

**Application**

**For**

**Prior Environmental Clearance**

**For**

**Development Of LNG Storage And Regasification Terminal  
At Village Chhara, Taluka Kodinar, Dist. Gir Somnath, Gujarat**

**Project Proponent:**

**HPCL Shapoorji Energy Limited**

January, 2014

## CONTENTS

Sr. No	Description
1	Application Letter
2	Form – 1
3	Draft TOR
4	Enclosure – 1 – Location Map
5	Enclosure – 2 – Layout Plan
6	PFR – Breakwater

# APPLICATION

**S. Mukundan**  
Director

TF : 022 6749 0291  
Cell: 99 300 12732  
Email Mukundan.srinivasan@shapoorji.com

Date: Jan 08, 2014

To

Shri Lalit Kapur  
Director (IA-III)  
Ministry of Environment and Forests  
Paryavaran Bhawan,  
CGO Complex, Lodhi Road,  
New Delhi - 110 003

**Sub: Application for Prior Environmental Clearance for Proposed "Development of LNG Storage and Regasification Terminal at Village Chhara, Taluka Kodinar, District Gir Somnath, Gujarat, India."**

Dear Sir

HPCL Shapoorji Energy Limited is planning to develop LNG Terminal at Chhara within the boundary of port under development by M/s Simar Port Limited. Environmental Clearance for the port project is under process.

We are submitting for deciding Terms of Reference for EIA study –

1. Application (Form-I)
2. Prefeasibility report.

We request you to kindly review the proposal and issue to us Terms of Reference.

Thanking you

Yours faithfully

for HPCL Shapoorji Energy Limited

  
S. Mukundan  
Director



# FORM - 1

## EIA Study for LNG Terminal at Chhara – Form I & TOR

### Form 1

#### (I) Basic Information

Sr. No.	Item	Details
1.	Name of the project/s	Development of LNG Storage and Regasification Terminal at Village Chhara, Taluka Kodinar, District Gir Somnath, Gujarat, India.
2.	Sl. No. in the schedule	Activity 6 (a)
3.	Proposed capacity / area / length / tonnage to be handled / command area / lease area / number of wells to be drilled.	<p><u>Stage – I :</u> Floating Storage and Regasification Unit (FSRU) : 2.5 MMTPA</p> <p><u>Stage – II :</u> Onshore LNG Terminal : 10 MMTPA</p> <p>(Capacity will be developed in two Phases of 5 MMTPA each)</p> <p>Land required – 47.08 ha (within Port Boundary of M/s Simar Port Ltd.)</p>
4.	New / Expansion / Modernization	New
5.	Existing Capacity/Area etc.	NA
6.	Category of Project i.e. 'A' or 'B'	Category 'A'
7.	Does it attract the general condition? If Yes please specify.	No
8.	Does it attract the specific condition? If Yes please specify.	No
9.	Location	Located within Port Boundary of M/s Simar Port Ltd.
	Plot/Survey/Khasra No.	-
	Village	Chhara
	Tehsil	Kodinar
	District	Gir Somnath
	State	Gujarat
10.	Nearest railway station/airport along with the distance in Km.	<p>Nearest railway station : Kodinar – approx. 7 km</p> <p>Nearest airport : Diu – approx. 47 km.</p>
11.	Nearest town, city, district Headquarters with distance in km	Town: Kodinar – approx. 7 km District HQ - Veraval – approx. 45 km
12.	Village Panchayats, Zilla Parishad, Municipal Corporation, Local Body (complete postal addresses with telephone nos. to be given)	1. Chhara Village Gram Panchayat Office, Chhara Village, Main Road, Taluka: Kodinar, Dist: Gir Somnath – 362720.

**EIA Study for LNG Terminal at Chhara – Form I & TOR**

Sr. No.	Item	Details
		2. Taluka Panchayat Office Govt. Hospital Road, Kodinar Town, Taluka: Kodinar, Dist: Gir Somnath – 362720.  3. Kodinar Municipal Corporation Govt.Hospital Road, Kodinar Town Taluka: Kodinar, Dist: Gir Somnath – 362720.
13.	Name of the applicant	HPCL Shapoorji Energy Limited
14.	Registered Address	B-210, ISCON Centre, 2nd Floor, Shivranjani Cross Road, Opposite Deepkala Junction, Ahmedabad – 380 015
15.	Address for correspondence : Name Designation (Owner/Partner/CEO) Address  E-mail Telephone No. Fax No.	S. Mukundan Director SP Centre, 41/44, Minoo Desai Marg, Colaba, Mumbai 400 005 <a href="mailto:mukundan.srinivasan@shapoorji.com">mukundan.srinivasan@shapoorji.com</a> 022 6749 0291 022 6749 0017
16.	Details of Alternative Sites examined, if any. Location of these sites should be shown on a topo-sheet.	No. Proposed facilities to be located within Port Boundary of M/s Simar Port Ltd. Location of Project attached as enclosure – 1 Layout Plan attached as enclosure – 2.
17.	Interlinked Projects	Extension of Breakwater by M/s Simar Port Limited
18.	Whether separate application of interlinked project has been submitted?	To be submitted
19.	If Yes, date of submission	To be submitted
20.	If no, reason	-
21.	Whether the proposal involves approval/ clearance under: if Yes, details of the same and their status to be given. (a) The Forest (Conservation) Act, 1980? (b) The Wildlife (Protection) Act, 1972? (c) The C.R.Z Notification, 1991?	No No Yes
22.	Whether there is any Government order / policy relevant / relating to the site?	EC for Development of Port by M/s Simar Port Ltd. received on dt. 06 <sup>th</sup> Jan, 14
23.	Forest land involved (hectares)	No

## EIA Study for LNG Terminal at Chhara – Form I & TOR

Sr. No.	Item	Details
24.	Whether there is any litigation pending against the project and/or land in which the project is propose to be set up? (a) Name of the Court (b) Case No. (c) Orders/directions of the Court, if any and it's relevance with the proposed project	No

### II. ACTIVITY

#### 1. Construction, operation/decommissioning of the project involving actions, which will cause physical changes in the locality (topography, land use, changes in water bodies, etc.)

Sr. No.	Information / Checklist confirmation	Yes / No	Details thereof (with approximate quantities / rates, wherever possible) with source of information data
1.1	Permanent or temporary change in land use, land cover or topography including increase in intensity of land use (with respect to local land- use plan)	No	Proposed facilities will be located within Port Boundary of M/s Simar Port Ltd.
1.2	Clearance of existing land, vegetation and buildings?	No	Proposed facilities will be located within Port Boundary of M/s Simar Port Ltd.
1.3	Creation of new land uses?	No	Proposed facilities will be located within Port Boundary of M/s Simar Port Ltd.
1.4	Pre-construction investigations e.g. bore houses, soil testing?	Yes	Location specific studies will be carried out during FEED stage.
1.5	Construction works?	Yes	<ul style="list-style-type: none"> <li>• LNG Berths – 2 Nos</li> <li>• Mooring Dolphins – 4 Nos</li> <li>• LNG Unloading facilities</li> <li>• Approach trestle including pipelines</li> <li>• Storage tanks- 1,85,000 M<sup>3</sup> capacity each – 2 Nos</li> <li>• Regasification Facilities</li> <li>• 15 MW Gas based Power Plant</li> <li>• Buildings like administrative building, fire station etc.</li> </ul>
1.6	Demolition works?	No	Proposed facilities will be located within Port Boundary of M/s Simar Port Ltd.
1.7	Temporary sites used for construction works or housing of construction workers		A temporary site for construction workers camp will be earmarked in nearby villages. Basic amenities such as water supply, housing, domestic fuel, sanitation facilities, and health

## EIA Study for LNG Terminal at Chhara – Form I & TOR

Sr. No.	Information / Checklist confirmation	Yes / No	Details thereof (with approximate quantities / rates, wherever possible) with source of information data
			centre etc. for construction workers will be provided.
1.8	Above ground buildings, structures or earth works including linear structure, cut and fill or excavations	Yes	Foundation and above ground construction work will be carried out for the project.
1.9	Underground works including mining or tunneling?	No	No mining or tunneling.
1.10	Reclamation works?	No	NA
1.11	Dredging?	No	NA
1.12	Offshore structures?	Yes	Jetty, mooring structures and approach trestle.
1.13	Production and manufacturing processes?	Yes	Regasification of LNG.
1.14	Facilities for storage of goods or materials?	Yes	Onshore LNG Storage Tanks (185,000 M <sup>3</sup> capacity each) Phase I - 2 Nos. Phase II - 1 No.
1.15	Facilities for treatment or disposal of solid waste or liquid effluents?	Yes	Municipal Solid Waste – Compost Plant Liquid Effluents – Treatment for recycle and reuse in green belt
1.16	Facilities for long term housing of operational workers?	Yes	Long term housing of operational workers will be provided in Kodinar town.
1.17	New road, rail or sea traffic during construction or operation?	Yes	<u>Construction Phase</u> Movement of construction equipment/material/manpower <u>Operation Phase</u> LNG Carriers
1.18	New road, rail, air waterborne or other transport infrastructure including new or altered routes and stations, ports airports etc.?	No	Not envisaged.
1.19	Closure or diversion of existing transport routes or infrastructure leading to changes in traffic movements?	No	Not envisaged.
1.20	New or diverted transmission lines or pipelines?	Yes	LNG Pipeline – Berth to Onshore Terminal NG Pipeline – FSRU to Grid and LNG Terminal to Grid Internal Power Transmission lines and Utility pipe lines.
1.21	Impoundment, damming, culverting, realignment or other changes to the hydrology of watercourses or aquifers?	No	-
1.22	Stream crossings?	No	-
1.23	Abstraction or transfer of water from ground or surface water?	No	Sea water will be used in FSRU for regasification

## EIA Study for LNG Terminal at Chhara – Form I & TOR

Sr. No.	Information / Checklist confirmation	Yes / No	Details thereof (with approximate quantities / rates, wherever possible) with source of information data
1.24	Changes in water bodies or the land surface affecting drainage or run-off?	No	Not envisaged.
1.25	Transport of personnel or materials for construction, operation or decommissioning?	Yes	Movement of construction equipment/material/manpower
1.26	Long-term dismantling or decommissioning or restoration works?	No	FSRU will be moved out after commissioning of Onshore LNG Terminal. Natural Gas pipeline from FSRU to grid will be blinded.
1.27	Ongoing activity during decommissioning which could have an impact on the environment?	No	Not envisaged.
1.28	Influx of people to an area either temporarily or permanently?	Yes	Temporary influx due to workers during construction phase. Marginal influx due to operational personnel during operation phase.
1.29	Introduction of alien species?	No	Not envisaged.
1.30	Loss of native species or genetic diversity?	No	Not envisaged.
1.31	Any other actions?	No	Not envisaged.

### 2. Use of Natural resources for construction or operation of the Project (such as land, water, materials or energy, especially any resources that are non-renewable or in short supply)

Sr. No.	Information / Checklist Confirmation	Yes/ No	Details thereof (with approximate quantities /rates, wherever possible) with source of information data
2.1	Land especially undeveloped or agricultural land (ha)	Yes	Proposed facilities will be located within Port Boundary of M/s Simar Port Ltd.
2.2	Water (expected source & competing users) unit: KLD	Yes	<u>Construction Phase</u> – Fresh water requirement : 100 KLD Will be sourced from third party supplier.  <u>Operation Phase</u> FSRU – 5,500 m <sup>3</sup> /hr Service water - 20 m <sup>3</sup> /hr Potable water - 3 m <sup>3</sup> /hr Fire water - 22,000 m <sup>3</sup>
2.3	Minerals (MT)	No	-
2.4	Construction material - stone, aggregates, sand I soil (expected source - MT)	Yes	Construction materials such as cement, steel, aggregate, etc. will be sourced from reputed manufacturer/suppliers.
2.5	Forests and timber (source - MT)	No	Not envisaged.

## EIA Study for LNG Terminal at Chhara – Form I & TOR

Sr. No.	Information / Checklist Confirmation	Yes/ No	Details thereof (with approximate quantities /rates, wherever possible) with source of information data
2.6	Energy including electricity and fuels (source, competing users) Unit: fuel (MT), energy (MW)	Yes	From Gujarat State electric grid, 66kV power supply from Substation at Sarkhadi village approx. 10 km from Project site.  Operation Phase Power Requirement – 15 MW
2.7	Any other natural resources (use appropriate standard units)	No	Not envisaged

### 3. Use, storage, transport, handling or production of substances or materials, which could be harmful to human health or the environment or raise concerns about actual or perceived risks to human health

Sr. No.	Information/ Checklist confirmation	Yes/ No	Details thereof (with approximate quantities /rates, wherever possible) with source of information data
3.1	Use of substances or materials, which are hazardous (as per MSIHC rules) to human health or the environment (flora, fauna and water supplies)	Yes	LNG is inflammable liquid.
3.2	Changes in occurrence of disease or affect disease vectors (e.g. insect or water borne diseases)	No	Not envisaged.
3.3	Affect the welfare of people e.g. by changing living conditions?	Yes	LNG Terminal will improve socio-economic condition of the region as well as bring economic benefit to the people. It will also increase business and employment opportunity.
3.4	Vulnerable groups of people who could be affected by the project e.g. hospital patients, children the elderly etc.	No	Not envisaged.
3.5	Any other causes	No	-

### 4. Production of solid wastes during construction or operation or decommissioning (MT/month)

Sr. No.	Information/ Checklist Confirmation	Yes/ No	Details thereof (with approximate quantities/rates, wherever possible) with source of information data
4.1	Spoil, overburden or mine wastes	No	Not envisaged.
4.2	Municipal waste (domestic and or commercial wastes)	Yes	During construction phase insignificant amount of waste will be generated. During the operation phase, small

## EIA Study for LNG Terminal at Chhara – Form I & TOR

Sr. No.	Information/ Checklist Confirmation	Yes/ No	Details thereof (with approximate quantities/rates, wherever possible) with source of information data
			amount of solid waste will be generated from administrative building, port user building and workshop.
4.3	Hazardous wastes (as per Hazardous Waste Management Rules)	Yes	Insignificant quantities of hazardous waste (such as used oil) will be generated in both construction and operation phases. This will be managed as per Hazardous Waste Management Rules.
4.4	Other industrial process wastes	No	Not envisaged
4.5	Surplus product	No	Not envisaged
4.6	Sewage sludge or other sludge from effluent treatment	Yes	Small amount of sewage sludge generated will be treated in compost plant.
4.7	Construction or demolition wastes	Yes	Construction waste will be properly segregated and utilized.
4.8	Redundant machinery or equipment	No	Not envisaged
4.9	Contaminated soils or other materials	No	Not envisaged
4.10	Agricultural wastes	No	Not envisaged
4.11	Other solid wastes	No	Not envisaged

### 5. Release of pollutants or any hazardous, toxic or noxious substances to air

Sr. No.	Information/Checklist confirmation	Yes/ No	Details thereof (with approximate quantities /rates, wherever possible) with source of information data
5.1	Emissions from combustion of fossil fuels from stationary or mobile sources	Yes	Emissions from power plant which will be using natural gas as fuel.
5.2	Emissions from production processes	No	Not envisaged.
5.3	Emissions from materials handling including storage or transport	No	Not envisaged.
5.4	Emissions from construction activities including plant and equipment	Yes	Fugitive dust due to movement of vehicles Emissions from DG sets
5.5	Dust or odours from handling of materials including construction materials, sewage and waste	Yes	Fugitive dust due to movement of vehicles.
5.6	Emissions from incineration of waste	No	Not envisaged.
5.7	Emissions from burning of waste in open air (e.g. slash materials, construction debris)	No	Not envisaged.
5.8	Emissions from any other sources	Yes	Flare during emergency gas leakages.

**6. Generation of noise and vibration, and emissions of light and heat**

Sr. No.	Information / Checklist confirmation	Yes/ No	Details thereof (with approximate quantities /rates, wherever possible) with source of information data
6.1	From operation of equipment e.g. engines, ventilation plant, crushers	Yes	Noise emission from: <ul style="list-style-type: none"> <li>• BOG Compressors</li> <li>• HP LNG pumps</li> <li>• Gas Engine generators</li> </ul>
6.2	From industrial or similar processes	No	Not envisaged
6.3	From construction or demolition	Yes	Noise due to construction equipment such as compressor, excavators, DG etc. No demolition is envisaged.
6.4	From blasting or piling	Yes	Construction of jetty and tanks would require piling.
6.5	From construction or operational traffic	Yes	Noise will be generated due to traffic movement during construction and operation phases.
6.6	From lighting or cooling systems	No	Not envisaged.
6.7	From any other sources	No	-

**7. Risks of contamination of land or water from releases of pollutants into the ground or into sewers, surface waters, groundwater, coastal waters or the sea**

Sr. No.	Information/Checklist confirmation	Yes/ No	Details thereof (with approximate quantities /rates, wherever possible) with source of information data
7.1	From handling, storage, use or spillage of hazardous materials	No	Not envisaged.
7.2	From discharge of sewage or other effluents to water or the land (expected mode and place of discharge)	No	Not envisaged.
7.3	By deposition of pollutants emitted to air, onto the land or into water	No	Not envisaged.
7.4	From any other sources	No	-
7.5	Is there a risk of long term build-up of pollutants in the environment from these sources?	No	Not envisaged.

## EIA Study for LNG Terminal at Chhara – Form I & TOR

### 8. Risk of accidents during construction or operation of the Project, which could affect human health or the environment

Sr. No.	Information/ Checklist confirmation	Yes/ No	Details thereof (with approximate quantities/rates, wherever possible) with source of information data
8.1	From explosions, spillages, fires etc. from storage, handling, use or production of hazardous substances	Yes	<p><u>Construction Phase –</u></p> <ul style="list-style-type: none"> <li>• Diesel storage</li> </ul> <p><u>Operation Phase –</u></p> <ul style="list-style-type: none"> <li>• Handling of LNG/NG</li> <li>• Storage of LNG</li> </ul>
8.2	From any other causes	No	Not envisaged.
8.3	Could the project be affected by natural disasters causing environmental damage (e.g. floods, earthquakes, landslides cloudburst etc)?	Yes	<p>Project located in Seismic Zone III-Moderate.</p> <p>No past record of cyclones at Kodinar coast.</p>

### 9. Factors which should be considered (such as consequential development) which could lead to environmental effects or the potential for cumulative impacts with other existing or planned activities in the locality

Sr.No.	Information/Checklist confirmation	Yes/ No	Details thereof (with approximate quantities /rates, wherever possible) with source of information data
9.1	Lead to development of supporting utilities, ancillary development or development stimulated by the project which could have impact on the environment e.g. <ul style="list-style-type: none"> <li>• Supporting infrastructure(roads, power supply, waste or wastewater treatment etc)</li> <li>• Housing development</li> <li>• Extractive industries</li> <li>• Supply industries</li> <li>• Other</li> </ul>	Yes	<p>Access road to the project site.</p> <p>Natural gas pipeline from project site to grid (will be developed by GSPL/GAIL).</p> <p>All supporting infrastructure will be developed within project site.</p> <p>Development of housing / extractive industries / supply industries not envisaged.</p>
9.2	Lead to after-use of the site, which could have an impact on the environment	No	Not envisaged.
9.3	Set a precedent for later developments	Yes	Proposed project would facilitate growth of industrial/ commercial activities.
9.4	Have cumulative effects due to proximity to other existing or planned projects with similar effects	No	Cumulative impacts, if any, will be identified and addressed in EIA.

## EIA Study for LNG Terminal at Chhara – Form I & TOR

### III. Environmental Sensitivity

Sr.No.	Areas	Name/ Identity	Aerial distance (within 15 km) of proposed project location boundary
1	Areas protected under international conventions, national or local legislation for their ecological, landscape, cultural or other related value	Nil	-
2	Areas which are important or sensitive or ecological reasons - Wetlands, watercourses or other water bodies, coastal zone, biospheres, mountains, forests	Forest:	There are four reserved forest and five patches of unclassified forest within 10 km of the proposed site. The forest types are open shrub type with dominant bushes which are found abundantly in arid zone.  Wildlife Sanctuary and National park: Gir Wildlife Sanctuary and National Park is located at a distance of approximately 22km from the proposed port site.
		Water bodies:	There are two fresh water bodies within 10 km radius of the proposed port site. These are Panchpipalva Bandhara and Sodam Bandhara
		Panchpipalva Bandhara	Approximately 9.0 Km towards North-East
		Sodam Bandhara	Approximately 3.0 km towards East
3	Areas used by protected, important or sensitive species of flora or fauna for breeding, nesting, foraging, resting, over wintering, migration	Nil	No such area close to proposed site. Baseline data collection in EIA will identify such areas, if any, in primary survey.
4	Inland, coastal, marine or underground waters	Saurashtra coast	The proposed port is located in Saurashtra coast.
5	State, National boundaries	Diu	13 km
6	Routes or facilities used by the public for access to recreation or other tourist, pilgrim areas	Nil	-
7	Defense installations	Nil	-
8	Densely populated or built-up area	Y	Following built-up are situated within 15 km radius area of the proposed port site. None of the above villages, except Kodinar

## EIA Study for LNG Terminal at Chhara – Form I & TOR

Sr.No.	Areas	Name/ Identity	Aerial distance (within 15 km) of proposed project location boundary																																																																								
			<p>town is densely populated.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;">Settlement</th> <th style="text-align: center;">Dist. (km)</th> <th style="text-align: center;">Directi on</th> </tr> </thead> <tbody> <tr><td>Sarkhadi</td><td style="text-align: center;">2.4</td><td style="text-align: center;">NE</td></tr> <tr><td>Chhara</td><td style="text-align: center;">3</td><td style="text-align: center;">W</td></tr> <tr><td>Malsaram</td><td style="text-align: center;">5</td><td style="text-align: center;">NE</td></tr> <tr><td>Damli</td><td style="text-align: center;">5.7</td><td style="text-align: center;">N</td></tr> <tr><td>Kaj</td><td style="text-align: center;">5.7</td><td style="text-align: center;">NE</td></tr> <tr><td>Kadodara</td><td style="text-align: center;">5.9</td><td style="text-align: center;">N</td></tr> <tr><td>Pipli</td><td style="text-align: center;">6.3</td><td style="text-align: center;">NW</td></tr> <tr><td>Pipalva Bavana</td><td style="text-align: center;">6.7</td><td style="text-align: center;">NE</td></tr> <tr><td>Devli</td><td style="text-align: center;">7.4</td><td style="text-align: center;">NW</td></tr> <tr><td>Panadar</td><td style="text-align: center;">7.7</td><td style="text-align: center;">NW</td></tr> <tr><td>Nanavada</td><td style="text-align: center;">8</td><td style="text-align: center;">NE</td></tr> <tr><td>Velan</td><td style="text-align: center;">8.6</td><td style="text-align: center;">E</td></tr> <tr><td>Jantrakhadi</td><td style="text-align: center;">8.9</td><td style="text-align: center;">NE</td></tr> <tr><td>Kodinar Town</td><td style="text-align: center;">9.1</td><td style="text-align: center;">NW</td></tr> <tr><td>Dudana</td><td style="text-align: center;">9.8</td><td style="text-align: center;">N</td></tr> <tr><td>Mul dwarka</td><td style="text-align: center;">9.9</td><td style="text-align: center;">W</td></tr> <tr><td>Ronaj</td><td style="text-align: center;">10</td><td style="text-align: center;">N</td></tr> <tr><td>Chauhan Ni khan</td><td style="text-align: center;">10.1</td><td style="text-align: center;">NW</td></tr> <tr><td>Mitiyaj</td><td style="text-align: center;">10.4</td><td style="text-align: center;">N</td></tr> <tr><td>Inchvadhani</td><td style="text-align: center;">11</td><td style="text-align: center;">N</td></tr> <tr><td>Malgam</td><td style="text-align: center;">11</td><td style="text-align: center;">NE</td></tr> <tr><td>Kotada</td><td style="text-align: center;">12.7</td><td style="text-align: center;">E</td></tr> <tr><td>Vannakwada (in Diu)</td><td style="text-align: center;">13.3</td><td style="text-align: center;">E</td></tr> </tbody> </table>	Settlement	Dist. (km)	Directi on	Sarkhadi	2.4	NE	Chhara	3	W	Malsaram	5	NE	Damli	5.7	N	Kaj	5.7	NE	Kadodara	5.9	N	Pipli	6.3	NW	Pipalva Bavana	6.7	NE	Devli	7.4	NW	Panadar	7.7	NW	Nanavada	8	NE	Velan	8.6	E	Jantrakhadi	8.9	NE	Kodinar Town	9.1	NW	Dudana	9.8	N	Mul dwarka	9.9	W	Ronaj	10	N	Chauhan Ni khan	10.1	NW	Mitiyaj	10.4	N	Inchvadhani	11	N	Malgam	11	NE	Kotada	12.7	E	Vannakwada (in Diu)	13.3	E
Settlement	Dist. (km)	Directi on																																																																									
Sarkhadi	2.4	NE																																																																									
Chhara	3	W																																																																									
Malsaram	5	NE																																																																									
Damli	5.7	N																																																																									
Kaj	5.7	NE																																																																									
Kadodara	5.9	N																																																																									
Pipli	6.3	NW																																																																									
Pipalva Bavana	6.7	NE																																																																									
Devli	7.4	NW																																																																									
Panadar	7.7	NW																																																																									
Nanavada	8	NE																																																																									
Velan	8.6	E																																																																									
Jantrakhadi	8.9	NE																																																																									
Kodinar Town	9.1	NW																																																																									
Dudana	9.8	N																																																																									
Mul dwarka	9.9	W																																																																									
Ronaj	10	N																																																																									
Chauhan Ni khan	10.1	NW																																																																									
Mitiyaj	10.4	N																																																																									
Inchvadhani	11	N																																																																									
Malgam	11	NE																																																																									
Kotada	12.7	E																																																																									
Vannakwada (in Diu)	13.3	E																																																																									
9	Areas occupied by sensitive man-made land uses (hospitals/schools/ places of worship/ community facilities)	Nil	No areas occupied by sensitive man-made land uses within project site. Baseline data collection, in primary survey, will identify, such areas, if any.																																																																								
10	Areas containing important, high quality or scarce resources, (ground water resources/ surface resources/ forestry, agriculture/ fisheries, tourism minerals)	Nil	No area containing important, high quality or scarce resources within project site. Baseline data collection, in primary survey, will identify, such areas, if any																																																																								
11	Areas already subjected to pollution or environmental damage. (those where existing legal environmental standards are exceeded)	Nil	Negligible industrial / commercial activities in the study region.																																																																								
12	Areas susceptible to natural hazard which could cause the project to present environmental problems, (earthquakes/ subsidence, landslides/	Saurashtra Coast	The project area is located in the moderately active seismic region. Saurashtra coast at Kodinar has																																																																								

## EIA Study for LNG Terminal at Chhara – Form I & TOR

---

---

Sr.No.	Areas	Name/ Identity	Aerial distance (within 15 km) of proposed project location boundary
	erosion or extreme or adverse climatic conditions)		been identified as area subjected to low erosion.

**DRAFT TERMS OF  
REFERENCE  
(TOR)**

### Proposed Terms of Reference for EIA Study

#### Objectives

- i. Collection of primary data supported by secondary data in the study area for assessment of baseline quality of marine environment including water, sediment and biological components and secondary data from state/local departments
- ii. Collection of existing hydrography data supported by secondary data already collected in offshore region in the vicinity of the project site during pre-monsoon and post-monsoon seasons
- iii. Assessment of the present status of air, noise, water, land, biological and socio-economic components of environment including parameters of human interest up to 10 km radial distance from the proposed site
- iv. Identification of potential impacts on various environmental components due to activities envisaged during construction and operational phases of the proposed project
- v. Prediction of impacts on the various environmental components using appropriate mathematical / simulation models
- vi. Preparation of environmental impact statement based on the identification, prediction and evaluation of impacts
- vii. Delineation of Environmental Management Plan (EMP) outlining preventive and control strategies for minimising adverse impacts during construction and operational stages of the proposed project along with the cost and time-schedule for implementation of EMP
- viii. Formulation of environmental quality monitoring programmes for construction and operational phases as per the requirements of statutory authorities
- ix. Assessment of proposed terminal site based on coastal zone regulation for obtaining clearance from Gujarat Coastal Zone Management Authority (GCZMA)
- x. Presentation of draft EIA in Public Hearing to be conducted for the project as per the EIA Notification 2006 and the compliance of the issues raised by the public and incorporation in the EIA-EMP report.

#### Activities for each Environmental Component

The details of work plan under individual environment components are as follows:

##### Air Environment

- Design of ambient air quality network based on prevailing meteorology and location of sensitive receptors.
- Assessment of existing levels of various air pollutants listed in NAAQS at 5 monitoring locations as per CPCB Guidelines (National Ambient Air Quality Monitoring Series : NAAQMS/ ... /2003-04, Table 4.1 and Section 4.2.4)
- Collection of meteorological data, viz. wind speed, wind direction, relative humidity, temperature, lapse rate and cloud cover by installing weather station at the site.

- Inventory of point, line and area sources of air pollution and quantification of emission in proposed project.
- Estimation of air emissions including fugitive emissions from the proposed project activities
- Evaluation of atmospheric emissions and prediction of Ground Level Concentrations of air pollutants (PM, SO<sub>2</sub> & NO<sub>x</sub>) through appropriate air quality models incorporating the requirements specified in the publication of Central Pollution Control Board “Assessment of Impact to Air Environment: Guidelines for conducting Air Quality Modelling”
- Assessment of anticipated changes in air quality and suggestions on mitigation measures
- Evaluation of the adequacy of the proposed pollution control measures to meet air quality emission standards.

### **Noise Environment**

- Measurement of noise levels in residential/ commercial/sensitive zones in the study area.
- Monitoring of noise levels due to stationary and vehicular sources near major roads/junctions in area within 1 km of the project site.
- Studies on existing traffic movement and impact of proposed activities on existing transportation system within 1 km of the project site. Keeping in view the increase in traffic movement, assessment of additional facilities to be created and suggestions on safety measures to be followed.
- Prediction and evaluation of impacts due to increase in noise levels arising out of the proposed project on the surrounding environment.
- Identification of high level noise zones requiring mitigation measures within project site.
- Evaluation of existing and proposed noise pollution control measures.
- Recommendations on mitigation measures for noise pollution

### **Inland Water Environment**

- Study of existing five ground and five surface water sources in study area with respect to quantity and quality (physico-chemical, biological and bacteriological characterization)
- Impact of project operations on water demand of other users.
- Assessment of wastewater quality and quantity to be discharged from the proposed project
- Study of existing drainage pattern and impact of the project on the drainage pattern.
- Evaluation of proposed wastewater treatment systems.
- Recommendations on water conservation measures

- Assessment of feasibility of water recycle and reuse for green belt development and irrigation

### **Marine Environment**

- Assessment of marine water quality in project impact zone for physical, chemical, and biological parameters including planktons and primary productivity
- Assessment of sediment quality in terms of texture, particle size distribution organic pollutants and heavy metals
- Assessment of sediment quality for biotic parameters such as benthos (micro and micro fauna)
- Assessment of mangrove forests/vegetation in the coastal and inter tidal zone
- Study the discharges, if any, during LNG operations
- Bathymetric study to assess tranquility conditions at the proposed site
- Impact on shore line changes along the stretch and suggestion on erosion prevention measures in the area
- Delineation of environmental management plan including post project monitoring
- Suggestion on contingency plan, taking into account the accident scenario and natural disasters
- Study of project site details from coastal zone regulation point of view for clearance from Gujarat Coastal Zone Management Authority (GCZMA)

### **Land Environment**

- Study of layout plan in the proposed site
- Study of existing landuse and cropping patterns, vegetation, forestry, wastelands Studies on soil characteristics in the study area
- Characterization of solid wastes likely to be generated and its safe disposal
- Assessment of impact of the project on the existing habitation and infrastructure, if any
- Impact of construction activities on the shore line and the terrestrial environment
- Delineation of options for solid and hazardous waste management
- Design of green belt and identification of suitable native plant species for the proposed green belt

### **Terrestrial Biological Environment**

- Collection of information about flora and fauna and determination of species diversity, density, abundance etc.
- Identification of rare and endangered species in the study area
- Assessment of impacts on terrestrial flora and fauna due to air emissions

- Delineation of measures for abatement/reduction of impact on biological environment

### **Socio-economic and Health Environment**

- Collection of baseline data related to socio-economic profile of the study area with reference to :
  - Stakeholders relevant to the Project
  - Human settlements, male/female ratio, occupational pattern, employment and income
  - Infrastructure resource base, viz. medical, education, water resources, power supply
  - Economic resource base, viz. agriculture, industries, forest, trade and commerce
  - Health Status, viz. morbidity pattern with reference to prominent and endemic diseases
  - Cultural and Aesthetic attributes in the study area including places of historical/ archaeological importance
- Assessment of economic benefits to community and environment due to existing and proposed developmental activities
- Socio-economic survey to assess the Quality of Life of the people in the study area and their perceptions about the projects
- Projection of anticipated changes due to the proposed project, and delineation of measures to minimize the impacts.
- Assessment of impacts on places of historical/archaeological importance and aesthetic impairment, if any.
- Assessment of economic benefits to community and environment due to the proposed projects.
- Delineation of regional socio-economic environment management plan through initiation of beneficial activities (welfare) for local communities providing financial support.
- Assessment of impacts due to the proposed activities on fishing and suggestion of management plan and provision to be made under Corporate Social Responsibility (CSR).

### **Environmental Management Plan**

- Delineation of Environmental Management Plan (EMP) separately for the construction and operational phase after identifying, predicting and evaluating the impacts on each component of the environment with a view to maximising the benefits from the project.

- Delineation of post-project environmental monitoring plan with identified parameters and associated cost
- Incorporation of safety aspects associated with the proposed activity/facilities.

### Risk Assessment Studies

#### Scope of Work

Preparation of Risk Assessment (RA) report based on hazard identification, hazard quantification with recourse to Maximum Credible Accident (MCA) Analysis and recommending risk mitigation measures and disaster management plan. Risk assessment would cover LNG handling and storage facilities in FSRU & Land Terminal.

#### Objectives of Study

The objectives of the Risk Assessment study are as follows:

- Hazard identification through computation of hazard indices and inventory analysis
- Generation of scenarios for accidental release of flammable chemicals
- Computation of damage distances based on consequence analysis for credible and worst case scenarios
- Assessment of risk and delineation of risk mitigation measures
- Preparation of emergency evacuation and Disaster Management Plan

#### Work Plan

##### Hazard Identification

- Collection of relevant information for the proposed development facilities
- Identification of hazard prone operations based on credible and worst case accidental release scenarios.
- Delineation of vulnerable operations

##### Hazard Assessment and Evaluation

Hazard prone operations would be critically examined with recourse to Maximum Credible Accident (MCA) analysis in order to arrive at hazards posed to the facilities and risk posed to the personnel on work place. The techniques proposed to be used are:

- **Consequence Analysis:** The damage distances will be computed due to accidental release of flammable chemicals causing pool fires, flash fires, jet fires and dispersion upto lower flammability limit. The extent of damage for 1% lethality and first degree burns will be assessed by plotting the damage distances on area maps
- **Individual Risk Curves:** The risk posed to the personnel working on critical zones (accident prone) will be computed by collecting data on probability values for identified failures scenarios.

