# NCEP Staff Background Paper –
# The Safety of Liquefied Natural Gas

# I. Introduction

Natural gas is an important source of energy for the U.S. economy, accounting for approximately one-fourth of the nation's primary energy needs. Historically, domestic demand for natural gas has been met by indigenous supplies and imports from Canada. Recent trends, however, indicate that traditional supply sources cannot keep pace with continued demand growth and traditional domestic gas resources are in decline. As a result, natural gas prices have risen to unprecedented levels and many experts expect that an increased reliance on imports—in the form of liquefied natural gas (LNG) which can be transported over long distances in large ocean vessels—will be necessary in coming years to help close the supply gap. The prospect of a significant increase in LNG carrier traffic off U.S. shores, and the need for additional coastal receiving facilities to transfer, store, and re-gasify LNG shipments has led to considerable public anxiety surrounding the safety and vulnerability of such infrastructure. In fact, several recent proposals to construct new LNG terminals have been stalled or even cancelled due to strong local opposition. It is clear that public perceptions concerning the hazards posed by LNG must be addressed if imported natural gas is to emerge as a significant supply option for the United States.

This paper presents basic information about LNG in an effort to clarify and provide perspective on the particular safety issues it raises. In doing so, this paper relies heavily on several comprehensive assessments of LNG safety and security that have recently been prepared by the University of Houston Institute for Energy, Law & Enterprise (IELE), the California Energy Commission (CEC), the Federal Energy Regulatory Commission (FERC), and the Congressional Research Service (CRS), among others. By and large, these assessments have concluded that the safety hazards involved in transporting and handling large quantities of LNG—while certainly real and requiring careful management—are not fundamentally different in kind or degree from those associated with other major energy products routinely used in the United States. Accordingly, safety issues, properly addressed, should not prevent the needed expansion of LNG infrastructure.

# II. LNG Hazards and Characteristics

### *What is LNG?*

Liquefied natural gas is simply natural gas that has been extensively cooled to minus 260 degrees Fahrenheit so that it changes from a gas to liquid. Natural gas consists primarily of methane (more than 85 percent) mixed with small amounts of propane, butane, ethane, and nitrogen. The natural gas is pre-treated to remove impurities such as water, nitrogen, carbon dioxide, hydrogen sulfide and other sulfur compounds to prevent them from forming solids when the gas is cooled. As a result, LNG is typically made up of about 95 percent methane. The liquefaction process reduces natural gas to roughly $1/600^{th}$ of its original volume as a gas, allowing for efficient transport over long distances via ship. Once the LNG reaches its destination, it is usually converted back into a gas at a receiving terminal and inserted into the terrestrial pipeline network. As discussed more extensively in later sections, this process is well-established and has been conducted with little incident in countries all over the world.

LNG is a cold, colorless, odorless liquid that, although non-toxic and non-corrosive, is considered a hazardous material due to its high energy content and potential flammability in vapor form.[1] It is lighter than water and its gaseous vapors are lighter than air, giving LNG several favorable environmental characteristics. In the event of a spill, for example, LNG will quickly warm and begin to boil off into vapor form, causing the surrounding moisture in the air to condense and creating a large white vapor cloud that closely resembles ordinary ground fog.[2] Because it is lighter than air, the vapor cloud will gradually rise and dissipate into the atmosphere. Unlike an oil spill, moreover, an LNG spill leaves no pollution or residue behind. If spilled at sea, LNG will float on top of the water until it vaporizes, leaving no fuel residues to mix into the water.[3]

***What properties of LNG create potential hazards?***

Several characteristics of LNG, however, do necessitate special handling and—as with all energy products—create potential hazards. A recent report by the California Energy Commission describes three major accident hazard categories that must be considered and vigilantly managed during LNG utilization. These three categories are (1) its extreme (cryogenic) temperature characteristics, (2) its flammability characteristics, and (3) its dispersion characteristics.[4] Key considerations and sources of hazard in each of these categories are summarized below. There are also other, less significant hazards such as direct exposure to an accidentally released vapor cloud. However, the circumstances under which this might occur are so remote that it can be considered a second order concern.

