

CALIFORNIA
ENERGY
COMMISSION

**LIQUEFIED NATURAL GAS
IN CALIFORNIA:
HISTORY, RISKS, AND SITING**

STAFF WHITE PAPER

JULY 2003
700-03-005



Gray Davis, Governor

CALIFORNIA ENERGY COMMISSION

Mignon Marks,
Principal Author

Susan Bakker
Mark DiGiovanna
Bob Haussler
Geoff Lesh
Monica Schwebs
Bob Strand
Chris Tooker
Rick Tyler
Contributors

Dave Maul
Manager
**NATURAL GAS & SPECIAL
PROJECTS OFFICE**

Terrence O'Brien,
Deputy Director
**SYSTEMS ASSESSMENTS &
FACILITIES DIVISION**

Robert L. Therkelsen
Executive Director

James D. Boyd
***Commissioner and Leader of
the Governor's Natural Gas
Working Group***

DISCLAIMER

This paper was prepared as the result of work by a member of the staff of the California Energy Commission. It does not necessarily represent the views of the Energy Commission, its employees, or the State of California. The Energy Commission, the State of California, its employees, contractors and subcontractors make no warrant, express or implied, and assume no legal liability for the information in this paper; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This paper has not been approved or disapproved by the California Energy Commission nor has the California Energy Commission passed upon the accuracy or adequacy of the information in this paper.

LIQUEFIED NATURAL GAS IN CALIFORNIA: HISTORY, RISKS, AND SITING

INTRODUCTION

The United States, including California, needs to develop additional supplies of natural gas to meet its growing demand. Because North American supply basins are maturing, the U.S. will need to rely more on imported supplies, including liquefied natural gas (LNG). Currently, the U.S. has four LNG-receiving and regasification terminals, but no terminal is located on the West Coast. Recently, however, a number of companies have proposed to site LNG import facilities in California, in other locations in the U.S, and in Baja California, Mexico.

In the early 1970s, California's gas utilities were planning to build an LNG import facility and import LNG. They identified the Port of Los Angeles, Oxnard, and Point Conception as possible sites. However, the three agencies involved in site approval could not agree on a preferred site. To address the conflict, at least at the state level, the project proponents turned to the Legislature, which enacted the LNG Terminal Siting Act of 1977. Under this act, the California Public Utilities Commission (CPUC), with input from the California Coastal Commission (Coastal Commission) and California Energy Commission (Energy Commission), could approve one site. The CPUC chose Point Conception because of its remote location, but the proponents cancelled the project when LNG became uneconomical.

In 1987, the Legislature repealed the LNG siting act, and no company has attempted to site an LNG import facility on the West Coast until recently. The current process for siting such facilities is unclear as a result of that repeal.

This paper describes LNG import facilities and summarizes the key safety and environmental issues that need to be addressed during the siting process. It is organized into the following sections:

- Background
- History
- Current Projects
- Siting Processes

This paper does not discuss the front end of the LNG supply chain (i.e., the exploration, production, and liquefaction of gas from distant and isolated locations), LNG economics, or the features and permitting of small LNG facilities for vehicle fueling or peak-shaving purposes. It also does not discuss the regulation of LNG facility operations, gas pipeline construction and operation, gas quality, or gas prices.

BACKGROUND

Properties of LNG

LNG is essentially no different from the natural gas used in homes and businesses everyday, except that it has been refrigerated to minus 259 degrees Fahrenheit at which point it becomes a clear, colorless, and odorless liquid. As a liquid, natural gas occupies only one six-hundredth of its gaseous volume and can be transported economically between continents in special tankers.

LNG weighs slightly less than half as much as water, so it floats on fresh or sea water. However, when LNG comes in contact with any warmer surface such as water or air, it evaporates very rapidly (“boil”), returning to its original, gaseous volume. As the LNG vaporizes, a vapor cloud resembling ground fog will form under relatively calm atmospheric conditions. The vapor cloud is initially heavier than air since it is so cold, but as it absorbs more heat, it becomes lighter than air, rises, and can be carried away by the wind. An LNG vapor cloud cannot explode in the open atmosphere, but it could burn.

Safety Concerns

LNG is considered a hazardous material. The primary safety concerns are the potential consequences of an LNG spill. LNG hazards result from three of its properties:

- Cryogenic temperatures
- Dispersion characteristics
- Flammability characteristics

The extreme cold of LNG can directly cause injury or damage. Although momentary contact on the skin can be harmless, extended contact will cause severe freeze burns. On contact with certain metals, such as ship decks, LNG can cause immediate cracking.

