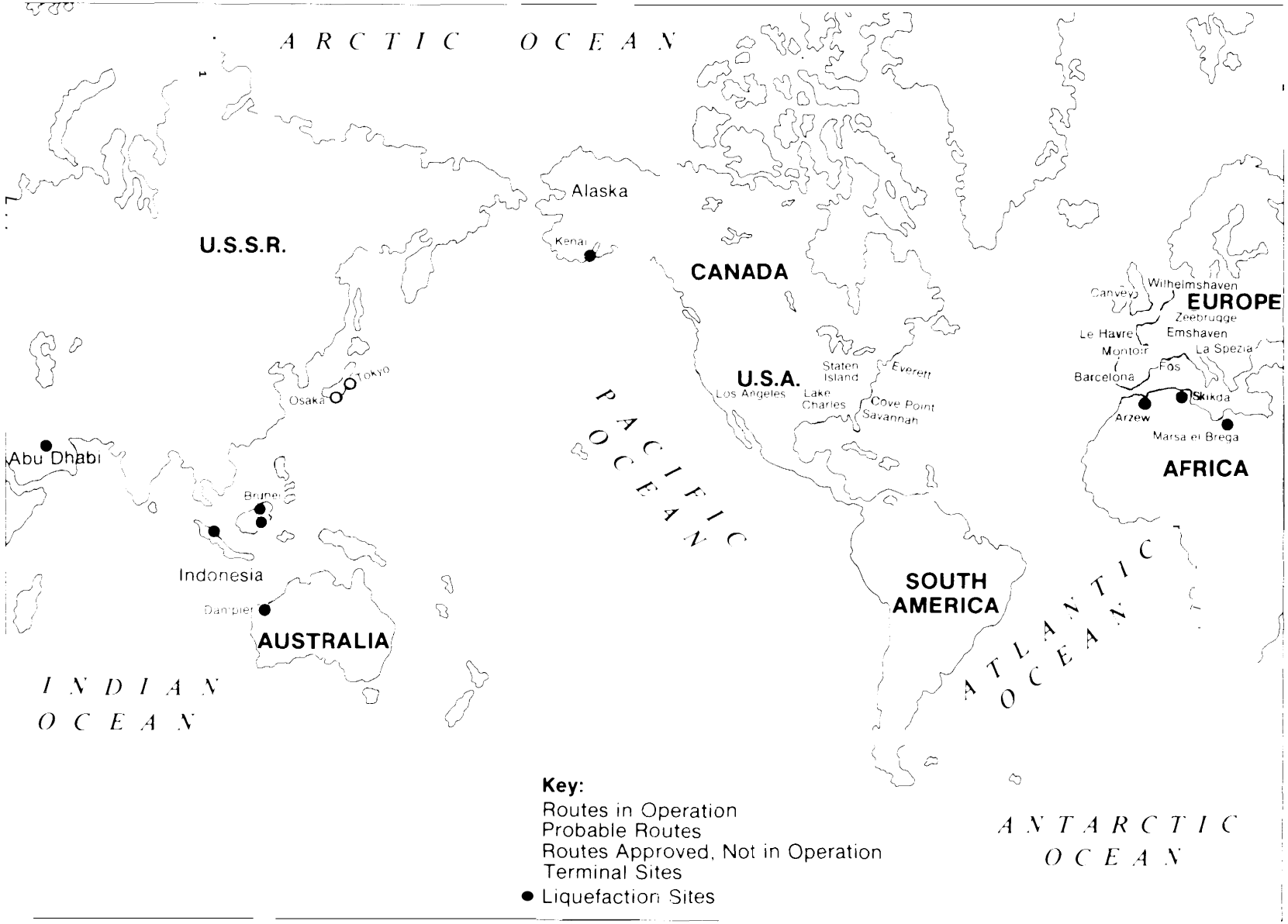
1. Summary

International LNG Trade Routes



1. Summary

Introduction

This assessment addresses whether or not additional liquefied natural gas (LNG) imports should be encouraged or restricted in the context of future national energy requirements and supply alternatives. In the past, public debate on this question has focused on both the safety and economics of LNG from overseas as a fuel resource.