*1. Temperature*

Because of its low temperature, physical contact with LNG can lead to serious injury and freezer burn. Therefore, all workers and facility personnel who could come in direct contact with LNG are required to wear gloves, face masks, and appropriate protective clothing. To address exposure hazards more broadly, on-shore LNG facilities are equipped with emergency spill containment systems that are designed to control up to 110 percent of an LNG tank's contents.[5] Besides minimizing the hazard of direct exposure, these systems mitigate the potential for rapid vaporization of LNG by capturing any unintended releases and containing them quickly. Finally, all piping and instrumentation at LNG facilities are equipped with built-in expansion loops to accommodate the expansion and contraction that can result from temperature changes. In general, the cryogenic hazard associated with LNG is likely to be a concern only within or near facility boundaries and is unlikely to pose a significant threat to outside communities or to the general public.[6] Thus, it is generally thought to be a lesser concern than the dispersion or combustion hazards discussed below.

*2. Flammability*

In a liquid state, natural gas cannot explode or burn under any circumstances.[7] However, natural gas vapors are flammable under specific conditions. Methane can burn in air only when

[1] CEC (2003), Pg. 2
[2] CEC (2003), Pg. 2
[3] CRS (2004), Pg. 6
[4] CEC (2003), Pg. 2
[5] CEC (2003), Pg. 5
[6] UH IELE (2003), Pg. 18
[7] FERC (Website)

its concentration is between five and fifteen percent by volume. If the concentration is below the lower flammability limit, there is not enough methane to burn. If the concentration of methane is greater than fifteen percent, there is not enough oxygen for combustion.[8] In the event that LNG vapors ignite, the resulting fire will burn until either all of the fuel is gone or the concentration of gas to air is no longer within flammability limits. In sum, the combustion hazard associated with an uncontrolled release of LNG is limited to the resulting vapor cloud which must form a concentration of methane within applicable flammability limits and encounter an ignition source in order to burn. In addition, LNG vapors have an auto-ignition temperature of 1004°F which is the lowest temperature at which the gaseous vapors will ignite spontaneously.[9]

One of the most common misperceptions regarding LNG is that it is a pressurized substance and thus highly susceptible to explosion. LNG is not pressurized and is not explosive.[10] In fact, the energy contained in LNG cannot be released fast enough to create the overpressures necessary for explosion in an open environment.[11] Explosion is possible, however, if LNG vapors are concentrated in a confined environment and if they encounter an ignition source (LNG vapors will not spontaneously combust unless exposed to high temperatures). Modern LNG facilities are designed to address the hazards associated with vapor build-up in confined spaces and utilize simple venting techniques to ensure that dangerous concentrations do not occur. LNG storage tanks today have impoundment systems that drain into an open topped concrete basin in the event of a spill. This significantly diminishes the surface area of the spill and reduces the size of the resulting vapor cloud. In addition, in the event of a spill, some LNG facilities are equipped to deliver high-expansion foam to the spill immediately. Initially, this foam can help to move LNG vapors away from potential ignition sources and, in the event of a fire, the foam provides some control over the rate of burning.[12]

*3. Dispersion*

The general dispersion characteristics of LNG in the event of a spill were described previously. As has already been pointed out they compare in some ways favorably to the dispersion characteristics of oil and refined petroleum products. However, there is a concern that the vapor cloud that would result from an LNG spill could, if it encountered an ignition source as it rose in the atmosphere, burn back to the source of the spill and cause a serious fire. In general, LNG will boil off much faster on water than on land because water provides a more significant thermal source for heat transfer. This is why an LNG vapor fire cannot be fought with water: the water would simply accelerate the liquid's vaporization and fuel the blaze. Also, an LNG spill on water is much more difficult to contain and spreads over a larger area than a spill on land. The evaporation disperses at a faster rate because of the high heat transfer rate and the water does not cool significantly. For these reasons, it is generally considered that shipping, on-loading, and off-loading of LNG present the greatest safety threats.[13] At modern LNG terminals, systems are in place to ensure that natural gas vapor cloud dispersion is enhanced, thus lessening the likelihood of a vapor fire.