Although not poisonous, exposure to the center of a vapor cloud could cause asphyxiation due to the absence of oxygen.

LNG vapor clouds can ignite within the portion of the cloud where the concentration of natural gas is between a five and a 15 percent (by volume) mixture with air.² To catch fire, however, this portion of the vapor cloud must encounter an ignition source. Otherwise, the LNG vapor cloud will simply dissipate into the atmosphere.

An ignited LNG vapor cloud is very dangerous, because of its tremendous radiant heat output. Furthermore, as a vapor cloud continues to burn, the flame could burn back toward the evaporating pool of spilled liquid, ultimately burning the quickly evaporating natural gas immediately above the pool, giving the appearance of a “burning pool” or

“pool fire.” An ignited vapor cloud or a large LNG pool fire can cause extensive damage to life and property.³

Spilled LNG would disperse faster on the ocean than on land, because water spills provide very limited opportunity for containment. Furthermore, LNG vaporizes more quickly on water, because the ocean provides an enormous heat source. For these reasons, most analysts conclude that the risks associated with shipping, loading, and off-loading LNG are much greater than those associated with land-based storage facilities.

Facility Descriptions

Preventing spills and responding immediately to spills should they occur are major factors in the design of LNG facilities. The following descriptions emphasize the safety features of LNG facilities.

Tankers

Ocean-going tankers transport large amounts of LNG from distant natural gas fields. They are equipped with up to five LNG-cargo tanks housed inside a double-walled hull. Each cargo tank can store several thousand cubic feet of LNG. These ships are up to 1,000-feet long, and, when fully loaded, require a minimum water depth of 40 feet.

The cargo tanks function like Thermos bottles. LNG is injected into the cargo tanks where it is stored and transported under normal atmospheric pressure. The insulation surrounding the tank is the main means by which the cargo is kept cold. Up to two feet of very efficient insulation surrounds each tank to minimize heat gain during the voyage from the liquefaction plant to the receiving terminal.

LNG tankers are equipped with specialized systems for handling the very low-temperature gas and for combating potential hazards associated with liquid spills and fire. The ship's safety systems are divided into ship handling and cargo system handling. The ship-handling safety features include sophisticated radar and positioning systems that alert the crew to other traffic and hazards around the ship. Also, distress systems and beacons automatically send out signals if the ship is in difficulty. The cargo-system safety features include an extensive instrumentation package that safely shuts down the system if it starts to operate out of predetermined parameters. Ships are also equipped with gas- and fire-detection systems.⁴

Onshore Receiving and Regasification Terminals

A shore-based LNG terminal — consisting of a docking facility, LNG-storage tanks, LNG-vaporization equipment, and vapor-handling systems — occupies approximately 25 to 40 acres of land. The location of a proposed LNG terminal would dictate the number and types of linear facilities, such as roads, electric transmission lines, and gas and water lines that would also be needed.

The docking facility is designed to accommodate the sizes of the anticipated LNG tankers. It normally consists of a pier about 1,800-feet long and 30-feet wide with

moorings and off-loading facilities. Moorings connect the tanker securely to the jetty so that the LNG can be transferred from the ship's tanks to the onshore piping.

In most respects, an LNG docking facility would be similar in size to those that currently handle supertankers delivering crude oil to California. One difference is that an LNG tanker has a much higher profile (125 feet). Therefore, when considering the placement of docking facilities, facility designers must account for the effect of prevailing winds on the maneuverability of those ships.

Despite peak flow rates of approximately 12,000 cubic meters per hour, unloading times for a full-sized LNG tanker average 12 to 15 hours. While unloading their cargoes, LNG tankers could be subject to substantial tidal and wave forces, which might jeopardize the integrity of the ship-to-shore interface. Therefore, LNG ports and jetties must have built-in safety features to prevent releases of LNG during ship-to-shore transfers.

A ship-to-shore emergency shutdown (ESD) system and associated shut-off valves allow rapid and safe shutdown of an LNG transfer. The ESD system will stop the ship's unloading pumps and close flow valves both on the ship and shore usually within 20 to 30 seconds. Quick-release couplings automatically disconnect the unloading arms during emergencies.

Transfer piping used to unload the cryogenic liquid from the ship's tanks can withstand a 200 degree Celsius temperature drop once LNG pump-out begins. Normally, the cryogenic piping is made of stainless steel, and one kilometer of stainless steel pipe, when cooled by 200 degrees C, will contract by nearly three meters. Expansion loops and expansion bellows are built-in safety features that compensate for this pipeline contraction.

