3$/hr ($40m^3$/hr x 18 ISO tanks) is envisaged. LNG from LNGC will be pumped from cargo tank to fill the 40' LNG ISO containers or Bowsers. The in-tank main cargo pump design flowrate is $600m^3$/hr. Throttling may be necessary from the LNGC. The flowrate can be reduced to $420m^3$/hr with throttling. Boil off gas (BOG) will be generated and returned to the LNGC via the vapour return line and will be compressed to CNG compressors on the jetty. Spray pump on the LNGC will be used during start-up / initial filling to cool down the whole system before starting the LNG transfer via the main cargo pump.

9.3 LNG Storage Depot

LNGe will establish an LNG ISO container storge depot at Northern Bypass at NLC Container Yard to store full and empty LNG containers. The ISO tank depot will be able to store about 300 ISO tanks. Fully loaded ISO tanks will be stacked 3 tiers high whilst empty LNG ISO tanks will be stacked 5 tiers high.



A rear filled ISO tank

Transfer of LNG from an ISO tank.

9.7 Estimated logistic demands

LNGe will deploy a hub and spokes model for the distribution of LNG across Pakistan. The main hub will be near Keamari where the LNG will be unloaded into containers and bowsers. It is anticipated that a small depot of filled LNG ISO containers are stored short term in close proximity to the port.LNG will be distributed to the end users and stored in the end users LNG storage tanks.

688

The following table shows the number of LNG trucks required for a given set of transport parameters.

Table: LNG Truck number sensitivity analysis. 15 MMscf/d gas supply

	150KM	500KM	1,000KM
Truck size m3	40	40	40
Truck capacity MMscf	0.87	0.87	0.87
Daily gas production MMscf/d	15	15	15
Annual gas production MMscf/y	5.475	5.475	5.475
Driving distance (km)	150	500	1000
Truck speed (km/h)	40	40	40
Travelling days	0.16	0.52	1.04
Number of truckloads per year	6094	6094	6094
Number of truckloads per day	17	17	17
Total number of trucks required (no spare)	7	19	37

The initial distribution of LNG by truck will be concentrating on the distribution to Karachi and immediate nearby areas of Karachi. Driving distances are expected to be less than 50 km from KPT. The above analysis is based on longer transport distances.

9.7.3 Logistics partners

LNG Easy has signed an MOU with Pakistan's largest logistics provider National Logistics Cell (NLC). NLC has more than 5,000 trucks / trailers available for transporting LNG. NLC will be in charge of moving the LNG containers.

9.7.4 Tracking of customer's LNG consumption

At the core of the business is a customer and trucking tracking system that lets LNGe know where the trucks are located, how much LNG is onboard, the temperature pressure and flowrates at the customers regas and storage tank. LNGe is working with a Chinese company that has developed a sophisticated tracking software specially made for LNG road distribution. This software is being repurposed for use in Pakistan. The tracking of the LNG molecules will be done with the transmitter mounted on the ISO tanks and the bowsers. The transmitter that is planned to be used shown below.

9.9 Unloading LNG to containers/bowsers via the MFP™

The LNG will be unloaded from an SSLNGc via MFP™ into the LNG ISO tanks or LNG Bowsers.

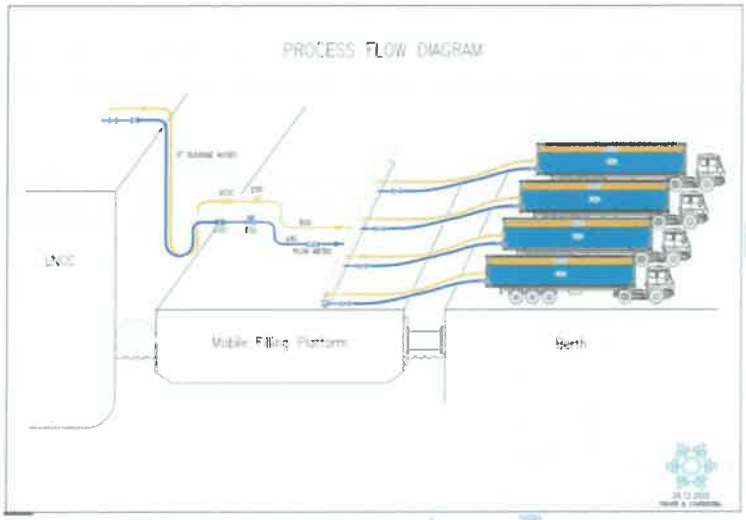


Diagram of ISO tanks being filled at KPT

LNG ISO tanks being filled at KPT

9.10 Land transport fleet of LNG

LNGe has contracted with NLC for the transport of ISO containers and bowsers for distribution to end users of the LNG. NLC will provide the trucks / trailers for the LNG ISO tanks.

Samples of Regas system

Gas Metering skid

Ambient Air Vaporizer and vertical tank

10.0 MARKETING STRATEGY

Customers: From Lowest Hanging Fruits to the End Game

Immediate Priority	**Industries**	➢ Industrial companies (textile, cement, ceramics etc.) need fuel to fire their boilers, furnaces and kiln. LNG can replace RLNG, furnace oil, LPG or diesel for the external combustion of these facilities. ➢ This is business is known as industrial point-to-point supply in China.
	Residential	➢ Residential clusters which are known locally as "housing societies" or "residential colonies" which have private mini-grids. They are inadequately supplied by the grid.
	Captive Power Plants	➢ Captive Power Plants (CPPs) are power plants run by the businesses instead of buying electricity from the grid. ➢ Government of Pakistan plans to stop supplying pipeline gas to CPPs with utilization below 55% from June 2021. LNG can be used for primary used for primary use or as back-up.
	Transport (CNG powered vehicles)	➢ Pakistan has more than 3,000 CNG refilling stations serving over 3.7 million CNG car nationwide which are often shut off the gas grid. ➢ CNG Stations can be served by L-CNG however this is a price sensitive sector.
	SNG (Various Sectors)	➢ Synthetic Natural Gas (CNG) is a system set up in Pakistan to cope with the acute shortage of natural gas. SNG is LPG mixed with air and sent through the existing gas pipeline operated by SSGC/SNGPL. SNG is supposed to have the same thing heating value as pipeline gas. There are about 15 installations in the country serving various sectors, Total demand is about 43mmcfd (about 314,000 per year).
Future Target Customer	Domestic Distributors	➢ LNGE aims to emulate the city gas franchise system started by British and developed by China. The distributor invests in gas-consuming infrastructure in return for the rights to supply exclusively to defined area
	Transport (LNG Powered Vehicles)	➢ LNG can be used by heavy duty trucks, buses, rail and mining trucks. This is a segment of the market that can only be served by LNG, not pipeline gas. LNG holds a very clear cost advantage over diesel plus strong environmental benefits.
	Rural Household	➢ Rural gasification – Vast majority of rural population face abject energy poverty. This is probably the end-game in demand generation.

can be very substantial/double digits in a country like Pakistan. But through CHP or CCHP, if the business in question can find the users for heat and cold, the efficiency can typically be raised to 85%+. This will give dual benefit of fuel replacement (LNG replacing more expensive fuel such as LPG and diesel), but also the efficiency gains from utilizing the heat energy obtained from the power generation process, which is normally wasted by centralized power plants.

11.1.3 Residential sector

China has most successfully transformed LNG from a very large B2B (business-to-business), LNG-to-power fuel to a small B2B and B2C (business-to-consumer) fuel. Over 500 million Chinese customers are connected to the city or rural gas distribution network using natural gas. The success in China is achieved through a franchise system under which the operators invest in gas-consuming infrastructure in return for rights to supply exclusively to a defined area. This franchise normally lasts for 30 years. LNG Easy intends to apply for franchises in many areas of Pakistan. The current consumption is about 0.5mtpa in LNG equivalent which has priority over other sectors in the winter, however, there are other unserved demand for "off-grid" areas. Defence Housing Authority (DHA) and Bahria Town in Karachi alone are building new projects for over 2 million residents.

ISO tank container-based mini-grid for village and housing colonies

11.1.4 Transport sector

The company plans to promote green energy in Pakistan by facilitating provision of cleaner fuel for heavy duty trucks and heavy buses. LNG will replace very expensive diesel on which most of these vehicles are running. Currently Pakistan spends a huge amount on import of diesel for the transport sector alone. Conversion of heavy-duty trucks and bus fleet to LNG, will result in savings for customers and less burden on country's foreign exchange reserves.

The table below shows prospective customers:

No	Name	Type of business	Current Fuel	Annual demand (tons)	Location
26	Zaman Textile	Textile	NG	6,500	Karachi
27	Hilal Food	Food	LPG/Natural Gas	1,000	Karachi
28	Orient Textiles/ Group	Textiles	Natural Gas	4,380	Karachi
29	Ittehad Chemicals Limited	Chemicals	Natural Gas	23,920	Lahore
30	Byco Refinery (through agent)	Refinery	Diesel	36,000	Karachi
31	Bulleh Shah Packaging (through agent)	Paper Board	Natural Gas	10,000	Lahore
32	Packages (through agent)	Mall	Natural Gas	6,500	Lahore
33	Zahid Jee Textiles (through agent)	Textiles	Natural Gas	8,480	Faislabad
34	Falcon Aluminium (through agent)	Alumiunium	Natural Gas	6,500	Faislabad
35	A B Exports (through agent)	Textiles	Natural Gas	8,000	Faislabad
36	Azgard 9 (through agent)	Textiles	Natural Gas	17,200	Lahore
37	Rafhan Maize Products (through agent)	Food Ingredient	Natural Gas / LPG	12,480	Faislabad
38	Gunj Glass (through agent)	Float Glass	Natural Gas/ Furnace	6,800	Haripur
39	Ghani Glass (through agent)	Glass Industry	Natural Gas/ Furnace	7,200	Faislabad
40	Power Chemical Industries (through agent)	Chemicals	Natural Gas/ Furnace	4,380	Faislabad
41	Zaman Textile	Textile	NG	6,500	Karachi
42	Hilal Food	Food	LPG/Natural Gas	1,000	Karachi
43	Orient Textiles/ Group	Textiles	Natural Gas	4,380	Karachi
44	Ittehad Chemicals Limited	Chemicals	Natural Gas	23,920	Lahore
			Total	324,234	

- LNGe is in discussions with below companies in phase 1 (combination of process and CPP):

No	Name	Type of business	Current Fuel	Annual demand (tons)	Location
1	Ghani Ceramics (through agent)	Ceramic industry	Natural Gas/ Furnace	11,500	Faislabad
2	Time Ceramic	Ceramic industry	RLNG	20,098	Faisalabad
3	Oreal Ceramic	Ceramic industry	Coal Gas	25,873	Punjab
4	Power Cement Ltd	Cement manufacturer	LPG/Natural Gas	11,710	Karachi
5	Shabbir Tiles & Ceremics	Ceramic industry	LPG/Natural Gas	7,300	Karachi
6	Karam Ceramics	Ceramic industry	LPG/Natural Gas	6,570	Karachi
7	Amrelli Steels	Furnace	Furnace Oil/Natural Gas	6,570	Karachi
8	Ismael Industries (Candyland)	Chocolate and candy manufacturer	LPG/Natural Gas	5,110	Karachi
9	Kulal Ceramics	Ceramic manufacturer	LPG/Natural Gas	5,110	Haripur
10	Dadex Eternit Limited	Pipe and rubber company	LPG/Natural Gas	4,745	Karachi
11	Oleocorp	Chemical	LPG/Natural Gas	908	Karachi
12	Artistic Milleners	Textile	LPG	4,380	Karachi
13	Liberty Mills	Textile	LPG/Natural Gas	4,380	Karachi
14	Bin Qasim Packages/ATM Industries	Packaging	LPG/Natural Gas	1,460	Karachi
15	Allied Cables	Copper cable	LPG	1,080	Karachi
16	Allied Copper Strip Co	Copper Rolling	Grid	1,200	Vinder Balochistan
17	HSJ Steel	Furnace	Furnace Oil/Natural Gas	1,000	Karachi
18	Agha Steel	Furnace	Natural Gas/ Furnace	2,000	Karachi
19	Soorty Textiles Group	Textiles	Natural Gas	4,380	Karachi
20	National Foods	Food/Spices	LPG	2,880	Norriabad , Karachi
21	General Tyre	Tyre	LPG/Natural Gas	7,560	Karachi
22	Habib Oil	Edible Oil	RLNG	8,480	Karachi
23	Artistic Fabric	Textile	RLNG	7,200	Karachi
24	Mapak Edible Oils (Pvt) Ltd	Edible Oil	Natural Gas	5,400	Karachi
25	EBM	Food	LPG/Natural Gas	8,000	Karachi

12.0 PRICING OF THE LNG

LNG pricing shall be as follows.

Selling Price = X% x Brent + Alpha

- Brent is the ICE Brent oil price being the average of the 3 preceding months
- Alpha is the sum of shipping, break bulking/terminal operations, trucking, regasification expenses and Company Margin.