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[8] UH IELE (2003), Pg. 13
[9] UH IELE (2003), Pg. 15-16
[10] UH IELE (2003), Pg. 12
[11] FERC (Website)
[12] CEC (2003), Pg. 5
[13] CEC (2003), Pg. 3

***How do the hazards associated with LNG compare to those of other fuels?***

Like nearly all energy resource options, LNG presents some risks of unintended energy release and is potentially susceptible to accidents and malicious attacks. The relevant question is less whether LNG can be made absolutely free of risks than whether the risks involved are greater than those associated with other common energy products (such as petroleum). The dialogue and efforts should be directed toward whether these risks can be reduced to levels that are both manageable and acceptable to the public.

In answering this question, the obvious comparison is to petroleum and petroleum products, which—like LNG—are characterized by high energy density and are routinely transported via large ocean-going vessels. In terms of simple energy content, a typical large oil tanker transporting 200,000 tons of crude oil contains some eight trillion Btu's of energy.[14] For comparison, a standard LNG vessel can contain up to 150,000 cubic meters of LNG, which equates to about three trillion Btu's of energy.[15] While crude oil does not combust as readily or with the same intensity as natural gas, refined products of oil, which are also routinely transported in large tankers, can be just as flammable (or more so) than LNG vapors. In fact, LNG vapors have a higher auto-ignition temperature than gasoline or propane[16] vapors, meaning that a higher temperature is necessary for spontaneous ignition.[17] In addition, the lower flammability limit for LNG is higher than that for gasoline, meaning that a greater concentration of fuel is necessary for combustion. The point of this comparison is not to suggest that tankers carrying petroleum products are unsafe. The important differences in the properties of these fuels combined with the manner in which they are handled and transported allow their risk profiles to be site-specific and case-specific. However, it is not clear that LNG poses a significantly greater hazard to society than, say, gasoline or propane.

Table 1 below reproduces, with some modifications, a table developed by the University of Houston Law Center Institute for Energy Law and Enterprise that compares gasoline, liquefied petroleum gas, and LNG across a number of key characteristics.[18] These factors provide a framework for evaluating the risk/benefit comparison with more familiar energy activities. One important distinction to be made here is that the safety risk for LNG and propane

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[14] Ultra-large crude carriers and very large crude carriers are among the largest ships in the world. They can carry anywhere from 200,000 to 500,000 tons of crude oil (http://generalmaritimecorp.com/newgencor5.html). According to the EIA (http://www.eia.doe.gov/pub/international/iealf/tablec2.xls) there are roughly 7.3 barrels of crude oil per metric ton and there are 5.8 million BTU's per barrel of oil (http://www.eia.doe.gov/kids/unitsindex.html). Combining these factors leads to a range from 8.1 to 20.9 trillion BTU's of energy per typical tanker-load.

[15] This LNG tanker size is from a report by the University of Houston Law Center Institute for Energy Law & Enterprise entitled "LNG Safety and Security" October 2003, Pg. 23. According to this report, most new LNG ships are designed to carry between 125,000 and 150,000 cubic meters of LNG or between 2.8 and 3.1 billion standard cubic feet of natural gas. With approximately 1,026 BTU's of energy per cubic foot of Natural Gas, this equals 3.1 trillion BTU's of energy in a 150,000 cubic meter LNG vessel.

[16] Propane is a hydrocarbon that is produced from both natural gas processing and crude oil refining in roughly equal amounts. It is often referred to as liquefied petroleum gas, LP-gas, or LPG.

[17] ABS (2004), Pg. 4

[18] UH IELE (2003), Pg. 14-15. Note that information on fundamental burning velocity was gathered from a similar table in an ABS consulting report prepared for FERC (ABS, 2004. p. 4). Fundamental burning velocity is the burning velocity of a laminar flame when ignited in a flammable vapor cloud. Lower fundamental burning velocities tend to generate lower overpressures. Also note, the autoignition temperature is the lowest temperature at which a flammable gas vapor will ignite spontaneously.

is most significant in the vapor phase, whereas the safety risk for gasoline lies in the liquid phase. In the event of a spill, a liquid like gasoline would have more manageable dispersion characteristics and be easier to contain but it would also have more unfavorable environmental impacts.

