

Critical Review of Components of LNG Import System

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.

¹U. 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

²Booz-Allen Applied Research Inc., *Analysis Of LNG Marine Transportation* (Bethesda, Md.: Booz-Allen Applies Research Inc., November 1973). v.1, p. VI-30-38.

³U.S. Department of Commerce, Maritime Administration, *Status of LNG Vessels* (Washington, D. C.: U.S. Department of Commerce, Mar. 15, 1977).

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

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.

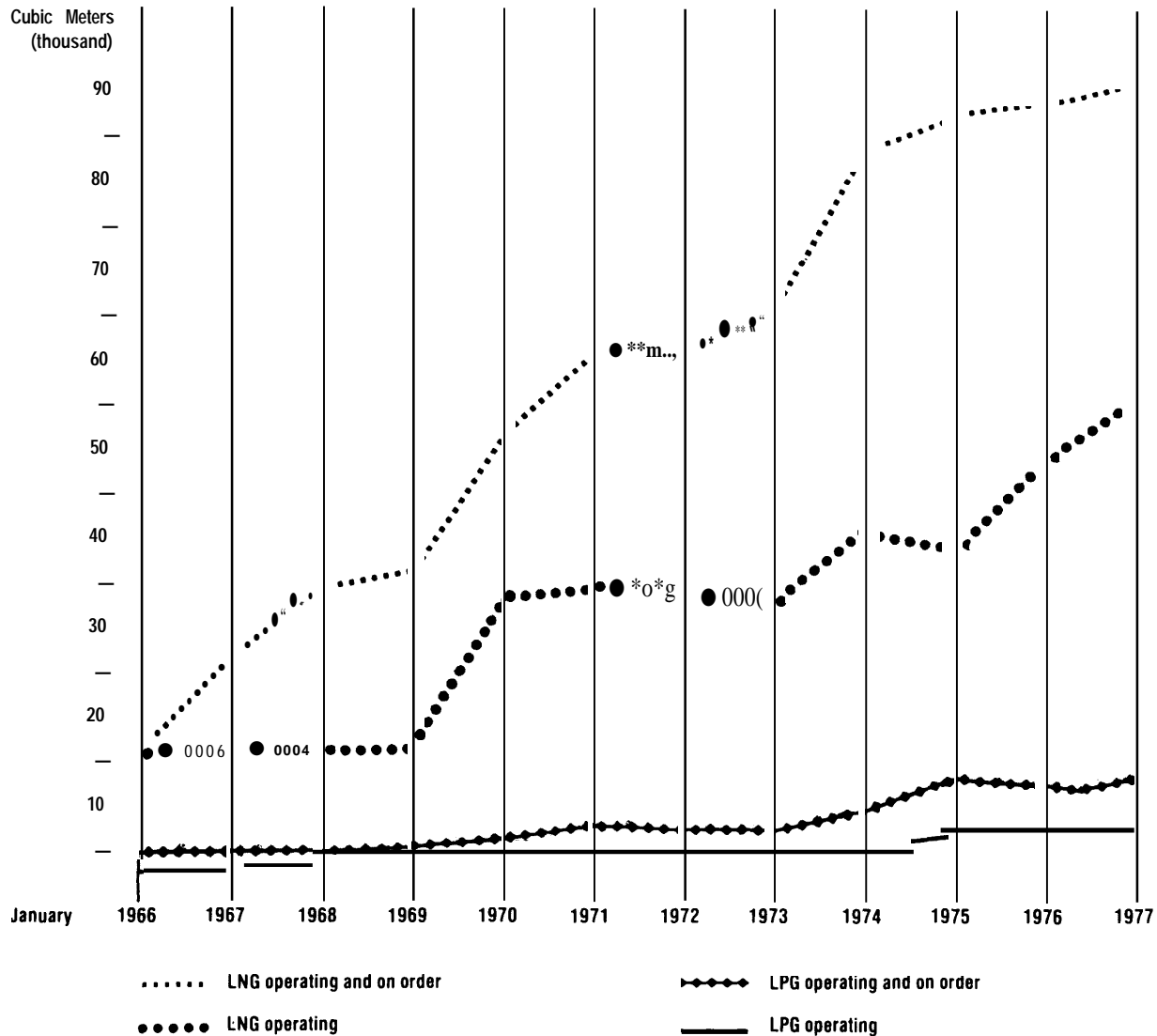
An interesting example of difficulties which may occur in getting a major new technical system in operation is provided by a recent accounts of the 125,000 cubic meter LNG tanker *Hilli*. Unloading of the tanker was halted in a Japanese harbor when a metal bolt was found in the cargo lines. The ship 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.