On one side of the issues, proponents of increased imports point to:

- declining domestic oil and gas production,
- proven LNG technology,
- lower costs compared to gas from Alaska or synthetic fuels,
- opportunities to diversify sources of foreign hydrocarbons,
- less severe impacts than oil imports on the balance of payments,
- environmental advantages of gas, and
- savings from any improvement in utilization of present gas transmission and distribution infrastructure.

opponents draw attention to:

- the high cost of LNG compared to regulated domestic gas,
- the potential of conservation to diminish the demand for additional fuels,
- the fact that LNG involves flows of dollars out of the United States,
- the concern over security of foreign supplies,
- the possibility that demand for gas from higher cost sources like LNG is an artifact of Government regulation and indirect subsidy,
- the desirability of protecting markets for synthetic fuels or Alaskan gas in order to encourage development of these resources, and
- the hazardous nature of LNG itself.

Some advocates of conservation and solar power argue further that the United States should not import more LNG until less costly efficiency improvements and renewable energy alternatives have been exhausted. At the same time, others feel that this position holds LNG hostage to fuel-efficiency measures which are equally likely to be adopted, regardless of any foreseeable volume of imports.

An OTA report, Transportation of *Liquefied Natural Gas,* published in September 1977, describes the technology, reviews the physical and institutional components of the LNG import system, and explores public awareness and concerns. Partly in response to questions raised by that study, the Senate Committee on Finance asked OTA to examine LNG import policy in the context of other energy alternatives, with emphasis on economic costs and benefits. The request arrived after President Carter, through the National Energy Plan, had relaxed a policy of the previous administration to limit LNG imports, and after the General Accounting Office (GAO) had suggested in a report to Congress that this new policy required reevaluation and further improvement, essentially because insufficient rationale appeared in the plan.

This assessment is part of an ongoing examination of alternative energy futures, and in response to the Senate Finance Committee's inquiry, it focuses on the economic and energy supply implications of the technology. Safety of LNG facilities has been excluded, in order not to duplicate the material in an earlier congressional report, *Liquefied Energy Gases Safety,* issued in July 1978 by GAO.

The purpose of this analysis is to assist Congress and Federal and State regulatory bodies in establishing or reevaluating the circumstances under which LNG imports are in the public in-

terest, and to aid in any further debate over policies that would encourage or restrict LNG imports in the future. Possible policy measures that could result from resolution of the present debate on this subject include the following:

- imposition of formal limits on the amount of LNG that may be imported from a particular supplier or from all foreign sources;
- reversal of the Department of Energy's present assignment of a low-priority status to LNG among potential future gas supplies;
- change in the treatment of LNG as an incrementally priced supplemental gas source under the Natural Gas Policy Act of 1978 (NGPA);
- refinement of criteria for case-by-case import project approval by Federal and State regulatory agencies;
- alteration of the balance of Federal, State, and local authority and autonomy in LNG project approval and regulation;
- change in present Maritime Administration and Export-Import Bank policies, under which components of LNG projects are eligible for credits and direct aid for specific purposes;
- encouragement or discouragement of LNG trades as an element of foreign policy; and
- decisions by private individuals and institutions to invest or not in LNG import projects.

This assessment does not decide which if any of these options would be appropriate, but it does provide the many participants in policymaking with information and analysis they will need in order to choose more wisely.

The project consisted of seven separate but related analytical tasks:

1. a compilation of the history of Government LNG import policy;
2. a review of' U.S. gas demand projections under alternative price and policy assumptions;
3. a survey of North American gas and oil resource estimates;
4. an investigation into the availability and cost of LNG in world markets;
5. a description of the cost and structure of LNG import projects, including financing and the distribution of risk among the public and other participants;
6. an analysis of the distribution of costs and benefits of imported LNG in domestic gas markets; and
7. a brief discussion of the broader social and environmental impacts of LNG imports.

The remainder of this chapter contains a list of issues and findings extracted from the rest of the study. They represent the principal conclusions from the the subsequent analysis.