**Disaster Management Plan**

Disaster management plan including evacuation during natural and man-made disaster like floods and other natural causes including cyclone, tsunami and earth quakes etc.

**Details of Storage Facilities**

Details of storage and Regasification, distribution network etc. and vulnerability of human habitation vis-à-vis proposed developmental activity associated risk.

**Declaration:**

I hereby give undertaking that the data and information given in the application and enclosures are true to the best of my knowledge and belief and I am aware that if any part of the data and information submitted is found to be false or misleading at any stage, the project will be rejected and clearance given, if any to the project will be revoked at the risk and cost.

Date:

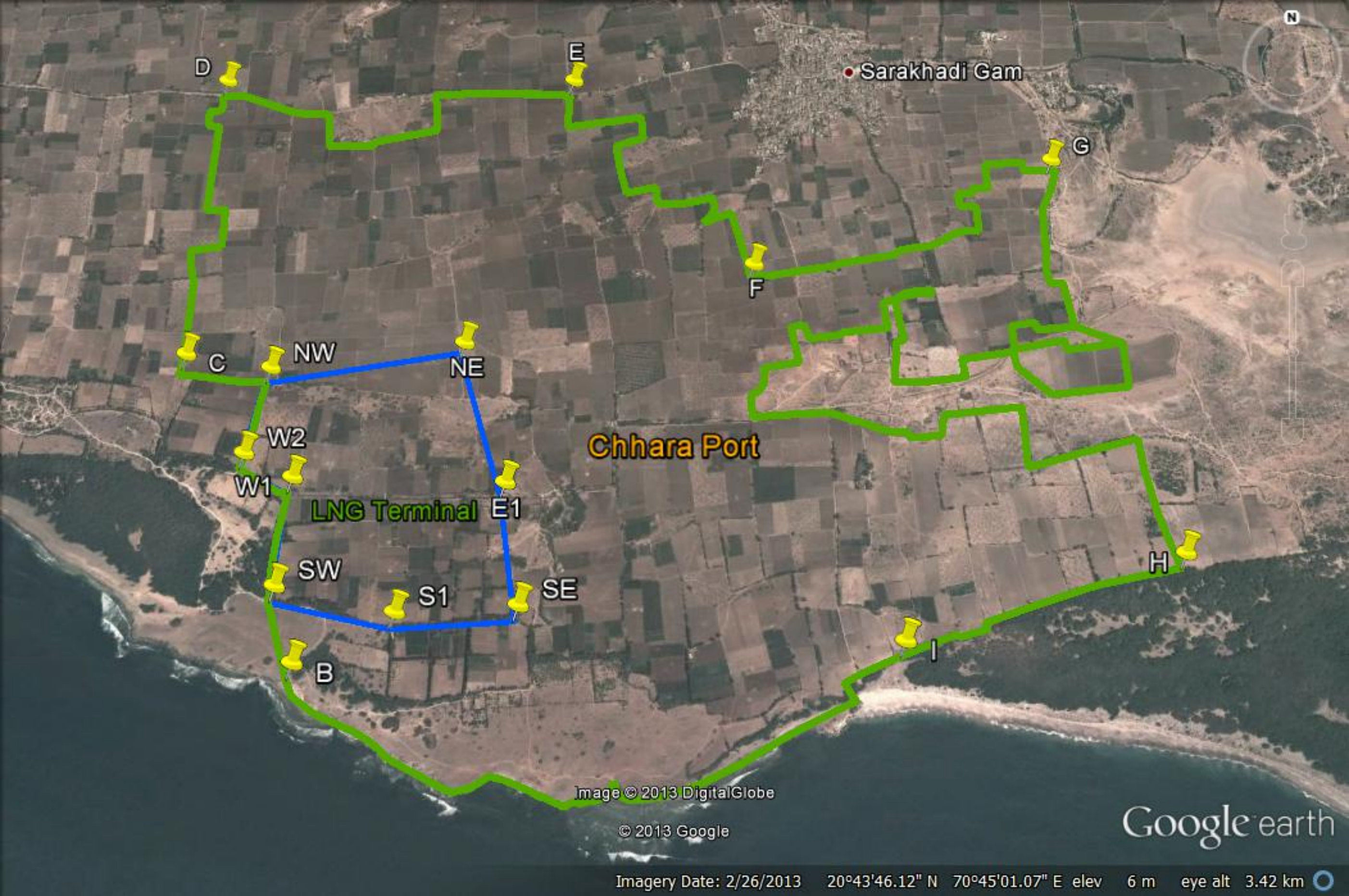
Place: Mumbai



S. Mukundan  
Director

HPCL Shapoorji Energy Ltd.

**ENCLOSURE – 1**  
**LOCATION MAP**



• Sarakhadi Gam

Chhara Port

LNG Terminal

D

E

G

F

C

NW

NE

W2

W1

E1

SW

S1

SE

H

B

I

Image © 2013 DigitalGlobe

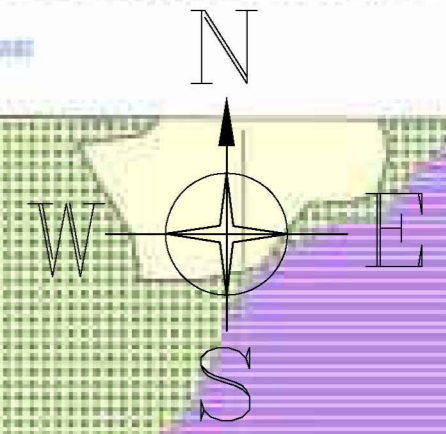
© 2013 Google

Google earth

Imagery Date: 2/26/2013 20°43'46.12" N 70°45'01.07" E elev 6 m eye alt 3.42 km

COASTAL REGULATION ZONE (CRZ) MAP AROUND PROPOSED PORT SITE NEAR CHHARA VILLAGE, IN JUNAGADH DISTRICT OF GUJARAT

CRZ AREA BETWEEN HIGH TIDE LINE (HTL) - LOW TIDE LINE (LTL) & 500 METERS FROM HTL IN UPDRIFT & 100 METERS OR WIDTH OF THE STREAM, AS APPLICABLE FROM HTL, TOWARDS LANDWARD SIDE OF COURSE OF RIVER



CHHARA

SARAKHADI

PROPOSED SITE FOR CHHARA PORT

20°44'0"N

70°45'0"E

70°45'0"E

COAL STACKYARD

GAUDHAR LAND

CRZ III

CRZ III

CRZ III

CRZ IB

POWER PLANT CONVEYOR

PUMP HOUSE (PROPOSED LOCATION)

LAND FILL PORT

500 METER RISE

TEMPORARY STOCK YARD BUILDING CONSTRUCTION

20°43'0"N

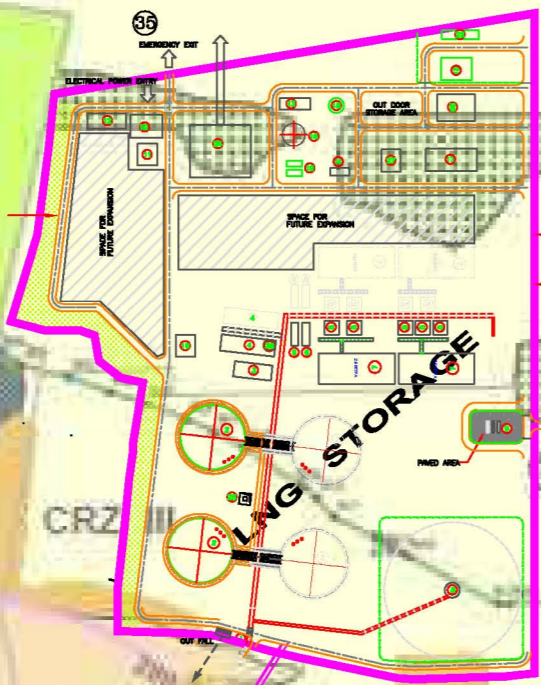
CRZ IV

CRZ IV

ARABIAN SEA

1:4,000

APPROACH TRESTLE



Legend:  
• PORT WITH UTILITY - LANDWARD SIDE  
• PORT WITH UTILITY - LANDWARD SIDE

Scale: 1:4,000

**ENCLOSURE – 2**

**LAYOUT PLAN**

REFERENCE/CONNECTING DRAWING

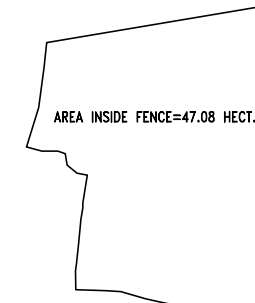
S.No.	DRAWING TITLE	DRAWING NO.
1	MASTER PLAN	2008054/MN/DPR/M-09

NOTES

- 1 ALL DIMENSIONS ARE IN METERS.
- 2 PROCESS EQUIPMENTS ARE SHOWN FOR 10 MTPA TERMINAL SEND OUT.

LEGEND

- |                                  |  |
|----------------------------------|--|
| ① TRESTLE                        | ⑫ CAPTIVE POWER PLANT                              |
| ② LNG TANKS                      | ⑬ FIRE WATER PUMP HOUSE                            |
| ③ BOG COMPRESSOR                 | ⑭ INSTRUMENT / PLANT AIR COMPRESSOR                |
| ④ HP PUMPS                       | ⑮ FIRE WATER TANKS                                 |
| ⑤ STV VAPORIZORS                 | ⑯ PROCESS SUB STATION                              |
| ⑥ SUBMERGED COMBUSTION VAPORIZOR | ⑰ CONTROL ROOM, LABORATORY & FIRE STATION BUILDING |
| ⑦ AIR HEATER                     | ⑱ SERVICE WATER                                    |
| ⑧ LP FLARE                       | ⑲ NITROGEN GENERATION                              |
| ⑨ TRUCK LOADING FACILITY         | ⑳ WORKSHOP / WARE HOUSE                            |
| ⑩ INCOMING SWITCHYARD            | ㉑ ADMINISTRATION BUILDING                          |
| ⑪ MAIN INCOMING SUBSTATION       | ㉒ PARKING  |
|                                  | ㉓ SECURITY GATE HOUSE                              |
|                                  | ㉔ NG SEND OUT & METALING                           |
|                                  | ㉕ IMPOUNDING BASIN                                 |
|                                  | ㉖ RE-CONDENSER UNIT                                |
|                                  | ㉗ UTILITY SUBSTATION                               |
- 
- |       |              |
|-------|--------------|
| ----- | SINGLE FENCE |
| ===== | ROAD         |
| ----- | PIPE RACK    |
| ----- | FUTURE       |



STATUS:

3	03.08.12	MK	SA	AKT	CLIENTS COMMENTS INCORPORATED
2	27.07.12	MK	SA	AKT	CLIENTS COMMENTS INCORPORATED
1	24.07.12	MK	SA	AKT	CLIENTS COMMENTS INCORPORATED
0	20.07.12	MK	AKT	AKT	PRELIMINARY ISSUE
REV.	DATE	SIGN	SIGN	SIGN	SUBJECT OF REVISION
	REVISION	DRAWN	CHECKED	APPROVED	

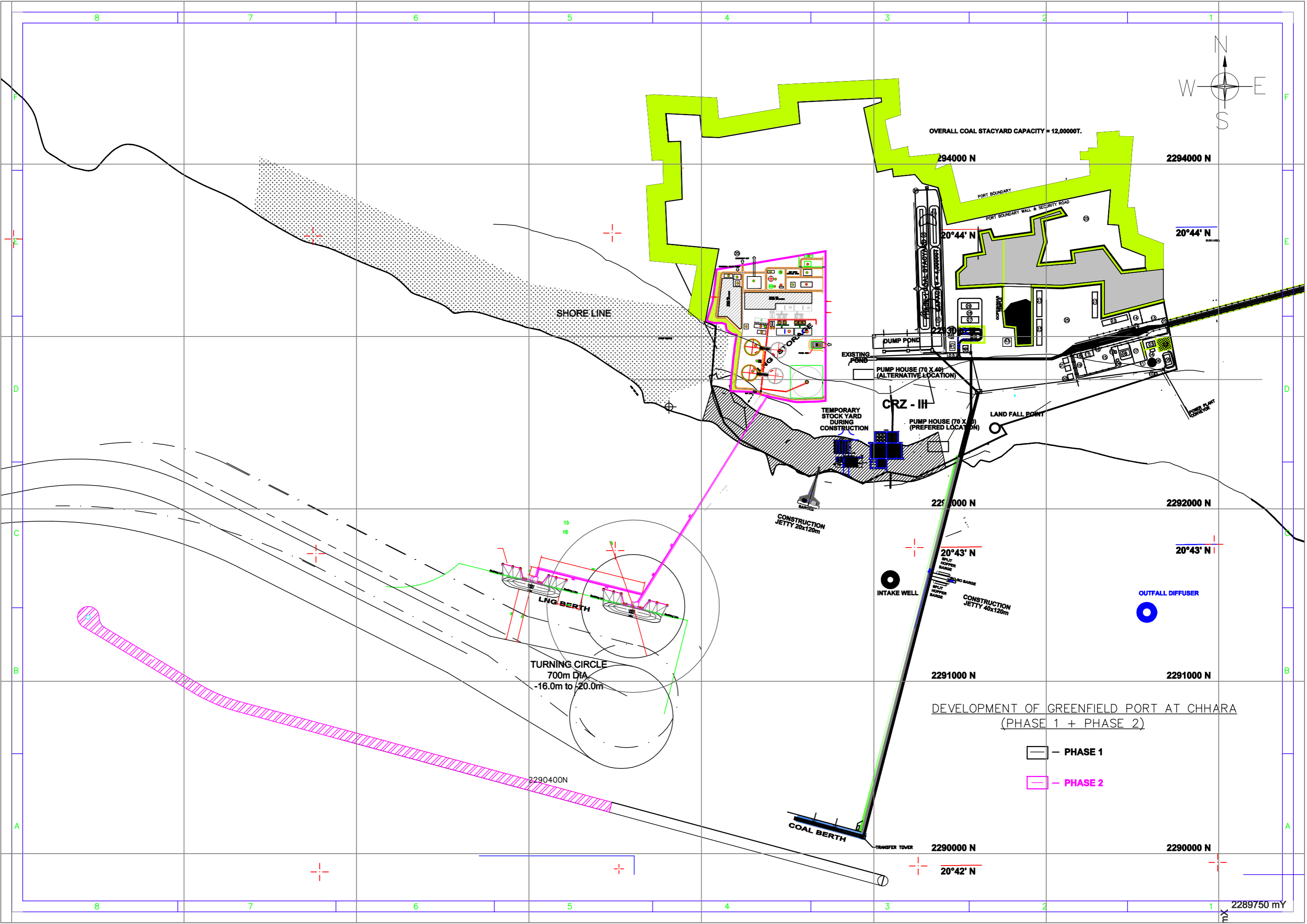
TITLE:

GENERAL PLOT PLAN

CLIENT: HINDUSTAN PETROLEUM CORPORATION LIMITED / SP PORTS Pvt Ltd.

PROJECT: DETAILED FEASIBILITY STUDY FOR CHARRA LNG TERMINAL AT CHHARA VILLAGE, GUJARAT

SIZE :	A1	SCALE :		SHEET :	1 OF 1
TRACTEBEL Engineering	DRAWING NUMBER				
	P.004049-C-14-2001		REV	3	



**PRE-FEASIBILITY  
REPORT  
LNG TERMINAL**

# **HINDUSTAN PETROLEUM CORPORATION LTD. / SP PORTS PVT. LTD.**

## **DETAILED FEASIBILITY REPORT FOR CHHARA LNG PROJECT**

### **EXECUTIVE SUMMARY**

4	21.1.13	Final	AKT	RM	CZ
3	26.12.12	Fourth Issue	AKT	RM	CZ
2	21.11.12	Third Issue	AKT	RM	CZ
1	14.09.12	Second Issue	AKT	RM	CZ
0	10.09.12	First Issue	AKT	RM	CZ
Rev.	Date	Subject of revision	Author	Checked	Approved

**TABLE OF CONTENTS**

**1.0 INTRODUCTION ..... 1**

**2.0 OBJECTIVES ..... 1**

**3.0 ASSUMPTIONS ..... 1**

**4.0 FINDINGS..... 2**

**4.1 Terminal Layout ..... 2**

**4.2 Terminal Facilities ..... 3**

**4.3 Project Schedule ..... 4**

**4.4 Project Cost Estimation ..... 4**

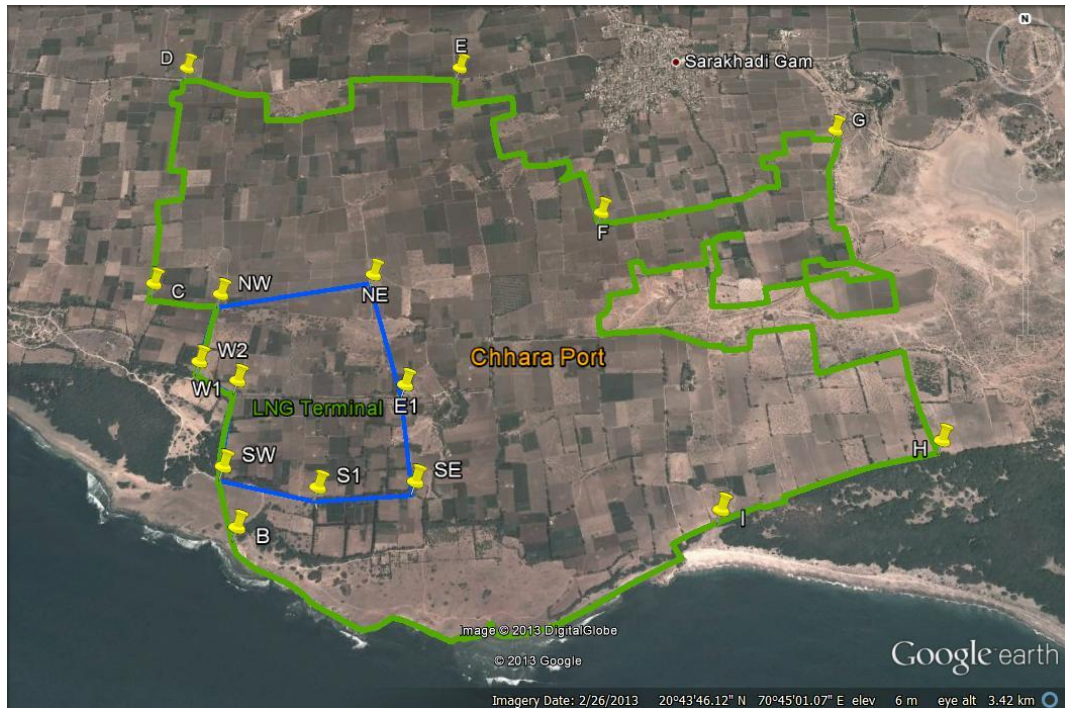
**5 CONCLUSIONS ..... 5**

Σ    Σ    Σ

## 1.0 INTRODUCTION

Hindustan Petroleum Corporation Ltd., (HPCL) and SP Ports Pvt Ltd (SPPPL) are planning to develop a LNG Receiving, Storage and Regassification Terminal at Chhara Port in Junagarh district, in the state of Gujarat, India.

Chhara site lies at extreme south coast of Gujarat state on the map of India. Chhara LNG Terminal is a part of Chhara Port expansion plan.



## 2.0 OBJECTIVES

The objective of the feasibility study is to present a techno-commercial analysis of the construction and operation of an LNG receiving, storage and regassification terminal on West Coast of India, at Chhara Port in Junagarh district, Gujarat.

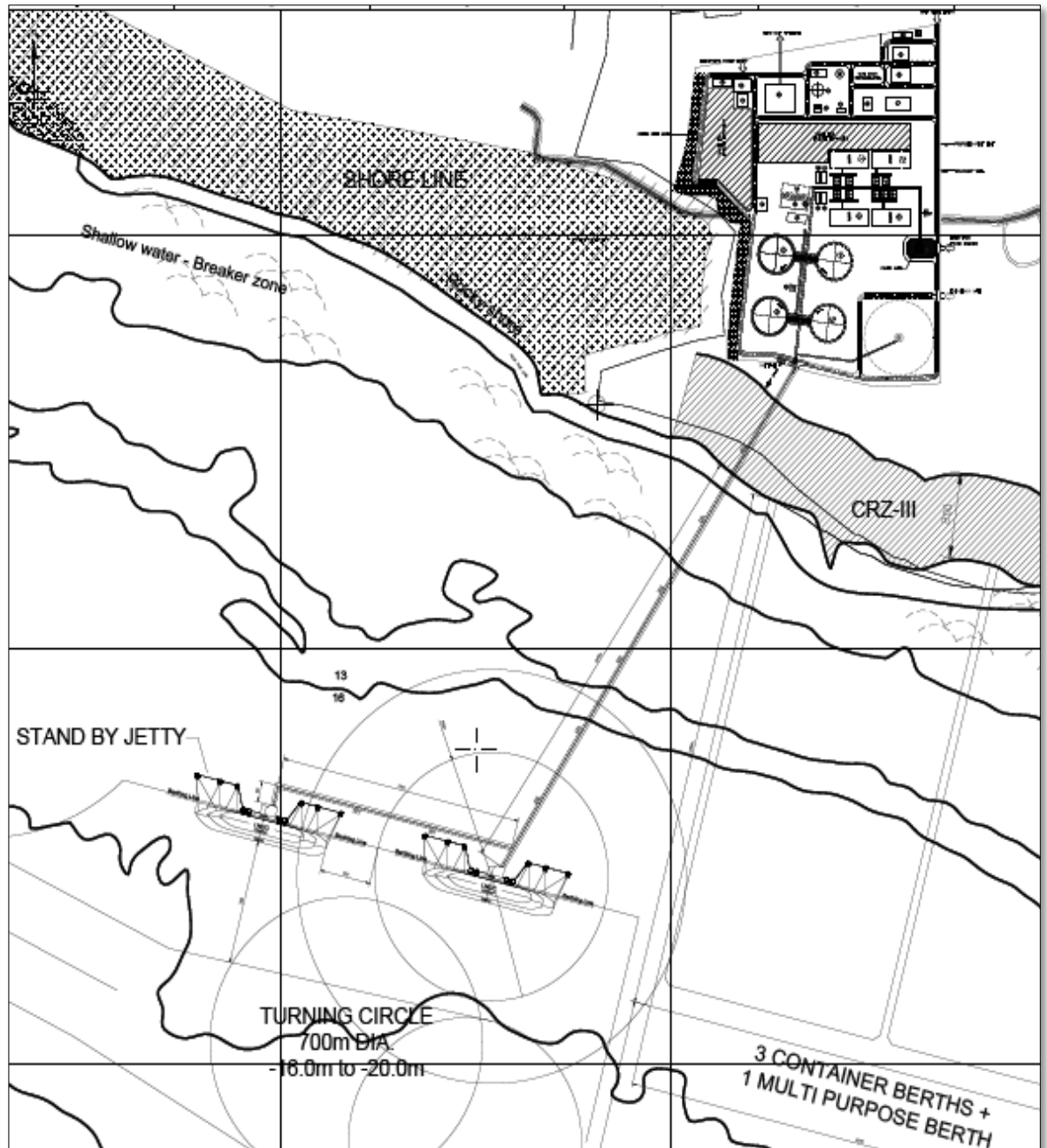
## 3.0 ASSUMPTIONS

The proposed development consists in developing the LNG terminal of 5 MMTPA send out capacity, (considered in this feasibility studies) further expandable to 10 MMTPA send out.

**4.0 FINDINGS**

**4.1 Terminal Layout**

Following Layout is the basis of Feasibility studies for development of LNG terminal at proposed Chhara Port:



## 4.2 Terminal Facilities

The LNG Regassification Terminal is including all facilities related to :

- a) The ship Unloading :
  - 1 berthing facility with provision of standby jetty for future
  - 1 Arm Station
  - 1 Local substation  
and associated piping and instrumentation.
- b) The LNG Storage:
  - 2 LNG Tanks
  - 3 transfer pumps per tank (Plus one spare pump well)
  - 2 monorails per tank  
and associated piping and instrumentation
- c) The LNG transfer and vaporization
  - 1 Absorber
  - 4 HP LNG Pumps
  - 4 Shell and Tube LNG Vaporizers with Air Heaters
  - 2 Submerged Combustion LNG Vaporizers  
and associated equipment, piping and instrumentation
- d) The gas sendout and metering
  - Metering facilities comprising of filter and turbine flow meter
  - Pig launching facilities at Terminal
  - Pipeline connecting Terminal to nearest Gas grid
  - Pig receiving facilities at Receiving terminal (connecting Gas grid)  
and associated equipment, piping and instrumentation
- e) The Boil off handling and flaring:
  - 3 Boil Off Gas Compressors
  - 2 KO Drums
  - 2 Drainage drums
  - 1 flare stack  
and associated equipment, piping and instrumentation
- f) The utilities production for:
  - Instrument Air and Plant Air
  - Service water
  - Gaseous Nitrogen production  
with all associated equipment, piping and instrumentation
- g) The Power distribution
  - Power from State grid
  - 2 Gas engine generators
  - 1 Emergency Diesel generator
  - 1 Main substation and 3 other substations  
with required MCC's.

**4.3 Project Schedule**

The estimated schedule of the project is 54 months from the date of project approval by HPCL/SP Ports Pvt Ltd.

The EPC contract schedule being 42 months.

**4.4 Project Cost Estimation**

Estimated capital cost of the project for a send out capacity of 5 MMTPA is as below:

<b>Description</b>	<b>Unit</b>	<b>Value</b>
<b>Capital Cost (without interest during construction (IDC))</b>	<b>Rs. Crores</b>	<b>4,796.85</b>
Interest During Construction (IDC)	Rs. Crores	611.97
<b>Capital Cost (with interest during construction (IDC))</b>	<b>Rs. Crores</b>	<b>5,408.82</b>

**5 CONCLUSIONS**

Based on the above analyses the following can be concluded:

- Chhara Port offers suitable conditions for an LNG Terminal to be built.
- Chhara LNG Terminal will be an important addition to India's energy infrastructure and help establish security of gas supply for Power plants and other business users.

Based on the above the following is recommended:

- HPCL / SP Ports Pvt Ltd should finalize FEED / EPC bid package.
- Additional Soil Investigations should be carried out prior to / during FEED studies.
- HPCL/SP Ports Pvt Ltd should start discussions with Pipeline transmissions companies and finalize an MOU for RLNG evacuation.

Σ Σ Σ

**HINDUSTAN PETROLEUM CORPORATION LTD. /  
SP PORTS PVT. LTD.**

**DETAILED FEASIBILITY REPORT FOR CHHARA LNG PROJECT**

**FEASIBILITY REPORT**

4	26.12.2012	Final	AKT	RM	CZ
3	19.11.2012	Client Comments incorporated	AKT	RM	CZ
2	20.09.2012	Project Opex revised	AKT	RM	CZ
1	14.09.2012	Second Issue	AKT	RM	CZ
0	10.09.2012	First Issue	AKT	RM	CZ
Rev.	Date	Subject of revision	Author	Checked	Approved

**TABLE OF CONTENTS**

**1.0 PURPOSE ..... 1**

**2.0 INTRODUCTION ..... 1**

**3.0 PORT FACILITIES ..... 4**

**4.0 SITE SELECTION ..... 5**

**5.0 DESIGN BASIS ..... 5**

**6.0 OPTIMIZATION STUDY AND RECOMMENDED FACILITIES IN LNG TERMINAL ..... 7**

**7.0 LNG UNLOADING FACILITIES AT THE PORT / MARINE FACILITIES ..... 8**

**8.0 MARINE FACILITIES ..... 8**

**9.0 ONSHORE FACILITIES ..... 9**

**10.0 RLNG EVACUATION PLAN ..... 10**

**11.0 PROJECT IMPLEMENTATION SCHEDULE ..... 10**

**12.0 CAPEX / OPEX ..... 11**

**13.0 POLLUTION CONTROL MEASURES ..... 11**

**14.0 SAFETY MEASURES ..... 12**

**15.0 PROVISION FOR FUTURE EXPANSION ..... 14**

**16.0 LIST OF EXCLUSIONS FROM FEASIBILITY REPORT AND FURTHER STUDIES /  
WORK TO BE CARRIED OUT ..... 14**

**17.0 CONCLUSIONS AND RECOMMENDATIONS ..... 14**

Σ Σ Σ

## **1.0 PURPOSE**

The aim of this Detailed feasibility report is to define proposed LNG Import, storage and regassification Terminal main characteristics as well as to assess the technical feasibility and financial viability of the project.

This report includes:

- Brief about HPCL / SPPPL
- Available infrastructure and Port future plans
- Port facilities
- Site selection report
- Design basis
- Optimization studies and recommended facilities in the LNG Terminal
- LNG unloading facilities at the Port
- Marine facilities
- Onshore facilities
- RLNG Evacuation plan
- Project Implementation schedule
- Capex / Opex
- Requirement of working capital
- Phasing of expenditure yearwise
- Pollution control measures
- Safety measures
- Financial analysis
- Provision for future expansion
- Details on maximization of Rupee cost
- List of exclusions from Detailed feasibility study and further studies recommended / work to be done
- Conclusions and recommendations

## **2.0 INTRODUCTION**

### **2.1. Background**

Simar Port Ltd, a Shapoorji Pallonji Group company is developing a deep draft, all weather multipurpose port on BOOT basis under concession from Govt. of Gujarat at Chhara, Junagarh district Gujarat.

Hindustan Petroleum Corporation Ltd (HPCL) along with SP Ports Pvt Ltd (SPPPL) are desirous of undertaking Detailed Feasibility Study for establishing technical and commercial viability of setting up a LNG Import and regasification Terminal of 5 MMTPA capacity at the port of Chhara, district Junagarh, Gujarat.

## 2.2. Brief about HPCL

HPCL is a Government of India Enterprise with a Navratna Status, and a Fortune 500 and Forbes 2000 company, with an annual turnover of Rs. 1,32,670 Crores and sales/income from operations of Rs 1,43,396 Crores (US\$ 31,546 Millions) during FY 2010-11, having about 20% Marketing share in India among PSUs and a strong market infrastructure.

HPCL operates 2 major refineries producing a wide variety of petroleum fuels & specialties, one in Mumbai (West Coast) of 6.5 Million Metric Tonnes Per Annum (MMTPA) capacity and the other in Vishakapatnam, (East Coast) with a capacity of 8.3 MMTPA. HPCL holds an equity stake of 16.95% in Mangalore Refinery & Petrochemicals Limited, a state-of-the-art refinery at Mangalore with a capacity of 9 MMTPA. In addition, HPCL is constructing a 9 MMTPA refinery at Bathinda, in the state of Punjab, as a JV with Mittal Energy Investments Pte Ltd.

HPCL also owns and operates the largest Lube Refinery in the India producing Lube Base Oils of international standards, with a capacity of 335 TMT. This Lube Refinery accounts for over 40% of the India's total Lube Base Oil production.

HPCL's vast marketing network consists of 13 Zonal offices in major cities and 101 Regional Offices facilitated by a Supply & Distribution infrastructure comprising Terminals, Pipeline networks, Aviation Service Stations, LPG Bottling Plants, Inland Relay Depots & Retail Outlets, Lube and LPG Distributorships. HPCL, over the years, has moved from strength to strength on all fronts. The refining capacity steadily increased from 5.5 MMTPA in 1984/85 to 14.8 MMTPA presently. On the financial front, the turnover has grown from Rs. 2687 Crores in 1984-85 to Rs 1,32,670 Crores in FY 2010-11.

## 2.3. Brief about SP Group

The Shapoorji Pallonji Group is an enterprise which draws vital support from its various individual entities to be able to execute turnkey projects, swiftly and efficiently. Along with the flagship company Shapoorji Pallonji & Company Limited (specializing in Construction, Design & Build and EPC), the other luminaries give the SP Group its strength and capability.

Today, with over 23,000 employees and a group turnover of US\$ 2.5 Bn, Shapoorji Pallonji Group has evolved and grown exponentially to become a huge conglomerate with multiple business segments with a progressive outlook and a thoroughly professional approach. The Group today has a strong presence in India and internationally including the Middle East and Africa. (With a rich legacy of 147 years and a consistently superior track record, the Shapoorji Pallonji Group remains committed towards excellence in each domain of its operations). SP group's business interests cover construction (including residential, commercial, industrial and infrastructure), real estate, infrastructure (comprising coal mining, power, ports and roads), biofuels and agriculture, consumer products, electro-mechanical and MEP services, facades and interiors, engineering, textiles, business automation and shipping and logistics.

