AECOM Delivering a better world

APPENDIX A3-3
LNG Terminal Design Concepts

Shannon LNG Limited
August 2021

Shannon Technology and Energy Park
Environmental Impact Assessment Report

Appendix A3-3 LNG Terminal Design Concepts

The Applicant reviewed various concepts for the LNG Terminal design. Six design objectives were considered:

1. Minimise environmental impact;
2. Optimise capacity / flexibility;
3. Minimise cost including construction and operations costs;
4. Minimise duration of construction; and
5. Ability to future transition of the plant to handle hydrogen.

Existing European LNG terminals were reviewed with a particular focus on those recently built with long-term capacity contracts (e.g. Croatia FSRU and Turkey FSRU LNG terminals). Lessons learned and insights from the Applicant's own experiences in operating LNG terminals at the Old Harbour offshore terminal and the San Juan hybrid terminal in the US were also applied, along with learning from site visits of four terminals in the UK and EU.

The choice of terminal concept is largely dependent on the project's commercial opportunity, objectives, and constraints. The recent trend has been to develop FSRU terminals with no onshore LNG storage or regassification capacity. The primary drivers have been the associated speed of execution, relatively lower capital costs, and lower environmental impact. Disadvantages of this option are the charter rates (operating costs) of the FSRU versus the anticipated amount of gas send-out, i.e. relatively high charter rates combined with low quantities of gas send out, leading to low profitability.

However, in order to consider the feasibility of future transitioning of the energy infrastructure to less carbon intensive fuel sources such as hydrogen, FSRU-based terminals with no onshore storage and a small footprint are more readily repurposed to deliver hydrogen, if and when that technology matures.

The terminal concepts were compared see Table A3.3-1 below and an FSRU based concept selected as follows:

Table A3-3.1 Rank Order for Each Terminal (1 – 3 with 1 Representing the Best Option)

	Land Based	FSRU	Hybrid
Optimized for Capacity Holders	1	3	2
Easily Manage Multiple Capacity Holders	1	2 [Tie]	
Minimise Environmental Impact	3	1	2
Short Construction time	3	1	2
Minimize Capital Costs	3	1	2
Minimize Operating Costs	1	2 [Tie – Function of Charter Rates]	

Technical options within the LNG Terminal considered are listed in Table A3.3-2 below.

Table A3-3.2 Technical Terminal Options

Item	Alternative 1 Onshore Terminal Design	Alternative 2 Hybrid FSU Design	Proposed FSRU Design
	Land based terminal	FSU + Landed Regas Plant	FSRU with minimum onshore infrastructure to support the terminal operation
Jetty required	Yes	Yes	Yes
Total developed area (Acres)	230	175	110
Storage	800,000 m^3 in 4 x 200,000 m^3 onshore tanks (with	Up to 180,000 m^3 onboard the Floating Storage Unit	Up to 180,000 m^3 via FSRU

	additional LNG Carrier storage of 150,000m^3 – 180,000 m^3		
Delivery Options	LNG Carriers up to Q-max (266,000 m^3)	LNG Carriers up to Q-max (266,000 m^3)	LNG Carriers up to Q-max (266,000 m^3)
Regasification (MTPY)	Up to 6	Up to 6	Up to 6
Ability to Land LNG	Yes	Yes	No
Key environmental considerations	Largest land take; Closer to sensitive receptors such as residential housing or the L1010 road, with potential for increased noise impacts, etc.	Larger footprint for onshore elements; Closer to sensitive receptors such as residential housing or the L1010 road, with potential for increased noise impacts, etc.	Smallest onshore footprint; Further from sensitive onshore receptors such as residential housing or the L1010 road, minimising noise impacts, etc.
On-Shore Power	600 MW Power Plant	600 MW Power Plant	600 MW Power Plant
Export Power	Yes	Yes	Yes
Construction Time (years)	4	2	1

There are 37 LNG import terminals in Europe (including the built, but not yet commissioned Croatia FSRU terminal), of which 8 have been built since 2013. Of the 8, 6 are FSRU based.

Table A3-3.3 FSRU Terminal Comparison

	Krk, Croatia	Etki, Turkey	Toscana, Italy	Klaipeda, Lithuania	Teeside, United Kingdom	Delimara, Malta
						
Vintage	Jan-21	Dec-16	Jan-14	Dec-14	Feb-07	Jan-17
Key Capacity Holders	Qatar	Botas | Engie	Qatar	Litgas	Trafigura	Shell
Design						
Marine Side	Gullwing w/ near shore jetty	Jetty	Offshore	Gullwing w/ near shore Jetty	Dockside Jetty	Gullwing w/ near shore Jetty
Configuration						
Mooring Dolphins	4	4	Single point mooring	6	N/A	6
Breating Dolphins	4	3	N/A	3	N/A	4
Piles	Concrete piles w/ caps	Steel piles w/ stell jackets	N/A	Steel piles w/ with concrete topsides	N/A	Concrete piles w/ concrete topsides
Structural Steel	Minimal	Minimal	N/A	Minimal	Minimal	Minimal
Tugs	4	4	4	4	4	4
Land Side Footprint	Minimal	Minimal	N/A (offshore)	Minimal	Medium	Large
Configuration						
N2 Ballasting	Yes	[ ]	Yes (onboard)	Yes	Yes	-
Onshore Buildings	Yes	[ ]	No	Yes	Yes	Yes
Fire Equip + Tank	Yes	[ ]	No	Yes	Yes	Yes
Generators	Yes – Diesel	[ ]	No	Yes	-	Yes
Others	Parking, Diesel Storage, Pigging & water/ drain	[ ]	No	-	Onshore meter	Onshore regas
FSRU Size	160 k – 265 k cbm	170 k cbm	137 k cbm	170 k cbm	150 k cbm	126 k cbm (FSU)
LNGC Size	125 k – 265 k cbm	Up to 217 k cbm	65 k – 180 k cbm	65 k – 160 k cbm	[ ]	125 k – 180 k cbm

When examining this list and using internal NFE experience of NFE's terminals, the Applicant identified 10 key design criteria:

Table A3-3.4 Key Design Criteria

Feature	Description
Regasification Capacity	Min / max volume of LNG that can be regasified at the design specification, including temperature and pressure.
Jetty Capacity	Range of ship sizes for the FSRU and LNGC that can berth, and the number of LNGCs that can be berthed at the same time.