The policy history, which comprises chapter 2, traces the development of administration attitudes toward LNG imports from President Ford's February 1976 energy message through the National Energy Plan and the formation of the Department of Energy to the present. The chapter also describes relevant programs of such agencies as the U.S. Export-Import Bank and Maritime Administration, and it includes expressions of congressional interest as evidenced by studies or recently introduced legislation. Finally, California provides an example of State involvement in LNG import decisions.

Chapter 3, on future gas availability and use, begins with a discussion of projected U.S. gas demand by specific categories of end use under different price and policy assumptions, reflecting the results of studies by several institutions. Following the demand discussion is an analysis, based on available studies, of North American gas and oil resources (since oil can often be substituted for gas) including conventional and unconventional extraction technologies, synthetic fuels, and reserves in Alaska, Canada, and Mexico. The latter part of the chapter addresses the volume of foreign gas available to be imported as LNG, taking into account such factors as reserves, proximity to competing markets like Europe or Japan, prior contractual commitments, and political considerations.

The next chapter (chapter 4) includes a description of the structure of LNG import projects, beginning with pricing policies of exporting nations and followed by the capital and operating costs of cryogenic tankers and of facil-

ities in the producing and receiving countries. After an extensive discussion of the possible sources of debt and equity financing and their practical implications, the chapter ends with a section on the distribution of financial risk associated with investment in LNG projects, with particular attention to any public liability for unforeseen economic losses.

Social costs and benefits are the subject of chapter 5. It begins with an analysis of who would receive additional gas if more LNG were imported and who would pay, given the complexities of the natural gas transmission and distribution system and of the regulatory framework within which it operates. The results are useful in ascertaining the value of the gas in terms of what would happen without it, and they are instructive as an example of the influence of NGPA as it affects gas markets generally. The effect of reduced gas supplies in the event of a curtailment of foreign deliveries is also treated in this part of the report. The rest of the chapter is devoted to the possible influences of gas availability on air quality and employment and the impact of LNG import projects on the balance of international payments.

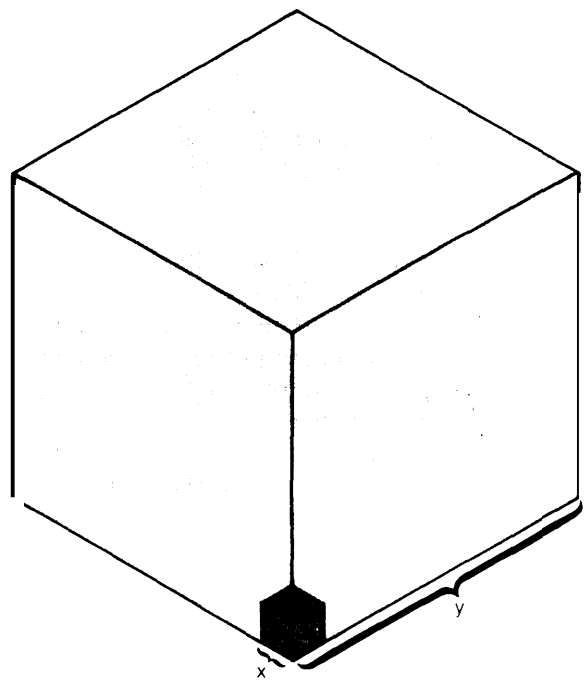
Three working papers prepared for this project contain more detailed material supporting chapters 3 through 5. These reports, referred to occasionally in the pages that follow, are published in a separate *Background Reports* volume and will be made available through the National Technical Information Service.

Background

Since the first voyage in January 1959, of the Methane *Pioneer* from Lake Charles, La., to Canvey Island on the Thames River near London, England, ocean transport of LNG at –2600 F has been a technological reality. The first regular commercial trade in the commodity began 5 years later, in 1964, with shipments from Arzew, Algeria, to Canvey Island and the French port of Le Havre. Today, 12 operating projects, 3 of which involve the United States, account for 1.75 trillion cubic feet (Tcf) of gas traded annually. The United States presently exports ().0.5 Tcf/yr from Alaska to Japan and imports 0.45 Tcf/yr from Algeria. Two more approved projects involving Algeria and Indonesia would add 0.38 Tcf/yr to import levels over the next few years.