***Table 1: Comparison of Properties between LNG, Gasoline, and Propane***

| | Gasoline | Propane | LNG |
|---|---|---|---|
| Hazardous Material? | Yes | Yes | Yes |
| Autoignition Temperature (°F)[18] | 495 | 850-950 | 1004 |
| Cryogenic Temperature[18] | No | Yes, if refrigerated | Yes |
| Environmental Clean-up if Accidentally Spilled?[18] | Yes | No | No |
| Stored Under Pressure?[18] | No | Yes, unless refrigerated | No |
| Forms Vapor Clouds?[18] | Yes | Yes | Yes |
| Flammable Vapors?[18] | Yes | Yes | Yes |
| Toxic?[18] | Yes | No | No |
| Fundamental Burning Velocity (ft/s)[18] | 1.3 | 1.5 | 1.3 |
| Risk of Catastrophic Event | Similar | Similar | Similar |

In sum, no single characteristic can be used to assess the relative risks associated with different energy options. Rather these risks must be evaluated in a comprehensive and methodical manner. The studies cited in this briefing paper, together with ongoing research and analysis being conducted by the federal government and others, attempt to provide a balanced analysis of the specific risks associated with LNG. As indicated in the introduction, they generally conclude that safety concerns can be managed and need not stand in the way of expanding domestic LNG infrastructure.[19]

# III. Risk of Catastrophic Accident or Malicious Attack

Public concern about the potential for a catastrophic LNG-related incident has understandably risen in recent years by the emergence of terrorist threats to the nation, and by the recognition that large energy infrastructure (of various types, not just LNG) could pose an attractive target for future attacks. In an effort to address the added risks of terrorism, most oil and natural gas companies are in the process of working with the Department of Homeland Security to ensure the security of ships and storage facilities, including those handling LNG.[20] The Maritime Transportation Act of 2002 required all ship and terminal operators to submit security plans to the U.S. government by the end of 2003. Some of the measures that have been

[19] Federal Energy Regulatory Commission, "FERC Chairman Welcomes Fed Chairman's Focus on LNG", Press Release, June 11, 2003, Available: http://www.ferc.gov/industries/gas/indus-act/LNG-wood.pdf
[20] CLNG (Website), LNG Facility and Ship Security

taken so far call for much more restricted access to LNG facilities, tighter security, and increased patrols. In light of current terrorism concerns, of course, all energy products must be handled with increased care. Here again, moreover, most available analyses conclude that LNG is not necessarily any more attractive or vulnerable to terrorist threats than other energy sources.

***Historical Safety Record of the LNG Industry***

Historically, the LNG industry has had an extensive and relatively safe track record with very few accidents. This is especially true for the LNG shipping industry. Since international shipping began in 1959, LNG ships have transported more than 33,000 shipments without any serious accidents at sea or in port.[21] Currently there are roughly 150 active LNG ships transporting 110 million metric tons of LNG annually (equivalent to more than 5 trillion cubic feet of natural gas).[22] Asia is more reliant on LNG trade than any other region and consequently has accumulated an extensive track record with handling the substance. In 2000, roughly eight LNG vessels a week safely entered Tokyo Bay. Comparatively, Boston Harbor received on average one ship a week.[23] Last year, the United States imported over 500 billion cubic feet of LNG without incident (approximately 2 percent of total U.S. natural gas consumption).[24] While LNG vessels have experienced some groundings and collisions, none have experienced major cargo spills or fatalities.[25]

The fact that most LNG ships have extensive safety features may partly account for the industry's largely successful marine safety record. The ships are typically double-hulled and surrounded by thick insulation, which makes them more robust and less prone to accidental spills than single-hulled tankers (such as the Exxon Valdez.).[26] Most LNG ships are also equipped with global positioning systems, radar, and automatic distress systems to signal when they are in trouble. Finally, these vessels are equipped with sophisticated fire and gas detection systems.