Feature	Description
Trestle	Above the water physical "bridge" that connects to land on which pipes and other electrical and mechanical systems (including grey water and other FSRU support systems) can be laid to reach the shore, and over which O&M personnel can reach the jetty from shore without the need for a work boat.
Landed Infrastructure	Buildings, equipment, and other infrastructure onshore to support FSRU operations and other terminal business, including land-based storage (either as buffer storage or strategic storage), if any;
Power	Grid connection and / or self-generation units to provide electricity to the terminal for operations.
Gas Conditioning	Nitrogen (N2) ballasting, odorization, trim heaters, and other inputs from FSRU and / or shore that need to be added to the regassified natural gas to bring it to within range of the gas specification required to enter the gas transmission network.
Expansion Potential	Embedded capacity in the systems to allow expansion of service over time with and without additional investment, including larger pipeline diameters, bigger electrical circuits, additional land available for development of other ancillary and complementary facilities.
Integration Opportunities	Configuration optimizations that use waste heat, cold energy, or shared infrastructure.
Permitting Considerations	The challenges and opportunities created by the commercially optimal design and the effects on timing (faster, slower, same) caused by design choices.
FSRU itself	Size, technology, capability, configuration of the ship itself and any modifications necessary to match the ship with the commercial opportunity and objectives.

In addition to observations made and documents reviewed related to other European terminals, the Applicant took lessons learned from prior developments, most notably NFE's Old Harbour terminal and San Juan hybrid terminal, team's observations from visiting four existing European terminals, and discussions with market participants (off-takers, terminal owners, etc.) and incorporated them into the development concepts at Shannon.

Old Harbour Offshore Terminal (March 2019)

NFE's Old Harbour terminal has a number of technical similarities to the current design for Shannon. Below are multiple "lessons learned" that are directly applicable to the Shannon terminal:

- **Lesson 1**: Evaluate the downstream uses and the required gas specifications to see how it matches up to the LNG spec for inbound cargos. A big difference with Shannon vs. OHP is that Shannon intends to inject gas into the Irish national gas network operated by Gas Networks Ireland (GNI). As a result, Shannon needs to comply with the GNI gas specification. This gas specification requires injecting Shannon gas with N2 if Shannon takes delivery of LNG from a number of terminals around the world. The OHP terminal serves specific power plants and those power plants have wide gas specs that required no gas conditioning. For Shannon, this requires adding N2 ballasting onshore, which adds to the capital costs or operating costs as over the fence.
- **Lesson 2**: Due consideration to how to deal with FSRU logistics around "grey" water, potable water, stores, maintenance, etc. OHP is served by workboats. This created logistical, costing, and permitting issues. The trestle at Shannon would provide the opportunity to pipe grey water from the ship and handle on shore as well as provide potable water, power, and easier access to replenishing the ship stores.
- **Lesson 3**: Eliminate weld in valves and use flanged connection. It is costly to replace a bad valve because you need to shut in gas production. As much as local codes allow at Shannon, we will use flanged in valves.

San Juan Puerto Rico Hybrid Terminal (April 2020)

Similar to the Old Harbour project, we can use the experience from developing NFE's terminal in Puerto Rico to help guide the design of Shannon, such as:

- Lesson: Make sure to track contractor's procurement schedule and delivery of long lead items is on track.

National Grid's Isle of Grain site visit November 2009 and October 2010

National Grid's Isle of Grain LNG Terminal is a world scale LNG import terminal located in the English Channel, 50 minutes from London and close to the major UK gas hub, NBP. Phase 3 of the terminal was built by CB&I (now McDermott) in 2012 under a 3.5-year, $612 million EPC lumpsum contract

South Hook LNG site visit February 2010

The South Hook LNG terminal in Wales is a world scale LNG import terminal. It is located remotely in Wales and hence required a ~150-kilometer gas pipeline from the site to the gas transmission system. The terminal was built in 2010 by CB&I (now McDermott) under an EPC lumpsum contract which was estimated at $750 million. We understand that marine operations are restrictive due to narrow shipping lane in the Milford Haven. The facility has 5 LNG storage tanks. The terminal was delayed and ran over on costs.

GATE site visit March 2012

The GATE terminal in the port of Rotterdam is a large, modern LNG terminal ideally located in the heart of Western Europe. The value of the fixed price EPC contract was €700 million, €200 million for the three storage tanks, and €500 million for the remainder of the scope. In total, the project took 44 months and was finished on-schedule in September 2011.

Dragon LNG visit in 2010

The Dragon LNG terminal in Wales is located adjacent to South Hook LNG in Wales. At the time of the visit, the terminal was under-utilized by Shell. However, we understood at the time that Shell considered it a valuable asset in its portfolio as it offered a home of last resort to mitigate the volume risks of LNG purchasing contracts.