The virtue of LNG lies in its high density. In liquid form, methane, the principal constituent of natural gas, fits into one six-hundredth of the space it requires as a gas at room temperature and atmospheric pressure (see figure 1). The gas industry has taken advantage of this property for storage purposes for half a century. With rising energy costs, more efficient liquefaction processes, and reliable performance of specially designed cryogenic tankers, the economics of

Figure 1.—Volume Reduction From Natural Gas to LNG



$\frac{x}{Y} = .119$ $\frac{}{Y'} = 1/600$

SOURCE Office of Technology Assessment

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shipping gas in this form over ocean distances have proven to be attractive.

The advantages and disadvantages of further LNG imports depend in large part on expected future levels of gas availability and use. As described in chapter 3, one part of U.S. gas demand involves applications in which conservation or fuel substitution is costly, and the other consists of applications in which alternative fuels or improved productivity could be substituted readily, depending on public policies or relative differences in fuel prices. The first category, or the "basic" demand, is projected at a level of **14** quadrillion Btu per year in **1990. In** the same year, however, an additional 12 quadrillion Btu could be used in "marginal" applications if it were available at prices comparable to those paid for gas today, and if electric utilities were permitted to burn oil and gas. Under those circumstances gas would be used in place of coal, oil, nuclear power, and conservation.

Findings

At least over the next decade, domestic gas production will probably satisfy essential requirements, but neither domestic sources nor pipeline imports from Canada **or Mexico are** likely to meet additional marginal demand except at costs equal to or greater than that of LNG. Furthermore, North American oil production will probably not be sufficient to alter the demand for gas by substitution. Viewed in this way, LNG imports are no more or less imperative than other potential energy supplies of equal size. The Nation has alternatives to LNG from overseas, but gas in this form may be desirable as part of a portfolio of energy sources and strategies to meet the projected future demand.

The advantages and disadvantages of LNG in relation to improved efficiency and fuels from other sources will depend on such factors as availability, security of supply, cost, specific use, distribution of costs among consumers, effect on the balance of payments, and environmental impact. Characterized in these terms, broad gas resource categories are not susceptible to simple ranking, and projects must be compared on their individual merits.

In many instances, choices are complicated because action by the Federal Government is limited to decisions on individual project proposals from the private sector. Denying one application for a license does not necessarily bring forth a better application, and a series of sound decisions taken one at a time does not always lead to a cohesive program. For example, advocates of energy conservation argue that LNG imports should be restricted, because they feel that improvements in energy productivity to save fuel are less costly than paying LNG prices, and hence that a rational policy would not include the imports. However, keeping LNG out of the country will not necessarily bring about any investment in demand reduction, and indeed according to one argument, LNG and other new supplies would promote conservation and improved energy technologies, because they would increase the average gas price paid by consumers. What follows are conclusions concerning the major issues to be faced in deciding the future of LNG imports.

1: *How much gas is available for import as LNG?*

The United States could import between 0.5 and 1 Tcf/yr of additional gas during the 1980's above the current approved level of 0.8 Tcf/yr. The maximum total of 1.8 Tcf/yr would represent between 7 and 13 percent of projected 1990 domestic gas use and would require three or four large terminal facilities in addition to those already planned.

The availability of gas was determined by surveying world proven gas reserves and assigning them to categories as follows:

- *Inaccessible or flared:* gas reserves that are too small or remote either to justify recovery of flared gas or full field development of nonassociated gas.
- *Deferred reserves:* reserves in large gas caps or undergoing gas injection for oil re-

covery, such that they are unlikely to be committed to market projects until some future time.

