ABSTRACT

Freeport LNG Development, L.P. (Freeport LNG), designed, built and now operates a world-class LNG receiving and regasification terminal in Freeport, Texas.

Freeport LNG believes the abundance of domestic reserves and low prices mean that the U.S. gas market itself should become a source for LNG export. Given this dramatic reversal of market conditions, Freeport LNG has launched its natural gas liquefaction project, proposing to add approximately 13.2 million metric tonnes per annum (MTA) (1.9 billion cubic feet per day) of liquefaction capability to its Quintana Island terminal facilities.

The feed gas will be derived from interconnecting intrastate pipeline systems, e.g., Dow Pipeline Company; Kinder Morgan Texas Pipeline, L.P.; Brazoria Interconnector Gas (BIG) Pipeline; or other yet-to-be-built pipeline(s), through Freeport LNG’s existing Stratton Ridge meter station.

The gas will be pretreated near Freeport LNG’s existing metering, compression and underground storage facilities. The pretreated natural gas will then be delivered to the terminal through Freeport LNG’s existing gas pipeline. At the terminal it will be liquefied and stored in full containment LNG storage tanks. LNG will be exported from the terminal by LNG carriers arriving via marine transit through the Freeport Harbor Channel.

Effective January 30, 2012, Freeport LNG and a joint venture comprised of Zachry Industrial, Inc. and CB&I (Zachry/CB&I JV) entered into a front end engineering and design (FEED) contract for the engineering and design of the Freeport liquefaction terminal near Freeport, Texas.

This paper presents the regulatory process, community relations, technical description, current status, and some of the challenges — including site preparation design — addressed during the FEED and ongoing development of the project.

INTRODUCTION/BACKGROUND

In 2008, Freeport LNG opened an LNG import and regasification terminal in the town of Quintana, TX, just southeast of the city of Freeport. At the time, the cost of finding and developing natural gas reserves in the United States was rising to a point that made importing LNG a competitive alternative. Since then, the innovations in extracting natural gas from shale have led to a reversal of market conditions, so exporting the LNG makes economic sense. As a result, Freeport LNG has begun the regulatory and engineering processes to expand their current terminal to include the capability to export up to 1.9 billion cubic feet per day (Bcf/d) of LNG.

Should the required regulatory approvals come through, the Freeport LNG terminal will be only the second permitted export terminal in the lower 48 states. The expansion will build off both Freeport LNG’s existing equipment, and the existing upstream infrastructure throughout Texas and the Gulf Coast region. Currently, the project is estimated to cost around $10 billion, and will generate over 3,500 jobs during construction, thus creating a tremendous boost to the local economy. After start-up, it will generate up to $4.6 billion per year in exports, or about a one percent improvement in the U.S. balance of trade.

Currently, Freeport LNG is awaiting approval from the Federal Energy Regulatory Commission (FERC) and the U.S. Department of Energy (DOE) to proceed with detailed engineering and construction of the expansion project. Since January 2012, a joint venture comprised of Zachry Industrial, Inc. and CB&I has been working on the FEED for the expanded terminal and corresponding pretreatment facilities.

Zachry and CB&I are both world-class engineering and construction companies, each with significant experience in the LNG industry. Zachry was a member of the consortium that designed and constructed the Freeport LNG Regasification Terminal. CB&I completed the turnkey design, engineering and construction of
a similarly-sized LNG liquefaction train near Lima, Peru in 2010, which used technologies and design requirements similar to those anticipated for the Freeport liquefaction terminal.

SAFETY

The liquefaction project team is committed to continuing the excellent construction and operating safety record that Freeport LNG has maintained since 2005, with design and construction of the current LNG terminal. Since the facility went into operation in 2008, there have been no injuries or major incidents. Freeport LNG has fostered a work environment where employees are educated not only on the hazards of what they work with, but also how those hazards can be mitigated to keep them and their surroundings safe. For the liquefaction project, the Zachry/CB&I Joint Venture will build their proactive employee health and safety program around the motto that “Every Employee Goes Home Safely Every Day.”

CURRENT TERMINAL SITE

The Freeport LNG regasification terminal is currently capable of unloading about 150 LNG tankers per year, transferring the LNG to storage, vaporizing the liquid and sending out up to 2.0 Bcf/d of pipeline quality natural gas. The site of the terminal, just southeast of the city of Freeport, is an ideal location for regasification of LNG (Figure 1). For incoming tankers, the 5.5 mile channel from open, navigable water to the Freeport LNG dock takes only one hour to traverse, considerably less than the trip into many other U.S. import terminals. Once processed, the gas is sent through Freeport LNG’s pipelines and metering station to meet up with the already built network of pipelines throughout the Gulf Coast region.

