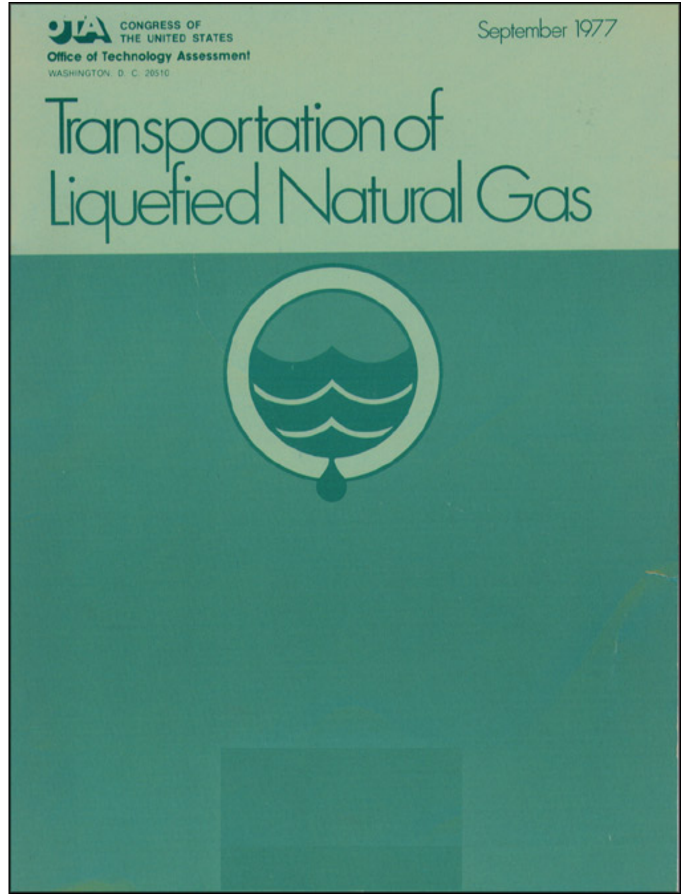
Transportation of Liquefied Natural Gas

September 1977

NTIS order #PB-273486



Congress of the United States
OFFICE OF TECHNOLOGY ASSESSMENT
WASHINGTON, D.C. 20510

DANIEL DE SIMONE
ACTING DIRECTOR

September 28, 1977

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Chairman, National Ocean Policy Study
U.S. Senate
Washington, D. C. 20510

Honorable Ernest F. Hollings
Vice-Chairman, National Ocean Policy Study
U. S. Senate
Washington, D. C. 20510

Gentlemen:

On behalf of the Board of the Office of Technology Assessment, we are pleased to forward the results of this assessment of The Transport at ion of Liquefied Natural Gas which was requested by your Commit tee.

This report provides a concise analysis of current LNG technology and possible trends in the use of LNG. It also identifies and discusses the major policy issues. We hope this report will be a useful resource to your Committee and to the Congress when it debates energy questions in which LNG is a factor.

Sincerely,

EDWARD M. KENNEDY
Chairman

Sincerely,

LARRY WINN, JR.
Vice Chairman

Foreword

This report is an assessment of the transportation of liquefied natural gas (LNG). The assessment was requested by the Senate National Ocean Policy Study for use in consideration of major new projects for the importation of natural gas, and of the competing alternatives for transporting natural gas from Alaska through Canada (pipeline all the way), or through Alaska only and thence via LNG tankers to the lower 48 States.

This report is divided into three parts: Chapter I presents a factual description of the LNG systems and facilities and the Federal regulatory process governing the development and operation of such systems. Chapter II presents a critical review of key portions of the LNG system where technological or political problems may occur. Chapter III outlines the kinds of actions desired by interested parties.

The report identifies nine areas which may be of concern to the Congress as it considers possible new legislation, oversees Federal agencies, and appropriates funds for agency operations and research. The areas of near-term concern are: the design and construction of LNG tankers, the regulation and inspection of LNG tankers and their operation, the regulation and inspection of LNG terminals and their operation, the Federal decisionmaking process in the certification of LNG import projects, and the status of current research on LNG and the need for further inquiry.

The areas of longer range interest are: regulations and criteria for the siting of LNG facilities, liability for LNG accidents, reliability of foreign suppliers of LNG, and policies for pricing LNG.

One LNG import terminal is currently operating in the United States. By early 1978, two others will be operational. As a result of these operations and other projects now proposed, LNG could make up 5 to 15 percent of the total U.S. natural gas consumption by 1985. Several pieces of legislation to regulate this growing industry are now before the Congress. Hence the timeliness and importance of this assessment for the Congress.

Two related studies for Congress are currently in progress: a safety study by the General Accounting Office, and an energy facility siting study by the Office of Technology Assessment.

This assessment was performed by Peter Johnson, project director, and the Oceans Program staff, under the overall direction of Robert W. Niblock, the Program Manager.

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Summary

It is possible that during the next two decades 5 to 15 percent of the U.S. natural gas consumption could be filled with LNG from Alaska or foreign countries. This would be a major increase over present LNG import levels. This gas will reach the United States by means of a complex and expensive system consisting of liquefaction facilities, specialized cargo tankers, and regasification and storage facilities.

To date, there have been few serious problems in the operation of small-scale LNG facilities existing in the United States. However, new ships and plants will be considerably larger than existing ones, and problems of scale and limited experience make it difficult to predict with any degree of certainty the safety of the LNG system.

It appears that the most serious incidents could occur as a result of an LNG tanker accident. Therefore, while the tankers appear to be well designed and constructed, better control of vessel traffic in U.S. ports and waterways, improved inspection procedures after the ship has been commissioned, and mandatory crew and inspector training are needed.

At the onshore facilities where LNG is received, stored, processed and sent into a gas distribution pipeline, improved inspection procedures are also needed to enhance the public safety. However, the major issue surrounding the onshore facilities is the question of where they should be located. There are currently no Federal guidelines for choosing sites of LNG or any other energy facility. There is considerable public pressure for such guidelines, particularly criteria which would limit facilities to unpopulated areas.

Regulation of LNG systems is hampered by jurisdictional overlaps (particularly between the Federal Power Commission and the Office of Pipeline Safety Operations), some gaps in enforcement (particular the lack of inspection to assure compliance with stipulations in FPC permits), and the lengthy Government procedures which do not result in timely decisions for the applicant and do not give the public adequate participation in decisions (particularly in the FPC licensing of LNG projects).

In addition, the lack of firm Government policy on such matters as LNG import levels, pricing mechanisms to be used, and the Federal role in siting of facilities makes planning difficult for both the gas industry and the public.

Past research has produced conflicting results and predictions about the safety of LNG and it is unlikely that future research will resolve the differences and come to firm decisions. For that reason, public policy decisions about LNG systems will probably be made principally on the basis of nonquantitative approaches. These decisions should result in prudent siting of facilities and strict design, construction and operation standards.

This report identifies nine areas which may be of concern to the U.S. Congress in its consideration of possible new legislation, oversight of Federal agencies with responsibilities for LNG systems, or appropriation of funds for agency operations and research.

The first five areas are concerns about existing equipment and procedures for facilities which are already operating or will be operating in the near future. Regulatory changes in these areas must be such that they can be applied to ongoing projects. These areas are:

- tanker design and construction (pages 42-45);
- tanker regulations and operations (pages 46-49);
- regulation of terminal operations (pages 50-52);
- decisionmaking process in certification of import projects (pages 53-57);
- safety research on LNG (pages 58-62).

The second four areas addressed have more long-range implications and will affect policies and facilities for future projects. These areas are:

- LNG facility siting (pages 63-67).
- liability for LNG accidents pages (68-70).
- reliability of supply (pages 71-75).
- pricing policy (pages 76-78).

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VOLUME RELATIONSHIPS

LNG Gas/Liquid Ratio 619.8 to 1
1086 Btu/Cu. Ft. Spec. Grav. 0.465

	LNG Conversion Factors	Gas		Liquid							Thermal
		Cubic Feet	MCF	Pounds	Gallons	Imp. Gal.	Cubic Feet	Barrels	Cubic Meters	Metric Tons	Therms
Gas	1 MCF	1000.0	-	46758	12070	10.051	1,6134	0.28735	0.045692	.02123	10.860
Liquid	1 Gallon	82850	0.082850	3.87390	-	0.8327	0.13367	0,02380	0,003785	0001759	0.89975
	1 Imp, Gal	99503	0.099503	4.6526	1,201	-	016054	0.02858	0,004546	000211	1,08059
	1 Cubic Foot	619.80	061980	28.981	7.4811	6.229	-	0.17810	0.02832	0.01316	6.7311
	1 Barrel	348008	3.48008	162,72	42,005	34,97	5,6148	-	0,15901	0.07388	37,794
	1 Cubic Meter	21,886	21,886	1023,3	264.16	220,0	35314	6.2888	-	0.46463	32768
	1 Metric Ton	47,103	**47103**	2202,4	568,53	473,4	75.996	13.535	2.1522	-	511 54
Thermal	1 Therm	92081	0,09208	4,3055	1.1114	0,92546	0,14856	0.02646	0,00421	0.00195	

Chapter I

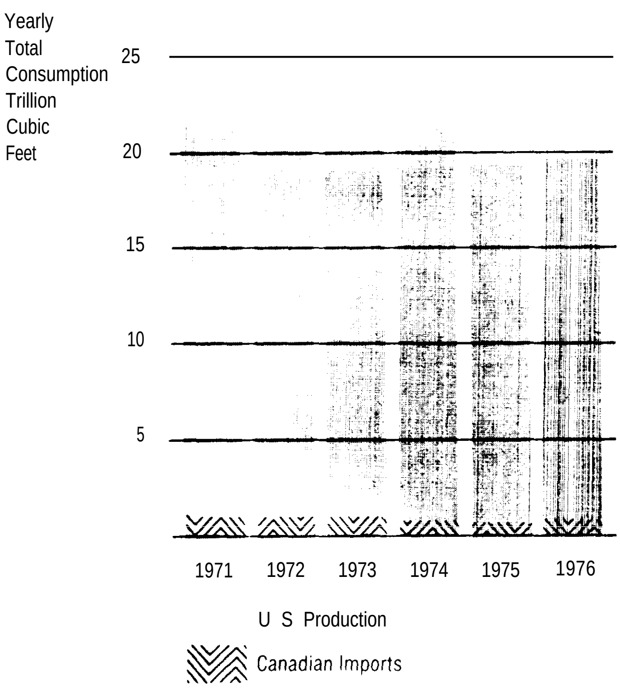
Description of LNG Technology and Import System

SUPPLY AND DEMAND

Natural gas is a major source of energy for the United States, supplying 20 trillion cubic feet, more than one-quarter of the total energy consumed in this country, during 1976.[1]

Although U.S. production of natural gas has been declining since 1971 (figure 1), there are significant supplies of natural gas in several regions of the world where there is lit-

Figure 1. U.S. Natural Gas Consumption 1971-1976



Source Federal Energy Administration **Monthly Energy** Review, March 1977

Figure 2. World Proportional Natural Gas Reserves By Major Supplier Country

Country	Percentage
USSR	33
Iran'	14
United States	10
Algeria*	10
Abu Dhabi*	8
Total	75

● Countries with little or no gas demand.

Source Department of the Interior World Natural Gas Annual – 1975

tle or no gas demand (figure 2). To date, much of this natural **gas** has been wasted—in 1975, **6.5** trillion cubic feet were vented or flared worldwide.[2]

To use the natural gas which would otherwise be untapped or wasted, importation of natural gas is one of several supplemental supply schemes used by those areas of the world with large energy demand, primarily the United States, Europe, and Japan. Natural gas has been carried overland by conventional pipelines, and about 1 trillion cubic feet of natural gas is imported in that manner from Canada to the United States each year. However, in order to import natural gas in a form practical for water transportation from Eastern Hemisphere nations, a system has been developed to convert the gas to liquid form at about 1/600th the volume. The lique-

[1]**Federal Energy Administration,** *Monthly Energy Review,* **March 1977.**

[2]**U.S. Department of the Interior, Bureau of Mines,** *World Natural Gas Annual* **(Washington, D. C.: U.S. Department of the Interior, Bureau of Mines, 1975).**

fied natural gas (LNG) is then shipped in specially constructed tankers, introducing a marine link in the supply and demand of natural gas. This marine link is a large component, consisting of the liquefaction facility at the source of the gas, the LNG tanker, and the receiving terminal and regasification facility at a location near a gas distribution network. It is a very capital-intensive system, which can cost more than $1 billion to construct. A large 500 million cubic feet per day project with four ships could require a $2 billion capital expenditure for liquefaction/export facilities ($1 billion), ships ($150 million each), and import/regasification facilities ($300 million to $400 million). Implementation of all announced LNG projects could require capital expenditures in excess of $35 billion worldwide. In the United States alone, construction of facilities and ships for the import of LNG could require $20 billion. a

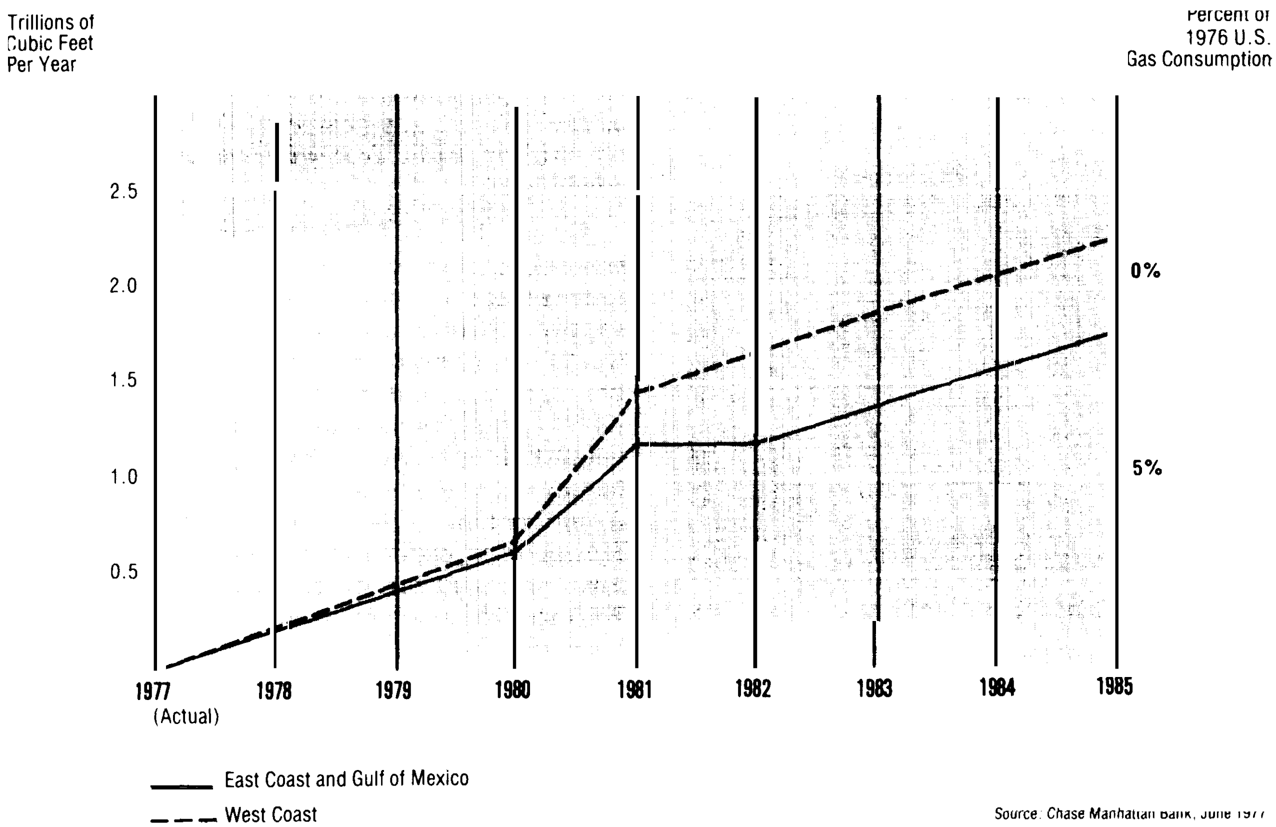
Figure 3. Existing International LNG Trade

Date Started	Supplier to Importer	Amount per Day (million cubic feet)
1972	Brunei to Japan	737
1977	Indonesia to Japan	550
1964	Algeria to France	400
1969	Libya to Italy	235
1969	Libya and Algeria to Spain	160
1969	Alaska to Japan	135
1964	Algeria to United Kingdom	100
1971	Algeria to Boston, Mass.	44

Source Pipeline and Gas Journal, June 1977

[3] "LNG Report," *Pipeline and Gas Journal* 204 (June 1977).

Figure 4. U.S. LNG Import Projection



Source: Chase Manhattan Bank, June 1977

Such huge capital expenditures are generally financed by a multinational mix of governments and private firms. The U.S. Government has already provided about $716 million in subsidies, loans, and loan guarantees in connection with LNG projects. More than two-thirds of that support has been given to the foreign portions of the projects. A

Europe became the first steady market for LNG in 1964 (figure 3). Japan took over as the key market about 1972, receiving about 49 percent of the LNG moving in international trade. However, the United States—which has used very limited imports of LNG only since 1971–is projected to become a major LNG customer if ventures now planned go forward. b

[4]Interview with Officials of Export-Import Bank of the United States, Washington, D. C., June 16, 1977.

[5]David Hawdon, *World Transport of Energy 1975 to 1985* (London: Stanil and Hall Associates Limited, April 1977), p. 39.

The United States is presently a net exporter of LNG. More than 32 billion cubic feet of natural gas in the form of LNG has been sent to Japan from southern Alaska each year for the past 5 years, while only about 15 billion cubic feet per year is imported from Algeria to Everett, Mass. The LNG imported to Everett is a very small amount, less than one-twentieth of 1 percent of the U.S. consumption of natural gas in 1976.[6] According to industry representatives, however, LNG could be 5 to 15 percent of the total U.S. gas consumption by 1985 (figure 4).[7] Projects are now proposed which could bring as much as 3.5 trillion cubic feet of LNG per year to the United States from foreign sources within the next 10 to 15 years (figure 5).

[6]Federal Power Commission, "Table of LNG Imports and Exports for 1976," News *Release,* June 3, 1977, and Federal Energy Administration, *Monthly Energy Review,* March 1977.

[7]Office of Technology Assessment LNG panel meeting, Washington, D. C., June 23, 1977.

Figure 5. Status of U.S. LNG Import Projects

Project	Start-up Date	Supply Source	Status (AGA/FPC)	Quantity (billion cubic feet/y r.)
Existing & Firm Foreign Imports				
Distrigas I	1972	Algeria	Existing/Operational	1,6
Distrigas IV	1978	Algeria	Firm/Pending	42*
El Paso I	1978	Algeria	Firm/Approved	365
Note -- Eascogas project is deleted here because of recent questions regarding approvals and project viability				407
Probable Foreign Imports				
Panhandle Eastern	1980	Algeria	Probable/Approved	179
Pacific Lighting Int	1980	Indonesia	Probable/Approved	197
El Paso II	1980-82	Algeria	Probable/Pending	365
				741
Possible Foreign Imports				
Tenneco-N B. Canada	1985	Algeria	Possible/Filed	397
Occidental-El Paso	1985 +/-	USSR	Possible/Not Filed	365
Brown/Root-Tenneco	1985 +/-	USSR	Possible/Not Filed	547
Kalingas	1985 +/-	Iran	Possible/Not Filed	285
El Paso-Iran	1985 +/-	Iran	Possible/Not Filed	547
Shell-BP	1985 +/-	Nigeria	Possible/Not Filed	237
				2,378
Grand Total				3,526

● Replaces Distrigas 1.

Sources American Gas Association and the Institute of Gas Technology,

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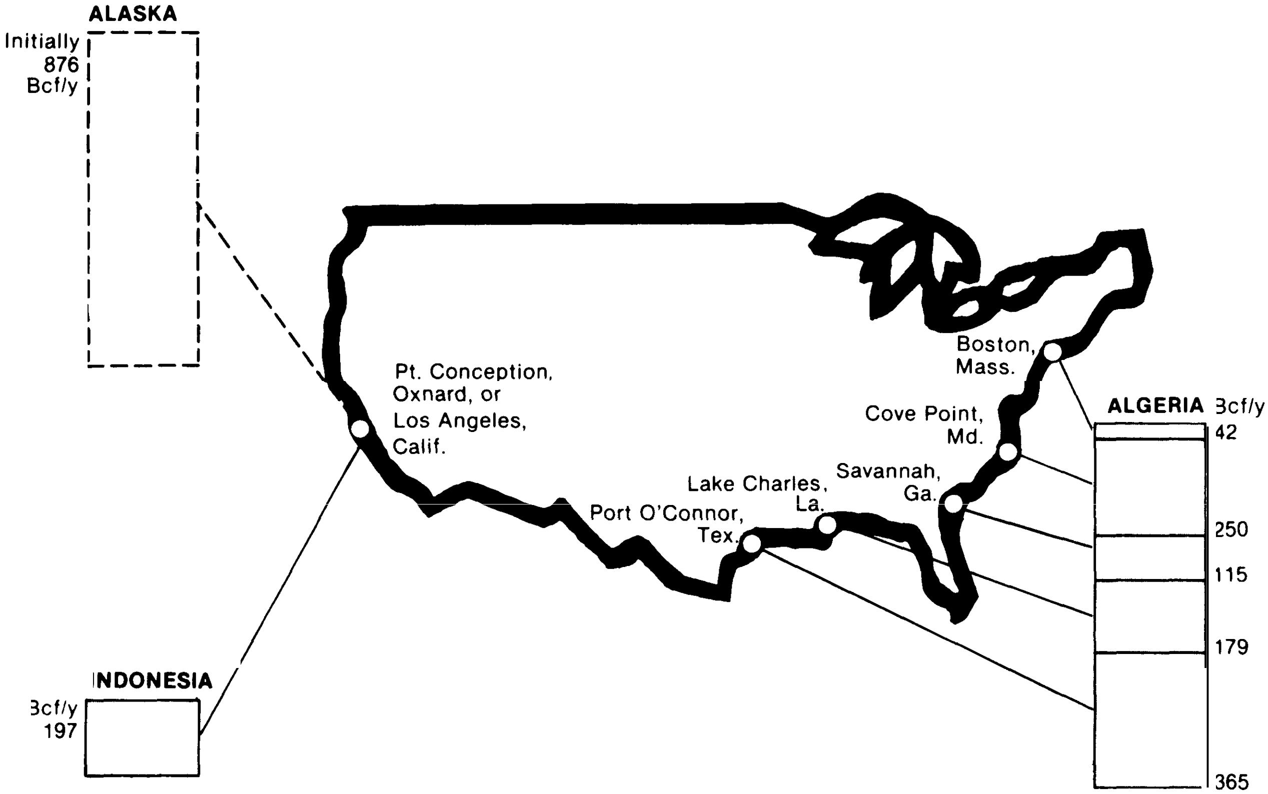
Figure 6. Sources and Destinations of Major Planned LNG Import Projects/1978 – 1985



Note Other possible future sources of LNG include Iran, Russia, and NIgerla
Bcf/y = billion cubic feet per year

Source OTA.

Ultimately, the supply of natural gas is limited, But since it is currently an under-utilized resource in many foreign countries, importing it as LNG could satisfy a significant portion of the U.S. energy demand for at least the next 20 years.

Imports of LNG could be particularly useful in alleviating near-term fuel shortages in certain sectors of the economy or parts of the country. In California, which accounts for 11 percent of U.S. natural gas consumption, s LNG could help to alleviate projected energy shortfalls and air quality problems.

If presently planned and approved projects move forward, Algeria would be the major source of the increased imports (figure 6). A smaller amount of LNG would come from Indonesia, and there is a possibility of supplies from the U.S.S.R, Iran, and Nigeria after 1985.[9] The stability of these foreign supplies and likely results of possible curtailment of LNG shipments to the United States has been identified by this study as one of the potential problems of the LNG system. Foreign supply is discussed further in the critical review section which follows this chapter.

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[8]**Douglas M. Considive, cd.,** *Energy Technology Handbook (New* **York: McGraw-Hill, 1977).**

[9]**American Gas Association, Gas** *Supply Review, 5* **(February 1977).**

In addition to foreign natural gas, new gas discoveries in Alaska could be transported to the west coast as LNG. This possible supply of gas from the North Slope and southern Alaska could be more than 1 trillion cubic feet a year as early as 1984.[10]

The North Slope is by far the largest of the two Alaskan supplies of natural gas. The method of transportation to be used to bring the North Slope gas to the west coast was to be determined by the President in September? A proposal to transport this gas by pipeline through Canada was being weighed against a proposal to use an LNG system.

DESCRIPTION OF LNG

Liquefied natural gas is not the only hazardous cargo transported in the United States today, or is it necessarily the most dangerous. Other cargoes which pose unique hazards when transported in large volumes include liquefied petroleum gas (LPG), chlorine, acids, and gasoline.

Liquefied natural gas and LPG are similar in many ways and are treated together as "liquefied gases' by most regulators. Liquefied petroleum gas, however, appears to be better known and accepted by the public. In 1976, 10 million tons of LPG were moving in world trade, most of it going to Japan from the Middle East countries. It is estimated that by 1980, LPG trade will more than double, and that U.S. demand will be as much as 12 million tons.[11] In 1977, there were 441 LPG tankers operating worldwide with a capacity of 3.5 million cubic meters. In comparison, 30 LNG tankers were operating worldwide at the same time with a capacity of 2.2 million cubic meters.

Some unique properties of LNG which affect the design of tankers or terminals are:

- it has an extremely low temperature of –259° F;
- it weighs about 28 pounds/cubic foot, slightly less than half the weight of water, and would therefore float;
- at normal ambient temperatures, it evaporates very rapidly and expands to about 600 times its liquid volume;
- in the vapor state, and when still very cold, the gas is heavier than air and, in the event of a spill, would hug to the earth's surface for a period of time until substantially dissipated;
- when the vapor warms up, reaching temperatures of about –100° F, it is lighter than air and would rise and dissipate in the air;
- in the vapor state, it is not poisonous, but could cause asphyxiation due to the absence of oxygen;
- in the vapor state, concentrations of 5 to 15 percent natural gas are flammable.

Liquefied natural gas is odorless and colorless. It looks much like water. Except for its extremely cold temperature, which requires special handling techniques and materials, the liquid is relatively safe. In bulk form it will not burn or explode. Momentary contact on the skin is harmless although extended contact will cause severe freeze burns, On contact with certain metals such as carbon steel ship decks, LNG can cause immediate cracking.

*NOTE: On September 8, 1977, the President announced that an agreement had been reached with Canada for a pipeline to carry natural gas across that country from Alaska to the west coast of the United States. The Congress has 60 days after formally receiving the President's plan in which to disapprove the choice if it so desires.

[10]Federal Power Commission, *Recommendation to the President Alaskan Natural Gas Transportation Systems* (Washington, D. C.: Federal Power Commission, May 1, 1977) p. I-44.

[11]H. Magelssen, "LPG-Transportation Cost, Market Potential and Future Charterers," *Gastech 76 Proceedings LNG and LPG Conference, New* York, Oct. 5-8, 1976, (Herts, England: Gastech Exhibitions, 1977).

The behavioral patterns of LNG vapor in the atmosphere, however, are not so well understood and may create hazards. If spilled on the ground, LNG would "boil," (vaporize) very rapidly for **2** or *3* minutes until the ground was frozen and no longer emitting heat to the LNG on top of it. This would slow the rate of vaporization and minimize cloud formation dangers.

If spilled on water in a large-scale accident, it is unlikely the water would freeze. Instead the water would continue to warm the floating LNG, vaporizing it and forming a spreading cloud. Researchers currently disagree on the shape, size, movement, and composition of the vapor cloud and the factors which will affect it. It is believed that the concentration of LNG vapor within the cloud is not homogeneous. At the edge of the cloud, where the greatest mixing with ambient air occurs, the concentration of gas is lowest. At the core of the cloud, the concentration is highest. Where the concentration falls within the flammable limits of 5 to 15 percent, the cloud may be ignited and burn back toward the source of the spill. It is generally agreed that, if the vapor from a large LNG spill ignites, it would be beyond the capability of existing firefighting methods to extinguish it.[12] Therefore, the key to reducing the hazard of an LNG fire is a strong prevention program.

The hazards of transporting LNG are somewhat similar to those of LPG, if the two are considered in equal volumes. However, LPG is somewhat more dense than LNG vapor at comparable temperatures. In the event of a spill of either liquid on water, the liquid would rapidly spread by gravity until a large vapor cloud would form. LNG would vaporize considerably faster than LPG because LNG is more volatile. Thus, the LPG vapor cloud would evolve over a longer period of time, and would be more cohesive than the LNG cloud. LPG has the greatest potential for detonation both in open air and confined. LPG stored in tanks continually heated by a surrounding flame causes a rise in pressure which leads to detonation. Open-air detonations of LPG[13] have been demonstrated by experiment whereas the same is not true of LNG.[14]

Research into the behavior of spilled LNG and an LNG cloud is another critical area discussed in the next chapter.

SAFETY RECORD OF EARLY USE OF LNG

Liquefaction of natural gas is achieved by cooling the gas to –259° F. The process was developed on a large scale during the first quarter of the 20th century to simplify the transportation and storage of natural gas, since the liquid state is l/600th the volume of the gaseous state.

Until recently, LNG was utilized primarily in operations which produced the liquid and stored it for use only during peak demand, for example, in cold winter weather. There are 89 of these facilities operating in the United States today to produce and/or store domestic LNG. Known as "peak shaving plants," they have a combined storage capacity of 2 million cubic meters.[15] In addition, one plant in Boston imports and stores foreign LNG. Its capacity is 146,000 cubic meters. The peak shaving plants have existed safely for years, without much public attention to either their location in heavily populated areas or their operations. Only one major incident has marred the safety record of these plants.

That accident occurred at the first LNG installation in 1944. At that time, a storage tank owned by East Ohio Gas Company in Cleveland ruptured, spilling 6,200 cubic meters of LNG into adjacent streets and sewers. The liquid evaporated, the gas ignited and, where confined, exploded, The disaster remains the

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[12] **Society of Naval Architects and Marine Engineers,** *Proceedings of Second Ship Technology and Research (STAR) Symposium* **(San Francisco, Calif.: May 25-27, 1977), p. 396.**

[13] **Telephone interview with staff of the Bureau of Mines, Pittsburgh, Pa., Sept. 7, 1977.**

[14] **Telephone interview with staff of Naval Weapons Laboratory, China Lake, Calif., Aug. 25, 1977.**

[15] **American Gas Association,** *LNG Information Book 1973* **(Arlington, Va.: American Gas Association, 1973).**

most serious LNG accident anywhere in the world. It resulted in 128 deaths, 300 injuries, and approximately $7 million in property damage.[16]

Based on investigations made by the U.S. Bureau of Mines after the accident, it was generally agreed that the tank failed because it was constructed of 3.5 percent nickel steel, which becomes brittle on contact with the extreme cold of LNG. Since the Cleveland disaster, it has become standard practice in the LNG industry to use 9 percent nickel steel, aluminum, or concrete and to surround storage facilities with dikes capable of containing the contents of the tank if a rupture occurs.

The only other significant accident related to LNG to date occurred at a Staten Island import facility in 1973; where 40 workmen repairing an empty LNG tank were killed when the roof of the tank collapsed as a result of a fire.

While the Staten Island tank disaster precipitated active local opposition to LNG, the gas industry has repeatedly argued that the accident was not due to any characteristic or handling of LNG[17], but was an industrial accident involving an insulation fire. However, a Bureau of Mines study of the accident indicated that there was enough LNG in the insulation that it could have been released very quickly into the tank once ignition had started.[18]

The only other accident in the United States mentioned in connection with LNG took four lives in Oregon. This accident, however, took place during construction of the storage tank before LNG had ever been introduced into the facility.[19]

Over the past 10 to 20 years, the peak shaving facilities have been engaged in all phases of LNG handlings: liquefaction, regasification, loading and unloading, storage, and shipment by pipeline, truck, rail, and barge. However, new LNG projects involve much larger scale facilities entirely dependent on marine shipment, and these are the focus of this study.

REGULATION OF IMPORT PROJECTS

Before any LNG import or export project can begin operation, more than 130 permits must be obtained from Federal, State, and local agencies (see appendix A), and 12 different Federal agencies are involved in approvals and controls. The Federal Power Commission (FPC), the Coast Guard, and the Office of Pipeline Safety Operations (OPSO), are the agencies most involved in LNG and are discussed in appropriate sections of this chapter. The others are explained in appendix B.

The most crucial agency in this milieu is the Federal Power Commission, which under the Natural Gas Act of 1938, has power to approve or reject any proposed project in three ways:[20]

- it must determine whether of not the public interest will be served by LNG importation;
- it must authorize construction or extension of any facilities to be used in the transportation or sale of interstate natural gas;
- it has the authority to establish the price at which the gas is sold.

[16] U.S. Department of the Interior, Bureau of Mines, *Report on the Investigation of the Fire at the Liquefaction, Storage and Regasification Plant of the East Ohio Gas Company, Cleveland, Ohio, Oct. 20, 1944.* (Washington, D. C.: U.S. Department of the Interior, Bureau of Mines, February 1946).

[17] Socio-Economic Systems, Inc., *Environmental Impact Report for the Proposed Oxnard LNG Facilities, Safety, Appendix B* (Los Angeles, Ca.: Socio-Economic Systems, 1976), p. 10.

[18] U.S. Congress, House, *Staten Island Explosion: Safety Issues Concerning LNG Storage Facilities.* Hearings before the Special Subcommittee on Investigations of the Committee on Interstate and Foreign Commerce. 93rd Cong., first sess., July 10, 11, 12, 1973, pp. 143, 145.

[19] "LNG Scorecard," *Pipeline and Gas Journal* 204 (June 1977): 22.

[20] 15 U.S.C. § 717 f (c) (1970).

The Federal Power Commission has broad discretionary powers in determining what is and what is not in the public interest and in stipulating conditions which must be met in order to meet the public interest.

To date, the FPC has been asked to rule on one LNG export project and 10 LNG import projects (see figure 5). The export project, with liquefaction facilities in Kenai, Alaska, has been approved and is operating. Of the import projects, three have received final approval; one has received initial approval, subject to review. One import project with its terminal and regasification plant in Everett, Mass., is in operation. Another, with import facilities 'in Cove Point, Md., and Savannah, Ga., is scheduled to begin operation later this year. Facilities for the approved project at Lake Charles, La., have not yet been constructed, nor have facilities for the Oxnard, Calif., terminal which has received only initial approval.