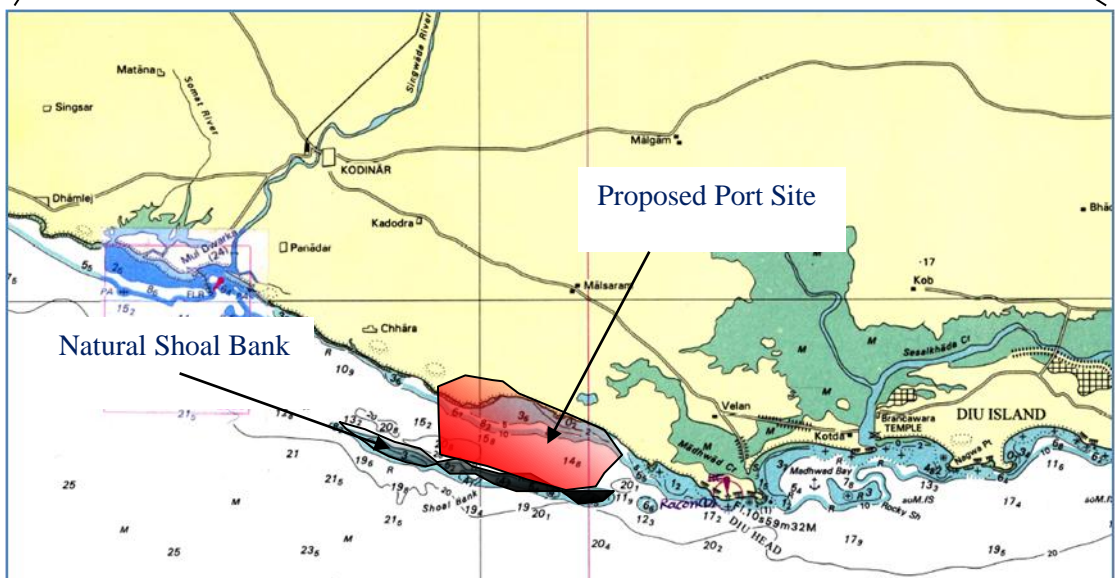
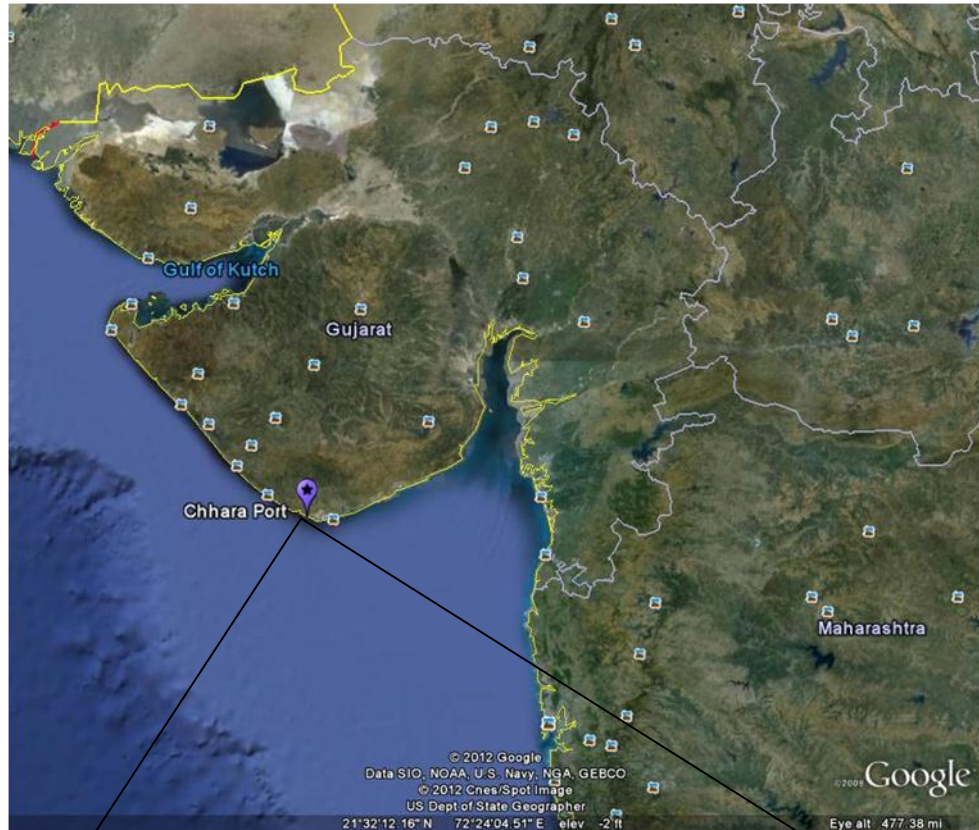
## 2.4. Details of Proposed Chhara Port

### 2.4.1. Port Location

Proposed Port is located near village Chhara located approximately at Latitude -20°43'19" N and Longitude -70°44'28" in the Kodinar Taluka Junagarh district of Gujarat state.

The shoreline is on the South face of the area stretching for a length of 2.5km. Kodinar is the nearest town and connected to the railway network. Chhara port is proposed to be all weather, multipurpose port with water depths available upto -20m CD. Nearest National Highway is NH 8E which is approximately 6.5 km on the north of proposed port site.

Location of Chhara port is shown on Google map as below:



Location of Chhara Port

**3.0 PORT FACILITIES**

**3.1. Proposed Berths**

Chhara Port is planned to be developed in 2 phases with following Berth availabilities:

Cargo	Phase 1	Phase 2
Coal	1	2
Bulk Jetty		1
Containers		3
Multipurpose Berth		1
LNG Jetty		1 + 1 (standby)

**3.2. Nautical Infrastructure**

As per Port master plan, nautical infrastructure details are as follows:

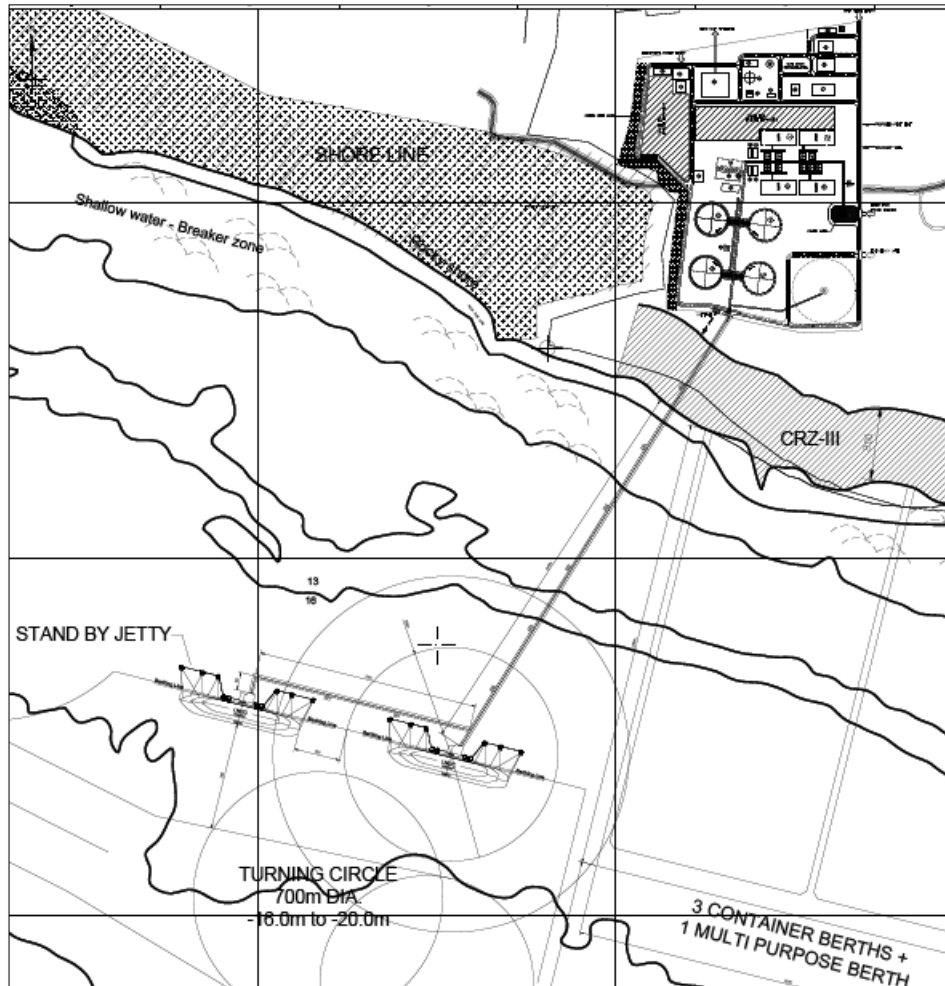
- The proposed approach channel is about 6.5 km long to reach offshore deepwater. The width of approach channel is expected to be 300m.
- Turning basin diameter of 600m and depth of -20.0m CD.
- The proposed Breakwater will be approximately 4.5 km long on the natural shoal bank (including extension of 1.25 km for providing tranquillity conditions for LNG jetty).

**3.3. Port services**

Simar Port Ltd would be providing safe, tranquil conditions for harbouring LNG vessels. Simar Port Limited will provide all necessary services associated with the safe transit and mooring of the LNG carriers that will unload the LNG at the terminal.

**4.0 SITE SELECTION**

On the basis of Site screening studies performed covered under document No. P.004049 N06 1003, following is the final selected layout:



**5.0 DESIGN BASIS**

**5.1. Unloading**

The receiving facility shall be sized to allow unloading of carriers of 80 000 m<sup>3</sup> to 266 000 m<sup>3</sup>.

There would be one Main jetty with a provision for one standby Jetty (in future). Trestle shall be provisioned for future LNG unloading lines for simultaneous unloading from Main and standby Jetty.

Unloading rate shall be 12 000 m<sup>3</sup>/hr.

## 5.2. LNG Characteristics

As Terminal is planned on the basis LNG supply through the Spot market, LNG characteristics will vary in a wide range. For this feasibility study, the heaviest and leanest compositions were considered as tabulated below:

Description	Unit	Rich Gas	Lean Gas
Methane C1	mole %	86.98	97.21
Ethane C2	mole %	9.08	2.49
Propane C3	mole %	2.53	0.14
I-Butane iC4	mole %	0.42	0.09
N-Butane nC4	mole %	0.62	0.02
I-Pentane iC5	mole %	0.00	0.00
N-Pentane nC5	mole %	0.00	0.03
Hexane C6+	mole %	0.00	0.00
Nitrogen N2	mole %	0.37	0.02
Carbon CO2	mole %	0.00	0.00
Oxygen	mole %	0.00	0.00
Total	mole %	100.00	100.00
Heating Value	BTU / Kg.	51 382	52 447
	GHV Volume (BTU/SCF)	1 137	1 034
LHV	Kcal/Kg	11 704	11 906
Density	Kg / CBM	460.3	428.83
Mol. Weight		18.50	16.49
Temperature(-)	TL(oC)	159.6	159.4

## 5.1. Send Out

- Send out pressure :

- Design : 98 bar
- Nominal : 95 bar
- Minimum : 50 bar

- Send out rates :

Average On yearly basis	5 MTPA
Peak	125% Average

## 5.2. Gas Characteristics

Gas characteristics will be according to Indian standard, OISD-STD-194 and Gujarat grid specifications

## 5.3. Performances to be guaranteed

The Plant performances will be guaranteed in order to maintain the required sendout and availability for both LNG importation and gas send-out.

## **6.0 OPTIMIZATION STUDY AND RECOMMENDED FACILITIES IN LNG TERMINAL**

### **6.1. LNG Storage Capacity Optimization**

Storage capacity optimization confirms the optimized tank capacity to be 2 X 185,000 m3 (Net).

This is represented by document “Ship and tank optimization” document no. P.004049 P05 0013.

### **6.2. LNG Storage Tanks Type Selection**

Following four different types of LNG storage tanks have been compared :

1. Single containment tank, self supporting type (SCT);
2. Double containment tank, self supporting type (DCT);
3. Full containment tank, self supporting type, with concrete roof (FCT);
4. Membrane tank with concrete roof (MT).

Based on the comparison studies, self-supporting, full containment tank with concrete roof (FCT) has been selected as the safest and most optimum solution.

This is represented in the document “LNG Storage Tanks Type Selection” – document no. P.004049 P21 0012.

### **6.3. LNG Vaporizers type selection**

Various options for Vaporization have been considered for Chhara LNG Terminal:

- Heat source: fuel gas
  - Submerged combustion vaporizers (SCV)
- Heat source: seawater
  - Open rack vaporizers (ORV)
  - Intermediate fluid vaporizers (IFV)
- Heat source: ambient air
  - Ambient air vaporizers (AAV)
  - Shell & tubes vaporizer combined with air heater

Based on the optimization studies covered under Optimized scheme and Estimated utility consumption, STV/air heaters supplemented by SCV for cold weather conditions are selected. Refer document No. P.004049 P08 0002

### **6.4. Power Source Optimization**

An optimization study is carried out to select the power source, and following 3 options were considered:

- Power supply from 66 KV Gujarat State Electricity grid and Gas Engine generators on standby
- Captive Power plant fed by Gas Engine generator and State Electricity grid power standby
- Captive Power plant fed by Gas turbine generator and State electricity grid power standby.

Based on the Optimization studies, grid power with backup from gas engine generators are considered as most optimum.

Refer document “Power Source Optimization” – document no. P.004049 E70 0453.

## **7.0 LNG UNLOADING FACILITIES AT THE PORT / MARINE FACILITIES**

### **7.1.1. Ship Berthing / Arm connection**

LNG will be delivered by LNG ships in the range of 80,000 to 266,000m<sup>3</sup> capacity. At ship arrival, the berthing and mooring manoeuvres will be managed by the port pilot with the assistance of pilots, tug boats and ship berthing monitoring system installed at the jetty which is connected to the master control room.

When the ship is safely moored and the communications from ship and shore are established, the vapour return arm and the LNG unloading arms will be connected. Subsequently cool down of the ship's transfer piping and the LNG unloading arms will be started with a small LNG flow from the ship after the confirmation of Emergency Shutdown System test.

### **7.1.2. Ship Unloading**

LNG will be unloaded by the ship unloading pumps. The LNG discharged from the LNG ship will flow via unloading arms to either or both the LNG storage tanks.

Three identical LNG Unloading Arms, each equipped with Powered Emergency Release Coupler (PERC) and Quick Connect/Disconnect Coupler (QCDC) for LNG unloading to the storage tank will be used to achieve the design ship unloading rate of 12,000 m<sup>3</sup>/h.

A Vapour Return Arm will be used to return some of the displaced gas from the LNG storage tanks back to the LNG ship by operating the Ship Return Gas Blower.

The flow rates into each LNG storage tank are adjusted by control valves installed on the tank's unloading line.

A part of BOG generated during unloading operation is returned to the cargo tanks of the LNG ship.

## **8.0 MARINE FACILITIES**

### **8.1. Jetty Head**

The jetty head will accommodate berthing of the LNGC and will be fit with equipment and systems that will allow safe and efficient operation works:

- The berthing dolphins with fenders and mooring hooks
- The mooring dolphins with mooring hooks
- The mooring line tensioning monitoring system
- The ship berthing assistance system
- The ship-to-shore link, for safe communication between ship and shore (phone, ESD and process signals), and its pneumatic back-up
- The LNG and BOG transfer arms, with their hydraulic package and position monitoring system. Each arm will be fitted with PERC to allow immediate disconnection in case of emergency and with QCDC to allow easy connection whatever would be waves and swells.
- The gangway and jetty crane
- Fire water monitors, installed on elevated platforms and remotely operated
- 1 dry chemical powder package, with monitor and flexible hoses, installed in main deck.
- The jetty K.O. drum

The operation will be monitored and controlled from the main control room (CCR) and from the jetty monitoring building.

To collect potential LNG spillage an impounding basin will be built at the jetty head.

## **8.2. Trestle**

The trestle (pipe rack) will connect the shore line to the jetty head. The space foreseen for the trestle shall be sufficient to accommodate the pipe installation whilst allowing the maintenance. The trestle supports the piping and also the power and instrumentation cable trays. Also a spare space will be included for the trestle connecting to Main jetty for additional unloading lines for future expansion.

The trestle will also support the access road to enable quick and safe access to the jetty head for safety and maintenance crews (including fire truck and crane access).

Expansion loop platforms will be installed every 300 m to accommodate pipe shrinkage and expansion.

The trestle, the structures and the piping systems will be designed to withstand all accidental and abnormal conditions (wind, earthquake, water hammers, wave shocks etc).

## **9.0 ONSHORE FACILITIES**

### **9.1. LNG storage**

LNG storage tanks will be full containment type as per API 620.

The net capacity of each one will be 185 000 m<sup>3</sup>.

Total storage capacity will be 370 000 m<sup>3</sup> (2 Tanks).

### **9.2. Terminal process**

The LNG terminal facilities are foreseen to cover the process functionalities:

- The connection with the marine facilities to receive the unloaded LNG and to return the boil-off gas to the ship.
- The storage of the LNG, as a buffer between the unloading and the send-out.
- The vaporisation of the LNG.
- The fiscal metering of the send-out gas.
- The pipeline connection (within the plant boundaries) with space for the pig station (launcher or receiver).
- LNG Truck loading facilities for export of LNG by Road tankers – 2 bays.

### **9.3. Ancillaries facilities**

Beside these process functionalities the following utilities and safety systems are foreseen:

- The electrical power supply, from Gujarat State Electricity Board grid.
- The control and monitoring system.
- The instrument and plant air supply.
- The nitrogen generation package for Wobbe Index adjustment, when required, and for sealing or maintenance purposes.
- The service water supply for make-up in cooling system and cleaning, from the port grid.
- The fire water system: service water tank, pumps (jockey and supply as per NFPA 20), the loop with hydrants and required accessories,
- The foam system and portable/mobile fire extinguishers to reduce fire impacts or to extinguish it.
- The nitrogen snuffing system to blow-off the fire at safety valves outlets.

**9.4. Buildings**

The LNG terminal buildings are:

- Security Gate house
- Administration building
- Workshop and warehouse
- Central Control Room building
- Jetty monitoring building
- High voltage incoming substation building
- Process electrical substation
- Utilities electrical substation
- Metering/ analyzer building
- BOG compressors and HP pumps shelters
- Watch towers at the corners

**10.0 RLNG EVACUATION PLAN**

For evacuating Regassified LNG cross country pipeline 30” diameter, approx 18.5 km of pipeline will have to be laid to connect to nearest Gas grid on GSPL network near Kodinar on Darod-Jafrabad section.

Refer “RLNG Evacuation plan” document No. P.004049 L78 0309

**11.0 PROJECT IMPLIMENTATION SCHEDULE**

Total Project duration from start of Project till commissioning works out to 54 Months.

**12.0 CAPEX / OPEX**

Description	Unit	Value
Capital Cost (without interest during construction (IDC))	Rs. Crores	4,796.85
Interest During Construction (IDC)	Rs. Crores	611.97
Capital Cost (with interest during construction (IDC))	Rs. Crores	5,408.82

**13.0 POLLUTION CONTROL MEASURES**

**13.1. Potential Emissions**

The LNG Import Terminal will produce various emissions during operations, summarized as follows:

Emissions to atmosphere

- Potential excess oxygen from the Nitrogen generation unit
- Exhaust gases from Gas Engine generators
- Exhaust gases from emergency back-up diesel generator
- Exhaust gases from emergency diesel fire water pump units
- Burned NG from the flare
- Pressure safety valve NG vent from KO drum at jetty
- Pressure safety valve NG vent from vaporisers.

Discharges to water

- Sanitary waste liquid effluent (after treatment in septic tank)
- Excess water from STV / Air heaters

Other emission sources (collected for controlled disposal)

- Laboratory chemical waste water
- Equipment lube oil leaks and oily water

Noise emission

- BOG Compressors
- HP LNG pumps
- Gas Engine generators

**13.2. Monitoring and Surveillance**

An environmental monitoring program will be developed and staffed with trained and qualified personnel to monitor the plant emissions and ambient conditions to ensure regulatory compliance.

Wastewater will be sampled and analysed on a regular basis.

An ambient air quality monitoring system will be established in the impact area, which will be determined using modelling results to sample particulates, SO<sub>x</sub>, and NO<sub>x</sub>.

Environment impact monitoring philosophy is covered in Continuous Emissions Monitoring System document no. P.004049 J21 0557

### **13.3. Environmental Impact**

SO<sub>x</sub> and NO<sub>x</sub> emissions will be controlled to meet applicable standards by the use of an appropriate stack height and gas exit velocity to promote dispersion, and also by the modern combustion control technologies, respectively.

Plant wastewaters will be treated and discharged to the sea after meeting the Central Pollution Control Board / Gujarat State control board norms.

All plant emissions will meet the regulatory standards imposed by the Central and/or Gujarat State Pollution Control Boards; therefore, no adverse impacts to the air or water quality in or around the site are anticipated.

Pollution control and mitigation measures are covered under Effluent disposal philosophy document No. P.004049 C61 0056 and Pollution Control Measures document No. P.004049 C61 0057.

## **14.0 SAFETY MEASURES**

### **14.1. Safety Philosophy**

The Safety philosophy is based on a staged approach from:

- Well defined plant operating envelopes and a high level of plant automation (within the Process Control Systems);
- An extensive detection systems of abnormal conditions (within the Safety Control System);
- An Emergency Shutdown System to isolate affected plant parts and limit the effects of abnormal conditions (based where practical on a “fail-safe” design practice), which is supplemented with, assisted by;
- Passive design solutions within the plant to minimise the effects of accidents, such as selective LNG spill collection, avoiding the collapse of main structures from cold splash or fire heat-flux influence, supplemented by;
- An active protection system, inclusive stopping of uncontrolled sources of ignition and a fire protection system. The fire protection systems are important either to cool surrounding facilities or to segregate process area and reduce the risk of further escalations of incidents. The active fire fighting systems rely on permanent facilities and use the operation crew as first line of defence.

The safety philosophy approach aspects are described in the document “Fire Hazard and Safety systems” document No. P.004049 S78 1009.

**14.2. ESD Philosophy**

The LNG terminal will be monitored and controlled from a continuously manned Central Control Room (CCR) located in the control Room building. Emergency Shut Down (ESD) system is part of the main Plant Control & Monitoring system.

ESD system shall be based on following principles:

ESD shall be designed to monitor key safety variables and equipment and respond automatically or to operator initiated commands, in such a way as to reduce the risk of hazardous or destructive incidents.

The ESD system shall be independent of the primary control system and will perform the following functions regardless of availability of the PCS:

- Monitor dangerous conditions and take appropriate shut-down action.
- Rapidly and reliably detect a fire condition, a LNG spillage, a leakage of flammable gas or any other specific incident.
- Respond to manual requests for shut-down, Reset and override from the operator consoles or from the field as per requirements.
- Record on a suitable Sequence of Event Recorder (SER) all events / alarms and actions taken by the ESD system.
- Indicate to the control operator that a trip has been initiated and has been successfully completed or has not been successfully completed.

The implementation of the ESD system shall consist in selecting for each safety function, an architecture which satisfies the specifications of said function and / or ensuring the P&ID requirements which also correspond to the safety integrity requirements.

The ESD System shall be based on fail-safe dual redundant Programmable Logic Controller (PLC).

I/O module, power supply module and communication module shall be redundant.

PLC shall have watch dog timer for self diagnosis.

Emergency Shut Down Philosophy (ESD) is described in document no. P.004049 J21 0558.

**15.0 PROVISION FOR FUTURE EXPANSION**

The plant layout has been developed in such a way that future extension can be realized from 5 MMTPA to 10 MMTPA. Also, the area considered takes care of the plant expansion up to 10 MMTPA.

Trestle from Terminal to Main jetty is designed with spare space for accommodating LNG unloading pipeline for simultaneous unloading of LNG cargo from Main and Standby jetty.

**16.0 LIST OF EXCLUSIONS FROM FEASIBILITY REPORT AND FURTHER STUDIES / WORK TO BE CARRIED OUT**

In this report Marketing study is not included.

Further studies / work to be performed are:

- FEED / EPC for LNG Terminal
  - Additional soil investigations for the proposed berth layouts and at tank location for accurate determination of foundation design
  - Higher diffraction co-efficient may be envisaged once dredging has been carried out and hence wave modelling will need to be carried out to assess the wave penetration within the harbour basin for proposed LNG Terminal.
  - Optimization of approach channel dimensions can be carried out during detail engineering
  - To assess the operational conditions within the harbour basins, 3D model studies will need to be conducted to assess the tranquillity conditions at the proposed LNG berths and ship motion studies.
  - Assessment for berth unavailability persistency to be carried out during detail engineering based on the persistence of cyclonic conditions in the area.
  - Ship simulation and manoeuvring studies can be conducted as an optional study for further optimization of the approach channel
  - Seismo tectonic study and Tsunami Wave record review
  - Detailed QRA for Jetty and Regasification facilities

**17.0 CONCLUSIONS AND RECOMMENDATIONS**

In order to achieve the project schedule aiming to start the Plant operation in Dec 2017, the next steps would include:

- Contract award for engineering partner.
- Seismo- tectonic survey and soil investigation
- Obtaining the construction and operation permits
- Area grading, backfilling and soil improvement
- The negotiations for LNG supply in order to define the LNG sources and its characteristics. These sources and characteristic will allow a correct and optimum sizing of the equipment and tanks.
- Discussions / signing of MOU with Gas transmission companies (GSPL) for RLNG evacuation pipeline connectivity to Gas transmission network.
- Select the most appropriate EPC contractor.

Σ Σ Σ

**PRE-FEASIBILITY  
REPORT  
FLOATING STORAGE &  
REGASIFICATION UNIT  
(FSRU)**

# **HPCL Shapoorji Energy Limited.**

## **Proposed LNG Terminal at Chhara Port – FSRU Study**



## **Feasibility Study Report**

**Early commissioning using FSRU**

**Final Report**

**December 2013**

# Proposed LNG Terminal at Chhara Port – FSRU Study

## Feasibility Study Report

### Early commissioning using FSRU

#### Final Report

## Prepared for

# HPCL Shapoorji Energy Limited.

#### Prepared under the management of:

Name: *Tarun Kaw*  
Position: *Project Manager*

Signature:

#### Reviewed and approved by:

Name: *Suren Vakil*  
Position: *Managing Director*

Signature:

Reference: *BMTI/1222/VER 1.2*  
Date: *December 2013*

## Executive Summary

M/s Hindustan Petroleum Corporation Ltd (HPCL) in a Joint Venture with SP Ports Private Limited (SPPPL) is in process of setting up a LNG re-gasification terminal at Chhara in district Junagadh, Gujarat through their joint venture company – HPCL Shapoorji Energy Limited (HSEL).

HSEL has carried out Detailed Feasibility Studies for the on-shore based storage and re-gasification terminal Through Tractable Engineering and is now desires to undertake technical feasibility studies for installation of FSRU based terminal as a bridging facility to bridge the gap between readiness of the port marine facilities and on shore topside facilities.

BMT Consultants India Limited (BMTCI) has been engaged by HSEL develop a technical feasibility report on marine and process aspects for early commissioning LNG terminal with FSRU. FSRU can be deployed to take advantage of the time lag between readiness of construction of marine facilities and on share storage and regasification facilities to feed the market early.

The main objectives of the study were:

- Assess the technical feasibility of the FSRU operations at Chhara
- Conceptual study for selection of possible options for FSRU and undertake a high level conceptual assessment and sizing of FSRU
- Assess the various aspects of the proposed jetty as designed in DFR Study for its suitability for FSRU operation.
- Prepare block cost estimates CAPEX/OPEX for the project investment.

Basis of design agreed with HSEL for the study was as follows:

- Regasification capacity to be considered - minimum of 2.5 MTPA
- Maximum size of LNG carrier sizes to be considered – Qmax

### Layout options

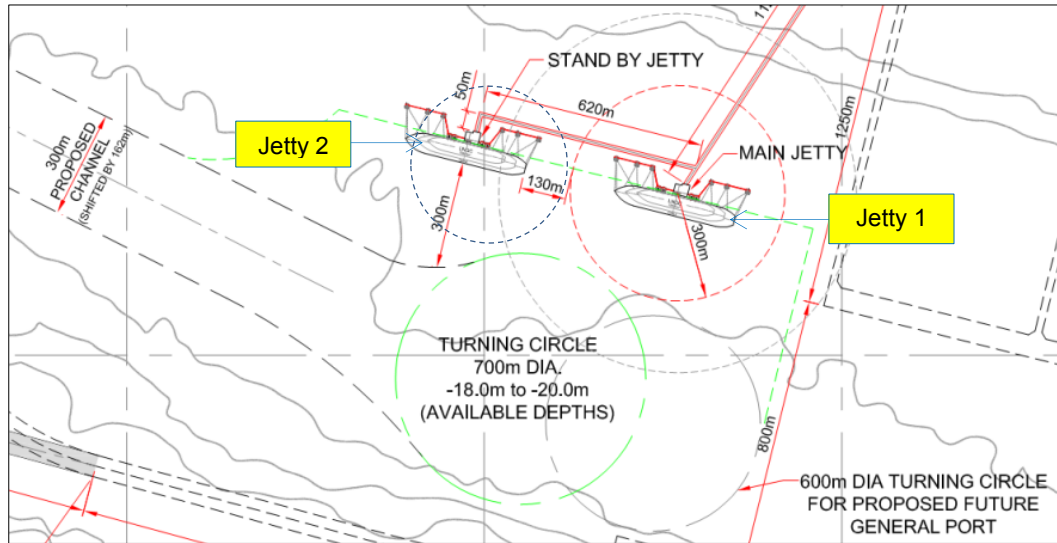
A detailed review of the available studies was undertaken, and a site information note has been provided in the body of the report. All the reports were made available to BMTCI by HSEL for review and carrying out the feasibility with various layout options was using following considerations:

- Existing jetty heads including stand-by jetty has been considered as final and no change in the location, orientation and configuration was allowed.
- Detailed report on the tranquillity studies for the Chhara Port was also reviewed and feasibility was established as detailed in the report. BMTCI also recommends more detailed and location specific tranquillity studies to be carried out in the advanced stages of the project execution for determining design and operating requirements for FSRU operations.

Following two options were shortlisted and studied in the report:

- Option A – Double banking at Main Jetty (Jetty 1)
- Option B – Tandem operations on Jetty 1 and stand-by jetty (Jetty 2)

Both the cases have been evaluated in isolation with an effort to arrive at a relative technical assessment of both the options.



### Infrastructure requirement

After finalisation of the layouts, a detailed assessment was carried out for understanding of the infrastructure and equipment requirements for both the options. Investments were categorised into the following sections;

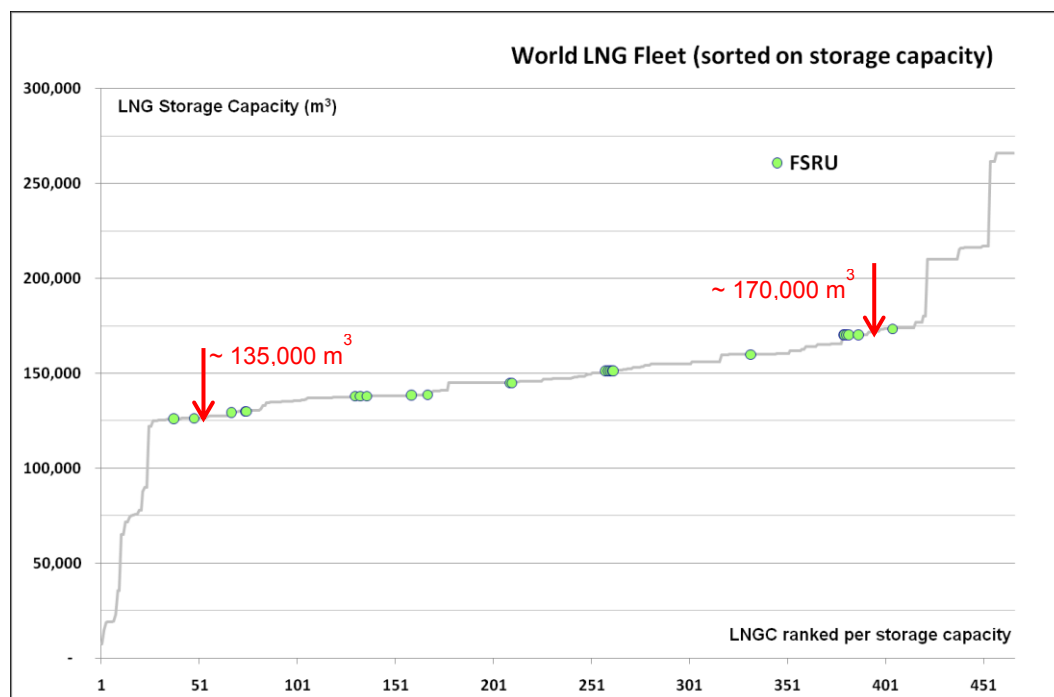
- **Block 1: Shared Investment:** - The infrastructure & equipment required by FSRU terminal that are common with land-based terminal phase-1, as well as those which are required to be advanced for eliminating delays in switchover to land-based terminal, are a part of this block.
- **Block 2: Additional Investment:** - The infrastructure & equipment required by FSRU terminal which are additional to land-based terminal phase-1, are a part of this block.
- **Block 3: Operational Expenditure:** - Operation & maintenance expenditure for all infrastructure & equipment in Block 1 & Block 2 are a part of this block.

Summary of the infrastructure requirements for both the options is as below:

Block	Sub-heads	Option A	Option B
BLOCK 1 : SHARED INVESTMENT	Trestle & Jetty	●	●
	Marine equipment	●	●
	LNG arms	●	●
	LNG equipment	●	●
	LNG pipeline	●	●
	Gas dispatch	●	●
	Power infrastructure	●	●
	Jetty control room and all safety system	●	●
Block 2 : ADDITIONAL INFRASTRUCTURE	Trestle & Jetty	●	●
	Marine equipment	●	●
	LNG arms	○	●
	LNG equipment	○	●
	LNG pipeline	○	●
	STS LNG hose	●	○
	NG arm and equipment	●	●
	Gas pipe line	●	●
LEGEND ○ Not Applicable ● Applicable			

### FSRU availability and sizing

All the existing and under construction FSRU specifications were reviewed and a detailed vessel size analysis for one FSRU was undertaken. Typically the LNGCs which have been refurbished and converted into FSRUs have a low storage capacity, while the FSRUs which are new-built have greater LNG storage capacity. The storage capacity vs. World LNG Fleet (numbers) is as given below, with the FSRUs marked in green markers.



Range of FSRU size availability falls between 135,000 m<sup>3</sup> to 170,000 m<sup>3</sup> as highlighted in the above graphic. Given the overall trend for large storage capacity new-built FSRUs, for the purpose of this study, design vessel size of 150,000 m<sup>3</sup> with a re-gas capacity of 2.5-3 MTPA has been considered.

Facility for receiving LNG including FSRU is designed for handling Q<sub>max</sub> vessels. This comes with a constraint that the capacity of the supply vessel is much larger than the storage vessel, which would translate into higher unloading time and berth occupancy or part shipment may be required. Typically, the supply vessel should be lesser or equal to the capacity of the FSRU. However, from design perspective, we do not anticipate any significant change in the technical feasibility and the costs.

## Marine assessment

Technical feasibility of the options was studied in detail from marine assessment perspective covering the following heads:

- Mooring layout as available in the DFR was studied and critically assessed for use with the two options under the purview of this study. Various mooring configurations were studied based on a desk top mooring assessment and it was concluded that:
  - For option A, two additional mooring dolphins will be required for safe mooring of LNGC. This assessment was done using Q<sub>max</sub> LNGC, but requirement of additional mooring dolphins is still envisaged for smaller supply vessels as well.
  - No changes in the mooring layout are envisaged for option B
  - An additional platform to accommodate the HP NG arm will be required adjacent to Jetty 1. However, as an Option, mooring of a FSRU with a 10m shift fore side to accommodate a HP loading arm on the unloading platform was also investigated and found feasible. The downside of this alternative is that the FSRU will have to be moored port side, and emergency sail out scenarios can be difficult. A detailed risk assessment for such a case needs to be carried out.

- No changes in the mooring layout are envisaged for option B
- Docking and mooring system requirements for both the options were studied and detailed requirements have been provided in the body of the report.
- Similarly, fendering requirements for both the options were studied and detailed requirements have been provided in the body of the report.
- Navigation safety and requirements were assessed from the perspective of:
  - During the offloading process, the mooring arrangement should ensure that the carrier manifold stays within the operating envelope of the loading arm during LNG transfer.
  - The FSRU will be equipped with either standard unloading arms or flexible hoses. The unloading arms will be similar to the type used in onshore terminals, but modified to account for relative motions between LNGC and FSRU. The FSRU will also be fitted with equipment for guiding the arms onto the carrier's connection flanges.
- General recommendations for operational wave height limits (Hs) for safe unloading arm operations were arrived at as follows:
  - Option A: Ship to Ship (STS) operations, Hs < 0.7m using hard arms.
  - Operating limits for use of cryogenic hoses must be studied in details, but are expected to be in the range of Hs = 0.7 to 1.5m.
  - Option B: Conventional operations. Hs < 1.5m
  - ***It must be noted that the above figures are indicative only and should be used with caution for planning purposes only. Detailing modelling and mooring analysis should be carried out and limits w.r.t. relative motions of the vessels must be known and cargo transfer system then designed accordingly.***
- Under Keel clearance was studied and considered adequate
- A desktop assessment for manoeuvring safety was carried out and considered adequate.

