2 DESCRIPTION OF PROJECT

2.1- Salient Features of Project

The project, while advancing to meet the challenges of present and future energy requirements, anticipated to supply re-gasified liquid natural gas (RLNG) by the end of first quarter of 2009. Initially 200 million standard cubic feet daily (mmscfd) would be supplied to the Sui Southern Gas Company (SSGC) existing system to power plants. Additional 200 mmscfd of re-gasified liquefied natural gas (RLNG) would be available from mid 2009. In terms of tonnage of LNG it would be 0.75 million tons per annum in 2007-08 and 3.28 million tons per annum in 2008-09. The supply so augmented will be available to SSGC grid for delivery to customers, including power production units, either for their own requirement or for onward transmission to the SNGPL system. The Project also envisages production of around 1,000 metric tones per day liquefied petroleum/propane gas (LPG) as a by-product of re-gasification of RLNG. The jetty required for the Project will serve the requirement of import of LNG and import/export of LPG.

Financing for the Project shall be through Long-term loans and Term Running Finance on a Debt-Equity Ratio of 75:25 with a 112% IRR.

The project involves permanently berthing of a LNG storage vessel at the port which will have a capacity to store about 3 billion cubic feet of gas. This quantity would be sufficient for 30 days if the demand is 100 million cubic feet per day and for 7 days if demand is 400 million cubic feet per day. The permanently docked storage vessel will be recharged through a conventional LNG tanker. The recharge will take place as per demand. This option has been chosen because it is the quickest and most cost effective to implement.

2.2- Project Justification

Project justification rests in the short development and delivery period. Whereas pipeline for import of gas from neighbouring countries or an on shore storage and re-gasification facility would require at least 6 years to build and operate incurring very high capital cost, besides increase in the cost of gas and its looming shortage, the LNG would be available to customers in a matter of months. Sui Southern Gas Company (SSGC) has large diameter 30 and 42-inch pipelines already operational in Port Qasim area and would not be difficult to connect. The location of PGPL project allows for equally easy connection to the west to meet the requirements of gas for power generation, major industries, commercial and residential customers. This pipeline can also be used to supply natural gas for coastal residential and commercial requirements.

The proponent's fast track cost effective project would augment natural gas supplies of Pakistan by 400 mmscfd i.e. by 10%. Given the urgent energy requirements of the country, this would a nationally important and landmark achievement.

Another contribution of the Project will be the supply of 1,000 metric tons of liquefied propane / petroleum gas (LPG) per day from re-gasification of RLNG. LPG too is in short supply in Pakistan, particularly in the Northern and rural areas. The production of LPG would commence as soon as the operations start with the installation of re-gasification and extraction facility i.e. in the second phase of the project. It is envisaged that the LPG would then be available for local consumption also as its demand is increasing day by day.

The project will also yield substantial revenues for PQA since its industrial area development will receive a boost with source of natural gas supply within its own boundary. It has been experienced that assured supply of natural gas at ports in other part of world has rapidly transformed them into hub of industrial activity.

Table 2.1: Salient Features of the LNG Project

GENERAL	
PROJECT	SETTING UP OF AN LNG TERMINAL AT PORT QASIM ON BOT BASIS
LOCATION	TWIN PIER JUST NORTH OF QUTUB POINT NEAR CONFLUENCE OF KADIRO & PHITTI CREEKS
CLIENT	PORT QASIM AUTHORITY
SPONSOR	ASSOCIATED GROUP/SPECIAL PURPOSE TERMINAL OPERATING COMPANY
EPC CONTRACTORS	To be selected
PROJECT LOCAL CONSULTANTS INTERNATIONAL CONSULTANT (DESIGN AND CONSTRUCTION SUPERVISION)	TECHNO-CONSULT INTERNATIONAL HALCROW INTERNATIONAL PARTNERSHIP
LNG TERMINAL FEATURES	
Max Vessel Dimension (LOA & Beam) Max Design Dredged Depth Alongside Vessel Displacement (GRT) LNG Vessel Capacity Unloading Arms	310 m LOA Beam = 50 m -18 m CD 120,000 Tonnes 70,000 m3 to 165,000 m^3 l 2 Nos. 16"LNG Liquid Uploading Arms l 1 No. 12" Vapour Return Arm l 1 up gas unloading Arm 35.5 m from CL
SHIPPING FEATURES	
LNG Supply Vessel Characteristics	Capacity = 138,000 m^3 165,000 m^3 Draughts = 12.32 m 12.32 m LOA = 271 m 271 m Beam = 43.2 m 50m
LNG Storage Vessel Characteristics	Capacity = 138,000 m^3 165,000 m^3 Draughts = 12.32 m 12.32 m LOA = 310 m 271 m Beam = 43.2 m 50m
LNG REGASIFICATION INFRASRUCTURE	
Gas Regasification Facility LNG Offloading Rate Natural Gas Production Rate Shore Delivering Line Approach Pipelines System Length Pipelines Systems (From Port to Land)	On FSRU 2 x 5000 m^3/hr 400 Phase 1 & 2 30 Inches 4.5 km 30" (Class 600 steel pipeline) 1 No. 12" 2 Nos.
Capital Dredging Requirements	
Total = Turning Circle Approach Channel Alongside Pocket & Passing Clearance	3,712, 078 m^3 389,000 m^3 12.5 m depth 842,078 m^3 12.5 m depth 2,481,000 m^3 = -15 m & -12 m CD

Table 2.1: Salient Features of the LNG Project

Navigability	
Pilot on Board	= Standard Procedure
Tug Requirement (Arrival)	= 3 Nos.
Tug Requirement (Departure)	= 2 Nos.
Bollard Pull	= 50.60 tons
Navaids	= Standard Protocol
Turning Circle	= 1.4 LOA
Shore Side Facility	
Area	50 Acres
Filling Requirements	= 224.632 cu.m
Built up Level	= + 4.5 CD
Utility Requirements	
Offshore Terminal	Water = From Muncipality pipeline Sewerage = Bowser Collection Telecom = Via Land line or Wireless Fire Fighting = Self-contained using seawater Power = standby Generation
Landside Facility	Sewerage = To nearest City Govt. Trunk Main Telecom = Through PTCL & Wireless Fire Fighting = Seawater Internal network

2.3- Objective of project

Government of Pakistan has decided to bridge the gap between supply and demand in energy through import of LNG from countries which have extensive gas reserves and have planned liquefaction plant for export of LNG. Government of Pakistan has therefore invited private entrepreneurs in energy sector to establish LNG receiving terminals.

- The objective of project is to import LNG and supply natural gas and LPG to industrial, commercial and residential costumers throughout Pakistan,
- To reduce the deficit and meet the increasing demand of natural gas, and
- To promote natural gas as cheaper and environment friendly fuel source natural gas to industrial and commercial customers throughout Pakistan.

2.4- Project location

The strategic location of the project will not only fulfil the local requirement of fuel procurement but also provide access and serviceability to several countries in the region that have no direct access to sea. The area around PQA is a major load centre for natural gas with current demand of between 400-600 mmscfd. Port Qasim Authority (PQA), Karachi ideally suits the siting of the project both because of its proximity to the consumers i.e. power plants, steel mills and fertiliser plants and availability of necessary transmission and delivery infrastructure.

The location of the terminal has been selected based on aerial and hydrographic surveys of the area as well as visits to the site, taking into account the bathymetry of the seabed, marine weather conditions, as well as onshore and near shore topography at the shore landing site.

Table 2.2: Impact Matrix for Site Selection of LNG Project

S.No.	Selection Criteria/ Description	KPT-OP 1	PQA-Engro Vopak	PQA-Progas	PQA-Qutub Point	PQA-FOTCO
1	Port Location/Infrastructure	Score: 1 = Negative (Unfavorable) Assessment 3 = Neutral Assessment 5 = Positive (Favorable) Assessment				
1.1	Harbour Location/Shelter Assessment	4	4	4	5	4
1.2	Traffic Assessment/Watery Usage/ Channel Restrictions	2	4	3	5	3
1.3	Maintenance/Capital Dredging Requirements	4	1	4	3	3
1.4	Vessel Traffic Control System	3	3	3	3	3
1.5	Navigation Charts and Publications	3	3	2	4	4
1.6	Port Authority/Vessel Support/Port Tariff/Fees	4	3	3	4	3
1.7	Pilotage/Tug Assessment	4	4	2	4	2
1.8	Operating Parameters/Restrictions	4	2	2	4	2
1.9	Safe Anchorage/OPL	3	3	3	3	3
1.10	Emergency/Incident Response	4	4	2	2	3
2	Berth Location Assessment					
2.1	Meteorological Assessment	3	3	3	3	3
2.2	Oceanographic Assessment	3	3	3	3	3
2.3	Bathyymetry	3	3	3	3	3
2.4	Harbor Maintenance	4	2	3	2	3
2.5	Aids to Navigation	5	3	3	3	3
2.6	Berth Compatibility/Interference Assessment	3	4	4	4	4
2.7	Mooring System Analysis/Assessment	3	3	3	3	3
2.8	Berth Utilization/Adjacent Berthing Impact Assessment	3	3	3	3	3
2.9	Berth/Watery Suitability for SIS Transhippment	2	4	2	4	2
2.10	Vessel Delay Impact Assessment	3	3	3	2	3
3	Health/Safety/Security/Environmental					
3.1	Safety Case Study/HAZID-HAZOP	5	4	3	4	4
3.2	Port Facility Security/ISPS Compliance	5	5	3	4	4
3.3	Proximity and Risk Assessment/ Population Centers	3	4	4	5	4
3.4	Shore Containment/Facility Casually Assessment	2	4	4	5	4
3.5	Vapor Plume Dispersion/Thermal Radiation Assessment	2	3	3	5	3
3.6	Vessel Surge/Interaction	3	4	2	3	2
3.7	Risk of Collision/Allision	2	4	3	5	3
3.8	Proximity of Stand-by Vessels	4	4	3	3	3
3.9	Terminal/Berth Operator Assessment	2	4	3	3	4
3.10	Emergency/Incident Response	3	4	3	2	3
3.11	Terminal Handbook	2	4	3	2	3
3.12	Environmental Assessment	4	4	4	4	4