- *Committed to domestic markets:* gas reserves that either are contracted to domestic markets or set aside to assure that domestic requirements will be covered.
- *Remote from existing market systems:* gas reserves that are clearly destined for a major industrial market but whose remoteness from this market raises questions about the feasibility of commercialization now. Examples would include North Slope and Arctic Island gas in North America and some North Sea gas reserves in Europe.
- *Committed to export markets:* gas reserves covering required deliveries usually under firm export contracts.
- *Exportable surplus:* blocks of remaining gas reserves that are large enough and adequately located to support export projects. In a limited number of cases, local national policy suggests that this gas will not be exported, and in other cases, discussions to sell the gas to other countries have proceeded to the point where it is no longer available to the U. S. market.

Most of the gas available for export in the near future is located in the U.S.S.R. and the nations surrounding the Persian Gulf, principally Iran and Saudi Arabia. The reliability of Iran and the Soviet Union can be questioned on political grounds, and some other major oil producers in the Middle East feel at present no economic need to export gas. Also, shorter transportation distances to European and Japanese markets make sales to the United States less attractive for these and other producing countries. For example, remaining Algerian supplies are now mostly committed to European purchasers, due in large part to regulatory delays affecting U. S. import projects. The most likely sources of LT. S. imports, other than by pipeline, include Nigeria, Indonesia, Australia, Malaysia, Trinidad, Colombia, and Chile.

Substantially more gas could become available to import as LNG during the 1990's if U. S. policy were to shift in such a way as to as to encourage this type of trade. Nations with undiscovered resources could actively search for new reserves if they perceived the United States as a more interested and reliable customer. Also, the impediments to the purchase of Soviet gas lie primarily in U.S. foreign policy.

z: now *does security of supply affect the desirability of LNG imports?*

Four of the six largest actual or potential exporters of natural gas from the Eastern Hemisphere—Algeria, Iran, Indonesia, and Nigeria—are members of OPEC. The fifth is the Soviet Union. Only the sixth, Australia, is a member of the Organization for Economic Cooperation and Development (OECD). Although not alone in this regard, OPEC members have demonstrated their readiness to impose increases in oil prices at short notice on existing contract terms. Some of them also have embargoed crude exports for political reasons. Curtailments and other abrogations of contract terms are thus possible and must be assessed for their likelihood and potential impact.

Typical LNG projects are technically and financially integrated, with ships and facilities dedicated to specific trade agreements covered by 15- to 25-year contracts. The producing country must invest as much as $2 billion for pipeline, liquefaction, and terminal facilities, and the funds are obtained through long-term loans often guaranteed by the central government. Therefore, exporters depend on a project's revenues and are unlikely to find alternative purchasers if trade ceases. For this reason, LNG suppliers and their governments face stronger incentives to continue shipments than do oil producers. The producer's stake in uninterrupted shipments to the United States increases when U. S. institutions are not involved in the ownership and financing of liquefaction and shipping facilities. A country willing to curtail supplies on political grounds could also be prepared to postpone or temporarily}' halt payments to U.S. creditors and shipowners, thereby softening the impact of forgone revenues. For this reason, Maritime Administration and Export-Import Bank financial participation does not enhance reliability.

Another important consideration is that since some potential LNG suppliers are not members

of OPEC and others produce relatively small amounts of oil, interruptions in oil and gas imports are less likely to coincide than they would be otherwise. During the oil embargo of 1973, for example, Algeria stopped oil shipments but did not interrupt LNG traffic to the United States. Therefore, LNG can help to diversify energy supplies with respect to fuel type and geography.

In the event of a curtailment, management of the shortfall could minimize the adverse impacts, partly because the distribution of added gas supply from LNG probably will be geographically diffuse. The present national priority curtailment system established in the winter of 1973-74, should preserve remaining gas for critical uses within the market served by any given transmission company, and voluntary sales and exchanges among transmission companies will alleviate inequities further. Also, the President is empowered by NGPA to redistribute gas among pipeline systems in an emergency. Finally, increased storage capacity, although costly, could ensure further against the impact of an interruption.