![Figure 1: Aerial View of Current Terminal](image)

Current Terminal Process Description and Key Equipment

Freeport LNG’s current receiving facility includes a large maneuvering area, a protected berth, and a marine dock that can accommodate vessels carrying between 88,000 and 267,000 cubic meters of LNG. Once pumped out, the LNG is piped to one of two 160,000 cubic meter, full containment storage tanks. To manage boil-off and reduce losses during periods of send-out inactivity, boil-off gas (BOG) is collected, re-liquefied, and sent back to storage via a BOG liquefaction system.

To convert the stored LNG to gas, the LNG is sent to the vaporization facility. Vaporization of the LNG occurs in vertical shell and tube-type heat exchangers with a water and glycol solution. Most LNG regasification facilities use boil-off gas from the storage tanks to fire heaters that vaporize the LNG, which creates large amounts of NOx emissions. To avoid this, the Freeport LNG process uses an air tower,
2) which relies on the warm and humid ambient Gulf Coast air to provide heat to the closed loop vaporization process. In the cooler months of the year, gas-fired heaters are used to supplement the air tower.

![Freeport LNG’s Innovative Air Tower](image)

**Figure 2: Freeport LNG’s Innovative Air Tower**

After vaporization, the natural gas is sent out of the terminal via a 42-inch diameter pipeline that runs 9.58 miles inshore to Freeport LNG’s Stratton Ridge Metering Station. At the metering station, the gas leaves Freeport LNG’s custody to reach the customers through a network of other pipelines. It can also be diverted to Freeport LNG’s underground storage cavern with a 4.5 Bcf working capacity. The underground cavern is located within the Stratton Ridge Salt Dome, which lies less than a mile from the metering station. Natural gas can be redirected to the storage cavern during periods of low demand or to manage shipping schedule disruptions. The gas can then be withdrawn from the cavern and sent to customers at a rate of up to 500 million cubic feet per day.

**EXPANSION TO LIQUEFACTION**

**Rationale**

Due to the recent increase in accessibility to the U.S. shale gas deposits, the U.S. now has more than a one hundred year supply of natural gas. In Texas, the natural gas infrastructure is already organized and strong. Freeport LNG’s existing terminal is located close to this infrastructure with proximity to the Eagle Ford, Barnett, and Haynesville-Bossier shale fields as well as two of the largest gas trading hubs in the country – the Houston Ship Channel and the Katy Hub. Expanding Freeport LNG’s existing terminal to include liquefaction and export capabilities will be an efficient solution to the surplus of natural gas because of its location and ability to use so much of the existing infrastructure. The changing market conditions in favor of LNG export reinforce the reasoning behind Freeport LNG’s expansion to liquefaction.

**Process Design**

Similar to the original regasification project, the natural gas will change custody at the Stratton Ridge metering site. The feed gas will be derived from several interconnected intrastate pipeline systems, including gas from the Dow Pipeline Company; the Kinder Morgan Texas Pipeline, L.P.; the Brazoria Interconnector Gas (BIG) Pipeline; or other yet-to-be-built pipeline(s). The underground storage facilities will be used, again, to balance the flow of gas into the new liquefaction facilities, thus creating a reliable LNG source for the terminal’s new customers. The natural gas from the Stratton Ridge station will then be sent down the existing pipeline to the proposed natural gas pretreatment facility.

Freeport LNG’s planned development is composed of multiple components, including facilities at and adjacent to the terminal and regional facilities located beyond Quintana Island. The main liquefaction components (Figure 3), located at and adjacent to the terminal, will be three propane pre-cooled mixed refrigerant trains (APCI C3MR process), each with a nominal nameplate capacity of 4.4 MTA of LNG (13.2 MTA in aggregate) for export, which equates to a total liquefaction capacity of approximately 1.8 Bcf/d of natural gas. Each train is capable of producing 4.51 MTA of LNG; beyond the 4.4 MTA that will be available
for export, the remaining 0.11 MTA, constituting a 2.5 percent margin, will become BOG to be used as fuel gas for the pretreatment facility or for flare pilots in the liquefaction process. Nameplate production is based on feed of 1.97 Bcf/d of pretreated natural gas, of which 1.8 Bcf/d is converted to LNG available for export.