Table 2.2: Impact Matrix for Site Selection of LNG Project

S.No.	Selection Criteria/ Description	KPT-OP 1	PQA-Engro Vopak	PQA-Progas	PQA-Qutub Point	PQA-FOTCO
4	Vessel Support					
4.1	Bunker Availability	3	3	3	3	3
4.2	Nitrogen Availability	3	3	3	3	3
4.3	Storing, Spare Parts, Victuals	4	4	3	4	3
4.4	Crew Change/Shore Leave	4	4	3	4	3
4.5	Local Medical/EMS Facility	4	4	3	4	3
4.6	Waste Management/MARPOL	3	3	3	3	3
4.7	Ballast Water/Stop Management	3	3	3	3	3
4.8	Local/Regional/National/International Transportation	3	3	3	3	3
4.9	Local M&R Facilities	4	4	3	4	3
5	Downstream/Interconnect					
5.1	Gas Offtake Capacity	1	4	4	4	4
5.2	Local Demand/Capacity	1	3	3	4	3
5.3	Interconnect Locations-Distance	1	4	3	4	4
5.4	Pipeline Routing	1	4	4	4	4
5.5	Pipeline Permitting Assessment	1	4	4	4	4
5.6	Time Requirement/Pipeline Construction	1	4	4	3	4
5.7	Pipeline Capex	1	5	4	3	4
5.8	Gas Quality Assessment/Processing Plant	3	3	3	3	3
6	Score/Overall Assessment	2.959	3.51	3,102	3.822	3.224

Another major factor in selecting is a green field location to adequately address the safety requirement of siting of LNG receiving terminal.

A number of sites were examined for their suitability for siting the LNG terminal and the preferred location has been proposed at a location just north of Qutub

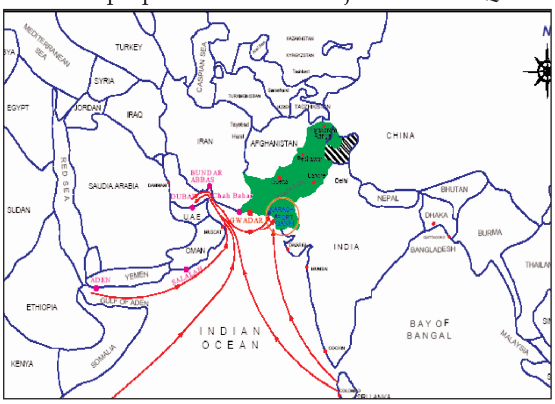

Figure-2.1: Project location in the region

Point in Kadiro Creek linking main Port Qasim navigation channel with Korangi Creek in Port Qasim waters. The proposed site for jetty has coordinates 24°47´25"N and 67°13´37"E whereas off-shore natural gas and LPG storage facility is planned at coordinates 24°48´51"N and 67°12´02"E approximately with elevation of 8ft AMSL.

2.5- Description of Alternatives

The following were the considerations made in regard to establish the criteria of selection of feasible alternatives for the project.

2.5.1- Technology alternatives

Project has advocated the procurement of environment friendly natural gas through import, in order to meet the primary and secondary demands of

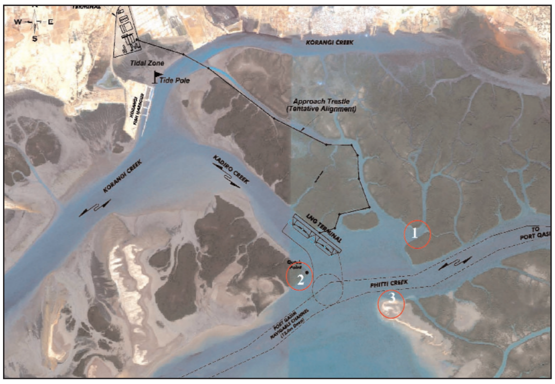

Figure-2.2: Satelline imagery showing proposed location of LNG Terminal and site alternatives

Figure-2.3: Mapping of LNG Terminal facility on the project location

energy sector. Alternatively, GOP is already importing high sulphur furnace oil and high speed diesel to meet the demands of power plants. The technology alternatives for extraction, storage, handling and transportation of natural gas are limited to the newer higher grade technology for converting the natural gas as mined into its liquefied form for safe, efficient storage and transportation.

Procurement of natural gas from the trans-

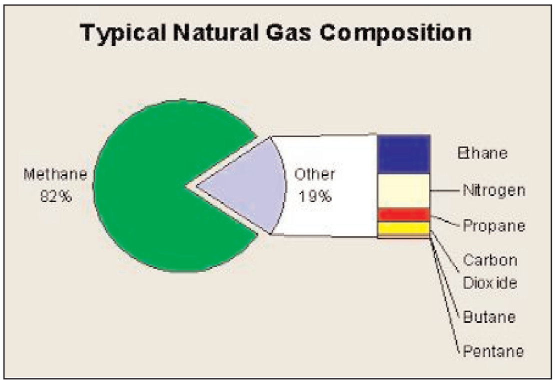

Figure-2.4: Typical composition of natural gas

boundary source through pipeline would pose a number of implications, such as; higher cost, safety issues and time period required materialising the project. There are number of extractable components from natural gas (Figure 2.4) of which propane gas (LPG) is proposed in the project to be extracted at the source as a commercial product which otherwise would not have been available in case of importing pure natural gas in gaseous form. Since the project also aims at extracting LPG from the imported LNG, the selected technology permits its extraction through re-gasification which is also cost effective. Secondly it will provide safety and involve lesser risk in associated operations for LNG over natural gas in its gaseous state.

Alternatives available within selected technology are shown as Figure 2.5.

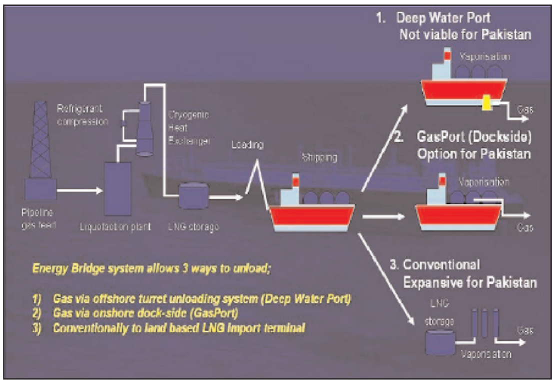

Figure-2.5: Schematic showing alternatives available within selected technology

2.5.2- Deep water port

This option requires the LNG to be imported through a vessel which would off-load its cargo at receiving vessel located in deep waters where vaporisation or re-gasification would take place and the gas would be supplied to shore through a long distance submerged pipeline. This option was not feasible as it was incurring high cost as well as advanced technology in laying of conduit, besides operation and maintenance.

2.5.3- Land based LNG terminal

The second option requires docking the LNG cargo vessel to a terminal located in port that would receive LNG and store it on-shore for subsequent re-gasification and supply of natural gas and allied components (LPG, etc.) to the industry. Developing an on-shore facility for LNG would have economic and technical implications, as special considerations would be required from safety and associated risks. Therefore, it is not a favourable option.

2.5.4- Dockside Option

The third option requires docking the LNG cargo vessel alongside either parallel or in line with a stationary receiving and storage vessel. In this case in-line configuration of docking of vessel was selected as the preferred alternative for the following reasons:

- It is technologically more efficient and safe.
- It is cost effective as it involves storage on a LNG carrier.
- The gas in its vapour state will be delivered through standard submerged conduit.

2.5.5- Location alternatives

The operations of LNG jetty include harbouring, berthing, unloading of cargo, storage and transmission of RLNG to off-shore installations. Reference to Figure 2.2 identifies a number of sites for the establishment of jetty and harbouring of storage and cargo vessels. The selected site has to offer least physical obstruction for coherent and sustained operations. Also the site should be secure and safe requiring least measures to minimise the risk involved. In order to demonstrate the suitability of the site for jetty / LNG terminal following points emerge for consideration:

- Site 1, 2 and 3 are situated very close to the main navigational channel, harbouring and jetting operation at the identified points will therefore hinder the navigational activities.
- The re-gasification will be carried on board FSRU and LPG extraction will be carried out at a onshore area.
- There are other jetties operational in the vicinity of the area (approximately 5½ km away from the existing jetty complex). Hence locating the LNG terminal in proximity to those terminals / jetties would affect the traffic flow and operational activities.
- The selected site is more secluded and considerably distant from the main navigational channel also providing good approach and manoeuvrability.
- The configuration and arrangement of berthing (storage and cargo) vessels is in concurrence with natural alignment of creek and the navigational channel.
- The proposed site considers minimal disturbance to ecosystem especially of the mangroves and other aquatic flora and fauna.

For locating the LPG on-shore terminal, three (3) sites A, B & C (Figure 2.7) were identified. Selection of the proposed site 'A' was made in view of environmental, technical and economic considerations. Hence the distance from the nearest jetty which is around 5-6 km and to the nearest habitat is 3-4 km is considered adequately safe.