3: How *much will LNG cost in the future?*

Delivered gas from LNG is likely to be approximately equivalent in cost to competing fuels—less expensive than synthetic fuels and distillates from foreign oil, and more costly than regulated domestic natural gas. * This equivalence is a deliberate outcome of the objectives of the parties in negotiating supply contracts. To the extent that LNG permits more economical use of present transmission and distribution capacity, the average price to the final consumer will be less, while any requirement for increased storage or additions to pipeline networks by utilities will add to the expense.

The cost of shipping LNG in tankers varies with the distance and other technical and financial features of a specific project, but it is expected to range between $2.60 and $3.50 in **1978** dollars per million Btu delivered in 1990 by a project beginning operation in 1985. This estimate encompasses all steps required to deliver the gas from the foreign wellhead to a domestic pipeline, including gathering, liquefaction, loading, shipping, unloading, vaporization, storage, and delivery (see figure 2).

An additional amount to cover production costs and the value of the resource to the supplier nation is the subject of extensive negotiation between the importer and exporter, and is included in the f.o.b. price provided in a supply contract. Generally these negotiations begin with the presumption that the delivered price must be competitive with those of petroleum products in the U.S. market, and that the exporter must recover his investment. Unless the distance is very great, the U.S. market price of gas from LNG, after subtracting the total transportation cost, will exceed the minimum required by the exporter, especially after several years of project operation with fixed capital charges and rising world energy costs. At least some of this surplus value will probably accrue to the foreign producer as a result of price formulas containing escalation provisions and periodic renegotiation of supply contracts.

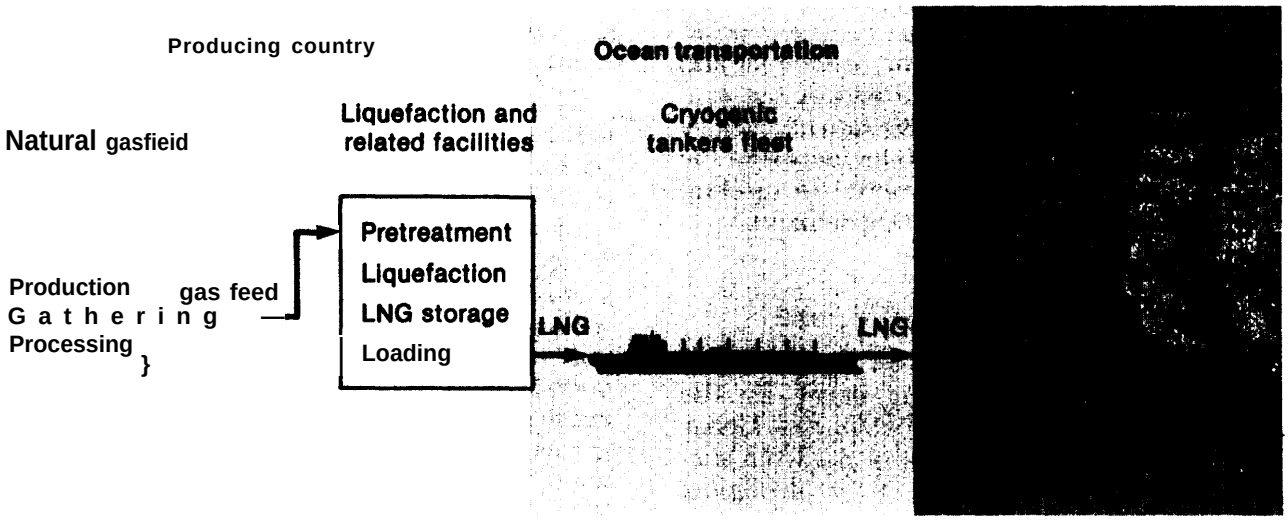
An important but subtle element of cost involves the consumer's exposure to financial risk. In a regulated utility environment, the final purchaser of gas is inevitably a partner in large energy projects, since financing depends on guarantees in the form of prices designed to allow investors to recover portions of their cost notwithstanding some kinds of failure or loss. * In two recently approved LNG projects, the consumer assumes: 1) the liquefaction facility investor's risk that the gas may not be economically attractive in the U.S. market for the life of the supply contract, 2) the shipowner's risk that shipments may be interrupted or reduced,** and 3) all of the creditors' risk related to receiving terminal and revaporization facilities after gas has begun to flow. In addition, the Federal

" Alaskanl gas would cost more initially than LNG, but its price would probably rise less rapidly in the future.