The FPC approves the import projects by means of an express order authorizing importation and certificates of public convenience and necessity (authorization and stipulations for construction and operation of facilities). The approvals are obtained by means of a complicated quasi-judicial procedure which routinely takes several years from the time an application is filed until it is approved. First, an evidentiary hearing is held before an administrative law judge, in which the applicant, staff, and interveners each present their views of the nature of the project, cost estimates, the need for additional supply of gas, and environmental consequences of the project. The evidence presented also includes an environmental impact statement prepared by the FPC, an engineering and safety review by the cryogenics division of the National Bureau of Standards, and a risk analysis by the FPC staff. On the basis of this evidence, the FPC administrative law judge makes an initial decision.

" Second, there is a period of review during which any of the parties may file exceptions to the decision. At the end of the review period, the commissioners make a final decision which may uphold the initial decision or change it completely. The final decision is subject to an appeal in one of the U.S. Courts of Appeal.

Since the historic role of FPC has been to regulate the entry of suppliers into the interstate natural gas market and to ensure that interstate sales of gas take place at prices that are "just and reasonable,"[21] the agency has limited its activities to licensing and ratemaking. There is little onsite inspection to assure compliance with stipulations contained in the licenses. The exception to this general rule occurs when a company wishes to expand existing facilities and submits a new application. In that context, FPC engineers inspect the facility to judge its operating performance.[22] A critical analysis of the decisionmaking process which leads to certification of LNG projects and the difficulties of pricing policies are discussed in the next chapter.

LNG TANKER TECHNOLOGY

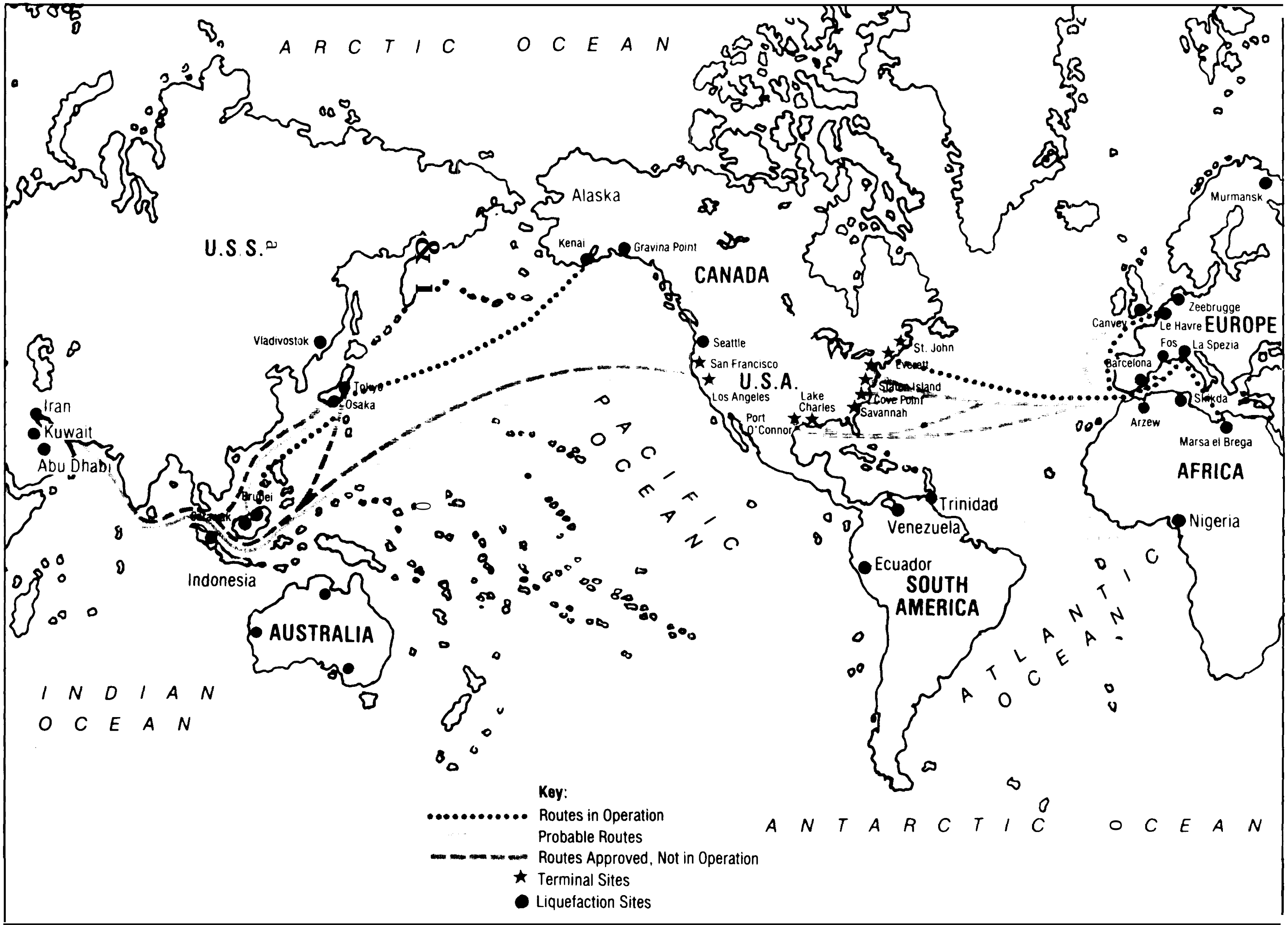
Liquefied natural gas import projects involve a complex consortia of energy and transportation companies. The gas supplier is usually represented by a foreign government or State-owned subsidiary company. The recipient of the gas at the import terminal is generally a consortia of gas utilities and/or pipeline companies, which use the gas in their own systems and sell to other distribution or utility companies. The supplier and receiver are connected by a transportation company, the subsidiary of an oil, gas, or pipeline company, which owns and operates the LNG tankers.

Liquefied natural gas tanker technology has been developed over the past 20 years to the point where, currently, about a dozen worldwide trade routes are either in operation, planned, or proposed for LNG shipping (figure 7). Growth in the world LNG fleet has

[21] 15 U.S.C. § 717 c (a) (1970).

[22] Interviews with Federal Power Commission staff, Washington, D. C., May 31 and June 24, 1977.

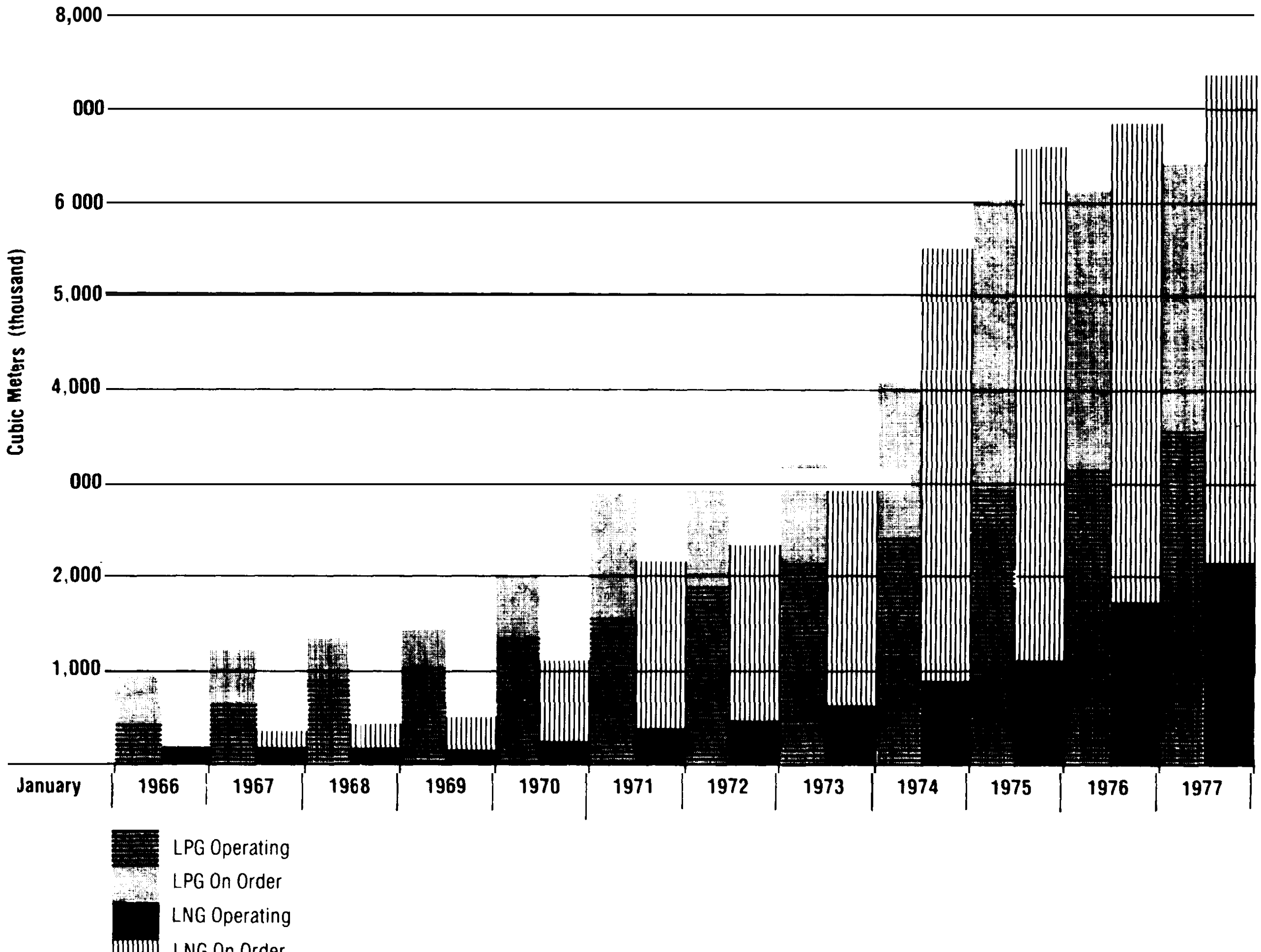
Figure 7. International LNG Trade Routes



Source: Raymond International Inc.

Figure 8. Total Capacity of World LNG and LPG Tanker Fleet

	26	51	39	28	32	44	34	22	30	67	66	60
No. of	145	172	209	242	274	307	339	352	379	404	418	441
vessels		4	6	9	13	23	24	28	45	49	42	43
	5	5	5	5	8	11	14	17	20	27	35	39
Total	176	232	259	284	327	385	411	419	475	547	561	583



Source Liquid Gas Carrier Register 1977

been rapid (figure 8). Seventy-two ships will be operational by 1980, with a possibility that 33 more would be required if all planned LNG projects go through. [23]

Currently, only one LNG tanker is engaged in regular import trade with the United States, that is the French ship, the *Descartes*, which has brought 25 shipments from Algeria

[23] *Edward Faridany, LNG: 1974-1990 Marine Operations and Market Prospects for Liquefied Natural Gas,* **(London: Economist Intelligence Unit Limited, June 1974), p. 69,**

Figure 9. LNG Tankers On Order or Under Construction In U.S. Shipyards

Shipyard	No. of Vessels	Containment System Design	
Avondale	3	Conch	Self-supporting aluminum alloy prismatlc tanks, British design
General Dynamics	10	Kvaerner-Moss	Spherical aluminum alloy tank, Norwegian design
Newport News	3	Technigaz	Stainless steel alloy membrane French design
Sun Shipbuilding	2	MacDonald Douglas/ Gas Transport	Invar (nickel-steel), American/French design

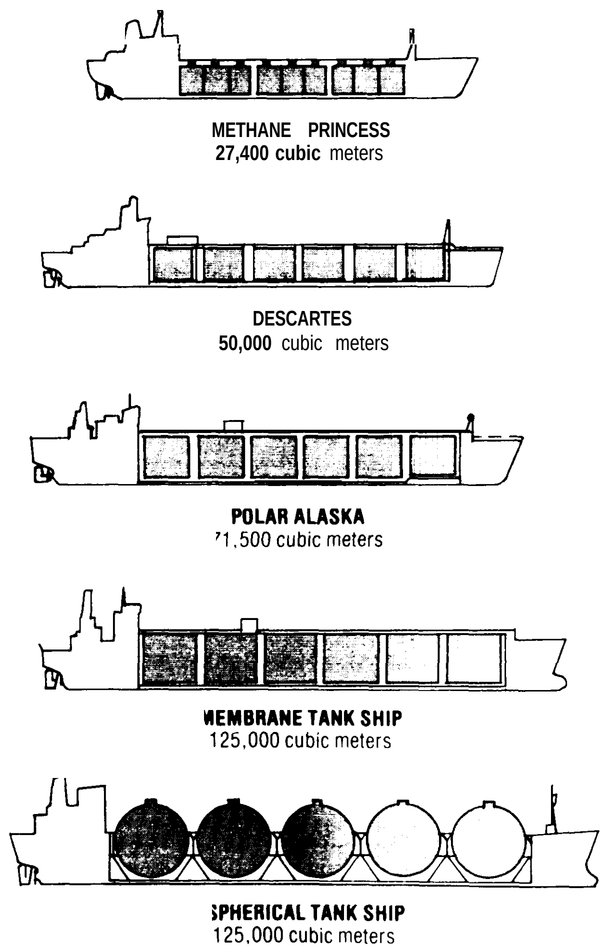
Source U S Maritime Administration

to the Distrigas peak shaving plant in Boston since July 1975.[24] Nine more LNG tankers will join the U.S. trade early next year when import terminals under construction at Cove Point, Md., and Savannah, Ga., begin operation, and five more when an import terminal at Lake Charles, La., is online about 1980 (figure 9). If other projects now proposed are approved, it is possible that 12 additional LNG tankers will be required for imports to the United States and 14 for shipments from Alaska to the continental United States. By 1985, a total of 41 tankers could be calling at continental U.S. ports. (In addition, two tankers are involved in export of LNG from Alaska to Japan through 1985).[25]

Liquefied natural gas tankers are bulk cargo ships which require unique design and materials to handle the very low-temperature gas.

Most LNG tankers range in size from about 40,000 cubic meters to planned ships of 165,000 cubic meters (figure 10). The industry standard has become the 125,000- to 130,000 -cubic meter ship. Each ship this size carries enough LNG to heat a city of 100,000 population for 1 month.[26]

Figure 10. Profiles of Typical LNG Ships



Source National Maritime Research Center

[24] Interviews with Officials of Distrigas Inc., Boston, Mass., June 15, 1977.

[25] a. "LNG Scorecard," *Pipeline and Gas Journal 203* (June 1976): 20.

b. American Gas Association, "Update of Status of LNG Projects," Gas *Supply Review 5* (February 1977): 8.

c. U.S. Department of Commerce, Maritime Administration, *Status of LNG Vessels* (Washington, D. C.: U.S. Department of Commerce, Maritime Administration, March 15, 1977).

d. U.S. Department of Commerce, Maritime Administration, *Status of LNG Projects* (Washington, D. C.: U.S. Department of Commerce, Maritime Administration, September 1976).

[26] Interview with official of General Dynamics Company, Boston, Mass., June 15, 1977.

By comparison to the better known crude oil tankers, the largest LNG ships are one-half to one-fourth the total size of the very large crude carriers (VLCC or "supertanker') (figure 11), some of which are more than 400,000 deadweight tons. A 130,000 cubic meter LNG tanker with a 143-foot beam and a 900- to 1,000-foot length is roughly equivalent to a 100,000-deadweight ton oil tanker.

The LNG tanker is a shallow draft vessel, about 36 feet, on which the cargo-carrying capacity is increased by adding to the length instead of the depth. It has an unusually large amount of freeboard, rising about 50 feet out of the water. Because of its visible length and height, the LNG tanker appears larger than some VLCCs.

The LNG tanker is a high-powered, high-speed ship, with an optimum service speed in the 20-knot range, about 5 knots faster than most oil tankers.

New LNG tankers are fueled by their own cargoes. Immediately upon being loaded in the tanker, LNG begins to evaporate and continues to do so throughout the entire voyage. In a typical design, the vapor produced during the voyage is used as the ship's fuel and may be sufficient to meet 100 percent of the fuel requirements. However, safety regulations require that the ship carry, and be equipped to use, fuel oil as well. After the ship is unloaded, a small percentage of the LNG cargo is retained in the tanks for cooling purposes and this supplies part of the fuel requirements for the return trip.

The tankers are equipped with specialized systems for handling LNG and for combating potential hazards associated with liquid spillage and fire. These include high-expansion foam and dry powder fire protection systems, water-spray systems for flooding deck piping, and pressure-, temperature-, and leak-monitoring systems. Cargo handling systems are provided for loading and discharging LNG, for cooling down and warming up tanks, for transmittal of boiloff gas to the ship boilers and, most importantly, to provide inert atmospheres in the spaces surrounding the cargo tanks and in the tanks themselves prior to and after aeration at the time of drydocking.

Each LNG tanker is a complicated vessel, representing approximately a $100- to $150-million investment.[27] Most U.S. flag LNG tankers are financed with a variety of aids from the Maritime Administration, including construction differential subsidies, operating differential subsidies, and ship mortgage guarantees.

[27] "General Dynamics Gets Tanker Job for $310 million, ' *Wall Street Journal,* July 28, 1977.

Figure 11, Comparison of LNG Tanker and Crude Oil Tankers

A comparison of the Principal Dimensions[a], Cargo Deadweight[b], and Full-Load Dlsplacement[c] of a 125,000 Cubic Meter LNG Ship and a Variety of Crude Oil Tankers

	80,000 dwt Oil Tanker	100,000 dwt Oil Tanker	137,000 dwt Oil Tanker	125,000 cu/m LNG Ship	476,000 dwt Oil Tanker	554,000 dwt Oil Tanker
Length	811	848	974	936	1,243	1,359
Breadth	125	128	134	144	203	207
Depth	57	65	85	82	118	118
Draft	44	50	54	36	93	94
Dwt	80,459	100,300	137,010	63,100	476,025	553,700
Full-Load Displacement	105,000	128,500	172,500	94,500	509.000	631,000

[a]IN FEET
[b]IN LONG TONS
[c]IN LONG TONS

Source Engineering Computer Opteconomics Inc

To date, the Maritime Administration has authorized approximately $270.3 million for subsidy of all LNG tankers.[28] (Federal financial aids are also provided by the Export-Import Bank, although that aid is made available to foreign governments in order to promote the use of U.S. goods and services in their projects. To date, the Export-Import Bank has provided approximately $483 million in loans and loan guarantees to Algeria to support construction of liquefaction plants and related facilities.)[29]

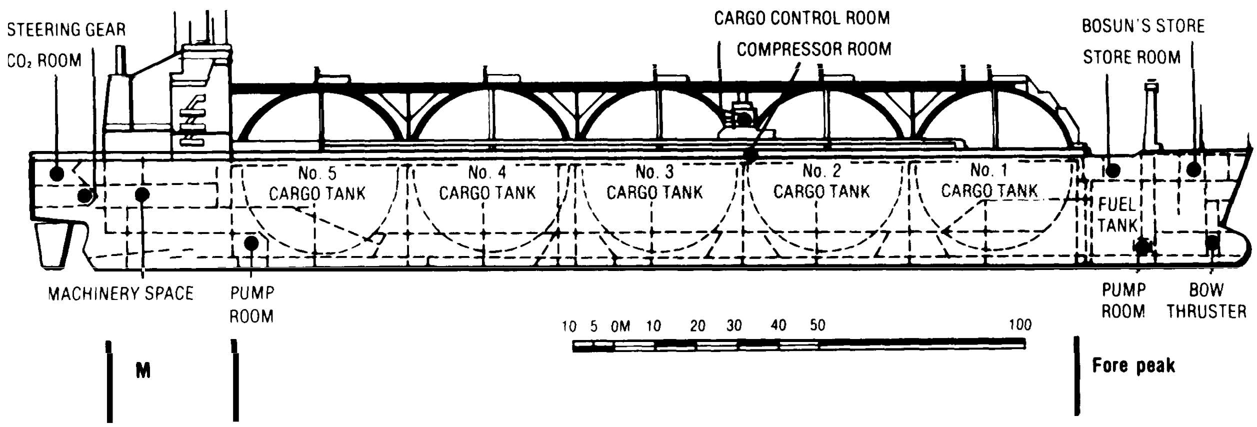
The construction cost of an LNG tanker is roughly twice that of an oil tanker of similar size. Most of the increased cost for LNG tankers is due to special design features of the containment system which holds the low-temperature, low-density cargo.

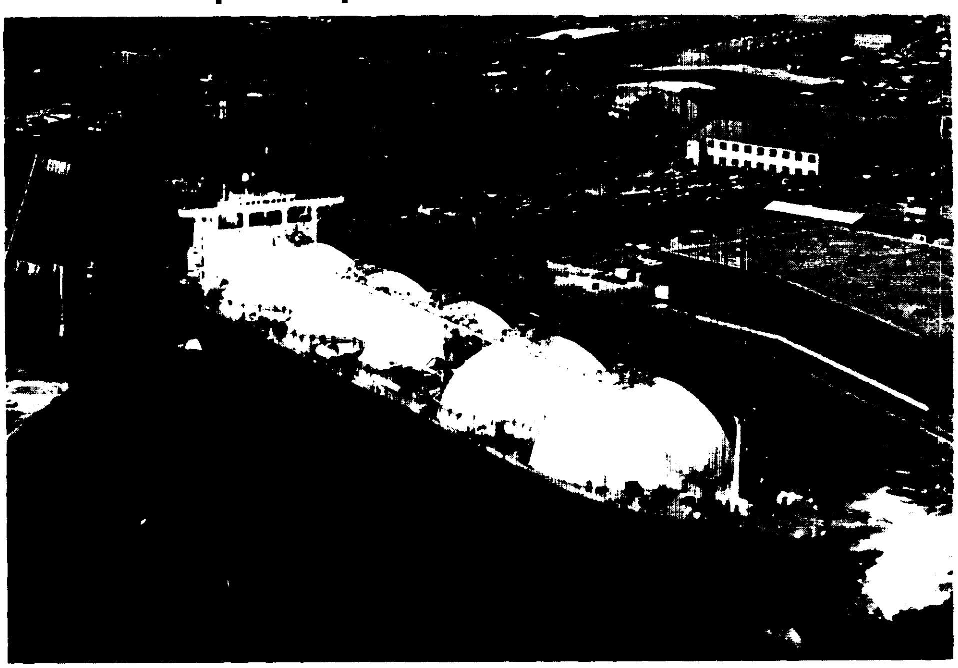
The standard 125,000 cubic meter LNG tanker usually has five cargo tanks, each with a capacity of about 25,000 cubic meters (figure 12). An eight-story building could fit inside

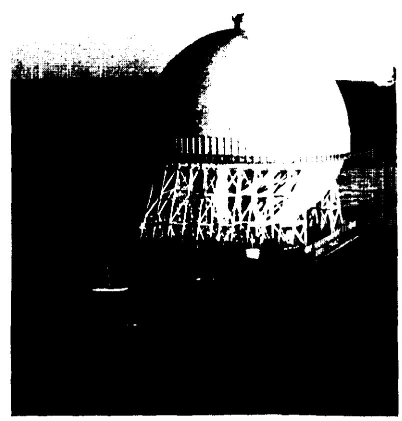
[28] "Subsidized Shipbuilding Contract Awards' *Statistical Quarterly* (First quarter 1977),

[29] Interview with officials of Export-Import Bank of the United States, Washington, D. C., June 16, 1977.

Figure 12. Inboard Profile of LNG Tanker







Liquefied natural gas tankers constructed by General Dynamics use five spherical tanks of about 25,000 cubic meters each Tanks for the ships are constructed in South Carolina and towed by barge to the shipyard at Ouincy, Mass , where they are mounted into the ship hull each of these large cargo tanks, which function in the same way as the common Thermos bottle. A cold product—LNG—is introduced into the container and the insulation surrounding the tank (comparable to the vacuum jacket in the Thermos bottle) is the sole means by which the cargo is kept cold. No refrigeration is employed on the LNG carrier.

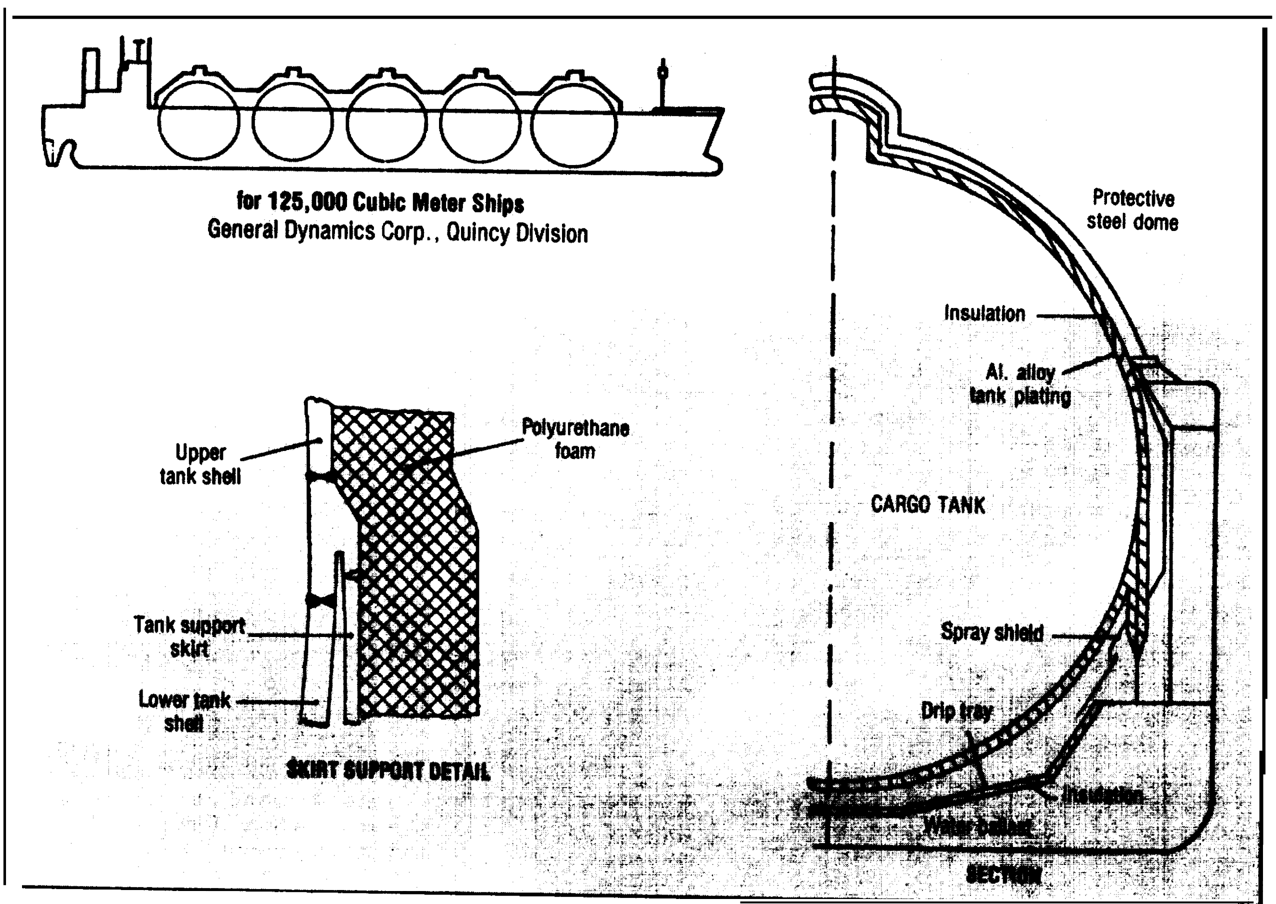
From the 15 or more cargo tank system designs, two basic types have become most common: the freestanding tank and the membrane tank.

The freestanding tanks are self-contained, usually spherical or prismatic in shape, made of aluminum alloy or 9 percent nickel steel with layers of insulation on the outside (figures 13 and 14). The tanks are welded to cylindrical skirts or otherwise tied to supporters which are welded to the ship structure.

With the membrane design (figure 15), the ship's hull, in effect, becomes the outer tank. Insulation is installed thereon, and a membrane placed on the inside to retain the liquid. The inner surface of this "double hull' is either high nickel steel or stainless steel.

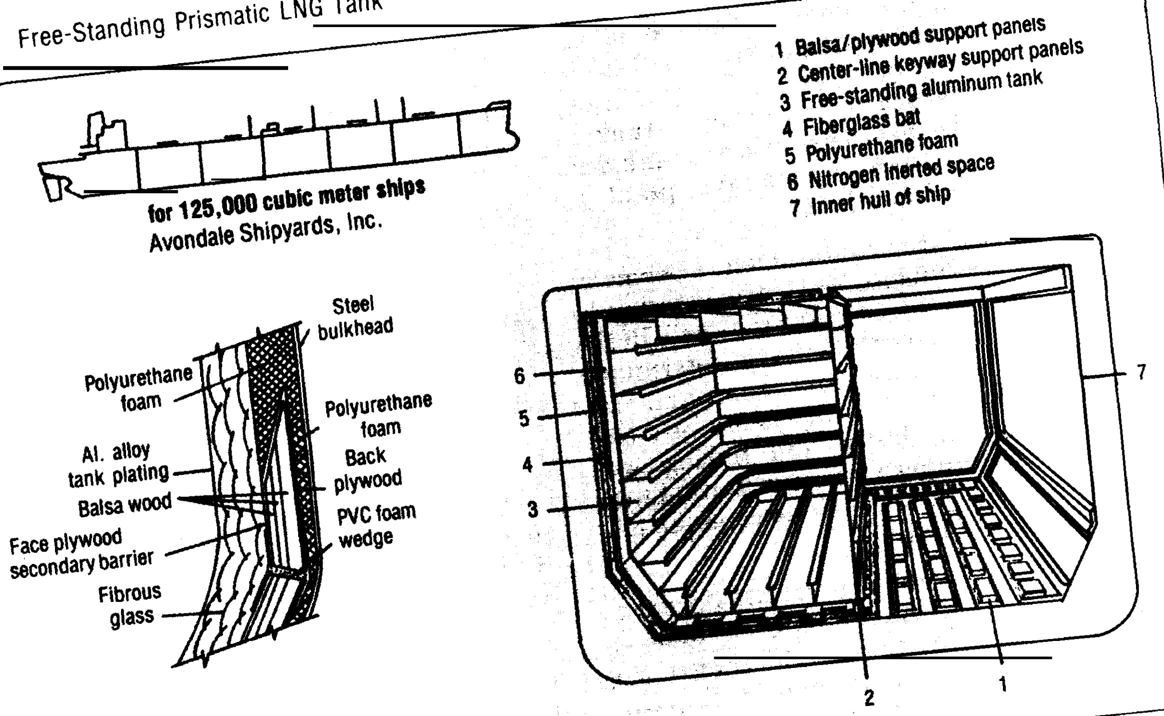
The unique design problems associated with LNG tankers stem primarily from the need to contain and insulate the extremely cold LNG cargo and from the fact that many materials such as mild steel will become brittle and fail at very low temperatures. Special materials used for the interior of cargo tanks must be able to withstand both the very low temperatures when filled with LNG and the normal temperatures when empty. When metals are subject to these temperature

Figure 13. Free-Standing Spherical LNG Tank



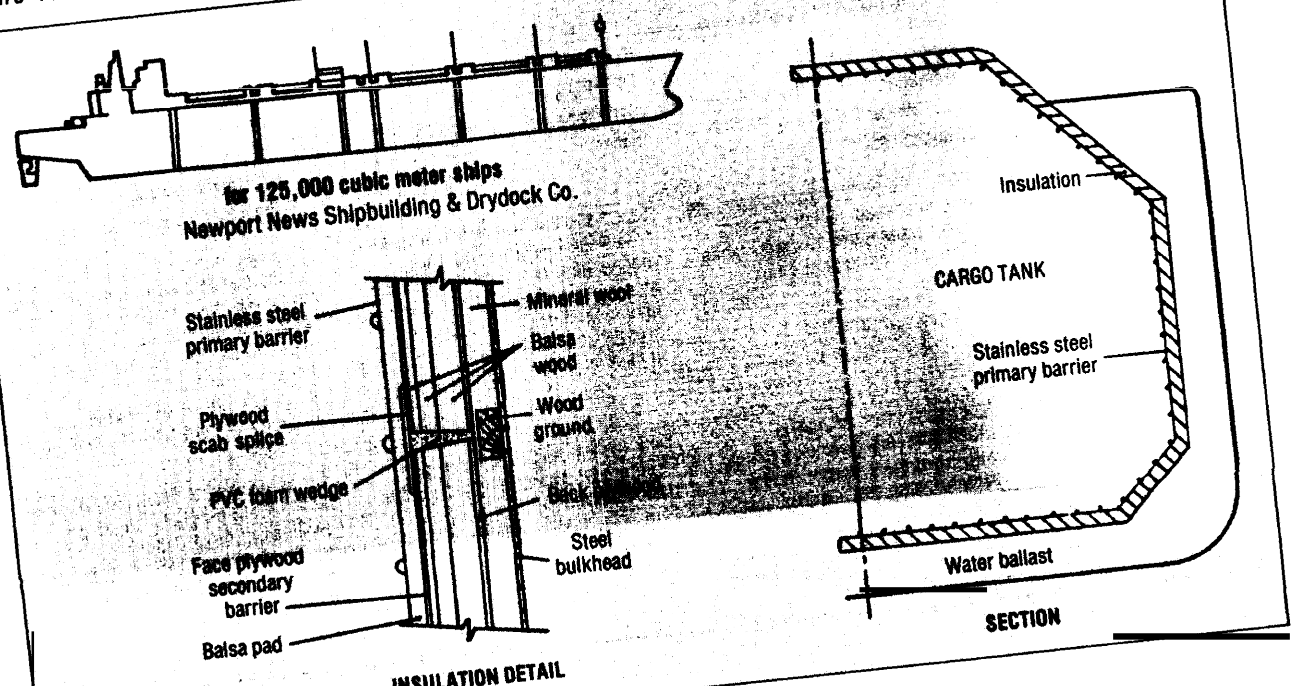
Source U S Maritime Administration

Figure 14. Free-Standing Prismatic LNG Tank



Source: U.S. Maritime Administration.

Figure 15. LNG Membrane Tank



Source: U.S. Maritime Administration.

changes of as much as 300 degrees, they expand and contract and, in the case of free-standing tanks, the whole structure of the tank interior must be able to move within the ship. In addition, up to 2 feet of very efficient insulation is necessary around each tank in order to minimize heat leak into the tank during the voyage from liquefaction plant to receiving terminal and back.