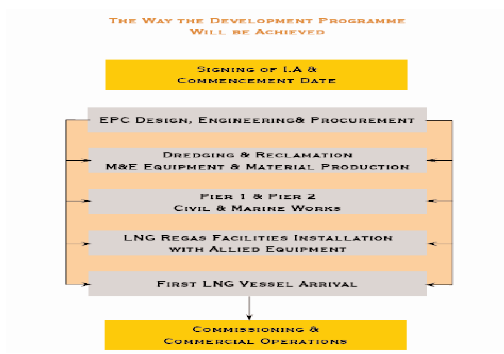

Figure-2.7: Project in brief

2.5.6- Fuel alternatives

The fuel alternatives comprise (i) continuation of import of crude oil and refining; (ii) import of petroleum products including high sulphur furnace oil (HSFO), gasoline, high speed diesel (HSD) oil, and LPG, and (iii) import of LNG. Inadequate refining capacity is a major constraint to alternative (i). Alternative (ii) suggesting import of petroleum products is, in view of their ever-increasing cost. LNG

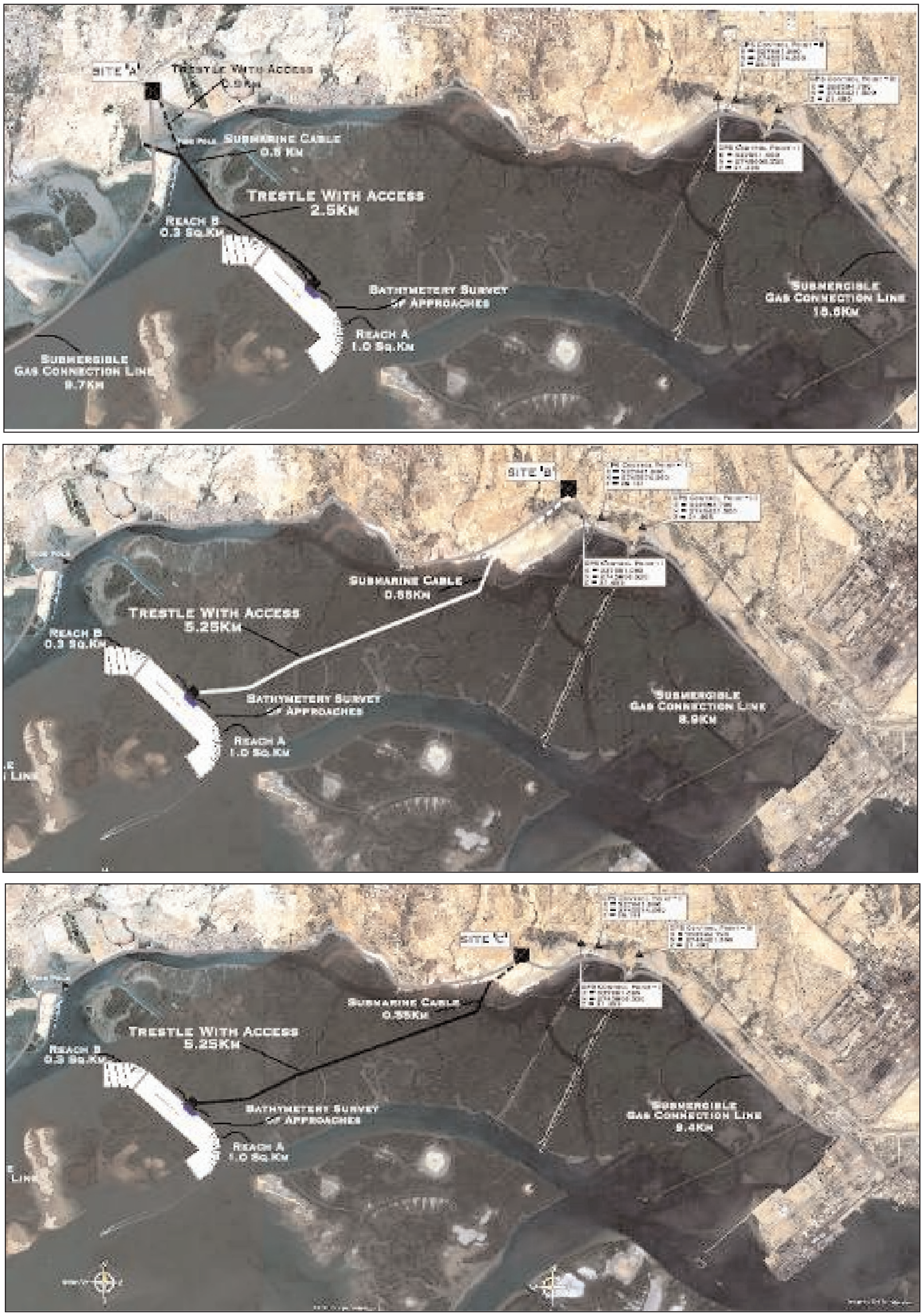

Figure-2.6: Location alternatives for siting LPG extraction terminal and transmission lines import is an economically viable alternative for Pakistan for two reasons (1) Rich LNG constitutes a number of extractable components other than methane depending upon the source. (2) LPG extracted from RLNG has ready market at local and national level. Hence RLNG provides the best alternative of fuel source through which multiple objectives can be achieved. Natural gas is considered the most eco-friendly fossil fuel. The use of HSFO and HSD as fuel for power generation on large scale is least desirable due to high contents of sulphur and consequent emissions of SO_x and NO_x. Thus the project brings environmental benefit on a macroscale in the region and to the entire country.

2.6- Magnitude of Project

The project, as stated earlier will at the outset augment the natural gas supply by 10% of the existing quantum. The project will have impact of considerable magnitude on the energy and fuel sector with an added feature of promoting environment friendly fuel. It will also increase the LPG supply. (Reference may be made to the data presented in Chapter-1, Background of the Project).

2.7- Project completion schedule

The LNG Project is an expeditious solution to put in place the infrastructure essential for the import and inland delivery of imported natural gas. In addition to augmenting the natural gas supplies of the country, the Project also involves the setting up, directly, a gas processing facility to extract LPG from the LNG thereby also augmenting Pakistan's LPG supplies.

2.8- Project components

The LNG import terminal is specifically designed to accommodate LNG cargo vessels and having re-gasification facility at the point of reception on FSRU. The product shall be transported to an offshore facility located four and a half kilometres via submerged pipeline lateral to shore installation. The other project facilities will include a jetty for the FSRU and cargo vessel with berth in double breasting position to FSRU, an RLNG receiving terminal containing measurement area, LPG extraction and storage tank / containment area and a RLNG gas send-out pipeline lateral. All project components are located within the asserted jurisdiction of Port Qasim Authority which include. The marine and land-based facilities have been designed for a project lifespan of approximately 40 years, with a provision of extension in serviceability.

The major components of the project can be summarised as:

- The marine terminal facilities, the infrastructure required for FSRU and LNG cargo vessel at the jetty terminal.
- The re-gasification process unit on a board FSRU; up to 400 mmscfd of natural gas (average daily throughput) to the national grid.
- LPG extraction and transport facility on land site.

2.8.1- Marine Structures

- Berthing facility for FSRU and LNG carrier vessel in double breasting position.
- A Platforms with RLNG unlaoding arm, a small crane for spares and other goods, a small standby diesel electric generator, RLNG pipe and a small craft docking area.

2.8.2- Pipelines

- 30" submerged natural gas pipeline

2.9- Processes & Operations

The project includes a FSRU berthing jetty where it will be permanently moored. Shuttle LNGCs will provide LNG to the FSRU vessel on ship to ship transfer basis.

2.9.1- Facilities platform

The facilities platform is a fixed platform structure that will include RLNG unlaoding

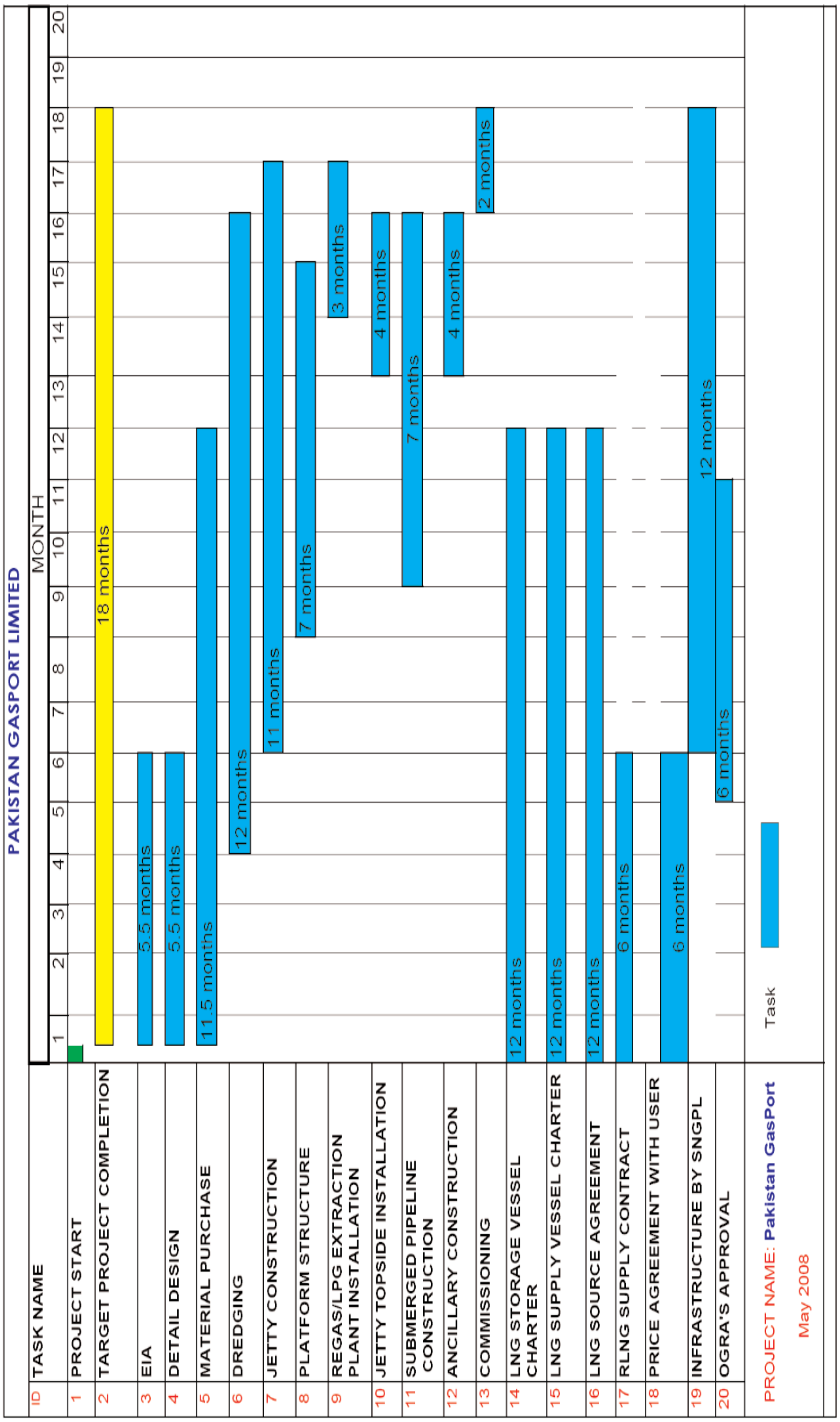

Figure-2.8: Project activity schedule

arms, a small crane for spares and other goods, a small standby diesel electric generator, RLNG pipe and a small craft docking area.