For the most part, the safety record of onshore LNG terminals has also been exceptional but there have been a small number of serious accidents over the past 50 years. Onshore LNG marine terminals are preferentially located on large plots of land, with safety features such as full containment tanks. They consist of docking stations, LNG handling equipment, LNG storage tanks, and interconnections to distribution pipelines. These large ports are equipped to handle high winds, tidal, and wave forces. In the event of an emergency, their emergency shutdown (ESD) systems will rapidly cut off the flow of LNG during on and off-loading.[27]

Federal safety regulations require that LNG facilities have exclusion zones. These zones specify the area surrounding an LNG facility where an operator legally controls all activities. Moreover, they are required to ensure that structures and public activities beyond the immediate LNG facility boundary are safe in the event of an accident. Federal regulations identify two types of exclusion zones—flammable vapor-dispersion protection zones, and thermal-radiation

[21] CRS (2004), Pg. 6
[22] CLNG (Website), LNG Vessel Safety
[23] CLNG (Website), LNG Vessel Safety
[24] EIA (Website)
[25] CRS (2004), Pg. 6
[26] CRS (2004), Pg. 6
[27] CEC (2003), Pg. 4

protection zones.[28] The first of these, flammable vapor-dispersion protection zones, are required to provide the maximum safe distance from LNG vapor clouds which have not been ignited but could migrate (with the wind) to an ignition source. Thermal-radiation protection zones are required to ensure that the heat released from an LNG pool fire within the facility boundary would not be severe enough at the property line to cause death or third degree burns.[29] These zones are highly site-specific dependent on unique characteristics of the area such as terrain roughness, weather conditions, and average gas concentrations in air. For example, the vapor-dispersion exclusion zone for the Cove Point facility in Maryland is 1,017 acres, as opposed to only 840 acres for the Elba Island LNG facility in Georgia.[30] These federal exclusion zone requirements are identified in 49 CFR 193.

Since 1944 there have been roughly 13 serious accidents at the approximately 40 LNG terminals located worldwide.[31] A brief description of three particularly notable incidents follows:

*1. Cleveland, Ohio 1944*

One of the most serious LNG accidents to date occurred at a Cleveland, Ohio storage facility in 1944. An LNG tank was built using what was later proved to be improper materials, leading to a material brittle fracture and major spill. Some of the LNG drained into a confined storm-sewer system, forming a confined vapor cloud that accidentally ignited within the sewer and spread the fire in a residential area. The resulting explosion and fire killed 128 people.[32]

The Cleveland incident highlights the fact that large LNG storage tanks likely represent one of the most vulnerable points in the LNG supply chain. A large-scale spill or leak from one of these tanks (which may hold as much as 3.5 million cubic feet of liquid natural gas) could produce a massive and potentially very dangerous vapor cloud. However, modern LNG storage tanks have a number of safety features that significantly reduce the risk of another Cleveland-like disaster. Modern types of storage containers include double-walled "single-containment" tanks with surrounding impoundment dikes; "double containment" tanks that have both primary and secondary tanks; and "full containment" tanks that are reinforced to withstand "realistic impacts from missiles or flying objects."[33] In addition, modern tanks are equipped with safety-vent valves (to prevent pressure buildup), in-tank cameras (to allow for visual safety inspections), and integrated fire detection and response systems.

*2. Cove Point, MD 1979*

The only other LNG related death in the United States occurred at the Cove Point, Maryland receiving terminal in 1979. An inadequately tightened electrical penetration seal on an LNG pump led to a leak into the electrical conduit leading to an electrical equipment building. The vapors accumulated in the building and they were ignited by a circuit breaker within the

[28] CEC (2003), Pg. 6
[29] CEC (2003), Pg. 6
[30] CEC (2003), Pg. 6
[31] CRS (2004), Pg. 6
[32] CEC (2003), Pg. 8
[33] CEC (2003), Pg. 4-5

substation building. The buildup of pressure within this confined space led to an explosion that caused the roof to collapse, and a falling beam killed one person and injured a second.[34]