In addition to the liquefaction plant, Freeport LNG plans to construct various facilities, both at and adjacent to the terminal and beyond Quintana Island, to support the liquefaction and export operation. These facilities include a natural gas pretreatment plant located about 2.5 miles north of the terminal, several interconnecting pipelines and utility lines, an additional full containment storage tank, an additional tanker berth, and other appurtenant structures.

The Quintana Island Terminal is connected to the regional natural gas pipeline system by Freeport LNG’s 9.58 mile long, 42 inch diameter natural gas send-out pipeline. When the terminal is operating in liquefaction mode, pipeline quality natural gas will be delivered through the reversed send-out pipeline and converted to LNG. However, this source of pipeline gas will require treatment to remove certain components (water, carbon dioxide, sulfur compounds, and mercury) ahead of the liquefaction process. All natural gas contains very small quantities of these four components, which are unnoticeable when the gas is burned for domestic, commercial, or industrial use but can negatively affect liquefaction equipment and LNG purity. The pretreatment units will each have an acid gas removal system that uses a proprietary solvent solution of activated methyl-di-ethanol-amine (BASF’s OASE) to remove carbon dioxide and sulfur compounds, a molecular sieve dehydration system to remove water, a mercury-removal unit to protect downstream aluminum equipment from corrosion, and a natural gas liquids recovery system to remove heavy hydrocarbons (pentane plus) that can freeze in the liquefaction process. To this effect, the gas flowing south from the meter station will be diverted to the pretreatment facility, where it will be compressed and treated, and then returned to the existing pipeline through which it will continue to the terminal for use in the liquefaction process.

The three liquefaction trains will use a propane pre-cooled mixed refrigerant process developed by Air Products and Chemicals, Inc. The treated gas will first be pre-cooled with propane refrigerant. Next, the natural gas will be sent to the main cryogenic heat exchanger, where the mixed refrigerant will cool and condense the natural gas at -260 degrees Fahrenheit. As the LNG leaves the heat exchanger, it is depressurized in a liquid expander and sent to the full containment storage tanks. The used mixed refrigerant is compressed and re-chilled before re-entering the heat exchanger for reuse.

The propane and mixed refrigerant compressors will be driven by variable speed electric motors. Each motor will be rated for 75 megawatts (MW). When all three liquefaction trains are operational, the electrical demand at the terminal will be approximately 700 MW.

While Freeport LNG’s expansion has been designed to use the existing terminal to the maximum extent, LNG liquefaction is a more complex process than regasification, and thus requires many more steps and more equipment. While some of the existing pieces will be repurposed to facilitate the liquefaction, their original purpose, to aide in regasification, will be preserved, as Freeport LNG still plans to operate the terminal for import purposes, as market conditions dictate. By maintaining both processes, Freeport LNG believes it will be able to maximize the value and efficient use of U.S. natural gas resources.
DESCRIPTION OF CHALLENGES AND HURDLES

The expansions to the terminal require not only modification to the existing property, but also acquisition of additional property. In May 2012, Freeport LNG acquired the rights to use an additional 170 acres adjacent to their current plot in Quintana for the three proposed liquefaction trains. Modifications to the port property will include widening the existing 400 foot wide ship channel to 600 feet to improve the efficiency of the shipping operations in and out of Freeport LNG’s docks.

The land leased for the liquefaction facilities is part of a Dredged Material Placement Area. As such, the soil condition of the area presents challenges for locating the heavy equipment. Extensive geotechnical studies have been conducted to develop a basis for foundation design. The area will require soil stabilization to a depth of 8 to 10 feet and all foundations will be supported on piles.

Because of the proximity of the LNG terminal to the Gulf of Mexico, the existing facilities are designed to withstand a category five hurricane event, with 180+ mph winds. All of the new facilities will also be designed to meet this criteria.

Marine Work Environment

Expanding the ship channel and constructing an additional tanker berth will create significant challenges in maintaining the current marine environment. Freeport LNG has made environmental protection a top concern. During construction of the existing terminal, contractors reused a large amount of the excavation materials; 750,000 cubic yards of material from the marine berthing area were used to build up the site and pad the pipeline. This avoided having to haul this fill material from elsewhere, thus reducing traffic in the area. Native coastal plants in the area were also recycled; usable vegetation in the path of construction efforts was harvested and replanted along the Intracoastal Waterway to mitigate erosion there.