Power and utilities for the loading facilities will be supplied from the FSRU across bridges that will include piping systems to receive LNG from LNGCs. Vaporized LNG (natural gas) will be delivered onshore through a 30" sub-sea pipeline.

A- LNG and LPG facilities

The LNG re-gasification facility will be designed for an average gas send-out rate of 400 mmscfd. The facility will receive LNG from the vessel storage.The LPG extraction facility will be designed to extractLPG onshore storage facilities area.

B- Berthing and Unloading / Uploading Facilities

The Terminal jetty facilities built on an open pile structure with RLNG unloading. The LNGC will berth along side the FSRU and will transfer LNG via unloading arms located on FSRU.

Loading and unloading arms will be powered and controlled by hydraulic units, electric power and associated utilities for the loading platform will be provided by the FSRU.

The berthing facilities will include breasting dolphins, mooring dolphins, quick release capstans and any other necessary equipment for safe berthing operations. The berthing facility will be designed to accommodate LNGCs from 70,000m^3 to 165,000m^3 with a maximum 310m LOA, 50m Beam and 12.3m Depth.

2.9.2- LNG Carriers

LNG Carriers will be scheduled to deliver regular supplies of LNG to the FSRU permanently moored to the berthing facility and continuously producing RLNG. Each LNGC storage capacity and RLNG production rate will determine the number of LNGCs required and loading schedule needed to insure continuous availability of LNG to the FSRU. The safety of design and operation of LNG vessels has been dealt separately in the text to follow.

2.9.3- Pipelines

A 30" pipeline will be installed from platform to on-shore to transfer RLNG to the Pakistan natural gas pipeline system.

2.9.4- Dredging

Approach channel and basin will be dredged to [-12.0m] CD with the vessel berth pockets at -15.0m CD. The dredging will include about 200m jetty safety distance, about 450m diameter turning circle, and about 800m approach linking the main navigable channel with Korangi Creek.

2.9.5- Functionality of the facility

The primary design requirement for the project is to deliver vaporized imported LNG to the local natural gas pipeline grid. Sufficient flexibility will be required to accommodate imported LNG supplied from a variety of supply sources, having LNG specific gravities from 0.425 to 0.478.

2.9.6- Supply Feed Conditions

LNG will be delivered to the terminal facility via conventional LNGCs. LNG will be offloaded at a minimum pressure of 11 barg (160 psig) min and a temperature of approximately -162°C (-260°F). The LNG composition depends primarily on its source, but the facility will be designed to vaporize a range of LNG compositions. The range of compositions the facility will process is defined by the compositions as it receives from different sources. Some of the identified sources providing basis for the design are listed in Table 2.4.

2.10- Available Utilities and Services

Utility systems for PGPL offshore facilities will include the following:

Table 2.3: Specifications of LNG carriers as used for the design of Terminal

Type	LOA (m)	LBP (m)	Beam (m)	Draught (m)	Dwt	CubicCap
5,000 m³ LPG	99.00	92.90	18.80	5.05	3,800	5,018
5,000 m³ LPG	105.00	98.00	19.82	6.01	5,586	5,022
8,000 m³ LPG	119.00	112.00	18.80	6.76	7,155	7,541
8,000 m³ LPG	119.97	115.00	19.00	6.80	8,064	8,300

Containment System (Membrane or Spherical) (m)	Cargo Capacity (m³)	LOA (m)	LBP (m)	Beam @Midships Moulded Depth @ Midships (m)	Moulded Depth @ Midships (m)	Loaded Draft (m)	Ballast Draft (m)	Bow to Forward Perp. (FP) (m)	Distance FP to Vapor Manifold (m)
LNG Membrane	70,000	243.3	230.0	34.00	21.00	9.5 to 10.35	8.00	5.4 to 8.5	108.6 to 116.45
LNG Spherical	125,000	281 to 285.3	268 to 273	44.3 to 47.3	25.00	11.50	9.4 to 10.5	5.7 to 8.4	103.6 to 117.0
LNG Membrane	165,000	283 to 299.5	273.0 to 286.0	43.4 to 46.0	26.00	11.50		5.50	137.50
LNG Spherical	165,000	283 to 295	286.0 to 295	48.7 to 50.9	27.8 to 28.3	12.00			

Table 2.4: LNG Composition and Range

Component	Lean LNG Composition Mole %	Heavy LNG Composition Mole %
Methane	96.07	86.52
Ethane	2.75	8.31
Propane	0.77	3.32
Iso-Butane	0.21	0.85
N-Butane	0.18	0.85
Iso-Pentane	0.01	0.06
N-Pentane	0.00	0.00
Hexane +	0.00	0.00
Nitrogen	0.01	0.09
Total	100.00	100.00
Higher Heating Value (BTU/SCF)	1051	1162

- Electrical power generated on board FSRU by steam turbine.
- Firewater supplied to Platform by a seawater pumping system;
- No shore based Personnel housing is required.
- No workshop and repair facilities provided on the Platform;
- Nitrogen produced on board FSRU.
- Slop oil will be stored on board FSRU.
- No waste material will be discharged / dispose off into the sea.

2.11- Process description

PGPL facilities will be constructed from newly purchased equipment. The facility will contain the following systems.

2.11.1- LNG / LPG Process

LNG will be received from the LNGC at a pressure of approximately 11 barg (160 psig) and -162°C (-260°F) via Loading Arms into a Receiving Manifold. From the Receiving Manifold, the LNG flows to the storage tanks. The LNG is pressurized to approximately 60 barg (882 psig) in the HP LNG pumps and is sent to the re-gas plant and transmitted to shore through a pipe line. The LPG will be extracted if required on the on shore area in a cryogenic plant with over 95% propane recovery. The Natural Gas (vaporized LNG) is conditioned to meet the gas quality requirements of RLNG which is then subsequently discharged to the gas sendout pipeline for distribution to the users. The LPG products are stored in storage tanks.

2.11.2- Onshore Storage Facility

The onshore facilities are planned on a trapezoidal plot of land measuring about 16 hectares. The layout of facilities is shown in Fig. 2.5. The spheres shall be located a safe distance from the buildings and loading areas. Plant exits shall be located such that personnel can evacuate the plant without travelling through the sphere area. A complete firewater system and fire extinguishers will be provided in accordance with NFPA. Monitors will be strategically located throughout the facility for use in an emergency. Six LPG storage spheres of 1500 T capacity each will be installed on the Eastern side of the plot. These tanks will be placed on a reinforced concrete platform, about 600 mm deep. These tanks are especially designed to withstand high pressure and will be cooled by a water sprinkling system. The LPG filling and cylinder storage area is located in the northern part of the plot and will contain LPG bullet cylinder, filling pump, cylinder filling skids, cylinder storage area and the loading bay for the trucks. Adjacent to this bay, the LPG loading pumps will be located. The firewater pumps will be located on the Western side of the plot. The emergency power generator and air compressor with diesel storage will be located in the northwest.

The office and control room with its parking area are located on the northern side of the plot adjacent to main entrance and security building. Truck loading and unloading bay is located in front of the main entrance, for easy maneuverability and quick processing of the trucks. In future, storage capacity will be expanded and two refrigerated tanks of 20,000 T and 30,000 T. capacity will be provided along with a refrigeration unit. The space for these facilities is allocated in the center of the plot, about 70 meters away from the phase-I storage spheres.

A gas detection system will be installed in the storage depot, e.g. at the tank man-ways, at the LPG outlet pipes, and the pump hoses etc. In the event of any LPG leakage, the detector leads will sense the leakage and set off an initial alarm. The audiovisual alarm showing the location of the leakage will also be provided in the central control room.

2.11.3- LPG Storage Tanks

The six spheres will be grouped and located in a containment enclosure at safe distance from the buildings and LPG loading area. The interior of the tank compound will be lined with an impermeable liner or geosynthetic material as recommended by designer. A storage sphere will be of 18440 mm internal diameter with capacity of 1,500 T, and will be designed for 1725 kPaa at 66ºC. Each sphere will be connected to LPG liquid delivery line from the terminal and the LPG vapour return line. The LPG supply line from the spheres, through the loading pump, will be connected to truck loading (bulk transport) facility and to the LPG Bullet (tank).

The top of each sphere will be provided with ball valves along with pressure relief devices which will automatically provide vapour releases to the atmosphere whenever pressure inside the tank exceed the design pressure of 1435 kPasg at 38ºC. The outlet from pressure relief valve to atmosphere is protected by cold water cape. The vapour collection system pipelines and the liquid LPG inlet and supply lines will be provided with internal access flow valves. Each sphere will be provided with instrumentation to indicate and record pressure, temperature and rotor LPG level gauge along with a level and temperature transmitter. A water sprinkler system will cool the storage spheres a soon as the ambient temperature rises to 40 ºC or above. Each LPG tank will be provided with a level gauge with local read out adjacent to the tanks and also remote readout in the Central Control Room. During normal operation the tanks will not be drawn down below 8-10% of their capacity. One of the level gauges will be fitted with a low alarm system which will activate audio visual alarm in the Central Control Room when level reaches 8-10%. The tanks will not be filled above 85% of the capacity. One of the level

Table 2.5: Design Considerations

Description	Data
LNGSUV Unloading Rate to LNGSTV	2 x5,000 m^3 per hour
Maximum LNGSTV Capacity	165,000 m^3
Maximum LNGSUV Capacity	165,000 m^3
Maximum Distance from Facility to Shore	4.5 km
Facility to Shore Gas Pipeline Nominal Diameter	30"
Gas send-out Rate, Minimum	Approx. 55 MMscfd
Gas send-out Rate, Maximum	750 MMscfd
Terminal Send-out Capacity (Average)	400 MMscfd
Processing Platform Gas send-out Pressure, Maximum	55 barg (809 psig)
Processing Platform Gas send-out Pressure, Minimum	27.6 barg (400 psig)
Natural Gas send-out Temperature, Minimum	59 ^oF
Minimum LPG Recovery Level	95 +%
Designed Propane Recovery	95 +%
Designed Butane Recovery	100 +%
Designed Pentane + Recovery	100 +%
Seismic Zone	2B
Maximum Wind Speed/Gust	50m/s
On Site Utility Power	Self generated
Electrical Voltage to be Generated	Set at 3300 or 11,800 volts
Electrical Frequency to be Generated	60 hz
Fire Safety System	Seawater to fire water system

gauges fitted with high level alarm system which at 85% level will activate an audio alarm locally and also an audio visual alarm in the Central Control Room. Besides, if the level reaches 88% then through the logic control panel the automatic shutdown valves on the combined feed/bypass line to the tank will be automatically closed.