So far, none of the containment systems in use has been established as clearly superior to the others (figure 16), and it is too early in the history of LNG carriers to have determined meaningful life-cycle cost comparisons. However, each of the present systems is based on many years of design and testing, and research is continuing into new containment systems using materials such as concrete and glass-reinforced plastic.

Safety analyses conducted for LNG projects have constantly identified a ship accident as the most likely event that could trigger the most serious type of LNG accident. A ship collision could result in the rupture of one or more cargo tanks and spill a large amount of LNG onto the water. A water spill would spread much farther and evaporate much more quickly than a land spill. While it is most likely that a collision would produce some source of ignition which could fire the LNG vapor around the ship, a huge vapor cloud could be generated if no ignition occurred.

A critique of LNG tanker design and construction is included in the next chapter.

LNG TANKER CERTIFICATION AND REGULATION

The Coast Guard has primary responsiblity for the safe construction and operation of the LNG tankers and activities in ports where the tankers call.

Under the Ports and Waterways Safety Act of 1972 and the Dangerous Cargo Act of 1970, the Coast Guard is required to establish and enforce design and construction standards for

Figure 16. Comparative Characteristics of Some LNG Tank Systems

Characteristics	Free-Standing Tanks: Prismatic	Free-Standing Tanks: Spherical	Membrane Tanks
1. System Designs.	Conch Esso McMullen A.G. Weser Hitachi/Esso	Kvaerner-Moss Technigaz Gaz Transport (Cylindrical) Sener	Gaz Transport Gazocean I.H.I. (semi-membrane) Bridgestone (Semi-membrane)
2. Safety in event of vessel grounding/collision or other emergency.	Compared with membrane system less likelihood of hull damage being transmitted to cargo tanks. More efficient use of cubic space.	Safest system in event of grounding or collision — tank structure independent of hull and most void space between vessel hull and cargo tanks. Spherical tanks can be pressurized for emergency discharge in case of cargo pump failure.	Damage to hull of vessel may be more easily transmitted to tank structure than with free-standing tanks. Membrane systems are also more liable to damage or puncture due to causes such as: a. surging of cargo in tank b. entry of tank for inspection or repair.
3. Reliability of Containment System.	Most ship years operating experience and most experience without primary barrier failure. Structure can be analyzed and risk of fatigue failures minimized. Tanks can be constructed and 100% inspected prior to installation in vessel.	Tank system easiest to analyze structurally: therefore can be made most reliable,	Structure cannot easily be analyzed and therefore difficult to assure absence of fatigue failures. This could potentially lead to costly off-hire and repair time over the project life.

Source National Maritime Research Center

U.S. flag LNG tankers and foreign flag LNG tankers entering the 3-mile territorial waters of this country. It does so by letters of compliance for foreign vessels and certificates of inspection for U.S. vessels.

The criteria used for both are essentially the same, however, Federal regulations which are specifically applied to U.S. flag ships are simply used as guidelines for foreign ships.

The Letter of Compliance program which is now in operation requires that the Coast Guard review the vessel with respect to cargo containment, cargo safety, and the safety of life and property in U.S. ports. Features covered by the review include:[30]

- design and arrangement of cargo tanks and cargo piping and vent systems;
- arrangement and adequacy of installed fire extinguishing system and equipment;
- safety devices and related systems which check the cargo and surrounding spaces to give warning of leaks or other disorders which could result in a casualty;
- isolation of toxic cargoes;
- compatibility of one cargo with another and with the materials of the containment system; and
- suitability of electrical equipment installed in hazardous areas.

The review is accomplished by inspection of detailed plans and specifications submitted in writing by the vessel owner, inspection of documentation that the vessel is accepted by a recognized foreign classification society whose standards provide the same degree of safety as comparable U.S. standards, and inspection of the ship itself on its first visit to a U.S. port. Coast Guard boarding parties examine the vessel's arrangement and cargo systems, tanks, piping, machinery, and alarms. They also observe the condition of the vessel, vessel operation, cargo handling operations, firefighting capability, and personnel performance. Serious problems, such as any involving inoperative safety equipment, leaking cargo piping, or nonexplosion-proof electrical installations, may require immediate correction. Minor problems may require correction prior to a return trip to the United States.

If the vessel meets all applicable requirements, a Letter of Compliance will be issued and the vessel must continue to meet the standards of the first visit on all subsequent calls at U.S. ports. To assure continued compliance, the Coast Guard makes a less extensive examination of the vessel each time it enters U.S. ports.

The Coast Guard requirements for the design, construction, and testing of U.S. flag vessels are contained in 46 CFR 38. New regulations are being drawn up but are not yet complete. The Coast Guard has also proposed regulations which would set minimum standards for persons employed on U.S. flag LNG ships and is working with international groups to develop standards for foreign crews. The regulations now in effect cover ship stability and survivability, ship hull materials, gas dangerous areas, electrical arrangements, firefighting arrangements, ventilation, cargo containment systems, temperature and pressure control, and instrumentation of the ship. They also cover systems relating to the transfer of LNG, such as the means of loading and offloading the cargo, piping materials, piping insulation, valving,' instrumentation, construction, and testing of the systems.

Inspections for compliance with these standards are carried out during construction of the vessels. In general, requirements result in the design of ships which the Coast Guard believes to meet a consistent and reasonable level of safety and provide for means of dealing with casualties such as tank overfilling, overpressuring, and emergency shutdowns. In general, the vessels are designed to Survive two-compartment flooding from collision or stranding with reserve stability. They are not designed to withstand a major collision or stranding without cargo release, but the

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[30] Department of Transportation, U.S. Coast Guard, *Liquefied Natural Gas, Views and Practices Policy and Safety* (Washington, D. C.: Department of Transportation, U.S. Coast Guard, Feb. 1, 1976), p. III-B (2).

design does limit the release to the tanks directly involved in an incident.

In addition to minimizing the possibility of collisions, strandings, or other incidents, the Coast Guard has specified operational controls on the vessels while entering, moored, or leaving a U.S. port. By regulations promulgated under 50 USC 191, Executive Order 10173, and the Ports and Waterways Safety Act of 1972, the Coast Guard Captain of the Port has control over any vessel within the territorial sea and may prescribe conditions and restrictions for the operation of waterfront facilities.[31] Under the regulations, the Captain of the Port in Boston has drawn up an Operations/Emergency Plan[32] for LNG shipments coming into the Everett, Mass., LNG facility. Similar plans will be drawn up for all LNG import terminals. The plan takes into account the individual geographic features and environmental characteristics of each import terminal and surrounding waterway as well as the unique nature of the LNG cargo. The result is a set of operational constraints on LNG vessels in order to enhance port safety. These constraints may include such things as the requirement for a Coast Guard escort; enforcement of a "sliding safety zone,' which is an area around the LNG ship from which all other vessels are excluded as the LNG tanker proceeds to its berth; restriction of operations to certain times of day; prohibitions against certain other types of work, such as welding, or the transfer of other types of cargo, such as LPG, during discharge of LNG; and others.[33]

The regulation of LNG tanker construction and operations is discussed in the following chapter.

31 33 C.F.R. §§6.04.8, 6.14-1 (1976),

32 Department of Transportation, U.S. Coast Guard, *The Port of Boston, LNG-LPG Operation/Emergency Plan* (Boston, Mass.: Department of Transportation, U.S. Coast Guard, Mar. 29, 1977).

33 Department of Transportation, U.S. Coast Guard, *Liquefied Natural Gas, Views and Practices Policy and Safety,* p. IV-3.

The Coast Guard claims jurisdiction over the entire portion of the LNG system that connects the tanker to the distribution system. Existing regulations give the Captain of the Port authority to control and monitor LNG waterfront operations. However, there currently are no Coast Guard regulations which specifically apply to the terminal facilities. Development of these regulations is underways[34] and publication is expected in the fall of 1977.

LNG TERMINAL TECHNOLOGY

The proposed LNG import projects and projects to receive LNG which may come from Alaska require the construction of large terminals to receive and store the product and gasification plants to return the liquid to its vapor form. A large terminal capable of supplying 500 million cubic feet of gas per day can represent an investment of more than $350 million by the sponsoring companies.

The technology for these terminals is an extrapolation of many small LNG peak shaving plants which have been operating for years. This technology has been proved operationally satisfactory for the small plants. Even so, baseload LNG import terminals, which are intended to provide a continuous flow of gas into commercial pipelines, are designed to meet much more stringent requirements than smaller peak shaving units.[35]

Offloading of the LNG tankers is accomplished at a specially constructed pier where the tanker is connected to pipelines by articulated unloading arms and the cargo is pumped ashore (figure 17).

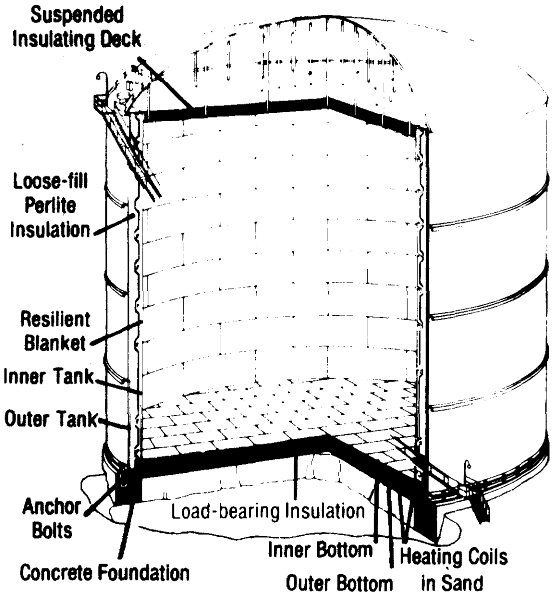
The LNG is stored in large insulated tanks on shore and later pumped to regasification facilities before it enters the distribution

34 Ibid., p. IV-4.

35 Conversation with officials of Columbia LNG Corporation, Cove Point, Md., June 8, 1977.

Figure 17. Specially constructed tankers bring LNG from foreign ports to the United States. The ships are connected to pipelines and regasification facilities by articulated arms on the offshore unloading piers at the receiving terminal.

Figure 18. Aboveground LNG Storage Tank



Source Scientific American.

system (figure 18). The storage capacity of the tanks is roughly equivalent to twice the capacity of a single LNG ship, but—unlike peak shaving storage tanks—the import terminal tanks are intended to hold LNG only briefly.

In either type of facility, the storage tanks represent a significant portion of the costs, and the gas industry has spent much time and money in research to develop effective storage systems.

Currently, there are four storage concepts: double-wall metal tanks, prestressed concrete tanks,' frozen holes, and mined caverns. Techniques for storing liquids in aboveground tanks are well established and the LNG industry has drawn on these techniques. In addition, the tanks are surrounded by earthen dikes. These dikes are a safety measure, in that they could contain the entire contents of a tank in the event of a spill. However, they increase the land requirements for aboveground storage several times over. Much research has focused on the idea of underground storage tanks because little or no insulation other than the earth appears to be needed and there is no need for diking to contain spills.

Underground storage tanks have been built for LNG in the United States, Algeria, England, and Japan. The U.S. tanks were built for peak shaving operations in New Jersey and Massachusetts, but have since been abandoned in favor of other types of storage because the units failed to perform satisfactorily.

In any type of tank, the one hazard most often mentioned in connection with the storage of LNG is a phenomena known as "roll over.'

Peak shaving plants have a greater potential for rollover due to weathering of the LNG and/or introduction of new LNG into a partially filled tank.

Rollover refers to the convection or motion of fluid which occurs when liquids of different densities exist in a storage tank. If different densities or stratification do occur within a tank such that a denser and warmer liquid is at the bottom of the tank and subject to heat leak, that liquid can ultimately become heated to the point that it is less dense than the liquid above it, and it will be rapidly moved by buoyant forces up the tank side walls to the surface. At this point, it experiences a sudden decrease in pressure and being above its normal boiling point vaporizes very rapidly in large quantities causing a significant pressure rise in the tank. As a result of this rapid expansion, cracks or even tank rupture can occur.

However, industry research on rollover has been extensive, resulting in deliberate controlled mixing of the tank contents, selected top, side, or bottom filling, careful monitoring of the temperature of the LNG contents throughout the tank, higher design tank pressures combined with low normal operating pressures, and improved venting. In addition, the potential of the phenomena occurring at a baseload plant is further reduced by an operational practice of unloading tankers into empty tanks, not partially filled tanks as can occur at peak-shaving plants.

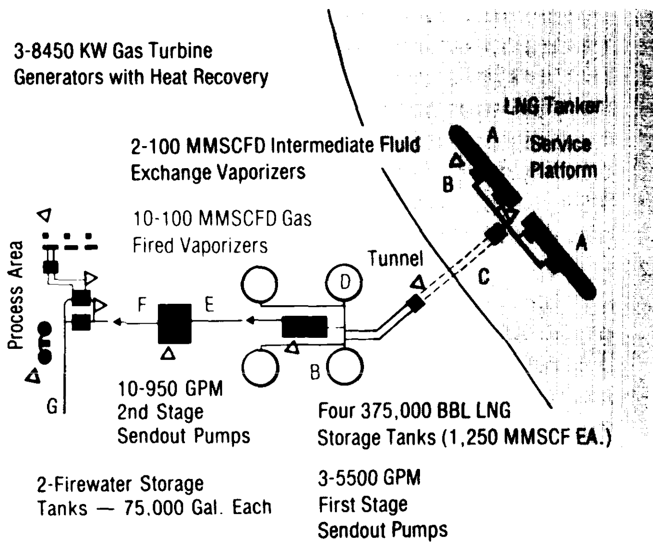
From the storage tanks, LNG is pumped to the regasification plant where it is vaporized by heating it. Frequently, the LNG is heated in systems using the naturally occurring heat in nearby seawater. Other systems use process heat from other equipment or have heat exchangers fueled with oil, electricity, gas, or ambient air. None of the vaporizer systems is obviously the most economical or technically superior. The choice depends primarily on the location and design of a specific terminal and environmental regulations.

The regasification facility is one of the least costly sections of the terminal, but is considered important because if it should fail to operate, the entire purpose of the plant—to provide natural gas—will have been defeated.

LNG TERMINAL SITING

There are several factors related to proposed LNG import terminals that set them apart from the existing peak shaving plants. The proposed terminals are large-scale operations located in the coastal zone and major shipping channels, some in major harbors-or near large population centers (figures 19 and 20). They require large amounts of land and capital, and represent a large concentration of energy at a single site.

Figure 19. Layout of Cove Point, Md., LNG Receiving Terminal

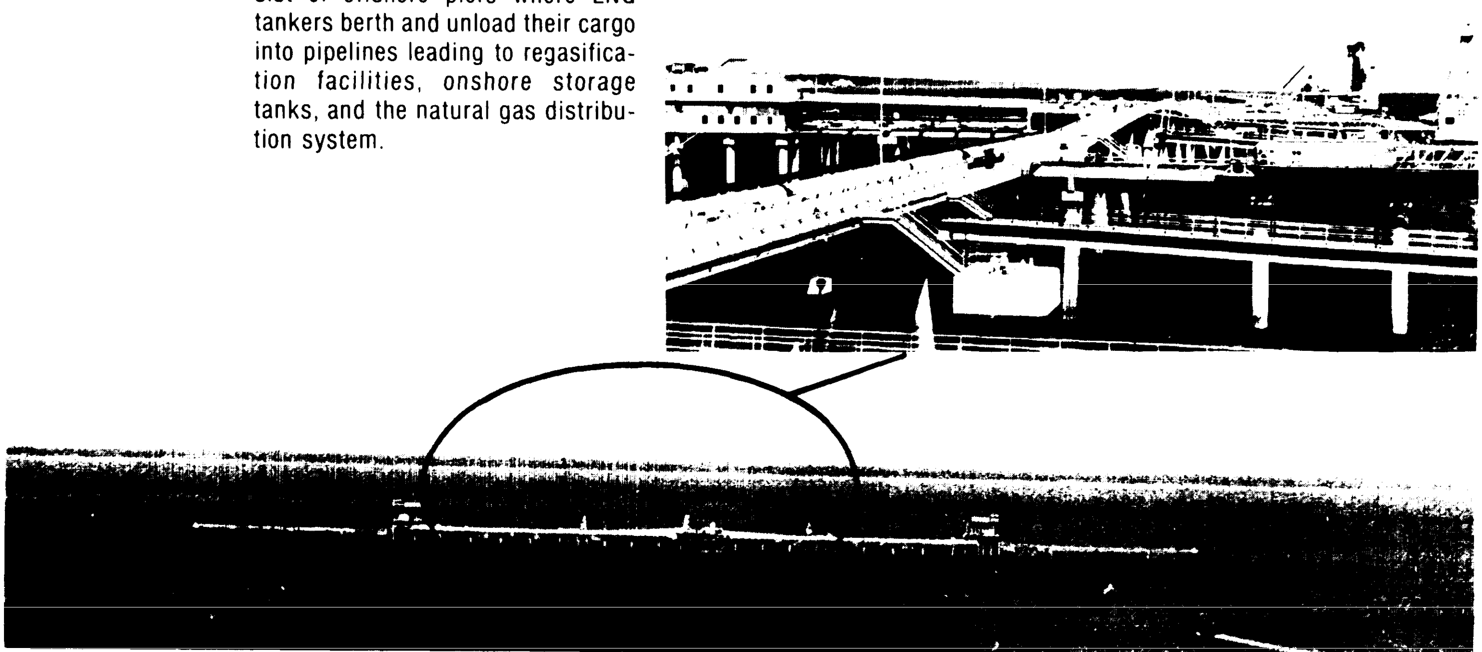


Process Flow Data

Location	Phase	Operating PSIG	Operating Temp.	Max. Flow Rate
A	Vapor/Liquid	1.0	-260°F.	—
B	Liquid	40.0	-260°F.	50,000 GPM
C	Liquid	75.0	-260°F.	50,000 GPM
D	Vapor/Liquid	2.0	-260°F.	—
E	Liquid	80.0	-260°F.	9,000 GPM
F	Liquid	1300.0	-260°F.	8,600 GPM
G	Vapor	1250.0	60°F.	1,000 MMSCFD

Source Columbia LNG Corp

Figure 20. Most receiving terminals will consist of offshore piers where LNG tankers berth and unload their cargo into pipelines leading to regasification facilities, onshore storage tanks, and the natural gas distribution system.



The location of a terminal can be a major factor in its safety. The magnitude and extent of any damage from an LNG spill can depend on the proximity of the terminal and storage sites to other industrial and residential areas.

The site selection process is currently conducted by the company or consortium proposing the project. Gas industry officials consider such factors as accessibility by large tankers, the availability of the market, which is largely determined by the proximity of an existing pipeline network; costs of land acquisition; availability of skilled labor supply; and availability of public facilities such as roads, electricity, sewers, etc. Some companies also consider area land-use characteristics and environmental sensitivities important aspects of site selection. The FPC position is that, unless otherwise stipulated, FPC approval of the facility allows Federal preemption of State and local laws relating to siting. Therefore, local and State land-use regulations could be overruled. A company makes application to the FPC only after it has done as much preliminary work as possible, which includes at least gaining control over, if not outright ownership of, the proposed site. Thus, neither the general public nor the Federal Government become involved in the site selection decision until it has already been made by the company. There are, at present, no Federal siting criteria, and those projects which are now proposed have a variety of sites, ranging from remote coastal and riverine areas with 1,000-acre buffer zones to as little as a 90-acre site on Staten Island.

LNG TERMINAL REGULATION

The construction and operation of LNG terminals are primarily regulated by three Federal agencies; the Federal Power Commission (FPC), and the Office of Pipeline Safety Operations (OPSO), and the Coast Guard.

Federal Power Commission jurisdiction over the terminals is included in the process of licensing import projects. The FPC considers approval of any LNG import project to be "a major Federal action significantly affecting the quality of the human environment" subject to the National Environmental Policy Act requirement that an environmental impact statement (E IS) be prepared.

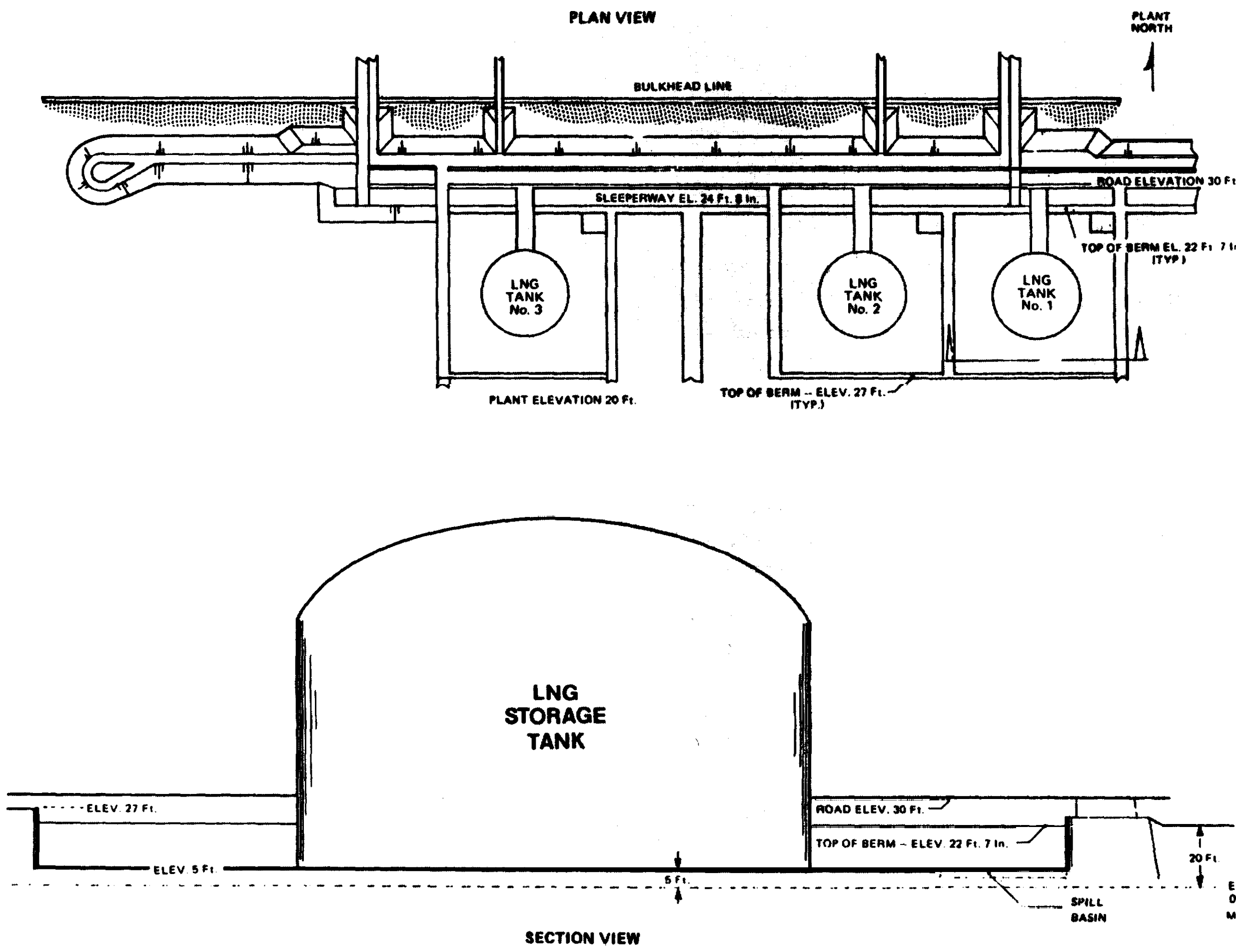
As a part of the EIS, the National Bureau of Standards' cryogenics division in Boulder, Colo., under contract to FPC, reviews engineering and safety aspects of the proposed terminal. Also as part of the EIS, the FPC staff prepare a quantitative risk analysis, which is its principal method for determining whether a project can be considered safe. The risk analysis considers the major events which might cause an LNG spill, such as ship collision, grounding, or ramming; failure of the unloading arms or other major pieces of equipment; and damage to the facility from natural phenomena or unusual accidents. The risk analysis determines the extent of damage and the number of deaths and injuries which may result from a disaster and the probability that certain types of disasters would occur. The death probabilities from natural disasters are typically about 1 in 10 million. In some recent applications, the FPC rejected a site because it posed a public risk to life with a probability of greater than 1 in 10 million. Therefore, that figure has become the informal criteria which projects must meet for FPC approval.[36]

The FPC exerts its influence over the facilities by attaching stipulations to the certification of public convenience and necessity which it issues if the project is approved. These stipulations are designed to minimize environmental consequences and to promote the safety of the facility. The applicant is required to comply with these stipulations if he accepts the certificate. Statements of compliance and operating reports are required regularly, but there is little or no post-certification oversight by the FPC. Onsite FPC inspection generally occurs only when a company wishes to expand its facilities and submits a new application.[37]

[36] Interview with staff of Woodward-Clyde Consultants, Washington, D. C., June 28, 1977, and Federal Power Commission, *Alaska Natural Gas Transportation System, Final Environmental Impact Statement,* Vol. 111, p. 425d and 4253. (Washington, D. C.: Federal Power Commission, 1976).

[37] Interview with staff of Federal Power Commission, Washington, D, C., May 31, and June 24, 1977.

Figure 21. Storage and Diking at Onshore LNG Plant



Source El Paso LNG Terminal Co

The safety of the terminal facilities is largely an OPSO responsibility. Under the Natural Gas Pipeline Safety Act of 1968, OPSO is responsible for establishing minimum Federal safety standards for all pipeline facilities in or affecting interstate or foreign commerce. Pipeline facilities have been given an extremely broad interpretation to include all components of an LNG import terminal, including the offloading facilities, storage tanks, regasification facilities and all associated pipelines.

Permits are not required by OPSO, which exercises its authority solely by inspecting facilities for compliance with Federal standards. The standards are currently built around the safety code of the National Fire Protection Association, known as 59(A). In addition to setting minimum standards for materials, equipment, and systems the code relies upon two basic concepts to protect the public from LNG hazards: the requirement for a diking and containment system and the requirement that specific distances be maintained between certain components and between components and the property line.

Dikes are the primary device used to prevent the uncontrolled spreading of an LNG spill on land (figure 21). The dikes make it possible to use either of two methods of control:

- In the event of an LNG spill, the liquid can be contained within the dike and the rate of evaporation slowed by the use of high expansion foam. All sources of ignition can be eliminated. In this way, the LNG can dissipate in harmless concentrations into the atmosphere.
- Or, in the event of an LNG spill, the liquid can be contained within the dike and its evaporation controlled or even ignited so that it immediately burns in the confined space where the fire can be controlled by known firefighting methods.

The NFPA 59(A) regulations currently adopted by OPSO specify the size and construction of the dike and the design of related equipment necessary for the diking system.

The other technique used to enhance safety is to establish the distance which must lie between the dikes around the storage tanks and the property line. The distance required is one which would assure that heat from an LNG fire inside the dikes would not be severe enough at the property line to cause death or third degree burns.

Current regulations require that this distance be 0.8 times the square root of the area inside the dikes.

Regulations also require that the facility be designed to meet the maximum earthquake specifications of the Uniform Building Code.

New LNG terminal standards have been proposed by OPSO and are being circulated for public comment. Generally, the proposed standards are more strict and cover more aspects of terminal design than do current standards, but in many cases they are less definitive. The standards increase the distance between dikes and property line, require a vapor dispersion zone or a redundant automatic ignition system, and set more stringent seismic design criteria.[38] It is expected that the proposed standards will seriously limit the choice of sites for LNG terminals.

The Coast Guard's responsibility for terminal facilities is an extension of the Captain of the Port's jurisdiction over waterfront facilities. The Coast Guard maintains that its jurisdiction, with regard to LNG vessel movements and waterfront facilities, is sufficient to promulgate and enforce safety requirements for the LNG transfer operations at the receiving terminal and, in that light, considers the pipelines between tanks and loading or offloading equipment, the loading and offloading equipment, storage tanks, and the entire portion of the LNG system which connects the tanker to the distribution system to be under its jurisdiction. The inland distribution system is not the responsibility of the Coast Guard.

The Coast Guard currently has no regulations specific to LNG terminals but has undertaken development of such regulations to implement appropriate sections of the Ports and Waterways Safety Act of 1972. In the meantime, the Captain of the Port in each area where LNG is handled exercises authority by developing contingency plans for operations.

A critique of the Government role in the regulation of LNG terminal siting and operations is included in the following chapter.

TRENDS IN LNG USE AND FACILITIES

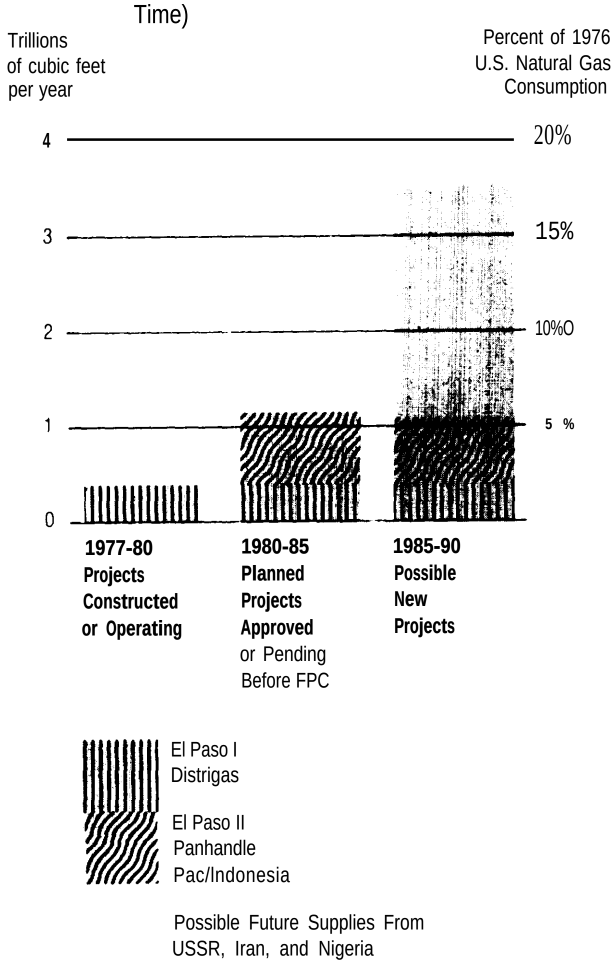
Liquefied natural gas could be an important short-term energy supply for the United States over the next few decades and could help alleviate some near-term fuel shortages in selected sectors of the economy. Ultimately, however, the supply of natural gas which may be sold to the United States as LNG is limited. LNG is not a major new source of energy which will allow unrestrained use of natural gas, and it is unlikely that many import projects will be forthcoming beyond those already proposed.

[38] U.S. Department of Transportation, Office of Pipeline Safety Operations, "Liquefied Natural Gas Facilities (LNG); Federal Safety Standards," *Federal Register 42,* no. 77, April 21, 1977, 20776-20800.

In the future, it can probably be expected that U.S. consumption of natural gas will continue to decline slightly and it is possible as much as 15 percent of the total natural gas consumed could be transported as LNG by 1985-95 (figure 22). This figure may be lower if a pipeline is used to transport Alaskan gas to the continental United States.

Imports of LNG to the United States currently come from Algeria, and there is some concern about the wisdom of becoming dependent upon any one country as the major source of supply. However, several other countries also control major portions of the world's natural gas reserves. For example, liquefaction and export facilities are being developed

Figure 22. Projected Future LNG Imports (Based on Proposed Projects and Reasonable Approval Time)



Source OTA

in Chile, Nigeria, and Colombia and there is a possibility of additional export projects if technology and reserves are proven in Russia, Iran, China, and Australia.[39] It is likely that sponsors of some U.S. import projects will turn to these exporters for additional supplies of LNG, thus reducing the dependency on Algeria.

Changes are also likely to occur in the sites chosen for U.S. import terminal facilities, in some types of equipment which may be used, and in the onshore distribution of LNG.

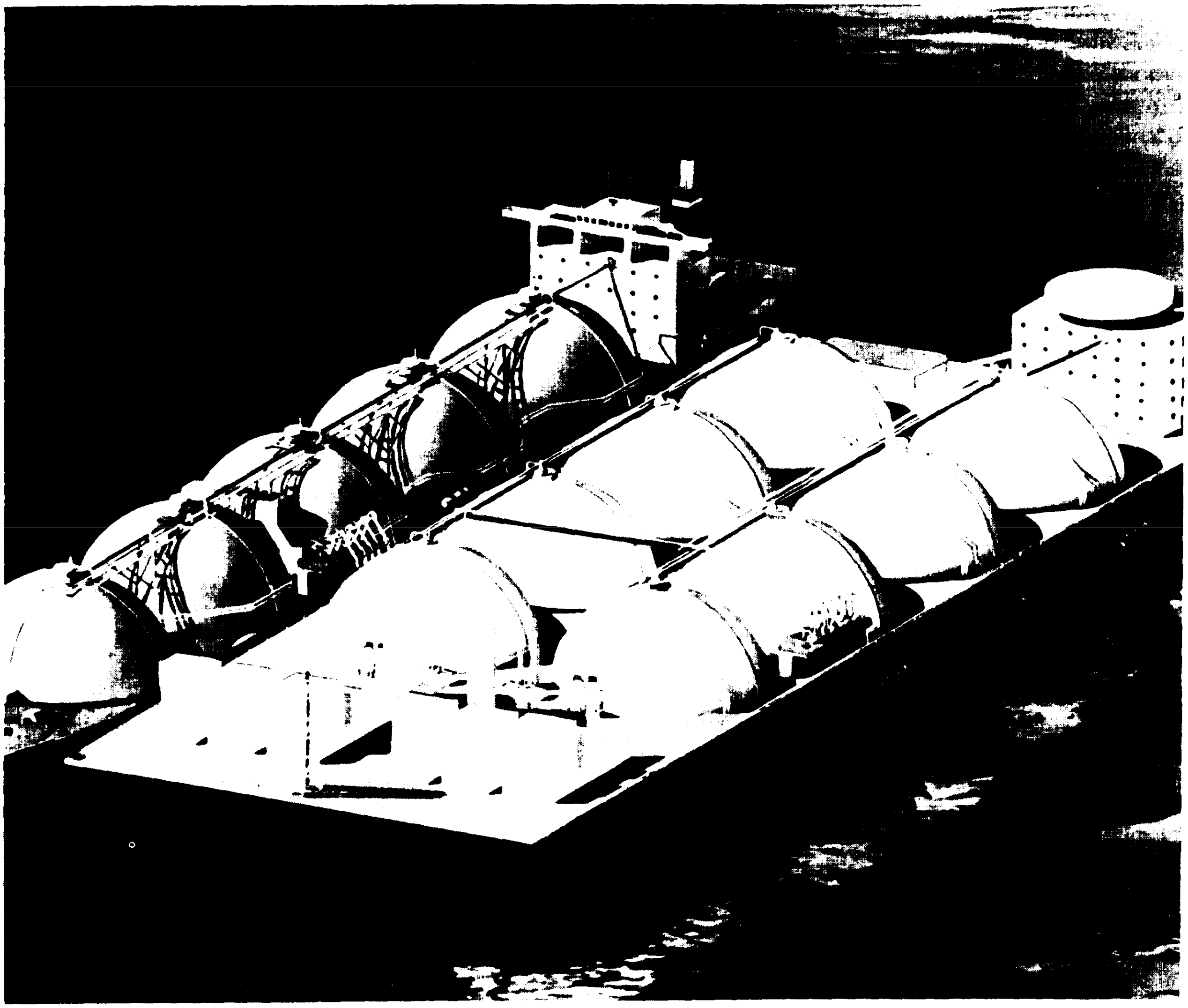
Currently, public pressure exists for, and the industry trend is toward, "remote" siting of LNG terminals and storage facilities. Controversy over the meaning of remote and the characteristics which make a site acceptable for an LNG facility, coupled with the difficulty firms may have in finding acceptable sites, have led to the suggestion that LNG facilities could be located offshore, away from populated areas and congested harbors and waterways.