***From an overall perspective both the options are considered technically feasible. For option A, the only major show stopper could be the tranquility conditions at the berth for STS operations. Indicative limits for STS operations have been provided.***

## Project timeline

The project timeline has been worked out, based upon industry benchmarks. In general the timeline is estimated to be 23 months and 27 months for the two options Option-A and Option-B. A broad outline follows:

- Marine activities fall on the critical path. Other activities are subject to the marine construction. Therefore all marine activities considered together have an estimated timeline of 18 months and 22 months for Option-A and Option-B respectively.
- Start of the topside activities are constrained by two issues. The equipment delivery lead-time and the availability and suitability of the location, i.e. trestle, jetty, foundation, etc. Considering all the process activities together, we estimate timelines of 18 months and 20 months for Option-A and Option-B respectively.
- A FSRU availability timeline of 15 months has been considered, which is a broad and conservative estimate. In practice this may vary from as low as 6 months to as high

as 24 months, depending on the current availability and the commitment status of different suppliers.

For Option A, FSRU procurement and delivery is the critical path activity and this is subject to market dynamics and may not eventually cause a time constraint. If FSRU is found not on the critical path, then long lead items such as high pressure NG arm and cryogenic LNG arms, along with jetty construction are found to be on the critical paths.

For Option B, since two jetties have to be constructed, the marine construction activities fall on the critical path. This leads to some process commissioning activities also to fall on the critical path. FSRU delivery is therefore a non-critical activity.

## Budget cost estimates

Cost estimates were based on secondary sources and therefore may be considered as budgetary costs estimates with a tolerance of +/- 20%.

Cost estimation for Block 1 activities were not made, and cost for development of additional infrastructure for both the options are as tabulated below:

Block	Million USD
Option A – Additional infrastructure CAPEX (Block 2)	30.90
Option A – OPEX (Block 3)	67.00
Option B – Additional infrastructure CAPEX (Block 2)	69.80
Option B – OPEX (Block 3)	71.80

Details on preservation costs and disposal values have been provided.

## Environmental considerations

Broad assessment of environmental consideration was carried out and it was concluded the activity is a permissible activity requiring environmental clearance from the Ministry of Environment and Forests (MoEF), Government of India. The typical process leading to environmental clearance has been provided in the report and is summarised as below:

- A fresh TOR for the LNG terminal with FSRU to be sought from MoEF for EC of the LNG Terminal..
- Following aspects need to be included in the EIA report of the LNG Terminal:
  - Description of the FSRU focusing on the process flow rates, seawater requirements for vaporizing LNG (125,000 KLD) and safety measures included in the design. The layout of the natural gas pipelines needs to be chosen such that future expansion of the port does not interfere with operations of the LNG terminal.
  - Prediction chapter needs to include
    - Thermal dispersion modeling identifying the intake and outfall location for discharge of coldwater
    - Impacts on marine ecology due to the disposal of cold water
    - Entrainment of marine life at the intake system
    - Release of free chlorine at the outfall
  - Risk Analysis

- Quantitative Risk Analysis - Consequence Analysis, frequency, computation of risk, separation zones for FSRU
- Navigational safety
- EMP/DMP
  - Include onsite and offsite plans, training, awareness and drills
- The EIA report for the LNG terminal including FSRU will need to be submitted for CRZ approval from State Government.
- An application for environmental clearance will need to be made together with the EIA study report, HTL/LTL demarcation, minutes of the Public hearing, CRZ approval and the Detailed Project Report.

### Way forward

After consideration of all the above factors, Option A is the preferred option owing to being the cost effective in relation to option B. **We recommend Option A be considered as the preferred option.**

We suggest the following way forward:

- Detailed and location specific tranquillity studies
- Application to MoEF for issue of TOR for the LNG terminal with an FSRU option.
- An application for environmental clearance together with the EIA study report, HTL/LTL demarcation, minutes of the Public hearing, CRZ approval and the Detailed Project Report.
- A separate risk assessment
- Undertake an operational-based and design-based mooring evaluation.

## Contents

<b>1</b>	<b>Introduction .....</b>	<b>1</b>
1.1	Background .....	1
1.2	Scope of work .....	1
1.3	Meetings and visits .....	2
1.3.1	<i>Project kick-off meeting and site visit</i> .....	2
1.4	Data consulted .....	2
1.4.1	<i>List of data received</i> .....	2
1.4.2	<i>Basis of design received from SP/HPCL</i> .....	3
1.4.3	<i>Data limitations</i> .....	4
1.4.4	<i>Design constraints</i> .....	4
1.5	Format of the report .....	4
<b>2</b>	<b>Site information.....</b>	<b>6</b>
2.1	Location.....	6
2.2	Chhara port .....	6
2.2.1	<i>Marine master plan</i> .....	6
2.2.2	<i>Land use</i> .....	7
2.2.3	<i>LNG handling facility</i> .....	7
2.3	Met-Ocean conditions .....	8
2.3.1	<i>Tides</i> .....	9
2.3.2	<i>Currents</i> .....	9
2.3.3	<i>Wind and waves</i> .....	9
<b>3</b>	<b>Discussion on layouts and infrastructure requirement.....</b>	<b>12</b>
3.1	Project description .....	12
3.2	Layout options .....	12
3.3	Discussion on options .....	13
3.3.1	<i>Option A</i> .....	13
3.3.2	<i>Option B</i> .....	15
3.3.3	<i>Pipeline rack adequacy</i> .....	16
3.4	Infrastructure requirements .....	17
3.4.1	<i>Shared investment –Block 1</i> .....	17
3.4.2	<i>Additional investment block – Block 2</i> .....	19
3.4.3	<i>Operational expenditure (OPEX)</i> .....	22
<b>4</b>	<b>FSRU availability and sizing .....</b>	<b>24</b>
4.1	FSRU availability.....	24
4.2	FSRU fleet.....	24
4.2.1	<i>Golar LNG</i> .....	25
4.2.2	<i>Hoegh LNG</i> .....	26
4.2.3	<i>Excelebrate Energy</i> .....	26
4.2.4	<i>BW Gas</i> .....	27
4.2.5	<i>OLT Offshore</i> .....	28
4.2.6	<i>Others LNG shippers</i> .....	28
4.3	FSRU sizing .....	28

4.4	Summary.....	29
<b>5</b>	<b>Marine assessment.....</b>	<b>31</b>
5.1	Mooring layout assessment .....	31
5.1.1	<i>Dolphin spacing</i> .....	32
5.1.2	<i>Mooring dolphin set-back</i> .....	32
5.1.3	<i>Mooring line angle criteria</i> .....	32
5.1.4	<i>Mooring layout</i> .....	33
5.1.5	<i>Gas discharge</i> .....	35
5.2	Docking and mooring systems.....	38
5.2.1	<i>Fendering requirement</i> .....	41
5.3	Navigational requirements .....	42
5.3.1	<i>Wave tranquility</i> .....	42
5.3.2	<i>Wind</i> .....	45
5.3.3	<i>Under Keel clearance</i> .....	47
5.3.4	<i>Manoeuvring safety</i> .....	49
5.4	Summary.....	50
<b>6</b>	<b>Early commissioning timelines and cost assessment .....</b>	<b>51</b>
6.1	Project time line.....	51
6.1.1	<i>Marine facilities</i> .....	51
6.1.2	<i>Topside facilities</i> .....	51
6.1.3	<i>FSRU timeline</i> .....	52
6.1.4	<i>Statutory clearances</i> .....	52
6.1.5	<i>Breakwater</i> .....	52
6.1.6	<i>DPR / FEED</i> .....	52
6.1.7	<i>Critical path</i> .....	53
6.2	Budget cost estimates.....	56
6.2.1	<i>CAPEX &amp; OPEX</i> .....	56
6.2.2	<i>FSRU lease estimates basis</i> .....	59
6.2.3	<i>Preservation &amp; disposal value</i> .....	59
<b>7</b>	<b>Process description and environmental considerations .....</b>	<b>60</b>
7.1	Brief description of FSRU .....	60
7.1.1	<i>LNG reception from LNGC</i> .....	60
7.1.2	<i>LNG Re-gasification to NG and dispatch</i> .....	61
7.1.3	<i>Boil-off gas (BOG) management</i> .....	61
7.1.4	<i>Infrastructure requirements</i> .....	61
7.2	Environmental considerations.....	62
<b>8</b>	<b>Conclusion and way forward .....</b>	<b>65</b>
8.1	Conclusion .....	65
8.2	Way forward.....	65
<b>9</b>	<b>Drawings.....</b>	<b>67</b>

## Tables

Table 2-1:	Predicted tide levels at Chhara - Indian Admiralty Chart 206 & 207 .....	9
Table 2-2:	Summary of offshore and near shore wave characteristics extracted from EIA report.....	11
Table 3-1:	Block 1 infrastructure requirements.....	19
Table 3-2:	Block 2 infrastructure requirements.....	22
Table 4-1:	Summary of FSRU fleet.....	29
Table 4-2:	FSRU generic specifications .....	30
Table 5-1:	Calculation of gross depth requirements.....	48
Table 6-1:	Budget CAPEX estimates Option-A; Block-2 .....	57
Table 6-2:	Budget OPEX estimates Option-A; Block-3 .....	57
Table 6-3:	Budget CAPEX estimates Option-B; Block-2 .....	58
Table 6-4:	Budget OPEX estimates Option-B; Block-3 .....	58

## Figures

Figure 2-1:	Google earth image showing location of the port.....	6
Figure 2-2:	Marine master plan of Chhara Port .....	7
Figure 2-3:	LNG berthing facility .....	8
Figure 2-4:	LNG back up area .....	8
Figure 3-1:	Location of options in proposed Chhara Port.....	13
Figure 3-2:	Pipe line routing superimposed with option A .....	15
Figure 3-3:	Pipe line routing superimposed with option B .....	16
Figure 4-1:	Storage Capacity (m <sup>3</sup> ) vs. World LNG Fleet.....	28
Figure 5-1:	Option A – Mooring arrangement on mooring layout proposed in DFR..	33
Figure 5-2:	Option A – Alternative mooring layout.....	34
Figure 5-3:	Option B – Tandem operations on adjacent jetties .....	35
Figure 5-4:	FSRU berthing SST.....	36
Figure 5-5:	FSRU berthing PST.....	37
Figure 5-6:	FSRU berthing PST – moored with a 10m shift fore of the ship .....	38
Figure 5-7:	Typical STS configuration.....	43
Figure 5-8:	Wind scatter table .....	46
Figure 5-9:	Conceptual design of underkeel clearance (UKC) requirements .....	49
Figure 6-1:	Project timeline – Option A.....	54
Figure 6-2:	Project timeline – Option B .....	55
Figure 7-1:	FSRU terminal block diagram.....	60

## Appendix

Appendix A:	Qualitative Risk Assessment
-------------	-----------------------------

## SYMBOLS AND ABBREVIATIONS

Symbols and abbreviations used are generally in accordance with the following list.

### 1 Proper names and organisations - India

BIS .....	Bureau of Indian Standards
BMT CI.....	BMT Consultants (India) Private Limited
Gol .....	Government of India
IMD .....	Indian Meteorological Department
MoEF .....	Ministry of Environment and Forests
MoS .....	Ministry of Shipping
NIOT .....	National Institute of Ocean Technology
Sol .....	Survey of India
HPCL.....	Hindustan Petroleum Corporation Ltd
SPPPL .....	Shapoorji Pallonji Ports Private Limited
HSEL.....	HPCL Shapoorji Energy Limited
CES.....	Consulting Engineering Services Pvt. Ltd

### 2 Proper names and organisations – Other

BA .....	British Admiralty
BS .....	British Standard
IMO .....	International Maritime Organization
ISPS.....	International Ship and Port facility Security code
NCEP .....	National Centre for Environmental Prediction
NCAR.....	National Centre for Atmospheric Research
OCIMF .....	Oil Companies International Marine Forum
PIANC .....	Permanent International Association of Navigation Congresses
OISD .....	Oil Industry Safety Directorate
SIGGTO.....	Society of International Gas Tanker and Terminal Operators

### 3 Other abbreviations

Approx. ....	approximately
cif .....	cost, insurance, freight
dia .....	diameter
fob.....	free on board
max .....	maximum
min .....	minimum

No .....	number (order) as in No 6
nr.....	number (units) as in 6 nr
DAS .....	Docking Aid System
DFR .....	Detailed Feasibility Report
DMP .....	Disaster Management Plan
EIA .....	Environmental Impact Assessment
EMP .....	Environment Management Plan
FSRU .....	Floating Storage and Re-gasification Unit
LNGC.....	LNG carrier
HAT.....	Highest Astronomical Tide
MHWS .....	Mean High Water Spring tides
MSL .....	Mean Sea Level
MLWS .....	Mean Low Water Spring tides
LAT .....	Lowest Astronomical Tide
HTL.....	High tide line
CD.....	Chart Datum
LOA.....	Length overall (of a ship)
LNG .....	Liquefied Natural Gas
M.....	“mega” or one million (10 <sup>6</sup> )
MoU .....	Memorandum of Understanding
NG .....	Natural Gas
ToR.....	Terms of Reference
UKC .....	Under Keel Clearance
STS.....	Ship to ship
QRMH.....	Quick release mooring hooks

**4****Units of measurement****Length, area and volume**

mm.....	millimeter(s)
m.....	meter(s)
km .....	kilometer(s)
n. mile .....	nautical mile(s)
mm <sup>2</sup> .....	square millimeter(s)
m <sup>2</sup> .....	square meter(s)
km <sup>2</sup> .....	square kilometer(s)

ha .....	hectare(s)
m <sup>3</sup> .....	cubic meter(s)
kl .....	kilo liter(s)
MSCMD .....	Million standard cubic metres(of natural gas) per day
MTPA.....	Million tonnes per day
mbtu.....	Million British thermal units

### Time and time derived units

s .....	second(s)
min .....	minute(s)
h.....	hour(s)
d.....	day(s)
wk .....	week(s)
mth.....	month(s)
yr.....	year(s)
mm/s .....	millimeters per second
km/h .....	kilometers per hour
m/s .....	metres per second
knot.....	nautical mile per hour

### Mass, force and derived units

kg .....	kilogram(s)
g.....	gram = kg x 10 <sup>-3</sup>
t.....	tonne = kg x 10 <sup>3</sup>
Mt.....	million tonnes = t x 10 <sup>6</sup>
displacement...	the total mass of the vessel and its contents. (This is equal to the volume of water displaced by the vessel multiplied by the density of the water.)
DWT.....	dead weight tonne, the total mass of cargo, stores, fuels, crew and reserves with which a vessel is laden when submerged to the summer loading line. (Although this represents the load carrying capacity of the vessel it is not an exact measure of the cargo load).

### Other units

°C .....	degrees Celsius (temperature)
tpd.....	tonnes per day
tph.....	tonnes per hour
MW .....	Mega Watts

# 1 Introduction

## 1.1 Background

M/s Hindustan Petroleum Corporation Ltd (HPCL) in a Joint Venture with SP Ports Private Limited (SPPPL) is in the process of setting up a LNG re-gasification terminal at Chhara in District Junagadh, Gujarat.

HSEL has carried out Detailed Feasibility Studies for the on-shore based storage and re-gasification terminal Through Tractable Engineering and is now desires to undertake technical feasibility studies for installation of FSRU based terminal as a bridging facility to bridge the gap between readiness of the port marine facilities and on shore topside facilities.

BMT Consultants India Limited (BMTCI) has been engaged by HSEL develop a technical feasibility report on marine and process aspects for early commissioning LNG terminal with FSRU. FSRU can be deployed to take advantage of the time lag between readiness of construction of marine facilities and on share storage and regasification facilities to feed the market early.

## 1.2 Scope of work

The purpose of this study is to arrive at a sufficiently accurate definition of planned marine facilities for setting up of a FSRU based terminal at the selected location for future LNG jetties at the proposed Chhara terminal.

The main objectives of the study are:

- To review available information on the proposed Chhara terminal provided by the client.
- Carry out conceptual study for selection of possible options for FSRU
- Assess the various aspects of the proposed jetty as designed in the DFR Study for its suitability for FSRU operation. Also, recommend changes in the jetty layout for accommodating a FSRU taking into account the following:
  - Berthing of FSRU and unloading arrangement for the LNG supply vessel.
  - Evacuation of RLNG from FSRU to sendout facilities of the proposed LNG terminal.
  - Environment & Safety considerations.
- Undertake a high level conceptual assessment and sizing of FSRU keeping in view the LNG volume as per client requirement defined above.
- Assess the Technical feasibility of the FSRU keeping in view the following aspects.
  - Total investment for 2/3/5 years (Capex, Opex, Contingencies, etc.) for leased unit.
  - Economics of vessels sizing and lease model for FSRU.
  - Identifying all regulatory and Environmental clearances required.

- Identifying various milestones & project timelines to start FSRU installation and operations keeping in view the project schedule for implementation of overall LNG re-gasification terminal decided upon in the DFR.
- Assess constructability aspects keeping in view the operating FSRU while LNG terminal construction is in progress.
- Undertake qualitative risk assessment for this scenario.
- Prepare block cost estimates CAPEX/OPEX for the project investment.

### 1.3 Meetings and visits

#### 1.3.1 Project kick-off meeting and site visit.

A kick off meeting to discuss the way forward and project kick off meeting was held at Mumbai on 1<sup>st</sup> October. Officials from SP, HPCL and BMT attended the meeting. Various options were discussed in the meeting and following two options were finalised to be studied:

- FSRU Double Banking with LNGC
- FSRU Tandem Berthing with LNGC (Using Two Jetties)

### 1.4 Data consulted

#### 1.4.1 List of data received

The following data was received from HSEL.

- Environmental Impact Assessment & Environmental Management Plan report for Phase 1 of Port at Chhara by CES
- Detailed Feasibility Report for Chhara LNG project by Tractabel Engineering. The contents of the DFR received were as follows:
  - Process Design Basis
  - Optimized Scheme & Estimated Utility Consumptions
  - BOG Handling
  - Send-out system-Relief System
  - Equipment Sparing Philosophy
  - Fire Water System
  - Marine specifications
  - Civil design basis
  - Effluent Disposal Philosophy
  - Pollution control and Mitigation
  - Piping Design Basis
  - Piping Material Specification
  - Site screening
  - Valves specification
  - Low Temperature Thermal Insulation

- Painting and Protective coatings
  - Welding, Heat Treatment and Inspection
  - Specifications for Cryogenic Marine Transfer Arms
  - Mooring line tensioning & Ship approach monitoring
  - Ship Access Gangway
  - Project Design Basis
  - Low Temperature Flare Stack Specification
  - Applicable Codes & Standards
  - Project Execution Plan
  - Project Schedule
  - List of Statutory and Regulatory Approvals
  - Operation and Maintenance Organization
  - Utilities and Auxiliary systems
  - Marine Design
  - Cryogenic Insulation Classes
  - Electrical Design Basis
  - Hazardous area classification and choice of electrical material
  - Power source optimization
  - Instrumentation Specification for package unit
  - Fire, Spill & Gas Detection system
  - Communication and Security
  - Instrument & Control system
  - Plant Control and Monitoring System
  - Continuous Emissions Monitoring System
  - Emergency Shut-down (ESD) Philosophy
  - Fire, Hazard & Safety Systems
  - RLNG Evacuation Plan
  - LNG Truck Tanker Loading facilities
  - Custody transfer description
  - Risk Analysis, & DMP
- Project drawings

#### 1.4.2 Basis of design received from SP/HPCL

Based on the advice received from SP/HPCL, the following design basis has been adopted:

- Regasification capacity to be considered - minimum of 2.5 MTPA.
- Maximum size of carrier to be considered –  $Q_{\max}$

### 1.4.3 Data limitations

The study was based upon available site information and data. Where these were unavailable, assumptions have been made. The data and related assumptions will need to be carefully elaborated and re-examined during subsequent stages of the project development.

The data limitations of this study apply in particular to:

- Numerical model studies for the terminal plan to understand the wave and current regime at the proposed jetty location. *Relevant reports for the overall port development were critically reviewed for the study and it is recommended detailed studies are undertaken location specific to LNG terminal in the advanced stages of execution of this project. Current review of the data is considered adequate for determination of the feasibility at this stage.*
- Design, alignment and extent of breakwater protection proposed for the LNG jetty location. *Detailed mathematical model studies will be needed to be undertaken in the detail design stage. Current review of the data is considered adequate for determination of the feasibility at this stage.*
- Risk assessment of FSRU. *Risk assessment for LNG terminal including marine facilities as carried out in Detailed Feasibility Study has been reviewed. A fresh study would need to be undertaken to update the report for FSRU and STS operations.*

The above list is not exhaustive.

### 1.4.4 Design constraints

Given the overall trend for large storage capacity new-built FSRUs, range of FSRU availability falls between 135,000 m<sup>3</sup> to 170,000 m<sup>3</sup>. For the purpose of this study, design vessel size of 150,000 m<sup>3</sup> with a re-gas capacity of 2.5-3 MTPA has been considered.

## 1.5 Format of the report

The following chapters constitute the remainder of this report:

**Chapter 2** provides the site information consolidated after review of the data available with BMT for the study. The section mainly elaborates on the environmental information specific to the site relevant for the feasibility of locating a FSRU based LNG terminal at the proposed LNG jetty in Chhara port.

**Chapter 3** elaborates on infrastructure requirements for the layout options, investment required thereof and discussion on various layouts

**Chapter 4** provides a detailed vessel size analysis for FSRU sizing.

**Chapter 5** elaborates on the technical feasibility of the options from the marine safety, mooring layout and manoeuvrability perspectives.

**Chapter 6** provides a detailed time lines for the options studied and cost estimates.

**Chapter 7** provides a brief explanation on the process description, environmental considerations and recommendations for obtaining environmental clearance

**Chapter 8** outlines recommendations and a way forward

**Chapter 9** Drawings

## 2 Site information

### 2.1 Location

Chhara village is located at Latitude 20°43'19.56"N and Longitude 70°44'28.73"E in the Junagadh District of Gujarat State. The proposed green field port is located at Latitude 20°43'14.23" N and Longitude 70°44'54.92"E.

**Figure 2-1: Google earth image showing location of the port**



### 2.2 Chhara port

#### 2.2.1 Marine master plan

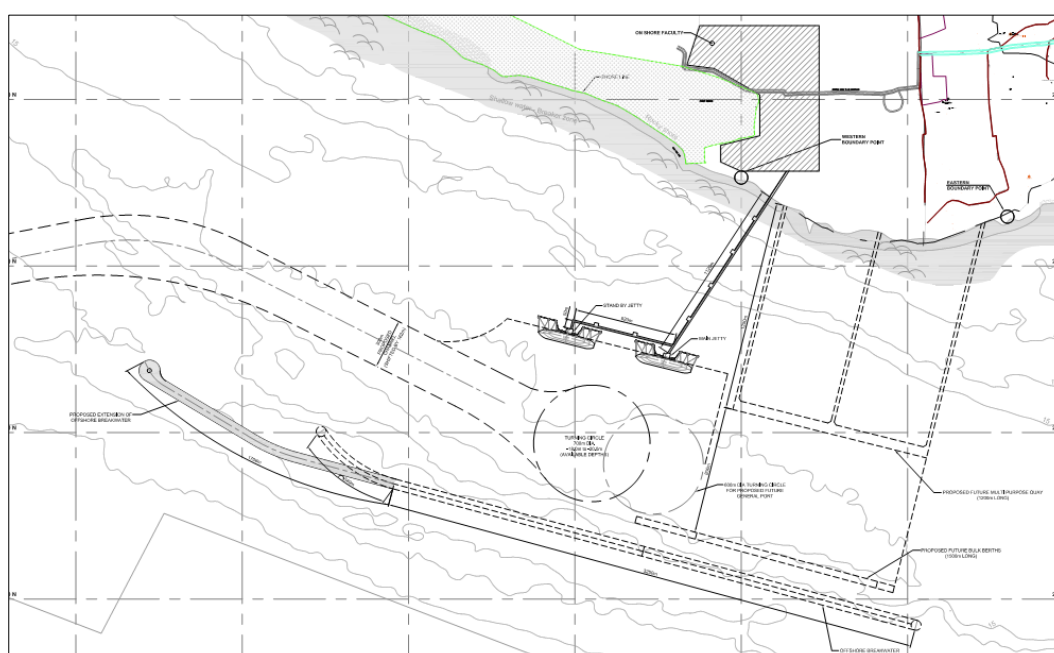
The port is intended to handle various cargoes like coal, LNG, containers and other cargoes etc. The construction of port involves construction of breakwater which is necessary to make the port suitable for handling cargoes in all seasons. It is intended to be an all-weather deep water port capable of handling cape size vessels.

The proposed marine master plan comprises the following:

- The approach channel of Chhara Port is about 6.5 km long to reach offshore deep water beyond the contour of -20.0m CD. The width of the approach channel is proposed to be 300m.
- Turning Basin diameter of 700 m and a depth of -18m and -20m CD for LNG operations.
- Additional 600m dia turning circle is proposed for the general port eastwards of the LNG turning circle.

- The basin is proposed to be protected by a rubble mound breakwater. The breakwater is at a distance of about 2.5 km from the shore and aligned parallel to the shore on the shoal bank.
- Two shore connected jetties are proposed for LNG operations, one proposed to act as a stand-by jetty. These jetties are connected to shore via 1120m long approach trestle common for two jetties.
- A 1200m long quay is proposed for multipurpose cargo operations east of LNG jetties, connected to shore with three approaches.
- Provision has also been made for an offshore 1500m long quay for bulk operations aligned to the breakwater.

**Figure 2-2: Marine master plan of Chhara Port**



### 2.2.2 Land use

The backup area has been planned with well demarcated areas of use for handling different types of cargo like, coal, containers, liquid, LNG etc. Study of the land use for other cargo is outside the purview of this study and the subsequent sections will be limited to discussions on LNG handling facility proposed at the port.

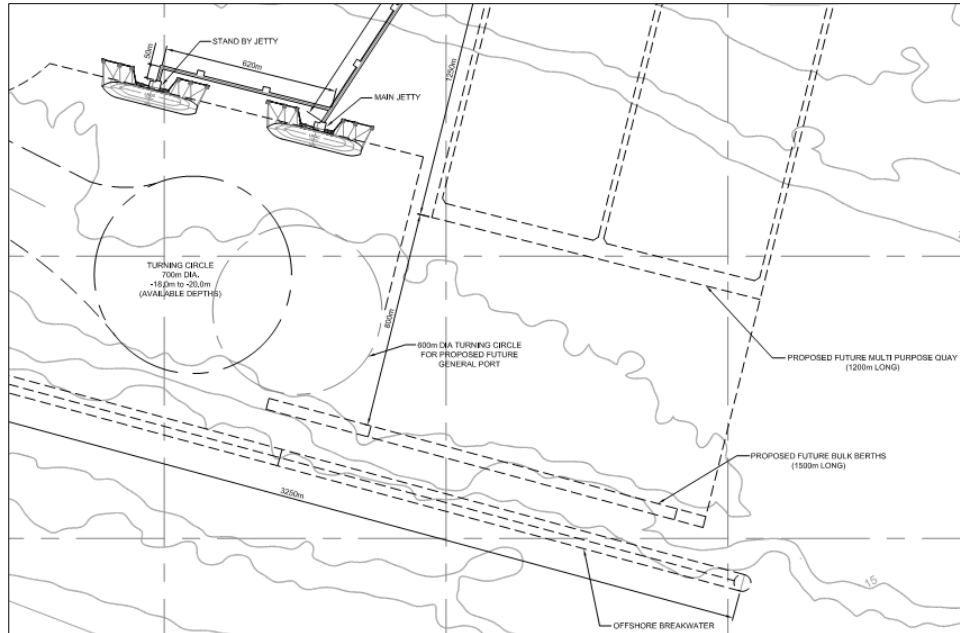
### 2.2.3 LNG handling facility

The LNG import terminal, storage and re-gasification facilities are being planned as an overall part of the port development.

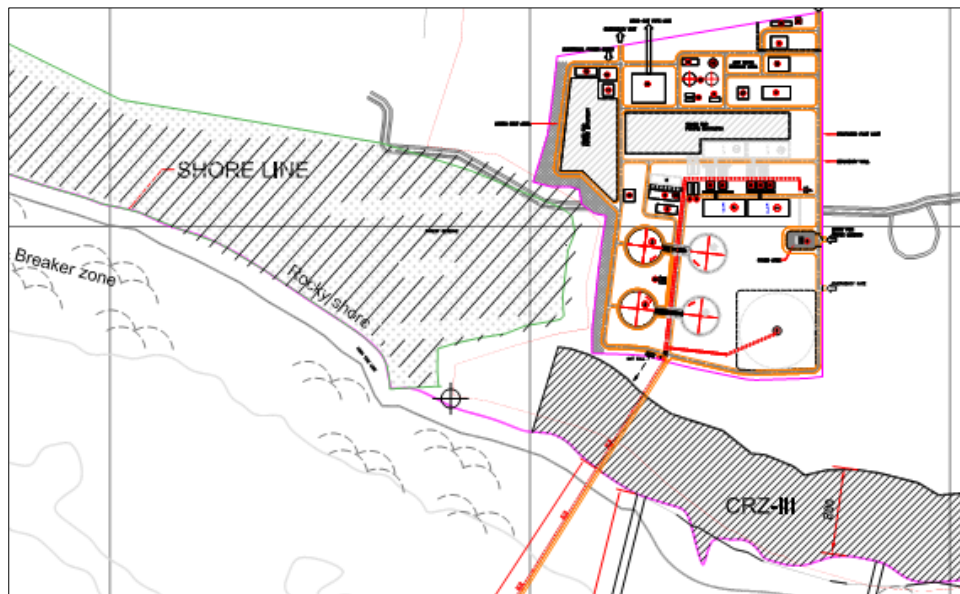
The LNG import terminal is planned to be developed with separate standalone jetty facilities west of the proposed coal berths. The storage/re-gasification plant is planned to be based on the landward side beyond high tide line (HTL).

The LNG terminal is planned to be developed in two phases, 5 MTPA during Phase-I with provision for expansion up to 10 MMTPA in Phase 2.

**Figure 2-3: LNG berthing facility**



**Figure 2-4: LNG back up area**



**2.3 Met-Ocean conditions**

The western coast of Gujarat is characterised by strong SW monsoons and relatively low intensity NE monsoons.

The typical climatic seasons are

- Pre-monsoon – March to May
- Southwest Monsoon – June to September
- Post monsoon – October to Mid-November
- Northeast Monsoon – Mid November to February

### 2.3.1 Tides

The tidal range at Chhara is predicted to be about 2.9m according to the Indian Admiralty Charts 206 & 207 with respect to Chart Datum are provided in Table 2-1 below

**Table 2-1: Predicted tide levels at Chhara - Indian Admiralty Chart 206 & 207**

Tide	Level (m)
Highest Astronomical Tide (HAT)	+2.80 m CD
Mean High Water Spring (MHWS)	+2.20 m CD
Mean Low Water Spring (MLWS)	+1.86 m CD
Mean Sea Level	+1.48 m CD
Mean High Water neap (MHWN)	+1.32 m CD
Mean Low Water Neap (MLWN)	+0.64 m CD
Lowest Astronomical Tide (LAT)	-1.0 m CD

### 2.3.2 Currents

Based upon the information provided in various reports made available by SP/HPCL, the general flooding current is predominant along the coast during the SW monsoon and is generally in the direction south east with a maximum speed at surface of about 0.83 m/s. Ebb currents are dominant on west directions with a maximum speed at surface of about 0.8 m/s.

This data has been collected at two off shore locations of current measurements and are therefore not site specific measurements. BMT has not carried out any independent data procurement or physical verification of the above data or on the existing current regime at the location and has used existing data for their assessment.

### 2.3.3 Wind and waves

Based upon the information provided in various reports such as EIA study, DFR, etc. the wind during the monsoon months of June, July and August is predominantly south westerly with speeds ranging from 15 to 30 knots. The wind during the pre-monsoon is generally westerly and towards the end has also recorded wind events ranging from 22 to 28 knots. Wind during the remaining months is predominantly north westerly with speeds ranging from 10 to 20 knots.

The wave climate is dominated by the monsoon conditions, with the most extreme waves occurring during the south west monsoon between mid-June and mid-October.

HR Wallingford's study for Chhara site shows that majority of offshore waves come from south-west and westerly direction sectors (195-285°N). The maximum significant wave height (up to 5.7m) is predicted in the sector 225-255°N. About 80 % waves are within the range 5 to 9s mean period. There are a number of longer period wave conditions with mean periods in the range 10 to 14s, though the associated wave heights are less than  $H_s = 3\text{m}$ . The predicted extreme offshore waves approach the site from the sector centered 240°N. The predicted 1 in 1 year significant wave heights from this directions  $H_s = 5.0\text{m}$  with peak period 10.25. This increases to  $H_s = 6.2\text{ m}$  for 1 in 200 year condition, with  $T_p = 11.4\text{s}$ .

Offshore and near shore wave climate results on the -10mCD, -15 m CD and -20mCD depth contours extracted from the SWAN model are shown in Table 2-2. For the frequently occurring conditions the largest near shore waves are generated by waves from the 240°N offshore direction. 1 in 1 year waves from this direction resulted in near shore waves of  $H_s = 3.6\text{m}$  on the -20mCD contour, shoaling to 3.7m on -10m CD contour. For the longer return periods the more southerly direction 180°N sectors become increasingly important. At the 1 in 200 year level, the predicted wave heights near the breakwater result in  $H_s = 4.5\text{-}5.0\text{m}$  and slightly reduce to 4.0-4.5m over the shoal bank. The predicted extreme waves approach the site from the sector centered on 240°N. The predicted 1 in 1 year significant wave height from this direction is  $H_s = 5.0\text{ m}$ , with a peak period  $T_p = 10.2\text{s}$ , which increases to  $H_s=6.2$  for 200 year condition, with  $T_p = 11.4\text{s}$ .

BMT has reviewed and used data made available from HSEL and other third party data on the existing current regime at the location for assessment.