*3. Algeria 2004*

The most serious recent international LNG incident occurred on January 19, 2004 at a liquefaction facility in Skikda, Algeria and involved an explosion that killed 27 workers and injured more than 70.[35] Officials at Sonatrach (Algeria's state-owned energy company) claim that a cold hydrocarbon leak from a pipe occurred in one of the liquefaction facilities. A gas vapor cloud formed within the facility. This cloud then encountered an ignition source (likely a steam boiler) which led to an explosion. The explosion destroyed three of the six liquefaction units – termed "trains" within the industry – at the plant. It did not affect the second separate processing plant nearby or three large LNG storage tanks located some distance from the accident location. This was the worst fire at an Algeria petrochemical plant in their 40 year history. It is commonly believed that it was caused by poor maintenance and safety procedures rather than by a facility design flaw. Nevertheless, the incident has raised questions concerning the relative safety of LNG. According to a report prepared by James T. Jensen for the National Commission on Energy Policy, "the fact that the trains were involved in a disastrous fire does some damage to the industry's credibility on the safety issue."[36] The relevance of the Algeria incident to domestic safety concerns is unclear. In general, the vaporization process (used by the receiver of gas) does not require the same equipment as the liquefaction process (used by the gas exporter). This accident is still under investigation and the most significant question that remains is whether or not the vapor cloud that created the explosion was methane or other heavier hydrocarbons (i.e. butane and propane) used in the refrigeration process. This is important for determining whether the LNG processing was the source of the explosion or if it was related to other hydrocarbon fuels.

***Risk of Malicious Attack***

The fact that the LNG industry has amassed a relatively good safety record may, of course, go only so far in assuaging more recent concerns about the potential for terrorist attacks. The Commission acknowledges that there are endless possibilities for malicious attacks on LNG infrastructure at countless points along the LNG supply chain. This report focuses on three major risk scenarios most relevant to the U.S. The first of these is the hijacking of an LNG vessel so that it can be grounded ashore and used as a weapon. The second is the potential for detonating an explosive beside the hull of an LNG vessel, spilling its contents, and igniting the gaseous vapors. The third type of event would involve a terrorist attack at an onshore LNG receiving terminal or storage facility.

It is important to realize that vulnerabilities are not unique to LNG and should be addressed across the range of energy products and hazardous materials utilized in the United States. A detailed report released by the city of Vallejo California in January of 2003 concludes that LNG terminals and carriers generally do not make good targets for terrorists because both

[34] CEC (2003), Pg. 8-9
[35] CRS (2004), Pg. 7
[36] Jensen (2004), Pg. 123

the LNG ships and terminal facilities have very robust design characteristics.[37] However, they do acknowledge the serious risks associated with such infrastructure.

*1. Vessel Grounding*

The Commission could not locate any existing literature or analysis on the potential consequences if an LNG vessel were hijacked and commandeered for use as a weapon against a coastal target. However, the safety record of LNG shipping to date suggests that it would be difficult to use an LNG vessel effectively against an on-shore target. On those occasions where LNG vessels have grounded or experienced collisions in the course of normal business activities in the past, no spills, deaths, explosions, or fires have occurred as a result. In addition there are limited coastal targets that can be attacked with a vessel collision because of the lack of adequate water depth outside of designated shipping channels. The few areas of the US where adequate water depth for an LNG ship exists near shore are under control of the USCG and surveillance of security agencies.[38]

*2. Terrorism near the Coast*

Professor James A. Fay of the Massachusetts Institute of Technology has explored the possibility that a boat bomb, such as the one that was used against the USS Cole in 2000, could be detonated alongside an LNG vessel to trigger an enormous LNG spill and fire. Fay uses a mathematical model to simulate the potential consequences of such an event at specific U.S. sites.[39] In one scenario, Fay has compared the modeled impacts of an LNG spill versus an oil products tanker spill in Boston Harbor. Importantly, Fay's analysis assumes that the volume of the oil products spill (at 1140 $m^3$) is much smaller than the LNG spill (14,300 $m^3$), because typical oil product tanker compartments are roughly one-tenth the size of LNG vessel storage compartments. Fay's analysis further assumes an essentially instantaneous release, vaporization, and ignition of all LNG energy content in the ship. While this assumption is standard convention for modeling LNG spills, in reality, it would likely take some time for the LNG to spill out, vaporize, and acquire the appropriate flammability concentration before combustion. Fay's analysis suggests that significant damage could occur as far as 1.1 km from the source of the spill in the case of the LNG vessel, and 0.9 km in the case of the oil products tanker. Fay also concludes that the LNG spill (and resulting vapor fire) would have an average heat release rate of 1.5 Terawatts as opposed to only 0.12 Terawatts for an oil products compartment vapor fire (this difference appears to be due largely to the assumed difference in spill size).[40] In the Vallejo study cited above, it is noted that in a worst case scenario of this type, a flammable vapor plume could disperse several miles, encounter an ignition source, and then burn back to the spill resulting in a very serious fire. Although such a scenario is possible, the Vallejo study also points out that this is unlikely because most LNG released through acts of terror would be ignited and burned immediately without having time to disperse.