Several designs have been proposed for offshore platforms to house LNG facilities, but no detailed design has been developed for any specific site. At the present time, these preliminary designs limit site selection to locations with water depths of 600 feet. Most of the design concepts are self-contained facilities which look like large floating barges installed to a mooring system (figure 23). Other concepts propose that the platforms be floated to a site, then grounded to the beach or seabed. There are also two other, more elaborate concepts: *One would* make use of subsea storage structures, similar to those used in the North Sea to store oil, with a semisubmersible or tension-leg concrete platform moored above for the liquefaction or regasification plant. The other features separate moored or jack-up platforms for the process plant and the storage structures.

According to industry figures, offshore facilities will require 3 to 4 years construction time. Crude estimates range from $175 million

[39] "LNG Report," *Pipeline and Gas Journal* 204 (June 1977).

Figure 23. Artist's Rendering of Offshore LNG Terminal



Source General Dynamics Corp

to $220 million for a receiving terminal with a 500 million cubic feet per day regasification plant and storage for 200,000 cubic meters and from $350 million to $425 million for a 500 million cubic feet per day[40] liquefaction plant.

There are many designs for LNG tankers and onshore facilities. However, with the limited operating experience now available, no particular designs for either ship cargo systems or onshore storage facilities have yet emerged as obviously superior. Therefore, it is likely that a variety of equipment will come into use as more projects are approved.

It is also possible that increased use of LNG will result in increased onshore transportation of LNG to secondary markets by means other than pipeline. Although the proposed

[40]Ibid.

baseload import terminals have no specific provisions for truck and rail shipment of LNG, such shipments appear to be possible and permissible in the future. Shipment by truck is already a reality at most peak shaving operations and from the import terminal at Everett, Mass.

Prior to 1969, only a few LNG trucking operations had been attempted in this country, using equipment originally designed for liquid nitrogen service. Based on the success of the operations, equipment was designed and fabricated especially for LNG. It is estimated that there are 75 LNG trucks currently in operation in the United States.[41] Typical of the trucking which has taken place was the shipment of nearly 4.5 million gallons of LNG from Philadelphia, Pa., to Lowell, Mass., during the winter of 1969. Since then large volumes have been transported all over the United States to help supply outlying communities, to provide temporary supplies when service is interrupted, and to provide small quantities for experimental work.

Liquefied natural gas could also be moved from import terminals or liquefaction plants by barges or railway tank cars.

The use of barges was first proposed to transport LNG up the Mississippi River to the Chicago Union Stockyards, and one barge was constructed and tested for this purpose in the 1950's. It was never used commercially. Another barge, the 297-foot *Massachusetts*, was constructed by Distrigas for distributing LNG from a Staten Island import terminal. However, that barge has been taken out of service because of opposition.

Railway tank cars have been proposed as a means of carrying LNG to isolated areas which do not justify construction of pipelines. Tank cars now in use hauling liquid oxygen, nitrogen, and hydrogen would be suitable for LNG service, but the economics are such that it is unlikely there would be much emphasis on rail movement of LNG.

4 I Interviews with officials of Distrigas Inc., Boston, Mass., June 15, 1977.

EXISTING AND PROPOSED PROJECTS, IN BRIEF

There are two operating LNG marine transport projects in the United States today, the "Distrigas" project importing gas from Algeria into Everett, Mass., and the "Phillips/Marathon' project exporting gas from Alaska to Japan. Construction of the first large baseload import project to be approved by FPC, "El Paso I," is nearing completion, and the facility is expected to become operational early in 1978 importing gas from Algeria to both Cove Point, Md., and Elba Island, Ga., (near Savannah).[42]

One additional large import project has recently been given final approval by FPC, but no construction has begun. This is the "Trunkline' project to import LNG from Algeria to Lake Charles, La.[43] The "Pacific-Indonesia' project to import LNG from Indonesia to Oxnard, Calif.,[44] has received only initial FPC approval and no construction has begun.

Three additional projects have been filed with the FPC for some time and decisions or approvals are expected soon. These are: the "El Paso II*' project to import LNG from Algeria to Port O'Connor, Tex., the "Pacific-Alaska" project to transport LNG from Cook Inlet in southern Alaska to California; and the "El Paso-Alaska" project to transport the huge North Slope Alaska gas reserves from Gravina Point, Alaska (after pipelining from the North Slope) to California.[45]

Since these eight projects have a reasonable probability of being operational in the future (the early 1980's), a brief description of each is included in this section. Other planned or pro-

42Dean Hale, "Cold Winter Spurs LNG Activity," *Pipeline and Gas Journal 204* (June 1977): 30.

43Federal Power Commission, *Trunkline LNG Company et al.*, Opinion No. 796-A, Docket Nos. CP74-138-140 (Washington, D. C.: Federal Power Commission, June 30, 1977).

44Federal Power Commission, "FPC Judge Approves Importation of Indonesia LNG,'' News *Release, No.* 23292, July 22, 1977.

45Dean Hale, "Cold Winter Spurs LNG Activity,": 31.

posed projects have not been included for various reasons. For example: the "Eascogas' project which was planned for Staten Island, N. Y., and Providence, R. I., terminals has been delayed so many times that its viability is in question. A project planned by Tenneco to import gas from Algeria to St. John's, N. B., in Canada, and then pipe the gas to the United State is now in the early review stages by FPC.[46] Another recently announced project is one by the Peoples Natural Gas Company of Chicago to import LNG from either Iran or Chile to a terminal near Corpus Christi, Tex.[47]

This report reflects the situation as of the summer of 1977. Many other projects are in the early planning states. Many factors affect these plans, however, and changes are common prior to actual construction of facilities.

1. The Distrigas Project (figure 24)

This project has been in operation since 1971. The 50,000 cubic meter LNG tanker *Descartes* is now on a regular delivery schedule on approximately a 20-day cycle.[48] The ship, which was built in France in 1971 and operates under the French flag,[49] has

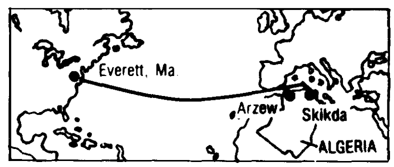
[46] Ibid., p. 31.

[47] Federal Power Commission, "NGP-LNG Inc., Application and Request for Phased Proceeding," *Federal Register 42, No. 131,* July 8, 1977.

[48] Interviews with officials of Distrigas Inc., Boston, Mass, June 15, 1977.

[49] U.S. Department of Commerce, Maritime Administration, *Status of LNG Vessels* (Washington, D, C.: U.S. Department of Commerce, March 1977).

Figure 24.
Project Data Sheet: Distrigas
Import Source: Skikda, Algeria
Import Terminal: Everett, Mass.



Skikda to Everett — 3,805 n mi

Companies revolved	Location of u s terminal	Project designation	Expected operational date	Contract volume Bcf/yr (M Mcfd)	FPC status (as of 9/1/77)	Number Ships/ Shipyard/ Capacity m³/ Tank design	Estimated investment ($10⁶) Tankers	Receiving terminal	Estimated price ($) delivered into pipeline/MMBtu
Supplier. Sonatrach (Algerian National Gas Co).									
Shipper. Alocean (Sonatrach subsidiary).	Everett, Ma,	Distrigas I	Operational since 1971	16 (43 6)	Approved 1972, Reopened 1974, Approved 1977	1/Chantier-Atlantique[1] (France)/ 50,000 m³/ membrane	—	33	1.90
U S. Importer: Distrigas Corp									
Distributors: Various gas companies in New England, New York, and New Jersey	Everett, Ma,	Distrigas III	1977 (1,5 yr. supplemental contract)	16 total (43.6)	Pending		—		2.80
Supplier. Sonatrach. Importer Distrigas (Project pending),	Everett, Ma,	Distrigas Iv[2]	1978	42 (115)	Filed Feb. 1977	1/Chantiers-Ciotat (France)/ 125,000 m³/ Spherical free-standing	—	9 – 1 0 (added investment)	2.91

CURRENT IMPORT TERMINAL CHARACTERISTICS

Storage capacity (MMcf)	Regasification capacity (MMcfd)	Type of storage containers	Number of storage tanks	Terminal acreage
3250	135	Aboveground 9% nickel steel	2	37

1 The 50,000 cubic meter ship "Descartes' will be taken out of service upon arrival of the latest contract (Distrigas IV).
2 The Distrigas I and III projects will be phased into the Distrigas IV project when the latter commences

Source OTA

been delivering LNG from Skikda, Algeria, to the terminal at Everett, Mass., at the rate of about 15 trips each year. The terminal is located on the Mystic River, up from the main Boston harbor and less than one-half mile from the Boston city limits, in a highly industrialized region with both LPG and gasoline terminals adjacent to the property.[50]

The Everett facility has operated without major incident for 6 years.

The principal market for this LNG is the Northeastern States with distribution made by both truck and pipeline. At present 40 percent of the LNG is distributed by trucks and more than 60 trucks operate out of the facility to other satellite storage tanks in the Northeast.[51] The Distrigas project has contracted for a supply of 16 billion cubic feet of gas per year, and in 1976 actual imports totaled slightly over 10 billion cubic feet.[52]

While this project has received FPC approval, a modification to expand the terminal and total import volume has been filed and is pending approval by FPC. Under the terms of a new 20-year contract with the Algerian National Gas Company, Distrigas would import 42 billion cubic feet of gas per year beginning in 1978.[53] This contract would replace the existing one and a new 125,000 cubic meter ship, the *Mostefa Ben Boulaid,* would be used in place of the *Descartes.* Additional unloading facilities, but no new storage tanks, are planned for this expansion.[54]

2. *The Phillips/Marathon Project (figure 25)*

The oldest operating marine LNG project in the United States is the project now exporting gas from fields in Cook Inlet in southern Alaska, through a terminal at Kenai, to Neigishi, Japan. This project has been operated by the Phillips Petroleum Company and Marathon Oil Company since 1969.

Two 71,500 cubic meter LNG tankers, the

[50] Interviews with officials of Distrigas Inc., Boston, Mass., June 15, 1977.

[51] Ibid.

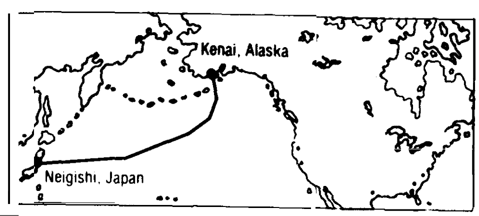
[52] Federal Power Commission, *United States Imports and Exports of Natural Gas 1976* (Washington, D. C.: Federal Power Commission, May 1977).

[53] Dean Hale, "Cold Winter Spurs LNG Activity,": 30.

[54] Interviews with officials of Distrigas Inc., Boston, Mass, June 1 1977.

Figure 25.
Project Data Sheet: Phillips/Marathon
LNG Export Source: Kenai, Alaska (Plant at Nikiski)
LNG Export Terminal: Neigishi, Japan

Kenai to Neigishi – 3,280 nmi



Companies Involved	Location of U S facility	Project designation	Expected operational date	Contract volume Bcf/yr (MMcfd)	FPC status (as of 9/1/77)	Number Ships/ Shipyard/ Capacity m³/ Tank design	Estimated Investment ($10°) Tankers	Receiving terminal	Exported price ($)-1976 /MMBtu
Gas Supplier: Phillips and Marathon Plant. Operator: Phillips Petroleum Shipper: Marathon Oil. Importers Tokyo Electric, Tokyo Gas.	Kenai. Alaska	Phillips/ Marathon	Operational since 1969 1 5-year contract)	49,3 (135)	Approved	2/K, M, Verkstads (Sweden)/ 71,500 m³/ membrane	–	—	1 66

CURRENT EXPORT SOURCE CHARACTERISTICS

Storage capacity (MMcf)	Liquefaction capacity (M Mcfd)	Type of storage containers	Number of storage tanks	Facility acreage
2300	185	Aboveground aluminum	3	

Source OTA

Arctic Tokyo and the *Polar Alaska,* were built in Sweden and operate under the Liberian flag with Italian crews.[55]

The contract to supply Tokyo Electric and Tokyo Gas companies is for 135 billion cubic feet of gas per year, and in 1976 about 50 billion cubic feet were actually delivered.[56] This project has operated without a major problem since initiation.

During the extreme winter of 1977 a special delivery of one shipload of LNG was made to Everett, Mass., from Alaska, after a waiver of the Jones Act prohibiting the use of foreign flag tankers in U.S. trade. A French-built 3,5,000 cubic meter tanker, the *Kenai Multina*, flying the Liberian flag **was** used.[57] This project contract expires in 1985. Beyond that, application may be made to bring the gas to southern California.

3. *The El Paso I Project (figure 26)*

The agreement between El Paso Natural Gas Company and Sonatrach (Algeria) will lead to the initial transport of the LNG

55U.S. Department of Commerce, Maritime Administration, *Status of LNG Vessels.*

56Federal Power Commission, *United States Imports and Exports of Natural Gas 1976.*

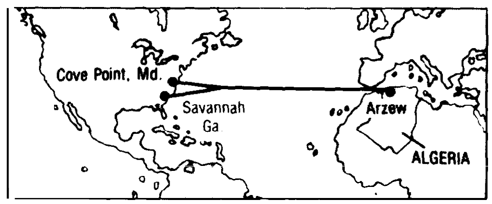
57Dean Hale, "Cold Winter Spurs LNG Activity ",: 21.

Figure 26.

Project Data Sheet: El Paso I

Import Source: Arzew, Algeria

Import Terminal: Cove Point, Md. and Elba Island, Ga.



Arzew to Cove Point– 3,570 n mi
Arzew to Savannah – 3,77o n mi

Companies involved	Location of U S terminals	Project designation	Expected operational dale	Contract volume Bcf/yr (MMcfd)	FPC status (as of 9/1/77)	Number Ships/ Shioyard/ Capacity m³/ Tank design	Estimated Investment ($10⁶): Tankers	Estimated Investment ($10⁶): Receiving terminal	Estimated price ($) delivered iinto pipeline/MMBtu
Suppliers: Sonatrach (Algerian National Gas Co.)	Cove Point, Md			3651 (1000)	Approved 1972, 1973: Reopened 1974	3/Chantiers-Dunkirk (France)/ 125,000 m³/ membrane		350 (Cove Point)	1.66-181
Shipper: El Paso Algeria Corp.									
Cove Point purchasers: Consolidated System LNG Co and Columbia LNG Co. (also operators)		El Paso I	1978		Approved 1-1977	3/Avondale (U.S.A.)/ 125,000 m³/ Free-standing Prismatic	1100 for all 9 ships		
Elba Island purchasers: Southern Energy Co (also operators)	Elba Island, Ga.							127 (Elba Is,)	1.70
Drstributors Columbia Gas Transmission Corp., Consolidated Gas Supply Co., Southern Natural Gas Co						3/Newport (U.S.A.)/ 125,000 m³/ Technigaz membrane			

CURRENT IMPORT TERMINAL CHARACTERISTICS

Location	Storage capacity (MMcf)	Regasification capacity (MMcfd)	Type of storage containers	Number of storage tanks	Terminal acreage
Cove Point, Md.	5000	1000	Aboveground, aluminum	4	60 (plant, structures) 300 acres allocated 1100 acre tract
Elba Island, Ga.	4000	325	—	3	150 acres allocated 800 acre tract

[1]Of this amount. Cove Point shall receive about two-thirds, Elba Island one-third

Source OTA

equivalent of 1 billion cubic feet per day (365 billion cubic feet per year) of natural gas to the United States.

The Columbia Gas System, along with the Consolidated Gas System, has entered into contract for some two-thirds of this gas. The LNG will be delivered to a terminal located on the Chesapeake Bay at Cove Point, Md. The terminal will be jointly owned by Columbia and Consolidated and will become operational early in 1978. The remainder of LNG will be delivered to Southern Natural Gas at a new terminal under construction on Elba Island, Ga.[58]

The Cove Point terminal has two tanker berths, four storage tanks and several process areas. The two tanker berths are located about 1 mile offshore along a 2,500-foot pier which is connected to shore by an underground tunnel containing both LNG pipes and vapor return lines. The initial operating plans call for about 140 ship arrivals per year. The Cove Point facility is located on a 1,100-acre tract of land along the Chesapeake Bay in Calvert County, Md.[59]

The gas will be piped from Cove Point to an existing pipeline in Loudoun County, Va., and then to markets in middle Atlantic States served by Columbia and Consolidated Natural Gas Companies.

The Elba Island terminal is on an 800-acre site of undeveloped land, wholly owned by Southern Natural Gas. It is located 5 miles downriver from Savannah, Ga., and will supply gas to southeastern U.S. markets. This LNG is expected to represent about 15 percent of Southern Natural Gas sales when the terminal is operational. It is planned that 50 LNG tankers will call at the Elba Island terminal each year, substantially increasing the ship traffic at the Savannah port entrance. GO

Nine 125,000 cubic meter LNG tankers are to be used to serve both El Paso I terminals. Three tankers were built in France, are now completed and laid-up, and are planned to be operated by El Paso under the Liberian flag. Six others are under construction at two U.S. shipyards (Avondale and Newport News), and are planned to be operated by El Paso under U.S. flag.[61]

The entire project is about 2 years behind schedule. The principal technical problem was completion of the large liquefaction facilities in Algeria. After one U.S. contractor failed to perform, the Algerian National Gas Company canceled the contract and hired a new contractor. The U.S. terminals and the U.S.-built tankers are now almost completed, after a slow-down to await completion of the Algerian terminal. The present schedule is for LNG shipments to begin in January 1978.[62]

The FPC approved the El Paso I project in June 1972.

4. *The "Trunkline" Project (figure 27)*

The Trunkline project was approved by FPC on June 30, 1977, after an appeal of an initial opinion in April.[63]

The proposed LNG facility would be near the Lake Charles Harbor in Louisiana and within the Terminal District Industrial Park. It would be located on a 139-acre site and would be used to unload, store, and ship LNG imported from Algeria. The LNG terminal would consist of a berthing dock for LNG unloading, an onshore facility consisting of three 600,000-barrel LNG storage tanks surrounded by a dike, two 25,000-gallon liquid nitrogen storage tanks, one 250,000 Bunker C fuel-oil tank for servicing the LNG tankers, and a process area which would contain equipment for all LNG transfer operations.

[58] Ibid., p. 30.

[59] Max Levy, "The Cove Point, Maryland LNG Terminal," *Conference on LNG Importation and Terminal Safety,* Boston, Mass., June 13-14, 1972.

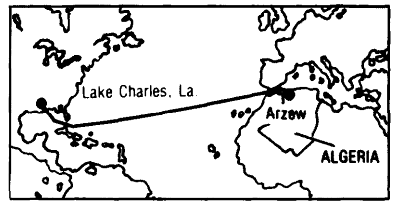
[60] Southern Natural Gas Company, *Facts on Elba Island, Savannah, Georgia LNG Terminal,* (n. p.: Southern Natural Gas Company, n.d.).

[61] U.S. Department of Commerce, Maritime Administration, *Status of LNG Vessels.*

[62] Ibid.

[63] Federal Power Commission, *Trunkline LNG Company et al.,* Opinion No. 796-A, Docket Nos. CP74-138-140 (Washington, D. C.: Federal Power Commission, June 30, 1977).

Figure 27.
Project Data Sheet: Trunkline
Import Source: Arzew, Algeria
Import Terminal: Lake Charles, La.



Arzew to Lake Charles — 5,070 n mi

Companies Involved	Location of U S terminal	Project designation	Expected operational date	Contract volume Bcf/yr (MMcfd)	FPC status (as of 9/1/77)	Number Ships/ Shipyard/ Capacity m³/ Tank design	Estimated investment ($10⁶) Tankers	Estimated investment ($10⁶) Receiving terminal	Estimated price ($) delivered into pipeline/MMBtu
Supplier Sonatrach (Algerian National Gas Co.)						2/General Dynamics (U. S.A.)/125,000 m³/Spherical free-standing;	310	193	3.36
Terminal builder & operator Trunkline LNG Co	Lake Charles, La	"Panhandle" "Trunkline" "Calcasleu"	1980-81	179 (490)	Approved				
Buyer & distributor Trunkline Gas Co (Subsidiary of Panhandle Eastern Pipeline Co)						3/125,000 m³/ shipyard & design not known			
Market Illinois. Indiana, Michigan, Ohio (primarily)									

CURRENT IMPORT TERMINAL CHARACTERISTICS

Storage capacity (MMcf)	Regasification capacity (MMcfd)	Type of storage containers	Number of storage tanks	Terminal acreage
6000	540	Above-ground, aluminum	3	75 (plant, structures) (139 acre site)

Source OTA

Ancillary facilities would include offices, equipment for wastewater treatment, fire control and detection, fire protection equipment, water supply, electrical power, and communications.[64]

The project is planned for importing 179 billion cubic feet of gas per year using five 125,000 cubic meter LNG tankers. The tankers would reach the facility at the arrival rate of 65 per year through a 24-mile channel from the Gulf of Mexico.[65]

Subsidiaries of Panhandle Eastern Pipe Line Company, General Dynamics, and Moore-McCormack Bulk Transport, Inc., have formed a partnership, Lachmar, to build, own, and operate two of the ships. These two ships are to be built at General Dynamics', Quincy, Mass., shipyard. The three other vessels for this project are expected to be provided by the Algeria National Shipping Company.[66]

5. The "Pacific Indonesia" Project (figure 28)

In an initial decision on July 22, 1977, an FPC Administrative Law Judge approved a proposal to import 200 billion cubic feet of gas per year from Indonesia to a terminal in Oxnard, Calif. The decision is subject to Commission review.[67] There is considerable controversy in California over the site, and some State legislation on siting is pending.

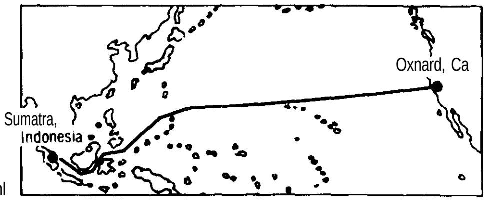
64 Federal Power Commission, *Final Environmental Impact Statement Calcasieu LNG Project Trunkline LNG Company Docket No. CP74- 138 et al.*, (Washington, D.C.: Federal Power Commission, September 1976).

65 Ibid.

66 Dean Hale, "Cold Winter Spurs LNG Activity,": 30.

67 Federal Power Commission, "FPC Judge Approves Importation of Indonesia LNG."

Figure 28.
Project Data Sheet: Pacific-Indonesia
Import Source: North Sumatra, Indonesia
Import Terminal: Oxnard, Ca.



Sumatra 10 Oxnard – 8,300 n ml

Companies involved	Location of U.S. terminal	Project designation	Expected operational date	Contract volume Bcf/yr (MMcfd)	FPC status (as of 9/1/77)	Number Ships/ Shipyard/ Capacity m³/ Tank design	Estimated investment ($10⁶) Tankers	Estimated investment ($10⁶) 'Receiving terminal	Estimated price ($) delivered into pipeline/MMBtu
Original supplier & liquefier: Pertamina (of Indonesia). LNG shipper: Pacific Indonesia LNG Co. Proposed builder and operator of U.S. terminal: Western LNG terminal Co. (Pacific-Indonesia Contractor). Buyers & distributors: Joint project of Pacific Gas and Electric and Pacific Lighting Corp. (will divide imports equally). Market: California.	Oxnard, Ca. (Port Hueneme)	Pacific-Indonesia Project	48 months after approval (Liquefaction facilities m Indonesia under construction)	200 (550)	Initial approval 6-77, subject to review	61U.S.A.)/ 125,000 m³/ shipyard & tank design not known; 2/ Chandlers-Atlantique (France)/ 125,000 m³/ membrane 1/Chantiers-Ciotat/ 125,000 m³/ Free standing spherical	155 per U S Tanker	270	306-360

PROPOSED IMPORT TERMINAL CHARACTERISTICS

Storage capacity (MMcfi)	Regasification capacity (MMcfd)	Type of storage containers	Number of storage tanks	Terminal acreage
7700	4600	Above-ground, 90/0 nickel steel	4	Plant, -structures 38 (ultimately 55) 21 O-acre site

Source OTA

The proposed Oxnard facility would be owned and operated by Western LNG Terminals. It would be located on a 210-acre site in the City of Oxnard, on the coast of California. This plant would import LNG at a rate of 546 million cubic feet of gas per day for markets within the State of California. The LNG storage and vaporization facilities would occupy 38 acres of the site containing two to four 550,000-barrel, double-wall, above--ground tanks, 240-feet in diameter with an overall height of 129 feet. The plant facilities would require 55 acres of the site, and the marine terminal would occupy 34 acres of leased subtidal land extending approximately 6,000 feet offshore at Ormand Beach. Unloading arms at the marine terminal would transfer the LNG from the ship to the storage facilities through 42-inch cryogenic pipes.[68]

Liquefaction facilities in Indonesia are now under construction.

Conditional agreements have been reached with shipping companies for nine 125)000 cubic meter LNG tankers. Pacific Indonesia will charter the ships, three of which will be French built and the remaining six U.S. built.[69] No U.S. ship construction contract has been announced.

68 Federal Power Commission, *Final* **Environmental** *Impa et Sta tern en t Pacific Indonesia Project* **(Washington, D. C.: Federal Power Commission, December 1976).**

69U.S. Department **of Commerce, Maritime Administration,** *Status of LNG Vessels.*

6. *The El Paso II Project (figure 29)*

The El Paso II project is pending before the FPC. The proposal is to transport 365 billion cubic feet of gas per year from Algeria to a new facility at Port O'Connor, Tex. TO A fleet of twelve 125,000 cubic meter LNG tankers would be required. It is planned that six of these would be U.S. flag and U.S. built, but no construction contracts have been announced.[71] Safety reports have been submitted and FPC hearings were held during the summer of 1977. Draft and final environmental impact statements have been issued.[72]

[70] Federal Power Commission, *Algeria II Project Outline of Contracts, El Paso Eastern Company, et al., Docket No. CP77-330, et al.* (Washington, D. C.: Federal Power Commission, n.d.)

[71] U.S. Department of Commerce, Maritime Administrat ion, *Status of LNG Vessels.*

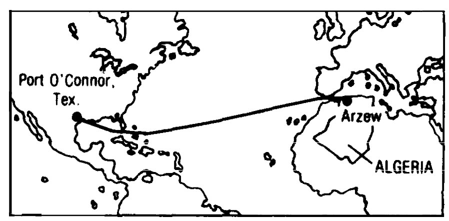
[72] Federal Power Commission, *Joint LNG Safety Report of El Paso Atlantic Company et al., Respecting the Proposed Algeria II Project,* Docket No. CP73-258, et al. (Washington, D. C.: Federal Power Commission, Apr. 1, 19'77).

7. *The "Pacific-Alaska" Project (figure 30)*

A project to transport LNG from Cook Inlet gas fields near Kenai, Alaska, to California is pending before FPC.[73] A terminal is planned at either Oxnard or Los Angeles, Calif. Questions of terminal siting now being addressed by the State of California are delaying some decisions on this project. It is planned that initially two 130,000 cubic meter tankers would be used to import 73 billion cubic feet of gas per year. Sun Shipbuilding Company has signed contracts for these ships with an affili-

[73] Dean Hale, "Cold Winter Spurs LNG Activity,": 31.

Figure 29.
Project Data Sheet: El Paso II
Import Source: Algeria
Import Terminal: Port O'Connor, Tex.



Arzew to Port O'Connor — 5024 n mi

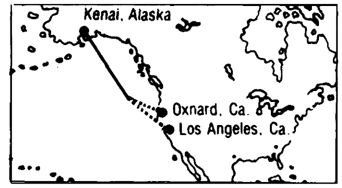
Companies Involved (project status)	Location of u s terminals	Project designation	Expected operational date	Contract volume Bcf/yr (MMcfd)	FPC status (as of 9/1/77)	Number Ships/ Shipyard/ Capacity m³/ Tank design	Estimated Investment (S10⁶) Tankers	Estimated Investment (S10⁶) Receiving terminal	Estimated price ($) delivered into pipeline/MMBtu
Supplier Sonatrach (Algerian National Gas Co.) Shipper El Paso Atlantic co Receiver El Paso Eastern Co Distributors El Paso, LNG Terminal, United Gas Pipeline.	Port O'Connor, Tx. Matagorda Bay	El Paso II	1982-83	365 (1 000)	Pending	12 125,000 m³, shipyard & tank design not known	2,000	457	—

CURRENT IMPORT TERMINAL CHARACTERISTICS

Storage capacity (MMcf)	Regasification capacity (MMcfd)	Type of storage containers	Number of storage tanks	Terminal acreage
4168	—	Aboveground	3	

Source OTA

Figure 30.
Project Data Sheet: Pacific Alaska
Import Source: Kenai, Alaska (Cook Inlet)
Import Terminal: Oxnard, Ca. and/or Los Angeles, Ca.



Kenai to Oxnard — 2,000 n mi
Kenai to Los Angeles — 2,080 n mi

Companies involved (project status)	Location of U.S. terminals	Project designation	Expected operational date	Contract volume Bcf/yr (MMcfd)	FPC status (as of 9/1/77)	Number Ships/ Shipyard/ Capacity m³/ Tank design	Estimated investment ($10⁶) Tankers	Estimated investment ($10⁶) Receiving terminal	Estimated price ($) delivered into pipeline/MMBtu
U.S. liquefaction plant builder and shipper: Pacific-Alaska LNG Co. Receiving terminal builder and operator: Western LNG Co.	Oxnard, Ca. and/or Los Angeles Ca. (receiving terminal)	Pacific-Alaska	48 months after approval	Initial: 73 (100) Total: 146 (400)	Pending	2/Sun Shipbuilding/ 130,000 m³/ membrane	414	270[1] (Oxnard)	—
Buyers and distributors: Pacific Gas and Electric & Southern California Gas. Market: California.	Cook Inlet, Alaska (liquefaction terminal)							187 (Los Angeles)	—

[1] Not the ultimate (combined) terminal, which will have an estimated cost of $460,000,000.

CURRENT LNG SOURCE AND TERMINAL CHARACTERISTICS

Location	Storage capacity (MMcf)	Liquefaction or regasification capacity (MMcfd)	Type of storage containers	Number of storage tanks	Terminal acreage
Terminals: Oxnard, Ca.	7700	4600	Aboveground 9% nickel steel	4	38-55 (210 acre site)
Los Angeles, Ca.	7700	5000	Aboveground 9% nickel steel	4	
Source: Kenai, Ak.	3000	400	Aboveground 9% nickel steel	2	

Source: OTA

ate of Pacific Lighting Company, but no construction has started.[74]

8. *The "El Paso--Alaskan" Project (figure* 31)

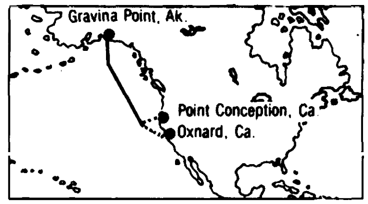
This project is one of the proposed transportation systems to deliver gas from the major Alaskan North Slope fields to the lower 48 States. While the other systems involve gas pipelines through Canada, this project proposes a gas pipeline from the North Slope along the present oil pipeline route to southern Alaska, A liquefaction facility would be built at Gravina Point, Alaska, and an initial fleet of eight 165,000 cubic meter LNG tankers are planned to deliver the LNG from that point to California. Designs have been prepared for the tankers but no construction contracts have been discussed.[75]

Initially, the project is planned to deliver 876 billion cubic feet of gas per year with distribution both to California and other States to the east. A proposed ultimate distribution level of 1.17 trillion cubic feet per year would require 11 ships. A California terminal is proposed at Point Conception, with an alternate site at Oxnard. The Point Conception terminal would incorporate an offloading pier almost 1 mile offshore and an onshore storage and regasification plant.

74 Federal Power Commission, *Recommendation to the President Alaskan Natural Gas Transportation Systems* (Washington, D. C.: Federal Power Commission, May 1, 1977).

75 Ibid.

Figure 31.
Project Data Sheet: El Paso-Alaska
LNG Source: Gravina Point, Alaska'
LNG Terminal: Oxnard, Ca. and/or Point Conception, Ca.



Gravina to Point Conception — 2,160 n mi
Gravina to Oxnard — 2,260 n mi

Companies revolved (project status)	Location of u s terminals	Project designation	Expected operational date	Contract volume Bcf/yr (MMcfd)	FPC status (as of 9/1/77)	Number Ships/ Shipyard/ Capacity m³/ Tank design	Estimated investment ($10⁶) Tankers	Receiving terminal	Estimated price ($) delivered into pipeline/MMBtu
Liquefaction plant budder and shipper El Paso Alaska Co	Oxnard, Ca and for					11/U.S.A./ 165,000 m³ shipyard &	1600	270[2]	—
Receiving terminal builder and operator: Western LNG Terminal Co.	Point Conception, Ca. (receiving terminal)	El Paso-Alaska	1983 (25 yr. contract)	876 (2400)	Pending	tank design not known		401	1.54
Buyers and distributors: Pacific Gas & Electric, Southern Calif. Gas, & probably: Columbia Gas, Transcontinental, Panhandle Eastern and others.	Gravina Pt., Ak. (liquefaction terminal)	"North Slope"							
Market: 25-50% California, 50-75% East of California.									