14.0 PROJECT FINANCIALS

P&L

PKR '000	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Volume (mmbtu)	16,974,173	17,143,914	17,488,507	17,840,026	18,198,611	18,562,583	18,933,834	19,312,511	19,698,761	20,092,737
Revenue	76,500,073	83,446,280	91,933,434	101,283,800	110,551,976	118,852,219	127,775,643	137,369,038	147,682,706	158,770,723
Cost of Sales	64,560,869	71,127,226	78,361,434	86,159,785	94,044,008	101,680,381	109,418,258	117,744,988	126,705,381	136,347,661
Gross Profit	11,939,204	12,319,053	13,572,000	15,124,015	16,507,968	17,171,837	18,357,385	19,624,050	20,977,324	22,423,062
Operating Expenses	8,722,558	8,835,883	9,638,181	10,565,894	11,467,938	12,156,014	12,824,595	13,529,948	14,274,095	15,059,170
Operating profit	3,216,646	3,483,171	3,933,819	4,558,121	5,040,030	5,015,823	5,532,790	6,094,103	6,703,229	7,363,892
Finance cost	806,353	671,299	519,011	347,296	153,328	39,700	41,685	43,770	45,958	48,256
Profit before taxation	2,410,293	2,811,872	3,414,807	4,210,824	4,886,703	4,976,122	5,491,104	6,050,333	6,657,271	7,315,636
Taxation	698,985	815,443	990,294	1,221,139	1,417,144	1,443,076	1,592,420	1,754,597	1,930,609	2,121,534
Profit after taxation	1,711,308	1,996,429	2,424,513	2,989,685	3,469,559	3,533,047	3,898,684	4,295,736	4,726,663	5,194,102

Contribution to National Exchequer in 10 Years

	10 Years	
	~USD Million	~PKR Billion
Customs Duty & Other taxes	175	52
Sales Tax	664	199
Income Tax	47	14
Port Charges & Dues	19	6
Total	**905**	**271**

16.0 KEY APPROVAL POINT SCHEDULE

OGRA License end 2022

1. Final NOC from KPT.	Received
2. Ministry of Defence.	Received
3. Department of Explosives.	Received
4. Environmental Protection Agencies.	Received
5. National Highway Authority.	Received
6. Civil Aviation Authority.	Received
7. Local Administration.	Under Process

APPENDIX B STANDARDS TO BE USED

TECHNICAL CODES AND STANDARDS

The operation of Small-Scale LNG Virtual Pipeline Project including allied facilities will satisfy inter-alia the following internationally recognized and proven codes, standards and guidelines for land transport, land based and offshore LNG installations (or equivalent).

Discussion on the Standards:

The most common standards are European Standards (EN), British Standards (BS), American Standards and Chinese Standards (GB). The EU standards and the British standards are mostly the same and have the same numbers denoted to the standards. EN standards are also slowly being incorporated to ISO standards replacing EN standards. National standards and ISO standard are widely used and acceptable for handling of LNG.

It is important to consider that some of these standards are applicable on Small-Scale LNG Virtual Pipeline Project and some are not. The purpose of these standards is to provide uniform standards that can be used for the project. A good example is the standards to apply for erection of a regas system at an industrial unit. If NFPA 59A is chosen as the standard to follow, a standard is being selected that was originally developed for large regas systems thereby ending up with unrealistic safety distances that are not practical for a regas system located nearby an industrial unit. However, if instead the standard issued by the EU or Britain is chosen, normally a standard such as BS EN 13645 would be selected. This standard is purposely made for smaller on land regas terminals with storage between 5mt and 200mt of LNG. BS EN 13645 will supersede standards such as BSEN1473. If it is chosen to use GB standard for the equipment this can be incorporated into the layout plan of the regas system using BS EN 13645 even though the equipment is built under GB standards.

Another example is with regards to the standards of the ISO tanks made for LNG. A GB standard and an ASME standard is largely the same. The GB standard for ISO tanks is virtually the same in terms of safety and redundancy. LNG Easy will apply the standards that are written in cursive below.

Marine land-based Facilities Standards

- Standard for the Production, Storage and Handling of Liquefied Natural Gas (LNG), NFPA 59A, NFPA.
- Installations and Equipment for Liquefied Natural Gas – Design of Onshore Installations, (BS EN 1473) CEN.
- Installations and Equipment for Liquefied Natural Gas – Design and Testing of Loading/Unloading Arms, (BS EN 1474) CEN.

Large Onshore LNG Terminal Standards

- Standard for the Production, Storage and Handling of Liquefied Natural Gas (LNG) – 2019, NFPA 59A, NFPA.
- API 620 Design and Construction of Large, Welded, Low Pressure Storage Tanks, Appendix R - Low pressure Storage tanks for Refrigerated Products.
- Installations and Equipment for Liquefied Natural Gas – Design of Onshore Installations – 1997, (BS EN 1473) CEN.
- Flat-Bottomed, Vertical, Cylindrical Storage Tanks for Low Temperature Service, (BS 7777).
- *Installations and Equipment for Liquefied Natural Gas – General Characteristics of Liquefied Natural Gas – 1997, (BS EN 1160) CEN.*
- GB/T26978 Production Storage and handling of liquified natural gas. Design and manufacture of site built, vertical, cylindrical, flat bottomed steel tanks for the storage of liquefied nature gases.
- GB/T20368-2012 Production, storage and handling of liquefied natural gas (LNG)
- GB/T 22724-2008 Installation and equipment for liquefied natural gas – Design of onshore installation.
- SY/T 6711-2014 Technical code for liquefied natural gas receiving terminal.
- Criteria for design and construction of refrigerated liquefied gas storage tanks 'EEMUA 147'.

Design of Smaller LNG Storage and Regas stations

- *BS EN 13645 ("Design of onshore installations with a storage capacity between 5 tonnes and 200 tonnes.*

LNG Road Transportation Standards:

International standard applicable for all countries

- *International Maritime Organisation Dangerous Goods (IMODG) code (this code only applies to ISO containers but not to LNG Bowsers/Road Tankers).*
- *IMO CSC International Convention for Safe Containers, 1972 (CSC 1972) 2014 Edition (IC282E) (this code only applies to ISO containers and not to LNG Bowsers/Road Tankers.)*
- *IMO Customs Convention on Containers (this code only applies to ISO containers and not to LNG Bowsers/Road Tankers.)*
- *Guidance ISO 16903:2015 "Petroleum and natural gas industries - Characteristics of LNG, influencing the design, and material selection gives guidance on the*

GB Standards of LNG ISO Container

- *TSG R0005-2011 Supervision regulations on safety technology for transportable pressure vessel.*
- *NB/T 47059-2017 Refrigerated liquefied gas tank container.*
- *T/CATSI 05001-2018 Portable vacuum insulated cryogenic pressure container vessel strain strengthening technical requirements.*
- *Procedure for inspection of containers -2016.*
- *GB/T 150.1 to 150.4-2011 Pressure vessel.*

Other GB Land standards

- GB/T 38530-2020 Town Liquefied natural Gas (LNG) gasification supply installations.
- *GB/T 36883 -2019 Technical specifications for LNG Vehicle.*
- *GB/T 36126 -2018 Liquefied Natural Gas Dispenser for vehicle*
- *GB/T 25986-2010 Filling Devise for Natural Gas vehicles*
- *GB/T 24510 -2017 Liquefied natural gas cylinders for vehicles*
- *GB/T 20734-20086 Mounting Requirements for liquefied natural gas design vehicle special equipment*
- *GB/T 26980-2011 Liquified natural gas vehicular fuelling systems code*

Standards for Cryogenic Bowsers ISO tanks

Manufacturing Standards

- ASME Boiler & Pressure Vessel Code ASME Section VIII Division 1.
- NB/T 47058-2017 Road tankers for refrigerated liquefied gas
- TSG R0005-2011 Supervision Regulation on Safety Technology for Transportable Pressure Vessel
- GB 7258-2017 Technical specifications for safety of power-driven vehicles operating on roads.
- GB 1589-2016 Limits of dimensions axle load and masses for motor vehicles trailers and combination vehicles.
- TSG R0005-2011 Supervision regulations on safety technology for transportable pressure vessel
- NB/T 47059-2017 Refrigerated liquefied gas tank container
- T/CATSI 05001-2018 Portable vacuum insulated cryogenic pressure container vessel strain strengthening technical requirements
- Procedure for inspection of containers -2016
- GB/T 150.1 to 150.4-2011 Pressure vessels

LNG Easy Private Limited

DESCRIPTION OF ANY NEW OR EXPANDED PUBLIC WORKS ENTAILED BY THE PROJECT WITH ESTIMATED COSTS AND COMPLETION DATES

This is to confirm that no new or expanded public works, undertakings or infrastructure will be entailed by the project as the project is being set up on the existing berth no. 23 of Karachi Port.

Yasir Hamid
Chief Executive Officer

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LNG Easy Private Limited

SIGNIFICANT RISKS TO SUCCESSFUL COMPLETION OF THE PROJECT

Risk Analysis

Risk management is recognized as an important aspect of project implementation. Structured risk assessment comprises a number of defined steps, starting with "threat" or hazard identification, followed by risk evaluation and definition of mitigation measures as required.

Objective

A preliminary risk analysis is one of the key steps of threat identification. The objective of a preliminary study is to identify and categorize hazards which may lead to unsafe situations or operability problems. These include but are not limited to the following;

- Downstream Market Risk
  - Downstream buyer credit risk
- Credit & Payment Risk/Counter Party Risk
  - LNG or Gas Off-taker credit worthiness
- Liquidity Risk
  - Cost overruns exceeding range agreed with authorities
  - Terminal Tariff-IRR not accepted by authorities
  - High Capex
- Political Risk
  - Withdrawal of Government support for project
  - Country Risk, war, terrorism, government change.
- General Economic Risk
  - LNG Vessel demand and supply
  - Tariff too high for off-takers

The preliminary risk analysis is carried out and remedial measures taken using a standard hazard identification methodology, utilizing guidewords to structure a brainstorming session for risk identification and mitigation.

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DNV·GL

LNG MOBILE FILLING PLATFORM FOR ISO CONTAINER OR CRYOGENIC LNG BOWSER/ROAD TRUCK AT KARACHI PORT

Quantitative Risk Assessment (QRA) Report

LNG Easy Pte Ltd

Report No.: TC689379, Rev. 3
Document No.: TC689379
Date: 2021-11-01

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- The marine exclusion zone distance set for LNGC is calculated to be 60m. This is the minimum distance for any passing vessels or marine vessels plying the area (except authorised vessel with appropriate ignition control measures in place) during LNG filling operations.
- Within the defined Safety Zone / MEZ radius, the following restrictions must be in place:
  - Unauthorised entry must be restricted within the Safety Zone / MEZ radius. Only dedicated personnel are allowed in the area.
  - On water, this restriction will include small boats, fishing vessels and other marine vessels.
  - No activities can be performed which can introduce ignition sources (e.g. hot work, hot surfaces, etc.).

3 INTRODUCTION

LNG Easy Pte Ltd (LNGE) is planning to set up a Liquefied Natural Gas (LNG) receiving and offloading facility for LNG ISO containers or Cryogenic LNG Bowser/Road Truck filling. Trucks will arrive with empty LNG containers which will be parked on the Jetty in Karachi Port and will be filled via a Mobile Filling Platform (MFP) from an LNG Carrier.

DNV GL has been commissioned by LNGE to conduct a Quantitative Risk Assessment (QRA) of the LNG receiving and offloading facility (MFP) for LNG ISO containers or Cryogenic LNG Bowser/Road Truck filling at Karachi Port.

Three berths are proposed for the LNG filling operation from the LNGC to the ISO Containers or Cryogenic LNG Bowser/Road Truck via the MFP at:

- Berth 18/19
- Berth 19
- Berth 23

This QRA report will assess the risks due to the LNG filling operations at these three berths in support of the selecting the LNG filling location at Karachi Port.

3.1 Objectives

The aim of this QRA is to systematically assess the likelihood and consequence of all credible potential process hydrocarbon risks of the proposed facilities, and:

- Ascertain if such risks are tolerable in accordance to 'UK HSE and DNV GL Recommended Practice Individual Risk Criteria; and
- Recommend the Safety Zone and Marine Exclusion Zone (MEZ).

3.2 Scope of Work

The boundary of the study is limited to the following:

- LNG Vessel
- Filling operation of ISO containers or Cryogenic LNG Bowser/Road Truck and;
- Departure of the trucks from the jetty (excluding the transportation risk).

This assessment is limited to normal operations, with the focus on Major Accident Hazards (MAHs) identified from the HAZID (Ref./1/).

The following scopes are excluded:

- Maneuvring of the LNG Carrier to and from the berth.
- Transport routing of the Cryogenic LNG Bowser/Road Truck from jetty.

Note that the scope of the QRA is limited to the MFP, including the ISO containers or Cryogenic LNG Bowser/Road Truck. Based on the layout of the MFP, there is no occupied buildings, and as such, occupied building risk assessment is not part of the scope of this QRA.

3.3 Report Structure

The remainder of this report is structured as follows:

4 FACILITY DESCRIPTION

4.1 Facility Layout

The MFP will be moored alongside the LNGC and jetty for LNG ISO Containers and Cryogenic LNG Bowser/Road Truck will be on the other side, as shown in Figure 4-1.

Figure 4-1 – Layout of LNGC, MFP and LNG ISO Container or Cryogenic LNG Bowser/Road Truck

4.2 LNG Filling Locations

LNG filling will take place via STS transfer operation to LNG ISO containers or Cryogenic LNG Bowser/Road Truck in Karachi Port. Trucks will arrive with empty LNG containers which will be parked on the Jetty in Karachi Port and will be filled via a Mobile Filling Platform (MFP) from an LNG Carrier.

Three (3) locations are proposed for the filling operation of LNG from the LNGC to the ISO Containers or Cryogenic LNG Bowser/Road Truck via the Mobile Filling Platform (MFP) as shown in Figure 4-2, Figure 4-3 and Figure 4-4 below:

- Berth 18/19
- Berth 19
- Berth 23

Figure 4-4 Proposed LNG Filling Operations at Berth 23

Refer to Section 7 for the risks at these locations due to the LNG filling operations.

4.3 Process Description

LNG from the LNGC will be unloaded to the LNG ISO containers or Cryogenic LNG Bowser/Road Truck will be filled via the Mobile Filling Platform (MFP) at the jetty. Operators will need to connect the filling hose and vapour return hose to each ISO Container or Cryogenic LNG Bowser/Road Truck. Vapour return from the ISO containers will be sent to LNG buffer tank where the gas will be heated and sent as fuel gas to the gas generators.