In a recent senate hearing, Professor Jerry Havens, an LNG expert at the University of Arkansas, expressed his concern for the lack of offshore exclusion zone requirements. He acknowledged the fact that current regulations for land based zones as present in 49 CFR 193 are

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[37] Vallejo (2003), Pg. 43
[38] Lewis
[39] Fay (2003)
[40] Fay (Boston)

based on good science and "adequate" for their purpose, but expressed "that it is imperative that the dangers to the public from possible releases from a LNG carrier onto water be considered in the siting of LNG terminals in our country."[41]

*3. Onshore Terminal Attack*

A third concern is the potential risk of a terrorist attack against onshore LNG infrastructure (e.g. LNG storage tanks). An attack on an LNG storage tank could be a serious event simply due to the volume of liquid involved and to the resulting hazard of a major LNG vapor fire. In evaluating the consequences of an attack, the rate of release is the more significant factor than the total volume. Acting to mitigate this hazard are the many safety features already built into the design of onshore LNG terminals and storage tanks to address accidental spills. In assessing this hazard, FERC has acknowledged that LNG-based fires are unpredictable but maintains that

> "the more extreme scenarios suggested by some LNG terminal opponents are too theoretical and do not realistically reflect the actual configuration and physical characteristics of LNG terminal infrastructure, including the comprehensive safety and security features required in terminal design."[42]

In addition, opponents' worst-case scenarios of this type tend to assume instantaneous liquid release, vaporization and delayed ignition. FERC seems skeptical of such a scenario, suggesting that it would be analogous to lifting an upside-down Dixie cup and releasing all of its contents at once – an event that is unlikely to occur because of the strength and design of LNG storage tanks.[43]

Finally, also in the Vallejo study, a worst case scenario involving the crashing of a 747 airplane with a full load of jet fuel into a land based storage tank is discussed. A catastrophic event of this type could cause a fireball with very high temperatures and extensive heat radiation. A fireball results when a large rich mixture of fuel and air are ignited creating buoyancy and turbulence that rapidly burns the rest of the fuel and causes it to rise into the atmosphere. The Vallejo study ultimately concludes that the circumstances necessary to cause a fireball of such intensity is unlikely.[44]

# IV. Regulation of the LNG Industry

The LNG industry in the United States falls under the regulation of several different federal agencies including the Department of Energy (DOE), the Federal Energy Regulatory Commission (FERC), the U.S. Coast Guard (USCG), the Department of Transportation (DOT), the Environmental Protection Agency (EPA), the U.S. Minerals Management Service (MMS), the U.S. Fish and Wildlife Service, the U.S. Department of Labor Occupational Safety and

[41] Havens (2004)
[42] CRS (2004), Pg. 14
[43] CRS (2004), Pg. 14
[44] Vallejo (2003), Pg. 50-51

Health Administration (OSHA), and the U.S. Army Corps of Engineers. It is also falls under state environmental protection agencies, and local police and fire departments. Finally, the non-governmental regulators and standards organizations that oversee LNG include the National Fire Protection Association (NFPA), the American Society of Mechanical Engineers (ASME), the American Society of Civil Engineers (ASCE), the American Petroleum Institute (API), the American Concrete Institute (ACI), and the American Society for Testing and Materials (ASTM).

Of these, DOT and FERC have the primary responsibility of onshore LNG terminals. The USCG is primarily responsible for the LNG ships and offshore terminals.

*Department of Transportation (DOT)*

DOT is responsible for security patrols, protective enclosures, lighting, monitoring equipment, and alternative power sources.[45] DOT operates under the authority of the Pipeline Safety Act of 1995 and is responsible for prescribing "minimum safety standards for determining the location of a new liquefied natural gas pipeline facility"[46] including:

- Design and construction guidelines for LNG facilities to withstand fire, wind, hydraulic forces, and erosion from LNG spills.
- Consideration of geophysical hazards, proximity hazards (i.e. to major cities), and the existing and proposed land use near the location.
- Regulation of the operations, maintenance, employee qualification, and security.