"'1'tl' The Federal Energy Regularory Commission and State public utility commissions are not bound by earlier decisions, so investors do assume some risk that regulation will change over the life of any energy project.

* " According to Columbia LNG Corporat ion officials, at least one possible future LNG project under discussion entails no consumer exposure to shipowners' risk.

Figure 2.—Major Segments of an LNG Import Project



SOURCE. Jensen Associates, Inc

Energy Regulatory Commission may permit tariffs to cover some types of project failure, delay, or overrun depending on the outcome of evidentiary hearings to determine the circumstances and the prudence of management actions.

Another part of the cost involves public services. The range of transportation and processing costs mentioned above includes taxes as a surrogate for public expenses, but does not include the value of Export-Import Bank credit for foreign liquefaction facilities and ships purchased from the United States, or for Maritime Administration subsidies and loans for building American-owned ships. The latter programs are designed to make U.S. goods competitive in the world market by equalizing the cost of U.S. and foreign goods, and thus they have little impact on LNG project viability or the amount consumers pay. This assessment does not address the wisdom of these programs and assumes they are worth what they cost in terms of employment, balance of trade, and health of the shipping and LNG equipment industries. Finally, LNG projects, like all waterborne trade, benefit from activities of the Coast Guard and navigation improvements by the U.S. Army Corps of Engineers.

4: *How would added gas supplies from LNG be used?*

The disposition of added supplies in gas markets is complex and will vary greatly from one case to another. The critical determinants include the mix of interruptible and firm customers in the service area, extent of present curtailments, availability of storage capacity, local regulatory policy concerning connection of new customers, and climate. In general, however, gas made available as a result of LNG imports will be used at least partly and possibly entirely in interruptible industrial and electric-generating applications. In this context, although the Power Plant and Industrial Fuel Use Act of **1978** (FUA) prohibits burning of oil and gas for most electric power generation after **1990,** LNG is specifically exempted under certain circumstances to meet air quality standards. The important implication is that the appropriate comparison in economic and environmental terms is not exclusively between LNG and No. 2 (home) heating oil derived from foreign crude, but must also include coal, residual oil, nuclear power, and improved energy productivity among the alternatives.

Over a long period of time, gas utility load patterns may change in such a way that higher

priority consumers receive a larger portion of the gas made available from LNG. If this shift occurs, present long-term import contracts could effectively reserve supplies for residential and commercial users toward the end of the century. Also, to the extent that the rate of delivery from a receiving terminal can be increased for brief periods, LNG can contribute to meeting short-term peaks in space-heating demand.

5: *How is the cost of LNG distributed among consumers?*

In regulated markets the cost of added supplies will not necessarily be borne by the customers receiving the additional gas. Under NGPA, part of the higher cost of gas from supplemental sources defined in the Act, including LNG projects not in operation or planned before May 1, **1978,** are paid exclusively by certain "non-exempt" large industrial purchasers, provided that these buyers do not pay a price higher than that of competing petroleum fuels. Once the "non-exempt" industrial price reaches this maximum, it will not increase further, and residential, commercial, electric utility, and the remaining "exempt" industrial customers will begin to pay higher prices resulting from subsequent purchases of more expensive gas by suppliers. *

Under the latter conditions, the price paid by "non-exempt" industrial customers, although high initially, would not increase as a result of LNG imports. The rest of the buyers, including electric utilities, commercial establishments, and households, would experience price increases, although all or part of the higher cost of gas could be offset by savings from the allocation of fixed charges for present transmission and distribution capacity over a broader volume of sales.