LNG is normally held on land in one or more specially designed storage tanks while it awaits regasification. The failure of one or more tanks could release an enormous volume of LNG (e.g., 100,000 cubic meters) with potentially disastrous consequences due to the size of the resulting vapor cloud. However, the design of modern storage facilities has improved from earlier designs. "The design practices and metallurgy that caused earlier accidents are totally unacceptable by today's standards."⁵

The following three types of LNG storage tanks are used today:

- Single-containment tanks are double-walled. An interior tank is made of nine percent nickel, while the outer tank is made of carbon steel.
- Double-containment tanks have primary and secondary tanks. The secondary tank, typically a concrete wall, is located usually six meters or less from the primary tank. In the event of a leak, the secondary tank contains the cryogenic liquid and limits the surface area and vaporization of an LNG liquid pool.
- Full-containment tanks have a nine percent nickel inner tank, plus a pre-stressed concrete outer tank. The outer tank, which includes a reinforced concrete roof

lined with carbon steel, can be designed to withstand realistic impacts from missiles or flying objects.⁶

The Mexican government's new LNG siting regulations mandate the use of full-containment storage tanks.

Safety Features of LNG Storage Facilities

Modern storage tanks have no side or bottom penetrations. All penetrations, including those for LNG sendout, are through the roof. This design substantially reduces the amount of LNG spilled in the unlikely event of a rupture or leakage in the sendout piping.

If LNG stratifies into layers of different densities within a storage tank, a phenomenon called "rollover" could occur. With "rollover," pressures within the tank could rise to excessive levels, and, without properly operating safety-vent valves, pressures could rise to levels that would cause structural damage. To detect the development of "rollover" conditions, modern LNG storage tanks contain instruments to monitor the pressure, temperature, and density of the LNG along the entire height of the liquid column. Furthermore, tank designers provide for LNG recirculation.

In-tank cameras enable plant operators to assess tank damage in the event of an earthquake and to visually inspect the tank contents in the event of unusual instrument readouts.

Fire detection and response systems are in place wherever combustible gas is stored or handled. Facility operators use low-temperature, gas, fire, and smoke detectors, supplemented by closed-circuit television cameras that can identify potentially hazardous situations such as LNG spills and leaks.

On land, LNG spills are contained using a walled and bermed system that drains all LNG into a basin constructed of reinforced concrete that is sized to contain a specific design-spill. In addition, LNG storage tank impoundments are designed to contain at least 110 percent of a tank's volume in the event of a sudden, uncontrolled tank failure.

Impoundments not only limit the spread of an LNG spill, they reduce the surface area of the liquid pool, thereby decreasing and controlling the size of the vapor cloud.

When detector readings activate an alarm in the LNG operations control room, some fire-suppression responses are automatic. For example, high-expansion foam generators produce and deliver foam automatically to a spill or leak area. Initially, the foam helps to disperse LNG vapors upwards and away from potential ignition sources. "Since potential sources of ignition are more likely found close to ground level, the upward dispersion substantially reduces the chances of ignition."⁷

In addition, if a "pool fire" develops at an LNG facility, foam provides some control over the rate of burning. Essentially, the foam blankets the liquid surface to limit heat

transfer from the air to the liquid, thereby reducing the rate of vaporization. Consequently, the rate of burn is limited since only the vapor will burn after it mixes with adequate oxygen. Foam will be applied repeatedly until all LNG has been burned in a controlled manner.

Water is ineffective in fighting LNG fires because it provides a heat source for vaporization. Instead, firefighters apply dry powder (e.g., sodium bicarbonate or potassium bicarbonate) to extinguish LNG fires in the open air. However, water sprinklers are used to cool building surfaces and protect fire-fighting and other equipment from thermal-radiation damage. Fireproofing of structures and equipment are additional mandatory safety features within LNG facilities.

Safety Features of LNG Facility Layout

LNG facilities are designed to assure adequate distances between the following parts of the terminal facility:

- Two or more LNG storage tanks
- The storage area and the jetty
- The vaporization process area and the other parts of the facility

In addition, LNG facilities must have exclusion zones — the area surrounding an LNG facility in which an operator legally controls all activities. These zones assure that public activities and structures outside the immediate LNG facility boundary are not at risk in the event of an on-site LNG fire or a release of a flammable vapor cloud.