2.11.4- Vent System

The handling, storage and un-loading facilities of the terminal are designed to have a closed vapour collection system. The LPG vapour collection pipelines run parallel to LPG delivery / supply lines to the tanks and facilities. The vapours will be collected from the truck loading and cylinder filling facilities and will be delivered to the storage tanks. During the unloading of liquid LPG from the vessel, the vapours will be collected also from the delivery line and the storage spheres and will return to the vessel delivering the liquid LPG at the unloading berth.

Any LPG vapour released to the atmosphere through pressure relief valves provided on the bottling and storage spheres would not create any environmental or fire hazard as the quantity and frequency would be negligible. In future, when on expansion of the storage capacity higher volumes will be handled, a flare system may be provided to bum the vapours as a means of disposal to atmosphere. World Bank Environmental Guidelines for atmospheric emission of $S0_2$ and NO_x from stationary combustion sources will be followed. Limits given in the guidelines are as follows:

SO_2: Maximum allowable increase in ground level concentration = 50 ug/m^3 (one year average);

NOx: 86 X 10^{-9} g/Joule heat input (fuel gas), 130 x 10^{-9} g/Joule heat input (when liquid fuelled);

Dust: When background levels of dust are high, dust emissions from the stack should not be greater than 100 mg/m^3.

2.11.5- Water Sprinkler System

The LPG storage area will be provided with automatic water sprinkling system to cool the LPG storage tanks in case tank temperature exceed 42ºC, to keep the pressure inside the tanks below 1725 kPag. The water generated by sprinklers over the tanks will be collected and re-circulated by cooling system. It is expected that 20% make up water will be required.

2.11.6- LPG Truck & Bottle Loading

There is no present consideration for bottling of LPG at the storage terminal, however bulk transport of LPG is proposed. Truck loading facilities will be built in such a way that three trucks could be loaded simultaneously. Each truck should be able to fill in 20 minutes. Each truck loading skid will be quipped with a loading hose or fully balanced loading arm for bottom loading on trucks. Automatic disconnection without spillage, should the truck drive away, will also be designed into the system. Each skid will also be equipped with either a turbine meter with densitometers or Coriolis Mass Flow Meter. The meter outputs will control the loading of the trucks and record and print out a delivery report. This system can be fully automated with a security system to allow the truck operators to load the truck without assistance from the terminal operators. This could significantly reduce manpower requirements at the terminal. The LPG from storage spheres will be loaded into pressurized tanks by a loading pump of capacity of 280 cubic meters per hour. This capacity of the pump is adequate to provide for simultaneous operation of three truck loading skids and four bottling connections.

The LPG for bottling will be delivered through a strainer and after injection of an odorant compound, will be stored in LPG bullet tank of 1245 mm internal diameter, 5665 mm long, designed for a pressure of 1725 kPa(g). The bottle loading pumps with rated capacity of 10 m^3 per hour will draw LPG from the bullet tank and deliver to four skids equipped with flexible hose and bottle connection coupling. Each filling station will be provided with a weighing scale.

The LPG for truck loading will also be injected with odorant compound. The connection to the truck will be provided through flexible pipe quick coupling with provision of emergency breakaway wall, so as to disconnect supply should the truck move away during the loading operation. During loading operation each truck will also be connected to LPG vapour return line. The LPG loading in trucks will be rated at 70 m^3 per hour and the weighbridges will be used for custody transfer of trucks. The loading of trucks and bottling system will also be designed for zero spill tolerance with containment provisions at site. During truck loading, vapour emission would be from venting the truck loading fittings. Also when filling there would be small release of LPG vapour when disconnecting the filling collector, the fugitive emissions of LPG during loading operations will then be insignificant.

2.11.7- Odorant Injection Package

The LPG is colourless and odourless. Regulatory codes dictate that LPG be odorized such that the gas is detectable by a distinct odour. Addition of odorant facilitates detection of leaks by humans prior to it being hazardous. An odorant injection package has been provided in the LPG supply pipeline to truck loading plant. The package would inject ethyl mercaptan at a recommended concentration of 1-2 lbs per 10,000 gallons of liquid LPG.

2.11.8- Fire Water System

The fire system will be completely self contained package in accordance with the requirement of NFPA. This system will comprise of two diesel pumps with electrical jockey pumps to continuously charge the system. The fire water loop will be installed underground and fire water monitors, hoses and fire extinguisher will be strategically located through out the facility.

The fire system will cover ships, tankers, unloading area, pressurized LPG storage spheres, refrigerated LPG storage tanks, truck loading area and LPG bottling plant. Fire water for the terminal will be drawn from the sea or untreated saline ground water will be used. The fire water for the on-shore LPG storage area will be obtained from the PQA water supply system. An underground water storage tank will be provided in the storage area with the capacity equivalent to fire fighting requirement for four hours. Fire system will comprise of underground water tank, primary tanks, fire water pump, jockey pump, valves, reducers, hydrants & monitors, etc.

2.11.9- Fresh Water Supply

Fresh potable water for daily consumption and use by the working staff will be provided through portable bottles that will be brought to the operation side through tankers / bowzers / etc.

2.11.10- Surface Drainage

The surface water from the storage facility will be collected from the internal roads, utility area and storage area and discharged into the Korangi creek through PQA's storm water drain system.

2.11.11- Sewerage System

The sanitary sewage from the offices, control cabins and guard houses will be collected in a septic tank. The sludge from the tank will be periodically removed through the local authority sludge remover truck. The water effluent from the septic tank will be discharged into a soak pit or the port drainage / sewerage system.

2.11.12- Compressed Air

For the instruments, compressed air is planned to be generated by compressors located under a shelter. The compressed air will be distributed to the terminal, jetty and truck loading area. The compressed air will be supplied at following rating.

- Design Pressure: 1035 kPag (150 psig)
- Available Pressure: 550 kPag (80 psig)
- Water Dewpoint: -45ºC (-49ºF)
- 2 x 1OO% compressors, minimum

2.12- Process Support Systems

2.12.1- Pressure Control Station

During steady-state operation it is expected that the pipeline pressure will be high enough that the re-gasification facility will operate satisfactorily while "riding" the pipeline pressure. At pressures below approximately 700 psig it will be necessary to hold a back-pressure on the facility in order to ensure that the LNG does not vaporize prematurely and affect the operation of the LNG Vaporizer.

2.12.2- Export Gas Heating

During times of low pipeline pressure, the temperature drop which occurs across the Pressure Regulating Station will result in export gas temperatures lower than the minimum design export temperature of 0ºC (32ºF). To meet this eventuality, export gas heating utilizing the heated propylene glycol/water mixture will raise the export gas temperature sufficiently to mitigate the concern.

2.12.3- Metering Station

A gas metering station is included in order to measure the gas exported to the pipeline at the custody transfer point. It is envisaged that the gas meters will be installed according to the specifications of American Gas Association for measurement. Lease Automatic Custody Transfer (LACT) will be included on the facilities platform to measure LPG.

2.12.4- Vapour Compressor

During cool-down, start-up, and similar off-design operations, small amounts of vaporized LNG will need to be processed. The base case design includes a vapour recovery compressor to pressurize the vapours to the gas pipeline pressure. A Vent Stack also included for handling the small amounts of vapours not captured by the vapour compressor.

2.13- Utility Systems

2.13.1- Instrument Air

An instrument air system will be required which will consist of two air compressors (100% standby), an air dryer, and an air receiver. The system will be large enough to provide moderate amounts of maintenance air, but it is expected that operations requiring large amounts of compressed air will be supported by portable air compressors. For Phase 1, compressed air will be supplied from land based sources.

2.13.2- Nitrogen

Nitrogen will be required to purge and inert facility to prepare for maintenance or start-up lengthy shutdown. For Phase 1, nitrogen will be supplied from land.

2.14- Electrical Systems

2.14.1- Power Generation

The power generation system on board FSRU will consist of boilers for steam turbine power units with full load redundancy. It will have capacity to provide power to jetty lighting and other loads.

2.14.2- Switchgear/MCC

The LNG re-gasification / LPG extraction facility will include switchgear, transformers motor control centres and cabling to receive the power from the generator sets and distribute it throughout the facility. The electrical equipment will be housed in a climate controlled building.

2.14.3- Lighting

The facility will include sufficient lighting to allow for night-time operation.

2.14.4- Emergency Power

There will be two (diesel engine coupled) 100% generators therefore an emergency power source will not be required as each generator is capable of supplying the full facility electrical demand.

2.14.5- Process Control

Control valves and actuated block valves will be operated by instrument air, with electronic instrumentation providing the control signals. The electronic control system will be housed in the climate-controlled power and control building.

2.15- Disposal of dredged waste and land reclamation

Cofferdam is to be constructed to hold dredged materials. Total length of the cofferdam shall be 3445m. The structure of cofferdam adopts sack-sand. Surface of the cofferdam shall have two layers of non-woven geo-textile and up layer a mix sack filter. Bottom layer will comprise 700mm thick stones with weight range from 50 to 100kg. It is estimated that around 3.8 million cubic meters of dredged material will be deposited and reclaimed as land. The disposal site for the dredged material would be along the shoreline in tidal waters at the designated area in proximity to the LPG onshore terminal.

2.16- Summary of Project components

Berthing facility will be constructed within the Port Qasim Area; with a 450m diameter turning circle, 200m jetty safety distance, and 200m approach linking the main navigable channel with Korangi creek.

The Project parameters include:

2.16.1- Main Jetty

- Open Pile jetty structure, breasting jetty head fitted with High pressure gas unloading arms, berthing dolphin and 2+2 mooring dolphins on either side.
- Quick release capstans, Heavy duty Fenders, Fire fighting equipment, Electric generators etc.