Up to 18 ISO containers or Cryogenic LNG Bowser/Road Truck can be filled simultaneously. Once filling is completed, operators will disconnect the hoses and the ISO containers/trucks will leave the jetty.

The filling rate to each ISO containers is 40m^3/hr. It is anticipated that it will take 1hr to fill the ISO containers. For offshore operation, flowrate of up to 720m^3/hr (40m^3/hr x 18 ISO tanks) is envisaged.

LNG from LNGC will be pumped from cargo tank to fill the 40' LNG ISO containers. The in-tank main cargo pump design flowrate is 1400m^3/hr and since the pumping capacity is much higher than the flowrate into the ISO containers, throttling is necessary from the LNGC. The flowrate can be reduced to 420m^3/hr with throttling. Boil off gas (BOG) will be generated and returned to the LNGC via the vapour return line and needs to be handled on the LNGC. Spray pump on the LNGC will be used during start-up / initial filling to cool down the whole system before starting the LNG transfer via the main cargo pump.

5.2.2 Non-pressurized liquefied natural gas spill

LNG is stored in bulk storage tanks at its atmospheric boiling point (approximately -162°C). Any boil-off gas is collected, and pressure relief valves are set to only allow a very low net positive pressure.

Most spill scenarios for the storage tank occur at atmospheric pressure plus any liquid head of LNG (i.e. the static liquid column above the point of release). The significance of this is that there is no pressure flashing of LNG to methane; the phase change occurs due to very rapid heat transfer and boil-off.

In small spills of LNG discharged from height, most of the LNG will vaporize before reaching the impoundment trenches, soil or water, due to heat transfer with air and concrete. For very large spills, air cannot transfer enough heat to vaporize all the LNG, so the spill forms a pool.

Spilled LNG will simultaneously undergo several physical processes. These include pool formation, spread and boil-off. Pool formation for cryogenic boiling liquids is a dynamic process.

5.2.3 Pressurized liquefied natural gas spill/leakage

In an LNG fuel supply chain, pressurised storage and transfer of LNG can occur via a truck storage tank or LNG cargo tank and other smaller intermediate storage units (e.g. LNG buffer tank and ISO Containers), as well as in piping.

In such cases, the spill rate of LNG will depend on the pressure in the intermediate storage tank in addition to the static head, and in cases where LNG has been stored for some time, the immediate flashing will depend on the level of superheating.

Due to the pressure, the reach of liquid sprays and jet scan can be significant, but the formation of liquid pools will be similar with unpressurised non-pressurized LNG spill.

5.2.4 Dispersion

Methane gas (plus other associated heavier hydrocarbons if present) that boils off from the pool will form a dense gas due to its cold temperature (initially -162°C). The condensation of atmospheric moisture will further contribute to increased gas density above the pool.

As the cloud disperses with the wind, it spreads due to gravitational (density) effects and mixes with air due to atmospheric turbulence (characterized by a stability measure). Processes also affecting this mixing include heat transfer with the air and the re-evaporation of condensed moisture.

Eventually, the cloud will reach a point of neutral density, at which point dense gas processes cease to be important and atmospheric turbulence dominates the mixing.

Depending on circumstances, the cloud may eventually become buoyant as methane is much lighter than air (mole weights of 16 g/mol and 29 g/mol respectively); however, the presence of heavier hydrocarbons and cold will reduce the buoyancy and the cloud may be so diluted before this occurs that the effect may not influence flammable hazards.

5.2.5 Rapid phase transformation

Rapid phase transformation (RPT) is a physical phase transformation of LNG to methane vapour mainly due to submersion in water. RPT does not involve any combustion and cannot be characterised as a detonation.

5.2.9 Vapour cloud explosion

A vapour cloud explosion (VCE) can occur when a large flammable mass of hydrocarbon vapour is ignited in a confined or partially confined space. The thermodynamics of the combustion of a stoichiometric mixture of hydrocarbon in air will result in an 8 times volume increase of hot combustion products compared to ambient reactants. This is mainly due to the high temperature of the combustion gases and partly due to an increase in the number of moles of gas. In a confined space (e.g. an enclosed box), the final pressure will be a maximum of 8 bar (about 120 psi). In an open space, an outdoors situation, there is no confinement and the experimental evidence is that methane gas will burn relatively slowly (in the order of 10 m/s) with all the expansion resulting in a vertical rise of gas. Ignition trails on dispersed unconfined LNG vapour clouds have confirmed that no significant overpressures are developed (<1 mbar).

Within methane (natural gas) clouds, flame propagation is slow, and the flame may be extinguished prematurely and not be sustained throughout the cloud. Sufficient flame velocity (i.e. >100 m/s) to create significant explosion overpressures will not occur over water if there is no congestion or confinement.

5.2.10 Jet fire

Dispersing clouds of hydrocarbons can be ignited anywhere where the concentration is above the LFL and below the UFL. The majority of clouds which are ignited do so at their edge as they disperse and meet a strong ignition source (e.g. open flame, internal combustion engine, sparks). An ignited cloud will "flash back" across all its flammable mass (i.e. that part within the flammable range – between the UFL and LFL).

It will then burn at the UFL boundary until all the hydrocarbon is consumed. This will almost always flash back to the source and lead to a residual jet fire. Factors affecting this include the material flame speed, the concentration (maximum speed at stoichiometric concentrations, lower speeds at LFL and UFL), the temperature, condensed moisture, the degree of turbulence and the presence of congestion or objects that enhance turbulence.

6 QUANTITATIVE RISK ASSESSMENT METHODOLOGY

A typical QRA methodology utilized by DNV GL is shown in Figure 6-1.

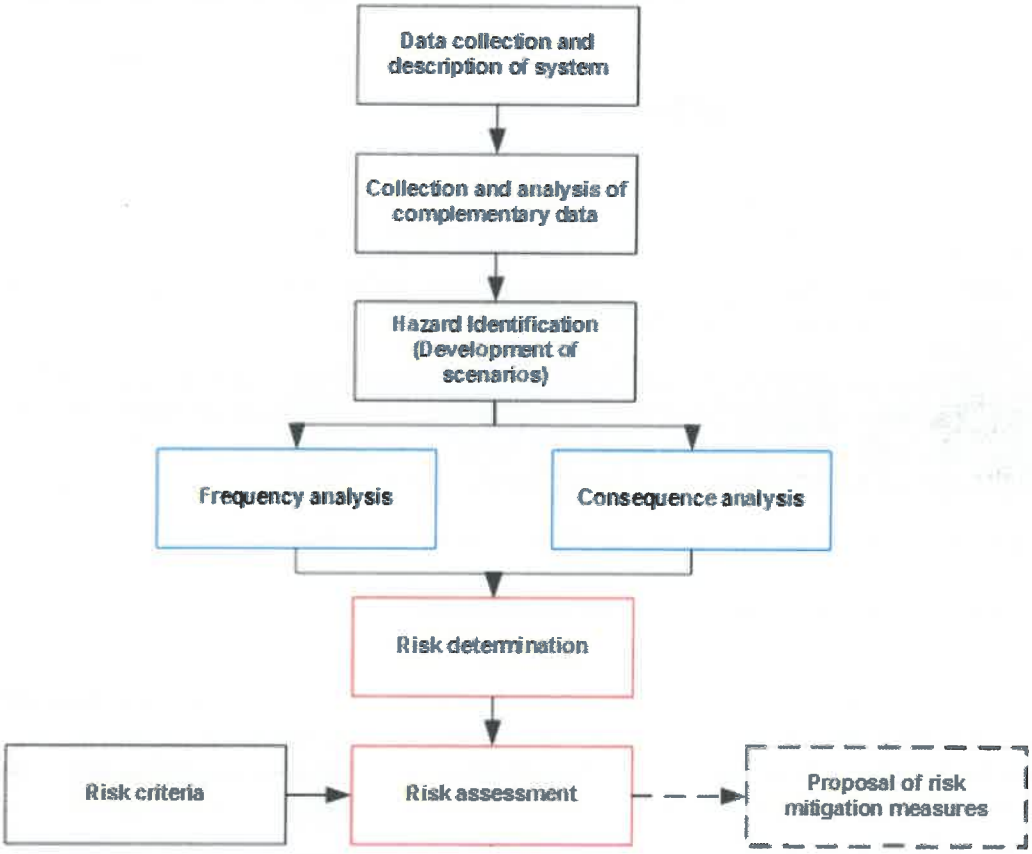

Figure 6-1 Typical QRA methodology

6.1 QRA Software Tool

The basis for this QRA study is DNV GL's proprietary risk modelling software, SAFETI software version 8.11 (also called Phast Risk). The SAFETI software has been in existence since the 1970s and has been under continual development and improvement ever since, which is managed by DNV GL's London-based software development division.

An electronic database of approximately 1400 materials is available to the SAFETI software, with the material properties regularly reviewed and if required re-adjusted, based on the latest available data. The SAFETI consequence modelling results (for each material) are regularly reviewed and where required re-calibrated, based on the latest available accident and test data.

The SAFETI software will calculate dispersion and consequence modelling results for all specified weather classes and wind speeds with the failure case specified release frequency data, specified weather class, wind speed, wind directional probability data, specified immediate ignition probability data, software calculated delayed ignition probability data, built-in event tree alternate consequence outcome branch probability data, fatal impact probability data for each alternate consequence outcome (e.g. jet fire, flash

- For each release case, SAFETI takes the failure case release frequency as initial input, multiplies this by the first weather class / wind speed probability, for the first of eight (8) wind directions.
- SAFETI takes this result and multiplies it by the immediate ignition probability, and delayed ignition probability.
- These two (2) results are multiplied by the first of the event tree consequence branch probabilities, relating to immediate or delayed ignition branch path.
- SAFETI takes the calculated consequence hazard range and verifies which grid points are within the consequence hazard area. For each grid point within range SAFETI then calculates the magnitude of the consequence at each grid point (e.g. explosion overpressure at a particular grid point may be 3 psi).
- The calculated consequence magnitude at each grid point is then compared to the SAFETI programmed impact criteria level, and the likelihood of fatality or damage calculated, based on the impact probability criteria specified in SAFETI, for the type of consequence and the magnitude of the consequence.
- This calculation is repeated for each event tree alternate consequence outcome at each grid point, for that weather class / wind speed and wind direction, and the result added to the previous risk level, at each grid point.
- The above calculations are then repeated for each of the eight (8) wind directions, cumulatively adding to the risk level at each grid point.
- The above calculations are repeated for all weather classes, wind speeds and wind directions, cumulatively adding these risk results at each grid point.
- Once all risk calculations at these grid points have been completed for the first failure case, the next failure case will be calculated, again adding all results cumulatively at each grid point. This is repeated until all failure cases have been calculated, while SAFETI also tracks the risk contribution made by each failure case at each grid point.
- Once completed, SAFETI produces individual risk contour results by linking points of equal risk, based on the pre-specified levels of individual fatality risk (or equipment damage) to be plotted, and using linear interpolation between relevant grid points. The risk contour results are super imposed on the electronic site map, entered in the SAFETI software.

6.2 Consequence Modelling

6.2.1 Consequence Impact Criteria

The following consequence impact are assessed in the study:

- Radiation distance to 35, 12.5 and 4 kW/m^2;
- LFL (100%);
- Overpressure of 0.3 and 0.1 bar.

Individual Risk (IR) – IR is the risk for an individual who is present at a particular location, continuously all year (i.e., 24 hours a day 7 days a week) without wearing personal protective equipment. Individual risk is the frequency at which an individual may be expected to sustain a given level of harm from the realization of specific hazards. Individual risk is often interpreted as an incident every X number of years. Examples of how to interpret individual risk are as follows:

- $1x10^{-3}$ per year is equivalent to one incident every 1,000 years
- $1x10^{-4}$ per year is equivalent to one incident every 10,000 years
- $1x10^{-6}$ per year or one incident every 1,000,000 years

These numbers do not imply that no event will occur for the specified time period. These risk levels are statistical representations of risk. They predict that an incident might occur within this average timeframe. The incident could happen tomorrow or sometime during the next 1,000 years.

Individual Risk is presented as isopleths similar to elevation contours on a map. The inner contour is the highest risk (often 10^{-3} or 10^{-4} per annum), and normally contours are plotted in declining order of magnitude circles until some very low level of risk is predicted, often 10-6 or 10-7 per annum. Figure 6-4 an example of an IR contour.

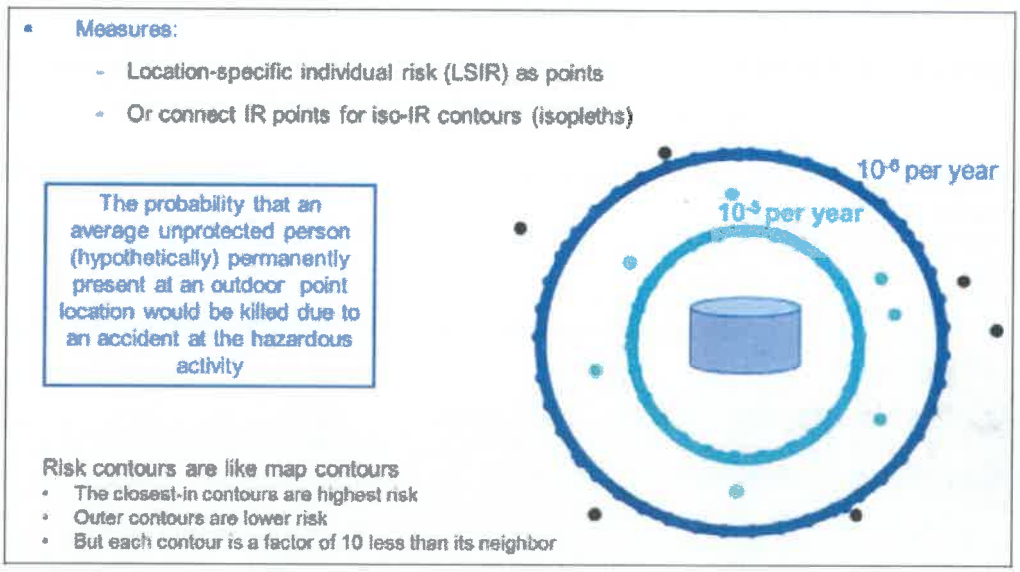

Figure 6-4 Individual Risk Presentation

Note: Societal risk is defined as the (cumulative) frequency per year of a particular group of people dying concurrently as a result of accidents, and can be calculated by combining the calculated levels of individual risk with the number of people indoors and outdoors at specific locations. Societal risk criteria have not been as widely used as individual risk criteria because the concepts and calculations involved are much more difficult as it would require the number of people indoors and outdoors at each required location to be provided. As such, because of the difficulty in obtaining accurate values for number of people indoors and outdoors at specific locations as well as time spent, societal risk is sometimes not presented. As such, this study had presented location specific individual risk (IR contours) instead.