Variations on this pattern will occur if non-exempt industrial prices have not reached the maximum corresponding to alternative fuels. In this instance, prices would rise more rapidly for large industrial customers, while exempt purchasers would enjoy equally any savings from improved pipeline utilization, provided the LNG project was initiated after May 1,1978. The cost of prior projects is averaged with that of domestic gas and affects the price paid by all customers approximately equally, as long as non-exempt prices are below the alternate fuel ceiling.

Thus, of the types of consumers likely to receive additional gas from LNG projects, industrial customers will probably pay a price close to that of alternate fuels and of the LNG itself; while electric utilities and purchasers of electricity are likely to receive a subsidy from other sectors in the form of '(exempt" prices, which will rise more slowly than "non-exempt" industrial prices, under NGPA. Although households and commercial establishments would probably receive little additional gas at least initially, the prices in these sectors would rise or fall depending on the costs and volumes of LNG purchased by transmission and distribution companies as well as the extent to which added sales alter the efficiency of the pipeline system's use.

6: *How strongly do LNG imports affect the balance of payments?*

Importing LNG entails a significant outflow of dollars from the United States compared to domestic alternatives. On the other hand, the direct impact on the balance of payments of purchasing equivalent amounts of foreign oil is more severe. With the exception of about 1 cent per million Btu for a small amount of U.S. shipping, almost all of the price of oil leaves the country, while as much as one-third of the transportation and processing cost of LNG may be returned to the United States in the form of purchases of equipment, construction services, shipping, and receiving port facilities. The returned portion of the cost consists primarily of amortized initial capital expenditures in the United States, so the favorable component of the impact of importing LNG is immediate and short term. After the facilities and ships are constructed the balance-of-trade impacts are more nearly comparable to those of oil.

The effect of being able to choose the lowest cost alternative from among LNG, foreign oil, domestic production, and conservation may outweigh the influence of direct payments associated with any specific trade by improving the competitive position of U.S. industry generally. As mentioned earlier, LNG prices will probably

* State public utilities commissions may alter this outcome by declining to implement the intent of the Natural Gas Policy Act.

be slightly less than those of fuels from foreign crude oil.

In conclusion, importing LNG appears more advantageous than buying foreign oil to a significant but uncertain extent due to differences among projects in terms of facility sales by U.S. firms, and to the fact that lower LNG costs relative to world oil may be the dominant factor. Nevertheless, LNG can represent a substantial outflow of dollars.

7: *How are present Federal policies likely to affect future LNG imports?*

While LNG represents only a single element of energy supply and foreign trade, a variety of Federal policies affects its future. Regulatory delays increase costs, and present Department of Energy policy discourages LNG imports in favor of sources located in North America. The attitude reflected in recent actions of the Department has been that even initially higher cost Alaskan gas and products of coal conversion technology are preferable to foreign LNG by virtue of the perceived public interest in developing domestic resources for the future.

Recent initiatives by the President to establish an energy mobilization board and to impose oil import quotas could facilitate LNG trade by eliminating foreign oil as a choice for some consumers and by removing obstacles to project approval. The effect of these programs would be reversed, however, if all foreign hydrocarbons are included in the quotas, or if the board adopts a policy to encourage domestic production in preference to energy imports of all forms.

Maritime Administration and Export-Import Bank programs, while ameliorating the balance-of-payments impacts of some LNG projects and providing benefits to the U.S. shipbuilding industry, tend to reduce the financial stake of foreign suppliers in uninterrupted deliveries. As mentioned earlier, the aid of these two agencies equalizes costs of domestic- and foreign-produced facilities and therefore does not encourage LNG projects except to the extent that sponsors appear more likely to gain Government approval if ships and machinery are built in the United States.

Both FUA and NGPA provide incentives to encourage domestic production of gas and conversion of oil- and gas-burning facilities to the use of coal. To the extent that this legislation is successful, demand for LNG may be slowed or reduced. The effect of FUA is partly to prohibit use of oil and gas for electric power generation after **1990.** However, the law contains numerous exemptions and exceptions, including one permitting utilities to burn gas from LNG if necessary for regional air quality. NGPA establishes an elaborate pricing mechanism for gas, which affects the distribution of LNG costs among purchasers, as mentioned before.