Federal regulations identify two types of exclusion zones: thermal-radiation protection (from LNG fires) and flammable vapor-dispersion protection (from LNG clouds that have not ignited but could migrate to an ignition source).

Thermal-radiation exclusion distances are determined by using the National Fire Protection Association (NFPA) standard for the production, storage, and handling of LNG, or by using a computer model that accounts for facility-specific and site-specific factors, including wind speeds, ambient temperature, and relative humidity. For example, the thermal-exclusion zone around the Cove Point LNG facility in Maryland is 1,600 feet.⁸ The required distances assure that heat from an LNG fire inside the dikes, for example, would not be severe enough at the property line to cause death or third-degree burns.

Safe distances from dispersing LNG vapor clouds are determined by the same NFPA standards or by a computer model that considers average gas concentration in air, weather conditions, and terrain roughness. The exclusion zones for the LNG facility in Cove Point cover 1,017 acres, and the exclusion zones for the Elba Island, Georgia facility cover 840 acres.⁹ The permitting authority, in cooperation with the DOT-Office of Pipeline Safety and the Coast Guard, would determine the exclusion zones for LNG tankers and port facilities.

HISTORY

LNG Receiving Terminals in the U.S.

In the late 1960s, the U.S. faced declining natural gas production as a result of federal price controls on interstate gas transactions. Because of these controls, producers withheld natural gas from interstate markets to avoid federal regulation. Since price controls did not apply to intrastate transactions, however, producers could sell gas in the state within which it was produced at prices above federal controls. These circumstances led to a perception that domestic natural gas reserves were declining, which, in turn, led some firms to explore LNG imports as an alternative source of natural gas.

In 1969, Distrigas Corporation started constructing the first U.S. LNG receiving terminal in Boston Harbor. In 1971, Distrigas's Everett, Massachusetts facility received its first delivery of LNG from Algeria. Two additional marine import and regasification facilities went into service during the 1970s, one at Elba Island, Georgia, owned by Columbia LNG Corporation and Consolidated Systems LNG Company, and one at Cove Point, Maryland, owned by Southern Natural Gas Company. These three companies purchased LNG from El Paso Algeria Corporation, operating under the title El Paso I LNG Project. In 1975, Trunkline LNG Company signed a long-term supply contract with Algeria's national oil and gas company for delivery of LNG to its planned Lake Charles, Louisiana facility.

In 1978, Congress passed the Natural Gas Policy Act lifting price controls on all domestic natural gas discovered after 1977. With price controls lifted, natural gas exploration and drilling expanded, and producers began to make domestic natural gas available to the interstate market. This change in federal policy diminished the cost advantage of imported LNG. As a consequence, U.S. imports of LNG declined after reaching an all-time peak of 253 billion cubic feet (Bcf) in 1979.

Around the same time, the El Paso I Project companies began to dispute the prices their Algerian LNG supplier, Sonatrach, was charging them pursuant to the terms of long-term contracts originally signed in 1969. These disputes were never resolved, and, in 1980, Algeria ceased deliveries to Elba Island, Georgia, and Cove Point, Maryland, leading to the closure of both facilities.

Trunkline suspended its LNG imports and shut down its Lake Charles facility in 1983 because, it claimed, the high price of the LNG made it unmarketable. Trunkline eventually resumed LNG imports during the late 1980s, in part, because of Algeria's willingness to enter into more flexible long-term contracts. In 1984, Distrigas became the sole importer of LNG in the U.S.¹⁰

LNG imports to the U.S. have rebounded significantly over the past seven years, increasing each year from the decade-low volume of 18 Bcf in 1995, to the second highest volume of LNG ever imported into the U.S. of 238 Bcf in 2001.¹¹ The increase is attributable to both increasing natural gas demand in the U.S., about 14 percent from

1990 to 2001, and declining prices for imported LNG as a result of substantially lower capital and operating costs over all segments of the LNG supply chain.¹² In 2000, the annual average price of imported LNG was actually lower than the price of pipeline gas.^{13, 14}

Lower prices led the owners of the remaining two LNG import facilities in the U.S. to resume operations. The Elba Island LNG facility, currently owned by El Paso, Inc., reopened in 2001 and, in October of that year, received its first LNG shipment in more than 20 years.¹⁵