PROPOSED LNG SOURCE AND TERMINAL CHARACTERISTICS

	Location	Storaqe capacity (MMcf)	liuefactlon or reqasification capacity (MMcfd)	Type of storaqe containers	Number of storage tanks	Terminal acreage
Terminals	Oxnard, Ca.	7700	4600	Aboveground 9% nickel	4	38-55 (210 acre site)
	Point Conception, Ca.	7700	3300	Aboveground 9% nickel	4	1000 acres
Source	Gravina Point, Ak.	6000	3375	Aboveground 9% nickel	4	

[1] via pipeline from the North Slope
[2] Not the ultimate (combined) terminal, which will have an estimated cost of $460 million

Source OTA

Under the Alaska Natural Gas Transportation Act of 1976, the President is required to recommend to Congress on the selection of the best transportation system and Congress will then have 60 days to review this recommendation. The President's recommendation was announced in favor of a trans-Canada gas pipeline on September 8, 1977, but formal recommendation had not yet been made to Congress at this printing.

Chapter II

Critical Review of Components of LNG Import System

Chapter II

Critical Review of Components of the LNG Import System

This chapter presents a series of discussions and critiques of important aspects of the liquefied natural gas (LNG) system which are essentially components of the existing and proposed projects described in chapter 1.

The aspects addressed were identified by OTA after consideration of public concerns and analysis of both near-term and longer term effects of deploying this technology in many locations around the country. Considering the present status and trends of developing projects and LNG technology, the nine subjects covered here were judged to be deserving of attention at the Federal Government level based on either public concerns, the possibility of significant problems developing, or both.

Since some LNG projects are already operating or approved and a significant amount of technology is already in place or developed, Federal attention seems to be desirable in two separate time frames:

- attention to near-term problem areas of technology, regulation, decisionmaking, or research which could affect many projects already operating or nearly so; and
- attention to longer term policies which may be more important as the technology develops and becomes more dominant on the national scene.

Each subject in this chapter is presented as a critical review of the present system with key problems highlighted. Some analyses of future trends and effects are also included.

The first five papers are principally subjects for near-term attention and could be used as basis for congressional review of regulatory agencies or general investigation of the safety issue in the context of existing projects and facilities. These papers are:

1. Tanker Design and Construction.
2. Tanker Regulations and Operations.
3. Regulation of Terminal Operations.
4. Decisionmaking Process in Certification of Import Projects.
5. Safety Research on LNG.

The remaining four papers are principally subjects which may require longer term attention following determination of policy in the national interest. There may be need for specific legislation to influence projects if major policy changes are determined. Some of the subjects require further study or investigation and these are noted in the discussions. The subjects are:

6. LNG Facility Siting,
7. Liability for LNG Accidents.
8. Reliability of Supply.
9. Pricing Policy.

Critical Review: Paper 1

LNG TANKER DESIGN AND CONSTRUCTION

The Coast Guard specifies and enforces design standards for U.S. flag ships and for foreign flag ships calling at U.S. ports. Standards for foreign ships were worked out in cooperation with the Intergovernmental Maritime Consultative Organization (IMCO), and a draft code is under consideration. In addition, the Coast Guard published proposed standards for self-propelled vessels carrying bulk liquefied gases on October 1, 1976. The proposed standards for U.S. flag ships differ only slightly from the IMCO code and the effective date for both sets of standards is the same. The new standard is intended to replace both the Letter of Compliance program for foreign vessels and existing 46 CFR, Chapter I regulations for domestic vessels.

As of September 1976, the existing fleet and scheduled deliveries of LNG ships totaled 79 vessels. All of these vessels and any additional ones contracted for prior to October 31, 1976, or delivered or converted prior to June 30, 1980, will not be subject to the new design and construction standards.[1] These vessels will comprise a significant portion of the fleet until the end of the century that will not be subject to the new regulations, although some of these vessels may still meet the new standards.

However, LNG ship technology has developed over the past 20 years and is currently in use in worldwide trade with only minor technical problems. Modern LNG ships have been in use for the past 5 years in Boston and 8 years in Alaska. No serious accidents have occurred and ***it appears that existing U.S. Coast Guard standards of design and construction are probably adequate to assure equally low risks of ship failures in the future.***

There is, however, concern about the risks of a major collision that would penetrate an LNG cargo tank. These concerns are not related to design and construction of the LNG tankers, but rather to the possibility that increased numbers of tankers and other ships will be operating in more and more congested harbors and coastal areas. This is an operational and regulatory problem which is discussed in the next section.

The two oldest LNG ships in operation appear to be typical of the quality of design and construction. The ships, the *Methane Princess* and the *Methane Progress*, are 27,000 cubic meters each, which are about the size of a single tank on 1977 LNG carriers, and have been transporting LNG from Algeria to England since 1964. No major accidents have occurred on these ships with over one million voyage miles each. A study done in 1973 presented an analysis of technical problems of these ships and the 71,000 cubic meter ships, *Arctic Tokyo* and *Polar Alaska,* which have been in service from Alaska to Japan since 1969.

The Methane ships' cargo tanks were an early freestanding prismatic tank design of aluminum construction. The Alaska ships had a later version of a membrane tank design with stainless steel interior lining. The Methane ships experienced minor problems with the insulation system, as the cargo tanks caused cold spots on the inner hull and some cracking in the mild steel hull. The problems were either repaired while in service or postponed until the next shipyard period. The average number of days out-of-service for repairs has been 25 per year for each of the Methane ships. This is only slightly higher than the 20 days per year usually planned for regular repairs to large, complex ships.

[1] U. S. Department of Commerce, Maritime Administration, *Status of LNG Vessels* (Washington, D. C.: U.S. Department of Commerce, Mar. 15, 1977).

The Alaska ships experienced much higher out-of-service rates (about 50 days per year) and several more operational problems in their first 4 years of service. Some factors that may have influenced this include: 1) the ships were much larger than previous designs; 2) the voyage from Alaska to Japan is much longer than previous LNG routes; and 3) the extreme temperatures and weather in Alaska. The problems experienced by the Alaska ships include damage to membrane and insulation due to tank-sloshing loads, damage to membrane due to a cable tray failure, over-pressurizing of barrier spaces around tanks, and various machinery failures. Some redesign and overhaul was necessary to correct the containment problems but none caused any serious personnel safety hazard. z

In fact, there have been no serious accidents or serious safety problems involving any of the 32 ships now in the worldwide LNG fleet.[3]

However, the new LNG tankers now entering the trade are larger and do employ some new systems. ***Although they have been carefully designed and constructed some concern is merited due to the increase in scale and new containment systems employed.***

Most of the LNG ships now under construction, built, or designed for the major U.S. import projects are of the 125,000 to 130,000 cubic meter size. Forty-seven of this size and none of any other size were under construction as of March 1977 (figure 32). Plans have been made for 165,000 cubic meter ships for the proposed North Slope Alaska to California project by El Paso but this project is not approved and no ship contract has been let. Some consideration has also been given to LNG ships as large as 300,000 cubic meters to serve offshore terminals, d but no firm plans have been made. The major concern about the development of much larger ships is that an accident will have more serious consequences. Before designs are firm it would be prudent to consider the need for limits on either tank sizes or total ship sizes. Some correlation between siting of facilities, ship or tank size, and research into LNG spill behavior may also be useful.

An interesting example of difficulties which may occur in getting a major new technical system in operation is provided by a recent accounts of the 125,000 cubic meter LNG tanker *Hilli.* Unloading of the tanker was halted in a Japanese harbor when a metal bolt was found in the cargo lines. The ship has been taken out of service and, along with two sister ships scheduled to enter service soon, is undergoing intensive inspections until the source of the bolt is found. It is estimated that the activity may take 2 months and could cost millions of dollars.[5]

However, such problems with new ships, carefully built, operated, and monitored in early stages of projects, appear to have a negligible effect on public safety. ***However, as the present fleet grows older, risks of failures could increase.*** Future concerns for projects now in the design and construction stages include:

- How well each ship will be maintained and kept in adequate condition.
- How well various new containment systems will perform over time.
- How well inspection and monitoring of ship and machinery condition and operation will be performed.
- How well foreign flag operation will continue to adhere to U.S. standards and whether countries such as Liberia will perform adequate surveys and inspections.
- How well shipyard repairs and surveys can be performed on these complex vessels with tight operating schedules.

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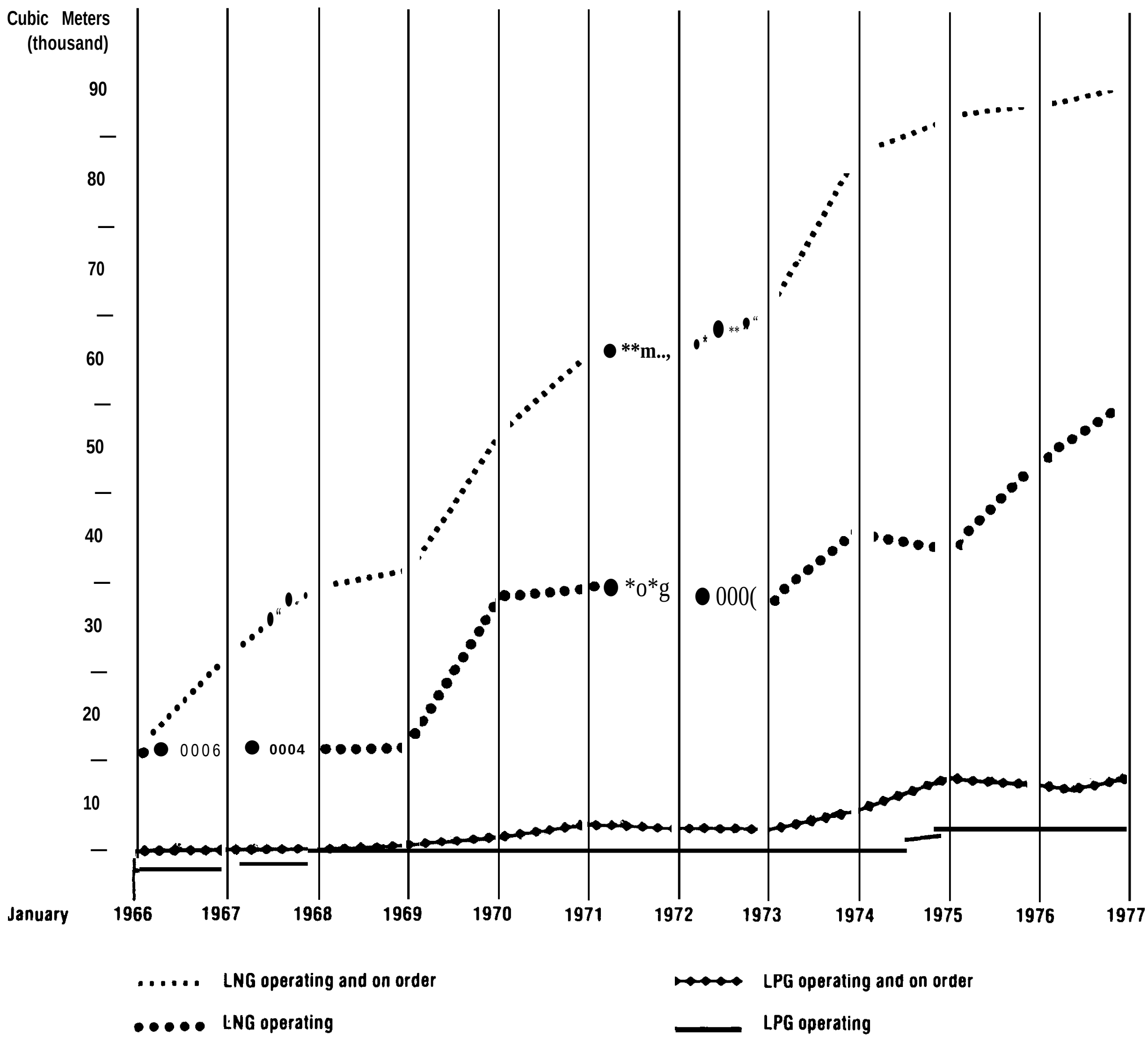
[2]Booz-Allen Applied Research Inc., *Analysis Of LNG Marine Transportation* (Bethesda, Md.: Booz-Allen Applies Research Inc., November 1973). v.], p. VI-30-38,

[3]U.S. Depart m ent of Corn m erce, Maritime Administration, *Status of LNG Vessels* (Washington, D. C.: U.S. Department of Commerce, Mar. 15, 1977).

[4]Henry Marcus, *offshore Liquefied Gas Terminals,* draft report (Cambridge, Mass.: MIT Center for Transportation Studies, July 1977).

[5]"LNG halt could last months," *Lloyd's* L&~, June 4, 1977, p.1.

Figure 32. Average Vessel Capacity of World LNG Tanker Fleet



Source: Liquid Gas Carrier Register, 1977.

During the public participation program which OTA conducted as a part of this assessment, it was learned that there appeared to be little concern about the design and construction of LNG tankers, but considerable concern about the operation.

Those participants who did discuss construction of LNG tankers spoke favorably about the jobs created in U.S. shipyards by contracts for LNG tankers.

In this study, OTA looked only at LNG tankers. However, the study indicated that it is logical that liquefied bulk gas carriers should be treated together for purposes of future controls on design, construction, and maintenance. Liquefied petroleum gas (LPG) carriers and other gas tankers have been in service for longer periods and in much more varied shipping circumstances than LNG carriers. Some of these other gas carriers have had more serious accidents.[6] In addition, many more U.S. ports are regularly receiving or shipping LPG and other gas cargoes.

The Coast Guard and international agencies have considered all liquefied gas carriers together in the past, and the Coast Guard's mandate for setting design and construction standards for LNG and LPG tankers stems from the same legislation.[7] Recently, however, public concern about LNG has forced the Coast Guard to give disproportionate attention to LNG tankers. In all design, construc***tion, and maintenance controls, LNG and all other hazardous cargo tankers should be considered together.***

[6] The *Yuyo Maru*—a hybrid gas carrier collided with a Liberian cargo vessel in Tokyo Bay in November 1974, resulting in a fire setting the naphtha alight in wing tanks which, in turn, eventually reached the LPG in other tanks.

[7] U.S. Congress, *Ports and Waterways Safety Act of 2972,* P.L. 92-340, 92d Cong., 1972.

Critical Review: Paper 2

LNG TANKER REGULATIONS AND OPERATIONS

Regardless of the design safeguards required for LNG tankers, the possibility and consequences of a major spill on water due to a ship accident are the most serious concerns. The gas industry, Government officials, and those who joined in OTA's public participation program during this assessment all agree on that fact.

As marine traffic in such hazardous cargoes as LNG and LPG increases in the future, much more attention will be needed in the whole area of vessel traffic monitoring and control, especially since the movements of other marine traffic in the vicinity of liquefied gas tankers may not be as predictable as the movement of the LNG ships.

Tanker Traffic

The Coast Guard has authority to grant the Captain of the Port the power to control any vessel within the territorial sea and to prescribe conditions and restrictions for the operation of waterfront facilities.

The only U.S. ports where LNG tankers are currently operating are Boston, Mass., and Kenai, Alaska. The Captain of the Port in Boston has prepared an operations/emergency plan specifically for LNG. The Captain of the Port in Kenai has not. He relies instead on a voluntary operations plan drawn up by the four industrial users of the port.[2]

The Boston plan requires that all LNG vessels bound for the Everett, Mass., terminal meet a Coast Guard cutter 4 miles out for an inspection of cargo systems prior to entering port. The officer-in-charge will then make a determination of whether the ship should be allowed to enter the harbor. From that point on, if permission to enter port is given, the Coast Guard cutter will escort the tanker to the terminal, remain berthed nearby during the unloading operation, and finally escort the tanker back out to the open sea. During the transit to and from the terminal, the Coast Guard broadcasts warnings to keep the harbor clear of all other traffic. Simultaneous unloading of LPG tankers in an adjacent berth is prohibited.

Due to the unique traffic problems with each LNG terminal site, local planning will always be required. ***However, the present method of operation—especially closing down long sections of Boston waterways during an LNG tanker transit-may be very costly and unworkable as increased numbers of LNG tankers enter service. Effective long-range planning to handle traffic problems is required now.***

With tanker deliveries once every 20 to 30 days into the relatively uncrowded Boston Harbor, the inconveniences and costs to other shipping activity are modest. However, when deliveries are made more regularly or into very busy harbors, pressures will exist for the Coast Guard to be less rigorous in their controls.

For example, LNG tanker deliveries to the new terminal at Cove Point, Md., are expected every 2 to 3 days. At the same time, more than 4,000 major ships per year pass Cove Point on their way to and from the Port of Baltimore, one of the 10 largest ports in the United States. (By comparison, Boston Harbor handles only 1,500 ships per year; the Delaware River, 5,000; New York Harbor, 10,000).[3] In addition, LNG ships bound for Cove Point will have to mix with other ship traffic in the Chesapeake Bay at Hampton Roads.

[1] U.S. Congress, *Ports and Waterways Safety Act of 1972,* P. L. 92-340, 92d Congress., 1972.

Conversation with officials of the U.S. Coast Guard, Washington, D. C., Aug. 12, 1977.

[3] U.S. Department of the Army, Corps of Engineers, *Waterborne Commerce of the United States, Calendar Years, 1973, 2974, 2975* (Vicksburg, Va.: U.S. Department of the Army, Corps of Engineers, 1974, 1975, 1976).

Probably the greatest single safety measure that could be taken to develop and to maintain safe LNG shipping and safer shipping in general would be the adoption of positive traffic control over vessels within harbors, rather than simply allowing ships to follow rules of the road.

Historically, oil tanker casualty data have indicated a need for improved marine traffic safety in U.S. ports and waterways.

The Ports and Waterways Safety Act of 1972 authorizes the Coast Guard to establish, operate, and maintain vessel traffic services (VTS) in congested waterways, require installation of electronics for implementation of traffic safety systems, and control vessel traffic where conditions require it through routing schemes and speed limits. While this is not a positive control system in the same sense that air traffic controllers exercise authroity over flight, it does give the Coast Guard the statutory authority to deal with hazardous cargo traffic in a concrete way.

The Coast Guard completed a detailed analysis of ports and waterways traffic in 1973.[4] VTS systems for San Francisco, Puget Sound, and the Houston Ship Channel are now operational, and systems for New Orleans and Valdez are expected to be operational late in 1977. A system is being developed for New York Harbor and its approaches.

Priorities for ports to be outfitted with VTS have been set by the Coast Guard based on historic information reflecting the level of traffic, the opportunity for accident, and the costs and benefits of installing the system. ***It now appears that the Coast Guard should also study harbors and waterways and possibly consider new VTS locations based on at least three additional factors related to the cargoes:***

- the percentage of ship traffic in hazardous cargoes in relationship to all traffic in the port;
- the potential for increased traffic in hazardous cargoes; and
- the impacts of various types of ship accidents which might occur in each harbor.

Admittedly, VTS are complex and costly systems. However, the complexity and cost of current practices--such as halting traffic around LNG tankers and providing individual Coast Guard cutter escorts for each LNG tanker—will become more unmanageable and less feasible as traffic increases.

Since all proposed sites for LNG import terminals are not now scheduled for VTS systems, special handling of the ships will probably continue to be required in the near term. However, in the future safety of all vessels around and including, hazardous cargo ships depends on implementation of some level of VTS system by the Coast Guard to reduce the probability of ship collisions.

In testimony before a Coast Guard hearing considering the need for VTS in the Chesapeake Bay, a representative of the firm which will operate the LNG tankers into Cove Point noted that working VHF radios and radar are not now required on ships entering the Bay. He indicated faith in the LNG tankers, which are so equipped, but added, “We are concerned, however, about the basis for entry and transit (of other vessels) and who will pass our berthed vessels at Cove Point.”[5]

Citizens who joined in OTA’s public participation program expressed considerable concern about the operation of LNG tankers in crowded harbors and the problems of tying up other ship traffic. One participant suggested that in order to minimize the possibility

[4]U.S. Department of Transportation, U.S. Coast Guard, *Vessel Traffic Systems Issue Study, Final Report* (Washington, D.C. U.S. Department of Transportation, U.S. Coast Guard, March 1973).

[5]Hearings before the U.S. Coast Guard on- the Chesapeake Bay Vessel Traffic System at Norfolk, Va., Jan. 27, 1977, John Boylston, marine manger of Methane Tanker Service Company.

of collision and to provide a large area of empty water in which an LNG spill might dissipate, LNG tankers be restricted to routes away from normal shipping lanes and terminals be restricted to isolated coastal points away from other shipping ventures.

Tanker Inspections

The Coast Guard assures the compliance of foreign LNG tankers to established standards by boarding the ships for an inspection when they enter U.S. ports.

Inspections are required at least every 2 years and may be carried out, as they are in Boston, on each arrival in a U.S. port.

These inspections are limited to cargo-handling systems, deck machinery and compartments, and fire and gas detectors for the cargo system. The general condition of the ship and the capability of the crew are not included in these inspections. ***Thus the inspection does not reduce the risk of failure of propulsion, navigation, and steering systems, or even verify the crew's training and experience.***

One very specific criticism of the Coast Guard's inspection procedures is that it relies totally on shipboard instrumentation during the inspection. While most systems can be checked by actuation of controls and by built-in self-test features, there is one very obvious oversight. The ability of the ship's gas detection system will be limited to sensor location in hazardous areas only.

The major questions to be raised about the inspection procedures are:

- Is the Coast Guard determining and using the best means of detecting gas in void spaces?
- Is the Coast Guard developing inspection procedures which will allow them to adequately inspect the growing fleet of vessels which will soon include ships of several different designs, with different foreign flags and crews of different nationalities?
- Are the Coast Guard inspectors available in sufficient numbers with adequate training in hazardous materials?

To date, Coast Guard inspectors have had little specific training in LNG or other liquefied gases. However, a 3-week course in hazardous materials, including LNG, is being developed and is scheduled to begin this fall. The course is designed to train more than 100 Coast Guard personnel each year in inspection techniques for hazardous material carriers. However, the course is a voluntary one, and it is not clear that all personnel involved in regulation and inspection of LNG carriers will actually receive training. G

A detailed course outline had not been completed when this report was written, but it appeared from preliminary materials that appropriate subjects would be offered.

Crew Training

The Coast Guard has already proposed regulations setting out minimum standards for persons employed on U.S. flag LNG tankers. T But there appears to be disagreement over whether the Coast Guard has a mandate to propose similar standards for personnel on foreign flag ships entering U.S. harbors. To date, the Coast Guard has preferred to work internationally to develop those standards and is participating in Intergovernmental Maritime Consultative Organization (IMCO) sessions on the subject. ***It is open to question whether this approach ensures an adequate level of training and competence among foreign crews.***

This situation could be changed significantly by S.B. 682, the Tanker Safety Act of 1977. If passed, the act would mandate crew standards on all tankers entering U.S. ports, regardless of flag.

Conversation with officials of the U.S. Coast Guard, Washington, D. C., Aug. 12, 1977.

[7]U.S. Department of Transportation, U.S. Coast Guard, "Qualifications of the Person in Charge of Oil Transfer Operations," *Federal Register 42,* no. 79, Apr. 25, 1977, 21190-21200.

Several training programs, funded by shipping companies and unions, are in existence, but training at these schools is not required currently by any Federal agency.

One particular area of concern is training in the use of fire protection equipment. Experience has shown that serious accidents which involve tankers with flammable cargo almost always result in a fire. As the Ad-Hoc Maritime Committee of the AFL-CIO states, "hands-on type fire prevention, detection, extinguishment, and containment training presently available to professional seamen, is lacking in magnitude, depth and scope. . . . Repetitive retraining, at various Maritime Administration sponsored field schools, . . . is, at best, presently capable of exposing personnel only to historically employed evolutions that require no prethinking, equipment selection or command decision capability.'[8] In fact, fire or explosion currently accounts for 90 percent of the deaths and injuries in all tanker collisions. The tanker casualty rate did not show a decrease between the years 1970 and 1975. The actual number of collisions increased with the increase in traffic. g Analysis of 825 fires aboard U.S. Navy ships shows a similar trend.[10]

Thus, minimum requirements for crew training in the use of fire prevention and protection equipment should be a cornerstone of the Coast Guard safety efforts.

[8]Ad Hoc Committee, (AFL-CIO), *Fire* Protection, *Detection, Containment and Extinguishment Proposal* (n.p.: Ad Hoc Committee, (AFL-CIO), n.d.)

[9]U.S. Congress, Office of Technology Assessment, *Oil Transportation by Tankers: An Analysis of Marine Pollution and Safety Measures* (Washington, D. C.: U.S. Government Printing Office, July 1975), p. 36 and 57.

[10]George G. Sharp, Inc., *Patrol Frigate Machinery Space Fire Protection and Safety Hazards Study* (n.p.: George G. Sharp, Inc., December 1972).

Critical Review: Paper 3

REGULATION OF TERMINAL OPERATIONS

Standards for Terminals

The existing industry standard for production, storage, and handling of LNG in land-based terminals is the National Fire Protection Association (NFPA) 59A. These standards have been adopted by many State agencies as well as by OPSO, making them part of the Federal regulations for LNG terminals.

To date, many portions of baseload LNG import terminals appear to have been designed to much more stringent requirements than the minimum specifications set forth in 59A. Still, a strong case can be made for more stringent requirements in many areas, particularly those relating to public safety. Industry is opposed to promulgation of tougher standards unless the need is clearly demonstrated. This opposition is at least partly because of the fear that such standards would be retroactively applied to existing peak shaving and import facilities which would be difficult and costly to modify. On the other hand, some members of the public interest groups which cooperated in OTA's public participation program are calling for retroactive application of new standards with a gradual phasing out of any facilities which do not meet these standards.

The prospect for retroactive application of new requirements does now exist with the proposed standards recently published by OPSO. [1]

There are several areas in which the proposed standards are considerably more comprehensive than the NFPA 59A standard. These include definition of a thermal exclusion zone, vapor dispersion zone, and seismic design criteria. In may other respects, however, the proposed standards are less definitive than the existing specification. These areas include specifications for concrete materials, equipment spacing within the facility, valves, piping, and electrical equipment. Industry representatives have criticized the regulations as being overly stringent in defining thermal and vapor dispersion exclusion zones, specifying inappropriate estimating techniques for determining these exclusion zones.

There is also concern that the proposed regulations do not allow for the development and use of several alternative means of controlling vapor cloud generation in the event of a spill. The proposed regulations stipulate the use of a buffer zone (which could be as large as 3 to 7 miles depending on the size of the diked area around storage tanks)[2] or provisions for automatic ignition of a vapor cloud.

The use of automatic ignition during an LNG release may have an effect opposite of that desired in a fire protection system; it could result in cascading equipment failures and much greater damage than would be the case with other methods of control.

Ideally, the regulations should provide for developing technology which both protects the plant and enhances public safety. Some typical alternatives which have been proposed and large-scale tested are the use of high-expansion foam systems for direct control of impounded LNG spill fires, the use of high-expansion foam systems for reductions in the downwind travel of vapors from LNG on land, the use of fixed dry chemical systems for im-

[1] **U. S. Department of Transportation, Office of Pipeline Safety Operations, "Liquefied Natural Gas Facilities (LNG); Federal Safety Standards,"** *Federal Register 42,* **no. 77, Apr. 21, 1977, 20776-20800.**

[2] **Wesson & Associates, Inc.,** *Compilation of Data on Wesson & Associates, Inc., Key Personnel, Major Experiences in LNG Technology—Safety—Fire Protection, Industrial LNG Fire Training School and Comparison of NFPA No. 59A with the Proposed OPSO LNG Facility Federal Safety Regulations,* **(Norman, Okla.: Wesson & Associates, Inc., 1977.**

pounded spill fire extinguishment, and the use of certain types of fireproofing coatings for cryogenic and thermal protection of structural steels.

In general, LNG spill and fire research has resulted in the improvement of and application for commercial fire protection and damage control systems in LNG facilities. While it is generally conceded that these type facilities have excellent safety records and accident-free histories, they can still be improved. It was also generally agreed during the December 1976 ERDA LNG Workshop, that adequate fire protection equipment performance and design requirements have been experimentally established for definition of the hazard-control systems for typical operating and impounded LNG spill conditions. However, one expert estimates that only 30 percent of the existing peak shaving facilities have adequately designed and installed fire protection systems capable of controlling a major LNG spill condition.[3] Thus, attention to these issues and recognition of the hazard reduction capabilities of experimentally proven fire protection and safety systems both in the development of regulations and in allocations for research and development programs would be well justified.

Concern about firefighting ability extends beyond that of the LNG facility. There has been considerable public discussion of whether local fire departments near an LNG facility have the expertise and financial resources to prepare themselves for dealing with a possible LNG emergency.

Those who contributed to the public participation program had few suggestions for specific changes in terminal regulations. They did, however, desire that regulations be clearly defined and strictly enforced. Many suggested that regulations include requirements for training of personnel employed at the terminals and the preparation of evacuation plans for the areas near an LNG facility in the event of a major accident.

[3]Wesson & Associates, Inc.

Inspection of LNG Facilities

Once standards for construction and operation of LNG facilities are clarified, there will still remain the necessity to inspect facilities for compliance with regulations.

It appears that there are gaps in current inspection procedures which could cause problems in the future.

The Office of Pipeline Safety Operations (OPSO) has the responsibility for inspection of all pipelines and other facilities used in transportation or sale of natural gas in interstate commerce. ***However, the small size of the OPSO staff limits its ability to inspect facilities.*** In fact, OPSO has been described by industry managers as "almost invisible in the field." A The small staff also impairs OPSO's ability to participate in FPC hearings although compliance with OPSO regulations is one subject of the hearings.

The Secretary of Transportation is therefore authorized to enter into agreements with State agencies to take over inspection duties.[5] These agreements require that:

- the State must adopt at least minimum Federal safety standards; and
- the State must submit an annual certification that it has adopted such standards and is complying with a number of other more technical conditions.

The Office of Pipeline Safety Operations does not have these agreements with all States and the inspection mechanisms vary in the States which do participate.[6] This could result in uneven enforcement of regulations concerning LNG facilities. For this reason, ***it appears that guidelines for inspection and enforcement should be included in OPSO regulations along with standards for construction and operation of the facilities.***

[4]Interview with officials of Columbia Gas Corp., Cove Point, Md., June 8, 1977.

[5]Natural Gas Pipeline Safety Act of 1968, 49 U.S. C. §§ 1671 *et seq* (1970).

Conversation with staff of State Programs Division of the Office of Pipeline Safety Operations, Department of Transportation, Washington, D. C., Aug. 10, 1977.

Guidelines for training of inspectors, methods of inspection, and how often facilities should be inspected could raise public confidence, enhance safety of LNG plants, and ensure equitable enforcement practices.

There also appears to be a problem of inspecting facilities for compliance with stipulations which may be imposed by FPC when it issues a certificate of public convenience and necessity. In some recent FPC rulings, these stipulations have been quite complex and technical. ***At the present time, however, there is no mechanism for enforcing these orders.*** The FPC staff is insufficient for performing followup inspections on a routine basis. Inspections are performed only when, and if, the applicant applies for modifications to an existing facility.[7] ***Thus, the conditions of certification are considered more as good faith agreements with the company than a regulatory order.***

In addition, the FPC can and does require occasionally higher standards than those contained in existing OPSO regulations.[8] However, OPSO does not verify compliance with these higher requirements during its inspection of LNG facilities.[9]

It appears that inspection of facilities for compliance with all similar requirements—regardless of the source of the requirement—should be fixed with a single agency. Since most of the duty already falls to OPSO or its delegated State authority, it appears logical OPSO should be charged with this expanded task.

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[7]Interviews with staff of Federal Power Commission, Washington, D. C., May 31 and June 24, 1977.

[8]Interview with staff of Federal Power Commission, Washington, D. C., June 24, 1977.

Conversation with staff of State Programs Division of the U.S. Department of Transportation, Office of Pipeline Safety Operations, Washington, D. C., Aug. 10, 1977.

Critical Review: Paper 4

DECISIONMAKING PROCESS IN CERTIFICATION OF LNG PROJECTS

The Federal Power Commission (FPC) is the lead agency in determining whether or not each individual LNG import project is in the public interest and, therefore, will be allowed.

However, both the LNG industry and concerned members of the public have found the agency unresponsive to their needs. Most criticism leveled against the agency can be collected into four areas:

- lack of clearly enunciated Federal policy and jurisdiction on import matters;
- length of time required for approval process:
- financial difficulties inherent in the approval process; and
- lack of adequate information and opportunity for intelligent participation in the decisionmaking process.

Lack of Clear Policy and Jurisdiction

Historically, the FPC's role has been to regulate the entry of suppliers into the interstate natural gas market and to ensure that interstate sales take place at prices which are "just and reasonable."[1] Early on in the import of LNG, that caused a problem of jurisdiction which has not yet been completely resolved. For an import facility where the gas is to be sold interstate, there is little difficulty since FPC approval is required for both the importation and the construction/operation of facilities to handle the gas. However, where the imported gas is to be sold intrastate, there has been confusion as to whether the FPC could require that facilities meet Federal standards.

In ***1974,*** a U.S. Court of Appeals ruled that the FPC could require certain standards of the intrastate facilities if the Commission first made an affirmative finding that such standards were necessary to protect the public interest.[2] As a result of the court decision, the Distrigas terminal outside of Boston came under FPC jurisdiction. It now appears likely that such jurisdiction will include any other terminals which may sell imported gas only to an intrastate market.

Jurisdiction is also clouded in another area where ***there is a lack of guidelines for the division of responsibility among the FPC, OPSO, and the U.S. Coast Guard in promulgation and enforcement of safety and siting standards which an applicant must meet.*** Since the Coast Guard's role has been mostly to review applications and advise the FPC in areas of Coast Guard expertise, the more serious present conflict is with OPSO. There are two major questions involved in the conflict:

1) To what extent can the FPC require higher standards than those contained in OPSO regulations?

   The two agencies clashed directly on this point in the past. In a controversy involving the Chattanooga Gas Company, the FPC temporarily closed down an LNG peak shaving facility which OPSO had inspected and approved.[3] This led to an effort between the two agencies to develop a memorandum of understanding delineating responsibilities; however, so far this effort has not been successful.

2) Which agency—if either—shall establish siting criteria for the location of import terminals?

[1] 15 U.S.C. § 717 c(a) (1970).

[2] *Distrigas* Corporation v. *Federal Power Commission*, 495 F,2d 1057 (D.C. Cir. 1974).