2.16.2- Pipelines system

- About 4.5 km long, pipelines system to transmit re-gasified natural gas shall be constructed.

2.16.3- Shore buildings / structures at jetty services area

- Jetty platform will accomodate RLNG piping
- Platform will have a fixed crane and a standby diesel generator
- Platform will have facility for landing small cargo and passengaer boats.

2.16.4- Shore-side / land installations

- LPG extraction and storage terminal: tanks, bottling and other related structures.
- Pipeline: 30" diameter gas pipeline serving the Korangi and Bin Qasim Power Stations laid along coast as submerged.

2.16.5- Design parameters

- LNG carriers from 70,000cbm up through 165,000cbm shall be accommodated at the piers, (310m LOA, 50m Beam and 12.3m depth).
- One LNG FSRU will be permanently moored and will also be utilized as storage vessel. The other LNG carrier (cargo vessel) will shuttle to bring regular supply.
- All RLNG pipelines will be either underground and in channel below sea bed.

2.16.6- Dredging requirements

- Approach channel and basin will be dredged to -12.5m CD with berth pocket at -15 m CD. On completion of deepening and widening of Port Qasim Navigational Channel, the approach channel and basin can be dredged further to allow larger vessels to achieve economy of scale.

2.17- Risk Mitigation

2.17.1- Overview

An LNG terminal is considered hazardous. Events that constitute risks to the LNG terminal under the Project are (i) the collision of LNG tankers with other ships, or LNG tankers running aground; (ii) an LNG leak during unloading; (iii) an LNG leak from safety valves; (iv) major earthquakes; and (v) terrorist activity & sabotage. The likelihood of these events must be minimized through strict application of rigorous standards in the design and operations of the terminal. If these events occur, their adverse consequences must be minimized through proper site of the facilities, and by institutionalizing a standard emergency response plan (ERP) and a disaster management plan (DMP). The Project will adopt these risk-management measures. A Quantitative Risk Assessment (QRA) is required and will be developed to internationally recognized standards. The initial Hazard Identification (HAZID) workshop was held in June, 2011 involving the design team for the project and PQA. This assessment will be followed by a full QRA study in the final design phase of the project, scheduled for completion by July, 2012. An initial assessment of the destructive impacts of a catastrophic loss of LNG shows no settlements would be affected. Based on a model of destructive blast zones developed by Sandia Labs, accepted as the standard for the industry, the nearest settlements are well outside of the potential impact zone and, based on a preliminary evaluation, would not be affected by a catastrophic loss of LNG from the FSRU (see discussion at Section 2.18).

2.17.2. Element of Safety in the Design of Project Facilities

The technology and design standards for LNG terminal facilities are well established.

Storage and Carrier Vessel design and construction

The typical ship size associated with the proposed LNG terminal would be between 125,000 and 165,000 cubic meters. LNG vessels of this size would typically have a total length of between 950-1000ft, a beam with of about 150ft and a loaded draft of about 40 feet.

The ships that transport LNG are specially designed and constructed to carry LNG cargo to long distances. LNG ships construction is highly regulated and consists of a combination of conventional ship design and equipment, with specialized materials and system designed to safely contain liquids stored at temperatures of -260ºF.

2.17.3- Profile

LNG ships have distinctive appearance compared to other transport ships. An LNG ship has a high freeboard (i.e. that portion of the ship above water) in comparison with other vessels because of comparatively low density of the cargo. Because of the high freeboard, wind velocity can adversely affect the manoeuvrability of the ship, particularly at slow speed, such as during docking.

2.17.4- Hull System

The International Maritime Organisation's (IMO) code for the Construction and Equipment of Ships Carrying Liquified Gas in Bulk (Gas Tanker Code) requires that LNG ships could withstand flooding of nay two adjacent compartments without an adverse effect upon the stability of the ship. The cargo tanks must be a minimum of 30 inches from the outer hull and minimum distance above the bottom of the ship equal to the beam of the ship divided by 15, or 6.5ft, whichever is less. This distance is intended to prevent damage to the cargo tanks in case of low-energy-type accidents that might occur in harbours and during docking. Most large LNG ships have a distance of 10-15ft between the outer hull and the cargo tank.

2.17.5- Containment System

The LNG containment system on an LNG ship consists principally of the cargo tank (sometimes also called as 'primary barrier'), the secondary barrier and insulation. The containment system also includes cargo monitoring and control and safety systems.

Three basic tank designs have been developed for LNG cargo containment:

- Prismatic free-standing,
- Spherical, and
- Membrane

The earliest form of LNG containment is the prismatic free-standing tank. It consists of an aluminium alloy or 9 percent nickel-steel, self supporting tank that is supported and restrained by the hull structure. Insulation consists of reinforced polyurethane foam on the bottom and the sides, with fibreglass on the top.

The spherical tank design consists of an unstiffened, spherical, aluminium alloy tank that is supported at its equator by a vertical cylindrical skirt, with the bottom of the skirt integrally welded to the ship's structure. This free standing tank is insulated with multi-layer close-cell polyurethane panels.

In the membrane containment system, the ship's hull constitutes the outer tank wall, with an inner tank membrane separated by insulation. Two forms of membrane are commonly used: the Technigaz membrane using stainless steel and Gas-transport membrane using invar.

LNG tankers are of double-hull design regardless of the containment system used. A double bottom and double sides re provided for the full length of the cargo area and arranged as ballast tanks, independent of the cargo containment in the event of grounding and collisions. Further, the segregated ballast tanks prevent ballast water from mixing with any residue in the cargo tanks.

Generally, multiple layers of protection create four critical safety conditions, all of which are integrated with a combination of *industry standards and regulatory compliance*, as shown in the following Figure.

Industry standards are written to guide industry and also to enable public officials to more efficiently evaluate safety, security and environmental impacts of LNG facilities and industry activities. Regulatory compliance should ensure transparency and accountability in the public domain.

The four requirements for safety - primary containment, secondary containment, safeguard systems and separation distance - apply across the LNG value chain, from production, liquefaction and shipping, to storage and re-gasification. (The term "containment" in this document refers to safe storage and isolation of LNG.)

Primary Containment

The first and most important safety requirement for the industry is to contain LNG. This is accomplished by employing suitable materials for storage tanks and other equipment, and by appropriate engineering design throughout the value chain.

Secondary Containment

This second layer of protection ensures that if leaks or spills occur, the LNG can be contained and isolated. For onshore installations dikes and berms surround liquid storage tanks to capture the product in case of a spill. In some installations a reinforced concrete tank surrounds the inner tank that normally holds the LNG. Secondary containment systems are designed to exceed the volume of the storage tank. Double and full containment systems for onshore storage tanks can eliminate the need for dikes and berms.

Safeguard Systems

In the third layer of protection, the goal is to minimize the release of LNG and mitigate the effects of a release. For this level of safety protection, LNG operations use systems such as gas, liquid and fire detection to rapidly identify any breach in containment and remote and automatic shut off systems to minimize leaks and spills in the case of failures. Operational systems (procedures, training and emergency response) also help prevent/mitigate hazards. Regular maintenance of these systems is vital to ensure their reliability.

Separation Distance

Federal regulations have always required that LNG facilities be sited at a safe distance from adjacent industrial, communities and other public areas. Also, safety zones are established around LNG ships while underway in waters and while moored. The safe distances or exclusion zones are based on LNG vapor dispersion data, and thermal radiation contours and other considerations as specified in regulations.

Industry Standards/Regulatory

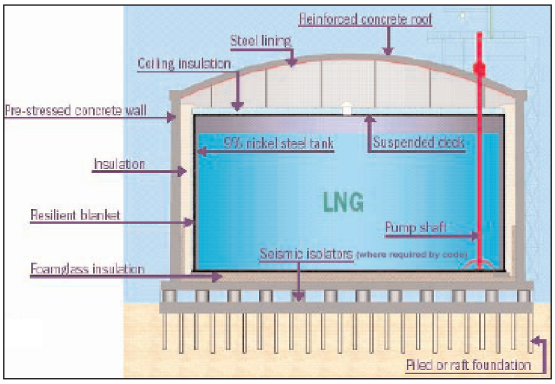

Figure-2.9: A typical on-shore LNG storage tank
(Source: Shell)

Figure-2.10: A typical LNG ship engaged in LNG transport

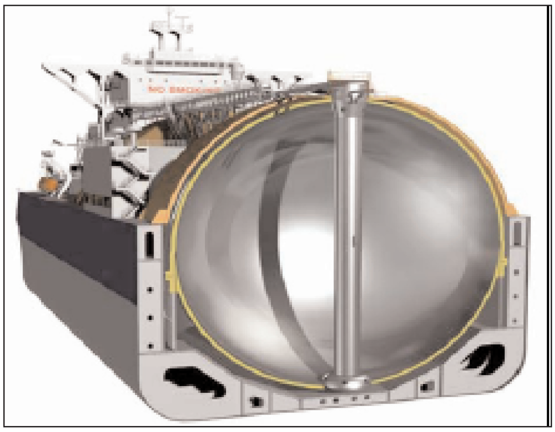

Figure-2.11: An example picture of containment system

Compliance

No systems are complete without appropriate operating and maintenance procedures being in place and with assurance that these are adhered to, and that the relevant personnel are appropriately trained. Organizations such as the Society of International Gas Tanker and Terminal Operators (SIGTTO), Gas Processors Association (GPA) and National Fire Protection Association (NFPA) produce guidance which results from industry best practices.

The four conditions described above for safety, along with industry standards and regulatory compliance, are vital to continuing the strong LNG industry safety performance.

2.17.6- LNG Properties and Potential Hazards

To consider whether LNG is a hazard, it is appropriate to understand the properties of LNG and the conditions required in order for specific potential hazards to occur.