**Table 2-2: Summary of offshore and near shore wave characteristics extracted from EIA report**

Return	Offshore			20m depth			15m depth			10m depth		
	Hs (m)	Tp (s)	Dir (° N)	Hs (m)	Tp (s)	Dir (° N)	Hs (m)	Tp (s)	Dir (° N)	Hs (m)	Tp (s)	Dir (° N)
1	1.2	4.7	120	0.7	4.9	142	0.6	4.9	146	0.7	4.9	143
	2.7	7	150	1.8	7.2	162	1.7	7.2	162	1.6	7.2	169
	3	7.9	180	2.2	7.9	184	2.2	8	180	2.2	8	188
	3.9	9.1	210	2.9	9.3	209	2.7	9.3	211	2.8	9.3	210
	5	10.2	240	3.6	10.4	230	3.4	10.4	231	3.7	10.4	228
	4	9.2	270	2.6	9.5	248	2.5	9.5	247	2.7	9.6	245
5	1.8	5.8	120	1	6	145	0.9	6	151	0.9	6	150
	2.8	7.2	150	1.8	7.3	163	1.7	7.3	169	1.6	7.4	169
	3.8	9	180	2.8	9.1	185	2.6	9.2	189	2.6	9.2	191
	4	9.1	210	2.9	9.3	209	2.7	9.3	211	2.9	9.3	210
	5.5	10.8	240	4	10.8	229	3.8	10.8	231	4.1	10.9	227
	4.4	9.6	270	2.8	9.6	248	2.7	9.6	247	2.9	9.7	245
10	1.9	5.9	120	1.1	6.2	146	1	6.1	152	0.9	6.1	151
	3.6	8.1	150	2.3	8.3	163	2.1	8.4	171	2.1	8.4	169
	3.9	9.1	180	2.8	9.3	185	2.7	9.3	189	2.7	9.3	191
	4.5	9.7	210	3.3	9.7	209	3.1	9.7	212	3.3	9.8	211
	5.5	10.8	240	4	10.8	229	3.8	10.8	231	4.1	10.9	227
	4.7	10	270	3	10.1	247	2.9	10.2	246	3.2	10.2	244
25	2.3	6.4	120	1.3	6.6	145	1.1	6.6	153	1.1	6.6	151
	4	8.5	150	2.6	8.7	164	2.4	8.7	172	2.3	8.7	170
	4.4	9.6	180	3.2	9.6	186	3	9.6	191	3	9.7	192
	4.8	10	210	3.5	10.2	209	3.3	10.2	212	3.5	10.2	211
	5.7	11	240	4.2	11.2	229	4	11.2	231	4.3	11.2	227
	4.9	10.1	270	3.2	10.3	247	3	10.3	246	3.3	10.3	244
50	2.7	7	120	1.5	7.2	146	1.3	7.2	154	1.3	7.2	151
	4.3	8.8	150	2.7	8.9	164	2.5	9	172	2.5	9	171
	4.8	10	180	3.5	10.2	186	3.2	10.2	192	3.3	10.2	194
	5	10.2	210	3.7	10.4	209	3.5	10.4	212	3.7	10.4	211
	5.9	11.1	240	4.3	11.3	229	4.1	11.3	231	4.4	11.3	226
	5.1	10.4	270	3.3	10.5	247	3.1	10.5	246	3.5	10.5	243
100	3.1	7.5	120	1.7	7.8	146	1.6	7.8	154	1.6	7.8	152
	4.5	9.1	150	2.9	9.3	165	2.7	9.3	173	2.6	9.4	172
	5.1	10.4	180	3.7	10.5	187	3.5	10.5	193	3.6	10.5	195
	5.2	10.5	210	3.9	10.5	209	3.7	10.6	212	3.9	10.6	211
	6	11.3	240	4.4	11.5	229	4.2	11.5	231	4.5	11.5	226
	5.2	10.5	270	3.4	10.5	246	3.2	10.6	245	3.5	10.6	243
200	3.5	8	120	2	8.2	147	1.8	8.3	156	1.8	8.3	151
	4.7	9.3	150	3.1	9.5	165	2.8	9.5	173	2.8	9.5	173
	5.5	10.8	180	4	10.8	187	3.7	10.8	193	3.8	10.9	196
	5.5	10.8	210	4.1	10.8	209	3.9	10.8	213	4.1	10.9	211
	6.2	11.4	240	4.5	11.5	229	4.3	11.5	231	4.6	11.5	226
	5.3	10.6	270	3.5	10.6	246	3.3	10.6	245	3.6	10.7	243

### 3 Discussion on layouts and infrastructure requirement

This section comprises discussion on the various layouts along with infrastructure requirement.

#### 3.1 Project description

Simar Port Limited is developing an all-weather port at Chhara to handle coal, other bulk cargo, containers and LNG. The port is proposed to be built in phases, with the first phase planned for coal handling only. M/s Hindustan Petroleum Corporation Ltd (HPCL) in a Joint Venture with SP Ports Private Limited (SPPL) is in process of setting up a LNG re-gasification terminal at Chhara. To take advantage of the time lag between readiness of construction of marine facilities and on shore storage and regasification facilities to feed the market early, early commissioning of LNG terminal with FSRU is being explored. A gas pipeline shall be laid connecting the proposed FSRU and the gas grid facility. The proposed FSRU system will be moored to a jetty.

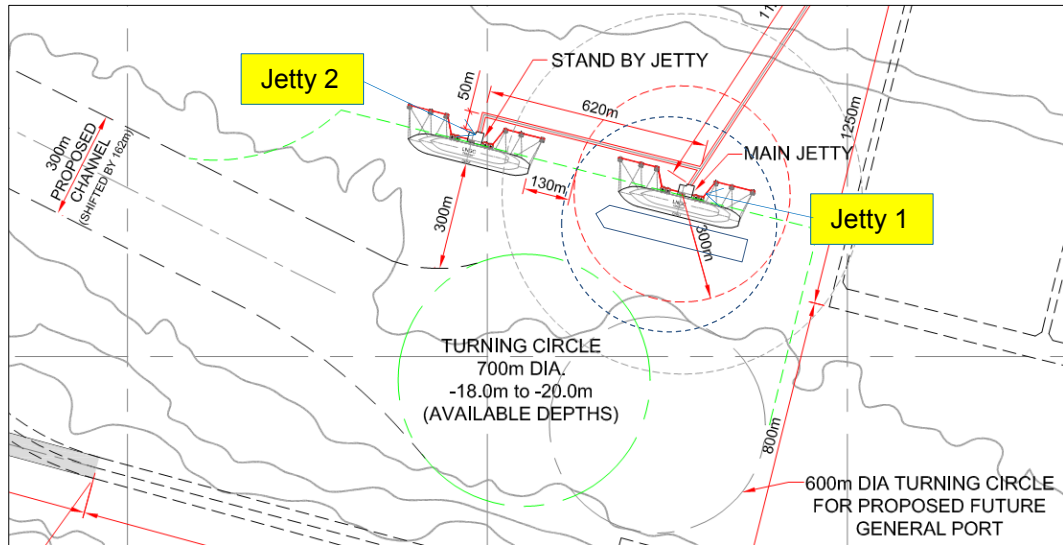
Once onshore storage and regasification facilities are constructed, FSRU will be moved out and land based terminal will be commissioned..

#### 3.2 Layout options

Various options were conceptualized following discussions at the initial kick-off meeting. Selection of layout options was constrained by the following factors:

- The existing jetty heads including the stand-by jetty was to be considered as fixed and no change in the location, orientation and configuration was allowed.
- Detailed report on the tranquillity studies for the Chhara Port was also reviewed and feasibility was established as detailed in the report. BMTCI also recommends more detailed and location specific tranquillity studies to be carried out in the advanced stages of the project execution for determining design and operating requirements for FSRU operations.
- BMT will however provide information on the allowable movements of the vessels from a safe operations perspective.
- Based on inputs and constraints listed above, following two options are studied further in this report for deployment of FSRU:
  - Option A – Double banking at Main Jetty (Jetty 1)
  - Option B – Tandem operations at jetty 1 and stand-by jetty (Jetty 2).

Both the cases have been evaluated in isolation in an effort to arrive at a relative technical assessment of both the options. Refer Figure 3-1 for location of both the options.

**Figure 3-1: Location of options in proposed Chhara Port**

### 3.3 Discussion on options

This section describes features and provisions to be made for each layout option.

#### 3.3.1 Option A

This layout is based using jetty 1 to moor the FSRU. The LNGC will be berthed with double banking on the FSRU and ship-to-ship transfer of LNG will be carried out.

- The Jetty is planned in natural depths of -15 m CD
- No additional dredging is envisaged.
- As the location falls on a pre-determined feasible location for LNG berthing, tranquility for mooring, maneuvering and berthing of the LNGC is not considered to be a significant issue.
- Tranquility requirements for double banking operations will need to be studied during advanced stages of the project development. Detailed mooring studies are recommended.
- The proposed approach channel of 300m width will be used for maneuvering in and out of the harbour. The water currents are reported to be about 1.6 knots during peak tidal conditions. These favorable oceanographic conditions at the port ensure easy and safe navigation of ships round the year.
- Future multi-cargo berths to the east and jetty 2 to the west are in the vicinity but are about 500m and 620m from the center of jetty 1. This is considered adequate to satisfy OISD requirements of a minimum of 500m separation distance with adjacent jetties. A separate risk assessment may be required to update the existing risk assessment done as part of the DFR to include FSRU operations. Although significant issues are not envisaged.
- The diameter of the existing turning circle is around 700m.

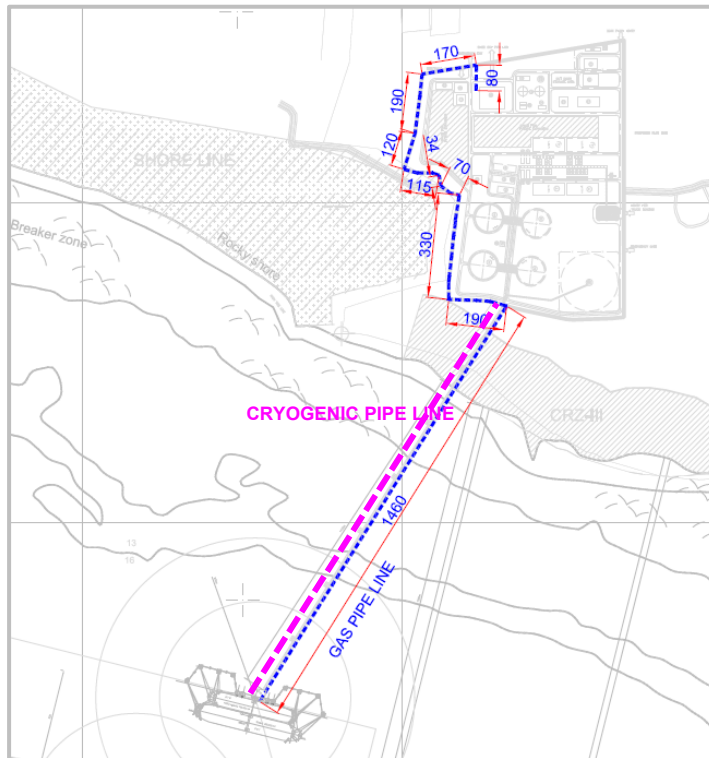
The following infrastructure needs to be constructed in case of Option A, which as described in the preceding section may fall either within the Block 1 CAPEX or additional CAPEX.

- Jetty 1 and approach trestle connecting to the shore needs to be constructed.
- All marine equipment for conventional LNGC berthing may not be appropriate for STS operations. Therefore mooring and fendering equipment designed for STS operations need to be installed. This would specifically include fendering arrangements between two vessels (typically pneumatic or foam filled fenders), mooring equipment for ship to ship and ship to shore mooring, etc.
- All LNG and process equipment including the cryogenic pipeline will need to be installed upfront, even though this will not be used in during FSRU operations. During regular operations on the FSRU, due to restriction affected due to the exclusion zone (to be determined during the QRA), no hot works will be allowed within the said zone, therefore resulting in no construction works possible on the jetty and some part of the trestle during FSRU operations. Therefore, in order to eliminate the construction downtime during FSRU to land-based terminal switchover (e.g. Cryogenic pipeline, LNG unloading arms, safety equipment, etc on the jetty and trestle).
- The gas evacuation line from jetty 1 to the dispatch station, metering & dispatch station, connecting the LNG terminal with the NG off-take transmission line is also required for FSRU operations.

The gas pipe line may be installed on pipe racks on the approach trestle, These pipeline to be blinded off once Onshore terminal is commissioned. NG and LNG lines will not be operational simultaneously. Therefore no major design changes are envisaged for the approach trestle. However, geometric design of the approach trestle must conform to this requirement.

The gas pipe-line on shore is proposed to be installed as buried line with suitable markers. The route of the pipe line on shore has been schematised in the Figure 3-1. Principally, the route is planned along the green belt zone at the periphery of the plot so as not to impede the construction activity for the on shore terminal. This will also mean that associated risks during the construction of the onshore terminal will be mitigated since the route is planned at the periphery and out of bounds of the main construction site. Primary protection in form of fencing, kerbing and signage is strongly recommended along the route.

- All necessary power and utilities infrastructure needs to be in place.
- Construction of the jetty control room and installation of all safety systems are included in this block

**Figure 3-2: Pipe line routing superimposed with option A**

### 3.3.2

#### Option B

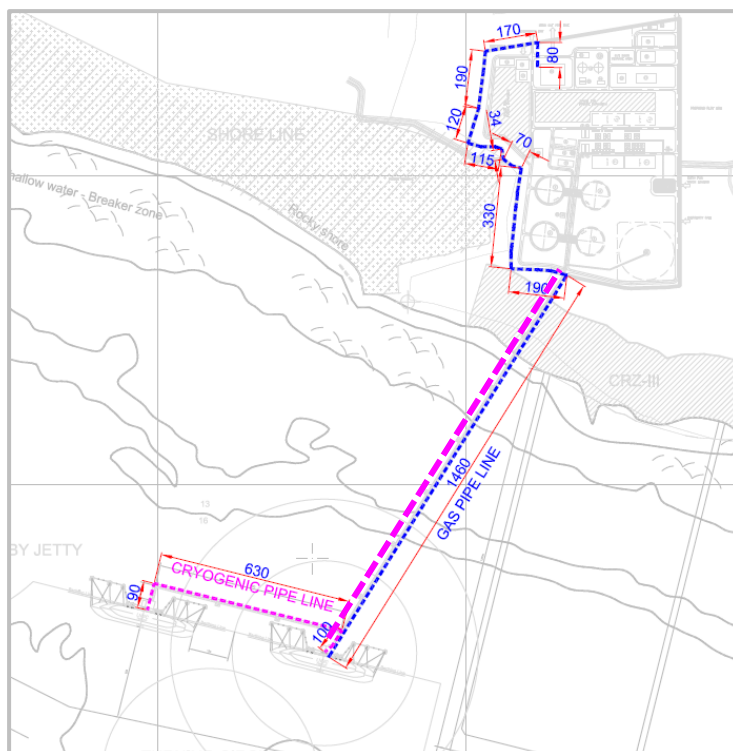
This layout is based upon using jetty 1 to moor the FSRU. The LNGC will be berthed at Jetty 2 with tandem operations.

- The Jetty is planned in natural depths of -15 m CD
- No additional dredging is envisaged.
- As the location falls on a pre-determined feasible location for LNG berthing. Tranquility for mooring, maneuvering and berthing of LNGC is not considered to be a significant issue.
- The proposed approach channel of 300m width will be used for maneuvering in and out of the harbour. The water currents are reported to be about 1.6 knots during peak tidal conditions. These favorable oceanographic conditions at Port ensure easy and safe navigation of ships round the year.
- Jetty 2 to the west is about 620m away. This complies with the OISD requirement of a minimum of 500m separation distance with adjacent jetties. A separate risk assessment may be required to update an existing Risk Assessment done as part of the DFR to include FSRU operations. No significant issues are envisaged though.
- The diameter of the existing turning circle is around 700m.

The following infrastructure needs to be constructed for Option B, which as described in the preceding section may be either a preponed CAPEX or additional CAPEX.

- Construction of Jetty 1 & Jetty 2. Approach trestle connecting to the shore and connecting jetty 1 to jetty 2 needs to be constructed.
- All marine equipment for conventional LNGC berthing will be required to be installed on both the jetties.
- All LNG and process equipment including cryogenic pipeline will need to be installed on both the jetties. Cryogenic pipeline and equipment for transfer of cargo from LNGC on jetty2 to FSRU on jetty 1 will be used for FSRU operations. However, as in the case of option A, even though the same will not be used in during FSRU operations, but to avoid any shut downs or time loss during conversion from FSRU to conventional on shore terminal operations, these equipment needs to be installed upfront.
- As in the case of option A, the gas evacuation line from jetty 1 to the dispatch station, metering & dispatch station, connecting the LNG terminal with the NG off-take transmission line is also required for FSRU operations.
- All necessary power and utilities infrastructure needs to be in place for both the jetties.
- Construction of jetty control room and installation of all safety systems are included in this block

**Figure 3-3: Pipe line routing superimposed with option B**



### 3.3.3

#### Pipeline rack adequacy

The approach trestle for the land-based terminal is designed with a 5.5m pipe rack width and 6.0m roadway in addition to 40" LNG line, 10" circulation line and 16" vapour return

line. In addition to these lines, the rack may host other utility pipelines and power & control cables.

For the FSRU project, an additional gas pipeline would be required to be added to the rack. We estimate that a 22-inch diameter gas pipeline would be sufficient for transferring 2.5 mtpa of RLNG from the jetties to the gas dispatch station located on land. This pipeline is sized conservatively so as to have adequate capacity even at lower regasification pressure of 50 barg. However, in favour of keeping adequate pipeline capacity, we recommend 26-inch pipeline, which would be adequate for transferring 3.5 mtpa of RLNG.

Given the available width of the pipe rack on the trestle, we estimate that the gas pipeline could be easily accommodated, and no additional design changes are required with respect to the pipe rack and trestle.

### 3.4 Infrastructure requirements

Development and requirement for infrastructure development and equipment installation for each option has been assessed. For the sake of clarity and assessment, the investment requirement has been categorised into following sections;

- Shared investment – Block 1
- Additional investment– Block 2
- Operational expenditure– Block 3

#### 3.4.1 Shared investment –Block 1

The infrastructure & equipment required by FSRU terminal that are common with land-based terminal phase-1, as well as those which are required to be advanced for eliminating delays in switchover to land-based terminal, are a part of this block. These facilities have to be preponed because they are required for FSRU terminal operations (e.g. trestle). During regular operations on the FSRU, due to restriction affected due to the exclusion zone (to be determined during the QRA), no hot works will be allowed within the said zone, therefore resulting in no construction works possible on the jetty and some part of the trestle during FSRU operations. Therefore, in order to eliminate the construction downtime during FSRU to land-based terminal switchover (e.g. Cryogenic pipeline, LNG unloading arms, safety equipment, etc on the jetty and trestle) The major heads in this block are as below:

- Marine civil works
  - Jetty
  - Approach trestle
  - Jetty control room and all safety systems
- Marine equipment
  - Fenders
  - Mooring hooks
  - Jetty control room monitoring equipment

- Environment monitoring station
- Etc.
- Process equipment
  - LNG arms
  - LNG pipeline
  - Gas dispatch
- Power infrastructure

### Marine civil works

- The marine Jetty-1 and the trestle connecting it to the land are included in this head. Related marine infrastructure such as connecting road, pipe-rack, jetty superstructure, etc. is included.
- Construction of the jetty control room and installation of all safety systems are included in this block

### Marine equipment

- All the marine equipment located on Jetty-1, required for proper functioning of the FSRU marine operations fall under this head. Marine equipment such as mooring system, navigational system, fendering arrangements on the jetty and other relevant marine equipment are included. Jetty based utilities & systems such as fire-water system, pumps, power panels, compressors etc. are included.

### Process equipment

- **LNG arms** are used for ship-to-shore connection for LNG unloading. Generally these are a set of 4-5 arms which are used for LNG unloading as well as vapour balancing. We have considered a set of 4 LNG arms based on the DFR information as well as related control and monitoring systems, located on Jetty-1 within this head.

Although, in option A the LNG arms and associated utilities may not be required for FSRU operations on Jetty 1, but in order to eliminate the construction downtime during FSRU to land-based terminal switchover, it is recommended to install all jetty based equipment upfront.

- **LNG Equipment** such as, knock-out drum, nitrogen units, control & monitoring sensors, control system, valves, desuperheater, etc. which are located on the Jetty-1 before the LNG pipeline flange are included in this head.

Although, the LNG arms and associated utilities may not be required for FSRU operations on Jetty 1, but in order to eliminate the construction downtime during the FSRU to land-based terminal switchover, it is recommended to install all jetty based equipment upfront.

- **The LNG pipeline** from the Jetty-1 across the trestle up to the land fall point is considered here. The distance between Jetty-1 and the land fall point is about 1120m. The head also includes related lines such as vapour-balancing line, re-circulation line etc.

Installation of LNG pipelines on the jetty and part of the trestle falling under the safety and exclusion zone (300 m) of unloading operations are a minimum to be considered being constructed upfront. For the sake of this study, we have considered installation of the pipe line on the entire length of the trestle, i.e. about 1120m.

- **Gas dispatch** and gas metering station, connecting the LNG terminal with the NG off-take transmission line is also required for FSRU operations.

#### Power infrastructure

- Jetty operations will require power connection. Though the FSRU will generate its own power, the jetty based equipment, pumps and control system will require external power. Though this does NOT require construction of a power substation as envisaged for the land-based terminal, suitable scaled-down power infrastructure will still be required.

**Table 3-1: Block 1 infrastructure requirements**

Block	Sub-heads	Option A	Option B
BLOCK 1 : SHARED INVESTMENT	Trestle & Jetty	●	●
	Marine equipment	●	●
	LNG arms	●	●
	LNG equipment	●	●
	LNG pipeline	●	●
	Gas dispatch	●	●
	Power infrastructure	●	●
	Jetty control room and all safety system	●	●
LEGEND ○ Not Applicable ● Applicable			

### 3.4.2 Additional investment block – Block 2

The infrastructure & equipment required by FSRU terminal which are additional to land-based terminal phase-1, are a part of this block. Major heads are as follow:

- Marine civil works
  - Jetty
  - Approach trestle
  - Jetty control room and all safety systems
- Marine equipment
  - Fenders
  - Mooring hooks
  - Jetty control room monitoring equipment
  - Environment monitoring station
  - Etc.
- Process equipment
  - LNG arms

- Ship-to-ship LNG Hose
- LNG pipeline
- NG Arm & equipment
- Gas dispatch

### Marine civil works

Option-A requires construction of two additional mooring dolphins in addition to the existing mooring infrastructure, in order to evenly distribute mooring loads during ship-to-ship mooring operations. Additionally, subject to detailed design review, an additional platform may be required to be constructed for mounting on the high-pressure NG arm. However, on conservative basis, we have included its cost in our estimates.

Option-B required Jetty-2 to be constructed upfront. Since Jetty-2 is not part of Phase-1 of the land-based terminal plan, Jetty-2 and the connecting trestle will be additional. Related marine infrastructure cost such as connecting road, pipe-rack, jetty superstructure, control room, etc. for Jetty-2 are included.

### Marine equipment

Option-A, involves ship-to-ship mooring & operations. Therefore, slight up gradation in marine equipment is required. We estimate additional requirement of two QRMH and up gradation of the existing four QRMH for greater mooring loads. Up gradation of pneumatic fender design and additional four foam-type fenders are estimated as required.

In Option-B all the marine equipment, systems and utilities located at Jetty-2 are considered as additional. However, similar equipment, systems and utilities located on Jetty-1 are considered under the Block 1.

### Process equipment

LNG arms:

Option-A does not require LNG arms during FSRU operations. However, no construction & erection work is possible during FSRU operations within the exclusion zone (likely to be in the order of 500 m). Therefore, in order to avoid downtime during FSRU to land-based terminal changeover, all the jetty based equipment has to be erected and commissioned before the FSRU berths at the Jetty-1. Since these arms are a part of Block-1, we do not consider these in Block-2 estimates.

In Option-B, the set of LNG arms located on Jetty-2 are considered as additional. As the jetty drawings indicate 4-arm set, we have considered this as the benchmark for our assessment. We have considered the set of LNG arms as well as related control and monitoring systems within this head.

### LNG equipment:

All LNG equipment located on Jetty-1 in Option-A are included in Block-1.

Option-B additionally requires all the LNG equipment such as LNG header, knock-out drum, nitrogen units, control & monitoring sensors, control system, valves,

desuperheater, etc. located on the Jetty-2. The costs for these are considered as additional investment in Block-2.

#### **LNG Pipeline:**

In Option-A, LNG pipeline across the trestle up to land-fall point is considered in Block-1. No additional pipeline costs are estimated in this option.

LNG pipeline across the connecting trestle between Jetty-1 and Jetty2 is considered additional in Option-B. We have considered an additional 700m of cryogenic LNG pipeline for our assessment. The head also includes related lines such as the vapour-balancing line, re-circulation line etc.

#### **LNG hoses:**

In Option-A, the FSRU and LNGC will be alongside moored. This arrangement will require LNG to be directly transferred between the LNGC and FSRU, where either LNG arms can be mounted on the FSRU, or flexible hose can be used. Mounting LNG Arms on the FSRU is not recommended as these arms are permanently mounted on the FSRU vessel and will sail-away along with the FSRU when the lease-term ends. Instead, flexible hoses can be used for LNG transfer. The only drawback for the hoses is lower LNG transfer rates, which may result in slightly longer berthing time for the visiting LNGC. Alternatively, hard arms can also be placed on the FSRU for cargo transfer, but bearing in mind that a short term lease is envisaged. It is considered difficult for a FSRU supplier to make such modifications. Therefore, we have considered LNG hoses as the cargo transfer conduits in Ship-To-Ship (STS) operations. Typically some FSRU suppliers have a set such cryogenic hoses on board their FSRU. Therefore, the additional CAPEX for such LNG hose connectors would be subject to availability with the FSRU supplier. However, we have conservatively included costs for such hoses in our estimates.

Option-B does not require any such arrangement as the LNG will be transferred by LNG Arms.

#### **NG arms;**

Both the options, Option-A and Option-B, require high pressure NG arms as ship-to-shore connection required for dispatching RLNG from the FSRU to the shore. Generally a single arm is suitable for handling high pressure gas up to 100 Bar. We have considered all associated equipment, control and monitoring systems within this head in both the options. FSRU operations are recommended to be carried out on Jetty 1 only, and therefore NG arms would be required on or near jetty 1 only for both the options.

#### **Gas pipe line:**

A common high pressure gas pipeline starting from the NG Arm, travelling across the trestle towards shore, across the land reaching the gas metering & dispatch station is required in both the options, Option-A and Option-B. Considering the gas pipeline route from the Jetty-1 to the gas dispatch, we have considered a gas pipe line of 26" diameter and length of about 3,000m for our cost assessment. All associated monitoring, control and maintenance equipment such as sensors, valves, protection, etc. are included. This

will be required for both the options. As explained above, since NG arms are located on jetty 1, the gas pipe line length would be same for both the options.

**Table 3-2: Block 2 infrastructure requirements**

Block	Sub-heads	Option A	Option B
Block 2 : ADDITIONAL INFRASTRUCTURE	Trestle & Jetty	●	●
	Marine equipment	●	●
	LNG arms	○	●
	LNG equipment	○	●
	LNG pipeline	○	●
	STS LNG hose	●	○
	NG arm and equipment	●	●
	Gas pipe line	●	●
LEGEND ○ Not Applicable ● Applicable			

### 3.4.3 Operational expenditure (OPEX)

Operation & maintenance expenditure for all infrastructure & equipment in Block 1 & Block 2 are a part of this block. This has been dealt in detail in the cost assessment section. OPEX is estimated on block cost basis and is divided into the following heads:

- FSRU charter
- Regas cost
- Terminal O&M

Additionally, we have also estimated a block cost for preservation or scrapping cost estimates for Block-2 additional Equipment which will be redundant after the on land LNG terminal is commissioned.

#### FSRU charter

Considering the requirement of a FSRU as a bridging arrangement for early commissioning of the LNG terminal by 2-3 years, it is envisaged that the FSRU will be procured on lease arrangement basis. As per short-lease requirement of the project, lease arrangement will be essentially a time-charter agreement, where the supplier will supply the FSRU vessel inclusive of ship-management arrangements

### **Internal Gas consumption**

FSRU uses gas for regasification operations as well for its own energy requirements. The internal gas consumption of the FSRU is dependent on the regasification scheme (closed loop vs. open loop) and broadly proportional to the terminal throughput.

### **Terminal O & M**

The O&M costs associated with the process (topside) infrastructure & equipment required for the FSRU terminal is included in this head. Costs related to preservation of early commissioned equipment which may not be used during FSRU operations (eg. LNG arms in Option-A) are also included. The power consumption of the FSRU terminal is assumed to be supplied from shore based power infrastructure, the cost of which is included in this head.

The O&M costs associated with all the marine infrastructure & equipment required for the FSRU terminal are included in this head.

### **Insurance**

The insurance for the terminal infrastructure as well as the cargo is assumed to be considered in the overall project costing. However, the insurance for FSRU as an asset is considered included in the charter lease.

## 4 FSRU availability and sizing

### 4.1 FSRU availability

A FSRU is essentially a LNG Carrier which has been modified and fitted with LNG regasification and high pressure Natural Gas dispatch systems. It is generally capable of simultaneously receiving LNG into its cargo tanks and sending out high pressure Natural Gas. It may be permanently moored to a port-based or offshore anchored jetty. Given the asset utilization flexibility, short decision to commissioning timeframe, and attractive leasing arrangements offered by major suppliers, FSRU concept has become popular with many terminal developers considering it as a viable alternative to land based configuration.

Awareness about floating LNG terminal solution has been increasing over the past decade. It is estimated that there are more than 30 FSRU based terminals are at various stages of development, and about 11 of them are already operational. As the number of floating terminals and the operating experience increase, there is bound to be greater requirement for FSRU ships.

Most of the large LNG shippers have entered into FSRU construction options with shipyards. For instance, Golar has an expansion plan with 13 additional new-built FSRUs, while Excelerate Energy has shipbuilding options for 8 additional new-built FSRUs. Also most large suppliers generally follow a strategy of having at least one uncommitted FSRU available for short-delivery commissioning, thereby giving them a time advantage. These they may exercise as their outlook matures.

Given this degree of activity in the FSRU market, the availability remains volatile with respect to demand-supply scenario. Therefore, it is recommended that all the suppliers may be contacted to seek availability for potential FSRU supply.

### 4.2 FSRU fleet

The major shipping companies own these FSRUs worldwide. In this section a brief description of each of the available FSRU categorised by their ownership/operatorship is provided. The description is limited to the following companies.

- Golar LNG
- Hoegh LNG
- Excelerate Energy
- BW Gas
- Others

## 4.2.1

### Golar LNG

#### Golar Spirit

Golar Spirit is a 129,000 m<sup>3</sup> storage capacity Moss type LNGC, built in 1981. It was refurbished and converted to FSRU in 2009, with a regasification capacity of 1.80 MTPA. Currently it is chartered with Petrobras (Brazil) up to mid-2018, with additional charter extension options up to 2023.

#### Golar Winter

Golar Winter is a 138,000 m<sup>3</sup> storage capacity Membrane type LNGC, built in 2004. It was refurbished and converted to FSRU in 2009, with a regasification capacity of 3.70 MTPA. Currently it is chartered with Petrobras (Brazil) up to 2024.

#### Golar Freeze

Golar Freeze is a 125,000 m<sup>3</sup> storage capacity Moss type LNGC, built in 1976. It was refurbished and converted to FSRU in 2010, with a regasification capacity of 3.60 MTPA. Currently it is chartered with Dubai Supply Authority (UAE) up to early-2020, with additional charter extension option up to 2025.

#### Nusantara Regas Satu (Golar Kannur)

Golar Kannur, now renamed as NR Satu, is a 125,000 m<sup>3</sup> storage capacity Moss type LNGC, built in 1997. It was refurbished and converted to FSRU in 2012, with a regasification capacity of 3.65 MTPA. Currently it is chartered with Nusantara Regas (Indonesia) up to 2022, with additional charter extension option up to 2025.

#### Golar Eskimo (Hull No. 2024; Samsung)

Golar Eskimo is currently under-construction at SHI (Korea), will be a 160,000 m<sup>3</sup> storage capacity Membrane type FSRU, with expected delivery by end-2014. It will have a regasification capacity of 3.80 MTPA. It has been committed for charter to Hashemite Kingdom of Jordan (Jordan) up to 2020, with additional charter extension option up to 2025.

#### Golar Igloo (Hull No. 2031; Samsung)

Golar Igloo is currently under-construction at SHI (Korea), will be a 170,000 m<sup>3</sup> storage capacity Membrane type FSRU, with expected delivery by early-2014. It will have a regasification capacity of 1.30 MTPA. It has been committed for charter to Kuwait National Petroleum Company (Kuwait) up to 2019, with 3 months stand-down window allowing other short-term commitments each year.

#### Golar Tundra (Hull No. 2056; Samsung)

Golar Tundra is currently under-construction at SHI (Korea), will be a 170,000 m<sup>3</sup> storage capacity Membrane type FSRU, with expected delivery by end-2015. It will have a regasification capacity of up to 5.65 MTPA. Currently Golar is evaluating options for its deployment.

## 4.2.2

### Hoegh LNG

#### GDF Suez Neptune

GDF Suez Neptune is a 145,000 m<sup>3</sup> storage capacity Membrane type FSRU, built in 2009. It has a regasification capacity of 5.65 MTPA. Currently it is chartered with GDF Suez (France) up to 2029, with additional charter extension option up to 2039.

#### GDF Suez Cape Ann

GDF Suez Cape Ann is a 145,000 m<sup>3</sup> storage capacity Membrane type FSRU, built in 2010. It has a regasification capacity of 5.65 MTPA. Currently it is chartered with GDF Suez (France) up to 2030, with additional charter extension option up to 2040. GDF Suez is believed to have sub-chartered this vessel to China National Offshore Oil Company (China).

#### Hull No. 2548 (Hyundai)

Hull No. 2548 is currently under-construction at HHI (Korea), will be a 170,000 m<sup>3</sup> storage capacity Membrane type FSRU, with expected delivery by mid-2014. It will have a regasification capacity of 1.80 MTPA. It has been committed for charter to PT Perusahaan Gas Negara (Indonesia) up to 2034, with additional charter extension option up to 2044.

#### Hull No. 2549 (Hyundai)

Hull No. 2549 is currently under-construction at HHI (Korea), will be a 170,000 m<sup>3</sup> storage capacity Membrane type FSRU, with expected delivery by early-2014. It will have a regasification capacity of 3.00 MTPA. It has been committed for charter to Klaipėdos Nafta, (Lithuania) up to 2024.

#### Hull No. 2550 (Hyundai)

Hull No. 2550 is currently under-construction at HHI (Korea), will be a 170,000 m<sup>3</sup> storage capacity Membrane type FSRU, with expected delivery by mid-2014. It will have a regasification capacity of 3.80 MTPA. It has been committed for charter to Colbún & AES Gener (Chile) up to 2024, with additional charter extension option up to 2029.