In early October 2001, the Federal Energy Regulatory Commission (FERC) authorized Williams Companies, Inc.¹⁶, then owner of the Cove Point facility, to reactivate its LNG receiving terminal and expand storage capacity. Following the terrorist attack of September 2001, however, FERC reconsidered its order, because the facility is within four miles of a nuclear power plant.¹⁷ Based on confidential evidence submitted by the FBI, Coast Guard, Nuclear Regulatory Commission, and Department of Transportation - Office of Pipeline Safety, FERC reaffirmed its finding that the proximity of the nuclear power plant to the Cove Point LNG facility does not raise a specific national-security concern.¹⁸ Restart of the facility is now scheduled for the end of 2003.¹⁹

In 2002, FERC also granted final approval for expanding the Trunkline LNG terminal in Louisiana.²⁰

Global demand for LNG has been on the rise, growing ten percent annually during 1999 and 2000. LNG demand continued to increase during 2001, albeit at a slower rate (4.5 percent) because of a weak global economy.²¹ The Energy Information Administration estimates that global natural gas demand will nearly double over the next two decades.²² A study released in July 2002 by the energy research firm DRI-WEFA concluded that the global proliferation of LNG liquefaction and regasification terminals will make natural gas a global commodity by 2025, much like oil is today.

Safety Record

The most notable safety incident occurred in Cleveland, Ohio in 1944 at a peak-shaving plant. The East Ohio Gas Company had built the plant in 1941 and its owners decided to add a new tank in 1944. Because certain stainless steel alloys were scarce during World War II, East Ohio built the new tank with a steel alloy that had low-nickel content (3.5 percent). Shortly after going into service, the tank failed, spilling its contents into the street and storm-sewer system. A disastrous explosion and fire within the confined space of the storm-sewer system killed 128 people.

The last death involving LNG in the U.S. occurred at the Cove Point, Maryland terminal in 1979. From the spring of 1978, when it began to operate, until the accident, more than 80 LNG ships had unloaded at Cove Point. The accident began when LNG leaked through an inadequately tightened electrical-penetration seal on an LNG pump. The LNG vaporized, passed through 200 feet of underground electrical conduit, and entered a substation building. The normal arcing contacts of a circuit breaker ignited the gas-air

mixture causing an explosion within the confined space of the substation building. The explosion killed one operator in the building, seriously injured a second, and caused \$3 million in damages.

From 1952 to the present, LNG ships have made more than 33,000 voyages worldwide and transported over three billion cubic meters of LNG. Of these voyages, more than 2,400 have been to or from U.S. ports. Types of tanker accidents include engine room fires, collisions, groundings, loss of containment, and temperature embrittlement from cargo spillage. There have been no cargo explosions, fires, or shipboard deaths.²³

LNG Terminal Development in California: The Point Conception Project²⁴

By 1972, several public utilities in California had announced plans to import LNG. Western LNG Terminal Company (Western), a subsidiary of Pacific Lighting Corporation (the parent company of Southern California Gas Company) and Pacific Gas and Electric Company planned to build three LNG import facilities: one at the Port of Los Angeles, one in Oxnard, and one at Point Conception. Western was proposing the Point Conception project on behalf of the El Paso Natural Gas Company, whose policy was to avoid siting an LNG facility within ten miles of a populated area.

Western commissioned risk assessments for the Los Angeles and Oxnard sites. Both studies found extremely low safety risk, based on the probabilities of marine and onshore LNG accidents and bad weather conditions. The Oxnard City Council, however, did its own study, which considered safety risks under worst-case scenarios. Oxnard's citizens opposed the project after the City's study showed up to 70,000 casualties from an LNG accident there. None of the risk assessments considered acts of sabotage.

Western needed local, state, and federal approvals. At that time, the California Coastal Commission had siting authority at the state level, and appeared unlikely to approve either the Oxnard or the Los Angeles site due to public-safety concerns. The remote Point Conception site also faced permitting problems because of potential environmental impacts on marine life, surfing breaks, and spectacular views, which were the very resources the Commission had been created to protect.

At the federal level, the Federal Power Commission (FPC), the forerunner of FERC, had oversight. While the FPC favored the Oxnard site over the others, the National Energy Plan called for LNG terminals to be sited remotely. The FPC appeared likely to deny the Port of Los Angeles site because of its proximity to an earthquake fault, even though the Los Angeles City Council supported the project for economic-development reasons.

Because these different governmental agencies favored different sites, project proponents turned to the California Legislature for help in averting a siting stalemate. They sought to remove siting authority from local authorities and from the California Coastal Commission, and to place it with the CPUC.