[3] In the time since original FPC certification, a number of homes had been constructed on land which the FPC felt was dangerously near the storage tanks. The FPC required the company to purchase the adjoining land.

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OPSO has proposed new safety standards for LNG terminals which bear heavily on the selection of specific sites. The effort has surfaced two problems:

a) There appears to be a statutory prohibition against OPSO standards prescribing the location of LNG facilities; A and

b) The FPC has expressed concern that it has exclusive jurisdiction over site selection. The FPC has received a request by the attorneys general of several east coast States to begin rulemaking on uniform siting criteria and has asked for comments on this request; however, the outcome of this issue is far from certain.

Until these jurisdictional problems are decisively resolved, it is difficult, if not impossible, to plan facilities which can be approved.

The LNG industry has been particularly critical of the FPC in the realm of decisionmaking. One representative told OTA that the recurrent theme of industry's relationship with the FPC was "we can't follow the rules because we don't know what the rules are or will be.'[5]

One of the underlying problems which frustrates the FPC's decisionmaking duties and processes is the fact that it is a regulatory agency, not a policymaking body. The questions of import levels, pricing mechanisms, and siting criteria which the FPC must regularly consider are all pieces of basic energy and environmental policy issues which should be determined before individual project decisions are made. There are currently no national policies for LNG which could be used as a basis for consistent FPC decisions on these subjects. However, the policy void in which the FPC now operates may be filled by the new Department of Energy.

Under the Department of Energy Organization Act,[6] the FPC will be absorbed by a new five member Federal Energy Regulatory Commission, which will be a semiautonomous body in the Department of Energy.

In general, the change is an effort to strike a balance between maintaining independent regulation of energy and fitting such regulation into a policy framework which is responsive to the President. In part, the Act sets out the following:

- the Commission has jurisdiction over natural gas prices and the granting of certificates of public convenience and necessity;
- the Secretary of Energy has responsibility for regulating imports and exports of natural gas and for issuing certificates of public convenience and necessity for imports and exports;
- the Secretary has the authority to establish natural gas curtailment priorities, which are then implemented and enforced by the Commission; and
- the Secretary may act as an intervener in the Commission's proceedings and may set reasonable time limits for the completion by the Commission of its rulemaking proceedings.

Currently, the relationship between the Secretary's import approval and the Commission's certification function is unclear and needs to be clarified. ***On the positive side, however, the Secretary's authority over imports provides at least the institutional***

[4]Natural Gas Pipeline Safety Act of 1968, 49 U.S.C.§ 1671 (4) (1970). "Pipeline facilities includes . . . new and existing pipe right-of-way and any equipment facility, or building used in the transportation of gas or the treatment of gas during the course of transportation *but 'rights-of-way 'as used in this chapter does not authorize the Secretary (of Transportation) to prescribe the location or routing of any pipeline facility. "* (emphasis added).

[5]Interview with officials of Algonquin Gas Transmission Company in Boston, Mass., June 16, 1977.

[6]U. S. Congress, House, *Department of Energy Organization Act,* Conference Report 95-539 to Accompany S.826, 95th Congress, 1st session, 1977.

possibility that LNG decisions will be made in the framework of conscious policy choices concerning the role of LNG in the Nation's energy mix, the acceptable level of imports, the preferred supplier countries, and trade-ofls between LNG and alternative domestic and imported fuels.

This policy framework has been lacking in the present structure and is sorely needed.

Meanwhile, the FPC practice of making case-by-case decisions on such matters makes planning difficult for the LNG industry or by opponents of any particular project. There is another troublesome policy question: In recent decisions, the FPC has issued its approval contingent upon receipt of all State and local approvals.[7] These decisions raised concern among some industry representatives that the FPC was abdicating its authority to local politicians.[8]

The issue here is one of Federal preemption. What if the FPC authorized a particular project and State authorities refuse to allow it? The Natural Gas Act provides for condemnation of land for pipelines, but does not specifically mention terminal facilities. Case law on the subject is limited and the question has never been decided directly by the courts (see appendix C). There is, however, a close analogy in the FPC's jurisdiction over hydroelectric facilities. There, the courts have expressly held that Federal jurisdiction preempts that of State authorities. g The Commission's jurisdiction over hydroelectric facilities comes from a different statute than the Natural Gas Act, but there is probably an equally strong or stronger argument to be made in favor of Federal preemption in natural gas. The balance between State and Federal powers in one LNG peak shaving plant has been described by a U.S. Court of Appeals in the Hackensack Meadowlands case—"Although the States are not precluded from imposing reasonable restraints and restrictions on interstate commerce, and although the authority to enact zoning ordinances under the State's police power is clear. . . , it is equally settled that a State may not exercise that police power where the necessary effect would be to place a substantial burden on interstate commerce.'[10] However, the FPC's recent action in the Trunkline case clouds the matter considerably.

Another area of uncertainty is the question whether provisions of the Coastal Zone Management Act apply to the various permits which the Federal Government grants in connection with LNG. Under the Act, applicants for any Federal license or permit for an activity in the coastal zone of any State with an approved coastal zone program are required to certify that their proposed project is consistent with the State's program. The Federal Government is prohibited from issuing the license or permit until the State concurs or fails to act within 60 days or the Secretary of Commerce makes a finding that the proposed project is consistent with the overall objectives of the Coastal Zone Management Act.[11]

There are two problems in this procedure as it relates to LNG: First, it is not entirely clear what kinds of authorizations are covered by the terms "license or permit' and, therefore, ***it is unclear if FPC certificates of public convenience and necessity would be included.*** Second, another provision of the Coastal Zone Management Act states that the Act is not to modify laws applicable to Federal agencies.

The FPC has announced its intention of conducting a rulemaking on the Act, but has

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[7]Federal Power Commission, *Trunkline LNG Company and Trunkline Gas Company,* Opinion No. 796, Docket Nos. CP74- 138, CP74-139,CP74-140 (Washington, D. C.: Federal Power Commission, Apr. 29, 1977.)

[8]Interview with officials of Algonquin Gas Transmission Company in Boston, Mass., June 16, 1977.

[9]*Washington Department of Game v. FPC,* 207 F.2d 391 (9th Cir. 1953); *FPC v. Oregon,* 349 U.S. 435 (1955); *City of Tacoma v. Taxpayers of Tacoma,* 357 U.S. 320 (1957).

[10]*Transcontinental Gas Pipe Line Corp. v. Hackensack Meadowlands Development Commission,* 464 F. 2d 1358, 1362 (3d Cir. 1972), *cert. denied,* 409 U.S. 1118 (1973).

[11]16 U.S.C. §§ 1451 *et seq.* (Supp. 1974).

not yet taken a position on what procedure it will adopt.[12]

Time Required for Approval

To date, the first LNG import project approved, the El Paso I project at Cove Point, Md., required 49 months to gain final FPC certification. The recent *Trunkline* decision took 43 months; the *Pacific-Indonesia* decision, which is still subject to review, has taken 44 months. However, the FPC has adopted an accelerated schedule for the El Paso II project and anticipates that the procedures will require only 9 months. ***Meanwhile, the long process coupled with the uncertainties such as what type of pricing scheme will be imposed as a condition of the final certificate, make it difficult for U.S. firms to compete successfully with foreign countries which are capable of making faster decisions (figure 33).*** The problem, however, lies not only with the FPC, but in the fact that the decisionmaking process in private industry in which long-range commitments are made early on is not compatible with the lengthy, sometimes unpredictable, Government process.

For example, before an LNG company makes application for Federal permits, commitments have been made for an LNG supply from abroad, for acquisition of the land, and for construction of the tankers which will carry LNG to the United States.[13] It is not difficult to understand that such early commitments may not always be approved or be compatible with plans which are approved.

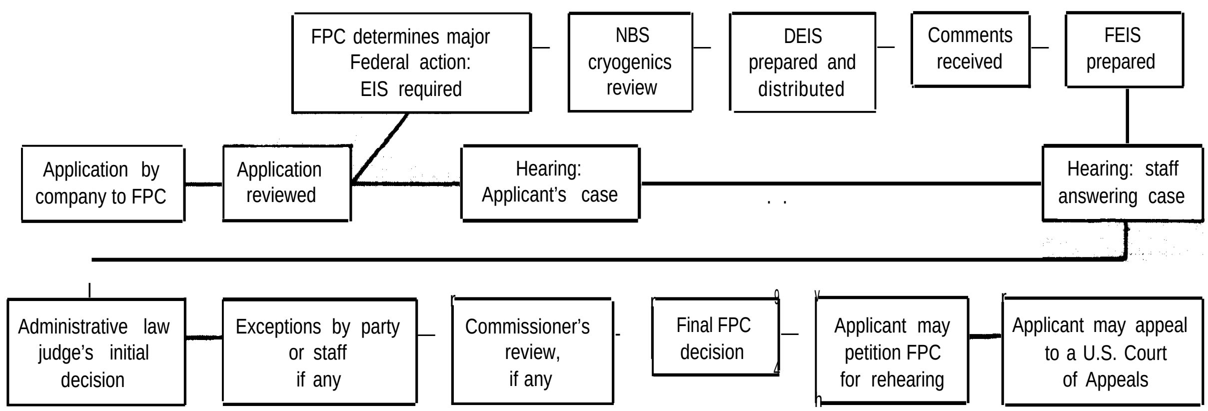
Much of the time used up by FPC is exhausted dealing with generic policy issues which could, and should, be decided in advance so that individual applications could move through a well-defined series of decision points. As noted earlier, there is the potential for considerable improvement in the time schedule for decisionmaking under the new Department of Energy.

Some citizens who joined in the OTA public participation program expressed concern that the United States could lose needed supplies of foreign gas if Government processes are not coordinated and expedited. However, others expressed concern that any attempt to streamline procedures may result in fewer opportunities for the public to be involved. There was strong support in all segments—the gas industry and related businesses, State and local governments, and public interest groups—for increased effort to make LNG approval procedures more open to those who are concerned.

[12] Interviews with FPC staff counsel, on May 31, 1977.

[13] Interviews with officials of Distrigas Inc., Boston, Mass., June 15, 1977.

Figure 33- Procedure for FPC Certificate of Public Convenience and Necessity



Source OTA.

Financial Diffiulties

The financial problems caused by the cumbersome approval procedure are on two levels: first, the lengthy process allows considerable cost escalation to occur resulting in a higher cost to the ultimate consumer; second, both the applicant and interveners who may oppose the applicant must invest considerable sums of money in the project prior to approval or rejection by the FPC.

The cost escalation which most routinely occurs is in the contract price paid to the supplier of the LNG. For example, in the case of the recently abandoned Eascogas project, contract price of the LNG rose form 44.75 cents per thousand cubic feet to $1.32 per thousand cubic feet as it was necessary to renegotiate the contracts during the 5 years in which the application was pending.[14]

In addition, industry claims a $5 million to $8 million investment in paperwork is necessary to get an import project moving through the approvals process.[15] These early costs are, of course, ultimately borne by the consumer.

The process is equally as expensive for members of the public who may wish to participate in the FPC process. In theory, the right to participate as an intervener at FPC proceedings is one of the most direct and effective public participation mechanisms in the executive branch. It is a formal opportunity for all interested parties to participate in the decisionmaking process. In actual practice, however, participation is limited to groups with sufficient finances and expertise to closely and continuously monitor FPC proceedings. This generally means that gas companies and State utility commissions are able to participate effectively, but other groups which are affected by FPC decisions, such as environmental and consumer groups, have not been able to participate extensively.

One of the major expenses facing groups which wish to participate as interveners is legal fees. Although representation by an attorney is not strictly required by Commission rules, the complexities of the quasi-judicial proceedings make a lawyer a practical necessity. Even at the reduced rates offered by public interest law firms, legal services for an average 20-day hearing would be approximately $25,000.16

Information and Opportunities for Participation

Adequate information about applications and FPC proceedings are necessary for effective participation in the decisionmaking process, However, the specialized nature of the subject and the quasi-judicial practices of FPC are a major deterrent to public involvement. Moreover, FPC, like most other Government agencies, relies on the *Federal Register* as its means of providing notice of applications and proceedings to the public. There is little, if any, effort to encourage participation from a broad range of groups which maybe interested in the proceedings or affected by the project.

In practice, the public input into OPSO and Coast Guard regulations appears to be less limited, and both agencies mail announcements to a list of interested parties in addition to publishing such announcements in the *Federal Register.* These actions are taken under the Administrative Procedure Act, and regulations which provide an opportunity for public hearings if the agencies deem them to be necessary.[17] Both OPSO and the Coast Guard also have technical advisory committees, although membership in these groups is generally limited to people with backgrounds in appropriate gas-related fields. Except for a subtask force of the Natural Gas Survey, the FPC has no advisory committee directly related to LNG.

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[14] Interview with officials of Algonquin Gas Transmission Company in Boston, Mass., June 16, 1977.

[15] Interview with officials of Algonquin Gas Transmission Company in Boston, Mass., June 16, 1977.

[16] Based on interview with an attorney in a public interest law firm. The figure includes 20 days of preparation and 20 days of hearings at a rate of $40 an hour plus other costs.

[17] 33 C.F.R. § 1.05 (1976) and 49 C.F.R. §§ 102.13, 102.15 (1975).

Critical Review: Paper 5

SAFETY RESEARCH ON LNG FACILITIES

Research to determine whether LNG facilities are safe for the public involves:

- postulating a "worst case" scenario;
- estimating the extent of a vapor cloud, which is a central key event of any LNG disaster scenario; and
- estimating the probability of other events occurring and their consequences (through fault tree and risk analysis).

Making sense of the LNG facility safety question requires examination of each of these subissues.

Scenarios

Postulating an LNG disaster scenario is clearly an almost limitless task. There are countless combinations of events which could lead to an accident. Of necessity, then, LNG safety researchers have simplified the task. It must be questioned, however, whether in the process of simplifying, important possibilities for faults have been overlooked, thereby leading to overly optimistic or pessimistic results. Since there has been little worldwide experience with shipping LNG, compared to the shipping of other cargoes, the historical record is scant and statistical evidence is limited. The creation of LNG disaster scenarios is, therefore, a somewhat subjective undertaking which is vulnerable to the biases of individual analysts.

The use of disaster scenarios to search for possible faults in a system is a useful analytical approach. ***But to infer, as most LNG safety reports do, however inadvertently, that all the important possibilities have been "covered" may be shortsighted.*** A review of the investigation of past disasters of other types shows how "failure paths' can be overlooked or summarily dismissed. This was true of NASA catastrophes, such as the death of three astronauts in the Apollo program, and of public works projects, such as the failure of the Teton Dam in Idaho.

Vapor Cloud Research

Researchers differ in their findings about the behavior of a LNG vapor cloud as it disperses into the atmosphere after a spill on water. From a safety perspective, the key issue is how far and how broadly a vapor cloud travels. Estimated distances vary from less than 1 mile to more than 50 miles.[1] Some have argued that these differences indicate the need for more investigation and more research.

However, combined past research is inconclusive because researchers use different initial assumptions about a spill, have different concepts about how the vapor cloud would behave, and different interpretations of data which is available. Further research could resolve only some of these differences.

DIFFERENT ASSUMPTIONS.-One of the reasons research results differ is that different weather conditions are assumed for the time of the spill. To some extent the meteorological research community has tried to standardize assumptions about weather conditions by using commonly accepted classifications of weather states. There are, however, several classification schemes in use.

Furthermore, some researchers use "worst case' (stable) weather conditions while others argue that such assumptions are pointless because an LNG tanker would not enter a harbor under these conditions because they only occur at night.

[1] U. S. Department of Transportation, U.S. Coast Guard, *Predictability of LNG Vapor Dispersion from Catastrophic Spills on Water: An Assessment* (Washington, D. C.: U.S. Department of Transportation, April 1977).

Further research will not resolve these types of differences in initial assumptions.

CONCEPTS.—Further research could however, minimize the differences in conceptual approaches used in LNG models.

For example, some researchers assume LNG is vaporizing from a single spot; others assume that the source is a line or an area. Some researchers visualize a vapor cloud as a continuous plume; others see it as a series of puffs. All of these different visualizations lead to different mathematical representations in the models and to different equations and results.

INTERPRETATION OF DATA.—Further experiments could also develop data which would help resolve differences in interpretation of raw data that is now available. For example, it has been shown that an LNG cloud is flammable only when the concentration of natural gas is between 5 and 15 percent.

Therefore, because there is a lack of data on large spills, researchers must make an educated guess about the maximum distance downwind a vapor cloud could still contain pockets of gas sufficiently concentrated to be flammable. This question bears directly on the issue of how far a plume must travel before it is unignitible. More data from further experiments could possibly answer this question with greater certainty than presently exists.

Most LNG researchers would like to see further experiments undertaken. ***But until there can be some agreement in the assumptions to be used in such experiments, and until there is some faith that the assumption are realistic, such investigations cannot be useful for public policymaking.***

Estimating the Risk to the Public

Fault-tree analysis and risk analysis have been applied successfully to equipment systems which have been in use over an extended period of time and for which there exists a firm data base of failure and repair records. In these situations, the techniques enable the risk analyst to determine with some confidence the probability that specific components will fail. In innovative situations, however, risk is less amendable to this kind of analysis.

One reliability/safety analyst with 11 years experience in the aerospace industry described in testimony before the FPC how, in the late 1950's, the aerospace industry was quite optimistic about risk-assessment methodology. But he points out:

> This optimism was soon dispelled by hundreds of cases of unexpected test and operational failures and thousands of system malfunctions. Many of the failures and malfunctions modes had either been previously analyzed and seemed to be noncredible events or had come as a complete surprise which previous analyses had not identified at all. By the early 1960's, it had become apparent that the traditional method of identifying potential failure events and assigning historical probabilities of occurrence to these events, as was done in the Little and Homer reports (Little was consultant to an LNG applicant before the FPC, Homer was a consultant to FPC) had consistently led to overly optimistic conclusions. Consequently, the failure rates were consistently underestimated. [2]

The risk assessment issue is also one of contention between the Department of Transportation agencies (U.S. Coast Guard and OPSO) and the FPC.

In his initial decision on the application by Pac Indonesia LNG Company and Western LNG Terminal Associates to import LNG to Oxnard, Calif., FPC Administrative Law Judge Samuel Gordon supported his opinion on LNG safety by citing the risk-assessment statistics of the applicants' consultant.

> The analysis shows that under the worst case, the highest fatality probability is one chance in 6.7 million per person per year within five-eighths of a mile of the site, decreasing to

[2] Federal Power Commission, Testimony of William Bryon before the Federal Power Commission in the application of Eascogas LNG, Inc., and Distrigas Corp., Docket Nos. CP73-47, and CP73-132, 1976.

> probabilities of one chance in 10 million per person per year or less within 1 mile of the site and to one chance in 1 billion to 10 billion per person per year or less beyond 3 miles of the site. The probability of one occurrence is 113,000 with a probability of one chance in 710 septendecillion (710 followed by 54 zeros) per years

In contrast, a DOT study on LNG took an opposite position regarding the applicability risk analysis:

> Several approaches may be taken in the analysis of potential system failures and the consequent risk. A statistical estimate of risk can be made if enough years of experience with the system are available. Unfortunately, the total operating experience of the LNG industry is not sufficient to demonstrate that risk levels are acceptably low on a purely statistical basis. For example, to assure that the risk of any fatality from an LNG facility is at a level of less than 10–5/year (equivalent to the risks associated with machinery) would require a statistical data base of about 500,000 plant-years of operation without major accident causing a fatality beyond the plant boundaries. Even with major growth in the LNG industry, experience accumulated through the next decade will be about two orders of magnitude below that required to assure a risk level of 1^{-5} fatality/year by statistical data. Therefore, a statistical approach is not sufficient to quantify LNG facility risks.[4]

Accordingly, OPSO and the Coast Guard do not use risk analysis in consideration of LNG operations.

It appears that fault-tree analysis and risk analysis are useful management techniques to identify "trouble spots' in a complex system so that preventive measures can be taken (figure 34). It is also useful for comparing one kind of a risk against another where a choice is to be made between types of equipment or procedures. Even in these applications however, a reliable data base and historical record of performance are important. ***As presently applied by the FPC, the use of fault-tree analysis and risk analysis to determine whether LNG facilities are safe is most questionable; worst of all such inappropriate use of the research techniques leads to a false sense of knowledge about the possible risks.***

Value of Further Research

Research on the behavior of LNG spills and the possible consequences of spill accidents has been conducted over the past 10 years by various Federal agencies and private industry groups. Recent Federal efforts have been primarily sponsored by the Coast Guard who have an annual budget of about $1 million designated for LNG safety researches These efforts have included experiments and analyses on many of the same subjects that are now being suggested by ERDA for much expanded research programs, ie: LNG vapor generation and dispersion; fire prediction and control; and, explosive characteristics. G

The most recent spill tests have been conducted at the Naval Weapons Center at China Lake, Calif., and have been jointly sponsored by the American Gas Association (AGA). T These have included vapor-cloud ignition tests, pool-ignition tests, and explosion tests. The vapor and pool ignition tests have resulted in data on evaporation rates, downwind vapor concentration, flame propagation, and radiation characteristics. The explosion tests have been exploring the applicability of such theories as dynamic self-mixing, which has been applied to recent weapons development and has been used to explain large variations in the energy yield from volcanic

[3] Federal Power commission, *Initial Decision Of Administrative Law Judge Samuel Gordon on Application of Pacific Indonesia LNG Company and Western LNG Terminal Associates*, Docket Nos. CP74-207 and CP75-83, Washington, D. C., July 22, 1977, p. 118-119.

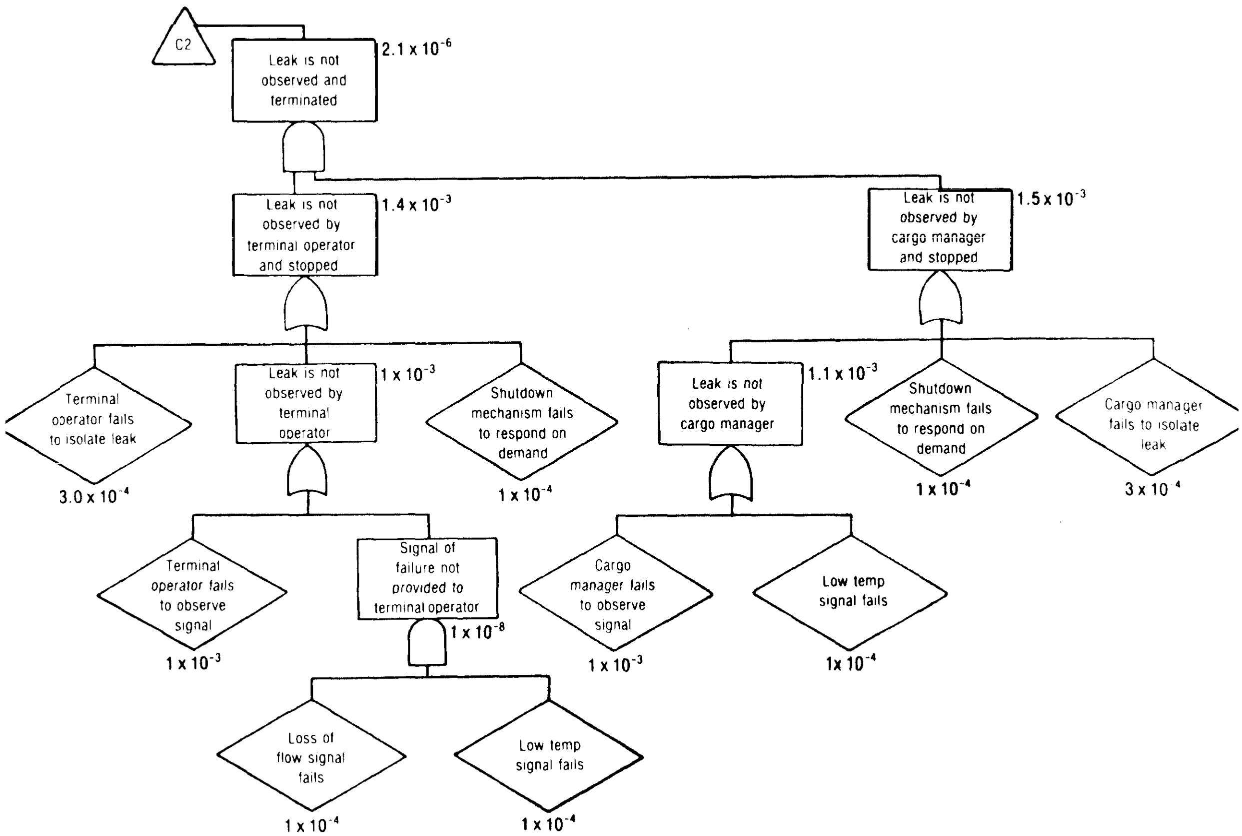
[4] Arthur D. Little, Inc., *Technology and Current practices for Processing, Transferring and Storing Liquefied Natural Gas*, (Cambridge, Mass.: Arthur D. Little, Inc., December 1974).

[5] Conversation with staff of U.S. Coast Guard, Washington, D. C., Mar. 18, 1977.

[6] *Summary of Workshop Recommendations on LNG Safety and Control* (n.p.: Energy Research and Development Administration, Dec. 15-16, 1976).

[7] R.V. DeVore and L.A. Sarkes, *LNG Research Programs* (n.p.: American Gas Association, Jan. 3, 1977).

Figure 34. Typical Fault Tree for Leak Which Is Not Isolated



Source Western LNG Terminal Co

explosions. If such theories do apply, it is considered possible that an unconfined LNG vapor cloud could be detonated. However, in all tests to date, no detonation of LNG clouds has been accomplished and efforts to detonate using explosive triggers have resulted in ignition and burning of the cloud but not explosion.

Some researchers believe that further tests are necessary to demonstrate that an unconfined LNG cloud will not detonate.

At the present time, the Energy Research and Development Administration is tentatively planning to conduct and study over a period of more than 5 years several major spills of LNG. The project is expected to cost about $50 million, making it the largest LNG research program ever undertaken. The research design is still in the formative stages and it has not yet been determined how many experiments will be conducted, how large they will be, and whether they will be on land or water.

There are three critical questions about this proposed research and any large-scale, long-range research which may be considered:

- FEASIBILITY: Is it possible to economically and safely transport large quantities of LNG to a test site, to set up reliable monitoring equipment, and generally to set off a large LNG fire which is both measurable and safe?

- VALIDITY: How valid will the results be from just one experiment or a small series of experiments? Unless a large enough number of spills are conducted, the arguments resulting from interpretation of a data base which is inadequate will continue.
- TIMELINESS: How timely will the results of this research be 5 or more years from now? How many significant LNG policy decisions will still remain to be resolved?

Past research has produced conflicting results and predictions, and it is unlikely that the United States can afford the time and money to conduct enough research to resolve the differences and come to firm decisions about the safety and behavior of LNG. ***For this reason, decisions about LNG systems should be made on the basis of nonquantitative approaches which result in prudent siting criteria and strict design, construction and operation standards.*** Existing research techniques should be used to identify potentially dangerous elements in the overall system so that specific research can be undertaken to find ways of improving the safety of those elements.

Many of these specific types of research were called for by those who joined the OTA public participation program during the LNG assessment. These suggestions included:

- site planning research to develop a nationwide siting plan and establish specific siting criteria;
- an independent detailed analysis of the LNG system to specifically identify the safety issues involved;
- further investigation to determine the most efficient methods of handling LNG fires, to assess the possible impacts of such fires, and to establish procedures for coordinating and mobilizing local fire-fighting efforts and evacuating neighboring areas;
- a study of the capabilities and equipment of agencies responsible for inspection of LNG tankers and facilities; and
- an analysis of the decisionmaking process for LNG project applications so that better procedures can be established to guarantee that the public will be able to express its concerns about the safety of facilities.

Critical Review: Paper 6

LNG FACILITY SITING

One of the most controversial aspects related to LNG is the location of major import terminals, storage facilities, and regasification plants.

Siting is closely related to safety or to the public's perception of the safety of facilities. Environmental, land-use, and aesthetic considerations are also important.

There is currently no operating experience with major baseload import terminals in the United States and only limited experience in LNG shipping throughout the world. Researchers, therefore, do not have sufficient data on which to predict with any degree of accuracy the likelihood that a major LNG spill will occur, how the spilled liquid and resulting vapors will behave, and what would be the impacts of a spill. Since little is known, some citizens are fighting LNG facilities and have urged that the facilities, if needed at all, be located at the sites which are remote from dense population centers.

The principal questions of the siting controversy are:

- Who should establish siting criteria?
- What criteria should be considered in approving an LNG site?
- What is a "remote site?"

Who should establish siting criteria?

Site selection is currently undertaken solely by the company or consortium proposing an LNG import project for approval. The considerations which lead to a final selection are technical and economic ones. The Federal Government's role is strictly reactive, in that it can approve or disapprove sites proposed by industry but does not tell industry in advance where it may or may not locate.

In addition, the Federal process is not designed to encourage local participation in consideration of industry's proposed site. The lack of such participation has been identified as a serious concern of most of the public interest groups contacted during this study.

The lack of any standards, which proposed sites must meet, has led many groups to suggest that specific siting criteria be established. It seems possible either that a standard site screening process could be established by the Federal Government or that a set of uniform siting criteria could be developed.

There are differing views on the advisability of establishing such criteria on a Federal level: The American Gas Association has stated that each site is unique and must be treated on its own merits, while some representatives of public interest groups have stated that a national LNG siting policy is needed to address safety and siting concerns.

During OTA's public participation program, the one concern most often voiced about siting criteria was that the public should be involved to the maximum extent possible in establishing such criteria. Groups also said they felt more public participation would be necessary in permit processes or decisionmaking procedures set in place by adoption of siting criteria.

Currently, three Federal agencies have some bearing on site selection: FPC, OPSO, and the Coast Guard.

- ***The FPC, which ultimately approves or disapproves a site, was asked by a group of Eastern States in May 1976, to establish siting criteria, but so far has taken no such action.***
- The Office of Pipeline Safety Operations, which is responsible for the safety of facilities and pipelines involved in interstate transportation of natural gas, has proposed regulations which will impact on site selection primarily by mandating the size of a buffer zone to protect sur-

rounding areas from the heat of a fire at the storage tanks and from the vapor cloud which might form as a, result of a tank rupture.[1]

Since the LNG terminal operator would have little control over property utilization outside his own property line, the result of the OPSO proposals is to require that the terminal and storage tanks be located on a large piece of property owned by the LNG company. Under the proposed regulations, a thermal exclusion zone would require that storage tank dikes be about one-half mile away from humans in any public area. In addition, there is a requirement for a vapor dispersion zone, which is the area necessary for vapor from an instantaneous spill of an LNG tank to dissipate to the point where gas concentration in the cloud is less than 2 percent. Depending on the size of the LNG tanks and the design of the dikes surrounding them, that area could range from 1,000 to 12,000 acres under the proposed regulations. z The alternative offered in the proposed regulations is a redundant automatic ignition system, which would set a spill afire and contain the heat in the one-half mile thermal exclusion zone.

- The Coast Guard has an indirect influence on site selection by exercising its a) responsibility to determine if ships will be permitted access to a proposed site, and b) its responsibility to advise all concerned parties of operational constraints and safety criteria which would be applied to the marine portions of the project if it is approved.

The Coast Guard assessment of marine transportation and safety aspects of a proposed project is made informally, either at the request of an applicant before FPC proceedings begin or in response to the environmental impact statement prepared by the FPC. The analysis considers such things as the depth and width of the channels to be used by LNG ships, the necessity of dredging, the adequacy of surveys and charts, and the density and location of other waterborne activity. ***However, the Coast Guard has no specific criteria to use in evaluating each of these areas or specific standards which proposed sites must meet.*** [3]

Obviously, if there are to be Federal siting criteria, the expertise of these three Federal agencies should be combined and a single set of regulations formulated. However, it is not clear that these criteria should, in fact, be set at the Federal level. The selection of acceptable sites for LNG facilities will involve many tradeoffs between environmental preservation, economics, and safety which can possibly best be made at the State and local level.

One possible mechanism for combining local preferences with the national interest is already in place. That is the Coastal Zone Management Act. The Act charges coastal States with formulating land-use and siting plans for coastal areas in exchange for Federal funds for planning, implementation, and impact compensation. It requires that facilities which require Federal licenses and permits comply with the State plan unless specifically exempted by the Secretary of Commerce. [4]

While the Act itself is still the center of some controversy and has yet to prove itself as a management tool, the Act could provide a framework in which to consider sites for LNG terminals and other energy facilities.

What criteria should be considered?

Distance and population density should not be the only criteria for siting LNG facilities. Many other factors also affect the safety and

[1] U. S. Department of Transportation, Office of Pipeline Safety Operations, "Liquefied Natural Gas Facilities (LNG); Federal Safety Standards," *Federal Register 42,* no. 77, Apr. 21, 1977, 20776-20800.

[2] Wesson & Associates, Inc., *Compilation of Data on Wesson & Associates, Inc. Key Personnel, Major Experiences in LNG Technology—Safety—Fire Protection, Industrial LNG Fire Training School and Comparison of NFPA No. 59A with the Proposed OPSO LNG Facility Federal Safety Regulations,* (Norman, Okla.: Wesson & Associates, Inc., 1977.

[3] Conversation with staff of U.S. Coast Guard, Washington, D. C., Aug. 15, 1977.

[4] *Coastal Zone Management Act of 1972, 16* U.S.C.§§ 1461 *et seq* (Supp. 1972).

acceptability of a site, and it is possible that in some aspects, such as availability of firefighting equipment, nearness to distribution lines, and ease of access, remote siting may be a drawback,

One list of such factors is included in an alternative site study conducted for the FPC during preparation of the environmental impact statement for the Tenneco Atlantic Pipeline Company (TAPCO) application to build a 495-mile pipeline to New York from an LNG terminal in New Brunswick.[5] In this study, a large section of the northeast coast was screened for oceanographic, bathymetric, navigational, and land-use conditions which would identify potential LNG terminal sites. The potential sites were then evaluated in relation to other land uses, other shipping activities, safety, the consequences of accidents, the possibility of system outages, environmental impact, and economic cost.

If the Federal Government were to establish siting criteria, an approach in three parts would probably be desirable. The first would cover very minimum standards that every site of a certain capacity would have to meet, the second would involve national strategic planning, and the third would be specific site evaluation based on established guidelines.

Minimum standards could cover:

1) Property dimension and distance from storage tanks or ship terminals to property lines;
2) Conditions of harbor entrances, shipping channels, turning basins, anchorages, and tanker berths;
3) Relations to other marine and land-use activities in the region, including impacts on natural resource values; and
4) Presence of unusual hazards or related hazardous operations in the region.