LNG Properties

Natural gas produced from the wellhead consists of methane, ethane, propane and heavier hydrocarbons, plus small quantities of nitrogen, helium, carbon dioxide, sulfur compounds and water. LNG is liquefied natural gas. The liquefaction process first requires pre-treatment of the natural gas stream to remove impurities such as water, nitrogen, carbon dioxide, hydrogen sulfide and other sulfur compounds. By removing these impurities, solids cannot be formed as the gas is refrigerated. The product then also meets the quality specifications of LNG end users. The pretreated natural gas becomes liquefied at a temperature of approximately -256°F (-160°C) and is then ready for storage and shipping. LNG takes up only 1/600th of the volume required for a comparable amount of natural gas at room temperature and normal atmospheric pressure. Because the LNG is an extremely cold liquid formed through refrigeration, it is not stored under pressure. The common misperception of LNG as a pressurized substance has perhaps led to an erroneous understanding of its danger.

LNG is a clear, non-corrosive, non-toxic, cryogenic(extremely low temperature below 100°F) liquid at normal atmospheric pressure. It is odorless; in fact, odorants must be added to methane before it is distributed by local gas utilities for end users to enable detection of natural gas leaks from hot-water heaters and other natural gas appliances. Natural gas (methane) is not toxic. However, as with any gaseous material besides air and oxygen, natural gas that is vaporized from LNG can cause asphyxiation due to lack of oxygen if a concentration of gas develops in an unventilated, confined area.

The density of LNG is about 3.9 pounds per gallon, compared to the density of water, which is about 8.3 pounds per gallon. Thus, LNG, if spilled on water, floats on top and vaporizes rapidly because it is lighter than water. Vapors released from LNG as it returns to a gas phase, if not properly and safely managed, can become flammable but explosive only under certain well-known conditions. Yet safety and security measures contained in the engineering design and technologies and in the operating procedures of LNG facilities greatly reduce these potential dangers.

The flammability range is the range between the minimum and maximum concentrations of vapor (percent by volume) in which air and LNG vapors form a flammable mixture that can be ignited and burn.

Figure-2.13 indicates that the upper flammability limit and lower flammability limit of methane, the dominant component of LNG vapor, are 5 percent and 15 percent by volume, respectively. When fuel concentration exceeds its upper flammability limit, it cannot burn because too little oxygen is present. This situation exists, for example, in a closed, secure storage tank where the vapor concentration is approximately 100 percent methane. When fuel concentration is below the lower flammability limit, it cannot burn because too little methane is present. An example is leakage of small quantities of LNG in a well-ventilated area. In this situation, the LNG vapor will rapidly mix with air and dissipate to less than 5 percent concentration.

A comparison of the properties of LNG to those of other liquid fuels, as shown in Table-2.6, also indicates that the Lower Flammability Limit of LNG is generally higher than other fuels. That is, more LNG vapors would be needed (in a given area) to ignite as compared to LPG or gasoline.

Methane gas will ignite only if the ratio or mix of gas vapor to air is within the limited flammability

Table 2.6: Comparison of Properties of Liquid Fuels

Properties	LNG	Liquefied Petroleum Gas (LPG)	Gasoline	Fuel Oil
Toxic	No	No	Yes	Yes
Carcinogenic	No	No	Yes	Yes
Flammable Vapor	Yes	Yes	Yes	Yes
Form Vapor Clouds	Yes	Yes	Yes	No
Asphyxiant	Yes, but in a vapor cloud	Same as LNG	Yes	Yes
Extreme Cold Temperature	Yes	Yes, if refrigerated	No	No
Other Health Hazards	None	None	Eye irritant, narcosis, nausea, others	Same as gasoline
Flash Point4 (°F)	-306	-156	-50	140
Boiling Point (°F)	-256	-44	90	400
Flammability Range in Air, %	5-15	2.1-9.5	1.3-6	N/A
Stored Pressure	Atmospheric	Pressurized (atmospheric if refrigerated)	Atmospheric	Atmospheric
Behavior if Spilled	Evaporates, forming visible "clouds". Portions of cloud could be flammable or explosive under certain conditions.	Evaporates, forming vapor clouds which could be flammable or explosive under certain conditions	Evaporates, forms flammable pool; environmental clean up required	Same as gasoline

Source: Based on Lewis, William W., James P. Lewis and Patricia Outtrim, PTL, "LNG Facilities - The Real Risk," American Institute of Chemical Engineers, New Orleans, April 2003, as modified by industry sources.

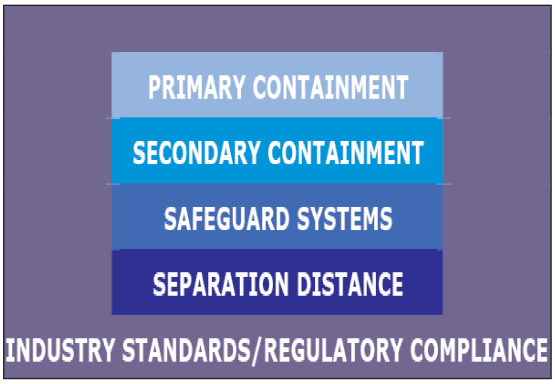

Figure-2.12: Critical Safety Conditions

range. An often expected hazard is ignition from flames or sparks. Consequently, LNG facilities are designed and operated using standards and procedures to eliminate this hazard and equipped with extensive fire detection and protection systems should flames or sparks occur.

The autoignition temperature is the lowest temperature at which a flammable gas vapor will ignite spontaneously, without a source of ignition, after several minutes of exposure to sources of heat. Temperatures higher than the autoignition temperature will cause ignition after a shorter exposure time. With very high temperatures, and within the flammability range, ignition can be virtually instantaneous. For methane vapors derived from LNG, with a fuel-air mixture of about 10 percent methane in air (about the middle of the 5-15 percent flammability limit) and atmospheric pressure, the autoignition temperature is above

Table 2.7: Auto-ignition Temperature of Liquid Fuels

Fuel	Auto-ignition Temp (°F)
LNG (primarily methane)	1004
LPG	850-950
Ethanol	793
Methanol	867
Gasoline	495
Diesel Fuel	Approx. 600

Source: New York Energy Planning Board, Report on issues regarding the existing New York Liquefied Natural Gas Moratorium, November 1998

1000°F (540°C). This extremely high temperature requires a strong source of thermal radiation, heat or hot surface. If LNG is spilled on the ground or on water and the resulting flammable gas vapor does not encounter an ignition source (a flame or spark or a source of heat of 1000°F (540°C) or greater), the vapor will generally dissipate into the atmosphere, and no fire will take place.

When compared to other liquid fuels, LNG vapor (methane) requires the highest temperature for autoignition, as shown in the Table-2.7.

In summary, LNG is an extremely cold, non-toxic, non-corrosive substance that is transferred and stored at atmospheric pressure. It is refrigerated, rather than pressurized, which enables LNG to be an effective, economical method of transporting large volumes of natural gas over long distances. LNG itself poses little danger as long as it is contained within storage tanks, piping, and equipment designed for use at LNG cryogenic conditions. However, vapors resulting from LNG as a result of an uncontrolled release can be hazardous, within the constraints of the key properties of LNG and LNG vapors - flammability range and in contact with a source of ignition - as described above.

2.17.7- Pressure and Temperature Control

A basic goal of all LNG containment systems is to maintain the LNG cargo at or near atmospheric pressure at a boiling temperature of the LNG. This is accomplished using "auto-refrigeration", a phenomenon that results from the constant heat flow into the tank and the removal of the associated vapour.

The vapour generated during auto-refrigeration is known as boil-off gas. Typical boil-off gas rates of LNG ships range from 0.15 to 0.25 percent (by volume) per day. Currently, all LNG ships burn the boil-off gas as fuel special arrangement with is fitted within an internalized combustion energy system that allows the ship boilers to consume all of the boil-off gas to fuel the ship's steam propulsion system. As a consequence, LNG ships have reduced emissions compared to conventional oil-fired ships.

2.17.8- Propulsion System

Almost all of the currently operational large LNG ships are steam turbine driven. Steam ships use boiler that is fired from the ship's natural cargo (boil-off gas). The boiler can also be fired with heavy fuel oil or in any ratio with natural gas.

2.17.9- Ballast Tanks

Sufficient ballast water capacity must be provided to permit the ship to return to the loading port safely under various sea conditions. LNG cargo tanks are not used as ballast tanks because these tanks must contain a minimal amount of LNG in them at all times, even when 'empty' in order to keep the tanks cold during normal operations. Consequently, LNG ships must be designed to provide adequate ballast capacity in other locations. Ballast water tanks of the LNG ships are arranged within the LNG ship's double hull. It is essential that ballast water does not leak into the containment system. To reduce the potential for leakage, the ballast tanks, cofferdams, and the walls of the void spaces are typically coated to reduce corrosion. LNG ships are also periodically inspected to examine the coating and to renew it as necessary.

A ballast control system, which permits the simultaneous ballasting during cargo transfer operations, is also incorporated into each LNG ship. This allows the LNG ship to maintain a constant draft during all phases of its operation to enhance performance.

2.17.10- Ship Safety Systems

LNG ships transporting cargo to a proposed terminal would be fitted with an array of cargo monitoring and control systems. These systems would automatically monitor key cargo parameters while the ship is at sea and during the remote control phase of cargo operations at the unloading terminal.

The system includes provisions for pressure monitoring and control, temperature monitoring of the cargo tanks and surrounding ballast tanks, emergency shutdown of cargo pumps and closing of critical valves, monitoring of tank cargo levels, and gas and fire detection.

2.17.11- Fire Protection

All LNG ships arriving at a proposed terminal would be constructed according to the structural fire protection standards contained in the International Convention for Safety of Life at Sea (SOLAS).

LNG ships using terminal would also be fitted with active fire protection systems that meet or exceed design parameters in International Standards, such as Gas Tanker Code and SOLAS, including:

- A water spray (deluge) system that covers the accommodation house and control room and all main cargo control valves.
- A traditional firewater system that provides water to fire monitors on deck and to fire stations found throughout the ship.
- A dry chemical fire extinguisher system for hydrocarbon fires, and
- A Carbon dioxide system for protecting the machinery, the ballast pump room, emergency generators, compressors etc.

The use of storage vessel in lieu of storage tanks has greatly minimised the risk and has increased safety due to its design and operational effectiveness.

2.17.12- Unloading Operations

Wind speeds and wave heights in the vicinity of the jetty are monitored continuously, and the data are transmitted to a central unloading control room at the jetty. Emergency responses to various wind and wave conditions, as well as to LNG leaks, are prescribed. Procedures are established and ready to be implemented. The jetty terminal is fully equipped with fire-fighting equipment. The water around the jetty also is patrolled regularly to ensure security. These safety operations are outsourced to a qualified port operator.