#### Hull No. 2551 (Hyundai)

Hull No. 2551 is currently under-construction at HHI (Korea), will be a 170,000 m<sup>3</sup> storage capacity Membrane type FSRU, with expected delivery by early-2015. It will have a regasification capacity of up to 2.80 MTPA. Currently Hoegh is evaluating options for its deployment.

## 4.2.3

### Excelerate Energy

#### Excelsior

Excelsior is a 138,000 m<sup>3</sup> storage capacity Membrane type FSRU, built in 2005. It has a regasification capacity of 3.78 MTPA. Currently it has firm charter commitments up to 2025, with additional charter extension option up to 2035.

### **Excelece**

Excelece is a 138,000 m<sup>3</sup> storage capacity Membrane type FSRU, built in 2005. It has a regasification capacity of 3.78 MTPA. Currently charter commitments for this ship are not available.

### **Exceleerate**

Exceleerate is a 138,000 m<sup>3</sup> storage capacity Membrane type FSRU, built in 2006. It has a regasification capacity of 3.78 MTPA. Currently it has firm charter commitments up to 2026, with additional charter extension option up to 2036.

### **Explorer**

Explorer is a 150,900 m<sup>3</sup> storage capacity Membrane type FSRU, built in 2008. It has a regasification capacity of 3.78 MTPA. Currently it has firm charter commitments up to 2033, with additional charter extension option up to 2038.

### **Express**

Express is a 150,900 m<sup>3</sup> storage capacity Membrane type FSRU, built in 2009. It has a regasification capacity of 3.78 MTPA. Currently it has firm charter commitments up to 2034, with additional charter extension option up to 2039.

### **Exquisite**

Excelsior is a 150,900 m<sup>3</sup> storage capacity Membrane type FSRU, built in 2009. It has a regasification capacity of 3.78 MTPA. Currently charter commitments for this ship are not available.

### **Expedient**

Excelsior is a 150,900 m<sup>3</sup> storage capacity Membrane type FSRU, built in 2010. It has a regasification capacity of 3.78 MTPA. Currently charter commitments for this ship are not available.

### **Exemplar**

Excelsior is a 150,900 m<sup>3</sup> storage capacity Membrane type FSRU, built in 2010. It has a regasification capacity of 3.78 MTPA. Currently charter commitments for this ship are not available.

### **Hull. 2402 (DSME)**

Hull No. 2402 is currently under-construction at DSME (Korea), will be a 173,400 m<sup>3</sup> storage capacity Membrane type FSRU, with expected delivery by mid-2014. It will have a regasification capacity of 6.00 MTPA. It has been committed for charter to Petrobras (Brazil) up to 2029.

## **4.2.4**

### **BW Gas**

#### **BW Gas FSRU**

BW Gas FSRU, which was ordered for construction at SHI (Korea), will be a 170,000 m<sup>3</sup> storage capacity Membrane type FSRU, with expected delivery by early-2015. Currently deployment and commitments for this ship are unavailable.

#### 4.2.5 OLT Offshore

##### FSRU Toscana (Golar Frost)

Golar Frost, now renamed as FSRU Toscana, is a 137,000 m<sup>3</sup> storage capacity Moss type LNGC, built in 2004. It was refurbished and converted to FSRU in 2012, with a regasification capacity of 3.75 MTPA. Currently it is owned by OLT Offshore (Italy) as a dedicated asset for Livorno Offshore project.

#### 4.2.6 Others LNG shippers

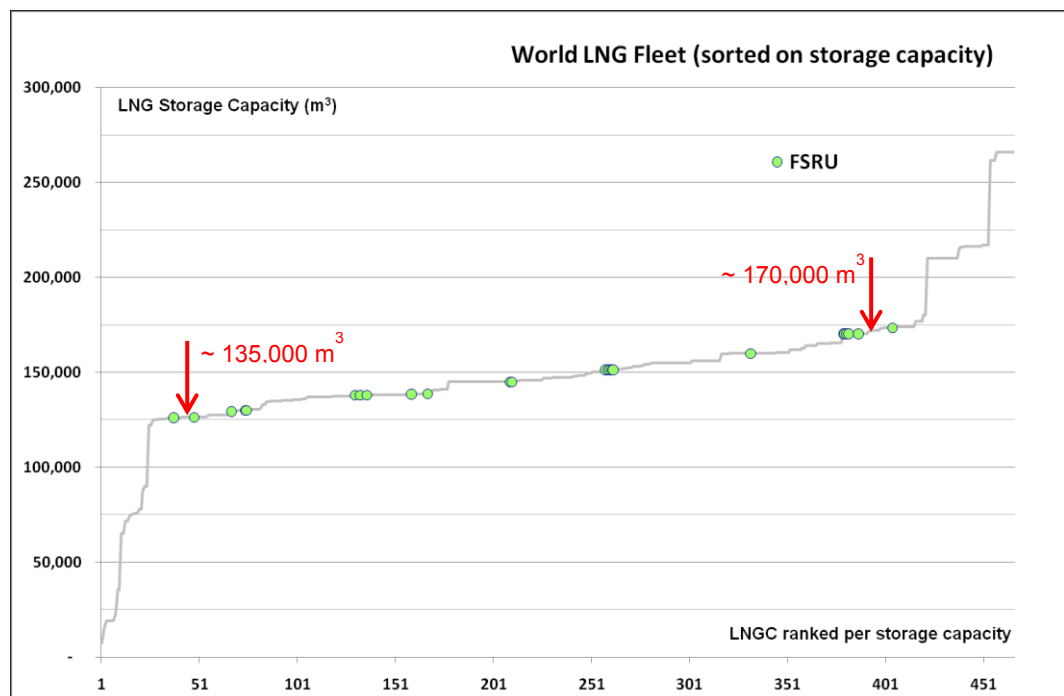
In addition to the above, large LNG shippers such as Teekay, MOL and other have shown interest in supplying FSRU to various project proponents. In addition, IHI of Japan also provide FSRUs.

### 4.3 FSRU sizing

As seen from the above, FSRUs come in different sizes. Typically the LNGCs which have been refurbished and converted into FSRU have low storage capacity, while the FSRUs which are new-built have greater LNG storage capacity.

The storage capacity vs. World LNG Fleet is as given below, with the above mentioned FSRUs marked.

**Figure 4-1: Storage Capacity (m<sup>3</sup>) vs. World LNG Fleet**



Summary of the available FSRUs and their characteristics is provided in the table below.

**Table 4-1: Summary of FSRU fleet**

Sr. No.	Operator	FSRU Identification	Hull (Year)	Storage (m <sup>3</sup> )	Regas (MTPA)	Committed to...	Com. Up to
1	Golar	Golar Spirit	1981	129,000	1.80	Petrobras, Brazil	2023
2	Golar	Golar Winter	2004	138,000	3.70	Petrobras, Brazil	2024
3	Golar	Golar Freeze	1976	125,000	3.60	DSA, UAE	2025
4	Golar	NR Satu	1997	125,000	3.65	NR Gas, Indonesia	2025
5	Golar	Golar Eskimo (SHI)	2014E	160,000	3.80	Kingdom of Jordan	2025
6	Golar	Golar Igloo (SHI)	2014E	170,000	1.30	KNPC, Kuwait	2019
7	Golar	Golar Tundra (SHI)	2015E	170,000	5.65	Open	N/a
8	Hoegh	GDF Suez Neptune	2009	145,000	5.65	GDF Suez, France	2029
9	Hoegh	GDF Suez Cape Ann	2010	145,000	5.65	GDF Suez, France	2030
10	Hoegh	Hull 2548 (HHI)	2014E	170,000	1.80	PT Perusahaan Gas Negara,	2044
11	Hoegh	Hull 2549 (HHI)	2014E	170,000	3.00	Klaipėdos Nafta, Lithuania	2024
12	Hoegh	Hull 2550 (HHI)	2014E	170,000	3.80	Colbun & AES Gener, Chile	2029
13	Hoegh	Hull 2551 (HHI)	2015E	170,000	2.80	Open	N/a
14	Excelerate	Excelsior	2005	138,000	3.78	Not Available	2035
15	Excelerate	Excelence	2005	138,000	3.78	Not Available	N/a
16	Excelerate	Excelerate	2006	138,000	3.78	Not Available	2036
17	Excelerate	Explorer	2008	150,900	3.78	Not Available	2038
18	Excelerate	Express	2009	150,900	3.78	Not Available	2034
19	Excelerate	Exquisite	2010	150,900	3.78	Not Available	N/a
20	Excelerate	Expedient	2010	150,900	3.78	Not Available	N/a
21	Excelerate	Exemplar	2010	150,900	3.78	Not Available	N/a
22	Excelerate	Hull 2402 (DSME)	2014E	173,400	6.00	Petrobras, Brazil	2029
23	BW Gas	BW Gas FSRU	2015E	170,000	N/a	Open	N/a
24	OLT Offshore	FSRU Toscana	2012	137,000	3.75	OLT Offshore, Italy	N/a

#### 4.4

#### Summary

Range of FSRU size availability falls between 135,000 m<sup>3</sup> to 170,000 m<sup>3</sup> as highlighted in the above graphic. Given the overall trend for large storage capacity new-built FSRUs, for the purpose of this study, design vessel size of 150,000 m<sup>3</sup> with a re-gas capacity of 2.5-3 MTPA has been considered. The technical design and cost estimates will also include possibility of berthing larger FSRU up to 170,000 m<sup>3</sup> capacity.

Generic specifications of design vessel for FSRU (150,000 m<sup>3</sup> to 170,000 m<sup>3</sup>) is as below.

**Table 4-2: FSRU generic specifications**

Information	FSRU
Ship Type	Existing FSRU
Class society	DNV, LR, ABS, BV
Gross Tonnage / Cargo capacity	112,000 GT / 170,000 m <sup>3</sup>
Containment Type	Moss / Membrane
LOA / Beam	300 m / 53 m
Max. draft	12.5 m
Moulded depth to main deck	20 m
Propulsion type	Steam or DFDE
Visiting LNG carrier capacity	Up to or less than the capacity of FSRU
Regas capacity	2.5 MTPA
Utilization (seasonality)	90% to 95%
Regas philosophy	Open or Closed loop
NG discharge pressure	86 to 94 Barg
NG discharge temperature	-2 to +15 DegC
Vaporizer type	Shell & Tube
SW discharge temperature	5 DegC lower than ambient
Spare philosophy	N + 1 on critical equipment
Internal Gas consumption	0.50 % of Regas
Seawater requirement	250,000 KLD (5.0 MTPA), 125,000 KLD (2.5 MTPA)

## 5 Marine assessment

The fundamental requirement for the terminal is for vessels to be able to enter and depart safely and, once berthed, to remain alongside for long enough to safely load or discharge their cargo. Additionally, for FSRU, since the vessel is to be kept in moored condition for a long time, environment persistence is necessary to be understood for safe and uninterrupted operations. Consequently, all relevant site-specific issues which could affect a ship's navigation and mooring must be taken into account. These include:

- Marine access for the vessel, including suitable turning/manoeuvring areas near the berth
- Suitable anchorage area(s)
- Provision of adequate navigation aids, VTS, tugs and pilots
- Sufficiently deep, protected water for the berth, to allow the vessel to safely moor and to load/discharge cargo
- Nature of the seabed and requirements for capital and maintenance dredging
- Tidal range
- Prevailing current, sea and weather conditions and the orientation of berths
- Passing ships
- Impact/conflict with other port traffic
- Security and unauthorised craft
- Proximity to population centres
- Environmental impact issues
- Hazardous zones analysis

This section describes assessment of the layout options from the marine navigation and safety perspective. Broad based assessment has been carried out under the following heads:

- Mooring layout assessment
- Docking and mooring systems
- Fendering requirements
- Navigation requirements

### 5.1 Mooring layout assessment

Proposed mooring layout is assessed for both the options. The design philosophy for the initial assessment of the mooring and berthing layout was based on the relevant guidelines published by the Oil Companies International Marine Forum (OCIMF guidelines – 2nd edition 1997) and relevant BS Codes. The main principles of the philosophy considered were as follows:

### 5.1.1 Dolphin spacing

- breasting (fender) dolphin spacing: 25% to 40% of LOA, to locate on parallel body side
- inner mooring dolphin spacing: 80% LOA
- Outer mooring dolphin spacing: 135% LOA.

### 5.1.2 Mooring dolphin set-back

The design philosophy for the layout of berthing and mooring dolphins has been optimised based upon OCIMF guidelines.

As a standard recommendation, 35-50 m setback shall be used.

However, more rigorous and detailed computational analyses for mooring, berthing / de-berthing, navigation, etc. should be undertaken during the detailed design stage to optimise the set-back value.

### 5.1.3 Mooring line angle criteria

**Head / stern lines:** Head stern lines are not normally efficient in restraining a ship on its berth due to their longer lengths and there can be a requirement for two additional outer mooring dolphins to be provided. Latest industry practice advocates that mooring facilities with good breast and spring lines should allow a ship to be moored virtually within its own length. Head and stern lines can be used if special pier geometry is encountered or there are large surge forces or unexpectedly severe weather conditions.

**Breasting lines:** Line angles  $10^{\circ}$  to  $15^{\circ}$  on plan (as perpendicular as possible and as far forward and aft as possible). If lines are too normal to the stern of the ship, then there is the possibility of lines breaking across it, which should be avoided.

**Spring lines:** Line angles  $80^{\circ}$  to  $90^{\circ}$  to the breasting / mooring dolphin on plan (as parallel to the vessel as possible).

**Vertical angles:** Lines run as close to the horizontal as possible (maximum  $25^{\circ}$  upwards)

Vessels with highly eccentric manifold positions may require special arrangements.

Two alternative layouts were considered in this layout assessment for option A and option B. Mooring layout available as part of the DFR studies have been adopted for further assessment and investigation of adequacy of the same for FSRU operations. The layout provided by client was assessed for the berthing and mooring of FSRU.

The jetty head comprises an unloading platform, breasting dolphins, mooring dolphins and personnel access ways (catwalks). The vessel size range considered in the mooring layout for LNGC is from 75,000 m<sup>3</sup> to 266,000 m<sup>3</sup> (Q<sub>max</sub>).

### 5.1.4 Mooring layout

#### Option A – STS operations

In this alternative, STS operation of LNG transfer will take place. The LNGC will berth alongside the FSRU. In this case, only 6 mooring dolphins are available for berthing and FSRU will need to be berthed on inner 4 mooring dolphins as the bigger vessels like Q<sub>max</sub> will need two outmost dolphins for mooring.

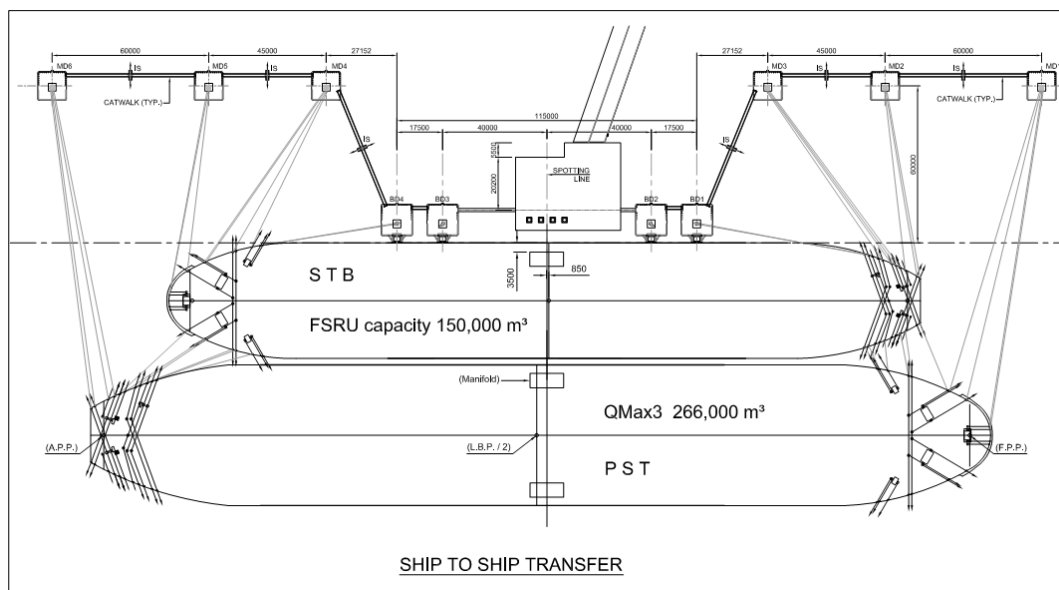
FSRU will be moored on four mooring dolphins, MD 1, MD2, MD 5 and MD 6. The innermost mooring dolphins, MD 3 and MD 4, are spaced at 85 m on each side of the unloading platform centred at centreline of the unloading arms which is 0.59 times LOA of the vessel.

MD 2 and MD 5 (intermediate mooring dolphins) are spaced at 130m on each side of the unloading platform centred at centreline of the unloading arms. This distance is 0.45 times LOA of vessel.

The outermost mooring dolphins, MD 1 and MD 6, are spaced at 190 m on each side of the unloading platform centred at centreline of the unloading arms which is 0.66 times LOA of vessel.

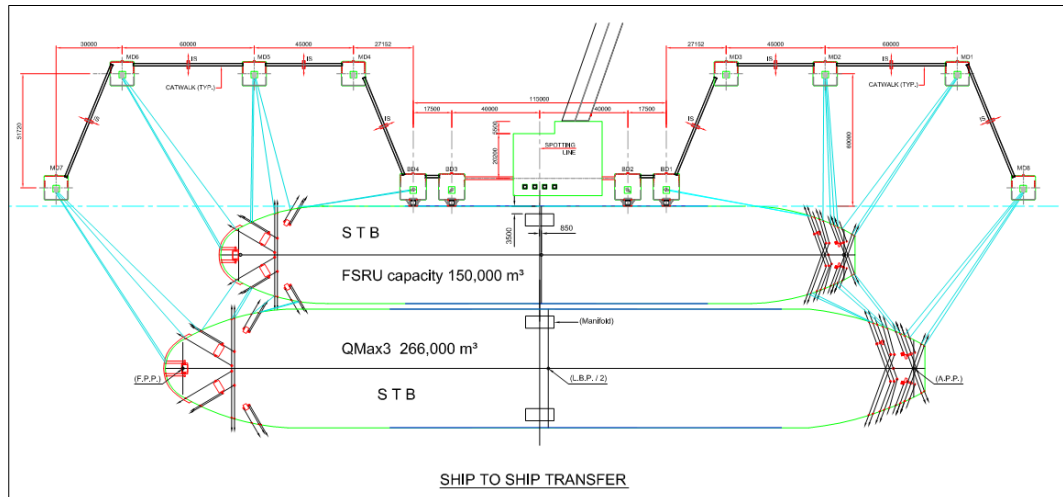
The mooring arrangement shown in the Figure 5-1 below is not considered effective since all the mooring lines of FSRU are directed towards inner side only and will not be effective in longitude restraint of the vessel. It is therefore considered not adequate for mooring of FSRU for permanent conditions if the supply vessel size considered is of Q<sub>max</sub>.

**Figure 5-1: Option A – Mooring arrangement on mooring layout proposed in DFR**



In view of the above, an alternative is proposed, wherein additional two extreme mooring dolphins are added for efficient mooring of LNGC. Recommended layout is present in Figure 5-2.

**Figure 5-2: Option A – Alternative mooring layout**



Alternative layout is tested for both Port Side (PST) and Star Board (SST) berthing of LNGC alongside FSRU.

Two additional mooring dolphins MD 7 and MD 8 are provided to support the berthing of  $Q_{max}$  vessel. These mooring lines will act as head and stern lines for LNGC. The alignment of these dolphins is kept in line with the berthing line to maintain a mooring setback of about 50 m for LNGC. The FSRU will be berthed on MD 1, MD 2, MD 5 and MD 6 and MD 3 & MD 4 will be unutilised.

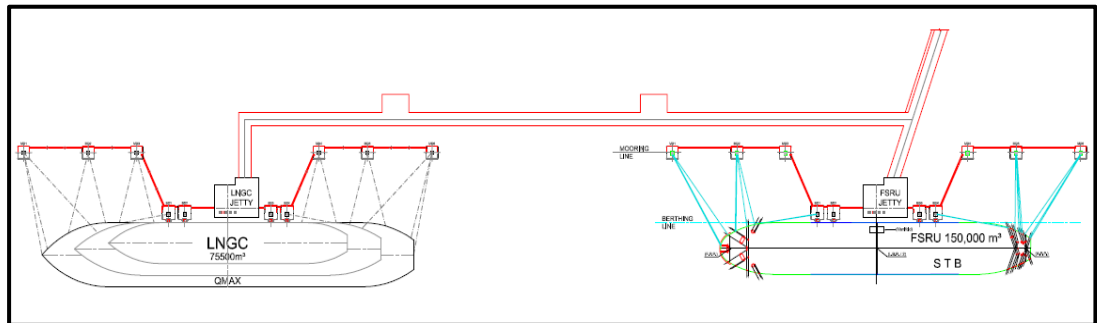
The maximum horizontal angle obtained was  $37^\circ$  which is within the limit. The setback distance provided between berthing and mooring line is **60m**. Due to availability of sufficient setback distance, the maximum vertical angle obtained for the mooring lines was  $11.53^\circ$  which is within the limit of  $25^\circ$ .

The innermost breasting dolphins are spaced 80m from each other. This is about 0.27 times of LOA of the vessel. The outer breasting dolphins are spaced at 115m from each other which is 0.39 times the LOA of vessel. Since these values are within the range of 0.25 LOA to 0.4 LOA, berthing dolphins' position is found adequate for FSRU berthing.

### Option B – Tandem operations on jetty

This alternative comprises LNGC and FSRU berthing on two separate jetties. The LNG from LNGC will be pumped to FSRU where regasification will take place. Jetty 2 falls outside the 300m exclusion zone of Jetty 1.

The horizontal angles for all the mooring lines were calculated in plan. The maximum horizontal angle obtained was  $37^\circ$  which is within the limits of  $45^\circ$ . This implies that layout shown below can accommodate an FSRU without any modification in the layout from mooring considerations as shown in Figure 5-3.

**Figure 5-3: Option B – Tandem operations on adjacent jetties**

In case of option B, the entire jetty construction, connecting approach trestle, topsides, etc. will need to be brought forward in the overall project schedules, as this was originally planned to be constructed in phase 2 of the development.

### 5.1.5 Gas discharge

The imported LNG from LNGC will be transferred to FSRU where regasification will take place. The regasified LNG will be transferred to shore by high pressure gas discharge flange on the vessel which is generally located at 30m c/c fore side of the manifold of the vessel.

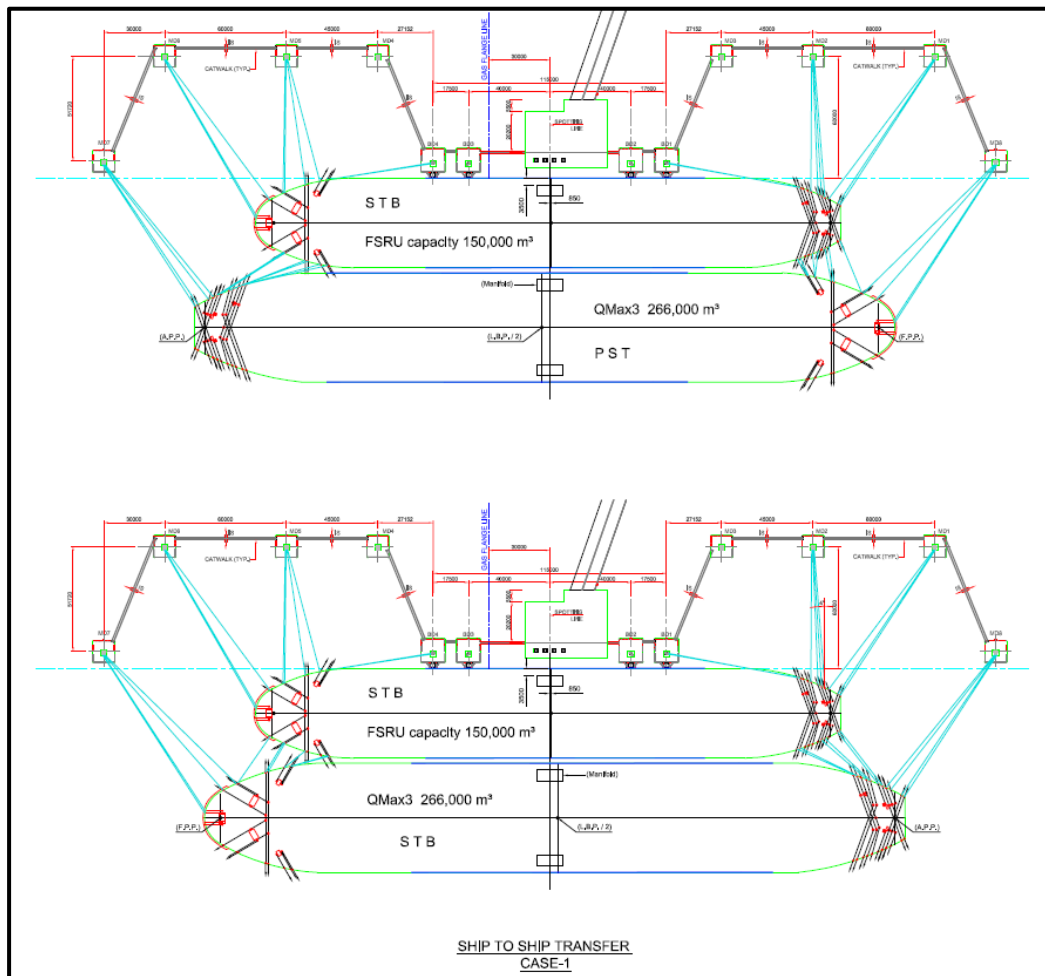
Placement of the HP gas loading arm on the jetty was investigated and two cases were considered

- FSRU berthing SST
- FSRU berthing PST

#### **FSRU berthing starboard side**

In this case, the gas flange line falls between breasting dolphin and unloading platform. An additional platform need to be constructed for unloading the regasified LNG.

**Figure 5-4: FSRU berthing SST**



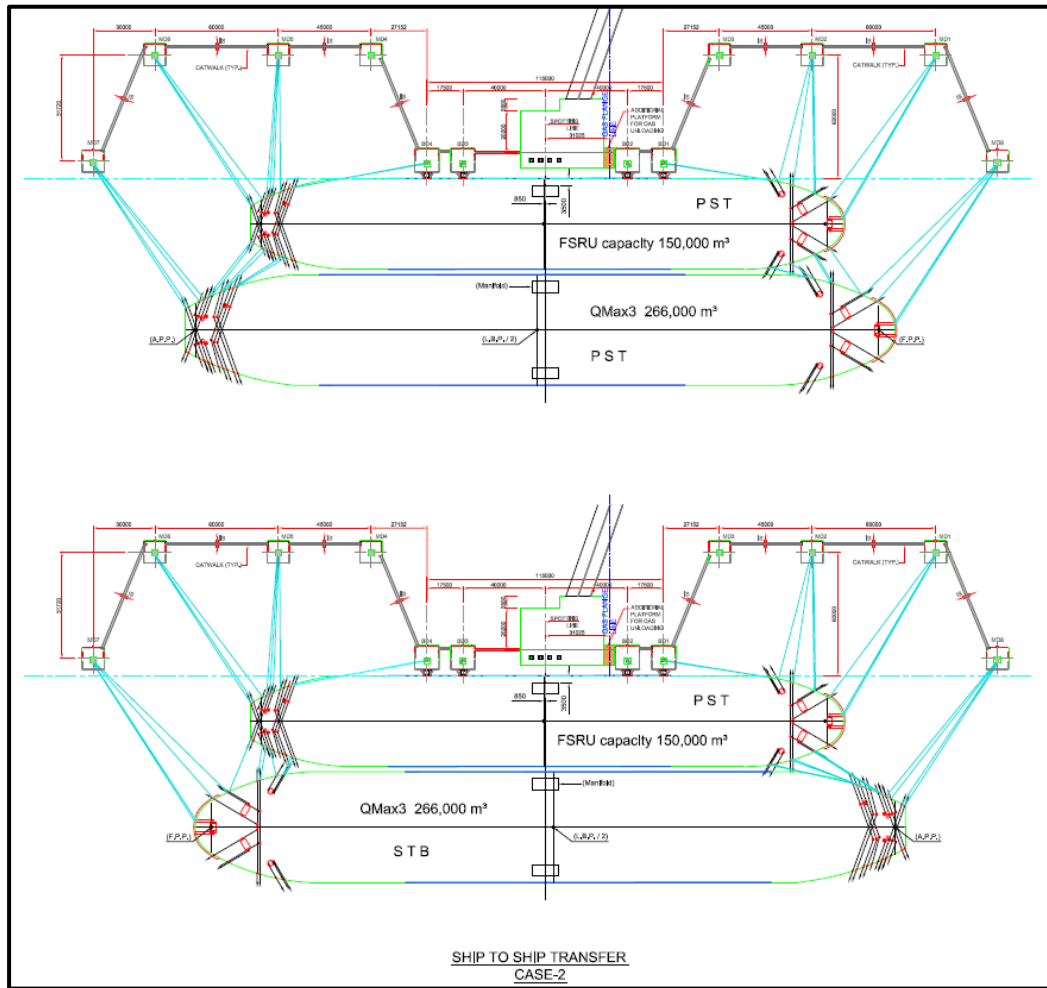
The above layout is also shown in the Drawing No. BMT/1222/HSEL/FR/001 at the end of the report.

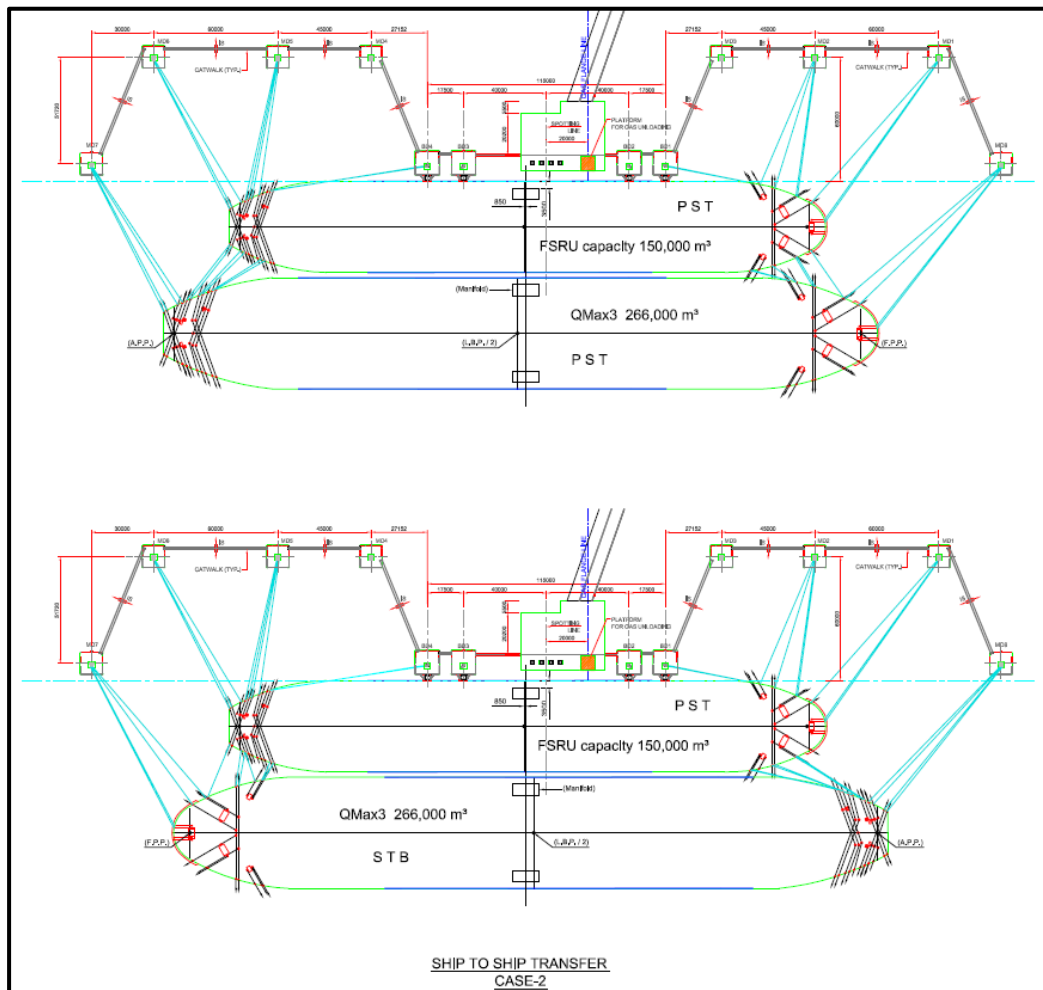
**FSRU berthing Port side**

If the FSRU is berthed on port side, the gas flange line falls just outside the unloading platform. To perform the gas unloading operation, an additional platform needs to be constructed. This can be done in two ways

- Construction of platform in addition to the unloading platform keeping the centrelines of ships manifold and unloading arms in one line.
- An alternative was investigated to check if the FSRU+LNGC can be moved by about 10 meters fore side i.e. towards the second jetty to accommodate the HP gas loading arm on the jetty platform.

Figure 5-5: FSRU berthing PST



**Figure 5-6: FSRU berthing PST – moored with a 10m shift fore of the ship**

The above two layouts are also shown in the Drawing No. BMT/1222/HSEL/FR/002 & Drawing No. BMT/1222/HSEL/FR/003 at the end of the report.

It is concluded that mooring of FSRU with a 10m shift fore side to accommodate the HP loading arm is safe. The only downside to this alternative is that the FSRU will be moored port side, and emergency sail out scenarios can be difficult. A detailed risk assessment for such a case needs to be carried out. On preliminary assessment, this option may not be a preferred option due to the fact that in case of sail away/emergency scenarios, additional tug power would be required for first swinging and then sailing away, especially in a case if the tugs are already been used to cater for any emergency scenarios such as fire, cyclone warning sail way notice for LNGC vessels, etc. Therefore, for the costing purposes, we are used additional cost of construction of an independent platform for erection of HP loading arms to be on a conservative side.

## 5.2 Docking and mooring systems

This section generally describes requirements of docking and mooring equipment and marine side utilities. Detailed performance, manufacturer and design specifications need to be detailed when preparing performance specifications for the Vendors.

Combining elements of both conventional jetty mooring and docking and offshore ship-to-ship mooring systems, and with more than two entities required to interface with each other, systems integration naturally becomes more complex and there is no “generic” docking, mooring and fendering package that can be applied to FSRUs.

For option A, which is a more complex case than option B using conventional mooring configurations, a comprehensive overview should be undertaken and the design requirement of all stakeholders aligned and coordinated.