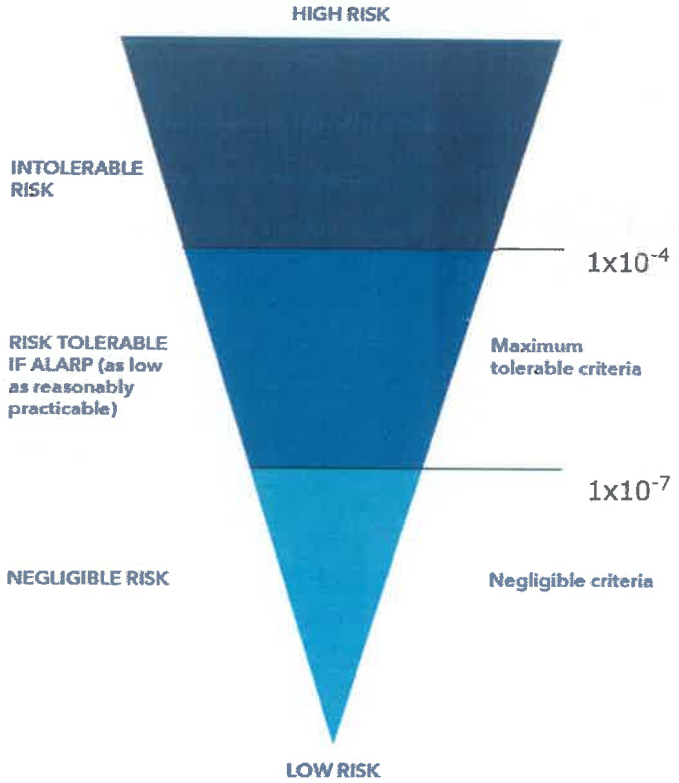

Figure 6-5 Framework for Three-band Risk Criteria

The risks are divided into three hierarchy levels, as below:

- The upper band is where the risks are usually considered intolerable irrespective of the benefits the activity may bring, and risk-reduction measures are essential whatever their cost.
- The middle band is where risk-reduction measures are desirable but may not be implemented if their cost is high relative to the benefit gained (i.e. the ALARP principle should be demonstrated).
- The lower band is where risks are negligible, or so small that no risk-reduction measures are needed.

Table 7-1 Input Parameters and Leak Frequencies for Identified Failure Cases

Failure Case No.	Failure Scenario Description	Pressure	Temperature	Total Inventory	Hole size	Discharge rate	Immediate Ignition probabilities	Delayed Ignition probabilities	Release Duration	Leak frequency
			(°C)	kg	mm	kg/s			minutes	/year
ISO-01	Liquid Manifold After ESD (V1) and Liquid Filling Line	0.7	-160	1632	10mm	0.38	5.28E-04	1.23E-03	71.67	2.43E-02
				1991	25mm	2.37	2.70E-03	6.31E-03	13.99	1.41E-03
				5407	75mm	21.35	1.77E-02	4.12E-02	4.22	3.16E-04
				28893	200mm	151.83	7.43E-02	1.73E-01	3.17	3.31E-04
ISO-02	Vapour Return Manifold After ESD (V2) and Vapour Return Line	0.7	-130	8	10mm	0.03	8.56E-05	2.00E-04	5.18	3.12E-02
				32	25mm	0.16	3.85E-04	8.99E-04	3.35	2.38E-03
				265	75mm	1.45	1.42E-03	3.30E-03	3.04	3.44E-04
				1049	150mm	5.81	6.78E-03	1.58E-02	3.01	2.53E-04
ISO-03	LNG filling hose at Filling Bay to ISO Containers	0.7	-160	1874	Rupture (50mm)	9.49	9.76E-03	2.28E-02	3.29	2.74E-03
ISO-04	Vapour return hose at Filling Bay	0.7	-150[1]	75	Rupture (40mm)	0.41	5.48E-04	1.28E-03	3.02	2.74E-03
ISO-05	20' LNG Buffer Tank	0.7	-160	8280	10mm	0.38	5.28E-04	1.23E-03	363.57	3.60E-04
				8280	25mm	2.37	2.70E-03	6.31E-03	58.17	3.00E-05
				8280	50mm	9.49	9.76E-03	2.28E-02	14.54	3.00E-05
				8280	Catastrophic	n/a	7.50E-03	1.75E-02	Instantaneous	3.00E-06
ISO-06	40' ISO Container	0.7	-160	18300	10mm	0.38	5.28E-04	1.23E-03	803.54	2.13E-02
				18300	25mm	2.37	2.70E-03	6.31E-03	128.57	1.78E-03
				18300	50mm	9.49	9.76E-03	2.28E-02	32.14	1.78E-03
ISO-07	Cryogenic LNG Bowser/Road Truck	0	-160	21942	Catastrophic	n/a	9.00E-02	2.10E-01	Instantaneous	2.96E-05

[1] Temperature is modified to -150 °C in the consequence modelling as the PHAST model only gives vapour phase at this temperature.

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The furthest radial distance extended by the 1E-06/year risk contour from the centre of the MFP is approximately 120m in length. 120m is thus recommended as the minimum distance between centre of the MFP and any on-shore/off-shore facilities, if applicable.

7.2.2 IR Contours for Public for Berth 19

The IR contour arising from the LNG filling operations at Berth 19 is presented in Figure 7-2, considering the risk contours extending outside of the LNG receiving and offloading facility. Similar to Berth 18, the intolerable risk for public, which is 1E-05/yr, does not extend beyond the jetty area (marginally extend beyond the MFP on the north), and the risk contour of 1E-06/yr is contained within the jetty area. As such, the risk to public is considered to be in the ALARP region.

Figure 7-2 IR Fatality Risk contour for LNG Filling and Receiving Facility at Berth 19

7.2.4 IRPA for Personnel on MFP

The IR contours for a person present continuously 100% of the time (i.e. 24 hours per day, 365 days a year) on the MFP are as presented in Figure 7-5.

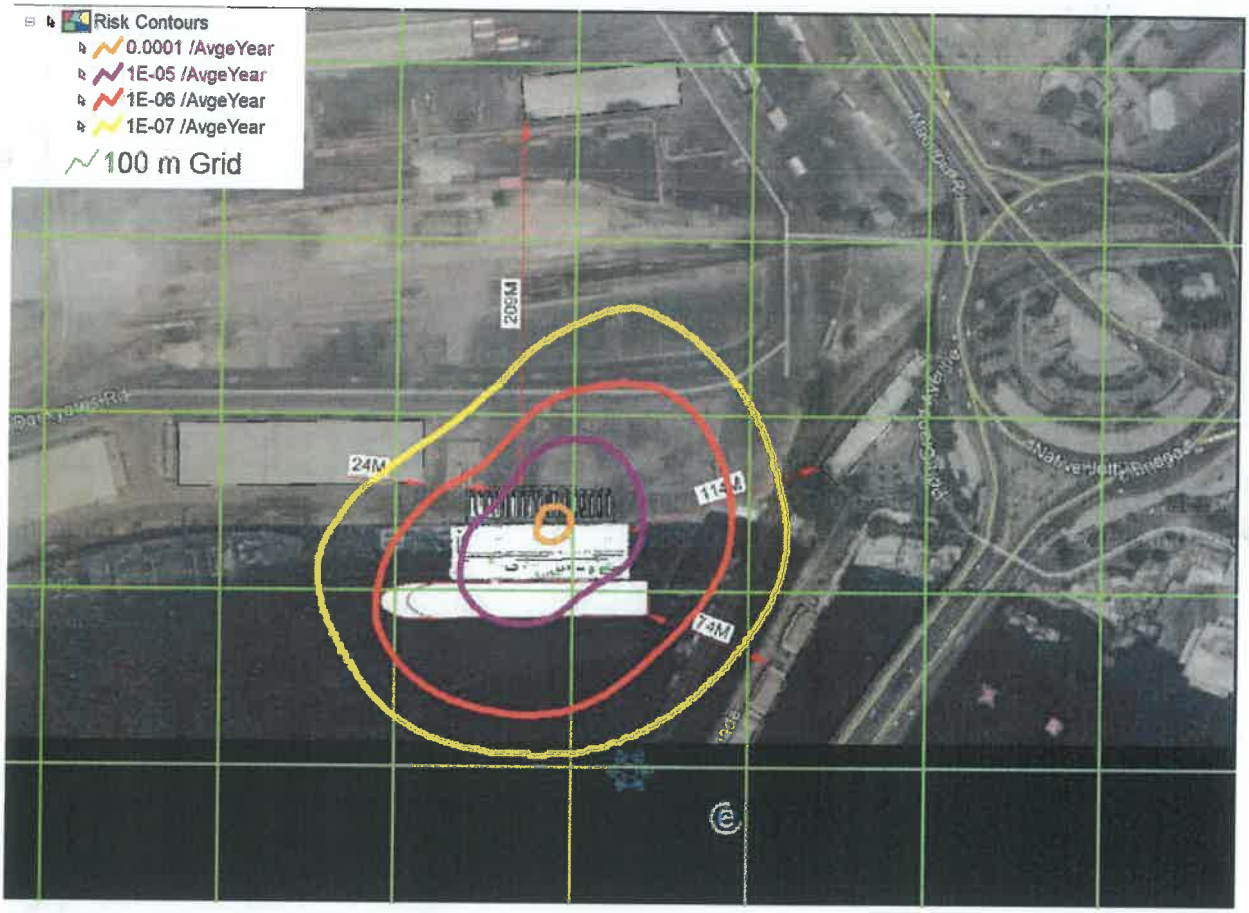

Figure 7-5 IR Fatality risk contour for LNG Filling and Receiving Facility (100m grid spacing)

The Individual Risk Per Annum (IRPA) for an individual working on the LNG Filling and Receiving Facility is estimated to be 2.15E-05 per year (regardless of which the berth the MFP will be located). This is calculated based on the risk for an arbitrary person working at a particular location (in this case personnel is assumed to be positioned at the MFP at the main header before splitting to the 3 filling bays), with a 12 hours work shift per day (split of 70% of time spent outdoor, 30% indoor in the indoor). The filling operation is assumed to take place 12 days in a month. The overall risk result shows that the IRPA for a worker on the MFP falls within the ALARP region (i.e. between 1E-07/year to 1E-04/year).

Figure 7-6 shows the risk transect across the risk contours, from centre of the MFP extending outwards.

7.2.5 Top Risk Contributors

Main contributors to IR fatality are presented in Table 7-2. It can be observed that the 50mm leak of the LNG Filling Hose and 50mm leak of ISO containers poses the highest risks at approximately 42.83% and 42.51% respectively.

Table 7-2 Top Risk Contributor Scenarios for IR

Scenarios	Sum of Risk Increment [/yr]	Sum of Contributions (%)
ISO-01 LNG Filling Manifold\Liq Filling\10mm\10mm Leak	**6.05E-09**	**0.0051%**
Continuous release with Rainout delayed Flash fire with eXplosion and Pool fire	2.37E-09	0.0020%
Continuous release with Rainout delayed Flash Fire with Pool fire	3.55E-09	0.0030%
Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects	1.30E-10	0.0001%
ISO-01 LNG Filling Manifold\Liq Filling\25mm\25mm Leak	**1.64E-08**	**0.0137%**
Continuous release with Rainout delayed Flash fire with eXplosion and Pool fire	3.51E-09	0.0029%
Continuous release with Rainout delayed Flash Fire with Pool fire	5.27E-09	0.0044%
Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects	7.61E-09	0.0064%
ISO-01 LNG Filling Manifold\Liq Filling\75mm\75mm Leak	**1.54E-07**	**0.1291%**
Continuous release with Rainout delayed Flash fire with eXplosion and Pool fire	3.98E-08	0.0333%
Continuous release with Rainout delayed Flash Fire with Pool fire	5.97E-08	0.0500%
Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects	5.45E-08	0.0457%
ISO-01 LNG Filling Manifold\Liq Filling\Rupture\200mm Leak	**1.65E-06**	**1.3820%**
Continuous release with Rainout delayed Flash fire with eXplosion and Pool fire	4.50E-07	0.3775%
Continuous release with Rainout delayed Flash Fire with Pool fire	6.75E-07	0.5662%
Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects	5.23E-07	0.4384%
ISO-02 Vapour Return Manifold\Vap Return\75mm\75mm Leak	**3.83E-10**	**0.0003%**
Continuous release No rainout Immediate Horizontal Jet fire Only	3.83E-10	0.0003%
ISO-02 Vapour Return Manifold\Vap Return\Rupture\150mm Leak	**9.18E-09**	**0.0077%**
Continuous release No rainout delayed Flash Fire Only	8.30E-10	0.0007%
Continuous release No rainout delayed Flash fire with eXplosion	5.53E-10	0.0005%
Continuous release No rainout Immediate Horizontal Jet fire Only	7.79E-09	0.0065%
ISO-03 LNG Filling Hoses-ISO Container\50mm\50mm Leak	**5.11E-05**	**42.8363%**
Continuous release with Rainout delayed Flash fire with eXplosion and Pool fire	1.35E-05	11.3552%
Continuous release with Rainout delayed Flash Fire with Pool fire	2.03E-05	17.0328%
Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects	1.72E-05	14.4483%
ISO-04 Vapour Return Hose-ISO Container\40mm\40mm Leak	**1.84E-07**	**0.1545%**
Continuous release No rainout delayed Flash Fire Only	2.87E-09	0.0024%
Continuous release No rainout delayed Flash fire with eXplosion	1.91E-09	0.0016%
Continuous release No rainout Immediate Horizontal Jet fire Only	1.80E-07	0.1505%
ISO-05 20'LNG Buffer Tank1\25mm\25mm Leak	**1.28E-08**	**0.0107%**
Continuous release with Rainout Delayed Flash Fire Only	1.05E-10	0.0001%
Continuous release with Rainout delayed Flash fire with eXplosion	7.03E-11	0.0001%

7.3 Risk Results – Cryogenic LNG Bowser/Road Truck

Figure 7-7, Figure 7-8 and Figure 7-9 presents the risks contours of the LNG filling operations to Cryogenic LNG Bowser/Road Truck at the respective proposed berths. The risk levels are lower compared to filling to LNG ISO containers (the 1E-05/year risk contour is slightly smaller compared to that for the ISO container filling). (Note that risk level higher than 1E-04/yr is not obtained, and hence not shown in the risk contours.)