[5] Resource Planning Associates, Inc., *Alternative Site Study, Northeast Coast Liquefied Natural Gas Conversion Facility* (Cambridge, Mass.: Resource Planning Associates, July 1977).

The Federal Government could prepare national plans for future LNG import projects based on:

1) the existing gas pipeline networks and projected demand;
2) the projected domestic supply of gas to these pipelines; and
3) the possible foreign countries with excess gas to export.

In this way an accurate number of future projects could be forecasted. The American Gas Association has stated that less than 10 additional LNG import terminals will be required, but logical locations and relative needs for these terminals have not been established. Following a national plan, evaluation of various possible sites or projects could be established utilizing guidelines covering such items as:

1) Location of sites relative to dense population centers and other land-use conflicts with terminal activities and consideration of specific safety hazards.
2) Location of terminal relative to other ship traffic and existence of special traffic control.
3) Local benefits of the specific industry base and possible satellite development.
4) Possible degradation of natural areas or residential areas due to establishing added industrial activities,
5) Location of populated areas exposed to specific accident scenario at a terminal.
6) Presence of specific external factors which may lead to accidents such as severe weather, active seismic zones, nearby airports, etc.
7) Availability of equipment and methods to control effects of accidents, such as firefighting equipment and emergency contingency planning.
8) Use of accident-prevention measures such as monitoring and inspection of facilities or operation, training of personnel, and control of shipping traffic.

A number of citizen groups say that offshore LNG terminals may be preferable from the standpoint of safety and land-use issues.

Technology for offshore LNG terminals, particularly mooring systems, transfer systems, cryogenic pipelines, and large storage tanks requires more detailed evaluation and development. Standards for this technology are not developed and the environmental, economic, and technical tradeoffs have not been evaluated. ***Offshore systems need detailed technical analysis and testing before they can be considered viable alternatives to onshore sites.***

What is remote?

Remote is not a definitive term; and even those who argue for remote siting of LNG facilities disagree on what they mean by the term. It generally implies a combination of distance and low-population density.

The unresolved question of what distance from population centers would be acceptable is related to the unresolved questions of how far and how fast an LNG vapor cloud from a major spill would disperse and what would happen if the cloud were ignited.

Research models have made a variety of predictions for the distance the cloud would travel following the largest possible spill on water and assuming the vapors would not ignite initially. The predictions ranging from 1 mile to more than 50 miles (figure 35).

An equally wide variety of distances have been suggested by parties interested in the LNG siting issue, suggesting that facilities be located between 1 to 25 miles away from populated areas.

There are currently no Federal requirements for remote siting, but proposed OPSO regulations could, if adopted in present form, make it necessary that some facilities be as much as 7 miles from populated areas.[6]

One piece of legislation which appears to define "remote" is the proposed California Siting Act. It specifies that an LNG site meet the following criteria:

- Within a radius of 1 mile of the site and the area within which maintenance and operation of the facility will occur, no person resides or works, other than persons who would be employed at the facility or at associated facilities that make substantial use of byproducts of LNG processing, such as facilities that utilize waste cold.

Figure 35. Distances a Vapor Cloud May Travel

Maximum Downwind Distance to 5 Percent Concentration Level Following 25,000 Cubic Meter Instantaneous Spill Of LNG onfo Water

Model	Distance (Miles)
U S Bureau of Mines	252-50.3*
American Petroleum Institute	5 2
Cabot Corporation	11.5
U S Coast Guard CHRIS	16.3**
Professor James Fay	17 4**
Federal Power Commission	075
Science Applications, Inc	1.2***

Note Assumes 5 mph wind except as noted and meteorological conditions considered applicable by investigating groups

● A range was presented to indicate uncertainty in vapor evolution rate

● *Wind velocity not considered explicitly m model

••● For 37,500 cubic meter instantaneous release, wind velocity = 6.7mph

Source U S Coast Guard

6Wesson & Associates, Inc., *Compilation of Data on* ***Wesson*** *& Associates, Inc., Key Personnel, Major Experiences in* ***LNG Technology—Safety—Fire*** *Protection, Industrial* ***LNG*** *Fire Training School and Comparison of NFPA No. 59A with the Proposed* ***OPSO LNG*** *Facility Federal Safety Regulations,* **(Norman, Okla.: Wesson & Associates, Inc., 1977.**

- Within a radius of 6 miles of the site and the area within which maintenance and operation of the facility will occur, there exists no residential or working, or both population that exceeds 60 persons occupying an area of 1 square mile, excluding persons who would be employed at the facility or such associated facilities.

- The site is so located that no ship transporting LNG will pass within the radial distances specified in the section at any time.[7]

Although "remoteness' (distance and population) is the siting criteria most often publicly mentioned it is not the only factor which should be considered, as has been discussed in the preceding pages.

[7]California *Assembly, Siting of Liquefied Natural Gas Facilities, No. AB220, 1977-78* **Regular Session, Jan. 17, 1977**.

Critical Review: Paper 7

LIABILITY FOR LNG ACCIDENTS

The liability issue is extremely complicated and the law concerning it is far from clear. ***It seems possible, however, that the most serious form of LNG accident, a ship accident, could leave injured parties with little or no effective compensation.*** Preliminary investigations indicate that the liability question is clouded by three areas of uncertainty:

- the extent to which maritime law would govern various possible accidents;
- the uncertainty within the maritime area as to how far the States can go in exercising jurisdiction concurrently with the Federal Government; and
- the variety of State laws that would apply in instances where nonmaritime law applies.

This is not to say that compensation for damage done in an LNG accident would definitely not be forthcoming; however, that possibility does exist. Therefore, this is an excellent area for more indepth analysis.

Maritime law

The most commonly discussed LNG accident scenario starts with a ship collision, and maritime law is, therefore, called into play. The most important consequences of maritime law is that, under the Shipowner's Limitation of Liability Act, a vessel owner's liability for "any act, matter, or thing, loss, damage, or forfeiture, done, occasioned or incurred, without the privity or knowledge of such owner' is limited to the value of the vessel after the accidental An exception is made for loss of life or bodily injury, in which case liability is limited to $60 per ton of the vessel.[2] The judicial construction of the terms "privity or knowledge' has been expanded so as to limit the number of petitions for limitation which are successful; nevertheless, the law remains on the books.

A difficult question would be posed if a fire originated onboard an LNG ship and spread to a surrounding harbor (or a vapor cloud from the ship spread over the nearby land area and subsequently ignites). That is: would the Limitation of Liability Act apply, since the accident originated with the ship? Another provision of the shipping laws, the Admiralty Extension Act of 1948, seems to indicate that it would, in that admiralty jurisdiction is to extend to all injuries "caused by a vessel . . . notwithstanding that such damage or injury be done or consummated on land."[3]

Since this Act was passed in 1948,4 it is doubtful that Congress had in mind the potential disasters which could conceivably be caused by LNG vessels. Furthermore, the charterer of a vessel may be deemed to be the owner in certain specific cases and thus reap the same benefits of liability limitation.[5]

The situation is further complicated by the complex patterns of vessel ownership which have evolved in the past 30 years. It is customary for a vessel to be owned by a special corporation which has no other assets besides that vessel (i.e., if a fleet owner has six ships, each one will be "owned' by a separate corporation). Although in maritime law a claimant can attach a vessel until all claims relating to it are settled (presumably bringing forth the true owners), in the case of an accident where the ship is lost there is obviously nothing to attach. Furthermore, the corporate-shell device frustrates any action against the owner, since without the ship the owner-

[1] 46 U.S.C. § 183 (a) (1970).
[2] Ibid. § 183 (b).

[3] 46 U.S.C. § 740 (1970).
[4] Grant Gilmore and Charles L. Black, Jr., *The Law of the Admiralty,* 2d ed. (Minneola, N. Y.: Foundation Press, Inc., 1975), p. 523.
[5] If the charterer "Mans, victuals, and navigates such vessel at his own expense' he is deemed to be the owner for liability purposes. 46 U.S.C. § 186 (1970).

corporation has no assets beyond its insurance coverage and any judgment against it would be correspondingly limited.

State versus Federal jurisdiction

To complicate matters still further, there has been considerable confusion recently as to the extent to which the States may exercise jurisdiction concurrently with the Federal Government regarding maritime activities. A 1973 Supreme Court decision refused to strike down as unconstitutional a Florida statute which set stricter State liability limits than Federal law for oil spills from tankers,[6] and a Washington law banning supertankers from Puget Sound will be reviewed by the Supreme Court during the fall term of 1977.[7] State-Federal jurisdiction in the maritime area is therefore in a state of flux.

Since New York already has an LNG bill which could be interpreted as providing for strict liability for LNG tanker owners for any accident occurring in port,[8] and California is currently working on an LNG bill, the ambiguity of State-Federal jurisdiction in the maritime area may come to plague LNG as well as oil.

Land-based liability

It seems relatively clear that if an accident which did not involve a ship occurred at an LNG terminal the law of the State in which the terminal was located would govern the terminal owner's liability. The key legal problem is whether there would be strict liability or whether a showing of negligence would be required. At least one State, New York, has adopted a statute for LNG which provided for strict liability, and this is an area where Congress could legislate, based on its powers over interstate and foreign commerce.

In the absence of statute, case law would govern. At a cursory look, there would not appear to be any uniformly applied analogy to LNG; there are cases where the storage of flammable liquids in proximity to population or property has been held to be an abnormally dangerous activity requiring strict liability, while the same activity in a wilderness or less obviously dangerous setting has not required such liability.[9] A more definite statement on land-based liability would require a closer look at the law in each of the States concerned. However, even where gas companies have liability insurance such insurance comes into play only after the company's liability has been proven.

Staff Working Paper No. 1

In November 1976, Senate Commerce Committee staff prepared a draft bill on LNG, Staff Working Paper No.1.[10] In addition to providing for an LNG damages fund to help pay compensation in the event of an LNG accident, the draft bill also provided for strict liability for both terminal and vessel owners and operators up to a specified dollar amount.[11] The fund would be used to pay for claims which exceeded the set liability limits.

The American Gas Association (AGA) supported the LNG damages fund in principle, although it considered the version in the draft bill "impractical." Strict liability was opposed by AGA, viewing it as "not consistent with the risks of LNG operations."[12]

Representatives from both the gas industry and public interest groups which joined

[6] *Askew v. The American Waterways Operators, Inc.,* 411 U.S. 325 (1973).

[7] Ray v. Atlantic Richfield Company, No. 76-930, as reported in the New *York Times,* Mar, 1, 1977, p. 16.

[8] Telephone interview with staff of New York State Assembly Services, Aug. 15, 1977.

[9] William L. Presser, *Handbook of the Law of Forts,* 4th cd., (St. Paul, Minn.,: West Publishing Co., 1971).

[10] Staff Working Paper No. 1, Nov. 12, 1976.

[11] In the case of vessels, $75 million or $1,000 per ton, whichever is less; in the case of terminals, an upper limit of $100 million.

[12] Letter from AGA president George H. Lawrence to Sen. Warren G. Magnuson, Feb. 2, 1977.

in OTA public participation program cited liability as a serious problem. Many said that terminal owners cannot buy liability insurance beyond $100 million and saw a need for either a liability fund financed by a tax on LNG sales or for legislation which provides for coverage of possible disasters such as that now in effect for nuclear powerplants.

Some members of the LNG industry have stressed that LNG systems should not be treated any differently in matters of liability and insurance than traditional commercial activities, especially shipping activities. And, in fact, the problems of liability and insurance dealing with LNG accidents are not greatly different than the problems of liability for nuclear accidents, large oil spills, or other catastrophic accidents. However, since many of these areas have already been the subject of public and congressional concern and debate which have not yet resulted in legislation (see appendix E), it may be desirable to consider all possible catastrophic accidents as a class and consider liability and insurance problems for the entire class, rather than for individual members of the class.

Critical Review: Paper 8

RELIABILITY OF LNG SUPPLY

In a decade in which the United States has suffered from an embargo on petroleum and a four-fold increase in crude oil prices, importation of any fuel raises legitimate questions about the reliability of the energy supply. Algeria, a member of OPEC, is currently the sole supplier of LNG imports to the United States. Indonesia, the next likely supplier, is also an OPEC member. Thus, reliability of these supplies and the results of a possible curtailment should be considered.

However, it is not likely that these two nations will remain the only sources of LNG. Several other countries also control major portions of the world natural gas reserves and may market LNG in the United States. These possible future suppliers include Chile, Nigeria, Colombia, the U. S. S. R., Iran, China, and Australia.[1] Any contracts with these other nations would, of course, provide greater diversity of supply and would minimize the potential for, and the impacts of, a disruption in LNG trade.

Reliability of suppliers

1n 1976, the Energy Resources Council (ERC) sponsored an interagency task force on LNG. One subject examined was the security of supply question. On the basis of a review conducted by the Department of State the ERC recommended that total imports of LNG be limited to 2 trillion cubic feet per year, and imports from any one country be limited to 1 trillion cubic feet per year.[2] The Carter Administration, however, changed the recommendations, adopting instead a more flexible posture that set no upper limit on LNG imports. Under the new procedure, the Federal Government would review each application to import LNG with regard to the reliability of the selling country, the degree of U.S. dependence such sales would create, the safety conditions associated with any specific installation, and all costs involved.[3] The new procedure also seeks to ensure that imports are distributed throughout the country, in an effort to limit regional dependence.

Any discussion of U.S. economic vulnerability to an LNG embargo should take the following factors into account:

1) IMPORTANCE.—Imported LNG currently accounts for only one-twentieth of 1 percent of the natural gas consumed in this country. In the future, however, that percentage may rise to as much as 15 percent.

2) SUPPLIERS.—The two major foreign suppliers of LNG, in the near term, will be Algeria and 1ndonesia.

Relations with Algeria over the past decade can best be characterized as strained but improving. As a result of the 1967 Middle East War and U.S. support of Israel, diplomatic relations between the United States and Algeria were severed. Algeria participated in the 1973 oil embargo organized by the Arab members of OPEC, but did not stop deliveries of LNG at that time. Since 1973, however, diplomatic relations have been restored and trade between the two countries has been increasing. The question remains whether Algeria would curtail exports of LNG to the United States as a result of future conflict in the Middle East or other political crisis.

United States gas company spokesmen are quick to point out two factors mitigating against a cutoff. First, Algeria itself has in-

[1] Dean Hale, "LNG Report," *Pipeline and Gas Journal* 204 (June 1977): p. 20.

[2] Executive Office of the President, *The National Energy Plan* (Washington, D. C.: U.S. Government Printing Office, 1977), p. 57.

[3] Executive Office of the President, *The National Energy Plan* (Washington, D. C.: U.S. Government Printing Office, 1977), p. 57.

vested large sums of money in gas production and liquefaction facilities and has borrowed heavily to finance these investments. Any overall supply cutoff would jeopardize Algeria's ability to repay these loans and its efforts to channel LNG revenues to internal economic development. Second, the gas industry claims to have had good experience in dealing with the country.

It seems fairly certain that an embargo would be imposed only in a time of crisis. Therefore, since the entire point of an embargo is to exert the maximum possible economic pressure in order to achieve political goals, Algeria's economic self-interest could be a minor factor in the debate on whether to embargo LNG supplies to the United States. This is not to say that Algeria will impose an LNG embargo in the event of any future Middle East crisis, It does mean, however, that ***a politically motivated disruption of LNG supplies is at least plausible and should not be dismissed quite as lightly as some LNG proponents have argued.***

Relations between the United States and Indonesia have, on balance, been good. Indonesia is a member of OPEC and has been a strong supporter of higher oil prices, but it did not participate in the 1973 embargo and does not advocate using oil as a political weapon.[4]

The State Department views U.S. relations with Indonesia as extremely good at the present time.[5]

There has been considerable concern among the international financial community in the last 2 years over Indonesia's foreign debt and financial problems within its State oil and gas company. This might limit Export-Import Bank credit to Indonesia for LNG facilities.

3) SUBSTITUTES,—In normal circumstances, petroleum, coal, and nuclear energy are alternatives to natural gas. However, as the natural gas shortage during the winter of 1976–77 demonstrated, conversion to these substitutes-even if they are availabl--cannot be undertaken rapidly and severe dislocations can result.

4) FEASIBILITY OF CARTEL ACTION.—This is not the question of whether a given country or group of countries might attempt cartel action, but rather the question of whether such an attempt is likely to be successful. There are four major conditions which a cartel must meet if it is to exercise sustained influence over international trade for a given material:[6]

- the concentration of exports among a few countries;
- inelastic demand for the material;
- inelastic supply of the material (or of close substitutes) from sources outside the cartel; and
- policy cohesion and export discipline among members to keep supply limited enough to maintain high prices or possibly to achieve other goals as well. Members of the cartel must be strong enough financially to accumulate stocks and forego current export earnings.

Liquefied natural gas is somewhat difficult to analyze along these lines. Trade in LNG is such that it meets all four of these conditions. In addition, since the present and likely future suppliers of LNG are OPEC members, the framework for concerted action is already in place.

However, there is one aspect of LNG which argues strongly against the probability of an embargo. That is, unlike oil or other products which can be delivered to a customer almost anywhere, LNG requires highly specialized and very expensive processing and handling equipment. The long leadtime required—3 to

[4]Robert F. Ichord, "Indonesi a,' in Gerard J. Mangone, cd., *Energy Policies of the World, v. 2: Indonesia, The North Sea Countries, The Soviet Union (New* York: Elseview, 1977), p. 68.

[5]Department of State, *Background Notes." Indonesia* (Washington: Department of State, July 1974), p. 7.

[6]Edward R. Fried, "International Trade in Raw Materials: Myths and Realities," *Science* 191 (Feb. 20, 1976): 641-646.

4 years to construct LNG facilities—fairly well limits the number of customers to whom a supplier can sell. The limited number of customers who can receive LNG shipments makes the supplier almost as dependent upon uninterrupted service as the receiver.

Impacts of an interruption in supply

Based on OTA's work, it does not appear that there is, at present, any serious threat to the national economy from dependence on imported LNG, nor is there likely to be a danger in the near future. However, regional or local dependence on LNG supplies could cause some problems.

It appears that about eight States could be dependent on LNG for a large part of their natural gas supplies by 1985 if currently planned import projects go into operation. These States are:

Alabama	New York
California	Ohio
Georgia	Pennsylvania
Michigan	South Carolina

These States stand to benefit directly from imported LNG; therefore, they also are the most vulnerable to any interruption in the supply.

For purposes of this study, a State's dependence on LNG was measured in terms of its natural gas supplies from all sources, including LNG. According to an earlier OTA study, domestic supplies of gas (excluding supplementary sources such as SYNgas or Alaskan gas) will decline 12 percent nationally by 1980 and 20 percent by 1985.[7] These are at best crude figures, which overlook regional differences. g Therefore, in estimating the total State supply in 1980 and 1985, the 1975 supply was reduced by 12 percent or 20 percent respectively, and then increased by the anticipated LNG supply.

The results are tentative because not all of the El Paso II LNG has been precisely allocated to the States. However, in most cases this imprecision is not significant.

This study indicates that in the next decade these eight States expect to get from 33 to 91 percent of their natural gas (figure 36) from a group of companies which plan to meet as much as half of their gas needs with imported LNG. As a result some individual States will be dependent upon imported LNG for nearly one-fourth of their natural gas supplies (figure 37).

Alaskan natural gas which might be moved as LNG was not counted in these calculations. Nevertheless, it is clear that reliance on LNG could be considerable.

Figure 36 States Dependent on Companies Using LNG as Part of Gas Supplies

State (consumption in Bcf)	Suppliers to use LNG	1975 volume delivered (in Bcf)	Percent of State consumption provided by suppliers listed
Ohio (957)	Columbia	490.4	
	Consolidated	269.2	
	Panhandle	66.9	86
Pennsylvania (654)	Columbia	211 2	
	Consolidated	987	47
Georgia (326)	Southern	269	91
California (1848)	El Paso	943	51
S. Carolina (122.9)	Southern	96.3	78
New York (576.8)	Consolidated	190.3	33
Michigan (887)	Trunkline	151 3	
	Panhandle	680	25
Alabama (264)	Southern	1677	64

Source OTA

[7]U. S. Congress, Office of Technology Assessment, *Analysis of the Proposed National Energy Plan (Washington, D. C.: U.S. Government Printing Office, August 1977), extrapolated from p. 30.*

[8]Current synthetic gas production from petroleum feedstock was included in the analysis but no additional production was estimated on account of recent governmental actions restricting it. If the contribution of SYNgas from coal in the early to mid-1980's is small, as seems possible in light of delays in starting proposed projects, then U.S. supplies of natural gas will be from domestic reserves and LNG almost entirely.

Figure 37. Percent of LNG in State Consumption and Company Supplies (Imports from Foreign Countries Only)

State	LNG supply if all projects approved and operating on schedule (in Bcf)		LNG use as a percent of total supply	
	1980	1985	1980	1985
California	**226**	**463**	**12**	**24**
Ohio	**122**	**143**	**13**	**15**
Pennsylvania	**41**	**48**	**7**	**8**
New York	**59**	**74**	**10**	**14**
Georgia	**61**	**94**	**18**	**30(20#)**
Alabama	**23**	**35**	**8**	**13**
South Carolina	**20**	**31**	**16**	**28 (22#)**
Michigan	**87**	**87**	**10**	**11**

(#) Percent of LNG use possible if domestic production is reduced by 20 percent and consumption remains relatively unchanged

Company				
Columbia	116	116	13	14
Consolidated'	136	190	26	44
Southern"	136	210	28	56
El Paso	0	237	0	26' •
Trunkline	902	902	52	66
Panhandle	738	738	17	23* ••
Pacific Gas & El	113	113	( )(	)
So Calif. & Pacific Lighting	113	113	( )(	)

● Assumes certain deliveries of LNG from El Paso II (United Gas Pipeline)

• 24% with planned production from coal gasification Included in supply

● *•18.2% with planned production from coal gasification included in supply

Source OTA

If Alaskan LNG is factored into the supplies, on the theory that technological as well as political problems could cause interruptions in supply, dependency in California would rise drastically (figure 38).

Technological interruptions are not out of the question. There has already been ample evidence that they are possible,

For example, the average delay in the construction of three LNG tankers at the Quincy Shipyard has been about 2 years. Part of the delay was planned because no terminals were ready for the ships, but many shipbuilding problems caused other actual delays.[9]

In addition, at all the U.S. shipyards involved with LNG tankers, there have been in-

Figure 38. Percent of LNG in State Consumption and Company Supplies (Including Alaskan Gas)

State	LNG supply if all projects approved and operating on schedule (in Bcf)		LNG use as a percent of total supply	
	1980	1985	1980	1985
California	**299**	**913**	**13#**	**43(24 #)**
Ohio	122	**265**	13	**30 (20#)**
Pennsylvania	**41**	**95**	**7**	**15**
New York	**59**	**74**	**10**	**14**
Georgia	**61**	**94**	**18**	30(20#)
Alabama	**23**	**35**	**8**	**13**
South Carolina	**20**	**32**	**16**	**28(22#)**
Michigan	**87**	101	10	**12**

(#) Percent of LNG use possible if domestic production is reduced by 20 percent and consumption remains relatively unchanged

Company				
Columbia	116	362	14	44
Consolidated' •*	136	190	26	44
Southern**	136	210	28	56
El Paso	0	383	0	39*
Trunkline	902	902	52	66
Panhandle	738	131.8	17	32*
Pacific Gas & El	113	259	( )	24
So Calif & Pacific Lighting	113	429	( )	40

'Includes SYNgas from coal m total estimate

•● Assumes 74 Bcf/yr from El Paso II (deliveries from United Gas Pipeline)

•* ● Assumes 54 Bcf/yr from El Paso II (deliveries from United Gas Pipeline)

Source OTA

[9] **Tom Connors, "Domestic LNG Vessel Construction, " paper presented at the Chesapeake Section Meeting of Society of Naval Architects and Marine Engineers, Bethesda, Md., May 1977.**

stances of subcontractor failures, startup difficulties after construction of new facilities, or other delays. State supplies could be just as seriously affected by this type of interruption or delay as by embargoes or cartel action.

Most members of OTA's public participation program were well aware of the need for more natural gas and understood the possibility that LNG could provide a significant portion of the supply. ***However, many of the citizens and public interest groups also indicated concern about the reliability and the cost of LNG supplies which would be coming from foreign nations.*** Several specifically questioned the political stability of supplier nations.

Critical Review: Paper 9

LNG PRICING POLICY

In the complex LNG system, the price for which the product can be sold is a key constraint on the development of new projects. There is no internationally accepted price of natural gas at the wellhead, but in most foreign markets gas supplies—including LNG—are price linked to alternative energy sources on a Btu-equivalency basis.

Foreign pricing mechanisms make it fairly likely that LNG will be price competitive with other fuels in the near future, thus making it likely these countries will be strong markets for LNG.

In the United States, however, the cost/price situation is extraordinarily complicated by the regulation of natural gas prices, making it more difficult to determine if LNG will be price competitive with other fuels.

In Western Europe, the threshold price for imported gas, whether it is transported by conventional pipeline or as LNG, will be set by North Sea gas and low-sulfur content imported fuel oil. On the basis of 1977 prices, importation of Algerian LNG should be price competitive for the foreseeable future. Depending on prices set by producing nations, LNG from Nigeria and the Persian Gulf could also be price competitive in the major Western European markets.

Japan is now importing low-sulfur fuels from several world suppliers and LNG from Indonesia and Alaska. Liquefied natural gas can command a higher price in Japan than can alternative fuels because its clean-burning properties offer a way of providing pollution-free, electric-power generation.

In the United States, where prices and mechanisms for passing prices on to the ultimate customer are established by the FPC, the following prices have been set for imported LNG:[1]

Distrigas (Boston)	$1.90 per million Btu (1972)
El Paso I (Md. & Ga.)	$1.80 per million Btu (1972)
Panhandle (La.)	$3.37 per million Btu (1977)
Pac/Indonesia (Calif.)	$3.59 per million Btu (1977)

The lower prices appear competitive with other fuels imported to the east coast, but there is consensus that future Algerian LNG will be increased to account for the costs of other alternative fuels.

In contrast, the wellhead price of domestic natural gas in interstate sales is now regulated by the FPC at a top price of $1.44 per million Btu's for gas produced from wells commenced on or after January 1, 1975, and at an average of about 76 cents per million Btu's for all U.S.-produced interstate gas. The President's proposed National Energy Plan places a ceiling on all new natural gas, produced from wells beginning in 1978, of $1.75 per million Btu's at the wellhead.

Thus, it appears probable that for the foreseeable future the price of imported LNG will be significantly higher than the regulated price-of 'domestic gas and probably of many other energy alternatives. In addition, the confused cost/price situation, in combination with the substantial technical and commercial risks associated with LNG, may limit growth beyond those projects which are now proposed.

At present there is no policy for the FPC to follow in making decisions about pricing LNG. The major debate centers on the use of

[1]The world market price for crude landed in U.S. during 1976 averaged $13.48 per barrel which is equivalent to $2.32 per million Btu's.

rolled-in pricing versus the use of incremental pricing.

Incremental pricing means that each customer using LNG is charged the full cost of the amount of LNG he actually uses. Under a rolled-in pricing formula, he would pay a price determined by the weighted average of all the flowing gas and LNG used in the system.[2]

In most cases industry has claimed that rolled-in pricing is necessary to the financial viability of LNG import projects.

Industry fears that the market will become so uncertain if the gas is incrementally priced, that the necessary financing will not be obtainable at acceptable interest rates. The argument is also made that rolled-in pricing is the best method to ensure maximum use of the existing pipeline system.

Since the gas pipeline system is a major capital investment and therefore a large fixed cost, when volumes decline the utilities are forced to charge customers a higher unit price for the gas. It is therefore argued that even if supplemental gas itself is very costly, rolled-in pricing will lower the unit charges to consumers because more of the pipeline will be filled.

The principal objection to rolled-in pricing is that the consumer does not pay the replacement cost for the gas he is using. He is given an incorrect signal as to the actual value of these incremental LNG supplies and has less incentive to look for more efficient ways to use gas or for alternatives that would be less costly. Therefore, adoption of rolled-in pricing would appear to be counter to the goals of energy conservation and replacement cost pricing set forth in the President's proposed National Energy Plan.

However, if LNG is incrementally priced it would probably sell for at least $3,00 per thousand cubic feet. Therefore, a customer could bid for new gas up to the $1.75 ceiling but would then be forced to jump to the $3.00 level if he wanted more than the $1.75 price would bring forth. Any natural gas that could be produced at intermediate prices would be foreclosed, which would defeat some of the purpose for going to incremental pricing in the first place.

Another difficulty with rolled-in pricing is that it forces all customers to subsidize LNG whether they use it or not. However, industry spokesmen argue that supplemental gas projects such as LNG are of direct benefit to all customers because they increase the quantity of gas supplies.

The main argument against incremental pricing is that it would raise gas prices to a point where the market for LNG may become unstable. Another argument against incremental pricing is that there is no feasible mechanism for separating and selling a certain portion of high-priced gas to specific customers. Finally, it is claimed that incremental pricing cannot be administered while also following a policy of curtailing gas for low-priority customers.

There were few comments addressed to the pricing issue during OTA's public participation program. There was, however, discussion of the fact that it is a complex issue which the public is still attempting to understand. There was also considerable discussion of the subject at OTA's LNG panel meeting.

In ***general, it appears that gas-related businesses and industries support rolled-in pricing while public interest groups support incremental pricing.*** The stand behind incremental pricing appears to be motivated by the desire to have energy priced at a true cost which will encourage conservation and the search for alternatives.

To date, the FPC has approved rolled-in pricing for all major new LNG import projects. And, traditionally, all new natural gas supplies have been priced on a rolled-in, or average, basis to the consumer. However, in

[2]For **"Rolled-in' versus "incremental' pricing** argument **see—" Incremental Pricing of Supplemental Gas" by** FPC **Office of Economics—Aug. 1976; Response to this report by Robert Nathan Associates, Dec. 1976; and "The Future of Natural Gas; Economic Myths, Regulatory Realities"** by FPC **Bureau of Natural** Gas**— Nov. 1976.**

the recent *Trunkline* case, the FPC made an initial decision for incremental pricing, which was later reversed.

Although it is not certain, it appears that rolled-in pricing may be the mechanism chosen in the future. When ***considering only the two pricing mechanisms, it appears that rolled-in pricing would provide less incentive for industry to seek new domestic supplies. It may, instead provide an incentive for importing LNG and using other expensive alternatives, the costs of which will be passed on to the consumer.***

Thus, pricing decisions for future LNG projects will have effects beyond the immediate cost of gas to consumers. They will also affect the supply, demand, and prices of other energy, and major energy decisions related to the national interest.

Ultimately, pricing is not strictly an LNG issue. It is an issue which now surrounds all forms of energy. No ***decision on LNG pricing should be made in isolation. Pricing of all forms of energy should be considered in the context of a national' policy.*** This issue should be one which gets early attention from the new Department of Energy. Some of the questions which should be addressed include:

- Should pricing mechanisms be used to encourage or discourage the development of LNG projects?
- Will the use of rolled-in pricing discourage the use of alternative energy sources which might be available at prices lower than the incremental price or have greater long-term security of supply possibilities, such as solar energy?
- Will rolled-in pricing give certain LNG projects unfair competitive advantage because customers will not notice the added cost?
- Will rolled-in pricing unfairly affect certain regions by encouraging use of LNG at the expense of developing more domestic supplies at a possibly lower cost ?
- Can incremental pricing be established in a way that will allow companies to produce and sell LNG separately from other gas and be compatible with curtailment policies?

Chapter III

Public Awareness and Concerns About LNG

Chapter III

Public Awareness and Concerns About LNG

Like many other types of energy and energy systems, the use of LNG as a method of transporting natural gas from distant sources has become a subject of public attention and controversy in recent years.

Thus, the range and diversity of views held by the people who will be affected by the use of LNG are important to Congress in its consideration of possible new legislation, oversight activities, and budget appropriations to Federal agencies involved in the regulation of LNG projects and facilities.

In order to provide Congress with information on these views, OTA conducted a public participation program in connection with this assessment of the transportation of liquefied natural gas. The program consisted of a daylong workshop in Washington, D. C., a questionnaire/interview survey in relevant coastal areas, and a review of this draft report by members of the public.

These activities were designed to obtain information about the opinions and beliefs of the public in four areas:

- the benefits and risks which various groups associated with the development of an LNG system or alternatives to that development;
- concerns about marine transportation of liquefied natural gas and the siting of LNG facilities;
- the adequacy of the decisionmaking and regulatory processes relating to LNG; and
- the need for Government action in the form of legislation, policymaking, or research.

More than 100 persons from gas utilities and related industries and financial institutions, organized labor, State and local agencies, and public interest groups were directly involved in the public participation program. Through them, OTA was able to identify the key issues which have been or will be raised in the public debate and which should be analyzed for possible Federal action. Through them, OTA was also able to appreciate the wide range of views on these issues and incorporate those views into its report to Congress.

Much of the discussion of LNG during the public participation program centered on specific LNG projects and the concerns which various interest groups have had about those projects. Public involvement with LNG projects has been limited to date, but has included participation in formal hearings before the FPC, legal action, and dissemination of information about the issues involved.[1]

Although individual opinions on issues varied, it was obvious from the public participation program that there are three major issues in the consideration of LNG systems:

- safety of LNG ships and terminals;
- criteria for siting of *LNG* facilities; and
- public participation in decisionmaking processes.

[1] Leonard E. Bassil, "Cove Point Liquefied Natural Gas Terminal, Calvert County, Md., " National Academy of Sciences National Research Board, Maritime Transportation Research (unpublished), and Andrew J. Van Horn and Richard Wilson, *Liquefied Natural Gas Safety Issues, Public Concerns, and Decision Making.* Cambridge: Harvard University, 1976.

The varied views of the public who worked with OTA in this effort are particularly reflected in the section, "Critical Review of Components of the LNG System." Their specific suggestions for action to help resolve major problems are itemized in the next section of this chapter. However, the public also expressed strong interest in several broader issues which are beyond the scope of this report. These broader questions which have not been answered to the satisfaction of many include:

- Is there a need for LNG in the first place?
- Will the development of LNG systems divert major amounts of capital and human resources away from the development of alternative types of energy?
- Will the development of LNG systems produce unwarranted confidence in traditional energy supplies and prevent a major commitment to energy conservation?

On the other end of that concern, many asked about the impact of ***not*** developing LNG systems. They argued that not proceeding could result in "an unprecedented economic disaster" by creating shortages of energy in critical industries, decreasing possible contributions to the gross national product, and increasing unemployment.