The Ship-to-Ship docking and mooring scope is a shipyard led activity, with a brief purely focused on the conversion of the vessel or a new build specification. However, from planning and design perspective the design of the jetty should be done keeping an emphasis on integrating the overall docking and mooring systems.

The docking and mooring system for FSRUs consists of mechanical, instrumentation and control and monitoring elements - all of which must function together to assure safe and efficient operation across the three constituents: jetty, FSRU and LNGC. Compatibility at each interface ensures improved operational control, data sharing and flexibility for the FSRU.

#### **Quick Release Mooring Hook (QRMH) system**

Quick Release Mooring Hooks (QRMHs) are an essential part of the docking and mooring system. QMRH system shall be designed to cast off the mooring lines of ships which are moored to the dolphins and which, following completion of the unloading activities, wish to put to sea and to ensure that these mooring lines can be safely cast off simultaneously.

Each hook shall be equipped with a manual release mechanism and the operations of the hooks shall be completely spark-free.

All mooring units shall be equipped with:

- Capstan motor assembly
- Reversible motor starter
- Foot switch to operate the capstan
- Remote release control system
- Mooring load monitoring system

QRMH will need to be mounted on the mooring and breasting dolphins of the jetty for FSRU mooring in case of Option A and on both the jetties for mooring FSRU and LNGC in case of option B.

In option A, additional QRMH will need to be installed on FSRU, specifically designed and rated QRMHs will need to be installed on FSRU for LNGC mooring on to the FSRU. STS operation requires the LNGC to be berthed with about 5-6 m separation from the FSRU, so the design of the QRMHs must take into account the reduced mooring line length in this STS configuration, as this affects shock absorption capabilities and the high transient loads may damage mooring lines particularly due to chafing through chocks. In this

respect, deflections of the lines mooring the LNGC to the FSRU should be kept to a bare minimum. Layout of mooring hooks on the FSRU requires careful planning.

In STS mooring arrangement, the mooring lines may be provided by the transient LNGC carrier which may result in lines of unknown condition and capacity. Consideration could be given to using dedicated lines stored on board and provided by the FSRU.

### **Berthing Aid System (BAS) or Docking Aid System**

The BAS monitors shall be installed to record the vessel approach and departure. It measures the distance from the unloading platform to the vessel and calculates the approach speed and angle. It shall be installed with a large LED display panel to display this information for the pilot and the jetty dock master in several ways. It shall also be equipped with audio-visual alarms, hand held pagers and small portable graphic displays.

For option A, BAS would need to be installed on the jetty as well as on the FSRU. In case of option B, BAS system will need to be installed on both the jetties.

### **Mooring Load Monitoring System (MLMS)**

The MLMS shall be provided to monitor mooring lines and warnings in case of dangerous loads. It shall be based on digital control network. Load cells mounted in the quick release hooks provide signals to the digital network via amplifiers mounted in the hook motor starter. A flash light and horn will be energized when the load on the mooring hooks exceeds the predestined value.

### **Ship to Shore Communications**

Ship Shore Link shall be used as per SIGTTO Recommendations and Guidelines for Linked Ship/Shore Emergency Shut-Down of Liquefied Gas Cargo Transfer in 1987. Primarily for Emergency Shut-Down (ESD), the systems support telecommunications and data transfer.

There are numerous considerations to take into account for the instrumentation, control and monitoring systems and key requirements to be considered are:

- The jetty  
Jetty will require plant operations and process oversight, as well as load monitoring data, Met-ocean data and berthing data. A jetty control room is therefore envisaged to be constructed to house all the marine operations. Alternatively the jetty control room may be unmanned with all jetty operations such as loading, ESD, Mooring Tension and Emergency Release being transferred to the FSRU control room.
- The FSRU  
FSRU will require plant operations and process oversight, as well as load monitoring data, Met-ocean data and berthing data. In many cases the FSRU may be used as the primary control centre for the monitoring of mooring line tensions from the jetty and those to the LNGC (in the case of Option A - STS mooring). The instigation of emergency mooring release of jetty and/or LNGC mooring lines will also be required from the primary control centre.

- The LNGC  
The LNGC needs to monitor and maintain the mooring system during cargo operations, so access to mooring line data is essential.

All of the above rely on a compatible SSL for Emergency Shutdown control, Emergency Mooring Release and load monitoring data transfer, hot line communications and, increasingly for FSRU operations, a common data link between the 3 platforms

### **Environmental Monitoring System (EMS)**

The EMS shall be capable of measuring, indicating, transmitting & recording signals and display in the control room. The sensors in the EMS shall be installed to monitor following environmental parameters:

- wind speed and direction,
- sea current speed and direction,
- air humidity,
- wave height,
- wave period,
- tidal elevation.

### **Gangway access tower**

A Gangway access tower with a telescopic gangway shall be provided on the unloading platform. Gangway access towers are proprietary products and shall have additional specs like the ability to cater to larger ship sizes, shall have a hydraulic crane, fire monitor, control cabin and metal coverage for protection of its users against extreme weather conditions.

One gangway tower would be needed for each option respectively.

## **5.2.1 Fendering requirement**

Conventionally, LNGC berthing against a hard panel are designed to withstand accidental berthing energy requirements of LNGC. Typically cone type fenders with front panels are found adequate.

In case of option A, the FSRU will be moored over the long term and will normally be hard up against fender panels due to the requirement to keep the mooring lines tensioned. This subjects fenders, fender panels and associated chain and hardware to constant stress. Also, berthing loads will significantly increase during STS berthing and also with the LNGC alongside the FSRU. Other considerations such as two floating body movements; fender response from the effect of passing vessels, etc. must be examined in detail. Detailed mooring analysis is recommended for the same. Selection of the correct fender is therefore not limited to Energy and Reaction performance requirements. Other factors such as rubber composition, aging, UV exposure, temperature and immersion must also be considered if longevity of the fender and its hardware is to be guaranteed. Likewise, reducing abrasion between fender facing and ship's hull and easy

change out of damaged facing sections are also relevant considerations for FSRU mooring.

The fender system must also be considered as part of the mooring system, and on the FSRU, their associated deployment and retrieval systems. Here, the smaller footprint that's essential on the STS operations needs to be considered. Pneumatic fenders with chain tire nets have been the traditional choice for Ship-to-Ship operations. The downside of pneumatic fenders is that they cannot offer flotation redundancy, once punctured they will sink and, if filled with water, may overload the fender deployment system if lifted.

However, foam fenders can be manufactured without chain tire nets and provide lower frictional resistance since the fender skin can be of a low friction polyurethane material rather than rubber. Virtually unsinkable they could be considered a heavy duty alternative solution to pneumatic fenders and better suited for some FLNG projects.

Foam-filled fenders can offer similar reaction and energy performance to pneumatic fenders and can be engineered to offer low hull pressure. Importantly, in the event of an LNG spill, foam fenders have been shown to be much more resistant to damage from low temperatures than pneumatic fenders.

Three types of fenders are therefore envisaged as follows:

- FSRU – Jetty fenders. They will be required for both the options, however, design rating will be different, and higher rated ones will be needed for option A.
- Conventional cone type fenders for LNGC berthing against the jetty in case of option B
- Pneumatic or foam filled fenders for LNGC to FSRU STS berthing.

## 5.3 Navigational requirements

The water area - the plan, dimensions and the water depths in the entrance/approach channel harbour/manoeuvring basin and at the berths should be sufficient to permit the largest vessels in terms of length overall (LOA), beam and fully laden draught to be serviced without causing the vessels to take undue risks.

This section assesses the options from marine navigation and safety perspective using following parameters:

- Wave tranquillity
- Wind
- Under Keel clearance
- Manoeuvring safety

### 5.3.1 Wave tranquillity

The wave conditions at the site can have a significant effect on ship manoeuvring and mooring. These can be categorised as locally wind generated (wind) waves and longer period (swell) wave conditions from more distant storms and weather systems.

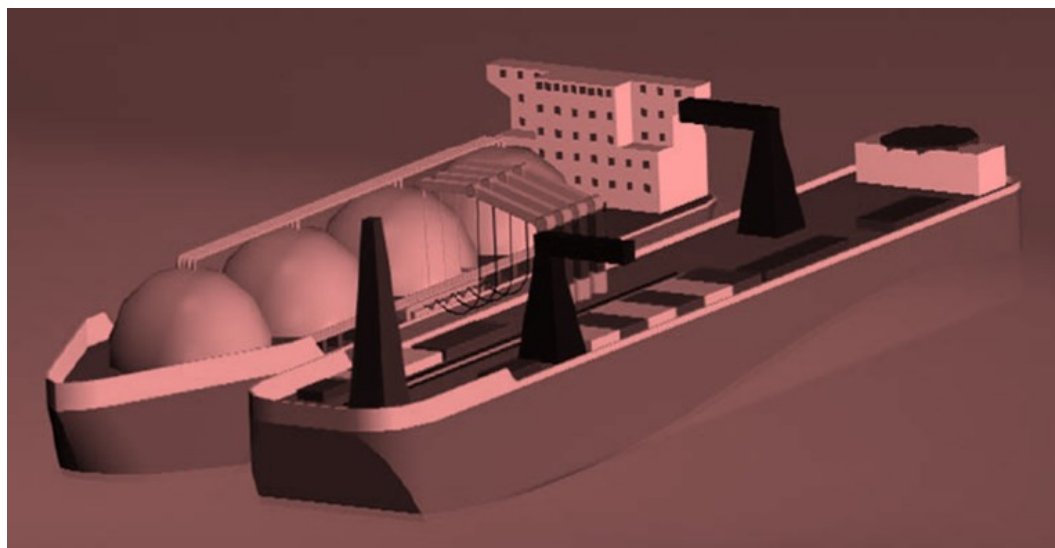
Waves can also originate from other sources, including pressure field effect (caused by passing ships).

An LNG STS transfer operation is an operation of some complexity and no specific guidelines are available due to lack of extensive industry experience of LNG. LPG and petroleum industry experience is exhaustive, and recently STS operations of LNG offshore have been on the rise, e.g. Excelerate recently announced their 500<sup>th</sup> STS operation offshore. However, STS operations in a sheltered harbour against hard jetty structures, though less complex than off-shore operations do not have many precedents in the past, even though recently some of the terminals worldwide have adopted such operations. Therefore, it is essential that the unique elements of the operations are recognised and that a full and thorough risk assessment is performed.

The weather conditions under which LNG STS transfers can take place may impose restrictions on the operations. Following Met-ocean conditions must therefore be carefully evaluated for planning purposes and operations.

- Visibility
- Wind direction
- Wind velocity
- Wave height
- Wave period and direction

**Figure 5-7: Typical STS configuration**



#### **Tranquillity requirements**

In option A, where STS operations are planned, environmental limits will differ from option B where conventional mooring is planned.

Vessel motions are recognised as having the potential for damaging impacts from sloshing within partly-filled LNG cargo tanks that have membrane containment systems. Since, the LNG operation in our case is proposed to be in sheltered waters, it may be

generally regarded that sloshing impacts will not pose a risk. A detailed assessment is recommended to be undertaken in the advanced stages of the project execution to investigate any potential of significant sloshing happening at the jetty specifically for option A for STS operations and for option B, this may not be required.

Tranquillity requirement also depends on the use of cargo transfer equipment to be used for STS operations. Cargo transfer can be done either with flexible hoses or hard arms. The design of the cryogenic transfer system and the related motion capabilities are the central boundary condition for the operational range of the entire STS operation.

*FMC Technologies' rigid Marine Loading Arms* are currently state-of-the art. They have been designed by FMC to handle relative motion amplitudes between the two vessels of  $\pm 1.0$  m in longitudinal,  $\pm 2.0$  m in transverse and  $\pm 1.2$  m in vertical direction. Due to these limitations, STS transfer with rigid loading arms is currently possible only for calm waters to moderate sea states. A detailed dynamic mooring analysis needs to be carried out to study the moored response of the two floating bodies under environmental loads to compute predicted vessel movements under moored conditions. The allowable movement is dependent on various parameters of wind and wave loading, and therefore a particular number of a wave height, period, etc. cannot be concluded without the detailed studies. However, based on the experience of past STS operations under sheltered conditions, it is believed that wave heights less than 0.7m and relatively smaller wave periods (~6s) would prove to be an upper limit of the wave conditions. This upper limit should not be considered as absolute recommendations as other parameters like wind speed, directions, currents, etc. play a very important role in vessel response.

Use of Flexible cryogenic hoses is now becoming popular for STS operations, wherein its upper limit for environmental parameters is considered to be much higher than the hard arms.

### Limits

During the offloading process, the mooring arrangement should ensure that the carrier manifold stays within the operating envelope of the loading arm during LNG transfer.

The FSRU will be equipped with either standard loading arms or flexible hoses. The loading arms will be similar to the type used in onshore terminals, but modified to account for relative motions between LNGC and FSRU. The FSRU will also be fitted with equipment for guiding the arms onto the carrier's connection flanges. This pre-coupling guide operation will be necessary to compensate for relative motion during coupling when the relative motion exceeds  $\pm 0.5$ m.

Operational wave height limits (Hs) for safe unloading arm operations are provided below.

- Option A: STS operations,  $H_s < 0.7$ m using hard arms. Operating limits for use of cryogenic hoses must be studied in details, but are expected to be in the range of  $H_s = 0.7$  to 1.5m.
- Option B: Conventional operations.  $H_s < 1.5$ m

***It must be noted that the above figures are indicative only and should be used with caution for planning purposes only. Detailing modelling and mooring analysis***

***should be carried out and limits w.r.t. relative motions of the vessels must be known and cargo transfer system then designed accordingly.***

### 5.3.2

#### Wind

The wind conditions at the site can have a significant effect on ship manoeuvring and ship mooring. The effect of the wind on a ship depends on the wind speed and relative direction, as well as the overall windage of the ship. In general, the maximum wind forces that act on a ship are associated with beam winds.

LNG carriers with a spherical containment system (Moss-Rosenberg) have proportionately higher windage than those with a prismatic/membrane containment system and vessels in ballast have relatively more windage than laden vessels because of the increase in freeboard. Consequently, while all ships will be affected by the wind conditions, LNGCs with spherical tanks and vessels in ballast will be more sensitive to the wind than laden vessels or those with membrane tanks.

#### Local conditions

The local wind in the region is mainly affected by the strong winds coming from south-west and relatively weak winds coming from North-east. In general the wind climate of the region is divided into four seasons as Pre-monsoon (March-May), SW-monsoon (June-September), Post-monsoon (October - November) and NE-monsoon (December-February).

From March to May the winds are mostly westerly. This period together with post-monsoon season) is also considered as the cyclone season. There are some records depicting wind speeds of 22-28 knots, coming also from the direction sector 105-195°N in these months. During SW monsoon the prevailing wind direction is south-westerly, with wind speeds regularly between 15 and 30 knots. There are a few outliers in direction sector 105-165°N with the exceedance in wind speed of about 20 knots. These events are probably associated with the tail-end of the cyclone season, with some cyclone events persisting into June. Post monsoon season is a transition period and the winds come from all directions with predominant wind direction from North. The maximum prevailing winds come from the NE quadrant 10 to 20 knots

Offshore annual average wind climate based on (UK) Met office predictions are shown in below Figure 5-8. The wind table for an offshore point located at 20.28° N, 70.42°E covers the period from May 1999-November 2008 based on UKMO Global Wave Model. The total number of hours recorded are 84048. The local region is mainly affected by the strong winds coming from S-W and relatively weak winds coming from N-E. During south-west monsoon i.e. June-September highest wind speeds between 15 to 30 knots from south-west directions are recorded. While westerly wind speeds up to 25 knots occur during the cyclone season i.e. March-May.

**Figure 5-8: Wind scatter table**

U1 To U2	P(U>U1)	Wind direction in degrees North												
		-15	15	45	75	105	135	165	195	225	255	285	315	
0	2	0.98	54	48	54	66	30	24	30	18	48	66	24	84
2	4	0.98	360	258	288	204	144	78	96	78	168	294	444	360
4	6	0.94	816	588	438	258	162	72	78	138	288	522	912	882
6	8	0.88	1044	726	414	252	156	48	102	192	450	1074	1710	1548
8	10	0.79	1524	1212	456	246	66	72	102	264	894	1734	2334	2010
10	12	0.66	1488	1218	702	150	48	60	168	246	1446	2610	2766	2124
12	14	0.50	900	978	492	114	24	54	60	234	1914	3096	3096	1878
14	16	0.35	516	774	480	30	6	36	102	138	1920	3210	2484	1368
16	18	0.22	210	522	276	12	24	36	54	126	1608	2688	1482	540
18	20	0.13	54	294	120	-	24	18	30	102	1608	1950	492	162
20	22	0.07	12	126	36	-	12	48	12	84	1206	1212	126	18
22	24	0.04	-	42	12	-	12	12	6	48	690	768	48	-
24	26	0.02	-	-	-	-	-	30	6	36	414	414	24	-
26	28	0.01	-	-	-	-	-	6	12	12	210	156	30	-
28	30	0.00	-	-	-	-	-	-	-	6	48	66	6	-
30	32	0.00	-	-	-	-	-	-	-	-	30	6	-	-
32	34	0.00	-	-	-	-	-	-	-	-	6	6	-	-
Parts per thousand for each direction			6978	6786	3768	1332	708	594	858	1722	12948	19872	15978	10974

**Limits**

The following limits may be considered as providing a guide for safe operations. However, detailed site and vessel-specific navigation simulations, mooring analysis, risk assessments and met ocean data analysis is recommended to be carried out in the detail design stage:

- Mooring equipment to be designed for 60 knots wind from any direction as per OCIMF recommendations, simultaneously with either:
  - 3 knots current at 00 or 1800
  - 2 knots current at 100 or 1700
  - 0.75 knots current from the direction of maximum beam current loading
- Approximately 10 m/sec or 20 knots is the recommended safe wind limit for berthing vessels with a projected wind area greater than 5000 m<sup>2</sup>. LNGC/FSRU of sizes 150,000m<sup>3</sup> would typically have windage area greater than 5000 m<sup>2</sup>
- Approximately 15 m/sec or 30 knots is the recommended safe wind limit for cargo transfer operations.
- Approximately 20 m/s or 40 knots is the recommended safe wind limit for disconnection of loading arms subject to confirmation from the manufacturers.
- Approximately 22 m/sec or 45 knots is the recommended safe mooring wind limit

These operational guidelines are applicable for sheltered berths (significant wave height less than 0.6 m). Decreased limiting criteria may be applicable for increased wave heights.

Wind speed is defined as the 30 second average mean wind (gust) speed as measured at a standard datum height of 10 m above the ground or water surface. Since the gust or 30 s average mean wind speed is not available at the moment, it is recommended to do a detailed wind and persistence study to establish down time for berthing and loading operations due to wind.

***It is also recommended to undertake an operational-based and design-based mooring evaluation. The design based mooring evaluation uses all combinations of vessel mooring equipment that will produce the highest load in the mooring structures and breasting dolphins, whereas the operational-based evaluation will use the combination of vessel mooring equipment which results in the highest stress in the mooring lines and largest vessel movements.***

### 5.3.3 Under Keel clearance

Dredged depth inside the port area is around -15.0 m CD. The water depth in the approach channel and the harbour basin, and in front of and alongside the berth should be sufficient for safe manoeuvring. The selected water depth is usually based on the following factors:

- draught of the loaded design ship
- tidal variations
- ship movements under wave action
- trim variations due to cargo operations
- squat (reduction in under keel clearance due to the suction effect induced by higher current velocity between sea bottom and the ship)
- character of bottom – a higher UKC will be needed for a rock bottom
- variations in actual dredged depths from the theoretical
- Allowance for sedimentation between two maintenance dredging programs.

An under keel clearance to account for squat, trim, rolling and pitching, current, velocity, inaccuracies in hydrographic survey, salinity, etc. is considered over and above the fully laden draught of design vessels in the planning for safe servicing of the vessels alongside the berth, Common Manoeuvring Area/Turning Circle and in the Access Channel. The UKC does not include allowances for sedimentation between two maintenance dredging programs.

A considerable amount of work had been carried out on this aspect by the PIANC, ICORELS Committee No. IV (Permanent International Association for Navigational Congresses - International Commission for Reception of Large Vessels). After a detailed study, the commission made the following general recommendations on UKC:

- Open sea area (in outer approach channel) : for those exposed to strong and long stern or quarter swell, where speed may be high, gross UKC should be about 20% of the maximum draught of ships.
- Channel: for sections exposed to strong and long swell, gross UKC should be about 15% of the draught.
- Channel: less exposed to swell, gross UKC should be about 10% of the draught.
- Manoeuvring and berthing areas for those exposed to swell (without full protection of breakwater): gross UKC should be about 10 to 15% of the draught.
- Manoeuvring and berthing areas protected (full protection by breakwater): gross UKC to be about 7% of the draught.
- A total UKC - to account for squat, trim, rolling and pitching, current velocity, inaccuracies in hydrographic survey, salinity etc. - of 10% of the fully laden draught

of the vessel at the berths, in the berth approach areas and in the turning circle and manoeuvring areas; and 20% in the approach channel will need to be provided.

Ship owners and charterers require minimum clearance of 10% of the draught at berth and clearance of 10% plus squat for safe navigation during manoeuvring

The draft of the channel should account for potential allowances in UKC policies of ship owners and charterers require minimum clearance of 10% of the draught at berth and clearance of 10% plus squat for safe navigation during manoeuvring as mentioned above.

Detailed calculations were carried out to investigate adequacy of the existing depths based on estimation of squat, estimation of increase in draught requirement due to heel / list, allowance for safety in manoeuvring, dredging tolerance etc., Gross UKC thus calculated is as below:

**Table 5-1: Calculation of gross depth requirements**

Location	Static draught (m)	Allowance for squat (m)	Allowance for heel/list (m)	Allowance for safety in manoeuvring (m)	Additional 10% margin of static draught (m)	Gross Depth (m)
Berth	12.5	0.09	0.46	0.8	1.25	15.10
Turning circle	12.5	0.09	0.46	0.8	1.25	15.10
Channel inside breakwater	12.5	0.35	0.46	0.8	1.25	15.36
Channel at entrance	12.5	0.35	0.46	1.4	1.25	15.96
Channel outside	12.5	0.35	0.46	2.6	1.25	17.16

Considering that Mean Lowest Low Water (MLLW) = +0.64 m CD and assuming ship manoeuvres are restricted to MLLW and at berth LLLW of 0.0 m

Therefore following dredge depths are estimated:

- Berth area inside breakwater = 15.10m. Therefore 15 m depth is considered adequate.
- Turning basins and approach channel inside breakwaters – 15.96 m. Therefore 15 m depth is considered adequate.

The PIANC WG 49 report provides guidance for the conceptual design of UKC requirements, as follows.

**Figure 5-9: Conceptual design of underkeel clearance (UKC) requirements**

Description	Vessel speed	Wave conditions	Channel bottom	Inner channel	Outer channel	
Depth, h	≤ 10 knots	None	-	1.10 T	-	
	10-15 knots		-	1.12 T	-	
	>15 knots		-	1.15 T	-	
	All	Low swell ( $H_s < 1$ m)	-	-	1.15 T to 1.2 T	
		Moderate swell ( $1 \text{ m} < H_s < 2$ m)	-	-	1.2 T to 1.3 T	
		Heavy swell ( $H_s > 2$ m)	-	-	1.3 T to 1.4 T	
	Add for channel bottom type:					
	All	All	Mud	None	None	
			Sand/clay	0.4 m	0.5 m	
Rock/coral			0.6 m	1.0 m		
Notes.						
1. Assumes ship draught, T, greater than or equal to 10 m. If draught is less than 10 m, then use values for 10 m draught						
2. Swell means waves with peak periods greater than 10 s						
3. For outer channel, use lower value for northern hemisphere and higher value for southern hemisphere						
4. Value of $H_s$ is dependent on required operation, design ship type, level of accessibility, wave period, and relative wave direction						
5. Salt-water assumed for ship draught so additional adjustments required for fresh water						

### 5.3.4

#### Manoeuvring safety

##### Turning circle

The turning area should usually be in the central area of the harbour basin. The size of the turning circle will be a function of the manoeuvrability and length of ships using the area. The area should be protected from waves and strong winds.

PIANC and IS: 4651 (Part V) recommend that where vessels turn by free interplay of the propeller and assisted by tugs, the minimum diameter of the turning circle should be 1.7 to 2.0 times (1.70 for protected locations and 2.0 for exposed locations) the length of the largest vessel to be turned. The largest vessel calling at this port will be the  $Q_{max}$  of an overall length (LOA) of about 345 m. These ships would be assisted with tugs in manoeuvring in the approach channel, in the harbour basin and to and from the berth.

The diameter of the proposed turning circle inside the harbour area is around 700m which is considered to be adequate for turning inside the harbour

##### Channel

A channel width of 300m is proposed.

The minimum width of a straight channel will primarily depend on the size and manoeuvrability of the ships navigating the channel and the effects of wind and current. The recommended total channel bottom width for single lane channels should be 3.6 to 6

times the beam of the design ship depending on the sea and wind conditions. The width of a restricted channel should be measured at the bottom of the dredged depth.

Width of approach channel and alignment was found to be adequate.

### **Ease in manoeuvring**

Detailed ship handling and manoeuvring simulations shall be carried out to confirm the manoeuvring requirements such as;

- Ability of vessels to arrive & depart from proposed berths in a safe, timely & efficient manner under the combined effects of current, wind, tide & swell.
- Ability of vessels to manoeuvre in the approach channel/turning circle in a safe, timely & efficient manner under the combined effects of current, wind, tide & swell.
- Confirm the suitability of the proposed size, location & orientation of the approach channel/turning circle for safe & efficient transit of the vessel under the effects of current, wind, tide & swell
- Preliminary confirmation on the size & number of tugs to safely & efficiently escort/assist the vessels during transit, turning, berthing/un-berthing including the ability to assist the vessel during emergency conditions
- Level of ease in manoeuvring, berthing and un-berthing.

## **5.4**

### **Summary**

Marine navigation and mooring systems have been reviewed and assessed in the preceding sections. In summary, from overall perspective both the options are considered technically feasible.

For option A, the only major show stopper for feasibility would be the tranquility conditions at the berth for STS operations. Indicative limits for STS operations have been provided.

## 6 Early commissioning timelines and cost assessment

This section describes a broad time line involved in early commissioning using FSRU option and block costs for the two options.

### 6.1 Project time line

The project timeline has been worked out based upon industry benchmarked estimates for each activity. However, site specific constraints may be considered as additional for evaluating the project completion timing. In general the timeline are estimated to be 23 months and 27 months for the two options Option-A and Option-B respectively. A tentative programme (schedule) is attached. The programme does not take into account the effect of monsoons as the actual start of construction is governed by the date of tender. As such BMT recommend that the Contractor is advised to amend the programme accordingly in order to achieve the time line. The basis for the programme is as stated below:

#### 6.1.1 Marine facilities

It has been assumed that the construction work under this scope shall progress from two fronts, one for the approach trestle construction which would be a land based start, and the other for the jetty head construction which would be a marine based start. Fabrication and erection of a land based piling gantry and a jack up platform will trigger the start of piling activities under the respective section of work.

For the approach trestle, the superstructure works pile cap & deck slab that follow the piling activity will have to be taken up when sufficient pile bents have been completed and this will follow the piling gantry till the completion of approach road. Subsequently the steel fit outs and other miscellaneous installations will be commenced and completed.

For the jetty head, the construction of pile cap and deck slab will have to be taken up once the piling activity is completed and the jack up may be moved to the next location once the steel fit outs and other miscellaneous starts.

Marine activities fall on the critical path. Most other activities are subject to construction of these. Therefore, considered together, Marine activities are estimated to have a timeline of 18 months and 22 months for Option-A and Option-B respectively.

#### 6.1.2 Topside facilities

The topside works includes installation of equipment on the approach trestle and jetty head, as well as tie-ins onshore.

Topside work on approach trestle can commence in a step-wise fashion once each section of the trestle is constructed and safety provisions (e.g., hand rails) are installed. The topside contractor will first install plinth foundations and pipe supports and then will

lay out pipe for installation of the large diameter unloading lines. This will be followed by installation of pipe rack and cable tray support sections, and then placement of utility piping on the racks. Coordination will be needed with the marine contractor to avoid interference with movement of materials and personnel. When the approach trestle is completed the topside contractor will finish all piping connections, install cable trays and lay cable.

Similarly, work on the Jetty Head can be accomplished as the marine contractor finishes work in local areas; for instance, when the marine contractor finishes the platform deck he may move to the dolphins, freeing up the platform area for the topside contractor to begin its installation work. When all topside facilities are installed, the topside contractor will perform final connections for piping and cabling, and perform all needed testing.

Topside activities have two starting constraints, the equipment delivery lead-time and the availability and suitability of location, i.e. trestle, jetty, foundation, etc. Considering all the process activities together, we estimate a timeline of 18 months and 20 months for Option-A and Option-B respectively.

### 6.1.3 FSRU timeline

In particular, the FSRU availability timeline of 15 months is a broad conservative estimate and may vary from as low as 6 months to as high as 24 months, depending on the current spare availability and commitment status of different suppliers.

### 6.1.4 Statutory clearances

As per client advice, we have not considered environment and other statutory clearances in this schedule. However these will be required for starting the construction work at site and could lead to un-due project delays if not available. As the site construction work cannot start before Environment clearance, it should be available within 6-9 months of the start date. During this time DPR/FEED can be undertaken.

Other statutory clearances for the project are assumed to be available.

### 6.1.5 Breakwater

As per specific client advice, we have not considered the breakwater in the project schedule, and it is considered built when required. However, given the overall time schedule of the FSRU terminal, breakwater should be available within 20 months and 24 months of the start date for Option-A and Option-B respectively.

### 6.1.6 DPR / FEED

The FSRU project DPR / FEED is the first major activity for the project. The design specifications developed here will be as the basis in all procurement tenders. We estimate time requirement of 6 months for this activity. However, DPR / FEED is assumed to be available for the timeline estimation purpose.

## 6.1.7

**Critical path****Option-A**

The FSRU procurement and delivery is the critical path activity in Option-A. As mentioned above, this is subject to market dynamics and may not eventually cause a time constraint.

Given the time estimates in the project schedule, it is observed that non-critical Marine & Process activities have a slack of 3 months and 1 month respectively.

If the FSRU is available earlier and not on the critical path, then long lead items such as high pressure NG arm and cryogenic LNG arms, along with jetty construction are found to be on the critical paths.

**Option-B**

Since two jetties have to be constructed in this option, the Marine construction activities fall on the critical path. This leads to LNG circuit commissioning activities also to fall on the critical path.

FSRU delivery is therefore a non-critical activity and has 3 months of estimated slack.

Schedule snapshots have been provided in the report. However, owing to large size, a separate schedule PDF is also provided for clarity and legibility.

Figure 6-1: Project timeline – Option A

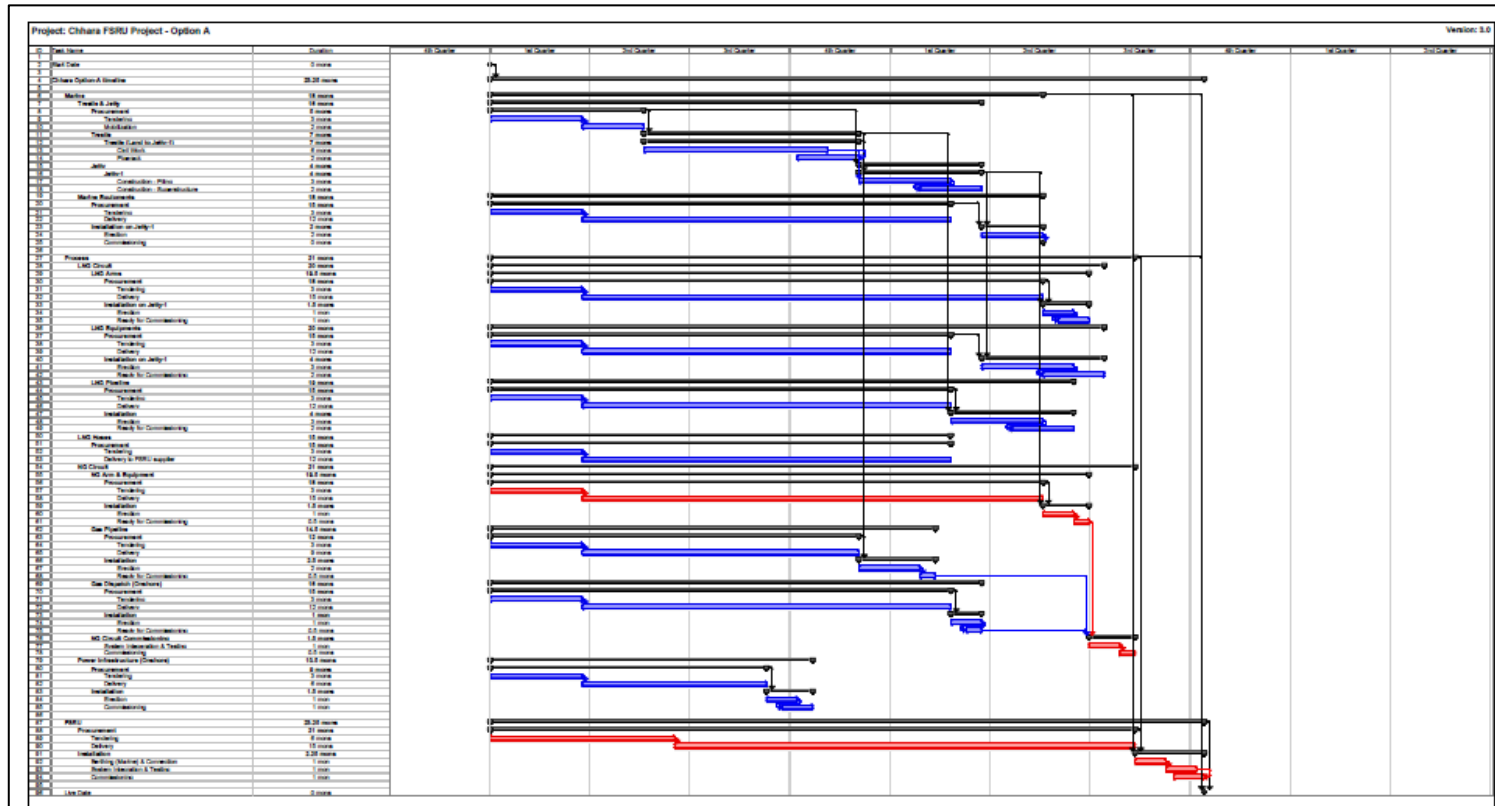
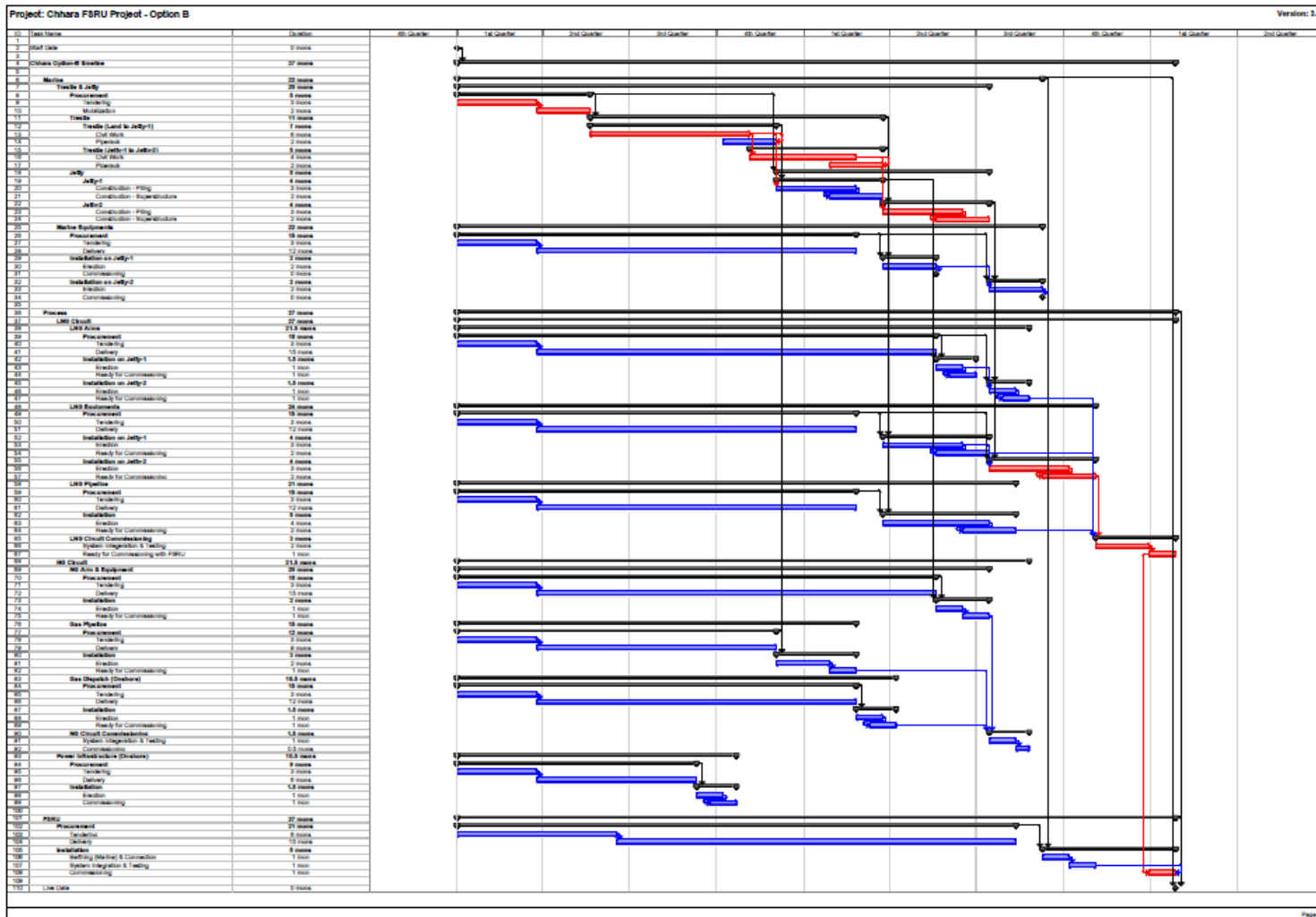


Figure 6-2: Project timeline – Option B



## 6.2 Budget cost estimates

### 6.2.1 CAPEX & OPEX

Given the scope of this study, the cost estimates are based on secondary sources and therefore may be considered as budgetary costs estimates with a tolerance of +/- 20%.