Based on the plots, it can be seen that the operations involving filling of Cryogenic LNG Bowser/Road Truck is likely to result in a slightly lower risk level compared to the operations involving filling of ISO-containers. As such, the risk results for filling of Cryogenic LNG Bowser/Road Truck will not be assessed further.

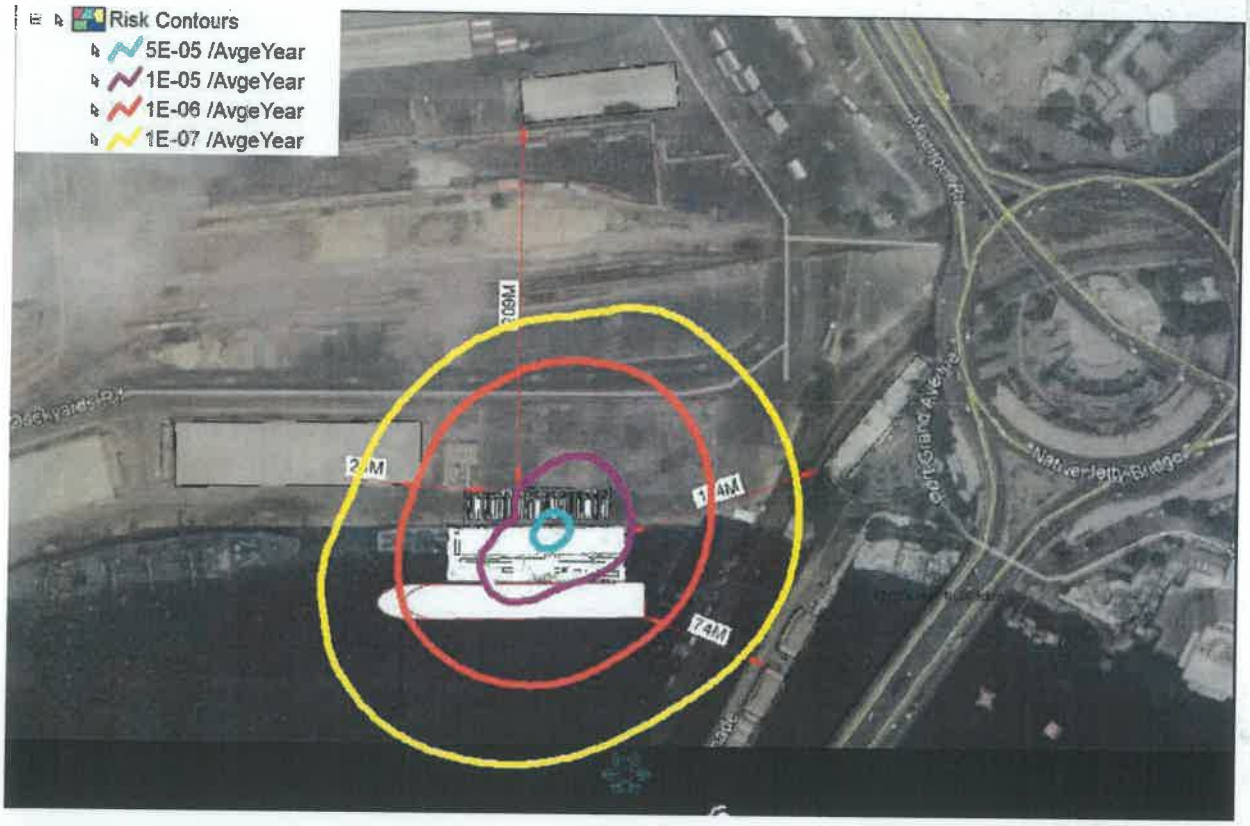

Figure 7-7 Risk contour for LNG Filling and Receiving Facility to Cryogenic LNG Bowser/Road Truck at Berth 18/19

7.4 Consequence Distances

The consequence distances for Flash Fire (LFL), Jet Fires, Pool Fires and Explosion for all the scenarios modelled are tabulated in Table 7-3.

Scenario	Weather	Mass flow rate	LFL	Jet Fire			Pool Fire			Explosion	
		(kg/s)	Distance (m)	Distance downwind to 4 kW/m² (m)	Distance downwind to 12.5 kW/m² (m)	Distance downwind to 35 kW/m² (m)	Distance downwind to 4 kW/m² (m)	Distance downwind to 12.5 kW/m² (m)	Distance downwind to 35 kW/m2 (m)	Distance downwind (0.1 bar) (m)	Distance downwind (0.3 bar) (m)
Study\ISO-05 20'LNG Buffer Tank1\Rupture	Category 1/F	-	115.741	-	-	-	102.2	59.4175	31.1116	127.636	66.9257
Study\ISO-05 20'LNG Buffer Tank1\Rupture	Category 3/C	-	177.111	-	-	-	109.466	69.6482	42.7401	-	-
Study\ISO-05 20'LNG Buffer Tank1\Rupture	Category 6/D	-	230.432	-	-	-	112.434	74.8074	51.3843	-	-
Study\ISO-06 40'ISO Containers\10mm	Category 1/F	0.3777	4.40655	22.1931	18.2934	n/a	11.8345	8.87074	6.6318	-	-
Study\ISO-06 40'ISO Containers\10mm	Category 3/C	0.3777	7.04186	19.286	15.4661	13.7032	11.3679	9.19272	7.41253	-	-
Study\ISO-06 40'ISO Containers\10mm	Category 6/D	0.3777	5.42567	17.6059	14.0164	11.8428	10.4299	9.06283	8.36761	-	-
Study\ISO-06 40'ISO Containers\25mm	Category 1/F	2.36062	65.9435	48.9549	39.0833	n/a	39.1403	25.3025	15.757	-	-
Study\ISO-06 40'ISO Containers\25mm	Category 3/C	2.36062	36.9263	42.7409	33.1154	28.5848	37.4339	26.1847	17.7046	-	-
Study\ISO-06 40'ISO Containers\25mm	Category 6/D	2.36062	28.2034	39.1364	30.3393	25.2937	33.6254	24.8302	18.2625	-	-
Study\ISO-06 40'ISO Containers\50mm	Category 1/F	9.44249	130.29	83.8918	65.8507	60.1148	73.5391	45.6164	26.912	-	-
Study\ISO-06 40'ISO Containers\50mm	Category 3/C	9.44249	75.527	78.4977	60.5067	50.8586	73.3118	49.0947	32.5597	-	-
Study\ISO-06 40'ISO Containers\50mm	Category 6/D	9.44249	64.092	71.947	55.2966	44.9265	69.3975	48.6059	35.3521	-	-
Study\ISO-07 Road Truck\Road Truck\Rupture	Category 1/F	-	146.039	-	-	-	149.827	86.9362	45.6573	169.465	84.5468
Study\ISO-07 Road Truck\Road Truck\Rupture	Category 3/C	-	225.182	-	-	-	158.428	100.236	60.838	258.721	171.948
Study\ISO-07 Road Truck\Road Truck\Rupture	Category 6/D	-	220.325	-	-	-	162.01	106.533	72.3748	245.381	156.392

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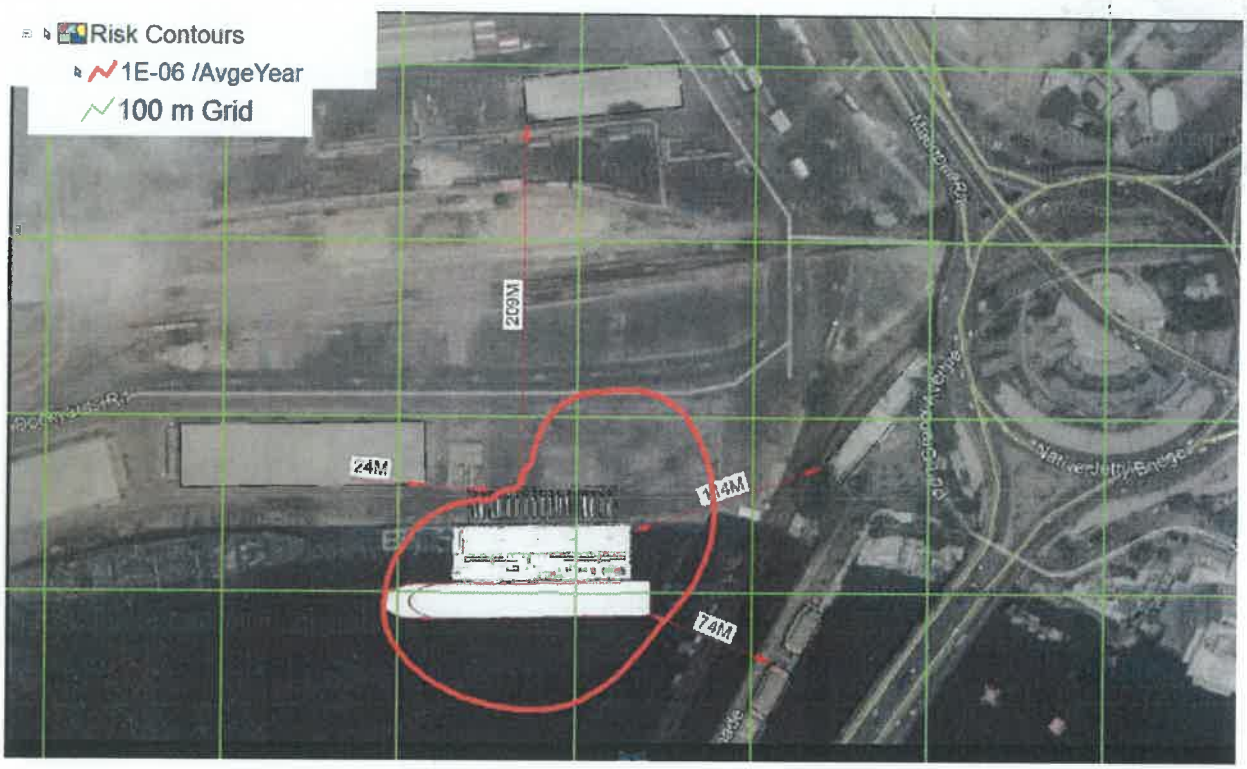

Figure 7-10: Flash Fire - LFL Contour at 1E-06/yr Frequency

Note: There is no hard and fast rule as to whether consequence-based approach or risk-based approach should be used – consequence-based approach is more conservative, but if the frequencies of events are low, then it could be overly conservative, and thus, a risk-based approach was typically chosen.

7.5.3 Marine Exclusion Zone

In this study, the Safety Zone defined from the LFL distance will be used to establish the Marine Exclusion Zone (MEZ), which is the minimum distance that the passing vessels should be prevented from passing the facility.

As discussed in preceding section, the safety distance established by the risk-based approach extends up to 120m, from the centre of the MFP. The marine exclusion zone distance set for LNGC are then calculated to be 60m, as illustrated in Figure 7-11. This is the minimum distance for any passing vessels or marine vessels plying the area (except authorised vessel with appropriate ignition control measures in place) during LNG filling operations.