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.⁶In 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

⁶The *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.

standards for LNG and LPG tankers stems from the same legislation. T Recently, however, public concern about LNG has forced the Coast Guard to give disproportionate attention to LNG tankers. In all design, construction, and maintenance controls, **LNG and all other hazardous cargo tankers should be considered together.**

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

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.

¹U.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.

³U.S. Department of the Army, Corps of Engineers, *Waterborne Commerce of the United States, Calendar Years, 1973, 1974, 1975* (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 authority 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

⁴U.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).

⁵Hearings before the U.S. Coast Guard on the Chesapeake Bay Vessel Traffic System at Norfolk, Va., Jan. 27, 1977, John Boylston, marine manager 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?

s 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.

⁷U.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.

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

⁹U.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.

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

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 many other respects,

¹U. 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.

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-

²Wesson & 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.

³Wesson & 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.***

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

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

⁶Conversation 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***

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

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. 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.

⁸Interview 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?

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

³In 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.

¹15 U.S.C. § 717 c(a) (1970).

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 decision-making. 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

⁴Natural 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).

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

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***

⁶U. 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-offs 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. 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

⁷Federal 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.)

⁸Interview 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).

¹¹16 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.

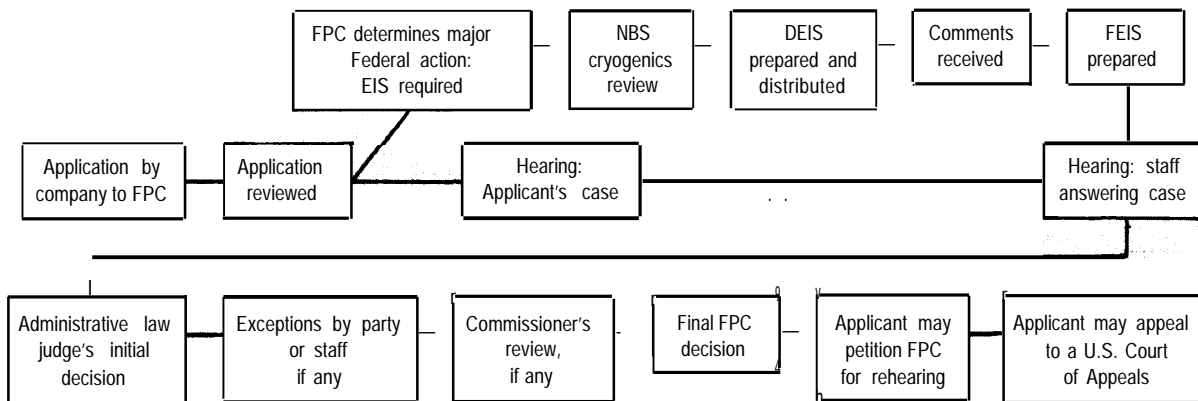
Much of the time used up by FPC is exhausted dealing with generic policy issues which could, and should, be decided in advance so that individual applications could move through a well-defined series of decision points. As noted earlier, there is the potential for considerable improvement in the time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

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

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

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



Source: OTA.

Financial Difficulties

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 from 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

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

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

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.

¹⁶Based 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.

¹⁷33 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
- c 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.

¹U. 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 unignitable. 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 policy-making.***

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

²Federal 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). 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

³Federal 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.