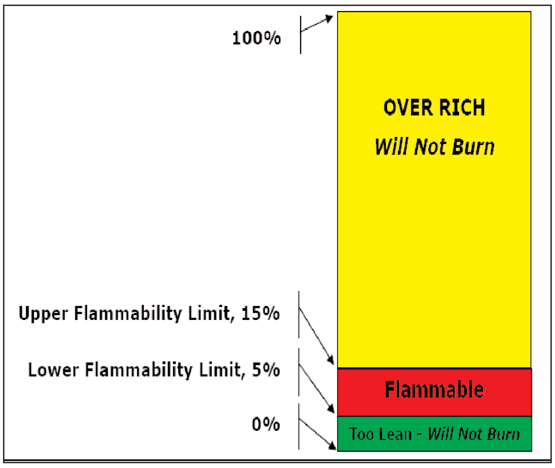

Figure-2.13: Upper and lower flammable limits of CH_4

2.17.13- Terminal Operations

Terminal operations are centrally controlled by computer. A data control system continuously measures and monitors all process parameters, such as pressure, temperature, flow rate, and mass. The real-time data are processed and interpreted by computer to ensure efficient process control and safety. The data control system allows immediate identification and location of leaks in the terminal system. Emergency signals and alarms are sent out automatically to ensure immediate response.

2.17.14 Likelihood of Tanker Collisions

A traffic control scheme, such as segregation of lanes with adequate separation distances and constant monitoring physically or through remotely operated devices, is evolved to minimize the risk of tanker encounters. Further, adequate navigational aids are installed to indicate channels, as well as separation distances. Their positions should be marked clearly on the charts. Proper policing is enforced to prevent vessels from discharging bilge, tanker washings, oily slop, etc. into the marine waters, as a part of the environmental management strategy.

2.18- Sandia Report

The US Department of Energy (DOE) in December 2004 released the results of a Sandia National Laboratories study on the potential effects of a large LNG release over water. With the publishing of report all governmental and private stakeholders in the LNG debate quickly realized that the Sandia study changed the landscape for evaluating public safety issues surrounding LNG terminals.

The study addresses difficult questions about LNG spill risks in an era of international security tensions and provides the most solid science platform yet for evaluating the risks of LNG transportation. It will be therefore appropriate to incorporate the report as policymakers were still evaluating and applying the study's conclusions to new and existing LNG terminals. The US Coast Guard (USCG) is integrating the Sandia study into its development of incident action plans for LNG vessel transits, which includes the required risk-mitigation measures. The US Federal Energy Regulatory Commission, with jurisdiction over the siting of onshore LNG terminals, has promised to review LNG projects under the microscope of new science as it emerges. It now appears to be folding Sandia into its detailed siting review process. And state and local governments are assessing the study's implications for LNG emergency preparedness.

The Sandia study's recommendations, therefore, are fast becoming de rigueur components in the risk-analysis processes of various stakeholders, from federal agencies to local firefighters. It remains to be seen how the study ultimately will affect the political debate over LNG, and uncertainties remain about how agencies will apply the study's conclusions. As each project or facility will face its own set of unique questions, one thing seems certain: US decision makers are viewing LNG risks through a new, more exacting lens.

Sandia study defines hazard zones, consequences

Several practical effects emerge from Sandia's LNG hazard study, but the most immediate of these is the study's three-zone approach to defining hazards and consequences from an intentional, large LNG spill over water and the resulting fire.

This hazard-zone model will help decision makers identity the areas at greatest risk, plan mitigation measures, and develop emergency response plans.

- In the first two hazard-zones, the biggest danger is thermal radiation generated by an LNG pool fire. The heat would be greatest in Zone 1, defined as the area within 500 m of an LNG vessel. Populations and structures within this zone would experience "severe negative impacts," according to the Sandia study.

As a result, the study recommends the "most rigorous deterrent measures" within Zone1 areas, including strict vessel security and control, and waterway traffic management. It also recommends careful evaluation and coordination of port security and emergency-response stakeholders.

Sandia also recommends using computational fluid dynamics (CFD) analysis to assess site-specific Zone1conditions and develop more precise and effective prevention and mitigation measures.

- The study defines Zone2 as the area between 500 m and 1.6 km of an LNG vessel. The consequences of an LNG fire would be lower within this zone than in Zone1, but injuries and property damage still could occur.

Sandia recommends that security and safety measures for Zone2 focus on vapor dispersion and fire hazards, with strategies to include emergency response planning and community education and warnings to ensure that inhabitants understand the risks and precautionary measures.

- Zone 3 is the area farther than 1.6 km from an LNG vessel. While the effects in Zone3 of a pool fire are significantly minimized, the chief danger is the possibility of a vapor cloud "burn back" to the source of a spill.

For this zone, the study recommends emergency response measures aimed at dealing with vapor cloud dispersion, as well as public education planning similar to that for Zone2.

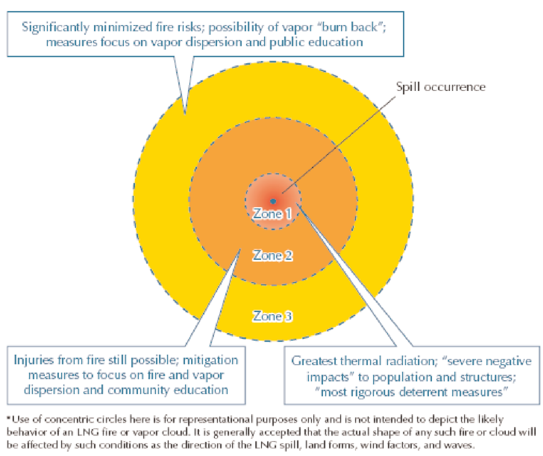

Figure-2.14: Sandia's normal hazard, consequence zones

Table 2.8: Estimated Impact of Intentional LNG Breaches, Spills on Public Safety and Property

Event	Potential ship damage, spill	Potential Hazard	Potential Impact on public spill safety[1]		
			-500	500-1,600 m	>1,600 m
Insider threat or hijacking	Intentional, 2-7 sq m breach and medium-to-large spill	Large fire	High	Medium	Low
		Damage to ship	High	Medium	Low
		Fireball	Medium	Low	Very low
	Intentional, large release of LNG	Large fire	High	Medium	Low
		Damage to ship	High	Medium	Low
		Vapor cloud fire	High	High-medium	Medium
Attack on ship	Intentional, 2-12 sq m breach and medium-to-large spill	Large fire	High	Medium	Low
		Damage to ship	High	Medium	Low
		Fireball	Medium	Low	Very Low

1 Distance to spill origin, varies according to site
Source: Sandia Report, p, 54

LNG stakeholders are now applying Sandia's three-zone model to existing and planned LNG terminals and shipping routes and, as a result, will re-evaluate the risks and adjust their plans accordingly.

The results of such analysis could pose difficult questions for some projects, but in general the Sandia model will yield fundamentally stronger public safety and security for the nation's LNG infrastructure.

2.19- Types of LNG Hazards

The potential hazards of most concern to operators of LNG facilities and surrounding communities flow from the basic properties of natural gas. As already described in the text above primary containment, secondary containment, safeguard systems, and separation distance provide multiple layers of protection. These measures provide protection against hazards associated with LNG. However, the following hazards are present with some probability of occurrence.

2.19.1- Explosion

An explosion happens when a substance rapidly changes its chemical state i.e., is ignited or is uncontrollably released from a pressurized state. For an uncontrolled release to happen, there must be a structural failure - i.e., something must puncture the container or the container must break from the inside. LNG tanks store the liquid at an extremely low temperature, about -256°F (-160°C), so no pressure is required to maintain its liquid state. Sophisticated containment systems prevent ignition sources from coming in contact with the liquid. Since LNG is stored at atmospheric pressure - i.e., not pressurized - a crack or puncture of the container will not create an immediate explosion.

2.19.2- Vapor Clouds

As LNG leaves a temperature-controlled container, it begins to warm up, returning the liquid to a gas. Initially, the gas is colder and heavier than the surrounding air. It creates a fog - a vapor cloud - above the released liquid. As the gas warms up, it mixes with the surrounding air and begins to disperse. The vapor cloud will only ignite if it encounters an ignition source while concentrated within its flammability range. Safety devices and operational procedures are intended to minimize the probability of a release and subsequent vapor cloud having an affect outside the facility boundary.

2.19.3- Freezing Liquid

If LNG is released, direct human contact with the cryogenic liquid will freeze the point of contact. Containment systems surrounding an LNG storage tank, thus, are designed to contain up to 110 percent of the tank's contents. Containment systems also separate the tank from other equipment. Moreover, all facility personnel must wear gloves, face masks and other protective clothing as a protection from the freezing liquid when entering potentially hazardous areas. This potential hazard is restricted within the facility boundaries and does not affect neighboring communities.

2.19.4- Rollover

When LNG supplies of multiple densities are loaded into a tank one at a time, they do not mix at first. Instead, they layer themselves in unstable strata within the tank. After a period of time, these strata may spontaneously rollover to stabilize the liquid in the tank. As the lower LNG layer is heated by normal heat leak, it changes density until it finally becomes lighter than the upper layer. At that point, a liquid rollover would occur with a sudden vaporization of LNG that may be too large to be released through the normal tank pressure release valves. At some point, the excess pressure can result in cracks or other structural failures in the tank. To prevent stratification, operators unloading an LNG ship measure the density of the cargo and, if necessary, adjust their unloading procedures accordingly. LNG tanks have rollover protection systems, which include distributed temperature sensors and pump-around mixing systems.

2.19.5- Rapid Phase Transition

When released on water, LNG floats - being less dense than water - and vaporizes. If large volumes of LNG are released on water, it may vaporize too quickly causing a rapid phase transition (RPT). Water temperature and the presence of substances other than methane also affect the likelihood of an RPT. An RPT can only occur if there is mixing between the LNG and water. RPT ranges from small pops to blasts large enough to potentially damage lightweight structures. Other liquids with widely differing temperatures and boiling points can create similar incidents when they come in contact with each other.