8 CONCLUSION

The following are conclusions derived from this QRA study:

- For public risk, the intolerable risk for public, which is 1E-05 per year, does not extend beyond the jetty area (marginally extend beyond MFP on the north), and the broadly acceptable risk level of 1E-06 per year is contained within the jetty area. As such, the risk to public is considered to be within the ALARP region.
- The Individual Risk Per Annum (IRPA) for an individual working on the MFP is estimated to be 2.15E-05 per year. This is calculated based on the risk for an arbitrary person working at a particular location (in this case personnel is assumed to be positioned at the main pipe rack area of the MFP), with a 12 hours work shift per day (split of 70% of time spent outdoor, 30% indoor). The filling operation is assumed to take place 12 days in a month. This risk result shows that the **IRPA for workers on the MFP falls within the ALARP region** (i.e. between 1E-07 per year to 1E-04 per year).
- The furthest radial distance extended by the 1E-06 per year risk contour from the centre of the MFP is approximately 120m in length or 87m measured from the edge of the MFP. 120m from centre of the MFP or 87m from edge of MFP is thus recommended as the minimum distance to any on-shore/off-shore facilities, if applicable.
- Using consequence-based approach (without consideration of the frequencies), the Safety Zone is determined to be 236m (based on largest LFL distance reached), which will encroach the train track, but will not reach the food street. This would mean that the proposed locations of Berth 18/19 and Berth 19 will not be appropriate due to the LFL distances reaching the train track, and therefore Berth 23 will have to be chosen instead. However, using a risk based approach (by considering the frequency of leakage, ignition probability and consequence), the Safety Zone has been determined to be approximately 120m from centre of the MFP (potential release at LNG filling hose connection at the filling bay) or 87m measured from the edge of the MFP. As such, the Safety Zone using risk-based approach will not reach the restaurants and food street, nor reach the train track based on the risk contour at 1E-06 per year.
- The marine exclusion zone distance set for LNGC is calculated to be 60m. This is the minimum distance for any passing vessels or marine vessels plying the area (except authorised vessel with appropriate ignition control measures in place) during LNG filling operations.
- Within the defined Safety Zone / MEZ radius, the following restrictions must be in place:
  - Unauthorised entry must be restricted within the Safety Zone / MEZ radius. Only dedicated personnel are allowed in the area.
  - On water, this restriction will include small boats, fishing vessels and other marine vessels that are unlicensed for harbour work and are carrying open air ignition sources.
  - No activities can be performed which can introduce ignition sources (e.g. hot work, hot surfaces, etc.).

Note: As the risks for workers and public falls within the acceptable region, no recommendations were made.

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APPENDIX A ASSUMPTIONS REGISTER

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About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil & gas and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our professionals are dedicated to helping our customers make the world safer, smarter and greener.

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LNG EASY HAZID/HAZOP – MOBILE FILLING PLATFORM FOR LNG ISO CONTAINER/ROAD TRUCK FILLING FOR KARACHI PORT

HAZID, HAZOP and SIL Classification/LOPA Report

LNG Easy Pte Ltd

Report No.: PP205958-A1 Report, Rev. 0
Document No.: 119FL113-2-A
Date: 24-05-2021

Table of contents

1 EXECUTIVE SUMMARY

LNG Easy Pte Ltd (hereinafter "LNGE") has requested DNV Singapore Pte. Ltd. (hereinafter "DNV") to conduct safety studies - Hazard Identification (HAZID), Hazard Operability (HAZOP), SIL classification/LOPA and QRA (Quantitative Risk Assessment) for the proposed LNG ISO container filling system of LNG ISO containers to customers.

This report documents the study basis, methodology and results from the HAZID, HAZOP and SIL/LOPA workshop. LNG Easy Pte Ltd (LNGE) is planning to set up a Liquefied Natural Gas (LNG) receiving and offloading facility for LNG ISO containers or Cryogenic LNG Bowser/Road Truck filling. Trucks will arrive with empty LNG containers which will be parked on the Jetty in Karachi Port and will be filled via a Mobile Filling Platform (MFP) from a LNG Carrier.

A HAZID Study is a systematic brain-storming type workshop, where representatives from various discipline study the proposed operations to identify any potentially hazardous conditions or operating problems that could arise from LNG filling and trucking operation.

A HAZOP is a formal technique to systematically examine the process design of Mobile Filling Platform (MFP) with deviations from the planned mode of operation by using selected guidewords.

The objective of the SIL Classification Study/LOPA is to determine the SIL required for each Safety Instrumented Function (SIF) identified on the P&ID. It also ensures there are sufficient protection/ safeguards for the process systems; and to decide whether the risk from each individual scenario (based on current design) is at an acceptable level.

HAZID workshop was conducted on 20th February of 2020 at Compass Energy's offices followed by one-day HAZOP and SIL/LOPA workshop was conducted on 18th May 2021 at Compass Energy Office, 12 Tuas Avenue 1, Singapore. The HAZID Workshop conducted on 20th February is also reviewed based on the current project drawings and diagrams. Action items were made where either the current provision of preventive or mitigating measures are insufficient to manage the hazard, or that further assessments are required to obtain a better understanding of the hazard.

A total of 6 action items were made during the HAZID workshop and 04 action items were raised in the HAZOP workshop. A further 2 Items was raised during the 2020-02-20 HAZOP workshop. No recommendations were made from SIL/LOPA Study. Only one Safety Instrumented Function (SIF) loop was identified from the ESD philosophy/Cause and Effect Matrix art for MFP and the loop is classified as SIL1 loop.

The findings from the HAZID, HAZOP and SIL/LOPA study should be given due attention by the responsible parties for ensuring that all required action items are closed and addressed as appropriate. If, for any reason, an action is not implemented, justification for such a decision should be documented. No changes are recommended as part of these workshop hence no changes or updates are envisaged for QRA study.

3 HAZID SCOPE AND METHODOLOGY

3.1 HAZID

A HAZID Study is a systematic brain-storming type workshop, where representatives from various discipline study the proposed operations to identify any potentially hazardous conditions or operating problems that could arise from LNG filling and shipping operation.

3.2 Objective

The objectives of the HAZID study are to:

- Identify all potential hazards and hazardous events that have the potential to result in a Major Accident Event (MAE);
- Evaluate the prevention, control and mitigation measures provided;
- To identify the credible major accident events;
- Identify actions and responsible parties for completion of the actions; and
- Provide input to and interface with other safety studies such as QRA.

3.3 Scope of Work

3.3.1 Study Boundary

The scope of work is limited to the following:

- Mooring of LNGC to MFP
- Mooring of the MFP to the Jetty;
- Collision risks by external vessels during operations, (un)mooring and movement of LNGC, or MFP;
- Filling of ISO containers/tank trucks on the jetty via the MFP or direct via the filling skid on the jetty.
- Operating the MFP filling skid; and
- Arriving or departing trucks when driving off from the immediate vicinity of the Jetty with the ISO container on the truck

This assessment was limited to normal and transient operations (if any). The general overview and layout of LNG filling on the MFP is shown above.

No.	Node Description
4	ISO Tank Filling Operations
5	Arriving and departing trucks on the jetty

3.3.3 Workflow

The HAZID was conducted as a team exercise. The team referred to the HAZID guidewords as a basis for identifying potential hazards associated with each node.

Once a hazard was identified, it was discussed and recorded on the worksheets. For each hazard, the causes, consequences, and barriers (preventive and mitigating) were identified and recorded in the HAZID workshop as indicated in Figure 3-1.

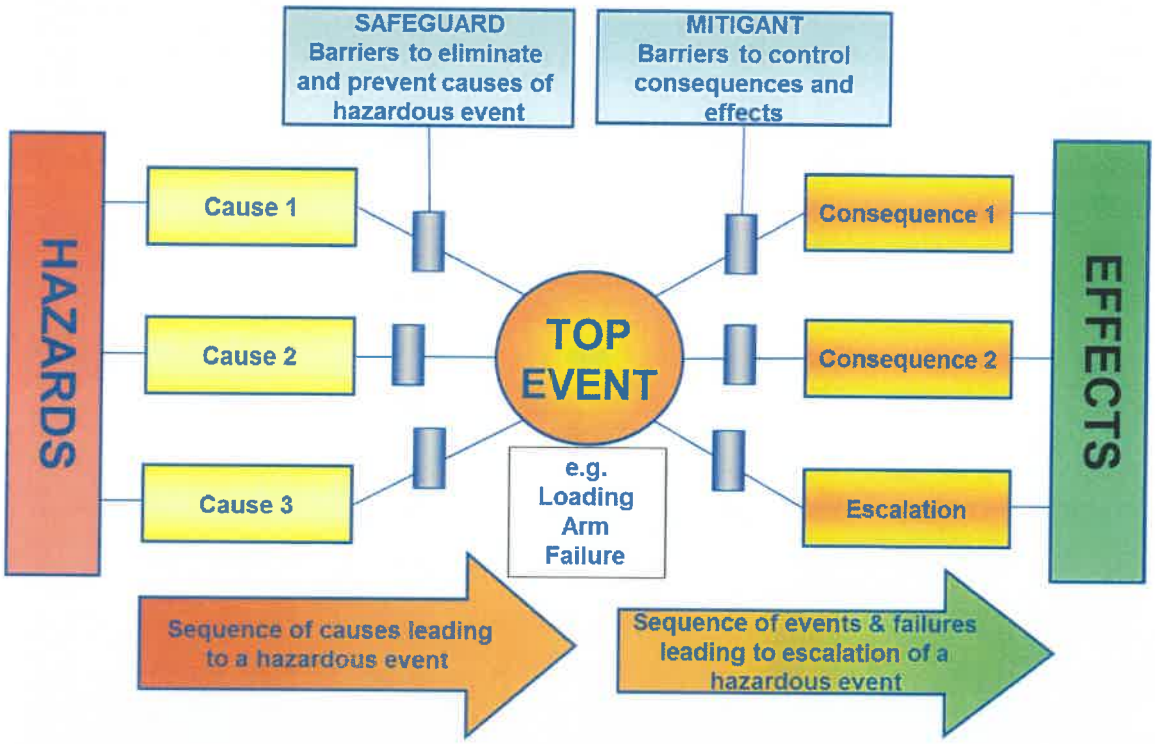

Figure 3-1 Bow tie hazard and effect model

The detailed methodology applied in the workshop follows the steps outlined below:

- **Identification of study nodes:** In order to assess the specifics of each individual area of the installation, the vessel has been broken down into a series of "nodes". For each node the following steps will be performed.
- **Node briefing:** In order for all team members to obtain a common understanding of the design and intended operation of the node, the discipline lead will give a brief introduction of the node in question.
- **Formulation of Hazards, their Cause and Consequences:** The team will consider each node in turn and, with reference to the guideword list, identify the hazards that apply to it. For each hazard identified, the potential causes for this hazard materializing into a MAE shall be identified, along with the potential consequences of such an event.

3.3.4 Guidewords

As the focus of the HAZID is related to Major Accident Events (MAEs), and with special emphasis on design issues, the following set of guidewords has been derived and was utilized during the HAZID workshop (as applicable for the context).

LOSS OF CONTAINMENT: • Corrosion and erosion • Material failure (Fatigue, Embrittlement) • Fluid properties and property changes • Vibration • Impact events • Temperature cycling • Operation outside design envelopes • Start-up/shutdown activities • Maintenance activities • Mechanical isolation • Human error–operations/maintenance • Human error–start-up/shutdown • Simultaneous operations • Escalation from other areas • Ingress of other fluids • Ingress into other systems • Ignition sources (electrical, hot surfaces) • Crane operations • Gas and Smoke movement • Cryogenic Spill • Rapid Phase Transition	**SHIPPING IMPACT:** • Warning times • Radar/ARPA • Stand-by vessel response procedures • Installation response procedures • Shipping density • Shipping lanes • Vulnerability of risers • Attendant vessels approach direction • Vulnerability of structure • Passing vessel hazards (e.g. Shuttle tankers, fishing, merchant, naval, submarines) • Attendant vessels (standby, supply, drilling, flotel, diving, others) • Drifting vessels • (Passing, attendant, loading, buoys/storage units, others
STRUCTURAL FAILURES: • Subsidence and scour • Seismic • Corrosion • Fatigue • Extreme weather • (waves, wind, snow & ice) • Extreme loading • Cranes • Primary/Secondary/Temporary structures • Tank Sloshing	**STABILITY/BUOYANCY LOSS:** • Structural damage • Collision • Flooding • Anchor/Mooring failures • Extreme weather • Loss of position keeping • Ballasting control failure • Weight control • Gas release under hull • Green Water
HAZARDOUS OPERATIONS • Diving operations • Life support failure • Construction work • Scaffolding • Pressure testing • Ionising radiations • Toxic materials • Explosives • Missile generation • Other hazardous operations – e.g. working at height, exposure to other personnel / health hazards • Man overboard • Security issues, e.g. piracy	**DROPPED OBJECTS:** • Dropped loads (overboard/onboard) • Swinging loads • Human errors • Mechanical failures • Equipment collapse • Overloading • Skidding operations **3RD PARTY** • Construction activities • Lifting operations • Vulnerable targets • Vehicle traffic • Mechanical failure • Security issues, e.g. piracy

5. **Identify, for each cause, all possible consequences without regard for any safeguards in place** – For each cause, identify the consequences on the presumption that the safeguards are not available;
6. **Identify all available safeguards to prevent the cause or to limit the consequences** – For each pair of cause and consequence, identify safeguards in place that can be expected to prevent an incident from occurring, as well as those intended to control its development or mitigate its consequence;
7. **Recommend any new safeguards where necessary** –If it is the belief of the HAZOP team that the current provision of safeguards are insufficient to manage the hazard, recommendation of new safeguard will be raised. If further assessments are required to obtain a better understanding of the hazard, this will be raised as an action item during the workshop. These recommendations and action items will be recorded in the worksheets and assigned to a responsible party.
8. Repeat steps 4 to 7, using the next HAZOP deviation;
9. Repeat steps 3 to 8 until all HAZOP deviations have been applied to the node;
10. Select the next node to be studied, repeating steps 1 to 9; and
11. Repeat until all nodes are studied.

4.1.4 Guidewords

After the nodes have been identified, predetermined HAZOP guidewords were used to initiate the causes for deviation from the design intent through a questioning process. Guidewords used involve parameters such as flow, temperature and pressure and a deviation. By combining a deviation (E.g. No/Less, More, As well as) to the parameters, each node was further analysed specific to the causes arising from the guideword. Examples of guidewords are 'No/Less Flow', 'High Level' and 'More Pressure'.

The following parameters were used in this HAZOP:

- Flow
- Pressure
- Temperature
- Level
- Contamination
- Utility/Service Failure
- Sampling/Testing
- Maintenance/Isolations/Access
- Static
- Start-up/Shutdown
- Instrumentation
- Material Selection
- F&G/Fire Protection/Area Classification
- Others (e.g. spares, lessons learnt, experience based)

The proposed deviations and the associated meaning are given in Table 3-3.