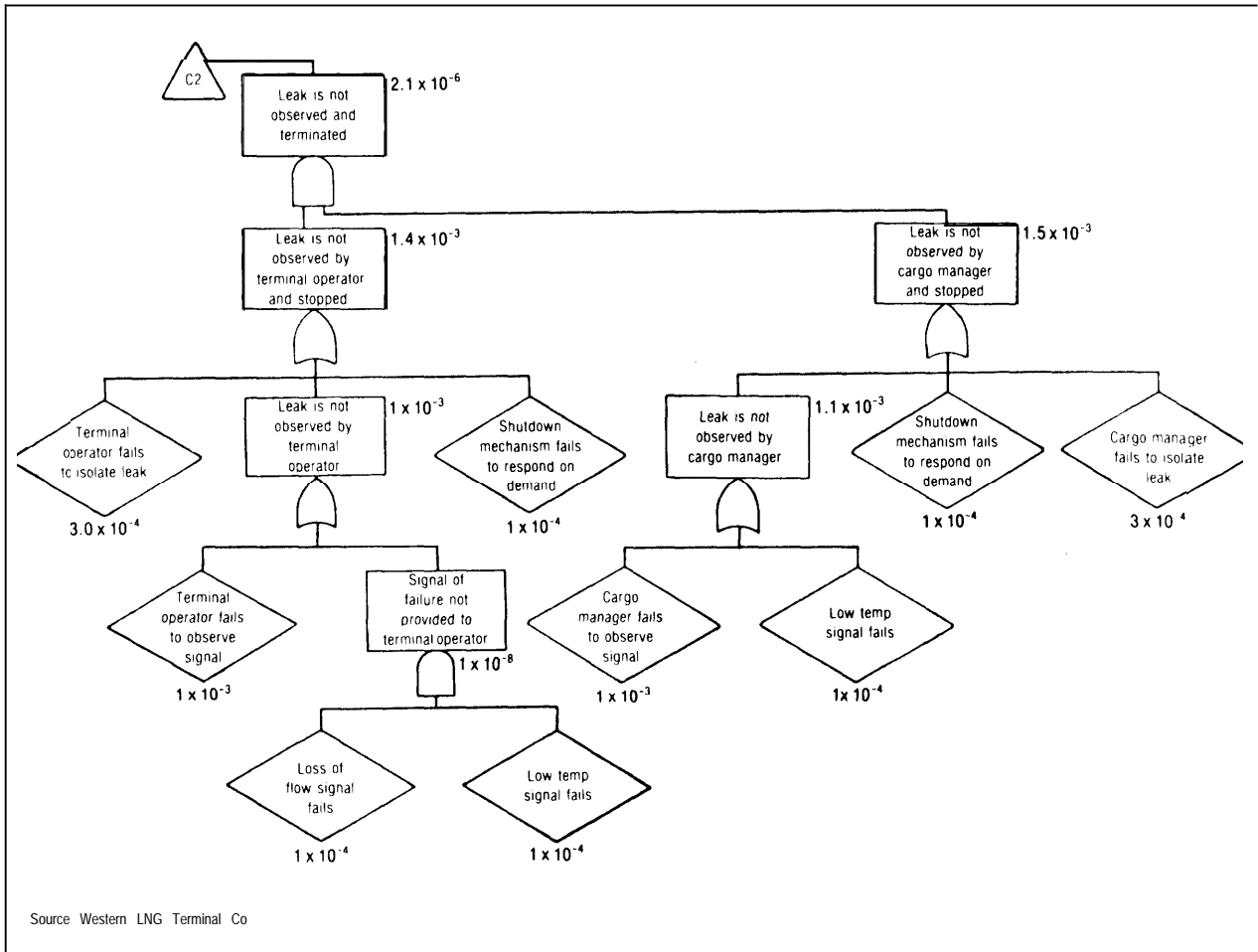
⁴Arthur D. Little, Inc., *Technology and Current practices for Processing, Transferring and Storing Liquefied Natural Gas*, (Cambridge, Mass.: Arthur D. Little, Inc., December 1974).

⁵Conversation 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).

⁷R.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



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

¹U. 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.

²Wesson & 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).

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

³Conversation 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. 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.

⁵Resource 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 onto 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	0.75
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 in 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.

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

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 suc-

cessful; 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-

³46 U.S.C. § 740 (1970).

⁴Grant Gilmore and Charles L. Black, Jr., *The Law of the Admiralty*, 2d ed. (Minneapolis, N. Y.: Foundation Press, Inc., 1975), p. 523.

⁵If 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).

¹46 U.S.C. § 183 (a) (1970).

²Ibid. § 183 (b).

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

⁹William L. Presser, *Handbook of the Law of Torts*, 4th ed., (St. Paul, Minn.: West Publishing Co., 1971).

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

¹¹In 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.

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

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

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

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

In 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 Indonesia.

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-

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

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

³Executive 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.

⁴Robert F. Ichord, "Indonesia," in Gerard J. Mangone, ed., *Energy Policies of the World, v. 2: Indonesia, The North Sea Countries, The Soviet Union* (New York: Elsevier, 1977), p. 68.

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

However, as the natural gas shortage during the winter of 1976–77 demonstrated, conversion to these substitutes—even if they are available—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

⁶Edward 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

⁷U. 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.

⁸Current 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.

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	86
	Consolidated	269.2	
	Panhandle	66.9	
Pennsylvania (654)	Columbia	211.2	47
	Consolidated	98.7	
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	25
	Panhandle	680	
Alabama (264)	Southern	167.7	64

Source: OTA

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	1980	1985	1980	1985
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	1980	1985	1980	1985
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

⁹Includes SYNGas from coal in 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

⁹Tom 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.

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

¹The 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

²For "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.

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

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?