During the proposed expansion, construction equipment will be maintained carefully to reduce the risk of any contamination, and further erosion mitigation efforts will be made along the Intracoastal Waterway. Activities will range from protection of native wildlife (including rattlesnakes and nesting terns) and the adjacent waterway from spills and contamination, to restoration of the Dredged Material Placement Area slopes and minimizing the erosion impacts of barges and incoming vessels on the shoreline. The liquefaction project
team will also construct during limited timeframes to minimize night noise and the traffic impact on the surrounding communities of Bryan Beach and Quintana. Studies have been performed during the FEED to detail a noise mitigation strategy for the operating plant and vapor dispersion containment on the project site.

Community Involvement
Due to the large estimated investment required for the project, it will affect the community in several ways. Freeport LNG has a long history of involvement with and concern for the local community. The project plans to tap into the local labor force and supplier base to the fullest extent possible. Many of the construction and operation personnel will reside in the Freeport and surrounding areas and lease or purchase properties in the neighborhood of the facility. As part of the normal business practices, the Zachry/CB&I Joint Venture will look for opportunities to support a local school and local activities. The workforce will be encouraged to participate in a variety of charitable activities.

Pretreatment Plant Site Selection
The pretreatment facility itself needs over 100 acres of land for the process equipment and supporting infrastructure, but does not need to be on the waterfront (Figure 4). In looking for space to house the proposed pretreatment facility, Freeport LNG considered several sites based on the following criteria:

- Proximity to the Stratton Ridge meter station, the existing 42-inch diameter pipeline, and the existing terminal
- Adequate space to include the three gas pretreatment trains, the required retention pond, and an allowance for a plant buffer to the neighboring community
- Ease of access to roads
- Availability within the project’s timeframe

The selected pretreatment facility site is regionally situated about 2.5 miles north of the Quintana Island Terminal and about 3.5 miles southeast of Freeport LNG’s Stratton Ridge underground storage site.

Regulatory Approvals
Based on the size and purpose of the Freeport LNG Expansion Project, many federal, state, and local authorities are required to approve the plans before construction of the expanded terminal can begin. The lead federal agencies that have jurisdiction over the siting, construction, and operation of the project are FERC, DOE, and U.S. Department of Transportation. FERC approval is required before construction can
begin. FERC, through the National Environmental Policy Act and the Natural Gas Act, evaluates the environmental impact that the project will have. In conjunction with the U.S. Coast Guard and Department of Transportation, FERC also reviews the safety aspects of siting and operating an LNG terminal and the impact resulting from LNG tanker traffic. The DOE approval is to confirm that the trade and sale of LNG, specifically to countries with which the United States has not entered into a free trade agreement (FTA), is in the best public interest. These federal regulators take local opinion into account as they hold meetings near the project site to gather concerns that should be addressed in the final Environmental Assessment/Environmental Impact Statement. Freeport LNG has hosted several open houses near both the terminal and proposed pretreatment facility locations to address any questions or concerns that residents or stakeholders in the area may have.

Other federal, state and local agencies that review the plant include, but are not limited to the U.S. EPA, U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, U.S Army Corps of Engineers, Texas Commission on Environmental Quality, Railroad Commission of Texas, Texas Parks and Wildlife Department, Texas Historical Commission, Texas General Land Office, and Brazoria County.

CURRENT STATUS

One hundred percent of the first train’s capacity has already been sold to Osaka Gas and Chubu Electric of Japan. Freeport LNG expects to have commitments for the second and third trains later in 2013, before commencement of construction.

Currently, Freeport LNG is negotiating with potential customers for the second and third trains’ capacity, continuing to complete the FEED work, arranging financing, and responding to data requests from FERC. In December 2010, Freeport LNG submitted a pre-filing request with FERC to begin the environmental review of the liquefaction project. A year later, in December 2011, Freeport LNG completed and filed drafts of all liquefaction resource reports for the FERC application. A formal application to FERC for all of the facilities was submitted in August 2012 per Section 3 of the Natural Gas Act.

Freeport LNG has filed two DOE applications, each for 511 Bcf/year of LNG exports, in December 2010 and 2011, respectively. They received approval from the DOE to export LNG to FTA countries in February 2011 and 2012, respectively. Further approval to export to non-FTA countries is expected in early 2013.

Should regulatory approvals be granted on schedule, i.e., by mid-2013, construction will start in the first quarter 2014, and the first train will be complete and commissioned in 2017. The second and third trains will follow, each about 6-9 months after the one before it.