Table 3-2 Deviation List

Deviation	Meaning
No/Not	Complete negation of the design intent
More	Quantitative increase
Less	Quantitative decrease
As Well As	Quantitative modification/increase
Part Of	Quantitative modification/decrease
Reverse	Logical opposite of the design intent
Other Than	Complete substitution

	for each Regasification IPF to aid in the design, i.e. whether to install instrument architecture or reduce intervals for test frequencies, etc which will be covered in the SIL Verification process (desktop study)
Post-Workshop	• Documenting findings and recommendations • Issue of SIL worksheet to all participants and MOSS to review and comment • Upon receipt of consolidated comments, finalise the draft report for review and comment.

5.1.3 SIF Concepts

The SIL Classification workshop's aim is to establish Safety Integrity Levels (SILs) for the Safety Instrumented Functions (SIFs). The SILs give constraints on the selection and design of the (components of the) Safety Instrumented System (SIS).

IEC61511-1 defines the term "Safety Instrumented Function" as follows:

- Safety function with a specified safety integrity level which is necessary to achieve functional safety and which can be either a safety instrumented protection function or a safety instrumented control function.

A "Safety Integrity Level" is defined as:

- Discrete level (one out of four) for specifying the safety integrity requirements of the safety instrumented functions to be allocated to the safety instrumented systems. Safety integrity level4 has the highest level of safety integrity; safety integrity level 1 has the lowest.

And a "Safety Instrumented System" is defined as:

- Instrumented system used to implement one or more safety instrumented functions. An SIS is composed of any combination of sensors, logic solvers, and final elements.

A "Final Element" is defined as:

- The critical element of the design (e.g. pump trip, XV closure, etc.) to prevent given consequence and does necessarily list all the initiating actions of the instrumented trip function from the C&E matrix.

5.2 Calibrated Risk Graph Method

The approach of SIL Classification using the Risk Graph method is based on a number of parameters, which together describe the nature of a hazardous situation when SIFs fail or are not available. The SIL review team is to choose each parameter from a set of possible values, and the combination of the parameters determines the SIL of the SIF. The possible outcomes of a risk graph and their interpretation are presented in Table 4-1. The risk graphs need to be calibrated, i.e. the parameters, their possible values and how their combination determines the SIL must be established upfront.

Table 5-2 Demand Rate (W)

Demand Rate (W)	Description
W1	Low: Once every 10 - 100 years.
W2	Medium: Once every 1 - 10 years
W3	High: Once every year or more

Consequences (S)

DNV obtained a version of "People Severity" parameters (S) from the HAZID Risk Matrix related to People shown in Table 5-3. Any of the below shall be taken as possible contributors towards selecting the severity of the event, hence, it will be a workshop decision to justify said severity justification. Note that assessment of consequence shall be the impact without taking credit for any safeguard.

Table 5-3 People Severity (S)

Risk Parameter (Safety)		Severity Level	Description
Consequence (C)	SA	Negligible	First Aid Injury
	SB	Moderate	Recordable Injury
	SC	Significant	Serious Injury
	SD	Severe	Single Fatality
	SE	Catastrophic	Multiple Fatalities

Occupancy (F)

In the SIL classification study, the term "Occupancy" is defined as follows:

- Occupancy relates to the probability of one or more people being present in the affected area at the time of the incident.

For the parameter "occupancy", the set of possible values are shown in the following Table 5-4.

Table 5-4 Occupancy (F)

Occupancy	Description
FA	Rare to more frequent exposure in the hazardous zone. Occupancy less than 0.1
FB	Frequent to permanent exposure in the hazardous zone

It should be noted that if the hazard being analysed is related to an operation which requires personnel to be present in the affected area of the hazardous event to perform the operation, then FB shall be selected.

MFP is a manned facility. As such, the Occupancy factor of FB is proposed to be selected for all scenarios in order to be conservative.

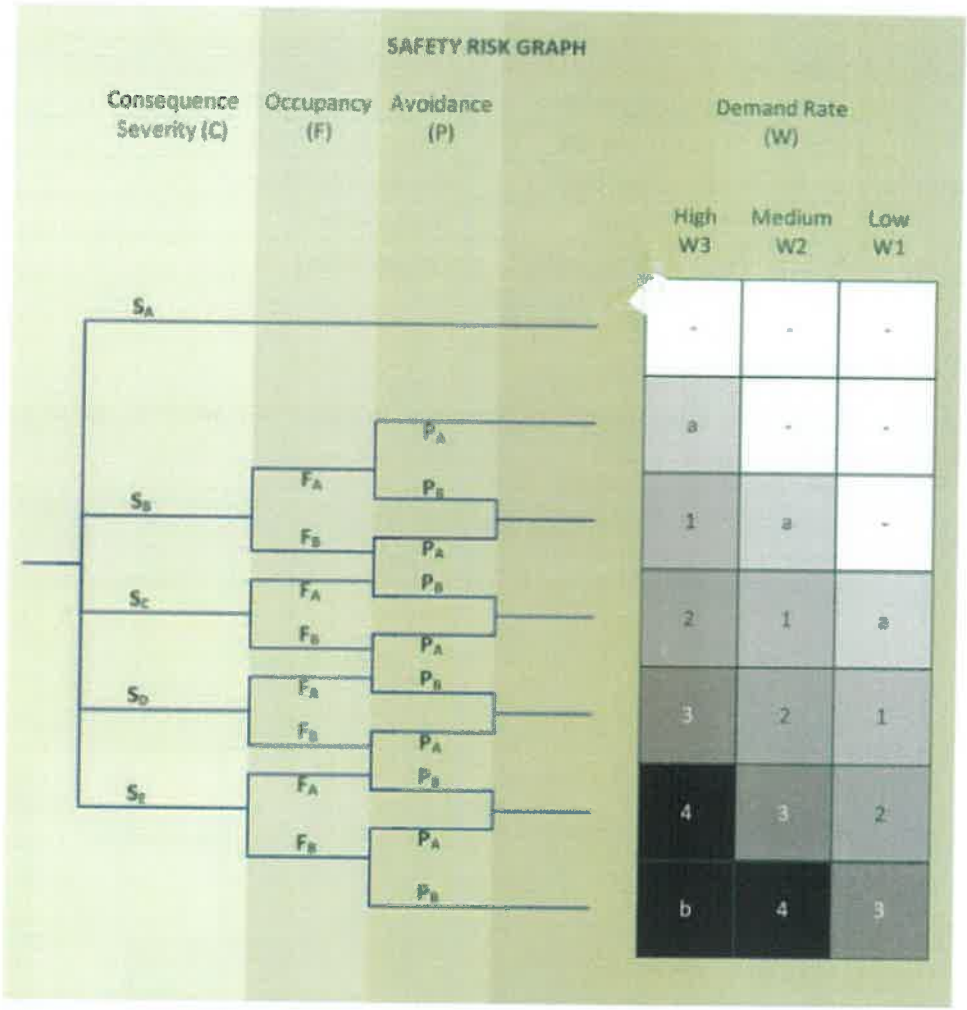

Figure: 5-1 Risk Graph for people

5.2.3 Environmental Risk

Parameters, W, P and F

The parameters W and P are the same as for people; please see Table 5-2 and Table 5-5 respectively. For environment, the parameter "Occupancy" (F) is not relevant, since the environment is continuously exposed.

Consequences

For the parameter "Environment" (E), the values are sourced from HAZID risk matrix, as shown in Table 5-6.

5.2.4 Asset Risk

Parameters, W, P and F

The parameters W and P are the same as for people; please see Table 5-2 and Table 5-5 respectively. For environment, the parameter "Occupancy" (F) is not relevant, since the environment is continuously exposed.

Consequences

For the parameter "Asset" (A), the values are sourced from HAZID risk matrix, as shown in Table 5-7.

Table 5-7 Asset Severity (A)

Risk Parameter (Asset)		Severity Level	Description
Consequence (C)	AA	Negligible	0 < $10,000
	AB	Moderate	$10,000 < $100,000
	AC	Significant	$100,000 < $1M
	AD	Severe	$1M <$10M
	AE	Catastrophic	$10M <==

Risk Graph for Asset

This leads to the following risk graph for risk to asset as presented in Figure 5-3 overleaf.

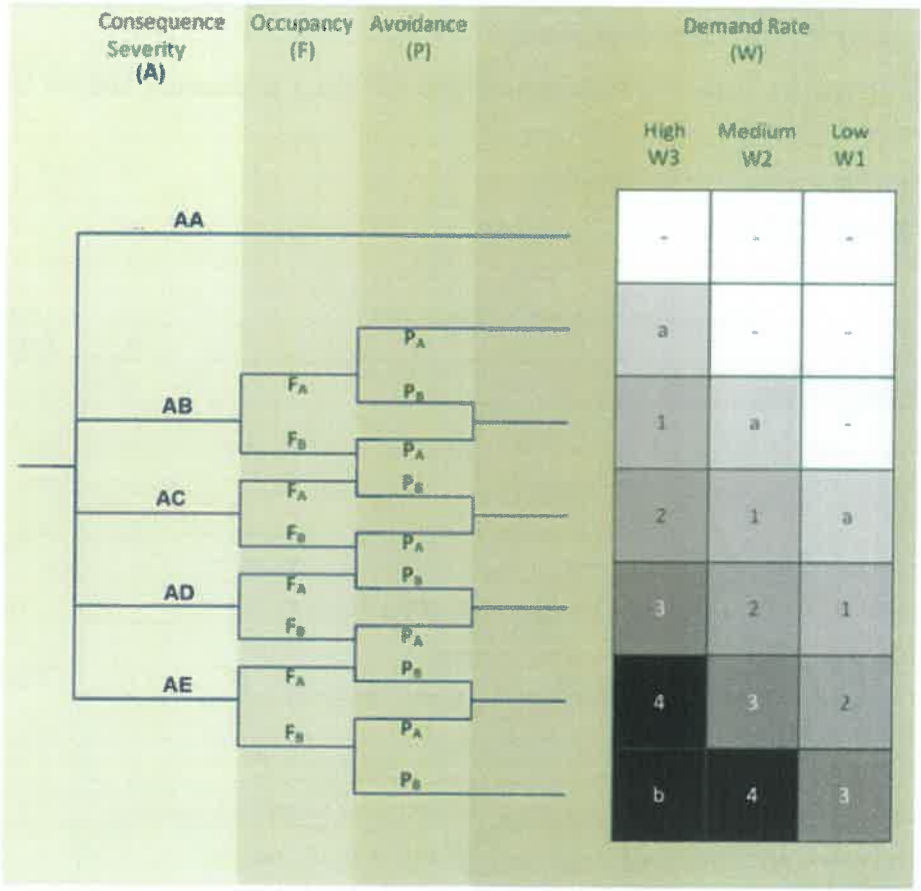

Figure: 5-3 Risk Graph for Asset

6 WORKSHOP ATTENDEES

The following list indicates the participants involved in the HAZID and HAZOP Workshop on the 18th May 2021 at Compass Energy Office, 12 Tuas Avenue 1, Singapore.

No.	Name	Position	Company	18th May 2021 (HAZID)
1.	Mahesh Lavand	Facilitator (HAZID HAZOP/SIL)	DNV	Full time
2.	Zainal Abdeen*	Facilitator (HAZID)	DNV	Full time
3.	Hans J. Hvide	Technical Director	LNGE	Full time
4.	Erik He	Project Engineer	LNGE	Full time
5.	Bing Han	Mechanical Engineer	LNGE	Full time
6.	Nandar Lin	Marine Manager	LNGE	Full time
7.	Fahad Hameed	General Manager (Pakistan)	LNGE	Full time
8.	Mohammad Sajid Muneer	Project Manager (Pakistan)	LNGE	Full time
9.	Masood Bhatty	Contracts (Pakistan)	LNGE	Full time
10.	He Yi Yong*	Commercial operations	LNGE	Full time

- Indicates presence for HAZID workshop held on 20th February May 2020

ID	Location/ Activity	Hazard/Guideword	Hazardous Event	Cause/ Threat	Residual Risk Ranking (with controls)		
					People (Health and Safety)	Environment	Property
		Ignition sources/Safety and Security Zones	Ignition of gas leakage/venting/fugitive emissions	Ignition source	3C	2C	2C
				Lightning	4B	2B	2B
		Inadvertent disconnection of flexible hoses	Inadvertent disconnection of flexible hoses	Adverse weather conditions	4B	1B	2B
Node 4: ISO Container Filling Operations							
Refer to HAZOP Worksheet							
Node 5: Arriving and departing ISO container trucks							
5.1	Parking of LNG containers	Loss of containment of LNG	LNG Spillage	Trucks back into another truck	1C	1C	1C
				Truck backs into the barrier and damage the tank	1C	1C	1C
5.2	Departing LNG truck	Loss of containment of LNG	LNG Spillage	Accidental impact with truck parked next to it	1C	1C	1C

7.2 HAZID Actions

The HAZID team identified the following items where either the current provision of preventive or mitigating measures are insufficient to manage the hazard, or that further assessments are required to prevent and mitigate the identified hazard. A total of 6 action items were recorded in the HAZID worksheets during the 20th February 2020 session and subsequently assigned to a responsible party.

Table 4-2 List of HAZID Actions

No.	ID	Actions	Responsible Party
1.	1.2	To confirm the supplier of tug lines	LNGE
2.	1.2	To install tyre fenders on the four corners of the barge	LNGE
3.	3.1	To confirm the shut-off pressure of LNGC cargo pump	LNGE
4.	5.1	To provide sufficient dry powder extinguisher/facility on the barge	LNGE
5.	5.1	Establish communication procedures/link between barge and LNGC	LNGE
6.	5.1	Employ signalmen at the Jetty for arriving and departing trucks. Construct barrier that does not impact on the LNG tank on the truck.	LNGE

7.3 HAZOP Actions

Recommendations were made in the HAZOP workshop by the team where there is a need for changes to be made to the existing design or where further safeguards are required to ensure that the risk is reduced A total of four recommendations were identified during the HAZOP workshop.