Actions Desired By

GAS UTILITY COMPANIES

Gas company respondents included representatives of the American Gas Association, Algonquin Gas of Massachusetts, Columbia LNG Corp., Southern California Gas, Central Power and Light Company in Texas, and United Gas Pipeline Company of Texas.

The respondents suggested the following:

- The Federal Government should streamline the regulatory process by declaring policies on LNG pricing, LNG facility siting, and other important aspects of LNG development.
- One Federal agency should coordinate all LNG procedures in order to accelerate the regulatory process and eliminate jurisdictional overlaps among the Federal Power Commission, the Office of Pipeline Safety Operations, and the U.S. Coast Guard.
- There should be Federal preemption on environmental and siting issues.
- Ceilings on LNG imports should be avoided, but the security of supply and the possibility of overdependence on a single source should be addressed on a project-by-project basis.
- The State and local approval processes should be consolidated where feasible.
- The Federal Government should establish clear safety criteria on a generic, rather than case-by-case, basis.
- The Federal Power Commission should approve a formula to allow companies to pass on escalations in the cost of foreign gas or transportation without new hearings.
- The Federal Power Commission should allow rolled-in pricing.
- The Federal Government should maintain existing financial incentives now available through the Maritime Administration and the Export-Import Bank.
- Congress should adopt legislation providing for adequate insurance coverage by means of a fund supported by LNG sales.

- The Federal Government should undertake additional studies of LNG safety, especially vapor cloud studies and risk analysis, with large-scale LNG spill tests to be carried out by the Coast Guard and the Energy Research and Development Agency.

Actions Desired By
ORGANIZED LABOR GROUPS

Respondents from organized labor groups included representatives of the AFL-CIO and other groups.

The respondents suggested the following:

- Congress should adopt legislation to correct deficiencies in the LNG regulatory process and eliminate counterproductive time lapses and delays.
- Ratesetting policies should not discourage the utilization of imported LNG.
- Congress should adopt legislation to mandate the use of U.S. flag ships with U.S. personnel for LNG transportation in order to increase national security and ensure full compliance with construction and safety standards.
- There should be a prompt decision on the gas transportation system to be used for North Slope Alaskan gas, including provision for a western delivery system.
- Federal preemption should be used if necessary to arrive at early decisions on LNG issues, but there should also be maximum State, regional, and local involvement in decisions.
- All Coast Guard procedures should be reviewed to determine the adequacy of ship traffic control and inspection of LNG tankers.
- The Federal Government should require agencies involved in LNG approval processes to act on permit applications within a given time frame.
- Additional studies should be undertaken to determine the capability of Coast Guard units assigned to aid LNG tankers and to assess the adequacy of equipment in use.
- Studies should also be undertaken to determine what industries are compatible and could be located near LNG terminals.

Actions Desired By
STATE AND LOCAL OFFICIALS

Respondents from State and local offices included representatives of the Public Utilities Commission staffs in New Jersey, California, Rhode Island, and Massachusetts; representatives of the cities of Providence, R. I., Oxnard and Los Angeles, Calif.; and representatives of the New York Department of Environmental Conservation, and the Georgia Coastal Zone Management Office,

The respondents suggested the following:

- The Federal Government, with the involvement of local interest groups and governments, should establish procedures for the selection of suitable locations for future LNG facilities.

- The Federal Government should, where practical, eliminate overlapping jurisdiction with respect to siting, construction and monitoring of LNG facilities.
- The Federal Government should expedite and consolidate the various permit processes required for approval of an LNG facility.
- The Federal Government should promulgate and enforce safety regulations and establish standards for transportation and storage of LNG.
- Congress should adopt legislation which will ensure that the costs of shipping LNG by oceangoing vessels are just and reasonable.
- Additional studies should be made of LNG spills on water, underground storage of LNG, and greater use of imported LNG as pipeline gas.
- The Federal Government should also promote research into alternative fuels which might be more abundant and possibly less costly; research into conservation methods; and studies of the possibility of curtailing the sales activities of gas distributors.

Actions Desired By RELATED INDUSTRIES

Respondents from businesses and industries related to the LNG industry included representatives of shipbuilding companies and associations, gas pipeline companies, safety consulting firms, marine engineering firms, the industrial construction industry and financial institutions.

The respondents suggested the following:

- The Federal Government should resolve the issue of who is in charge of siting and safety matters and should establish a "one stop' permit process.
- Clearly defined policies and fair regulations should be adopted to accelerate the regulatory process.
- The Federal, State and municipal permit processes should be coordinated.
- The Federal Government should assist industry in meeting energy demands and in determining the safest, most viable means to transport, store, and distribute LNG in interstate commerce.
- The Federal Government should ensure a smooth transition to the new Department of Energy.
- The Federal Government should develop a pricing structure which will ensure adequacy of supply.
- The Federal Government should adopt a clear policy on incremental and rolled-in pricing.
- Additional study should be made of pipeline vs. LNG systems of transportation, including study of the political, security of supply, safety, and environmental issues.
- Studies should also be made which would improve LNG vapor dispersion analysis and allow refinement of vapor dispersion models to take into consideration local topography and manmade obstructions.
- Studies should be undertaken to identify the problems and solutions associated with transportation and distribution of LNG to and from inland baseload and peak shaving plants.*

*Note: one respondent **said further studies were not desirable because they would only cause additional delays in development of LNG.**

Actions Desired By
PUBLIC INTEREST GROUPS

Respondents from public interest groups included representatives of California-based national groups such as the Natural Resources Defense Council and the Sierra Club; Washington-based national groups such as the Environmental Policy Center; and local citizens groups in Maryland, California, Rhode Island, New Jersey, New York, Massachusetts, and Texas.

The respondents suggested the following:

- Congress should adopt legislation to restrict LNG storage tanks and terminals to isolated areas.*
- The Federal Government should take a more active planning role in LNG terminal siting and should establish broad Federal policy on siting in advance of individual project decisions.
- Federal siting policy should be developed through public hearings on generic safety and siting considerations.
- The Federal Government, in conjunction with State and local groups, should identify and review available sites which could be potential LNG terminal locations without waiting for specific applications.
- The Federal Government should act to ensure rational land-use planning by the States through the Coastal Zone Management Act or other means.
- The Federal Government should determine whether and how much LNG is needed and limit LNG imports so that they do not become a major part of the U.S. gas supply.
- The Federal regulatory procedure should be improved to allow for timely selection of sites, if they are needed, with maximum public participation in the process.
- The Federal Power Commission should mandate incremental pricing for LNG, and keep a close watch on price and supply.
- Federal supervision of daily operations of LNG facilities should be increased.
- Existing LNG tanks that do not meet new siting criteria should be phased out.
- The Federal Government should set mandatory conservation standards and determine uses of natural gas in order to diminish reliance on natural gas.
- The Federal Power Commission should develop procedures for ensuring effective public participation, including adequate notice of pending proceedings and payment of attorney and witness fees for intervenors.
- The environmental impact statement process should be simplified and should include consideration of safety issues.
- The Coast Guard should strictly control the movement of LNG tankers and other ship traffic on the LNG tanker route.
- There should be intensive training of all personnel involved in the inspection and regulation of LNG tankers and facilities.
- Transportation of LNG by truck should be controlled with procedures similar to those which regulate the movement of LNG tankers.
- The Federal Government should mandate development of evacuation plans by

*Note. Respondents varied in siting criteria. Some said LNG terminals and tanker routes should be at least 1 mile from populated areas. Other suggested distances ranging up to 25 miles from populated areas. Several said terminals should be restricted to offshore sites. One said terminals should be located in already industrialized areas with small populations.

local jurisdictions near LNG facilities and ensure that there will be adequate local firefighting capability.

- Congress should adopt legislation to ensure that there will be adequate liability insurance which defines coverage and responsibility for accidents.
- There should be additional studies of large marine spills of LNG, vapor dispersion, and other safety questions, including the consequences of large terminal accidents, the effect of such accidents on homes and industries supplied by the terminal, the time required to rebuild a terminal, alternate energy sources available after an accident, size of the area endangered, methods of combating LNG fires, and methods of protecting citizens in endangered areas.
- Studies should also be made of LNG import projections under all regulatory circumstances (i.e., with and without import restrictions, with rolled-in pricing, with incremental pricing, etc.) and the economic consequences of LNG embargoes by producing nations.
- Studies should be made to find appropriate alternatives to the development of LNG systems.
- Siting of LNG facilities in areas which have prime ecological or aesthetic values should be avoided.

Appendixes

Appendix A

Cove Point, Md., Permits

Terminal

Regulatory Agency	Description of Action	Application Date	Permit Date
Board of County Commissioners of Calvert County, Md.	Rezoning 317.722 acres from Al to Il.	—	8/11/70
Federal Power Commission.	Opinion No. 622 CP71-68.	9/21/70	6/28/72
Federal Power Commission.	Opinion No. 622A CP71-289.	6/ 4/71	10/ 5/72
Federal Power Commission.	Amended—Tunnel plan	12/ 8/72	3/30/73
Calvert County Department of Inspection and Permits.	Site grading for office building	6/ 9/72	6/14/72
Calvert County Health Department	Deep-drilled well and sewage-disposal system.	6/19/72	7/13/72
	Completion certificate.		11/15/72
Calvert County Department of Inspection and Permits.	Construction of office and maintenance building.	6/22/72	7(21172
Department of the Army, Baltimore District, Corps of Engineers.	Construction of pier.	4/ 7/71	9/ 1/72 8/31/72
State of Maryland, Department of Natural Resources.	Water quality certification.	—	12/18/72
State of Maryland, Department of Natural Resources.	Wetlands license.	12/ 4/72	12/26/72
Department of the Army, Baltimore District, Corps of Engineers.	Construct unloading terminal and tunnel and dredge in Chesapeake Bay.	12/ 4/72	12/29/72
State of Maryland, Department of Natural Resources	Appropriate and use ground water for sanitary facilities.	10/21/72	11/28/72
State of Maryland, State Highway Administration.	Construction of two entrances. Extension.	11/20/72	3/12/73 7/ 5/73
Calvert Soil Conservation District.	Erosion and sediment control measures	4/ 5/73	5/14/73
Calvert County Department of Inspections and Permits	Site grade and preparation for construction; LNG terminal process area,	4/ 5173	5/18/73

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Regulatory Agency	Description of Action	Application Date	Permit Date
Calvert County Department of Inspections and Permits	Construction of cofferdam	8/14/73	8/15/73
State of Maryland Fire Marshal	Approval of office and warehouse		8/31/73
State of Maryland, Department of Forests and Parks	Burning debris		9/17/73
State of Maryland, Department of Natural Resources	Small pond permit		10/ 1/73
Calvert County Department of Inspections and Permits	Site grading in lowland area.	10/12/73	10/12/73
Calvert County Department of Inspections and Permits	Construction of LNG storage tanks.	10/15/73	10/24/73
State of Maryland Comptroller of the Treasury	Sales and use tax direct payment permit.		1/ 2/74
Calvert County Health Department	Construction of deep drilled well and sewage disposal system.	10/25/73	1/29/74
	Completion certificate.		2/24/75
Calvert County Health Department	Construction of deep drilled well and sewage disposal system.	10/25/73	1/29/74
	Completion certificate		1/ 7/75
State of Maryland, Water Resources Administration	Appropriate and use water for sanitary facilities, cooling water, testing and fire protection		1/31/74
Federal Communications Commission	Radio license.		4/15/74
State of Maryland Fire Marshal	Approval of fire protection plan.		5/30/74
Department of Transportation, U.S. Coast Guard	Private aids to navigation (five lighted survey towers)	7/ 5/74	7/18174
State of Maryland Fire Marshal	Approval of use of tunnel by personnel		8/26/74
Calvert County Department of inspections and Permits	Construction of two firewater storage tanks	9/18/74	9/20/74
Calvert County Department of Inspections and Permits	Construction of 12 buildings for use with receiving terminal	10/21/74	10/23/74
State of Maryland Environmental Health Administration	Construction of emergency vent heater	7/11/75	9/16/75

Regulatory Agency	Description of Action	Application Date	Permit Date
State of Maryland Environmental Health Administration	Construction of LNG vaporizer	7/1 1/75	9/16/75
State of Maryland Environmental Health Administration	Construction of emergency purge nitrogen vaporizer	7/1 1/75	9/17/75
State of Maryland Environmental Health Administration	Construction of firewater tank heater	7/1 1/75	9/17/75
State of Maryland Environmental Health Administration	Construction of gas turbine fuel gas heater	7/1 1/75	9/17/75
State of Maryland Environmental Health Administration	Construction of boil-off gas reheater	7/1 1/75	9/17/75
State of Maryland Environmental Health Administration	Construction of gas turbine generator	7/1 1/75	9/17/75
Calvert County Department of Electrical Inspections	Electrical permit for onshore ventilation building		9/ 5/75
Calvert County Department of Inspections and Permits	Construction of seven offshore buildings	1/23/76	2/ 3/76
State of Maryland Fire Marshal	Review of electrical area classifications		6/ 4/76
Calvert County Fire and Rescue Commission	Inspection of fire apparatus		8/ 3/76
Calvert County Department of Inspections and Permits	Site grade for warehouse		8/1 1/76
Calvert County Department of Inspections and Permits	Construction of warehouse		8/1 1/76
Calvert County Department of Inspections and Permits	Construction of sign at terminal entrance	8/27/76	8/31/76
United States Department of the Interior	Seagull depredation permit.		**11/ 9/76**
United States Coast Guard	Approval of survival capsules.		**6/17/76**
State of Maryland, Department of Licensing and Regulation	License and regulation certificate for offshore elevator.		**1/ 7/77**
United States Coast Guard.	Certificate of Inspection for Miss *Methane.*		**9/30/76**
United States Coast Guard.	License of vessel under 20 tons for *Miss Methane.*		**1/31/77**
State of Maryland, Water Resources Administration	Oil operations permit	3/ 3177	**5/ 5/77**

Pipeline

Regulatory Agency	Description of Action	Application Date	Permit Date
Maryland Board of Public Works—Department of Natural Resources.	Wetland license.	4/ 1/74	9/19/74 4/25/75
Maryland Department of Natural Resources.	Construction in a waterway.	4/ 1/74	4/23/75
Corps of Engineers.	Construction of five 36-inch pipeline submarine crossings.	4/10/74	4/15/75
	Amended.	3/ 7/75	12/31/75
Maryland Department of Natural Resources.	Water Quality Certification five pipeline crossings.		8/22/74
	Revised.		9/10/74
Virginia Marine Resources Commission	Dredge and backfill a trench for pipeline crossing of Potomac River	3/ 7/75	8/27/74
	Revised.		3/25/75
Viginia State Water Control Board	Dredge and backfill a trench for pipeline crossing Potomac River.	7/15/74	9/26/74
	Amended,	3/ 7/75	4/ 3/75
Virginia Department of Taxation	Sales and use tax direct payment permit.		3/ 1/75
Federal Power Commission	Amended route.		4/10/75
	Change construction dates.		8/ 1/75
Commonwealth of Virginia Department of Highways and Transportation (Fairfax County)	Permit for temporary entrance to right-of-way #754738.		August 1975
Commonwealth of Virginia Department of Highways and Transportation (Fairfax County)	Permit for temporary entrance to right-of-way #754826,		August 1975
Commonwealth of Virginia, Department of Highways and Transportation (Fairfax County).	Permit for temporary entrance to right-of-way #754513.		July 1976
Commonwealth of Virginia Department of Highways and Transportation (Fairfax County).	Permit for temporary entrance to right-of-way #754950.		October 1975
Commonwealth of Virginia Department of Highways and Transportation (Fairfax County).	Permit for temporary entrance to right-of-way #755740.	11/ 7175	11/19/75
Commonwealth of Virginia Department of Highways and Transportation (Fairfax County)	Permit for temporary entrance to right-of-way #755739	11/ 7/75	1 1/19/75

Regulatory Agency	Description of Action	Application Date	Permit Date
Commonwealth of Virginia Department of Highways and Transportation (Fairfax County)	Permit for temporary entrance to right-of-way #75511		October 1975
Commonwealth of Virginia Department of Highways and Transportation (Fairfax County)	Permit for temporary entrance to right-of-way #755008		September 1975
Commonwealth of Virginia Department of Highways and Transportation (Fairfax County)	Permit for temporary entrance to right-of-way #755734	10/31/75	December 1975
Commonwealth of Virginia Department of Highways and Transportation (Loudoun County)	Permit for temporary entrance to right-of-way #756041	12/ 9/75	12/17/75
Commonwealth of Virginia Department of Highways and Transportation (Loudoun County)	Permit for temporary entrance to right-of-way #756040	12/ 9/75	12/17/75
Board of County Commissioners of Charles County, Md.	Grading permit, pipeline right-of-way.	10/21/74	10/24/74
Washington Suburban Sanitary Commission-Prince Georges County	Sediment Control Permit, pipeline right-of-way.		7/16/74 9/16/74
State of Maryland-Maryland Forest Service, Department of Natural Resources	Roadside tree permit (Calvert, Charles & Prince Georges Counties)	7/14/75	7/22175
Department of Inspections and Permits, Calvert County, Md.	Zoning approval, pipeline right-of-way	6/17/75	6/18/75 6/23/75
Department of Inspections and Permits, Calvert County, Md.	Grading permit, pipeline right-of-way	6/ 7/74	10/11/74 6/13/75
Department of Inspections and Permits, Calvert County, Md.	Grading permit, access road to right-of-way Cove Point	7/24/74	7/24/75
Department of Inspections and Permits, Calvert County, Md.	Use and occupancy permit	2/17/75	2/18/75
Department of Public Works, Prince Georges County, Md.	Construction within public right-of-way (three road crossings)	6/10/75	8/ 4/75
Department of Transportation, State of Maryland (Calvert County)	Pipeline road crossing #5-C10943-75		May 1975
Department of Transportation, State of Maryland (Calvert County)	Pipeline road crossing #5-C-1088O-75		April 1975
Department of Transportation, State of Maryland (Calvert County)	Road crossing (cable) #50C-11046-75		August 1975
Department of Transportation, State of Maryland (Charles County)	Pipeline road crossing #5-CH-10881-75		July 1975

Regulatory Agency	Description of Action	Application Date	Permit Date
Department of Transportation, State of Maryland (Charles County)	Pipeline road crossing #5-CH-10942-75		May 1975
Washington Suburban Sanitary Commission (Prince Georges County, Md.)	Pipeline road crossing #17090, 3-pg. 208-75		May 1975
Washington Suburban Sanitary Commission (Prince Georges County, Md.)	Pipeline road crossing #17094, 3-pg. 282-75		June 1975
Washington Suburban Sanitary Commission (Prince Georges County, Md.)	Pipeline road crossing #17089		May 1975
United States of America, U. S. Navy Railroad (Maryland)	Pipeline railroad crossing #NF(R)26225		7/21/75
Calvert Soil Conservation District	Sediment and erosion control for Calvert County, Md.	6/ 7/74	3/12/75
Charles Soil Conservation District	Sediment and erosion control for Charles County, Md.	9/25/74	10/24/74
County of Fairfax, Va.	Sediment and erosion control for Fairfax County	11/ 7/74	2/13/75 8/22/75 9/ 5/75
County of Fairfax, Va.	Occupancy permit	September 1975	September 1975
County of Fairfax, Va.	Site plan waiver for pipeline construction		3/ 3175 9/10/75
Department of Environmental Management, Fairfax County, Va.	Pipeline road crossing # 1043O		2/17/76
Zoning Administrator, Loudoun County, Va.	Zoning permit for measuring station at Loudoun	4/ 8/76	4/ 8/76
Department of Engineering and Inspections, Loudoun County, Va.	Building permit for instrument and transducer buildings at Loudoun	4/14/76	6/ 1/76
Department of Engineering and Inspections, Loudoun County, Va.	Electrical permit for instrument and transducer buildings at Loudoun	7/ 8/76	7/ 8/76
Health Department, Loudoun County, Va.	Permit to install sewage disposal system and water well	4/14/76	5/24/76
Maryland Board of Public Works	Wetlands license		9/19/74
Fairfax Planning Commission	Construction approval for modified route per settlement agreement		2/13/75
Fairfax County Board of Supervisors	Final approval given modified route		3/ 3175

Regulatory Agency	Description of Action	Application Date	Permit Date
Fairfax Board of Zoning	Zoning approval given modified route		3/10/75
Charles County	Pipeline construction report filed		5115175
Calvert County	Pipeline construction report filed		6/30/75
Fairfax County	Sediment and erosion control plan approved		8/22/75
State of Maryland	License to cross Calvert Cliffs State Park		9/29/75
Prince Georges County	Special ordinance authorizing pipeline construction		11/24/75
Loudoun County	Sediment and erosion control plan filed-permit not required		1/23/76
Loudoun County Planning Commission	Pipeline route approved		1/26/76
Maryland Department of Natural Resources	Surface water appropriation for hydrostatic test	3/29/76	
Maryland Department of Natural Resources	Permit for discharge of test water	3/29/76	

Appendix B

Federal Agencies Involved in LNG Import Projects

Council on Environmental Quality. The FPC submits preliminary and final environmental impact statements to CEQ for review.

Department of Defense. DOD is consulted by the FPC for views on national security implications of each LNG import application.

Department of the Interior. Permits are required if construction or operation of a terminal affects wildlife in the area.

Department of State. State is consulted by the FPC for views on national security implications of each LNG import application.

Environmental Protection Agency. Permit is required from EPA if there are any discharges into the ocean adjacent to an LNG terminal.

Export-Import Bank. Provides loans to foreign governments to support purchases of U.S. goods and services in the construction of liquefaction and related LNG facilities.

Federal Communications Commission. Licenses are required for radio operations.

Federal Power Commission. The FPC regulates importation and the interstate transportation and sale of natural gas.

Office of Pipeline Safety Operations. OPSO establishes and enforces minimum Federal safety standards for all pipelines in or affecting interstate or foreign commerce.

U.S. Army Corps of Engineers. Permit is required for any dredging activity and construction of any object in the navigable waters of the United States.

U.S. Coast Guard. The Coast Guard is responsible for the safety of the marine link of LNG import operations, by certification of LNG ships to ensure that minimum design and construction standards, and the establishment of operating procedures for bringing LNG into U.S. ports.

U.S. Maritime Administration. MARAD provides a variety of financial aids for the construction and operation of U.S. flag LNG tankers.

Appendix C

Laws and Cases Relevant to LNG

STATUTES AND EXECUTIVE ORDERS

Administrative Procedures Act, 5 **U.S.C. §§551 et** *seq* (1970)

Establishes the minimum procedures which agencies of the executive branch must follow in establishing rules and regulations.

Admiralty Extension Act of 1948, 46 U.S.C. § 740 (1970)

Provides that admiralty jurisdiction is to extend to all injuries caused by a vessel even if such damage or injury is "done or consummated" on land.

Coastal Zone Management Act of 1972, 16 U.S.C. $$1451 et *seq* (Supp. 1972)

Authorizes the Secretary of Commerce to make annual grants to any coastal State to assist in developing a management program for land and water resources of its coastal zone. Such grants are contingent on approval by the secretary of the State's program, i.e. that it meets certain criteria specified in the Act. After approval of a State's program, no Federal permit or license for an activity affecting that State's coastal zone unless that activity **has been certified as consistent with the State's program.**

Dangerous Cargo Act, 46 **U.S.C. §170** (1970)

Directs the Coast Guard to identify all dangerous cargoes, prescribe regulations establishing standards for containers and handling of explosives and other dangerous cargoes and for inspection to ensure compliance with these regulations.

Department of Energy Organization Act **of** 1977, P.L. 95-91

Creates a new Department of Energy consolidating many of the energy organizations of Government. Of particular interest to LNG is the creation of semiautonomous Federal Energy Regulatory **Commission, which will absorb many of the functions of the Federal Power Commission as they relate to LNG. The major exception is that the Secretary of Energy will have authority to approve or disapprove import applications.**

Executive Order *10173-Regulations relating to the safeguarding of vessels, harbors, ports, and waterfront facilities of the United States.*

Authorizes the Coast Guard to "supervise and control" the transportation, loading and unloading of dangerous cargoes. Also allows the Coast Guard to require owners and operators to obtain a Coast Guard permit for the waterfront facilities used in the handling of such cargo. (The Coast Guard does not currently require such a permit.)

Federal Water Pollution Control Act, Amendments of 1972, 33 U.S.C. §§ 1251 *et seq* **(Supp.** 1972)

A comprehensive act aimed at cleaning up the Nation's waters. Discharges of pollutants require permits administered by EPA and the Army Corps of Engineers. In certain cases, this permit authority may be delegated to the States.

National **Environmental** Policy Act **of** 1969 **(NEPA)** 42 **U.S.C. §4321** *et seq* (1970)

Provides that each "major Federal action significantly affecting the quality of the human environment' must be preceded by an analysis of that action's environmental impact.

Natural Gas Act **of** 1938, 15 U.S.C. §§ 717a *et seq* (1970)

Gives the Federal Power Commission *broad* **powers to regulate imports, exports, and the interstate transportation and sale of natural gas. Under Section 3, no imports or exports may proceed without an order from the Commission. Under Section F, no facilities for interstate transportation or sale**

may be constructed without a certificate of public convenience and necessity from the Commission, The Commission's authority over interstate sales of natural gas includes setting the prices at which the gas is sold.

Natural Gas Pipeline Safety Act of 1968, 49 U.S.C. $$1671 et *seq* (1970)

Authorizes the Secretary of Transportation to set minimum Federal safety standards for pipelines, establishes a cooperative State-Federal enforcement program, and provides for Federal aid to States to bring State standards up to the level of Federal standards.

Outer Continental Shelf Act, 43 U.S.C. $$1331 et seq (1970)

Declares U.S. jurisdiction over the subsoil and seabed of the Outer Continental Shelf and establishes the system for Federal leasing of these lands for resource development.

Ports and Waterways Safety Act of 1972, 33 U.S.C. $$1221 et *seq* (Supp. 1972)

Title I provides that the Secretary of the Department in which the Coast Guard is operating may prescribe standards and regulations to promote the safety of vessels and structures in or adjacent to the navigable waters of the United States and $0 protect such waters and their resources from environmental harm due to vessel damage or loss.

Title II provides that the Secretary shall prescribe minimum design, construction, and operation standards for vessels carrying certain cargoes in bulk (e.g. oil).

Shipowners Limitation of Liability Act 46 U.S.C. §§181 et *seq* (1970)

Provides that shipowners may limit their liability after an accident involving their vessels to the value of the vessel and its cargo after the accident. An exception is made for loss of life or bodily injury, in which case liability is limited to $60 per ton of the vessel.

Submerged Lands Act 43 U.S.C. §§ 1311 et seq (1970)

Provides for State resource management of the seabed out to a distance of 3 miles from shore (3 marine leagues in the case of the States bordering the Gulf of Mexico). The Federal Government retains control over the waters over such lands for purposes of commerce, navigation, national security, and international affairs.

CASES AND FPC OPINIONS

Distrigas Corporation v. Federal Power Commission, 495 F.2d 1057 (D.C. Cir. 1974).

Decided that the FPC may, under the Natural Gas Act, impose the equivalent of Section F certification requirements for LNG imports even if the gas is to be sold intrastate. This authority is discretionary, and must be preceded by the Commission's finding such requirements to be necessary to protect the public interest.

Federal Power Commission, Opinion No. 795, Trunkline LNG Company and Trunkline Gas Company, Docket Nos. CP74-138, 139, 140, issued April 29, 1977.

Opinion No. 796-A, Issued June 30, 1977.

The first Trunkline opinion ordered incremental pricing and conditioned the certification upon Trunkline compliance with all other Federal, State, and local laws and regulations. In the second opinion, the FPC reversed itself as to pricing (allowing rolled-in pricing) but kept its condition of compliance with other laws and regulations.

Washington Department of Game v. Federal Power Commission 207 F.2d 391 (9th Cir. 1953); Federal Power Commission v. Oregon, 349 U.S. 435 (1955); City of Tacoma v. Taxpayers of Tacoma, 357 U.S. 320 (1957).

The above cases conclusively determined that, in the permitting of hydroelectric facilities, the jurisdiction of the Federal Power Commission preempts that of any State commission or body.

Transcontinental Gas Pipe Line Corp. v. Hackensack Meadowlands Development Commission, 464 F.2d 1358 (3d Cir. 1972), cert. denied, 409 U.S. 1118 (1973).

Action by natural gas company to enjoin regional development commission from interfering with an LNG peak shaving facility. Subsequent to the construction of the facility, New Jersey passed a law establishing the Hackensack Meadowlands Development Commission. The gas company, wishing to construct an additional storage tank at the facility, secured a certificate of public convenience and necessity from the FPC. The Hackensack Meadowlands Development Commission, however, refused to issue a permit for the addition. The Federal courts enjoined the State commission from interfering, finding its refusal to grant a permit an unreasonable restraint on interstate commerce.

Appendix D

Congressional Hearings Conducted on Liquefied Natural Gas

U.S. Congress Senate Committee on Commerce. **Hearing on S. 2064, 93d Congress, 2d session. 1974.**

The Committee hearings were held on June 12, 13, and 14. The Bill was introduced by Senators Magnuson and Cotton June 25, 1973, to amend the laws governing the transportation of hazardous materials. The Bill:

1. **"Would provide additional methods of enforcement, extend regulatory coverage and remove existing restraints upon the Secretary of Transportation to delegate regulatory authority.'**
2. **Review hazardous material statutes and evaluate Federal agency responsibilities and jurisdictional overlaps concerning transportation of hazardous materials.**

. S U.S. Congress House Committee on Interstate and Foreign Commerce. **Special subcommittee on investigations. Legislative issues relating to the safety of storing liquefied natural gas. Hearings, 93d Congress, 1st session. July 10-12, 1973. Washington, D. C., U.S. Government Printing Office, 1976.**

The hearings focused on the Staten Island explosion February 10, 1973. To obtain legislative information, the subcommittee investigated:

1. **the enforcement and adequacy of storage-tank safety regulations;**
2. **FPC and OPSO LNG safety responsibilities authorized by the Natural Gas Act of 1938 and the Natural Gas Pipeline Safety Act of 1968;**
3. **the question; "Is the state-of-the-art of cryogenic storage sufficiently advanced to be safe?'**

U.S. Congress House Committee on Interior and Insular Affairs, **Subcommittee on Public Lands. Alaska Natural Gas Transportation System. Hearings, 94th Congress, 1st session, October 9, 1975. Washington, D. C., U.S. Government Printing Office, 1975. 340 p. serial no. 94-36.**

This report delves into the land-use implications of the three proposed natural gas systems. The environmental as well as social impacts of each of the applications are discussed.

U.S. **Congress Senate Committee** on Interior and Insular Affairs/Committee on Commerce. The transportation **of Alaskan natural gas. Hearing, 94th Congress, 2d session, part 1 and 2, February 17, 1976. Washington, D. C., U.S. Government Printing Office, 1976.1515 p. serial no. 94-29.**

The purpose of the hearings was to explore energy, economic, and environmental policy issues in connection with the production and transportation of the Prudhoe Bay gas reserves. The discussion revolved around the necessity for additional gas, gas distribution, and financial arrangements for the proposed project.

U.S. Congress Senate Committee on Interior and Insular Affairs/Committee on Commerce. **The transportation of Alaskan natural** gas, Hearings, 94th Congress, 2d session, part 3. March 24 and 25, 1976. Washington, D. C., U.S. Government Printing Office, 1975.2030 p. serial no. 94-29, (Commerce), 94-29 (Interior).

The hearings concentrated on four bills, S. 2510, S. 2778, S. 2950, and S. 3167. S. 2510 was introduced by Senator Gravel on October 9, 1975. The bill requires that the FPC make a decision by June 30, 1976, on the applications posed by El Paso and Alaska Arctic Gas. S. 3167 also introduced by Senator Gravel is another attempt to expedite an FPC decision on the gas pipeline proposals. S. 3167 directs the FPC to make a decision and transmit that decision to the President by January 1, 1977. By February 1, 1977 the President would have requested agency reports. The reports would be due

by August 1, 1977, and the President's decision forthcoming. S. 2778, introduced by Senator Stevens, requires the FPC and other Federal agencies to approve only those gas transportation systems located in the United States or subject to international jurisdiction. S. 2950 introduced by Senator Mondale requires that all appropriate agencies provide the necessary permits and approvals to authorize the construction of the Arctic Gas pipeline. The Bill waives NEPA procedural requirement.

U.S. Congress House Committee on Interstate and Foreign Commerce. Subcommittee on Energy and Power. Transportation of Alaskan natural gas. Hearings, 94th Congress, 2d session. May 17-19, 1976. Washington, D.C. U.S. Government Printing Office, 1976.

The hearings revolve around 14 separate bills which would either expedite administrative procedures for selecting a delivery system and limit agency judicial review actions or allow Congress to select the route.

U.S. Congress House Committee on Interior and Insular Affairs. Subcommittee on Indian Affairs and Public Lands. Transportation of Alaskan natural gas. Oversight Hearings 95th Congress, 1st session. February 17, 1977 Part 1. March 17, 18 and 29, 1977 and April 5, 1977 Part 2. Washington, D. C., U.S. Government Printing Office, 1977.

The purpose of the hearings was to gather detailed and comprehensive information on the three methods of transporting Alaskan natural gas. The three proposals are the El Paso Alaskan LNG project, the Alaskan Arctic gas project, and the Alcan or Alaskan Highway project. Representatives from the gas industry, American and Canadian labor unions, environmental organizations, public officials, academicians, and Canadian Indians presented their proposals and various arguments.

Appendix E

Proposed Legislation Concerning Liquefied Natural Gas

H.R. 6844, Dingel (D-Mich.), introduced on May 3, 1977, and referred to the Committee on Interstate and Foreign Commerce. The bill would:

1. **direct the Secretary of Transportation to issue rules and regulations for siting, construction, and operation of LNG facilities;**
2. **require a permit from the Secretary of Transportation prior to construction and operation of an LNG facility;**
3. **provide for a limited State veto over project approval where a facility would be located in an area with a prescribed population density; and**
4. **direct the President to make a 10-year projection of the need for liquefied natural gas imports.**

Staff Working Paper No. 1, November 12, 1976, prepared by Senate Commerce Committee staff. The draft would:

1. **require a license from the Secretary of Transportation for the siting, construction, and operation of LNG facilities;**
2. **prescribe procedures for granting such a license;**
3. **direct the Secretary of Transportation to prescribe siting criteria for LNG facilities;**
4. **provide for State veto over LNG facilities;**
5. **provides for strict liability, with upper limits, for LNG accidents; and**
6. **establish a fund to compensate claims over and above the limits on company liability.**

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