It must be noted that,

- Estimates especially for the topsides equipment, mechanical process equipment, utility and fire water piping, electrical equipment, instrumentation associated with the process and utility equipment includes our estimate of material costs, shipping and installation.
- These estimates do not include any factor for inflation, construction management burden, etc. Relevant factors may be introduced into these costs for Indian conditions in the detailed cost estimates, but we do not foresee a significant impact on the overall cost of the scheme and also these not being variables for the selection of an option.
- Taxes & duties are considered at the below aggregate rates
  - EPC work-order rate – 4% of order value
  - T&D on domestic equipment – 12% of equipment value
  - T&D on imported equipment – 35% of equipment value

However, it must be noted that the market is very buoyant at present with most contractors having empty order books. Further the prices of principal materials like steel, cement have shown significant changes over past few years. The cost estimate therefore must be therefore adopted with caution bearing in mind the above uncertainties.

Cost estimates for both the options are as tabulated below,

**Table 6-1: Budget CAPEX estimates Option-A; Block-2**

Sub-Heads	Million USD	Million INR
Trestle & Jetty 2# Mooring Dolphins & Walkway NG arm platform	-	80
Marine equipment 2# QRMH 4# QRMH upgrade 4# Foam Fenders	1.1	-
LNG arms	-	-
LNG equipment	-	-
LNG pipeline	-	-
STS LNG hose 1# LNG hose set	11.3	-
NG arm and equipment 1# HP NG arm + systems	13.5	-
Gas pipe line 3km gas pipeline	-	105
<b>Total</b>	<b>25.9</b>	<b>185</b>
Total in USD (@ 63 INR/USD)		<b>28.9</b>
Contingency (@ 7% of CAPEX)		2.0
<b>Total Costs</b>		<b>30.9</b>

**Table 6-2: Budget OPEX estimates Option-A; Block-3**

Sub-Heads	Million USD	Million INR
FSRU Charter Bare-boat Lease + Ship Management	54.1	-
Internal Gas consumption 0.5% of throughput (2.5 MTPA) Gas cost @ 13 USD/mmbtu	6.8	-
Terminal O&M Marine & Process O&M Maintenance of unused Block-1 infra. Utilities & Safety systems Port Charges	2.7	202
Insurance @ 0.5% LNG cargo value 150,000 m3 LNG cargo assumed	0.2	-
<b>Total</b>	<b>63.8</b>	<b>202</b>
Total in USD (@ 63 INR/USD)		<b>67.0</b>

**Table 6-3: Budget CAPEX estimates Option-B; Block-2**

Sub-Heads	Million USD	Million INR
Trestle & Jetty Jetty-2	-	901
Marine equipment All Marine equipment on Jetty-2	2.4	-
LNG arms Set of 4 LNG arms on Jetty-2	17.0	-
LNG equipment All LNG equipment on Jetty-2	11.1	-
LNG pipeline 700m LNG pipeline	4.7	36
STS LNG hose 1# LNG hose set	-	-
NG arm and equipment 1# HP NG arm + systems	13.5	-
Gas pipe line 3km gas pipeline	-	105
<b>Total</b>	<b>48.7</b>	<b>1042</b>
Total in USD (@ 63 INR/USD)		<b>65.3</b>
Contingency (@ 7% of CAPEX)		4.5
<b>Total Costs</b>		<b>69.8</b>

**Table 6-4: Budget OPEX estimates Option-B; Block-3**

Sub-Heads	Million USD	Million INR
FSRU Charter Bare-boat Lease + Ship Management	54.1	-
Internal Gas consumption 0.5% of throughput (2.5 MTPA) Gas cost @ 13 USD/mmbtu	6.8	-
Terminal O&M Marine & Process O&M Maintenance of unused Block-1 infra. Utilities & Safety systems Port Charges	5.4	336
Insurance @ 0.5% LNG cargo value 150,000 m3 LNG cargo assumed	0.2	-
<b>Total</b>	<b>66.5</b>	<b>336</b>
Total in USD (@ 63 INR/USD)		<b>71.8</b>

## 6.2.2 FSRU lease estimates basis

FSRU lease cost estimates are as per industry benchmark. Two recent FSRU charter agreements are mentioned below. However, these instances are based on publically available information.

- Jordan FSRU:
  - Government of Jordan on July 31, 2013 agreed to charter a purpose built FSRU from Golar LNG for a period of 10 years.
  - FSRU Golar Eskimo, with 160,000m<sup>3</sup> LNG storage capacity and 3.8 MTPA (5.6 MTPA peak) gas send-out rate is chartered under this agreement.
  - FSRU will be moored at Red-sea port of Aqaba, starting 1<sup>st</sup> quarter 2015.
  - Golar will earn yearly EBITDA of 46 million USD for the 1<sup>st</sup> 5-year term & 43 million USD 2<sup>nd</sup> 5-year term.
- Kuwait FSRU:
  - Kuwait National Petroleum Company on August 4, 2013 agreed to charter a new-built FSRU from Golar LNG for a period of 5 years.
  - FSRU is chartered for 9-months each year, with a 3-month winter stand-down window in which it can pursue other business opportunities.
  - FSRU Golar Igloo, with 170,000m<sup>3</sup> LNG storage capacity and 1.3 MTPA gas send-out rate is chartered under this agreement.
  - FSRU will be moored at Mina Al Ahmadi port, starting 2<sup>nd</sup> quarter 2014.
  - The contract value is 213 million USD for the 5-year term.

## 6.2.3 Preservation & disposal value

Once the land-based LNG tanks and vaporization facilities are commissioned, the FSRU will sail-away and operations will switch to land based terminal. This will leave the dedicated assets of FSRU terminal redundant. The major equipment which are dedicated for FSRU operations fall under the following CAPEX heads are,

- Marine Equipment (part)
- LNG Hoses
- NG Arm & Equipment
- Gas pipeline

Redundant equipment can be either preserved for future utilization or can be decommissioned and disposed, as envisaged. The preservation cost of such equipment for future utilization is estimated to be of the order of 0.7 Million US \$ per year. Alternatively, the estimated net revenue from disposal is estimated to be of the order of 6 Million US \$.

## 7 Process description and environmental considerations

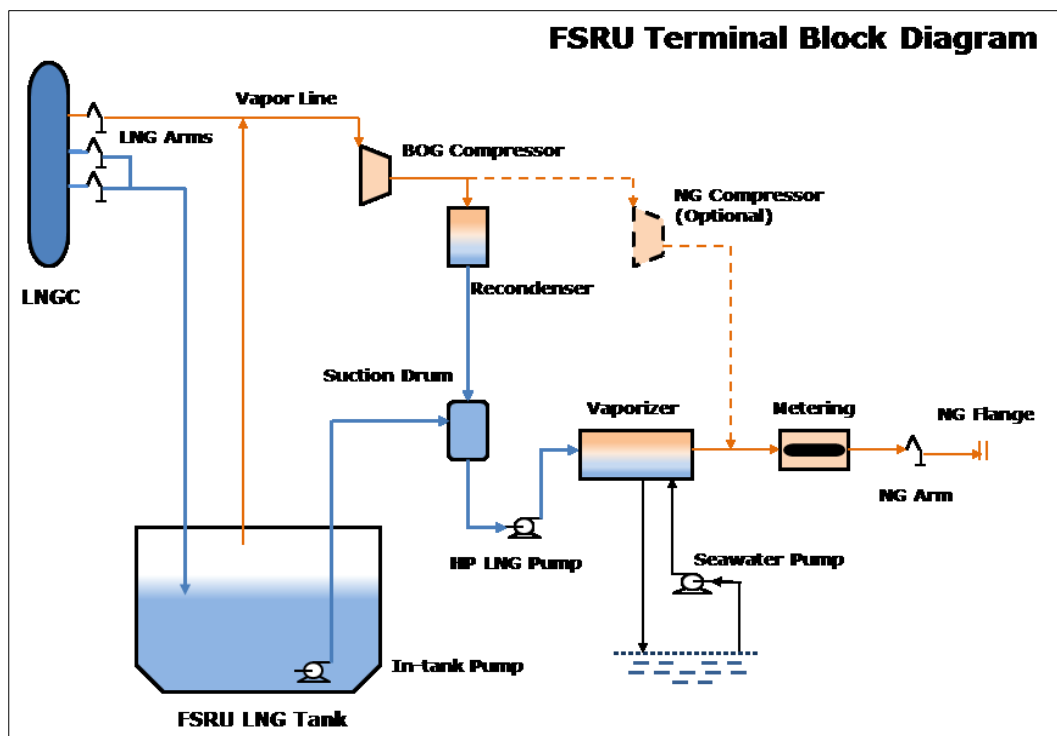
### 7.1 Brief description of FSRU

This section describes the broad FSRU re-gasification process flow. The following essentially is a typical description of LNG handling, re-gasification and NG dispatch in the FSRU. The exact layout of the equipment may vary depending on the overall terminal layout, mooring design, envisaged LNGC berthing etc. These will get suitably finalized as the process design and engineering progresses.

The main system of the FSRU comprises of three major processes:

- LNG reception from LNGC
- LNG Re-gasification to NG and dispatch
- Boil-off gas (BOG) management

**Figure 7-1: FSRU terminal block diagram**



#### 7.1.1 LNG reception from LNGC

As the LNG carrier arrives at the port and berths at the jetty, the hard LNG transfer lines as well as vapor return lines are connected to the LNGC and the unloading process is initiated. LNG unloading and transfer to the FSRU is done in a "closed" circle. While the LNG is transferred by the in-tank pumps of the carrier, the vapor in the FSRU tanks are

transferred to the carrier tanks. The vapor return line balances the pressure across the transferring tanks and avoids vapor locks or back pressure in the tanks. If the pressure in the tanks cannot be maintained within acceptable limits, compressors are used, or unloading rates must be reduced. The LNG receiving operations are to be so designed that they are independent with respect to the continuous re-gasification operations of the FSRU.

The LNG offloading pumps of the LNGC are typically rated such that they can offload their LNG cargo within 15-18 hours from the time of connection, with a tug-boat-to-tug-boat turnaround time estimate of 24 hours.

### 7.1.2 LNG Re-gasification to NG and dispatch

The re-gasification unit of the FSRU comprises of multiple re-gasification trains which operate in parallel. Typically these trains are sized with inbuilt redundancy such that they operate in configurations of 2-working-1-standby or N-working-1-standby mode. The re-gasification trains comprise of LNG booster pumps and vaporizer systems. Given the location and local conditions, only seawater based open-loop vaporizing system is envisaged. Variable speed booster pumps may be considered to match the changes in the gas dispatch requirements.

The in-tank LNG low-pressure pumps transfer the LNG from the tank to a common suction drum. This suction drum is connected to multiple booster-pump-vaporizer re-gasification trains. The booster pumps increase the liquid pressure up to the pressure slightly higher than that required at the NG dispatch point. While the vaporizers gasify the LNG into NG, which is thereafter metered and dispatched to the jetty via high pressure NG unloading arms.

### 7.1.3 Boil-off gas (BOG) management

LNG stored in cryogenic state in the low pressure storage tanks of the FSRU. As the surrounding heat leaks into the storage tank, proportionate amount of LNG boils off and increases the pressure of the tank. If this pressure is not timely reduced, it could cause un-due stress to the tank walls leading to fatigue and breach of containment. Under steady state this boil-off gas is evacuated from the storage tank and the pressure is kept within acceptable limits. The boil-off gas is at very low tank pressure, and therefore is first compressed to workable pressure of about 8 barg by the boil-off compressor. Thereafter, in an FSRU the compressed boil-off gas can be managed in one of the following processes, 1) it could be either sent to on-board steam boiler or turbine to be fired and produce steam or electricity respectively; or 2) it could re-liquefied in a re-condenser and sent back into the LNG tanks for storage; or 3) optionally, it could be further compressed and injected into the NG dispatch system.

### 7.1.4 Infrastructure requirements

The proposed project will involve land side and marine facilities. The land side facilities primarily involve a corridor for pipelines for natural gas, access road and power.

On the water side, the infrastructure proposed will consist of a harbour with breakwater, construction of jetties and mooring dolphins, a service jetty for tugs and pilot vessels, permanent berthing of a Floating Storage and Regasification Unit (FSRU), dredging, pipelines for seawater intake and outfall and access road on a trestle up to the LNG jetty. Navigational aids, pilotage, movement, etc. will be required as part of this project during operations.

In addition, seawater based LNG re-gasification process using an open loop system using the heat of the seawater as an unfired heat source for vaporizing LNG will be required.

Seawater temperature across the year will remain well above the required re-gasified LNG temperature and thus SP is likely to consider seawater as heat source for vaporizing LNG. The intake well with sea pumps may be located within the harbour basin to provide lower sediment laden water. The quantity of seawater required is about 125,000 KLD at  $\Delta T$  of 5°C. Seawater taken from sea typically is expected to have a temperature range from 20°C to 30°C. The seawater intake system will consist of various filters to remove debris and hypo chlorination plant to reduce the corrosive effect of water on vaporizer and to prevent bio fouling. The discharge free chlorine concentration will need to be below 1mg/L.

This seawater will be brought in contact with LNG with a shell and tube heat exchanger to vaporize LNG flowing through closed tubes. Seawater will absorb cold energy from LNG and vaporize LNG. Seawater temperature will drop to by 5° to 7°C and cold seawater will be discharged in the sea. Regasified LNG will be fed in to gas grid at the battery limit of FSRU at 5°C temperature and 90-100 bar pressure.

## 7.2 Environmental considerations

The environmental clearance process will primarily be driven by the requirements of the *Environmental Impact Assessment Notification 2006* and the *Coastal Regulatory Zone Notification 2011*. Both these notifications are issued by the Ministry of Environment and Forests under the *Environmental Protection Act 1986*.

As per the EIA notification, projects and activities are broadly categorized into two categories - Category A and Category B, based on the spatial extent of potential impacts on human health, natural and manmade resources. Category A projects are to be accorded environmental clearance by the Central Government, while Category B projects are under the State Government.

Ports and harbours with less than 5 Mtpa of cargo handling capacity and/or ports/harbours with greater or equal to 10,000 tpa of fish handling capacity fall under Category B projects. The project exceeds 5 MTPA and thus requires clearance from the Central Government (MoEF). There is no specific mention of pipelines in the EIA notification, except for pipelines passing through forest areas.

Since the project lies in the Coastal Zone, which for the sake of brevity in this report, can broadly be described as areas on the coast within 500 m from the high tide line on the landward side, the area between high tide line and low tide line and up to 12 nautical miles for the offshore area. The reader is directed to the CRZ Notification in [www.envfor.nic.in](http://www.envfor.nic.in) for the complete text of the Notification. The CRZ Notification requires

clearance for pipeline projects in the coastal zone from the Central Government after the State Coastal Zone Management Authority recommends the project.

The CRZ notification specifies activities that are prohibited /permissible on a number of criteria, the most important of which is the classification of the site in terms of CRZ-I, II or III. CRZ-I areas are ecologically sensitive areas, where development activities are generally prohibited, CRZ-II apply to areas in urban areas, while CRZ-III applies to location in the coastal zone not falling under CRZ-I and II. The classification of the coastal areas is based on the Coastal Zone Management Plan prepared by each State and approved by MoEF.

The CRZ notification also requires a comprehensive EIA with three seasons for sites considered to be undergoing Low to Medium shoreline erosion. The EIA conducted by CES covers three seasons and thus fulfils this requirement.

The other clauses of the CRZ Notification that indicate that the project is not prohibited as per the CRZ notification are:

1. The coastal regulation zone notification does not prohibit the transfer or handling of ammonia as per clause 3(i)(a)

*“Prohibited activities within CRZ,- The following are declared as prohibited activities within the CRZ,-.....*

*(i) Setting up of new industries and expansion of existing industries except,-*

*(a) those directly related to waterfront or directly needing foreshore facilities; Explanation: The expression “foreshore facilities” means those activities permissible under this notification and they require waterfront for their operations such as ports and harbours, jetties, quays, wharves, erosion control measures, breakwaters, pipelines, lighthouses, navigational safety facilities, coastal police stations and the like.;*

2. While transfer and handling is permitted through pipelines, the activities are controlled as per Clause 4(i)(a) and 4(ii)d

*4. Regulation of permissible activities in CRZ area.- The following activities shall be regulated except those prohibited in para 3 above,-*

*(i)(a) clearance shall be given for any activity within the CRZ only if it requires waterfront and foreshore facilities”*

*.....*

*“(ii) the following activities shall require clearance from MoEF, namely:- ....*

*(d) laying of pipelines, conveying systems, transmission line”*

Thus, it can be concluded that the activity is a permissible activity requiring environmental clearance from the Ministry of Environment and Forests (MoEF), Government of India.

The typical process leading to environmental clearance requires the following steps:

- **Terms of Reference Approval.** Fresh TOR for LNG terminal including FSRU from MoEF to be sought..

- **Conduct EIA through a QCI approved agency.** EIA report to be prepared for LNG terminal shall include following aspects related to FSRU:
  - Description of the FSRU focusing on the process flow rates, seawater requirements for vaporizing LNG and safety measures included in the design. The layout of the natural gas pipelines needs to be chosen such that future expansion of the port does not interfere with operations of the LNG terminal.
  - Prediction
    - Thermal dispersion modeling identifying the intake and outfall location for discharge of coldwater
    - Impacts on marine ecology due to the disposal of cold water
    - Entrainment of marine life at the intake system
    - Release of free chlorine at the outfall
  - Risk Analysis
    - Quantitative Risk Analysis - Consequence Analysis, frequency, computation of risk, separation zones
    - Navigational safety
    - The Chemical Accidents (Emergency Planning, Preparedness, and Response) Rules, 1996, Ministry Of Environment & Forests Notification, (New Delhi, The 1st August, 1996)
    - Manufacture, Storage and Import of Hazardous Chemical Rules, 1989, Ministry of Environment and Forests, (Department Of Environment, Forest And Wildlife) Notification, New Delhi, The 27th November, 1989
  - EMP/DMP
    - Include onsite and offsite plans, training, awareness and drills
- **Demarcate the HTL/LTL and CRZ through a MoEF approved agency.**
- **Public hearing.** A Public Hearing has been held for coal handling. Clarifications may be required from MoEF on the need for conducting the public hearing again with the revised activities
- **CRZ approval from State Government.** EIA report for LNG terminal with FSRU will need to be submitted
- **Environmental Clearance application to MoEF.** An application for environmental clearance will need to be made together with the EIA study report, HTL/LTL demarcation, minutes of the Public hearing, CRZ approval and the Detailed Project Report.

## 8 Conclusion and way forward

From an overall perspective both the options are found technically feasible. However, as per this study, **we recommend Option A be considered as the preferred option.**

### 8.1 Conclusion

Following parameters were assessed for checking feasibility of early commissioning of the terminal with FSRU:

- **Infrastructure:** infrastructure created for Land based terminal is utilized by both the options A & B, as described in Block-1. Additional FSRU-project specific infrastructure is also required to be created as described in block 2.
- **Marine Assessment: AS PER** Desktop mooring analysis carried out, 2 additional mooring dolphins were envisaged to be required in case of option A. For option B original layout is adequate. The tranquillity requirements for considered for mooring and operation of LNGC and FSRU are as below:

Operational wave height limits (Hs) for safe unloading arm operations:

- Option A: Ship to Ship (STS) operations, Hs < 0.7m using hard arms.
- Operating limits for use of cryogenic hoses must be studied in details, but are expected to be in the range of Hs = 0.7 to 1.5m.
- Option B: Conventional operations. Hs < 1.5m
- **Project timeline:** The project completion timelines for Option A and Option B are estimated to be 23 months and 27 months respectively.
- **Costs:** Block 1 infrastructure costs have not been estimated since they will be shared with the land based. Add on CAPEX for FSRU project in the form of block 2 as well as OPEX in the form of block 3 are as shown in table below:

Block	Option A (Million USD)	Option B (Million USD)
Block 2 (CAPEX)	30.90	69.80
Block 3 (OPEX)	67.00	71.80

- *Cost estimates were based on secondary sources*
- *Tolerance of +/- 20%*

### 8.2 Way forward

We envisage that following should be addressed to facilitate early commissioning of the terminal using FSRU:

- Detailed and location specific tranquillity studies to be carried out in the advanced stages of the project execution for determining design and operating requirements for FSRU operations.
- Fresh TOR from MOEF to be sought for LNG terminal with FSRU option.

- An application for environmental clearance will need to be made together with the EIA study report, HTL/LTL demarcation, minutes of the Public hearing, CRZ approval and the Detailed Project Report.
- A separate risk assessment may be required to update the existing risk assessment done as part of the DFR to include FSRU operations.
- Undertake an operational-based and design-based mooring evaluation. The design based mooring evaluation uses all combinations of vessel mooring equipment that will produce the highest load in the mooring structures and breasting dolphins, whereas the operational-based evaluation will use the combination of vessel mooring equipment which results in the highest stress in the mooring lines and largest vessel movements.

**9**

**Drawings**

# **Appendix A : Qualitative Risk Assessment**

## Qualitative Risk Assessment

The properties of gas are well understood and its behaviour, when released to the atmosphere, can be modelled within tolerances that allow for realistic contingency planning and safety management.

Accidental release of LNG, (although rare) can create localised or greater scale hazard situations. Risk exposures entailed in a LNG port project should therefore be analysed by a Quantitative Risk Assessment (QRA) study. Such a study must involve the operations at the terminal and the transit of vessels through the port. Risk assessments do not themselves improve safety, but they should be regarded as decision tools in order to satisfy company safety policies and statutory requirements.

### Risk Assessment for Chhara LNG terminal

Risk Assessment for the LNG terminal for Chhara has been carried out by the HSEL. Two documents, viz. "Risk analysis, Disaster Management and Emergency Plan" and "Fire hazard and safety systems" were critically reviewed. The studies covered:

- *Study of facility parameters* - this involved collection of pertinent project information, process engineering details such as flows, temperature, pressure, hydraulics and other parameters.
- *Hazard Identification or HAZID* - this included estimation of possible hazards through a systematic approach covering identification of possible failure scenarios through generic methods for estimating potential failures based on historical records based on worldwide LNG accident data bases.
- *Consequence Effects Estimation* - covering assessing the damage potential in terms of heat radiation and establishing the vulnerable zone or distance/ area of interest for fatalities or damage to important equipment/ structure etc.
- *Probability Estimation* - covering estimation of event probabilities, ignition probabilities and estimates on "how often" the events are likely to occur.
- *Risk Estimation* - covering estimating risk levels for members of the general public and risk reduction recommendations.
- *Emergency Response Plan* - for the identified risks, an emergency management structure is proposed for dealing with major emergencies during the operational phase.
- *Safety philosophy*

Risk assessment for the marine terminal and subsequent establishment of safety zones was also carried out. The following safety distances and limiting conditions have been recommended for safe and effective operations for a proposed LNG terminal at Chhara:

Exclusion zone	Boundary Limit
1000m gas dispersion zone	Emergency area around the Jetty head due to potential gas leak and dispersion with a risk of ignition up to LFL.
500m radius around manifold	Upper boundary limit- where space is not constraint and/or in the strong and prevailing wind directions. Hence we have allowed for a distance of 500m from the corner of the container berth, which is considered a main source for ignition.
400m restrictive access during unloading	Restriction area around the jetty head within 400m due to potential radiation in excess of 5 kW / m <sup>2</sup> in case of major accident.
300m radius around manifold	Lower boundary limit- where space is constraint and/or any larger distance results in costly additional infrastructure like for example the extension of the breakwaters. Hence in the two berth situation in Chhara, considering development of an LNG berth in future, it is recommended that the safety circle of 300m from the ship manifold during LNG transfer operations shall not be breached.
200m between LNG Cargo and any traffic	No traffic within 200m from any LNGC at berth or during approach / manoeuvring
600m manifold to manifold	For the other LNG vessel to be berthed alongside LNG vessel, a minimum of 130m clearance from exclusion zone to the vessels hull shall be provided. This includes 40m tug length + 40m length of line pull + 50m manoeuvring area. Together with the 300m radius as advised above, half a vessel length and 130m, this shall be 600m.

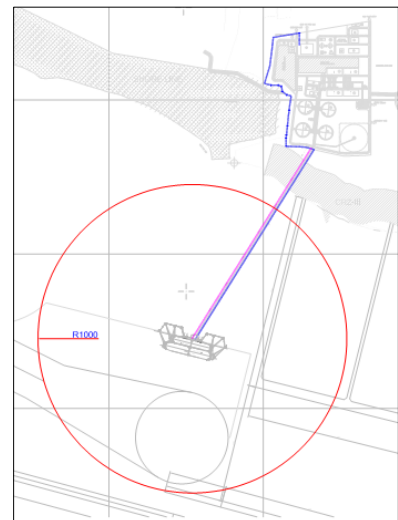
The study also concluded that to establish a more accurate value for the safety zone radius quantitative risk analysis (QRA) shall be carried out before detailed design.

## Risks during construction of LNG terminal

Two major items are perceived as major risks during construction of the LNG terminal:

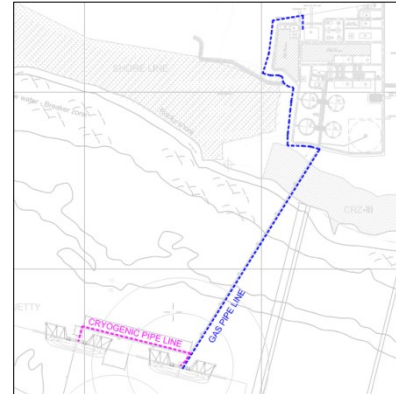
### Construction activities on the jetty and approach trestle during FSRU operations

- The risk assessment done earlier concluded 1000m radius as emergency area around the Jetty head due to potential gas leak and dispersion with a risk of ignition up to LFL.
- During FSRU operation on option A or option B, due to the restrictive 1000m radius for source of ignition, no hot works would be safe to be allowed during cargo transfer and regasification operations on the FSRU.
- The adjacent figure illustrates the extent of the restrictive zone
- Construction on approach and jetty would comprise installation of cryogenic pipeline, LNG unloading arms, all utilities, safety equipment, deck furniture, etc.
- It is therefore recommended that no construction works are planned on the jetty and approach trestle during FSRU operations.
- It is recommended that such construction works are completed along with jetty and trestle construction.



### Construction activities on shore

- HP gas pipe line is being routed from jetty over the trestle to land based gas dispatch station.
- A circuitous route passing through the green area has been chosen in order to minimize interference with land-based terminal construction.
- The pipeline is recommended to be buried underground from the land-fall point up to the gas dispatch station.
- The pipeline route shall be marked with visible markers and a fence along the route to provide restriction to unintended access.
- All crossings shall be suitable designed with culverts to cover any risks during construction to ensure pipe line integrity.



### Risk assessment for FSRU operations

The earlier risk assessment was carried out for conventional LNG operations involving LNG operations at the jetty, LNG transfer and storage which will be relevant for Option B. However, in the current context of FSRU operations for option A, it is recommended that the detailed QRA to include additional risks associated with FSRU operations, especially considering STS cargo operations, double banking mooring operations, double banking berthing, etc. High pressure ship to shore gas transfer and associated risk will be relevant for both the options.

This section illustrates qualitatively major risks and most credible scenarios associated with FSRU operations and NG transfer from jetty to shore.

- LNG transfer from LNGC to FSRU (STS operations)
  - Leakage/rupture in LNG transfer hoses during ship-to-ship LNG transfer in Option-A
  - Leakage/rupture in LNG arms during LNG transfer across Jetties 1 & 2 in Option-B
- High pressure NG transfer from FSRU to shore
  - Leakage/rupture in high-pressure NG arm on Jetty-1 in both options
  - Leakage/rupture of high pressure NG pipeline from Jetty-1 to gas dispatch area (land terminal)

### STS operations

An LNG STS transfer operation is complex, therefore it is essential that the unique elements of each transfer are recognized and a thorough risk assessment is performed. It should cover both physical and operational hazards, and the means by which they are managed. The risks identified for double banked STS operations will vary from conventionally moored LNGC operations and as a minimum must consider the following:

- Vessel compatibility
- Location
- Personnel
- Equipment
- Environment
- Emergency planning

#### Examples of high risks associated with STS operations

- *Low energy collision*: Inadequate control during berthing/unberthing operations may lead to hull to hull contact/collision leading to physical damage on one or both ships.
- *Mooring operations*; inadequate control during mooring, unmooring operations may lead to personnel injury or fatality.
- *High energy collision*: Inadequate navigational control by supply LNGC or third party passing vessel may cause high energy collision with FSRU or LNGC during berthing, unberthing or transfer operations resulting in significant damage, fatalities and loss of containment
- *Loss of containment (LNG)*: Inadequate control, hardware failure, overflow or over pressure during transfer operations may lead to an uncontrolled event resulting in a full flow loss of containment and LNG release resulting in injury / steel damage
- *Loss of containment (LNG vapour)* : Inadequate control during transfer operations may lead to an uncontrollable loss of containment and vapour release leading to ignition back to source resulting in fatalities / injury / hardware/steel damage
- *Loss of containment (LNG vapor in confined space)*: Inadequate control during transfer operations may lead to an uncontrollable loss of containment and vapour collection in a confined space leading to ignition with explosion causing fatalities / injury / hardware/steel damage
- *Loss of containment (LNG to water)*: Inadequate control during transfer operations may lead to an uncontrollable loss of containment and LNG release to water leading to Rapid Phase transition resulting in hull plating of fender damage.
- *Personnel transfer*: Failure or improper use of equipment used in personnel transfer may lead to loss of control during transfer operations resulting in fatality or injury
- *Damage to cargo containment system*: Cargo sloshing due to ship motions in the prevailing swell conditions may result in damage to primary cargo containment resulting in ship being unfit. Damage is only recognized during dry dock inspection and may result in incremental cost of repair.

#### Guidelines

Industry guidelines are available for STS operations, and must be consulted while doing the detailed risk assessment for STS operations. Some of the important ones specifically for STS operations are:

- OCIMF/SIGTTO 'Ship to Ship Transfer Guide (Liquefied gas)
- ICS/OCIMF 'Ship to Ship Transfer Guide (Petroleum)

- OCIM 'Mooring Equipment Guidelines'
- EN 1474 – 'Installation and Testing of Liquefied natural Gas – Design and testing of Marine Transfer Systems.'
- Tanker Safety Guide (ICS)

### High pressure NG transfer from FSRU to shore

High pressure NG transfer from FSRU to shore will have an independent fast-response Emergency Monitoring System (EMS) which will monitor the gas parameters such as pressure, temperature, gas detectors at flange & joints, etc. The EMS also monitors the arm's movements in a 3-envelop scheme with halt, stop, disconnect philosophy. The arm's EMS will be integrated with the FSRU and Jetty EMS so as to ensure required cascading of emergency alerts and responses. Appropriate fire-response systems will be actuated in case any gas leakage is detected.

### Leakage/rupture of high pressure NG pipeline from Jetty-1 to gas dispatch station

The risk of leakage of high pressure NG pipeline is minimal on the jetty and trestle as the access to these areas is controlled. Additionally gas detectors, pressure & temperature indicators at regular intervals will be connected to the pipeline monitoring system. In case of any leak detection, gas flow will be stopped, and pipeline will be isolated. If required by the level of emergency, pipeline line-pack will be diverted to a flare, located at a safe distance.