Table 4-3 List of HAZOP Actions

No	Recommendations	Place(s) Used	Responsibility
1.	Include the description and intent of NOTE 2 on the N2/LNG interface on the P&ID.	Causes: 1.3.1.2	LNGE
2.	Indicate manual valve V8 on the supply line to Gas Genset as Lock Closed (LC) as this will be used only during emergency scenario.	Causes: 1.6.1.1	LNGE
3.	Include low flow alarm on the flowmeter FM2	Causes: 1.1.1.1	LNGE
4.	Include high flow alarm on the flowmeter FM2	Causes: /1.2.1.1	LNGE

7.4 SIL/LOPA Actions

No actions have been raised for SIL/LOPA session. Based on the SIL classification workshop, only one SIF (TTLL-2) has been identified with SIL assigned as SIL 1 rating. The details of this SIF are provided below:

8 REFERENCES

/1/ DNV, HAZID, HAZOP and SIL Terms of Reference, PP205958-TOR, RevA

/2/ LNGE P&ID Diagram for MFP, P265-01-067-MD2001, Rev: A

/3/ International Electrotechnical Commission, IEC 61508 - Functional safety of electrical/electronic/programmable electronic safety-related systems, 2005.

/4/ International Electrotechnical Commission, IEC 61511 - Functional safety: Safety Instrumented Systems for the process industry sector, 2003.

/5/ ISO 17776:2000 Petroleum and natural gas industries — Offshore production installations — Guidelines on tools and techniques for hazard identification and risk assessment

/6/ IEC 61882:2016 Hazard and operability studies (HAZOP studies) - Application guide

ID N°	Location/ Activity	Hazard/Deviation	Hazardous Event	Cause / Threat	Prevention & Detection Barrier	Consequence	Control & Mitigation Barrier	Actions (Responsible Party) (Numbering as listed in separate sheet)	People (Health and Safety) Residual Risk Ranking (with controls)			Environment Residual Risk Ranking (with controls)			Property Residual Risk Ranking (with controls)			MAE (Y/N)	Comments / Reference
									S	L	R	S	L	R	S	L	R		
1	Movement & Unmooring of LNGC/ Barge																		
1.5	Tugs and other traffic	Loss of containment of LNG	Vessel in port collides with LNGC	Vessel operator looses control	Location of the operation is located at the end of a channel where only small boats (Berth 18/19) and smaller ships and barges at berth 23.	Breach of LNG Tanks and spillage into the channel.	Impose exclusion zone for the operation.	LNGE/Port operator	4	A	4A	2	A	2A	4	A	4A		
			Tug collides with LNGC	Tug operator looses control	Slow speed of tug always required, Tug has venders all around the hull of the tug		Impose slow speed on Tug operator	LNGE/Port operator	4	A	4A	2	A	2A	4	A	4A		
2	Connection and Disconnection																		
2.1	Disconnection of flexible hose for STS operations	Cryogenic Spill	Refer to "Inadvertent disconnection of flexible hoses" hazardous event.																
	Refer to Node#3 for STS Operations between LNGC and Barge.																		
3	STS Operations between LNGC and Barge																		
3.1	STS Operations	Loss of Containment LNG	Loss of Containment LNG	Overpressure due to closure of ESD valves on barge side				1. To confirm the shut-off pressure of LNGC cargo pump. (Shipload)											
				More flow from LNGC than required filling rate on the barge	-Recirculation on LNGC and liquid return line on the barge	No major consequences													
				Hose/Fitting leakage/ rupture	-Hose handling procedure -Certification of Flexible hose -Annual Pressure test of flexible hose -Drip trays on LNGC side -Cryogenic paint beneath the manifold on barge side -Cryogenic PPE for operators	-Fire & Explosion -Cold burns -Damage to deck due to brittle fracture	-ESD system -ERP -Dry powder Fire fighting extinguisher -Water curtain on LNGC		4	B	4B	2	B	2B	3	B	3B	Y	
		Ignition sources/Safety and Security Zones	Ignition of gas leakage/venting/fugitive emissions	Ignition source	-Safety zone (determined through QRA study) -Intrinsically safe instruments on LNGC side -Zone 2 classified area on barge side with ex-proof -Insulating flanges on LNGC side to prevent static build-up	-Fire & Explosion	-ESD system -ERP -Dry powder Fire fighting extinguisher		3	C	3C	2	C	2C	2	C	2C		
			Ignition of gas leakage/venting/fugitive emissions	Lightning	-Weather monitoring system -Stopping STS operations -Operator seek shelter on barge	-Fire & Explosion -Fatality	-ESD system -ERP -Dry powder Fire fighting extinguisher		4	B	4B	2	B	2B	2	B	2B		
		Inadvertent disconnection of flexible hoses	Inadvertent disconnection of flexible hoses	Adverse weather conditions	-SOP on weather limitations . -Weather forecasting -Scheduled operations -Operations in relatively calm waters (maximum wave height recorded between 2010 - 2014 is 1.12m) -ESD 2 (Dry breakaway coupling) -Stopping of STS operations during adverse weather conditions	-Fire & Explosion	-ESD system -ERP -Dry powder Fire fighting extinguisher		4	B	4B	1	B	1B	2	B	2B		
		Blackout	Blackout on barge	Loss of power generation on barge	-Standby portable diesel generator -2x100% gas generator	-No major consequences													
4	ISO Tank Filling Operations																		
	Refer to HAZOP Worksheet																		
5	Arriving and departing ISO container trucks																		
5.1	Parking LNG trucks	Loss of Containment of LNG	LNG Spillage	Trucks back into another truck	Containers are double walled	Container damage	Employ signal men at site to direct parking	LNGE operation manager at the port	1	C	1C	1	C	1C	1	C	1C	N	
				Trucks backs into the barrier and damage the tank	Barrier made so that the wheels catches the barrier. Barrier is not reaching the tanks	Container damage	Employ signal men at site to direct parking. Design barrier lower than bottom of LNG Tank	LNGE operation manager at the port	1	C	1C	1	C	1C	1	C	1C		
5.2	Departing LNG trucks	Loss of Containment of LNG	LNG Spillage	Accidental impact with truck parked next to it	Keep distance between trucks large enough	Container damage	Employ signal men at site to direct parking	LNGE operation manager at the port	1	C	1C	1	C	1C	1	C	1C		
5.3	Departing LNG trucks	Loss of Containment of LNG	LNG Spillage	Unintentional drive away of the LNG truck while loading is ongoing	Breakaway coupling	-LNG Spillage/leak - Hose and filling skid damage/rupture - Container damage - Fire & Explosion	- ESD System - ERP -Dry powder Fire fighting extinguisher - Port Firefighting Facilities	LNGE operation manager at the port	NA	NA	NA	2	A	2A	1	A	1A		
					Filling connection/dis-connection procedures														
					Trained and competent operators														

C = consequence
L = likelihood
R = Risk

Note: The hazard management strategy for each identified hazard must be recorded in such a way that the prevention barriers are clearly linked to the causes. Threats and the detection; control and mitigation barriers are clearly linked to the consequences.

HAZOP Study Worksheet

Node: 1. LNG Filling Manifold/vapour return and filling piping to ISO Trucks
Drawings / References: Design Conditions/Parameters: -162 degC / 10 barg

Deviations		Causes	Consequences	Effective Safeguards	Recommendations		Remarks
					Recommendations	Responsibility	
1.	No Flow/ Less Flow	1. On/off valves (V1/V107) on the filling line are inadvertently closed	1. Delay in filling operations	1. Local/remote position indicator on the valve			
			2. Potential overpressure of the upstream piping, fittings and hose due to surge pressure resulting into LOC leading to fire and explosion. Single fatality.	1. The upstream piping, fittings and hoses are rated for maximum upstream pressure (150#- ~20 barg on ship side).			
				2 V1/V3 are selected as slow closing valves to avoid the surge pressure			
				3 High pressure alarm (on ship side) and local Pressure transmitter on upstream of V1/V3.			
				4 Pressure relief valve on the upstream side of V1/V3			
		2. Manual valve V4 closed in error (during one bay filling only)	1. Delay in filling operations for one bay	1. Line-up procedure in place			
			2 Potential overpressure of the upstream piping, fittings and hose due to surge pressure resulting into LOC leading to fire and explosion. Single fatality.	1 The upstream piping, fittings are rated for maximum upstream pressure (150# with design pressure of 10 barg).			
				2 High pressure alarm (on ship side) and local Pressure transmitter on upstream of V1/V3.			
				3 Pressure relief valve on the upstream side of V4			
		3. Manual valve (V94) on the LNG buffer tank supply line closed in error during cooling down operation	Delay in cooling down operation -no major consequence				
		4 Manual valve V6 on the BOG return line is closed in error during filling operation	1. Pressure build-up inside ISO container	Manned filling operation (monitor the isocontainer pressure and level) - Filling Line up procedure			
			2. Potential delay in filling of one bay	Filling Line up procedure			
		5 On/off valve (V2) inadvertently fail closed on the BOG return line	1. Potential vapour build-up into the vapour return line . The maximum pressure build up is 8.0 bag (relief pressure).	1. Pressure monitoring on the BOG return line (PT14/15)			
			Potential delay in filling of one bay resulting into lower filling flowrate.	Filling Line up procedure			
		6 V8/PV1 on the supply line to Gas genset is closed in error when required	1. Loss of fuel gas supply leading to disruption in power generation from the gas generator - no major consequence as this gas genset is used as back-up supply. During normal operation, power supply will be from shore.	1. Standby Diesel generator			
2.	More Flow	1. Ramping up of flow from LNGC due to loss of control on ship side	1. Potential backpressure on the liquid manifold filling line- No major consequences identified	VHF communication between barge filling crew and LNGC control room operator to control the flow from main LNGC tank pump.			
				Flow monitoring on the liquid filling line			
3.	Reverse/Misdirected flow	1. Manual valve V36/V37 opened inadvertently during filling operation	1. Potential flow of nitrogen gas into the filling line resulting into back pressure into the liquid filling line. Also, nitrogen will go back into the LNGC through isocontainers and BOG return line. No major consequence as the nitrogen buffer tank volume is 2 m3.	1. The nitrogen piping, valves are SS304 which can handle the LNG cryogenic temperature (-160 deg C). 2. Check valves are provided at the N2/LNG interface.			
		2 LNG backflow into the nitrogen line	1 Potential contamination of the nitrogen	1 Check valves are provided at the N2/LNG interface.	1 Include the description and intent of NOTE 2 on the N2/LNG interface on the P&ID.		
4.	Low pressure	1. No major causes identified					

HAZOP Study Worksheet

Node: 1. LNG Filling Manifold/vapour return and filling piping to ISO Trucks
Drawings / References: Design Conditions/Parameters: -162 degC / 10 barg

Deviations		Causes	Consequences	Effective Safeguards	Recommendations		Remarks
					Recommendations	Responsibility	
15.	Start-up / Shutdown	1. No additional cause identified for this deviation					
16.	Instrumentation	1. No cause identified for this deviation					
17.	Material Selection	1. SS304 is selected for all cryogenic application, liquid and vapour line. For cryogenic valves, SS304/316 is selected. SS304 piping is selected for nitrogen supply lines and valves.					
18.	F&G / Fire Protection / Area Classification	1. Refer to HAZID report					

APPENDIX C
Marked-up P&IDs

APPENDIX D
SIL Classification/LOPA Worksheet

APPENDIX E
Risk Matrix

Risk Assessment Matrix					A	B	C	D	E
					Likelihood Description (Probability or Frequency)				
		Severity Description			Very Unlikely Never occurred in LNG industry	Unlikely Has occurred in industry but is rare	Possible Occurs in industry every year	Likely Occurs in industry every year	Very Likely Occurs in industry several times a year
		Harm to People	Harm to Environment	Harm to Property or Asset	10000 years / 10^{-4} / site	1000 years / 10^{-3} / site	100 years / 10^{-2} / site	10 years / 10^{-1} / site	1 year / site
1	Negligible	First Aid Injury or Occupational Illness (FAC)	No measurable effect on ecosystem No breach of legislation or licence Not reportable to regulator	Insignificant damage 0 < $10,000					
2	Moderate	Recordable Injury or Occupational Illness (RWC or MTC)	Minor, local effect on ecosystem Recoverable by site / vessel Breach of licence or legislation Reportable to Regulator	Minor damage $10,000 < $100,000					
3	Significant	Serious Injury or Occupational Illness (LTI/LWC)	Measurable effect on ecosystem Recovery may require external assistance Breach of legislation or licence which may result in fines, penalties or prosecution	Significant damage within local area $100,000 < $1M					
4	Severe	Single Fatality or Permanent Disability	Severe effect on ecosystem Recovery requires external assistance < 12 months Breach of legislation or licence resulting in fines, penalties or prosecution	Damage over several areas $1M < $10M					
5	Catastrophic	Multiple Fatalities or Permanent Disabilities	Chronic effect on ecosystem Recovery requires external assistance > 12 months Breach of legislation or licence resulting in prosecution	Extensive damage or loss of facility $10M < ∞					

Note For full definitions refer to COSWP (Code of Safe Working Practices)

FAC	First Aid Case
RWC	Restricted Worst Case
MTC	Medical Treatment Case
LTI	Lost Time Incident
LWC	Lost Workday Case

1A	1B	1C	1D	1E
2A	2B	2C	2D	2E
3A	3B	3C	3D	3E
4A	4B	4C	4D	4E
5A	5B	5C	5D	5E