Finally, the Department of Transportation is also responsible for issuing the licenses for new LNG offshore terminals under the authority of the Deep Water Port Act.

*Federal Energy Regulatory Commission (FERC)*

While the DOT regulates these aspects of an onshore LNG terminal, it does not have authority to approve or deny specific LNG sites; this is the role of FERC under the Natural Gas Act (NGA) of 1938. Under Section 3 of the NGA, FERC requires that LNG terminal applicants provide evidence (with detailed site engineering and design information) that an LNG site will be able to properly and safely receive or deliver LNG. In addition, under Section 7 of the NGA, FERC is charged with authorizing the construction and operation of interstate natural gas pipelines that may be associated with LNG facilities.[47] Finally, under the National Environmental Policy Act of 1969, FERC must prepare an environmental impact statement in its review of an LNG terminal siting application.

*United States Coast Guard (USCG)*

The USCG is primarily responsible for the regulation of offshore marine terminals and LNG ships and marine terminals under the Magnuson Act, the Ports and Waterways Safety Act of 1972, and the Maritime Transportation Security Act of 2002.[48] As indicated above, this includes primary responsibility for the security of incoming LNG ships and docked vessels, as

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45 DOE (Website)
46 CRS (2004), Pg. 7
47 Interagency Agreement (Website)
48 Interagency Agreement (Website)

well as matters relating to vessel engineering, safety standards, and navigation safety. In addition, under the authority of the Deep Water Port Act, the USCG is the lead agency for conducting the environmental review for proposed offshore terminals.

*Department of Energy (DOE)*

The Department of Energy's Office of Fossil Energy is the federal entity that improves the importation of LNG (the commodity). This office has recently asked Sandia National Laboratory to undertake a detailed examination of LNG safety. This report is expected to be completed in 2004. In addition, FERC, the USCG, and DOT all recently announced an interagency agreement in 2004 to "provide for the comprehensive review of land and marine safety and security issues at the nation's LNG import terminals."[49]

## V. Conclusion: Is LNG Safe Enough?

It is clear that the cryogenic nature of LNG, its flammability under certain conditions, and its dispersion tendencies do present a number of potential safety hazards during transport and handling. However, the empirical evidence – based on the extensive track record of the industry – indicates that these hazards can be adequately managed under normal operating conditions. Based on current understanding, LNG does not appear to pose a greater societal safety hazard than other widely used sources of energy such as petroleum and its by-products.

The emergence of an ongoing terrorist threat in recent years has added a new and potentially more challenging dimension to existing concerns about the risks involved in importing large quantities of LNG. As a result, the specific vulnerability of LNG transportation and storage facilities to malicious attack must be convincingly addressed before policymakers, insurers, investors, and the public consent to considerable expansion of the existing LNG infrastructure. Potential attacks on LNG vessels or storage facilities are, of course, likely to be most concerning if they occur near a populated area. Hence some recent proposals would locate the offloading process many miles offshore. In such a scheme, energy-laden LNG vessels need not approach the coastline but would instead offload their cargo via a pipeline connection at sea. An off-shore receiving facility of this type is currently being constructed 116 miles off the coast of Louisiana and others are under consideration.[50]

To what extent improved understanding of the genuine hazards posed by LNG would actually translate to greater public support for new receiving terminals and increased carrier shipments remains an open question. NIMBY-type opposition to the siting of major energy infrastructure is, after all, not unique to LNG. (This more general issue is addressed elsewhere in other Commission work and not explored in this paper.) While more research is underway on the full range of hazards involved—in particular research on the damage potential associated with a large LNG vapor fire—several recent assessments by knowledgeable sources suggest that these hazards are not different in kind or degree from those associated with other fuels or types of energy infrastructure and can be successfully managed with existing market and regulatory arrangements. Given the nation's need for adequate and reasonably priced supplies of natural

[49] DOE (Website)
[50] Globe (2004), Pg. A1

gas, the Commission recommends that concerted efforts be made to educate the public regarding LNG-safety issues, and ensure that safety concerns are addressed during the siting process.

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